Trade Effluent Recycling and Reuse in the Food and Beverage Manufacturing Sector

By

Yolla Bishara McCoy

A thesis submitted to

the University of Birmingham

for the degree of

DOCTOR OF PHILOSOPHY

School of Civil Engineering

College of Engineering and Physical Sciences

The University of Birmingham

April 2016

ABSTRACT

Water is an essential natural resource that is vital for the survival of all living organisms. Dwindling water resources are having a significant impact on the availability of fresh water supplies worldwide. In the UK it is projected that water demand is likely to outstrip available supplies by 2050. Water recycling and reuse can help alleviate the reliance on natural and non-renewable water sources and can assist in bridging the gap between water availability and demand.

This research specifically focused on evaluating the water savings that could be achieved from Trade Effluent Recycling and Reuse (TERR) in the UK Food and Beverage Manufacturing Sector (FBM) and on identifying the current and future factors that can impact on the success of this application in the UK.

The data used in this research mostly relied on primary sources which was then analysed to address the guiding research questions.

The research data suggest that the water regenerated from a widespread application of TERR in the FBM can potentially satisfy 44% of future increases in water demand. However, TERR was only reported in 0.25% of the 404 FBM companies that were evaluated in this research. It was evident from the research findings that there is a need to clarify implementation strategies and validate the safety, reliability and economic feasibility of TERR projects before this application can be approved by the salient stakeholders in the FBM.

The data that emerged from an economic feasibility study at a dairy manufacturing site suggest that more work is needed to improve the return on investment from TERR applications. The payback period of the TERR project was 8.6 years, this was lowered to 6.2 years when including the current UK Government incentives. Based on the stakeholders' analysis a payback period lower than 24 months is essential for the approval of TERR projects.

Finally, alternative future scenarios were developed to evaluate the impact that changes in the environmental and socio-economic domains (ESE) are likely to have on TERR in the FBM. It was evident from the narratives that emerged from these scenarios that future changes in ESE are likely to have a positive impact on the approval of TERR projects. The findings also highlight the key role that TERR can potentially play in improving the resilience of the UK against future water shortages through providing a significant percentage of the projected future increases in water demand: i) 78% under innovation scenarios; ii)76% under local resilience scenarios and iii)14% under uncontrolled demand scenarios.

The knowledge gained from this research highlight the significant role that TERR in the FBM can play to improve the resilience of the UK against future water shortages. The findings from this research should act as an incentive for policy makers, the stakeholders in the FBM and the manufacturing sites to work together in order to generate interest and facilitate the approval of TERR projects.

DEDICATION

To my husband David for his unconditional love and support. Without his encouragement this work would have not been achieved.

To my beautiful daughter Samantha not only for her unconditional love and affection but also for having to be independent from a very young age so that I can work on this research. This was done without a whisper of protest or complaint and for that I am truly proud and grateful.

ACKNOWLEDGEMENTS

Completing this PhD was a challenge that at one stage I thought I will be unable to complete. However, I was helped by so many individuals that made juggling research work with a full time employment and running a family possible.

Firstly I would like to express my gratitude to my current employer and sponsor Suez who supported me along this journey.

I would also like to thank my supervisor Dr Cynthia Carliell- Marquet for her guidance and support in the past six years. Her insight and gentle guidance made this work possible.

Special thanks and appreciation also go to Professor John Bridgman for persevering with me throughout the time it took me to complete this research and for supporting me whenever I needed his help and advice.

Finally I would like to thank the representatives from the food and beverage manufacturing sectors, the water industry, UK Government officials and everyone whom I have emailed, interviewed and contacted as part of this research.

Guide for Readers

Chapter 1:
Introduction

- Provides an overview of the thesis background and describes the thesis structure.
- Sets out the research aim , objectives and hypotheses.

Chapter 2:
Establishing the Importance and Current Position of Trade Effluent Recycling and Reuse in the Food and Beverage Manufacturing Sector in the UK

- Reviews current knowledge and highlights research gaps.
- Establishes the current state of water recycling and reuse in the FBM in the UK.
Supported by appendices 2-1 to 2-4.

Chapter 3:
Stakeholder Analysis

- Provides a detailed analysis of the stakeholders that can impact on current TERR applications in the FBM.
Supported by appendices 3-1 to 3-6.

Chapter 4:
Economic Evaluation of TERR in the FBM
A Case Study at a Dairy Manufacturing site

- Presents the results from a case study at a dairy manufacturing site that evaluates the economic benefits that can be achieved from TERR applicatiosn in this sub-sector.
Supported by appendices 4-1 to 4-9.

Chapter 5:
The projected future of TERR in the FBM in the UK
Impact of Future Scenarios

- Evaluates the impact that changes in the environmental and socio-economic domains can have on the stakeholders in the FBM.
- Evaluates the future water savings that can potentially be achieved from a widespread application of TERR in the FBM in the UK.
Supported by appendices 5-1 to 5-4.

Chapter 6:
Discussion

- Provides a self critical analysis of the points that emerged from the research and relates the research findings to the wider literature.

Chapter 7:
Conclusion

- Reflects on the research key findings and contributions to knowledge.

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LIST OF ABBREVIATIONS

AW	Anglian Water
BOD	Biological Oxygen Demand
CAPEX	Capital Expenditure Costs
CFA	Chilled Food Association
CIP	Cleaning in Place
CMR	Carcinogenic, Mutagenic toxic and Reproductive substances
COD	Chemical Oxygen Demand
DAF	Dissolved Air Floatation
DEFRA	Department for Environment Food and Rural Affairs
DWRR	Direct Water Recycling and Reuse
EA	UK Environment Agency
ECA	Enhanced Capital Allowance scheme
ESE	Environmental, Socioeconomic
FBM	Food and Beverage Manufacturing Sector
FBI	Food and Beverage Industry
FOG	Fats Oil and Grease
FHC	Federation House Commitment
FISS	Food and Industry Sustainability Strategy
F/M	Food to Microbial Ratio
FSA	Food Standards Agency
GSG	Global Scenario Group
GTM	Grounded Theory Methodology
HACCP	Hazard Analysis Critical Control Point
HRT	Hydraulic Retention Time
KPI	Key Performance Indictors
IBC	Intermediate Bulk Container
l/p/d	Litres per Person per Day

MBR	Membrane Bioreactor
mg/l	Milligram per litre
MF	Micro Filtration
ML/D	Million Litres per Day
MLSS	Mixed Liquor Suspended Solids
Mm^3	Million Cubic Meters
NF	Nano Filtration
O2	Oxygen Requirement in Kg/day
OFWAT	The economic regulator of the water sector in England and Wales
OPEX	Operating Costs
ppm	Parts Per Million
Q	m^3 of influent water to the MBR /day
RO	Reverse Osmosis
S	COD of MBR Permeate
S_0	COD value of the influent water to the MBR
SELL	Sustainable Economic Level of Leakage
SM	Stakeholder Management
SRT	Solids Retention Time
SS	Suspended Solids
TERR	Trade Effluent Recycling and Reuse
THM	Tri-halo- methane
UF	Ultra Filtration
UKWIR	UK Water Industry Research limited
UU	United Utilities
UV	Ultra Violet Radiation
WRAP	Waste and Resource Action Programme
WRR	Water Recycling and Reuse

LIST OF DEFINITIONS

Food Wholesomeness	Has no negative impact on product shelf life or quality.
Holistic Approach	Refers to understanding the environmental, social, cultural and economic factors that can interact, influence or impact on trade effluent recycling and reuse in the food and beverage manufacturing sector.
Potable Water	**A**lso known as drinking water. Water safe for drinking and food preparation.
Return on Investment (ROI)	The benefit to the investor resulting from an investment of some resource. ROI is one way of considering profits in relation to Capital Invested.
Salient	Most noticeable or important.
Shareholders	Investors who have equity in a firm.
Stake	An interest or involvement in an application or enterprise.
Stakeholders	Any group or individual who can affect or is affected by the achievement of the organisation’s objectives.
Sustainable Development	Development that meets the needs of the present, without compromising the ability of future generations to meet their own needs.

Trade Effluent recycling and reuse	Treating the trade effluent water to potable standards and reusing the regenerated water in all manufacturing processes.
Water Resilience	The ability of water systems to resist or recover from change and disturbance to water availability and supplies.
Water Scarcity	When water supply cannot meet the water demands due to a number of factors within a given boundary of time and space.
Water Security	Availability of water supplies that are reliable, available, resilient, affordable and sustainable.

1 Introduction

1.1 Background

Water is regarded as one of the most essential natural resources in the world and the availability of fresh water supplies is vital for the survival and development of businesses, communities and the environment (Ceeney, 2011). However, demographic and climatic changes are having a significant impact on the availability of fresh water supplies and it is projected that 66% of the world population might be living in areas of scarce water supplies by 2050 (IChemE, 2015; Maddocks et al., 2015).

In the past, concerns relating to water shortages have been restricted to arid regions. However, rapid population growth, changes in public water demand, urbanisation and climatic change are having a profound impact on water availability in countries that were thought to be insulated from the possibility of having water shortages and unmet water demands (DEFRA, 2011b; Henly, 2012; Pearson, 2013).

Challenges associated with water security and the possibility of not being able to meet the continually growing demands are currently being faced by nearly half the European Community, where intervention is going to be needed in order to avoid critical water shortages by 2050 (EA, 2011a; EC, 2006). Countries such as the UK, France and Italy are expected to be the most affected, as they are projected to have the highest levels of population growth during this period (DEFRA, 2011a; EUROSTAT, 2015).

The population in the UK is expected to grow by 10 million by 2030 and 15 million by 2050 (EA, 2013b). This is expected to have a direct impact on the domestic water demand in the UK which is projected to increase by around 365 Million Cubic Meters (Mm^3) of water per annum (EA, 2013b).

Meeting these future expansions in water demand are expected to be challenging for the UK, as erratic weather and a likely decrease in summer precipitation and greater variability in annual rainfall are expected to have a significant impact on lowering future surface and underground water reserves (EA, 2009; EA, 2013b; Wade, 2013). It is therefore unlikely that the future increases in water demand will be met by increases in natural fresh water supplies. As a result, alternative approaches are currently being either evaluated or implemented by the UK Government to assist in improving the future water availability and resilience in the UK. According to the available literature these approaches aim to encourage sustainable behaviour through minimising water wastage and improving water efficiency and are/ or will be assisted by the following schemes: i) improving the public and businesses' awareness regarding the value of water, ii) reviewing water costs, iii) implementing strategies that will enable the sustainable growth of water provision, iv) improving the distribution network to minimise water wastage through leakage and v) investing in strategies that would allow for waste minimisation and water recycling and reuse (UK Parliament, 2006; UKWIR, 2012; EA, 2013b).

Based on the case studies and progress reports that have been published by the UK Government, there is a clear indication that progress has already been made in a number of the above focus points mainly: i) reviewing water costs for the domestic and the industrial sectors, ii) expanding water metering of domestic water supplies, iii) improving the efficiency of the distribution network and iv) working with the industrial manufacturing sectors to improve efficiency and minimise water wastage (UK Parliament, 2006; UKWIR, 2012; EA, 2013b). However, a critical examination of the progress reports emerging from the UK and the support and advice that is currently being provided by the UK Government clearly highlight that the emphasis to improve water efficiency in the industrial sector currently mainly focuses on water metering and detecting leaks. Limited progress has been made and insufficient data is currently available on the possibilities and benefits that can be achieved from water recycling and reuse (WRAP, 2011; WRAP, 2013).

Nevertheless, as detailed in section 1.2, water recycling and reuse, particularly in some industrial sectors such as the food and beverage manufacturing sub-sector (FBM), can play a significant role in reducing water usage and wastage in the UK. It is therefore important to critically evaluate and determine the potential renewable water provisions that can be achieved from water recycling and reuse in this sub-sector.

1.2 Water Usage in the Food and Beverage Manufacturing Sub- Sector

Industry is a main water user in the UK and the manufacturing sector alone utilises more than 50% of the total consumptive water (non- tidal) used in the UK. The future water demands are also expected to increase in this sector in line with population growth and increases in the living standards (WRAP, 2011; WRAP ,2013). The manufacturing sector in the UK embodies a number of sub-sectors, however, the largest in terms of water usage and wastage is the Food and Beverage Manufacturing sub-sector (FBM) (RAENG, 2010; WRAP, 2013).

It is estimated that the water demand of the FBM is around 36% of the total water used in manufacturing and is around 200-250 Mm^3 per annum (RAENG, 2010; WRAP, 2013). In addition, what mainly differentiates the FBM from the other manufacturing divisions is the high percentage of water that is wasted during the preparation and cleaning processes. According to figures published in 2013, 90% of the total water used in the FBM is not embedded in the final products and if not reused will end up as industrial trade effluent (WRAP, 2013).

Minimising water usage and wastage in the FBM became a key government target in 2006 with the publication of the Food Industry Sustainability Strategy (FISS) (DEFRA, 2006). The primary objective of the strategy is to lower water usage in the FBM by 20% by 2020 (DEFRA, 2006). The FISS does not address the water that is embedded in the products but focuses on water use minimisation in areas such as: i) cleaning, ii) preparation processes, iii) cooling and iv) steam generation.

The FISS is currently being governed by the Department for Environment Food and Rural Affairs (DEFRA) with the help of the Waste and Resource Action Programme (WRAP). The success and implementation of the strategies stated in the FISS rely on voluntary agreements between the UK Government agencies and the FBM. This initiative is known as the Federation House Commitment (FHC) and has current representation of around 24% of the FBM (WRAP, 2015; WRAP, 2014a). Signatories to the FHC have to pledge addressing four main areas to assist in minimising water wastage within the manufacturing premises (WRAP, 2015):

i. Altering water pressure in the factory
ii. Repairing leaks
iii. Fitting recirculating systems and
iv. Optimising cleaning operations

After critically reviewing all the reports that have been published by the UK Government and associated agencies, what seemed to be absent is addressing and identifying the potential role that water recycling and reuse can play in improving water use efficiency in the FBM.

Although the above four strategies are important and have so far been successful in achieving a reduction of 15.4% of the total water used by the FHC signatories (WRAP, 2015), there is a need to explore additional strategies that might enable further reductions in water usage and wastage in the FBM.

One of the areas that can potentially complement the four FHC guidelines stated above, is recycling and reuse of the trade effluent generated from the manufacturing processes (trade effluent recycling and reuse) (TERR).

According to the UK Environment Agency and WRAP, 90% of the water used in the FBM is currently wasted as industrial trade effluent (EA, 2013a, WRAP, 2013). Based on a total usage figure of 200-250 Mm^3 per annum (WRAP, 2013), the volume of water that can potentially be considered for recycling from TERR applications is between 180 and 225 Mm^3 per annum. If treated to the correct standards, TERR in the FBM can therefore potentially lead to significant reductions in the annual water usage in the UK. However, as detailed in chapter 2 of this thesis, limited published data is currently available on general water recycling and reuse (WRR) and TERR in the FBM. This limitation applies to the data emerging from both inside and outside the UK. This lack of literature created a major challenge for this research. As detailed in chapter 2, this was partly overcome by conducting an initial field survey to establish and critically evaluate the current water management practices, including TERR applications that are currently being followed by the FBM in the UK.

Findings from the literature review and the field survey were then used to identify the knowledge gaps that require further research and analysis.

1.3 Aim and Objectives

Research Aim

The primary aim of this thesis is to carry out a holistic study to establish and critically evaluate the factors that can currently impact on the uptake and success of trade effluent recycling and reuse in the FBM and to determine the role that this application can play in the provision of sustainable water resources and in improving the future water resilience of the UK.

Due to the dynamic nature of TERR, the above will be evaluated taking into account current and future environmental and socioeconomic conditions.

Research Objectives

The research aim was achieved through the following main objectives:

1- To critically review the literature in order to evaluate the strategies that are currently being adopted to minimise water usage and wastage in the FBM in the UK.
2- To establish the current position of TERR in the FBM and to identify and provide detailed and pioneering understanding of any existing applications in the UK.

The above two objectives will be used to identify gaps in the existing knowledge and areas that will require further research and analysis.

3- Applying an innovative combination of Grounded Theory Methodology and Freeman's Stakeholder Analysis in order to critically analyse and identify the stakeholders that can currently impact on the success or failure of TERR projects in the FBM; using the generated data to identify possible future drivers of change.

4- Design and critically analyse a comprehensive case study at a main FBM sub-sector; using the data from the case study to examine the economic feasibility of TERR in the FBM in the UK.

5- Develop bespoke future scenarios that are specific for TERR in the FBM in the UK and to use the narratives from these scenarios to assist in re-examining the behaviour of the stakeholders as the new scenarios unfold.

6- Evaluate the impact of the future scenarios on the projected water contributions that can potentially be achieved from a widespread application of TERR in the FBM in the UK.

1.4 Hypotheses

1- Climatic and demographic changes will impact on the future of water availability in the UK, making it essential to consider alternative and renewable water sources that will assist in bridging the gap between water supplies and water demands.

2- Current water wastage is significant in the FBM; hence TERR in this sector could play a significant role in improving the future water resilience of the UK.

3- There are currently no technical or legislative challenges that will inhibit TERR applications in the FBM.

4- The stakeholders in the FBM are many and can interact in complex ways to impact on the decisions taken by the manufacturing sites.

5- For TERR to be adopted by the FBM, the approval of the salient stakeholders is necessary.

6- The economic benefits that can be achieved from TERR in the FBM will have an impact on the uptake of TERR applications in the FBM.

7- TERR in the FBM is a dynamic process and will be affected by changes in the environmental and socio-economic domains.

1.5 Thesis Structure

In order to achieve the primary aim of the research, the thesis is guided by the following two main research questions:

1. What are the factors that can impact on the success or failure of TERR applications in the FBM?
2. What are the water saving contributions that can be linked to TERR in the FBM and what impact might a widespread application of TERR in the FBM have on the future water availability and resilience of the UK?

In order to provide answers to the above guided questions; these were further sub-divided into the following:

a) How are future changes likely to impact on the water availability in the UK?
b) What is the current state of TERR in the FBM and what are the water saving contributions that can be projected from a widespread application in the UK?

c) Who are the current salient stakeholders that can impact on the success or failure of TERR in the FBM? What are the possible future drivers of change?

d) Are there currently any financial incentives associated with TERR applications in the FBM? How would this impact on the uptake of this application in the UK?

e) Would future changes in the environmental and socio-economic domains impact on how the stakeholders perceive TERR in the FBM? How might these changes impact on future applications in the UK?

f) How would a widespread application of TERR in the FBM impact on the future water resilience and security of the UK?

Varied methodologies had to be evaluated and where applicable used to answer the above guiding questions, this had a significant impact on the structure of the thesis. In order to enhance the clarity for the reader the relevant literature reviews and associated methodologies were presented in the individual chapters. This applies to chapters 2, 3, 4 and 5.

In order to achieve consistency throughout the thesis the above chapters are divided into the following main sections:

1. The specific aim that the chapter is trying to achieve
2. Critical Literature review specific for the chapter
3. Methodologies and Research design specific for the chapter
4. Field data and representation of results
5. Interpretation of results
6. Chapter discussion and summary

The thesis is split into the following seven chapters:

Chapter one- Introduction: This chapter provides a general introduction into the research work, guided questions and the structure of the thesis. Chapter one also sets out the overall aim of the research, the research hypotheses and the specific objectives that have to be addressed to fulfil this aim.

Chapter Two- Establishing the importance and Current position of TERR in the FBM in the UK: The critical literature review and data presented in this chapter aim to define and set up a clear direction for the research. The chapter is divided into five main parts:

1. Critically reviewing and evaluating the available data on water resources and water availability and management in the UK.
2. Establishing the importance of evaluating and researching TERR in the FBM.
3. Critically evaluating the UK Government reports on TERR in the FBM.
4. Critically evaluating any regulatory and or legislative matters that can impact on the uptake of TERR in the FBM.
5. Carrying out an extensive field survey to establish state of the art knowledge and understanding of the current water saving initiatives and TERR applications that are currently implemented by the FBM in the UK.

The survey presents results from 404 FBM manufacturing sites and according to our knowledge is the first of its kind in the UK. The knowledge gaps identified in this chapter are used in the planning and design of the subsequent chapters of this thesis.

Chapter Three- Stakeholder Analysis: This chapter provides an in- depth qualitative analysis of the stakeholders that have the potential to currently impact on the uptake and success of TERR in the FBM. The stakeholders are analysed from a manufacturing (site) perspective in order to identify current drivers, barriers and future drivers of change.

The data in this chapter is collected using semi – structured interviews following the Grounded Theory Methodology (GTM). The qualitative data is then analysed using GTM and Freeman's stakeholder analysis.

Chapter Four – Case Study: The main aim of this chapter is to provide an in depth examination and analysis of the current economic feasibility of TERR in the FBM. The case study is based at a dairy manufacturing site and utilises actual site data to provide a comprehensive cost / benefit analysis of TERR applications in the FBM. According to our knowledge this detailed and comprehensive evaluation is the first of its kind in the UK.

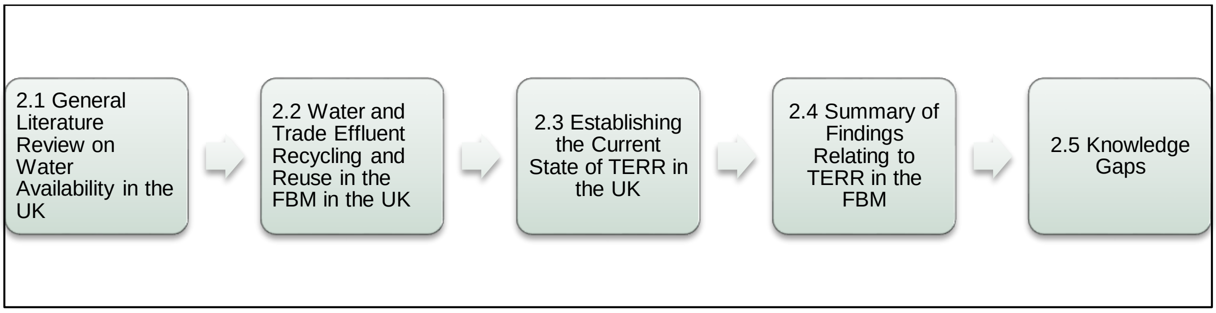
Chapter Five – Future Scenarios: The chapter examines the impact that future changes in the environmental, social and economic domains can have on TERR in the FBM in the UK. Future scenarios' narratives that are specific for TERR in the FBM are developed as part of this chapter. The stakeholders that are researched in chapter three, are re-evaluated under the new emerging environmental and socio- economic domains. This chapter also examines the future role that TERR in the FBM can play in improving the future water resilience and security of the UK.

Chapter Six – **Discussion**: The chapter provides a critical discussion and analysis of the points that emerged from this research in relation to the wider literature.

Chapter Seven- This chapter provides the overall conclusion and recommendations for future work.

Due to the confidentiality of some of the data presented in this research some appendices are only provided on a CD ROM and will be deposited as confidential material. This will be highlighted where applicable throughout the thesis.

2 Establishing the Importance and Current Position of Trade Effluent Recycling and Reuse in the Food and Beverage Manufacturing Sector in the UK



The main purpose of this chapter is to establish the current knowledge relating to the two guiding questions listed below as well as identifying any knowledge gaps that require further research or analysis.

1. How are future changes likely to impact on the water availability in the UK?
2. What is the current state of TERR in the FBM and what are the water saving contributions that can be projected from a widespread application in the UK?

In order to achieve the aim of chapter 2, the chapter is divided into the following main sections:

Section 1

1. General literature review on water availability in the UK
2. Literature review on general water recycling and reuse (WRR) and TERR in the FBM to assist in:
    a. Establishing and critically evaluating the work and strategies that are currently implemented or encouraged by the UK Government and the private and academic sectors regarding WRR and TERR applications.
    b. Critically evaluating current field data on WRR and TERR in the FBM.
    c. Evaluating the contributions in water savings that can be linked to TERR in the FBM.
3. Review of EU and UK regulations that might impact on TERR applications in the FBM.

Section 2

4. A comprehensive field survey in order to provide:
    a. An in-depth knowledge of the general water management practices and effluent treatment strategies that are currently followed by the FBM in the UK.
    b. Identify and analyse applications that are specific to TERR applications in the FBM.

As indicted earlier, findings from this chapter will be used to identify the knowledge gaps that require further research and investigation.

2.1 General Literature Review on Water Availability in the UK

Water is regarded as one of the most essential natural resources in the world. However, due to demographic and climatic changes, fresh water supplies are becoming either scarce, or expensive to provide. According to recent projections, 66% of the world's population is expected to be living in areas of scarce water supplies by 2050. This is compared to just 7% in 2015 (IChemE, 2015; Maddocks et al., 2015). In addition, the demand on fresh water is expected to outstrip supply by a staggering 40% by 2030 (Ceeney, 2011; IChemE, 2015). Although similar concerns have been highlighted more than 15 years ago, limited progress has been made to provide promising and effective solutions to avoid global shortages of fresh water supplies (Postel, 2000; Lee, 2009). According to Hope and Rouse, this lack of progress is partly due to the slow, uneven or largely inadequate policies that have been devised to address the nature and scale of the global water scarcity issues (Hope and Rouse, 2014).

Until recently, concerns relating to water shortages were thought to be a problem mainly affecting arid areas; most European countries were considered to be insulated from the possibility of having water shortages or unmet water demands. However, due to population growth, over abstraction and climatic change, the balance between water availability and demand has reached critical levels in many European Countries (EUROSTAT, 2015).

According to figures published by the UK Government and the European Commission, the possibility of not having enough water is currently considered a serious threat for nearly half the European Community, particularly in countries where the current per capita water availability is less than 4000 m^3 per annum (figure 2-1) (EC, 2006 ; EC, 2007; EEA, 2009; EA, 2010). Figure 2-1 does not include the per capita water availability for the Republic of Ireland. However, according to the figures published by the UNESCO this is currently around 13,000 m^3 per capita per annum (UNESCO, 2016), placing Ireland next to Hungary on the graph. Due to demographic and climatic changes, future challenges relating to water availability and security are likely to affect a number of countries in Western Europe, mainly the UK, France and Italy where population growth is expected to be the highest (EA, 2008b; EC, 2012; DEFRA, 2011a; EUROSTAT, 2015). The population in the UK is expected to grow by 10 million by 2030 and 15 million by 2050 (EA, 2013b). This is projected to have a direct impact on increasing the domestic water demand in the UK. Based on the current daily water usage figures of 100-130 litres per person per day (l/p/d), at least1000 million litres of water per day (Ml/d) will be additionally needed by 2030 to satisfy the domestic water requirements that are directly linked to population growth (EA, 2009; EA, 2013b). However, additional future water provisions might be challenging for the UK as the above period of population growth is also projected to be met by a decrease in the average summer rainfall. This is expected to have a negative impact on river levels, making it unlikely for the expected increases in the future water demands to be met by increases in fresh water supplies (EA, 2008b; UKCP, 2009; Wade et al., 2013). This is expected to have a significant impact on the future security and availability of fresh water supplies in the UK (DEFRA, 2011a; EA, 2011a; EA, 2013 c).

Addressing water security is currently high on the UK Government agenda and is driven by the possibility of not having enough water to meet the ever-growing demands. The seriousness of this situation is highlighted in a number of official government reports.

1. The availability of surplus freshwater supply in England and Wales has been lower than the desired level of 30% since 1999 (figure 2-2) (EA, 2008 a). As discussed earlier and due to the projected changes in population growth and climatic change this is likely to become more critical in the future (EA, 2008b; Wade et al., 2013).
2. In 2011 the South West, South East and the Midlands regions of England were declared as having near drought conditions (DEFRA, 2011 b).
3. In 2013 an evaluation of the water resources in England and Wales established that most water suppliers are currently experiencing serious or moderate stress levels in meeting the water demands (EA, 2013 c). A summary of the findings is presented in (table 2-1). Based on the projections provided by UKCP09 and which indicate that long-term averages of summer rainfall are more likely to reduce during the 21st century (UKCP,2009), the above stress levels are unlikely to change in the near future (EA, 2013c; EA, 2014).
4. Similar results were also reported by a private research study carried out by Wade et al in 2013. Data was taken from a number of river hydrological studies in the UK and modelled to generate river catchment hydrological

models illustrating the impact of climatic change on future river flows in a England and Wales (figure 2-3) (Wade et al., 2013).

The factors that are currently and will in the future impact on the availability of fresh water supplies in the UK are complex but can be briefly outlined as follows (Barford and Everitt, 2012; DEFRA, 2014; DEFRA, 2011a; EA, 2011a; EA, 2012):

1. Population growth is expected to increase by 10 million by 2030 (Barford and Everitt, 2012; DEFRA, 2011a).
2. Population shift to big cities, particularly in the South East of England and London. According to Wade et al, the majority of population in the UK will be living in this area by 2020 (Wade et al., 2013). As can be seen from table 2-1 this area is already experiencing high water stress levels. The situation is also expected to become more challenging in the future due to an expected increase in the regional temperatures of around 1.3-4.6 degrees Centigrade (DEFRA, 2011 a). This can potentially lead to an 80% decrease in summer run- off and gatherable rain water. Groundwater supplies, particularly in sandstone areas, are also projected to be lower due to lower replenishment rates (EA, 2012).
3. Climatic change: In addition to the above changes that are specific to the South East of England, climatic change is expected to have a widespread impact on England and Wales where water deficit is anticipated to be a challenging problem in half the river basins by 2050 (EA, 2011a).
4. More intense weather conditions are projected in the future. This is expected to lead to longer dry summers and wetter winters with the increased risk of flooding (EA, 2011a; Wade et al., 2013). Based on figures

published by DEFRA, the dry summers will have a significant impact on the water reserves and might lead to long term deficiency issues, particularly those relating to underground water supplies (DEFRA, 2014b).

5. Long term underinvestment in the water distribution infrastructure: This is currently contributing to significant losses through leakages and failures in the distribution network. Although significant improvements have been made in recent years, water wastage from the distribution network is still considered high (OFWAT, 2011). This will be further detailed in section 2.2.1.

Although higher than average rainfall was recorded in the UK in 2012 and 2014, future projections regarding possible water shortages have not changed. This is mainly due to the high probability of deterioration of the water reserves should the UK face another multi-year drought (EA, 2014).

Due to the seriousness of these projected issues the UK Government is actively evaluating future interventions that might be necessary in order to avoid severe water shortages by 2030 (EA, 2012; EA, 2014).

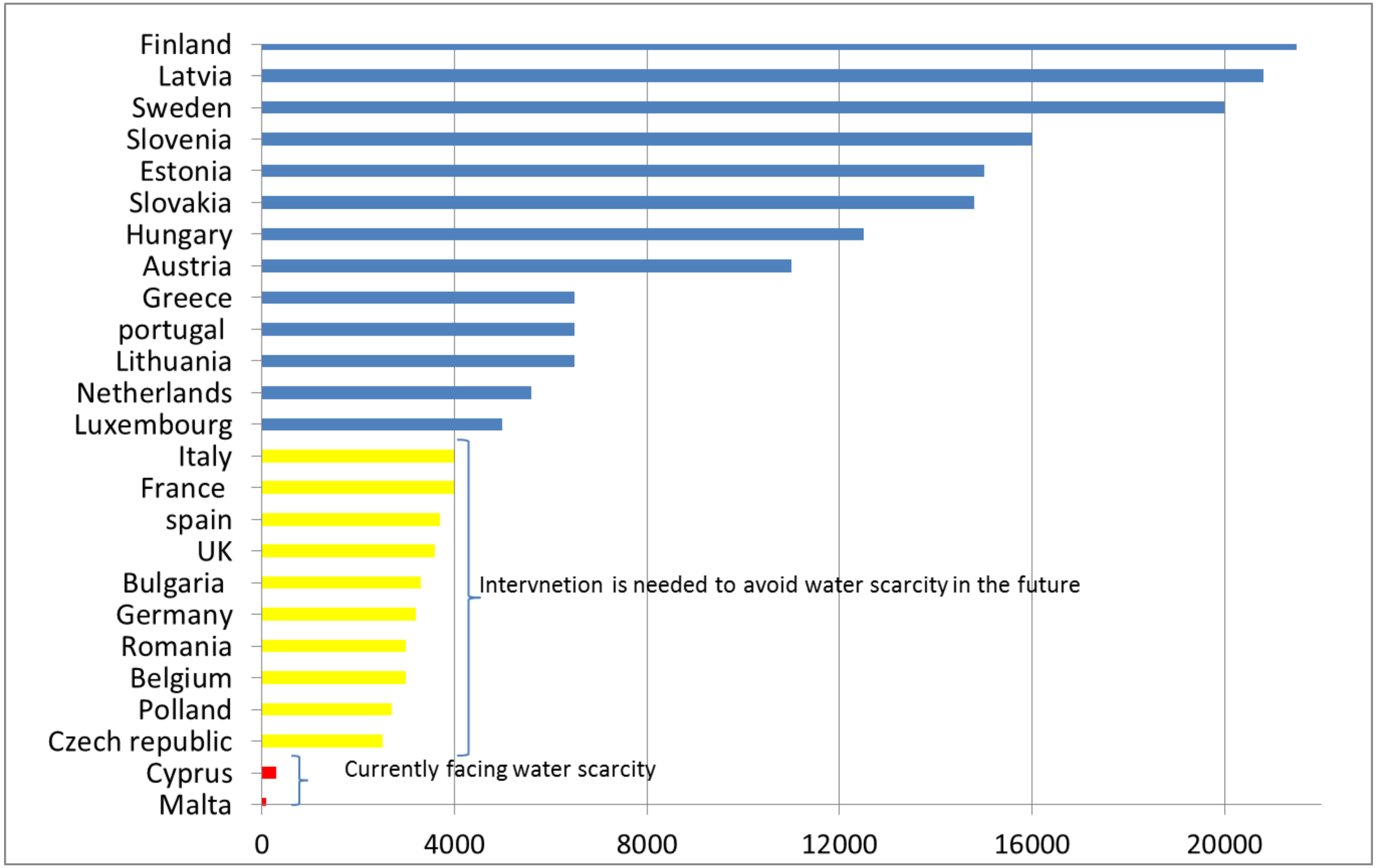


Figure 2-1 Water availability per capita in EU countries (m^3 per annum) (derived from EC, 2006)

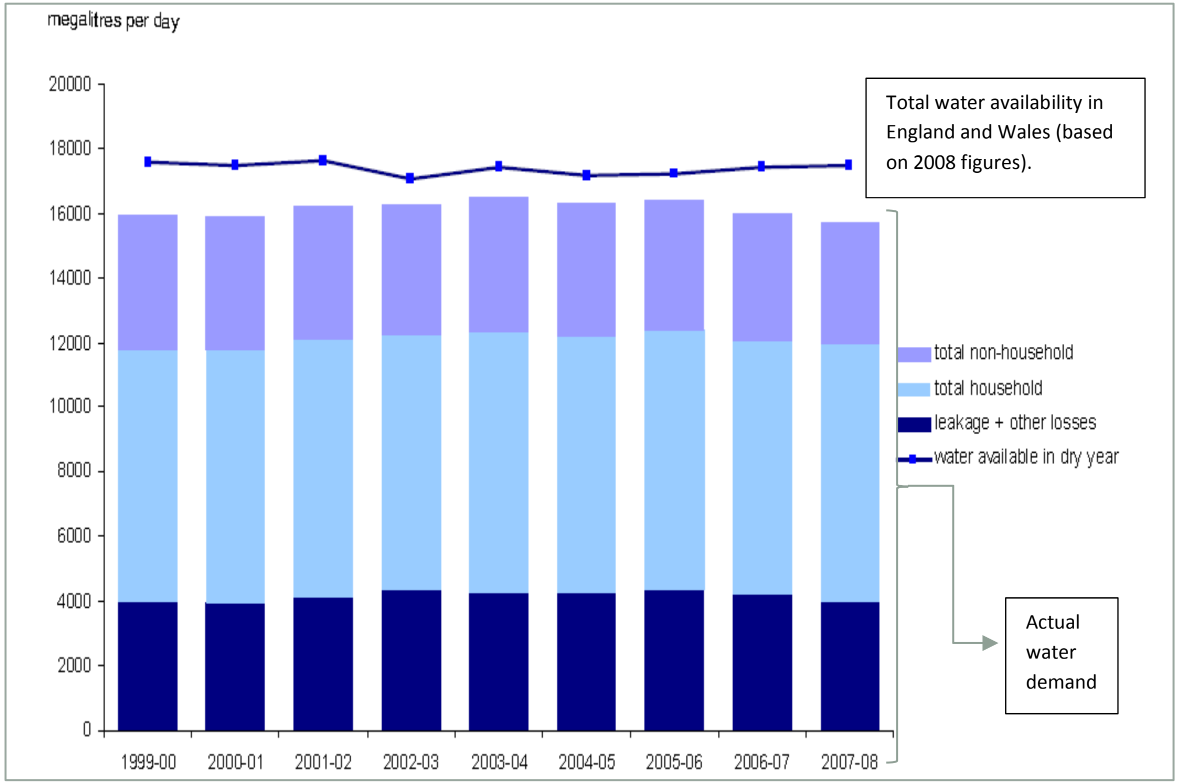


Figure 2-2 Water availability versus demand in England and Wales (EA, 2008 a)

Table 2-1 Water Stress Classifications per Water Supply Area (derived from EA, 2013c)

Water Company area	Current Stress
Affinity Water (formerly Veolia water Central)	Serious
Affinity Water (formerly Veolia water East)	Serious
Affinity Water (formerly Veolia water South East)	Serious
Anglian Water	Serious
Bristol Water	Moderate
Cambridge Water	Moderate
Cholderton and District Water	Moderate
Dee Valley Water	Moderate
Dwr Cymru Welsh Water	Moderate
Essex and Suffolk Water	Serious
Northumbrian Water	Moderate
Portsmouth Water	Moderate
Sembcorp Bournemouth Water	Low
Severn Trent Water	Moderate
South East Water	Serious
South Staffordshire Water	Moderate
South West Water	Moderate
Southern Water	Serious
Sutton and East Surrey Water	Serious
Thames Water	Serious
United Utilities	Moderate
Veolia Water Projects	Moderate
Wessex Water	Moderate
Yorkshire Water	Moderate

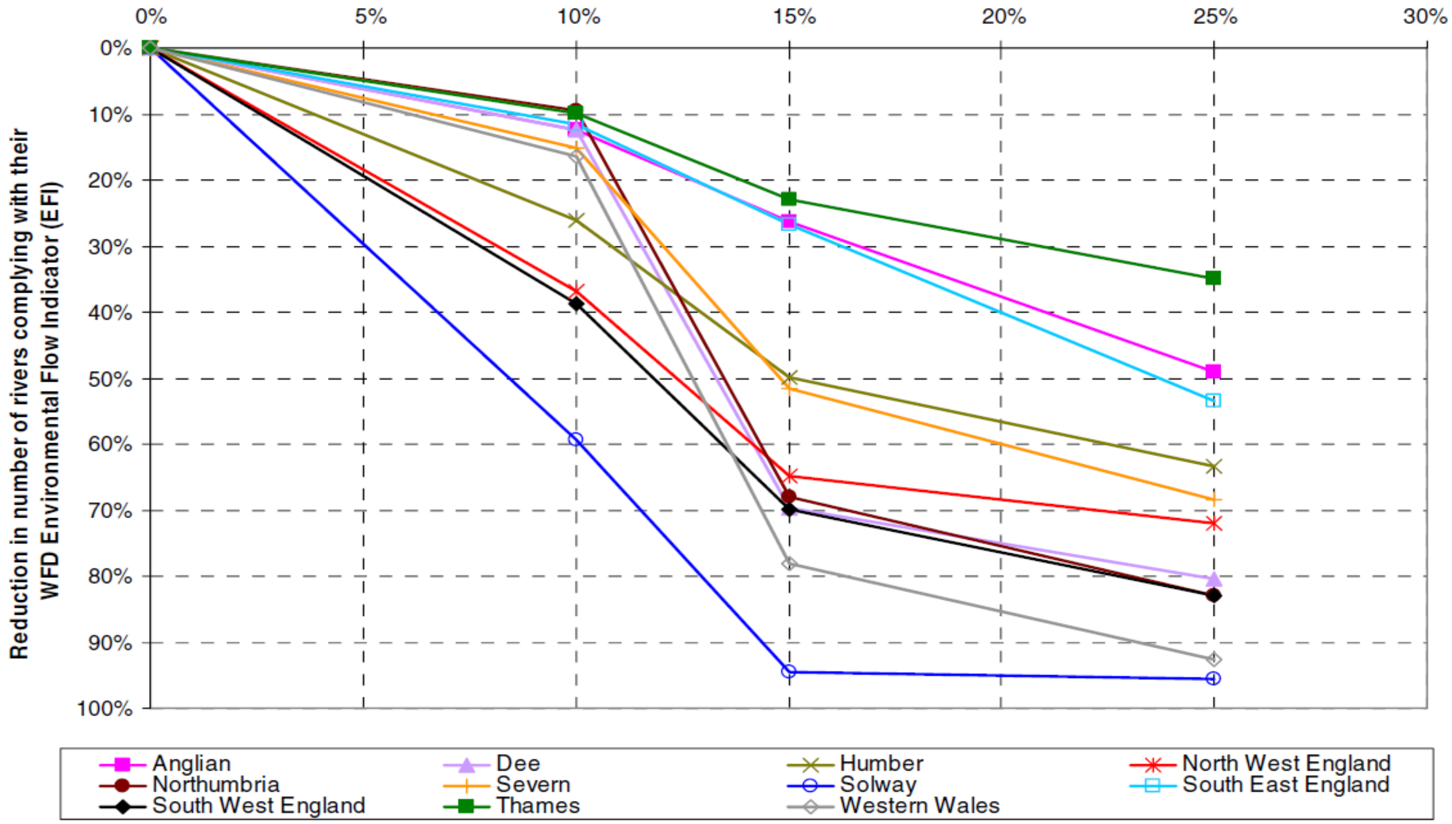


Figure 2-3 Reduction in compliance with the Water Framework Directive (WFD) and Environmental Flow Indicators (EFI) against changes in river flow statistics by the 2020s (Wade et al., 2013)

2.2 Water and Trade Effluent Recycling and Reuse in the FBM in the UK

A detailed literature search going back to the 1980s highlighted the lack of academic papers on both general water recycling and reuse and TERR in the FBM. This limitation applied to data emerging from inside and outside the UK. A number of UK Government reports were found to address water management practices in the FBM. These were published by DEFRA and associated agencies such as the Environment Agency (EA) and WRAP.

In the absence of academic papers, these official reports were critically reviewed to assist in evaluating the water management strategies that are currently being recommended and or implemented by the UK Government.

2.2.1 UK Government Strategies Addressing Water Availability

Strategies relating to water management and water conservation in the FBM are part of the general water efficiency schemes that are currently being evaluated by the UK Government. It is therefore essential to examine and understand these schemes prior to exclusively scrutinising the FBM sector. The UK Government reports provide a clear indication that the projected future threats to water availability and security are being taken very seriously. Strategies and interventions are being evaluated on an ongoing basis to assist in preventing a future crisis of water demand exceeding available water supplies by 2050 (DEFRA, 2008; EA, 2009; DEFRA, 2011a; EA, 2013c).

The following strategies are currently being either evaluated or implemented in order to assist in easing the pressure on satisfying the projected future increases in water demand (UK Parliament, 2006; DEFRA, 2011a; DEFRA, 2011b; EA, 2013b; UKWIR, 2012):

1. Improving and promoting a better understanding of the value of water. This has been identified as key to minimise wastage and improve water efficiency by households and businesses. The current government target is to reduce the per capita consumption from its current value of 130 l/p/d to 100 l/p/d by 2030. This is estimated to save around 300ML/d (DEFRA, 2011a; EA, 2013b).

   A number of programmes have been implemented to assist in improving water awareness in the UK:

   a. Expanding the introduction of water metering to domestic households. The aim is to double this application to 65% by 2030 (DEFRA, 2008; Hope and Rouse, 2014)
   b. Working with the industrial sector to link water usage to energy costs, mainly those involved in (DEFRA, 2011b):
      i. Abstraction
      ii. pumping
      iii. water treatment

The data published by DEFRA highlight the positive impact that water metering is having on reducing water usage and wastage in the domestic sector. Figures from the South East of the UK indicate a 50% reduction in water usage in households that are currently under the water metering scheme (DEFRA, 2011b).

No data is found on evaluating the impact that linking water and energy usages might have on the industrial sector. There is a need to investigate this area in further detail. The impact that this might have on TERR in the FBM will be included in the stakeholder analysis and will be further investigated in chapter 3 of this thesis.

2. Introducing seasonal tariffs. This is currently being trialled by Wessex water and if proven successful will be extended to other areas in the UK. The aim of this scheme is to increase domestic water charges during periods of low water availability to encourage minimising water wastage in the domestic sector (Wessex Water, 2013). However, this programme can only apply to areas that are already under the water metering scheme.
3. Moving away from capital intensive and short term solutions to more holistic and long term strategies that will provide more sustainable provisions of water (UKWIR, 2012). It was evident from the literature that at the moment there is no general accepted definition for sustainable growth or regulation in the water industry but the move away from intensive solutions has been driven by the following concerns:
    a. The adverse environmental impact of some technologies that have been previously used in the UK. The UK currently has one desalination plant based on the river Thames. Although this is only used in extreme drought conditions, figures show that the plant is highly energy intensive and there are concerns regarding the impact on marine life and the environment. These concerns

are mainly associated with the generation and disposal of the highly concentred brine (Jowit, 2010; Roberts et al., 2010).

b. There has also been reluctance in providing planning permission to building new water storage reservoirs, as there are concerns regarding the negative impact on the local ecosystem. In addition, reservoirs are expensive to build and based on previous experiences, they can become less effective in meeting long term water demands unless other factors are being addressed. This is mainly due to the limited storage capacity of reservoirs and their reliance on rain water (Barford and Everitt, 2012).

4. Investment in the existing infrastructure to enable the catchment of more water (OFWAT, 2011).
5. Improving the distribution infrastructure. Although significant improvements have been achieved in recent years, leaks still account for the loss of nearly 1800ML/D. It is expected that this figure will drop by 3% by the end of 2015 (OFWAT, 2011). However, there are limits beyond which further improvements might become difficult to economically justify. This is known as the “Sustainable Economic Level of Leakage (SELL)” beyond which it would cost more to reduce leakage than it would to save water. Both the UK Government and OFWAT are currently working with the water industry to evaluate and define this level per water basin or catchment area, taking into account issues relating to water availability (OFWAT, 2011).
6. Introducing changes to the abstraction licensees in order to restore sustainable levels mainly by the industrial sectors (DEFRA, 2016;

DEFRA, 2014b). No data is available on how this is going to impact on water usage in industry or the timescale for introducing these changes.

The impact that this might have on TERR in the FBM will be investigated in further details in chapter 3 of this thesis.

7. Supporting the development of new innovations and technologies that will assist in improving water efficiency and in minimising water wastage mainly:
    a. Encouraging water recycling and reuse.
    b. Treating the water to standards that are necessary for a particular use.

Due to the importance and relevance of item 7 to the research on TERR, this will be examined in further detail in section 2.2.4.

8. Evaluating the financial and environmental cost of water.

    Information is currently lacking in this area and more work and input is going to be needed from the water suppliers in order to assist in quantifying this link.

Whilst some of the above factors and strategies can be addressed by the UK Government and the water suppliers, the input from the manufacturing sector is essential and can play a significant role in lowering water wastage in the UK. This is mainly due to the high water usage and wastage in industry as further detailed in section 2.2.2. and 2.2.3. A summary of the above eight points is presented in table 2-2. Areas relating to the FBM sector are highlighted in grey.

Table 2-2 Summary of the current water conservation strategies and main target groups (derived from DEFRA, 2011a; EA, 2013b)

Strategy		Target group	Outcome	Future Strategies /research needs
Improving awareness	Water Metering	Domestic	Positive reduction in water usage	Doubling this application to 65% by 2030.
	Linking water usage to energy costs	Industrial sector including the FBM	No data is currently available	Further research is needed to address this area. This will be further investigated in chapter 3 of this thesis.
Evaluating the financial and environmental cost of water		Water Providers	No data is currently available	More data is needed from the utility water provider to quantify this correlation.
Sustainable provision of water supplies and expanding catchment facilities		UK Government & water providers	Limited progress has been achieved in this area	There is a need to define sustainable growth in the water industry

Table 2-2 continued

Strategy	Target group	Outcome	Future Strategies /research needs
Improving the distribution infrastructure	Water Providers	Significant improvements have already been made. This is evaluated on an ongoing basis.	There is a need to define the "Sustainable Economic Level of Leakage". This has to be evaluated taking into account the current and future pressures on water resources.
Introducing changes to the abstraction licensing	Industrial sector including the FBM	Limited data is available on the impact this will have on the FBM.	This will be further investigated in Chapter 3 of this thesis.
Encouraging water recycling and reuse	Industrial sector including the FBM	This will be further discussed in section 2.2.4	

2.2.2 Water Usage in the UK Industrial Sector

Although in recent years the manufacturing sector in the UK has faced some decline, industry is still a major water user and accounts for more than 50 % of the total consumptive water[1] used in the UK (table 2.3) (RAENG, 2010; WRAP, 2011; WRAP, 2013).

One of the biggest individual manufacturing sub sectors is the food and beverage manufacturing sectors (FBM) with estimated usages of around 36% of the total water used by manufacturing (RAENG, 2010; WRAP, 2011; WRAP, 2013). It is estimated that the annual water usage by the FBM can range from 200 – 250 million cubic meters (Mm^3) per annum (table 2-3). Due to the important impact that the FBM can have on the water resources in the UK, dedicated government departments are currently working to improve water usage and minimise wastage in this sector. This is reviewed in further details in section 2.2.5.

[1] Where non consumptive water is defined as the water returned to the environment from whence it came requiring little or no wastewater treatment. This is mainly dominant in power generating plants where tidal water is usually used.

Table 2-3 Water consumption in the UK (RAENG, 2010; WRAP, 2011; WRAP, 2013).

Water abstracted (Billion m^3 per annum)		Sector	Main Source	Main Type
6		Public water supplies	Surface and ground water	Consumptive
1.01	0.55	General manufacturing sectors including the FBM	Surface and ground water	Consumptive
	0.2	FBM	63% public water 37% ground water	
	0.46	Agriculture	Surface and ground water	Consumptive
4.99		Generating electricity	Tidal sources	Non – consumptive

2.2.3 Water Usage in the Food and Beverage Manufacturing Sectors

The FBM is one of the largest manufacturing sectors in the UK with a turnover of around £78.7 billion and a contribution of around £20 billion in gross value to the UK economy (FDF, 2012).

In addition to its direct economic contribution, the FBM has a wider and a more prevalent impact on the UK. This can be summarised as follows (DEFRA, 2007a ; DEFRA, 2007b; EEA, 2009; WRAP, 2013):

1. Main employer in the UK manufacturing sector, employing more than 402 thousand employees.
2. Produces more than 80 million tonnes of food per annum to satisfy the domestic and foreign markets.
3. Produces 53% of the total food consumed in the UK.
4. The sector is a main water and energy user spending around £300 million on water and £800 million on energy per annum.
5. The only manufacturing sector that has not been affected by the economic downturn. In contrast the FBM has been growing on an annual basis to satisfy increases in public demand. It is expected that population growth will continue to drive up the demands at home and abroad.
   Although the increases in the domestic demand are unlikely to be fully met by the domestic market, the FBM in the UK is expected to grow between 1-1.4 % on an annual basis by 2030 (DEFRA, 2014a; FDF, 2014).

6. Uses more than 36% of the total water used by the entire manufacturing sectors. The future expansion listed above is also forecasted to increase water demand in the FBM by 24% by 2030 (DEFRA, 2014a).

Due to the high current and projected future water usages in the FBM a number of initiatives are currently being led by the UK Government to evaluate and improve water efficiency in this sector as detailed below.

2.2.4 Water Saving Initiatives that are Specific for the FBM

Minimising water usage and wastage in the FBM became a key UK Government strategy in 2006 with the publication of the food and industry sustainability strategy (FISS). FISS aims to lower water usage in the FBM by 20% by 2020. This reduction is based on the 2007 consumption baseline (DEFRA, 2007b). The above strategy does not cover all the water used by the FBM but focuses on reducing the water usage that is not embedded in the products (WRAP, 2010).

In order to achieve the above, a voluntary agreement, known as the Federation House Commitment (FHC) has been initiated by DEFRA and managed by WRAP, the Food and Drink Federation and Dairy UK (DEFRA, 2007b; FDF, 2012; WRAP, 2012). Currently 70 signatories across 284 sites have signed up to this agreement (WRAP, 2015). This represents around 24% of the food and beverage manufacturing sites in the UK and includes representation from all the main subsectors as listed in figure 2-4 (WRAP, 2012; WRAP, 2014a).

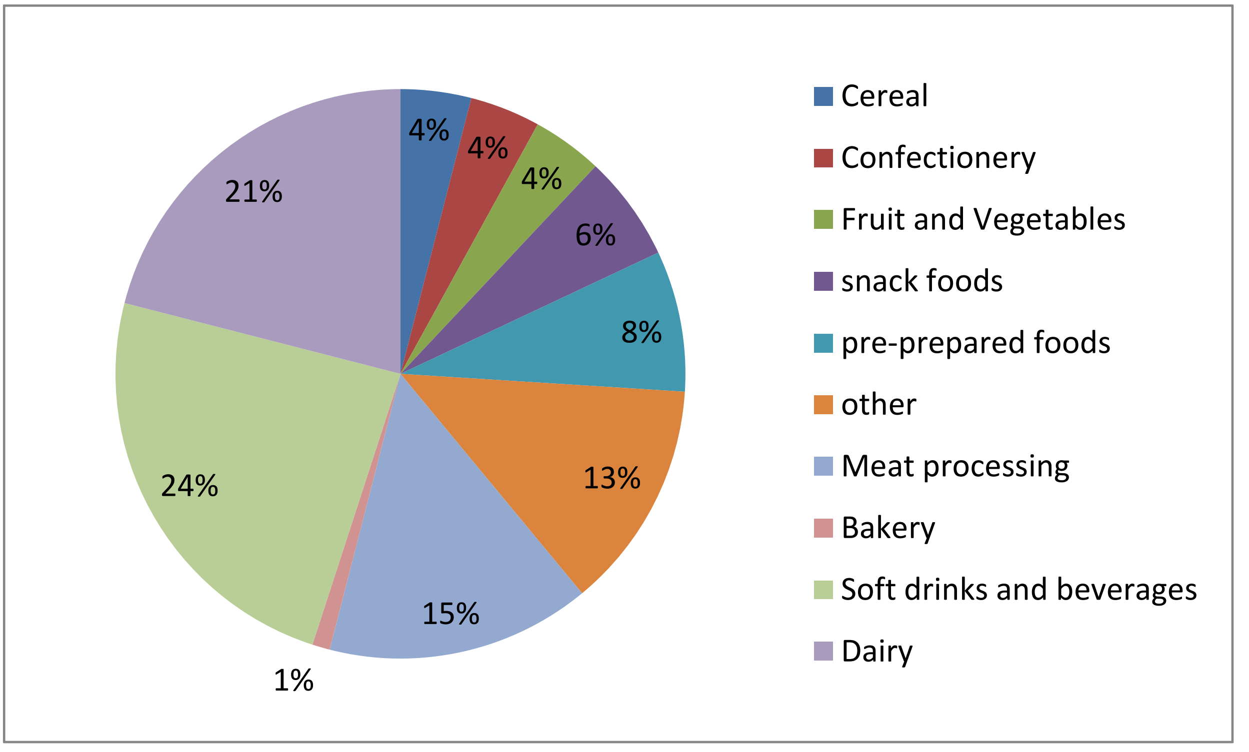


Figure 2-4 Percentage of the number of companies that are members of the FHC per FBM subsector (WRAP, 2012)

Signatories to the FHC are asked to sign up to the following six steps as part of their commitment to reducing water wastage on their premises (WRAP, 2012; WRAP, 2015):

1. Establish company baseline for water use.
2. Calculate Key Performance Indictors (KPIs) based on the water used per tonne of final product.
3. Understand water use and develop a water balance specific for individual sites.

4. Identify key water saving initiatives and develop some specific action plans.
5. Implement the actions identified in the action plans.
6. Report the annual water use, cost savings and production data to WRAP and associated agencies.

In return the sites will be entitled to free consultancy visits from WRAP. These visits are aimed to assist the signatories in identifying and implementing water saving strategies.

It is stated by WRAP that these consultancy visits will focus on identifying the following possibilities:

1- Reducing water pressure where possible
2- Repairing leaks and overflows
3- Fitting water recirculation systems
4- Optimising cleaning operations

A summary of the work that has been achieved by the FHC between 2007 and 2015 is discussed in section 2.2.5.

Addressing the limitations of this scheme is analysed in section 2.2.6.

2.2.5 Water Savings Achieved by the FHC

Between 2007 and 2015 the signatories to the FHC were collectively successful in achieving 15.6% reduction in the water used that is not embedded in the products. The FHC is currently projecting hitting its target in reducing water usage in the FBM by 20% by 2020. However, examining all the data published by the UK Government between 2007 and 2015 provide a clear indication of the following (WRAP, 2014a; WRAP, 2014c; WRAP, 2015):

1. The majority of the water savings have been achieved through process optimisation (mainly cleaning in place- CIP) and detecting leaks (WRAP, 2015).
2. Amongst the 284 sites that are signatories to the FHC only 4 water recycling applications are reported. In addition, all these are in the vegetable sub-sector and involve simple purification technologies such as removing soil and debris (WRAP, 2014c).
3. No recycling and reuse applications are reported outside the vegetable subsector. Even within corporate groups that operate across different FBM subsectors such as Heinz, water recycling and reuse is only reported in the vegetable washing operations (WRAP, 2014c).

A summary of these water recycling and reuse applications is presented in table 2-4. Based on these results and after critically evaluating the data available from the UK a number of limitations to the FHC scheme emerged. This is further discussed in section 2.2.6.

Table 2-4 Summary of the recycling and reuse applications that are published by the UK Government (WRAP, 2014c)

Company Name	Site Activity	Application	Use of recycled water	% reduction in water use	Direct Contact with Product	Technical data provided
Heinz – Westwick	Produces frozen oven chips and potatoes	Regenerating and re-using the water from the trade effluent plant	Steam Boilers Cooling chillers	23.7%	No	None
Greenvale AP	Fresh potato packing	Treating and reusing the wash water	The recycled water is reused within the same system (recirculation loop).	65%	Yes	Limited

Table 2-4 continued

Company Name	Site Activity	Application	Use of recycled water	% reduction in water use	Direct Contact with Product	Technical data provided
Barnston's	Potato Washing	Treating and reusing the wash water	Washing potatoes	60%	Yes	None
Kane Foods	Salad Washing	Treating and reusing the site trade effluent water	Washing Salads	70%	Yes	Brief description of the technologies used

2.2.6 Limitations of the Current UK Government Initiatives and the FHC Scheme

The current UK Government initiatives are critically evaluated taking into account:

1. The water savings that existing schemes have been able to successfully achieve between 2007 -2015.
2. The potential water savings that can potentially be achieved by using alternative strategies such as TERR.
3. Any regulatory or technological aspects that might impact on the implementation of alternative strategies such as TERR in the FBM.

It is clear from the data presented in sections 2.2.4 and 2.2.5 that most of the government strategies currently focus on water minimisation and that limited advice and resources are currently directed towards either WRR or TERR in the FBM. The impact that this direction might have had on the strategies followed by the FBM requires further investigation and will be evaluated in further details in chapter 3 of this thesis. However, the following clearly emerged by further analysing the current available data:

1- The 15.6% reduction in water usage that has been reported by the 284 signatories to the FHC, has been mainly achieved through the implementation of the four main strategies that are adopted by the UK Government: i) Reducing water pressure, ii) identifying leaks, iii) installing recirculation systems and iv)optimising CIP cleans (WRAP, 2012).

2- As can be seen from table 2-4, less than 1.5% of the signatories to the FHC have applications relating to more advanced water management strategies, such as water recycling and reuse.

Four main challenging questions emerged from the above points:

1. Taking into account the projected deficit in water availability that is expected to face the UK by 2050, why is the UK Government satisfied in only achieving 20% reduction in water usage by 2020?

Taking into account the large volumes of water that are currently reported to be wasted by the FBM and which can exceed 90% of the total water used in this sector (WRAP, 2013), there is a justifiable need to evaluate and quantify the savings that could potentially be achieved through extending the current initiatives to include trade effluent recycling and reuse in this sector. This will be evaluated in section 2.2.6.1.

2. Is it coincidental or are there any reasons why all the reported recycling and reuse applications are in the vegetable sector?

This will be further investigated in chapter 3 of this thesis.

3. As the signatories to the FHC only represent 24% of the FBM, there is a need to widen the data coverage in order to establish whether similar water management practices are being followed by non FHC members. This will be further researched in the field survey that is presented in section 2.3 of this chapter.

4. What are the reasons behind the low percentage of companies that have already signed to the FHC and can more be done by the UK Government to encourage a wider inclusion?
   Is the voluntary nature of the agreement working? What more can be done by the UK Government to encourage the uptake of TERR in the FBM?
   This will be further addressed in chapter 3 of this thesis.

2.2.6.1 Potential Water Savings that can be Achieved from the FBM

The FBM is generally characterised by low water efficiency and high water wastage per tonne of finished product , this is mainly due to the high levels of water that are used in the cleaning and preparation processes (table 2-5) (figure 2-5) (Chmiel et al., 2000; WRAP, 2004; Vourch et al., 2005; DEFRA, 2007b; Avula et al., 2009). As indicated previously and according to the figures published by the UK Government, more than 90% of the water used across the FBM subsectors is currently not embedded in the products and ends up as industrial trade effluent (WRAP, 2013; EA, 2013 a). It is therefore reasonable to assume that if this trade effluent is treated to specific standards, the regenerated water can potentially be recycled and reused within the factory, so that the water system is relatively a closed loop (den Aantrekker et al., 2003).

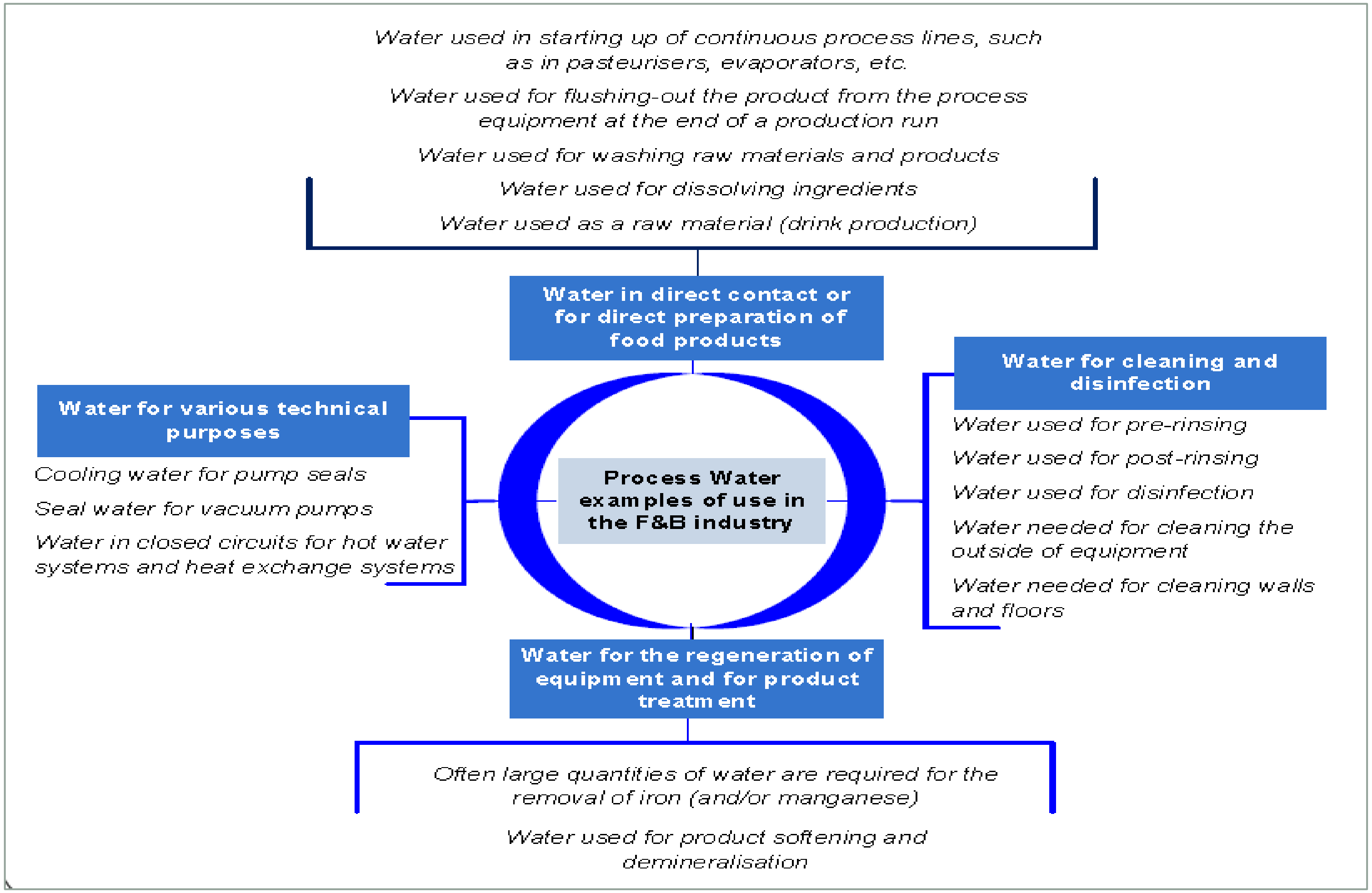


Figure 2-5 Uses of water in the FBM (Valta et al., 2014)

Table 2-5 Water used in the FBM versus final product weight or volume (Chmiel et al., 2000; WRAP, 2014a; DEFRA, 2007b)

Food Processing		Water (m^3) used per m^3 or tonne product
Cheese production		9.0
Milk processing		10.0
Meat processing		4.7
Fish processing		6.0
Poultry Processing	Chicken	8.0-15.0
	Turkey	40.0 - 60.0
Fruit Juice	Orange Juice	5.0
	Apple Juice	1.2
Vegetable processing		30.0
Soft drinks		3.7
Beer		4.2
Oven potatoes		10.0

A detailed analysis of the data published by the UK Government project that the following reduction in water usage can potentially be achieved from a widespread application of TERR in the FBM in the UK:

1- Water usage in the FBM is projected to increase from the 2010 baseline of 200 Mm^3 per annum to 248 Mm^3 per annum by 2030 (WRAP, 2013; DEFRA, 2014a; FDF, 2014).
2- Based on the 90% water wastage figure presented earlier, 223 Mm^3 of water can potentially be treated to generate potable water quality. The ability to regenerate 70% potable water from the FBM trade effluent is demonstrated in chapter 4 of this thesis. Based on this figure TERR can potentially provide 156 Mm^3 per annum of potable water quality that can potentially be reused in the manufacturing processes.
3- Taking into account a per capital consumption of 100 l/p/d and an estimated population growth of 10 million by 2030 (EA, 2013b), the future domestic consumption is likely to increase by 365Mm^3 per annum. Based on a recycling potential of 156 Mm^3 per annum, around 44% of the future increases in domestic water demand can be met by TERR in the FBM. This figure is compared to 13.6% by solely implementing the strategies that are currently adopted by the FHC initiatives.

The significant additional contributions that can be achieved from TERR in the FBM are summarised in figure 2-6.

In order to understand whether excluding TERR from the FHC key strategies is justifiable, there is a need to further examine the literature in order to identify any valid reasons that might have impacted on the current UK Government strategies. This will be discussed in section 2.2.6.2.

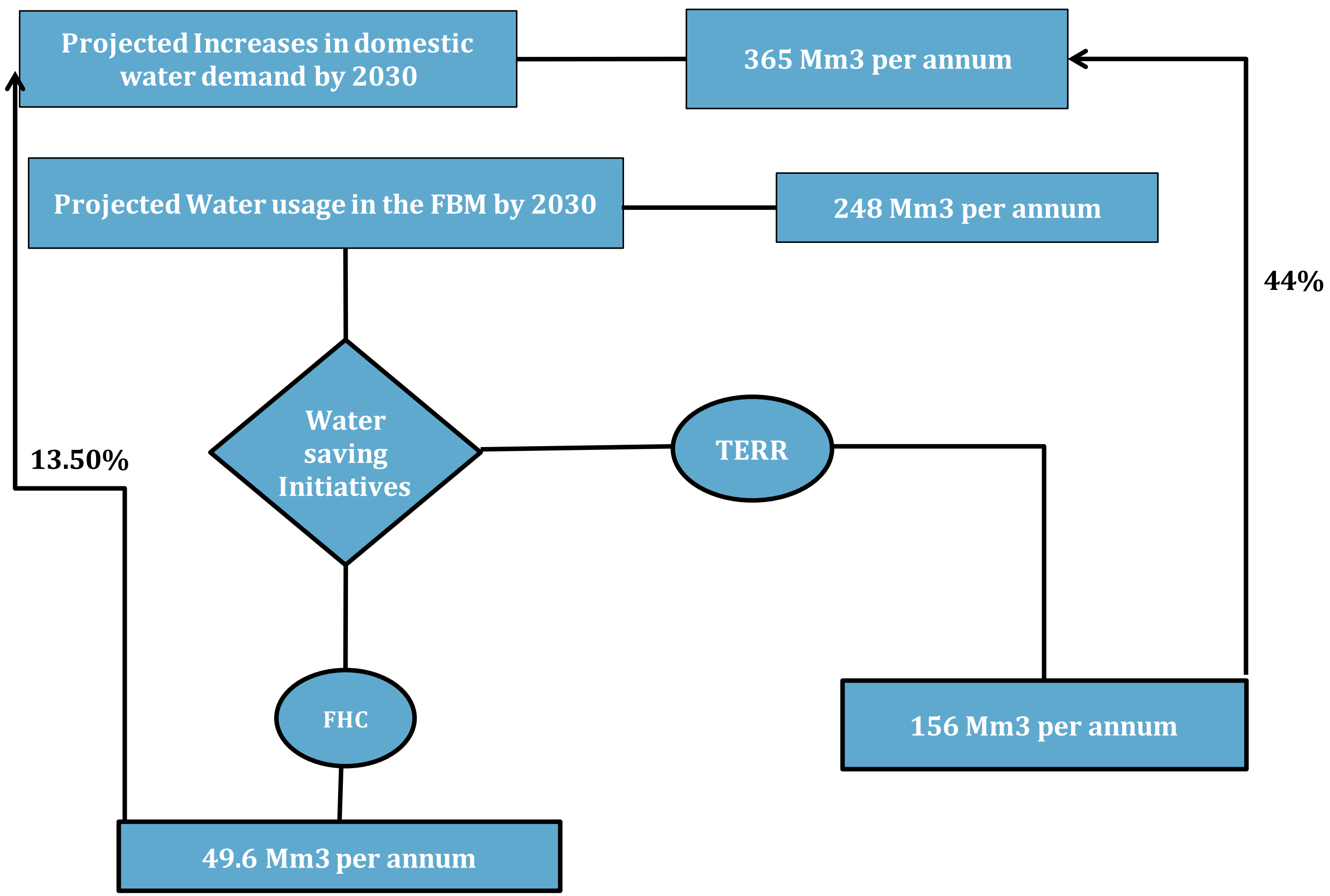


Figure 2-6 Water savings that can potentially be achieved from TERR versus FHC

2.2.6.2 Review of Available Literature on TERR in the FBM

A wide literature search covering areas relating to engineering, conservation, sustainability, food hygiene, water technology, food technology, economy and microbiology only picked up a limited number of publications relating to TERR in the FBM as summarised in table 2-6. However, a critical review of these publications identified a number of limitations regarding the usefulness of the published data in providing a comprehensive understanding of the current TERR applications in the FBM. These limitations are mainly caused by the limited scope of the individual studies and their focus on specific areas relating to WRR or TERR. None of the cited work took a holistic approach to assist in fully understanding TERR applications and what might impact on their success or failure in the FBM.

In general the published data was found to be divided into two categories:

1. Hygiene – focusing on the hygiene principles that have to be followed when considering WRR and TERR applications in the FBM.
2. Technological – evaluating the technologies that can be successfully used in WRR and TERR applications.

Table 2-6 Critical review of the literature on WRR and TERR

Research Leader	Period	Main areas covered
Sandra Casani: a leading Danish food hygiene scientist who established and provided guidelines for HACCP applications for water reuse in the FBM. Although her work is nearly 10 years old, she is still considered a leading researcher in this area and has been cited in recent work (Holah, 2012; Wu et al., 2013a; Wu et al., 2016)	2002-2006 (Casani & Knochel, 2002) (Casani et al., 2005) (Casani et al., 2006)	1- Identified the important role and significant water savings that can be achieved from WRR & TERR in the FBM. 2- Highlighted the limited research on WRR and TERR in the FBM and linked these limitations to the fears associated with hygiene and the lack of guidance in this area. 3- Formally introduced the Hazard Analysis Critical Control Points system (HACCP) as a quality control measure for water reuse in the FBM. 4- Provided a detailed list of the microbiological contaminants that have to be considered in WRR and TERR projects. 5- Highlighted that both WRR and TERR might be easier to implement in applications that involve vegetable preparations, fluming of unprepared products and scalding water for meat and poultry.

Table 2-6 Continued

Research Leader	Period	Main areas covered
Casani – continued		6- Provided a general list of the stakeholders that might impact on the uptake of WRR and TERR: Environmental, economical, legislative, technological, quality, social, food industry and academia.

<u>Limitations</u>

Although the work carried out by Casani and her team addressed areas relating to WRR and TERR that have not been studied in the past, a critical review of her papers identified a number of limitations:

1- The work focused on the HACCP principles that can be implemented following the approval of the water recycling projects but failed to address the steps that have to be taken to attain this approval.

2- (Casani et al., 2005) provided a general list of the stakeholders that have to be considered when planning WRR and TERR project. The work however, did not evaluate how these stakeholders might impact on the success or failure of WRR and TERR in the FBM and no further analysis was provided in order to identify the salient stakeholders that have to be considered when planning WRR and TERR applications in the FBM.

Table 2-6 Continued

Research Leader	Period	Main areas covered
3- Although one of Casani papers stated that WRR and TERR can be easier applied in the vegetable sector, no data was provided in order to assist in the interpretation of this statement. Nevertheless this confirms with the data published by the UK Government where the limited water recycling applications were found to be in the vegetable sector as detailed in table 2-4. 4- The research did not specify the steps that have to be taken to provide sufficient guidance to assist in WRR and TERR applications in the FBM. All these points will be further researched in chapter 3 of this thesis.		
Roy Kirby A leading scientist at Unilever UK	2003 (Kirby et al., 2003)	Similar to the work carried out by Casani, the research identified the potential contributions that can be achieved from WRR and TERR in the FBM. The work also briefly described the HACCP principles that can be followed to safely apply water recycling in the FBM.
<u>Limitations</u> The research did not specifically address WRR or TERR in the FBM but provided a high level review of the legislations that have to be considered when evaluating recycling projects. These will be examined in details in the section 2.2.6.3.		

Table 2-6 continued

<table>
<tr><th>Research Leader</th><th>Period</th><th>Main areas covered</th></tr>
<tr><td>V. Mavrov and H. Chmiel
Leading researchers at the Institute for Environmentally Compatible Process Technology , University of Saarland , Germany</td><td>1997- 2002
(Mavrov et al., 1997)
(Mavrov and Belieres, 2000)
(Mavrov et al., 2001)
(Chmiel et al., 2002)</td><td>1- The focus of the research carried out by this team was to demonstrate the ability of the available technologies in generating potable water from the trade effluent generated by the FBM manufacturing processes.
2- Although potable water standards were generated the recommendations for reuse were limited to non- process areas such as steam boilers and cooling towers.
3- A laboratory study using synthetic water also evaluated the costs involved in the recycling applications.</td></tr>
<tr><td colspan="3"><u>Limitations</u>
1- The evaluations presented in the above papers are more than 13 years old and there is therefore a need to re-examine the cost and capabilities of the current available technologies.
2- The papers don’t provide any explanations behind limiting the reuse of the regenerated potable water to non-process areas or provide guidelines as to what has to be implemented to allow the water reuse inside the factory.
3- The trials were carried out on synthetic water and lacked field validation.</td></tr>
</table>

Table 2-6 Continued

Research Leader	Period	Main areas covered
Simon JUDD A professor of membrane technology at the Centre for Water Science at Cranfield University	2003- 2014 (Judd and Jefferson, 2003) (Judd, 2011) (Judd, 2014)	The research focused on demonstrating the ability of available technologies in generating potable water from trade effluent. Emphasis was given on evaluating membrane bioreactor technologies and ultrafiltration.
Limitations The work did not address areas relating to the acceptance and success of WRR and TERR projects in the FBM. The technologies presented by professor Judd and his team will be further analysed in chapter 4 of this thesis.		

Table 2-6 continued

Research Leader	Period	Main areas covered
George Holah A leading consultant at Campden BRI- A private consultancy institute providing research, advice and innovation for the FBM.	2012 (Holah, 2012)	1- The work provided details regarding the steps that have to be taken in order to carry out HACCP analysis to ensure product safety when applying WRR & TERR in the FBM. These recommendations were mainly based on the work carried out by Casani and her team as detailed previously in this table. . 2- The publication provided useful references that can be used for guidance when considering WRR and TERR in the FBM, mainly: Codex Alimentarius and the EU directive 98/83/EC. These will be examined later on in this chapter.
Limitations Similar to the previous references the publication dealt with one particular aspect relating to WRR and TERR but provided limited information on the holistic and comprehensive approach that has to be followed for the success and approval of these applications.		

Table 2-6 continued

Research Leader	Period	Main areas covered
Wu, Dan A leading Chinese researcher on water recycling and reuse.	2013- 2016 (Wu, D. et al., 2013a) (Wu, D. et al., 2016)	The work provides details regarding the technologies that can be used to reclaim water from the washing processes in a Mandarin canning factory.
Limitations The technologies used are simple filtration applications that will only be applicable to reclaiming low contaminated water such as those generated from fruit and salads packaging plants.		

In order to assist in understanding the reasons behind the limited research on TERR in the FBM it is necessary to identify whether there are any regulatory, quality control or technological challenges that can negatively impact on this application. This is discussed in sections 2.2.6.3-2.2.6.5 respectively.

2.2.6.3 World Health Organisation and EU Directives

Based on the literature review, there are currently no regulations that would stop or act against water recycling and reuse in the FBM (Wu et al., 2013a). However, there are a number of conditions that have to be met for the safety and approval of this application.

A. The FAO and WHO CODEX Alimentarius 2001

In 2001 the FAO and WHO provided detailed information regarding the steps that have to be followed when considering water reuse in the food and beverage manufacturing sectors (Codex-Alimentarius, 2001). These can be summarised as follows:

1- The water shall be safe for its intended use and should not jeopardise safety.
2- Reuse should not have an impact on the suitability and characteristics of the product.
3- If the water is to be incorporated in the food, it must at least meet the potable water quality in that area.
4- Monitoring should be in place on an ongoing basis to ensure the regenerated water quality.

5- The water treatment should take into account the quality of water needed for reuse.
6- The system must be routinely checked to ensure reliability.

As can be seen from the steps listed above, CODEX Alimentarius does not object to water reuse in the FBM as long as safety procedures are being adhered to.

B. EC Directives

In the past, water reuse in the FBM has been hampered by EC directives that only allowed the use of drinking water in production areas (Casani et al., 2005; EU - Directive,1993). However, in 1998 a new directive was issued to deal with the quality of water used in the food and beverage industry. This directive consents to the use of alternative sources of water as long as the safety standards are being met. The European Community Directive 98/83/EC (1998) states that “water used in the food industry should be at least equal to the highest standards for the drinking water required by the local authorities”.

The above change provides legal space for the use of alternative qualities and sources of water as long as this does not impact on the wholesomeness of the produce (Council-Directive,1998).

Based on the above, if water of potable standard is produced from the trade effluent, there should be no legal or regulatory reasons against reusing this water in process areas even when the water is in direct contact with the products.

2.2.6.4 Conditions Relating to Quality Control

When considering water reuse in the FBM, there is a need to evaluate both the quality of the regenerated water and more importantly understand and evaluate the interaction and impact that the water reuse might have on the finished product quality (Casani et al., 2005).

Quality control measures are well used and tested in the FBM and there should be no reasons why these can't be extended to include the quality control and safety of reusing the regenerated water. One of the most commonly used programmes in the FBM is the Hazard Analysis Critical Control Point (HACCP).

A. <u>Hazard Analytical Critical Control Point (HACCP) (Codex-Alimentarius 2001)</u>

HACCP was introduced in 2001 as a quality control mechanism to enable testing and controlling contaminants before they enter the products (Havelaar et al., 2010).

In order to achieve this, the HACCP system incorporates safety control into the design of the whole process rather than relying solely on the end product testing (Kirby et al., 2003; Trienekens and Zuurbier, 2008).

HACCP principles mainly focus on the following steps (ISO-Insider, 2004):

1- Carrying out a detailed risk assessment to identify the risks. The risk assessment has to be site and process specific.
2- Managing the identified risks to acceptable levels.
3- Reviewing the risks and the management strategies that have been put in place on a regular basis.
4- Communicating the above within the relevant bodies.

HACCP is considered as one of most stringent quality control measures that can be taken by the FBM and is a compulsory standard that have to be followed by all food and beverage manufacturers in the EU (Codex-Alimentarius 2001).

Although HACCP principles have been originally introduced to monitor the biological risks in the food processing chain, these principles have been adapted over the years to control other parameters in this sector (Havelaar et al., 2010); a detailed analysis of the steps that have to be followed in HACCP clearly indicate that there should be no difficulties in applying these principles to evaluate and control the risks that might be associated with water reuse applications on the FBM processing sites. This was successfully tested and evaluated by Casani in 2006 on a shrimp processing plant (Casani et al., 2006) .

B. ISO 22,000

ISO 22,000 standard is a quality management standard that was established in 2004. The aim of the standard is to provide an auditing tool to evaluate safety in the food chain. This standard follows the HACCP principles but provides additional tools that can assist in auditing and gaining accreditation (ISO-Insider, 2004).

There are also other private food and safety standards that are run by the British Retail Consortium, large European retailers and private auditing companies but they all fundamentally follow the HACCP principles(Trienekens and Zuurbier, 2008).

2.2.6.5 Technology and Water Quality

The trade effluent generated from the FBM may contain complex mixtures and constituents. Therefore, the characteristics of the trade effluent has to be taken into account when considering the regeneration of potable water for reuse purposes (Casani et al., 2005).

The capability of the current available technologies in providing potable water quality from industrial trade effluent is well documented in the literature (Judd, 2014; Judd, 2011; Vourch et al., 2008).

The technologies used might differ depending on the FBM subsector and consequently the quality of the trade effluent generated. However, in most cases will include several combinations of the following:

a. Sedimentation
b. Dissolved air floatation
c. Micro or Ultrafiltration
d. Conventional activated sludge
e. Membrane bioreactors
f. Reverse Osmosis
g. Chemical oxidation
h. Ultraviolet treatment

Some of these technologies will be evaluated in further details in chapter 4 of this thesis.

2.3 Establishing the Current State of TERR in the UK

Initial Field Survey

As the signatories to the FHC only represent 24% of the total manufacturing sites in the UK more data was deemed necessary in order to assist in understanding and evaluating the general water management practices that are currently being followed by the FBM in the UK.

The above was achieved by carrying out a detailed electronic survey following the steps detailed in section 2.3.1. The Survey analysed the electronic data of 404 FBM sites in the UK varying in size, location, production processes, trade effluent quality and the final manufactured products.

Based on the number of companies that took part in the survey it is acceptable to state that at least 30% of the participants in the survey are non-signatories to the FHC (figure 2-7).

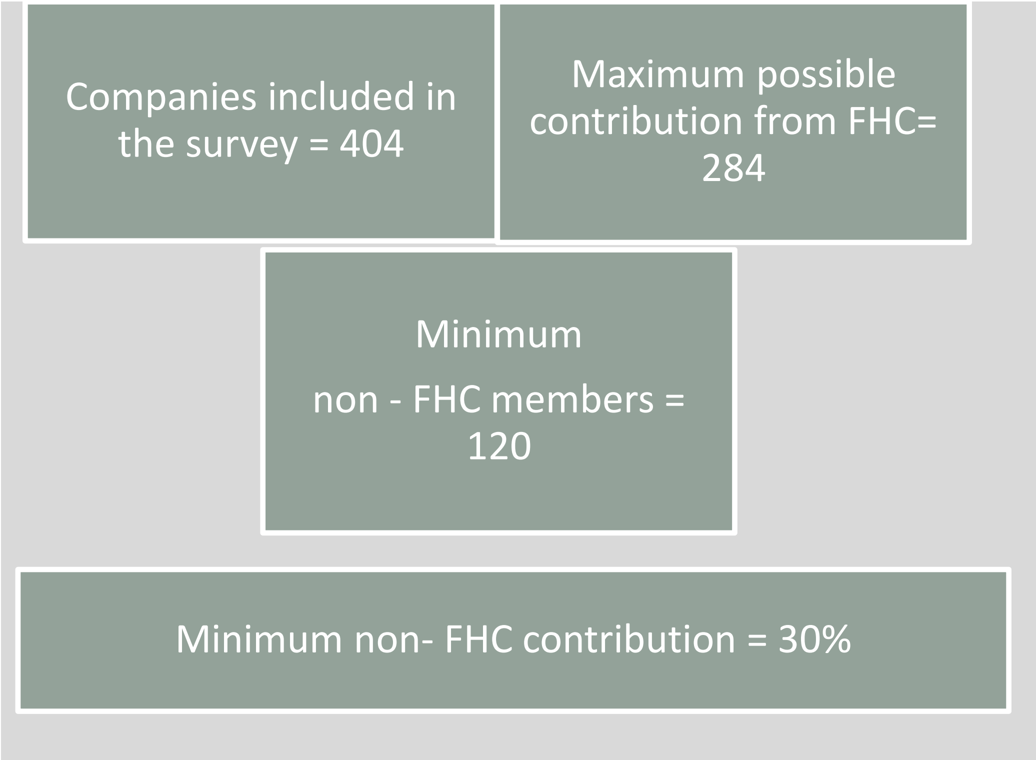


Figure 2-7 Representation in the survey based on the data published by WRAP (WRAP, 2015).

2.3.1 Methodology Followed in the Survey

The data base of six leading water treatment providers was analysed to assist in evaluating the water management and trade effluent discharge practices that are currently followed by the FBM. The main data was collected between August 2011 and June 2012. A more recent discussion was held with the water treatment providers in 2015 with the aim of identifying any recycling and reuse applications that might have been implemented since 2012.

A list of the companies that took part in the survey is provided in appendix 2-1[2]. The above approach was chosen after careful consideration, taking into account the approved codes of practice and general industrial protocols that are generally followed by the water treatment industry. Based on the practices listed below, analysing the electronic data was identified as the most effective approach to assist in expanding our knowledge regarding the current water management and trade effluent discharge practices that are currently being followed by the FBM sector in the UK:

1- All water systems are usually identified and listed by the water treatment providers, even those that are not part of the water treatment contract (HSE, 2014; LCA, 2016). This is mainly to assist companies identify the risks that might be present at a specific manufacturing site and to enable addressing those risks even if they are not part of the contractual agreement.
2- More than one chemist or water treatment specialist can be in charge of an individual site. These individuals often have limited knowledge outside their specialised areas.

Based on the above, using alternative methodologies such as the key informants approach, or interviews with key account managers would have been limiting and might have provided us with partial and incomplete data especially for big and complex sites.

[2] Due to the confidential nature of this information, appendix 2-1 will be only provided on the enclosed CD-ROM

All the water treatment companies that accepted to take part in the survey were either partners or own label customers to the research sponsor (SUEZ). Attempts were made to include water treatment companies from outside the above group but none accepted to take part in the survey; there was an evident reluctance in sharing sensitive data with a researcher working for a competitor.

The following information was extracted and analysed from the data base:

1- Trade effluent quality generated by the participating sites (table 2-7)
2- Effluent treatment programmes, prior to discharge
3- Trade effluent discharge route
4- Water management practices
5- General water recycling and reuse applications
6- Trade effluent recycling and reuse applications

The above was achieved analysing the following electronic sources:

1- Contract agreements
2- Tender documentations
3- Chemicals used on site
4- Routine consultancy service reports sheets
5- Equipment maintenance programmes
6- Field and laboratory analytical results
7- Consent levels regarding trade effluent discharge

The information that emerged from the survey relied on first hand data that was either collected by the researcher or the IT teams of the water treatment providers; this was done under the supervision and constant communication with the researcher.

Due to the limited available resources and time restrictions set by the water treatment companies, the data evaluating the general trade effluent quality and route of disposal relied entirely on the information analysed from the companies' electronic data base. However, the data was examined in further details when reuse applications were identified. This was done through further discussions with the water treatment companies in order to verify and provide more details regarding the water reuse applications.

It is worth mentioning that the financial data was not made available to us during the survey and we were therefore unable to evaluate the financial gains that could or have been achieved from certain applications. In order to facilitate the data analysis, the effluent treatment applications were grouped into four main categories following the definitions provided in the literature (Lens et al., 2002; Tchobanoglous et al., 2004; Gray, 2010; Judd, 2011). These are as follows:

1- **No Treatment**: The trade effluent is discharged to the sewer as it leaves the factory without any physical or chemical treatment.
2- **Primary Treatment**: This involves any or a combination of physical separation and /or pH control.
3- **Secondary Treatment**: In addition to the primary treatment, the trade effluent in this category undergoes additional treatment steps to remove or reduce COD/BOD, suspended solids and fat and grease. Applications such

as sedimentation, coagulation and or dissolved air floatation fall under this category.

4- **Tertiary Treatment**: This involves further treating the trade effluent to remove the remaining BOD/COD, suspended solids, bacteria or specific components. Tertiary treatment is usually applied to enable the final effluent comply with standards that are more stringent than can be achieved by secondary treatment alone.

In order to assist in analysing the data, the manufacturing sites that were included in this survey were divided into thirteen subsectors. This followed the general divisions provided by the UK Government and included manufacturers from both the food and the beverage sub-sector (table 2-7)(WRAP, 2013; EA, 2013 a) .

Table 2-7 Representation in the survey and trade effluent characteristics

Sub sector	Number of companies / representation in the survey	pH	COD (mg/l)	Suspended Solids (mg/l)
Water bottling plants	13 3.2%	6-8.5	<100	30-100
Soft Drinks	23 5.7%	6-10	2000-10,000	50-100
Alcoholic beverages	30 7.4%		8000-20,000	600-1000
Fresh fruits and vegetables	38 9.4%	7.5-11	400-1000	80-200
Cereals	25 6.2%		15000 - 20000	2000-4000
Pre-packed salads	11 2.7%		400-1000	50-100
Dairy	60 14.8%	5-12.5	10000-25000	400-1300

Table 2-7 continued

Sub sector	Number of companies / representation in the survey	pH	COD (mg/l)	Suspended Solids (mg/l)
Confectionary	32 7.9%		10000-15000	300-2000
Hot drinks	13 3.2%		5000-8000	200-2000
Bakery	41 10%	9-13	10000-15000	2000-5000
Pre-prepared foods	67 16.6%	5-12.5	700-20000	250-4000
Snack foods	21 5.2%	7.5-13	10000-20000	1000-3500
Meat and poultry	30 7.4%	6.5-10.0	15000-25000	800-3000

2.3.2 Survey Findings

2.3.2.1 General Data Analysis

The data from the survey clearly demonstrates that the effluent discharge charging structure and consent parameters currently have a significant impact on the strategies and effluent treatment levels that are being implemented prior to effluent discharge. When trade effluent is discharged to the sewer, the discharge costs in the UK are calculated according to the Mogden formula (WRAP, 2014b; Tchnobanoglous et al., 2004) . In the Mogden formula, biological oxygen demand (BOD) or chemical oxygen demand (COD) and suspended solids (SS) are used as indicators to determine the polluting strength of the water. Discharging costs are then levied accordingly by the water treatment works (appendix 2.2)(Gray, 2010).

The charging tariff and cost reductions that can be achieved by lowering the COD, BOD and or SS values can differ based on (WRAP, 2014b):

1- The geographic location of the operating site and
2- The method of treatment used by the water treatment works (primary vs biological treatment), with the latter being the more expensive.

The Mogden formula however, does not apply when the trade effluent is discharged to surface or controlled waters. These are often regulated by DEFRA and the Environment Agency and have to usually comply with stricter discharge consents in order to comply with the water resource act and the following directives (DEFRA, 2010):

1- Water Framework Directive
2- Freshwater Fish Directive
3- Bathing Waters Directives
4- Shellfish Waters Directive
5- Dangerous Substance Directive; and
6- Urban Waste Water Treatment Directive

In addition to the general charging structure, some specific consent limits might be required for some sites. Deviations from these limits will often lead to prosecutions or fines. These consent limits are usually site specific and are often drawn as part of the site trade effluent discharge agreement. The consent parameters are affected by the site manufacturing processes and the capacity and capability of the water treatment works in the local area. As can be seen from the data presented in table 2-7 the variations in the trade effluent quality is significant amongst the sites even within the same FBM subsector, making it necessary for the regulators to be able to negotiate individual and more specific consent limits when needed. These can for example include one or a combination of the following:

1. pH
2. Temperature
3. Turbidity and colour
4. Maximum volume of discharge per hour
5. Limits detailing specific concentrations

Three main points emerged from the general survey data. These highlight the strong link between the practices that are currently followed by the FBM manufacturing sites and the effluent consent and charging structure:

1- Firstly- Priority is often given to monitoring parameters that can directly impact on the discharge charging costs. These are tested and audited on a regular basis.

    a. 75% of companies recorded data relating to :

        - Volume of effluent discharged
        - Chemical oxygen demand (COD)
        - Suspended Solids (SS)

    b. 35% of companies recorded the pH values prior to discharge.

2- Secondly – The quality of the raw trade effluent COD and SS has a strong impact on the level of trade effluent treatment that is implemented by the manufacturing sites. Companies generating trade effluent with higher COD and SS often deploy more complex treatments to reduce the cost of the effluent discharge. This is summarised in figure 2-8 and appendix 2-3.

3- Thirdly – Although the Mogden formula has the strongest impact on the levels of treatments applied, for a minority of sites additional discharge limits must be met. These are usually linked to specific site processes and or discharge routes.

The impact that the effluent quality and discharge route are currently having on the effluent treatment practices is detailed in sections A and B below.

A. Impact of COD, BOD and SS on the trade effluent treatment practices

It is clearly evident from the figures presented in table 2-7 that there is a strong link between the effluent treatment applications that are followed by the FBM manufacturing sites and the COD and SS values of the site's raw trade effluent. This can be summarised as follows (figure 2-8):

1- N**o treatment**: This is mostly common in sub-sectors having COD values lower than 400 mg/l and either low or medium suspended solids (<200 mg/l).

The subsectors included in this category are mainly:

a. The water bottling plants
b. Fresh fruits and vegetables
c. Pre-packed salad

2- **Primary treatment:** This is most common in the soft drinks and the hot drinks sub sectors (47.8% and 38.4% respectively). However, due to variations in the effluent water quality within these subsectors other treatments such as secondary or tertiary treatments are also observed.

3- **Secondary treatment**: For the majority of the other sub-sectors the trade effluent is treated by primary followed by secondary treatment prior to discharge. The trade effluent of the majority in this subgroup is characterised by COD values of greater than 5000 mg/l and Medium to high suspended solids (>200 mg/L). The data also provides a clear indication that all companies in this group are using a combination of dissolved air floatation and chemical treatment to reduce the COD and SS values.

4- **Tertiary treatment:** This is only documented by a small percentage of the sites (less than 5%). The data provides clear indication that this treatment is mainly driven by the trade effluent disposal route rather than the effluent characteristics. 16 out of the 17 companies in this group reported the need to discharge the trade effluent to surface drains as discussed in section B. The distribution of the tertiary treatment as a percentage of the individual FBM subsector is as follows (table 2-8 & Appendix 2-3).

The methods used in the tertiary treatment varied and included one or a combination of the following:

a. Activated sludge and sedimentation
b. Membrane bioreactor
c. Reverse osmosis
d. Ultrafiltration
e. Reed beds
f. Ultraviolet treatment
g. Chlorine dioxide.

5- 7.5% of the companies had no information relating to the effluent treatment practices on site. This might be either due to the effluent treatment not being looked at in the past or incomplete documentation by the water treatment providers.

Table 2-8 Tertiary Treatment Distribution

FBM Sub sector	% Subsector representation in the survey	% Tertiary treatment /sub sector	% Tertiary Treatment application
Soft Drinks	5.7	17.4	0.99
Alcoholic Beverages	7.4	6.6	0.49
Fresh Fruits and Vegetables	9.4	2.6	0.25
Dairy	14.8	13.3	1.97
Confectionary	7.9	6.25	0.49
Other	58.6	0	0

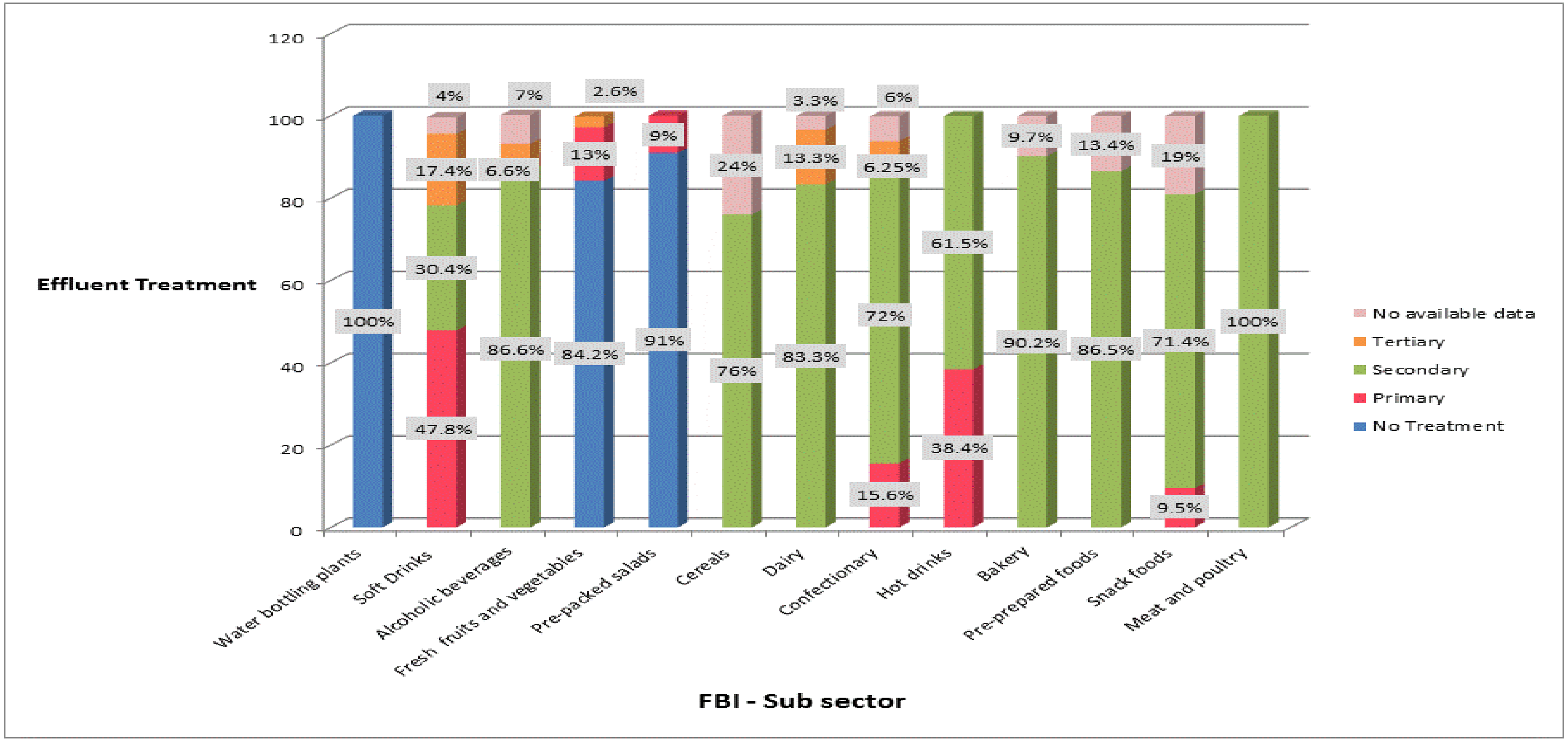


Figure 2-8 Effluent treatment per sub-sector (based on 404 observations)

B. Trade effluent discharge routes

As previously discussed, the majority of companies (88%) studied in the survey currently discharge their industrial trade effluent into a designated sewer that is linked to the main water treatment works for the area. The companies in this group are then charged on the basis of the effluent characteristic, mainly COD/BOD and suspended solids (WRAP, 2013). However, for a minority of companies, representing less than 4% of the participants, disposing the trade effluent to the sewer is not an option. For this group the trade effluent has to be discharged to surface waters such as rivers, lagoons, canals or local brooks (figure 2-9). Unlike the previous group, the discharge consent and the level of treatment needed prior to discharge to surface waters are set by DEFRA and the Environment Agency rather than the water treatment works. It was evident from the sites' data that the consent parameters are characterised by the following:

1- The need to achieve low COD and SS levels prior to discharge. It was evident from the data that emerged from the survey that although the methods of effluent treatment varied, all were designed to achieve a final COD value of less than 100 part per million and suspended solids of less than 50 ppm.
2- Audits and analytical checks are routinely carried out on these sites by the EA to monitor the performance of the effluent quality prior to discharge.
3- Compared to the other groups, more recycling applications are observed amongst this group. This is further examined in section 2.3.2.2.

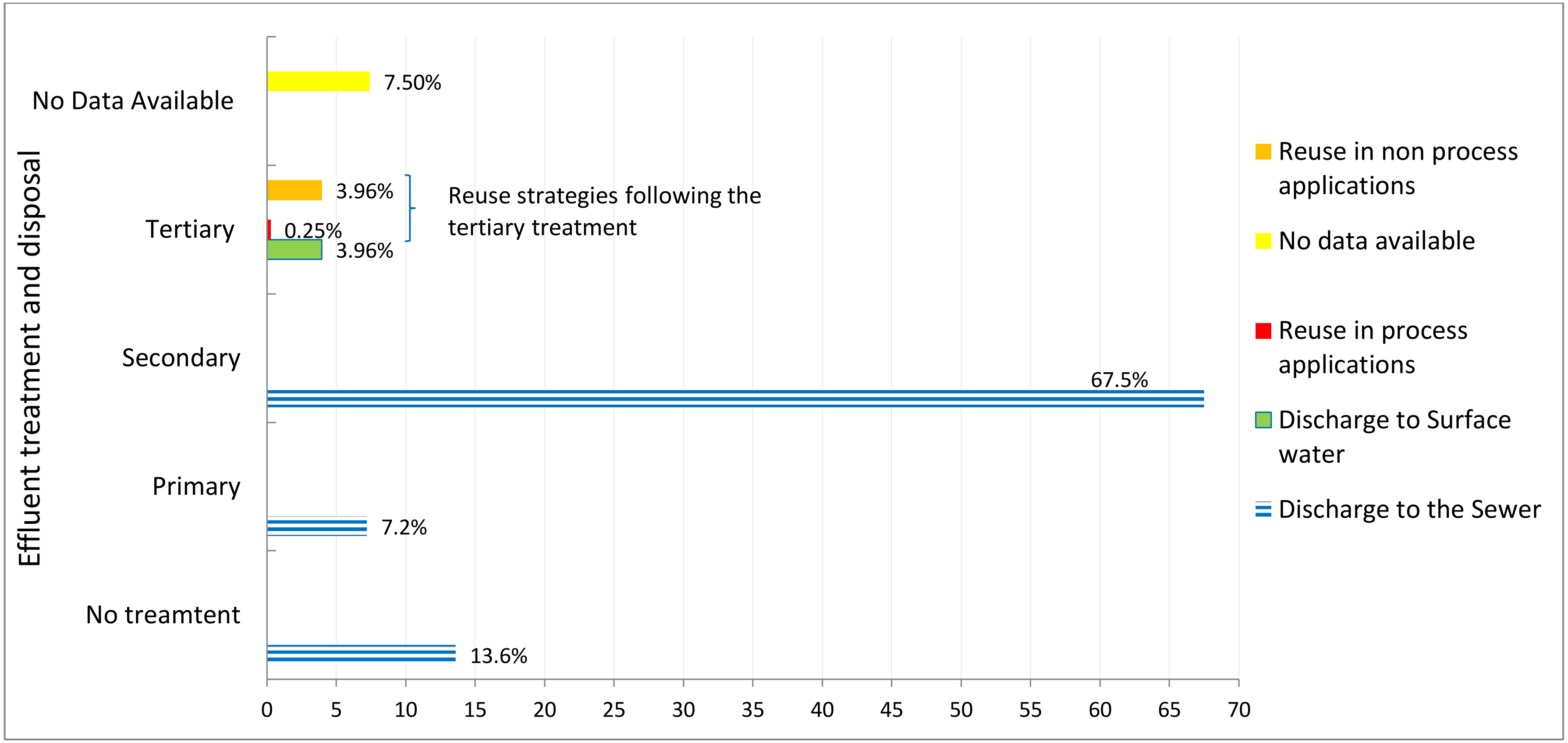


Figure 2-9 Effluent treatment and routes of effluent disposal

2.3.2.2 Water Reuse Applications

Water recycling and reuse applications were reported in only 17 companies (4.2%) out of the 404 sites that were included in the survey. The discussions that were carried out in 2015, indicated that a main coffee manufacturer in Carlisle is currently evaluating the possibility of reusing the potable water that is generated from the site trade effluent in the steam boilers. However, this was still not approved by August 2015.

Five main common points emerged from the data analysis:

1- All the above 17 sites are applying tertiary treatment to generate high quality water with the following characteristics from the trade effluent:
   a. COD < 100 ppm
   b. SS < 50 ppm
   c. pH between 7-9
2- Based on the information cited in the literature, it is clear that the technologies used by this group has the capability of producing potable water standards from the trade effluent (Mavrov et al., 1997; Judd, 2011). The sites in this category are using one or a combination of the following technologies as detailed in table 2-9.
   a. pH correction - dissolved air floatation using chemicals to assist in flocculation and separation- activated sludge- clarifiers- reverse osmosis (RO) - ultra violet radiation (UV) (or chlorine dioxide) (referred to as treatment 1 in table 2-9.

b. pH correction - dissolved air floatation using chemicals to assist in flocculation and separation- membrane bioreactor - ultrafiltration – chlorine dioxide (referred to as treatment 2 in table 2-9)
c. pH correction - dissolved air floatation using chemicals to assist in flocculation and separation- reed beds- ultrafiltration – RO- chlorine dioxide (referred to as treatment 3 in table 2-9)
d. PH correction - ultrafiltration – RO chlorine dioxide (referred to as treatment 4 in table 2-9).

3- Although high water quality is being regenerated, the majority in this group (16 out of the 17 companies) are only reusing the regenerated water outside the process areas in applications that are not in direct contact with the products (figure 2-9).

These reuse applications are confined to one or more of the following areas:

a. Cooling towers
b. Steam boilers
c. Washing the yard
d. Lorry washing

This group is mainly characterised by utilising a small percentage of the regenerated trade effluent water which on average is around 10-15%. The remaining regenerated water is then discharged to surface waters.

4- At the time of the survey, only one company, representing 0.25% of the companies' studied in the survey, recorded the reuse of the regenerated trade effluent water in processes that are in direct contact with the products. Further examination of the data highlighted the following:

   a. The application is at a salad packaging site. This site is one of the four sites presented in the UK Government case studies as detailed previously in table 2-4.

   b. Significantly higher reuse percentages are reported if compared with the other 16 sites. This is stated as 100% of the regenerated trade effluent water.

5- The technologies used amongst all the recycling applications are very similar and all have the capacity of generating potable water from the industrial trade effluent. For the salads packaging factory these includes:

   a. Segregation to remove any big parts

   b. Dissolved air floatation including chemical addition to assist in flocculation and separation

   c. Membrane Bioreactor including Ultrafiltration

   d. UV treatment

Based on the above, strong similarities emerged between the tertiary treatments that are currently implemented by all the 17 sites. Due to the higher recycling potential that can be achieved when the regenerated water is used in process areas, discussions were held with the water treatment companies to establish the factors that might be contributing to restricting the water reuse applications to non-process areas. This was attributed to the high risks involved. However, none of the water treatment companies were able to confirm what these risks are or what strategies can be implemented to encourage a wider usage of the regenerated water.

Table 2-9 Tertiary trade effluent treatment per FBM sub-sector

Tertiary Treatment Combinations	% of total companies	Combination as % of tertiary treatment	Sub Sector	Number of companies	% per sub sector (figure 1)
1 &2	3.5%	82.3%	Dairy	8	13.3%
			Confectionary	2	6.25%
			Alcoholic beverages	1	3.3%
			Soft Drinks	2	8.7%
			Salads	1	2.6%
3	0.25%	5.9%	Alcoholic beverages	1	3.3%
4	0.5%	11.8%	Soft Drinks	2	8.7%

2.4 Summary of Findings Relating to TERR in the FBM

The following points clearly emerged from the initial field survey:

1- TERR applications are generally very limited in the FBM particularly in areas where the regenerated water can be in contact with the preparation processes. TERR applications in the manufacturing processes were only observed in 0.25% of the companies that took part in the survey.
2- The quality of the regenerated is playing a limited role in encouraging reuse applications in process areas, even when potability standards are being met.
3- The above is leading to the loss of more than 80% of this potentially reusable water to surface waters.

Overall, the data presented in this section provides a clear indication that the current UK Government initiatives are having limited impact on promoting TERR applications in the FBM. With the growing need to save water and the significant contribution that can be achieved from TERR in the FBM further work is going to be needed in order to assist in answering the following two questions and in identifying the steps that have to be taken in order to successfully expand TERR applications in the FBM.

1- What are the factors that are currently limiting the uptake of TERR applications in the FBM in the UK particularly in areas where the regenerated water is in direct contact with the production processes?
2- Are there any reasons that will make TERR applications easier or more acceptable in the vegetables and fruits subsectors?

2.5 Knowledge Gaps

The critical literature review included in this chapter highlights the significant role and high volumes of reusable potable water that can potentially be regenerated from TERR in the FBM. The figures that emerged from this chapter clearly indicate that a wide application of TERR in the FBM in the UK can assist in providing more than 44% of the expected increases in the domestic water demand by 2030. However, although the above contributions can be significant in lowering the UK demand on non- renewable water supplies, it was evident from the data presented in this chapter that limited resources are currently being directed to provide guidance, identify potential applications, or assist in the uptake of TERR in this sector. The above limitations are also coupled with a general lack of academic data from inside and outside the UK. The limited field applications of TERR in the FBM also strongly emerged from an electronic field survey that covered 404 FBM manufacturing sites. Only one company (0.25%), reported the reuse of the regenerated trade effluent water in the process areas.

In summary, the data that emerged from this chapter clearly indicate that further research is going to be needed in order to provide a better understanding of the following key questions:

1- What are the reasons behind the current limited uptake of TERR in the FBM in the UK?
2- What steps can be taken to encourage this application in the future?
3- How will future changes in the environmental and socio-economic sector impact on the uptake of TERR in the FBM in the UK?

The thesis will aim to answer the above questions through:

1. Providing an in-depth analysis of the stakeholders that can currently impact on the uptake of TERR in the FBM.
2. Evaluating how future changes in the environmental and socio- economic domains can impact on the future of this application in the UK.

Addressing the above will be the focus of the subsequent research chapters.

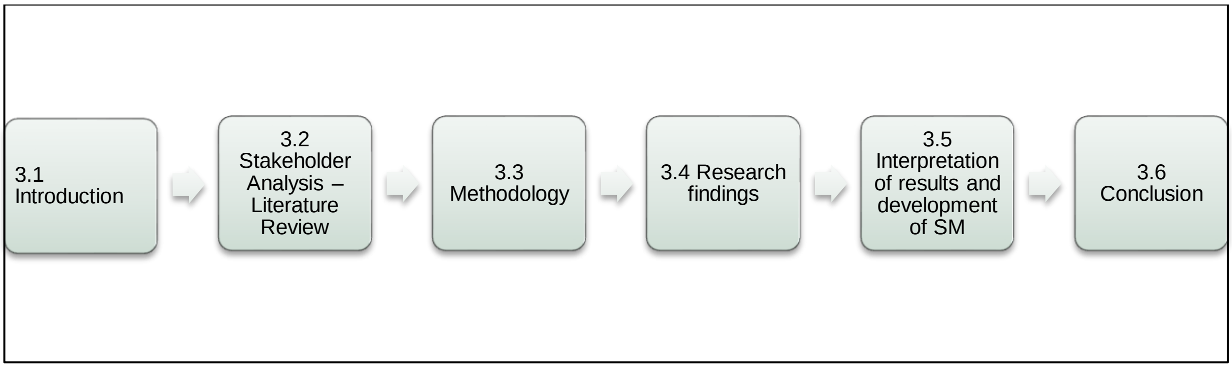
To summarise, the research carried out in this chapter examined and analysed the literature to project the impact that future climatic and demographic changes are likely to have on water availability in the UK. First hand data from an extensive filed survey were also used to understand the current water management practices that are being followed by the FBM and to evaluate the potential role that TERR in this sector can play to provide sustainable water resources that can assist in improving the UK resilience against future water shortages.

The results from this chapter support hypothesis 1, 2 and 3 of this research:

1. Climatic and demographic changes will impact on the future of water availability in the UK, making it essential to consider alternative and renewable water sources that will assist in bridging the gap between water supplies and water demands.
2. Current water wastage is significant in the FBM; hence TERR in this sector could play a significant role in improving the future water resilience of the UK.
3. There are currently no technical or legislative challenges that will inhibit TERR applications in the FBM.

It is concluded that although TERR in the FBM can play an important role in assisting the UK meet the future increases in water demand, there are a number of areas that have to be further investigated in order to provide the incentives and or necessary solutions to the current limited TERR applications in the FBM.

3 Stakeholder Analysis



The main aim of chapter 3 is to test the following research hypotheses:

1- The stakeholders in the FBM are many and can interact in complex ways to impact on the decisions taken by the manufacturing sites.

2- For TERR to be adopted by the FBM, the approval of the salient stakeholders is necessary.

Chapter three will also address the main knowledge gap that emerged from chapter two of this thesis through identifying and evaluating the reasons for the current limited uptake of TERR in the FBM in the UK.

3.1 Introduction

Findings from chapter 2 highlight the significant role that TERR in the FBM can potentially play in reducing the reliance of the UK on fresh water supplies. Although significant, results from this previous chapter underlined the limited uptake of TERR applications in the UK, which was reported in less than 0.25% of the 404 companies that were evaluated.

Further research will be carried out in this chapter to assist in understanding the reasons behind the current limited applications of TERR in the FBM in the UK. This will be achieved by carrying out a detailed stakeholders analysis to assist in providing an in depth knowledge of all the factors that can currently impact on the approval and uptake of TERR in the FBM in the UK.

Based on an extensive literature review and discussions with the UK Government departments that currently operate and/ or regulate areas relating to water provision and water sustainability (appendix 3-3), it is believed that this is the first detailed study on TERR in the FBM in the UK.

3.2 Stakeholder Analysis – Literature Review

Following an extensive literature review it was evident that in order to investigate the reasons behind the limited uptake of TERR in the FBM in the UK, there is a need to understand and evaluate the dynamics of the decision making processes within this manufacturing sub-sector. It was also evident from the literature that this can be best achieved by carrying out a detailed stakeholders' analysis that can assist in fully understanding the relationship between the FBM and its internal and external stakeholders. The role that stakeholder analysis can play in achieving the above understanding is well documented in the literature as discussed below (Romanelli et al., 2011).

3.2.1 General Background

Stakeholder analysis which is also referred to in the literature as stakeholder management (SM), stakeholder methodology or stakeholder theory was originally developed by Freeman in 1984. According to Freeman (1984), “the aim of SM is to facilitate the ability of organisations to manage unpredictable situations or environments where decisions can be affected by a variety of forces such as organisational, environmental, economic or socio-political” (Freeman, 1984). SM relies on the development of a conceptual schemata that can assist in understanding and analysing how different forces might interact to impact on a complex situation in an integrated fashion (Grimble and Wellard, 1997; Romanelli et al., 2011). In doing so, the data that emerges from SM can assist in understanding the interaction and relationship of those who have an interest or can impact on how businesses are conducted in a firm (Freeman, 1984). This is essential as these interactive and influential groups can have conflicting views and can exert conflicting influences on the organisation with the aim of optimising and /or protecting their own benefits and interests within an organisation (Ferrary, 2009). It was evident from the literature that when conflicts of interests arise, it is usually the role of managers within the organisation to decide which stakeholders they should satisfy in order to guard the interests of the organisation (Wolfe and

Putler, 2002). This might be vital for the survival of the firm as the stakeholders whose interests are not met tend to cease supporting the organisation (Freeman,1984; Hung, 2011; Neville et al., 2011; Minoja, 2012). As a result significant resources are usually directed to assist managers identify whom they should be paying attention to and what requests must be prioritised and implemented (Wolfe and Putler, 2002). This is usually achieved through communication, negotiations and managing the relationships with the stakeholders (Harrison and St John, 1994).

The steps that are followed in understanding the relationship between the stakeholders and an organisation are discussed in further details in section 3.2.6.

3.2.2 Variations in the Stakeholder Management Approach

As mentioned earlier SM was first introduced by Freeman in 1984. Since then a number of variations have been debated or introduced; based on an in-depth literature review, it was evident that these centred around five main areas as detailed below:

A. <u>Characterisations of the stakeholder:</u>

1- Based on Freeman's definition: "a stakeholder is defined as any group or individual who can have an impact or be affected by the decisions taken by an organisation" (Freeman, 1984).

2- In 2002, Van Asselt & Rijkens-Klomp added knowledge and experience to Freeman's definition. According to the authors "a stakeholder is defined as someone involved in, affected by, knowledgeable of, or having relevant expertise or experience on the issue at stake" (Van Asselt & Rijkens-Klomp, 2002).

3- In Contrast, a less inclusive definition was published by Orts and Strudler in 2002. Whilst original work by Freeman and Stone advocated the right to include non- human entities in the stakeholders' analysis (Freeman, 1984; Stone, 1974), Orts and Strudler argued that stakeholders should be characterised by the ability to think and understand (Orts and Strudler, 2002).

The above definition was however contradicted by a number of researchers who argued that excluding resources such as water, air and economic input can significantly impact on the true understanding of how businesses are conducted (Dyllick and Hockerts, 2002; Stead and Stead, 2004; Onkila, 2011).

Due to the nature of this research on TERR in the FBM, the more inclusive definitions will be adopted in this thesis. As detailed later on in this chapter the stakeholders are evaluated in terms of their impact, knowledge and expertise on TERR in the FBM and include non- human entities such as:

- Economic feasibility
- Technical know- how and advancement of technology
- Regulatory aspects and legislation
- Hygiene standards and quality control
- Water availability

B. <u>Addressing the relationship between the stakeholders and the stakes:</u>

Freeman's methodology is often criticised in the literature for the minimal focus it provides to understand the interaction between the stakeholders and the stake, where the stake is the interest or share that the stakeholders have in an undertaking (Rowley, 1997; Wolfe and Putler, 2002).

This understanding will be essential for this research in order to assist in evaluating what can motivate the stakeholders to accept and encourage TERR applications in the FBM. Although Freeman's methodology will be followed to categorise the stakeholders, the questionnaires used in collecting the qualitative data will be designed to allow the analysis and understanding of the interaction between the stakeholders and the stakes. This will be further detailed in the methodology section.

C. <u>The nature of the Stakeholder Approach:</u>

Some researchers argue that Freeman's methodology focuses on an instrumental approach and does not include a normative or descriptive criteria, where:

1- The normative stakeholder analytical approach is usually followed to legitimise the decisions taken by an organisation through the involvement of the key and representative figures (Donaldson and Preston, 1995).

Based on the literature, this approach is commonly used by the stakeholders to negotiate conflicting goals in order to agree collectively on an action (Checkland, 1999).

2- The instrumental stakeholder approach is more directed to identifying and understanding how the stakeholders view a certain application. This approach provides organisations with the necessary tools to achieve a desired outcome from the stakeholders (Reeds et al., 2009).

   It was evident from the literature that this approach has been widely and successfully used in natural resource management, sustainability and environmental studies, to assist in understanding the needs that have to be met for the success of an application or a project (Cuppen et al., 2010; Johnson et al., 2004; Sprengal and Busch, 2011).

3- The descriptive stakeholder approach is mainly used to explain specific corporate characteristics and behaviours and is usually used in both the instrumental and normative approaches (Donaldson and Preston, 1995).

The claim that Freeman's methodology only follows an instrumental approach was categorically rejected by Freeman in 2010, who argued that his methodology includes all the above approaches (Freeman, 2010). However, based on an extensive review of the literature it was evident that although Freeman's methodology can be extended to include normative analysis, most of the past applications focused on the instrumental approach (Cuppen et al., 2010; Richter, 2011; Wolf, 2013).

Anyhow, as the aim of this chapter is to understand the interaction and the impact of the stakeholders on TERR in the FBM, the instrumental/ descriptive approaches will be best suited to achieve the aims of this chapter.

D. The entity of the Stakeholders Approach:

In some papers the stakeholder approach is also referred to as the stakeholder theory. There are large number of papers that are dedicated to discussing what kind of entity the stakeholder theory is or whether it can actually be classified as a theory (Hasnas, 2013; Miles, 2012).

According to Freeman the stakeholder approach or methodology is a framework comprising a set of ideas. Each of these ideas can be further developed to derive theories and propositions that can then be tested (Freeman, 2010). In 2012 Freeman provided further clarification to the above debate. According to him a theory is usually assessed “in terms of the comprehensiveness of its account of the problems it addresses” (Freeman et al., 2012). As the aim of the stakeholder methodology is to provide managers with tools that can be used to understand how to better manage their organisation, the stakeholder methodology does not satisfy the theory criteria (Freeman et al, 2012).

E. Usefulness of the Stakeholder Approach :

One of the main criticisms in the literature relates to the failure of Freeman’s approach in providing managerial direction and a coherent framework of how to resolve conflicts of interests that might arise between the stakeholders or between that stakeholders and the firm (Zakem, 2008). However, it was evident from the literature that the above can be resolved by collecting the necessary field data as indicated in section B. This will be further discussed in the methodology section.

3.2.3 Stakeholder Management in Environmental and Sustainability Studies

It was evident from the literature that although stakeholder management is more than 32 years old it is still widely used in environmental and sustainability studies (Carroll and Bucholtz, 2006 ; Romanelli et al., 2011; Johnson et al., 2004; khan and Gerrard, 2006). In addition, in recent years the pressure on organisations to become more socially and environmentally responsible has widened the concept and applications where the stakeholder management approach can be used, to include proactive environmental strategies[3] (Dahlmann et al., 2008; Delgado-Ceballos et al., 2012; Miles, 2012). Based on the definition provided in the literature (Sharma and Vredenburg, 1998), it is believed that TERR in the FBM fits into this category. What was also evident from the literature is that stakeholders' analysis in sustainability studies can involve many components that are difficult to quantitatively measure (Cuppen, 2012; Elias, 2012). The use of well-established qualitative data collection tools such as interviews surveys and workshops are widely documented in the stakeholders' analysis literature (Delgado- Ceballos and Correa, 2012; Hill, 2005; Marcus and Geffen, 1998; Poncelet, 2001; Studer et al., 2008).

[3] Proactive environmental strategy is defined as "a company's systematic approach to environmental issues that voluntarily goes beyond the organisation's legal obligations" (Sharma and Vredenburg, 1998).

Varied methodologies have been reported to be used in analysing the qualitative data. Based on an extensive literature review four main categorises emerged. A summary of these categories and the applicability to the research on TERR in the FBM is presented in table 3-1.

Table 3-1 A summary of methodologies that have been documented in environmental and sustainability Studies

Methodology	Characteristics	The researcher view regarding the applicability of the methodology to research TERR in the FBM
Q Methodology (Cuppen et al., 2010; Cuppen, 2012; Elias, 2012).	A qualitative non statistical analytical approach that relies on purposive sampling and small sample sizes. The data for the Q methodology is collected using interviews that are based on alternative pre-defined perspectives.	Reasonable knowledge of the application under study is needed in order to define the closed ended alternative questions that are used in the questionnaires. The methodology can be limiting in providing the freedom for the stakeholders to express their own views on the subject. Q Methodology is best applied when the salient stakeholders are already identified (Cuppen, 2012), thus limiting its suitability to research TERR in the FBM.
Cluster Analysis **Likert – Style Analysis** (Sprengel & Busch, 2011; Plaza -Ubeda et al., 2009; Richter, 2011; Romanelli et al., 2011).	This was the most widely cited approach. Qualitative interviews or workshops are used to collect the data. Structured well defined questions are then used to obtain a scaled response from the participants.	Statistical representation is needed in this methodology. As detailed in section 3.3 and due to size of the FBM sector and financial and time restraints, this would have been difficult to achieve.

Table 3-1 continued

Methodology	Characteristics	The researcher view regarding the applicability of the methodology to research TERR in the FBM
Cluster Analysis Likert – Style Analysis (Continued)		The methodology can also be limiting in providing the freedom for the stakeholders to express their own views on the subject and is best suited to refine and fine tune existing knowledge on a subject. As limited information is currently available on TERR in the FBM, the freedom of the participants to express their views was considered to be essential for achieving the aim of the research. This will be further detailed in section 3.3.
Combination of qualitative and Quantitative analysis (Wolf, 2013)	In this approach both qualitative and quantitative data is collected from interviews, case studies and existing published data.	No data is currently available to allow for the inclusion of quantitative analysis. In addition, statistical representation is needed in this methodology. As detailed earlier due to size of the FBM sector and financial and time restraints, this would have been difficult to achieve.

Table 3-1 Continued

Methodology	Characteristics	The researcher view regarding the applicability of the methodology to research TERR in the FBM
Systematic Coding (Barraquier, 2013)	A literature review going back to the early 1990s highlighted only one study that followed systematic coding in the development of stakeholder management analysis. Although no particular methodology name was given to the research, a critical and detailed review of the steps that were followed in this paper revealed a great similarity to Grounded Theory Methodology as detailed later on in section 3.3. The paper in summary followed the following criteria which are specified by Grounded Theory Methodology: 1. Followed a Non statistical approach 2. Relied on coding the exact phrases used by the interviewees 3. Data collection stopped when saturation point was reached	Grounded theory was identified as being best suited for this research. This will be discussed in further details in the methodology section of this chapter.

3.2.4 Applicability of the Stakeholder Analysis to this Research

The suitability of stakeholder management to this research on TERR in the FBM lies in the ability of SM to achieve the following four points which were identified as being key to answering the guided questions that this chapter aims to address. These are widely cited in the literature and according to (Cheng and Fan, 2010; Romanelli et al., 2011; Cuppen, 2012) can be summarised as follows:

1- Identifying the key actors or stakeholders that can impact on the decisions taken by a firm regarding the implementation and approval of innovative projects.

2- Providing a full understanding of the stakeholders that are perceived to be essential for the growth and survival of a manufacturing site.

3- Understanding the interests and power of the stakeholders in the system.

4- Understanding the changes that might impact on the future interaction between the stakeholders and /or between the stakeholders and the organisation.

3.2.5 Development of the Stakeholder Management Analysis (SM)

SM was carried out in this chapter by following a well-defined and structured approach consisting of four main steps (Reed, et al., 2009; Romanelli et al., 2011):

1- Identifying the need to study the issue
2- Identifying the research boundaries
3- Data collection within the research boundaries
4- Applying the SM matrix

A. Identifying the need to study TERR in the FBM

The need to research TERR in the FBM in the UK was identified and discussed in detail in Chapter 2 of this thesis.

B. Identifying the research boundaries

Establishing a well- defined research boundary is essential to facilitate the interpretation of the field data that emerges from SM. Without defined boundaries the ability to conceptualise the raw field data and to characterise the influence and power of the stakeholders can be become too complex (Müller et al., 2012; Onkila, 2011).

The research in this chapter will focus on understanding the impact of the stakeholders on TERR applications within the areas highlighted in grey (figure 3-1). These include:

1- The point at which the water enters the factory: This can be mains or any water source treated to potable standards.

2- The trade effluent discharge points: This can be raw or treated trade effluent water.

3- The trade effluent treatment plant.

4- Water recycling and reuse applications of the trade effluent regenerated water. Only regenerated water of potable standards will be considered in this study.

The SM analysis in this chapter will not include the following areas:

1- Municipal waste disposal or any recycling potentials associated with the municipal effluent stream.

2- Raw materials other than the regenerated potable water.

3- Agricultural or horticultural practices involved in the production of the raw materials.

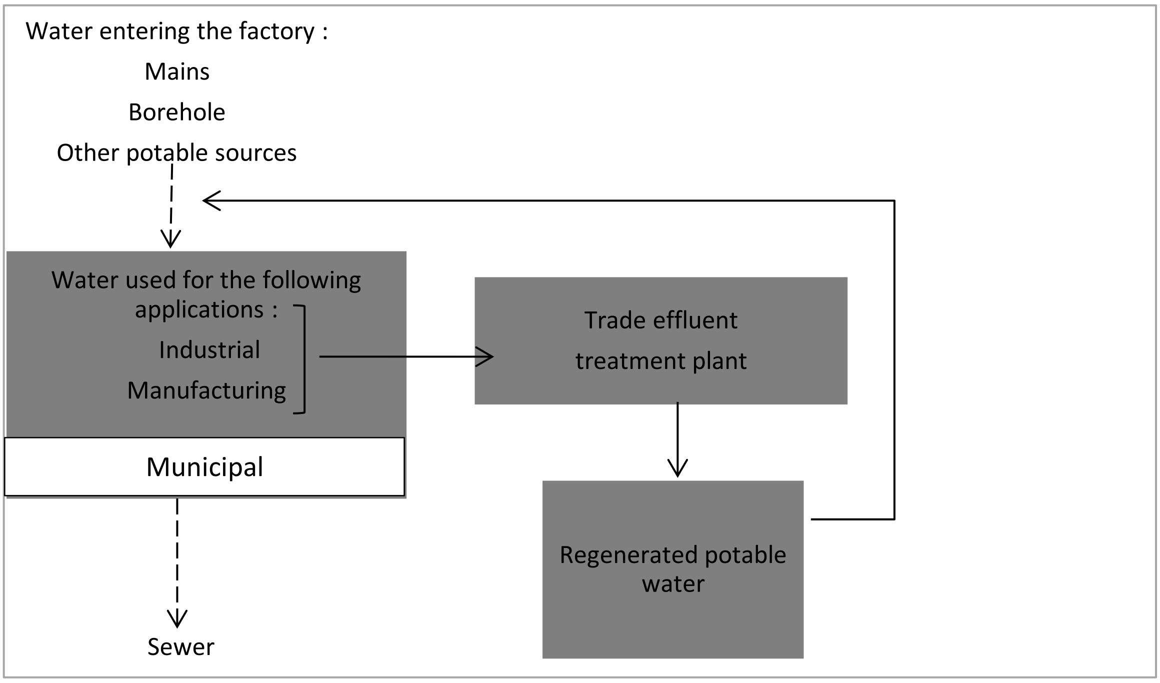


Figure 3-1 Research boundaries - presented in the grey shaded areas.

C. Data Collection within the research boundaries

An extensive literature review was carried out to establish the best methodology that can be used to collect the data for the stakeholders' analysis. Due to large volume of the existing literature, the review focused on data relating to sustainability and environmental studies. A list of the various methodologies that emerged from the literature has been previously presented in table 3-1.

The data used for the development of SM was collected using semi structured interviews. Grounded Theory methodology was identified as being best suitable to facilitate the stakeholders' analysis in this chapter. Grounded Theory Methodology (GTM) was used to design, deliver and analyse the qualitative data that emerged from the semi-structured interviews. The suitability of GTM to this research and the steps that were followed in collecting and analysing the data is discussed in further details in section 3.3 of this chapter.

D. Development of the Stakeholders Management Matrix

In this step the field data is further analysed to assist in evaluating the stakeholders according to the matrix proposed by Freeman (Freeman, 1984). The reasons for choosing the Freeman's matrix is discussed later on in this section. Four steps are followed in the development of the stakeholders' matrix:

1- Identifying the stakeholders
2- Defining and categorising the individual stakeholders
3- Investigating the relationship between the stakeholders
4- Categorising the stakeholders in terms of influence and power

Step 1- Identifying the stakeholders

The relevance of the stakeholders listed below to this research was identified from the literature and from the findings that emerged from chapter 2 of this thesis (Casani et al., 2005; Gonzalez- Benito and Gonzalez- Benito, 2010; Freeman, 1984; Reed et al., 2009; Miles, 2012; Glaser and Strauss, 1967). In total 13 stakeholders were identified from the above sources:

1- Employee and technical know how
2- Customers (trading bodies and supermarkets)
3- Public opinion (consumers
4- Shareholders and investors
5- Business community and creditors
6- Success of competitors in TERR applications
7- UK Government (regulatory enforcement)
8- Economic Feasibility
9- Suppliers (gas, electricity, water)
10- Environmental (water availability)
11- NGOS and consumer groups
12- Media
13- Rising cost of energy

In addition to the above it was apparent after the first two interviews that the following stakeholders should be added to the analysis:

14- Perceived impact of TERR on product hygiene

15- Reliability of the current technologies

16- Availability of guidelines on TERR in the FBM

Step 2- Defining and categorising the Stakeholders

An extensive literature review was carried out to assist in including all the categories that have been previously cited in the literature. Ten main categories emerged:

1- **Driver:** These are the stakeholders that can have a positive and motivating impact on an application or on the decisions taken by the organisation (Massoud et al., 2010; Giurco et al., 2011).

2- **Barrier:** These are the stakeholders that can have a negative impact on an application through creating constraints, uncertainties and lack of incentives (Delgado-ceballos et al., 2012 ; Giurco et al., 2011).

In additions, the drivers and barriers can be either:

i. primary or secondary

ii. Internal, external or regulatory

3- **Primary**: These are the stakeholders that the organisation cannot survive without and are those that have direct powers on the corporation (Onkila, 2011).

In this research the primary stakeholders are those that can have a direct influence (last say) on the decisions taken by the manufacturing site regarding TERR projects.

4- **Secondary**: Secondary stakeholders are those who affect and are affected by the organisation but are not engaged in the transactions with it. These stakeholders are therefore not considered to be essential for the survival of the organisation (Onkila, 2011).

In this research, the secondary stakeholders are those who have no direct impact on the company decisions regarding TERR applications but might indirectly influence or be influenced by the primary stakeholders.

In order to facilitate the interpretation of the field data, the stakeholders are also evaluated in terms of the following categories (Haigh and Griffiths, 2009; Gonzalez- Benito and Ganzalez- Benito, 2010):

5- **Interna**l: Organisational – directly managed by the company.
6- **Externa**l: Not directly managed by the corporation.
7- **Regulatory (public)**: Government and other regulatory agents fall under this category and they are usually considered as a sub group of the primary stakeholder (Onkila, 2011).

In addition to the above, the stakeholders will also be further analysed for the proximity of their impact. This was based on research findings which identified that more proximate stakeholders (short term and actual) are viewed as being more salient to managers and decision makers (Haigh and Griffiths, 2009; Neville et al., 2011) .

Based on this, three additional categories are included in the data analysis:

8- Short term vs long term impact
9- Actual vs potential impact
10- Unlikely to have an impact

Step 3- Investigating the relationship between the stakeholders

It is well documented in the literature that the stakeholders don't only interact with the organisation itself but they also strongly interact amongst themselves in order to guard their individual benefits and interests (stakes) and maximise their influence on the firm (Ferrary, 2009). It is therefore important to understand the dynamic nature of the interaction between the salient stakeholders in order to correctly assess the overall impact on the organisation (Ferrary, 2009; Reed et al., 2009).

In this study the stakeholders are considered to be salient if they have:

1- High or medium current impact on TERR applications in the FBM and
2- This impact is short term and actual

The linkage matrix methodology is used in this chapter to understand the interaction between the salient stakeholders (Onkila, 2011). This is achieved by listing all the salient stakeholders in the rows and columns of a table creating a grid. The grid is then used to understand the interaction amongst the salient stakeholders based on the following five categories that emerged from the literature:

1- **Competitive:** These can also be known as conflicting stakeholders. The conflict might arise between one or more stakeholder or between the stakeholder(s) and the organisation. The latter relationship usually occurs when the stakeholders' demands are perceived of being in opposition to the interests of the company or even weakening the possibilities of the corporation in implementing certain strategies (Onkila, 2011).

2- **Power based**: This can be further divided into two power directions:

   a. **Corporation power**: This can be summarised in the ability of the corporation to influence the stakeholders. The knowledge and skills of the corporation are used to influence suppliers, customers and the other stakeholders (Haigh and Griffiths, 2009; Onkila, 2011).

In this research, this will be evaluated in terms of the ability of the manufacturing sites in influencing the other stakeholders on matters relating to TERR through their technical knowhow and expertise in this area.

   b. **Stakeholder power**: In this definition the stakeholders have the power to influence the actions taken by the corporation. Under this definition the manufacturing sites act by responding to external demands and the stakeholders play the role of monitoring, assessing and even demanding certain actions from the company (Onkila, 2011).

Power based relationship can be achieved through (Onkila, 2011):

i. **Threatening (withholding strategy):** The stakeholders can threaten to withdraw resources unless certain conditions are being met.
ii. **Usage strategy**: The stakeholders can impose conditions for the continued cooperation or provision of services.

3- **Cooperative (collaborative):** Unlike the power based relationship which is driven by the power and status of the actor, collaborative stakeholder relationships are based on equality and strong interaction and cooperation between the stakeholders. The cooperative relationship is based on striving for achieving a common goal and sharing common interests (Onkila, 2011).

4- **Complementary:** In this relationship the stakeholders are seen to contribute to the cooperation and vice versa. As with the cooperative approach, no power laden terms are used, but the contribution is described in a positive way with mutual benefits to both the stakeholder and the corporation (Onkila, 2011).

5- **Trade-off:** Trade-off is the process of balancing conflicting objectives by a particular stakeholder group. This arises when the stakeholder faces more than one objective towards a resource that cannot simultaneously be achieved (Grimble and Wellard, 1997).

In addition to the above and based on the findings from chapter 2, it was felt necessary to add two more categories in order to assist in understanding the impact that the lack of knowledge and field data is potentially having on the uptake of TERR in the FBM:

6- Limited work or limited knowledge in the area of TERR in the FBM
7- No direct relationship to TERR in the FBM.

A summary of the above categories and the associated codes that were developed as part of this research are presented in table (3-2).

Table 3-2 Relationship matrix used in evaluating the relationship between the stakeholders

Relationship		**Codes used**		**Degree of impact**	**Code used**	**Mode of impact**	**Code used**
Competitive		COM		Limited (low)	L	Positive	+
Power		P		Medium	M	Negative	-
	Threatening Strategy	T		High	H	Neutral (no current impact)	0
	Usage Strategy	U		Not applicable	N/A		
	Stakeholder Power	S					
	Corporation power	C					
Collaborative or complementary		COL					

Table 3-2 – continued

Relationship		**Codes used**		**Degree of impact**	**Code used**	**Mode of impact**	**Code used**
Trade offs		T					
No Direct Relationship		ND					
Limited knowledge or limited work been done in this area		LK					

Step 4- Categorising the stakeholders

This is the last and most important step in SM and is used to determine how the stakeholders interact with the corporation to influence the decisions taken by the organisation (Freeman, 1984).

Freemans's model is referred to in the literature as the most widespread and accepted model in both academic and business circles (Fassin, 2009; Frooman, 1999). It was evident form the literature review that the majority of published papers follow Freeman's matrix and characterise the stakeholders in term of their interest and power (Freeman, 1984; Linderberg and Crosby, 1981; Mitchell et al., 1997; Salam and Noguchi, 2006; Romanelli, 2011).

Fewer papers cited alternative methodologies such as the reconstructive approach (Reed et al., 2009; Dryzek and Berejikian, 1993). The characteristics of each of these methodologies are as follows:

A. <u>The analytical categorisation approach (Freeman's Model)</u>:

This top down analytical approach was introduced by Freeman in 1984 and classifies the stakeholders in term of their influence and power over a certain phenomenon (figure 3-2) (Freeman, 1984; Reed et al., 2009).

The strength of the Freeman's model is in its ability to provide a visual representation of the stakeholders and how they can potentially interact according to their positions in the stakeholders mapping (Fassin, 2009; Romanelli et al., 2011).The stakeholders in this model are divided into four categories:

1- Key players: Stakeholders with high influence (power) and high interest (Freeman,1984; Romanelli et al., 2011).
The key players are the group that the company should pay attention to and groom as they are the stakeholders with the highest influence over a certain application (Reed et al., 2009).
2- Context setters: Stakeholders that are highly influential but have little interest (Freeman,1984; Romanelli et al., 2011). This group of stakeholders should be managed properly otherwise they can be a risk to the application (Reed et al., 2009).
3- Subjects: Stakeholders with high interest but low influence (Freeman,1984; Romanelli et al., 2011).
Although this group is mainly considered as supportive to an application, they usually lack the capacity to have an impact on the decision making processes. However, this group can become influential by forming alliance with other stakeholder groups. It is therefore important for the project managers to support and empower this group (Reed et al., 2009).
4- Crowd: Stakeholders with little influence or interest (Freeman,1984; Romanelli et al., 2011). There is little need to consider this stakeholders' group (Reed et al., 2009).

An interpretation of how these definitions are used in this research is detailed in table 3-3.

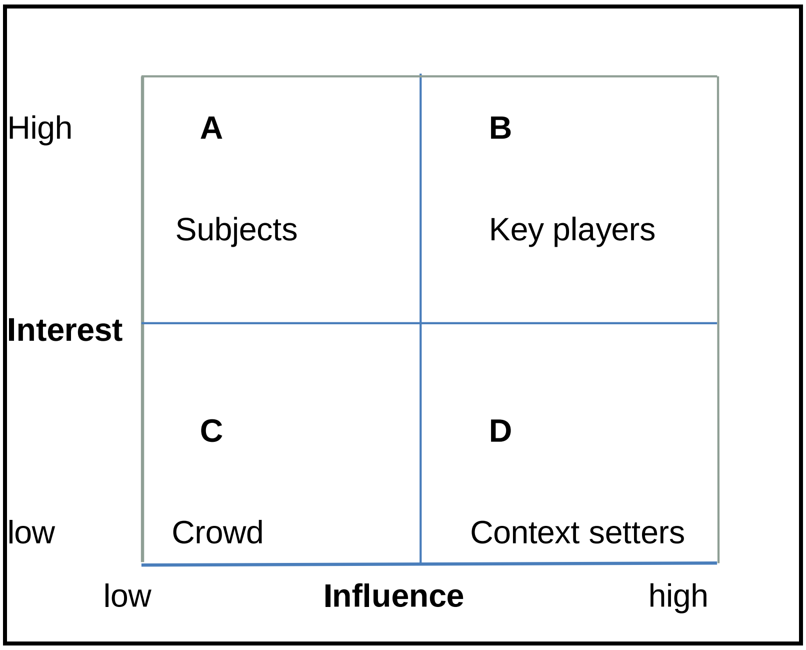


Figure 3-2 Classification of the stakeholders according to Freeman (Freeman,1984).

Table 3-3 Applying the Freeman's Matrix to evaluate the impact of the stakeholders on TERR in the FBM

Classification of the stakeholder's group (Freeman, 1984)	Definition with respect to impact on TERR applications in the FBM
Key Players	Stakeholders in this group are the influential players whose engagement and acceptance is necessary for the approval of TERR in the FBM in the UK.
Context Setters	Stakeholders in this group can potentially have a strong impact on TERR in the FBM in the UK but at the time of the study this impact was diminished by either the lack of interest or involvement in TERR applications.
Subjects	Stakeholders in this group are characterised by lobbying or having an impact on the other stakeholders. Stakeholders in this group are also evaluated in terms of their ability to act as drivers of change.
Crowd	Stakeholders in this group are characterised by having limited interest or influence on TERR applications in the FBM.

B. Reconstruction Approach:

This is a bottom up reconstruction method. As indicated earlier unlike the Freeman's approach the reconstruction approach has been cited in only limited number of papers (Reed et al., 2009; Dryzek and Berejikian, 1993). The reconstruction approach allows the categorisations of the stakeholders to be defined by the stakeholders themselves. Although this approach allows the stakeholders to express their concerns and views more closely as compared to the analytical categorisation approach (Hare and Pahl-Wostl, 2002), the data that emerges from this approach is usually limiting in providing the necessary information needed to interpret the relationship between the stakeholders (Hare and Pahl-Wostl, 2002).

In order to achieve the aim of this chapter understanding the interaction between the stakeholders was identified as being essential and the Freeman's model was deemed to be better suited for this study.

However, although Freeman's model is widely used in environmental and sustainability studies, a number of limitations have been identified from the literature. These limitations were taken into account during the design of this research as detailed in table 3-4.

Table 3-4 Limitation of the Freeman's matrix and the impact on this research

Characteristics	Limitations Identified from the Literature	Impact on the research
Uneven representation of the stakeholders	Freeman's matrix might lead to the under-representation of minority or less influential groups (Calton and Kurland, 1997).	An inclusive and wide range of stakeholders were evaluated in this study as listed in previous sections.
Subjective analysis	The categorisation is usually carried out in the absence of the stakeholders and can therefore be subjective reflecting the biases of the researcher rather than the perception of the stakeholders (Reed et al., 2009)	The stakeholders were heavily involved in the categorisation of the influence and power matrix as detailed in the methodology section.
Simplifying the relationship between the stakeholders	The matrix does not extend to evaluate who is having an influence on the stakeholders (stake watchers) (Fassin, 2008 ; Fassin, 2009)	The visual simplicity of the analytical matrix in the Freeman's approached is attributed to the success of the methodology (Fassin, 2008). Due to the large number of stakeholders evaluated in this study it was important to use a format that can clearly visualise the relationships between the stakeholders. There is also enough evidence from published data to verify that Freeman's Stakeholders' matrix provides good approximation to reality (Fassin, 2008).

3.3 Methodology

Semi –structured interviews were used to collect the data for the stakeholders' analysis. Grounded Theory Methodology (GTM) was then applied to analyse and interpret the data in order to understand and categorise the relationship between the stakeholders and the FBM. GTM was chosen for this research due to the characteristics of the methodology that were deemed suitable and essential to achieve the aim of this chapter. These are detailed in section 3.3.1 (table 3-5).

3.3.1 Grounded Theory Methodology (GTM) – Introduction

GTM is an interpretive qualitative research methodology originally introduced by Glaser and Strauss in 1967 (Glaser and Strauss,1967). GTM is particularly suited to research subjects where little is known about the situation under investigation. (Martin and Taylor,1986; Glaser and Strauss,1967). Whilst conventional forms of qualitative research require the researcher to preselect a path of investigation in a method which is primarily deductive, GTM works in a manner which is contrary to the conventional path by being inductive(Jones and Kriflik, 2005). In order to achieve this inductive approach GTM follows an exceptionally rigorous approach and provides a mixture of structure and flexibility in collecting and analysing the data. The following main steps are followed (Chiovitti, 2003; Corbin et al., 2008; Glaser and Holton, 2005; Holton, 2010; Jones and Alony, 2011):

1- GTM uses open ended, semi- structured interviews rather than pre-established list of questions (Ekstrom et al., 2005). The narrative from the interviews is then analysed to derive conceptual data that is used to provide a probability statement explaining the majority of behaviour of the participants (Glaser, 1998; Glaser, 2003; Holton, 2010).
   This makes GTM suitable to understand complex and multifaceted concepts where overlapping parameters have to be considered (Glaser and Strauss, 1967).
2- GTM allows researchers to include field observations to assist in the interpretation of the qualitative narrative obtained from the semi-structured interviews (Glaser and Strauss, 1967).
   This offers a powerful framework to learn about perceptions and attitudes and will assist in the interpretation of the participants' feedback and behaviour.
3- Due to the above GTM is particularly suitable in evaluating research that fall under the socio-technical domain (Jones and Alony, 2011).
4- GTM allows researchers to maintain an open mind about the direction of the research. This is usually driven by the interviewees who are given the opportunity and are encouraged to talk about what is important to them regarding a given context (Charmaz, 2006).
5- GTM does not seek statistical representation or statistical analysis of the data, but relies on in-depth interviews and a structured comparative analysis of the data to understand a specific phenomenon (Glaser and Holton, 2005; Jones and Alony, 2011).

Data in GTM is collected until theoretical saturation is reached. Theoretical saturation is defined as the point at which no new relevant information emerges from the field data (Jones and Kriflik, 2005).

The summary of the above characteristics and the suitability of applying GTM to this research is summarised in table (3-5).

Table 3-5 Relevance of GTM to the research

<table>
<tr><th>GTM Characteristics</th><th>Relevance to the research</th></tr>
<tr><td>Uses an inductive approach which does not require the researcher to pre-select the path of investigation.</td><td rowspan="2">Due to the limited knowledge on TERR in the FBM, an inductive approach and an open mind was identified as being essential to progress this study.</td></tr>
<tr><td>Allows the researchers to maintain an open mind about the direction of the research</td></tr>
<tr><td>Provides rigorous approach to assist in understanding perceptions, attitudes and participants behaviours.</td><td>This is essential to provide the data needed for the SM analysis as detailed in section 3.2.</td></tr>
</table>

Table 3-5 Continued

<table>
<tr><th>GTM Characteristics</th><th>Relevance to the research</th></tr>
<tr><td>GTM is suitable to understand complex and multifaceted concepts where overlapping parameters have to be considered.</td><td rowspan="2">The research identified the need to establish the impact of 16 stakeholders on TERR in the FBM. These might act and interact in complex ways to affect the uptake of TERR by the FBM. In addition and as can be seen from the list presented in section 3.2 some of the stakeholders fall under the socio – technical domain.</td></tr>
<tr><td>GTM is particularly suitable to evaluating issues that fall under the socio-technical domain.</td></tr>
<tr><td>GTM does not seek statistical representation or statistical analysis of the data.</td><td>Due to the magnitude of the FBM sector in the UK and the limited resources available for this research, obtaining a large enough representative sample would have been very challenging.</td></tr>
</table>

3.3.2 GTM- Research Questionnaire

In line with GTM semi structured interviews with open ended questions were used to collect the qualitative field data. The interviews were aided by prompt questions when no response was forthcoming or when it was felt necessary to gain more information or clarify a certain point or area (Bryant and Charmaz, 2007; Birks and Mills, 2011). The questionnaire presented in appendix 3-1 was only used as a guideline. Participants were allowed during any stages of the interview to express their personal views or elaborate on areas of importance to them even if those were not part of the interview (Flick, 2006; Blaikie, 2011).

By applying the above, the interviews were kept flexible. However, in order to assist in obtaining the information needed for SM, the interviews tried to cover the following areas:

1- General information regarding the manufacturing sites.
2- Background to water saving initiatives on site.
3- State of water recycling and reuse within the factory, including reuse applications in the manufacturing processes.
4- Identifying, defining and understanding the impact that the stakeholders currently have on the decisions taken by the manufacturing sites relating to TERR applications.
5- Understanding and identifying the stakeholders that can potentially act as main drivers of change.

The stakeholders that were included in the questionnaire are those listed in section 3.2.4.

Due to the confidentiality of the information presented in the actual interviews these are only available on the enclosed CD –ROM under “corporate interviews”.

3.3.3 Data Selection

In line with GTM, participants were not chosen statistically but were selected according to their usefulness to the research (Holton 2010; Glaser and Strauss, 1967). The participants for the initial or site interviews were chosen according to their role and responsibility within the manufacturing sites and were chosen to cover different subsectors within the FBM as detailed in table 3-6.

The information that emerged from these site interviews was later verified by carrying out more specific and targeted interviews with the regulatory, public and consultancy bodies that currently have links with the FBM. A list of the organisations that took part in the targeted interviews is provided in appendix 3-3. The targeted interviews were also used to explore in further details specific areas that emerged from the initial interviews (Levy, 2011; Elliott and Higgins, 2012).

Due to the confidentiality of the information presented in the actual interviews these are only available on the enclosed CD ROM titled “official interviews”.

3.3.4 Data Coding

GTM follows a qualitative modelling process in which the information gathered from the semi- structured interviews is coded according to clear guidelines. This assists in conceptualising, linking and validating the ideas that emerge from the interviews. The conceptualised data is then used for further analysis, such as SM in case of this research (Glaser and Holton, 2005; Bryant and Charmaz, 2007; Birks and Mills, 2011). In this study the narratives from the interviews were coded following GTM open coding procedures as detailed below. The codes were then used to identify the type and degree of impact that each of the stakeholders can potentially have on the uptake of TERR in the FBM within the research boundary as defined earlier in section 3.2.

The following three main GTM coding steps were applied (Glaser and Holton, 2004; Elliott and Jordan, 2010; Birks and Mills, 2011):

<u>Step 1- Open Coding</u>

Initial or open coding was used as the first step of analysing the data that emerged from the semi – structured interviews. The line by line coding practice was applied using the direct information, words and phrases provided by the participants (In - Vivo coding) (Glaser and Holton, 2004; Elliott and Jordan, 2010; Birks and Mills, 2011). At this initial stage the data was divided into 6 categories using the exact phrases or words used by the participants. Each of the six categories included results and phrases that were used by the interviewees and that were interpreted of having similar/ comparative impact on TERR applications in the FBM. A list of the in- vivo codes that were obtained from the participants' narrative is presented in appendix 3-2. The coding that emerged from the individual interviews is also provided on the CD – ROM. These initial categories were then further examined to identify patterns or associations and were used to assist in identifying emerging concepts as detailed in step 2 (Levy, 2011; Glaser and Strauss, 1967).

Step 2- Selective Coding or axial coding

This is the intermediate and second coding stage in GTM. This stage uses the data from the open coding stage and compares the phrases and narratives to identify emerging concepts (Walker and Myrick, 2006; Levy, 2011). The six categories that were established in step one were further categorised to establish and specify the impact of the individual stakeholders on TERR in the FBM. The following six main categories emerged:

1- Low impact on TERR
2- More information is needed to understand the impact on TERR
3- Medium positive impact
4- High positive impact
5- Medium negative impact
6- High negative impact

During the interviews there was a continual move between the initial and intermediate coding stages in a process of data comparison. This on-going comparative analysis was used as an aid to minimise variation in the interpreting of the qualitative phrases that were used by the interviewees (Elliott and Jordan, 2010; Levy, 2011).

<u>Step 3- Theoretical coding</u>

This is the final stage of coding and was used to examine the emerging concepts and to further filter the data into two main categories according to their impact on TERR:

1- Driver : primary or secondary
2- Barrier : primary or secondary

These were defined in accordance with SM as previously detailed in section 3.2.

The data that emerged from GTM was then used in the SM analysis.

3.3.5 Data Saturation and Sample Size

As indicated previously the manufacturing sites for the initial interviews were chosen to represent different sub sectors within the FBM (table 5-3). These subsectors were identified based on the description provided by the UK Government (WRAP, 2014a).

Participants were chosen based on their influence on the implementation of water management and TERR projects and were initially contacted via email or telephone. Those who agreed to take part in the interviews were provided with details regarding the aim of the study and the confidentiality of the data gathered from the interviews (appendix 3-1). This was then followed by setting up a date for the interview. All interviews were conducted face to face at the FBM manufacturing sites. Further details regarding the role of the participants within the FBM sites are provided in figure 3.3.

The data presented in this study, represents findings from 137 FBM sites (table 3-6). Due to the corporate nature of some of the manufacturing sites, this was achieved by carrying out 22 interviews[4]. New data stopped emerging after the 22nd interview and it was decided that the saturation point as defined by GTM (section 3.3.1) has been reached.

We were unable to get representation from following subsectors:

1- Pet food manufacturers
2- Animal feed
3- Milling

[4] The corporate nature of the individual participants and the number of factories that they embody is detailed in section 2 of the individual interview sheets and can be found on the CD –ROM.

Table 3-6 Participants- including subsectors within the FBM

FBM Sub sector	Representation in the interview (number of manufacturing sites)	% contribution to water use in the FBM - derived from (WRAP, 2013; EA, 2013 a)	Average million m^3 /annum that can be saved through TERR- derived from (WRAP, 2013; EA, 2013 a)
Dairy	13	13.4%	15.6
Chicken processing plants	14	27%	31.0
Red meat Processing Plants	14		
Hot Drinks	1	27%	27.0
Soft drinks	3		
Brewery & Cider	6		
Chilled and frozen Pre – prepared foods	58	4.5 %	4.8

Table 3-6 continued

FBM Sub sector	Representation in the interview (number of manufacturing sites)	% contribution to water use in the FBM - derived from (WRAP, 2013; EA, 2013 a)	Average million m^3 /annum that can be saved through TERR- derived from (WRAP, 2013; EA, 2013 a)
Snack Food and Sandwich filler	2	5.25%	5.8
Cereal	8	10.8%	12.25
Healthy Foods	3	No data available	No data available
Salads and fresh fruits	5	24%	29
Confectionary	5	2.8%	3.1
Bakery	5	2%	4.4

Table 3-6 continued

FBM Sub sector	Representation in the interview (number of manufacturing sites)	% contribution to water use in the FBM (WRAP, 2013; EA, 2013 a)	Average million m^3 /annum that can be saved through TERR- derived from (WRAP, 2013; EA, 2013 a)
Animal Feed	0	0.78%	0.9
Pet Food	0	4.6%	4.7
Milling	0	0.25%	0.3

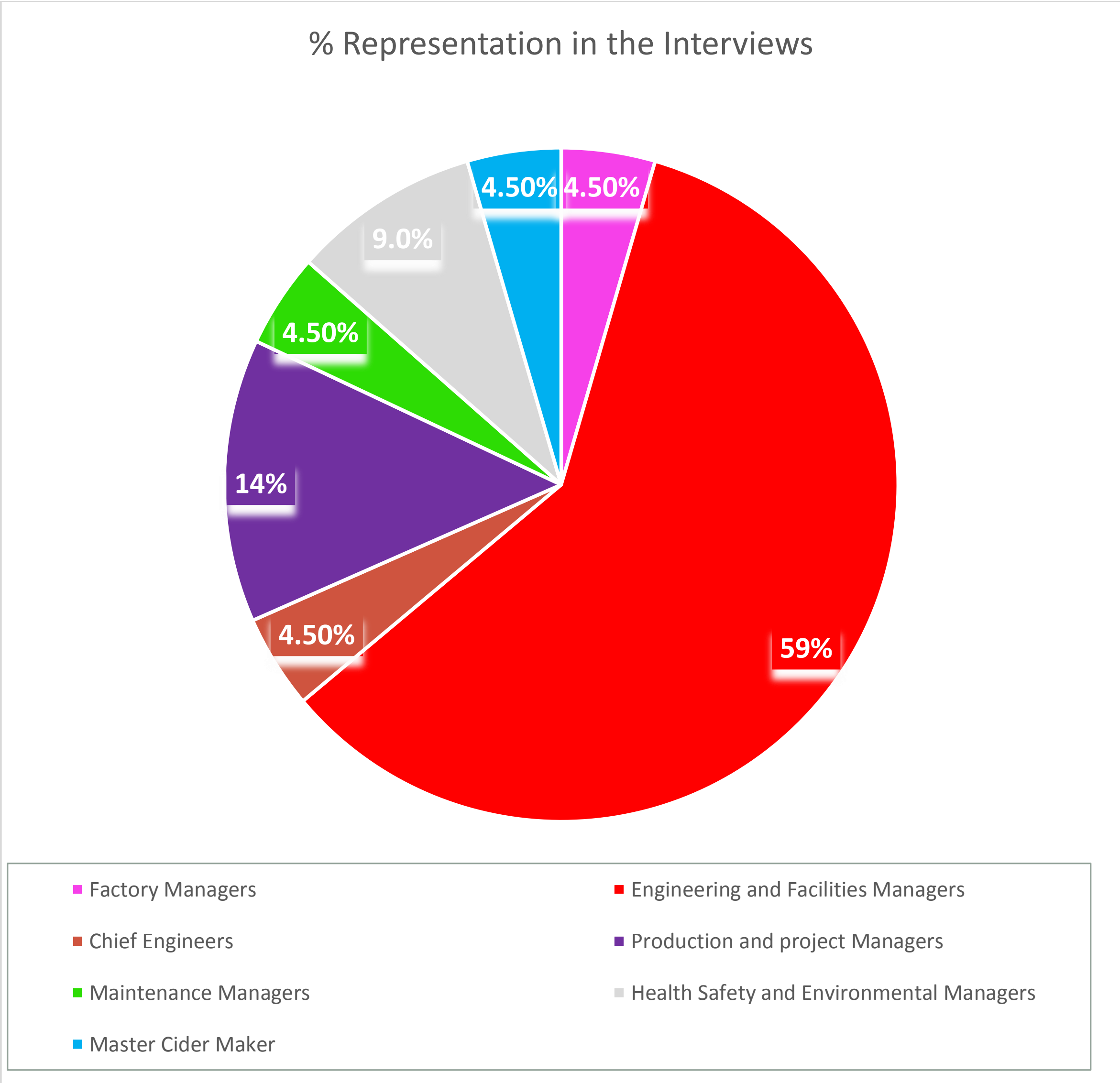


Figure 3-3 The role of participants that took part in the Survey

3.4 Research Findings

The data from the semi-structured interviews were used to understand the perspective of the manufacturing sites with regards to the impact that the stakeholders can currently have on the success or failure of TERR applications within the research boundaries. The findings from these interviews were then further investigated and verified with the regulatory, service providers and consultancy bodies that currently work with the FBM.

These interviews took place between May 2012 and March 2013 and included representations from 137 FBM manufacturing sites. To put this into perspective and based on the figures presented in chapter 2, the survey covered an equivalent to 48% of the total signatories to the FHC and more than 11% of the total FBM sector in the UK. The data that emerged from the individual interviews and the associated In-Vivo coding is available on the CD-ROM. A summary of the overall results is presented in table 3-7 below. In this table the figures represent the results that were derived from the axial coding of the narratives that emerged from the semi-structured interviews. These provide an interpretation of the participants' views regarding the impact that the individual stakeholders are perceived to have on the success or failure of TERR projects in the FBM.

This data was then further analysed in conjunction with the narratives from the interviews to develop SM.

Table 3-7 Summary of the field data – Derived from the in-vivo coding

Stakeholders	Low impact	More information is needed	Primary Driver	Secondary Driver	Primary Barrier	Secondary Barrier
Employee and technical know how	71%			24%		5%
Customers (trading bodies and supermarkets)		9%	5%	9%	77%	
Public opinion	72%	14%		5%		9%
Shareholders and investors	90%	5%	5%			
Business community and creditors	95%	5%				
Competitors	14%	19%	5%	62%		
Regulatory enforcement		5%	95% 76% (unlikely to be introduced)			
Economic Feasibility	9%	71%	30%	52%		
Suppliers (gas, electricity, water)	86%			9%		
Environmental (water availability)	86%			9%		
NGOS and consumer groups	100%					
Media	62%	19%			14%	

Table 3-7 Continued

Stakeholders	Low impact	More information is needed	Primary Driver	Secondary Driver	Primary Barrier	Secondary Barrier
Rising cost of energy	76%					14%
Cross Contamination	14%				86%	
Reliable Technology	14%		14%	57%		
UK Government - awareness – guidance	14%		5%	62%	5%	

3.4.1 Risk of Cross Contamination

It was clear from the narratives that were provided by the participants that significant resources are currently being deployed by the FBM to ensure product quality and hygiene standards. All participants expressed the need to clarify the impact that TERR might have on the finished products before they can possibly consider evaluating this application:

1- According to all participants proving the safety of TERR applications in maintaining existing hygiene standards is an essential condition that has to be met particularly when considering water reuse applications in process areas. Concerns regarding the impact that TERR might have on the product quality and company image were widespread amongst the participants although it was made clear, at the start and throughout the interviews, that only water of potable standards will be considered for reuse.

2- 14% of participants expressed an environmentally driven interest in evaluating TERR within their organisation. However, according to this group, this would only be considered after the provision of guarantees regarding the quality of the regenerated water and the ability to maintain potable water quality at all times.

   Specific concerns were expressed regarding the ability of maintaining the quality of the regenerated water and the lack of trust in the current available technologies. This will be further discussed in 3.4.3.

3- The majority of participants (86%) had strong objections regarding the principal of re-using recycled water in process areas. For this group the quality of the regenerated water played no role in changing the perceived negative impact that TERR might have on product quality and hygiene.
It was clear from the phrases used by the participants in this group that the above concerns currently outweigh any other benefits whether environmental or financial that can be achieved from the TERR applications. These concerns mainly centred on the potential consequences of a degradation in the quality of the regenerated water and the catastrophic impact that this could have on the marketing image and survival of the organisation. Participants indicated that the FBM market is currently very competitive and recovery from a contamination scandal would be very challenging for the manufacturing sites.

In addition to the above general concerns, the following two points emerged from the following subsectors:

a. Participants from the meat and egg sub-sectors expressed strong opposition against TERR applications. This was mainly due to the particularly high perceived risks associated with viral contamination and Salmonella.
There was also reference to a “disgust factor” that might be associated with re-using water that might have been in contact with animal bi- products and or blood.
b. Similar level of strong opposition was expressed by the speciality product manufacturers. The marketing powers of this sub-sector lie

in the public willing to pay extra for a premium, higher quality and purer products. According to this group, the use of recycled water will have a detrimental impact on their marketing powers.

In addition to the above, 86% of participants expressed an overall uncertainty regarding the liability of maintaining the quality of the regenerated water. The following questions emerged:

a. Who will be responsible for maintaining the potable quality of the regenerated water?
b. How would this be managed and by whom?

Most participants expressed their reluctance in becoming responsible for maintaining the quality of water that is used in process areas. A list of the complex analysis that is currently being tested by the water treatment providers was presented to us during one of the site interviews (appendix 3-5). More concerns were expressed by this site regarding:

c. Who will carry out these complex analyses if the potable water is to be regenerated on site?
d. What impact will this have on the site resources?
e. What training needs will be required and how can these be met?
f. What laboratory and other equipment facilities will be required?
g. How will all the above impact on the site operating costs?

Due to its significance, the liability aspect will be discussed in further details later on in this section.

In order to assist in interpreting the field data, targeted interviews were carried out with the EA, DEFRA, CFA and FSA. A brief description of the role of these organisations is presented in appendices 3-3 and 3-4. In line with GTM, these interviews were used to further explore and verify the findings that emerged from the manufacturing sites regarding the impact that the perceived risk of cross contamination can have on TERR in the FBM.

Three key points emerged from these targeted interviews:

1- Firstly that the current UK legislations governing water usage in the FBM make no distinction between the source of water used in the production areas whether mains, borehole or recycled water, as long as:
    a. The water quality achieves potable water standards and
    b. The water used has no impact on the safety and wholesomeness of the finished product (s).

All agencies agreed with the concept of the water quality being the overriding factor, rather than the water source. There was a general consensus that if the regenerated water is of potable standards, there should be no greater risks associated with using the recycled water as compared to for example mains or borehole water.

All agencies also indicated that as long as potable quality water is being used, there will be no need to indicate the source of the used water on the product labels.

2- Secondly, although in theory there should be no objections to using the potable regenerated water in process areas, limited knowledge is currently available to verify the safety of this application. There is therefore a need to officially verify the safety of TERR applications in the FBM. It was evident from the discussions held by DEFRA that comprehensive and trusted validation studies and field trials on TERR will be required before the UK Government can recommend, promote or comment on the safety of TERR applications in the FBM. These validation studies can also be used to enhance the understanding and knowledge of the official bodies working with the FBM on TERR applications.
3- Thirdly, once the safety of TERR is established there will be a need to clarify areas relating to liability and who would be responsible for maintaining and controlling the quality of the regenerated water.

DEFRA highlighted that the domestic water quality provided by the current UK water suppliers is one of the best in the world. This is mainly due to the long term experience and resources that have been invested to guarantee the high quality of the mains water supply. In DEFRA’s view more work is going to be needed to research the safety and reliability of small private recycling plants. Trusting these private applications will not be gained overnight and will take time to mirror the trust that has been gained by the water treatment works.

The interview took place prior the large scale contamination of the drinking water supplies that took place in Lancashire in August 2015. However, the serious implications that the Cryptosporidium contamination has caused, demonstrates the importance of guaranteeing and maintaining the water quality where potable water standards are required. A brief summary of the bacterial contamination problem in the North West of England is presented in appendix 3-6. (BBC News, 2015; University of Salford, 2015).

Due to the importance of the liability aspect and it being mentioned in the initial and targeted interviews, it was felt essential to investigate this area in further details. Interviews were carried out with two main water providers in England: United Utilities and Anglian Water. A brief description of the role of these providers is presented in appendix 3-3.

Two key points emerged:

1- Transfer of liability: The responsibility of maintaining the quality of the regenerated water can be transferred to the utilities companies via a contractual agreement with the manufacturing sites. Based on these agreements the water providers can either own or operate the water treatment plants on behalf of the manufacturing sites.
   Such agreements would allow the manufacturers to revert the responsibility of maintaining and testing the quality of the regenerated water to the water suppliers.
2- Clearer guidelines: Although in theory the liability aspect can be transferred, there are still many unknowns as to how to operate and manage such projects. Both water providers indicated that for the above to work, there is

a need to establish detailed guidelines and an approved code of practice or a regulatory code detailing how to govern and regulate the liability transfer contracts. Both water providers also highlighted the need to clarify and define the charging structure and the provision of emergency water supplies should the site water treatment plant fail.

Due the complexity of the above, both United Utilities and Anglian Water indicated that these agreements cannot be successfully planned and implemented by simply entering a contractual agreement with the manufacturing sites. The UK Government input is going to be essential in defining and regulating these contracts.

In addition to the above, the following points emerged from the discussions with the water treatment providers:

1- Both companies are currently not playing a proactive role in promoting TERR applications in the FBM. However, both water providers indicated that they will be willing to consider such projects if they were approached by the manufacturing sites.
2- It was also apparent from the discussions that a widespread application of TERR will have a significant impact on the operational strategies of the water and effluent treatment providers. This is mainly due to the impact that a widespread application of TERR can have on:
    a. Reduction in mains water usage
    b. Changes to the trade effluent quality
    c. Reduction in the trade effluent discharge volumes

Both United Utilities and Anglian Water indicated that if there was a widespread interest in TERR in the FBM, the water supply sector will have to evolve to guard its interests and competitiveness in the UK market. However, both companies indicated that this cannot happen overnight and that long term planning and investment will be needed.

In summary, the qualitative interviews clearly indicate that TERR will only be accepted by the FBM if guarantees are provided to ensure that this application will have no impact on the marketing powers of the company, product quality, shelf life and hygiene. For the above to be possible, validation work is still needed to demonstrate the safety of TERR applications and to improve the knowledge and understanding of this application.

Clearer guidelines will also be needed to establish safe operating procedures of the water regeneration plants and to assist in managing the liabilities associated with the regenerated water quality.

3.4.2 Relationship with the Customers (The Supermarkets)

It is clear from the results that emerged from the interviews that maintaining a satisfactory relationship with the supermarkets is considered essential for the survival of all the manufacturing sites. All participants indicated that they are currently operating under strict contractual agreements that have been drawn up by the supermarkets. Due to these contractual obligations, the supermarkets currently hold strong powers over the manufacturing sites, making them the most influential regulatory and quality control body governing the FBM in the UK.

Based on the narratives that were provided by all manufacturing sites, the supermarkets currently have the power to exert strict guidelines regarding what can or cannot be used in the manufacturing processes. Any deviations from these guidelines can result in the supermarkets terminating the contracts with the manufacturing sites. From the phrases used by the participants, the supermarkets are viewed as a feared partner and as such all guidelines and parameters set by the supermarkets are currently being followed unchallenged by the industry.

Although participants expressed different views regarding the position of the supermarkets in relation to TERR, they all agreed that the supermarkets' approval is going to be necessary for the approval of TERR applications in the FBM (100%). The view of the majority of participants (77%) is that the supermarkets will currently reject the implementation of TERR projects, making it difficult for them to even consider this application. With the exception of the salads sub sector the majority of participants based the above on previous experiences with the supermarkets and indicated that TERR will be evaluated and rejected based on the following criteria:

1- Perceived high risk of cross contamination which can potentially lead to product recall of the supermarkets' own label brands:
    a- This can cause the supermarkets direct financial losses and can damage their brands' name and public trust.
    b- Most supermarkets would have invested heavily in marketing their own brands and will therefore be reluctant to take this risk.
    c- Although the supermarkets exert strong powers to regulate their own brands, their specifications regarding water usage can have an

impact on all the processes within a manufacturing site. Most factories in the UK are more than 15-20 years old and usually have one water supply. It would be therefore very difficult to use two sources of water within the same manufacturing site.

2- Lack of technical know-how of the supermarkets' representatives that are currently appointed to evaluate innovative projects. This is creating a tendency to reject technical and innovative applications on perceived rather than scientific facts.
3- In the current competitive market, priorities are given to strategies that are driven by the supermarkets. These are usually applications that are linked to direct financial gains. As changing the source of water is unlikely to have a direct impact on the supermarkets' profitability, TERR evaluations are currently not given priority.

As mentioned previously a more positive view was expressed by the salads sub sector. As similar findings also emerged from chapter 2 of this thesis, it was deemed important to investigate the reasons behind the differences between the salads and vegetables sub sectors and the other FBM subsectors.

Discussions with the manufacturing sites and DEFRA highlighted the following five points that can make TERR operations simpler in the salads and vegetables sub sectors; according to DEFRA this subsector is characterised by the following:

1- Simpler operations that in some cases only involves washing the products prior to dispatching to the customers.
2- The contaminants are of simpler nature and are mostly of soil and general debris.

3- The only bi-products that are added to the water during the preparation processes are the preservatives which are added to keep the products fresh. These will have no negative impact if found in traces in the regenerated water.

4- Most fresh fruits and vegetables packages have instructions to rinse or wash the products prior to use.

5- The effluent water quality from this subsector is chemically very similar to the mains water quality, making it easier and possibly cheaper to treat back to potable standards.

In contrast, the above can be very complex in the other FBM sub-sectors making TERR a more challenging and sensitive application.

Numerous requests were made to interview the main supermarkets in the UK but none were granted. In order to cover this area as best as possible meetings were held with Campden BRI (a renowned research institute working on behalf of the supermarkets in the UK and Europe), CFA and DEFRA. The strong controlling powers of the supermarkets identified from the initial interviews were reiterated in these interviews. Moreover, additional key points emerged highlighting the indirect impacts that the supermarkets can have on TERR applications in the FBM. These can be summarised as follows:

A. <u>Indirect influence of the supermarkets</u>

1- According to the CFA, the FBM is currently being financially squeezed by the supermarkets and is left with very limited resources to deploy for research and development. Under such circumstances and in order to strengthen the relationship with the supermarkets, priorities are often given to areas that interest the supermarkets. As TERR is not on the supermarkets' current agendas, research on TERR has not been prioritised by the FBM. This in turn is leading to limited field studies and validations.

As discussed in section 3.4.1, these field validations will be essential for the approval of TERR projects and their absence will negatively impact on the uptake of TERR by the FBM.

2- The supermarkets are only offering the FBM short term, 24 months contracts. This is creating business insecurity and is having a direct impact on long term planning strategies and on the ability of the FBM to invest in continuous improvement projects. The impact of these short term contracts is strongest on applications similar to TERR where the return on investment is expected to exceed two years.
   According to the CFA, the UK Government should work and lobby the supermarkets to provide the FBM longer contracts in order to assist in triggering investment in environmental projects such as TERR.
3- The auditors working on behalf of the supermarkets are usually from a financial background and have limited technical knowledge. This is impacting on the evaluation and approval of new innovations such as TERR. In addition, during these audits, focus is usually given to evaluating areas of high interest to the supermarkets. Applications such as TERR which don't fit into this category are either ignored or rejected.

B. Negotiating powers of the FBM

According to DEFRA the FBM has to deal with a number of internal issues in order to improve the ability to negotiate and communicate with the supermarkets. One of the key areas that have to be addressed is improving the technical knowledge of the decision makers in the FBM. According to DEFRA this is currently an issue in many manufacturing sites where the managers are semiskilled engineers and seem to lack the ability to carry out convincing arguments with the supermarkets. This in turn might be having an impact on the negotiating powers between the supermarkets and the manufacturing sites.

However, the above statement was contradicted by the views expressed by the manufacturing sites. This will be presented in further details in section 3.4.3.

C. Role of the UK Government

Contradictory to previous findings, Campden BRI expressed their reservations in assigning the responsibility of evaluating and approving TERR in the FBM to the supermarkets. According to Campden BRI this role can best be fulfilled by the UK Government who should be working with the supermarkets and the FBM to understand, validate and resolve any issues or concerns that are currently linked to TERR. Once this is established, the UK Government can play a crucial role in the development and provision of clear guidelines regarding the safety and methodologies that have to be followed to successfully implement TERR applications. The current role of the UK Government will be discussed in section 3.4.4.

The research findings clearly identify that the supermarkets' approval is key for the success of TERR applications in the FBM. However, more input is going to be needed from the manufacturing sites and the UK Government to initiate discussions with the supermarkets to work towards making TERR approval possible.

3.4.3 Technical know-How and Reliability of the Available Technologies

Contradictory to the concerns expressed by DEFRA in section 3.4.2 regarding the technical know-how of the decisions makers in the FBM, 71% of the participants from the FBM indicated that the technical know-how of decision makers in the FBM does not currently play a significant role in negotiating the approval of TERR or any other technical projects. Based on the narrative that emerged from the interviews, this was mainly due to the following:

1- There are currently a number of significant barriers that have to be resolved before the negotiating powers of the manufacturing sites can be used to assist in the approval of TERR projects:

   a. 71% of participants indicated that TERR will only be evaluated for approval once issues relating to the risk of contamination are resolved and the approval of the supermarkets are granted.
   b. Whilst 14% of participants believed that providing guarantees regarding the safety and reliability of the technologies might act as a driver of change, 57% indicated that other barriers have to be first overcome for this to be possible.

2- In addition to the above, there was a common agreement amongst the participants from the FBM that once TERR is an accepted application, training will be provided by the technology suppliers, who it will be in their interest to improve the technical know -how of the decision makers in the FBM. The above statement was based on current experiences by decision makers in the FBM who are regularly invited to free seminars, training sessions and marketing events. These are used as marketing tools by the suppliers to introduce new technologies and applications.

The CFA expressed their frustration regarding the lack of communication in this area. According to the CFA, reliable technologies that can be used in TERR applications might be already available in the market. But to be accepted by the FBM, validation studies following specific guidelines that are set by the FBM and the stakeholders have to be followed. According to the CFA the following conditions have to be met for the validation work to be approved by the FBM:

a. The validations have to be done by research associations that are approved by the FBM and must follow well defined and specific protocols.
b. Prior to marketing, pilot studies will be required at a number of manufacturing sites. Results from these studies will be essential to demonstrate the safety and reliability of the technologies under field conditions.

This view was also shared by Campden BRI who indicated that irrespective of how good or reliable a technology is, the approval and accreditation can only be awarded by the stakeholders in the FBM if specific validation procedures have been followed.

The importance of the field validations also indirectly emerged from the initial interviews; 67% of participants indicated that the success and validation of TERR by a competitor will make future approvals of TERR applications easier. In addition to proving and evaluating the safety of the technologies used in TERR projects, the CFA reiterated the need to evaluate the economic feasibility and payback period of these technologies. As indicated in the previous section and due to the short term contracts with the supermarkets, for TERR applications to be approved by the FBM, the payback period of TERR projects must not exceed 2 years. This will be further discussed in section 3.4.5.

3.4.4 Regulatory Enforcement and Clearer Government Guidelines

95% of participants believed that introducing a regulatory element can have the biggest and quickest impact on expanding TERR applications in the FBM. However, 76% of this group indicated that in their view this is unlikely to be introduced by the UK Government in the near future. According to this latter group, a regulatory element can only be introduced if there were guarantees that TERR applications will not impact negatively on manufacturing in the UK. The following conditions emerged as being essential for such a move.

1- Scientific and field evidence proving the safety and reliability of TERR applications.
2- Availability of reliable technologies.

3- Approval by the supermarkets.

4- Proving the feasibility of TERR applications.

5- Guarding the competitiveness of the UK market and safeguarding manufacturing in the UK.

6- Provision of clearer guidelines regarding the management of TERR projects.

As can be seen from the above list some of these conditions have already been discussed in details in the previous sections. There was a general agreement amongst the participants that alternative and effective interventions can be introduced by the UK Government to encourage TERR applications and that don't involve the introduction of a regulatory element. 62% of participant's believed that the provision of clear guidelines can have a significant positive impact on TERR in the FBM through its indirect impact on improving the awareness and perception of the stakeholders regarding the safety of TERR applications. Discussions were held with the main regulatory bodies in the UK (DEFRA and the EA) to explore their views regarding introducing a regulatory aspect to TERR in the FBM. Three key points emerged from these interviews:

1- The UK Government will do everything possible to avoid introducing a regulatory element to TERR in the FBM. In their view such a move will increase the regulatory burden on an already heavily regulated industry and might move businesses to outside the UK.

2- Regulatory enforcement will only be considered as a last resort if there were potential risks of severe water shortages with imminent impact on the UK food and water security.

3- For regulatory enforcement to be possible there is a need to fully evaluate and validate TERR applications. This has already been discussed in the earlier sections.

Campden BRI acknowledged the difficulties associated with introducing an additional regulatory burden to the FBM but agreed with the views expressed in the initial interviews regarding the alternative options that are available for the UK Government. According to Campden BRI companies will currently find it very difficult to know where to start and what has to be done should they be interested in evaluating TERR applications. Priority has to be given to clarifying which authority in the UK is currently responsible for approving the reuse of the regenerated water. This step is essential to comply with the EU regulation 852/2004 (EC, 2004)[5]. According to Campden BRI there is currently no appointed body in the UK to deal with the approval of TERR applications. Due to the importance of this statement further discussions were held with DEFRA, EA and the FSA to clarify their view regarding the above.

The official bodies confirmed that at the moment the approval to use recycled water in the FBM does not fall under the remit of any of the central government departments and would have to be evaluated by the regional environmental health officers. However, it was apparent from the discussions with DEFRA that no training or guidelines have been provided to the local environmental health officers to deal with requests associated with TERR in the FBM.

[5] EU 852/2004 seeks to ensure the hygiene of food at all stages of the production process, from the primary production stage (mainly farming, hunting or fishing) to the final consumer. This EU law does not cover issues relating to nutrition, composition or quality, or the production or preparation of food in the home but deals with ensuring the quality of food manufactured or packaged at manufacturing or processing plants. The Regulation and its annexes define a set of food safety objectives that firms working with food must meet. EU 852/2004 focusses on applying the HACCP principles as detailed in chapter 2 in all food processing stages.

Further discussions with Campden BRI highlighted a number of difficulties that might arise from the above:

1- In the absence of clear government strategies, local environmental health officers might be reluctant to provide approvals for TERR projects, as this might be seen as a personal decision, which is not backed up by a central strategy or policy. Due to the high sensitivity of the FBM sector, guidelines will be essential to assist in directing the decisions taken by the local environmental health officers.
2- Without a well-defined government strategy, decisions will vary greatly depending on the knowledge and technical know-how of the local environmental health officers.

In summary there is a clear indication that the UK Government can play an active and important role in assisting TERR applications through the provision of clear guidelines and through clarifying and defining the steps that can be taken for the approval and safe implementation of TERR in the FBM.

The above will have to be given priority if the UK Government is serious about improving the uptake of TERR in the FBM.

3.4.5 Economic Feasibility

The importance of understanding the economic feasibility of TERR in the FBM was highlighted in earlier sections.

The qualitative narrative that emerged from the primary interview confirmed that 82% of participants believe that proving the economic feasibility of TERR can play a significant primary or secondary role in encouraging the uptake and approval of this applications in the FBM.

1- 52% believed that once other barriers are resolved, linking TERR to financial gains will assist in generating an interest in the application.
2- 30% believed that financial gains can act as a main driver of change and can generate an interest and direct more resources to validate TERR applications. Once these validations are available, they can in turn assist in gradually overcoming any existing barriers.

Although the majority of participants considered the economic feasibility to be a primary or secondary driver of change, 71% expressed their lack of knowledge regarding the cost and /or financial benefits associated with TERR in the FBM. Both DEFRA and the CFA, indicated that this lack of knowledge on the economic feasibility can only be resolved through more research and field validations as discussed earlier in this chapter. Due to the potential role that economic feasibility can play in directing more resources to validate and encourage TERR applications, this will be further investigated in chapter 4 of the thesis.

3.4.6 Associated Costs

Results were slightly surprising as the majority of participants failed to identify significant connections between TERR in the FBM and water, energy and trade effluent discharge costs. The majority of participants considered these to have low impact on TERR applications in the FBM.

DEFRA confirmed that more has to be done to improve the awareness of the UK public and industry. In the past 10 years resources have been directed to improve energy awareness and improving water awareness has been left behind. According to DEFRA, this is a key issue that will have to be given priority by the UK Government.

3.4.7 Public Opinion

Results regarding the impact of public opinion on TERR in the FBM were unexpected and highly surprising. Although there is no data available on TERR applications, studies for example on the approval of using grey water or reuse of recycled municipal waste water, demonstrates the importance of public acceptance for the success of these projects (Friedler et al., 2006; Kantanoleon, et al., 2007; Domènech and Saurí, 2010). In contrast, 72% of participants considered that the British public will have no impact on the success or failure of TERR applications in the FBM. Only 9% of participants belonging to the speciality /premium products subsector considered that the pressure from the public will stop them from using recycled water in process areas. 5% indicated that due to its environmental benefits the public might support TERR applications.

The diminished impact of public opinion can be attributed to the following:

1- The source of water does not have to be declared on the product label as long as water of potable quality is being used. This was confirmed by the FSA who compared this to the use of borehole water which is currently not declared on the packaging.
2- There are currently strong external influences that can manipulate and have an impact on the public opinion. There was a general agreement amongst the majority of participants (72%) that the public can be directed and influenced by the UK Government and the supermarkets through effective marketing and media campaigns.

This view was also shared by the CFA who indicated that if recycling was linked to financial gains, the supermarkets will be capable through very clever marketing strategies and special offers to promote the use of recycled water in the products.

3.4.8 Media

Due to the same reasons provided in section 3.4.7, 62% of participants indicated that the media will have very limited impact on TERR in the FBM. Only 14% considered the media to be a primary barrier.

3.4.9 Water Scarcity

The majority of participants (86%) expressed their strong doubts regarding the possibility of having serious water shortages in the UK. In addition, there was a general agreement that if this was to happen, organisations will relocate their manufacturing processes and it will be very difficult to safeguarding the FBM sector in the UK.

Representatives from DEFRA were not surprised by our findings and they indicated that they are aware of the urgent need to improve the awareness of businesses and the public regarding the possibility of the UK facing water shortages in the future.

3.4.10 Other Stakeholders

The following stakeholders were considered to have very limited impact on TERR in the FBM by more than 90% of the participants:

1- Shareholder and investors
2- Business Community and financiers
3- NGOs and consumer groups

3.5 Interpretation of Results and Development of SM

3.5.1 Categorising and Evaluating the Interaction between the Stakeholders

Based on the findings presented in section 3.4 and the narrative provided by the participants further analysis was carried out on the field data to categorise and evaluate the interaction between the current and influential stakeholders; results are presented in tables 3-8 and 3-9 respectively.

Following the steps detailed in the methodology the results from these tables were then conceptualised to carry out the last step of SM analysis, the classification of the stakeholders in terms of interest and power. This final step is presented in section 3.5.2.

Table 3-8 Categorising the stakeholders

Stakeholders	Primary		Secondary			Current impact On DWRR			Proximity of impact
	Internal	External	Internal	External	Regulatory	Barrier	Driver	No /low impact	
Consumers		√						√	Long term Potential
Customers		√				**H**			**Short term** **Actual**
Shareholders	√							√	Unlikely to have an impact
Business partners				√				√	Unlikely to have an impact
Company (Employers – technical know-how)	√							√	Long term Potential

Table 3-8 Continued

Stakeholders	Primary		Secondary			Current impact On DWRR			Proximity of impact
	Internal	External	Internal	External	Regulatory	Barrier	Driver	No/low impact	
UK Government		√			√	**M** (Lack of legislation and lack of guidelines)			**Short term Actual**
NGOs & consumer groups and media				√				√	Long term Potential

Table 3-8 Continued

Stakeholders	Primary		Secondary			Current impact On DWRR			Proximity of impact
	Internal	External	Internal	External	Regulatory	Barrier	Driver	no impact	
Environment (Water availability industry perception)		√						√	Long term Potential
Technology				√		**M** (lack of validation)			**Short term Actual**
Competitors				√		**M** (lack of information and field validation)			**Short term Actual**
Economic feasibility	√					**M** (Lack of knowledge)			**Short term Actual**

Table 3-8 Continued

Stakeholders	Primary		Secondary			Current impact On DWRR			Proximity of impact
	Internal	External	Internal	External	Regulatory	Barrier	Driver	no impact	
Suppliers (Water providers)		√				L (lack of provision of guidance)			Short term Actual
Industry standards	√					**H**			Short term Actual
Consultancy bodies				√				√	Unlikely to have an impact

Table 3-9 Interaction between the current medium and high influential stakeholders[6]

Stakeholders	**Customers**	**UK Government**	**Technology**	**Manufacturing site/ Competitors**	**Economic feasibility**	**Industry standards**
Customers		ND	COM M -	COM P -T- U- S H -	ND	COL H -
UK Government	ND M -		ND M -	ND M -	ND M _	ND H -
Technology	ND M -	ND M _		ND M -	LK M _	LK H _

[6] Details of the coding system used in this table is detailed in methodology in table 3-1

Table 3-9 Continued

Stakeholders	Customers	UK Government	Technology	Manufacturing site/ Competitors	Economic feasibility	Industry standards
Competitors	LK M –	N/A	LK M –		LK M –	N/A
Economic feasibility	LK M -	N/A	LK M -	LK M -		N/A
Industry standards	COL H –	COL H –	LK H -	N/A	LK M –	

3.5.2 Categorising the Stakeholders in Terms of Influence and Power

This is the final and most important step in SM. In this research this was achieved through combining the data from all the previous sections in order to arrive to a conceptualised understanding of the influence (power) and interest matrix of the stakeholders.

Key Players

Two stakeholders fitted into this category:

1- Industry standards and

2- The FBM customers (the supermarkets).

According to the research findings, these have the highest current impact on the approval and uptake of TERR applications by the FBM. As shown in table 3-9, both stakeholders are currently acting as strong barriers against the uptake of TERR in the FBM. It was also apparent from the phrases used by the participants that the relationship between the supermarkets and the manufacturing sites is driven by stakeholder's power. From the in-vivo coding that emerged from the semi-structured interviews it was apparent that the usage strategy, as defined in the methodology, is being used by the supermarkets to enforce a power based relationship on the manufacturing sites. This relationship is having a strong impact on limiting the ability of the manufacturing sites to challenge or deviate from what is currently requested by the key players. The impact of the usage strategy is further enforced by the lack of knowledge on the safety, field validations and available guidelines on TERR applications.

It was also apparent from the data that emerged from the interviews that five main areas have to be addressed in order to assist in changing the nature of this power based relationship:

1- Verifying the reliability, safety and effectiveness of the technologies that can be currently used to generate potable water from industrial trade effluent.
2- Carrying out pilot studies according to protocols that are specified by the FBM and the stakeholders to prove the safety of TERR applications under actual field Conditions.
3- Provision of government guidelines to assist in the approval and uptake of TERR projects.
4- Improving the knowledge and the technical know-how of the advisory teams working on behalf of the supermarkets, so that TERR projects are evaluated based on technical facts and data.
5- Improving the knowledge on the economic feasibility of TERR applications.

Subjects – Drivers of Change

Two main stakeholders emerged as main drivers of change:

1- The economic feasibility that can be achieved from TERR projects.
2- Field validations of TERR projects.

Based on the data from the interviews, the economic feasibility of TERR emerged as a main driver of change. In the absence of regulatory enforcement and for TERR to be voluntarily considered and approved by the stakeholders, there is a need to demonstrate the economic benefits that this application can generate. In addition, if there were any financial gains associated with TERR, resources will be directed to establish and validate the safety of this application. This in turn will assist in providing answers to the current uncertainties surrounding TERR applications in the FBM. It is evident from the research findings that the current lack of knowledge and inability to link TERR to financial gains is having a direct negative impact on generating an interest in TERR applications in the FBM. A detailed evaluation of the financial benefits that can be linked to TERR in the FBM will be presented in chapter 4 of this thesis.

Context Setter

Context setters are the stakeholders that can potentially have a significant impact on TERR but currently have limited involvement in this application. From the data that emerged from the survey, the UK Government fit into this category. It was clear from the research findings that even in the absence of regulatory enforcement, more can be done by the official bodies to facilitate and make the approval of TERR projects easier. Seven steps emerged as being necessary:

1- Training the relevant UK Government personnel and the salient stakeholders to improve their competence in dealing with enquiries and applications relating to TERR applications.
2- Providing organisations with the mechanisms and incentives to carry out research and field trials to evaluate and validate the safety of TERR in the FBM.
3- Evaluating the economic benefits associated with TERR. This will impact on whether the industry views TERR as a burden or as a positive move.

4- Providing the necessary training schemes to improve awareness on TERR and the water saving benefits that can be achieved from this application.

5- Providing clearer guidelines as to how TERR projects can be managed and what parameters should be met.

6- Establishing a specialised body for the approval of TERR projects and /or providing the necessary training for the local environmental health officers if they were to provide these approvals.

7- Lobbying the supermarkets to sign longer term contracts with the FBM. Longer contracts will generate security for the manufacturing sites and will enable better investment in R&D projects such as TERR. AS highlighted previously the current 24 months contracts with the supermarkets are having a negative impact on all innovative projects.

To summarise the lack of government intervention is currently having a negative impact on TERR applications. There is therefore a need for the UK Government to direct more resources towards TERR to enable the development of rigorous guidelines and strategies that will generate an interest and facilitate the approval of TERR applications by the salient stakeholders in the FBM.

Crowd

The stakeholders in this category are viewed to have limited impact on TERR applications in the FBM. 10 stakeholders fitted into this category as listed in figure 3-4.

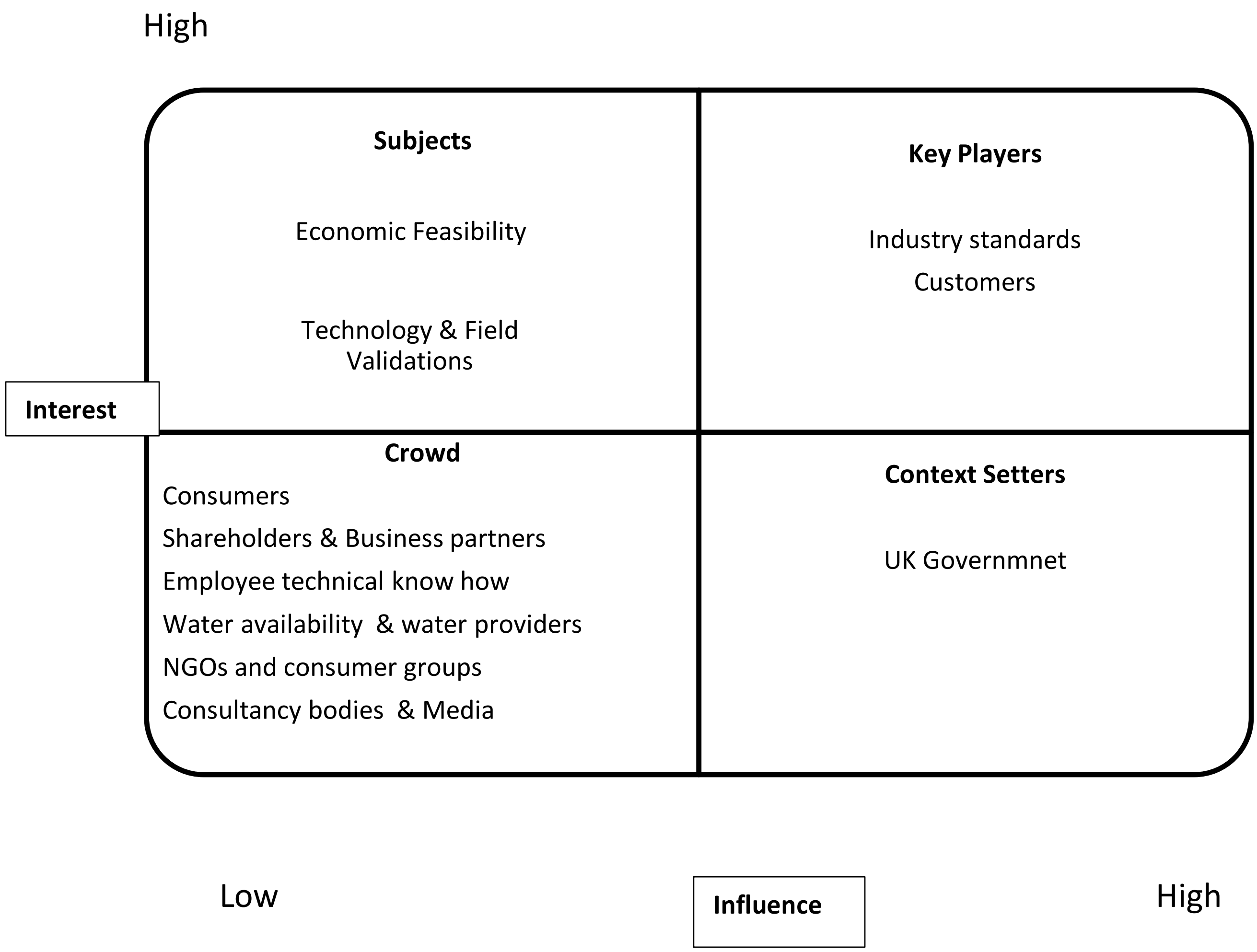


Figure 3-4 Power & Interest Matrix

3.6 Conclusion

Chapter three provides detailed analysis of the relationship between the stakeholders and the FBM manufacturing sites. The chapter also analyses the impact that the salient stakeholders currently have on the approval of TERR projects in this sector. This was achieved by using Freeman's Stakeholder Management Matrix and Grounded Theory Methodology.

Two main salient stakeholders emerged from the data:

1- The FBM customers (the supermarkets)
2- Industry standards

It was clear from the data presented in tables 3-8 and 3-9 that more work is going to be needed before the above stakeholders can support TERR applications in the FBM. The lack of information and validation regarding the safety of TERR projects is a main barrier impacting on the approval of the above key players. It was also clear from the findings that are presented in this chapter that the key players don't work in isolation and can affect and be affected by the other stakeholders in the FBM mainly, the subjects and the context setters (figure 3-4). These in turn can interact with each other and with the key players to exert their influences on the decisions taken by the FBM regarding TERR applications (figure 3-5). This can be summarised as follows.

1- The UK Government can through the implementation of the following strategies have a significant positive impact on the decisions taken by the supermarkets regarding the approval of TERR applications:

a. Funding of research and development projects to validate the safety of TERR applications in the FBM.
b. Providing clear guidelines to facilitate the approval and uptake of TERR projects.
c. Initiating discussions with the stakeholders in the FBM to establish the requirements needed for the approval of TERR applications.
d. Appointing a qualified and well trained body to evaluate the approval of TERR projects.

2- It was also clear from the data that emerged from the stakeholders' analysis that in the current economic environment, investment and approval will be prioritised and directed more easily towards projects that can offer good financial returns and present low financial risks. Although TERR may be desirable from an environmental point of view, the application has to be economically viable to be voluntarily adopted by the salient stakeholders.

3- If TERR was found to generate financial gains, more resources will be directed to initiate laboratory and field validation studies. Once the safety of TERR is validated it will become easier for TERR to be accepted by the key players.

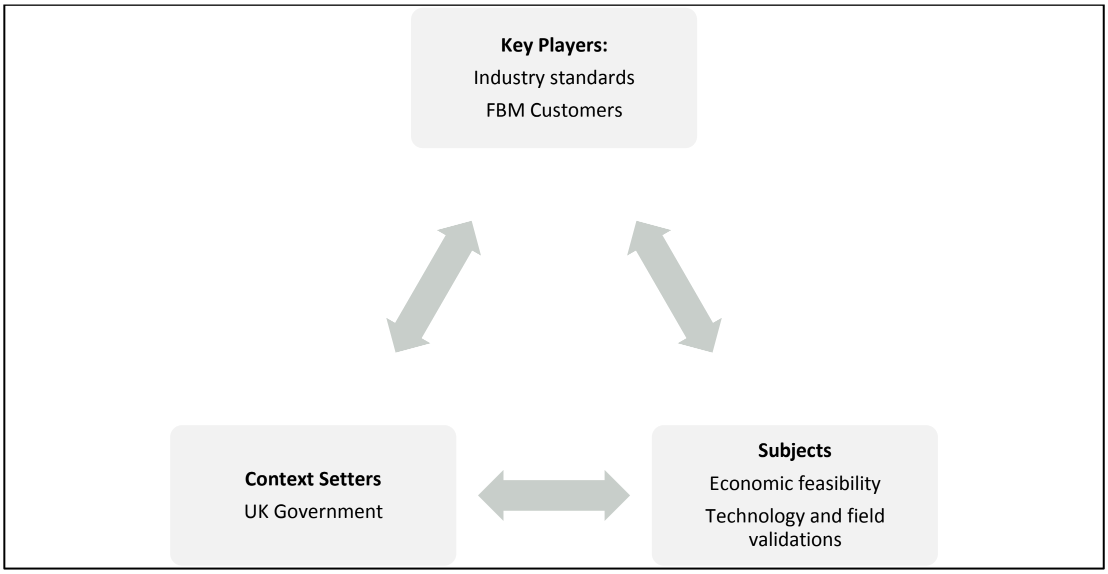


Figure 3-5 The interactive nature of the stakeholders in the FBM

The SM presented in this chapter was based on the relationship that existed between the manufacturing sites and the stakeholders between 2012-2014. However, as stated in the literature review, SM is a dynamic process that is influenced by changes in the enviro/ socio- economic factors (ESE). It is therefore important to evaluate how future changes in ESE might impact on the stakeholders' studied in this chapter. This will be investigated in further details in chapter 5 of this thesis.

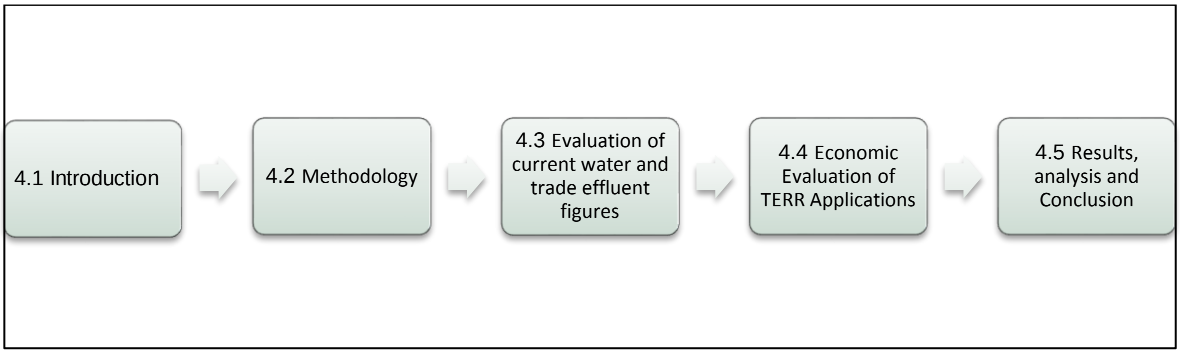
To Summarise, the research carried out in this chapter relied on analysing first hand data to fully understand how the stakeholders in the FBM can currently interact to impact on the uptake of TERR projects in this sector.

The results that emerged from the semi-structured interviews clearly confirm hypothesis 4&5 of this thesis:

1- The stakeholders in the FBM are many and can interact in complex ways to impact on the decisions taken by the manufacturing sites.
2- For TERR to be adopted by the FBM, the approval of the salient stakeholders is necessary.

Based on the research findings it is concluded that more work is still needed before the salient stakeholders are in a position to support TERR applications in the FBM. What is evident from the research findings is that a structured approach including incentives and well defined guidelines will be essential for the development and widespread approval of TERR applications in the FBM; for this to be achieved the cooperation between the FBM sector, the stakeholders and the UK Government is essential.

4 Economic Evaluation of TERR in the FBM
A Case Study at a Dairy Manufacturing Site



4.1 Introduction

As confirmed from the findings that emerged from chapter 3, linking TERR to economic gains can act as a driver of change to encourage the uptake of this application by the FBM sector.

Three main points relating to the economic feasibility emerged from the stakeholders' analysis:

1- In the absence of regulatory enforcement, TERR in the FBM will only be accepted voluntarily, if it was proven to be economically viable.
2- Due to the current short-term contracts between the FBM and the supermarkets, the payback of the reuse applications must fall within 24 months period (section 3.4.3).
3- Limited knowledge is currently available to assist the stakeholders in evaluating the financial gains that can potentially be achieved from TERR projects.

A wide literature search was carried out in order to assist in evaluating the financial gains that can be achieved from TERR applications in the FBM.

The following limitations emerged from both academic and marketing sources:

1- Academic data: In addition to being limited, it was evident that the focus of the published academic work is on evaluating the availability and capability of the current technologies in generating potable water from trade effluent (Comerton et al., 2005; Arévalo et al., 2009). An in-depth review of the academic papers highlighted their limited inclusion of the following steps that are essential for evaluating the cost / benefit analysis of TERR projects:
   a. Full capital and operating costs
   b. Auxiliary systems
   c. Pre and post treatments
   d. Civil Engineering Work
   e. Polishing treatments

2- Marketing data: A number of case studies are available in trade features and edited books. However, these are published by plant manufacturers and do not provide enough details regarding capital and /or operating costs associated with TERR applications (Judd and Jefferson, 2003; Le-Clech et al., 2005; Judd, 2011; Judd, 2014).

The main aim of this chapter is to carry out a detailed cost/benefit analysis on TERR applications in the FBM. The research will take a holistic approach to include all parameters and applications that can have a financial impact on TERR projects to include capital and operating costs and payback period.

4.2 Methodology

4.2.1 Data Collection for the Case Study

Due to the wide range of information needed to conduct the case study, the following sources were used to collect the necessary data:

1- Data from the literature was used for:
   a. Choosing the subsector and the technologies to be evaluated in the case study. This will be further detailed in section 4.2.2 and 4.2.3 respectively.
   b. Designing the MBR plant as detailed in sections 4.4.2.2.
   c. Calculating some of the operating costs: Sludge production and CIP protocols 4.4.2.2.

2- The Capital costs (CAPEX) of existing installations were provided to us by the site and the companies that originally provided these systems (Appendix 4-3).

3- The operating costs (OPEX) of existing applications were calculated based on the actual site figures; these included:
   a. Sludge production and disposal
   b. Chemical usages and associated costs
   c. The cost of effluent discharge after the DAF plant.
   d. Labour and labour costs

4- The new systems were designed based on:

   a. The data collected from the experimental site between January - October 2013.

      The site data was downloaded from the site's electronic monitoring equipment as presented in appendix 4-1 (A-G).

      Some additional data was identified as being essential for the case study. This was collected by taking direct field measurements between September - December 2013.

   b. The influent water quality to the individual systems and the desirable permeate characteristics. This will be further discussed in section 4.4.2.2.

5- Pipework and civil installation costs associated with the new installations were based on actual site measurements.

6- The pricing structures of the technologies used in the case study were based on either published data and /or data from leading equipment manufacturers.

Where manufacturers' prices are used, the figures provided are the average value of a minimum of 3 quotes.

The list of companies that assisted in providing the costs for the case study are listed in appendix 4-3. Due to the confidentiality of this data, this is only presented on the attached CD- ROM.

7- The effluent discharge costs were estimated using the Mogden Formula. Biological treatment discharge costs that are specific for the location of the case study were used (North West- England) (OFWAT, 2013; WRAP, 2014b). This is further detailed in sections 4.3.4.1, 4.3.4.2, 4.4.5.1 and in appendix 4-2.

8- Energy costs of existing applications were based on the actual site usages and the current kWh site tariff which is £0.08.

9- The energy usage of any new equipment was based on the manufacturer's guidelines or costs from similar applications. The running cost was then calculated using the above tariff of £0.08/ KWh.

10- Water costs were calculated using the actual site water charges which is £1.20 per m^3 of mains water.

In addition to the above, the following assumptions were included in the case study:

1- After the final treatment the regenerated water can be added to the existing bulk tanks and distributed to the factory using the existing plumbing system. A detailed discussion with the manufacturing site indicated that if a new distribution pipework system is to be installed it's length would be equivalent to around 5 Km with various distribution pipework sizes ranging from 0.5 – 3 inches in diameter. Installing this parallel system will significantly add to the cost of the project and will require a prolonged shutdown, making the project impractical.

2- The research does not take into account the impact that the MBR and the RO retentate might have on the effluent discharge costs. In the case study it was assumed that the reject water will have no significant impact on the discharge costs due to the possibility of re-routing the retentate back to the DAF plant.

4.2.2 Evaluating a sub sector for the case study

Following an in depth evaluation of the data emerging from the UK, the dairy manufacturing sub-sector was chosen for the case study. This was mainly due to the following:

1- **The importance of the dairy sub-sector to the UK economy**:

The UK is one of the 9th largest milk producers in the world and the third largest in the EU after France and Germany.

In addition, the dairy sector is currently considered as one of the largest food grocery categories in the UK worth over £8 billion.

Although the milk farming sector has been facing a number of challenges in recent years, this have had limited impact on the dairy manufacturing side which has been growing year on year (Dairy-Statistics, 2014).

2- **The large volumes of water used in the production processes**:

In addition to its economic importance, the dairy sub-sector is one of the top 3 water users in the UK with an estimated usages of around 15 million m^3 of water per annum (WRAP, 2013). These high figures are mainly due to the large volumes of water used in the preparation processes which include sanitisation, heating, cooling and floor washing (Andrade et al., 2013).

Amongst the other FBM sub-sectors, the dairy industry is characterised as being the highest in terms of water wastage. Some processes in this subsector can generate up to 10 litres of trade effluent per 1litre of processed product (Sarkar et al., 2006; Vourch et al., 2008).

3- **The quality of the dairy effluent** :

The trade effluent from the dairy processes does not generally contain toxic chemicals (Sarkar et al., 2006); making it an ideal candidate for an initial detailed case study on TERR in the FBM.

4- **Feedback from DEFRA and associated agencies** :

Discussions that took place with DEFRA as part of the interviews in chapter 3, reemphasised the importance of the dairy sub-sector in the UK. In addition, DEFRA highlighted a number of characteristics relating to the nature of the trade effluent generated from the dairy subsector, which contributed to choosing this sub-sector for the case study:

a. The trade effluent generated from the dairy industry is usually high in COD, fats, oil and grease and resembles in its characteristics other main FBM subsectors with the exception of the fruit and salad subsector.

b. Although similar in chemical characteristics, the trade effluent generated from the dairy processes does not have meat and blood bi- products, making approvals easier in this sub-sector. Therefore, the data that emerges from the case study can be used as a bench mark by the other FBM sub-sectors.

4.2.3 Technologies Considered for the Case Study

I. Primary and Secondary Treatments :

Based on findings from the literature the following primary and secondary treatments will be evaluated in this case study:

i. pH Correction
ii. Dissolved Air Floatation (DAF) combined with chemical additions to assist in flocculation and coagulation.

DAF technology is one of the most common and successful trade effluent treatments used in the food manufacturing sector. DAF is particularly suited to treat trade effluent high in fat, oil and grease such as the dairy industry. This is mainly due to the simple design of DAF units and their high efficiency in removing suspended solids and fats oil and grease (Yoo and Hsieh, 2010).

It's well documented in the literature that when operating efficiently with chemical addition and primary treatment such as pH control, DAF plants can reduce up to 90% of COD , 97 % of total suspended solids and 98% of fats, oil and grease (FOG) (Tchobanoglous et al., 2004; Yoo and Hsieh, 2010).

In addition to the above, the widespread application of DAF emerged from the initial survey presented in chapter 2 of this thesis. As previously indicated in figure 2-8, DAF technology is currently being used by more than 65% of the FBM.

DAF Operating Principles

In a DAF unit a saturated solution of air and water is formed in a pressure vessel which is then injected into a floatation tank. The sudden pressure drop in the tank causes the release of very fine air bubbles. These fine bubbles play a crucial role in the high separation efficiency of the DAF process as detailed below (Gray, 2010; Yoo and Hsieh, 2010):

1- The air micro- bubbles adhere to the suspended particles in the wastewater increasing the buoyancy of the particles. This results in the particles floating to the surface in a form of sludge.
2- The floated sludge is then skimmed off from the top of the reactor or collected through the screening in the downstream.

In industries such as the dairy industry, DAF units are usually used to achieve the following two main roles (Sarkar et al., 2006):

1- Reduce discharge costs by lowering the usually very high trade effluent COD/BOD values and FOG.
2- Improve the efficiency of the tertiary treatments, otherwise, the high levels of protein and associated high COD and suspended solids will have a significant impact on lowering the efficiency of more advanced treatment technologies.

Tertiary Treatments

The following tertiary treatments were evaluated in the case study. These were chosen based on their ability to generate water of potable standards from industrial trade effluent:

1- Bioreactor Technology (MBR)
2- Reverse Osmosis (RO)
3- Chlorine Dioxide (CLO_2)

According to recent studies, the combination of MBR and RO treatment technologies is considered as one of the most efficient available technologies capable of producing high quality water for reuse applications (Wu et al., 2013b).

A. **Membrane Bioreactor Technology (MBR)**

MBR technology is currently widely used to generate water of potable standards from lower quality water. This is mainly due to the ability and effectiveness of MBRs in removing viruses, bacteria, micro- pollutants and CMR substances (carcinogenic, mutagenic toxic and reproductive substances) (Fuerhacker, 2009; Rodríguez et al., 2011).

Large MBR applications are widespread and have been used for many years in treating municipal waste to dischargeable or reusable water standards. There are 1000s of these applications worldwide and a large number of publications in this area (Judd, 2011). In contrast, recent published data indicate that there are only around 30 industrial applications of MBRs worldwide (Judd, 2011; Judd, 2014). In addition, limited data is currently available on the efficiency, design and capital and operating costs of these smaller industrial applications (Judd, 2011; Rodríguez et al., 2011; Mutamim et al., 2013).

It was also evident from the literature that the data between small industrial and large municipal applications cannot be interchanged. This is mainly due to the significant differences in capital and operating costs between the two applications (Fletcher et al., 2007; Verrecht et al., 2010). In addition to the above, the limited MBR applications in the dairy sub-sector has been recently highlighted in a comprehensive review carried out by Andrade in 2013 and which identified only a few applications in this sub sector(Andrade et al., 2013). However, an in-depth analysis of these applications highlighted that they were either laboratory based, using synthetic water or very small applications that will have limited correlations to field applications.

MBR Operating Principles

MBRs combine biological treatment with membrane separation, enabling the production of very high quality water (Fletcher et al., 2007; Rodríguez et al., 2011). The membranes used in MBRs can vary in their properties but are mainly divided into three groups (Gray, 2010):

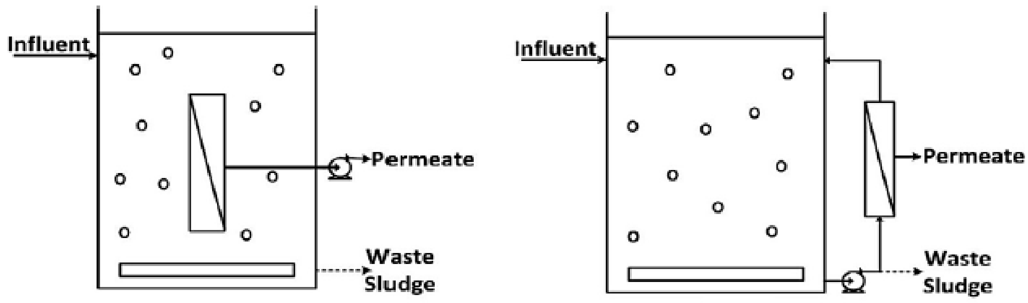
a. Micro filtration (MF): Membranes in this category have a pore size between 0.1-0.2 microns and can remove most suspended solids and bacteria (Gray, 2010).
b. Ultrafiltration (UF): Membranes in this category have pores ranging between 0.1 microns and less than 5 nm and can remove in addition to what can be achieved from MF, bacteria and viruses (Gray,2010).

The use of UF can lead to the production of excellent quality water with < 2 ppm BOD, <0.5 ppm suspended solids and < 0.2 NTU turbidity values (Gray, 2010).

c. Nano filtration (NF): Membranes in this category have pores ranging from 10-1 nm and can remove colour, pesticides and any other colloidal substances to generate ultra-pure water (Gray, 2010). However, NF membranes are highly prone to clogging and are therefore not commonly used in Industrial MBR applications (Judd, 2014).

Based on the above characteristics ultrafiltration membranes will be used in the case study. In addition to the variations in the membranes that can be used in MBR systems, MBRs can have two main configurations: immersed and side-stream as detailed in figure 4-1.

The immersed MBR configuration will be evaluated in the case study. This is mainly due to the higher efficiency and lower energy running costs of this configuration. The higher operating costs of the side stream configurations are linked to the high energy needed to operate the circulation loop between the membrane and the bioreactor (Mutamim et al., 2013).



(a) (b)

Figure 4-1 Basic Schematic of MBR (a) Immersed MBR and (b) side-stream MBR (Mutamim et al., 2013).

B. Polishing Treatment - Reverse Osmosis (RO)

Although MBR technology can generate high quality water, MBR followed by RO treatment can enhance the removal of trace organic compounds to further purify the water (Allinson et al., 2007; Alturki et al., 2010). The importance of this step has been identified as a key factors for the approval and acceptance of potable reuse applications (Schäfer and Beder, 2006).

<u>RO Operating Principals</u>

Osmosis is the process by which water migrates through a semi permeable membrane from the weaker solution to the stronger solution, until both are of the same concentration. Reverse Osmosis involves applying a differential pressure to reverse this natural flow, forcing water to move from the more concentrated solution to the weaker (Binnie and Kimber, 2009).

Unlike MF and UF, reverse osmosis uses semi permeable membranes that do not have pores and can remove particles below 0.001µm (Binnie and Kimber, 2009;

Gray, 2010). It is well documented in the literature that when operating efficiently, ROs can produce water that meets or even exceeds the drinking water standards as stipulated in the US- EPA and WHO guidelines (Appendix 3-5) (Comerton et al., 2005; Tam et al., 2007; EPA, 2014; WHO, 2014).

C. Final Chemical Treatment - Chlorine Dioxide

In addition to ultra-purifying the water using reverse osmosis, most reuse application consider a final treatment of UV or chemical oxidation to ensure microbiological safety particularly after storage (Judd, 2011).

A number of treatments were evaluated for the case study. However, based on the characteristics identified from the literature review (table 4-1), chlorine dioxide emerged as being the best suitable final treatment for the case study. This is mainly due to the following properties that characterises this application (Tchobanoglous et al., 2004; Binnie and Kimber, 2009; Gray, 2010):

a. Strong oxidation power
b. Residual oxidation effect
c. No carcinogenic by products such as trihalomethanes (THMs)

Although chlorine dioxide treatments can generate oxidation by-products, this can be limited and controlled through adjusting the levels of ClO_2 dosage per m^3 of water (Gray, 2010).

Chlorine Dioxide Principles

Chlorine dioxide is a non-stable gas that decomposes rapidly upon storage. The gas is usually generated onsite before its application by mixing Sodium chlorite with either acid or chlorine. For safety reasons this is usually carried out in a specially designed reaction vessel (Tchobanoglous et al., 2004; Binnie and Kimber, 2009).

In order to comply with the UK drinking water regultation the dosage of chlorine dioxide should not exceed 0.5mg/l as ClO_2 (DWI, 2013).

Table 4-1 List of current available disinfection Options and applicability to the case study (Tchobanoglous et al., 2004; Binnie and Kimber, 2009; Gray, 2010)

Disinfection methodology	Properties	Advantages	Limitations	Applicability for case study
	<u>Applications with no residual properties</u>			
Ozone	Chemical oxidation	- Has powerful oxidation properties - A dose of 1 ppm destroys all bacteria within 10 minutes	-No residual action -More expensive than chlorine based products -Has to be generated on site	The non-residual treatments are best suited for applications where the regenerated water is used directly without any storage involved. In the case study the water will be pumped from the RO plant to the bulk storage tank using 300m of pipework (Appendix 4-4) These applications will therefore be unsuitable due to the possibility of biofilm development and bacterial growth within the distribution pipework and during storage.
Ultraviolet radiation	Kills through the radiation penetrating organisms and initiating a photochemical reaction within the cells inhibiting or killing the organisms.	-chemical free application	- No residual effect - Effective against bacteria and viruses but less effective on protozoa.	

Table 4-1 – continued

Disinfection methodology	Properties	Advantages	Limitations	Applicability for case study
Applications with residual properties				
Chlorination using hypochlorite	Chemical oxidation	-Has lasting residual action -Relatively easy to handle -A widely used and cost effective treatment	The main issues in treating potable waters is the formation of trihalomethanes (THMs)	Although the organic loading of the water is expected to be very low, alternatives to hypochlorite will be considered to avoid concerns relating to THMs.
Chlorine Dioxide	Chemical oxidation	-A very strong oxidant - More effective than chlorination against viruses -Does not lead to formation of THMs	- Can lead to formation of chlorate and chlorite by-products - More complex to generate than hypochlorite and if not generated properly can lead to health hazards from the generation of chlorine gas.	-The formation of by products can be controlled by limiting the dosage to 0.5mg/l ClO_2 as a maximum dosage. - Using specially designed equipment will assist in making the generation safe and reliable.

4.3 Evaluation of the Site Current Water and Trade Effluent Figures

The case study was carried out at a leading dairy manufacturing plant in the North West of England. The site specialises in producing household brands of butter, spread and yoghurt for the UK and the European markets. The company is a part of a large manufacturing chain which is currently considered as one of the biggest players in the dairy industry with more than 10 manufacturing sites across the UK.

The site water usages and current water treatment facilities are detailed in sections 4.3.1– 4.3.3.

4.3.1 Site water usages

The site water usage target is set at 140 m^3 per day. However, as detailed in the figures presented in Appendix 4-1D, significantly higher water usages are often reported. Based on the data presented in appendix 4-1D, the average water usage at the time of the case study was 270 m^3 per day. Figures close to the site target usage point were only achieved on five occasions between January and October 2013. There are a number of very low usage readings in March and May 2013; discussions with the site indicated that these were recorded during shutdown periods and do not represent usages under normal operating conditions. We were unable to verify the background behind the target usage figure of 140 m^3 per day, however, we were informed that this has been set by the manufacturing group and is currently proving very difficult to achieve. The site water consumption figures were analysed in further details to assist in mapping the water usages on site. This was then used to provide an in-depth understanding of the water recycling potential that can be achieved from applying TERR.

The following emerged from analysing the site data (table 4-2):

1- <10% of the total water used is embedded in the product (water phase).
2- 72% of the total water used is currently discharged to the trade effluent plant.
3- Non process areas only utilise 15% of the total water used on site.
4- More than 75% of the water consumed by the site is used in CIP, cleaning and preparation processes.

These results are in line with the figures published in the literature relating to the very large volumes of water that are used and wasted in the preparation processes in the dairy industry (Sarkar et al., 2006; Vourch et al., 2008). Based on the above figures, 72% of the total water used by the site can potentially be considered for TERR applications.

Table 4-2 Mapping the site water usage (January –October 2013)

Average water usages	Average trade effluent water	Average process water		Average non process water	
273 m^3 per day	197m^3 per day (Appendix 4-1C)	232 m^3 per day		41m^3 per day	
% of total water lost to trade effluent	72%[7]	85%		15%	
Estimated volume that can be considered for TERR = 197m^3 per day		**Water phase [8]**	**11%**	Boilers	29% (Appendix 4-1F)
	As part of the 85%	CIP	30%	Cooling towers	68% (Appendix 4-1E)
	As part of the 15%	Other cleaning and preparation processes	59%	Other usages	3%

[7] The difference between the water used in the water phase and the amount that can be recycled can be accounted for by evaporation loses and the water used in the amenities.

[8] Water phase represents the water that is embedded in the product.

4.3.2 Current Treatment of the Incoming Mains Water Supply

The site currently uses mains water for all its processes. Prior to entering the factory the water is stored in 2x 500m^3 tanks. These tanks are used in parallel to feed the factory and utilities services. The water as it leaves the tanks is treated with chlorine dioxide to achieve a reserve of between 0.3-0.5 ppm ClO_2. A schematic detailing the existing water systems is presented in appendix 4-4. The chlorine dioxide levels are tested by the site's quality control department on a daily basis. Further microbiological checks are carried out by an independent laboratory on weekly basis. These microbiological tests are specific for monitoring E.coli, Coliform and Cryptosporidium within the production water outlets. In addition to the above, the site has an appointed environmental health officer who carries out six monthly checks on the water quality.

4.3.3 Current Trade Effluent Treatment on site

Prior to discharge, the process trade effluent currently undergoes primary and secondary treatment consisting of: balancing tanks, pH adjustment and control, dissolved air floatation (DAF) and chemical addition. This excludes municipal waste which is discharged to the sewer.

The DAF plant was installed in 1998 and is a standard rectangular unit very similar in design to the plant described in (figure 4-2) (Ross et al., 2003). Further details regarding the plant design, associated systems and capital and operating costs are presented in the section 4.3.4.

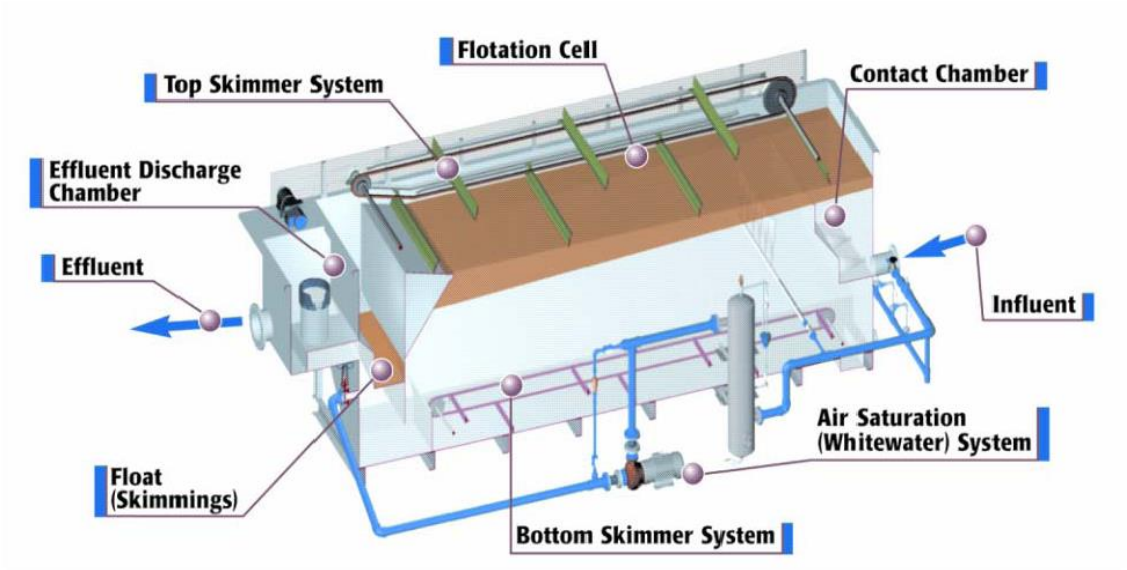


Figure 4-2 Standard rectangular DAF design (Ross et al., 2003).

4.3.4 Trade Effluent Characteristics and Discharge Costs

The average trade effluent generated by the site is around 197 m^3 per day and has the following characteristics (appendix 4-1 A):

a. Average Crude COD load : 2612Kg/day
b. Average COD value: 11,000 mg/L
c. Average pH value of 7.83.
d. The figures for suspended solids are not electronically monitored by the site. Results from 6 samples taken between October and December 2013 indicated an average value of 600 mg/L.

As shown in appendix 4-1A there are high fluctuation in the effluent characteristics. Further discussions with the site linked the high COD values and extremes in pH figures to certain activities within the factory mainly:

a. Leaks during CIP cleans
b. Days with extra cleaning activities, such as cleaning the floors or deep cleaning the equipment.
c. Spillages and poor housekeeping practices such as diverting spillages to the trade effluent plant. Although spill kits are provided throughout the factory, we were informed that these are rarely used and it is a common practice for the operators to flush spilt materials into the drains.

4.3.4.1 Theoretical Discharge Cost of the Trade Effluent without the DAF Treatment

Based on a crude COD value of 11,000 mg/L (appendix 4-1A), a discharge volume of 72000 m^3 per annum (appendix 4-1C) and the current trade effluent charging structure for the site (appendix 4-2A), the cost of discharging the untreated effluent would be around £480,000 per annum (OFWAT, 2013).

As can be seen from the figures presented in section 4.3.4.2 significant reductions are currently being achieved by the DAF treatment plant.

4.3.4.2 Current Discharge Cost Following the DAF Treatment

It is clear from the site figures that the DAF unit is successful in achieving a significant reduction in the effluent COD values and associated discharge costs. Based on the figures presented in appendix 4-1 B, the DAF treatment combined with pH control and chemical flocculation and coagulation is being effective in reducing the crude COD value by around 84%, a reduction from 11,000 mg/L to 1715 mg/L. This in turn is translated to significant savings of around £370,000 in discharge costs per annum (table 4-3) (Appendix 4-2B) (OFWAT, 2013). The full economic evaluation of the DAF plant is analysed in further details in section 4.4 below.

4.4 Economic Evaluation of TERR Applications

In order to evaluate the economic feasibility of TERR, the capital and operating costs associated with the individual treatments are calculated.

4.4.1 Economic Evaluation of the DAF Plant

4.4.1.1 Current Plant Design

The current DAF plant has the capacity to treat between 10-15 m^3 per hour. In addition to the DAF unit itself, the system has the following ancillary units (Appendix 4-4):

1- 2 Break (balancing) tanks
2- 2 sludge tanks
3- A flocculator
4- Chemical dosing equipment

5- Chemical storage tanks

6- In addition, the DAF unit itself has the following main parts as detailed in appendix 4-5

   a. Sludge scrapper belt

   b. Gear Box pumps for the top and bottom skimmer systems

   c. Sludge pump

   d. Air saturation pump

When the trade effluent leaves the manufacturing areas, it currently undergoes the following treatments prior to its discharge to the sewer:

1- The trade effluent from various processes is collected in interceptors which are distributed throughout the factory.

2- The trade effluent is then gravity fed from these interceptors to two over ground balancing tanks. Each tank has an individual capacity of 400m^3.

3- The pipe work used to transfer the trade effluent from the factory to the balancing tanks is buried in a duct 1meter below the surface. Discussions with the site indicated that this is necessary in order to protect the pipework from frost and traffic. The length of this pipework is approximately 300m.

4- The DAF unit itself is rectangular in shape (figure 4-2) and has the following dimensions :

   a. Depth 2000mm

   b. Width 1000mm

   c. Height 3000mm

5- Two 50 m^3 over ground tanks are used for storing the sludge that is generated from the DAF unit. The sludge is then tankered away from site for disposal.

6- Three chemicals are used to improve the efficiency of the DAF unit.
All these chemicals are currently being supplied from IBCs that are changed by the commodity chemical supplier on an adhoc basis.
Based on the site consumption figures (Appendix 4-1E), the following average chemical volumes are used per annum:

a. Sodium Hydroxide (32%) : 28 tonnes

d. Poly Aluminium Chloride (PAC) (18%): 45 tonnes

e. Hydrochloric acid (32%): 24 tonnes

The pH of the effluent is continuously monitored by in-line probes. When the reading is out of specifications, chemicals are automatically dosed to adjust the pH value.

The PAC dosage is manually adjusted depending on the quality of the permeate leaving the DAF unit and COD results. These are tested by the plant operators on daily basis.

The detailed capital and operating costs associated with the above plant are presented in appendix 4-5. The results are discussed in section 4.4.1.2 & 4.4.1.3.

4.4.1.2 Capital and Operating Costs of the DAF Plant

A detailed analysis of the capital and operating costs associated with the DAF unit is presented in appendix 4-5.

A summary of these results is presented below:

1- **The total capital cost** of installing a DAF unit similar to the one currently operating on site = **£343,000** (CAPEX 1)
2- **The total operating costs** = OPEX 1 + OPEX 2 = £93583+£31768.5= **£125,000 approximately per annum**.

6.4.1.3 Economic Evaluation of the DAF unit

The economic feasibility of the DAF unit was calculated taking into account the following:

1- The initial capital expenditure needed to install the plant and supplementary units
2- Ongoing operating costs
3- The actual savings that are currently achieved by the DAF plant (table 4-3 & appendix 4-2).

Taking all the above into account, the annual savings that are achieved from the DAF plant are calculated as follows:

Annual savings= Direct savings relating to discharge costs (table 4-3) – Operating costs = £370,000 - £125,000 = £ 245,000

Payback period of the DAF plant = Capital cost / Total annual savings =

£343,000/ £245,000 = around **16 months**

Table 4-3 Comparative Discharge costs (Crude effluent vs DAF permeate)

Treatment	Water Volume (m^3 per annum)	COD value (mg/L)	Discharge cost (Appendix 4.2)	Total annual Savings
Raw effluent	72000	11,000	£480,541	
DAF permeate	72000	1715	£105,453	
Direct Savings relating to effluent discharge costs			Around	£370,000 per annum

4.4.2 Economic Evaluation of the MBR Plant

4.4.2.1 Data Used in Calculating the Capital and Operating Costs

The MBR plant was designed based on the quality and volume of the trade effluent water generated from the DAF unit.

The plant design is discussed in further details in section 4.4.2.2 and includes of the following parts as presented in appendix 4-4:

1- Screens to remove any suspended solids remaining in the DAF permeate
2- UF Membranes
3- Actual MBR tanks
4- Blowers to supply air for the microorganisms and for cleaning the membranes
5- Mixing Equipment
6- Pumps
7- Storage and permeate tanks
8- Housing
9- Data loggers
10- CIP automated plant to clean the membranes

The detailed capital and operating costs associated with the above plant are presented in appendix 4-6.

4.4.2.2 MBR Design

As discussed in the methodology, the MBR evaluated in this case study is an immersed MBR configuration (iMBR) using UF membranes. The plant was designed to achieve the following characteristics:

1- Optimise the MBR efficiency including capital and operating costs
2- Minimise membrane fouling
3- Treat the DAF permeate to achieve a final water quality of potable standards as specified in table (4-4).

The individual parameters that are used to design the overall MBR system are detailed in table 4-5 and sections A-E below.

Table 4-4 Water quality parameters expected during the individual stages of the case study derived from the site data (Appendix 4-1) & (Blöcher et al., 2002; Schäfer and Beder, 2006)

Parameter	Raw Water	DAF permeate (MBR influent)	MBR permeate (RO influent)	RO permeate
Suspended Solids (mg/l)	600	50	<1	0
Electrical Conductivity(µS/cm)	N/A[9]	N/A	2500- 4300	<50
COD mg/L	11,000	1750	<50[10]	<5
COD Loading [11] Kg/day	2612	456	<5	<5

[9] Not applicable or no data available
[10] A value of 25mg/l is used later in calculating the plant design
[11] Based on a trade effluent volume of 197 m^3 per day.

Table 4-4 Continued

Parameter	Raw Water	DAF permeate (MBR influent)	MBR permeate (RO influent)	RO permeate
FOG mg/L	N/A	N/A	Nil	Nil
Total Bacteriological Count (CFU/ml @37 0C)	N/A	N/A	10^3- 10^5	<50
Faecal streptococci	N/A	N/A	Absent	Absent
Viruses	N/A	N/A	Absent	Absent
Trace organic compounds	N/A	N/A	traces	Below detection limit

Table 4-4 Continued

Parameter	Raw Water	DAF permeate (MBR influent)	MBR permeate (RO influent)	RO permeate
E.coli	N/A	N/A	Absent	Absent
Coliform	N/A	N/A	Absent	Absent
Cryptosporidium	N/A	N/A	Absent	Absent
Taste and Odour	N/A	N/A	N/A	Same as mains water supply

Table 4-5 Design Parameters used in the case study

Parameter	Definition (Fletcher et al., 2007; Judd, 2011)	Value used – Reference
Hydraulic retention time (HRT)	Time taken for the liquid phase to pass through the MBR tank	Calculated in (equation 4-1) (Eckenfelder and Musterman, 1998)
Solids Retention time (SRT)	The time taken for the solids (particulate) phase to pass through the tank	40 days (Rodríguez et al., 2011) & (MBR suppliers) (Appendix 4-3)
Mixed Liquor suspended solids (MLSS)	The biomass containing slurry formed in the bioreactor during the biological processes	16,000 – 18000 mg/L (Arévalo et al., 2009) & (MBR suppliers). A value of 17000 mg/L is used in the MBR design
Flux	Quantity of material passing through a unit area of membrane per unit time	10-15L/m^2/hr (Judd, 2011) & (MBR suppliers). An average of 12.5 L/m^2/hr is considered in the MBR design
Food to microbial ratio (F/M ratio)	Rate at which the substrate is fed to the biomass compared to the mass of biomass solids	0.13- 0.15 (Judd, 2011) (MBR suppliers). A value of 0.14 is used in the MBR design.

Table 4-5 – continued

Parameter	Definition (Fletcher et al., 2007; Judd, 2011)	Value used –Reference
Bioreactor Volume	Volume of the bioreactor tanks	Calculated based on HRT value and volume of effluent (equation 4-2) (Gray, 2010).
Membrane area needed	Membrane area needed to achieve the plant design	Calculated from flux (equation 4-3) (Judd, 2011).
Sludge Production	Amount of sludge produced from the MBR	Calculated in (equation 4-4) (Eckenfelder and Musterman, 1998; Judd, 2011)
Oxygen Demand	Oxygen needed to provide aeration for the microorganisms and for the degradation of the organic material in the influent water	Calculated in (equation 4-5) (Eckenfelder and Musterman, 1998)

The individual parameters presented in table 4-5 are calculated as follows:

Calculations used in designing the MBR system

A. Hydraulic retention time (HRT)

Determining the HRT of a MBR system is an essential initial step as the HRT will have a direct impact on the following other parameters within the MBR system:

1- Bioreactor volume
2- Sludge production
3- Oxygen demand

HRT days = S_o/(F/M x MLSS) Equation 4-1

(Eckenfelder and Musterman, 1998)

Where S_o is the COD value of the influent water feeding the MBR = 1750 mg/L (appendix 4-1B)

F/M = 0.14 (table 4-5)

MLSS = 17000 mg/l (table 4-5)

HRT = 0.74 days

B. Bioreactor Volume

It is essential to correctly calculate the bioreactor volume of the MBR plant, so that the system can operate efficiently without unnecessarily increasing the capital and operating costs of the treatment:

1- Larger systems will directly impact on the capital costs

2- There is an indirect impact on the operating costs, due to bigger systems requiring higher energy input to mix the liquor (Verrecht et al., 2010)

However, the bioreactor tank has to be big enough to enable the treatment of the effluent within a specific HRT time (Gray, 2010).

Tank Volume = (HRT x Daily influent volume) + 25% capacity [12] Equation 4-2 (Gray, 2010)

Where HRT = 0.74 days calculated (equation 4-1)

Daily influent value = 197m^3 per day (appendix 4-1C)

Tank volume = (0.74 x197) + 25% capacity = **182.2 m^3.**

After having discussions with the MBR suppliers and based on the information provided in the literature (Judd, 2011), it was decided to design the system with two bioreactor tanks in order to allow:

1- Sufficient flexibility in operating the system
2- Ability to provide partial treatment if one of the systems failed
3- Isolate one system when lower volumes of effluent are being generated
4- Allow cleaning and maintenance provision without completely halting the effluent treatment process.

Based on the above the MBR plant in this case study will have two bioreactor tanks of 100 m^3 each.

[12] 25% additional capacity was recommended by the MBR suppliers to compensate for the time lost during CIP cleans and to cope with peak flows.

C. Membrane area

The membrane area used in the MBR design will have a direct impact on the capital and operating costs:

1. CAPEX: Area of membrane needed and associated costs
2. OPEX: Maintenance and replacement costs.

Membrane area = Peak flow rate L/ hr /Flux + (30%) [13] Equation 4-3

(Judd, 2011)

Flux = 12.5L/m^2/hr (table 4.5)

Peak flow rate 10m^3/hr = 10,000L/hr (based on site data)

Membrane area = 800 m^2+ *30%* **= 1040m^2**

D. Sludge Production

Sludge production can impact on the capital cost through its impact on the size of the sludge tanks. However its main impact is associated with the operating costs and sludge disposal charges.

Sludge Production g/m^3 of effluent = $a(S_0-S) - bX_dF_bX_VT$ Equation 4-4

(Eckenfelder and Musterman, 1998; Judd, 2011)

Where:

a= biomass yield coefficient: estimated as 0.45 for the food industry

S_0= COD of the influent water feeding the MBR= 1750 mg/L (appendix 4-1B)

S= COD of MBR permeate = 25 mg/L (table 4-4)

[13] 30% compensation for gradual drop in trans membrane pressure between the main CIP cleans

b= endogenous decay coefficient = 0.1/day

SRT= 40 days (table 4-5)

X_d= biodegradable fraction of the biomass = 0.8/(1+0.2bSRT)= 0.44

F/M= 0.14 (table 4-5)

F_bX_v= biomass under aeration = S_0/(F/M) = 1750/0.14= 12500

T= HRT= 0.74 (equation 4-1)

Sludge production g/m^3= (0.45x1725) – (0.1x0.44x12500x0.74)

= 776.25- 407= 369.25 g per m^3

Average sludge production per day = 197x369.25= 72742g per day = **73 Kg per day.**

Average sludge production per month = 2,220 kg sludge per month.

Based on the above figure the MBR is designed to include 2x2m^3 sludge tanks. Each tank is expected to be require emptying approximately once per month.

E. Oxygen Demand

Oxygen demand can significantly contribute to the capital cost of the MBR through its impact on the size of the air scouring equipment needed.

However, the main impact is on the operating costs through the direct impact on the energy used to generate the aeration for the bioreactor.

Air is needed in the bioreactor for two main functions (Eckenfelder and Musterman, 1998):

1- Satisfying the oxygen demand of the effluent under treatment

2- Provide enough oxygen for the respiratory needs of the microorganisms.

$O2$ Kg/day = $Q([a'(S_0-S) + b'F_bX_VT])$ /1000 Equation 4-5

In equation 4-5, the first part refers to the substrate oxidation and the second part refers to biomass respiration as a direct relationship to F/M, MLSS and HRT.

Where:

O2= Oxygen requirement in Kg/day

Q = m^3 of influent water to the MBR /day

a'= Oxygen requirement coefficient for the fraction of organics that are to be oxidised. In industrial water this can range from 0.2-0.7 (a value of 0.5 has been used in this calculation)

S_0= COD influent water into the MBR= 1750 mg/L (appendix 4-1B)

S= COD of MBR permeate estimated as 25 mg/L (table 4-4)

b' = Endogenous oxygen coefficient related to the biodegradable fraction of the biomass = 0.07

F_bX_V= biomass under aeration = S_0/(F/M) = 1750/0.14= 12500

T= HRT= 0.74

Oxygen needed per day = 197[(0.5x1725)+(0.07x12500x0.73)]/1000= 300 **kg O2/day**

All the above figures will be used in designing the MBR plant and in calculating the capital and operating costs as detailed in appendix 4-6.

4.4.2.3 Capital and Operating Costs of the MBR

The design of the MBR system was based on the calculations and figures provided in section 4.4.2.2 above.

The capital and operating costs associated with this design are detailed in appendix 4-6. This includes the MBR unit itself and all the ancillary components that are detailed in the case study schematic (Appendix 4-4).

The following capital and operating costs emerged from the data presented in Appendix 4-6.

1- Total Capital costs of the MBR plant = CAPEX2+CAPEX3+CAPEX4

=£75720+ 176320+45000

Total CAPEX of the MBR plant is around £300,000

2- Total Operating costs of the MBR plant per annum**=**

OPEX3+OPEX4+OPEX5+OPEX6

=£6016+£29864+£2250+£42149

Total annual operating costs of the MBR plant is around £80,000 per annum.

The above figures will be used in carrying out the economic evaluation of the MBR/RO/ chlorine dioxide systems in section 4.4.5.

4.4.3 Economic Evaluation of the RO Plant

In the case study it was assumed that the permeate generated from the MBR is equivalent to 80% of the total influent to the MBR unit. Based on an inlet volume of 197m^3 per day (appendix 4-1), a value of 160 m^3 per day was used. Based on this figure the RO plant was designed to treat 8 m^3 per hour.

Following discussions with the RO suppliers (appendix 4-3), the RO unit was designed to have the following parts and characteristics:

1- 9 banks of membranes (8inch x1 m each)

   To ensure the highest quality and yield of permeate, high performance composite polyamide membranes were used. According to the RO suppliers:

   a. The polyamide membranes are exceptionally efficient in removing traces of organic compounds and viruses.
   b. The membranes can also yield a high permeate percentage of around 80%

2- A permeate tank of 50m^3 and associated pump. The main function of this tank is to allow the storage of 40% of the water generated by the RO plant. It was felt unnecessary to provide a bigger storage tank as it was deemed more feasible to utilise the other tanks that are already included in the plant design should there be any operational issues with the RO plant. As listed in appendix 4-4 these are:

   a. The MBR permeate tank
   b. The MBR holding tank
   c. The DAF permeate holding tank

3- Automated CIP station and chemical cleaning dosage.

The capital and operating costs associated with the RO plant are presented in Appendix 4-7.

Total Capital cost of the RO plant is around £70,000

Total operating costs = OPEX7+OPEX 8 = £17,000 approximately per annum

The above figures will be used in carrying out the economic evaluation of the MBR/RO/ chlorine dioxide systems as detailed in section 4.4.5.

4.4.4 Economic Evaluation of the Chlorine Dioxide Treatment

The chlorine dioxide unit was designed to treat the RO permeate, which is estimated to be 80% of the total influent to the RO unit (section 4.4.3)

Based on the above, the chlorine dioxide unit was designed to treat 130m^3/day (6m^3/hour)

The capital and operating costs of the chlorine dioxide plant are detailed in Appendix 4-8 and summarised below:

Total CAPEX of the CLO_2 unit is around £18000

Total OPEX of the CLO_2 unit is around £7000 per annum

In addition to the above, the following capital costs will be incurred to transfer the water from the chlorine dioxide treatment plant to the factory bulk tanks. The costs detailed below are based on the possibility utilising the existing duct that is currently been used to carry the trade effluent from the factory to the DAF unit. However, if a new underground duct is to be constructed the cost of the system might increase by around £40,000.

- Pipework installation utilising the existing duct

£4000 CAPEX 7

- 300 m pipework (1.5” diameter) : £4 per m

£1200 CAPEX 8

- Pumping cost from the RO permeate tank to the plant room

£500 OPEX 10

4.4.5 Full Economic Evaluation of the MBR/RO/CLO_2 unit

This section evaluates the total savings and payback period that can be achieved by further treating the DAF permeate using the MBR, RO and chlorine dioxide treatments detailed above.

4.4.5.1 Savings that can be Achieved by the MBR/RO/ClO_2 Treatment

The savings that can be directly achieved from treating and reusing the potable water generated from the above plants are summarised in table 4.6. The following figures were used in calculating these savings:

1- An initial total trade effluent volume of 72000 m^3 per annum

2- The site current discharge costs as presented in Appendix 4-2[14].

3- The ability to regenerate around 46000 m^3 per annum of water to meet the chemical and microbiological properties listed in table 4-4.

The above potential recycling volume was based on:

a. MBR capacity to generate 80% of the total DAF permeate.

b. RO capacity to generate 80% of the total MBR generated water

[14]As presented in table 4-6 this value will no longer be charged to the site as the trade effluent leaving the DAF unit will be diverted from the water treatment works to feed the MBR system.

Table 4-6 Annual savings that can be achieved by treating and reusing the DAF permeate

Treatment	Water volume per annum (m^3)	COD value (mg/L)	Discharge costs	Savings using MBR/RO/CLO_2
DAF Permeate	72000	1715	£105453[15]	£105453[16]
Treatment	**Water volume per annum (m^3)**	**Cost /m^3**	**Commodity cost**	**Savings using MBR/RO/CLO_2**
Recycled water	46000[17]	£1.20[18]	£55200	£55200
Total Savings that can be achieved is around				**£160,000**

[15] Appendix 4-2
[16] We are assuming that all the water regenerated will be reused in other processes and will not enter the discharge drains. The reject from the MBR and the RO is assumed to go back to the DAF plant
[17] Based on the total potable water that can be regenerated from the MBR/RO/CLO_2 systems.
[18] Current site charging structure

4.4.5.2 Economic Evaluation and Payback Period

The capital and operating costs presented in the previous sections of this chapter were used to calculate the overall economic benefits that can be achieved from the case study. These are as follows:

Total capital cost = Total CAPEX of MBR + Total CAPEX of RO + Total CAPEX of CLO_2 + CAPEX 7+ CAPEX 8 (section 4.4.2-4.4.4)

Total capital cost per annum = £300,000+ £70,000+ £18,000+ £4000+ £1200 = approximately £390,000.

Total operating cost = Total OPEX of MBR + Total OPEX of RO + Total OPEX of ClO_2 + OPEX 10 + Interest rate [19]

1- **Total operating cost** = £80,000 + £17,000 + £7000 + £50 0+ £10548 **= around £115,000** per annum
2- The total net savings that can be achieved per annum = Savings as detailed in (table 4-6) – operating costs = £160,000- £115,000= £45,000 per annum
3- **Payback period** = Capital cost / Savings per annum = £390,000 /45,000= **8.6 years**

It is worth mentioning that the UK Government is currently running a financial incentive scheme to assist in reducing the cost of sustainability projects. The

[19] The payback period was roughly calculated without including the interest rate. The value derived was then used to estimate the duration of the loan and to calculate the interest rate. The interest rate has been based on a loan of 102 months.
The interest rate over 8.6 years was calculated as £89663 = £10544 per annum (Appendix 4-9)

contributions that can be achieved from this scheme are presented in section 4.4.5.3.

4.4.5.3 Enhanced Capital Allowance Scheme (ECA):

The ECA water scheme is a current incentive run by the UK Government to encourage business investments in technologies that save water and improve water use efficiency. ECA can assist companies deduct the whole cost of buying a qualifying water-efficient technology against the taxable profits in the year the technology has been bought in (DEFRA, 2015, HMRC, 2015). For the purpose of this study the ECA is estimated to have a value of 21% of the total capital cost of the project.

Total capital cost including ECA= £390,000- 21% Tax rebate = approximately £**300,000**

In addition to the impact on lowering the capital cost, the ECA will impact on the operating costs through reducing the term of the payback period and the associated interest paid during the duration of the project.

Total operating cost per annum = Total OPEX of MBR + Total OPEX of RO + Total OPEX of CLO_2 + OPEX 10 + Interest rate[20]

Total operating including the ECA = £80,000+ £17,000 + £7000 + £500 + 8152 **= around £112,000/ annum**

[20] The payback period was roughly calculated without including the interest rate. The value derived was then used to estimate the duration of the loan and to calculate the interest rate. The interest rate has been based on a loan of 75 months.

The Total net savings per annum = Savings achieved – operating costs = £160,000- £112,000 = £48,000

Payback period including the ECA= Capital cost / Annual Savings = 300,000/ 48,000= **6. 2 years a**pproximately.

4.5 Results, Analysis and Conclusion

The main aim of the case study presented in this chapter is to evaluate the economic feasibility of TERR applications in the FBM. The importance of understanding the financial benefits of TERR in the FBM clearly emerged from the previous chapters:

1- In the absence of regulatory enforcement, TERR will only be adopted voluntarily by the FBM if there were direct economic benefits associated with this application.

2- Due to the current short term contractual agreements between the supermarkets and the FBM the payback period from TERR must be less than 24 months for the approval of this application by the FBM.

The case study was carried out at a dairy manufacturing plant in the North West of England. The dairy subsector was chosen based on its significant contribution to the UK economy and the quality and high volume of trade effluent wastage in this sector.

In order to allow reusing the regenerated water in process areas the case study was designed to generate potable water quality from the trade effluent. This was achieved by including the following water treatment technologies:

1- Dissolved air floatation (DAF)
2- Membrane Bioreactor (MBR)
3- Reverse Osmosis (RO)
4- Chlorine Dioxide

The case study was carried out at a site where a DAF plant is already being used to lower the discharge costs of the trade effluent. This is being achieved through significant reduction in COD and suspended solids values. From the site data the DAF unit is being successful in lowering COD and SS by 80 and 90% respectively. Savings in excess of £350,000 per annum are currently attributed to the DAF unit. In addition and based on actual CAPEX and OPEX figures, the payback period of the DAF plant is less than two years. Therefore, based on the data that emerged from the stakeholder analysis, if this project is to be considered at present, it is likely receive the approval of the stakeholders as it had done in 1998.

In contrast, when further treatment is introduced to generate potable water from the DAF permeate the payback period was in excess of 8 years. Incorporating the ECA scheme helped in slightly reducing the capital and operating costs associated with the project and lowered the payback period to around 6 years.

The long payback period that emerged from the case study was a direct result of the complex technologies that had to be used in the generation of potable water from the DAF permeate and that were characterised with high capital and operating costs. Based on the data presented in chapter 3 and the current economic situation and high levels of uncertainty in the FBM, it is unlikely that this project will be currently accepted by the stakeholders in the FBM. It is worth mentioning that the charging structure used in the case study was based on using mains water at a cost of £1.20 per $m^{3.}$ This cost can be significantly cheaper when using borehole water, making the payback period of similar projects even longer for sites that are abstracting underground water. Borehole water in the UK is usually high in iron and manganese and will require further treatment to achieve the potability standards listed in Appendix 3-5. However, recent market figures held on the Suez data base indicate that the average cost of using borehole water including pre-treatment and pumping costs is around 40 pence per m^3. Additional data to include drilling costs will be essential to estimate the return on investment. Although this is outside the scope of this project, these figures highlight the need to evaluating whether the current water tariffs and abstracting licences reflect the true value of water. This will be further discussed in chapter six of this thesis. Following these findings further discussions were held with the dairy manufacturing site where the case study was based. It was apparent from these discussions that although the site mangers understand and value the environmental benefits that can be achieved from TERR applications, the payback period that emerged from the case study will make the approval of this project very challenging.

Due to the current pressures on the availability of potable water supplies in the UK and the significant contributions that can potentially be achieved from TERR in the FBM, the case study highlights the need to identify the steps and strategies that are needed to make TERR applications in the FBM economically feasible.

Based on the figures that emerged from the case study, it is evident that there is a need for the technology suppliers, research community, UK Government, water suppliers, governing bodies and the supermarkets to work together and carry out further research to address the steps that must be taken in order to:

1- Improve the economic feasibility of TERR in the FBM.
2- Improve the efficiency and establish the possibility of lowering the capital and operating costs of the technologies needed to produce potable water from the FBM trade effluent.
3- Improve the current contractual agreements between the FBM and the supermarkets so that projects with longer term payback periods can become acceptable by the industry.

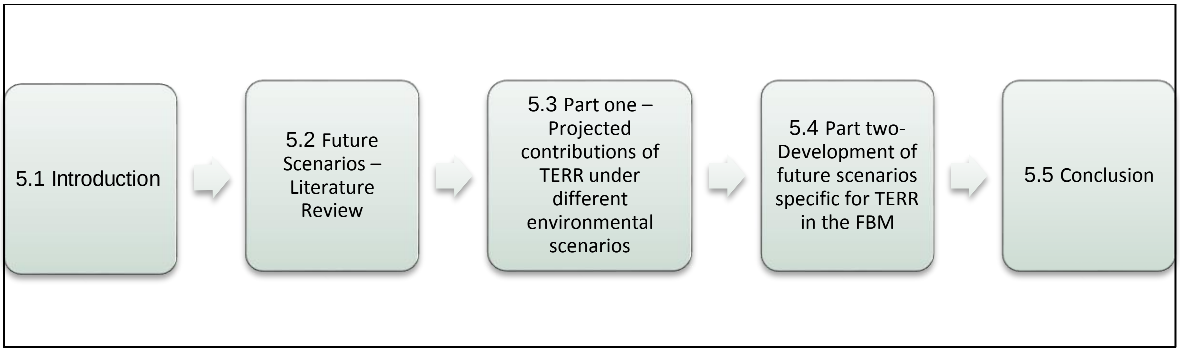
To summarise the data that emerged from this chapter highlighted the significant role that economic feasibility can have on the acceptance of TERR projects in the FBM.

The results from this chapter support hypothesis 6 of this thesis: The economic benefits that can be achieved from TERR in the FBM will have an impact on the uptake of TERR applications in the FBM.

Based on the findings that emerged from this case study, more work is going to be needed to lower the cost of TERR applications in order to make them economically viable and acceptable by the FBM.

5 The Projected Future of TERR in the FBM in the UK

Impact of Future Scenarios



5.1 Introduction

The main aim of chapter 5 is to evaluate the potential future role that TERR in the FBM can play in improving the water resilience of the UK and to project how changes in the environmental and socio-economic domains (ESE) are likely to impact on the decisions taken by the stakeholders regarding TERR applications in the FBM. In order to achieve its aims, chapter five is divided into two main parts:

1- Part one: Evaluates the current water usage and wastage in the FBM in the UK and projects the future role that TERR in this sector can play as alternative environmental scenarios unfold.
2- Part two: Evaluates how future changes in ESE might impact on the way the stakeholders perceive TERR applications in the FBM.

Following a detailed literature review, future scenarios methodology was identified as being the best suitable to achieve the aims of this chapter. This is mainly due to the ability of this methodology to:

a. Test and analyse applications with low predictability and high uncertainty (O'Brien, 2004; Alcamo, 2008; Wright and Goodwin, 2009).
b. Incorporate a wide range of possibilities (Peterson et al, 2003; Rialland and Wold, 2009).
c. Treat a large number of variable and combinations of uncertainties which allows the provision of different views of how the future might be (Peterson et al, 2003; Rialland and Wold, 2009).

This is be further detailed in section 5.2.

5.2 Future Scenarios – Literature Review

5.2.1 General Overview

Future scenarios are an important and an essential tool that have been used for many years by governments and strategic planners to assist in devising future strategies and generating long-term policies and plans. The power of future scenarios lies in their ability to give an indication of what the future might look like under a given set of assumptions, allowing strategy makers to explore the possibility and impact of alternative futures (Alcamo, 2008; WRAP, 2009). Scenarios, however, cannot be used as a predictive tool to forecast future outcomes, as they describe the futures that could be rather than what will be.

Future scenarios usually include complex uncertainties in a structured yet creative manner. The interaction of these uncertainties is in most cases described in a narrative detailing how various elements might interact under certain conditions (Schoemaker,1995; Peterson et al., 2003; Alcamo, 2008).

In environmental and sustainability studies, similar to those addressed in this chapter, scenarios can also be used as useful means for identifying ‘early warning’ indicators or patterns that might signal a shift towards a certain kind of future (Alcamo, 2008; O’Brien, 2004).

The application of future scenarios to evaluate and analyse environmental and sustainability issues go back to the beginning of the 1970s when future scenarios were used in the well-known global environmental study “limits to growth”. In this study future scenarios’ analysis was applied to illustrate possible futures of society and the environment (Meadows et al.,1972; Turner, 2008). Scenarios have been used ever since to assist planners and policy makers to (Peterson et al., 2003):

1- Enhance the ability to respond quickly and effectively to a wide range of potential futures.
2- Avoid potential traps through improving preparedness.
3- Improve leadership through identifying potential opportunities.

In addition, what emerged from the literature review is that for sustainability studies such as this research on TERR in the FBM, the importance and relevance of using future scenarios is in their ability to (O’Brien, 2004; Alcamo, 2008):

4- Incorporate a virtually unlimited number of environmental components.

5- Enable the evaluation of the interaction between these components and the society.
6- Provide an interdisciplinary framework for analysing complex environmental problems, providing a picture of future alternative states of the environment.
7- Can work with perceptions and opinions and do not necessarily rely on hard data. Based on the data that emerged from chapter 3, this will be essential to understand and project how the stakeholders might perceive TERR in the FBM under alternative ESE domains.
8- Can be used to identify and evaluate the robustness of a particular environmental policy under different future conditions and as such can help policy makers think big about environmental issues.
9- Have the ability to illustrate how alternative policy pathways may or may not achieve an environmental target. This will help the users and stakeholders look at a situation in a new way and might impact on the decision making processes and the development of future and alternative public policies.

The following characteristics emerged from the literature review which differentiate future scenarios from other planning methodologies such as contingency planning, sensitivity analysis and simulation model, making them more suitable for this research on TERR in the FBM (table 5-1) (Schoemaker,1995; Peterson et al., 2003).

Table 5-1Future scenarios compared to other planning methodologies and the applicability to this research – derived from (Schoemaker,1995; Peterson et al., 2003)

Future scenarios	Contingency plans, sensitivity analysis and simulation models	Research characteristics and needs [21]
Explore the joint impact of various uncertainties which stand side by side as equals.	Explore one uncertainty at a time.	Complex variables and uncertainties can interact in different ways to impact on TERR in the FBM.
Evaluate the impact of change of several variables at a time without keeping the other variables constant. Have the ability to capture the new states that will develop after major shocks or deviations in the key variables.	Analyse and examine the effect of a change in one variable keeping all others fixed.	More than one variable can change at one time to impact on TERR in the FBM. These changes can also have an indirect impact on a number of secondary variables that might in turn play a role in the decisions taken by the FBM.

[21] Based on findings from chapter three of this thesis.

Table 5-1 – continued

Future scenarios	Contingency plans, sensitivity analysis and simulation models	Aspects that identified future scenarios as best suited for the research
Scenarios often include elements that cannot be formally modelled such as new regulations and values. Scenarios go beyond the objective analysis to include subjective interpretation.	Rely on objective data.	Based on the data that emerged from the previous chapters there is a need to include elements that cannot be quantified mainly: Regulatory aspect, innovation, and personal perceptions and views

5.2.2 Types of Scenarios

Scenarios can in general be described as stories or narratives set in the future to explore how the world would change if certain trends were to strengthen or diminish, or various events were to occur. Scenarios can be developed by following a number of methodologies that can differ in structure and design. Based on the literature, scenarios can fall into two main categories (Alcamo, 2008):

1- **Inquiry driven scenarios**: In general, Inquiry driven scenarios involve limited interaction between the researchers and the stakeholders (Alcamo, 2008). These scenarios are usually developed by the scientific community with limited interaction with policy makers or the non-scientific community (Alcamo, 2008).

   Strategy driven scenarios: Unlike the inquiry driven scenarios, strategy driven scenarios entail intense engagement between the scenarios builders and the end users including the stakeholders (Alcamo, 2008). These scenarios are mainly used in planning and aim to improve environmental quality and achieve sustainability (Alcamo, 2008).

In addition to above differences, strategy driven scenarios usually include a much wider set of viewpoints than those represented in inquiry driven scenarios and tend to be more qualitative than quantitative (Alcamo, 2008).

Based on the results that emerged from chapter 3 detailing the complexity of the interaction between the stakeholders that have to be considered when evaluating TERR in the FBM, strategy driven scenarios were identified as being best suited to assist in achieving this chapter's aims and objectives. This will be further discussed in the methodology section (5.2.4).

Although future scenarios might differ in their approach, to be successful, both inquiry and strategy driven scenarios have to satisfy the following criteria (Rialland and Wold, 2009):

1- The scenarios must be plausible, and internally consistent (logically assembled).
2- Must be based on rigorous analysis
3- Must be relevant for today's decision makers.

In order to achieve these characteristics, scenarios follow specific steps during their development as detailed in section 5.2.3.

5.2.3 Scenarios Development Procedures– Strategy Driven Scenarios

The literature outlines three main methodologies that have been followed in the past by governments and leading international agencies to develop strategy driven future scenarios (IPCC, 2000; EMCC, 2006; Foresight, 2009; EA, 2013 a):

A **Two axes method**

In this methodology two intersecting axes are used to form four quadrants. A narrative is then developed for each of the quadrants to represent a contrasting scenario that is specific to an issue. This is done by placing a major factor influencing the future of the issue on each of the two axes, which are usually referred to as "axis of uncertainty" (figure 5-1) (DEFRA, 2005). It is important for the factors chosen for the axes to be high impact and high uncertainty in order to ensure that the four spaces defined by their intersection are clearly differentiated (Foresight, 2009).

Due to the methodology used in their development, the 'two axes' scenarios have the following characteristics (DEFRA, 2005; EA, 2013a; Foresight, 2009):

1- They are illustrative rather than predictive in nature.
2- Tend to be high-level, although additional layers of details can be subsequently added to address more specific issues.
3- Are particularly suited to testing medium to long-term policy direction, 10-20 years ahead.

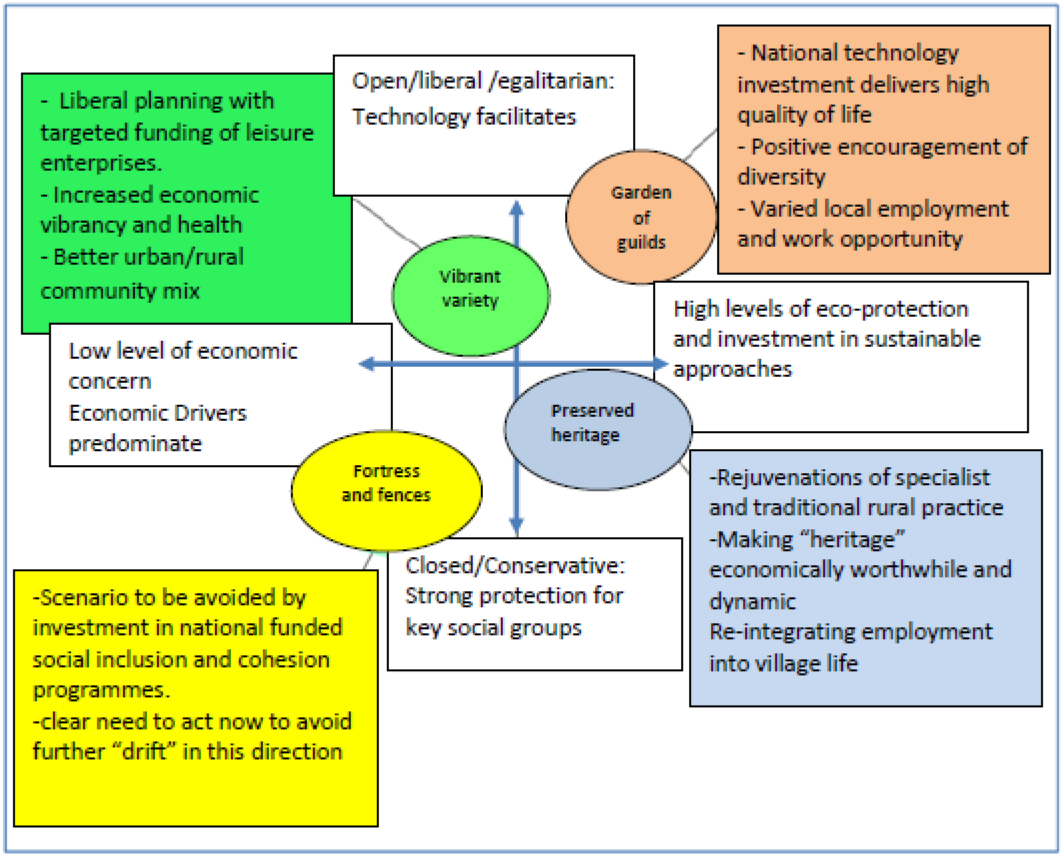


Figure 5-1 Rural future projects - Four Scenarios for 2054 Derived from (DEFRA, 2005).

B Branch analysis method

In the Branch analysis method, a 'branch' process is used to develop a range of potential futures. Starting with the top level question, important events are identified in a systematic, sequenced way. The potential consequences of these events are then mapped onto a branching diagram (figure 5-2) (Foresight, 2009).

The 'branch analysis' method is suited to developing scenarios around specific turning-points that are known in advance (e.g. elections, a referendum or peace process). This approach works best for a shorter time horizon: generally up to five years (Foresight, 2009).

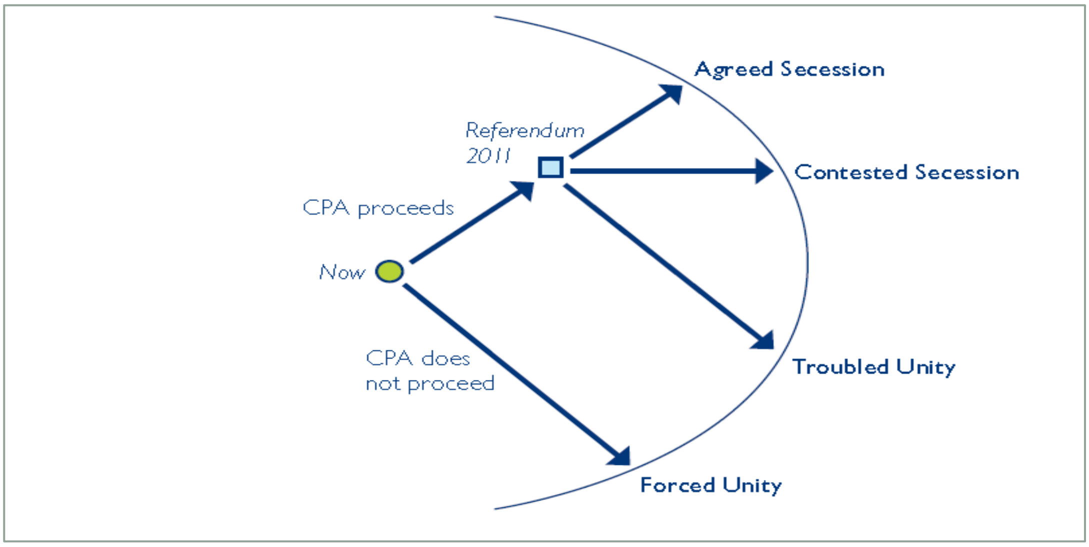


Figure 5-2 Example of Branch Scenario (Foresight, 2009)

C <u>Cone of plausibility method</u>

The 'cone of plausibility' method offers a more deterministic model of the way in which drivers lead to outcomes. This is achieved by explicitly listing assumptions and how these might change. Of the three techniques, this approach is most suitable for shorter-term time horizons (e.g. a few months to 2-3 years), but can be used to explore longer-term time horizons. This method mainly suits contexts with a limited number of important drivers as detailed in figure 5-3 (Foresight, 2009).

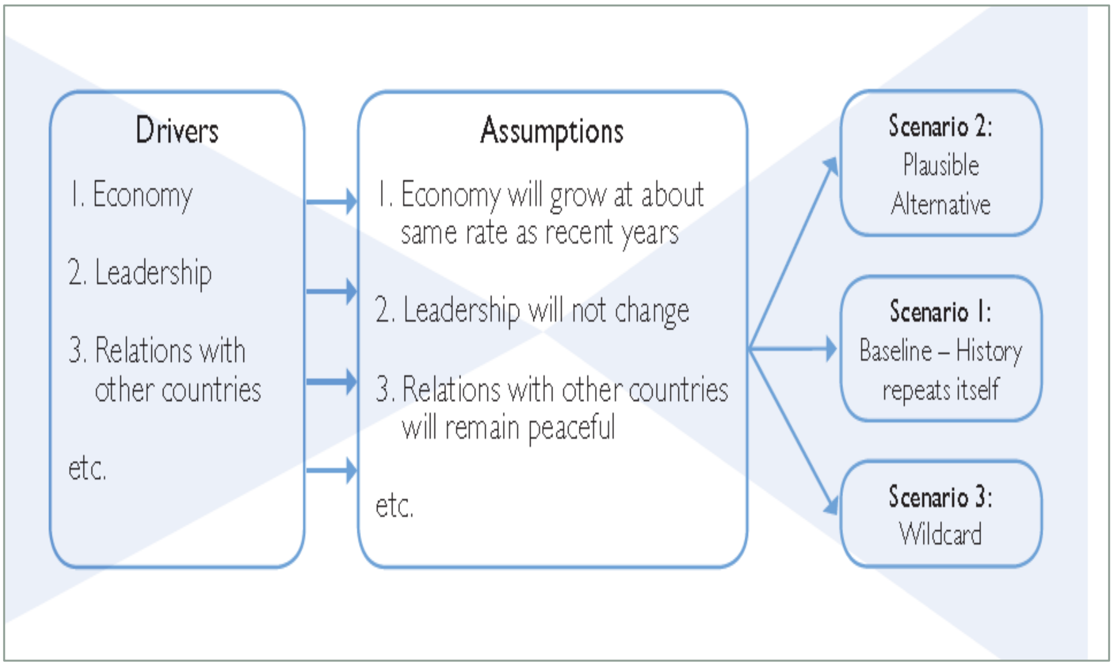


Figure 5-3 Cone of plausibility method (Foresight, 2009)

Based on the above characteristics, the two axis methodology emerged as being the best suited for this research. This is mainly due to the ability of this methodology to fulfil the following characteristics that are needed to meet the research needs:

1- Test complex interactions between a large number of variables – this will be further detailed in section 5.4.
2- Assist in long term planning. This was identified as being essential in order for the findings from this chapter to complement other studies that have

been carried out by the UK Government and associated agencies. These take into account the impact that future scenarios might have on the natural resources in the UK by 2050 and beyond (DEFRA, 2005; DEFRA, 2011; EA, 2009; EA, 2013 a). This will be further detailed in section 5.2.4.

5.2.4 Selection and Development of Suitable Scenarios

The objective of this section is not to critically evaluate existing scenarios, as this has been recently completed by experts in this field (Hunt et al., 2012 a; Hunt et al., 2012 b), but to find the best suitable scenarios that can be used to achieve the main two aims of this chapter as stated in section 5.1.

A. <u>Evaluation of Current Published Scenarios</u>

In recent years 100s of scenarios have been developed to evaluate the impact that future changes in ESE might have on natural resources, society and the environment. Some of these scenarios address general global environmental issues (IPCC, 2000; UN, 2006; WBCSD, 2006) , others are more specific to Europe and the UK. An extensive literature search identified a number of future scenarios that provides alternative narratives detailing the impact that changes in ESE might have on the future of water consumption and availability in the UK (Farmani et al., 2012; Hunt et al., 2012b). A critical analysis of the scenarios' narratives identified the following:

1. The narratives from these scenarios can potentially be used to project the future contributions that can be achieved from TERR in the FBM. A full list of these scenarios is provided in section 5.3 and will be used in part one of this chapter.
2. On the other hand the extensive literature review failed to identify published scenarios that can assist in understanding how future changes in ESE might impact on the approval of TERR applications in the FBM and the future interaction of the stakeholders.

As detailed below these had to be developed as part of this research.

B. Development of Scenarios Specific for the FBM

Following a detailed analysis of all the scenarios' that evaluate the future of water availability and demand in the UK, EA (2009) emerged as being the most fitting to be used in the development of scenarios that can assist in projecting the impact of future changes on the approval of TERR applications in the FBM. The scenarios in EA (2009) provide alternative detailed narratives describing how future changes in ESE are likely to impact on water availability and demand in the UK by 2050 (EA, 2009). As with all the UK Government scenarios, EA (2009) follows the two axes methodology, creating four quadrants that are built around two axis of uncertainty: governance and consumptive patterns (figure 5-4).

Due to its relevance the full narratives of the EA (2009) scenarios are presented in appendix 5-1.

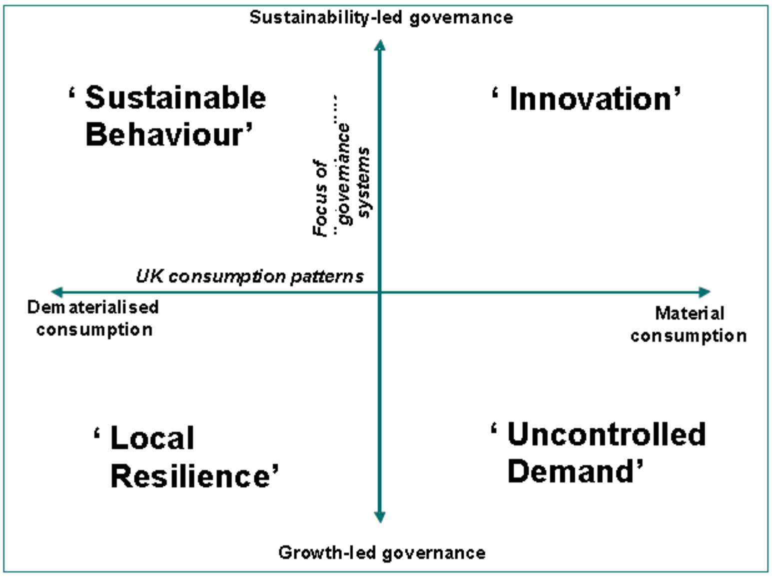


Figure 5-4 Environmental scenarios as presented by the EA (EA, 2009**)**

Discussions were held with DEFRA and the EA in January 2013 to explore the possibility of working together to develop future scenarios that are specific to TERR applications in the FBM. Although both DEFRA and the EA expressed their interest in the research, they indicated that the above will be too specific to what they are trying to achieve. However, both agencies expressed their interest in further developing EA, 2009 to project how future changes in ESE are likely to impact on water usage in the FBM by 2050. A number of workshops were organised and run by DEFRA and the EA between May-October 2013 (WRAP, 2013; EA, 2013a). Details regarding the organisation, agenda, questions and assumptions that were followed in the workshops are detailed in appendix 5-2. A list of the FBM subsectors that took part in the workshops is presented in table 5-2. The narratives that emerged from these scenarios are presented in appendix 5-3 (EA, 2013a); these narratives project how changes in ESE are likely to impact on:

1. Water usage and demand in the FBM
2. Food consumption and production patterns
3. Food and water security

The scenarios presented in appendix 5-3 required further expansion to develop narratives that are specific to TERR applications in the FBM as further detailed in section 5.4.

Table 5-2 List of contributors in the EA 2013 workshops
Water usage and potential savings that can be achieved per subsector (WRAP, 2013; EA, 2013 a)

List of contributors	**Sub sector**	**Total (million m^3/annum)**	**Excluding in product (million m^3/annum)**	**% Process that can be[22] potentially recycled**
Dry Food	Milling	0.3	0.30	100
	Animal Feed	0.9	0.9	100
	Cereals	12.5	12.2	98
	Bakery	2.4	1.3	54
	Confectionary	3.2	3.1	97
	Snack foods	6	5.8	97
Total for the sector		**25.3**	23.6	Average 93%

[22] Calculated based on the data presented in columns 3 & 4.

Table 5-2 continued

List of contributors	Sub sector	Total (million m^3/annum)	Excluding in product (million m^3/annum)	% Process that can be potentially recycled
Wet Processing Sector	Fish Processing	5.7	5.6	98
	Dairy	15.6	15.6	100
	Fruit and Vegetables	27.8	27.8	100
	Meat Processing	31.4	30.8	98
Total for the sector		**80.5**	79.8	Average 99 %
Pre-prepared food manufacturing sectors	Pet Foods	5.36	4.7	88
	Pre- prepared Foods	5.2	4.8	92
Total for the sector		**10.56**	9.5	Average 90%

Table 5-2 continued

List of contributors	Sub sector	Total (million m^3/annum)	Excluding in product (million m^3/annum)	% Process that can be potentially recycled
Beverage Sector	Wine	2		
	Cider and Malting	8		
	Soft Drinks	10		
	Spirits and Brewing	65		
Total for the sector		**85**	65	Average 76%
Total (million m^3 /annum)		**201**		**90%** **181 (million m^3 /annum)**

5.3 Part one – Projected Contributions of TERR in the FBM under Alternative Environmental Scenarios

As mentioned earlier existing future scenarios were evaluated in this section to assist in extrapolating the future contributions in water savings that can potentially be achieved from a widespread application of TERR in the FBM in the UK.

It was apparent from the literature review that a number of agencies are currently working on evaluating the impact that alternative future scenarios might have on the water availability and demand in the UK. Due to the assumptive nature of future scenarios this is leading to some variations in the published figures (figure 5-6) (Hunt, et al., 2012 a). In order to achieve consistency throughout this section, it was decided to use the UK Government scenarios and associated projections throughout this section.

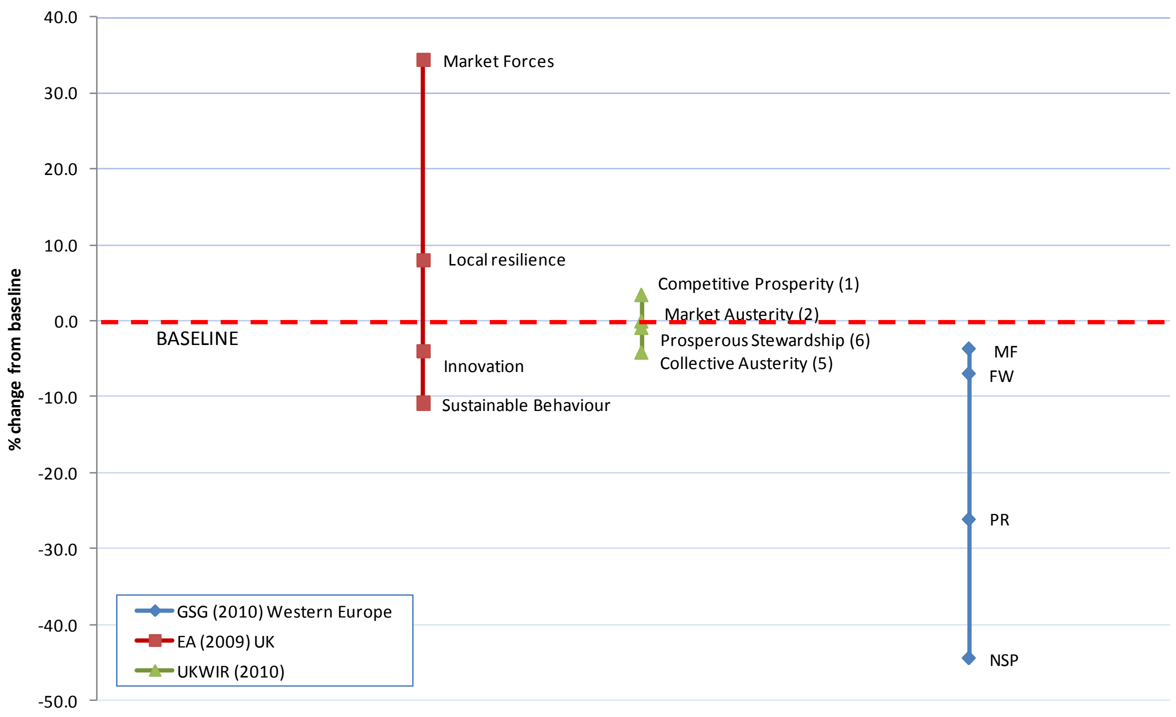


Figure 5-5 Relative changes in total water demands for 2050 scenarios (Hunt, et al., 2012 a) .

Following an in-depth evaluation of all the future scenarios published by the UK Government and associated agencies, the following six scenarios emerged as being the best suitable to achieve the aim of this section:

1- Food and drink manufacturing water demand projections to 2050 (EA, 2013a) (appendix 5-3A & table 5-2).

2- Projected population growth in the UK (EA, 2009) (appendix 5-3B).

3- Demand of water in the 2050s (EA, 2008b; EA, 2009) (Appendix 5-1).

4- Impact of population growth on future water demand in the UK (EA, 2008 b).

5- Changes in total water demand in the UK (EA, 2011a; WRAP, 2013).

6- Impact of climatic change on water availability in the UK (EA, 2011b) (appendix 5-4).

A summary of the figures that emerged from these scenarios is presented in tables 5-3 and 5-4. The alternative projected changes in water demand by the above scenarios were then used in conjunction with the water usage figures from the individual FBM sub-sectors (table 5-2) to estimate the projected future contribution that can be achieved from TERR in the FBM as the new scenarios unfold. These are also presented in tables 5-3 and 5-4 below.

Table 5-3 Potential contribution of TERR in the FBM in relation to future demands associated with population growth

Column number (C)	Parameter	2010 Baseline	Sustainable behaviour	Innovation	Local Resilience	Uncontrolled Demand	Reference /calculated
1	Changes in water Demand in the FBM		28% decrease	5% increase	5% increase	70% increase	Appendix 5-3 (EA, 2013 a)
2	Projected total water demand in the FBM (million m^3 per annum)	201 (table 5-2)	145	211	211	342	
3	**Changes from base line of water demand in the FBM (million m^3 per annum)**		-56	+10	+10	+141	(C2 figures – baseline)
4	Expected population growth in the UK		21% increase	32% increase	18% increase	42% increase	Appendix 5-3 (EA, 2013 a)
5	Population (million)	54.5	65.9	71.94	64.31	77.39	(EA 2009; EA, 2013 a)
6	Changes in public demand		30% decrease	20% decrease	10 % decrease	6% increase	(EA, 2008 b)
7	Expected domestic demand l/p/d	156	109	125	140	165	(EA, 2009 a)
8	Total expected domestic demand ML/d	8502	7183	8992.5	9003.4	12769	= (C7xC5)
9	**Total expected domestic demand (million m^3 per annum)**	3103	2622	3282	3286	4661	= (C8x365)/1000

Table 5-3 - Continued

Column number (C)	Parameter	2010 Baseline	Sustainable behaviour	Innovation	Local Resilience	Uncontrolled Demand	Reference
10	**Changes from base line of domestic demand (million m^3 per annum)**		- 481	+ 179	+ 183	+ 1558	(C9 figures – baseline)
11	**Changes from the baseline figures: Combined contribution of domestic and FBM water demands (million m^3 per annum)**		Lower by 537 million m^3 per annum	higher by 189 million m^3 per annum	higher by 193 million m^3 per annum	Higher by 1699 million m^3 per annum	= (C3+C10)
12	Total savings that can be achieved from TERR in the FBM (million m^3 per annum) (70% total used) (table 5.2) (WRAP, 2013)	181	101.5	148	148	239	= (C2 x90%)
13	**% increased demand that can be met TERR**			**78%**	**76%**	**14%**	= (C12/C11)x100

Table 5-4 Potential contribution of TERR in the FBM in relation to future total water demand in the UK (EA, 2011; WRAP, 2013)

Column number (C)	Parameter	2010 Base	Sustainable Behaviour	Innovation	Local Resilience	Uncontrolled Demand	Calculated
1	Total water demand by 2050		-11%	-4%	+8 %	+35%	
2	Expected Demand by 2050 ML/day	19300	17177	18528	20844	26000	
3	Total water demand (million m^3 per annum)	7044.5	6269.6	6762.7	7608.06	9490	= (C2 x365)/1000
4	Changes from base line in total demand (million m^3 per annum)		Drop 775 (million m^3 per annum)	Drop by 281.8 (million m^3 per annum)	Increased by 563.56 (million m^3 per annum)	Increased by 2445.5 (million m^3 per annum)	(C3 figures – baseline)

Table 5-4 Continued

Column number (C)	Parameter	2010 Base	Sustainable Behaviour	Innovation	Local Resilience	Uncontrolled Demand	Calculated
5	Total savings that can be achieved by TERR (million m^3 per annum)	181 (table 5-2)	101.5	148	148	239	
6	**% increased demand that can be met by TERR**				26%	9.77%	=(C5/C4)x100

The figures that emerged from tables 5-3 and 5-4 clearly highlight the significant future role and contributions that can potentially be achieved from a widespread application of TERR in the FBM:

1- Impact of population growth: Population growth is projected to have a significant impact on increasing water demand in the UK.
   a. With the exception of the sustainable behaviour scenario, where water consumption is projected to be lower by 2050, water demand is expected to be higher under the innovation, local resilience and the uncontrolled demand scenarios.
   b. Based on the current water wastage figures that are reported in the FBM, TERR can potentially assist in providing a significant percentage of the projected increases in water demand:
      i. 78% under the innovation scenario
      ii. 76% under local resilience
      iii. 14% under uncontrolled demand.
2- Total future water demand in the UK: The overall water demand in the UK is expected to be higher under the local resilience and the uncontrolled demand scenarios by 8% and 35% respectively.
   The contributions from TERR in the FBM can potentially satisfy:
   a. 26% of the increases in total water demand under the local resilience scenario.

b. Nearly 10% of the increases in total water demand under the uncontrolled demand scenario.

However, it is critical to highlight that the scenarios narratives presented in tables 5-3 and 5-4 only describe the projected changes in water demand in the UK by 2050 and don't address the future availability of fresh water supplies during the same period or the capability of meeting the projected increases in future water demands in the UK. In order to evaluate the above there is a need to examine how future changes in the UK are likely to impact on water resources and availability. According to figures published by the EA, climatic change is likely to have a significant impact on the future availability of fresh water supplies in the UK by 2050. A future scenario study carried out by the EA in 2011 projected that lower annual rainfall, erratic weather and drier summers are expected to lead to significant water shortages in the UK even under the sustainable behaviour scenarios (EA, 2011a) (Appendix 5-4). Although the figures provided in this report don't allow estimating the volume of expected water shortages, they provide a strong indication of the possibly of having future unmet water demands under all future scenarios.

It can therefore be argued that the future role of TERR in the FBM can be significant under all four scenarios to either:

1- Assist in meeting the projected increases in future water demand and or
2- Contribute to lowering the impact that climatic change can potentially have on the availability of fresh water supplies

Based on the figures presented in this section it is evident that TERR in the FBM can potentially play a significant role in bridging the gap between future water availability and demand in the UK.

Further work is carried out in section 5.4 to assist in understanding how the future changes presented in this section are likely to impact on the future approval of TERR applications in the FBM in the UK.

5.4 Part Two- Development of Future Scenarios that are Specific for TERR in the FBM

This section evaluates how future changes in ESE are likely to impact on how the stakeholders in the FBM perceive TERR applications by 2050.

As discussed earlier EA (2013a) was developed by DEFRA and the EA to provide scenarios' narratives that are specific to water usage in the FBM by 2050. As part of this research, these narratives were then further analysed in conjunction with the findings from chapter three to develop scenarios' narratives that are specific to TERR applications in the FBM.

Two main steps were followed to achieve the above:

1. The narratives and primary impact points from EA (2013a) were analysed to develop primary impact points that are specific to TERR applications in the FBM (tables 5.5- 5.8).
2. Based on the knowledge that emerged from chapter 3, the newly developed primary impact points were further analysed to project how the stakeholders in the FBM are likely to perceive TERR applications (table 5-9).

Table 5-5 Primary impacts on TERR applications in the FBM under sustainable behaviour

Taxation	Increase in the value and cost of water
•**Impact :** •Introduction of government targets to improve water efficiency and minimise water wastage including TERR in the FBM. •Increased interest in sustainbility applications such as TERR in the FBM. •Creating an interest in developing safe technologies to enable safe applications of water recycling and reuse in the FBM. •The focus will be on the use of sustainable technologies that are both energy and water efficient.	
Public sustainability	**Consumers choose to be green - Preference is given to purchasing green goods**
•**Impact:** •Increased competitiveness of products using recycled water. •The above will lead to changes in product labelling to clearly indicate the products that have used recycled water. •Purchasing preference will be given to product with TERR on the label. •Price has become a secondary driver for purchasing goods. •Consumers are willing to pay more for products that have used recycled water. •In order to maintain competitiveness in the market, there is an increased interest in developing technologies that will enable water recycling and reuse.	
Legislation	**Stricter legislation and higher taxation against water wastage.**
•**Impact:** •Introducing a regulatory body to monitor water use efficiency and effluent discharge. •Increased Investment in TERR in the FBM to avoid compliance costs. •Treating the trade effluent water to high standards to be able to discharge, making it easier and more economically viable to consider TERR applicaitons. •Interest in the development of technology that will assist in meeting the stricter government targets.	

Table 5-6 Primary impacts on TERR applications in the FBM under Innovation

Advancement in Technology	Ability to produce potable water cheaply and efficiently from a variety of sources

•**Impact:**
•Lowering the value of water, however, more water is needed to meet the increases in production demands, making water reuse essential.
•Improving the efficiency and reliability of water treatment technologies making TERR in the FBM a safe, reliable and feasible application.
•Development in TERR technologies is driven by water demand rather than environmental concerns.
•Introducing strict guidelines and legislations to monitor the technologies used. Only the most efficient technologies and those that can generate very high quality water can be used.
•Treating trade effluent on site has become much cheaper than abstraction or mains water making TERR a feasible application.

Water Availability	This is no longer a primary concern

•**Impact:**
•Although water demand has increased this has been met by generating potable water from a number of sources including trade effluent.
•Many companies are self sufficient and they have a closed loop system in place.
•Water efficiency targets have been introduced to promote the use of the most efficient technologies and TERR is essential to meet the increased water demand.

Globalisation of the market	Competition is very strong to produce food cheaper and quicker

•**Impact:**
•Investment in TERR to improve water resources to meet production demands.
•Investment in TERR to lower the cost of water.
• However, due to the complexity and cost of the technologies needed only big manufacturing sites will be able to survive.

Table 5-7 Primary impacts on TERR applications in the FBM under local resilience

Rise of localism

Diminishing power of the global market

- **Impact :**
- There is a need for local economies to be self sufficient and water conservation is needed for survival. Water conservation is given priority in areas where water availability is critical.
- Increase in the value of water, however, limited available technologies led to very limited development in TERR.
- Although Water reuse is prevalent in some areas, this is mainly restricted to using traditional rather than technological conservation measures.

Back to basics

Widespread use of low tech production technologies

- **Impact:**
- Increase in water use intensity.
- Limited technological ability and limited capability for applying TERR in the FBM.

Table 5-8 Primary impacts on TERR applications in the FBM under uncontrolled demand

Maximising profits — Significant increase in production and profitability

- **Impact :**
- Producing more and cheaper is essential for survival.
- The environment and saving water is not a priority and environmental issues are not taken into account. However, increased production has led to increased demand on water.
- The above has led to water becoming more expensive and the risk of water shortages have increased. This has generated interest in TERR applciations in the FBM in order to maintain cheap and intensive production.

Technology for efficiency — Having enough resources to increase production and to do this cheaply

- **Impact:**
- Investment in technologies that will increase water availability in order to maximise production and profit. The options don't take into account sustainability but will vary depending on the financial capability and power of the company. These options can include TERR, private water supplies or exploitation of natural resources.
- Only the most powerful can survive in this highly competitive market and this has led to the closure of small factories.
- The FBM is controlled by the wealthiest in society.

Legislation — The government has introduced no regulations or taxation to reduce water consumption

- **Impact**
- Water recycling is left to individuals.
- The main aim of water recycling is to allow factories expand production in a cheap manor .

Table 5-9 Future scenarios narrative – response of the stakeholders

Stakeholders-necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
Approval of the supermarkets to purchase products using recycled water	The public have become more sustainable and there is preference to purchase sustainable and “green” Products. All products are clearly labeled to indicate how “green” they are and products using regenerated water are selling better. The supermarkets are putting pressure on the manufacturers to produce products using regenerated water as the market has become increasingly sustainable. Producing green goods has become the key for expanding businesses and for gaining more shares in the UK market.	There is strong competition in the market and there is a need to produce food cheaper and quicker. The source of water is not a concern as long as it meets the strict policy and regulatory guidelines. No questions are raised regarding the source of water used in production as the reliability of the technologies used to generate potable water from trade effluent is well verified and established. The supermarkets want their shelves full and if this requires using recycled water to meet the production demand they will provide the FBM their full support.	The big supermarkets have lost their power in controlling the national businesses. Most of the big chains have disappeared and there is a growth in regional markets and local farm shops. The supermarkets are no longer an influential stakeholder.	The focus is on how the products look and taste rather than on the overall water usage. The supermarkets will not address water intensity in their products, but in order to keep up with the demand they will accept purchasing products that have used recycled water. The supermarkets want their shelves full and if this requires using recycled water to meet the production demand they will not object to TERR in the FBM.

Table 5-9 Continued

Stakeholders-necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
System must not compromise safety standards	High safety standards have to be met and only water of potable quality is authorised to be used in production areas. Improvement in the reliability of TERR technology is driven by the increase in the value of water and the support from the UK Government. Extensive research has been done to demonstrate the safety of TERR making the approval of this application easier.	High standards have been put in place to control water recycling projects and a number of regulatory parameters have been introduced to govern TERR projects. Only high efficient technologies that can generate water of potable or higher standards are considered. Due to the improvement in technology and ability to generate potable water from a variety of sources, meeting hygiene standards is not considered to be an issue.	Food manufacturing is back to its basic form. Although standards have slightly relaxed, the quality and safety of water to be used in the FBM is still a priority. The lack of investment in advanced technologies and the small scale of production is making it harder to generate potable water from trade effluent. This is having an impact on limiting TERR applications.	Standards are divided between the rich and the poor and water of lower quality might be allowed to be used within the factory in specified low quality products. Technologies used to generate potable water from trade effluent are expensive and this has resulted in limiting TERR applications to big companies that can afford it (big multinationals). Water and other resources have become unavailable to smaller companies and this has led to many closures in the UK.

Table 5-9 Continued

Stakeholders- necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
The need to use recycled water must be justifiable	The need is driven by the sustainable behaviour of the public and the increase in the cost of water. TERR has become essential for the survival of the manufacturing sites. This is linked to its importance in satisfying the criteria set by the public and the supermarkets. In Addition, the economic benefits from TERR is generating a "win win situation".	Water availability is not a concern but recycling has become essential to meet the expanding demands of food and beverage production. Due to advancements in technology, generating potable water from trade effluent has become cheaper than using mains water or abstracting form rivers or underground sources. Companies have become self-sufficient and many have "closed loop" water systems.	Although the need of recycling water can differ from one area to another the means of doing so are very limited. The ability of applying TERR is very limited due to limitations in technology.	Water availability is not a concern but recycling is essential to meet future demands.

Table 5-9 Continued

Stakeholders-necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
Technology must be reliable to minimise the risk of Cross contamination	In order to meet public demand, compliance and minimize water wastage, investment and research have been directed to technologies that can lower water consumption. This has improved the efficiency and reliability of TERR technologies. The focus has been on the development of sustainable technologies and linking water and energy optimization.	Technology is well developed and is highly reliable. Research has been driven by increases in production and associated increases in water demand. Water efficiency targets have been monitored by both the UK Government and the FBM sector and only the most efficient technologies can be used. This has led to a reduction in the cost of TERR applications which have become cheaper than using other sources of water.	Innovation in technology has been very limited and the focus is on using basic methodologies to treat the water. Limited research has been done on advanced methods that would allow the generation of potable water from trade effluent. Technologies specific to TERR are therefore very limited.	In order to meet increases in water demand, more efficient technologies have been developed. This includes technologies that will enable the generation of potable water from trade effluent. The sustainability of the technologies is not taken into account and the main aim is to make more water available in order to meet the increasing demands.
TERR is verified by the industry	Due to more funding, marketing pressure and better reliability of TERR technologies, there is sufficient field data to verify the safety and feasibility of TERR applications.	Highly efficient technologies have been developed to enable potable water to be generated from a variety of sources including trade effluent.	There has been a move away from the global market and the importance to verify applications nationwide has lost its importance. In addition, in the localized markets, there is less reliance on advanced applications such as TERR.	This has been verified by big companies who can afford investing in new equipment. There is no interest of sharing or providing assistance for smaller companies who are finding it harder to compete in this highly competitive and polarised market.

Table 5-9 continued

Stakeholders – Necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
System must be economically feasible	The focus on sustainability has increased the value of water and effluent discharge costs. There have also been tighter limits on effluent discharge consent. Taxation on water has also been introduced making it essential for companies to compete in the market. Due to increases in taxation and water costs the payback period from TERR in the FBM for most companies started to meet the standards set by the industry. In addition, due to the large investment dedicated towards sustainability project the efficiency of TERR in the FBM have significantly improved, lowering both capital and operating costs.	The value of water has decreased as innovation has increased its availability. However, improvement in technology is making it cheaper to invest in TERR technologies than to use mains or abstracted water.	Not Applicable. The market has lost its competitive power. In addition the ability to use modern and advanced technologies have become very limited.	The increased demand on water has led to increases in water prices making TERR in the FBM economically feasible. However, the technologies used in TERR applications are only available for big multinational companies.

Table 5-9 continued

Stakeholders-Necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
The application is supported by Legislation	Legislation has been introduced to regulate water wastage and the UK Government has introduced a regulatory body to monitor the efficiency of water usages in the FBM. High fines have been introduced for companies that don't comply with the standards. Although the regulatory aspect is having an impact on the widespread application of TERR, the highest impact is linked to the Government increasing the prices of water and effluent discharge. Effluent consent limits have also become stricter forcing companies to treat their trade effluent to very high standards, making TERR a more feasible consideration.	Water efficiency targets have been set by the UK Government in order to avoid future water shortages and in order to enable expansion in production to meet current and future demands. This has resulted in an increase in TERR applications.	In areas where water is scarce local regulatory standards have been introduced. This has resulted in increasing the value of water. However, due to the limited advancement in technologies, the impact of the above has been limited to conservation strategies rather than recycling and reuse.	No taxation or regulations introduced to regulate water consumption

Table 5-9 – continued

Stakeholders- Necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
Guidelines provided for the FBM and the other stakeholders	In order to assist companies comply with the new legislations, the UK Government has worked hard to provide the necessary guidelines so that there is no impact on the UK economy. This has been helped by the data emerging from the research and field applications on TERR in the FBM.	Guidelines have been provided to ensure the efficiency of generating potable water from trade effluent.	No guidelines provided and there is no government interest in addressing TERR.	No guidelines provided and there is no government interest in addressing TERR
External Pressure from NGOs business partners , shareholders and the media	The green and sustainable behaviour of the public is putting pressure on the industry and the supermarkets to recycle and reuse water. This is driven by the majority of stakeholders and the full support for TERR projects is therefore provided.	The value of water has decreased and there is no pressure from these groups to recycle water.	There is pressure relating to minimising water wastage but there are limitations as to how much can be achieved in terms of TERR	None exists

Table 5-9 Continued

Stakeholders- Necessary conditions	Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
Summary of impact	A number of factors have contributed to a wide spread application of TERR in the FBM in the UK. Under this scenario TERR is considered essential for the survival of the manufacturing sites due to: - Public pressure - Regulatory enforcement - Economic feasibility Products using recycled water are selling better and all the stakeholders are working together to encourage the uptake of TERR projects. TERR has become a necessity for survival in this highly sustainable market.	TERR has become a widespread application in the UK. Unlike under sustainability behaviour the drive for TERR is not to save water but rather to have enough water in order to meet the ever growing demands. Increased food production meant that unless TERR is applied, there would be limits to the capability of expansion in the FBM sector. TERR applications are also helped by the advancement in the safety and efficiency of the available technologies making TERR safe, reliable and economically feasible. TERR is essential for survival in this highly competitive market and there are no barriers acting against this application.	Although saving water is viewed as being essential in this fragmented society, there are technological and financial limitations as to what can be achieved. Traditional conservation measures are followed but the capability to extend this to more advanced applications such as TERR is very limited.	The interest in TERR has emerged in order to meet the increasing demands in food and beverage production. There are no environmental concerns regarding what technologies are used or the affordability of the available technologies. Only the most resourceful can survive in the highly polarised and competitive market and TERR in the FBM is used as means to increase competitiveness and ability to produce more and cheaper. However, complex technologies are only available for multinational and big companies and this has led to disadvantaging small and medium enterprises who have gradually started disappearing from the UK economy.

It is clear from the narratives presented in table 5-9 that changes in ESE are likely to have a significant impact on the dynamics of the stakeholders in the FBM. The future scenarios narratives project that with the exception of the local resilience scenarios, future changes in ESE are likely to have a positive impact on TERR applications in the FBM. It is evident from the scenarios' narratives that the support of the stakeholders' can be driven by two main factors:

1- The need to comply and/ or satisfy high sustainability standards.
2- The need to provide additional sources of water to enable expansion in production.

5.5 Conclusion

Chapter five evaluates the impact that four future scenarios can potentially have on:

1- The contributions in water savings that can be achieved from TERR in the FBM in the UK.
2- The impact that changes in ESE are likely to have on how the stakeholders in the FBM perceive TERR in the future.

Although it is unlikely that only one scenario will occur in the future and it is most probable to have a mixture of combinations from each scenario, the data presented in section one of this chapter highlights the important role that TERR can play in improving the UK resilience against future water shortages under all future scenarios.

Future scenarios that are specific to TERR in the FBM were developed in part two of this chapter. Comparing the results that emerged from the future scenarios to those that were presented in chapter 3 highlight a significant shift in how the key players might perceive TERR applications in the FBM. With the exception of the local resilience scenarios, there is a strong indication that the majority of stakeholders will be supportive of TERR application as the new scenarios unfold. The support of the stakeholders was mainly triggered by one or more of the following factors:

1- Improving the awareness and the sustainable behaviour of the public. This can have a direct impact on favouring the consumption of environmentally produced products and will lead to an overall support of TERR in the FBM.
2- Improving the efficiency and reliability of the technologies used to generate potable water from trade effluent.
3- Evaluating the current prices linked to water and trade effluent discharge costs. This will have direct impact on the economic feasibility of TERR.
4- Linking water saving initiatives to reward/taxation.
5- Introducing a regulatory body to monitor water wastage.
6- Providing support and guidance from the UK Government.

It is clear from the findings that emerged from this chapter that understanding the above points will be key for the success of future TERR projects in the FBM. The data and methodologies that emerged from this chapter can therefore be used by policy makers and planners to evaluate the robustness and applicability of future strategies that are aimed to improve TERR applications in the FBM.

To summarise, future scenarios that are specific to TERR applications in the FBM were developed and their impact was then tested on the stakeholders that were researched in chapter three of this thesis.

The narratives that emerged from the future scenarios clearly confirm hypothesis 7 of this thesis: TERR in the FBM is a dynamic process and will be affected by changes in the environmental and socio-economic domains.

In addition and based on the projected narratives that emerged from these scenarios, it is concluded that future changes in ESE are likely to act as an incentive to encourage the implementation of TERR projects in the FBM.

6 Discussion

The work set out in this thesis is the first study in the United Kingdom to provide a comprehensive research on trade effluent recycling and reuse (TERR) in the food and beverage manufacturing sectors (FBM). The research throws light on an important application that can assist in the provision of sustainable water supplies and that can potentially bridge the future projected gap between water demand and water supply in the UK.

The contributions of the research can be summarised as follows:

1- It provides a detailed investigation and analysis of the renewable water resources that can potentially be regenerated from a widespread application of TERR in the FBM in the UK, an application, that although significant has been characterised by low funding and limited research. In doing so the research projects the potential role that TERR in the FBM can play in assisting the UK meet the ever growing demands on potable water supplies.

2- According to our knowledge this is the first research to provide an in-depth evaluation of the water management, trade effluent and recycling and reuse practices that are currently adopted by the FBM sector in the UK.

3- It provides detailed analysis of the impact and interaction of the current stakeholders on TERR applications in the FBM. In addition to this being the first study in the UK, the research uses pioneering methodologies by combining Freeman's stakeholder analysis with grounded theory methodology (Freeman, 1984; Glaser, 2003).

4- It evaluates the economic feasibility of TERR applications in the FBM and provides detailed analysis of the potential impact that this might have on the development and approval of this application in the UK.

5- Alternative future scenarios that are specific to TERR applications in the FBM are developed as part of this research to assist in understanding how future changes in the environmental and socio economic domains (ESE) are likely to impact on the future of this application in the UK.

Based on the data that emerged from the literature review we believe that this is the first study in the UK where future scenarios are used to project the interaction and influence of the stakeholders under alternative ESE narratives.

The FBM manufacturing sites that are evaluated in this study cover a variety of sub-sectors that vary in size, production practices, ownership and location within the UK. This variation provides a good representation of the diversity of the FBM sector in the UK.

The summary and discussion of the findings that emerged from the research data are presented in the individual research chapters. This is further expanded in this chapter to assist in critically analysing, interpreting and relating the research findings to the wider literature. This is achieved through:

1- Examining water recycling and reuse practices in industrial applications outside the FBM.
2- Evaluating how past technological advancements have been viewed by the stakeholders in the FBM and analysing the contributors that have led to the success or failure of these applications.

6.1 Establishing the Importance and Current Position of TERR in the FBM in the UK

The findings that emerged from chapter two confirmed hypotheses 1, 2 and 3 of this thesis:

Hypothesis 1: Climatic and demographic changes will impact on the future of water availability in the UK, making it essential to consider alternative and renewable water sources that will assist in bridging the gap between water supplies and water demands.

Based on the climatic and demographic changes that are discussed in chapter two and a projected increase of domestic water consumption of around 1000Ml/day by

2030, future intervention is likely to be needed in order to avoid the possibility of water demand outstripping available supplies by 2030.

Hypothesis 2: Current water wastage is significant in the FBM; hence TERR in this sector could play a significant role in improving the future water resilience of the UK.

It is evident from the data presented throughout this thesis that significant renewable water supplies can be generated by treating the trade effluent from the FBM to potable standards and reusing this regenerated water in process applications within this sector. Based on the figures that emerged from chapter two of this thesis, a widespread application of TERR in the FBM can potentially generate around 44% of the projected future increases in the domestic water demand by 2030(figure 2.6). However, although these savings are significant, the data that emerged from the field survey clearly highlight the current limited applications of TERR in the FBM which was only reported in 0.25% of the 404 companies that were included in the survey (figure 2.8). There is an apparent increase to 4% when the intended use of the regenerated water is outside the process areas, however, further analysis clearly indicate that the demand from these non-process applications rarely exceeds 20% of the regenerated water, often leading to significant losses of reusable quality water to surface drains (figure 2.6 & 2.8). In addition, it is evident from the research data that environmental concerns and improving water efficiency are in most cases a secondary driver to these non- process reuse applications which are in the majority of applications driven by the need to discharge the trade effluent to surface waters and the associated requirements to comply with stricter trade effluent discharge parameters (figure 2.9). This will be discussed in further details later on in this chapter.

Hypothesis 3: There are currently no technical or legislative challenges that will inhibit TERR applications in the FBM.

It is evident from the data presented in chapter two that there are currently no regulations that would stop or act against TERR applications in the FBM. What emerged from the data presented in this chapter is the possibility of adapting a number of existing quality control mechanisms to include TERR applications. This will be discussed in further details later on in this chapter.

It is evident from the literature that the limited application of TERR that emerged from the field survey is not specific to the UK, but has a worldwide prevalence in the FBM sector. The findings from this research correspond with the data presented by Judd in 2014 as part of a world-wide evaluation of TERR applications in the FBM; although the work by Judd might not be inclusive of all the current applications in the FBM sector, it provides a strong confirmation regarding the limited TERR applications in process areas. Only two applications are reported by Judd following a review of the FBM sector in the USA, Canada, Europe, South

America, the Far East and Australia[23] (Judd, 2014; Judd, 2011). However, as discussed in the literature review a number of limitations emerged from the work carried out by Judd and other leading researchers in the field of TERR applications in the FBM (Kirby et al., 2003; Wu et al., 2013a; Wu et al., 2016). Detailed analysis of previous published data clearly indicate that all previous work focused on evaluating the capability of the current available technologies in treating the trade effluent generated from the FBM to potable standards on the expense of: i) analysing the reasons behind the limited water reuse applications in process areas and ii) addressing what can be done to encourage this reuse application in the FBM. In our view what is particularly surprising is the limited TERR applications in the FBM sector in arid developed countries such as Australia where recycling and reuse applications in the general industrial sector are reported to be as high as 40% (Almeida et al., 2013). The reasons that might be behind this significant gap between the FBM and the general industrial sectors will be analysed in further details later on in this chapter. Compared to Australia, lower water recycling levels

[23] It is worth mentioning that one of these applications is in the UK and is in the salads washing processing plant that was identified from the research survey and from the discussions that were held with DEFRA and the EA in chapters two and three of this thesis.

are reported in the industrial sectors in Europe which currently stand at around 4% (Almeida et al., 2013; CBS, 2011). Although no official figures are available for the UK, the data presented in this thesis clearly indicate that the industrial sector currently heavily relies on consumptive mains or underground water supplies (table 2.3) (RAENG, 2010; WRAP, 2013).

What is clearly evident from the literature review is that although more could and should be done to encourage water recycling and reuse in the industrial sectors there are main differences and additional challenges and barriers that can further complicate TERR applications in the FBM sector. These can be divided into three main categories:

1. Availability of data and guidelines

The negative impact that the lack of data and guidelines is having on TERR applications in the FBM is evident from the findings that emerged from chapter three of this thesis and will be discussed in further details in section 6.2 of this chapter. In contrast, information is widely available on applications in the general industrial sector where technical, economical and software programmes are commercially available to assist in the implementation and projection of the financial benefits that can be achieved from TERR projects (ADOPBIO, 2007; BATTLE, 2008; Vajnhandl and Valh, 2014). In our view and based on the data that emerged from the stakeholders analysis we believe that similar programmes will be essential for the progress of TERR applications in the FBM.

2. Trade effluent characteristics and differences in the regenerated water requirements

As demonstrated from the data presented in the case study, the trade effluent generated from the FBM processes can be very high in sugar, carbohydrates and fat, oil and grease (FOG) (appendix 4-1) (Da Sliva et al., 2014) . This usually leads to high soluble COD values that cannot be removed by simple treatments such as coagulation and floatation but will often require advanced biological treatments such as MBR, ultrafiltration and reverse osmosis (appendix 4-4) (Tchobanoglous et al., 2004). These advanced treatments are technically demanding and can often result in increasing the cost and complexity of regenerating water of reusable standards from the FBM trade effluent. In comparison, the trade effluent generated from the general industrial sector is often lower in COD values which in most cases is in the non –soluble form. As a result simpler treatments such as DAF followed by membrane filtration can be used to generate reusable water quality from the industrial trade effluent (Amar et al., 2009; Gutterres et al., 2010; Karthik et al., 2011). This is often helped by the lower standards that are required for reuse applications in the general industrial sector as compared to potable water qualities that are required for all reuse applications in the FBM. For example:

- In the textile sector only 10-20 % of the total water used has to be of high quality (Vajnhandl and Valh, 2014; Lopez-Grimau et al., 2013).

- In the steel industry water can be reused back in the processes after a simple RO treatment to remove the suspended and dissolved solids (Colla et al., 2016).
- In the tannery processes the water generated from the bating washings can be used in the de-liming steps without any pre-treatment (Gutterres et al., 2010).

The impact that high capital and operating costs can have on the success or failure of TERR projects in the FBM is further discussed in section 6.2.

3. Simpler stakeholders

It is well documented in the literature that the success of water reuse applications in the industrial sector are mainly driven by economical and technical factors (Liaw and Chen, 2004). In contrast and based on the findings that emerged from chapters three and four of this research it is evident that the stakeholders that can impact on the success or failure of TERR applications in the FBM are more varied and complex. This is discussed in further details in section 6.2.

Based on the above discussion it is evident that although more could and should be done to encourage TERR applications in the UK general industrial sector, there are currently more complex and unknown factors that can impact on the success of this application in the FBM. As demonstrated throughout this thesis understanding the interaction and influence of the stakeholders is key to resolve many of the current unknown factors surrounding TERR applications in the FBM.

6.2 Stakeholder Analysis

The findings that emerged from chapters three and five confirmed hypotheses 4, 5, 6 &7 of this thesis:

1- The stakeholders in the FBM are many and can interact in complex ways to impact on the decisions taken by the manufacturing sites.
2- For TERR to be adopted by the FBM, the approval of the salient stakeholders is necessary.
3- The economic benefits that can be achieved from TERR in the FBM will have an impact on the uptake of TERR applications in the FBM.
4- TERR in the FBM is a dynamic process and will be affected by changes in the environmental and socio-economic domains.

The findings from chapter three strongly verify the complexity of the interaction between the stakeholders and their strong impact on the success or failure of TERR projects in the FBM.

The dynamic nature of the stakeholders is strongly demonstrated in chapter five through examining the impact that future changes in ESE are likely to have on the interaction of the stakeholders and the future of TERR in the FBM.

The results that emerged from chapter three reflect the current views of the decisions makers in the FBM, representatives from the UK regulatory bodies, consultancy institutes and non- government organisations that currently work with or on behalf of the FBM sector. Five main points emerged from the stakeholders' analysis, these will be further discussed in relationship to the wider literature and the findings from chapter five throughout this section:

1- The supermarkets are a powerful stakeholder and their approval is essential for the success of TERR applications in the FBM sector. What is evident from the data that emerged from the semi structured interviews is that although the supermarkets in the UK try to portray a green and an environmentally conscious image, sustainability projects such as TERR applications seem not to have been given enough attention or support by this salient stakeholder. The research data also provide strong evidence that the lack of the supermarkets' support is currently having a strong negative impact on TERR application in the FBM (this is further discussed on pages 288, 289 and 290).
2- The high quality of water that can be generated by using the current available technologies seems to have limited impact on the perceived high risks associated with reusing the regenerated water in process areas. Although quality control procedures such as HACCP and ISO 9000 are well established and followed by all the companies that took part in the survey, there was an evident reluctance by the decision makers in the FBM to extend these quality control programmes to incorporate monitoring the safety of TERR applications (this is further discussed on pages 291 – 292).

3- Whilst the UK Government is supportive of increasing water efficiency in the FBM, limited resources are currently being directed to evaluate, validate or provide guidelines to assist in the implementation of TERR applications in this sector. The research findings also provide strong evidence that there is strong reluctance from the UK Government to regulate water efficiency in the UK industrial sector or to increase the cost of industrial water or trade effluent discharge tariffs; it is clear from the narratives that were provided by DEFRA that this reluctance is mainly driven by the fear of impacting on the competitiveness and security of an already heavily regulated and cut-throat sector. This is discussed in further details in section 6.3.

4- Although decision makers in the FBM are interested in considering environmental projects such as TERR, the approval of these project is largely dependent on the support of the salient stakeholders and on the economic viability and return on investment.

What is evident from the research findings is that in the current competitive market and in the absence of regulatory enforcement TERR will only be voluntarily considered if it was linked to financial gains. This is discussed in further details in section 6.3.

5- Public perception and the media are viewed by the majority of participants as non-influential stakeholders. The data revealed that there is a general consensus amongst the decision makers in the FBM that as long as the regenerated water meets potable standards, the source of water does not have to be stated on the products' labels. Based on the discussions that were held with the Chilled Food Association and the Food Standards Agency, it is clear that this has resulted in diminishing the perceived impact of both the public and the media on the success or failure of TERR projects in the FBM (this is further discussed on pages 293 & 294).

The strong control of the supermarkets that emerged from this research corresponds with findings form the literature. Based on market figures emerging from the UK, we believe that the strong power of the supermarkets is a direct result of their dominance in the UK grocery market, in which they currently have more than 80% control (Bett et al., 2010; Blythman, 2004, Nicholson and Young, 2012). It is evident from the data presented in chapter three that this is weakening the negotiating powers of the manufacturing sites and is impacting on introducing any changes prior to getting the support and approval of the supermarkets. In addition, this approval is often dependent on obtaining the consent of the retail buyers, who can play a crucial part in securing the contracts with the supermarkets. The majority of participants indicated that based on previous dealings with the supermarkets, the retail buyers will currently reject products that have used regenerated water and that this will inevitably lower the interest of investigating the possibility of TERR applications within the manufacturing sites.

These results correspond with findings relating to other innovative applications in the FBM. For example, the objection and negative impact of the retail buyers on purchasing products that contain genetically modified crops is well documented in the literature. However, in contrast to the findings from this research, these were mainly driven by the perceived negative impact on the acceptance of the consumers (knight et al., 2008; Woodside et al., 2005). As discussed later on in this section, the data that emerged from this research suggest that the impact of public opinion on TERR applications in the FBM is currently low and should not act as a barrier against this application. In addition, the data from this research provide strong evidence that the reasons behind the perceived rejection of the retail buyers to TERR applications can be multiple: i) lack of technical know-how, ii) low interest in projects that are not directly linked to improving the financial gains of the supermarkets and iii) perceived negative impact on the quality and shelf life of own- label products.

In the literature the power and strong control of the supermarkets is mostly reported on processes involving own label products (Hyde et al., 2001), however, what is evident from this research is that due to the nature of water as a raw ingredient, the decisions taken by the supermarkets regarding TERR applications will have a strong impact on the overall water management practices on a processing site. This is mainly due to the complexity of having two or more sources of water within the same manufacturing site.

In the absence of the support of the retail buyers, the results clearly indicate that the UK Government can play an important role in promoting TERR applications in the FBM. The research findings provide strong evidence that a number of strategies can be evaluated and if successful be introduced to assist in making TERR applications easier to implement by the FBM sector: i) provision of clear strategies and guidelines detailing how to safely implement and manage TERR projects, ii) initiating field trials to demonstrate the safety and reliability of the current available technologies, iii) running educational campaigns to improve the awareness and technical know-how of the retail buyers, decision makers in the FBM and government auditors and iv) introducing financial incentives to improve the financial return on investment of TERR projects. Unfortunately and based on the data that emerged from this research none of the above is currently being addressed by the UK Government.

The important role that the UK Government can potentially play to assist in the uptake of TERR applications was further emphasised by the narratives that emerged from the future scenarios. These narratives highlight the significant positive impact that the provision of clear guidelines, improving the knowledge of the stakeholders and introducing incentives, taxation and penalties can have on gradually driving the acceptance of both the decision makers in the FBM and the salient stakeholders including the supermarkets.

In our view it is inevitable that innovative applications in any sector will entail a certain amount of risk. However, a number of strategies are already in place in the FBM sector to identify, allocate and manage a variety of risks that can impact on product quality and shelf life. As detailed in the literature review, HACCP principles have been applied to ensure the quality of drinking water in the FBM since 1994 (Havelaar, 1994; Trienekens and Zuurbier, 2008) and the use of HACCP for water reuse applications was proposed by Casani in 2002 (Casani and Knochel, 2002). In addition to HACCP, all of the FBM sites that took part in the qualitative survey followed additional quality control assurance schemes such as ISO 9000. However, what is apparent from the research findings is the lack of understanding and associated reluctance of the decision makers in the FBM to incorporate these systems to monitor the quality and safety of the regenerated water. In our view and taking into account the data that emerged from this research, we believe that this is mainly due to: i) the uncertainties that currently surround TERR and which are currently amplified by the lack of field data and guidelines and ii) the lack of knowledge regarding how to integrate and manage HACCP in TERR applications. It is clear from the narratives provided by the decision makers in the FBM that incorporating an additional application to the existing quality control schemes is currently considered as a quality challenge and a constraint.

These findings reemphasise the important role that the provision of training and the introduction of clear guidelines can have on facilitating TERR applications in the FBM through detailing the steps that are needed to integrate TERR applications with existing methodologies and quality control strategies. What is also evident from the research data is that the FBM will only adopt tried and tested applications that have been proven to be safe, reliable and successful by competitors from similar FBM sub-sectors. It is clear from the data that emerged from the semi-structured interviews that in an attempt to minimise the risk of exposure all FBM sites seemed to be reluctant to take the lead in considering TERR projects. It can therefore be argued that changes to TERR applications are more likely to be incremental rather than radical.

Based on the narratives that emerged from the future scenarios it is projected that a number of factors can play an effective role in introducing these incremental changes, mainly: i) pressure from the consumers, ii) water shortages that can impact on producing more and cheaper, iii) water shortages that can limit market expansion and competitiveness and iv) linking TERR applications to financial gains. The impact of the public and economic feasibility on TERR applications will be discussed in further details later on in this section.

The perceived diminished role of the public on the acceptance of TERR applications is one of the most unexpected outcomes of this research and contradicts findings from the literature regarding previously studied water reuse projects. Public acceptance has been identified as an essential factor for the success of a number of greywater and regenerated municipal water reuse applications (Domenech and Sauri, 2010; Friedler et al., 2006)). There are also examples in the literature where the public were able to stop water recycling projects, even after the approval of official bodies (Hurlimann and Dolnicar, 2010). As mentioned earlier, we believe that the views reported by the stakeholders are strongly influenced by the food labelling requirements in the UK. Both the manufacturing sites and the official bodies indicated that as long as the regenerated water is of potable standards there would be no regulatory obligations to state the source of water used in the products. However, we believe that it is still important to explore the impact that the public can potentially have should they become aware of TERR applications in the FBM. In our view this is important as there is market evidence that in that past supermarkets have used independently certified labels such as the “FAIRTRADE” mark or “free from GM” to either promote or sell against competitors’ products (Carlsson et al., 2004). We also believe that it is important to ethically debate the right of the consumers to know if regenerated water is being used in the products that they are consuming.

Similarly and based on the factors listed above the research contradicts results from the literature regarding the significant role that the media can play in highlighting or raising alarms regarding the use of regenerated water in process areas (Cope et al., 2010; Jeffers et al., 2014).

In contrast to the above findings, results from the future scenarios clearly demonstrate the potential power that the public can have in driving TERR applications should they become supportive and/ or more inclined to purchasing goods that have used regenerated water. The data that emerged from the future scenarios highlight the importance of establishing the steps that are needed to develop the consumers' confidence in TERR applications in the FBM and to improve the awareness of the public regarding the potential sustainability benefits that can arise from a widespread application in the UK. The narratives from the future scenarios clearly indicate that increasing the awareness of the public and the stakeholders on the future risks that might face the UK in terms of water and food security is likely to have a significant impact on how the stakeholders view TERR projects in the FBM. Lessons could be learnt from previous applications in the FBM sector where education, clever marketing and government and supermarket campaigns have been successful in introducing significant changes to food preparation practices, new ranges of flavours and different diets in the UK (Havelaar et al., 2010).

6.3 Economic Feasibility

Results from the stakeholders' analysis clearly indicate that linking TERR applications in the FBM to economic gains can play a crucial role in initiating a number of incremental changes that are identified as being necessary to facilitate the approval of future projects in the UK: i) directing more funds towards research and development, ii) initiating field trials and iii) gaining the support of the salient stakeholders.

What is evident from the research findings is that in the absence of regulatory enforcement and lack of current market pressures, TERR in the FBM will only be voluntarily considered by the FBM if it was linked to financial gains. The results also indicate that due to the current uncertainties surrounding the FBM sector and which is driven by the short term contracts with the supermarkets, the payback period of TERR applications must fall within 24 months period for the projects to be approved.

The case study presented in chapter four provides a comprehensive cost benefit analysis of a TERR application in a major FBM sub sector. Although the findings presented in this chapter are specific to the dairy processing sector, the methodologies, technologies and trade effluent treatment plants used in the case study can be extended to evaluate the economic feasibility of TERR applications in other FBM sub-sectors.

The trade effluent treatment plant was designed based on the actual trade effluent characteristics that were measured during the duration of the case study (appendix 4-1). Due to the chemical and physical characteristics of the trade effluent and the need to regenerate water of potable standards, advanced tertiary treatments including MBR, ultrafiltration and reverse osmosis are evaluated in the case study.

The economic feasibility is evaluated taking into account the capital and operating costs and the site mains water and trade effluent discharge costs. Based on a capital investment of around £390,000 per annum, the payback period is estimated to be around 8.6 years. This is lowered to around 6 years when including the current financial incentives that are provided by the UK Government to assist in the implementation of sustainability projects. These results clearly indicate that even when including the government incentives the payback period remains significantly higher than the 2 years conditional limit that was specified by the stakeholders in chapter three of this thesis.

In our view, the above findings are not surprising considering the current cost of mains water in the UK and the complex technologies and testing protocols that have to be followed to ensure the quality of the regenerated water. As detailed below this necessitates further analysis in order to explore alternative options or interventions that can assist in improving the economic feasibility of TERR projects in the FBM. Results from the literature clearly demonstrate that the long return on investment figures that emerged from the case study are not unique to TERR application in the FBM but are common in most sustainability applications (Badi and Pryke, 2016). We therefore believe that there is a need to investigate the possibility of extending some of the strategies that have been proven successful in lowering the initial financial burdens of some sustainability projects to TERR applications in the FBM:

1- Establishing social enterprises that can fund TERR projects: Based on successful applications in the energy sector this could involve funding the projects over a long period of time and recuperating the costs from sharing the annual savings that are generated from the project (Horst, 2008).

2- Extending the role of the UK Green Bank to include TERR applications in the FBM. The UK Government established the Green Bank in 2012 to provide long term funding (20-25 years) for sustainable energy projects such as solar energy and wind farms. In 2015 it was reported that the bank has invested around £8 billion on these green projects (WMIN, 2015).

Based on the data that emerged from the case study the payback period within which the Green Bank and the social enterprises operate can be achieved by a 50% contribution of the net savings that are estimated from the case study. However, based on the actual site figures the above payments will reduce the net annual savings that can be achieved from the project to around £20,000 per annum. In our view and if only evaluating the project in terms of financial gains these annual savings might not be high enough to generate an interest in TERR applications particularly when taking into account the current complexities that surround this application. There is therefore a need to include additional benefits in these evaluations such as the sustainability benefits including the role that TERR in the FBM can play in improving the ability to meet future increases in water demands and in enabling the expansion of manufacturing and levels of production. However, as discussed throughout this thesis, more work is still needed from the UK Government to improve the awareness regarding the direct and indirect non-economic benefits that can be achieved from TERR applications in the FBM.

In our view there is also a need to further investigate other areas that will have a significant direct impact on the economic feasibility of TERR projects mainly the cost of mains water and trade effluent discharge costs.

3- Establishing the true value of water: The average cost of mains water in the UK is around £1/m^3 and is one of the lowest in Western Europe. This is for example compared to £4.7/m^3 in Denmark (Vajnhandl and Valh, 2014). It is clear from the data presented in chapter four that using the Danish water tariffs will result in significantly lowering the payback period of the project to under two years. Similar reductions in the payback period can also be achieved by increasing the discharge costs of the trade effluent. However, it is evident from the discussions that were held with DEFRA that although the UK Government is aware that the current tariffs don't reflect the true value of water, there is a current reluctance in increasing the industrial tariffs of both mains water and trade effluent discharge costs. This reluctance is mainly driven by serious concerns regarding the negative impact that the above changes might have on the competiveness and security of the FBM sector in the UK. Similar views were also expressed by DEFRA regarding tightening the trade effluent discharge consent parameters. Based on the data that emerged from the field survey and associated discussions with DEFRA and the EA, it is evident that tighter discharge limits are currently only enforced in a minority of cases when the trade effluent is discharged to surface waters. Although the data presented in figure 2.9 clearly indicate that treating the trade effluent to higher standards will encourage water reuse applications, it is evident from the research findings that no future plans are currently in place to tighten the discharge consent limits for the majority of companies that can discharge to the sewer.

4- Water Synergy models: Alternative approaches are reported in countries such as Australia where the industrial water is centrally treated and regenerated to variable standards depending on the reuse applications. However, it is evident from the literature that in most cases these projects are heavily subsidised by the government and will require separate distribution network (Molinos-Senante and Hernandez-Sancho, 2013). In our view such programmes will not benefit the FBM sector where water of potable standards is needed, in addition, these projects will require huge investment and a new and dedicated distribution infrastructure. Taking into account the challenges that are currently facing the utilities providers in maintaining the existing distribution network (OFWAT, 2011), it is unlikely that funds will be made available to install parallel water distribution systems. Taking these factors into account we believe that it would be more economically feasible to subsidise on -site projects through social enterprises and/or publically owned banks.

5- Future decrease in the cost of technologies: Although a widespread applications of TERR in the FBM might yield to a slight decrease in capital costs (Judd, 2011), based on the figures that emerged from the case study an unlikely reduction of more than 70% will be needed to reduce the payback period to around 2 years.

Based on the above one can argue that if the value of water is not truly reflected in its cost, water recycling and reuse projects will inevitably be too expensive to implement. Based on the findings that emerged from this research we believe that there is a need to include non-financial factors when evaluating the benefits that can be achieved from TERR projects, mainly the impact on future water security. There is also a need to investigate whether a 2 years payback period is realistic for complex sustainability projects such as TERR applications in the FBM. As detailed in chapter three more input is needed from the UK Government to improve the current short term contracts with the supermarkets; providing longer term security for the manufacturing sites will assist in extending the payback period requirements of innovative projects including TERR.

In summary the following main points emerged from evaluating the economic feasibility and return on investment of TERR projects in the FBM:

1- Subsidising TERR applications is the most favourable option which if implemented effectively could assist in funding the initial capital investment that is needed to set up TERR projects.

2- A number of industrial funding mechanisms are already in place but there is a need to establish the possibility of extending those to support TERR applications.
3- More options could be available to reduce the payback period of TERR applications should the UK Government review the cost of industrial water and trade effluent discharge costs.

6.4 Conclusion

The important role that TERR in the FBM can play in providing renewable water supplies is well demonstrated in this research. Based on the projected figures of population growth, urbanisation and changes in consumption patterns it is inevitable that applications such as TERR are going to be essential to bridge the projected future gap between water demand and available water supplies. However, it is evident from the research findings that more investment is going to be needed in order to address a number of areas that can currently make TERR applications in the FBM challenging to implement. These can be summarised as follows:

1- Improving the economic feasibility of TERR projects and providing financial support and incentives.
2- Provision of clear guidelines regarding the implementation of TERR projects and extending existing quality control and management schemes to incorporate these projects.

3- Initiating field trials and pilot studies to validate the reliability and safety of TERR applications in the field.

4- Improving the knowledge and awareness of all the stakeholders that can play a part in the approval of TERR projects including the FBM sites, the retail buyers and the government and auditing officials.

5- Getting the support and approval of the salient stakeholders particularly the supermarkets.

It is clear from the data that is presented in this thesis that these changes can only be possible with the involvement, support and cooperation of the UK Government, decision makers in the FBM and the salient stakeholders.

It is hoped that this research will direct the light on an important application that can assist in minimising the significant water wastage that currently characterises the UK FBM sector and which can play a role in improving the future water resilience and food security of the UK.

Although the focus of this research is on TERR applications in the FBM sector in the UK, results and methodologies are transferable to sustainable water management applications in other countries and other industries.

7 CONCLUSION

7.1 Introduction

The work presented in this thesis is pioneering in providing a holistic research on trade effluent recycling and reuse in the food and beverage manufacturing sector. This was achieved through:

1. Evaluating the current state of TERR in the FBM in the UK and establishing the water savings that can be achieved from this applications under current and alternative future conditions.
2. Providing detailed analysis and evaluation of the current and future interaction of the stakeholders and their impact on the decisions taken by the FBM to approve TERR applications.
3. Evaluating the economic feasibility of TERR applications in the FBM.

Based on an extensive literature review and discussions with a number of UK Government department, consultancy bodies and the FBM, we believe that this is the first comprehensive study on TERR in the FBM in the UK and Europe.

7.2 Contributions to knowledge

The following contributions emerged from the work presented in this thesis:

1- The research is the first study in the UK to quantify the current and potential future water savings that can be achieved from a widespread application of TERR in the FBM in the UK.
2- According to our knowledge, the field survey presented in chapter 2 of this thesis is the first comprehensive evaluation of the current water management practices that are followed by the FBM in the UK.
3- The research is unique in combining Freeman's stakeholder methodology with grounded theory methodology to provide a comprehensive understanding of how the stakeholders in the FBM interact to impact on the approval of TERR projects.
4- The research is the first to develop future scenarios' narratives that are specific to TERR applications in the FBM and to combine future scenarios with stakeholders' analysis.

   In the literature future scenarios are used to test the resilience of a certain policy or strategy under alternative environmental and socio-economic (ESE) conditions. In addition to the above, future scenarios have been used in this thesis to understand how the stakeholders' in the FBM can potentially interact to impact on TERR applications as the projected alternative ESE conditions emerge.

5- The case study presented in chapter 4 of this thesis is the first in the UK and Europe to provide a comprehensive analysis of the economic feasibility that can be achieved from TERR applications in the FBM.

7.3 Summary of Research Findings

A common theme emerged from the thesis and linked the findings from all the research chapters.

TERR in the FBM can potentially contribute to significant water savings in the UK; these are likely to remain significant under all the projected future changes in ESE. However, in spite of this potential role in improving the current and future water resilience of the UK, limited resources are currently directed towards researching, evaluating or implementing TERR applications in this sector. This is having a negative impact on the uptake of TERR and is leading to limited applications across all the FBM subsectors.

In order for TERR to be widely considered by the FBM it is essential to direct more research and resources in order to assist in establishing the steps and strategies that are needed for the approval and implementation of TERR projects.

It is evident from the research findings that change can only be possible through the collective effort and collaboration of all the stakeholders in the FBM.

The data that emerged from this thesis highlight a number of areas that will be essential for the success and widespread application of TERR projects. These can be summarised as follows:

1- Validation of the technologies used in the generation of potable water from trade effluent.

2- Improving the awareness and knowledge of the stakeholders that are involved in the approval of TERR projects. This can only be possible through the input and support of the UK Government to:

   a. Finance trials to validate the safety of TERR applications in the FBM.

   b. Provide guidelines to assist in the approval and implementation of TERR projects, including expanding existing quality control schemes to include TERR applications.

3- In the absence of regulatory enforcement there is a need to improve the current economic feasibility of TERR projects. This can only be possible by addressing the following areas:

   a. Providing long term funding to cover the initial high capital costs.

   b. Providing incentives that can contribute to lowering the return on investment.

   c. Reviewing the water pricing structure, effluent discharge costs and effluent consent parameters.

d. Improving the awareness of the stakeholders in the FBM so that the sustainability and environmental benefits are included in the return on investment evaluations.
e. Improving the contractual agreements between the supermarkets and the FBM to assist in the approval of TERR projects even if the payback period exceeded 24 months.

Given the significant current and projected future water savings that can be achieved from TERR in the FBM, it would be desirable for the above steps to be given more investment and attention by all the stakeholders in the FBM including the UK Government and the supermarkets.

It is hoped that the findings that emerged from this thesis will act as an incentive to increase the interest in trade effluent recycling and reuse in the FBM in order to lower the dependency of this sector on non-renewable water resources.

7.4 Further Research Requirements

A number of potential possibilities for further research were recognised during the course of this project:

1- We were unable to get the approval to interview any of the supermarkets in the UK. As an alternative, interviews were carried out with a main research institute that currently works on their behalf to evaluate innovative projects. However, it might be beneficial to re-address this in the future in order to get a direct perspective of this influential group.

2- There is a need to explore how the public might react to the use of regenerated water in food processing applications and to ethically debate the right of the consumers to know the type of water that is used in the food products.

3- Based on the thesis findings, it is important that future work is carried out by the UK Government and the water providers to evaluate the impact that changes in water and effluent discharge costs might have on TERR applications.

4- There is a need to investigate the possibility of extending the role of the Green Bank to support TERR applications in the FBM and to explore alternative ways to improve the economic feasibility of TERR applications.

5- Future work will also be needed to investigate the liability of operating and maintaining the water recycling systems that can be used in TERR projects.

6- It might be also beneficial to verify the findings from the case study by implementing a pilot study at a dairy manufacturing site. This can then be rolled out to other sub sectors within the FBM.

7- The work on future scenarios can be extended to carry out further workshops in order test the stakeholders’ interaction that was projected in this thesis.

References

ADOPBIO (2007). Advanced Oxidation Process and Biotreatments for Water Recylcing in the Textile Industry. www.cordis.europa.eu.

Alcamo, J. (2008). Environmental futures : The practice of environmental scenario analysis . Boston: Elsevier.

Allinson, G., D. Halliwell, et al. (2007). "Closing the loop on a large, multi-disciplinary dairy waste project." The Australian Journal of Dairy Technology **62**(3): 135-153.

Alturki, A. A., N. Tadkaew, et al. (2010). "Combining MBR and NF/RO membrane filtration for the removal of trace organics in indirect potable water reuse applications." Journal of Membrane Science **365**(1–2): 206-215.

Almeida, G, J.Vieira, A. Marques, A. Kiperstok, A. Cardoso (2013). "Estimating the potential water reuse based on fuzzy reasoning". Journal of Environmental Management **128**: 883-892.

Amar, N.B., N. Kechaou, J. Palmeri, A. Deratani, A. Sghaier (2009). "Comparison of tertiary treatment by nanofiltration and reverse osmosis for water reuse in denim textile industry". Journal of Hazardous Materials **170:** 111-117.

Andrade, Motta, et al. (2013). "Treatment of dairy wastewater with a membrane bioreactor " Brazilian Journal of Chemical Engineering **30**(4): 759-770.

Arévalo, J., G. Garralón, et al. (2009). "Wastewater reuse after treatment by tertiary ultrafiltration and a membrane bioreactor (MBR): a comparative study." Desalination **243**(1–3): 32-41.

Avula, R. Y., H. M. Nelson, et al. (2009). "Recycling of poultry process wastewater by ultrafiltration." Innovative Food Science & Emerging Technologies **10**(1): 1-8.

Badi, S.M., S. Pryke (2016)."Assessing the impact of risk allocation on sustainable energy innovation (SEI)". International Journal of Managing Projects in Business **9** (2): 259-281.

Barford, V. and L. Everitt (2012). Eight radical solutions for the water shortage. www.bbc.com/news.

Barraquier, A. (2013). "A Group Identiity Analysis of Organizations and Their Stakeholders: Porosity of Identity and Mobility of Attributes". Journal of Business Ethics **115**:45-62.

BATTLE (2008). Best Available Technique for Water Reuse in Textile. www.life-battle.bologna.enea.it.

BBC News (August 2015). Petition for parliamentary inquiry into Lancashire water bug. www.bbc.co.uk/news.

Bett, C., J.O. Ouma, H. De Groote (2010). "Perspectives of gatekeepers in the Kenyan food industry towards genetically modified food". Food Policy **35**: 332-340.

Binnie, C. and M. Kimber (2009). Basic Water Treatment . Bristol: Thomas Telford.

Birks, M. and J. Mills (2011). Grounded Theory a Practical Guide. London: Sage.

Blaikie , N. (2011). Designing Social research .Cambridge: Polity press.

Blöcher, C., M. Noronha, et al. (2002). "Recycling of spent process water in the food industry by an integrated process of biological treatment and membrane separation." Desalination **144**(1–3): 143-150.

Blythman, J. 2004. Shopped: A Shocking Power of the British Supermarkets.

Bryant, A. and K. Charmaz (2007). The Sage Handbook of Grounded Theory. London: Sage.

Business-Dictionary (2013). "Business Dictionary www.businessdictionary.com."

Calton, J.M and N.B. Kurland (1996). A theory of stakeholder enabling: giving voice to an emerging postmodern praxis of organizational discourse. Sage Publicatios , London.

Carlsson, F., P. Frykblom, C.J. Lagerkvist (2004). Consumer benefits of labels and bans on genetically modified food- An emperical analysis using Choice Experiments. Paper presented at the American Agricultural Economics Association Annual Meeting, Denver, Colorado.

Carrol, A. and A. Buchholtz (2006). Business and Society: Ethics and Stakeholder Management. Thomson South- Western, Belmont CA.

Casani, S. and S. Knochel (2002). "Application of HACCP to water reuse in the food industry.pdf." Food Control **13**: 315-327.

Casani, S., T. Leth, et al. (2006). "Water reuse in a shrimp processing line: Safety considerations using a HACCP approach." Food Control **17**(7): 540-550.

Casani, S., M. Rouhany, et al. (2005). "A discussion paper on challenges and limitations to water reuse and hygiene in the food industry." Water Research **39**(6): 1134-1146.

CBS (2011). Israel, Central Bureau of Statistics. www.cbs.gov.il.

Ceeney, L. (2011) No drop in the ocean. Sustainable Business. www.sustainablebusinessonline.com

Charmaz, K. (2006). "Constructing Grounded Theory: A paractical guide through qualitative analysis". London: Sage.

Checkland, P. (1999). "Systems thinking, systems practice: a 30 years retrospective. John Wiley and Sons. Chicester.

Cheng, L.H. and H.K. Fan (2010). "Drivers of Environmental Disclosure and Stakeholder Expectation: Evidence from Taiwan." Journal of Business Ethics **96**: 435- 451.

Chiovitti, R. F. (2003). "Rigour and grounded theory research." Journal of advanced nursing **44**(4): 8.

Chmiel, H., M. Kaschek, et al. (2002). "Concepts for the treatment of spent process water in the food and beverage industries." Desalination **152**(1-3): 307-314.

Chmiel, H., V. Mavrov, et al. (2000). "Reuse of vapour condensate from milk processing using nanofiltration." Filtration & Separation **37**(3): 24-27.

CIWEM (2011). "Integrated Water Management". Chartered Institute of Water and Environmental Management. www. ciwem.org.

Codex-Alimentarius (2001). Poposed draft guidlines for the hygienic used of processing water in food plants. FAO/WHO Food Standards Programme. www.codexalimentarius.org/standards.

Colla, V., T.A. Branca, F. Rosito, C. Lucca, B.P. Vivas, V.M. De;miro (2016). "Sustainable Reverse Osmosis application for wastewater treatment in the steel industry." Journal of Clean Production **130**: 103-115.

Comerton, A. M., R. C. Andrews, et al. (2005). "Evaluation of an MBR–RO system to produce high quality reuse water: Microbial control, DBP formation and nitrate." Water Research **39**(16): 3982-3990.

Cope, S., L.J. Frewer, J. Houghton, G. Rowe, A.R.H. Fischer, J. de Jonge (2010). "Consumer Perception of best practice in food risk communication and management: Implications of risk analysis policy". Food Policy **35**: 349-357.

Corbin, J., A. Strauss, et al. (2008). Basics of qualitative research: Techniques and procedures for developing grounded theory. California: Sage

Council-Directive (1998). Council Directive 98/83/EC of 3rd November 1998 on the quality of water intended for human consumption. www.eea.europa.eu/council-directive

Cuppen, E. (2012). "A quasi-experimental evaluation of learning in a stakeholder dialogue on bio-energy." Research Policy **41**(3): 624-637.

Cuppen, E., Breukers S., Hisschemoller M. & Bergsma E. (2010). "Q methodology to select participants for a stakeholder dialogue on energy options from biomass in the Netherlands". Ecological Economics **69**: 579-591.

Dairy-Statistics (2014). "Dairy Statistics www.dairyco.org.uk."

Dahlmann, F.,Brammer, S., & Millington, A. (2008). "Barriers to proactive environmental management in the United Kingdom: Implications for business and public policy". Journal of General Management, **33**(3):1-20

DEFRA (2005). Rural Futures Project: Scenario creation and Backcasting project SD0303. www.DEFRA.gov.uk.

DEFRA (2006). Food Industry and Sustainbility Strategy . www.defra.gov.uk

DEFRA (2007a). Environmental Impact of Food Production and Consumption. www.defra.gov.uk.

DEFRA (2007b). Report of the Food Industry Sustainability Strategy Champions' Group on Water www.defra.gov.uk.

DEFRA (2008). Future water- The government's water strategy for England . www.defra.gov.uk.

DEFRA (2010). Environmental Permitting Guidance Water Discharge Activities. www.defra.gov.uk.

DEFRA (2011a). Water white paper: Water for life. www.defra.gov.uk.

DEFRA (2011b) . Drought declared in the Anglian Region. www.defra.gov.uk.

DEFRA (2012). The Federation House Commitment Report . www.defra.gov.uk.

DEFRA (2014a). Food Statistics. www.defra.org.uk.

DEFRA (2014b). Water abstraction reform and drought. Supporting infromation for digital dialogue on drought. www.defra.org.uk.

DEFRA (2015). Enhanced Capital Allowance Scheme for Water Efficient Technologies www.defra.org.uk.

DEFRA (2016). Reforming the water abstraction management system: making the most of every drop. www.defra.org.uk.

Delgado-Ceballos, J., J.A. Aragon Correa (2012). "The effect of Internal Barriers on the Connection Between Stakeholder Integration and Proactive Environmental Strategies" Journal of Business Ethics **107**: 281-294.

Den Aantrekker, E. D., A. Van Der Padt, et al. (2003). "Modelling the effect of water recycling on the quality of potato products." International Journal of Food Science and Technology **38**(4): 427-434.

Domènech, L. and D. Saurí (2010). "Socio-technical transitions in water scarcity contexts: Public acceptance of greywater reuse technologies in the Metropolitan Area of Barcelona." Resources, Conservation and Recycling **55**(1): 53-62.

Donaldson , T., Perston L. (1995). "The stakeholder theory of the modern corporation: Concepts , evidence and implicaitons". Academy of Management Review **20**: 65-91.

Dryzek, J.S. and J. Berejikian (1993). "Reconstructive democratic theory. The American Political Science Review **87**:48-60.

Dyllick,T. and K. Hockerts (2002). "Beyond the business case for corporate sustainability". Business Strategy and the Environment **11**(2):130.

DWI (2013). Drinking water products www.defra.gov.uk.

EA (2006). "Environment Agency Scenarios 2030 , Science Report SC050002 . www.environment-agency.gov.uk."

EA (2008 a). Environment Agency: Water resources in England and Wales - current state and future pressures. www.environment-agency.gov.uk.

EA (2008 b). Environment Agency : Climate change and river flows in the 2050s. www.environment-agency.gov.uk.

EA (2009). Environment Agency : Demand of water in the 2050's. www.environment-agency.gov.uk

EA (2010). Environment Agency : Water for people and the environment : Water resources action plan for England and Wales. www.environment-agency.gov.uk

EA (2011a). Environment Agency : The case for change- Current and future water availability. www.environment-agency.gov.uk

EA (2011b). Environment Agency : The case for change- reforming water abstraction management in England. www.environment-agency.gov.uk.

EA (2012). Environment Agency: Water resources and Drought Prospects for summer/autumn and winter 2012/2013. www.environment-agency.gov.uk.

EA (2013 a). "Environment Agency: Food and drink manufacturing water demand projections to 2050. www.environment-agency.gov.uk."

EA (2013 b). Environment Agency : Water for Live and Livelihood. www.environment-agency.gov.uk

EA (2013 c). "Environment Agency: Water stressed areas- final classification. www.environment-agency.gov.uk."

EA (2014). "A monthly review of the water situation in England. www.environment-agency.gov.uk."

EC (2004). Guidance document on the implementation of certain provisions of regulation on the hygiene of foodstuffs (EC) No 852/2004. ec.europa.eu/food/food/biosafety/guidance_doc_852-2004

EC (2006). European Commision : Water scarcity and drought- in depth assessment. www.europa.eu

EC (2007). European Commision : Addressing the challenge of water scarcity and drought in the European Union. www.ec.europa.eu. E. Commision. Brussels.

EC (2012). European Commision : Population and population growth statstics. www.ec.europa.eu/eurostat.

Eckenfelder, W. and J. Musterman (1998). Activated Sludge: Treatment of Industrial Wastewater. New York CRC Press

EEA (2009). European Environment Agency : Water resources across Europe :

Confronting water scarcity and drought. www.eea.europa.eu.

Ekstrom, H., J.Esseveld and B. Hovelius (2005). "Keeping my ways of being: Middle -aged women dealing with the passage through menapause". The Grounded Theory Review **5**(1):21-53.

Elias A.A. (2012). "A system dynamics model for stakeholder analysis in environmental conflicts". Jounral of Environmental Planning and Management **55**(3): 387-406

Elliott, N. and A. Higgins (2012). "Surviving Grounded \theory Research Method in an Academic World: Proposal Writting and Theoretical Framework." The Grounded Theory Review **11**(2): 12.

Elliott, N. and J. Jordan (2010). "Practical strategies to avoid the pitfalls in grounded theory research " Nurse Researcher **17**(4): 29-40.

EMCC (2006). European Monitoring Centre on Change: Trends and drivers of change in the food and beverage industry in Europe: Three scenarios. www.eurofound.europa.eu.

EPA (2014). United States Environmental Protection Agency :Gound Water and Drinking Water. www.water.epa.gov/drink/contaminants/index

EU-Directive (1993). Council Directive 93/94/EEC of 14 June 1993 on the hygiene of foodstuffs. www.ec.uropa.eu/food.

EUROSTAT (2015). People in the EU: Who are we and how do we live? ec.europa.eu.

Farmani, R., D. Butler;, et al. (2012). "Scenario- based sustainable water management and urban regeneration ". Engineering Sustainability **165**(1): 89-98.
FDF (2012). The UK Food and Drink Industry : A 20/20 vision for growth. Food and Drink Federation. www.fdf.org.uk

Fassin, Y. (2009). "The Stakeholder Model Refined". Journal of Business Ethics **84**:113-135.

Fassin, Y. (2008). Imperfections and Shortcomings of the Stakeholder Model's Graphical Respresentation. Journal of Business Ethics **80**: 879-888.

FDF (2014). Delivering sustainable growth through innovation. Food and Drink Federation. www.fdf.org.uk

Ferrary, M. (2009). "A Stakeholder's Perspective on Human Resource management." Journal of Business Ethics **87**: 31-43.

Fletcher, H., T. Mackley, et al. (2007). "The cost of a package plant membrane bioreactor." Water Research **41**(12): 2627-2635.

Flick, U. (2006). An introduction to qualitative research. London: SAGE.

Foresight (2009). Scenario Planning London Government Office for Science . www.bis.gov.uk.

Freeman, R.E et al (2012). "Stakeholder Theory(ies): Ethical Ideas and Managerial Action". Journal of Business Ethics **109**:1-2

Freeman, R.E. et al (2010). Stakeholder Theory : The State of the Art. Cambridge University Press. Cambridge.

Freeman,R. E. (1984). Strategic Management: A stakeholder Approach. Pitman, Boston.

Friedler, E., O. Lahav, et al. (2006). "Study of urban population attitudes towards various wastewater reuse options: Israel as a case study." Journal of Environmental Management **81**(4): 360-370.

Frooman, J. (1999). "Stakeholder Influence Strategies". Academy of Management Reviews **24**(102):191-205.

Fuerhacker, M. (2009). "EU Water Framework Directive and Stockholm Convention." Environmental Science and Pollution Research International **16**: 92-97.

Giurco, D., A. Bossilkov, et al. (2011). "Developing industrial water reuse synergies in Port Melbourne: cost effectiveness, barriers and opportunities." Journal of Cleaner Production **19**(8): 867-876.

Glaser, B. G. (1998). Doing gounded theory: Issues and perspectives California: Mill Valley.

Glaser, B. G. and J. Holton (2004). "Remodeling grounded theory." qualitative Social Research **5**(2): 1-17.

Glaser, B.G. (2003). The Grounded Theory Perpective II. Mill Valley, CA: Sociology Press.

Glaser, B. G. and J. A. Holton (2005). "Staying Open: The use of theoretical codes in grounded theory." The Grounded Theory Review **5**(1): 1-20.

Glaser, B. G. and A. L. Strauss, Eds. (1967). The discovery of grounded theory: Strategies for qualitative research. Chicago: Aldine Publishing company.

Gonzalez- Benito, J. and O. Ganzalez- Benito (2010). "The study of determinant factors of stakeholder environmental pressure precieved by industrial companies " Business Strategy and the Environment **19**: 164-181.

Gray, N. F. (2010). Water Technology: An Introduction for Environmental Scientists and engineers . London: Elsevier.

Grimble, R. and K. Wellard (1997). "Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities." Agricultural Systems **55**(2): 173-193.

Gutterres, M., P.M. Aquim, J.B. Passos, J.O. Trierweiler (2010). " Water reuse in tannery beamhouse process". Journal of Cleaner Production **18:** 1545-1552.

Haigh, N. and A. Griffiths (2009). "The natural environment as a primary stakeholder: the case for climate change " Business Strategy and the Environment **18**: 347-359.

Hare, M. and C. Pahl-Wostl (2002). "Stakeholder categorisation in participatory integrated assessment" Integrated Assessment **3**:50-62.

Harrison, J.S., St John, C.H. (1994). Strategic management of organisations and stakeholders. West Publishing Company. St Paul.

Hasnas, J. (2013). "Whither Stakeholder Theory? A Guide for the Perplexed Revisited" Journal of Business Ethics **112**: 47-57.

Havelaar, H. (1994). "Application of HACCP to drinking water supply". Food Control **5**: 145-152.

Havelaar,H., A., B. Stanley, et al. (2010). "Future challenges to microbial food safety." International Journal of Food Microbiology **139** S79-S94.

Henly, S (2012). "Water shortage promts action". Crops **10**:27-29

Hills,P. (2005). "Environmental reform, ecological modernization and the policy process in Hong Kong: an exploratory study of stakeholder perspective. Journal of Environmental Planning and Management **48**(2): 209-240.

Holah J. (2012). "Guidelines on the reuse of potable water for food processing operations" CAmpden BRI. www.campden.co.uk.

HMRC (2015). CA - Capital Allowances Manual. www.hmrevenueandcustoms.gov.uk

Holton, J. A. (2010). "The Coding Process and its Challenges." The Grounded Theory Review **9**(1): 21-40.

Hope, R and M. Rouse (2014) Risks and responses to universal drinking water security. Philosophical Transactions of The Royal Society. www.rsta.royalsocietypublishing.org

Horst, D. (2008). "Social enterprise and renewable energy: emerging initiatives and communities of practice". Social Enterprise Journal **4** (3): 171-185.

Huang Cheng-Li, Fan-Hua Kung (2010). "Drivers of Environmental Disclosure and Stakeholder Expectation: Evidence from Taiwan" Journal of Business Ethics **96**: 435-451.

Hung, H. (2011). "Directors' roles in corporate social responsibility : A stakeholder perspective " Journal of Business Ethics **103**: 385-402.

Hunning - Richter, U. (2011). "Drivers of change: A multiple- case study on the process of institutionalization of corporate responsibility among three multinational companies " Journal of Business Ethics **102**: 261-279.

Hunt, D. (2010). Using Scenarios to expolre urban UK futures: A review of futures literature from 1997- 2010 143.

Hunt, D., D. R. Lombardi, et al. (2012 a). Urban Futures Monograph- Using Scenarios to Explore Urban UK Futures: A review of Futures Literature from 1997 to 2011.

Hunt, D., D. R. Lombardi, et al. (2012 b). "Scenario Archetypes: Converging Rather than Diverging Themes." Sustainability **4**(4): 740-772.

Hurlimann, A., S. Dolnicar (2010). "When public opposition defeats alternative water projects- the case of Toowoomba Australia". Water Research **44**: 287-297.

Hyde, K.M., Maier, H.R., Colby, C.B. (2005). "A distance-based uncertainty analysis approach to multi-criteria decision analysis for water resource decision making". Journal of Environmental Management **77**(4): 278-290.

Hyde, K., A. Smith, M. Smith, S. Henningsson (2001). " The challenge of waste minimisation in the food and drink industry: a demonstration project in East Anglia, UK". Journal of Cleaner Production **9:** 57-64.

Ian Barker, Teresa Evans, et al. (2005). Water shortage in the UK. British Science Association. www.britishscienceassociation.org.

IChemE (2015) IChemE calls for global action to cut water usage in food production. www.icheme.org

IPCC (2000). "IPCC Special Report: Emissions Scenarios. www.ipcc.gov.uk."

ISO-Insider (2004). ISO 22000 to ensure integrity of food supply chain. www.iso.org/iso/tool

Jeffers, A.E., B. Lin, S., Romero, L.A. DeGaetano (2014). "Is it time for companies to capitalize on sustainability? The CPA Journal: 6-10

Johnson, N., Lilja, N. et al (2004). "Practice of participatory reseach and gender analysis in natural resource management". Natural Resources Forum **28** (189-200).

Jones, M. and I. Alony (2011). "Guiding the use of Grounded theory in Doctoral Studies - An example from the Australian Film Industry " International Journal of Doctoral Studies **6**(95-114).

Jones, M. and G. Kriflik (2005). Grounded theory: A theoretical and practical applciation in the Australian film industry. International Quailtative Research Convention Malaysia, Qualitative Research Association Malaysia.

Jowit, J. (2010). Thames water opend first large scale desalination plant in the UK. The Guardian. www.theguardian.com

Judd, S.(2011). The MBR book: principles and applications of membrane bioreactors in water and wastewater treatment . London : Elsevier.

Judd, S. (2014). Industrial mbrs- membrane bioreactors for industrial water treament . Bedfordshire: Judd and Judd ltd

Judd, S. and B. Jefferson (2003). Membrane for Industrial Wastewater. Oxford: Elsevier Science

Kantanoleon, N., L. Zampetakis, et al. (2007). "Public perspective towards wastewater reuse in a medium size, seaside, Mediterranean city: A pilot survey." Resources, Conservation and Recycling **50**(3): 282-292.

Karthik, Manikavasagam, R. Dhodapkar, P. Manekar, P. Aswale and T. Nandy (2011). "closing the loop in a paper mill section for water conservation and reuse". Desalination **281**: 172-178.

Kerr, J and L. Foster (2011). "Sustainable consumption- UK Government activity". Nutrition Bulletin **36**: 422-425.

Khan, S. J. and L. E. Gerrard (2006). "Stakeholder communications for successful water reuse operations." Desalination **187**(1–3): 191-202.

Kirby, R. M., J. Bartram, et al. (2003). "Water in food production and processing: quantity and quality concerns." Food Control **14**(5): 283-299.

Kjrculff, U.B., Madsen, A.L. (2013). "Bayesian Networks and influence Diagrams: a guide to construction and analysis. Springer publishing.

Knight, J.G., Holdsworth, D.k., Mather D.W. (2008). "GM food and neophobia: connecting with the gatekeepers of consumer choice". Journal of the Science of Food and Agriculture **88**:739-744.

Le-Clech, P., A. Fane, et al. (2005). "MBR focus: the operators' perspective." Filtration & Separation **42**(5): 20-23.

Lee, B. (2009). "Managing the interlocking climate and resource challenges." International Affairs **85**(6): 1101-+.

Lens, P., L. Pol, et al., Eds. (2002). Water Recycling and Resource Recovery in Industry IWA Publishing.

Levy, Y. (2011). "Guiding the Use of Grounded Theory in Doctoral Studies - An Example from the Australian Film Indsutry." International Journal of Doctoral Studies **6**: 95-114.

Liaw, C.H. and Chen, L.C. (2004). "Rational Industrial water Reuse Ratios ". Journal of the American Water Resoources Association August: 971-979.

Lindenberg, M.M. and B.L. Crosby (1981). Managing Development: the political dimension. Kumarian Press, West Hartford, CT.

Lopez-Grimau, V., C. Gutierrez- Bouzan, J. valldeperas and M. Crespi (2013). " Conitnuous reuse of water and electolyte from decolorized reactive dyebaths". Desalination and Water Treatment **51**: 4593-4602.

Maddocks, A., R.Young and P. Reig (2015). "Ranking the World's Most Water - Stressed Countires in 2040." World Resources Institue . www.wri.org

Marcus, A. and Geffen, D. (1998)."The dialectics of competence acquisition: Pollution prevention in electric generation". Strategic Management Journal **19**(2): 1145-1168.

Martin, P. Y. and B. A. Taylor (1986). "Grounded Theory and Organizational Research." The Journal of Applied Behavioral Science **22**(2): 141-157.

Massoud, M. A., R. Fayad, et al. (2010). "Drivers, barriers and incentives to implementing environmental management systems in the food industry: A case of Lebanon." Journal of Cleaner Production **18**(3): 200-209.

Mavrov, V. and E. Belieres (2000). "Reduction of water consumption and wastewater quantities in the food industry by water recycling using membrane processes." Desalination **131**(1-3): 75-86.

Mavrov, V., H. Chmiel, et al. (2001). "Spent process water desalination and organic removal by membranes for water reuse in the food industry." Desalination **138**(1–3): 65-74.

Mavrov, V., A. Fahnrich, et al. (1997). "Treatment of low-contaminated waste water from the food industry to produce water of drinking quality for reuse." Desalination **113**(2-3): 197-203.

Meadows, D., D. Meadows, et al. (1972). The limited growth, Macmillan

Miles, S. (2012). "Stakeholders: Essentially contested or just confused? ." Journal of Business Ethics **108**: 285-298.

Minoja, M. (2012). "Stakeholder Management Theory, Firm Strategy and Ambidexterity " Journal of Business Ethics **109**: 67-82.

Mitchell, R.K.; B.R., Agle and D.J. Wood (1997) "Towards a theory of stakeholder identification and salience: defining the principle of who and what really counts" Academy Management Review **22**: 853-886.

Müller, O., N. Groesser, et al. (2012). "How do we know who to include in collaborative research? Toward a method for the identification of experts." European Journal of Operational Research **216**(2): 495-502.

Mutamim, N. S. A., Z. Z. Noor, et al. (2013). "Membrane bioreactor: Applications and limitations in treating high strength industrial wastewater." Chemical Engineering Journal **225**(0): 109-119.

Neville, B., S. Bell, et al. (2011). "Stakeholder salience revisited : refining, redefining and refueling an underdeveloped conceptual tool." Journal of Business Ethics **102**: 357-378.

Noronha, M., T. Britz, et al. (2002). "Treatment of spent process water from a fruit juice company for purposes of reuse: hybrid process concept and on-site test operation of a pilot plant." Desalination **143**(2): 183-196.

O'Brien, F. A. (2004). "Scenario planning—lessons for practice from teaching and learning." European Journal of Operational Research **152**(3): 709-722.

OFWAT (2011). Investigating leakage failure. www.ofwat.gov.uk.

OFWAT (2013). "Mogden Formula www.ofwat.gov.uk/trade/mogden."

Onkila, T. (2011). "Multiple Forms of Stakeholder Interaction in Environmental Management: Business Arguments Regarding Differences in Stakeholder Relationships." Business Strategy and the Environment **20**: 379- 393.

Orts, EW., Strudler, A. (2002). "The ethical and environmental limits to stakeholder theory". Business Ethics Quarterly **12**(2):215-233.

Pearson, J. (2013). "The pending water shortage". Chemical Engineering **5**:120-126.

Peterson, G., G. Cumming, et al. (2003). "Sceanrio Planning : A tool for conservation in an Uncertain world." Conservation Biology **17**(2): 358-366.

Plaza-Ubeda, J.A., J. Burgos-Jimenez, C. Liston-Heyes (2009)."The Win-Win Paradigm and Stakeholder Integration". Business Strategy and the Environment **18**:487-499.

Poncelet, E.C. (2001). "A kiss here and a kiss there": Conflict and collaboration in environmental partnerships". Environmental Management **27**(1):13-25.

Postel, S. L. (2000). "Entering an era of water scarcity: The challenges ahead." Ecological Applications **10**(4): 941-948.

PROWATER (2007). Sustainable water management in the textile wet industry through an innovative treatment process for waste water reuse. www.ec.europa.eu.

RAENG (2010). Global Water Security. Royal Academy of Engineering. www.raeng.org.uk

Reed, M. S., A. Graves, et al. (2009). "Who's in and why? A typology of stakeholder analysis methods for natural resource management." Journal of Environmental Management **90**(5): 1933-1949.

Rialland, A. and K. Wold (2009). Future Studies, Foresight and Scnearios as basis for strategic decisions Norwegian University of Science and Technology

Richter, U.H. (2011) "Drivers of change : A multiple-case study on the process of institutionalization of corporate responsibility among three multinational companies". Journal of Business Ethics **102**:261-279.

Roberts, A., L. Johnston and A. Knott (2010). "Impact of desalination plant discharges on the marine environment: A critical review of published studies". Water Reseach **44** (18): 5117-5128

Rodríguez, F. A., J. M. Poyatos, et al. (2011). "Kinetic study and oxygen transfer efficiency evaluation using respirometric methods in a submerged membrane bioreactor using pure oxygen to supply the aerobic conditions." Bioresource Technology **102**(10): 6013-6018.

Romanelli, A., H. E. Massone, et al. (2011). "Stakeholder Analysis and Social - Biophysical Interdependencies for Common Pool Resource Management : La Brava Wetland (Argentina) as a Case Study." Environmental Management **48**: 462-474.

Ross, C., G. Valentine, et al. (2003). Recent Advances and Applications of Dissolved Air Flotation for Industrial Pretreatment North Carolina AWWA/WEA Conference North Carolina Environmental Treatment Systems

Rowley, T.J. (1997). Moving beyond dyadic ties. A network theory of stakeholder influences. Academic Management Review **22**: 887-910.

Ryan A.M., Splash C.L. and Measham, T.G.(2009). "Socio-economic and psychological predictors of domestic greywater and rainwater collection: Evidence from Australia" Journal of Hydrology **379**: 164-171.

Salam, M.A. and T. Noguchi (2006) "Evaluating capacity development for participatory forest mangement in Bangladesh's Sal forests based on 4Rs stakeholder analysis" Forest Policy and Economics **8**:785-796.

Salgot, M. (2008). "Water reclamation, recycling and reuse: implementation issues." Desalination **218**(1-3): 190-197.

Sarkar, B., P. P. Chakrabarti, et al. (2006). "Wastewater treatment in dairy industries — possibility of reuse." Desalination **195**(1–3): 141-152.

Schäfer, A. I. and S. Beder (2006). "Relevance of the precautionary principle in water recycling." Desalination **187**(1–3): 241-252.

Schoemaker, P. J. H. (1995). "Scenario Planning: A Tool for Strategic Thinking " Sloan Management Review **36**(2): 25-40.

Sharma, S. & Vredenburg, H. (1998). Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities". Strategic Management Journal **19**(8): 729-753.

Sprengel, D.C., T. Busch (2011)."Stakeholder Engagement and Environmental Strategy - the Case of Climate Change". Business Strategy and the Environment **20**:351-364.

Stead, JG. and Stead WE.(2004). Sustainable Strategic Management. Sharp: Armonk.

Stone CD. (1974). Should Trees Have Standing? Towards Legal Right of Natural Objects. Kaufmann: Los Altos.

Studer, S., et al (2008). "SMEs and voluntary environmental initiatives: a study of stakeholders' perspectives in Hong Kong". Journal of Environmental Planning and Management **51**(2): 285-301.

Tam, L. S., T. W. Tang, et al. (2007). "A pilot study for wastewater reclamation and reuse with MBR/RO and MF/RO systems." Desalination **202**(1-3): 106-113.

Tchobanoglous, G., F. Burton, et al. (2004). Wastewater Engineering - Treatment and Reuse New York, Metcalf & Eddy.

The-Guardian (2013). "Loan repayment calculator www.theguardian.com."

Trienekens, J. and P. Zuurbier (2008). "Quality and safety standards in the food industry, developments and challenges." International Journal of Production Economics **113**(1): 107-122.

Turner, G. (2008) A comparison of the limits to grwoth with thirty years of reality. www.csiro.au

UK Parliament (2006). Water Management in the UK Science and Technology Committee. www.parliament.uk/science-and-technology-committee.

University of Salford (2015). Water contamination in Lancashire, public health put at risk? http://www.salford.ac.uk/onecpd/courses/the-future-of-public-health-in-england.

UKCP (2009). UK Climate Projections Briefing Report. ukclimateprojection.metoffice.gov.uk

UKWIR (2012). Sustainable Regulation - Report Reference 12/RG/08/4, UK Water Industry Research Limited. www.ukwir.org

UN (2006). Millennium Project - 2020 Global Energy Scenarios. www.unmillenniumproject.org.

UNESCO (2016). Water resources; land and population except for the united states. unesco.org.

Utility Weekly (2011). Tariffs Guide : Water use. utilityweek.co.uk/news.

Valta, K., K. Moustakas, et al. (2014). Adaptation measures for the food and beverage industry to the impact of climate change on water availability .

Vajnhandl, S., J.V. Valh (2014). "The status of water reuse in european textile sector". Journal of Environmental Management **141**:29-35.

Van Asselt, M., N. Rijkens-Klomp (2002). "A look in the mirror: reflection on participation in integrated assessment from a methodological perspective". Global Environmental Change **12**,167-184.

Verrecht, B., T. Maere, et al. (2010). "The cost of a large-scale hollow fibre MBR." Water Research **44**(18): 5274-5283.

Vourch, M., B. Balannec, et al. (2005). "Nanofiltration and reverse osmosis of model process waters fromthe dairy industry to produce water for reuse." Desalination **172**(3): 245-256.

Vourch, M., B. Balannec, et al. (2008). "Treatment of dairy industry wastewater by reverse osmosis for water reuse." Desalination **219**(1-3): 190-202.

Wade ,S.D., J. Ranle and N. Reynard (2013). "The UK climate change risk assessment 2012: Assessing the impact on water resources to inform policy makers". Water Resource Management **27**:1085-1109.

Walker, D. and F. Myrick (2006). "Grounded Theory: An Exploration of Process and Procedure." Qualitative Health Research **16**(4): 547-559.

WBCSD (2006). World Business Council for Sustainable Development: Water scenario to 2025: Business in the world of water. www.wbcsd.org.

Wessex Water (2013). Water the way ahead 2015-2040: Wessex water's long term strategy. www.wessexwater.co.uk.

WHO (2014). Drinking Water Quality - World Health Organisation. www.who.int.drinking-waterquality

WMIN (2015). UK Green Investment Bank. www.world market intlligence news.

Wolf, J. (2013). " Improving the Sustainable Development of Firms: The Role of Employees". Business Strategy and the Environment **22**: 92-108.

Wolfe, R. and D. Putler (2002). "How tight are the ties that bind stakeholder groups." Organisation Science **13**(1): 64-80.

Woodside, F., Ogunmokun, G., Brown, L.R. (2005). "Measuring the attitudes of Australian food manufacturerstowards genetically modified foods. Paper presented at the ANZMAC 2005 Conference.

WRAP (2004). Reducing water and waste costs in fruit and vegetable processing. www.wrap.org.uk

WRAP (2009). Meeting the UK Climate Change : The contribution of resource efficiency. www.wrap.org.uk

WRAP (2010). Progress Report : Reducing water use within the food and drink industry. www.wrap.org.uk.

WRAP (2011). Freshwater availability and use in the United kingdom. www.wrap.org.uk

WRAP (2012). The Federation house Commitment: Helping the food and drink industry improve water efficiency www.wrap.org.uk

WRAP (2013). Water use in the food and drink industry. www.wrap.org.uk

WRAP (2014a). "Federation House Commitment Report. www.wrap.org.uk ".

WRAP (2014b). Mogden formula. www.wrap.org.uk.

WRAP (2014c)"Case Studies: Water Efficiency in the Food and Drink Industry. www.wrap.org.uk ".

WRAP (2015). "Federation House Commitment: Food and Drink Water use Reporting www.wrap.org.uk ".

Wright, G. and P. Goodwin (2009). "Decision making and planning under low levels of predictability: Enhancing the scenario method." International Journal of Forecasting **25**(4): 813-825.

Wu, B., T. Kitade, et al. (2013b). "Impact of membrane bioreactor operating conditions on fouling behavior of reverse osmosis membranes in MBR–RO processes." Desalination **311**(0): 37-45.

Wu, D. et al. (2016). " Feasibility Study on water reclamation from the sorting /grading operation in mandarin orange canning production" Journal of Cleaner Production **113**: 224-230.

Wu, D. et al. (2013a). "Quality monitoring for a water reclamation system in a mandarin orange canning factory". Desalination and Water Treatment **51**:3138-3144.

Yoo, S. and J. Hsieh (2010). "Advanced water recycling through electrochemical treatment of effleunt from dissolved airfloatation unit of food processing industry." Water science and technology **61**(1): 181-190.

Zakem, A. (2008). "Staekholder Management Capability: A Discourse-Theoretical Approach" Journal of Business Ethics **79**:395-405.

APPENDICES

2 Appendices Relating to Chapter Two

2-1 Participants from the water treatment sector

Due to the confidentiality of information provided, this appendix is only available on the CD ROM.

2-2 Mogden Formula (Tchobanoglous et al., 2004; Gray 2010)

The Mogden Formula is the most widely charging system for effluent discharge in Europe. It calculates the charge for treatment and disposal of sludge by comparing the strength of the wastewater to normal domestic sewage and then calculating the fixed charge for collection via the sewerage network.

$C=R+V+(Ot/Os)B+(Sc/Ss)S+M$ pence m^3

Where

C= the cost in pence per m^3

R= Fixed charge for collection via the sewerage network

V= Preliminary and primary treatment cost per m^3

B= Secondary (biological) treatment cost per m^3

S= cost of treatment and disposal of sludge

M= cost of discharge via long sea outfall

Ot= COD of the discharged wastewater

Os= Average strength of domestic wastewater

Sc= The suspended solids of the discharged wastewater

Ss= Average suspended solids of domestic wastewater

<u>Chemical Oxygen Demand (COD):</u>

A test used to measure the oxygen equivalent of the organic material in wastewater that can be oxidised chemically using dichromate in an acid solution.

<u>Biochemical/Biological Oxygen Demand</u>:

A test used to measure the dissolved oxygen consumed by microorganisms in the biochemical oxidation of organic matter.

<u>Suspended Solids</u>:

Insoluble particles or soluble particles that are too large to dissolve quickly or too small to settle out of suspension under prevailing turbulence and temperature conditions. The type and concentration of suspended solids have a significant impact on the turbidity and transparency of the water.

2-3 Initial data analysis

Sub sector	Number of companies	No treatment	Primary	Secondary	Tertiary	No Data Available
Water bottling plants	13	13 (100%)				
Soft Drinks	23		11 (47.8%)	7 (30.4 %)	4(17.4%)	1 (4%)
Alcoholic beverages	30			26 (86.6%)	2 (6.6%)	2 (6.6%)
Fresh fruits and vegetables	38	32 (84.2%)	5 (13%)		1 (2.6%)	
Pre-packed salads	11	10(91%)	1 (9%)			
Cereals	25			19 (76%)		6 (24%)

2-3 continued

Sub sector	Number of companies	No treatment	Primary	Secondary	Tertiary	No Data Available
Dairy	60			50 (83.3%)	8(13.3)	2 (3.3%)
Confectionary	32		5 (15.6%)	23 (72%)	2(6.25%)	2 (6.25%)
Hot drinks	13		5 (38.4%)	8 (61.5%)		
Bakery	41			37 (90.2%)		4 (9.7%)
Pre-prepared foods	67			58 (86.5%)		9 (13.4%)
Snack foods	21		2 (9.5%)	15 (71.4%)		4 (19%)
Meat and poultry	30			30 (100%)		

3 Appendices Relating to Chapter Three

3-1 Research Questionnaire

Water Recycling and re-use in the Food and Beverage Industry

1. <u>Introduction</u>

The University of Birmingham is evaluating the current state of water recycling and reuse in the food and beverage manufacturing operations. We are seeking input from the food and beverage industry to build:

- *A realistic picture of present applications in the UK*
- *Understand the current and future influences that might impact on water recycling and reuse in this sector*.

Your responses will be strictly confidential. Data from this research will be only used for academic purposes keeping all company details anonymous.

If you require any further information or you are interested in knowing the outcome of this study you can contact us on or on

Thanks you for taking part in this Interview. Your contribution is much appreciated.

Note: As part of the introduction the following terminologies must be made clear:

- *The source of recycled water is the manufacturing site trade effluent.*
- *Only trade effluent that has been treated to potable standards will be considered for reuse in the manufacturing processes.*

2. General Information

Company name:

Group:

Number of factories in the UK:

Meeting with:

Personal information on interviewee:

Date of interview:

Any other data:

3. Background to water saving initiatives within the company

Q1 – Can you please briefly tell me about your company's current position regarding water recycling and water saving initiatives?

Sub Q1 - Can you please elaborate further the areas where water recycling is applied and why?

Note: (this section will have to be altered depending on the answers obtained in Q1)

4. Water recycling and reuse in manufacturing areas

Q2- can you please tell me about the company current strategy regarding water recycling and reuse in production areas?

Sub Q2- Ask more questions to help in elaborating the ideas presented in Q2.

5. Identification of the stakeholders

Q3- I am now going to present you with a list of factors. Can you please indicate, based on your knowledge and current company policy which is currently having/ or has the potential to impact on water recycling and reuse in production areas? And why?

i. Employee and technical know how
ii. Customers (trading bodies and supermarkets)
iii. Public opinion
iv. Shareholders and investors
v. Business community and creditors
vi. Competitors
vii. Regulatory enforcement
viii. Economic Feasibility
ix. Suppliers (gas, electricity, water)
x. Environmental (water availability)
xi. NGOS and consumer groups
xii. Media
xiii. Rising cost of energy
xiv. Any other

6. <u>Potential Impact of Future changes</u>

Q4- Can you please indicate as to whether you will expect any changes in the future regarding water recycling and reuse in production areas?

Sub Q4- Based on our discussion what will you expect to have the strongest impact on the future of water recycling and reuse?

Note: Due to the confidentiality of the information presented in the individual interviews, these will be only provided on the attached CD which will be deposited at the university as a sensitive and confidential document.

3-2 In vivo - Data Coding – Grounded Theory

	In-vivo codes resulting from the field narrative				
Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
No Impact Low impact Can't see it happening Not a priority	Not sure Have not been evaluated Need to be investigated	Reliable Become important if …. Change opinion Will have impact Introduce change Will only go ahead if ….. Might introduce change Can impact on decision Important Assist Provide credibility	Trigger change Increase awareness Lack of incentive Force rethinking /re-evaluation Validate There would be no other option Essential Important Most powerful Can exert pressure Impact	Worry Hurdle Will not accept No allowed Maintain image Difficulties Bad PR Reluctance Upsetting Nervous Bad News Blame	Ruin Risk Damage Terminate contract Contaminate Impact on purity Put neck on the line Against Kill the product Reputation Product Recall Under no circumstances Scared Fear Reject Disaster Catastrophic Unacceptable Health Issues Unreliable Outbreaks
The above codes are based on the exact words provided by the participants during the interviews. They were clustered in 6 categories to reflect the type and strength of the impact of individual stakeholders on TERR. The categories were then consolidated to 6 axial coding categories.					

3-2 Continued

Axial coding – Emerging concepts					
Low Impact	More information is needed	Medium Positive Impact	High Positive Impact	Medium Negative Impact	High Negative Impact
Theoretical Codes - Main categories					
		Driver ✓ Primary (immediate impact) ✓ Secondary (conditional , other factors are needed)		Barrier ✓ Primary (immediate impact) ✓ Secondary (conditional , other factors are needed)	

A copy of the detailed narrative can be found on the CD- ROM- “corporate interviews”

3-3 Targeted Interviews

A brief summary of the services provided by the organisations that took part in the targeted interviews:

Department for environment food and rural affairs (DEFRA): The UK government department responsible for policy and regulations on environmental, food and rural issues. The priorities of DEFRA are to grow the rural economy, improve the environment and safeguard animal and plant health. Further information on DEFRA can be obtained from: www.defra.gov.uk

The environment agency (EA): An Executive Non-departmental Public Body with the principal aims to protect and improve the environment, and to promote sustainable development. Further information on EA can be obtained from: www.environment-agency.gov.uk

Envirowise (Federation House Commitment - FHC): A UK Government funded consultancy working with a wide range of partners, from major UK businesses, trade bodies and local authorities through to individuals looking for practical advice. The main aim of the FHC is to improve sustainability and minimize waste. Further information on FHC can be obtained from: www.wrap.org.uk

Food standards agency (FSA): The Food Standards Agency is an independent government department responsible for food safety and hygiene across the UK. The FSA works with businesses to help them produce safe food, and with local authorities to enforce food safety regulations. Further information on FSA can be obtained from: www.food.gov.uk

3-3 continued

Chilled Food Association (CFA): The role of the CFA is to champion best practice hygiene standards for UK chilled prepared food – one of the fastest-growing, most innovative and advanced food markets in the world. CFA represents many of the best-known UK chilled food manufacturers and campaigns actively on their behalf. Further information on CFA can be obtained from: www.chilledfood.org

Campden BRI: The UK's largest independent membership-based organisation carrying out research and development for the food and drinks industry worldwide. Further information on Campden BRI can be obtained from: www.campdenbri.co.uk

United Utilities (UU): Main water provider in the North West of England. Further information on UU can be obtained from: www. united utilities.com

Anglian Water (AW): Main water provider in the East and South East of England. Further information on AW can be obtained from: www.anglianwater.co.uk

3-4 List of the stakeholders Identified for SM analysis in this study

Stakeholder	Mode of impact on DWRR	Data verification in GTM
UK government (regulator)	Department(s) responsible for developing policies regarding DWRR	DEFRA EA FSA Envirowise
Company (employee)	Technical know- how of decision makers regarding DWRR	Feedback from company interviews
Business Partners	Company Financiers, investors and shareholders	Feedback from company interviews
Consultancy bodies	Institutions that are currently providing advice to verify and implement new technologies (DWRR)	CFA Campden BRI
Customers	Companies directly purchasing goods from the manufacturing sites	Company interviews Consultancy bodies Government regulators.
Consumers	End users (general public)	Company interviews Consultancy bodies Government regulators
Suppliers	Companies responsible for supplying water to the manufacturing sites	United Utilities Anglian water

3-4 continued

Stakeholder	Mode of impact on DWRR	Data verification in GTM
Economic feasibility	Will impact on payback period and return on investment	Company interviews Consultancy bodies Government regulators
Media		Company interviews
NGOs	Environmental pressure groups	Company interviews Government regulators.
Environment	Water availability and its impact on DWRR. Environmental awareness and current existing policies on water minimisation and the impact on DWRR.	Company interviews Consultancy bodies Government regulators Water suppliers
Competitiveness	Success of a competitor Available technology Financial benefits associated with DWRR	Company interviews Consultancy bodies Government regulators Water suppliers
Industry standards	Specific production and hygiene protocol for the FBI that might impact on DWRR (hygiene)	Company interviews Consultancy bodies Government regulators Water suppliers

3-5 Potable Water Quality Testing Parameters (www. united utilities.com)

Parameter	Description	Standard
1,2-dichloroethane	1, 2-dichloroethane is found in industrial solvents. Occasionally it is detected in water source in trace amounts. Solvents are removed using specialist water treatment.	3 μg/l
Acrylamide	Acrylamide does not occur naturally in water. Trace amounts may be found in polyacrylamides, which are used in water treatment to help remove impurities. The use of polyacrylamide in drinking water treatment is strictly controlled by product and dose specification.	0.1 μg/l
Aluminium	Aluminium occurs naturally in most water sources and is removed effectively during treatment. Aluminium compounds are used in water treatment to help remove impurities from the source water and are removed during the treatment process.	200 μg/l
Ammonium	Ammonium ions are present naturally in most water sources and are usually broken down during disinfection.	0.5 mg/l
Antimony	Antimony is not found naturally in water sources. Traces found in water supplies are likely to be due to contact with brass fittings or solders used in domestic plumbing systems.	5 μg/l
Arsenic	Very low concentrations of arsenic can occur naturally in some groundwater sources. Where present, arsenic is removed using specialist treatment.	10 μg/l

3-5 Continued

Parameter	Description	Standard
Benzene	Benzene is used in industry for making plastics, rubber, resins and synthetic fabrics like nylon and polyester. Benzene can occasionally be detected at trace concentrations in water sources. Where present, benzene is removed in water treatment.	1 μg/l
Benzo(a)pyrene	Benzo(a)pyrene may be found in bitumen linings which were used in the past to protect water mains from corrosion. Traces may occasionally be found in water supplies where bitumen linings are still present.	0.01 μg/l
Boron	Boron can be found occasionally at trace concentrations in some water sources. Boron is found in detergents and can enter water sources which receive treated wastewater. In the North West very few water sources receive treated wastewater.	1 mg/l
Bromate	Bromate may be detected in water supplies at very low concentrations. It can be caused by the presence of bromide in compounds used during the disinfection of water supplies.	10 μg/l
Cadmium	Very low levels of cadmium can occur naturally in some groundwater sources. Where present, cadmium is removed using specialist treatment.	5 μg/l
Chloride	Chloride occurs naturally in all water sources and is not removed during treatment. The concentrations present in water do not present any risk to health.	250 mg/l
Chromium	Chromium is rarely found in water sources but may be present at low concentrations if the water has passed through rocks containing naturally occurring chromium.	50 μg/l

3-5 Continued

Parameter	Description	Standard
Coliform bacteria	Coliform bacteria are found widely in the environment and are normally removed during water treatment. They are not necessarily harmful. Their presence in treated water may indicate a possible source of contamination, which may be the customer's tap. A prompt investigation is always conducted following any detection of coliforms in treated water.	0 per 100 ml
Colony counts after 3 days/Colony counts after 2 days	This is a measure of the naturally occurring harmless bacteria found in water.	No abnormal change
Colour	Water occasionally has a slight tinge which may be caused by naturally occurring substances.	20 mg/l Pt/Co scale
Conductivity	Conductivity is a measure of the amount of naturally occurring dissolved inorganic substances in water.	2500 µS/cm at 20 ºC
Copper	The presence of copper in water supplies is usually due to contact with domestic plumbing.	2 mg/l
Cyanide	Cyanide is rarely found in water sources, but may be present at low concentrations if the water source has passed through rocks containing naturally occurring cyanide compounds.	50 µg/l

3-5 Continued

Parameter	Description	Standard
***E.coli* / /Enterococci / *Clostridium perfringens* (including spores)**	These organisms are present in the gut of warm-blooded animals. On rare occasions, low numbers of these organisms are detected in treated water. Their presence in treated water indicates possible faecal contamination. Detection of these organisms does not indicate an immediate risk to health. United Utilities always carries out prompt investigations following any detection in treated water supplies.	0 per 100 ml
Epichlorohydrin	Epichlorohydrin does not occur naturally in water. It may be found in trace amounts in polyamine water treatment chemicals, which help remove impurities from the source water. The use of polyamines in the treatment of drinking water is strictly controlled by product and dose specification.	0.1 µg/l
Fluoride	Fluoride can occur naturally in water sources and can be added to water supplies in some areas as a protection against tooth decay.	1.5 mg/l
Hydrogen ion (pH)	pH measurement gives an indication of the acidity of the water. pH 7 is neutral. pH values below 7 indicate acidic characteristics and pH above 7 indicates alkaline characteristics.	6.5 – 9.5
Iron	Iron is found naturally in most water sources and is removed effectively during treatment. Iron in water supplies can occur due to corrosion of iron pipes. The concentrations present in water are not harmful to health. Iron compounds are used in water treatment to help remove impurities from the source water and are removed during the treatment process.	200 µg/l

3-5 Continued

Parameter	Description	Standard
Lead	Lead is not normally found in water sources. Any lead found in drinking water is usually due to contact with lead pipes that may be in some customers' properties. United Utilities treats water supplies in order to minimise pick-up of lead from lead pipes.	10 µg/l
Manganese	Manganese occurs naturally in most water supplies and is removed during treatment.	50 µg/l
Mercury	Mercury is rarely found in water sources but may be present at extremely low concentrations if the water has passed through rocks containing naturally occurring mercury.	1 µg/l
Water Q		
Nickel	Nickel is not found naturally in water sources. Traces of nickel found in water supplies are likely due to contact with protective coatings on taps and fittings within customers' properties.	20 µg/l
Nitrate	Nitrate occurs naturally in water. Increased concentrations in water sources can occur as a result of fertiliser use. Nitrate concentrations are reduced during water treatment.	50 mg/l
[Nitrate] / 50 plus [Nitrite] / 3 Nitrite	This is a measure of the ratio of the concentrations of nitrate and nitrite in water supplies.	≤1
Nitrite	Nitrite in water may be associated with use of ammonia and chlorine for disinfection. United Utilities does not use ammonia during disinfection of water supplies.	0.5 mg/l

3-5 Continued

Parameter	Description	Standard
Pesticides - aldrin, dieldrin, heptachlor and heptachlor epoxide	Traces of pesticides can occasionally be found in water sources as a result of agricultural and non-agricultural use of pesticides in the environment. However, these pesticides are persistent in the environment and so are no longer used in the UK. United Utilities has installed water treatment processes to remove pesticide residues where present.	0.03 µg/l
Other pesticides	Traces of pesticides can occasionally be found in water sources as a result of agricultural and non-agricultural use of pesticides in the environment. United Utilities has installed water treatment processes to remove pesticide residues where present.	0.1 µg/l
Pesticides - total	This is the sum of the concentrations of the individual pesticides detected.	0.5 µg/l
Polycyclic aromatic hydrocarbons (sum of 4 PAHs)	The 4 PAHs include benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene. These compounds are present in bitumen linings which were used in the past to protect water mains from corrosion. Traces may occasionally be found in water supplies where bitumen linings are still present.	0.1 µg/l
Quantitative taste and odour	Odour and taste occur naturally. A formal method is undertaken in the laboratory to assess the taste and odour of water.	Acceptable to consumers no abnormal change

3-5 Continued

Parameter	Description	Standard
Radioactivity - gross alpha	Radiation exposure through water is typically very small. Where present, it is due to naturally occurring radioactive species, at levels that are not harmful. Gross alpha activity is monitored for the calculation of Total Indicative Dose.	0.1 Bq/l (screening value)
Radioactivity - gross beta	Radiation exposure through water is typically very small. Where present, it is due to naturally occurring radioactive species, at levels that are not harmful. Gross beta activity is monitored for the calculation of Total Indicative Dose.	1 Bq/l (screening value)
Total and free chlorine residual	Small amounts of chlorine are added to water to kill any harmful bacteria.	No standard
Selenium	Selenium is rarely found in water sources but may be present at extremely low concentrations if the water has passed through rocks containing naturally occurring selenium.	10 µg/l
Sodium	Sodium occurs naturally in all water sources. The concentrations normally found in water do not present any risk to health.	200 mg/l
Sulphate	Sulphate occurs naturally in all water sources. The concentrations normally found in water do not present any risk to health.	250 mg/l

3-5 Continued

Parameter	Description	Standard
Tetrachloroethene and trichloroethene	This standard applies to the sum of the concentrations of tetrachloroethene and trichloroethene. These are solvents which can occasionally be detected at trace concentrations in water sources. Where necessary, solvents are removed using specialist water treatment.	10 μg/l
Tetrachloromethane	Tetrachloromethane is a solvent which can occasionally be detected at trace concentrations in water sources. Where necessary, solvents are removed using specialist water treatment.	3 μg/l
Total organic carbon	The total organic carbon content of water represents the amount of naturally occurring organic material present in the water.	No abnormal change
Total Indicative Dose (for radioactivity)	Total Indicative Dose is the effective dose of radiation exposure through water. It is required to be measured if the gross alpha or gross beta activities exceed the screening values.	0.10 mSv/year
Trihalomethanes - total	Trihalomethanes can be formed during disinfection of water supplies if chlorine reacts with naturally occurring organic substances. Water treatment is carefully controlled to minimise any formation of trihalomethanes.	100 μg/l

3-5 Continued

Parameter	Description	Standard
Tritium (for radioactivity)	Tritium is a radioactive isotope of the element hydrogen that occurs naturally in the environment in very low concentrations. It is not normally present in water sources. Tritium is produced in the upper atmosphere when cosmic rays strike air molecules or as a by-product in reactors producing electricity. The Environment Agency carries out regular monitoring for radioactivity in water sources used for the supply of drinking water.	100 Bq/l
Turbidity	This is a measure of the clarity of the water.	4 NTU
Vinyl chloride	Vinyl chloride does not occur naturally in water. It may be present in polyvinyl chloride (PVC) pipes in trace amounts, as a residual of the manufacturing process. Vinyl chloride is strictly controlled by product specification.	0.5 µg/l

Note
mg/l = milligrammes per litre or one part in a million
µg/l = microgrammes per litre or one part in a thousand million**Standards**

3-6 Contamination of mains water supply in Lancashire (BBC News, 2015; University of Salford, 2015)

In August 2015 more than 300,000 households were warned by United Utilities of the risk of the tap water being contaminated with the Cryptosporidium Bacteria.

Advice was given to boil the water prior to use to prevent potential illnesses such as gastroenteritis, diarrhoea, vomiting and nausea. There were also serious concerns regarding the side effects that can be caused by the bacteria for those with weak immune systems and the elderly.

This impacted on households, local pubs, restaurants, nursing homes and hospitals.

Supermarkets could not cope with the increased demand and there was a depletion of bottled water from the supermarket shelves.

The contamination issue continued for more than 6 weeks and United Utilities are in the process of dealing with the compensation claims that have been raised by business users and the public.

It is estimated that the financial compensations claims are going to be around 25 million pounds.

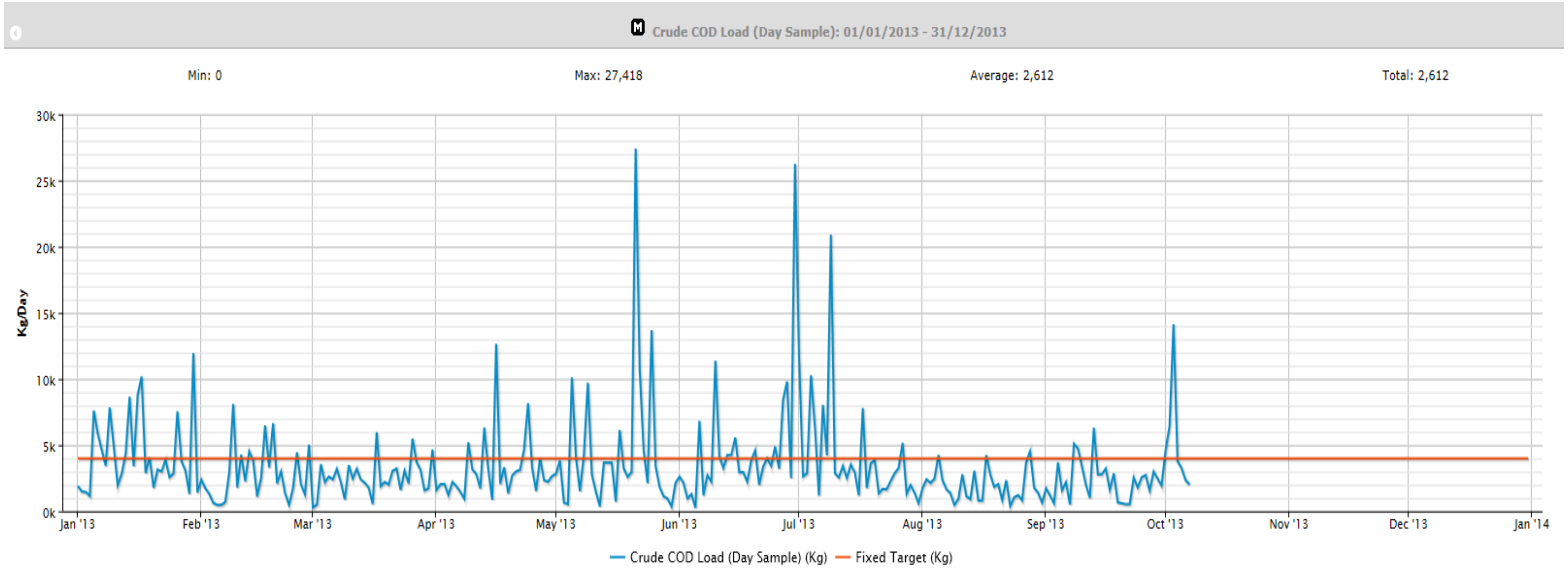
The way and speed that United Utilities has dealt with the issue will also be officially reviewed and investigated by the UK parliament.

4 Appendices Relating to Chapter Four

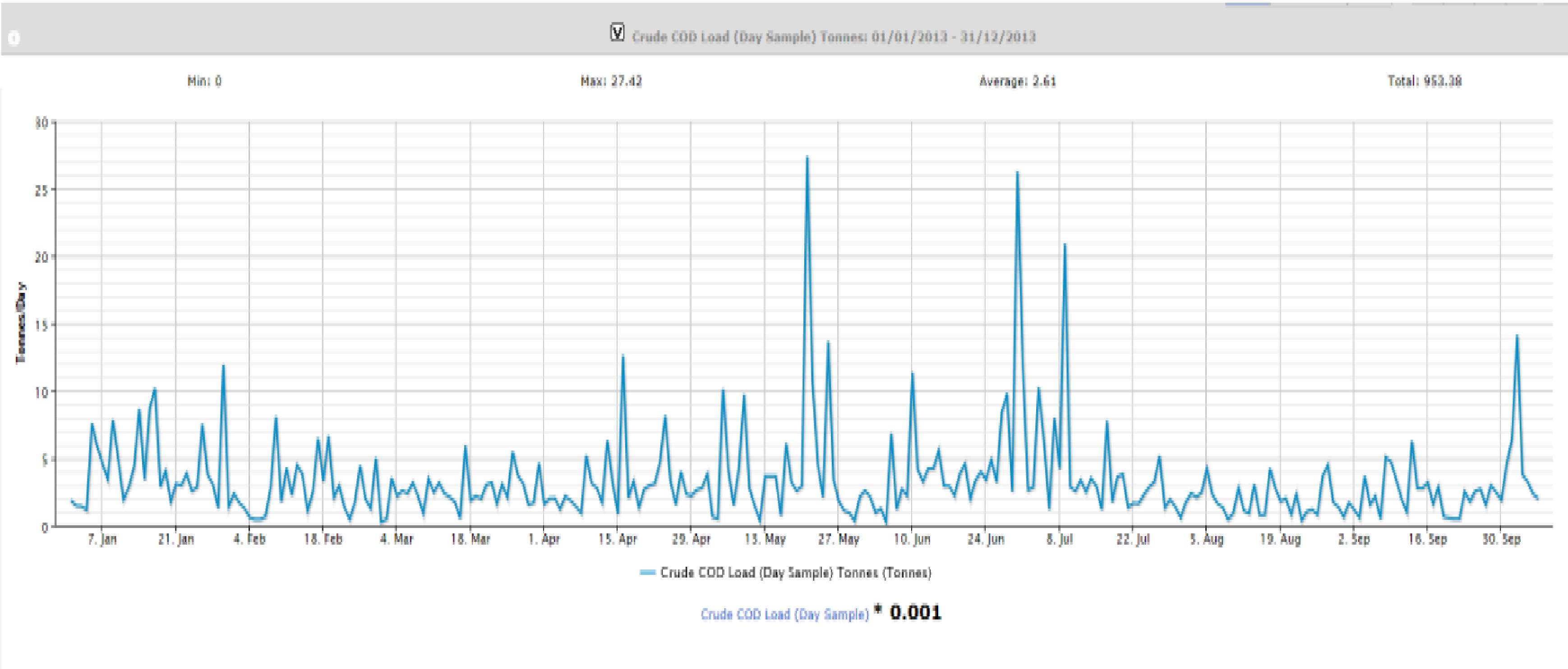
4-1 Site Electronic Data

A: Crude Data

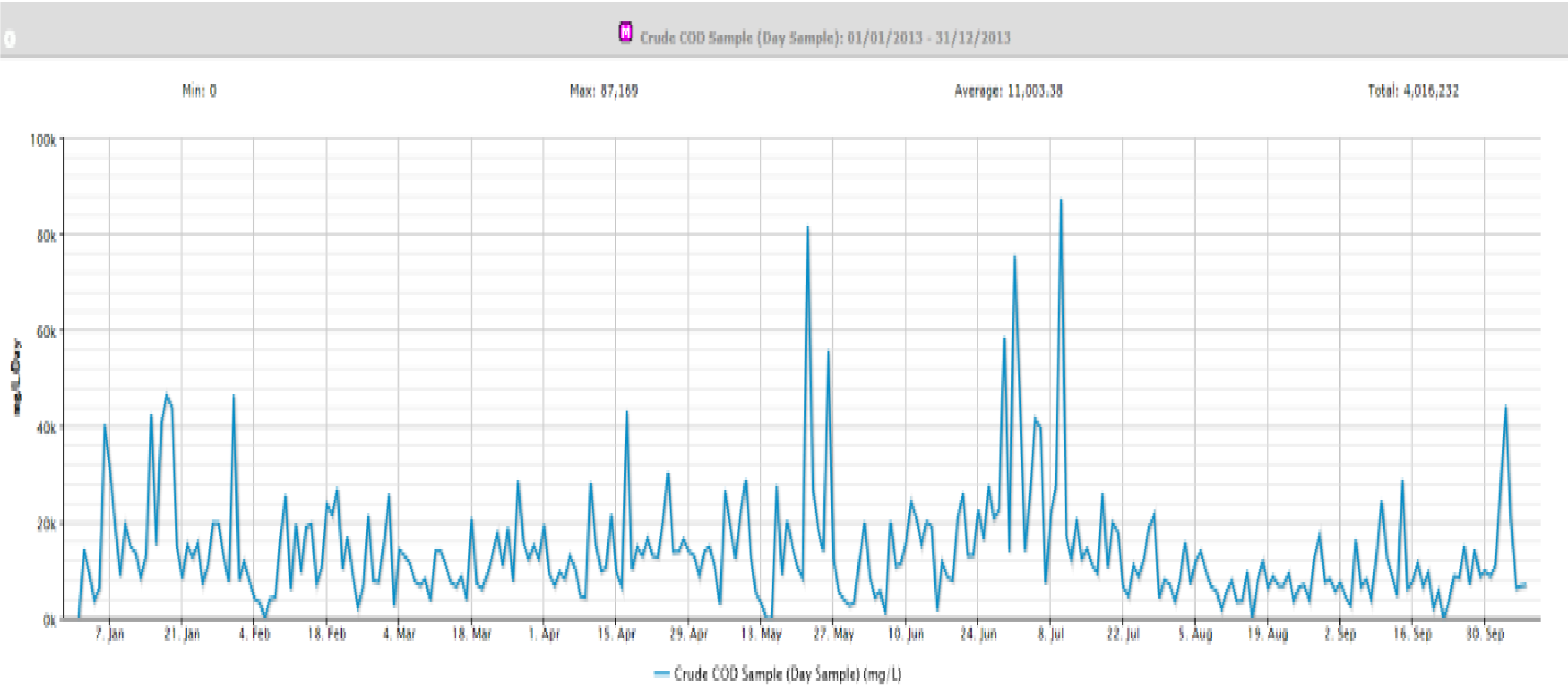
COD Load (Kg/day)



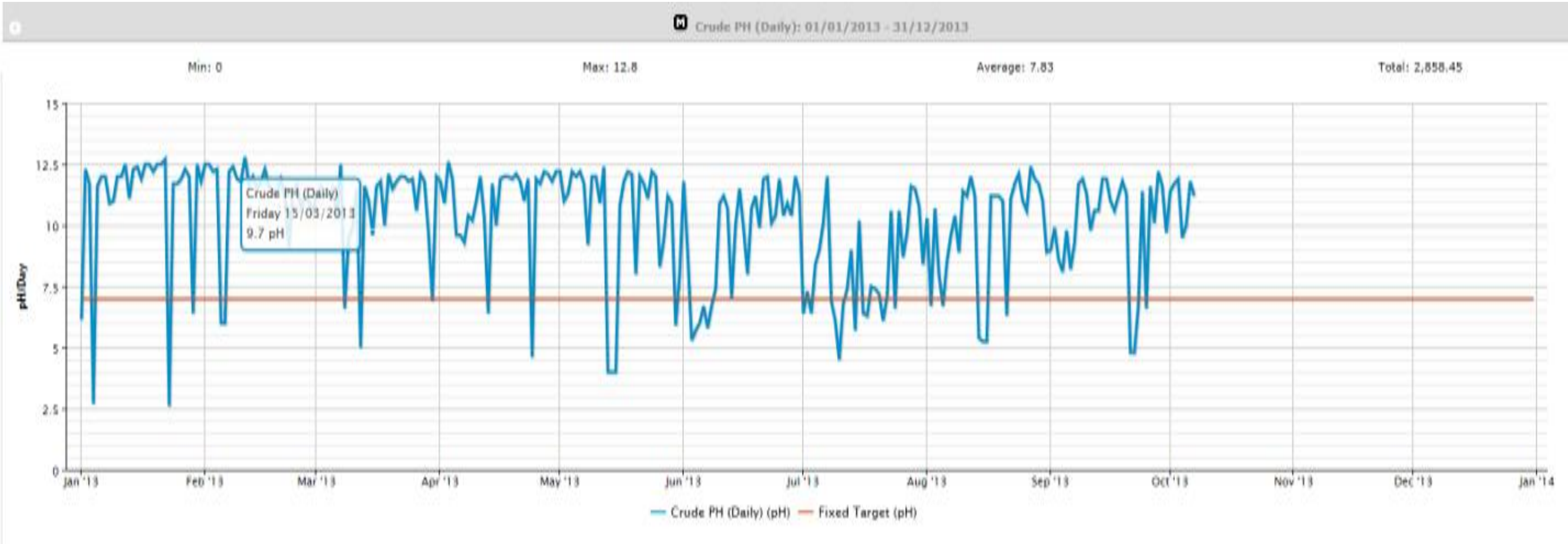
COD Load (tonnes /day)



COD Load (mg/L)

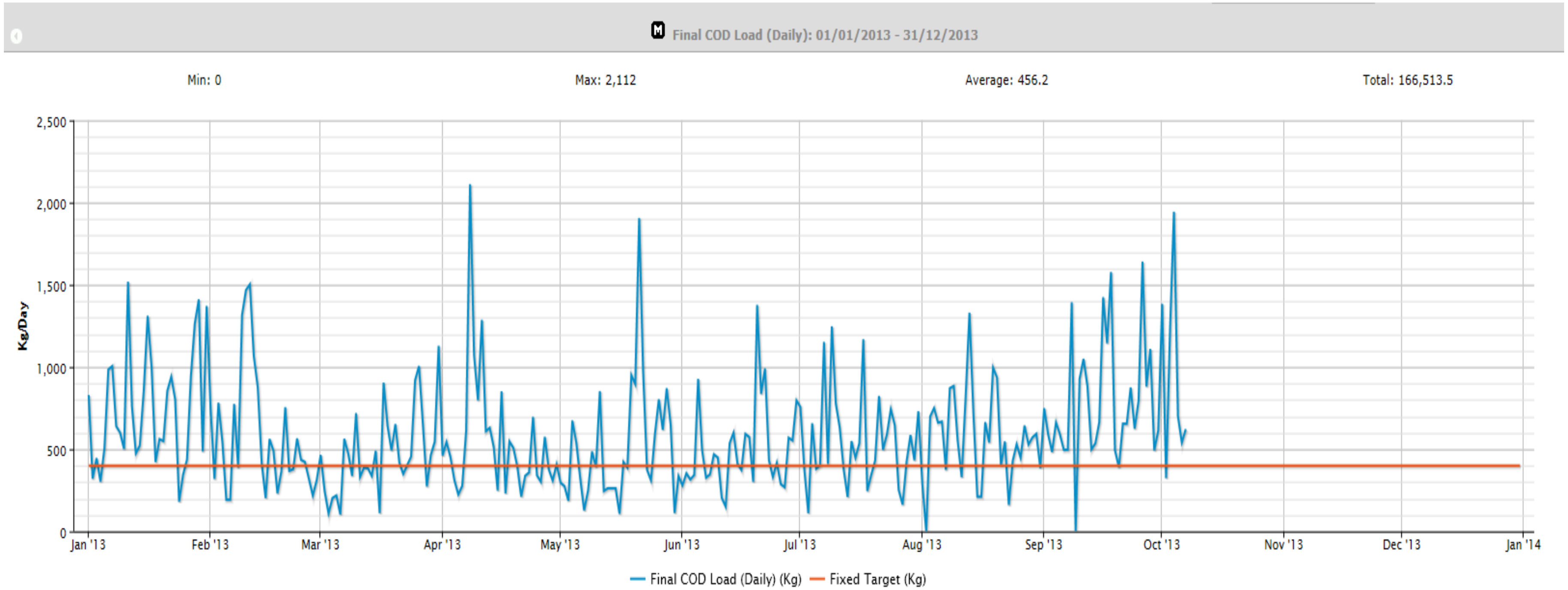

Crude COD Sample (Day Sample): 01/01/2013 - 31/12/2013
Min: 0
Max: 87,169
Average: 11,003.38
Total: 4,016,232
100k
80k
60k
40k
20k
0k
7. Jan
21. Jan
4. Feb
18. Feb
4. Mar
18. Mar
1. Apr
15. Apr
29. Apr
13. May
27. May
10. Jun
24. Jun
8. Jul
22. Jul
5. Aug
19. Aug
2. Sep
16. Sep
30. Sep
Crude COD Sample (Day Sample) (mg/L)

pH

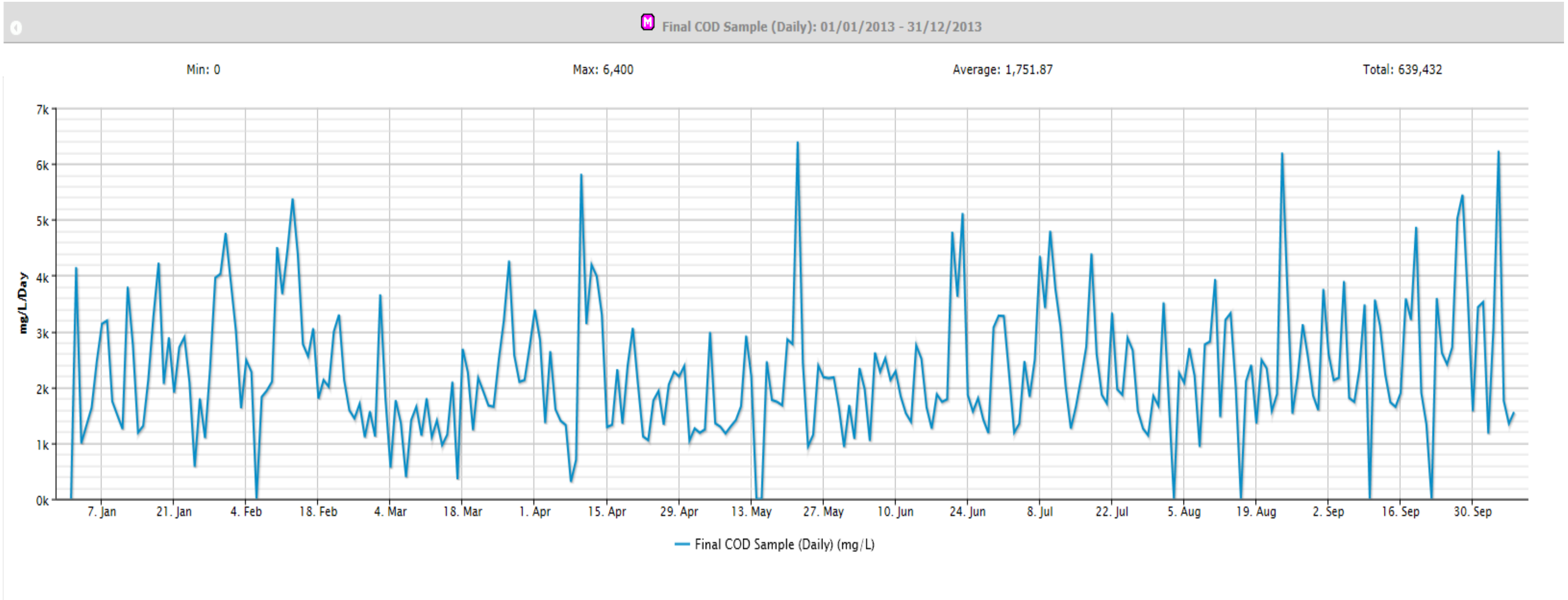

Crude PH (Daily): 01/01/2013 - 31/12/2013
Min: 0
Max: 12.8
Average: 7.83
Total: 2,858.45
Crude PH (Daily)
Friday 15/03/2013
9.7 pH
pH/Day
Jan '13
Feb '13
Mar '13
Apr '13
May '13
Jun '13
Jul '13
Aug '13
Sep '13
Oct '13
Nov '13
Dec '13
Jan '14
Crude PH (Daily) (pH)
Fixed Target (pH)

B Final Discharge Data

COD (Kg/day)

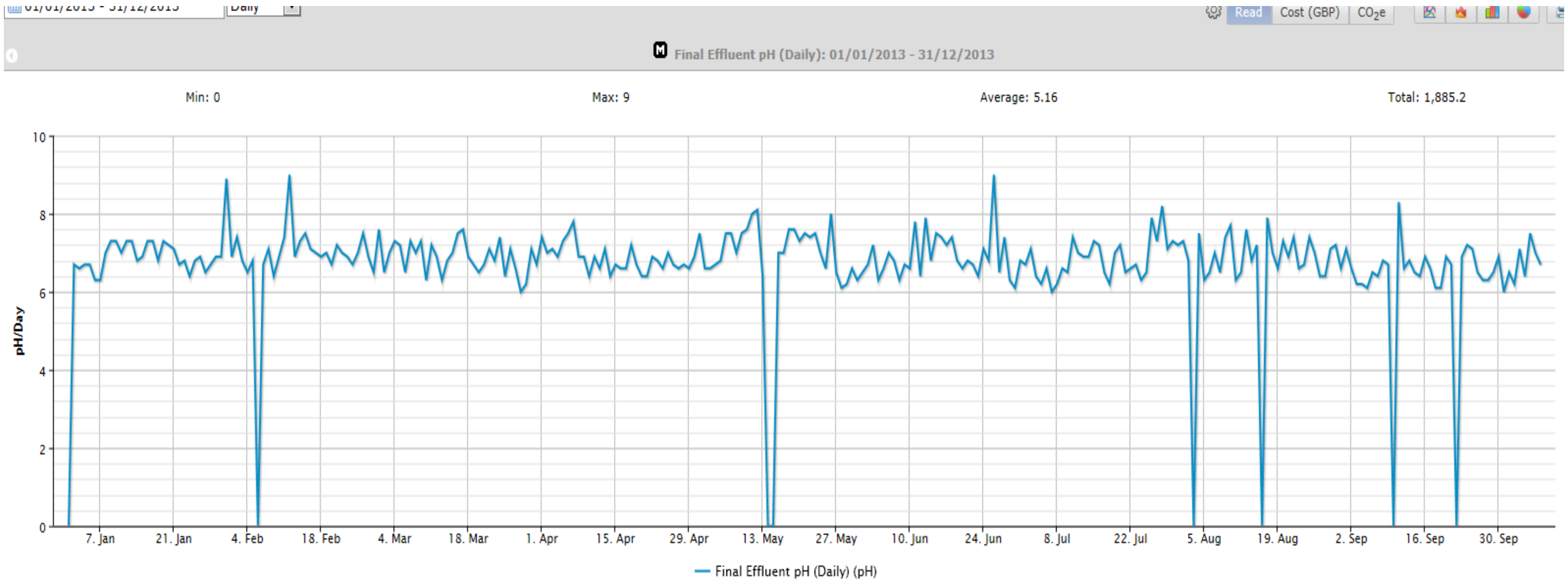


COD (mg/L)



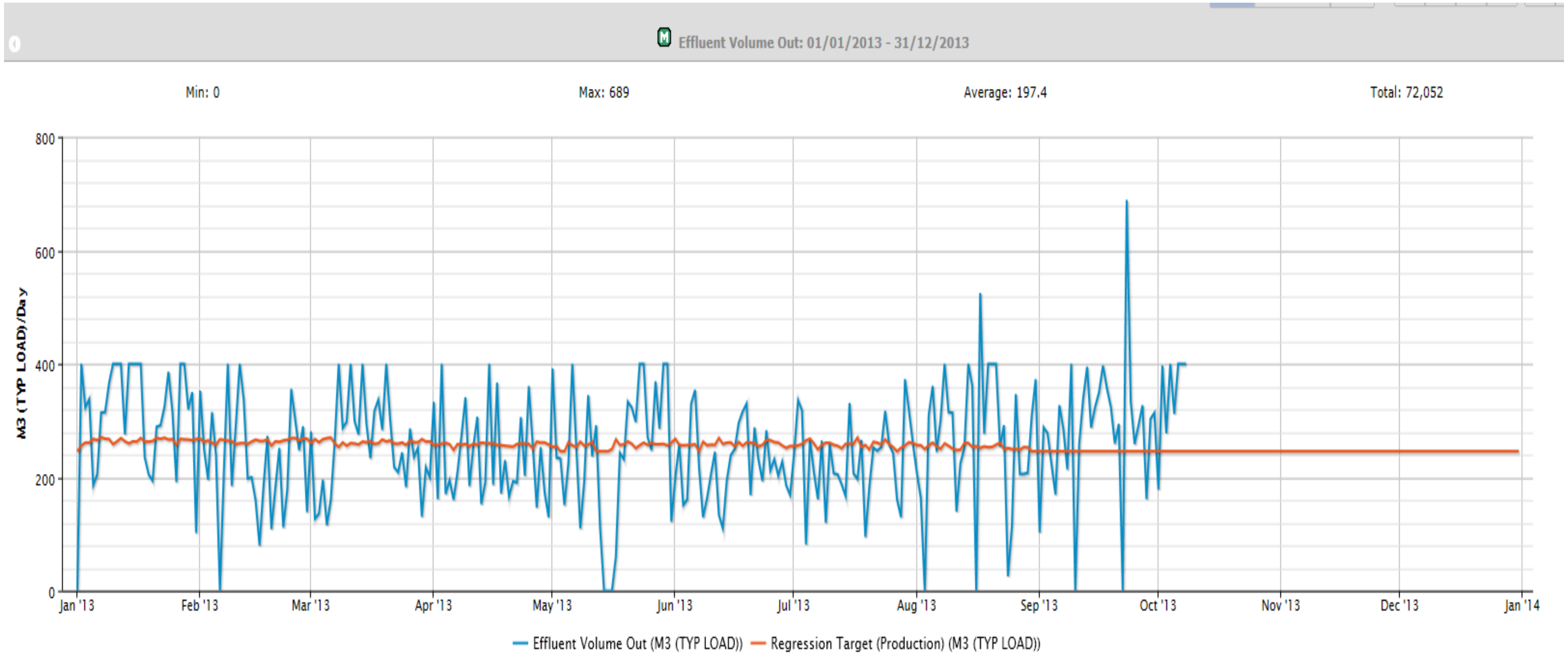
Final COD Sample (Daily): 01/01/2013 - 31/12/2013
Min: 0
Max: 6,400
Average: 1,751.87
Total: 639,432
mg/L/Day
7k
6k
5k
4k
3k
2k
1k
0k
7. Jan
21. Jan
4. Feb
18. Feb
4. Mar
18. Mar
1. Apr
15. Apr
29. Apr
13. May
27. May
10. Jun
24. Jun
8. Jul
22. Jul
5. Aug
19. Aug
2. Sep
16. Sep
30. Sep
Final COD Sample (Daily) (mg/L)

pH

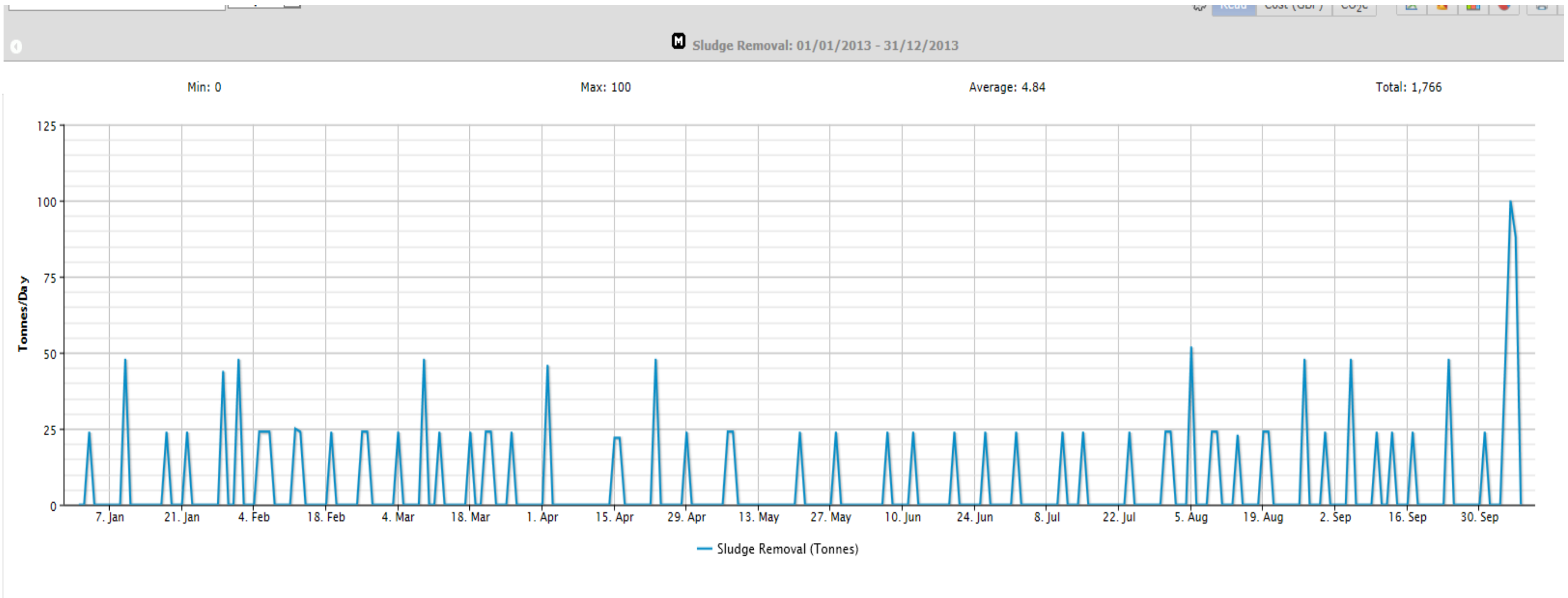

01/01/2013 - 31/12/2013
Daily
Read
Cost (GBP)
CO2e
Final Effluent pH (Daily): 01/01/2013 - 31/12/2013
Min: 0
Max: 9
Average: 5.16
Total: 1,885.2
pH/Day
10
8
6
4
2
0
7. Jan
21. Jan
4. Feb
18. Feb
4. Mar
18. Mar
1. Apr
15. Apr
29. Apr
13. May
27. May
10. Jun
24. Jun
8. Jul
22. Jul
5. Aug
19. Aug
2. Sep
16. Sep
30. Sep
Final Effluent pH (Daily) (pH)

C: Effluent Volume and Sludge Removal

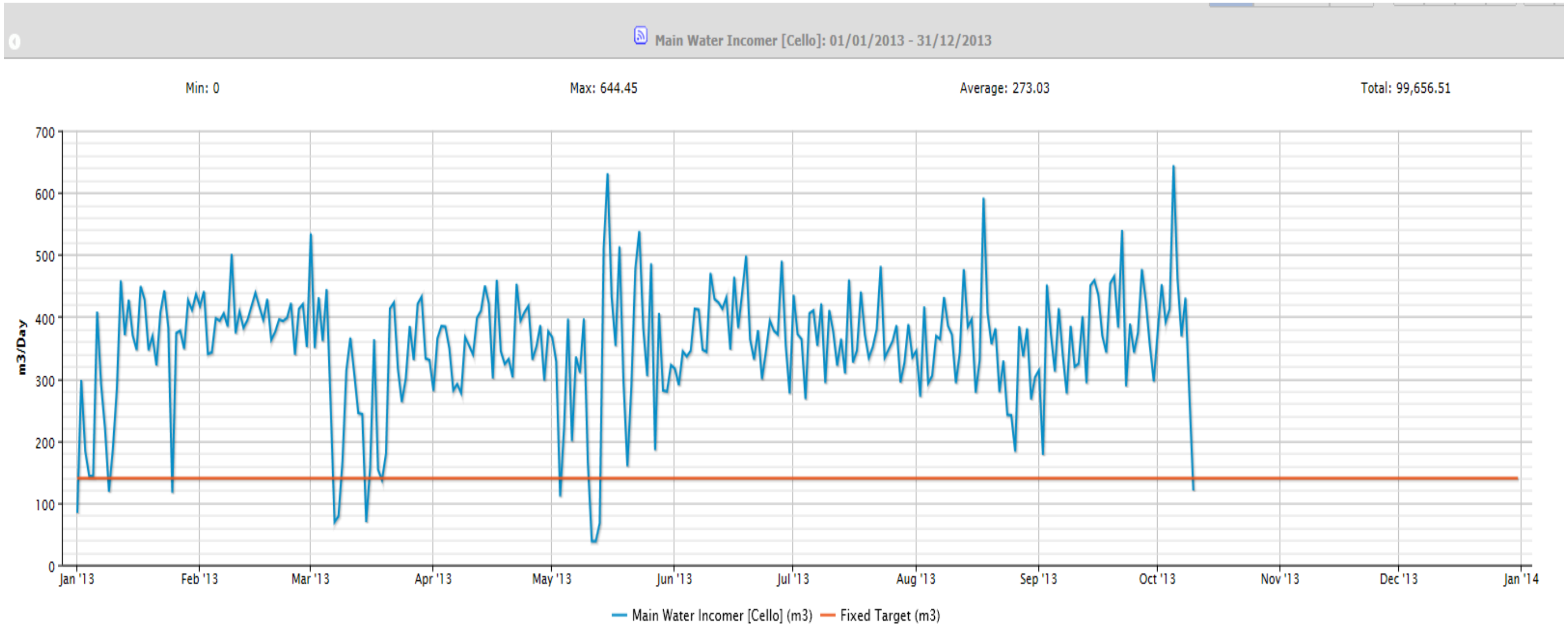
Volume out (m3)



Sludge (tonnes per day)



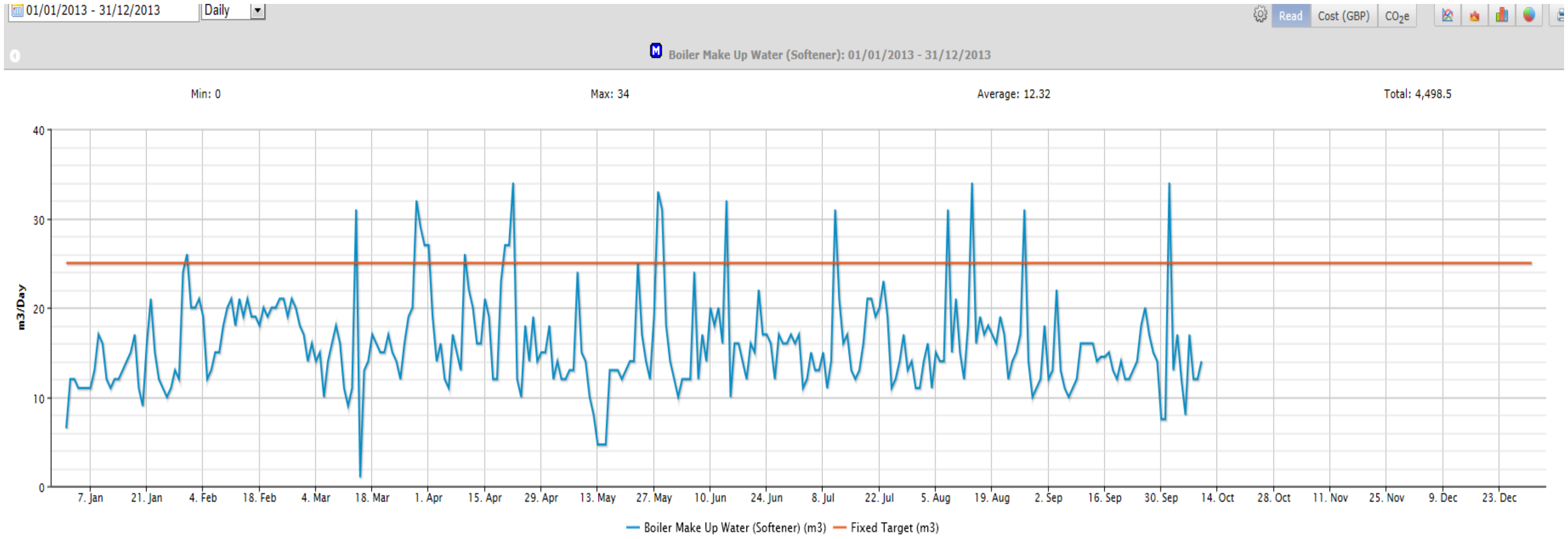
D: Water Usage (m3/day)



E : Effluent Chemical Usages (l/day)

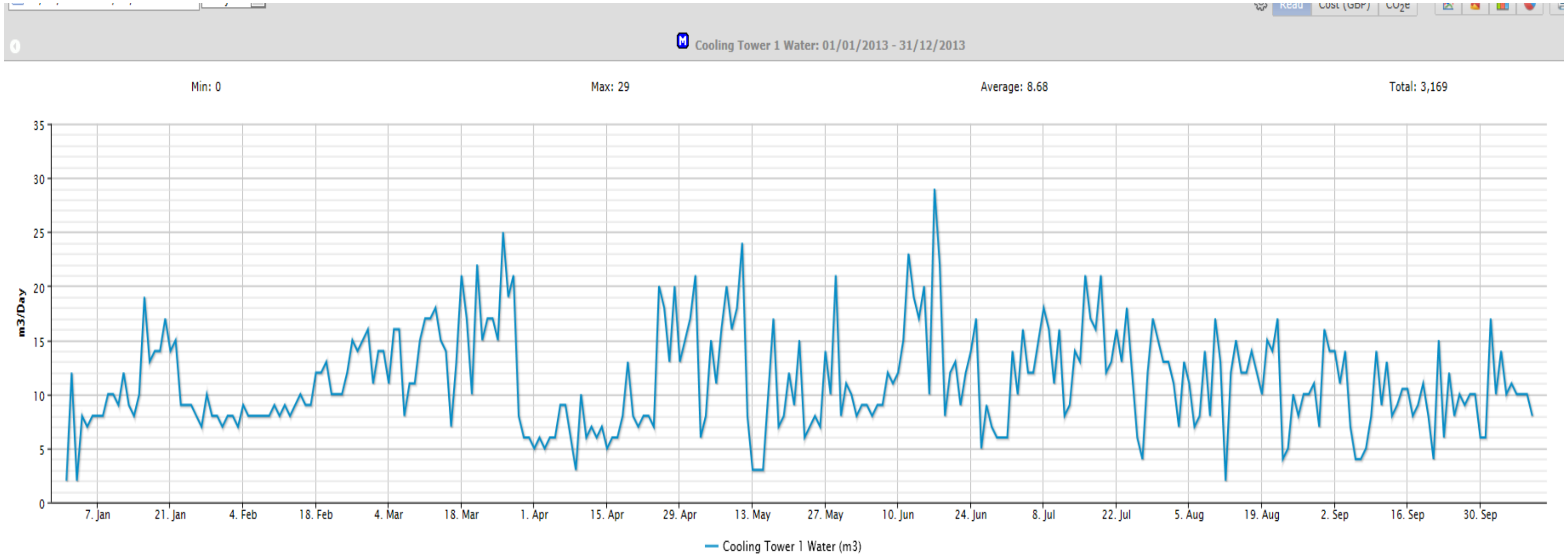
Chemical	Strength	Usages Per annum (tonnes)	Cost per tonne (£)
NaOH	32%	28	470
PAC	18%	45	600
HCl	32%	24	480

F: Boiler Water Demand

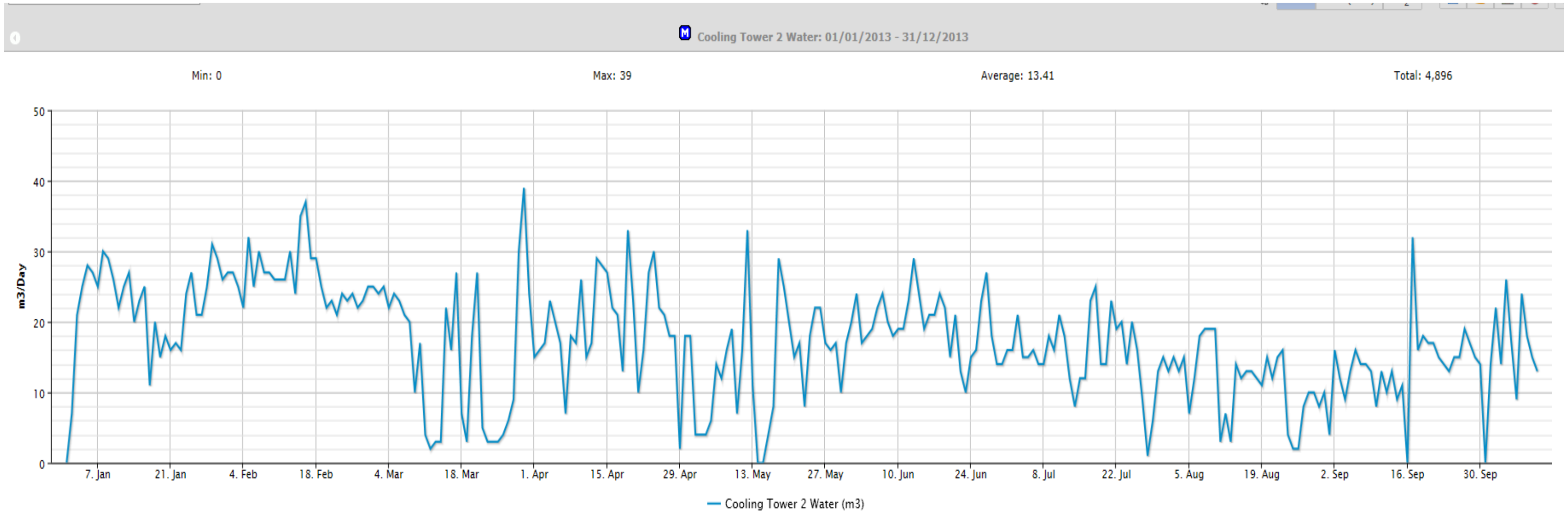


G: Cooling Towers Demand

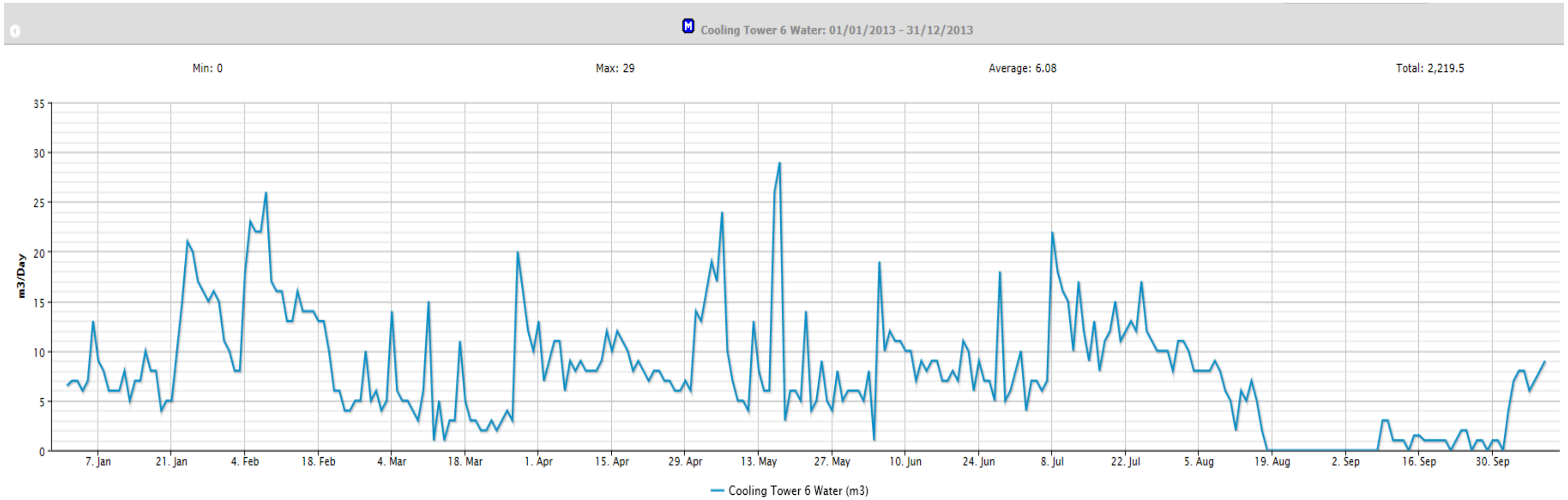
CT1



CT2


Cooling Tower 2 Water: 01/01/2013 - 31/12/2013
Min: 0
Max: 39
Average: 13.41
Total: 4,896
m3/Day
0
10
20
30
40
50
7. Jan
21. Jan
4. Feb
18. Feb
4. Mar
18. Mar
1. Apr
15. Apr
29. Apr
13. May
27. May
10. Jun
24. Jun
8. Jul
22. Jul
5. Aug
19. Aug
2. Sep
16. Sep
30. Sep
Cooling Tower 2 Water (m3)

CT6


Cooling Tower 6 Water: 01/01/2013 - 31/12/2013
Min: 0
Max: 29
Average: 6.08
Total: 2,219.5
m3/Day
35
30
25
20
15
10
5
0
7. Jan
21. Jan
4. Feb
18. Feb
4. Mar
18. Mar
1. Apr
15. Apr
29. Apr
13. May
27. May
10. Jun
24. Jun
8. Jul
22. Jul
5. Aug
19. Aug
2. Sep
16. Sep
30. Sep
Cooling Tower 6 Water (m3)

4-2 Effluent Discharge Costs (OFWAT, 2013)

A: Discharge cost of the crude effluent

Sewerage undertaker: United Utilities Treatment : Biological Treatment

Charge/ m^3 =R+V+(Ot/Os)B+(Sc/Ss)S+M pence m^3

Effluent Volume (m^3)	71,905
COD of effluent , Ot (mg/l)	11,000
Suspended Solids, St (mg/l)	600
Theoretical Charge without the DAF plant	£480, 541.12

B: Discharge cost after the DAF Unit

Sewerage undertaker: United Utilities Treatment : Biological Treatment

Charge /m^3 = R+V+(Ot/Os)B+(Sc/Ss)S+M pence m^3

Effluent Volume (m^3)	71,905
COD of effluent , Ot (mg/l)	1,751
Suspended Solids, St (mg/l)	50
Current charge	£105,453.28

Where

R= Fixed charge for collection via the sewerage network

V= Preliminary and primary treatment cost per m^3

B= Secondary (biological) treatment cost per m^3

S= cost of treatment and disposal of sludge

M= cost of discharge via long sea outfall

Ot= COD of the discharged wastewater

Os= Average strength of domestic wastewater

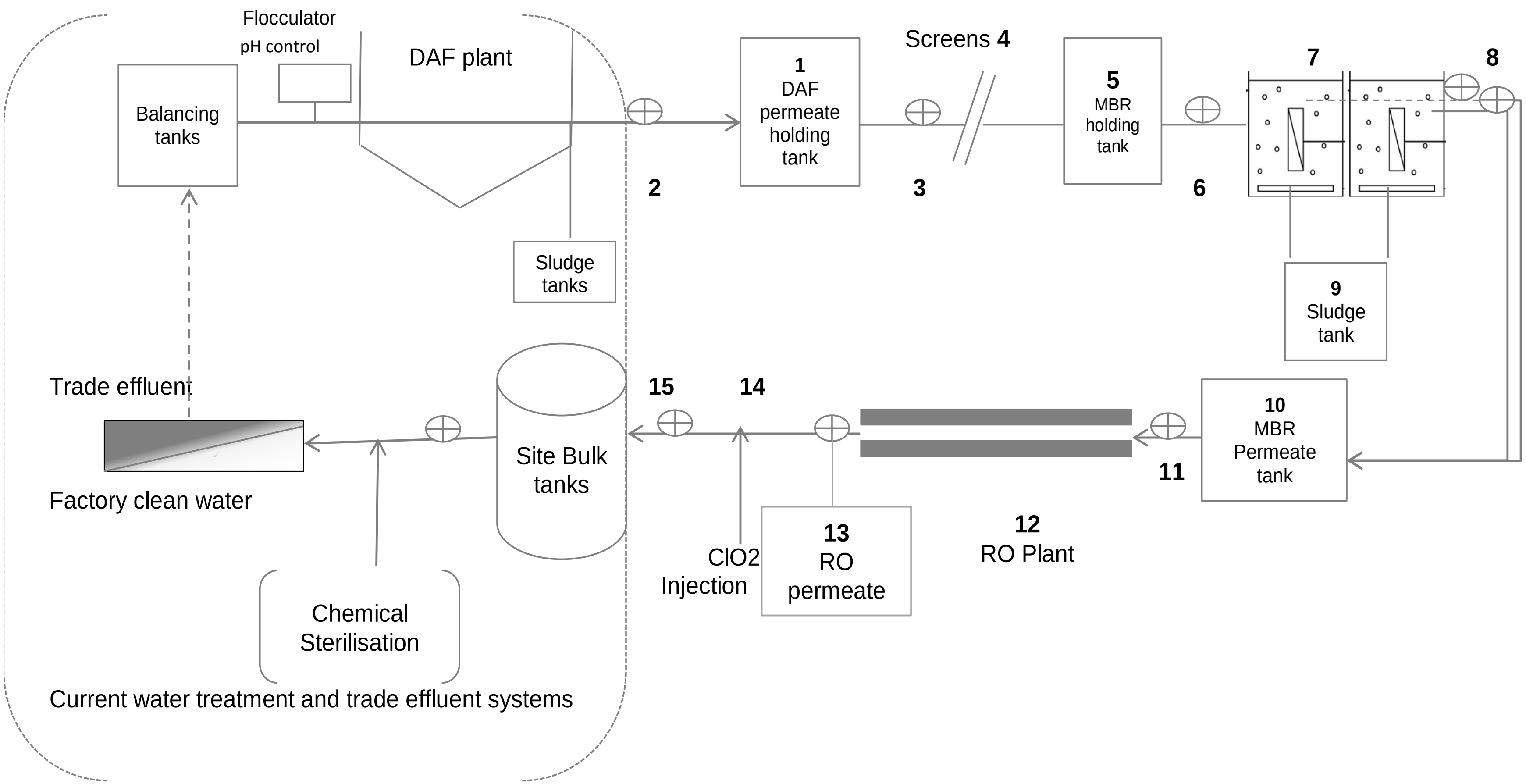
Sc= The suspended solids of the discharged wastewater

Ss= Average suspended solids of domestic wastewater

4-3 List of Companies that contributed to the case study

Due to the confidentiality of the information presented in this appendix, it is only provided on the CD-ROM

4-4 Case Study Schematic – not to scale



4-5 Economic Evaluation of the DAF Plant

A: CAPEX Analysis [24]

Component	Dimensions	Estimated unit cost	Total price (£)[25]
DAF plant including flocculator and sludge scrapper	Depth 2000mm Width 1000mm Height 3000mm	DAF manufacturer who originally installed the unit	120,000
Sludge Scrapper Belt	2xunits	£4000	8000
Gear Box Pumps – for top and bottom skimmer systems	2xpumps	£1000 each	2000
Sludge pump		£500	500
Air Saturation Pump		£1000	1000
Break tank	2x 400 m^3	£180 per m^3 capacity	144,000

[24] The capacity of the DAF plant and associated systems are designed to deal with peak flows and might appear to exceed the requirements of the average figures used through the case study.

[25] The colours correspond to the values used in calculating the OPEX in table 6-5C

A - Continued

Component	Dimensions	Estimated unit cost	Total price (£)
Sludge tank	2x50m^3	£180 per m^3 capacity	18,000
Pipe work	3 inch diameter 300 m length	£11 per m	3,300
Civils to install pipe ducts	1M underneath the surface	Estimated by groundwork's engineering company	40,000[26]
Pipework installation cost		Engineering company currently working at the site	4000
Dosing Equipment	3 pumps and on line pH controller	Water treatment suppliers	2000
Total CAPEX			**£342,800(CAPEX1)**

[26] This cost can only been verified after doing a proper survey to identify the underground structure and other installations that might be found at the 1M depth. The £40,000 assumes a straight forward job.

B: OPEX Analysis

Component	Cost per unit	Usages	Total cost to treat 71905 m^3 per annum (£)
Energy operating costs	£0.08 per kwh	1.2 kwh/m^3	6,903
DAF chemicals (Appendix 5.1 E)			
32% NaoH	£470 per tonne	28 tonnes	13,160
PAC(18%)	£600 per tonne	45 tonnes	27,000
HCL(32%)	£480 per tonne	24 tonnes	11,520
Sludge disposal	£15 per tonne + 100 per tanker visit	50 tonnes 2 times per month	20,400
Maintenance time	£15 per hour	2 hours per day	10950
Sampling	£10 per day		3650
Total direct operating costs			**£ 93583 (OPEX1)**

C: Other contributing costs

Component	Lifespan, years (manufacturer's data)	Total cost	Contribution to OPEX (£) per annum
DAF Plant and tanks	20	282,000	14,100
Installations	20	47300	2365
Pumps	5	3500	700
Scraper belt	3	8000	2666
Dosing Equipment	5	2000	400
Interest on capital cost		5% [27]	11537.5 (Appendix 5.5A)
Indirect Operating costs			**£31768.5 (OPEX 2)**

[27] The payback period was roughly calculated without including the interest rate. The value derived was then used to estimate the duration of the loan and to calculate the interest rate. The interest rate has been based on a loan of 15 months (Appendix 6-9A). Due to the short term of the loan the interest rate is added to the first year of the operating costs.

4-6 Economic Evaluation of the MBR

A: Supplementary components to the MBR plant - Capital and associated operating costs [28]

Ref on (Appendix 5.4)	function	size	Price per unit	Total cost	Operating lifespan Years	CAPEX	OPEX Per annum
1	DAF permeate holding tank	200m^3 [29]	£180/m^3	£36,000	20	£36,000	£1800
2	Pump from DAF plant to tank 1	10m^3/hr		£400	5	£400	£80
3	Pumps from holding tank 1 to screens and MBR balancing tank	10m^3/hr		£400	5	£400	£80
4	2x 0.5mm screens	Capacity: 10m^3/hr	£4000 each	£8000	10	£8000	£800
5	MBR holding tank	50m^3	£180/m^3	£9000	20	£9000	£450
6	Pump from tank ref. 5 to the bioreactors	10m^3/hr		£400	5	£400	£80

[28] The figures are based on the information provided to us by the market suppliers

[29] This is the main backup tank designed to hold one day worth of effluent to allow for emergency repairs and water storage should any of the treatments stop performing efficiently or to the specified standards.

A- continued

Ref on (Appendix 4)	function	size	Price per unit	Total cost	Life expectancy Years	CAPEX	OPEX Per annum
8	Permeate pump per MBR	$5m^3$/hr		£300 each	5	£600	£120
9	Sludge tanks	2x2m3	£180/m^3	£720	20	£720	£36
	CIP system and data logger			£10,000	5	£10,000	£2000
	CIP tanks and bunds and cam locks	2x1000L		£800	20	£800	£40
10	MBR permeate tank	$50m^3$	£180/m^3	£9000	20	£9000	£450
11	Pump from tank ref. 10 to RO	$10m^3$/hr		£400	5	£400	£80
Capital and operating costs based on the MBR design						**CAPEX 2 £75720**	**OPEX 3 £6016**

B: Costs directly associated with the Membrane Bioreactor[30]

Function	size	Price per unit	Total cost	Operational Life span Years	CAPEX	OPEX Per annum
Air blower per reactor	Approx. 7.5 kg/O2/hr (eq.5)	£2400	£4800	5	£4800	£960
Mixing Equipment	Capacity 5 m^3/hr in a tank volume of 100m^3	£2500	£5000	5	£5000	£1000
Recirculation pump	Capacity 5 m3/hr in a tank volume of 100 m^3	£2500	£5000	5	£5000	£1000
MBR tanks	2x100m^3	£180/m^3	£36000	20	£36000	£1800
2x Sludge pumps	2x2m^3	£360	£720	5	£720	£144
MBR membrane	1040 m^2	£120 /m^2	£124800	5	£124800	£24960
					CAPEX 3	**OPEX 4**

[30] The figures are based on the information provided to us by the market suppliers

Capital and operating costs directly linked to the MBR unit	**£176320**	**£29864**

C: Costs associated with unit housing and installations [31]

Unit	Cost	Operational life span (years)	CAPEX	OPEX
Housing the MBR unit in a prefabricated unit	£30,000	20	£30,000	£1500
Installation costs and pipework	£15,000	20	£15000	£750
Capital and operating costs linked to Civil and installation work			**Capex 4** **£45000**	**OPEX 5** **£2250**

[31] The figures are based on the information provided to us by the market suppliers

D: Direct operating costs of the MBR plant

Operation	Figure used in calculation	Reference	Operating cost per annum
Total energy costs	4KWh/m^3 £0.08/KWh	Market suppliers and site charging tariff.[32]	£23,000
Pumping costs x6 (appendix 5.4)	Power per pump 0.75KW[33] (£0.08/KWh)	Pump manufacturers	£3153.6
Sludge disposal	2.2 tonnes /month £15 /tonne	Calculated equation 4. Disposal costs are based on current site sludge disposal costs	£396
CIP chemicals	Use of NaOCL and Citric Acid	(Judd 2011)	£1000
Maintenance	2 hours per day £20 /hour	Senior technicians rate	£14600
Total direct operating costs			**OPEX 6 £42149.6**

[32] Based on plant design and 197 m^3 per day
[33] The plant has 6 pumps with a maximum flow rate capacity of 15m^3/hr. Power to run the pumps at a maximum head of 16 meters= 0.75 KW = £525.6 per pump

E: Explanatory Notes relating to Appendix 4-6

a. Energy costs were estimated taking into account the following:

- Bioreactor Volume : 100m^3 each
- MLSS : 17000 mg/L
- COD values of influent and permeate water : 1750 and 25 ppm respectively
- Aeration needs of 298 kg O_2 per day
- Plant design including all the pumps (considering no pumping gradient)

Based on the above the energy cost per m^3 was estimated. An average figure of 4KWh per m^3 was provided to us by the suppliers. Based on 71905 m^3 per annum of trade effluent water and a site energy tariff of £0.08 per kWh, the total annual cost of running the MBR system is estimated to be around £23,000.

b. Sludge disposal costs were based on:

- The calculations presented to us in equation 5.4. The unit is expected to generate around 2.2 tonnes of sludge a month
- Site actual sludge disposal costs of £15 per tonne

Based on the above a total annual cost of £396 was used for sludge disposal.

It was assumed that the sludge generated from the MBR plant will be emptied at the same time as the DAF plant sludge and will not incur any visit charges.

c. CIP chemicals

The cost was calculated based on a chemical clean every 14 days and an intensive clean twice per annum using sodium hypochlorite and Citric acid (Judd 2011)

d. Routine maintenance time

This was roughly estimated as 2 hours per day at a rate of £20 per hour.

4-7 Economic Evaluation of the RO Plant

A: Capital and associated operating costs of the RO plant [34]

Element	Ref (appendix 4.4)	size	Price per unit	Total cost	Life expectancy years	CAPEX	OPEX Per annum
RO plant	12	Capacity $8m^3/hr$	£40,000	£40,000	10	£40,000	£4000
Membranes		9 banks (8”x1m)	£1200	£10800	5	£10800	£2160
CIP station & data logger				£10,000	5	£10,000	£2000
Chemical Tank & bund		300L	£300	£300	20	£300	£15
RO permeate tank	13	$50m^3$	$180/m^3$	£9,000	20	£9,000	£450
Pump from RO to CLO2 treatment plant	14	$8m^3/hr$		£350	5	£350	£70
Capital and associated operating costs of the RO plant						**CAPEX 5 £70,450**	**OPEX7 £8695**

[34] The above data is based on the information provided to us by the market suppliers

B: Direct operating costs [35]

Operation	size	Price per unit	OPEX Per annum
Energy running costs	11KW= 96360KWh	£0.08 (based on current site tariff)	£7708
Chemical Treatment	233 L per annum[36] (anti-scalent)	£1.25 per L	£291
Maintenance cost			Included in the MBR maintenance cost
Direct operating costs associated with the RO plant			**OPEX 8** **£7999**

In this case study we have assumed that the RO reject can be discharged into the sewer. The cost of disposal is not considered in this report.

[35] The above data is based on the information provided to us by the market suppliers
[36] The chemical consumption is based on a continuous dosage of an antiscalent a rate of 4 mg/L (assuming a flow rate of 160 m^3/day)

4-8 Capital and operating costs of the Chlorine Dioxide plant [37]

Element	Ref (appendix 5.4)	size	Price per unit	Total cost	Life expectancy years	CAPEX	OPEX Per annum
Chlorine dioxide generator	15	Capacity to treat $6m^3$ per hour		£17,000	10	£17000	£1700
Chemical dosing pumps x2		Can deliver up to 1l/hr	150	£300	5	£300	£60
Chemical bunds and tanks x2		300L	£300	£600	20	£600	£30

[37] The above data is based on the information provided to us by the market suppliers

4-8 Continued

Element	Ref (appendix 4)	size	Price per unit	Total cost	Life expectancy years	CAPEX	OPEX Per annum
Chemical costs (equation		NaOCl (7.5%)	£2.5/L	2.5x527[38]= £1317.5			£1792.5
		HCL (8%)	£0.90/L	0.9x527= £475			
Testing water quality on weekly basis for E.coli and coliform			£65				£3380
Total Capital and Operating costs of the chlorine dioxide unit						**CAPEX 6**	**OPEX 9**
						£17900	**£6962.5**

[38] Based on generating CLO2 using Sodium Chlorite and Hydrochloric acid to a reserve of 0.5 ppm (DWI 2013).

4-9 Calculating the interest rate Interest Rate associated with the case study

(The-Guardian, 2013)

A Interest rate associated with the DAF Plant

Loan payment

Enter the amount of the loan: £ 342800

Enter the interest rate (APR): 5 %

Payments on the loan will be made: Monthly

Enter the number of payments: 15 (ex. monthly for 30 years = 360 payments)

Loan repayment schedule

Pmt#	Balance	Interest	Principal	Payment
1	342,800.00	1428.33	22194.17	23622.50
2	320,605.83	1335.86	22286.64	23622.50
3	298,319.19	1243.00	22379.50	23622.50
4	275,939.68	1149.75	22472.75	23622.50
5	253,466.93	1056.10	22566.39	23622.50
6	230,900.54	962.09	22660.42	23622.50
7	208,240.13	867.67	22754.83	23622.50
8	185,485.29	772.86	22849.65	23622.50
9	162,635.65	677.65	22944.85	23622.50
10	139,690.79	582.04	23040.46	23622.50
11	116,650.34	486.04	23136.46	23622.50
12	93,513.88	389.64	23232.86	23622.50
13	70,281.02	292.83	23329.66	23622.50
14	46,951.35	195.63	23426.87	23622.50
15	23,524.48	98.02	23524.48	23622.50

Total Paid = £23622.50x15= £354337.5

Interest paid = £354337.5-£342800= £11537.5

B & C were calculated using the same programme

B: Interest rate associated with MBR/RO & CLO2

Loan payment

The amount of the loan: £ 390590

The interest rate (APR): 5%

Payments on the loan will be made: Monthly

The number of payments: 102 = £4708.35 each

Total Money paid= 480251.7

Interest paid over 8.5 years = £89662

Interest paid in one year = £10548

C: Interest rate associated with MBR/RO& CLO2 plant including Enhanced Capital Allowance Scheme

Loan payment

The amount of the loan: 308566
The interest rate (APR): 5%

Payments on the loan will be made: Monthly

The number of payments: 75 = £ 4798.97 each

Total Money paid= 359923

Interest paid= £51357.69

Interest paid in one year = £8152.0

5 Appendices Relating to Chapter Five

5-1 Demand of water in the 2050s- Brief Scenario Narrative (EA, 2009)

Innovation

This scenario sees a highly technological driven and knowledge led UK. Consumers continue to consume in a relatively resource intensive manner. Environmental concerns are perceived to be the problem of manufacturers and service providers, who have responded by becoming increasingly resourceful at engineering new (and less carbon intensive) solutions to the problems of meeting consumption demands. Closed loop systems have become widespread in an attempt to ensure that nothing gets wasted. Supply side regulation has now become an accepted and integral part of the economy – and in the UK the influence of EU legislation is particularly strong. This is a world in which there have been a wide range of scientific breakthroughs, including in nanotechnology, genetics, transport pharmaceuticals and health diagnostic technologies. However these are in the context of heavy government intervention around innovation patterns, ensure that efficient resource use is prioritised by business. Huge numbers of people now work in regulation and compliance; a new army of what the public call ‘men in green coats’. However, the loss of jobs from manufacturing has caused societal inequality amongst the unskilled workforce.

Uncontrolled Demand

In this world, there is broad awareness of environmental issues – but for many consumers these issues are not heavily pressing. Economically, Britain is doing well by 2050, and a historic commitment to free trade and open markets has helped to keep overall GDP levels among the world’s highest. However, there is also considerable inequality and polarisation in this world. The wealthiest 20 per cent of society enjoy a high standard of living – but increasingly cut themselves off from the rest of society. At the other end of the scale, there is also a growing underclass, which by 2050 represents around 20 per cent of the population, unable to sufficiently adapt to the changing demands of the globalised labour market. This significant minority includes the British-born poor, many climate change refugees and second generation immigrants. Meanwhile, the middle class has also found economic life increasingly challenging, experiencing stagnant wage growth and feeling economically and materially worse off than previous generations. The picture of national prosperity therefore masks significant disparities.

Service provision (including provision of water) in this world is dominated in many cases by private companies, leading to heavy disparities in the quality and reliability of provision, depending on income levels.

Appendix 5-1 Continued

Local Resilience

In Local resilience, ‘Peak Oil’ turned out to happen much sooner than the consensus suggested, resulting in a series of economic shocks triggering recession and inflation. Protectionism followed, and the market model which dominated the global economy in the late 20th century was not designed for a world in which underlying resources – especially energy – was scarce. One result was that governments spent less on infrastructure as social payments absorbed more of their shrinking revenues. Transport schemes were cut, telecoms infrastructure deteriorated, investment in sewage and water schemes was cancelled, and the electricity grid became less reliable. Systems which had been national have frequently been localised. As a result, ‘local resilience’ (and technologies to facilitate this) has a high degree of importance. Moreover, the cost of resources means that people have adapted their houses to reduce energy consumption and water use. Food is more seasonal and more local and there is also more ‘urban agriculture’. People have also become used to reusing goods. Online networks help people find things cheaply that they need – second-hand, and ‘Decluttering’ is a widespread social phenomenon. GDP has declined in importance as a measure of social success, as other measures of social wellbeing and welfare have become more prominent. There is less concern for the environment, and some habitats have suffered. But eco-system services have a far greater importance, and bio-diversity has increased.

Sustainable Behaviour

Those living in Sustainable Behaviour have a strong sense of their role and responsibilities within the wider world, and recognise the need for action against climate change. Governments around the world have responded to these concerns, and over the past decades we have witnessed a virtuous circle of growing public awareness and policy developments. Sustainable behaviour in the home and business has consequently increased. This focus on sustainability resulted in increased prices across the board, and reduced purchasing power. However, levels of social cohesion are high, reinforced by local or regional delivery of a number of services and shared ownership schemes for now expensive goods (e.g. cars). Moreover, local governance is increasingly important in this world. There has also been a shift towards public ownership of key utilities, and mutualisation is common in a number of industries, including water, energy supply and waste. The greater focus on regional governance has resulted in variable levels of service quality. Whilst some areas have prospered under engaged and enthusiastic representatives keen to meet the needs of their community, others have suffered from less effective leadership. With moving out of the area unaffordable for the majority, the idea of a ‘postcode lottery’ determining the quality of service provision is becoming a key concern.

5-2 Food and drink manufacturing water demand projections to 2050 (Development of the Scenarios) (EA, 2013 a)

The following steps and stages were followed by DEFRA and the EA to generate the scenarios that are specific to water demand in the FBM:

An electronic invite was sent to all FBM companies that are currently members of the Federation House Commitment, the main UK supermarkets and the following institutes:

- Academic and research community
- British Retail consortium
- Campden BRI
- Chilled food association
- Dairy UK
- Food Standards Agency
- London food trading association
- Raw ingredients providers such as Tate and Lyle
- Ricardo Energy and Environment
- UK Brewers Association
- WRAP

There was representation from all the above with the exception of the supermarkets.

Workshop 1 (21st March 2013)

The workshop covered the following points:

a. Background to the scenarios – using **“** Demand of water in the 2050's “ scenarios (EA 2009)
b. Identify the main demand indicators
c. Assess the impact of these demand indicators on the scenarios
d. Evaluate the impact of scenarios on subsectors within the food and beverage industry
e. Quantify the impact on water demand

Four sub sectors were chosen to represent the food and beverage industry: Snack foods, meat processing, pre- prepared foods and brewing.

Participants were divided in “expert groups” and rotated through four tables, each discussing the impacts of the scenarios on their sector.

Participants were advised by the EA to consider the following assumptions during the workshop:

a. Climate change is real
b. Energy prices will continue to rise for the foreseeable future
c. Overall UK water demand and water stress will increase
d. Long- term economic shift from the West towards Asia, Latin America and Africa
e. World population levels will continue to grow
f. Other resource pressures will emerge

Based on the information that emerged from the initial workshop the EA produced the scenario narrative. A second workshop was organised to discuss the draft report.

Workshop 2- Check and challenge event (15 May 2013)

The workshop covered the following points:

a. Results from initial workshop and draft projections
b. Check and challenge the narrative
c. Check and challenge the quantitative data
d. Applying the findings and quantifying impacts for the wider food and drink manufacturing sub sectors

Final consultation – (11th June 2013)

A draft report was emailed to all participants to check whether the report is a true reflection to the view of the participants

The final version of the report was issues in October 2013.

5-3 Food and drink manufacturing water demand projections to 2050 (EA, 2013 a)

A Brief Scenario Narrative

Innovation

"Our scientists and technologists can solve the problems of environmental damage through their ideas and innovation"

In response to a stagnating economy, the government chooses to drive the UK into a large scale wave of industrial investment in sustainable technologies, attempting both to kick-start the economy and avoid an impending wave of resource shortage. The result is a world in which sustainable behaviour is "designed in" to urban and social life. One consequence is a world, in which the interests of business and government are aligned.

Summary of primary impacts

Technology advances – Developments in technology have enabled the use of alternative water sources and water quality has become less of a concern. However, only large producers have been able to afford the new and more efficient technologies.

Water efficiency – In addition the advancement in technologies has increased production proficiency which has become faster, more efficient and cheaper. Technology advancements have also improved water use efficiency and resulted in alternative sources of water being available. Although there has been an overall increase in water use driven by increased demand, the significant progress in water technology limited this increase.

Water value - The value of water has decreased as innovation has increased its availability. Water availability is no longer a primary concern due to a wider range of sources being accessed. This has driven investment in technology that will enable the use of alternative water sources.

Increased food production - Demand has increased significantly due to change in lifestyle, fewer ethical issues, and improved food quality. The market has driven production to where it is most efficient. Alternative sources of water had to be found to meet the increased production demand.

Increased polarisation - A split between the rich and the poor has resulted in the rich consuming higher quality products compared to the synthesised foods eaten by the poor.

Higher quality standards – This has been driven by increased policy and regulation, increase in quality standards and investment in process and production. This resulted in the loss of small producers and the domination of bigger and more efficient ones, leading to a reduction in the number of manufacturers.

Uncontrolled Demand

"The rich shall inherit the earth – because we're worth it"

Political and economic systems were dominated by the interests of the wealthy, and as a result, they were able to shrug off protests designed to provoke a rethink of prevailing political and economic models. Increasing resource shortage meant that previous patterns of polarisation between the rich and poor intensified. The top 20% continue to consume without moderation, while the less affluent people are squeezed, relying on handed down products and poorer infrastructure.

Security, water, energy and health move from being publicly provided to being increasingly privatised, with minimal basic provision levels supplied for all.

<u>Summary of primary impacts</u>

Increased polarisation – The gap is growing between the rich and poor. With poorer people consuming cheaper, low quality products.

Maximise profits – There is more emphasis on producing food more cheaply and thus more profitably.

Centralisation of production- In order to maximise food production, larger more efficient factories have prospered, this has led to the reduction in water use intensity. However, in contrast there has also been an increase in exploiting water resources.

Low sustainability – the key focus is on producing food more quickly and environmental issues not taken into account. This has led to the exploitation of water resources particularly by the big and powerful manufacturers.

Increased production of high value goods for export (UK, EU) – the wealthiest within society have more disposable income and have a tendency towards luxury products. Private and well off companies have become able to invest in water efficient technologies whilst others have had to adopt a "make do and mend" approach with older equipment which are less efficient.

Demand for water has significantly increased and the risk of water shortages has increased - In order to meet increases in demand, production has significantly increased impacting on water availability in the UK. This has led to an increase in the price of water. Less water availability also resulted in developing technologies that improve efficiency. This was done to guarantee continued production and not for environmental reasons.

Local policy and regulatory standards- No taxation or regulation introduced to reduce consumption.

Local Resilience

"It is better to have fewer wants than greater resources"

Sustained political and economic crises of the 2010s were not successfully resolved, leaving the UK in a low-growth world despite the best efforts of politicians. Rationing and unwillingness for countries to work together made the UK turn inwards, and local regions focus more on how to solve their own problems. The direction of economic innovation has been away from international financial flows and finance, concentrating on helping money to circulate locally to support local and regional economies. Consumption is less intensive and more focused on local services than expensive (often imported) manufactured products.

Summary of primary impacts

Rise of localism - There has been a move away from global markets towards regional and local economies with communities becoming more self-sufficient.

Localised production - Food production has been driven by the growth local regional markets

Local policy and local regulation standards- This has driven an increase in the value of water and water reuse have become prevalent in certain areas. There is strong geographical variation in water availability and in some areas the level of water availability is crucial. Pronounced regional differences in the availability and quality of water have affected the location of operations.

Reduced diversity - due to lack of global ingredients and small batch production, production costs have increased. Environmental drivers are linked to strong geographical variations as processors need to be close to farms and the level of water availability is crucial.

Back to basics - social behaviour has resulted in the use of low tech home grown raw materials. This has resulted in an increase in water use intensity.

Water use efficiency and reuse technologies – This has become priority depending on location however, existing knowledge rather than innovation has become the focus eg reed bed systems low tech /low investment applications.

Sustainable Behaviour

"We can cut out resource use through new ways of managing our societies and our relationships"

With growth hard to find, government focused on social welfare as the way to keep citizens content, while environmental disasters in the 2010s provoked international engagement with the low carbon agenda, and tighter regulations.

Consumers choose to be green, pushed along by more regulation, which makes products reflect the full costs, including the pollution they cause. The sense of a collective project and collective action around environmental protection for social welfare means they are happier to trust the government to legislate for the national good. There is a greater role for public management, also driven by infrastructure costs that are unattractively high for private sector firms."

<u>Summary of primary impacts</u>

Increased prices – The focus on sustainability has resulted in increased prices across the board, and reduced purchasing power.

Taxation and water value – Taxation on water led to increasing the cost of water to reflect its true value. This has led to the development of technologies that can improve water efficiency and minimise wastage. The increased cost of water has also led the industry to set targets for efficient water use and water budgets.

Public perception – Consumers choose to be green and there is preference towards purchasing sustainable goods.

Legislation- Introduction of taxation and legislation has driven an increase in demand of sustainable practices and an increase in compliance costs.

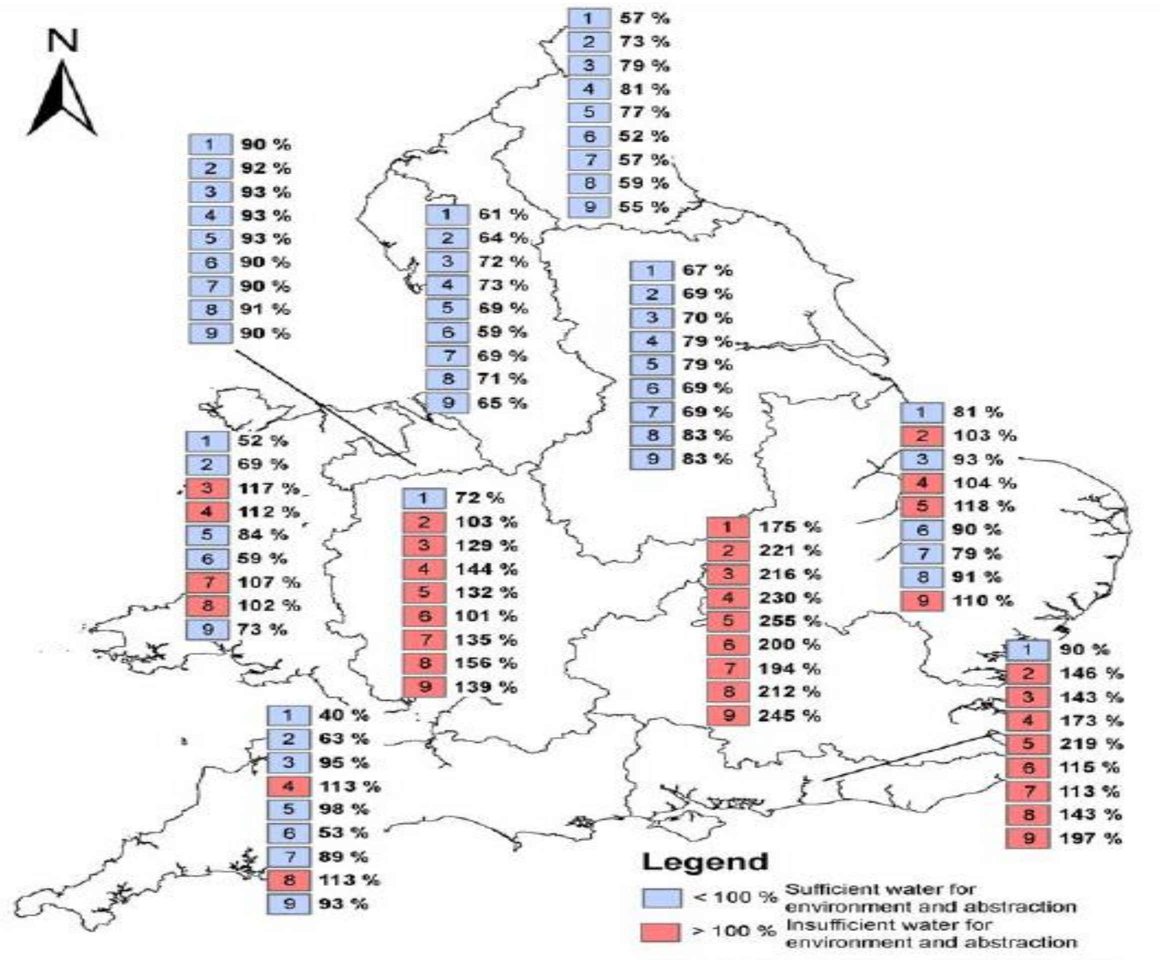
Polarisation of food infrastructure – technology uptake is dependent on whether it aligns with sustainability principles. Innovation has focussed on creating less damaging forms of production. Different quality of water sources started to be used depending on the requirement of the ingredient versus water use.

Recycling – greater uptake of recycling technologies has reduced the impact on the environment. New technologies have been developed to meet water use targets and new sources of water supply such as rainwater harvesting are being utilised.

B: Summary of the impact of the scenarios on water demand and population growth

Future scenarios					
Impact		Sustainable behaviour	Innovation	Local resilience	Uncontrolled demand
	Water demand in the FBI	28% decrease	5% increase	5% increase	70% increase
	Population growth in the UK	21% increase	32% increase	18% increase	42% increase

5-4 Future river flow and potential unmet demand in the 2050s (EA, 2011a)



Publications in Preparation

1. **McCoy Y**, Bridgeman J and Carliell-Marquet CM (2016). Characterisation of the stakeholders in the food and beverage manufacturing sectors and their role in the approval of trade effluent recycling and reuse projects. Pending submission to Resources Conservation and Recycling.

2. **McCoy Y**, Bridgeman J and Carliell-Marquet CM (2016). Reduction of water consumption on a dairy manufacturing site by establishing a closed loop water reuse system. Pending submission to Desalination and Water Treatment.

3. **McCoy Y**, Bridgeman J and Carliell-Marquet CM (2016). Economic feasibility of trade effluent recycling and ruse in the food and beverage manufacturing sectors. Pending submission to Resources Conservation and Recycling.

4. **McCoy Y**, Bridgeman J and Carliell-Marquet CM (2016). Improving the future water resilience in the UK through water recycling and reuse in the food and beverage manufacturing sectors. Pending the approval of DEFRA