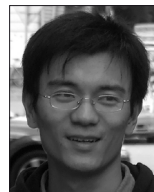


# INVESTIGATING THE WATER FOOTPRINT OF TETRA PAK CARTON ECONOMY'S BEVERAGE PORTFOLIO

by CONG LI<sup>1</sup> and STEPHEN UGOCHUKWU NWOKOLI<sup>2</sup>

1 XiangShan WenFengXiaoQu 36Zhuang 78Ti 204Shi  
Ningbo, Zhejiang, China, 315700  
e-mail: xiaoshulc@hotmail.com

2 e-mail: ugoonwokoli@yahoo.com



## Abstract

A growing number of companies and organizations have started to recognize the importance of water to their business and have started programs to improve the sustainability of freshwater in their processes. Virtual Water and Life Cycle Analysis are methods used to measure the impact of water trade between countries and businesses. The concept of a Water Footprint has been developed and defined for countries, businesses and products.

This paper develops the explanation of Water Footprint and discusses the difference between gross green water, net green water and embedded water. The concepts of “water use” as opposed to “water consumption” are developed to assist the understanding of the main water processes at Tetra Pak. A water footprint model for the Tetra Pak cartons is presented.

For Tetra Pak the difference between the gross green water footprint and the embedded water footprint is large. This is one of the major findings of this work. Gaps in Tetra Pak data collection and challenges connected to the water footprint throughout the production processes are discussed with the aim to assess and understand the impact on the environment.

*Key words* – Water footprint; Tetra Pak; environment; green water; water use; water consumption; embedded water; carton package; virtual water; LCA

## 1. Introduction

### 1.1. Background

Water is one of the most important natural resources on our planet and a fundamental element of life whose preciousness requires diligent management. Apart from this fact, people use water for other activities such as cooking, drinking and washing but even large amounts for producing things such as food, clothes, papers etc. Only 2.5 percent of the total amount of water is freshwater and only 1 percent is easily accessible as groundwater or surface water. The increase in population, social and economic activities in the world during the past decades has affected the availability of world freshwater resources.

Freshwater of good quality is important and necessary for human societies and natural ecosystems. The recent increase in the use of freshwater as a result of human

activities has lead to serious water scarcity in many regions (Gerbens-Leenes et al, 2008).

For instance, countries like Singapore, China and India are considered as water-poor countries while countries like Sweden and France are water-rich countries. Having many factories and companies in the water-poor countries may lead to water shortage or scarcity in the future if proper measures are not taken.

### 1.2. About Tetra Pak

Tetra Pak is a multinational company that develops, produces and markets complete processing, packaging and distribution systems for food stuffs. Tetra Pak operates with 21,640 employees in over 150 countries around the globe (Tetra Pak, 2009).

Tetra Pak produces both aseptic and non aseptic car-

ton packages. The first Tetra Pak package was in the shape of a triangular pyramid, which was launched in 1953. It was made using a system of plastic and aluminum coated paperboard combined with an aseptic filling system. Today it is called Tetra Classic Aseptic. Tetra Brik is a rectangular cuboid carton which was introduced in 1963 by the company. Also, after Tetra Classic Aseptic and Tetra Brik Aseptic package, other packaging formats were introduced such as Tetra Wedge Aseptic (wedge shaped), Tetra Prisma Aseptic (round octagonal shaped), Tetra Fino Aseptic (pouch shaped).

### 1.3. Tetra Pak value chain

In order to deal systematically with the water use in connection with Tetra Pak packages the complete production system –including external actors – is presented below within the framework of the Tetra Pak value chain. Here follows a short description of the five steps in this chain and how information was collected with respect to the water use involved.

#### *I. Raw materials*

The aseptic beverage carton is made of three different types of materials, namely paper, plastic and aluminum. Information was mainly collected from open sources.

#### *II. Converting*

Converting is the process of turning raw materials into packaging material. The first step in the data collection was to visit the local converting factory in Lund, Sweden, to understand how water is consumed or used. Based on the information, questionnaires were designed and sent to three other converting factories. The aim was to have multiple sources of information regarding volume and how, where and what type of water was used.

#### *III. Filling*

Filling is the process of putting the liquid product into the package/container. The focus was on Tetra Classic Aseptic, Tetra Fino Aseptic and Tetra Wedge Aseptic, i.e. three series and twelve different types of package. Based on the types of package, information about the capacity and water used by six different types of filling machines was obtained.

#### *IV. Processing*

This step depends on the product such as for example cheese, ice cream, beverages, prepared food etc. For this study milk and juice were selected because they are the most common products packed in carton packages. Information was obtained by conducting a face to face interview with a person from processing solutions de-

partment. Based on the interview, it was clear that this process varies depending on product and country.

#### *V. Product*

This step refers to activities outside (before) the actual involvement of Tetra Pak. The research interest was limited to two types of products namely milk and juice. Information was mainly collected from open sources.

### 1.4. Objectives

The overall objective of this work was to determine the water footprint of the Tetra Pak carton economy beverage portfolio. The specific objectives included:

- To provide an overview of the concept of water footprint.
- To find the important parts of water footprint in this analysis.
- To develop a model based on available data and information about each process.
- To identify gaps in Tetra Pak data collection and discuss challenges, potentials and improvements.

## 2. Concepts and Definitions

### 2.1. Water stress and water scarcity

Nowadays, parts of many large countries, such as India, China, and even USA, are facing water stress or water scarcity. In 2025, around 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the people all over the world will be under water stress conditions.

“Water scarcity and water stress are concepts describing the relationship of water between demand and availability.” (Abrams, 1997). They occur when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use (UNEP, 2009).

When the annual water supplies drop below 1,700 m<sup>3</sup> per person per year in a country or region, it is said to experience “water stress”; at levels between 1,700 and 1,000 m<sup>3</sup> per person per year, there will be periodic or limited water shortages. When the annual water supplies drops below 1,000 m<sup>3</sup> per person per year, the country faces “water scarcity”.

### 2.2. Virtual water

Virtual water is defined as the amount of water used to produce a product. The term “virtual” is used since the amount of water contained in the product can be negligible compared to the amount used in the production (Chapagain and Orr, 2009). For example, to produce

1 kg of cheese 5 m<sup>3</sup> of water is required and for 1 kg of beef on average 16 m<sup>3</sup> of water is required (Hoekstra, 2003a). Due to large distance and cost, trading of real water between water-rich and water-poor countries is generally impossible but trade in the form of water-intensive products is realistic and common. Virtual water trade is one of the ways through which countries affect the water system in other parts of the world (Hoekstra, 2003b). According to Hoekstra & Hung (2002), “recent research shows that the impact of global trade on regional water system is at least as important as the impact of the climate change on regional water system.” Import of water-intensive products (virtual water trade) can also be seen as an alternative way of relieving pressure on water resource of importing countries.

### 2.3. Water Footprint

In the past few years the concept of “water footprint” has started to gain recognition within governments, non-government organizations, businesses and media as a useful indicator of water use (Hoekstra, 2008).

Water footprints can be defined for countries, businesses and products. To produce one type of product more water is needed than the water embedded in it. For example, to produce 1 kg of beef 16 000 litres of water is needed. And to produce a cup of coffee requires 140 litres of water. Meanwhile, the water footprint also differs from country to country, for example: In China, the water footprint is about 700 m<sup>3</sup> per year per person, while it is 1150 m<sup>3</sup> in Japan (WFN, 2009).

#### Definition of water footprint

Water footprint is defined as an indicator of water use that takes into account both direct and indirect water use by a consumer or producer. A water footprint refers specifically to the type of water use and where, when and how the water was used. The aim is not to be limited by

the fact that water resources management is generally seen as a local issue or a river-basin issue at most (Hoekstra, 2008). For instance, the water footprint of a product which is produced in China and transported to another country like Sweden is expanded from China to Sweden. The global dimension of water resources management and the relevance of the structure of the global economy have been ignored by most of the water science and policy community (Hoekstra, 2003 a).

A water footprint is more than a number for the total volume of water used, it refers specifically to the type of water use and where the water was used; it may also specify roughly the time when the water was consumed in different processes. For the impact assessment, it is also useful that one explicitly shows the blue, green and grey elements (these three elements will be explained below) of the water footprint of a product, since the impact of the water footprint will depend on whether it concerns evaporation of abstracted ground water, evaporation of rainwater used for production or pollution of freshwater (Hoekstra and Chapagain, 2007). The impact of the water footprint of products will depend on the vulnerability of the local water system, the actual competition over the water in this local system and the negative externalities associated with the use of the water (Hoekstra, 2008).

A water footprint includes three elements: consumptive use of rain water bound in the soil (green water); consumptive use of water withdrawn from groundwater or surface water (blue water) and pollution of water (grey water), associated with the production of goods and services. Grey water is calculated as the volume of water that is required to dilute pollutants in wastewater to meet quality standards.

The components of the water footprint of a product can usually be divided into three parts: The supply-chain water footprint, the operational water footprint and the end-use water footprint (see figure 1).

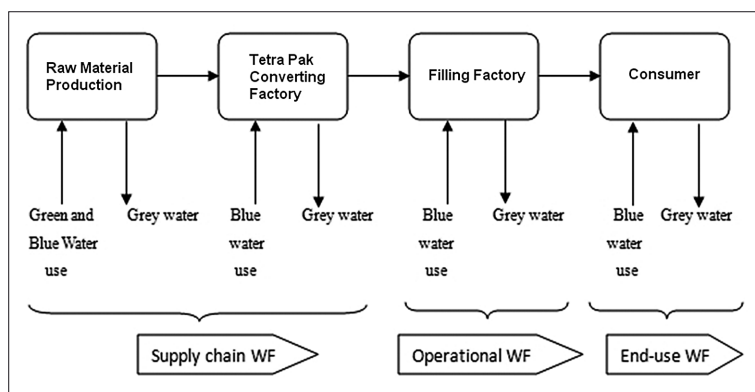


Figure 1. General idea of the types of water involved in the water footprint (Based on Hoekstra, 2008).

- The supply-chain water footprint is the water used by the producer's supplier. It can be considered as indirect water use which mainly is green water and also an amount of blue water (for example: pumping water from river to irrigate crops). Indirect water use refers to the embedded water which is used in the supply-chain to produce raw materials. This step generally does not lead to much grey water.
- The operational water footprint is the direct water use by the producer which mainly includes blue water from groundwater or surface water, and grey water which is used during the processes. Depending on the products, green water can also be a small part of it.
- The end-use water footprint is the water use inherently associated with the consumption of the products by others. It can be considered as direct water but is mainly in the form of grey water. Compared to other components, the volume of this part is usually small, so it can often be ignored.

#### *Green water and Blue water*

The difference between “green” and “blue” water is the point of origin. The freshwater in aquifers, lakes and rivers is referred to as “blue water”, while “green water” is bound in the soil and plants and released by evapotranspiration and returned to the atmosphere. Blue water can be transported and is therefore the only source for drinking water. Green water cannot be transported since it is bound in the soil. For example, between rain-fed agriculture and irrigated agriculture of crop production, there is a significant difference in the opportunity cost. Green water usually has a lower opportunity cost than the blue water, since blue water is usually transported from river, lake or groundwater for irrigation by pumping and using other ways or tools (Horleman et.al, 2007).

#### *Gross Green water and Net Green water*

Since water used by evapotranspiration usually occupies the main part of total water used, especially for the crop products of the supply chain, some raw materials and product industries (for example: paper producing companies, food companies), challenge the difference between the substantial green water used by the natural vegetation and the amount of green water used by the raw materials. Their arguments go as follows: vegetation consumes a certain amount of water and this amount does not change if the material is used for production of goods or simply left to grow. The definition of “gross green water” is the total green water used for crop products. So the standpoint of “net” green water has been indicated. A “net green water footprint” is the difference between the amount of water used by crop evapotranspiration and the natural evapotranspiration (WWF, 2009).

#### *Grey water*

Grey water is defined as the indirect water consumption used to dilute a pollutant; it is generally seen as a part of blue water or green water if the pollutant is diluted by rainfall directly. In the broad picture, grey water is the amount of water which is associated with the production of goods and services, and required to dilute pollutants in wastewater to meet quality standards (WWF, 2009).

## 2.4. Other Methods and Organizations

Life cycle analysis (LCA) is one of the ways to assess the impact of a product on the environment (Chapagain and Orr, 2009). It assesses both the potential and environmental impacts associated with a product, process, or service.

Life cycle analysis (LCA) and virtual water (VW) are analysis tools that have been used to measure amounts of water used in the production of various products. However neither of these methods emphasize the problem of water scarcity, shortage and opportunity cost of water during the production (Millà i Canals et al, 2008).

The concept of water as an environmental issue is still evolving and is at a much more primitive stage compared to the corresponding carbon footprint. It is still gaining recognition by governments, non-governmental organizations and companies. Below is a list of organizations and initiatives which focus on water sustainability:

- Water Footprint Network (WFN)
- World business council for sustainable development (WBCSD)
- Global environmental management initiative (GEMI)
- Alliance for water stewardship (AWS)
- Water stewardship initiative (WSI)
- European water partnership (EWP)

There are other organizations, and institutes supporting and promoting water related issues, such as UN, EU, The CEO Water Mandate, the Global Reporting Initiatives, the Stockholm International Water Institute, and the Pacific Institute. Their aim is to provide information on water issues and support water related research and projects.

## 3. Methodology

A research approach refers to the approach or methodology that is used to conduct the research. It usually involves the selection of research questions, research methods and a conceptual framework. Research is usually performed using three main approaches or methods namely quantitative approach, qualitative approach and mixed methods approach.

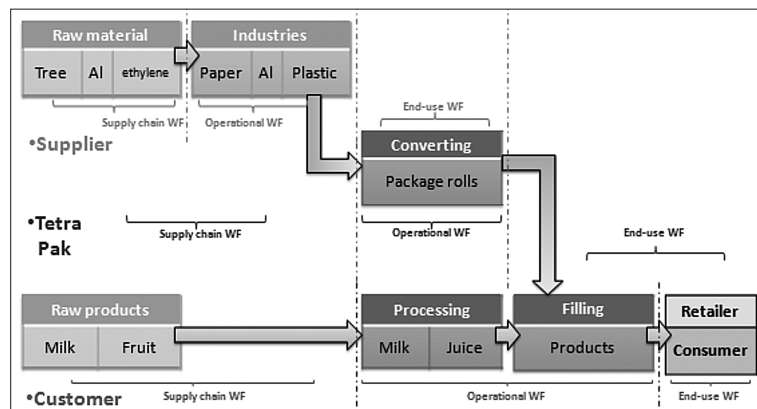


Figure 2. A flow chart of water footprint modeling in Tetra Pak.

Five steps in the Tetra Pak value chain (which was described in section 1.3) were considered in this project namely: (I) raw materials, (II) converting, (III) filling, (IV) processing and (V) products. A mixed method was used since some processes require a qualitative approach while others require a quantitative approach or rather a combination of both methods. Mixed method approach combines both the strengths and limitations of qualitative and quantitative methods. Quantitative research places the emphasis on measurement when collecting and analyzing data and it usually employs highly structured procedures during the research process. Data are collected using sampling techniques and structured questionnaires and carried out in various forms such as face to face interview, by telephone, by email, via web-surveys or by post (Willis, 2009). Qualitative approach employs the use of questionnaires to get necessary information, information is usually collected in form of open-ended observations, interview or group discussions and it takes place in a natural setting. Quantitative method was used for raw materials, filling and products while a qualitative method was used for processing while for the converting process both methods were used.

## 4. Modeling

In this project a model has been developed in order to analyse and calculate the water footprint of the five steps in the Tetra Pak Value Chain.

### 4.1. Model Structure

In order to calculate the water footprint of the Tetra Pak Carton Economy's beverage portfolio, one has to understand the Tetra Pak value chain and how water is con-

sumed, since this forms the basis from which the model is developed.

The Tetra Pak value chain starts (see Fig. 2) with wood and other raw materials (bauxite, ethylene), which are processed in several steps and delivered to the converting factory, as paper, aluminum and plastic. In the converting factory raw materials are converted and laminated to package material. The package material is then transported to the customers where they are used to make packages.

However the total water footprint of a Tetra Pak package is more complex than this value chain implies. Apart from the package there is also the product contained and the process used to refine it. This paper focuses on the total product water footprint of a Tetra Pak package, defined as the total volume of water that is used directly or indirectly to produce the packages and the contained product including water that is either evaporated or polluted. Thus, the analysis concerns not only the Tetra Pak supply chain but also the supply chain of a Tetra Pak customer. The model includes the total volume of fresh water that is used from the raw material through the various steps of the different production chains all the way to the consumer.

Hence, based on this environmental performance of Tetra Pak value chain and basal knowledge, a flow chart of the model is created (see figure 2).

This flow chart illustrates three different points of view of the water footprint, i.e. that of the supplier, Tetra Pak and the customer. In the supplier's view, the supply chain water footprint will be the water used by the raw materials, i.e. primarily the trees (bauxite mining for the aluminum and 99.9% pure ethylene for the plastic as original sources do not need any water use before processing); the operational water footprint will be the water consumed during refining and processing of



the raw material. To the supplier Tetra Pak is a part of the end-use water footprint.

From Tetra Pak's view, both raw materials and the industries which process raw materials are a part of the supply chain water footprint. The process at the converting factory is treated as the operational water footprint; the water used in the filling process as well as by the consumer is considered as end-use water footprint.

From the customer's view, the supply chain water footprint will be the total water footprint of the customers supply chain, including raw materials in the form of wood, aluminum, plastic as well as the product and the refinement of these. The operational water footprint includes the processing of the product and the filling.

Therefore, depending on whether the water footprint is based on the perspective of the raw materials supplier, Tetra Pak or the Tetra Pak customer the three components of the water footprint, supply chain water footprint, Operational water footprint and end-use water footprint will be different. This model will look at all of these processes, with a focus on the Tetra Pak packages.

## 4.2. Input and output

### *Input*

The input to the model is divided into two parts. The first part is for the model users who want to find out the water footprint information of their packages. It consists of only three choices: type of package, type of product and country. This simplified input data is used to search the database (second part of input) for relevant data such as the amount of water consumed during different parts of the process. The database can be updated by Tetra Pak, to add, amend and update the included factors as more information becomes available.

### *Output*

The output from the model gives the results for the type of package which has been selected in the input part. Basically, the output lists the water footprint for five main processes and the total value.

- At the top, the package name, the location (where) and water stress situation is shown, to give the general information and idea about if there is any water problem in the region or country.
- Using the result of the second part, the third part will show the percentages of the water used in these processes to better understand how and what types of water that is used. This is also illustrated by graphs.
- The model can be used to compare different Tetra Pak packages to better understand any differences. It can also be used to compare with other types of packages, like for example a PET bottle.

## 4.3. Boundaries and limitations

Since, the concept of water footprint is still evolving there were challenges in finding relevant data from previous studies. The major challenges were encountered during the data collection, mainly on the supply-chain calculations parts. For the operational water footprint there is no uncertainty on the available data which are obtained from the Tetra Pak data base.

Another aspect of the data issue was dealing with the electricity and energy water footprint. Apart from the plastic process, the water footprint of electricity and energy were not considered in this research work. This omission was due to the fact that the available data or information is very limited.

The water footprint is a geographically explicit indicator which shows the various locations where the water is used. For the operational water footprint this presents no difficulty since the company knows the source of water and the consumption units of its factories. For the supply-chain water footprint, it is possible to trace back the location and time but the resources and time did not permit that within the present project.

The volume of grey water is just calculated as the amount of polluted water, since it is difficult to analyze the dilution factors.

## 5. Data Collection

### 5.1 Data sources

Data collection was based on internal sources from within Tetra Pak as well as external sources. All of the package information, filling machine data, converting factory data, and processing raw data was supplied either directly by Tetra Pak or by interviews with Tetra Pak personnel. Other information concerning raw materials and products were researched from public sources.

### *General Package information*

From the Tetra Pak database, the twelve different types of package's information were collected. The following package information is included: package name, corresponding package area ( $m^2$ ), paper weight (kg/package), aluminum weight (kg/ package) and plastic weight (kg/ package). The data shows that the paper represents a high percentage of the total weight of package in each type of package.

### *I. Raw material*

The "raw material" in this project means the materials provided to a Tetra Pak converting factory by the suppliers. It includes paper, aluminum and plastic, as well as some other materials. These "other materials" (for exam-

ple: ink) will be ignored due to the small amount of water which is used.

#### *Paper*

Paper is the main material of the carton package. Two steps are used to find out the water footprint of paper.

##### *Step 1. Water footprint of tree growth;*

For the 1<sup>st</sup> step, these questions were considered:

- How much water does a tree need to absorb daily?
- How many years does a tree need to grow to be available to make paper?
- How much paper can be made from a tree?
- Where does the water come from?

From public sources and calculations, it was found that:

- The water need of a tree is roughly estimated as 700 litres of water per day during its growing period from young till mature. This was used as an average number (Sammis and Herrera, 2005).
- The time needed for a tree to grow enough to make paper is assumed to be 20 years as an average number (TAPPI, 2001).
- The amount of paper produced from one tree is 400 kg (Goyal and Eng, 2009).
- The source of water is difficult to specify, since it does not only depend on where the paper industry gets trees from. It also relates to the status of forest, if it is an irrigation forest or an original forest. Here the water used for growing trees is all counted as green water for an original forest. So, according to the model, there is no blue water used for tree's growing.

With regards to grey water, it is assumed there is no water is polluted during the growth period of trees.

##### *Step 2. Water footprint of the paper producing processes in the paper industry*

Based on the main steps in the mechanical pulping processes, water usage information was collected. The total water footprint of paper raw material from 20 year old trees after processing in the paper industry to be paper is given in Table 1 (IPPC, 2001).

#### *Net Green water*

The green water which is given above is gross green water. As discussed in the literature study, the definition of net green water footprint is the difference between the amount of water used for crop evapotranspiration and the natural evapotranspiration (WWF, 2009). The value for net green water should be very low for this case.

#### *Embedded water*

The water embedded in the trees could be considered as more relevant (than net green water) for comparison with the gross green water. The reason is that the trees continue to consume the gross green water all their lives, and water consumed by the evapotranspiration does not lead to any pollution. On the contrary it is a necessary part of the water cycle. An average value for water embedded in the tree is 26 % of total weight. The average weight of trees is 2000 kg. So the embedded water for a tree is about 500 kg which is 500 litres. So the embedded water per kg paper is  $500/400=1.25$  litre water per kg paper.

#### *Aluminum*

The data collection is based on the "Environmental Profile Report for the European Aluminum Industry" (EAA, 2008). The life cycle of an aluminum product includes five main steps. In the Tetra Pak converting factories, the supplied aluminum product is aluminum sheet, so in this case, all these five steps were included in the water footprint of aluminum raw material for the supply chain.

Based on these processes, the water input and output to produce one ton of product in each step is collected. Then because the value of products is reduced from one process to the next process, so the transition of water footprint volume is needed with the passage of value of products from step to step. The water footprint of aluminum is listed in Table 1.

#### *Plastic*

The water footprint of plastic is quite difficult to determine. The industry and business of plastic is all over the world, and the products of plastic and processes of manufacturing are multifarious. The plastic provided to Tetra Pak converting factories for their twelve types of carton products is LDPE (low density polyethylene).

According to research done for a polyolefin industry – Borealis Group, the average Water footprint is  $13.7 \text{ m}^3/\text{ton}$  out of which 20.4 % ( $2.78 \text{ m}^3/\text{ton}$ ) is used for electricity power. In this research, only blue water was included (Stylianios Katsoufis, 2009).

Table 1. *The water footprint of paper, aluminium and plastic in litre water per kg material (IPPC, 2001).*

	Type of material		
	Paper	Aluminum	Plastic
Green water (l/kg)	12775	0	0
Blue water (l/kg)	26.6	33.1	13.7
Grey water (l/kg)	14.1	24.3	0

The source of water is blue water and no green water is involved. According to Borealis' research, extensive wastewater treatment is applied in most facilities. It is therefore assumed that there is no grey water produced (Katsoufis, 2009). The water footprint of plastic is shown in Table 1.

## II. Converting

In the converting factory the raw materials paper, aluminum and plastic are processed to rolls of package material. A questionnaire was designed and sent to three converting factories, namely Jurong, Singapore, Izmir, Turkey and Lund, Sweden. The questions were mainly designed to collect specific information and detailed data regarding: a) water environment (to find out if that region or country has water stress or not); b) where is the water from; c) how much of it is used; d) what happens after the process.

According to the collected questionnaire data, Jurong, Singapore is facing water stress problems, while Lund and Izmir do not have this problem. Because of the variety of package rolls produced in the different converting factories, the data of water use is not possible to specify as an exact number for a given type of package. However, the capacity of MSP (million standard packages) for each converting factory is available. The water consumption is mainly due to washing which depends on the frequency and individual converting factory standards. The water use also includes cooling which takes place at a certain time and amount in a closed recycle system. From this background information, the way to calculate water footprint is based on the capacity of MSP (million standard package = 78 890 m<sup>2</sup> of package material) and the specific area of each package to find out the water footprint for every type of package. For the water footprint calculation, the yearly water used is available.

## III. Filling

The filling process takes place in the customer's factories. The types of filling machine can be found according to the package and the corresponding capacity (package/h) as well as the cooling (l/h) water and steam (kg/h) consumption. All water used is of drinking water quality and comes from public water supply systems. Accordingly the source of water is blue water, and there is no green water involved in this process.

## IV. Processing

According to the Tetra Pak processing department the processing standard varies from customer to customer, country to country and even from time to time. It depends on how many and what kinds of products the customer is producing, which standard of water quality

Table 2. *Water use in the processing part. Mix water (%) is the percentage of water added to the concentrated product.*

Product	Water consumption (litre water/ litre product)	Mix water (%)
Milk	1	0
Juice	0.8	70

is required for the products in that country or region, if there is any recycling system applied as well as what kind of recycling system it is, and also how to they treat the washing water. Due to these uncertainties it was suggested to use the raw data below (see Table 2). In this project only two products, namely milk and juice are considered.

## V. Products

### Milk

The following questions are used to consider the water footprint of milk:

- How much milk does a cow produce?
- How much water does a cow drink?
- How much grass does a cow eat?
- How much water does grass need to grow?

The Water footprint of milk is the total volume of direct water a cow drinks and indirect water from grass growth. The data is collected and selected after comparing between different public sources. In this case, since the source of water for grass is assumed to be from rainfall and then bound in the soil, it is green water. The source for water which the cows drink is mainly surface water, so it counts as blue water. The grey water is assumed to be the same volume of water as a cow drinks (see Table 3).

### Juice

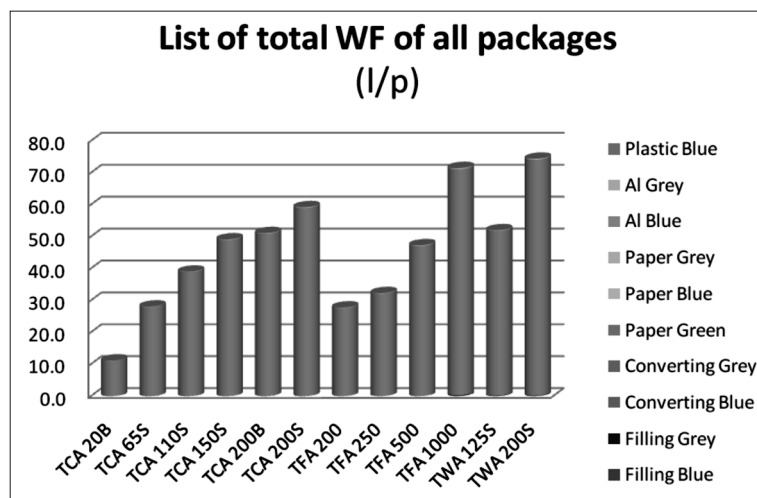
The data for the water footprint for Juice was estimated in a similar way as Milk. About 3 kg of apple result in 1 liter of juice, and one apple tree can produce 150 litres

Table 3. *Water footprint of milk and juice in litre water per litre product.*

	Type of product	
	Milk	Juice
Green water (l/l)	120	1500
Blue water (l/l)	2	0
Grey water (l/l)	2	0



Figure 3. Total water footprint of all packages. Gross green water totally dominates the water footprint.



of apple juice per year. As assumed at the beginning of paper data collection part, an apple tree is also assumed need to absorb 700 litres water per day. So to make a litre of juice, 1500 litres of water is needed.

The water used is considered as green water, while the amount of grey water is assumed to be negligible. The resulting water footprint of juice is given in Table 3.

## 6. Results and Discussion

### 6.1. Results – general

The results part is split into two parts: output frame and diagrams. The output frame (not shown in this paper) gives a general idea and clear view of the data. The output data is also shown in diagrams to give a visual representation. The output frame shows the package and product name, location and the water environment, what level of water stress that the region is facing. The water use, water consumption and green, blue and grey water are shown for each process. This gives clear information about the water footprint through the entire value chain.

### 6.2. Total Water footprint of all packages

The gross green water is the absolutely dominating part of the total water footprint of all the analysed packages (see Figure 3), and the other parts only make up a small percentage. The largest water footprint is made by the TWA200S which is about 74.4 litres per package. The smallest water footprint is made by TCA20B. The latter package has the smallest volume which means that it has the smallest package area and least material weights. TFA1000 has the biggest volume of the 12 investigated

packages but it has a smaller water footprint than TWA200S. This is due to different design which essentially means that it has a different thickness of the paper layer. From this general overview, the package system with the lowest water footprint is the TFA series while TCA series has slightly higher and the TWA series has the largest water footprint. This result is consistent with the amount of raw materials used in the packages.

### 6.3. Water footprints of packages with the same volume

Three packages – TCA200S, TFA200 and TWA200S – were selected for comparison, since they have the same volume, but different designs. Only the package itself is considered here. Here we present the results for water footprint based on gross green water and net green water respectively, see Figure 4.

The total water footprint is mainly gross green water, consumed in the supply chain – the trees. Based on the previous discussion between the gross green water and net green water, an assumed percentage of 10 % of gross green water, is used to calculate net green water. The influence of the other processes are more visible though still a small part. The total water footprint, based on gross net green water, is less than 7.5 litres per package for the TWA package.

### 6.4. Water footprint per litre package (gross green & embedded water)

Four packages of the TFA series were selected. They are TFA200, TFA250, TFA500 and TFA1000. The meaning of the coding is that the volumes of the packages are 200, 250, 500 and 1000 ml respectively.

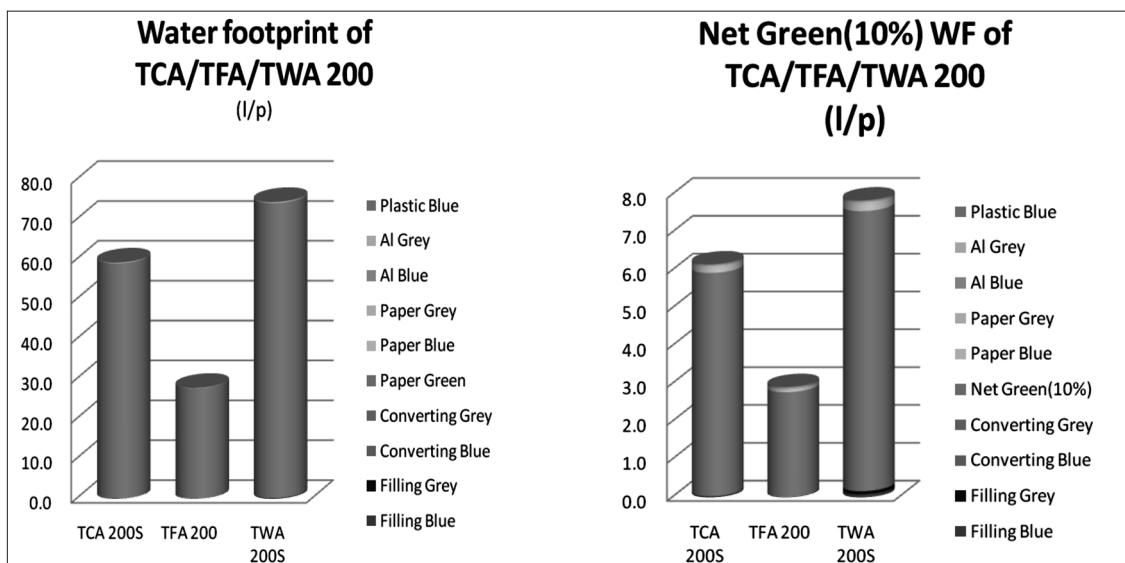


Figure 4. Water footprint of three packages with the same volume. To the left: water footprint based on gross green water, which is totally dominating. To the right: water footprint based on net green water (10%), which dominates. In this case there is a slight impact of (paper) blue water.

Looking at the water footprint per litre package (see Figure 5, left) it is seen that the TFA1000 package has the lowest water footprint, 70 litres per litre package in this case. The TFA200 package has the highest at about 140 litres per litre package. Still, the green water of raw materials is the main part.

The embedded water footprint is less than 0.8 litre per litre package (see Figure 5, right). TFA500 has the lowest water footprint at about 0.52 litre per litre packages. The blue water used in paper industry is the largest part for TFA200, TFA250 and TFA500, but the TFA1000 has larger water footprint in the filling pro-

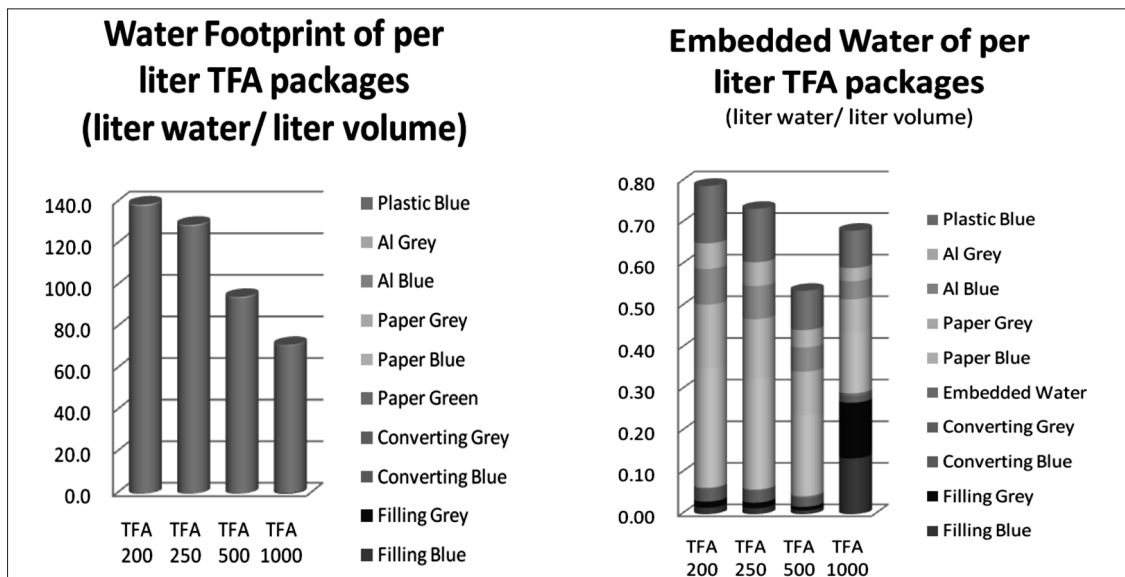


Figure 5. Water footprint of TFA series per litre package. To the left: total water footprint, dominated by (paper) green water. To the right: water footprint based on embedded water only. In this case (paper) blue and grey water is dominating.

Table 4. *The water footprint (WF) of 1 litre volume packages. Tetra Pak carton package compared with that of a PET bottle.*

	TFA 1000			PET
	Gross Green	10% Net Green	Embedded	
Supply chain WF	71.25 litre	7.125 litre	0.40 litre	0.224 litre
Operational WF	0.016 litre	0.016 litre	0.016 litre	2 litre
End-use WF	0.267 litre	0.267 litre	0.267 litre	–

cess. This is the reason why TFA1000 has more embedded water than TFA500 per litre package.

### 6.5. Carton/PET Comparing

In order to have a good idea on water used during the production of carton packages it has been compared with that of PET bottles. The weight of 1 litre capacity PET bottle is 40 grams, out of which the bottle is around 38 grams and the cover is about 2 grams. Two litres of water are consumed in the production process (Pacific Institute, 2009). The two litres of water is only the direct water consumed in the operational process and does not include the indirect water use.

Using a TFA1000 package to compare with the PET package, the operational water footprint of TFA1000 is only 0.016 litre (see Table 4). If the supply chain water footprint is included, the figures change. For TFA1000 package most of the water footprint is consumed there, and for the PET package it is only 0.224 litre (Katsoufis, 2009). But if embedded water is used to represent the supply chain water, the footprint of TFA1000 is only 0.4 litre.

## 7. Conclusions

### 7.1. Achievement

The concept of water footprint was developed in the paper. Also the difference between gross green water, net green water and embedded water was discussed with comparisons between different packages. Furthermore, the definitions of water use and water consumption were developed in order to ease understanding. Data was collected for the main processes after setting the boundaries and limitations. A water footprint model of Tetra Pak carton packages was developed and the volume of water footprint in each process was calculated.

### 7.2. Water footprint of Tetra Pak packages

Green water for the raw material, paper, is the dominating part of the total water footprint. Therefore, the way

in which green water is calculated makes a great impact on the total water footprint of the Tetra Pak carton packages. The difference between gross green water footprint and embedded water footprint is large.

### 7.3. Gaps and limitations

Since the concept of water footprint is still developing, not all parameters necessary were available from the converting factories during the data collection process. For example, the data collected for grey water from the converting factory in Izmir, Turkey has the amount of water required to dilute the pollutants, whereas Jurong, Singapore only has the total output.

Similarly, it has not been possible to go into details about the raw materials. The data needed to calculate the raw materials water footprint with reliability and certainty is simply not there yet. There might also be some other impacts like the water footprint of electric power which should be included.

Because of lack of information regarding the supply chain, water footprint as a geographical indicator could not be well addressed in this study. The geographical aspect is important for indicating the problems of water stressed countries. These problems might sometimes be related to international business trades between regions with different water stress conditions.

### 7.4. Potential for improvements

To reduce or offset the water footprint, Tetra Pak can invest in wastewater treatment plants in their converting factories, and apply recycling systems like in Izmir.

### 7.5. Water footprint in the future

Water is one of the most important natural resources. More and more countries face water stress and water scarcity and therefore water footprint is likely to be a key concept to understand and assess the impacts on environmental issues and businesses.

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