Energy-from-Waste in Brent

An Interactive Qualifying Project Report submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
In partial fulfilment of the requirements for the Degree of Bachelor of Science

28 April 2012

Submitted by

Nicholas Broulidakis

Nicolás Martínez

Bradley Merrill

Joaquín Serrano

Sponsor

The London Borough of Brent

Liaison

Joyce Ip

Advisors

Terri Camesano

Kathryn Fisler

1.0 Abstract

London's waste production is unsustainable. As an alternative to landfilling non-recyclable, non-reusable waste, energy-from-waste (EfW) recovery can be implemented in order to maximize sustainability. The following report supplies an overview of the various EfW technologies, conveys the political, environmental, economic, and social implications of its development and lastly, provides recommendations for EfW's application in Wembley City. Overcoming the negative public perception of incineration and other EfW technologies will be a major driver for the technologies' progress.

2.0 Authorship

Each of the four group members contributed equally to the writing of the paper. Bradley Merrill contributed heavily to the editing of the documents. Interviews were conducted by all group members at the beginning of the data collection stages. At later stages of the IQP Nicolas Martinez and Joaquin Serrano conducted most of the remaining interviews. Most archival research was conducted by Nicholas Broulidakis and Bradley Merrill in order to complete the data and analysis section as well as the recommendations.

3.0 Acknowledgements

The team would like to thank our WPI faculty advisors, Professors Terri Camesano, Kathi Fisler, Paul Davis, and Domenic Golding for their guidance and support. The team would also like to thank our council liaisons, Joyce Ip and Ken Hullock, as well as the London Borough of Brent, for their support and hospitality. Lastly, we would like to thank all of our interviewees; without you this report would not have been possible.

4.0 Executive Summary

London's waste production is unsustainable. In 2009 – 2010, 3.8 million tonnes of Municipal Solid Waste (MSW) were produced, of which approximately 50% was sent to landfill. This left-over residual waste generated nearly 460,000 tonnes of greenhouse gas emissions. The Landfill Tax is set to continue increasing until at least 2014 when it will be £80 per tonne, resulting in an expenditure of roughly £300 million for sending waste to landfill (Greater London Authority, 2011). Efforts are being made to improve London's waste management and reduce the amount of waste sent to landfill, however there will always remain some amount of residual waste. Changing the way this residual waste is handled is a crucial decision for London's future.

The Mayor of London is promoting the implementation of a more sustainable waste management strategy through the revised waste hierarchy, which places priority on reducing, reusing, and recycling. Energy recovery and landfilling waste are last resorts if the other methods cannot be utilized. By 2031 the Mayor wishes to send zero waste to landfill and manage 100% of London's waste within the city's boundaries. Doing so would help people realize that rubbish is a resource that cannot be wasted. The London Plan sets out the spatial policies to support the Mayor's strategies. Under the Local Development Framework (LDF), Policy 5.17 states boroughs must allocate sufficient waste management facilities to achieve the Mayor's goals.

The Borough of Brent produced 107,000 tonnes of MSW last year of which 60% was sent to landfill. Treating this waste in the Borough via state of the art energy recovery methods, such as Advanced Thermal Treatment (ATT) technologies or Anaerobic Digestion (AD), could help to reduce the negative impacts associated with landfilling waste while also producing sustainable energy and sustainable heat through combined heat and power (CHP) systems. By processing Brent's waste in the borough an opportunity is created to engage with residents and increase waste awareness, which may in turn lead to a decrease in waste production (Dow Jones Architects, 2009).

The Brent Council has created the Wembley Area Action Plan to guide Wembley's development throughout the next 15 years. Once fully adopted, the document will become part of the LDF. The Plan's section on waste management policy will be subjected to public consultation this summer of 2012.

The team's role consisted of providing evidence to support the procurement of future policy to facilitate EfW recovery, from non-reusable, non-recyclable waste. Assessment of the feasibility for the implementation of an EfW programme in Wembley industrial park, an area deemed most suitable for such a project, is supplied in this report. To supplement information gathered through archival research of case studies and government documents, the team conducted interviews with key stakeholders and informants, such as Council officers, government agencies, representatives from EfW companies, Wembley Area Developers, and local residents.

We have also developed a set of recommendations and conclusions for the London Borough of Brent with regards to EfW in the borough. As a final deliverable, a technology comparison matrix which outlines the major technologies available today is included in a simple, user friendly format.

Overcoming the negative public perception of incineration and other EfW technologies will be a major driver for their progress. Future proposals will have to meet standards laid out by planning policy documents such as the Waste Incineration Directive (WID) and the Integrated Pollution Prevention and Control (IPPC) regime. Although it is inevitable that some repercussions will result from EfW development, the team concludes that the benefits will far outweigh the drawbacks (Environment Agency, n.d.).

Table of Contents

List of Figures

List of Tables

5.0 Introduction

“The traditional approaches to waste management of ‘flame, flush or fling’ are outmoded customs which have resulted in an unsustainable society” (Seadon, 2010). In the London borough of Brent, managing waste has become a pressing issue. Today there are many options to consider for the development of a sustainable waste management system. The borough is currently working its way toward a ‘zero waste’ community. To achieve this, the borough follows a waste hierarchy that prioritizes reducing, reusing and recycling. Diverting residual waste from landfills for energy recovery, so called energy-from-waste (EfW), is one potential way to combat waste issues; however the goal of the Brent council is not focused on energy from waste as an end-all solution to their waste problems. “The government’s aim is to get the most energy out of waste, not the most waste into energy” (Defra, 2011).

As an alternative to land-filling unrecyclable waste, energy recovery can be implemented to maximize sustainability. Waste is generally considered an exceptional source of feedstock for UK bio-energy needs. Projections show that beyond 2050 there will still be enough waste production in London for EfW programs to grow, even with the expected reductions in waste production through reuse and recycle programs (Defra, 2011). Non-recyclable waste can be converted directly into electricity or heat by incineration, or into a combustible fuel commodity through advanced thermal treatments (ATT) such as pyrolysis or gasification.

The London Borough of Brent is interested in procuring future policy to facilitate EfW recovery and thus our goal was to aid Brent in this endeavour. Brent is experiencing considerable commercial and residential development, and the Council is eager to know where EfW might fit in terms of handling waste and generating energy.

Through a technology comparison matrix, the team has addressed what the advantages and disadvantages of the different EfW technologies are. Evaluated in this matrix are key criteria such as capital cost, payback period, emission levels, and energy efficiencies.

To form recommendations and conclusions we have addressed the following:

- Clarified the goals and objectives of the Brent Council with regards to EfW in the Wembley Regeneration Area
- Determined how waste is handled in Brent
- Characterized the state of the art in EfW Technologies
- Evaluated and recommended EfW options suitable for Wembley

The team has conducted a series of interviews with key informants, including Council members, waste management experts, and stakeholders in the Wembley Regeneration Area in order to gather views and opinions on EfW. The following report was developed for the Brent Council in order to present a view of the available technologies, looking at both the advantages and disadvantages of each, as well as provide recommendations for application in Wembley.

6.0 Background

6.1 Waste Generation and Disposal in the United Kingdom

A 2001 newspaper heading declared "Waste mountain threatens London" (Gruner, 2001). This clearly portrays the ever increasing problem that the United Kingdom and London are faced with in this new millennium.

Almost 300 million tonnes of waste were produced in the United Kingdom in 2008. As can be seen in Figures 1 and 2, more than 65% of the waste in the UK is generated by the construction and mining industries, while the household, industrial, and commercial sectors make up the remaining waste.

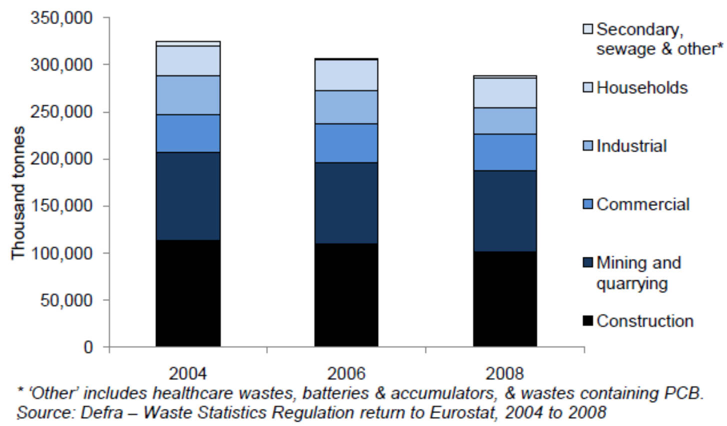

Figure 1: Total UK waste generation by sector

(Department for Environment, Food and Rural Affairs, 2011)

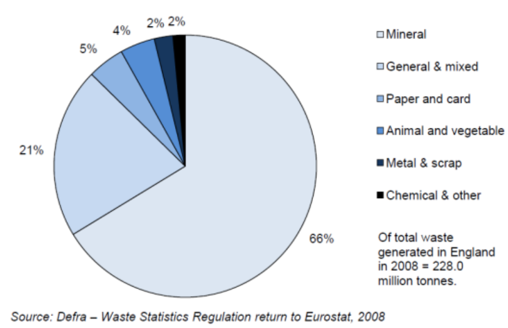

Figure 2: Total waste generation in England by waste type, 2008

(Department for Environment, Food and Rural Affairs, 2011)

As a consequence of the diversity of sources and composition for the waste stream in the United Kingdom, along with the limitations of the existing facilities, waste is treated by one of the three following methods: landfill, recycling, or incineration. Figure 3 shows how the volume of waste treated by these methods has changed over the past decade.

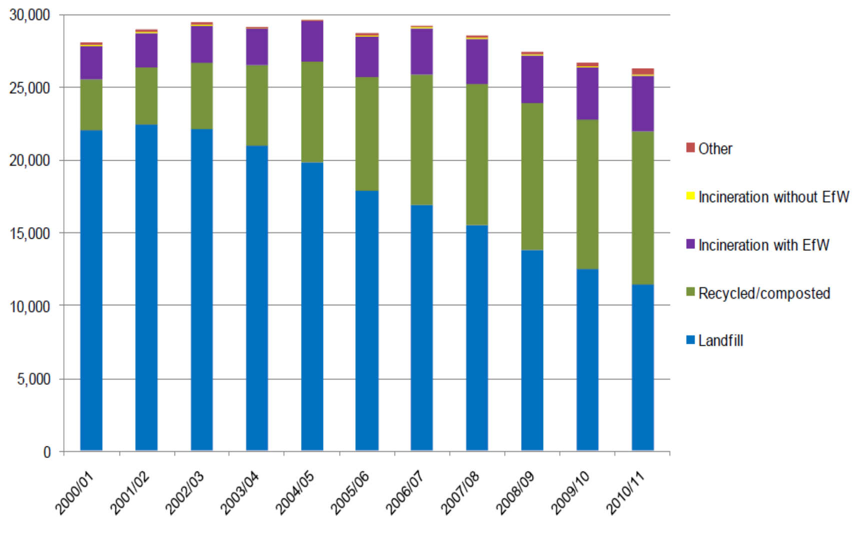

Figure 3: Local Authority Collected Waste Management Methods in England (tonnes)

(Defra, 2011)

The amount of waste collected by local authorities in England has declined in recent years. In particular, Figure 3 shows that the amount of waste going to landfill has declined by almost 50% since 2001, whereas the amount being recycled and composted has doubled. Incineration (with or without electricity generation) has remained a relatively minor disposal method throughout this period.

6.2 Zero-Waste in the UK

In order to deal with the unsustainable levels of waste production in the UK, the governing authorities are working toward a zero waste program. Defra published the Waste Policy Review, a document in which the government reports their findings on waste management and addresses a series of actions to achieve a zero waste economy in England (Waste and Recycling, 2012).

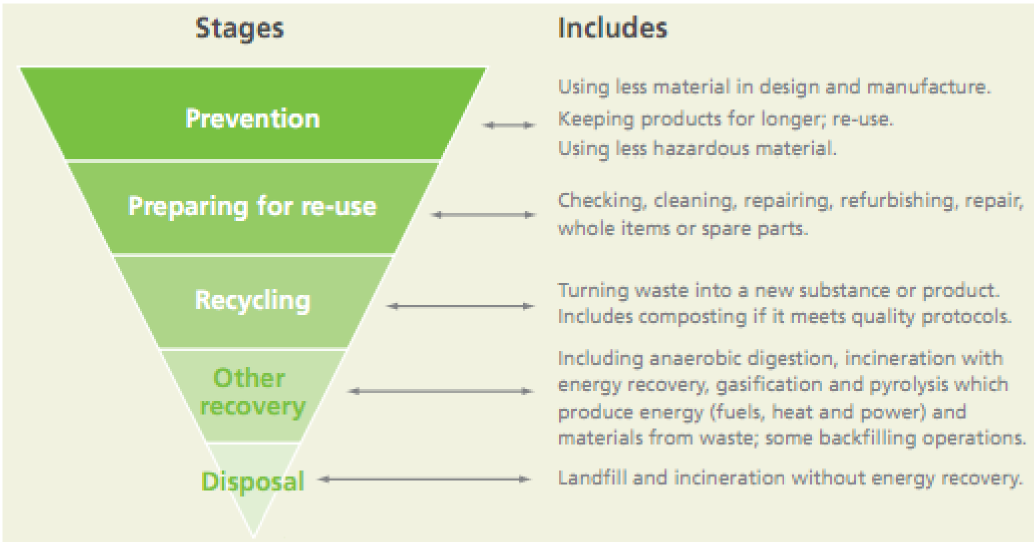

Figure 4: Waste hierarchy

(Defra 2011)

UK policy steers the country towards a more efficient waste hierarchy management, giving top priority to waste prevention, followed by re-use and recycling and other types of recovery such as Energy-from-Waste (EfW), leaving land-filling as a last resort for waste management (Defra, 2011).

To achieve this ‘waste hierarchy’ prioritization, the UK is committed to complying with the Waste Framework Directive (WFD), which was signed in 2008 by the European Union member states. Under this legislation the UK must recycle 50% of household waste by 2020, and recover at least 70% of construction and demolition waste (Defra, 2011). Specific guidelines are set by the WFD in order for the member states to attain such ambitious goals. One example is the Polluter Pays Principle (PPP), which requires companies to offer compensation for any environmental damage that occurs through harmful processes (Waste Prevention Legislation, 2011).

6.3 Landfill Concerns

Figure 5 shows that approximately 60% of London's municipal waste goes to landfill or incineration, often without any form of pre-treatment to recover materials that could be recycled.(Municipal Waste Management Strategy, 2010).

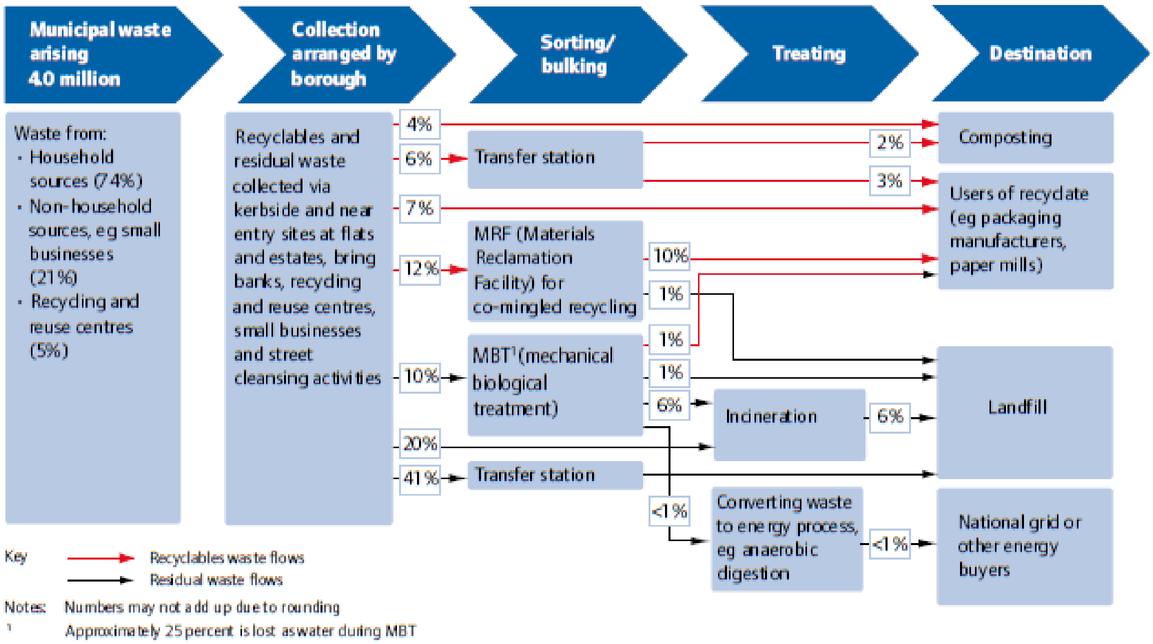

Figure 5: Waste Flow in London

(Greater London Authority, 2011)

The quantities of waste being sent to landfill are causing space for disposal to diminish. In 2008, east and south east England had 80% of landfill capacity available in 1999; however, in the city of London landfill capacity is dangerously close to running out.

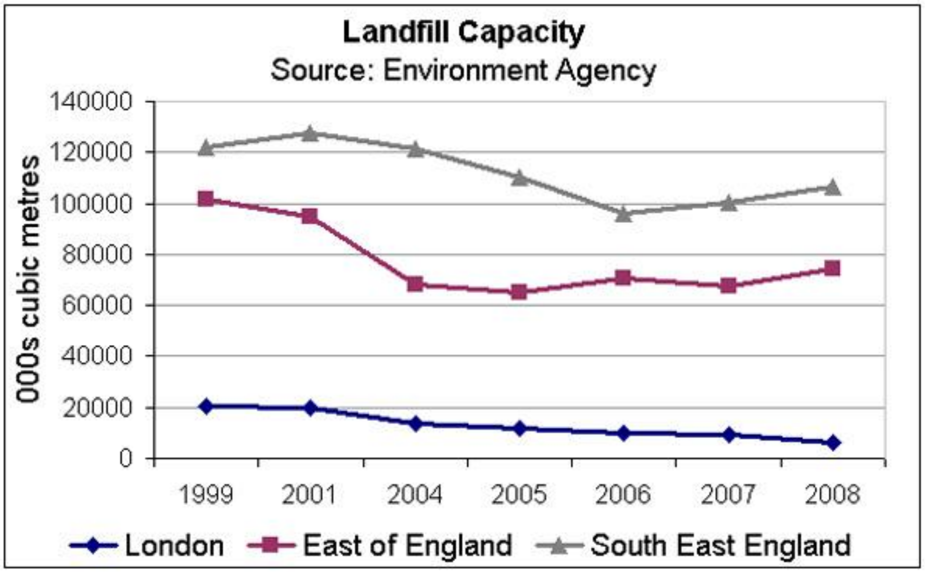

Figure 6: Landfill Capacity

(The Environment Agency, 2010)

The State of the Environment quantifies this reduction: "Landfill capacity within London has decreased since 2000/01, from 20 million cubic meters to 6 million cubic meters in 2008" (The Environment Agency, 2010).

The decreasing landfill space is largely a result of the increasing cost of sending waste to landfill. That is, the expansion of landfills is not economically feasible. In 2010/11 the landfill tax was set at £48 per tonne and will increase every year by £8 until it reaches £80 per tonne. In 2005 the tax was only £3 per tonne. The EU Landfill Directive and Landfill Allowance Trading Scheme (LATS) both set guidelines for the amount of biodegradable municipal waste (BMW) that may be sent to landfill which stipulates anaerobic digestion as a method for managing BMW (London Borough of Brent, 2009)). Under the Waste and Emissions Trading (WET) Act of 2003, the WLWA and the six other collection authorities of London have agreed to split the landfill allowances specified by the LATS equally. Brent must ensure that sufficient municipal waste is delivered to the appropriate recycling, composting, and residual treatment facilities as to not exceed their allocated landfill limitations under the WET(London Borough of Brent, 2005).

6.3.1 Diverting Waste from Landfill with Energy-from-Waste (EfW)

After waste reduction, re-use and recovery, the diversion of waste from landfill can be maximized by converting the residual rubbish into energy. There are several methods through which EfW can be achieved: pyrolysis, gasification, incineration, etc., each with respective advantages and disadvantages further analysed in our Data and Analysis section. EfW is an essential step that the UK must take in order to achieve a zero waste economy.

The UK government does not aim specifically to allocate more waste to the energy recovery process, but instead to get the most energy out of waste. (Defra, 2011). In their review of waste policy, Defra acknowledges some of the benefits of EfW programs, such as the net reduction of greenhouse gas emissions and the reduction of landfill use. Energy recovery is an excellent way of processing waste that cannot be re-used and would otherwise go to landfill.

Even with the projected improvements in waste prevention and in particular reuse and recycle, analysis shows that through 2020 and beyond 2050, enough waste will be available for EfW programs to grow (Defra, 2011). Currently there is the potential for the growth of EfW industry. In 2009/10, 13.6% of local authority collected waste was used for energy recovery and 46.9% was landfilled. It is evident that the waste hierarchy is not being applied to its potential.

Compared to natural gas research indicates that biomethane generated from residual waste could produce greenhouse gas savings of between 66% and 92%. Waste provides a valuable source of biomethane that could be extracted through a number of technologies including anaerobic digestion, gasification and pyrolysis (Defra, 2011).

6.4 Waste Management in Brent

The London Borough of Brent is composed of residential, industrial, and commercial land, making it a challenge to develop a waste management strategy that best suits the needs of the entire Borough. There are also several areas in Brent considered to be deprived which has been associated with discouraging residents to participate in recycling in the past. Many waste management strategies are currently being implemented and developed to pave Brent's pathway towards a sustainable future.

6.4.1 Municipal Waste

"The Brent Household Waste Collection Strategy" (London Borough of Brent, 2009)) was created to improve household waste management in Brent. The primary goal of this strategy is to help Brent make the transition towards "One Planet Living" (London Borough of Brent, 2009)), which targets waste solely as a resource. This strategy correlates back to the waste hierarchy, in that the reduction and reuse waste management techniques should always be the first options considered. Reduction and reuse do not place a demand on new resources and they minimize the environmental impact and costs associated with waste treatment and disposal facilities. Under this strategy new policy has been implemented to improve waste collection throughout Brent. The main objectives derived from this strategy are:

- To encourage greater consideration by residents and communities of waste as a resource through emphasis on reduction, reuse, recycling and composting
- To stimulate investment on reduction and reuse initiatives and take maximum advantage of the economic opportunities that such initiatives could represent for Brent residents
- To stimulate investment in recycling and composting collection schemes to deliver better coordinated services on the ground, improve the environmental performance of waste management operations and achieve high recycling and composting targets
- To target action on materials with greatest scope for improving environmental and economic outcomes
- To achieve efficiency savings and deliver value for money services
- To increase the engagement with residents and partners by communicating and supporting the needed behavioural change

Brent's waste collection and related services, such as domestic refuse collections, bulky waste disposal, and street cleaning, are assumed under the authority of StreetCare's Waste Services Department. The disposal of household waste arising in the London Boroughs of Brent, Harrow, Hillingdon, Ealing, Hounslow, and Richmond upon Thames, is the responsibility of the West London Waste Authority (WLWA).

6.4.2 Recycling and Land-filling

Beginning in October 2011, Brent has a required "kerbside" (Capital Waste Facts, 2011) recycling collection program operated by Veolia Environmental Services which serves 87,927 households. Collections of residual waste and recycling are made on alternating weeks. Recyclables are placed in 240 or 140 litre bins and can contain the following items: aerosols, aluminium foil, cans, cardboard, food and drink cartons, glass bottles and jars, paper, plastic bottles, mixed plastics, and telephone directories. In addition, batteries (car and household), motor oil, shoes, and textiles may be recycled in a separate bag. Mixed garden and food wastes are collected via a 5 litre kitchen caddy and a 240 litre green wheeled bin, or a 23 litre kerbside container. Organic recycling is currently only available for kerbside residents and not those of blocks or flats. There are 97 recycling "bring" sites throughout the borough, of which the following items can be recycled: aerosol, aluminium foil, books, cans, cardboard, cartons (food and drink), CD's and videos, glass bottles and jars, light bulbs, paper, plastic bottles, mixed plastics, shoes, textiles, toner cartridges, telephone directories. Other items, such as wood and televisions may be recycled at the Brent Council reuse and recycling centre. Under Provision W7: Local Recycling Points and Facilities of the Unitary Development Plan (UDP), it is suggested that recycling points be located in accessible, visible, and unobtrusive locations and locations which would be harmful to residential amenity should be prevented. They should also be located in areas that have the ability to attract large amounts of residents such as supermarkets, or public parking lots. Furthermore the recycling points should always be able to handle the waste originating from or around the site (London Borough of Brent, 2004). Residual waste is sorted at transfer stations in Ruislip and Hendon before being transported by railway to Calvet Landfill in Buckinghamshire or Stewartby Landfill in Bedfordshire (Capital Waste Facts, 2011). These landfills are roughly 50 miles outside of London which means that there is much energy to be saved if this waste were to be processed closer to Brent.

It is estimated that 74% of material from an average household waste bin could potentially be recycled in Brent (London Borough of Brent, 2005)). Figure 7 indicates how large a discrepancy there has been between actual and potential recycling rates in the past. It can be seen that from 2004/05 to 2007/08, waste management policy has had a noticeable effect in diminishing waste going to landfill as well as increasing composting and recycling rates. In 2008/09 Brent was recycling 28.2% of its household waste. The targets for recycling in Brent for the years to come are 40% by 2011/12, 50% by 2014/15, and 60% by 2019/20, while the target for overall household waste is to see no yearly increase from 2008/09 to 2014/15. From October 3 of 2011 to January 3 of 2011 Brent has maintained a 42% recycling rate, which is a dramatic increase from the previous years' (London Borough of Brent, 2012).

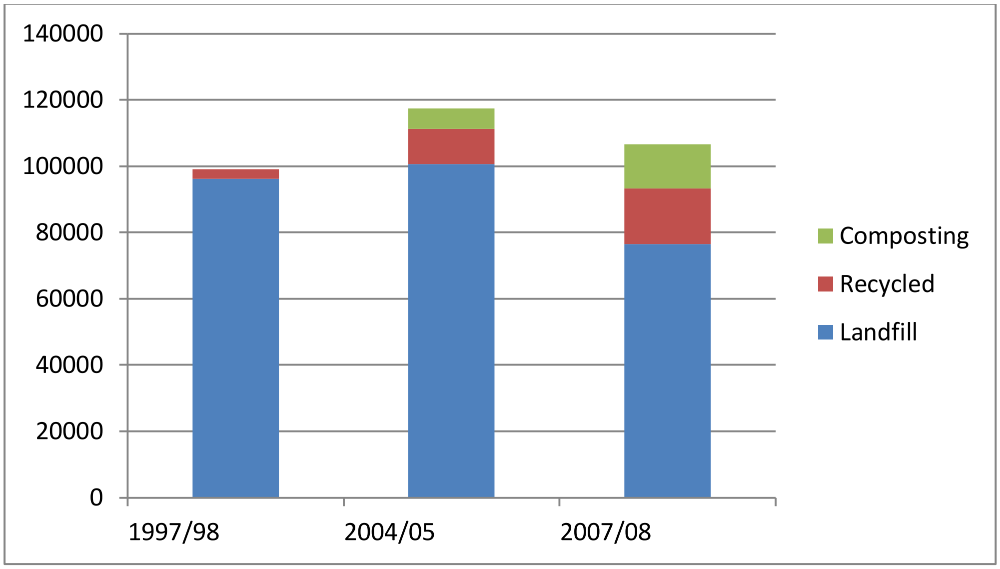

Figure 7: Waste Generation in Brent (tonnes)

Data gathered from (London Borough of Brent, 2005; London Borough of Brent, 2009)

6.4.3 Commercial Waste

Under the UDP, Brent's responsibility for waste land use involves determining applications for change of use to, or development of waste management facilities. The Borough may also need to deal with applications of planning permission of waste which falls outside the Borough's responsibilities, such as private waste transfer facilities and incinerators. The ability for Brent to implement a strategy for dealing with construction, demolition, and commercial waste is not as discernible as the household waste strategy, largely because there is a shortage of available space for large scale recycling facilities combined with the fact that the borough is not responsible for the actual handling of commercial wastes. "The Minerals Planning Guidance 6: Guidelines for aggregates provision in England" suggests that on-site crushing and recycling facilities be a minimum of 4-6 Hectares (Ha). This amount of land is simply not available in Brent. Furthermore, due to the increasing cost of aggregates and the landfill tax, the constructions waste industry will likely increase (London Borough of Brent, 2004)). For this reason, an integral part of our project proposal was assessing how to best address commercial wastes from a policy planning and environmental standpoint.

Although there are many initiatives set in place aimed at decreasing the amount of waste sent to landfills, there will remain some amount of unusable waste. Moreover, as energy costs continue to increase, moving waste to locations outside the borough is cost ineffective. The Wembley Area Action Plan (WAAP) highlights EfW as a possible resolution of two serious issues; waste management and sustainable energy. There are many questions to be answered when evaluating EfW possibilities in Brent: Is it economically feasible? How much land is required for facilities? Can EfW facilities be integrated into existing waste management facilities? What type of job opportunities are there? How we will go about evaluating the various questions that arise with EfW in Brent is discussed in greater detail in our methodology section.

7.0 Methodology

7.1 Introduction

The London Borough of Brent is currently procuring future policy to facilitate energy-from-waste (EfW) recovery from waste that cannot otherwise be reused, or recycled. Our overall project goal was to assist the procurement of this policy. Specifically, we were asked to evaluate the possibility of an EfW program in the Wembley Regeneration Area. The four objectives that we have developed in order to accomplish this project goal include:

- Clarify the goals and objectives of the Brent Council with regards to EfW in the Wembley Regeneration Area
- Determine how waste is handled in Brent
- Characterize the state of the art in EfW Technologies
- Evaluate and recommend EfW options suitable for Brent

Our final deliverable to the Brent council is a technology comparison matrix that contains a condensed version of our results. The first column of the matrix contains the different available EfW technologies and the rows of the matrix are comprised of the criteria with which the technologies were evaluated. The unfilled matrix can be seen in Figure 8. The information contained in the matrix is discussed in the Data and Analysis chapter (Chapter 8).

	ECONOMICAL			TECHNICAL SPECIFICATIONS													ENVIRONMENTAL								SOCIAL
WTE Technologies	Capital Cost (000,000 GBP)	Pay Back Period (years)	Government Incentives	Expected Lifetime (Years)	Energy Yield (kWh/ton of MSW)	Net Energy Efficiency (%)		Net Calorific Value of Syngas (MJ/N-m^3)	Land Required (ha)	Building height (m)	Stack Height	Modular Capability	Type of Feedstock	Quantity of Feedstock (000 tpa)	Number of operational facilities using the technology in the UK	Emissions (mg/N-m^3)						Byproducts Created	Lifecycle assessment of greenhouse emissions (Kg CO_2 eq)	Average Workforce Required
						Electricity only	CHP									PM10 (10)	NOx (200)	HCL (10)	SOx (50)	Hg (0.05)	Dioxins/Furans (0.1 ng/N-			
Pyrolysis																								
Gasification																								
Plasma Arc Gasification																								
Anaerobic Digestion (AD)																								
Incineration																								
Landfill																								

Figure 8: Blank EfW Technology Comparison Matrix

7.2 Objective 1: Clarify the goals and objectives of the Brent Council with regards to EfW in the Wembley Regeneration Area

In order to clarify the goals and objectives of the Brent Council with regards to our project goal, a combination of archival research and interviews or conferences were used. We first triangulated energy and waste policy within the Brent Council, Greater London, and National Policy and Planning documents, such as the Local Development Framework (LDF), Brent's Waste Strategy, the GLA's Waste Strategy and Energy Strategy, and the National Policy Planning Framework. Another important document closely tied into our project is the WAAP and more specifically the "Business, Industry and Waste", and "Response to Climate Change" chapters. These chapters highlight EfW as a joint solution to manage waste effectively while also providing renewable energy.

As we worked alongside the planning department, it was important to have working knowledge of how the planning department functions, as well as what role they play in large scale developments such as EfW. We consulted Joyce Ip, our liaison with the Brent Council, to generate an understanding of how this type of policy gets developed. The Brent Council does not have the capital to invest in an EfW development. Instead the council's role is to encourage and guide private developers to implement an EfW recovery scheme through their planning policy and guidance documents.

Interviews with Joyce Ip, our liaison within the council, and Ken Hullock, head of the Planning Services targeted three goals: The first was to generate a precise understanding of the scope of our project in order to provide Brent with information that would be most useful. The second objective was to fully understand the policy making and political dynamics of the London Borough of Brent. The third was to gain contacts within the council as well as other organizations, such as the WLWA, the GLA, the LWRB, and key developers in Wembley such as Quintain that could assist us in our research. From our initial interviews we confirmed that the Council hoped to obtain evidence to determine the feasibility of EfW in the Wembley regeneration area from an economic and environmental standpoint. More specifically, the Council is looking for evidence to support a new section of the WAAP on waste management, which will be subjected to public consultation this summer. Mr Hullock and Ms Ip had many suggestions for who we should start getting in touch with, including valuable contacts within the council as well as other organizations affiliated with waste management.

7.2.1 Council Interviews:

Before each in-council interview we did background research on the interviewee's role in the council, and sent them a list of some of the information we were hoping to acquire during the upcoming meeting. As we interviewed more staff we enhanced our knowledge of what factors must be addressed when considering the feasibility of an EfW recovery program in Wembley. With each interview came more answers as well as more questions. Below is a list of the Council members that we have consulted, and a general summary of the type of information that we acquired from them.

7.2.1.1 Recycling and waste:

- **David Pietropaoli** – Waste Policy team Leader

Explained the waste flow of Brent in detail, expressed his support for EfW and how the community would benefit from such a project

- **John Rymer** – Recycling and Environment team Leader

Further explained waste flow in the borough, how dirty Material Recovery Facilities (MRF) work, and what companies are in charge of commercial waste disposal in Brent.

- **Chris Whyte** – Head of Environment Management

Provided more details of the waste flow, explained the responsibilities of the council and the WLWA regarding waste management.

7.2.1.2 Civic Centre:

- **Russell Burnaby** – Project Coordinator for the Civic Centre

Provided information on the sustainability of the new Civic Centre, specifically details of the CHP running on fish oil that will provide for the building's energy requirements.

7.2.1.3 Environment and Protection

- **Yogini Patel** - Senior Regulatory Service Manager

Explained the possible health impacts the technologies might have and what parameters are the most important to consider.

- **Stephen Inch** – Enforcement Officer

Explained the regulations relevant to EfW, at national, regional, and local levels, and expanded on possible barriers for EfW implementation in the borough.

7.2.1.4 Area Planning:

- **David Glover** – Deputy team Manager

Explained the process of approving planning proposals.

- **Neil McClellan** – Area team Manager

Explained the process of planning proposals and possible overrules by the Mayor or central government in special circumstances. Explained what approaches might be taken by the Council to support EfW initiatives.

- **Stephen Weeks** – Head of Area Planning

Explained the national policy on waste management, emphasizing recent changes. Also explained the process of public consultation and vision of possible outcomes of EfW in Brent.

7.2.1.5 Environment and Projects Policy:

- **Jeff Bartley** - Environment Projects and Policy Manager

Provided information on the movement and efforts of the Council and Brent residents to promote environmental sustainability. Gave his opinion on why he does not endorse EfW, and is looking for evidence to convince him otherwise.

- **Emily Ashton** - Environmental Projects and Policy Officer

Gave us insight on environmental standards that Brent is trying to achieve which an EfW program will have to comply with.

After conducting the interviews above, some criteria in the EfW technology comparison matrix were updated in order to reflect the comments and suggestions of the interviewees.

7.3 Objective 2: Determine how waste is handled in Brent

There are two distinct waste management operations to consider when evaluating the waste flow in the borough: collection and disposal. These operations cannot be combined since the Brent Council is only responsible for the collection of municipal waste, whereas disposal is the responsibility of the West London Waste Authority. The Brent Council is not responsible for the collection of commercial waste, which further reduces the council's decision-making power regarding waste management. Interviews with external stakeholders provided valuable insight on the implications of the current waste operation logistics and how EfW fits in.

7.3.1 Collection of Brent's Waste

Council members were able to help us understand Brent's flow of waste in supplement to data that we could not find archived online on resources such as Defra and the Brent Council archives. Defra has statistics regarding the waste of the greater London area, such as waste production by type, sector, and how those trends have evolved over time, as well as projections for the future. We were unable to find any in depth statistics on Defra specific to Brent which is critical for judging the requirements of an EfW facility. The Brent archives showed improvements on how Brent manages their waste and what tactics are being used to manage waste more effectively.

We sought a breakdown of the most recent tonnages of waste produced in Brent, including what waste streams composed of what percentage in relation to the total amount of Brent's waste. The ideal result of EfW would be that Brent makes the move towards self-sufficiency.

Garden and food waste are currently being collected and disposed of together, which has implications for potential EfW developments. Within the Brent Council, John Rymer, Recycling and team Leader, Chris Whyte, Head of Environment Management, and David Pietropaoli, Waste Policy team Leader, were interviewed to obtain the data indicated above.

7.3.2 Disposal of Brent's Waste

To identify where each waste stream goes we interviewed Jim Brennan, the director of the Waste London Waste Authority. Mr Brennan explained the difference between the two types of MRFs that handle Brent's waste and where waste is sent after it is processed at MRFs. He also discussed the WLWA's procurement of a contract for EfW treatment of their waste. This is a major consideration for our project as it puts constraints on EfW development in Wembley.

7.3.3 Commercial Waste in Brent

We interviewed key stakeholders involved in Wembley's Regeneration, such as representatives in Quintain Estates & Development PLC and Wembley Stadium, to gather information on how commercial waste streams are handled in the area. Quintain is the main developer of the Wembley regeneration area. They own approximately 85 acres of land in Wembley City, which represents the majority of the regeneration area. Gaining knowledge on their views regarding waste management and EfW was crucial. Wembley Stadium is the landmark of the borough and a national symbol around which the development area is centred. Their standpoint on EfW is an important consideration for any potential EfW project.

Commercial waste is an important consideration in determining the feasibility of EfW recovery in Wembley, but it is also something the Council currently has no authority over. Veolia is a major waste management entity in the UK for both commercial waste streams. The company is also responsible for the disposal of consumer, food, and garden waste in Brent. We interviewed James Saunders and Anne Clements, from Quintain, to acquire information on how Quintain's waste streams could contribute to an EfW development. They also provided us with information on their experience in trying to implement district wide CHP. They explained the specific changes and conditions required for these two things to happen. Adrian Wyatt, CEO of Quintain, provided us with his views on how EfW could be incorporated into Quintain's developments.

7.4 Objective 3: Characterize the state of the art in EfW Technologies

To assess the feasibility of an EfW development in Wembley, the next step was to identify the available EfW processes, as well as how each process works. Data on the processes was available through archival research, however many EfW schemes in the UK were looked into further. Data was gathered from the analysis of case studies, scholarly articles, and interviews with several EfW developers in the UK.

The team interviewed experts on EfW, including Brent Council personnel as well as individuals from the private sector. Russell Burnaby, a Project Coordinator for the Civic Centre, gave us information on the fish oil micro-renewable project that will power the Civic Centre. Chris Lee, from Environmental Power International (EPi), a pure pyrolysis start-up company, Jon Garvey from Shore Energy, a pyrolysis company in Scotland, provided us with metrics of the pyrolysis technology and views on the future market outlook. Patrick McConville, of Energos, gave us specific information on the gasification process, and Roger Saverin, of Wheelabrator Millbury, explained the state of art in incineration. Through interviewing these experts in the field, key data, views, and opinions that could not be found through archival research were gathered. For example, we wished to know if the increase in recycling rates would have negative impacts on the economics of EfW. We also wanted to know what the payback periods were for the different types of plants, as well as what feedstock they use to fuel the facilities.

A document called Rubbish in Resources out, by Dow Jones Architects and Arup, outlines design ideas for potential waste facilities in London and provides interesting case studies of some of the newest plants. In this document generic locations are identified for EfW concept designs; one location was an industrial park. We interviewed Arup to discuss Wembley Industrial Park as a possible site for EfW.

A list of all the external companies and major stakeholders interviewed is included below:

7.4.1 Government agencies:

7.4.1.1 London Waste and Recycling Board

- **Antony Buchan –** Business Development Unit Member

Explained the role of the LWARB as a strategic investor for critical environmental projects. Provided information on what the organization considers viable proposals for EfW.

7.4.1.2 West London Waste Authority

- **Jim Brennan** – Director

Provided data on the waste distribution among the six boroughs that the authority governs. Gave details of the procurement currently being undertaken by the WLWA to build a medium size EfW facility that processes waste from all six boroughs.

7.4.1.3 North London Waste Authority

- **Stephen Cook –** Arup Consultant

Explained that the North London Waste Authority is focused on implementing more incineration programs in the area because incineration is a proven technology, whereas ATT technologies are not. This is what makes the funding procurement process of non-proven technologies difficult.

7.4.1.4 Greater London Authority

- **Larissa Bulla & Peter North** – Environment Programme

Provided us with the Central Government's view on EfW technologies and their vision of where these technologies will fit in the larger scheme of things in the long term future.

7.4.1.5 Environment Agency

- **Mike Tregent -** Principal Officer (Waste and Resource Management)

Explained the Environment Agency's stance on EfW, specifically its technology neutral position and its selection criteria based on EU emissions regulations and its compliance with the waste hierarchy. The Environment Agency does favour CHP due to increase in efficiency.

7.4.2 Energy-from-Waste & Private Waste Management Companies

7.4.2.1 Energos Ltd.

- **Patrick McConville** – Business Development Manager

Provided an overview of the company's gasification technology, as well as benefits and constraints faced during the planning process.

7.4.2.2 Environment Power International

- **Chris Lee –** Business Director

Explained the company's patented pure pyrolysis technology. Provided valuable information of the economic aspects of the EfW market.

7.4.2.3 Shore Energy Ltd.

- **Jon Garvey** – Project Director

Explained the project the company is currently undertaking at Carnbroe, at the A8 road that connects Glasgow and Edinburgh. Further emphasized the importance of public perception on EfW and how it impacts the local politics and decision making.

7.4.3 Local Developers:

7.4.3.1 Quintain Estates & Development PLC

- **Adrian Wyatt** – CEO

Provided us with his views on sustainability and how EfW can be implemented in future developments. He provided us with contacts in Quintain.

- **Louise Ellison** – Head of Sustainability

Considers EfW as a medium term solution to the current landfill problem. Quintain would invest in EfW only if it justifies the capital investment and the technology in question is proven. Explained the initiative behind the development of the ENVAC system.

- **James Saunders & Anne Clemens –** Operational Activities in Wembley & Planner

Explained that the company plans to steer the regeneration area development towards district heating in the future. Quintain would not build an EfW facility; they would participate by providing the land.

7.4.3.2 Wembley Stadium

- **James Huartson** – Head of Sustainability

Explained the stadium is already a zero-waste-to-landfill facility. 75% of waste collected after games is recycled, the remaining 25% is sent to EfW. The main driver is to reduce waste and buy energy from the most sustainable provider. The Stadium has looked into anaerobic digestion.

7.4.4 Other:

7.4.4.1 Brent resident

- **Rosamund Baptiste** – Local Energy Advice Centre

Commented that local residents might approve an EfW project depending on its location. Mentioned that there will always be opposition but also highlighted how the community might benefit from such project (access to cheaper energy).

7.5 Objective 4: Evaluate and recommend EfW options suitable for Brent

After analysing each technology, we needed a method for realizing which would be the most applicable in the Wembley Regeneration Area. To do this we created a technology comparison matrix in consultation with waste experts and council staff, in which key criteria for choosing an EfW technology can be evaluated efficiently. Our hope is that in the future when an EfW project is being considered, a matrix such as ours could be utilized to identify a technology to research further.

Planners will likely have to negotiate with private energy-from-waste developers so it is important that the council has knowledge on what technologies are available, and how to identify the feasibility of a specific technology. We developed this report for the Council to characterize the state of the art in EfW and makes recommendations for application in Wembley. The goal of the Data and Analysis section is to provide information on the available technologies, looking at both the advantages and disadvantages of each, while also providing technical data and case studies that could be used by the planning department for future developments.

8.0 Data and Analysis

"It is clear that for too long we have worried about how to dispose of waste, but not enough about the use we can make of it" (Defra 2011).

8.1 Overview of waste pre-treatment and *EfW* Technologies

The following section provides detailed descriptions of the technologies that were considered to be potentially applicable for the Wembley area.

8.1.1 Pre-treatment

Before waste can be converted into energy it must be sorted in order to maximize efficiency. Waste should be separated and dried before being sent to an EfW facility either through mechanical biological treatment (MBT), mechanical heat treatment (MHT), or by processing it through a material recovery facility (MRF). This processing is not only important for preparing the waste but it also achieves higher reuse and recycling rates, complying with the mayor's waste hierarchy. After processing, the residual waste can be utilized for energy recovery using thermal or non-thermal technologies.(Dow Jones Architects, 2009)

8.1.1.1 Material Recovery Facility (MRF)

MRF's are often used in conjunction with EfW to process and sort waste to supply a feedstock that can be converted to energy more efficiently. MRF's are used to separate materials for recycling by manual and/or mechanical separation methods. There are two types of MRF's that are utilized in waste management: clean (source-separated) MRF and dirty (non-source-separated) MRF. Clean MRF's are used to further separate these recyclables so that they can be reprocessed. Dirty MRF's take waste from Brent's streets as source separation cannot be monitored. This waste is then separated into residual waste and comingled recyclables.

There is one dirty MRF located in Hannah Close, Wembley, operated by Seneca Environmental Solutions. The facility operates continuously, currently processing 100,000 tpa of waste, but has the capacity to process 1.1 million tpa. The company has a 2 year, renewable contract with the West London Waste Authority (WLWA). About 90% of Seneca's throughput is from the WLWA and 10% is from commercial establishments. Once waste arrives at their facility, it is registered, weighed and then sorted by size. Anything larger than 50 mm is hand sorted and smaller materials are moved down to a flip flow screen, where waste is further separated into fine material (0-10 mm) and larger diameter material (11-50 mm). At this stage, ferrous metals are retrieved by a large magnet. After separation, material is baled and stored for dispatch to reprocessing and remanufacturing facilities. Materials that are rejected are processed as solid recovered fuel (SRF) (Seneca, 2011). A view of the Seneca facility in Wembley can be seen in Figure 9.

Figure 9: Seneca Facility

(Seneca, 2011)

8.1.1.2 Mechanical Biological Treatment (MBT)

MBT is a term for the processes involved in sorting and treating MSW, in order to be usable for EfW or other waste management methods. MBT is separated into two stages: a mechanical treatment followed by a biological treatment. The mechanical stage can vary at each facility however in most cases it involves the removal of recyclable materials and the breakdown of waste into smaller parts. The biological stage most commonly uses an anaerobic digestion system (see section 8.1.2.1) in order to produce a small amount of energy in the process. The purpose of the biological stage is the breakdown of biodegradable material. After the two stages are complete, the waste has significantly decreased in volume. This occurs due to the removal of waste components suitable for traditional recycling, as well as the removal of moisture during the biological treatment. The leftover solid waste is known as solid recovered fuel (SRF) which can be used for energy recovery or sent to landfill if energy from waste is not an option (Friends of the Earth, 2008).

8.1.1.3 Mechanical Heat Treatment (MHT)

MHT are the processes used to pre-treat MSW, involving the mechanical (separation) and thermal (heat) treatment of waste. In most cases the mechanical stage is the same used in a MBT process. The most common thermal stage is known as autoclaving, which is a steam treatment process often used for treating clinical waste. MSW is processed for 45-60 minutes within a pressurized container to reduce the material to a 'fibre' that contains the majority of the solid organic matter, in addition to metals and plastics. Metals and glass are partially cleaned by the process and can easily be removed and recycled. Plastics are deformed in the process and some types become suitable for recycling. Once recyclables have been removed the remaining material (SRF) can be used for EfW.

Steam is applied, as shown in Figure: 10, at a temperature in the range of 120-170 ^{0}C, which is sufficient to destroy bacteria present in the waste. This has benefits in terms of storage, transport and handling of the outputs as they are sanitised, and are free from the biological activity that may give rise to odour problems. There is also a significant volume reduction of the waste. (Defra, 2011)

Figure 10: Mechanical Heat Treatment Vessel

(Defra, 2007)

8.1.2 Proven Technologies

8.1.2.1 Anaerobic Digestion

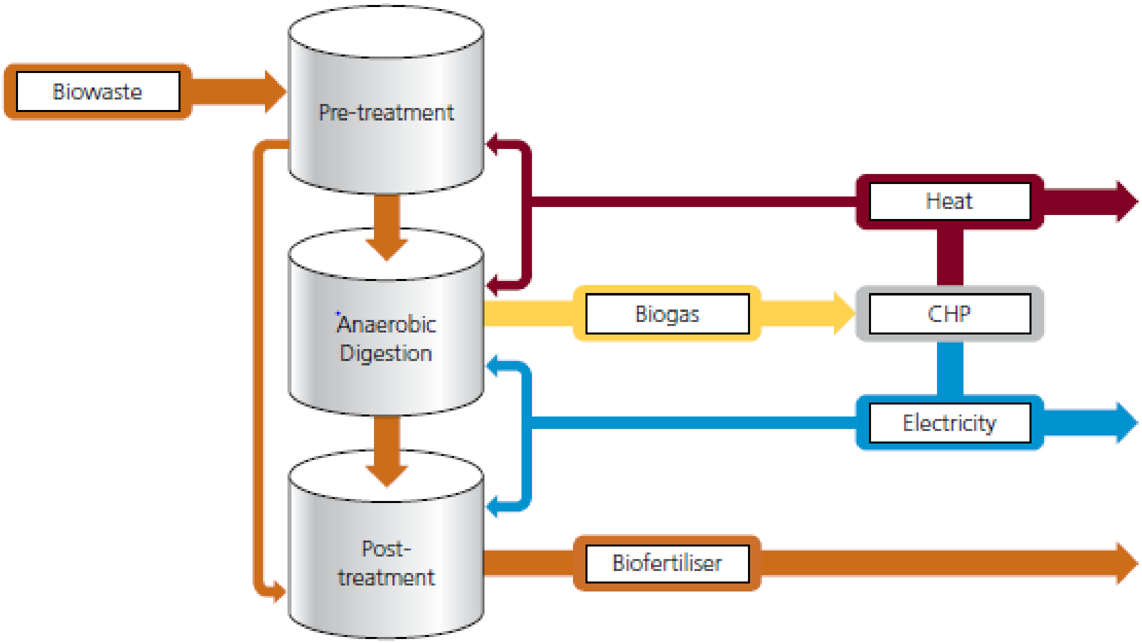

Figure 11: AD Facility Configured to Produce Energy and Biofertiliser from Bio-Waste

(Defra 2011)

Anaerobic digestion (AD) is usually performed as part of MBT. It can be performed on its own, however the energy yields are relatively low and long term sustainability becomes an issue. Without an initial mechanical separation the process can become ineffective because garden waste and non-organics may slow down the digestion. In order to break down organic material, feedstock is put into an anaerobic digester tank and kept at a relatively constant temperature. Bacteria thrive in the warm anaerobic environment and begin to breakdown the biomass. The last phase of the breakdown is done by a methane producing bacteria. This methane gas is then harvested and used for energy.

AD is separated into two types, mesophilic and thermophilic digestion. Mesophilic digestion is performed at around 30-35°C, and requires relatively little energy to maintain that temperature. Thermophilic digestion occurs at temperatures of around 55°C. This type has a quicker throughput and more energy yield; however maintaining this temperature requires significantly more energy. (Friends of the Earth, 2008)

Technical Specifications

- Feedstock: 5,000 -100,000 (tonnes per annum)tpa of Organic Waste Products: Biogas (60% methane 40% CO2); Digestate used as soil conditioner and fertilizer
- Fuel applications: Gas Engines; Vehicle Fuel; Direct Combustion
- Weight Reduction: 50 – 70%
- Energy Recovery: Self Sustainable; Surplus of 0.2MWh/tonne
- Heat Surplus: 0.18MWh/tonne
- Modular Technology

  (Dow Jones Architects, 2009)

Issues and Mitigation techniques

Table 1: AD Issues and Mitigation techniques

Issues	Mitigation Techniques
Requires a consistent feedstock	Mechanical separation of waste stream
Odours	Negative pressure air systems. Limiting the quantity of waste stored at any one time. Mechanical ventilation. Scrubbers
CO_2 emissions from methane combustion	N/A
Other emissions	Each stage of process should be enclosed and airtight so no toxins are emitted before treatment.

(Dow Jones Architects, 2009)

8.1.2.1 Incineration

Incineration involves the combustion of typically unprepared (raw or residual) MSW. To allow the combustion to take place a sufficient quantity of oxygen is required to fully oxidise the fuel. Incineration combustion temperatures are in excess of 850^{0}C and the waste is mostly converted into carbon dioxide and water. Non-combustible materials (e.g. metals, glass, stones) remain as solids known as Incinerator Bottom Ash (IBA) (Defra, 2012)In a municipal incinerator the process consists of three separate stages: “incineration, energy recovery and air pollution control” (Charles H. K. Lam, Alvin W. M. Ip, John Patrick Barford, & Gordon McKay, 2010). The incineration step consists of continuously feeding a furnace with MSW. Much like a traditional coal power plant, the heat produced by the incineration process is used to heat a boiler which creates steam. The steam is then sent through a steam turbine which generates electricity.

Direct burning of MSW releases harmful pollutants into the air. The final step in incineration is reducing these harmful emissions. “A dry/wet scrubber is used to spray fine atomized slurry or lime powder into the hot exhaust gas in order to neutralize the acidic gases such as sulphur oxides and hydrogen chloride.”(Charles H. K. Lam et al., 2010) Several processes afterward work to reduce as much pollution as possible before releasing it into the atmosphere. After the air emissions are monitored, the ash from incineration must be either dumped or recycled if they are composed of heavy metals or other useful properties.(Charles H. K. Lam et al., 2010). The bottom ash typically represents 20% - 30% of the original waste feed by weight, and only about 10% by volume.

For the purposes of this study, this technology is not being researched any further because it is not modular and it would likely lead to an undesirable plant size.

8.1.3 Advanced Thermal Treatment (ATT)

Advanced thermal treatment technologies are different in how the waste is processed and the energy liberated for recovery, i.e. incineration directly releases the energy in the waste, whereas ATT thermally treats the waste to generate secondary products (gas, liquid and/or solid) from which energy can be generated (Defra, 2007b).

8.1.3.1 Pyrolysis/Gasification

Pyrolysis and gasification are often performed in succession in order to maximize energy output per tonne of waste.

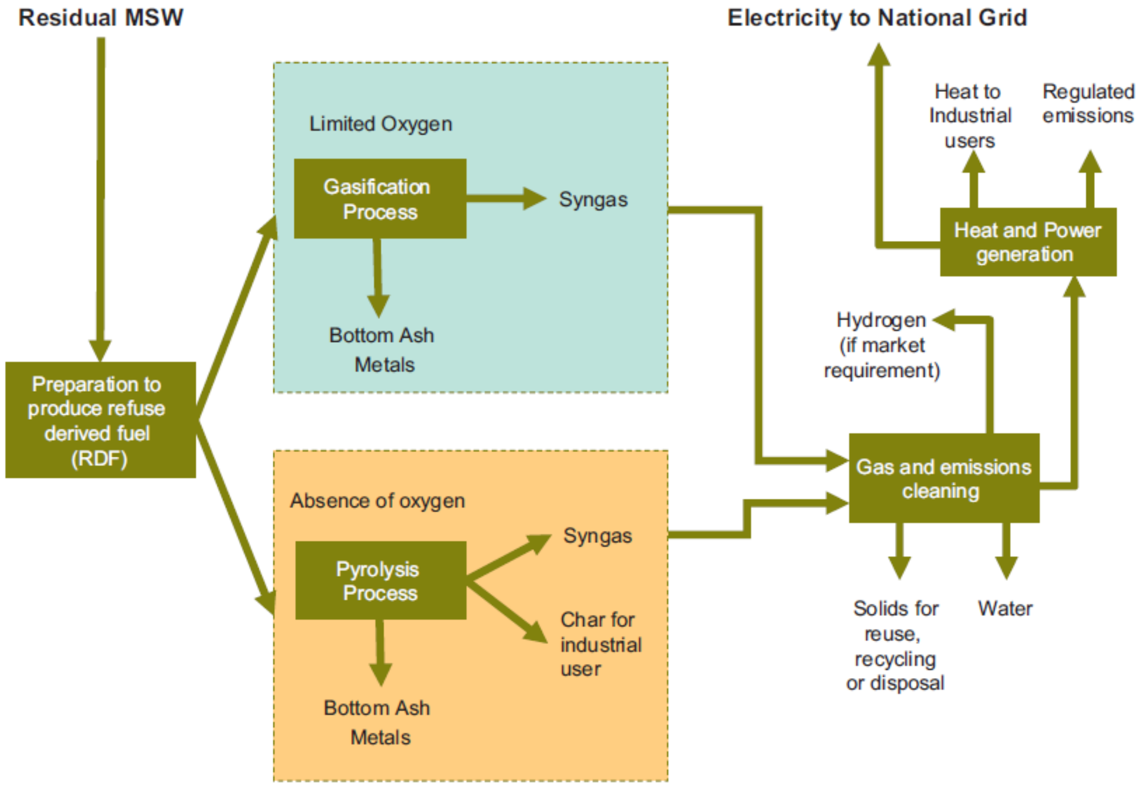

Figure 12: Overview of the Pyrolysis/Gasification Process

(Defra 2011)

Pyrolysis

The pyrolysis process involves creating a synthesis gas, or syngas, by the treatment of MSW or other carbon and hydrogen based materials. To chemically breakdown the waste it is put into an anaerobic atmosphere and heated. With the removal of oxygen, no combustion occurs. The high temperatures break the bonds of organic molecules which produce smaller molecules such as carbon monoxide and hydrocarbon gasses (Young, 2010). These gases make up the syngas which is stored for later use. In combined pyrolysis/gasification any liquids or solids left over from the anaerobic heating process are then sent through a second reactor where gasification is performed.

Gasification

Unlike pyrolysis this reactor is in a low oxygen environment. With the addition of oxygen, combustion occurs. Once the waste has combusted, the oxygen is quickly absorbed and the process becomes anaerobic which creates more hydrocarbon gasses. This syngas, composed of mostly CO and H_2, must first be cleaned extensively in a process known as syngas cleaning to remove particulates and pollutants, such as tars, ammonia, metals, dioxins, and acid gases, before it can be accepted as a fuel into an internal combustion engine (Bartocci, 2009). As an alternative to being used directly as a fuel to generate electricity, biochemical processes can be used to convert the syngas into other practical fuels or chemicals (J.G. Press, 2006). The pyrolysis and gasification processes can both be separately implemented, although several cases show that the two processes together produce a higher energy yield (Young, 2010).

More recently however, emerging pyrolysis technologies suggest that pure pyrolysis plants may offer both higher energy yields as well as an environmentally safer process due to the lack of combustion (Lee, 2012).

Technical Specifications

- Feedstock: 10,000 – 200,000 tpa of high level carbonaceous biodegradable waste (plastics, paper, cardboard, wood, food and green waste), or SRF
- Products: hydrogen rich synthesis gas
- By-products: Char, ash, liquid residues, heavy metals
- By-product applications: Char used as aggregate, heavy metals recycled
- Fuel applications: Gas engines, fuel cells, gas – fired boilers, synthesis of chemicals
- Weight Reduction: 70% (Lee, 2012)
- Energy Recovery: Self-Sustainable; Surplus of 0.7MWh/tonne
- Heat Surplus: 2.0MWh/tonne
- Caloric Value of feedstock: 10 MJ/kg – 17MJ/kg
- Calorific value of syngas (gasification): 4 – 10 MJ/N-m^3
- Calorific value of syngas (pyrolysis): 10 – 20 MJ/N-m^3
- Conversion efficiency: approx. 30%,when combined with CHP up to 70%
- Modular Technology

  (Dow Jones Architects, 2009), (Defra, 2007a)

Issues and Mitigation techniques

Table 2: Pyrolysis & Gasification Issues and Mitigation techniques

Issues	Mitigation Techniques
Odours	Negative pressure air systems, proper storage of waste, mechanical ventilation, air-locks.
CO_2 emissions from methane combustion	N/A
Other emissions	Extensive scrubbing, active carbon, cyclones, electrostatic precipitators, fabric filters.

8.1.3.2 Plasma Arc Gasification

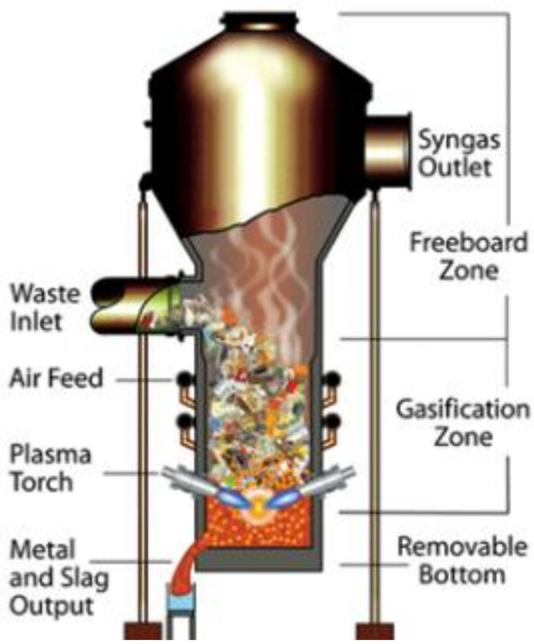

Figure 13: Plasma Arc Gasification Facility

(Bhasin, 2009)

A more recent method called plasma arc gasification uses a process similar to high temperature pyrolysis. In plasma arc gasification, plasma torches heat the air ejected from nozzles to a temperature of about 4000 - 7000 °C (Young, 2010), hotter than the surface of the sun. At these high temperatures, organic materials break down in a process called molecular dissociation in which the molecules become volatized (i.e. turned into gases). The resultant synthetic gas (syngas) can be used as a fuel source (Strickland, n.d.).

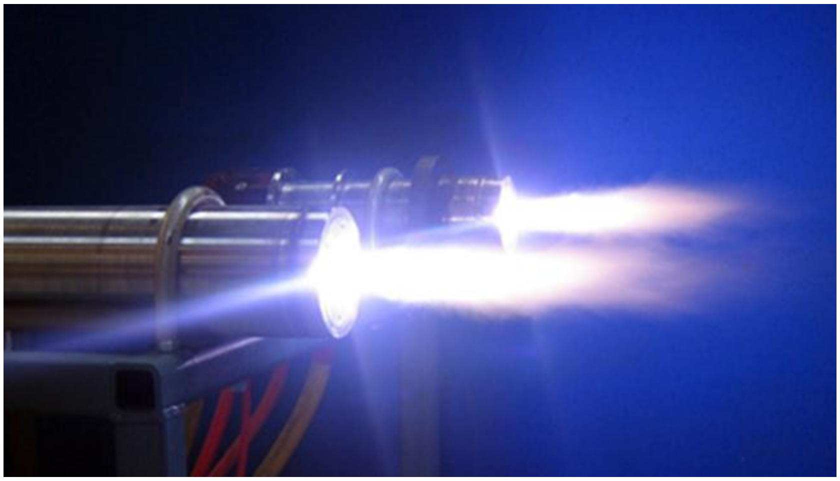

Figure 14: Plasma Torches

(Strickland, n.d.)

“The inorganic substances of the feedstock [waste] are melted by the high-temperature air to form a solidified vitrified slag in which undesirable materials such as heavy metals and dangerous acids are trapped” (Zhang, Dor, Fenigshtein, Yang, & Blasiak, 2011). The slag, which is a rocklike material, can then be cleaned and processed into building material to completely eliminate the need for disposal of its components (Zhang et al., 2011). Unlike incinerators, there is no burning (or oxidation), in the process. Instead, the heat from the plasma causes pyrolysis. With most of the harmful components captured in the vitrified slag, there is a large reduction in pollutants emitted from a plasma arc facility. Although it is costly to maintain plasma torches at such a high temperature, the energy yield of plasma arc gasification is larger than some other options.

Technical Specifications

- Feedstock: 10,000 tpa –70,000 tpa of any residual waste
- Products: Hydrogen rich synthesis gas
- By-products: Vitrified slag
- Fuel applications: Gas engines, *fuel* cells, gas – fired boilers, synthesis of chemicals
- Weight Reduction: 80%
- Volume Reduction: 95% (Strickland,)
- Energy Recovery: 1MWh/tonne
- Heat Surplus: *No Information*
- Caloric Value of feedstock: *No Information*
- Conversion efficiency: *No Information*

(Dow Jones Architects, 2009)

Issues and Mitigation techniques

Table 3: Plasma Arc Gasification Issues and Mitigation techniques

Issues	Mitigation Techniques
Not Proven Technology in UK	NA
Vitrified slag is difficult to find buyers for	Companies can contract developers interested in the building material
Plasma arc gasification requires a non-separated waste stream to operate at peak efficiency	Smaller scale facilities will require less feedstock to be self-sustainable.

8.2 Current flow of Waste in Brent

8.2.1 Municipal Solid Waste

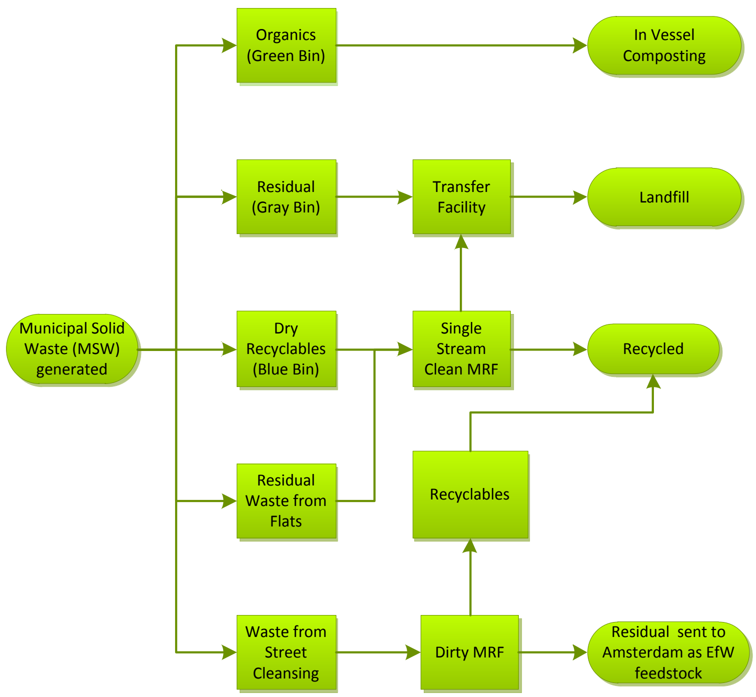

Figure 15: Flow Chart for Brent's MSW

In the borough there are two distinct actions to handle waste; collection and disposal (Brent Council). The Council is in charge of the collection of consumer waste, while the disposal is handled by the West London Waste Authority (WLWA). According to Jim Brennan, the director of the WLWA, 700,000 tonnes of municipal solid waste (MSW) are currently produced per year in the six boroughs which the WLWA is responsible for. These boroughs are Harrow, Richmond Hillingdon, Brent, Ealing and Hounslow. In 2010-2011 Brent produced 106,573 tonnes of MSW (approximately 15.3% of the total managed by WLWA).

Not all waste collected in the borough can be considered for EfW. The total amount of waste aforementioned can be further broken down into several categories: The total waste stream consists of approximately 20% dry recyclables, 20% food and organic waste, and 60% is residual waste. Out of that 60% residual waste, most is sent to landfill and there is a small percentage being sent to energy recovery facilities. Residual waste is sorted at transfer stations in Ruislip and Hendon before being transported by railway to Calvet Landfill in Buckinghamshire or

Stewartby Landfill in Bedfordshire (Capital Waste Facts, 2011). These landfills are roughly 50 miles outside of London. Dry recyclables should not be considered as part of the potential waste stream due to the borough's focus on reuse and recycling over EfW recovery. (Pietropaoli).

8.2.2 Industrial Waste

Industrial waste would not be an optimal feedstock for an EfW facility in Wembley. Waste produced in industrial applications in Brent is currently the responsibility of the developers and not that of the Council. To handle their waste, developers must contract private companies such as Veolia, Biffa, Viridor or other waste collection organizations. The construction and demolition industries are currently London's best recyclers, recycling nearly 85% (Dow Jones Architects, 2009) of their waste produced, whereas consumers are recycling roughly 40%. With such a high recycling rate, the construction and demolition waste streams are not suitable for an EfW facility. Furthermore, construction waste would not be optimal for energy conversion because most materials in this waste stream do not have a high calorific value.

8.2.3 Commercial Waste

Commercial waste could play a role in an EfW facility for Brent. Commercial waste is sometimes included in the MSW collected by the councils; however this is not the case in Brent. The collection and disposal of the commercial waste stream is the responsibility of the business that produces it. To handle their waste businesses in Brent contract waste collection companies independently. There is very little information available on this waste stream as a consequence of it being handled privately.

8.2.4 Envac System

Figure 16: Envac Disposal System

(Envac Group, n.d.)

The Envac system transports waste and recyclables using underground vacuum technology which replaces old-fashioned refuse rooms and bins. The system is housed beneath the ground which eliminates the need to come into contact with waste bags or containers. This mitigates the typical problems associated with waste such as unpleasant odours and sights. The waste bags are sent into the underground network and are sucked away to the waste collection station at speeds of up to 70 km/h and over distances as long as 2 km from the waste inlets. The system has the potential to serve 8,000 residential units within the Quintain master plan in Wembley City (Envac Group, n.d.).

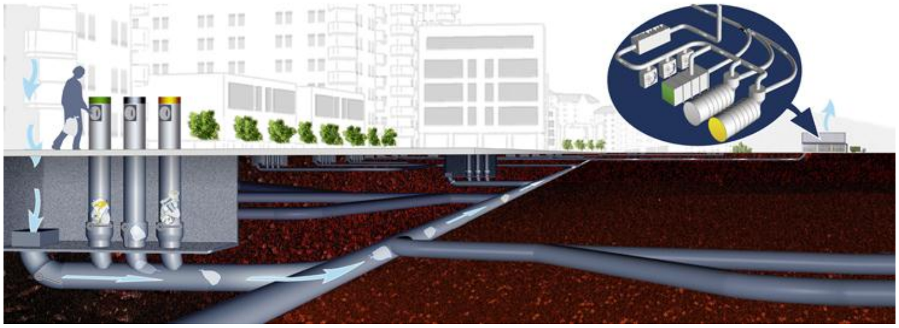

Figure 17: Envac Subterranean Illustration

(Envac Group, n.d.)

8.2.5 Future Projections

8.2.5.1 MSW Projections

Although there is expected increases in reuse and recycling in the borough, the total amount of waste produced in Brent is expected to increase throughout the next decade (London Plan). According to the Mayor's waste management strategy, London will pursue a 50% recycling rate by 2020 and a 60% recycling rate by 2031.

The London plan estimates Brent's MSW production for the next two decades; however the estimate for the first projection year, 2011, is close to 30,000 tonnes greater than the actual MSW production in the borough. We thus projected Brent's future waste production by taking the linear regression of Brent's projected waste increments (from the London Plan) and used the current waste production value of 2011/12 as the initial point. The mayor's recycling targets for upcoming years were used to find the left-over residual waste. Our MSW projections are illustrated in Figure: 18.

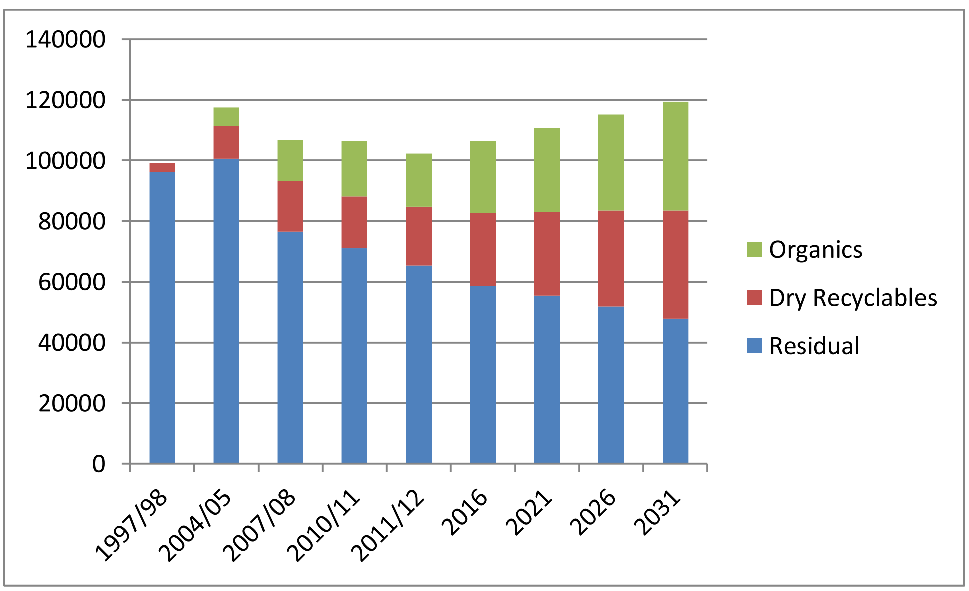

Figure 18: MSW Projections 1997-2031

Our residual MSW projections for 2020 and 2031 are shown in Table: 1

Table 4: Projected Residual Waste

Future Date	Projected Recycling Rate	Projected Tonnage MSW (tpa)
2021	50%	55,000
2031	60%	48,000

Using the same model above we can estimate the amount of food-waste that would be available for anaerobic digestion in the borough. Currently half of the total recycled material in the borough is organic waste. Combined, the amount of garden and food waste is roughly 20,000 tpa. Assuming half of this figure is food waste, there is about 10,000 tpa of food waste currently available for AD. Using this model, we estimate future food waste production by using the organic waste projections from Figure: 18. Organic waste is not currently being collected from flats. If this were to change there would be an additional increase in the amount of food waste available for AD.

Table 5: Projected Food Waste

Future Date	Projected Recycling Rate	Projected Tonnage Food-waste (tpa)
2021	50%	14,000
2031	60%	18,000

8.2.5.2 Combined Commercial& MSW Projections

An EfW facility could potentially treat both commercial/industrial and MSW. By using the preceding model with the Mayor's 70% commercial recycling/reuse target and Brent's commercial/industrial waste projections, we can predict Brent's total (commercial/industrial & MSW) waste production for upcoming years. The combined MSW & Commercial Projections can be seen in Figure: 19.

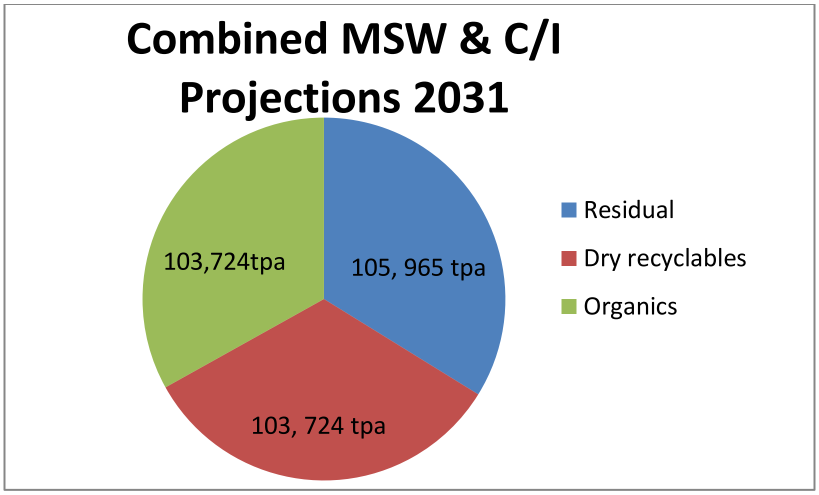

Figure 19: Combined MSW & Commercial/Industrial Projections 2031

In conclusion, Brent's residual waste production will decrease over time, whereas organic and dry recyclable production will increase. Our projected waste stream values for 2031 would be manageable by both ATT and AD.

8.3 Political and Economic Background

Waste management is a complex issue. There are many different stakeholders involved in waste management, including the central and local government, and the public and the private sectors. The Council is in charge of funding the collection and disposal services, and hires private contractors to do collect waste. The WLWA is in charge of the actual disposal of the waste. The collection and disposal of the waste is a frontline service, funded through taxes, and is one of the major interactions the residents have with the council. The public thus expects the proper collection and disposal of their waste. As a consequence of all of the various stakeholders, EfW implementation is a difficult feat.

One major barrier that the technologies face is securing capital funding. Financial risk is directly related to each technology and it is often challenging to attract finance for less proven technologies. This can lead to difficulty in proving emerging technologies, and thus a vicious circle is created. The government has already acknowledged this issue, and it is well explained in the Government Review of Waste Policy in England:

The Government will also provide the necessary framework to address market failures and ensure the correct blend of incentives are in place to support the development of recovery infrastructure as a renewable energy source (*Government Review of Waste Policy in England 2011*.).

8.4 Financial Incentives

Capital investment can be daunting for companies procuring EfW contracts, as they generally require substantial funding. Companies are uninterested in pursuing EfW options unless they are presented with a feasible economic case. Renewable energies, such as EfW technologies, can benefit from financial incentives if they meet specific criteria.

8.3.1 London Waste and Recycling Board

The London Waste and Recycling Board (LWARB) and the central government offer financial incentives for certain EfW projects. "The LWARB was established by the GLA Act [in] 2007 to promote and encourage the production of less waste, an increase in the proportion of waste that is re-used or recycled and the use of methods of collection, treatment and disposal of waste which are more beneficial to the environment in London." (LWARB, 2011) The LWARB will invest 10%-25% of the capital needed to fund projects depending on the size and cost of the facility. There are two types of investments: The Infrastructure fund, and the Innovation Fund. The Infrastructure fund does not commonly invest in pilot technologies, but instead invests in proven ones. The Innovation fund was created to help push proven technologies to greater efficiencies. This fund focuses on changing the operating conditions in order to improve the technology.

8.3.2 Renewable Obligations (RO) & Renewable Transport Fuel Obligation (RTFO)

The major government incentive that supports renewable energy is the renewable obligations (RO) program, which came into effect in the UK in 2002. This program requires that energy suppliers disclose that a percentage of energy supplied to their customers comes from renewable sources. RO awards renewable obligations certificates (ROC's) to companies that produce energy from renewable sources. On average, a company will receive one ROC for each MWh of energy produced. The energy generators can then sell their ROC's to suppliers, who must meet a set amount of ROC's in order to avoid a fee at the end of each fiscal year. The proportion of renewable energy from suppliers is steadily rising and it is expected that by 2015 15.5% of energy supplied will be sourced from renewable energy generators (BWEA, n.d.).

8.3.3 Landfill Deterrents

Mitigation techniques used to divert waste from landfill encourages EfW as a viable alternative to managing waste. Some significant incentives are the landfill tax, the EU Landfill Directive targets for biodegradable municipal waste (BMW), and LATS. In 2010/11 the landfill tax was set at £48 per tonne and will increase every year by £8 until it reaches £80 per tonne. In 2005 the tax was only £3 per tonne. The EU Landfill Directive and Landfill Allowance Trading Scheme (LATS) both set guidelines for the amount of BMW that may be sent to landfill stipulating anaerobic digestion as a method for managing BMW (London Borough of Brent, 2009)). Under the Waste and Emissions Trading (WET) Act of 2003, the WLWA and the six other disposal authorities of London have agreed to split the landfill allowances specified by the LATS equally. Brent must ensure that sufficient municipal waste is delivered to the appropriate recycling, composting, and residual treatment facilities as to not exceed their allocated landfill limitations under the WET(London Borough of Brent, 2005).

8.3.4 Renewable Heat Incentive (RHI)

The renewable heat incentive was created to provide financial support for renewable heat suppliers and users. Under this program, companies and end- users can receive financial awards for utilizing excess heat produced through CHP systems, as well as exporting surplus biogas (bio-methane for AD) back to the grid. The tariff adjustments for ATT and AD, as of 2012 can be seen in Figure 20, in ‘‘Bio-methane and Biogas combustion.’

YEAR FROM 1 APRIL 2012

Tariff name	Eligible technology	Eligible sizes	Tier	Previous tariff (pence / kwth) up to 31 March 2012	New rounded tariff (pence / kwth) from 1 April 2012
Small commercial biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	Less than 200 kWth	Tier 1	7.9	8.3
Small commercial biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	Less than 200 kWth	Tier 2	2	2.1
Medium commercial biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	200 kWth and above; less than 1,000 kWth	Tier 1	4.9	5.1
Medium commercial biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	200 kWth and above; less than 1,000 kWth	Tier 2	2	2.1
Large commercial biomass	Solid biomass including solid biomass contained in municipal solid waste (incl. CHP)	1,000 kWth and above	N/A	1	1
Small commercial heat pumps	Ground-source heat pumps; water source heat pumps; deep geothermal	Less than 100 kWth	N/A	4.5	4.7
Large commercial heat pumps	Ground-source heat pumps; water source heat pumps; deep geothermal	100 kWth and above	N/A	3.2	3.4
All solar collectors	Solar collectors	Less than 200 kWth	N/A	8.5	8.9
Biomethane and biogas combustion	Biomethane injection and biogas combustion, except from landfill gas	Biomethane all scales, biogas combustion, except from landfill gas	N/A	6.8	7.1

The tariffs set out in the table above have been increased by 4.8%, which was the increase in the retail price index in 2011. As set out in the RHI Regulations, tariffs are rounded to the nearest 10th of a penny. Therefore, the large biomass tariff has remained unchanged at 1p/kWh.

Figure 20: RHI Tariffs

(DECC, 2012)

8.3.5 Feed-in-Tariffs

EfW facilities are not eligible for financial incentives provided by the Feed-In-Tariff as they are sufficiently catered for in the Renewable Obligation (Wolfe Ware, 2012).

8.4 Political Constraints

An EfW facility will need to meet several political constraints before it can be constructed in Wembley. The WLWA is currently developing a contract with an EfW company to divert waste from landfill. For the WLWA to support an EfW facility located in Wembley the contracted company would either have to be the same company currently developing the facility, or a new contract must be settled. One simple way to avoid this contractual issue is by using a commercial waste stream, such as Quintain's, as feedstock.

8.4.1 Public Disapproval

The general public regards EfW as an environmentally destructive technology that should not be used near residential areas or other locations where pollution is already an issue (Patel, Yogini). Certain past EfW projects have led to major public disapproval, such as the Edmonton Incinerator. In this case many environmental activists believed that infant mortality rates rose downwind of the incinerator. In the report it is mentioned that the data should be considered with scepticism, however much of the public overlooks these details in any studies regarding health and environmental issues (*Infant Mortality Rates and Incinerator Location.*2008).

The general public is frequently unable to discern the differences between incineration and ATT. Although most of these advanced techniques have made breakthroughs on environmental and social issues, the data provided by energy companies is often seen as theoretical by investors and the general public. An interview with Jon Garvey, of Shore Energy Pyrolysis plant, revealed that the emissions from their facility were less than the pollutants from traffic next to the A8 highway at Carnbroe, which connects Glasgow and Edinburgh. Furthermore, an analysis performed by the Environment Agency showed that air emissions from the plant would actually be much cleaner than the surrounding air quality.

Due to the influence that the population has on local politics, public perception has a considerable impact on the approval of waste management projects. For instance, initial authorization of the Carnbroe project was revoked by the councillors after massive public objection, despite the fact that the effect on the local community was negligible. Shore Energy is currently in the process of appealing this decision.

Defra suggests remedies for approaching the negative public perception regarding ATT:

"Experience in developing waste management strategies shows the necessity of proactive communication with the public over waste management options. The use of realistic and appropriate models, virtual 'walk-throughs'/artist impressions should be used to accurately inform the public. Good practice in terms of public consultation and engagement is an important aspect in gaining acceptance for planning and developing waste management infrastructure."

(Defra, 2007a)

8.4.2 Emission Regulations

In order for an EfW facility to be approved it has to meet strict emission standards as laid out by the Waste Incineration Directive (WID). This document monitors air, soil, groundwater, and surface water pollutants, such as NO_x, SO_2, HCL, as well as volatile organic compounds (VOC), carbon monoxide (CO), PM10, heavy metals, and dioxins and furans. Several pollutants and their mitigation techniques can be seen in Figures 21 and 22.

Emission levels set by EC Waste Incineration Directive

Substances	EC Waste Incineration Directive (2000)
Dust	10
Total Organic Carbon	10
Hydrogen Chloride	10
Hydrogen Fluoride	1
Sulphur Oxides	50
Carbon Monoxide	50
Nitrogen Oxides	200
Metals	
Group 1: Cadmium, Thallium	0.05
Group 2: Mercury	0.05
Group 3: Antimony, Arsenic, Lead, Chromium, Cobalt, Copper, Manganese, Nickel, Vanadium	0.5
Dioxins and Furans	0.1 ng/m^3

Notes:
(a) All concentrations are given in units of milligrams per normal cubic metre of stack gas, corrected to 11% oxygen at 273K and 101.3KPa except dioxins, which are expressed in nanograms of international toxic equivalent (I-TEQ) per normal cubic metre of stack gas.
(b) Values relate to 24 hour averages except metals which are 30 min – 8 hour and dioxins which are 6 hour – 8 hour averages.

Figure 21: WID Emission Levels

(127 Enviros Consulting Limited, Office of the Deputy Prime Minister 2004)

Pollutant	Techniques
Particles	Electrostatic precipitators Wet electrostatic precipitators Condensation electrostatic precipitators Ionization wet scrubbers Fabric filters Cyclones and multi-cyclones
Acid gases (HCl, HF, SO_x, …)	Wet-scrubber Semi-dray scrubber (e.g. suspension of lime) + bag filter Dry-scrubber (e.g. lime or sodium bicarbonate)
Direct desulphurisation	Injection of adsorbents (e.g. calcium compounds) directly into the incineration chamber
Oxides of nitrogen (NOx)	Primary techniques: air and temperature control, flue-gas recirculation, Secondary techniques: Selective Non- Catalytic Reduction (SNCR) and Selective Catalytic Reduction (SCR).
Hg	Primary techniques: separate collection, restrictions of receipt contaminated wastes Secondary techniques: scrubber by adding oxidants, activated carbon, furnace coke or zeolites
Other heavy metals	Converted into no-volatile oxides and deposited into fly ash, all techniques referred to remove particles can be applied. Activated carbon injection into scrubbing units.
Organic carbon compounds	Adsorption on activated carbon. SCR used for NOx. Catalytic bag filters Static bed filters Rapid quenching of flue-gas
Greenhouse gases (CO_2, N_2O)	All techniques used for NOx. Increase energy recovery efficiency
APC residues	Treated (e.g. solidification/stabilization and disposed of) Thermal treatment (vitrification, melting, sintering) Extraction and separation Chemical stabilisation
Bottom ash	Separation of metals Screening and crushing Treatment using ageing conditions High temperature slagging rotary kilns

Figure 22: Common techniques for treating flue gases from EfW.

(Quina, Bordado, & Quinta-Ferreira)

Specific Emissions and mitigation techniques are also investigated in the Technology Comparison Matrix.

8.4.3 Stack Height

There is no precise minimum stack height specified in any planning policy document however the WID suggests that stack height be laid out in such a way to "safeguard human health and the environment." The purpose of large stack heights is mainly to minimize ground level pollution by dispersing any emissive particles into the atmosphere. Thus, there is a trade-off between the pollution impact on the ground and aesthetic impact caused by the stack height.

8.5 Closing Statement

The preceding section served to present a view of the available EfW technologies, their advantages and disadvantages, and the logistical constraints that should be considered for application in Brent. The Technology Comparison Matrix located below summarises the information gathered on the various energy from waste technologies discussed in this document. In the section that follows we will present our recommendations regarding EfW development specific to the Wembley Regeneration Area.

8.6 EfW Technology Comparison Matrix

	ECONOMIC			TECHNICAL SPECIFICATIONS											
WTE Technologies	Capital Cost (Million GBP)	Pay Back Period (years)	Government Incentives	Expected Lifetime (Years)	Energy Yield (kWh/ton of MSW)	Net Energy Efficiency (%) Electricity only	Net Energy Efficiency (%) CHP	Net Calorific Value of Syngas (MJ/N-m^3)	Land Required (ha)	Building height (m)	Stack Height (m)	Modular Capability	Type of Feedstock	Quantity of Feedstock (thousand tpa)	Number of operational facilities using the technology in the UK
Pyrolysis	50.0	7 - 8	RO, RHI	20-25	571.00	20 - 27	44 -51	10 - 20	1 -2	15 -25	30 - 70	Yes	MSW, SRF	10 - 200	2 -3
Gasification	45.0	7 - 8	RO, RHI	20-25	685.00	20 - 27	44 -51	4 - 10	1 -2	15 -25	30 - 70	Yes	MSW, SRF	10 - 200	
Plasma Arc Gasification	55.9	-	RO, RHI	20-25	816.00	32.7	-	-	1 - 2	10	-	Yes	MSW, SRF	10 - 70	0
Anaerobic Digestion (AD)	43.1	5-10	RO, RHI	25	200.00	-	-	20 - 25	0.6	7	-	Yes	Food waste	5 - 100	68
Incineration	25.0	6 -10	RO, RHI	25	544.00	17 - 28	49	-	2 - 4	15 - 25	65 -80	No	MSW, SRF	23 - 500	19
Landfill	4	-	-	30 - 50	-	-	-	15 - 21	-	-	-	-	-	-	450

	ENVIRONMENTAL								SOCIAL
WTE Technologies	Emissions (mg/N-m^3) PM 10 (10)	NOx (200)	HCL (10)	SOx (50)	Hg (0.05)	Dioxins/Furans (0.1 ng/N-m3)	Byproducts Created	Life cycle assessment of greenhouse emissions (Kg CO2 eq)	Average Workforce Required
Pyrolysis	0.3	<50	5	<2	0.005	<0.003	Ash, char	412.13	2 - 4
Gasification	0.3	<50	5	<2	0.005	<0.003	Ash, char	412.13	2 - 4
Plasma Arc Gasification	12.8	150	3.1	26	0.0002	0.009245	Vitrified slag	-	-
Anaerobic Digestion (AD)	-	-	-	-	-	-	Fibre, liquor, biofertilizer	-	5
Incineration	0.1 - 4	20 -180	0.1 - 6	0.2 - 20	0.0002 - 0.05	0.0002 - 0.08	Ash	424.40	2 - 6
Landfill	-	-	-	-	-	-	-	746.46	-

8.6.1 EfW Technology Comparison Matrix Sources

The data presented in the matrix were obtained from the following sources:

Energy yield of the various thermal treatments was obtained from:
Circeo, L. J.*Plasma Arc Gasification of Municipal Solid Waste.* Retrieved 03/12, 2012
http://www.energy.ca.gov/proceedings/2008-ALT-1/documents/2009-02-17_workshop/presentations/Louis_Circeo-Georgia_Tech_Research_Institute.pdf

Net energy efficiencies were obtained from:
Mayor of London. (2011). *London's Wasted Resource: The Mayor's Municipal Waste Management Strategy.* Retrieved 03/17, 2012,
http://www.london.gov.uk/sites/default/files/Municipal%20Waste_FINAL.pdf

Capital cost and payback period of AD were obtained from:
Local Government, Improvement and Development. (2011). *Energy from Waste.* Retrieved 04/07, 2012,
http://www.idea.gov.uk/idk/core/page.do?pageId=23211031

The number of MSW digesters in the UK was obtained from:
The UK's National Centre for Biorenewable Energy, Fuels and Materials. (2011). *Number of anaerobic digesters in UK increases by 20 per cent over past 12 months.* Retrieved 04/21, 2012
http://www.nnfcc.co.uk/news/ad-sites-increase-by-20-in-uk-over-past-12-months

The capital cost, of plasma arc gasification was obtained from:
Ducharme, C. (2010). *Technical and economic analysis of Plasma-assisted Waste-to-Energy processes.* Retrieved 04/16, 2012
http://www.seas.columbia.edu/earth/wtert/sofos/ducharme_thesis.pdf

Emissions from plasma arc gasification processes were obtained from:
Dovetail Partners, I. (2010). *Plasma gasification: An examination of the health, safety, and environmental records of established facilities.* Retrieved 04/18, 2012
http://www.dovetailinc.org/files/u1/PlasmaGasificationRptFinal6710.pdf

Emissions from incineration were obtained from:
Quina, M. J., Bordado, J. C. M. & Quinta-Ferreira, R. M.*Air Pollution Control in Municipal Solid Waste Incinerators.* Retrieved 04/16, 2012
http://cdn.intechopen.com/pdfs/18646/InTech-Air_pollution_control_in_municipal_solid_waste_incinerators.pdf

Area required, building height, capital cost, feedstock quantity and average workforce for incineration were obtained from:
Defra. (2007b). ***Incineration of Municipal Solid Waste.*** **Retrieved 04/19, 2012,**
http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/incineration.pdf

Calorific value of syngas produced by gasification and pyrolysis were obtained from:
Defra. (2007a). ***Advanced Thermal Treatment of Municipal Solid Waste.*** **Retrieved 04/17, 2012**
http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/att.pdf

Life-cycle assessment of the technologies was obtained from
Zaman, A. U. (2010). ***Comparative study of municipal solid waste treatment technologies using life cycle assessment method.*** **Retrieved 04/26, 2012**
http://www.bioline.org.br/request?st10022

Expected lifetime of landfill was obtained from:
DHEC's Office of Solid Waste Reduction and Recycling.How Landfills Work. Retrieved 04/26, 2012
http://www.scdhec.gov/environment/lwm/recycle/pubs/landfill_102.pdf

Capital cost of AD was obtained from:
Arsova, L. (2010). ***Anaerobic Digestion of Food Waste: Current Status, Problems and an Alternative Product.*** **Retrieved 04/23, 2012,**
http://www.seas.columbia.edu/earth/wtert/sofos/arsova_thesis.pdf

Calorific value of landfill gas was obtained from:
DHEC's Office of Solid Waste Reduction and Recycling.***How Landfills Work.*** **Retrieved 04/26, 2012**
http://www.scdhec.gov/environment/lwm/recycle/pubs/landfill_102.pdf

Payback period of AD was obtained from:
Scottish Environment Protection Agency.***Generate Your Own Renewable Energy.*** **Retrieved 04/21, 2012**
http://www.business.scotland.gov.uk/bdotg/action/detail?itemId=1081290675&site=202&type=RESOURCES

Energy efficiency of plasma arc gasification was obtained from:
Galeno, G., Minutillo, M., & Perna, A. (2010). From Waste to Electricity through Integrated Plasma Gasification/Fuel Cell (IPGFC) System. ***International Journal of Hydrogen Energy, 36,*** **04/26/2012.**
http://www.ewp.rpi.edu/hartford/~stephc/EP/Research/Plasma%20Cycle/Galeno(2010)-From%20wast%20to%20electricity%20through%20integrated%20plasma%20gasfication-fuel%20cell%20(IPGFC)%20system.pdf

Number of operational landfills obtained from:
Parkes, L. (2009). *Ten Years of the Landfill Directive.* Retrieved 04/27, 2012
http://www.letsrecycle.com/news/special-reports/ten-years-of-the-landfill-directive

Other:
Enviros Consulting Limited, Office of the Deputy Prime Minister. (2004). *Planning for Waste Management Facilties; a Research Study.* Retrieved 04/17, 2012,
http://www.communities.gov.uk/documents/planningandbuilding/pdf/148385.pdf

9.0 Recommendations

With sustainability as the overarching premise of our project, we have developed conclusions and recommendations for the London Borough of Brent regarding an EfW strategy within the Wembley Regeneration Area. This section outlines the possible methods of mitigating actual and perceived environmental and social issues.

Any large scale development will require planning permission before it can be constructed. Many of the key issues that will need to be addressed are outlined in DEFRA's "Government Review of Waste Policy in England 2011," "Advanced Thermal Treatment of Municipal Solid Waste," and more thoroughly explained in Planning Policy Statement 10: Planning for Sustainable Waste Management (Enviros Consulting Limited, 2007). The following section serves to supplement the issues covered in these documents with a focus on the Wembley Regeneration Area.

9.1 Plant Site

We recommend that a facility be located on land that already has industrial uses. This would ensure easy integration into other existing waste management facilities, while keeping the facility away from highly populated residential areas. In order to avoid public opposition, Patrick McConville, from Energos, recommends locating an EfW facility further than 500 m from residential areas.

In addition, locating a facility near a major road or rail station could potentially reduce traffic caused by waste transfer, and is supported by the Mayor of London. The Envac system can also alleviate traffic concerns by keeping most of waste travel underground.

9.2 Public Concerns

Addressing public concerns is crucial in the planning and development of an EfW program. The public perception of incineration and other EfW technologies will have the same impact on planning as that of a technical expert. The team recommends that the Council has proactive communication with local residents when informing them about the benefits of EfW.

Properly conducted public consultations are essential for gaining approval for the construction of new EfW facilities. Jon Garvey, from Shore Energy, recommends not having too many technological options during consultations. Having too many options will cause controversy as it will overwhelm the majority of the public. According to Mr Garvey, neutrality towards the technologies will also create disappointment and approval could take three or four times as long. On the other hand, presenting too few options in the consultation could make the public feel there is no room for discussion. The planning department should not overlook the importance of considering an appropriate number of options before consultation.

9.2.1 Visual Concerns

EfW technologies require tall smokestacks and cooling towers, which are visually unattractive and cause unrest in residential and high traffic areas. Integrating smokestacks into the main body of the facility can reduce the visual impact of the smokestack to the community.

Any visible emissions, such as gas or water vapour, commonly have a negative impact on public opinions towards EfW. Cutting edge emission control can eliminate the need for visible gas. For example, one energy company, Energos, controls pollution via an air cooling system, eliminating the need for water vapour emissions. This process renders the emissions invisible under normal atmospheric conditions.

When possible, an EfW facility should be designed in an attractive, iconic, and innovative fashion. Traditionally, power generation facilities have been designed in a manner that promotes utility over innovation. A modern EfW facility should be aesthetically pleasing and bolster the appearance of its environment. One example of an innovative facility is the Concord Blue Tower gasification plant in Germany which can be seen in Figure: 23. Another is the Isle of Man incinerator which was designed by Savage & Chadwick Architects to represent a Viking sailboat, located in Figure: 23.

Figure 23: Left: Isle of Man Incinerator; Right: Blue Tower in Germany

9.2.2 Lack of Public Awareness of EfW

Negative public perception of EfW is commonly based on fear, misinformation, or lack of information. Educating the public on ATT processes eliminates unrest based on a lack of information. Facilities should be encouraged to hold information sessions as well as guided tours of the facility. EfW facilities should not seem closed off or secretive to the public, a concern that can be alleviated through proper design. For example, facilities can be designed with large bay windows or transparent façades in order to reveal the internal processes to individuals traveling past the facility.

Successful measures have been taken elsewhere to counteract negative public perception. Educating school-aged children of waste management practices can yield positive reception. The Blue Tower, shown in Figure 23, received a best practice achievement in education through relating the facility to a cartoon character which can eat any waste without harming the environment, while also producing energy.

9.3 Environmental Quality Control

9.3.1 Emissions

To ensure compliance with the Waste Incineration Directive (WID) and the safety of local residents we recommend the implementation of a continuous emission monitoring system (CEMS). In such a system, flue gas emissions can be monitored in real-time, so that any breaches in the EA's limitations can be immediately identified.

Emissions produced by ATT can be mitigated using state-of-the-art scrubbing technologies. The systems mentioned in Figure 22, usually used in succession, are the most effective methods for drastically reducing the emission of pollutants into the environment. For the specific emission data consult the technology comparison matrix.

Although EfW provides great benefits in terms of carbon emissions compared to landfill, there is the inevitable release of carbon and greenhouse emissions caused by combustion. The relative net carbon impact of these processes will depend on the feedstock composition and technology used along with other variables. The team recommends performing financial and mathematical modelling of ATT and AD to evaluate life-cycle assessments. The results from these models will provide further insight on the environmental impact of the facility.

Particulate matter (PM) emissions can be detrimental to the health of nearby residents and should be moderated by the facility in order to ensure a safe atmosphere. The EA sets standards for PM_{10}. To ensure the health and safety in a heavily populated area, it could be necessary for companies to moderate the levels of $PM_{1.5}$ or lower.

9.3.2 Odours

EfW can produce unsettling odours if the correct processes are not being used. AD facilities should ensure that each stage of the process is enclosed and emissions and by-products are cleaned before being exposed to the environment. EfW facilities should utilize negative pressure systems, air-locks and other odour mitigation techniques so that emissions cannot escape into the environment until odours are properly neutralized. To counteract odours a facility should also ensure that waste is not stored in open areas and facilities should be cleaned regularly.

9.4 Operational Considerations

Several operational considerations should be taken in order to maximize efficiency, minimize environmental impact and receive support from investors. Facilities should be designed in a way that utilizes all of the available revenue streams, including:

- Gate fess or tipping fees for waste disposal.
- Sale of extracted recyclables and metals from the waste stream.
- Sale of surplus electricity back to the grid or through a decentralized energy network.
- Sale of surplus heat through decentralized heating networks.
- Financial incentives for pursuing renewable technologies.
- Sale of non-hazardous by-products

Utilizing all revenue streams will not only benefit the local economy, but will also result in an environmentally friendlier facility.

Companies should have a system in order to clean by-products so that they may be disposed of safely without the need for hazardous storage. Early in the planning stages contracts should be procured to utilize by-products that can be used in other applications instead of sending them to landfill. Potential uses for by-products can be seen in the technology sections in the Data & Analysis chapter.

9.4.1 Stack Height

The amount of emissions and ground pollutants is determined by several factors including stack height and scrubbing systems. Given that there are negative connotations associated with large stack heights, it would be best to minimize the stack height while still maintaining an acceptable height to control emissions. A company should provide an analysis of their emission characteristics as well as a model of the air dispersion from their facility in order to determine an effective stack height.

9.4.2 Securing Feedstock

If an AD facility is proposed in the Wembley area it may be necessary for garden and food waste to be collected separately. Garden waste does not breakdown as quickly as food and a separate waste stream for food waste may be necessary for an efficient facility (Friends of the Earth, 2008).

EfW facilities will need to secure a sufficient and consistent stream of feedstock to be economically viable. In addition to arrangements with the WLWA, contracts can be made with large waste producers in Wembley such as Quintain or other developers in the regeneration area. In the past, mass-burn incinerators signed contracts with waste companies for at least 25 years to make the project economically attractive. Most ATT technologies have shorter payback periods than incineration and are modular in nature. They are thus able to provide a greater degree of flexibility and shorter feedstock contract requirements than incineration.

9.5 Technology

9.5.1 Pre-Treatment

The team recommends that pre-treatment and sorting processes are integrated into any EfW processes. Pre-treatment processes, such as mechanical heat treatment (MHT) or mechanical biological treatment (MBT) could enhance the production of EfW technologies by producing a solid recovered fuel (SRF), which has a higher calorific value than MSW.

9.5.2 Facility Size

We suggest that an ATT plant not supersede the maximum projection of combined MSW and commercial and industrial (C/I) waste produced in 2031. From our estimate this will be close to 105,000 tonnes. Although ATT plants are capable of handling more waste, processing more waste than the equivalent that the borough produces would counteract the motives to move towards decentralized heat and power.

9.5.3 Technology Selection

After a careful study and review of the different available technologies, the team recommends three technologies for application in the Wembley Area: They are AD, gasification, or pyrolysis.

Incineration and plasma arc gasification are not recommended by the team for the Wembley regeneration area. Although modern incinerators offer much of the same benefits as ATT processes, they require larger waste volumes (normally they are economically viable for feedstock capacity greater than 100,000 tpa) and are not modular.

Plasma arc gasification is an innovative technology but is still emerging from its pilot stages. We have only found information on two running Japanese plasma arc gasification plants that use MSW as a feedstock. The technology promises a higher energy efficiency, is robust and flexible (it can handle anything but nuclear waste) and produces environmentally friendly by-products. We recommend that the technology be looked into further when more evidence of its performance is available.

AD is a commercially established technology and not only widely accepted in the UK but also incentivized through the Central Government's Anaerobic Digestion Strategy. Although gasification and pyrolysis are not yet commercially established, they are widely accepted in other countries, and are on their way to becoming acknowledged in the UK.

We have recommended AD and pyrolysis/gasification over other options because they would be best suited for Wembley. They have both lower minimum feedstock capacities and modular capability. Their modular design allows for a more flexible feedstock input which can cope with the drastic changes that are occurring in the Wembley regeneration area.

10.0 Conclusion

Landfilling waste is unsustainable. There are several government initiatives aimed at decreasing waste sent to landfill, however there will always remain some amount of residual waste. Changing the way this residual waste is processed will be a critical decision for London's future.

Our research has identified that there is a lack of public knowledge regarding the disposal of the waste that individuals create. This lack of knowledge causes residents to disassociate the responsibility that they have for the disposal and treatment of the waste they produce. Providing the public with a direct connection of what is happening to their waste and where it is being disposed of will be a key factor in changing people's behaviour to comply with the Mayor's new waste hierarchy.

Energy-from-Waste (EfW), such as advanced thermal treatments (ATT) or anaerobic digestion (AD) are 21st century solutions to the problems associated with landfilling waste. Mass-burn incineration is a technology of the past: Brent needs a solution that is clean, efficient, sustainable and productive.

The Wembley Regeneration Area would be an ideal setting to exemplify the benefits of what a state of the art EfW development can bring to the local community. EfW is becoming increasingly recognized as an approach to resolving two issues in one: sustainable energy and waste management. With the ability to connect with existing decentralized heating networks through combined-heat-and-power (CHP), there is an opportunity created to provide sustainable heat and/or electricity to the surrounding area.

Existing waste management infrastructure, such as Seneca MRF and Quintain's Envac system could be incorporated into an EfW programme so that feedstock is secured. Traffic caused by movement of waste can thus be reduced, as the collection and disposal will occur closer together, or in an ideal situation, at one central location.

ATT technologies and AD have the ability to operate at district-wide-levels. Such a facility should process the equivalent amount of waste created by the Brent Borough. Although the technologies are capable of handling more waste, processing more waste than Brent produces would counteract the motives to move towards decentralized energy and will lead to negative public opinion, by associating the EfW with past practices of mass-burn-incineration facilities.

Implementing EfW sooner rather than later would make the most economic sense. Currently there are several financial incentives that can help bolster EfW's development, including the Renewable Obligation (RO), Renewable Transport Fuel Obligation (RTFO), Renewable Heat Incentive (RHI), backing from the London Waste and Recycling Board (LWARB), and incentives associated with deterring sending waste to landfill.

Through the EcoBuild conference and other professional interviews, we confirmed that the vast financial incentives currently available will not last forever. Once the technologies are commercially accepted, more EfW facilities will be procured and it will become difficult to secure feedstock. For this reason we advise the Planning Department to seriously consider EfW proposals.

Following the proximity principal and decentralized heating incentives, an anaerobic digestion plant would be best located in a central location of the Regeneration Area or close to existing district wide heating networks. There are no commercial-scale composting facilities that process organics in the Borough, so the ideal location for an AD plant would be one which can best utilize any excess heat. Likewise, an ATT facility should be incorporated in proximity to Seneca MRF to reduce waste transport.

To facilitate the development of an EfW scheme requires synergy amongst the central government, local government, and whoever is contracted to run the plant. The contractor will likely be most concerned with the economics of the facility. The GLA will assist in making EfW economically competitive compared to other forms of energy production. The Brent Planning

Service will be most concerned with whether or not EfW's benefits will outweigh its drawbacks, and should work with the contractor to accommodate each other's demands. Although the most important goals for each entity may differ during the procurement of such a facility, one common goal should be to lead Brent into a more sustainable future.

Although some technologies are not yet established in the United Kingdom, the team concludes that ATT will become commercially proven and accepted. Financial institutions observe how reliable the technologies are through analysing their past performances. Within the next decade the productivity of EfW will be acknowledged. In due time recovering energy-from-waste will no longer be the alternative to landfilling, it will be the regularity.

11.0 References

About Food Waste LFHW.*Love Food Hate Waste.* Retrieved 02/26, 2012, from http://www.lovefoodhatewaste.com/about_food_waste

Adu-Gyamfi, K. A., Villa, R. & Coulon, F.*Renewable Energy, Landfill Gas and EfW: Now, Next and Future* Retrieved 04/23, 2012, from http://www.geotech.co.uk/Downloads/Geotech%20sponsored%20paper.pdf

Amann, M., Cofalla, J. & Klimont, Z. (2010). *Mitigation of primary PM emissions.* Retrieved from http://www.slideserve.com/Angelica/mitigation-of-primary-pm-emissions

Anonymous.*Greater London Waste/Refuse and recycling centres.* Retrieved from http://www.alloageorge.com/rubbish.html

Anonymous. (2008, May 30). Mayor chairs waste board. *Planning,* 5.

Anonymous. (2009). ANALYSIS: Waiting for Defra. *Public Private Finance,* 13.

Anonymous. (2009, February 25). Landfill sites to be full by 2010. *BBC,*

Anonymous. (2010). Three through in South London Waste. *Euromoney Institutional Investor PLC,*

Anonymous. (2010). Waste Management Research; New waste management research reported from University of London, Imperial College. *Ecology, Environment & Conservation,* 189.

Arrandale, T. (1993, February). Promises and Problems. *Governing Magazine,*

Arsova, L. (2010). *Anaerobic Digestion of Food Waste: Current Status, Problems and an Alternative Product.* Retrieved 04/23, 2012, from http://www.seas.columbia.edu/earth/wtert/sofos/arsova_thesis.pdf

Bar-Hillel, M. (2010). **Poor vital networks threaten London's world-class status**. *The Evening Standard,* pp. 30.

Bartocci, A. (2009). *Gasification syngas cleaning.* Retrieved, 2012, from http://www.envitechinc.com/air-pollution-control-innovations/bid/20053/Gasification-syngas-cleaning

Berg, B. L. (2009). The Dramaturgical interview. *Qualitative Research Methods for the Social Sciences* (pp. 107)

Bhasin, K. C. (2009). *Plasma-Arc-2.pdf.* Retrieved, 2012, from http://www.electronicsforu.com/EFYLinux/efyhome/cover/February2009/Plasma-Arc-2.pdf

Brent Local Assessment Report. (2011). *Brent Council.* Retrieved 02/27, 2012, from http://issuu.com/brentcouncil/docs/brent_local_assessment_report#download

Brent's Borough Profile. (2011). ***Brent Council.*** Retrieved January 30, 2012, from http://www.brent.gov.uk/evidencebase.nsf/Files/LBBA-105/$FILE/borough_profile_part_one.pdf

Brignall, D. (2012). *Pyrolysis and Gasification: Planning and environment impacts.* Retrieved 04/15, 2012, from http://www.rsc.org/images/DavidBrignall_tcm18-216271.pdf

BWEA.*The Renewables Obligation.* Retrieved, 2012, from http://www.bwea.com/business/roc.html

Capital Waste Facts. (2011). ***London Borough of Brent Waste and recycling summary information***. Retrieved 2/25/12, 2012, from http://www.capitalwastefacts.com/data/commercial-waste.aspx

Chaerul, M., Tanaka, M., & Shekdar, A. V. (2008). A system dynamics approach for hospital waste management. *Waste Management, 28*(2), 442-449. doi:10.1016/j.wasman.2007.01.007

Charles H. K. Lam, Alvin W. M. Ip, John Patrick Barford, & Gordon McKay. (2010). Use of Incineration MSW Ash: A Review. *Sustainability, 2*(7), 1943-1968.

Cimren, E., Bassi, A., & Fiksel, J. (2010). A System Dynamics Approach to Policy Assessment for Sustainable Development: A Waste to Profit Case Study. *Sustainability, 2*(9), 2814.

Circeo, L. J.*Plasma Arc Gasification of Municipal Solid Waste.* Retrieved 03/12, 2012, from http://www.energy.ca.gov/proceedings/2008-ALT-1/documents/2009-02-17_workshop/presentations/Louis_Circeo-Georgia_Tech_Research_Institute.pdf

Cleveland, C. J. (n.d.). *Encyclopedia of Energy, Volumes 1 - 6* Elsevier. Retrieved from http://www.knovel.com/web/portal/browse/display?_EXT_KNOVEL_DISPLAY_bookid=1714

Commission urged to ban landfilling of recyclables. (2012). *Let,* 2/10/2012.

Council departments. (2011). Retrieved January 31, 2012, from http://www.brent.gov.uk/home.nsf/Main%20static%20pages/LBB-19?OpenDocument&pp=200026%3E

Courtauld Commitment. (2012). *WRAP.* Retrieved 02/26, 2012, from http://www.wrap.org.uk/retail_supply_chain/voluntary_agreements/courtauld_commitment/index.html

Crawford, S. (2012). *Waste-to-Energy Facilities Provide Significant Economic Benefits White Paper The Solid Waste Association of North America (SWANA).* (White Paper).The Solid Waste Association of North America.

Daniel, G. (2011). *Brent Council.* Retrieved 1/21/2012, 2012, from http://www.brent.gov.uk/home.nsf/Chief%20Executive/LBB-729

De Lucia, V. (2010). *Polluter Pays Principle.* Retrieved February 13, 2012, from http://www.eoearth.org/article/Polluter_pays_principle

DECC. (2012). *Renewable Heat Incentive - Department of Climate Change.* Retrieved, 2012, from http://www.decc.gov.uk/en/content/cms/meeting_energy/Renewable_ener/incentive/incentive.aspx

Defra. (2007). *Advanced Thermal Treatment of Municipal Solid Waste.* Retrieved 04/17, 2012, from http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/att.pdf

Defra. (2007). *Incineration of Municipal Solid Waste.* Retrieved 04/19, 2012, from http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/incineration.pdf

Defra. (2007). *Mechanical Heat Treatment of Municipal Solid Waste*.Crown.

Defra. (2011). *Anaerobic Digestion Strategy and Action Plan.*Crown.

Defra. (2011). *Government Review of Waste Policy in England 2011.* Retrieved February 13, 2012, from http://www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf

Defra. (2012). *Incineration of Municipal Solid Waste.*

Department for Business Innovation & Skills. (2011). *Green Investment Bank.* Retrieved 02/02, 2012, from http://www.bis.gov.uk/greeninvestmentbank

Department for Environment, Food and Rural Affairs. (2009). *Environmental Permitting Guidance The Landfill Directive* Retrieved 02/10/2012, 2012, from http://archive.defra.gov.uk/environment/policy/permits/documents/landfill-directive.pdf

Department for Environment, Food and Rural Affairs. (2011). *The Economics of Waste and Waste Policy*.Department for Environment, Food and Rural Affairs.

Department for Environment, Food and Rural Affairs. (2011). *LOCAL AUTHORITY COLLECTED WASTE MANAGEMENT STATISTICS FOR ENGLAND – FINAL RELEASE OF QUARTERS 1, 2, 3 AND 4 2010/11.* (STATISTICAL RELEASE).

Department for Environment, Food and Rural Affairs. (2011). *Waste Data Overview*.

Renewable Heat Incentive, (2011).

DHEC's Office of Solid Waste Reduction and Recycling.*How Landfills Work.* Retrieved 04/26, 2012, from http://www.scdhec.gov/environment/lwm/recycle/pubs/landfill_102.pdf

Dovetail Partners, I. (2010). *Plasma gasification: An examination of the health, safety, and environmental records of established facilities.* Retrieved 04/18, 2012, from http://www.dovetailinc.org/files/u1/PlasmaGasificationRptFinal6710.pdf

Dow Jones Architects, A. (2009). *Rubbish in Resources Out*.

Ducharme, C. (2010). *Technical and economic analysis of Plasma-assisted Waste-to-Energy processes.* Retrieved 04/16, 2012, from http://www.seas.columbia.edu/earth/wtert/sofos/ducharme_thesis.pdf

Duran-Encalada, J. (2009). System Dynamics Urban Sustainability Model for Puerto Aura in Puebla, Mexico. *Systemic Practice and Action Research, 22*(2), 77-99.

ECOTEC Research and Consulting Limited. (1999). *BEYOND THE BIN: THE ECONOMICS OF WASTE MANAGEMENT OPTIONS*

Election Results. (2010). *Borough Council election - Thursday, 6 May 2010.* Retrieved Jan/19, 2012, from http://democracy.brent.gov.uk/mgElectionResults.aspx?ID=7&RPID=2265748

Envac Group.*Envac - Residential Areas.* Retrieved from http://www.envacgroup.com/areas_of_application/stadsmiljo_1/residential_areas

Environment Agency. *Energy from waste - regulation.* Retrieved from http://www.environment-agency.gov.uk/static/documents/Business/3_wip_regulation_2147973.pdf

Environment Agency. (2011). *Report on facilities covered by environmental permitting England's waste infrastructure.* (No. ISBN: 978-1-84911-221-5).

Environment Agency. (2011). *Waste Management 2010*.

Environment Committee. (October 2009). *Where there's Muck there's BrassWaste to energy schemes in London.* (No. SE1 2AA). London: Greater London Authority.

Enviros Consulting Limited. (2007). *Advanced Thermal Treatment of Municipal Solid Waste*.Crown.

Enviros Consulting Limited, Office of the Deputy Prime Minister. (2004). *Planning for Waste Management Facilties; a Research Study.* Retrieved 04/17, 2012, from http://www.communities.gov.uk/documents/planningandbuilding/pdf/148385.pdf

EPA. (2012). Health | Nitrogen Dioxide | US EPA.

European Commission. (2012). *The Waste Incineration Directive.* Retrieved, 2012, from http://ec.europa.eu/environment/air/pollutants/stationary/wid/legislation.htm

Friends of the Earth. (2008). *Mechanical and Biological Treatment (MBT).* Retrieved from http://www.foe.co.uk/resource/briefings/mchnical_biolo_treatmnt.pdf

Galeno, G., Minutillo, M., & Perna, A. (2010). From Waste to Electricity Through Integrated Plasma Gasification/Fuel Cell (IPGFC) System. *International Journal of Hydrogen Energy, 36*, 04/26/2012.

Gilbert, A. (2009). *Is Producing Energy from Waste via Gasification a Viable Option in the UK?* Retrieved 2/12, 2012, from http://attachments.wetpaintserv.us/xC_SRJhe4859aQp_yJARWQ871455

Ginger, B. (Mar 2011). Waste to Energy. *Pollution Engineering, 43*(3), 20.

Government Review of Waste Policy in England 2011. Retrieved 12/2, 2012, from http://www.defra.gov.uk/publications/files/pb13540-waste-policy-review110614.pdf

Greater London Authority. (2011). *The London Plan, Spatial Development Strategy for Greater London.* Retrieved 02/23, 2012, from http://www.london.gov.uk/sites/default/files/The%20London%20Plan%202011.pdf

Greater London Authority. (2011). *London's Wasted Resource*. Mayor of London.

Greater London Authority, Environment Agency, Natural England, The Forestry Commission. (2011). *LONDON'S ENVIRONMENT REVEALED.* (No. ISBN: 978-1-84781-449-4).

Griffin, M. (2012, January 31). CITY'S pounds 15 BILLION BID; Cities across Britain are competing to host a new Green Investment Bank and Coventry has now entered the race. But what are our chances, how would it benefit the city and who is our hottest competition? MARY GRIFFIN finds out. *Coventry Evening Telegraph (England),* pp. 13.

Gruner, P. (2001, 15 June 2001). Waste mountain threatens London. *Evening Standard,* pp. http://ic.galegroup.com/ic/bic1/NewsDetailsPage/NewsDetailsWindow?displayGroupName=News&disableHighlighting=false&prodId=BIC1&action=e&windowstate=normal&catId=&documentId=GALE%.

Gunamantha, M., & Sarto. (2012). Life cycle assessment of municipal solid waste treatment to energy options: Case study of KARTAMANTUL region, Yogyakarta. *Renewable Energy, 41*(0), 277-284. doi:10.1016/j.renene.2011.11.008

Iakovou, E., Karagiannidis, A., Vlachos, D., Toka, A., & Malamakis, A. (2010). Waste biomass-to-energy supply chain management: A critical synthesis. *Waste Management, 30*(10), 1860-1870. doi:10.1016/j.wasman.2010.02.030

Infant Mortality Rates and Incinerator Location. (2008). Retrieved 2/13, 2012, from http://incineratorfreemecklenburg.files.wordpress.com/2011/02/infant-mortality-rates-and-incinerator-location.pdf

iom incinerator.*Iom_Incinerator.* Retrieved from http://www.savagechadwick.com/gallery/slideshow/iom_incinerator.jpg

J.G. Press. (2006). GASIFICATION OF WASTES 101. *Biocycle, 47*(4), 67.

Koroneosa, C. J., & Nanakib, E. A. (2012). **Integrated Solid Waste Management and Energy Production - A Life Cycle Assessment Approach: The Case Study of the City of Thessaloniki**. *Journal of Cleaner Production,* January 29, 2012. Retrieved from http://www.sciencedirect.com/science/article/pii/S0959652612000224?v=s5

LDF Core Strategy. (2012). *Brent Council*. Retrieved 01/21, 2012, from <http://brent.limehouse.co.uk/portal/planning/cspo/adopted_cs?pointId=1253569#document-1253569>.

Lee, C. (2012). In Martinez N. (Ed.), *EPi Pyrolysis*

Local Government, Improvement and Development. (2011). *Energy from Waste.* Retrieved 04/07, 2012, from http://www.idea.gov.uk/idk/core/page.do?pageId=23211031

London Borough of Brent. (2004). *Unitary Development Plan: Waste.* Retrieved 2/24, 2012, from http://www.brent.gov.uk/tps.nsf/Files/LBBA-807/$FILE/12%20WASTE.pdf

London Borough of Brent. (2005). *THE LONDON BOROUGH OF BRENT WASTE STRATEGY.* Retrieved 2/12, 2012, from http://www.brent.gov.uk/tps.nsf/Files/LBBA-225/$FILE/Brent%20Waste%20Strategy%202005.pdf

London Borough of Brent. (2009). *Household Waste Collection Strategy 2010-14 EXECUTIVE SUMMARY.* Retrieved 2/12, 2012, from http://www.brent.gov.uk/stratp.nsf/Files/LBBA-348/$FILE/Household%20Waste%20Strategy%20Executive%20summary.pdf

London Borough of Brent. (2011). *Budget Book 2010/2011.* Retrieved 1/20, 2012, from http://www.brent.gov.uk/councilfinance.nsf/Files/LBBA-93/$FILE/Introduction.pdf

London Borough of Brent. (2011). *General Fund Budget Summary.* Retrieved 1/19, 2012, from http://www.brent.gov.uk/councilfinance.nsf/Files/LBBA-94/$FILE/General%20Fund%20Summaries%20for%202010.11.pdf

London Borough of Brent. (2011). *Wembley Area Action Plan Issues and Options.* Retrieved 2/12, 2012, from http://democracy.brent.gov.uk/mgConvert2PDF.aspx?ID=5941

London Borough of Brent. (2012). ***Latest statistics - 16 February 2012***. Retrieved 2/25, 2012, from http://www.brent.gov.uk/streetcare2.nsf/Recycling%20collections/LBB-109

London Canada. (2012). *Waste Disposal Fees.* Retrieved 02/10, 2012,

London Remade. (2012). ***What would it mean to be dealing with London's waste 'efficiently'?***. Retrieved 02/10/2012, 2012, from http://www.londonremade.com/waste-efficiency

LWARB. (2011). *Overview.* Retrieved, 2012, from http://www.lwarb.gov.uk/page/?identity=aboutus-overview

Mayor of London. (2011). *London's Wasted Resource: The Mayor's Municipal Waste Management Strategy.* Retrieved 03/17, 2012, from http://www.london.gov.uk/sites/default/files/Municipal%20Waste_FINAL.pdf

Merriam Webster. (2012). *Landfill.* Retrieved 2/1, 2012, from http://www.merriam-webster.com/dictionary/landfill

Miranda, M. L., & Hale, B. (1997). Waste not, want not: the private and social costs of waste-to-energy production. *Energy Policy, 25*(6), 587-600. doi:10.1016/S0301-4215(97)00050-5

Muir, H. (2000, 28 Jul 2000).

Waste disposal kicks up a stink. *London Evening Standard,*

Municipal Waste Management Strategy. (2010). *Boris Jhonson, Mayor of London.* Retrieved 02/20, 2012, from http://legacy.london.gov.uk/mayor/environment/waste/docs/draft-mun-waste-strategy-jan2010.pdf

North London Waste Authority. (2012). Retrieved February 2, 2012, from http://www.nlwa.gov.uk/about-us/our-services

North London Waste Authority. (2012). *Waste Treatment Facilities: Your guide to waste disposal.* Retrieved February 2, 2012, from http://www.nlwa.gov.uk/docs/waste-recycling-guides/yourguidetowastedisposal.pdf

Office of National Statistics. (2001). ***Key Figures for 2001 Census: Census Area Statistics***. Retrieved 01/20, 2012, from http://neighbourhood.statistics.gov.uk/dissemination/LeadKeyFigures.do;jsessionid=TRjxPdnJ0q1myG4w4GS3c9MTmBlk3t5sQdrkhMfQp98WjQtmjvpx!1574692961!1327327049950?a=7&b=276747&c=Brent&d=13&e=16&g=328340&i=1001x1003x1004&m=0&r=1&s=1327327049950&enc=1&nsjs=true&nsck=true&nssvg=false&nswid=1366

Office of the Deputy Prime Minister. (2004). *Planning for Waste Management Facilities:*

A Research Study. Enviros Consulting.

Palmquist, M. (2009). In Wydra D. B., Henry K. S. (Eds.), *The Bedford Researcher* (Third ed.). Boston: Bedford/St. Martin's.

Parkes, L. (2009). *Ten Years of the Landfill Directive.* Retrieved 04/27, 2012, from http://www.letsrecycle.com/news/special-reports/ten-years-of-the-landfill-directive

Pietropaoli, D. (2012). In Serrano J. (Ed.), *Waste Policy Team Leader*

Powney, J. (2010). *Adopted Core Strategy.* Retrieved January 31, 2012, from http://brent.limehouse.co.uk/portal/planning/cspo/adopted_cs?pointId=1253569

Psomopoulosa, C. S., Bourkab, A., & Themelisc, N. J. (2009). **Waste-to-energy: A review of the status and benefits in USA**. *Waste Management, 29*(5), January 29, 2012.

Quina, M. J., Bordado, J. C. M. & Quinta-Ferreira, R. M.*Air Pollution Control in Municipal Solid Waste Incinerators.* Retrieved 04/16, 2012, from http://cdn.intechopen.com/pdfs/18646/InTech-Air_pollution_control_in_municipal_solid_waste_incinerators.pdf

Redcliffe-Maud, B. W. (1974). *English Local Government Reformed*

Salestransformation. (2010). *Brent restructures and welcomes five new directors;* Retrieved January 30, 2012, from http://www.sales-transformation-limited.co.uk/market-intelligence/view/224/Brent-restructures-and-welcomes-five-new-directors-

Scottish Environment Protection Agency.*Generate Your Own Renewable Energy.* Retrieved 04/21, 2012, from http://www.business.scotland.gov.uk/bdotg/action/detail?itemId=1081290675&site=202&type=RESOURCES

Seadon, J. K. (2010). Sustainable waste management systems. *Journal of Cleaner Production, 18*(16–17), 1639-1651. doi:10.1016/j.jclepro.2010.07.009

Seneca. (2011). *MRF | Seneca.* Retrieved, 2012, from http://seneca.co/mrf/

Severn Wye Energy Agency. (June 2008). *BIOGEN Twinwoods Anaerobic Digestion (AD) Plant.* Retrieved 2/24, 2012, from http://www.biogasregions.org/doc/shining_examples/38.pdf

Simpson, F. (2012, January 31, 2012). New argument to digest. *The Times (London England),* pp. 12. Retrieved from http://go.galegroup.com/ps/i.do?id=GALE%7CA278507930&v=2.1&u=mlin_c_worpoly&it=r&p=AONE&sw=w

Strickland, J.*How Plasma Converters Work.* Retrieved, 2012, from http://science.howstuffworks.com/environmental/energy/plasma-converter.htm

Structure and democracy. (2012). *Brent Council.* Retrieved 01/21, 2012, from <http://www.brent.gov.uk/home.nsf/Main%20static%20pages/LBB-19?OpenDocument&pp=200026>.

Sustainability. (2012). *Brent Council.* Retrieved 01/21, 2012, from <http://www.brent.gov.uk/nv/lbb-2?OpenDocument&l1=100006&pid=200105>.

The Environment Agency. (2010). ***Landfill capacity in and around London – indicator three.*** Retrieved February 10, 2012, from http://www.environment-agency.gov.uk/research/library/publications/41035.aspx

The UK's National Centre for Biorenewable Energy, Fuels and Materials. (2011). ***Number of anaerobic digesters in UK increases by 20 per cent over past 12 months***. Retrieved 04/21, 2012, from http://www.nnfcc.co.uk/news/ad-sites-increase-by-20-in-uk-over-past-12-months

Tobin, L. (2011, 21 Jan).

OFT looks at turning Britain's waste into energy. *London Evening Standard,*

Waste and Recycling. (2012). Retrieved, 2012, from http://www.defra.gov.uk/environment/waste/

Waste and Recycling. (2012). Retrieved February 13, 2012, from http://www.defra.gov.uk/environment/waste/

Waste Prevention Legislation. (2011). *European Commision - Environment.* Retrieved February 13, 2012, from http://ec.europa.eu/environment/waste/prevention/legislation.htm

Wolfe Ware. (2012). *Excluded installations | FI Tarrifs.* Retrieved, 2012, from http://www.fitariffs.co.uk/eligible/energies/excluded_installations/

Young, G. C. (2010). *Municipal solid waste to energy conversion processes: economic, technical, and renewable comparisons*. Hoboken, N.J: John Wiley.

Zaman, A. U. (2010). *Comparative study of municipal solid waste treatment technologies using life cycle assessment method.* Retrieved 04/26, 2012, from http://www.bioline.org.br/request?st10022

Zhang, Q., Dor, L., Fenigshtein, D., Yang, W., & Blasiak, W. (2011). Gasification of municipal solid waste in the Plasma Gasification Melting process. *Applied Energy, 90*(1), 106-112. doi:10.1016/j.apenergy.2011.01.041

Zsigraiová, Z., Tavares, G., Semiao, V., & Carvalho, M. d. G. (2009). Integrated waste-to-energy conversion and waste transportation within island communities. *Energy, 34*(5), 623-635. doi:10.1016/j.energy.2008.10.015

Appendix A: Case Studies

EPI Pyrolysis, Kula, Manisa Turkey

Figure 24: EPi Pyrolysis Plant

Background

The majority of the waste stream (~70%) used consists of construction, commercial and industrial waste. The waste management companies had a static income due to landfill tax, therefore new methods of disposal needed to be used. EPi has been developing a pure pyrolysis system for the last 15 years and has only just begun the commercial phase in the last 2 years. Chris Lee, Business Manager at EPi, emphasized that the process was not a waste destruction technology, but in fact an energy production technology.

The Process

EPi operates by aggregating modules. Each module can process approximately 5700 tonnes of SRF. The facility can scale up to 5-6 modules at a time depending on the amount of feedstock that is available. The 1st module is termed the master module which houses the electronics and programming that control the process and feeds into the other modules. The process is inaudible which removes the need for noise control inside the facility. The modules are designed to accept a varying feedstock in order to stay competitive in changing market conditions.

The waste is heated in an airtight box to 900-1000˚C. It is then sent through an aqueous quenching system to bring it back to temperature. The created syngas is sent through a cyclone process which removes undesired solids and particulate matter. Once this process is complete the gas is scrubbed using sodium hydroxide and cooled down to ambient temperature in a buffer tank. The company boasts a 99% cleaning efficiency of the syngas. This gas can then be used directly in a reciprocating engine in order to generate electricity.

Technical Specifications

- Energy Yield – 16.5 MJ/m^4 – 23.5 MJ/m^4
- Power Generation – 1.4 MW per 1000kg
- Electrical Efficiency - 36%
- Emissions (based on WID allowance)
    - 40% hydrogen
    - 30% methane
    - 30% CO_2
- Size – 25,000 ft^2
- Payback Period – 24-30 months
- Lifecycle – 15 years
- Costs (Excluding installation)
    - Master Module - £1.55 Mil
    - Other Modules - £1.25 Mil
- Output - Fuel Gas (Cleansed Syngas)
- Fuel Applications – Direct Fuel for Gas Engines
- By-products – Char, Filter Material, "Cake"
- By-product Applications:
    - Char sold as aggregate
    - Cake has high energy value (39MJ/kg)
- Mean Waste Input – 30,000 tonnes

Note: Information for this case study was gathered from resources on the internet and data gathered from an interview with Chris Lee, Business Manager at EPi.

Shore Energy, Carnbroe, Scotland

Shore Energy has received planning permission to develop a mechanical biological treatment as well as a pyrolysis facility at a site adjacent to the A8 at Carnbroe. The proposal is for a plant which will handle 160,000 tonnes of waste per annum. The facility is designed to achieve high levels of diversion from landfill and extract recyclable materials such as ferrous and non-ferrous metals, plastics and inerts.

The facility received negative views from the public in earlier stages of planning. The local residents did not approve of a facility located near a major road. Concerns were raised about the emission levels due to the heavy traffic and added emissions from the EfW facility.

Contrary to the public views, an air quality official reported that air emitted from the facility was cleaner than the surrounding environment. More specifically the facility was responsible for less than 1% of the total emissions from the major road.

By utilizing MBT before it is harnessed for energy generation, shore energy hopes to recycle 50% of the incoming feedstock. This means out of the 160,000 tpa being sent to their facilities, approximately 80,000 tpa will be used for energy generation. Jon Garvey, who is in charge of the development of the facility, stressed the benefits of having a combined pre-treatment and EfW process. Combining the two processes lowers transport costs and provides a more reliable feedstock.

Note: Information for this case study was gathered through a phone interview with John Garvey, the project director for Shore Energy.

Visit to Wheelabrator Millbury Inc. USA

The Wheelabrator incinerator at Millbury provides disposal of MSW for 35 communities in Massachusetts, while generating surplus electricity back to the local power grid. Roger Saverin, an employee of the facility since 1987, was interviewed.

Interview transcript:

- Waste feedstock corrodes the tubing much faster than if other fuels were used.
- Environmental impact is minimized; scrubbers are lined with lime in order to control SO_2 emissions. Urea is sprinkled on the flame tips with the objective of keeping the oxygen and nitrogen released from the combustion separated.
- The Continuous Emission Monitoring System (CEMS) runs 24/7. The Environmental Protection Agency (EPA) has real-time access to all the information provided by the system.
- The facility operates two burners. On average, each burns 750 tonnes of waste per day.
- Approximately 200 trucks take 2200 tonnes of waste every day to the facility, four days a week. The excess waste is used to run the facility the remaining 3 days of the week.
- The trucks unload the waste in the tipping floor, two operators are in charge of thoroughly mixing the waste and storing it efficiently before it is burned. If waste is not well mixed, problems can arise, such as unwanted air pockets. Thus, decreasing the furnace temperature and rendering the burning process inefficient.
- The facility has the capacity to store 6000 tonnes of waste; including the tipping floor this number increases to 10000 tonnes.
- The area occupied by the plant is roughly 14-15 acres.
- The plant produces 45 MW of energy, 5 MW are used by the plant for its operations and 40 MW are sold to the power grid.
- The facility has approximately 55 employees and contractors, 6 employees run the plant operation during nights and weekends.

- The ash produced during the process is disposed in a nearby landfill owned by Wheelbrator. A 90% reduction in waste volume is achieved after the incineration process.
- The furnace is covered by water pipes on every side. The energy released by the combustion is absorbed by the water, which turns into superheated steam. The steam flows at a pressure of 850 psi, and passes through a General Electric turbine that operates at 3600 RPM.

According to Mr Saverin, over the past decade dramatic decreases have been seen in the amount of waste coming to the facility. Wheelabrator has begun to take waste from other communities as far as Rhode Island and Connecticut, as to not interrupt the production of energy.

Note: Information for this case study was gathered through a visit to the Wheelabrator Incinerator in Millbury.

Appendix B: Sponsor Profile

The London Borough of Brent was created by the London Government Act 1963 and came into effect on April 1, 1965. The Borough was made up from the merger of the former Municipal Borough of Wembley and the Municipal Borough of Willesden of Middlesex and owes its name to the River Brent. The Borough of Brent is one of the 19 Outer Boroughs and is located in the north-west part of the city (Figure 25). It is the 12th most populous borough of London, with a population close to 300,000 residents (Brent's Borough Profile, 2011)

According to the 2001 Census there were 127,806 male residents and 135,658 female residents.

Figure 25: Boroughs of London

http://www.allinlondon.co.uk/boroughs/brent/

From the residents that indicated their religion; 47.71% were Christian, 17.71% were Hindu, 12.26% were Muslim and 10% had no religion (Office of National Statistics, 2001). Brent is an incredibly diverse borough, it has the highest number of people born outside the UK after Ealing, in fact about 71% of its population is of an ethnicity other than white British (see Figure: 26). Brent has the 3rd lowest average income level of London;

many of its habitants unfortunately experience high levels of socio-economic deprivation (Brent's Borough Profile, 2011).

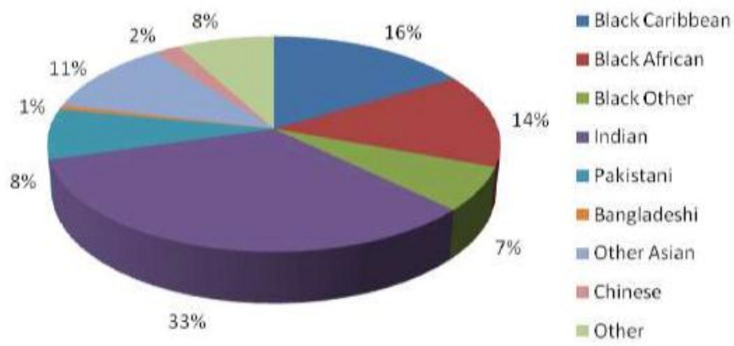

Figure 26: Demographics of Brent

http://www.brent.gov.uk/evidencebase.nsf/Files/LBBA-105/$FILE/borough_profile_part_one.pdf

Regarding the economics, Brent had a total of 12,000 business units registered in 2008 (Brent Local Assessment Report, 2011). A thorough distribution of the borough's economic distribution by sector can be seen in the Figure below.

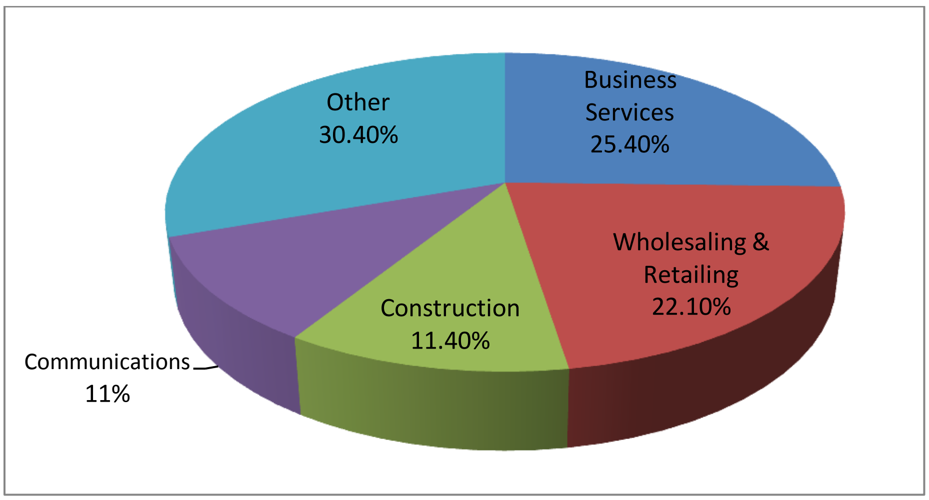

Figure 27: Brent's economic distribution by sector

http://issuu.com/brentcouncil/docs/brent_local_assessment_report#download

London's total economic output in 2008 stood at £245 billion. In the same year Brent's economy generated £4.4 billion output. Representing 16% of west London's economic output and 2% of the city's total output. During the last 5 years the economic growth in Brent has been of 1.4% per annum, below the 3.3% pa growth of London and 2.4% of the UK (Brent Local Assessment Report, 2011).

The Boroughs are part of a two-tier local government system that includes the Greater London Council and 32 London Borough Councils and the City of London. The Borough is governed by an elected borough council and is regulated by the Municipal Corporations Act 1882 and the Local Government Act 1933. The Boroughs are responsible for a variety of public services including: personal health services, welfare services, children´s services, libraries, refuse collection, swimming baths, weights and measures, public health inspections, cemeteries and crematoria, and the collection of rates (i.e., local property taxes). The Boroughs share with the Greater London Council the provision of various other public services, including: education, roads, planning, housing, sewage, and traffic control (Redcliffe-Maud, 1974).

The Brent Council is a local governing body which represents the borough as a whole. The borough is split into 21 wards which each elect three councillors to represent them in the council. These councillors have frequent meetings in order to develop major policies and vote on budget issues. In charge of the council is an Executive which is composed of one leader and nine other councillors appointed by the leader. Each member of the executive is in charge of a certain division such as public safety and housing. Working in these divisions are the council staffs, which are non-elected positions. Each department can have hundreds of staff working under the councillors. They are responsible for carrying out the goals of the elected council leaders.

Currently the council is composed of 40 members from the Labour party, 17 members from the Liberal Democrat party and 6 Conservatives.(Election Results, 2010) Because the Labour party has the

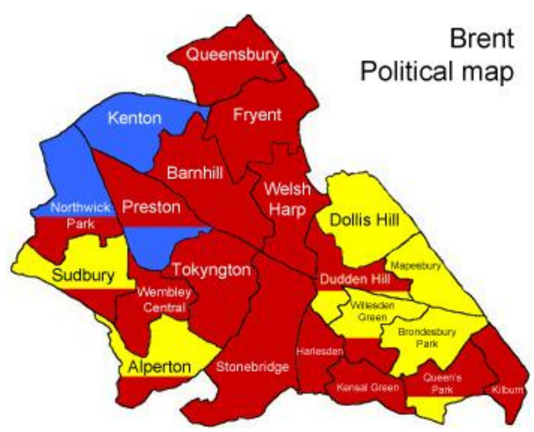

Figure 28: Ward map of the Borough of Brent.

Yellow-Liberal Democrats / Blue-Conservative majority the leader of the council is selected from their party. In charge of oversight of the council is a single Chief executive which is an unelected position. The Chief Executive is responsible "for ensuring that Brent's workforce delivers the council's key strategies and meets its aims and objectives" (Daniel, 2011).

The council's budget is aimed at providing numerous services to its residents with the theme of turning Brent into a prosperous "borough of opportunity" (London Borough of Brent, 2011). The budget requirement is met through a variety of funding methods, the two prominent methods being a Formula Grant and a Council Tax. The Council Tax is comparable to the property tax in the United States and the Formula Grant is a grant provided by the central government and is determined using a variety of factors to assess monetary need including elements such as population density and wealth distribution. The total budget requirement for 2010/2011 was £286,489,000 and below, Figure 29 illustrates the budget expenditures amongst the different departments. Figure 30 shows how revenue was generated. In Figure 29 it should be noted that *Levies* are "charges levied on the Council by the Lee Valley Regional Park, London Pensions Fund Authority, Environmental Agency and the West London Waste Authority." Furthermore, due to recent budget cuts the council has undergone major restructuring and the charts below are therefore not representative of current budget allocations.

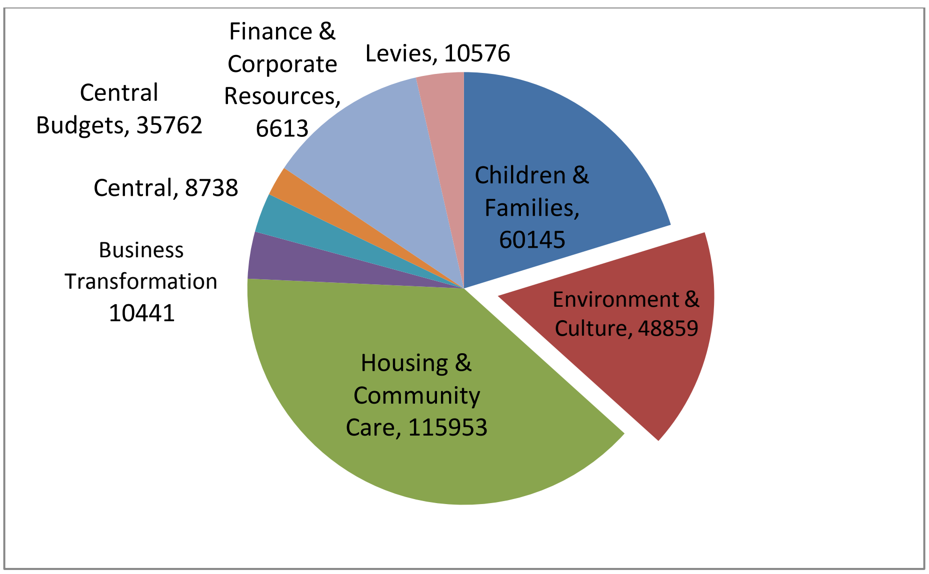

Figure 29: 2010/2011 Budget Summary (in £'000)

http://www.brent.gov.uk/councilfinance.nsf/Files/LBBA-94/$FILE/General%20Fund%20Summaries%20for%202010.11.pdf

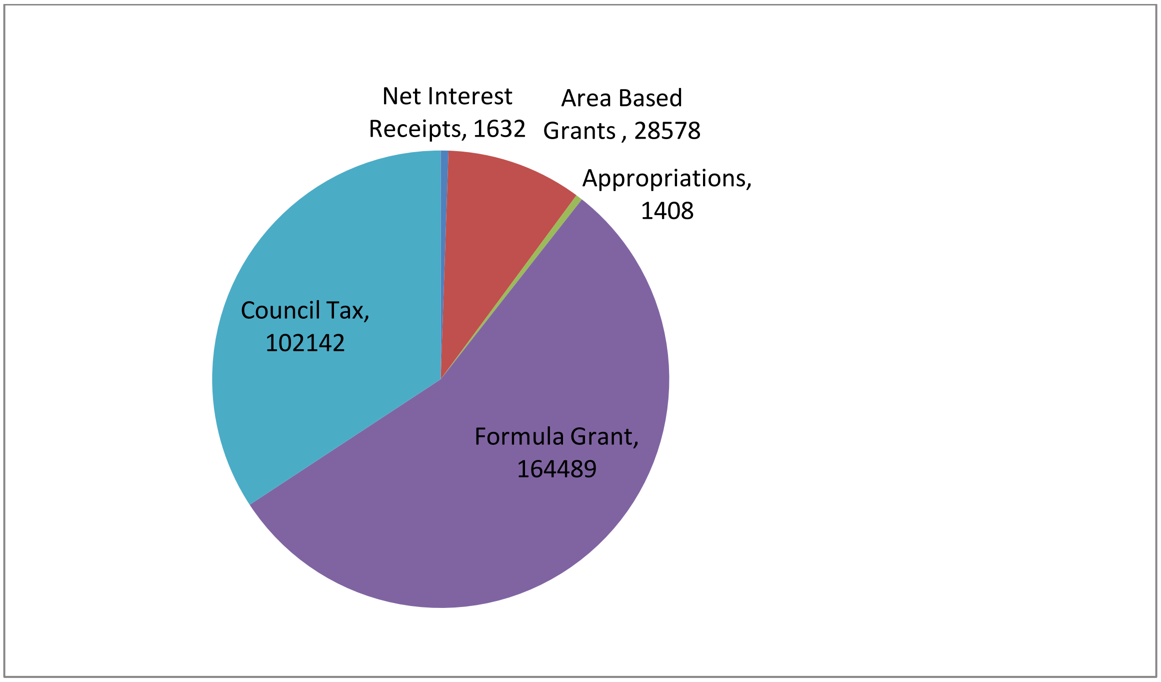

Figure 30: 2010/2011 Budget Funding (in £'000)
http://www.brent.gov.uk/councilfinance.nsf/Files/LBBA-94/$FILE/General%20Fund%20Summaries%20for%202010.11.pdf

The council is composed of eight departments, each providing a wide range of services to the community. The Regeneration and Major Projects (responsible for housing and planning) consumes the largest fraction of the budget, followed closely by the Children and Families Department (in charge of services such as schools, adoption, children welfare, etc.) and the Environment and Neighbourhood Services Department (in charge of recycling, arts and the libraries). Smaller budgets are allocated to the Finance and Corporate Services Department, Customer and Community Engagement Department, the Strategy, Partnership and Improvements Department, the Legal and Procurement Department, and finally the Adult Services Department (Brent's Borough Profile, 2011).

During our stay in London we'll be collaborating directly with the Regeneration and Major Projects department. The department is very committed to fighting climate change, for instance they have the goal of diverting 60 per cent of household waste from landfill by 2015 through recycling programs, and the goal of reducing carbon emissions by 25 per cent by 2014 (14 Sustainability 2012) . To attain these goals of reducing pollution and congestion, the department promotes walking and cycling, as well as car-sharing, car pools and car clubs.

The Regeneration and Major Projects Department is developing the Local Development Framework, which lays out the spatial vision of how Brent should be in 2026 and how this will be achieved (13 LDF Core Strategy 2012). In a nutshell, the plan is to convert Brent into a dynamic borough by renovating the Wembley area and providing new jobs, homes and leisure attractions. The council wants to attain this goal sustainably; our sponsor will have to make sure that occurs as intended. The strategic objectives (9 and 10) of the LDF are preserving and increasing the borough's open space for recreation and biodiversity, reducing energy demand from current building regulation standards, particularly in growth areas and by achieving exemplar low carbon schemes and Combined Heat and Power plants (13 LDF Core Strategy 2012). Most importantly, Objective 11 is to treat waste as a resource, which is directly related to our project.

Waste is a major concern for the council as it has been under a lot of pressure to manage it in a sustainable manner. Brent collected a total of 111,000 tonnes of municipal waste in 2007/08, it is estimated that by 2015 Brent will generate 381,000 tonnes of municipal, commercial and industrial waste and 442,000 tonnes by 2020 (13 LDF Core Strategy 2012). Hence, in the future waste will be considered as a resource, disposal will be deemed only as the last option. Currently the Regeneration and Major projects Department is committed to reducing the amount of waste that goes to landfill in Brent, promoting ways to reduce, reuse and recycle. The department has located bins for street recycling and the blue top recycling bin in residential areas. However, additional measures will have to be taken to ensure that the LDF plan occurs according with the expectations.

Appendix C: Preliminary Interview Transcript

The appendix below includes the main questions we will be asking according to our research in order to get a working flow chart for our interviewees. The questions are divided into four topical areas which take into consideration the different expertise of each expert we interview. In order to select the relevant questions we will consult with our sponsor and advisors before each interview to tailor our questions to each individual. In addition, we will have the complete list of questions available at every interview to be able to adjust each interview as it progresses.

What experience do you have in WTE?

- Policy
  - What approaches does you're department take in order to encourage WTE policy?
  - What factors, such as environmental standards or public acceptance, needed to be considered before implementing WTE policy?
  - How does the GLA affect the policy making procedure in the boroughs?
    - Are there regulations set by the GLA or other organizations that must be taken into account before pursuing waste management policy?
- Technology
  - What specific WTE technologies do you have experience with?
    - Based on our current understanding of waste-to-energy conversion methods we have come up with a decision matrix with certain important criteria. Do you believe these are appropriate and are there other factors we should be looking into?
      - Environmental impact
      - Payback Period
      - Energy yield
      - Specific types of waste needed
      - Government Incentives
      - Integration with current facilities
      - Land required

- General waste management
    - What is your personal opinion on the usage of WTE processes to divert waste from landfill?
    - Do you have any insight on the general public's opinion on WTE?
    - What are some of the potential problems when considering implementing a waste to energy program?
    - Are there any locations in the Wembley area that may be suitable for a WTE facility?
    - What are the sectors in Brent that generate the most waste?
        - What types of waste are generated in these sectors?
        - How is waste processed through waste transfer sites?
- Economics
    - What are the most recent government incentives for pursuing a WTE program?
    - Which technology is encouraged and funded the most?
    - What is the approximate payback period for each technique?
    - What is the minimum spatial requirement for an effective facility?