waterwise

Hidden Waters

We consume a lot more water than we can even imagine, and our water footprints extend far beyond our own nation's boundary.

A Briefing, February 2007

WHO WE ARE

waterwise
1 Queen Anne's Gate | London | SW1H 9BT
+44 (0) 207 344 1883
info@waterwise.org.uk

www.waterwise.org.uk

Waterwise is an independent, not for profit, non-governmental organisation focused on decreasing water consumption in the UK, and on building the evidence base for large scale water efficiency. We are the leading authority on water efficiency in the UK. We sit on the UK Environment Minister's Water Saving Group alongside the water industry and regulators. We also convene the Saving Water in Scotland network.

Our aim is to reverse the upward trend in how much water we all use at home and at work by 2010. We will develop a framework supported by a robust social, economic, and environmental evidence base to demonstrate the benefits of water efficiency. Through this effort water efficiency will become a part of everyone's lives.

To achieve our aims we work with water companies, governments, manufacturers, retailers, non-governmental organisations, regulators, academics, agricultural groups, businesses, domestic consumers, and the media.

This Briefing is an introduction. It is intended to be a brief review of the literature and recent research on embedded water.

Written by Joanne Zygmunt, Head of Research, Waterwise.

For questions or comments related to this briefing, please email Joanne at jzygmunt@waterwise.org.uk.

For media enquiries, please contact Chris Philpot, Media and Campaigns Manager, on +44 (0)207 957 4615.

Waterwise would like to thank Tony Allan for his time and patience in answering the author's many queries, and for reviewing this Brief.

Waterwise would also like to thank A.Y. Hoekstra for his response to our query, and Kate Hadjipateras for her comments on the draft.

PREFACE

Water is a finite resource. And unlike oil, there is no substitute for water.

Of all the water on Earth, less than 1 percent is easily accessible freshwater for human consumption, and this water has to be shared with the natural environment. The little bit of water that we are left with is unevenly distributed in space and time, and sometimes is polluted. Over a billion people still lack access to improved water supplies, and one-third of us already live in water stressed areas.

The UK has already witnessed some of its worst droughts ever. Though we might envision our nation as lush and rainy, we are not immune from water scarcity problems. We, too, can run out of water.

If present levels of consumption continue, two-thirds of the global population will live in areas of water stress by 2025. Increasing human demand for water coupled with the effects of climate change mean that the future of our water supply is not secure. But there is hope. Proper water management can lead to a secure future.

Waterwise is dedicated to reducing water wastage, and there is lots of room for improvement. Water consumption in many nations is around 90 litres per person per day, but the average Briton uses 150 litres daily. And as this Briefing shows, we all consume a whole lot more. The average Briton really consumes over 3400 litres every day! This amount includes the water we use daily in our homes, but it also includes the amount embedded in all that we consume.

Water is hidden in all that we see: in our cars, our clothing, and in our sandwiches. But we can significantly and easily reduce our water footprints. We can buy water efficient white goods, turn off the tap while we brush our teeth, fix leaks, and make many other easy efforts. We can start asking shops to provide information on how much water is embedded in their products. And we can ask our leaders to make water use efficiency across all sectors of society a priority. It is time for us all to act!

Global concern over climate change has led to an understanding of embedded energy and carbon footprints. In fact there is a lot of energy embedded in our water, and our water use has a massive carbon footprint due to pumping, treating, and heating. Water and energy are linked, and both are related to climate change. While our water footprints are expanding, climate change is exacerbating water scarcity in many parts of the world – places are running out of water. And since our water footprints extend beyond the UK, our consumption does affect water supplies in other parts of the world.

Waterwise has produced this Briefing to raise awareness of our true water consumption, to highlight the need both nationally and internationally for the proper management of our shared global water resources, and to provide an introduction to a key part of the global water debate. Water efficiency at all levels – home, city, nation, and planet – is crucial to ensure the security of our water supply. By eliminating water wastage today we can make certain that we will have enough water tomorrow, and we can make sure that there will be enough to go around to all, including the natural environment with which we live.

Please think about how much we all rely on water. And realise that water is both finite and shared. We have to optimise the use of our water; we have to use every drop efficiently. There is no other way.

In the future Waterwise hopes to issue more reports on embedded water, and on the relationships between water, energy, and climate change. For more information about us please visit www.waterwise.org.uk.

CONTENTS

SUMMARY 06

INTRODUCTION: A THIRSTY PLANET 08

EMBEDDED WATER: OUR REAL CONSUMPTION 10

- Embedded Water in Agricultural Goods 10
- Embedded Waters in Food: Green & Blue 13
- Embedded Waters & Our Eating Habits 17
- Embedded Water in Industrial Goods 18

OUR WATER FOOTPRINTS 20

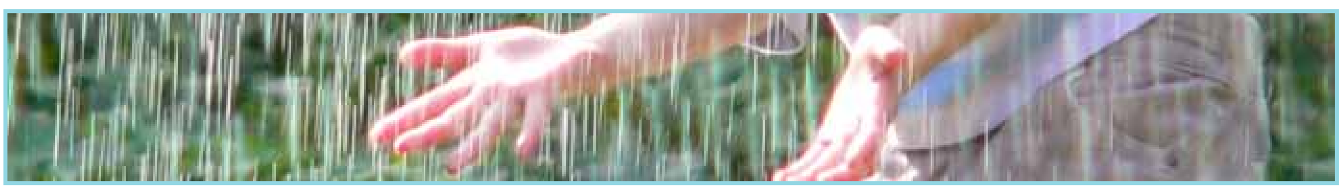
- Water Footprints around the World 21
- Water Scarcity, Dependency, & Trade 22
- Trading Drought Globally 24
- A Bit More on Trade 25

CONTROVERSY & OBSTACLES 28

SAVING THE PLANET ONE DROP AT A TIME 30

NOTES 32

WORKS CITED & REFERENCES 33



SUMMARY

Fancy a burger and a pint for lunch? And how about some water to wet your whistle after you enjoy your meal – would 3000 litres suffice? Assuming you had only one pint of beer and a burger on bread with egg and cheese, you just ate enough water to fill a do-it-yourself fish pond in your garden – about 2825 litres! And more than half of this water came from places far, far away, as far away as Australia or South Africa.

The average Briton drinks about 2 to 5 litres of water each day, and then uses another 145 or so litres for cooking, cleaning, washing, and flushing. Does that sound like much to you? Now multiply that figure by 23, and you have just uncovered a hidden truth: the average Briton really consumes about 3400 litres of water every day – well over a million litres a year!

There are hidden waters in everything that we see. Climate change has forced an understanding of embedded energy and carbon footrpints, but somehow water has been forgotten. There is also a concept out there called embedded water, and this idea will gain ever more attention as climate change begins to affect the world's finite water resources.

Embedded water refers to the amount of water necessary to produce a product. It takes about 140 litres to grow one cup of coffee; about 11,000 litres to produce a pair of jeans; and about 400,000 litres to build a car. When we add to the amount of water running from our taps the amount hidden in *everything* we consume, our true water consumption is exposed – about 34oo litres per Briton per day.

About 65 percent of this water is hidden in the food we eat. It takes a lot of water to grow food, and then much more water to feed and service the animals that we eat. Animal products almost always have a higher embedded water content than crop products because it takes huge quantities of water to grow feed. There are some plants, however, that are particularly water intensive such as cotton, rice, and coffee.

Industrial products, too, contain embedded water. Globally only about 20 percent of the world's freshwater withdrawals are for industrial uses, but here in the UK about 45 percent of our freshwater is withdrawn for use in industry. A single microchip may have 32 litres of water embedded in it! But the amount of water embedded in industrial goods does vary from product to product and also from make to make. Not all BMW models will have the same amount of embedded water, and these BMWs will differ from a Ford or Volkwagen.

Just as the amount of water embedded in industrial goods varies, so too does it differ for agricultural products. A kilogram of oranges from the USA has about 175 litres of embedded water but a kilo from Australia has over three times more. Embedded water content varies between and even within nations due to differences in climate, in irrigation and production techniques, and in technology. Furthermore, different species of the same plant may also differ in water requirements. Maris Piper potatoes, for example, require much more water than Desiree potatoes.

To complicate things even more, the *type* of water embedded in products also varies. The first type, called 'blue water', refers to surface and ground waters. Blue water is what we see flowing down our rivers into lakes. The other type of water is called 'green water'. This is water stored in the soil as moisture. Unlike blue water, green water cannot be extracted nor piped and it is always free. Green water can only be taken up by natural or cultivated vegeation. Because green water is hidden from view it is often overlooked, but in fact the vast majoirty of the world's crops are grown using only green water.

Green water use is typically an efficienct utilisation of water resources in comparison to blue water irrigation. Blue water withdrawals usually cause greater ecological harm because of the energy used for withdrawal and also because the ecosystems from which the water is taken are sensitive to water level changes. Shockingly, the tiny portion of crops that are irrigated together consume 70 percent of all the freshwater that we withdraw globally! And much of this irrigation is not efficienct.

Globally we already use 40 to 50 percent of available blue water running off the land – and our demand for water is rising. As the global population continues to increase, as people go on leading ever more water-hungry lifestyles, and as the effects of climate change begin to manifest, it is a real worry where our all this water will come from. Our planet will not be able to cope indefinitely with this strain.

What's more is that our consumption has effects on water resources all over the world, not just here in the UK. About 70 percent of the UK's water footprint is external, meaning that along with the products that we import we are also 'importing' embedded water. Our consumption here in the UK could well be draining lakes, rivers, and aquifers in other nations.

We are all interconnected through the global water cycle as rains evaporate from our soils and then move along to fall in France or Denmark. But it is international trade that makes all waters everywhere a resource shared by all. Sure, there are rivers and lakes that do litarally defy political boundaries, but even the Thames' water is shared by the world when it is used to make products for export. We here in the UK regularly draw on the Nile's waters as we import cotton and other products from Egypt.

Interdependence can lead to international cooperation over our water resources. When we start to think about the amount of water embedded in all products, we may be able to collaborate to increase the world's water use efficiency. Trade may make it possible to supply dry nations with water intensive goods, thus easing pressure on those nations' water resources. While there may be opportunity for action at the global level, there is also plenty of opportunity here at home. So goes the old adage: think globally, act locally.

By making a few simple efforts, we can all reduce the amount of water that we waste. By turing the tap off while we brush we save about 5 litres each time; when we fix a leaky tap we save over 3000 litres each year; and when we hold on to that cotton t-shirt for another year, we are saving another 2500 or so litres.

When we all start thinking abut how much we rely on water, we will use it wisely at home. Then we can pressure our leaders to bring water use efficiency up the agenda both nationally and globally. We can also demand that retailers, manufacturers, and agricultural producers stop wasting water, and that they let us know how much water is embedded in their products.

There is a local, regional, national, and ultimately global need for water use efficiency. The overall message is a simple: we cannot take water for granted. Water is finite. Water is irreplacable. And ultimately water is shared by us all – globally.



INTRODUCTION: A THIRSTY PLANET

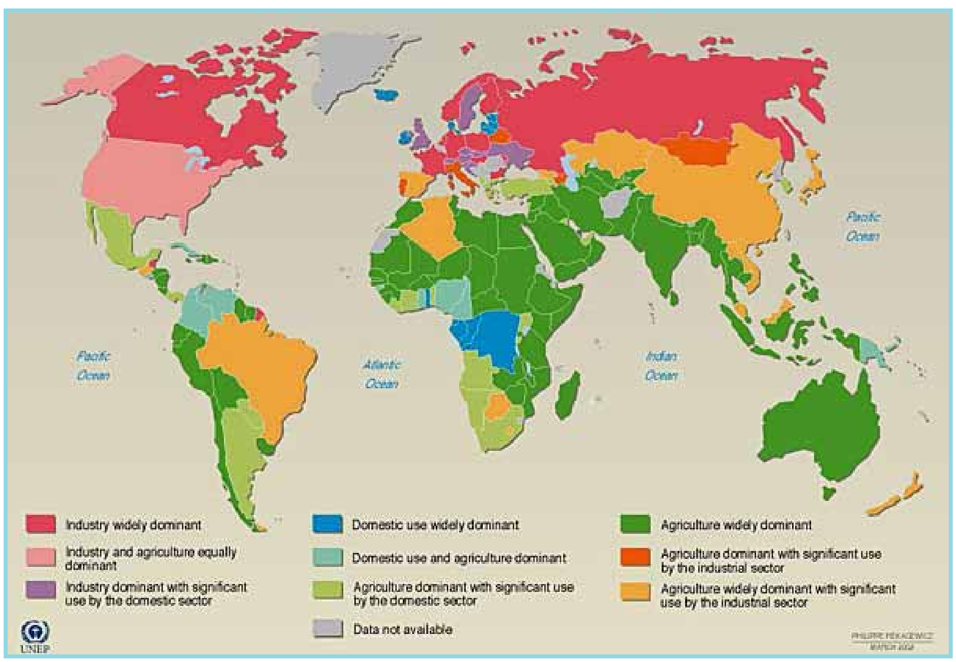
To produce 3000 calories of food a day for each of the world's 6.7 billion people, we annually use enough water to fill a canal one kilometre wide, as deep as Big Ben is tall, and long enough to circle the Earth twice. It would take the Thames over 3500 years to fill such a canal. Yet this canal would hold only enough water to grow one year's worth of food.

Now add 3 billion people to the planet by 2050, take into account changing diets from cereals to water intensive meats, and you will need to widen, deepen, and lengthen this canal a lot. This canal would now reach halfway to the moon, yet it would still only hold enough water to feed us for one year.

The average Briton consumes about 150 litres of freshwater every day – but not really. In fact it's much, much more. True consumption is over 3400 litres per person per day.[1] That's well over a million litre bottles per person annually. This volume includes the water you use at home for drinking, cooking, flushing, and washing but also the hidden water embedded in all that you consume.

We use an unimaginable volume of water every day, the majority of which is used to produce our food. It has been estimated that global water use for agricultural production amounts to about 6390 billion cubic metres[2] per year, including irrigation and soil water.[3] In other words, we use more than 200,000,000 litres *per second* to grow our food!

FIGURE 1. **Global freshwater withdrawals by sector.** Source: UNEP 2002.



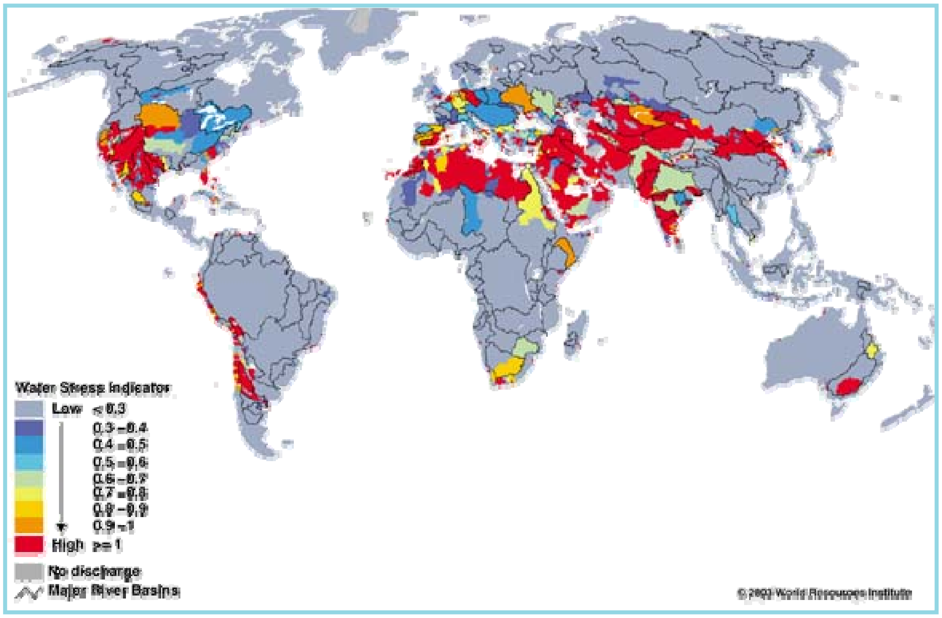
Of all the crops produced worldwide, only about 15 percent are irrigation fed; the rest rely on natural rainfall. Yet 70 percent of global freshwater withdrawals are for irrigation, and the Food and Agricultural Organisation of the United Nations forecasts that irrigation will play an even greater role in global food production in the coming decades.[4] Where will this water come from?

Withdrawals for industrial and household uses are small compared to the agricultural demand for freshwater. Only about 20 percent of global freshwater withdrawals are for industrial uses, and about 10 percent of withdrawals are for cooking, cleaning, drinking, toilet flushing, and other household uses. As the global population increases, as more people adopt water-hungry lifestyles, and as more people move into urban areas, household water withdrawals will undoubtedly increase.

At the global level agriculture is the big abstractor, but at the national level sector use varies tremendously (figure 1). In most developed nations industry accounts for the majority of freshwater withdrawals, but in developing nations agriculture is still the dominant user. In the UK agriculture accounts for only about 3 to 15 percent of freshwater abstractions; industry and households are the major users.[5]

Competition between household, industrial, and agricultural users for finite water resources is intense, and nature must also compete with these heavyweights. While the amount of global freshwater supply is adequate to meet global demand, as population continues to increase and as people urbanise and consume more, our global freshwater resources will come under increasing strain. Climate change will further stress water resources in many parts of the world. According to the United Nations Environment Programme, every person on Earth had about 9000 cubic metres of freshwater available to them 20 years ago; 10 years later this figure was down to about 7800. By 2025 it is expected to fall even more – to about 5100 cubic metres.[6]

FIGURE 2. **Water stress in international river basins.** Source: Smakhtin, Revenga, and Döll 2004. Environmental needs are factored in.

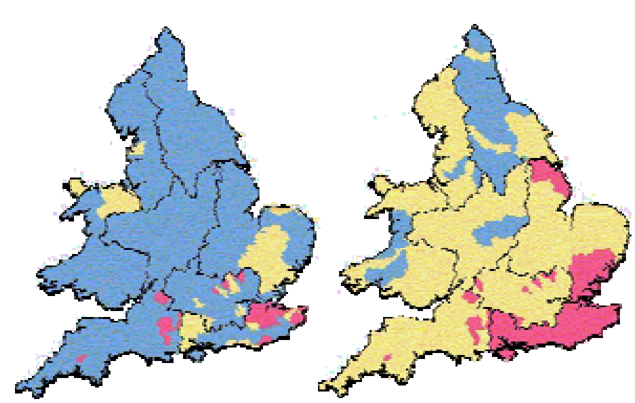


If freshwater supplies were evenly distributed around the world, 5100 cubic metres per person would be sufficient; however, freshwater is not evenly distributed between nations, regions, or seasons. Two-thirds of the global population live in areas receiving only one-quarter of the world's rainfall. And about 40 percent of the global population currently live in water stressed areas (figure 2). Experts predict that this figure will rise to between 50 and 65 percent by 2025.[7]

Currently we use 40 to 50 percent of all available freshwater running off the land, and withdrawals continue to rise.[8] Rivers are drying, aquifers are draining, and wetlands are disappearing. In the past 100 years, we have lost 75 percent of our ponds and floodplain grasslands here in the UK. Globally over the last 40 years withdrawals from lakes and rivers have doubled and are expected to increase another 35 percent within the next 15 years.[9] Even in such 'wet' countries as the UK, water is not readily available in many regions (figure 3). All over the world there are areas where water is not readily available.

Forget oil: water may soon become the world's blue gold. Yet water is much harder to transport than oil. And there are no alternatives to water.

FIGURE 3. **Water availability in England and Wales, winter *left* summer *right*.** Source: EA 2003.



EMBEDDED WATER: OUR REAL CONSUMPTION

'Embedded water' is simply the water used to produce a good like an apple, T-shirt, or bicycle. Tony Allan[10] first coined[11] the term in the early 1990s while examining the water resources situation in the Middle East. He noticed that water scarce nations like Jordan heavily imported water intensive goods. Allan went on to suggest that water scarce nations around the world could ease pressure on their internal freshwater resources by importing water intensive goods, thus sparing their nation the stress of having to use scarce water supplies to produce goods with high embedded water contents. Water embedded in products could thus be seen as a supplemental water source, next to national water resources. Global trade could be used to redistribute what is an unevenly distributed natural resource.

'Embedded water' is also referred to as 'virtual water', 'embodied water', or 'shadow water'. This Briefing will refer to the concept as embedded water, hoping to allude to the concepts of embedded energy and carbon footprints, terms which most people are already familiar with.[12] Furthermore, we believe that there is nothing 'virtual' about virtual water, and so that term may be misleading for some.

Embedded water refers to the amount of water required to produce a good from start to finish. Embedded water is most commonly used with reference to agricultural products but may be applied to non-agricultural goods as well, such as to computers. There have been no comprehensive studies that have undertaken the enormous task of calculating embedded water in industrial goods, either nationally or internationally.

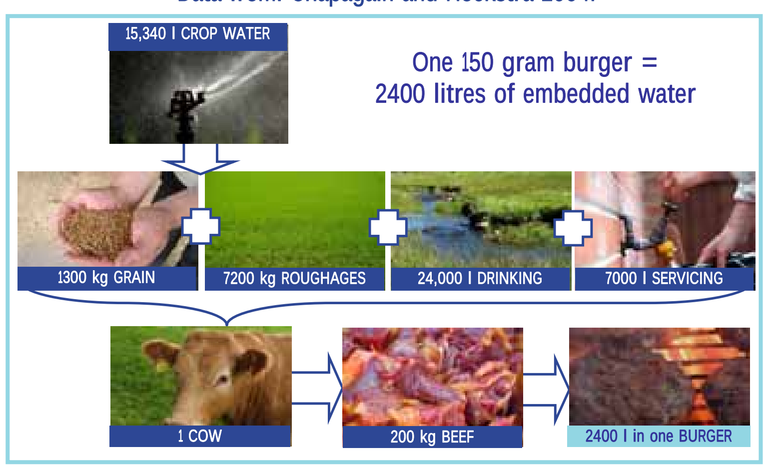
The most complete study to date of embedded water was carried out by A.Y. Hoekstra[13] and A.K. Chapagain[14] in 2004. Unless otherwise cited, numbers used in this Briefing are from the Hoekstra and Chapagain report. The study focused primarily on agricultural goods and, unlike other studies done on embedded water in crops, the study took into account both irrigation water and soil water. For animal products the study included the water necessary to produce feed and to service the animals, and also animal drinking water. Processing water and the amount of water embedded in packaging, transport, or retail was not included.

The study did consider industrial products, but only generally. Since the industrial products category is so vast, production methods varied, and with detailed statistics on consumption and production hard to find, the study only calculated a per country average embedded water content per dollar added value.

Embedded Water in Agricultural Goods

To produce 1 kilogram of wheat about 1000 litres of water are needed, but for beef about 15 times as much is required! This is because water is used to grow crops which are then fed to animals that also drink water. Water is also used to service livestock. For this reason meat and diary products unavoidably have higher embedded water contents than most crop products. As water cycles up the production chain, more becomes embedded in our food (figure 4).

FIGURE 4. Embedded water adds up.
Data from: Chapagain and Hoekstra 2004.



Of all major crops traded internationally, rice is the largest user of water. Global rice production annually consumes about 1359 billion cubic metres of water – about 21 percent of the total volume of water used for crop production. The second largest water absorber is wheat. Wheat annually uses about 793 billion cubic metres of water, about 12 percent of global crop water use. Figure 5 shows the proportion of crop water consumed by major international crops. It is important to note that both blue and green water (which will be explained in the next section) are included in these numbers, and that irrigation losses are not accounted for. These figures also assume that crop water requirements are fully met.

Some may interpret figure 5 to mean that rice, wheat, and maize have the highest embedded water contents: this would be incorrect. Just because these crops use the most water in total does not mean that they use the most water per kilogram. Figure 6 shows the average embedded water content per kilogram of some selected products. Notice that coffee, which consumes only 2 percent of global crop water, actually has the highest embedded water content of all the products shown. Each kilo of coffee has about 20,000 litres of embedded water!

FIGURE 5. Percent of global crop water (green and blue) consumed by major crops. After: Chapagain and Hoekstra 2004.

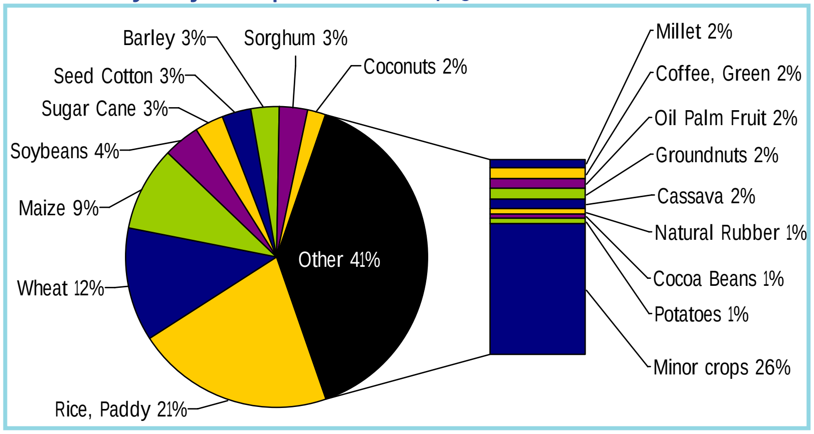


FIGURE 6. Global average embedded water content of some major agricultural products. Data from: Chapagain and Hoekstra 2004.

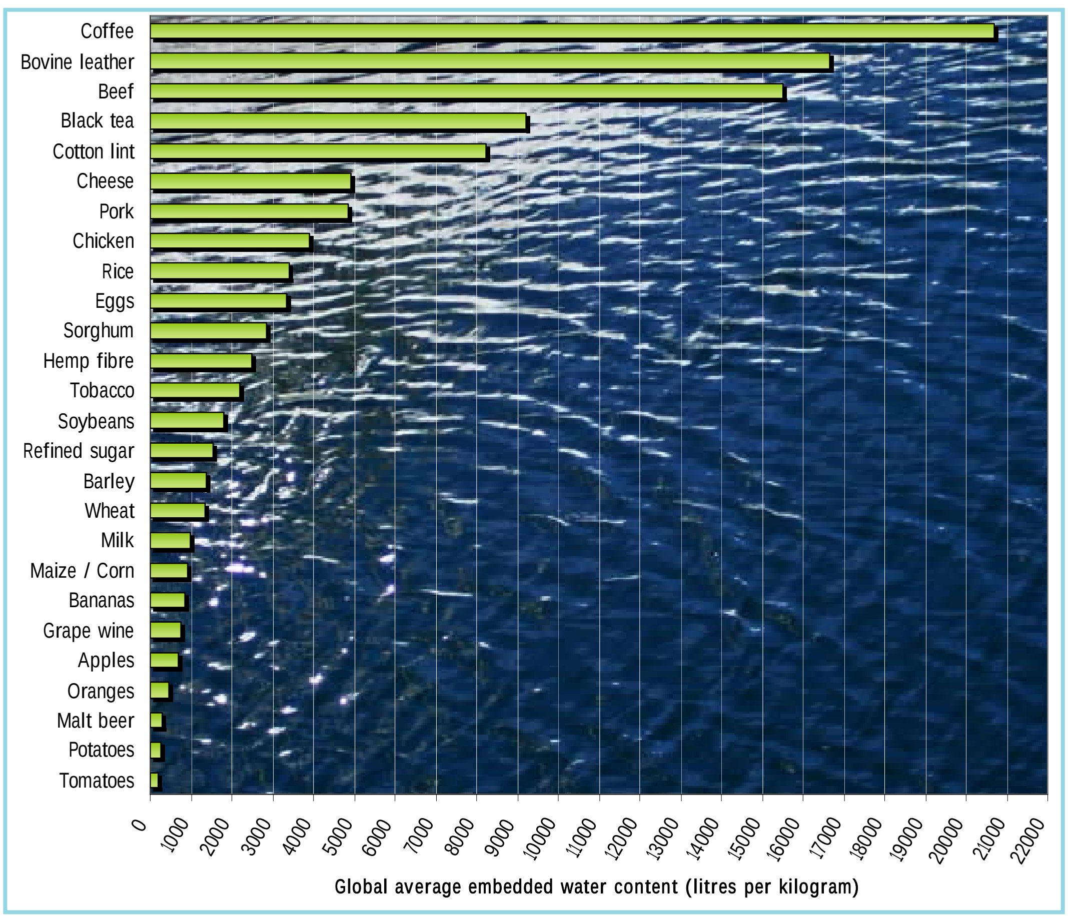
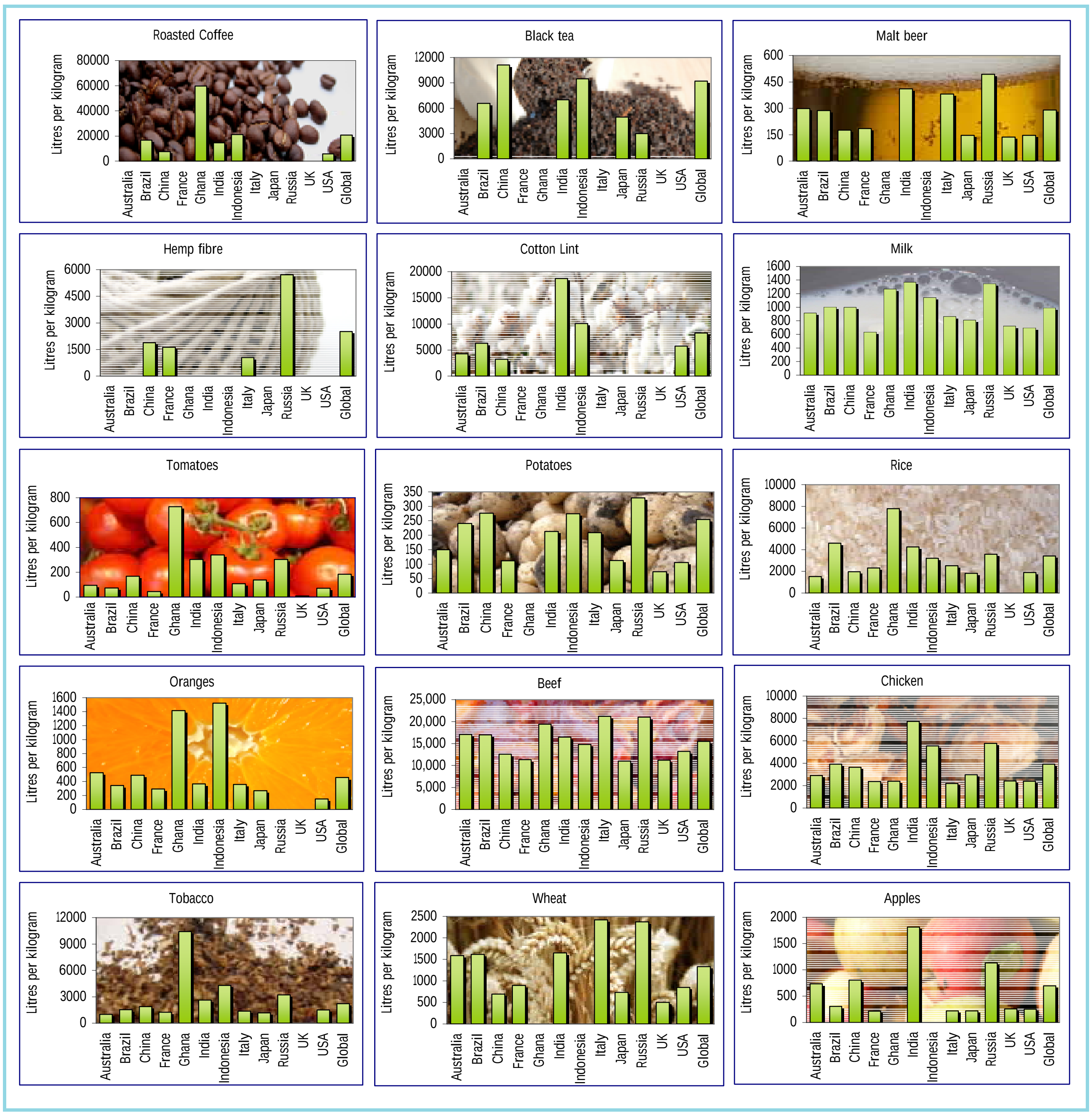


Figure 6 compared the global *average* embedded water content for some selected agricultural goods, but as figure 7 shows, embedded water can vary significantly depending on country (or even region) of production. For example, a kilogram of tomatoes produced in the UK has an average embedded water content of 8 litres, but a kilo from Indonesia contains about 340 litres of embedded water!

There are many factors which influence how much water is embedded in a product: climate (growth conditions), yield, crops species requirements, methods and technology, and irrigation efficiency are only a few of the variables which do have an effect. And not only does the amount of water embedded in food vary, but also the type of water embedded.

FIGURE 7. Embedded water differs depending on country of production. Data from: Chapagain and Hoekstra 2004. Nations with no bar either do not produce the good or do not trade it internationally.



Embedded Waters in Food: Green & Blue

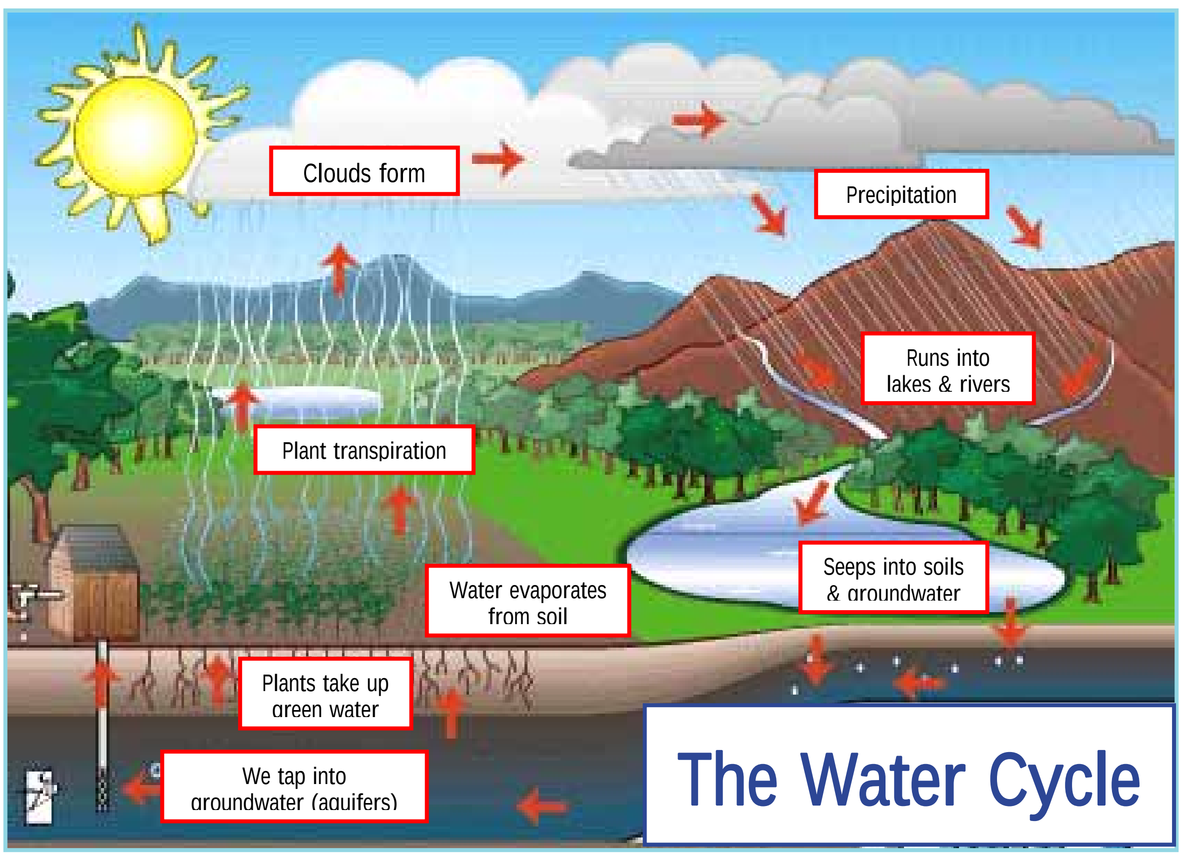
Which is better in terms of embedded water: a kilogram of Thai rice embedded with about 5500 litres of water, or a kilo from the USA embedded with 2000 litres? It may seem straightforward, but in reality embedded water is much more complicated. (Hint: These numbers do not convey all information).

There are two types of embedded water: 'blue' and 'green'. When most people think about water they are thinking about the blue kind: the surface waters in our lakes and rivers, and also the ground waters stored in aquifers. Blue water is what we see every day; it can be extracted and piped, and usually must be paid for. Blue water can be managed for many uses including household use, industrial production, power generation, agriculture, recreation, and ecosystem health.

But there is also another colour of water. Malin Falkenmark[15] introduced green water to the world in the early 1990s; however, 15 years later few people have ever heard of it. Green water is hidden in soils, and so often goes unrecognised. It is repeatedly undervalued. Yet green water is what enables 85 percent of the world's crops to grow.

Of all the rains that fall on the planet, only about 40 percent make it into an aquifer, lake, or river. The rest of these waters become trapped in soils as moisture (figure 8). This moisture is referred to as green water and it is invisible. Green water can neither be piped nor drunk and is completely free; it cannot be managed like blue water. Yet green water is essential for vegetal growth, both natural and cultivated, and it is vital for much of the world's food production. Without green water we would have to rely on our lakes, rivers, and aquifers to irrigate all of our food – and there certainly would not be enough blue water.

FIGURE 8. The water cycle. Source: U.S. National Park Service.
After rain falls, water that never makes it into a river, lake, or aquifer ('blue' water) becomes trapped in soil – this is called 'green' water. In this figure green water is in the light brown layer, where plants, both cultivated and natural, take it up for growth. In reality the water cycle is more complicated as exchanges do occur between blue and green water.



Only about 15 percent of the world's crops are irrigated, but this tiny group is responsible for 70 percent of the world's blue water withdrawals. And we are already consuming about half of the freshwater running off the land. As withdrawals for irrigation increase at a rate predicted to be about 0.6 percent every year for at least another 15 years[16] – where will all of this water come from? As the global population continues to rise, more crops and meats will be needed to feed everyone. Agricultural demand for water will intensify, but so will demand from factories and households. The natural environment, too, requires a share of this water.

Understanding the difference between green and blue water is crucial in order to better manage our water resources. Though coffee, tea, and rice – responsible for about 23 percent of the world's blue and green crop water use – are notorious water guzzlers, the majority of these crops are grown using green water which has less of an impact on the environment than the use of blue water. In contrast, cotton, which only uses about 2 percent of agricultural water (green and blue), is 70 percent irrigated. Irresponsible irrigation of cotton in some parts of the world has led to ecological disaster, for example to the shrinking of the Aral Sea[17]. Table 1 shows the average embedded water content of some cotton products. This calculation also includes dilution water which is the amount of water necessary to assimilate the pollution caused by insecticides and fertilisers used during cotton growth.

TABLE 1. **Average amount of water embedded in some cotton products.** Source: Chapagain et al. 2005.

	Litres of embedded water			
	Blue water	Green water	Dilution water	Total water
Jeans, 1000 g	4900	4450	1500	10,850
Bed sheet (single), 900 g	4400	4000	1350	9750
T-shirt, 250 g	1230	1110	380	2720
Diaper, 75 g	370	330	110	810
Cotton bud, 0.333 g	1.6	1.5	0.5	3.6

The best way to manage our shared water resources, and the only way to reduce embedded water in foods, is to maximise green water use and then top up – only if absolutely necessary – with efficient and responsible blue water irrigation. Planting crops suitable to climate is also essential.

For example, rice is a tropical/subtropical grass which relies on plenty of water for growth. In the USA rice is grown mostly in California, Arkansas, and Louisiana, places which, with the exception of Louisiana, are not humid and are certainly not exceptionally rainy. Ricelands in the US rely exclusively on blue water for irrigation.[18] In contrast rice from Thailand, the world's largest rice producer, is grown in paddies which readily receive annual monsoon rains. Less than one-third of Thai rice is grown under irrigation.[19]

With the exception of Louisiana, all these places are running out of water. Thailand has serious water problems during the dry season when millions of farmers rely on scarce blue water for irrigation; California already has to import water from other states; and Arkansas' aquifers are rapidly emptying, forcing officials to consider pumping water out of the Mississippi River. According to embedded water theory (more of which will be discussed later), these places should certainly not be growing rice for export and should even consider importing it for domestic consumption.

The decision, however, is complicated. For both Arkansas and California there seem to be very few good reasons as to why rice, a low value crop, should continue to be grown in water scarce areas. For, Thailand, however, there are some convincing reasons as to why rice should continue to be grown despite its embedded water content.

Thailand does use immense quantities of water to cultivate rice; however, the majority of rice in this humid monsoon country is produced during the rainy season when there is actually too much water. This water can either be captured in paddies to grow rice, or it can be left alone to wreak flood havoc and then eventually flow out to sea. It seems like rice paddies may be effective users of this extra water. If enough paddies were actually eliminated, water scarcity in Thailand could increase during the dry season because aquifers would receive less seepage from the paddies. Furthermore, paddies are critical habitat for many native Thai species. So while a kilo of Thai rice does contain a lot of embedded water, it may be argued that this water is used efficiently so long as rice cultivation is discouraged during the dry season (which is exactly what the Thai government is trying to do, and it seems to be working).

For these reasons Thai rice may be a better alternative to US rice if embedded water is the consideration. Rice is suitable to Thailand's climate and it uses a greater share of green water. US rice, in contrast, relies primarily on scarce blue water which has a greater opportunity cost than green water.

The example of rice, however, should not be interpreted to mean that all irrigated crops are wasteful. In fact many crops grown under irrigation are done so efficiently and responsibly – but presently these make up a small minority of the world's food production. Of all the blue water withdrawn for agriculture worldwide, only about 40 percent is effectively utilised. The remaining 60 percent evaporates away or seeps into the soil before reaching crop roots, and some of it is taken up by weeds instead of crops. Methods to increase efficiency and so to minimise the amount of blue water embedded in food do exist. Using drip irrigation instead of conventional methods can reduce the volume of water applied by 30 to 70 percent, and as an added bonus crop yields under drip irrigation tend to be 20 to 90 percent higher.[20] While this method is used on 90 percent of Cyprus' fields, in Spain and South Africa this figure is only 17 percent, in the USA it is only about 4 percent, and in China and India it is less than 1 percent. A lot of water is being wasted globally.

It is easy to waste blue water but because it can be managed there are steps that can be taken to increase efficiency. Green water, on the other hand, cannot really be 'wasted' in the same way as blue water, nor can green water be managed to the same extent. With green water the options are much more limited: green water can either be left for natural vegetation to subsist on, or it can be harnessed for agriculture. The management of green water is really more about land management than conventional water management. An example of Sudanese goats may help explain this concept better.




Many people in arid nations rely on goat herding for their livelihoods. Goat products have much more embedded water than most crop products and so one may think that a dry nation like the Sudan, which heavily relies on the export of goat for its foreign income, should move away from exporting goats and instead move toward the cultivation of less water intensive products. Herding goats, however, is actually an efficient means through which to make use of what little green water is trapped in Sudan's semi-arid soils.

Goats feed on the grasses and shrubs which manage to grow from the little bit of green water trapped in dry Sudanese soils. Crops would not be able to grow in such areas unless extensive irrigation was applied, but the Sudan does not really have enough blue water to allot for this purpose. Therefore, there are no other beneficial alternatives for the use of this land and its green water but to use it for herding goats. So while the Sudan does suffer from severe water scarcity, goats are actually a good way to make use of what little water is available. (Of course too many goats will lead to the desertification of the land forever, so herding does have to be carefully managed and people do have to be provided with other options for income).

Decisions become more difficult when land and its waters have many alternative uses. Take for example pasture and ranch. Many pastures and ranches around the world are actually not natural but the result of forest clearings; this is especially true of many areas in the Amazon rainforests. These areas of land could be used for many purposes: 1) the land may be left to regenerate into a forest and then this area may be valued for erosion control, selective timber harvesting, forest product gathering, biodiversity, recreation, and tourism; 2) the land may be converted into a multicrop plantation in which shade grown coffee is cultivated along with other crops; 3) the land may be completely cleared and planted with a monocrop such as maize; 4) the land may be left for pasture or ranch; 5) the land may be developed into a village; or 6) perhaps natural resources can be mined. These are only some possible uses, and there are likely may more.

Whatever the land use decision, it will also be a water use decision. Green water is harnessed for agriculture in choices 2, 3, and 4 above; in choice 1, green water is left for the natural environment; in choices 5 and 6 green water is completely ignored and its value deemed too little for benefit. The point is that in situations where land and its soil water have many uses, consideration of the value of alternatives, sometimes even of non-traditional options like national parks, is necessary if water resources are to be managed effectively. It's all about optimisation: 'more crop per drop' is not necessarily the goal, but instead 'more value per drop' – value here meaning not only economic but also social and environmental.

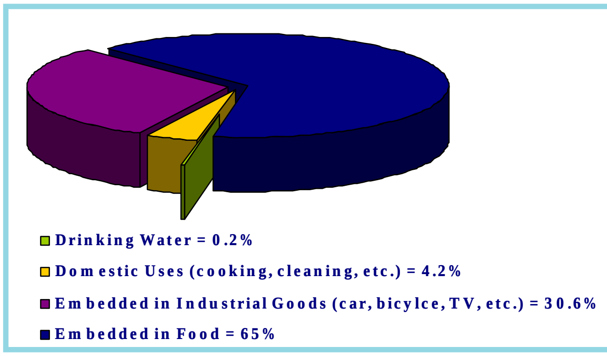
Embedded waters are obviously complicated. What is important to take away from this colour confusion is that embedded water figures aggregate green and blue water, and therefore can be misleading. If efficiently done irrigation using blue water may be favourable over some water intensive rain fed goods. Similarly, many rain fed agricultural goods (in other words, those grown only with green water), even if water intensive, may be water efficient if the green water has no other uses which are more beneficial. Of course what is or is not more beneficial is controversial.

Understanding the difference between green and blue waters, and truly appreciating green water, can help us to understand the relationships between rain, running waters, soils, and land. We cannot successfully manage our global water resources until we take a holistic view.

Embedded Waters & Our Eating Habits

The majority of the water that we consume is embedded in our food (figure 9). As we have already seen, a lot of water is required to grow crops, especially grains, and even more water is needed to produce meat, dairy, eggs, and other animal products. The cycling of water through crop and then the cycling of crop through animal can never be wholly efficient. It is unavoidable that foods higher on the food chain will require more water to produce.

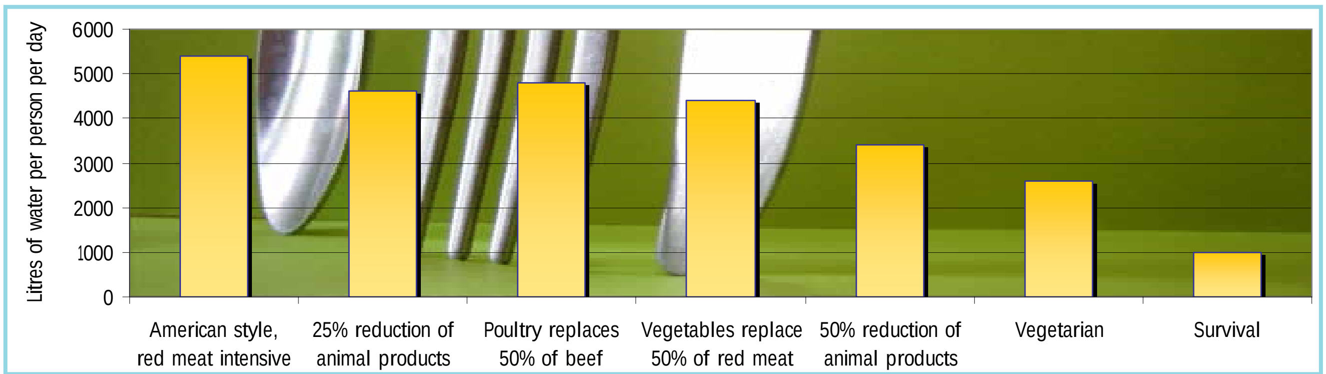
FIGURE 9. Our real water consumption in the UK. Data from: Chapagain and Hoekstra 2004.



The efficient use of irrigation water, the effective utilisation of green water, the use of feed that requires low water inputs, and also water-conscious servicing of animals can all help reduce the amount of water embedded in animal products.

That being said, carnivorous diets are unavoidably more water and land intensive than low-meat or vegetarian diets (figure 10). It has been estimated that if the entire world population were to adopt a Western-style diet, 75 percent more water would be necessary for agriculture.[21] As mentioned quite a few times already, globally about 40 to 50 percent of our surface freshwaters are already being withdrawn. If the entire world were to eat a Western-style diet, we could well run out of water.

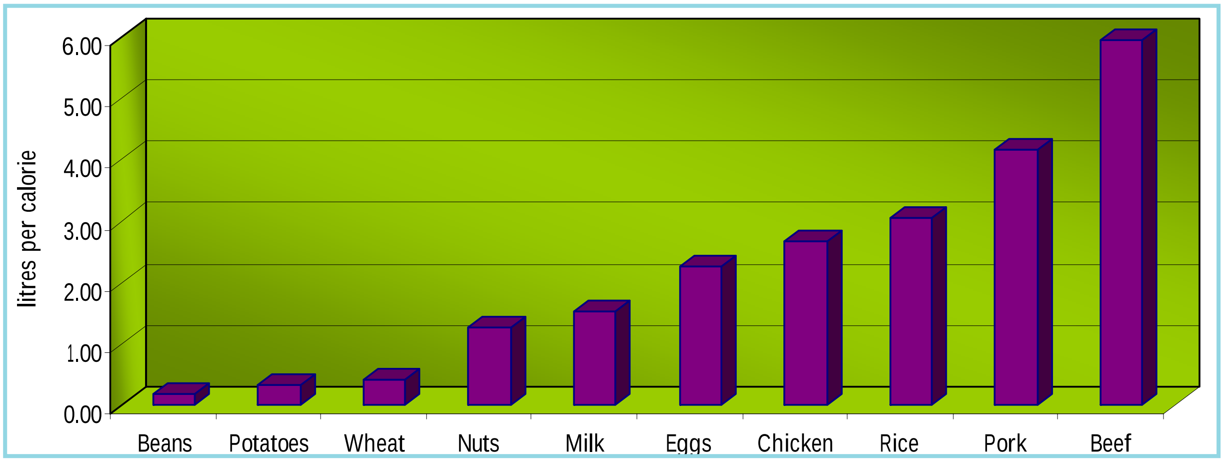
FIGURE 10. Water intensity comparison of various diets. After: Renault and Wallender 2000.



Instead of comparing how much water is embedded in a kilogram of an agricultural product, another way is to compare how much is embedded in a single calorie. Comparing foods in this way is a little bit fairer since meats typically have more calories than starches, and calorie intake is what really matters for health. When comparisons are made in litres of water embedded per calorie (figure 11), animal products are still more water intensive than crops (with the exception of rice being more water intensive than chicken). Kilogram for kilogram, beef is ten times more water intensive than wheat (refer back to figure 6); however, calorie for calorie, beef is actually twelve times more water intensive. Litres per kilo shows that wheat is more water intensive than milk, but litres per calorie shows that wheat actually uses two-thirds less water than milk.

As customers we do not have much control over the amount of water embedded in our food, unless we decide to alter our diets. But we should not have to make these changes yet, since there are many steps which farmers, water managers, and governments can take to ensure that the water used to grow our food is efficiently utilised. But we must encourage our leaders to take these steps. And we must tell our retailers and manufacturers that we want to know how much water is embedded in what we buy.

FIGURE 11. Water embedded in foods, per calorie of food.
Data from: Chapagain and Hoekstra 2004 and the author's own calorie estimates.

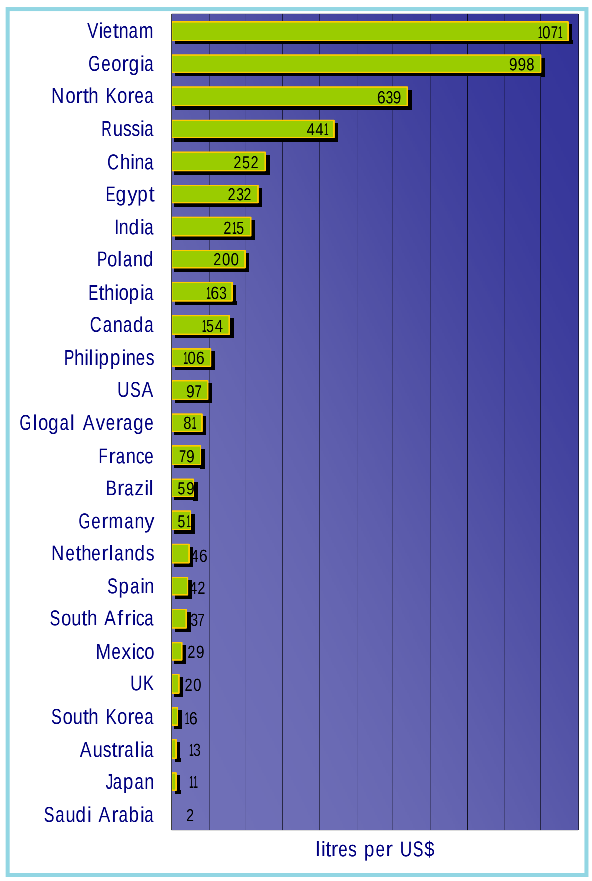


Embedded Water in Industrial Goods

Globally, the majority of the world's water is used to produce food; however, at the national level agriculture is not always the major water withdrawer. In many industrialised nations, including the UK, the majority of water withdrawals are for household and industrial use (refer back to figure 1). For nations like the UK it is important to understand how internal water resources are being used to produce cars, bicycles, teacups, and the like – particularly because industry usually uses only blue water for production (though rainwater harvesting is becoming more common). As industrial production increases around the world, it is crucial that the amount of water embedded in these goods is kept at an absolute minimum.

Unfortunately there is not much information out there as to the total amount of water embedded in industrial goods. Most studies only look at water during the main production stages and ignore the before and after. There has been one study, however, which did estimate the amount of water embedded in industrial goods per dollar added value.[22] This study estimated that the global average embedded water content of industrial products was about 80 litres per US$, but this figure varies dramatically from nation to nation (figure 12).

FIGURE 12. Average embedded water in industrial products per US$ added value. Data from: Chapagain and Hoekstra 2004.



Just as industrial water use varies between countries, it also varies between products. And prices for these products also vary considerably. Though products from the USA have about 100 litres of embedded water per dollar added value, this does not meant that the nation is more wasteful than, say, the UK, where the average embedded water content is about 20 litres per dollar. Looking at figure 11 does not tell us much about industrial water efficiency within a nation, and it does not contain enough detail for us to conclude that one nation wastes more water than another. It does, however, give us a *rough* idea of how much water nations are using to produce a dollar of product.

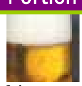
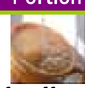
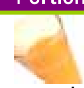
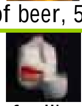
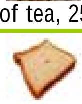
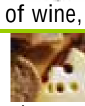
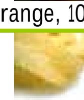
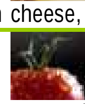
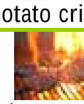
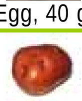
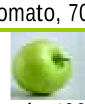
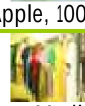
Table 2 estimates in a bit of detail the amount of water embedded in a single industrial product, a car. The average 1.1 tonne passenger car has about 400,000 litres of water embedded in it! And this figure is a conservative estimate because it does not include other car materials such as carpeting, other fabrics, glues, engine chemicals, leathers, other metals, and petrol. Note also that different makes and models of cars will have different amounts of water embedded in them because materials and production methods vary. For example some manufacturers may use synthetic rubber instead of natural rubber.

TABLE 2. An average car has at least 400,000 litres of water embedded in it!
Data from: Chapagain and Hoekstra 2004; Treloar et al. 2004; and Australian Food & Grocery 2003.

Material	Kg per car	Embedded water per kg	Embedded in car
Steel	750	39	29,250
Plastic	120	187	22,440
Glass	40	7	280
Rubber	25	13,058 (natural rubber)	326,450
Other	165	n/a	n/a
Process water			5,300
TOTAL	383,720 + other materials (see explanation in text above)		

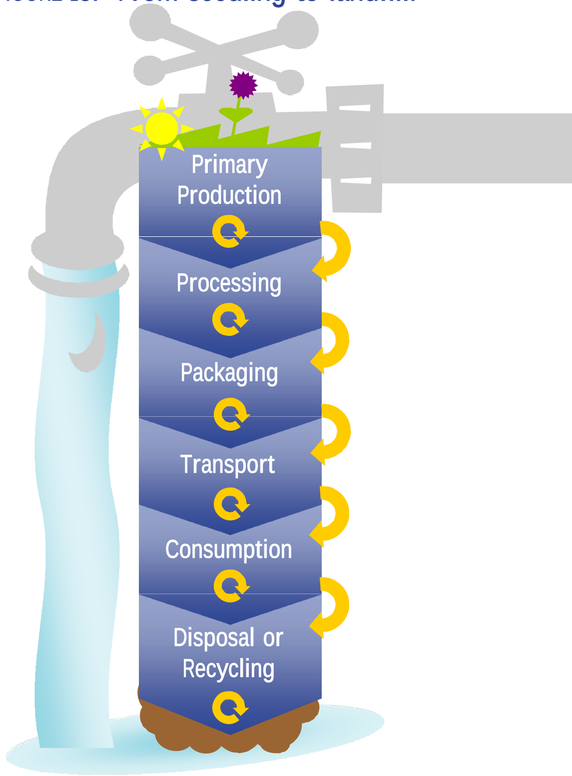
Water is embedded in absolutely everything. Table 3 lists the amount of water embedded in some of the things we eat and use every day – this table shows the amount of water embedded in a *single* serving. To produce *one drop* of tea, about 136 drops of water are required; to produce one drop of coffee about 1100 drops of water are needed!

TABLE 3. Average litres of water embedded in a single portion, excluding most processing and all packaging.
Data from: Chapagain and Hoekstra 2004; Williams, Ayres, and Heller 2002.

Portion	Litres	Portion	Litres	Portion	Litres
 Pint of beer, 568 ml	170	 Cup of coffee, 125 ml	140	 Glass of orange juice, 200 ml	170
 Glass of milk, 200 ml	200	 Cup of instant coffee, 125 ml	80	 Glass of apple juice, 200 ml	190
 Cup of tea, 250 ml	35	 Glass of wine, 125 ml	120	 Orange, 100 g	50
 Slice of bread, 30 g	40	 Bread with cheese, 30 g + 10 g	90	 Bag of potato crisps, 200 g	185
 Egg, 40 g	135	 Tomato, 70 g	13	 Hamburger, 150 g	2400
 Potato, 100 g	25	 Apple, 100 g	70	 Bovine leather shoes	8000
 Sheet of A4, 80 g/m^2	10	 Cotton tee, Medium 500 g	4100	 Microchip, 2 g	32

Embedded water accumulates from start to finish. Figure 13 illustrates a generic production chain for an industrial or agricultural good. The carrot-coloured arrows indicate transport within and between stages; here, too, embedded water builds up.

FIGURE 13. From seedling to landfill.



Even your home has water embedded in it. Though no studies have been done on homes in the UK, a 2004 study in Australia estimated that a typical Australian house represents about 15 years worth of operational water – 15 years of water for cooking, cleaning, washing, drinking, toilet flushing and gardening all embedded within a single home![23] This study estimated that a kilo of concrete has about 2 litres of embedded water, a kilo of timber about 20 litres, a kilogram of steel about 40 litres, a kilo of aluminium about 88 litres, and that a kilogram of plastic has about 185 litres of embedded water. It is safe to assume that a British home will also have loads of water embedded in it!

Once you add up all the embedded water in the food you eat and in the products you buy, and then factor in how much water is embedded in other products like your home and car, and then finally add to that sum the 150 litres or so of tap water that you use daily – only then will you have a rough estimate of your real water footprint. All of our footprints are enormous in comparison to the 150 litres of water that we thought we used in a single day!

OUR WATER FOOTPRINTS

'Ecological footprints' were developed in the mid-1990s to help describe the impact we were having on our planet.[24] It was demonstrated that industrialised nations such the UK used up substantially more natural resources than could be found within their own boundaries. In fact, we globally consume more than the whole planet can provide.[25]

Water footprints are an extension of this concept. In 2002 A.Y. Hoekstra applied the idea of footprinting to water resources so that nations would have a better consumption-based indicator of water use. The water needs of a nation were traditionally assessed by adding up domestic withdrawal, agricultural withdrawal, and industrial withdrawal. Though this method was and still is useful, it only provides a fuzzy picture of a nation's true water demand. The traditional method does not account for the amount of water embedded in imported products, nor does it consider how much water we use for producing goods for export.

A nation's real water demand may be much higher than total internal water withdrawals suggest if loads of water intensive products are imported. The reverse may also be true: a nation's water demand may be much lower than suggested by internal withdrawals if water intensive products are exported.

Whereas an ecological footprint specifies the land area required to maintain a nation's lifestyle, a water footprint indicates the volume of water needed to sustain a nation at current levels of consumption and with present technology. Unlike an ecological footprint, a water footprint does not tell us whether we are above or below sustainability – it does, however, help us to better understand our demand for water and our dependence on it.

A water footprint is defined as the total volume of water used to produce the goods and services consumed by an individual, company, nation, or planet. A water footprint adds together the amount of internal water resources withdrawn (excluding those waters which are exported as embedded water) with the amount of external water resources used. External water refers to water embedded in imported goods, but it may also be actual water imported from another nation. A complete water footprint takes into account both blue and green water use.

Water Footprints around the World

The global water footprint is 7450 billion cubic metres per year, or about 1,240,000 litres annually per person.[26] Variations between nations are huge (figure 14): the USA has a water footprint of 6800 litres per person per day, while China's is only about 1900 litres per person per day – a difference of almost four times! At about 3411 litres per person per day, the UK is at the global average of about 3405.

India, China, the USA, Russia, Indonesia, Nigeria, Brazil, and Pakistan together contribute 50 percent to the global water footprint; however, they are also home to half the world's population.

There are four major factors that influence the water footprint of a nation:

- Amount and type of consumption (often positively related to income);
- Consumption patterns (for example, high versus low meat consumption);
- Climate (growth conditions); and
- Agricultural practice (for example, irrigation efficiency or availability of technologies).

Depending on how these factors combine, a nation might have an unexpected footprint. For example, the UK may seem to have a low water footprint compared to other industrialised nations, but this is largely due to climatic conditions which are favourable for crop production. The USA and Canada both have large water footprints partly because of the amount of meat and industrial products consumed within each nation. Malaysia's footprint is big in part because of low crop yields.

Figure 15 illustrates which nations have water footprints greater than the global average (in red) and those which are lower than or at average (in green).

Figure 16 on the following page compares the water footprints of the UK, USA, and India to the global

FIGURE 14 Water footprints of nations. Data from: Chapagain and Hoekstra 2004.

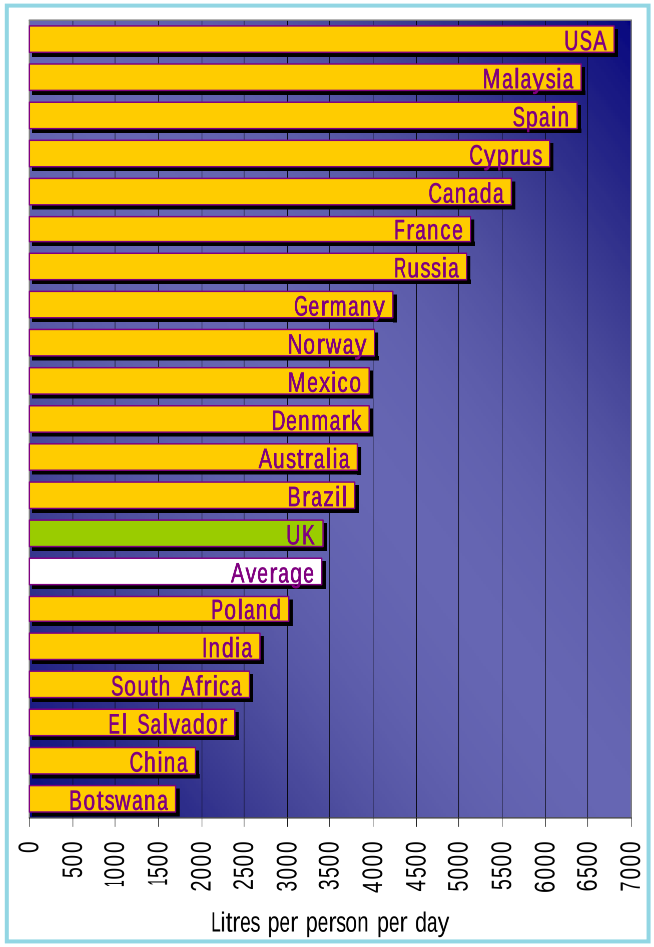
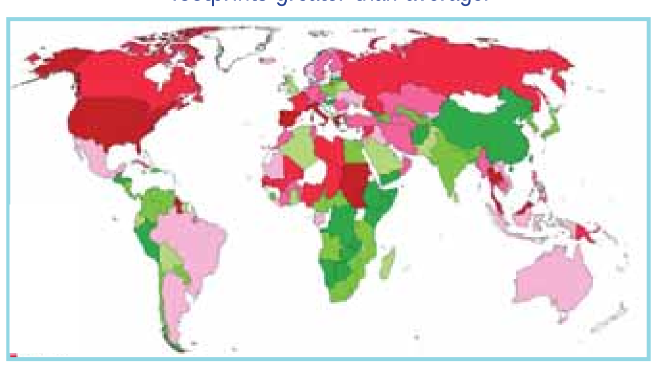
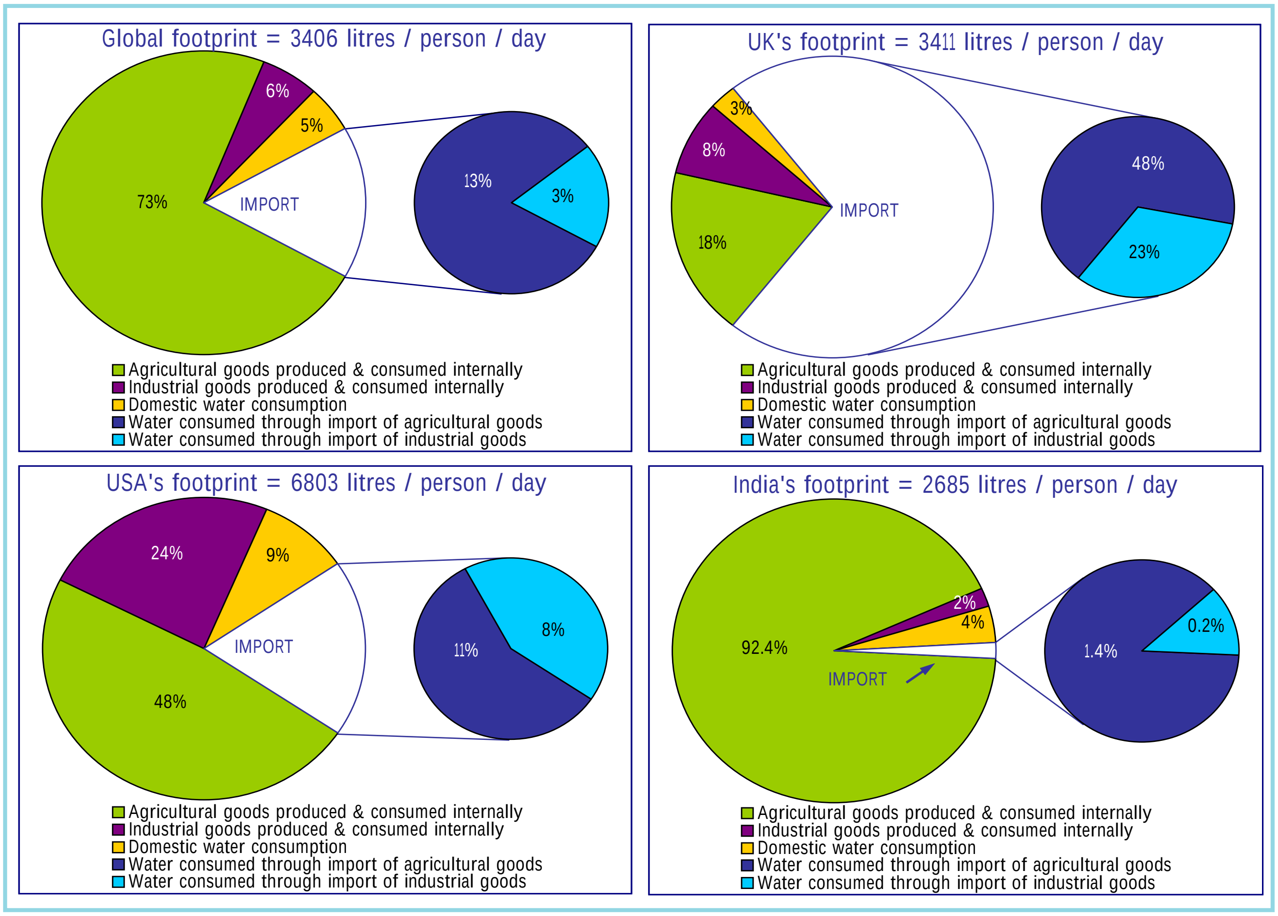


Figure 15 Water footprints, 2004. Source: Chapagain and Hoekstra 2004. Green nations have water footprints below or at global average; red nations have footprints greater than average.



footprint. Consumption of agricultural goods by far contributes the most to water footprints. Notice that the majority of the UK's water footprint is in the form of imports, while the majority of the USA's lies within its own boundaries. India's water footprint is almost entirely internal.

FIGURE 16. **Composition of some national water footprints.** Data from: Chapagain and Hoekstra 2004.



Water Scarcity, Dependency, & Trade

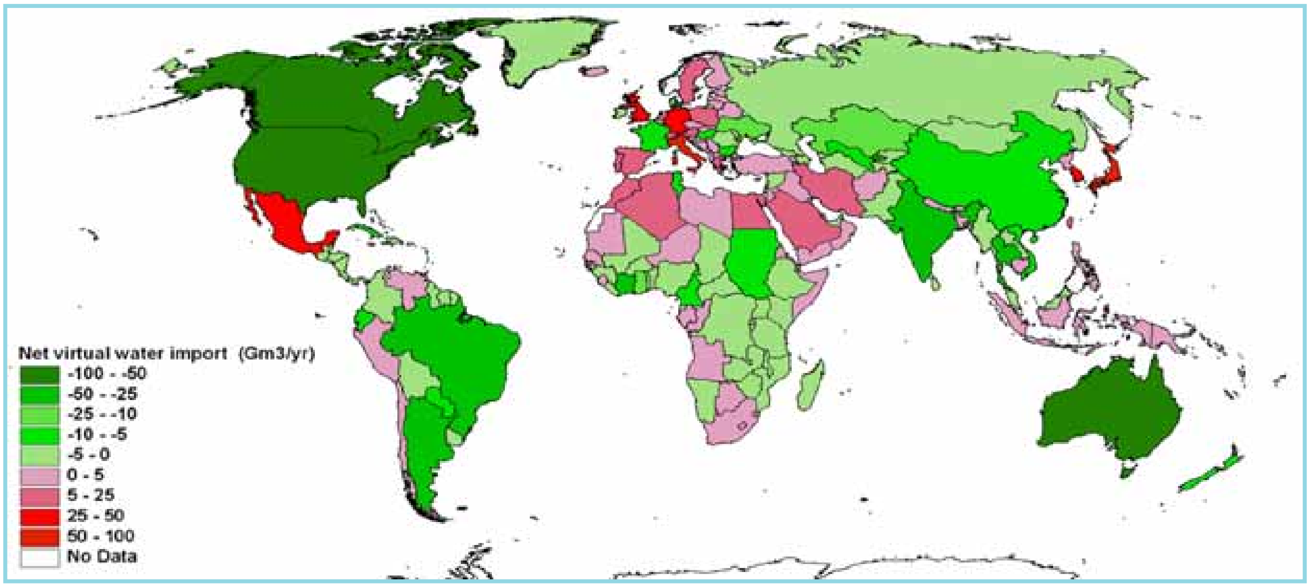
Through the trade in commodities, an enormous quantity of embedded water flows around the world – at least 1000 billion cubic metres every year.[27] The majority of this embedded water, about 80 percent, is embedded in agricultural goods. Beef, soy, and wheat contribute the most to global embedded water flows. Though rice may use more water globally than wheat, wheat is actually traded more and so more embedded water flows around the world through wheat.

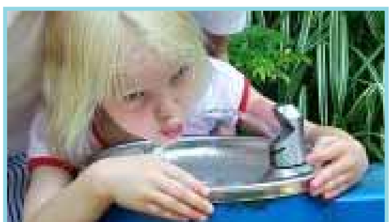
Table 4. Nations' embedded water exports and imports. Data from: Chapagain and Hoekstra 2004.

Top Gross Exporters		Top Gross Importers	
Countries	Export,Gm^3/yr	Countries	Export, Gm^3/yr
USA	229.3	USA	175.8
Canada	95.3	Germany	105.6
France	78.5	Japan	98.2
Australia	73.0	Italy	89.0
China	73.0	France	72.2
Germany	70.5	Netherlands	68.8
Brazil	67.8	UK	64.2

If you look back at figure 16 you will notice that, depending on the nation, a significant chunk of a country's water footprint is often from the consumption of external water embedded in imported goods. Table 4 lists the world's largest gross embedded water 'exporters' and 'importers'. The USA and France are both significant importers, but they also export huge amounts of embedded water. The UK, Japan, the Netherlands, and Italy are all top importers, but none of them are significant exporters. One might guess that their embedded water accounts skew toward imports of embedded water, but from table 4 this is not immediately clear. Figure 17 gives us a more complete picture of nations' net embedded water balances (exports minus imports of embedded water).

FIGURE 17. **Embedded water balances.** Source: Chapagain and Hoekstra 2004.





From this map we see that even though the USA and France export *and* import massive volumes of water, these two nations are actually net water exporters. Australia – the driest inhabited continent on Earth– is also a net exporter of embedded water. The UK, Japan, the Netherlands, Italy, Mexico and South Korea are all net importers. And as figure 16 illustrated, the UK's water footprint is actually composed of about 70 percent imports. In fact, only Japan and Italy import more embedded water.

If we take the internal water footprint of the UK and divide it by its total water footprint, we find that the UK is only 30 percent self-sufficient. This means that the UK depends on foreign imports to satisfy 70 percent of its consumptive demand for water. At the global level interdependencies are significant: about 16 percent of global water use (green and blue) is for the production of goods for export.[28]

You may be wondering whether the UK could make do with its own internal water resources. One way of estimating the water scarcity of a nation is to divide its total water footprint by its internal water availability. Done for the UK, we find that our nation has a water scarcity level of about 50 percent. This means that if the UK were to import absolutely nothing but instead produce all agricultural and industrial goods within its own boundaries, about 50 percent of our water resources would be consumed.

In theory it would be possible for the UK to import absolutely nothing (of course this also depends on availability of skill and labour, land, other natural resources, etc.); however, in reality this would not be a sensible strategy to pursue. The water scarcity ratio assumes that all waters within a nation are available for human consumption; the ratio does not take into consideration how much water the natural environment needs in order to survive. For this reason, consuming 50 percent of all the UK's internal waters would most likely not be sustainable in the long term if we wish to maintain ecological stability.

Trade, therefore, enables nations like the UK to preserve internal water resources for other uses. Along these same lines, then, it may be possible for water scarce nations to conduct trade so that internal water is 'saved' through the import of water intensive goods. Instead of trying to mobilise limited internal water resources for production, nations can 'import' embedded water in the form of agricultural and/or industrial products. The import of water intensive goods thus frees up water in that nation which may then be used for other purposes, such for the maintenance of ecosystems or for use in households and industries.

As wet nations export water intensive products to dry nations, and as dry nations export low-water goods to wet nations, interdependencies are created. But how long can wet nations supply water intensive products before they themselves dry out?

Trading Drought Globally

"Before you've finished eating breakfast this morning, you will have depended on half the world." — M. L. King Jr.

Through trade the world is becoming more and more interdependent. Not only are we importing goods and services into our nation, but we are also bringing in other nations' natural resources – including their water. Through the import of goods which require water for production, we annually import millions of litres of embedded water from places as close as Spain to as far away as Brazil, from wet nations and dry ones. Of course we do export our own waters, too.

We have already seen that the water embedded in products varies from nation to nation (refer back to figure 7). A kilogram of black tea from China has about 11,000 litres of embedded water, but a kilo from Japan has less than half that amount! We must all realise that when we import tea from China or from Japan we are having an impact on those nations' economies, societies, and also on their natural environments. We are indirectly supporting land use and other resource decisions made in those nations. Some of the goods we purchase here in the UK may directly contribute to pollution, land degradation, and species extinction in nations around the world. And above all else, perhaps, we are literally eating up the water resources of other nations – some of which suffer from chronic droughts.

Table 5 lists a handful of nations which have recently suffered or still suffer from water scarcity stress. The table also indicates how much net embedded water these nations export. After looking at this table you may be wondering whether these nations should be exporting embedded water at all.

TABLE 5. Nations recently hit by drought and their net export of embedded water. Export data from: Chapagain and Hoekstra 2004.

Nation	BBC Headline	Date	Net Export, million m^3
India	'Drought hits India bird reserve'	04 Jan 07	25,337
Australia	'Drought slows Australia's economy'	06 Dec 06	63,991
Kenya	'Warning signs on Kenya's drought road'	14 Nov 06	2,272
USA	Canada fights to keep its water [from the USA]'	12 Sep 06	53,491
China	'Drought worsens China water woes'	31 May 06	9,839

There is no straightforward answer to that question. Many water stressed nations have no choice but to export water intensive goods because of the way their economy is structured and also because of the way the international market may be functioning. Many developing nations, for example, rely on the export of agricultural products in order to earn foreign currency, but these nations often do not have the resources – human, technical, financial – to implement changes which would conserve their internal water resources.

On the other hand, you may be wondering whether we should continue importing water intensive goods from water scarce nations. Again there is no simple answer. Many of our imports do support developing nations, local peoples, and even environmental protection efforts. And a good chunk of the water intensive goods that we import actually come from water scarce developed nations. If the UK were to stop importing goods from faraway places, no matter the embedded water contents of the products, many nations and their peoples would suffer. And we would have to find a replacement for those nations waters, and the replacement might have to be our own waters.

The impacts that our consumption have on other nations' water resources should not be overlooked. Some of our imports do indirectly cause harm; others provide benefit. The situation really is muddled and extremely complex because of the way in which causes, effects, and interdependencies intertwine.

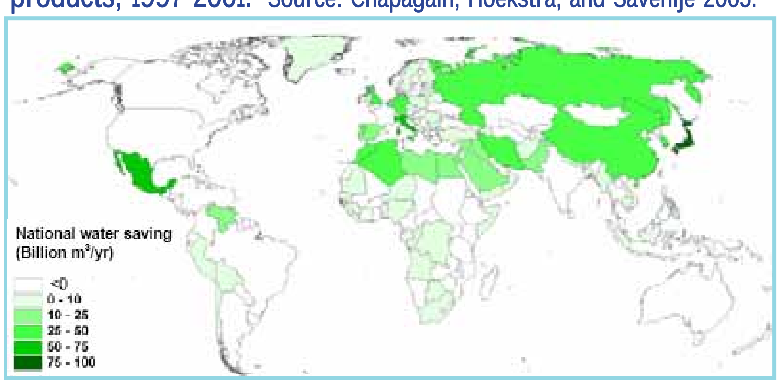
Having read all that, you may be feeling slightly disenchanted. But there is hope! We are all ever so slowly coming to realise that we live on the same shared Earth (and not just on it but with it). And we are ever so slowly beginning to realise how much we rely on water – a scarce, finite, and shared resource. In order to address issues of water use efficiency in other nations, we can encourage our leaders here at home to bring water conservation up the agenda and to begin working globally to solve our global water worries. We can all start asking questions about where our food and non-food products come from, how much water they use, and whether these goods were made sustainably.

A Bit More on Trade

Every year about 1625 billion cubic metres of embedded water flow around the world through the trade in commodities.[29] Of all the blue and green water used worldwide, about 16 percent is used for the production of exports; but if we look only at blue water we find that about 50 to 70 percent of this scarce resource is withdrawn for the production of exports.

With so much hidden water moving around

FIGURE 18. National water savings from trade in agricultural products, 1997-2001. Source: Chapagain, Hoekstra, and Savenije 2005.



the world, are we actually saving any water, or is this process wasteful? A handful of studies have shown that the global trade in agricultural goods actually saves water, about 350 to 450 billion cubic metres of green and blue water every year.[30] Savings result when nations import products which are produced with less water than if these products were produced by the importing nation. Egypt, for example, 'saves' about 4 billion cubic metres every year by importing wheat instead of internally producing it. Japan saves about 94 billion cubic metres of water every year, and the UK about 33 billion cubic metres. Figure 18 illustrates savings in other nations.

Blue water is scarcer than green water and its withdrawal usually has greater negative social and ecological impacts than the use of green water. For these reasons, blue water tends to have a higher opportunity cost than green water. Therefore, global water losses may be acceptable if blue water is actually being saved at the expense of green water. Blue water can be saved when nations import products that have maximum green water values and minimum blue water values.

To say that a nation like Egypt actually 'saves' water by importing wheat is both true and false. By importing wheat instead of producing it internally with domestic water resources, Egypt does spare itself the stress of having to bring together enough water to grow the crop. Through the import of wheat Egypt does free up its domestic water resources for other uses. So the savings is real; however, trade is almost never conducted with only embedded water in mind.

Trade is driven by interacting variables: supply and demand forces, differences in productivity between nations, political considerations, and other factors such as land and labour.[31] Water scarcity almost never influences trade decisions in a direct way, though there are a handful of nations that have begun to consider embedded water in their trade decisions (more on that later). Globally, most trade actually takes place between nations which are water abundant.[32]

The national water savings illustrated in figure 18 cannot be wholly attributed to water scarcity within those nations, so it may be slightly misleading to say that these are actual 'savings'.[33] For wet nations such as the Nordic countries, trade just happens to 'save' them water. Furthermore, not all water 'savings' in nations can be reallocated for other uses. For the Nordic countries, the water that they save is an added bonus but not a necessity. Whatever is saved may just be 'extra'.

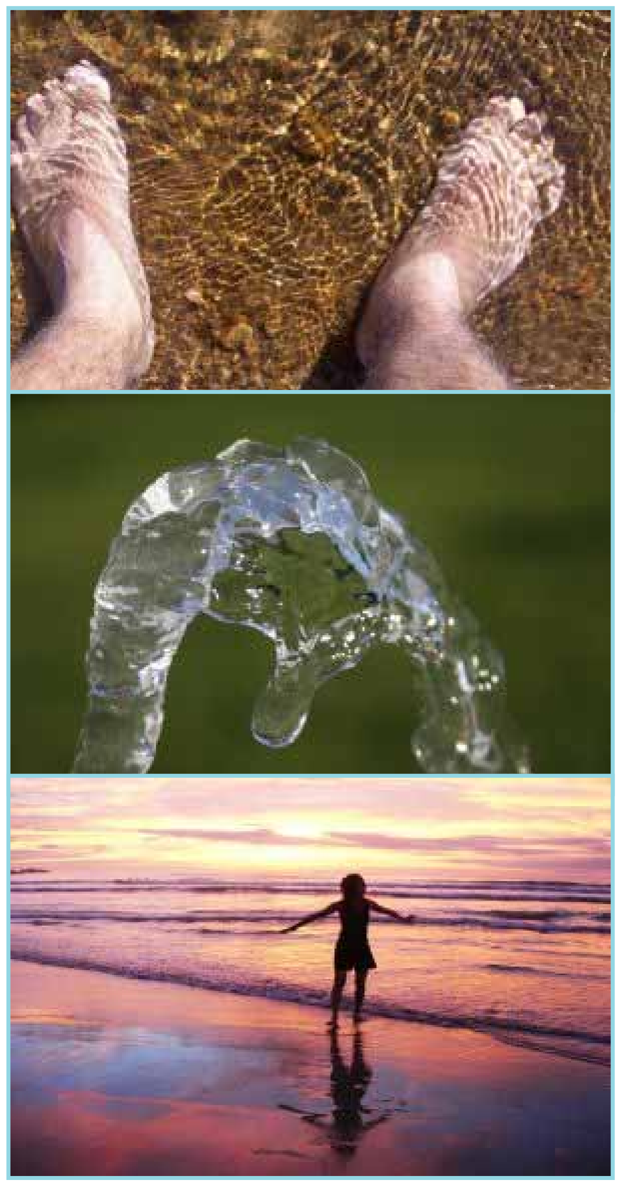
In an ideal world with a completely open economy, a country would seek to maximise profit by exporting products that are produced with resources that are abundantly available within that nation – water would be a real consideration. In this sort of world dry nations would import water intensive products if the production of these products within their own boundaries was not the most valuable option (value, again, refers to economic, social, and environmental). Wet nations would produce water intensive products if doing so would result in the most valuable use of their waters.

This sort of exchange, however, could only be sustainable if the *true* value of water was revealed. Water around the world is presently undervalued, and its true social, economic, and financial cost is not reflected in commodities. The valuation and pricing of water is a complex and contentious issue beyond the scope of this Briefing, but it must be mentioned here because trade with consideration of embedded water will never work unless water is properly valued.

Few have attempted to price water according to its real value in terms of economy, society, and natural environment. What we pay for water today in our homes, factories, and farms does not reflect water's worth. Because water is a relatively cheap 'commodity' (many would be horrified with this term, believing that water is a basic human right), many households, businesses, and industries have no incentive to save water.

For many agricultural water users the incentive to save water is even less. Government subsidies in many parts of the world allow farmers to receive water for next to nothing, for even less than the price that urban residents pay. In California's Central Valley, for example, farmers get about one-fifth of all the water used in California – at rates less than 2 percent of what urban residents in Los Angeles pay![34] And the majority of these subsidises are not going to small family farms who need the help, but to huge agribusiness operations.

If water is not properly valued it will be wasted locally, nationally, and ultimately globally. If dry nations do move toward importing water intensive products then they will be the ones who gain the most from present arrangements – as Tony Allan notes, "every subsidized tonne of wheat imported at the millennium has been associated with 1000 cubic metres of free water".[35] The costs associated with water withdrawals will remain external for importing nations and will be felt most by the exporting countries. Unless goods are valued at true cost, global water use efficiency will not be possible. And wet nations may become dry.



We must be careful when we talk about trade and embedded water. There is no actual 'trade' in embedded water: trade occurs in commodities like wheat or beef.[36] Embedded water is simply the water used for the production of these commodities. Embedded water is hidden in these goods. Another way of thinking about embedded water is to call it 'shadow water' since it shadows commodities around the world.[37]

But just because there is no actual trade in embedded water does not mean that the concept is not useful for analytical purposes. Billions of pounds are made every year in the trade of 'futures' which do not really exist and, as Tony Allan has pointed out, there are no transactions in shadow prices either yet the concept is useful. Embedded water simply exposes our true water consumption, helps us recognise our global interdependencies, and makes us more conscious of the effects our consumption may be having 3000 kilometres away.

Just because the water embedded in products cannot be poured into a cup, does not mean that the water is not real. Embedded water is very real. Aquifers, rivers, and lakes around the world are drying up as proof. Embedded water trade may be the mechanism through which economic growth and environmental sustainability are harmonised.[38]

CONTROVERSY AND OBSTACLES

If one were to suggest to a water scarce nation that it should stop producing water intensive food products and instead import these from other countries, chances are that the nation would reply defensively saying that domestic food production is essential to national security.

Food security is already closely linked with water security, and embedded water brings these two even closer. Because of this association, embedded water and its implications are controversial. Furthermore, in bringing all nations together into a global sharing of water resources, embedded water brings to the forefront questions about the fair distribution of water resources.

Like oil, food and water are strategic commodities – both have been fought over in the past. Unlike oil, water is irreplaceable. For these reasons most nations strive not to be dependent on other nations for food or for water. Security of water resources (supply, distribution, and quality) is increasingly becoming a hot topic for national governments particularly because climate change will impact water resources all over the world, thus potentially affecting food production and therefore national – and global – security.[39]

Like climate change, water resource management is a global issue. This Briefing has already demonstrated how embedded water and water footprints link all peoples together. But the water cycle itself also links us: as rains evaporate in one nation they move on to fall in another. And there are, of course, waters which do defy political boundaries. Worldwide there are 261 watersheds which are shared by two or more nations. The global water cycle, embedded water and water footprints, and trade all create interdependencies between nations. As nations we may choose either to fight over shared water resources, or to cooperate.

For some governments the realisation that they are dependent on other nations for certain goods, along with the water embedded in those goods, may be destabilising.[40] Some in the UK may be disturbed when they realise that 70 percent of the water we consume as embedded water comes from foreign nations. Other nations, however, have come to accept global interdependence and have learned to make the most of it.

A handful of dry nations have recently begun to consider seriously embedded water and its implications.[41] Some of these nations have even begun to move away from producing water intensive goods and now instead import these products. Nations such as Israel, Jordan, Tunisia, Egypt, and South Africa have consciously formulated policies to save water by reducing the export of certain 'wet' goods, and these nations have instead moved toward importing these water intensive products.[42] Though these nations do continue to export some water intensive products, these usually bring in high profits for each unit of embedded water. These nations have identified alternatives for the use of their scarce water resources and have decided that the export of low value water intensive goods was not worthwhile.

As Tony Allan notes, "more water flows into the Middle East each year as virtual [embedded] water than flows down the Nile into Egypt for agriculture".[43]

Sri Lanka is an example of the potential benefits of embedded water 'trade'.[44] In normal years Sri Lanka imports scarcely any food; however, in 1996, 1997, and 1998 the monsoon rains were well below average.

During this period Sri Lanka's imports of food shot up – so much so that from 1995 to 1999 Sri Lanka even surpassed Japan as the world's top embedded water importer.[45] Importing food was much easier fro Sri Lanka than trying to mobilise enough water to grow a normal year's worth of crops.

There is a strong case for nations to consider trade in embedded water:[46]

- Increased trade in embedded water may lead to improved global water use efficiency because nations will be able to share global waters, and thus will be able to optimise the use of their internal waters without having to worry about food and water security issues.
- In comparison to large-scale water transfers via elaborate pipelines/canals or in comparison to the construction of enormous energy-intensive desalinisation plants, the trade in embedded water may be a more practical means through which water scarce nations (or regions within a nation) can achieve water security.
- Embedded water trade has the potential to lessen environmental damage resulting from over-abstraction of local and regional water resources.

In theory, trade in embedded water may sound wonderful; however, the idea immediately raises a number of contentious issues. If we believe that water is a basic human right, how does that belief translate into action? With about 40 percent of the world's population currently living in water stressed areas, and with over a billion people still lacking access to safe drinking water – what is the responsibility of the rest of the world to these people? Are wet nations obligated to produce water intensive products for dry nations? And do dry nations then a right to access the water of wet nations? Will wet nations be able to supply water indefinitely or will they too run out? As consumers, are we responsible for draining other nations' rivers, lakes, and reservoirs, even though we have no direct control over water management in those countries?

And these questions are only scratching the surface of a debate that every nations should be having. Where does water privatisation fit in to all of this? Should water resources be globalised economically and politically? And if they were globalised, would that not lead to a tragedy of the commons? We would need an international water management organisation? What role would the World Trade Organisation play? Would we need a global and enforceable pact that would reassure all nations that water and food embargoes would never happen? Again, we're only scratching the surface here.

Many of the questions which arise from a discussion on embedded water, water footprints, and trade may be uncomfortable to think about; but until we do begin thinking about these issues, the future of our water supplies will not be secure. Climate change is creating more insecurity: dry nations may turn into dessert and temperate nations may become dry. Those nations which stay wet will have to make up for all the agricultural land which might be lost to drought in other nations. And these wet nations may have to worry about being too wet.

Whether embedded water does play a role in remedying water scarcity may hinge more on political processes then on scientific studies or academic debates over embedded water.[47] And there are many obstacles which will need to be overcome of the idea is to be embraced.

Arguably the biggest obstacle to global cooperation over water resources is distrust. Though a solid argument for global cooperation over water resources can be made, the feelings, passions, prejudices, and fears of people do and may continue to get in the way. For every statement supporting trade in embedded water there may well be a counterstatement against the idea. These days, most if not all nations feel uncomfortable depending on other nations, even if dependency exists on both sides. In order for trade with consideration of embedded water to work, nations must first trust one another, or at least have some sort of organisation or law to turn to if trust fails. Many nations might fear that a dependency will create a security gap through which another nation may slip in and interfere in internal affairs. Even worse, what if a dependency were used for coercion? Would global trade in embedded water lead to cooperation or to conflict?

Another obstacle to trade in embedded water is the simple fact that trade is not determined by only one variable. Access and availability of capital, the cost of labour, availability of land, technological limitations, tax policies, trade arrangements, market advantage, and all sorts of other variables influence what is traded internationally. Labour standards, tariff and quota regulations, standardisation rules, free trade agreements, and other policies, both national and international, may interfere with trade in embedded water.

To overcome these obstacles, do the proper national and international structures currently exist? If they do, are they able to deal successfully with possible complications? And if the structure and methods are already present, then the international market needs to be examined. How accessible is the international food market? Do all have equal access? And what about the effects of agricultural subsidies?

Embedded water has many implications, almost all of which are controversial. There are already many questions that need to be answered, and many more that have yet to be asked. There are issues surrounding capacity for change, for example, in dry nations which heavily rely on water intensive agricultural goods for export. For a dry nation to stop exporting water intensive goods is no easy feat. For this to happen alternative means for earning foreign currency would first have to be found, and that would involve massive internal restructuring to ensure that people have alternative jobs to turn to. This whole effort would involve a lot of planning, spending, and follow-through – and would require strong leadership.

SAVING THE PLANET ONE DROP AT A TIME

While many people are aware of embedded energy and carbon footprints, few have ever heard of embedded water or water footprints. Even water managers and policymakers have yet to discuss fully these ideas and their implications. Now is the time for us all to start thinking about embedded water and about our water footprints.

The world is becoming more and more water stressed, and we need to start examining all possible remedies. While we focus on energy use and greenhouse gases as causes of climate change, we must not forget that climate change will have effects on global water supplies – what are we going to do about these impacts?

Waterwise has compiled this Briefing

- To raise awareness of embedded water and of green water;
- To reveal how much water we really consume;

- To inform people of the extent of our water footprints, and how they reach beyond our nation;
- To expose global water interdependencies;
- To promote water use efficiency in all sectors of society and at all organisational levels;
- And above all, to spark interest and so encourage people to start talking about water.

The wise use of water will not happen until we all start talking about the need for sustainable water consumption; and that will not happen until we all realise how much we really rely on this finite and shared resource.

The concept of embedded water helps us to realise the extent of our dependence on water. Appreciating that water is hidden in absolutely everything, and that global trade really is a sharing of water resources globally, enables us to optimise the use of our water resources according to social, environmental, and economic values. If embedded water becomes a trade concern then we may be able to use it as a means to improving global water efficiency, to attaining water security in water scarce nations, and to relieving stress on environments which have suffered from unsustainable water withdrawals.[48]

The need for responsible water management is great: many areas around the world are already water stressed and these places, along with many new ones, will come under even greater strain in the future if actions are not taken today to efficiently use what water we have. Climate change is predicted to have the greatest impact on developing nations; these are the nations which rely most heavily on agriculture. Northern nations may need to begin producing more food as southern nations become too dry and too hot. But many northern nations are already water stressed. It is essential that we begin to manage both blue and green water wisely to ensure the future security of both our food and our water.

Sustainable water use begins in the home and at work. We cannot expect to resolve international water scarcity issues unless we first address these same issues at home. We do waste a lot of water every day. Yet if everyone made a few small changes in their behaviours and buying habits then we could save millions of litres of water every day. Simple changes will lead to huge water savings.

When we turn off the tap while brushing our teeth, we save about 6 litres of water each time. When we use a washing up bowl or an efficient dishwasher instead of washing up under a running tap, we are saving more water. When we cut a minute off our showering time, we are saving even more!

There are dozens of small actions that we can take to reduce our waste of water. Some are simple behavioural changes and others are quick technological fixes. There are also big leaps we can make if we feel really motivated! There are solutions for small businesses, huge industries, local schools, remote farms, busy hospitals, and for everyone in between.

Please visit us at www.waterwise.org.uk for more tips on how you can reduce your water wastage and for information about calculating your personal water footprint. If you have some water saving tips you'd like to share with us, or if you have any questions or comments on this Briefing, please do contact us! Also look out for more Waterwise reports about embedded water, our water footprints, and water and climate change.

NOTES

1 Chapagain and Hoekstra 2004
2 A cubic metre equals 1000 litres
3 Chapagain and Hoekstra 2004
4 FAO 2000
5 UK Environment Agency, WRI, and the FAO
6 UNEP 2002
7 Revenga 2000; UNEP 2002
8 MA 2005
9 Revenga 2000
10 Water Issues Group, School of Oriental and African Studies, University of London
11 The same idea was expressed by Gideon Fishelson et al. in the late 1980s, and the World Bank started to refer to this idea as the 'water, food, and trade nexus' in the mid-1990s
12 An extensive debate surrounding proper terminology does exist; however, this Brief will not attempt to delve into that discussion
13 Water Engineering and Management, Department of Civil Engineering, University of Twente, The Netherlands
14 Water Engineering and Management, Department of Civil Engineering, University of Twente, The Netherlands
15 Senior Scientist at the Stockholm International Water Institute
16 FAO 2000
17 Once the world's fourth largest inland sea, the Aral has now all but disappeared after its waters were pumped out to irrigate cotton in the desert. Cotton, a plant which prefers humid and warm climes, is still grown (under irrigation) in such dry places as Israel, Tanzania, Pakistan, and Australia.
18 USDA Briefing on Rice, available at http://www.ers.usda.gov/briefing/rice/background.htm
19 Thai Rice Foundation, online at http://www.thairice.org/eng/aboutRice/future_thaiRice_2.htm
20 Postel 1999
21 Renault and Wallender 2000
22 Chapagain and Hoekstra 2004
23 Treloar et al. 2004
24 Wackernagel and Rees 1996
25 WWF, GFN, and ZSL 2006
26 Chapagain and Hoekstra 2004
27 Chapagain and Hoekstra 2004; Hoekstra and Hung 2002; Chapagain and Hoekstra 2003; Zimmer and Renault 2003; Oki et al. 2003
28 Chapagain and Hoekstra 2004
29 Chapagain and Hoekstra 2004
30 Chapagain, Hoekstra, and Savenije 2005; Oki and Kanae 2004; Oki at al. 2003
31 Yang et al. 2003
32 de Fraiture et al. 2004
33 de Fraiture et al. 2004
34 EWG 2004
35 Allan 2003
36 Merrett 2003
37 'Shadow water' was coined by a water expert in the Middle East whose name Waterwise does not know. Thanks to Professor Allan for revealing this term to us.
38 Turton 1999
39 For more information about the possible effects of climate change on agriculture see the FAO at http://www.fao.org/clim/impacts.htm
40 Allan 2003
41 van Hofwegen, Allan, and Hoekstra 2003; Allan 2003
42 Allan 1996
43 Allan 1997
44 Allan 2003
45 Hoekstra and Hung 2002
46 Turton 2000
47 Allan 2003
48 Turton 1999

WORKS CITED AND REFERENCES

Allan, J.A. 1996. Policy Responses to the Closure of Water Resources: Regional and Global Issues. In: Water Policy: Allocation and Management in Practice, edited by P. Howsam and R.C. Carter.

Allan, J.A. 1997. Virtual Water: A Long-term Solution for Water-Short Middle Eastern Economies? Paper presented at British Association Festival of Science, 6 September, Leeds, UK.

Allan, J.A. 2003. Virtual Water – the Water, Food, and Trade Nexus: Useful Concept or Misleading Metaphor? Water International, vol. 28, no. 1, pp. 4-11.

Allan, J.A. 2004. Beyond the Watershed: Avoiding the Dangers of Hydro-Centricity and Informing Water Policy. Presented 10-14 October at the IPCRI Conference on Middle East Water.

Australian Food and Grocery Council. 2003. Environment Report 2003. Available online at http://www.afgc.org.au, accessed 3 November 2006.

Chapagain, A.K. and A.Y. Hoekstra. 2003 a. Virtual Water Flows between Nations in Relation to Trade in Livestock and Livestock Products. UNESCO-IHE Value of Water Research Report Series No. 13. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Chapagain, A.K. and A.Y. Hoekstra. 2003 b. The Water needed to have the Dutch Drink Coffee. UNESCO-IHE Value of Water Research Report Series No. 14. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Chapagain, A.K. and A.Y. Hoekstra. 2003 c. The Water needed to have the Dutch Drink Tea. UNESCO-IHE Value of Water Research Report Series No. 15. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Chapagain, A.K. and A.Y. Hoekstra. 2004. Water Footprints of Nations, vols. 1 and 2. UNESCO-IHE Value of Water Research Report Series No. 16. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Chapagain, A.K., A.Y. Hoekstra, and H.H.G. Savenije. 2005. Saving Water through Global Trade. UNESCO-IHE Value of Water Research Report Series No. 17. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Chapagain, A.K., A.Y. Hoekstra, H.H.G. Savenije, and R. Gautam. 2005. The Water Footprint of Cotton Consumption. UNESCO-IHE Value of Water Research Report Series No. 18. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

de Fraiture, C., X. Cai, U. Amarasinghe, M. Rosegrant, and D. Molden. 2004. Does International Cereal Trade Save Water? The Impact of Virtual Water Trade on Global Water Use. Comprehensive Assessment Research Report 4.

EA. 2001. Water Stress. UK Environment Agency. Available online at http://www.sustainable-development.gov.uk/regional/summaries/17.htm, accessed 20 November 2006.

EWG. 2004. California Water Subsidies. Environmental Working Group Report. Available online at www.ewg.org/reports/watersubsidies/execsumm.php.

FAO. 2000. World Agriculture towards 2015/2030, summary report. Food and Agricultural Organisation.

Hoekstra, A.Y. 2006. The Global Dimension of Water Governance: Nine Reasons for Global Arrangements in Order to Cope with Local Water Problems. UNESCO-IHE Value of Water Research Report Series No. 20. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Hoekstra, A.Y. and P.Q. Hung. 2002. Virtual Water Trade: A Quantification of Virtual Water Flows between Nations in Relation to International Crop Trade. UNESCO-IHE Value of Water Research Report Series No. 11. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

MA. 2005. Living beyond Our Means: Natural Assets and Human Well-Being: a Statement from the Board of the Millennium Ecosystem Assessment. Available online at http://www.maweb.org/en/Products.BoardStatement.aspx, accessed 20 November 2006.

Merrett, S. 2003. 'Virtual Water' and Occam's Razor. Water Issues Group Occasional Paper No. 62, SOAS.

Oki, T. and S. Kanae. 2004. Virtual Water Trade and World Water Resources. Water, Science, and Technology, vol. 49, issue 7, pp. 203-209.

Oki, T., M. Sato, A. Kawamura, M. Miyake, S. Kanae, and K. Musiake. 2003. Virtual Water Trade to Japan and in the World. In: Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade, edited by A.Y. Hoekstra, Value of Water Research Report Series No. 12. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Postel, S. 1999. Pillar of Sand: Can the Irrigation Miracle Last? Worldwatch Institute, Washington, D.C.

Renault, D. and W. W. Wallender. 2000. "Nutritional Water Productivity and Diets." Agricultural Water Management, vol. 45, pp. 275-296.

Revenga, C. 2000. "Will There be Enough Water?" In: Pilot Analysis of Global Ecosystems: Freshwater Systems, edited by G. Mock. World Resources Institute. Available online at http://earthtrends.wri.org/features/view_feature.php?theme=2&fid=17, accessed 14 January 2007.

Simms, A., D. Moran, and P. Chowla. 2006. The UK Interdependence Report. Published by the New Economics Foundation.

Smakhtin, V., C. Revenga, and P. Döll. 2004. Taking into Account Environmental Water Requirements in Global-scale Water Resources Assessments. Comprehensive Assessment Research Report 2.

Treloar, G., M. McCormack, L. Palmowski, and R. Fay. 2004. Embodied Water of Construction. Environment Design Guide, May issue, pp. 1-8. The Royal Australian Institute of Architects.

Turton, A.R. 1999. Precipitation, People, Pipelines and Power: Towards a 'Virtual Water' based Political Ecology Discourse. MEWREW Occasional Paper No. 11, SOAS. Available online at www.soas.ac.uk/waterissues/occasionalpapers/OCC11.PDF, accessed 15 January 2007.

Turton, A.R. 2000. Precipitation, People, Pipelines and Power: Towards a Political Ecology Discourse of Water in Southern Africa. In: Political Ecology: Science, Myth and Power, edited by P. Stott and S. Sullivan.

UNEP. 2002. Vital Water Graphics. United Nations Environment Programme. Available online at http://www.unep.org/vitalwater/, accessed 14 January 2007. Based on UNESCO. 2000. Water Use in the World: Present Situation/Future Needs.

van Hofwegen, P., J. A. Allan, and A. Hoekstra. 2003. Voices on Virtual Water: Three Articles from Stockholm Water Front, June 2003. Available online at www.worldwatercouncil.org/fileadmin/wwc/Programs/Virtual_Water/Virtual_Water_voices.pdf.

Wackernagel, M. and L. Jonathan. 2001. Measuring Sustainable Development: Ecological Footprints. Centre for Sustainable Studies, Universidad Anahuac de Xalapa, Mexico.

Wackernagel, M. and W.E. Rees. 1996. Our Ecological Footprint: Reducing Human Impact on the Earth. New Society Publishers, Gabriola Island, BC.

Water Footprint and Virtual Water at http://www.waterfootprint.org/. Website maintained by the UNESCO-IHE Institute for Water Education in collaboration with the University of Twente, the Netherlands. Accessed 24 January 2007.

Williams, E.D., R.U. Ayres, and M. Heller. 2002. The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices. Environmental Science and Technology, vol. 36, no. 24, pp. 5504-5510.

World Water Council. 2004. E-Conference Synthesis: Virtual Water Trade—Conscious Choices, March 2004.

WWF, GFN, and ZSL. 2006. Living Planet Report 2006. World Wide Fund for Nature. Available online at http://www.footprintnetwork.org/.

Yang, H., P. Reichert, K.C. Abbaspour, and A.J.B. Zehnder. 2003. A Water Resources Threshold and its Implications for Food Security. In: Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade, edited by A.Y. Hoekstra, Value of Water Research Report Series No. 12. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.

Zimmer, D. and D. Renault. 2003. Virtual Water in Food Production and Global Trade: Review of Methodological Issues and Preliminary Results. In: Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade, edited by A.Y. Hoekstra, Value of Water Research Report Series No. 12. Available online at http://www.waterfootprint.org/Publications.htm, accessed 24 January 2007.