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Adaptation measures for the food and beverage industry to the impact of climate change on water availability

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ABSTRACT

Water is used as an ingredient, as an essential processing element, as a cooling agent and for the cleaning of equipment and installations in many food and beverage industries. Consequently, the sector is affected by the impact of climate change of reduced water availability. This paper presents current issues related to water demand in the food and beverage industry and addresses adaptation measures in response to reduced water availability. The food and drink industry is a large drinking quality water consumer. Owing to that, the sector has to adopt reduction and minimisation measures in line with the Best Available Techniques. In particular, some general measures can be adopted by all industries of the sector, while other measures are sector-specific measures including the meat and poultry processing sector, the fish processing sector, the fruit and vegetables division, dairies and the drink manufacturing industry. Through widespread adoption of water reducing and minimisation measures, the sector will move towards sustainable development achieving decoupling of economic growth from resource use as response to reduced water availability.

Keywords: Food and beverage industry; Water demand; Climate change; Water availability; Adaptation measures

1. Introduction

Food and beverage industrial sector constitutes a leading pillar of the European economy representing 1.9% of the European Union (EU) gross value added, while comprising the largest manufacturing sector in terms of turnover, value added and employment at European level for 2011 [1]. Water is key input for the food and drink industry as process water, cooling water and boiler feed-water [2] and, as a result, the food and drink industry is directly affected by low water availability due to climate change. Water management constitutes a major field for climate change adaptation. In general, climate change can increase water, while shrinking water supplies resulting in reduced water availability. Although a certain amount of water use is unavoidable for the manufacture of food and drink products, water management practices should be considered for the sector so as to ensure its

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sustainability. To date, the scientific community has mainly focused on food security issues under conditions of water scarcity in agriculture, while little research has addressed the effect of climate change on water used in food industries. This paper presents information concerning water usage and demand in the food and beverage manufacturing industry as well as adaptation measures in response to reduced water availability as an impact of climate change.

2. Water consumption in the food and beverage industry

The food and beverage industry is one of the most important sectors in the EU in terms of financial and social significance owing to its continuous and constant growth. In 2011, the turnover of the food and beverage industry of EU-27 reached €1,017 billion (increase of 6.8% compared to 2010), while the direct employment was stable compared to 2010 (4.25 million employees) [2]. Food and Beverage (F&B) industry includes various sub-sectors aiming at manufacturing different types of products. Based on the "Nomenclature générale des Activités économiques dans les Communautés Européennes (NACE)" *(Statistical classification of economic activities in the European Communities) Rev. 2*, food and drink industry is identified by the division C10 for food products and C11 for drinks. The NACE division of food manufacturing is organised by activities dealing with different kinds of products organised in nine groups, while the beverage manufacturing NACE division is composed of seven classes organised into one group (Fig. 1).

As illustrated in Fig. 2, in 2010 the highest percentage (54%) of companies of the F&B industry within the EU-27 manufactured "bakery and farinaceous products", while the "meat processing industry" occupied the second position. In line with this trend, "bakery and farinaceous products" division employed 32% of the total number of employees, followed by the "meat processing industry" with 21%. In 2010, the "meat processing sector" occupied the first place in terms of turnover and the forth in terms of value added contributing with 20 and 15% to the total turnover and value added of the sector of EU-27, accordingly. Moreover, in 2010, the "drink sector" contributed with 15% to the total turnover and 18% to the total value added of the sector of EU-27, ranking first in terms of value added [1].

Overall F&B industry is considered as a large water consumer and in particular of drinking quality water. In general, in the food and beverage industrial sector as a whole, 75% of water used is of drinking quality [2]. According to the *Environment Agency*, the food and drink sector is the third largest industrial user of water [3], and is responsible for approximately 1.8% of Europe's total water use [4,5]. In the UK, water use in food and drink manufacture represents 56% of the total water used in industry [6].

The "Draft Reference Document on Best Available Techniques in the Food, Drink and Milk Industry"

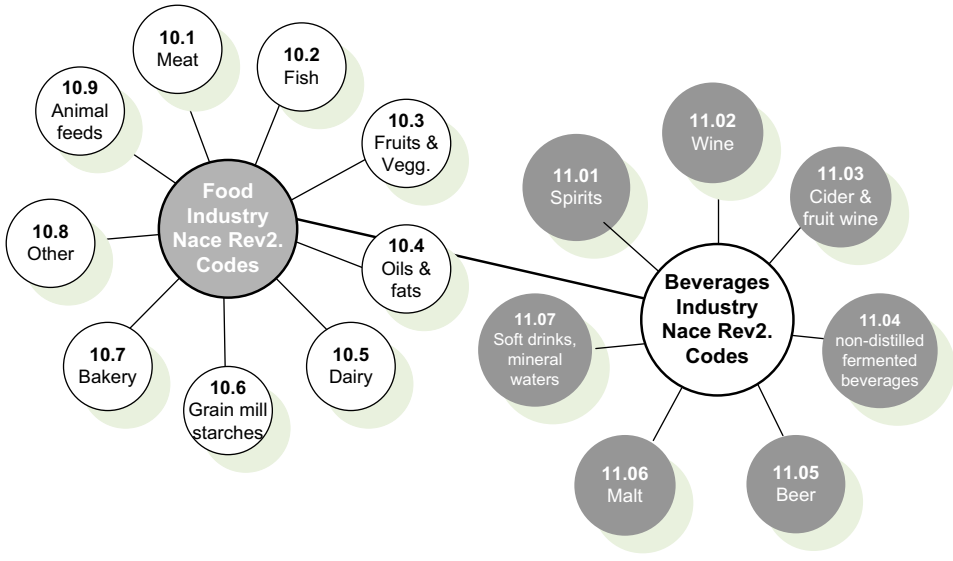

Fig. 1. Presentation of the divisions of Food and Beverage (F&B) industry according to NACE rev.2.

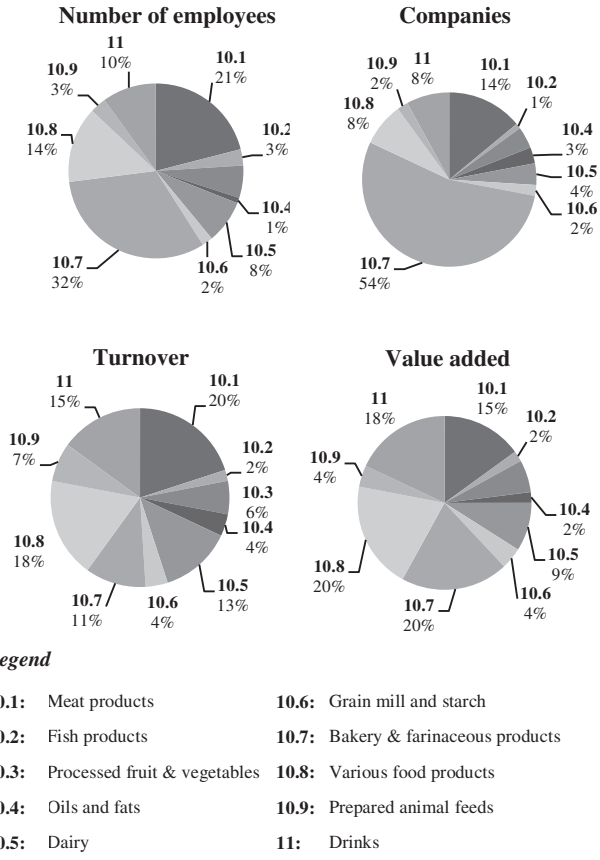

Fig. 2. Distribution (%) of turnover, value added, number of employees and companies in F&B industry, 2010 [1].

distinguishes three basic water categories: process water, cooling water and boiler feed-water. *Process water* is defined as water which usually comes into contact with foodstuffs directly or indirectly, or water used for technical purposes and which in somehow influence food product quality [2]. Examples of process water are detailed in Fig. 3 [2]. Process water is mostly of drinking quality. In principle, in every case where water is in direct contact with food, it must be of drinking quality. Moreover, although it is improbable, water utilised for the outer cleaning of equipment and floors as well as for various technical purposes, meet drinking water quality so as to avoid any risk in case of a failure [2].

Cooling water is the water used for the removal of heat from process streams and products. Common applied cooling systems in the food industry include: (a) once-through cooling systems, with no recirculation of cooling water, (b) closed circulation cooling systems (chilled water, brine), (c) open circulation cooling systems (cooling towers) and (d) cooling by direct contact with cooling water. In general, once through cooling systems are characterised by the highest levels of water demand compared to closed circulation cooling systems, cooling towers or air cooling [2].

Finally, *boiler feed-water* is the water used for steam generation through boilers with working pressures up to about 30 bars. Steam is used for the sterilisation of tanks and pipelines, in ultra high temperature treatment with direct steam injection, e.g. for heating the product or for adjusting the water content of the raw material. Since, in all these cases more or less, direct contact between steam and the food product is possible, the boiler feed-water also needs to meet the drinking water quality requirements [2].

Water consumption in the food and drink industry varies depending on different factors, such as: diversity of each manufacturing sub-sector, number of end products, capacity of the plant, type of applied processes, equipment employed, level of automation, system used for cleaning etc. [4]. Current quantitative data on water usage within the food and drink industry are very little in literature and is often expressed in different ways, e.g. as the volume of water consumed either per finished product or per raw material processed, which makes it hard to compare data from different studies or sources [4,7]. In 2013, *Waste & Resources Action Programme* (WRAP), aiming at obtaining a better understanding on how much water is used within the UK food and drink industry in response to the *Federation House Commitment (FHC)*,[1] considered two *key performance indicators (KPIs)* relative to water use: (a) *the absolute KPI*: water use (excluding that in product),[2] and *relative KPI or water intensity*: water use (excluding that in product) per tonne of product. Total water use[3] or water use (excluding that in product) depends on the size of each sub-sector within food and beverage industry, while water intensity is a more comparable indicator and usually utilised for benchmarking as, for instance, water consumption may increase on a site, but this may be a direct result of increased production [7,8].

[1]FHC is a voluntary commitment which was launched in 2008 by the Britain's food and drink producers in order to reduce water use and contribute to an industry-wide reduction target of 20% by 2020 against a 2007 baseline.
[2]Water use (excluding that in product) is calculated by total water use minus water in product (WIP). WIP is the amount of water that is used as a raw material in product also referred to as "ingredient water" and is determined by the water requirements of the product and the manufacturing process.
[3]Total water use, which includes all water used at a manufacturing site including water in product (WIP).

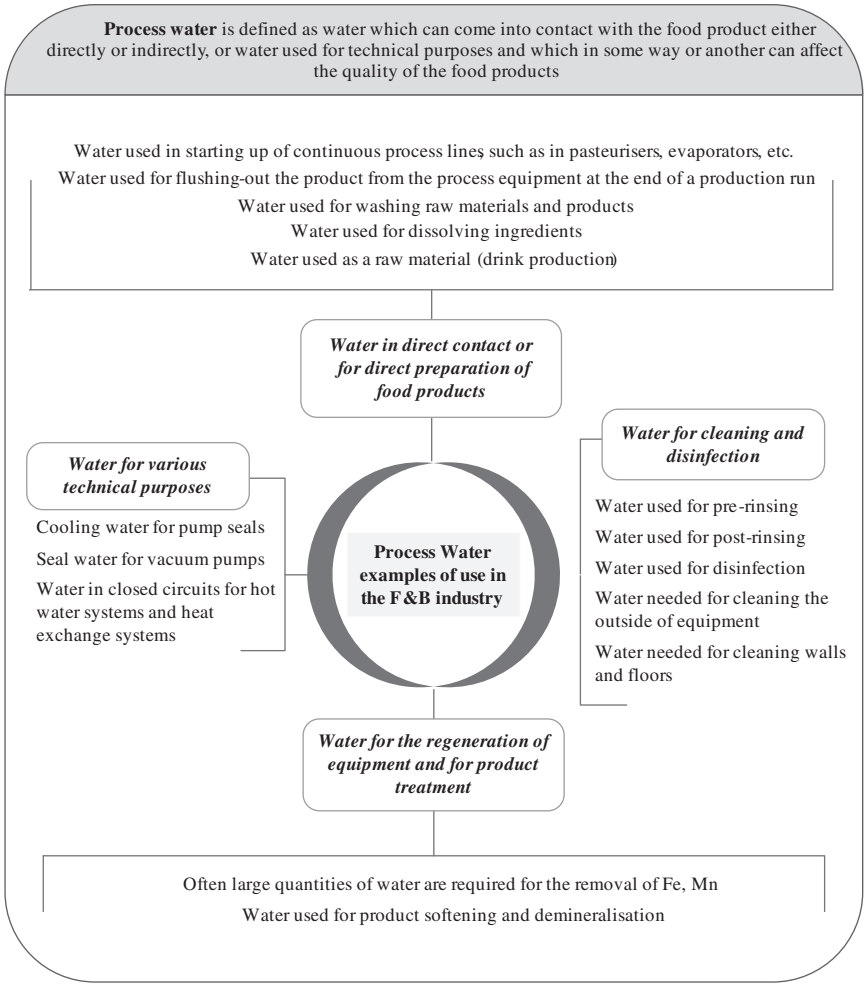

Fig. 3. Uses of process water in the F&B industry.

The *International Water Association* defines benchmarking as: *a tool for performance improvement through systematic search and adaptation of leading practices*. Benchmarking consists of two consecutive steps: performance assessment and performance improvement [9]. It is important to distinguish between different metrics often used in the literature to express water consumption. For instance, the specific water consumption for the manufacture of a product in a given time can be characterised as a performance indicator. Such indicators for the beverage industry are illustrated in Fig. 4.

As indicated by the European Commission (2003), benchmarks on water consumption can be derived through total water input and output analysis in the factory [2]. Such benchmarks may include: (a) specific water consumption (m^3 water consumed/tonne of raw material or finished product), (b) specific wastewater discharge (m^3 wastewater discharge/tonne of raw material or finished product), (c) ratio of water costs between water input and water output and (d) water cost per product-unit [2]. *Target benchmarks* usually represent a theoretical optimum range of values of specific water consumption for a product. By the comparison of benchmarks within a factory with target benchmarks (external) it can be evaluated whether or not water savings are possible for a specific plant. In Table 1 target benchmarks for some sectors published by the *Environmental Agency* are illustrated. The achievement of these benchmarks is considered as Best Available Technique (BAT).

3. Adaptation measures for the food and beverage industry

Minimising water consumption and contamination has been addressed by EC in the *Reference Document on Best Available Techniques in the Food, Drink and Milk*

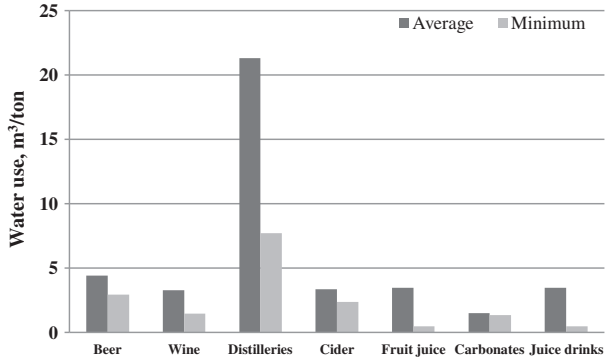

Fig. 4. Specific water consumption for the drink industry [7].

Table 1
Water consumption target benchmarks for some products [7,10–13]

Product	Specific water consumption benchmark (units)
Cattle	700.0–1,000.0 (L/live animal)
Pigs	160.0–230.0 (L/live animal)
Sheep	100.0–250.0 (L/live animal)
Chicken	8.0–15.0 (L/live bird)
Turkey	40.0–60.0 (L/live bird)
Milk	0.6–1.8 (L water/L milk)
Powdered milk	0.8–1.7 (L water/L milk)
Ice-cream	4.0–6.5 (L water/kg ice-cream)

Table 2
Adaptation measures for the food and beverage industry in response to the impact of climate change on reduced water availability [2,7,10–14]

A. General adaptation measures for the entire F&B sector

A1. Measures to reduce water consumption

(1) Apply a Water Management Programme (WMP) through execution of the following actions:

- Ensure senior management commitment
- Implement a water consumption analysis in order to trace water savings options
- Assess water quality requirements in each production process/line
- Estimate minimum water consumption
- Identify measures for reduce water consumption (*see below for more detail*)
- Evaluate the technical, financial and environmental impacts of the alternative water minimisation measures
- Implement the measures to reduce water consumption and water pollution

(2) Identify measures for reduce water consumption by considering the following directions:

- Eliminate water use e.g. *transport of solid raw materials, products, co-products, by-products and waste (where possible) in dry, control overflows, use automation to shut down the equipment*
- Optimise applied processes so as to reduce water usage
- Recycling and reuse of water in cases that it is allowed e.g. *reuse cooling water, recover process water*
- Good housekeeping e.g. *apply meters to record water consumption, use automated water start/stop controls to supply process water only when it is required, control of water supply pressure to normal levels etc.*
- Maintenance e.g. *repair process leaks within the process equipment, check for leakage on the distribution network*

(3) Maintain the WMP in order to keep the required level of water consumption and for assessing improvements

A2. Measures related to cleaning

(1) Implement dry cleaning if possible
(2) Perform appropriate housekeeping practices e.g. *install trays, use water hoses only for only cleaning the equipment and the floors and not for inappropriate uses (as a broom)*
(3) Schedule the cleaning programme and optimise washing e.g. *manufacture the same products in sequence in order to minimise the number of product changes and subsequent cleanings between products*

(*Continued*)

Table 2 (*Continued*)

A. General adaptation measures for the entire F&B sector

(4) Optimise your cleaning operations:

- In manual cleaning e.g. *apply high pressure water for cleaning, use trigger nozzles on hoses to reduce flow*
- In automated cleaning e.g. *reorganise and programme the Cleaning-In-Place (CIP) systems, use optimised cleaning sequences, recover solutions used in CIP*

(5) Apply high-pressure jet cleaning, foam and gel cleaning for open equipment, walls and floors

A3. Measure related to wastewater treatment

(1) When preparing a new installation consider to segregate wastewater streams

B. Additional adaptation measures for specific food industry sectors

B1. Measures for the meat and poultry processing sector

Meat

(1) Avoid using once-through cooling systems
(2) Fully synchronise dosing of chemicals with cleaning processes
(3) Set and maintain of water consumption benchmarks i.e. for *cattle: 700–1,000 L/live animal, pigs: 160–230 L/live animal* and *sheep: 100–250 L/live animal*

Poultry

(1) Avoid using once-through cooling systems and recycle water when it is allowed
(2) At the stage of defeathering apply nozzles instead of irrigation pipes
(3) During evisceration apply appropriate washing equipment in order to minimise water consumption
(4) Fully synchronise dosing of chemicals with cleaning processes
(5) Set and maintain of water consumption benchmarks i.e. *for chicken: 8–15 L/live bird & for turkey: 40–60 L/live bird*

B2. Measures for the fish sector

(1) For thawing of fish apply immersion in a container including water mixed by bubbling air and maintain water level by recirculation
(2) Reduce the size as well as the number of the spray nozzles

B3. Measures for the fruit and vegetables sector

(1) Apply steam peeling of fruit and vegetables through a batch or a continuous process without using cold water to condense the steam, unless the recipe requirements cannot be met
(2) When steam peeling cannot be used, perform dry caustic peeling, unless the recipe requirements cannot be met
(3) Apply water re-use of water taking into account that adequate hygiene and food quality standards are maintained

B4. Measures for dairies

(1) Minimise water pollution through the application of just-in-time filling
(2) Improve initial filtration and clarification of milk in order to minimise the number of cleaning centrifugal separators
(3) Set and maintain of water consumption benchmarks i.e. *for milk production: 0.6–1.8 L water/L milk, for milk powder production: 0.6–1.7 L water/L milk, for ice-cream production: 4–5 L water/kg ice-cream*

B5. Measures for the drinks sector and brewing

(1) Minimise water consumption during bottle rinsing
(2) During beer manufacturing, optimise the re-use of hot water from wort cooling and recover heat from wort boiling
(3) Re-use of bottle pasteurising overflow water
(4) Set and maintain of a water consumption benchmark i.e. 0.35–1 m^3/hl (1 hl = 0.1 m^3) of beer produced

Industries in the framework of Integrated Pollution and Prevention Control. In this regard adaptation measures for the sector can be identified between BATs in the concept of preventing and minimising water consumption as presented in Table 2.

In the framework of a study on water management for the food and beverage industry conducted by WRAP, based on site visits to food and industry factories in the UK, water saving opportunities have been identified. From the potential savings identified,

the top five frequently encountered opportunities were: elimination of once-through cooling systems, checking water balance and fixing supply leaks, automatic shut off, control of overflows and optimising water supply pressure [14].

4. Conclusions

The food and drink industry is a large drinking quality water consumer. Current quantitative data on water usage within the food and drink industry are scarce in literature and are often expressed in different ways, which makes comparison between them difficult. In general, key performance indicators of water consumption include either total water consumption or specific water consumption, i.e. normalised water consumption per tonne of product typically used during benchmarking processes. Since water is an important resource for the food and beverage industry, reduced water availability due to climate change is expected to affect the sector if no adaptation measures are undertaken. Minimising water consumption has been addressed by the EC in the Reference Document on Best Available Techniques in the Food, Drink and Milk Industries. In this regard, adaptation measures can be addressed in the framework of Best Available Techniques. To this end, general measures, such as the application and maintenance of a methodology for preventing and minimising water consumption, the implementation and systematic monitoring of an EMS including water consumption benchmarking, checking for leakage on the distribution system, repairing of leaks within the process equipment, controlling overflows, reusing water after achieving appropriate water quality, eliminating of once-through cooling systems, optimising water supply pressure etc. may be adopted by all food and beverage industries. Moreover, additional adaptation measures can be adopted by some specific sectors. Most of these measures can be easily implemented by the food and beverage industry, contributing to a strategic and long-term approach for managing climate change.

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References

[1] FoodDrinkEurope: Data & Trends of the European Food and Drink Industry (2012). Available from: <http://www.fooddrinkeurope.eu/uploads/publications_documents/Data__Trends_%28interactive%29.pdf>. Accessed January 2014.

[2] European Commission, Integrated Pollution Prevention and Control, Draft Reference Document on Best Available Techniques in the Food, Drink and Milk Industry, Draft, (2003). Available from: <http://gasunie.eldoc.ub.rug.nl/FILES/root/2003/2665985/2665985.pdf>. Accessed January 2014.

[3] Environment Agency, (2014). Available from: <http://www.environment-agency.gov.uk/business/sectors/138194.aspx>. Accessed February 2014.

[4] K. Valta, T. Kosanovic, D. Malamis, K. Moustakas, M. Loizidou, Overview of water usage and wastewater management in the food and beverage industry, Desalin. Water Treat. 53(12) (2015) 3335–3347, doi: 10.1080/19443994.2014.934100.

[5] FoodDrinkEurope: Environmental Sustainability Vision Towards 2030, Achievements, Challenges and Opportunities (2012). Available from: <http://www.fooddrinkeurope.eu/uploads/publications_documents/temp_file_USE_SustainabilityReport_LDFINAL_11.6.20123.pdf>. Accessed February 2014.

[6] Environment Agency, Food and drink manufacturing water demand projections to 2050, (2013). Available from: <http://a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/LIT_8767_4d1fe5.pdf>. Accessed January 2014.

[7] Waste & Resources Action Programme (WRAP), Technical Report: Water Use in the UK Food and Drink Industry, 2013. Available from: <http://www.wrap.org.uk/sites/files/wrap/Summary%20report%20-%20Water%20use%20in%20the%20food%20and%20drink%20industry_0.pdf>. Accessed January 2014.

[8] Waste & Resources Action Programme (WRAP), The Federation House Commitment Progress Report 2013, 2013. Available from: <http://www.fdf.org.uk/industry/FHC-ANNUAL-REPORT-2013.pdf>. Accessed January 2014.

[9] European Benchmarking Co-operation, 2014. Available from: <http://www.waterbenchmark.org/content/benchmarking.html>. Accessed February 2014.

[10] Environment Agency, The Red Meat Processing (Cattle, Sheep and Pigs) Sector (EPR 6.12), 2009. Available from: <http://cdn.environment-agency.gov.uk/geho0209bpja-e-e.pdf>. Accessed February 2014.

[11] Environment Agency, Dairy and Milk Processing Sector (EPR 6.13), 2009. Available from: <http://cdn.environment-agency.gov.uk/geho0209bpix-e-e.pdf>. Accessed February 2014.

[12] Environment Agency, Treating and Processing Poultry (EPR 6.11), 2009. Available from: <http://cdn.environ

ment-agency.gov.uk/geho0209bpiz-e-e.pdf>. Accessed February 2014.
[13] Environment Agency, The Food and Drink Sector (EPR 6.10), 2009. Available from: <http://cdn.environment-agency.gov.uk/geho0209bpiy-e-e.pdf>. Accessed February 2014.
[14] Waste & Resources Action Programme (WRAP), Business Resource Efficiency Guide-Water Minimisation in the Food and Drink Industry, 2013. Available from: <http://www.wrap.org.uk/sites/files/wrap/Water%20Minimisation%20in%20FD%20Industry.pdf>. Accessed February 2014.