

# A Comprehensive Introduction to Water Footprints

© 2011 Arjen Y. Hoekstra

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[www.waterfootprint.org](http://www.waterfootprint.org)



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## Overview

- Freshwater scarcity & pollution
- The water footprint of products
- National water footprint accounting
- The water footprint of a business
  
- WF sustainability assessment
- Response: reducing water footprints
  
- Water Footprint Network

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## Freshwater scarcity and pollution

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 The water footprint of a product

- ▶ the volume of fresh water used to produce the product, summed over the various steps of the production chain.
- ▶ when and where the water was used: a water footprint includes a temporal and spatial dimension.

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### The water footprint of a product

- Green water footprint**
  - ▶ volume of rainwater evaporated or incorporated into product.
- Blue water footprint**
  - ▶ volume of surface or groundwater evaporated, incorporated into product or returned to other catchment or the sea.
- Grey water footprint**
  - ▶ volume of polluted water.

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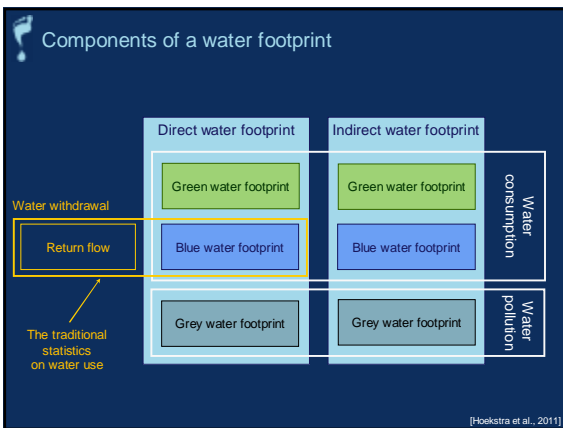
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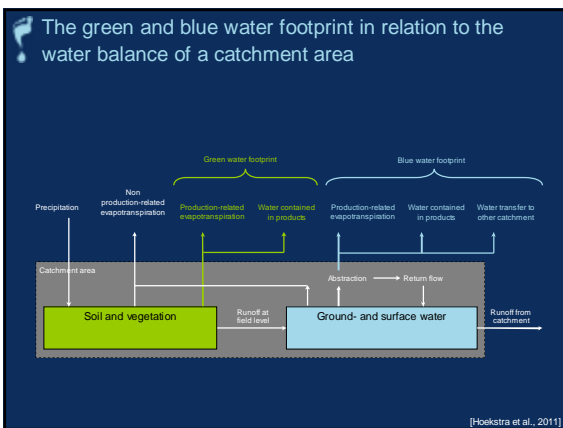
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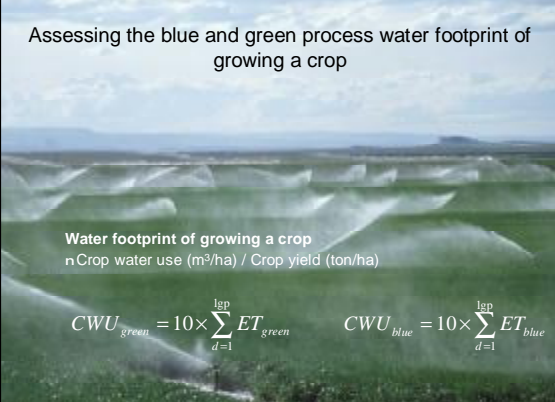
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Assessing the blue and green process water footprint of growing a crop



Water footprint of growing a crop  

$$n \text{ Crop water use (m}^3\text{/ha)} / \text{Crop yield (ton/ha)}$$

$$CWU_{green} = 10 \times \sum_{d=1}^{lsp} ET_{green} \quad CWU_{blue} = 10 \times \sum_{d=1}^{lsp} ET_{blue}$$


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Crop water use



Green water evapotranspiration =  
 $\min(\text{crop water requirement, effective precipitation})$

Blue water evapotranspiration =  
 $\min(\text{irrigation requirement, effective irrigation})$

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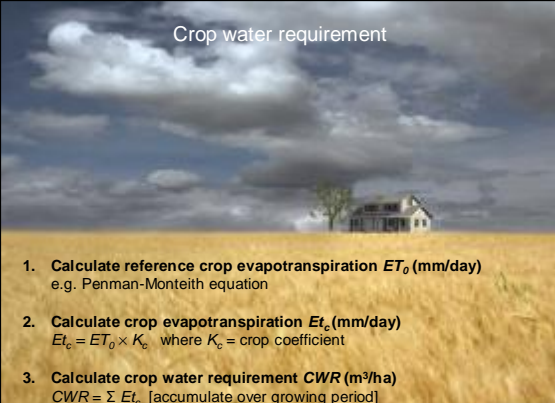
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Crop water requirement



1. Calculate reference crop evapotranspiration  $ET_0$  (mm/day)  
 e.g. Penman-Monteith equation
2. Calculate crop evapotranspiration  $E_t$  (mm/day)  
 $E_t = ET_0 \times K_c$  where  $K_c$  = crop coefficient
3. Calculate crop water requirement  $CWR$  (m<sup>3</sup>/ha)  
 $CWR = \sum E_t$  [accumulate over growing period]

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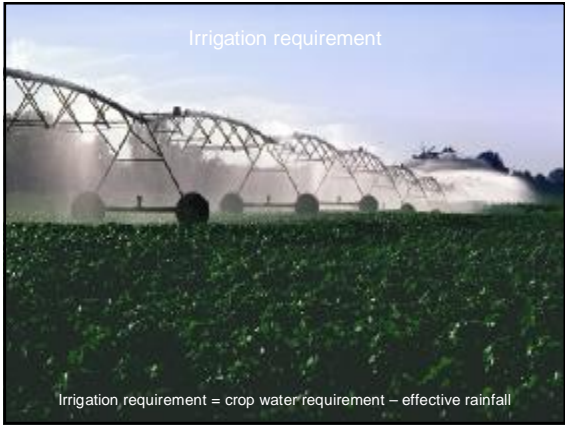
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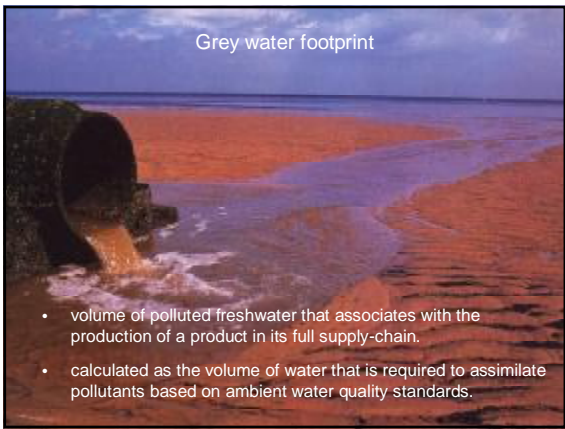
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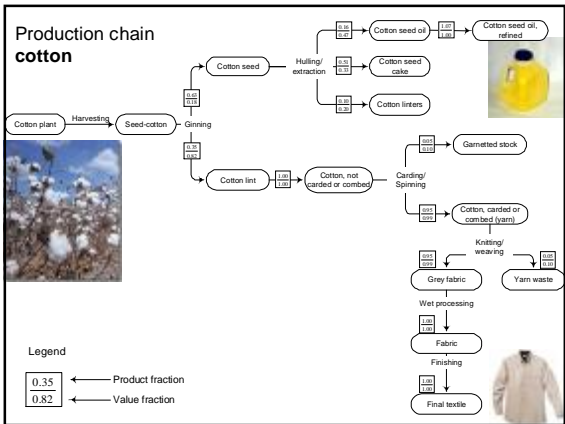
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[Hoekstra & Chapagain, 2008]

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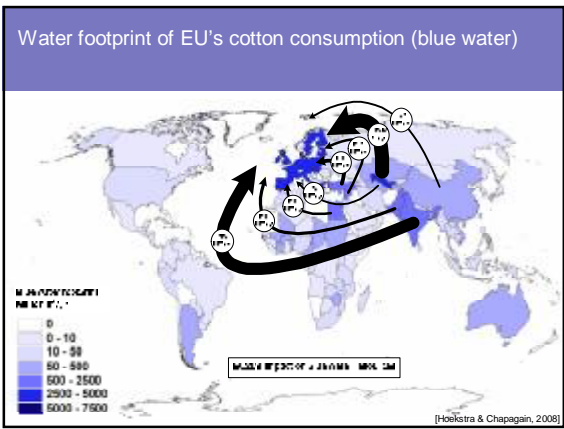
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[Hoekstra & Chapagain, 2008]

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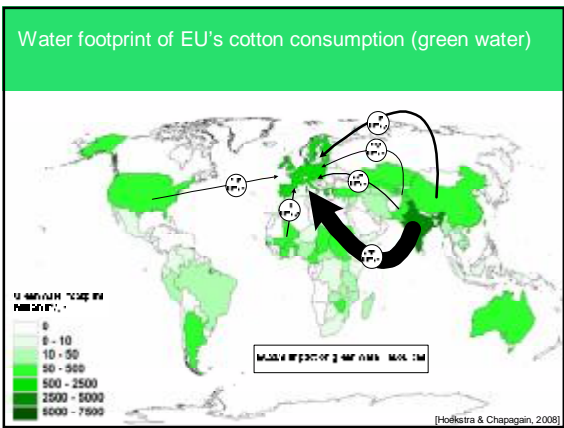
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[Hoekstra & Chapagain, 2008]

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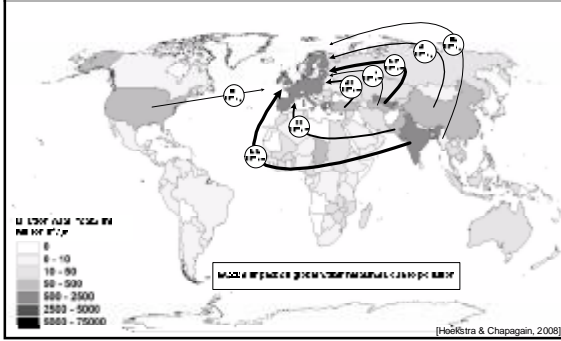


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Water footprint of EU's cotton consumption (grey water)



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The water footprint:  
making a link between consumption in one place and  
impacts on water systems elsewhere



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The water footprint:  
making a link between consumption in one place and  
impacts on water systems elsewhere



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This is a **global average** and **aggregate** number. Policy decisions should be taken on the basis of:

1. Actual water footprint of certain coffee at the precise production location.
2. Ratio green/blue/grey water footprint.
3. Local impacts of the water footprint based on local vulnerability and scarcity.



[Hoekstra & Chapagain, 2008]

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[Hoekstra & Chapagain, 2008]

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[Hoekstra & Chapagain, 2008]

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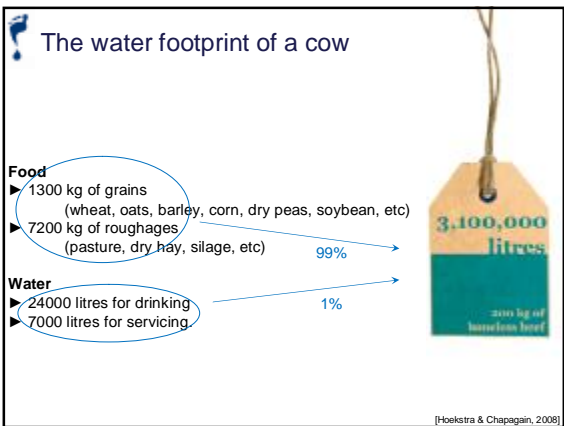
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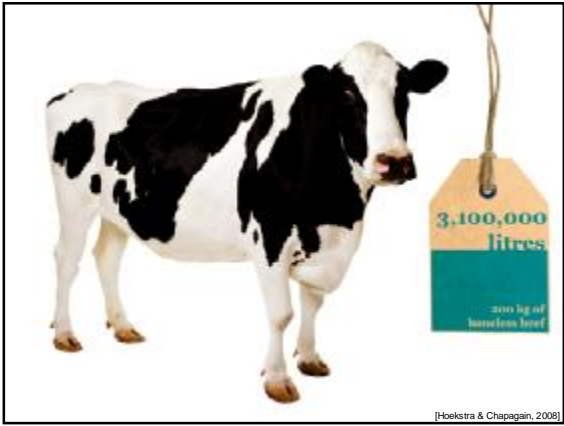
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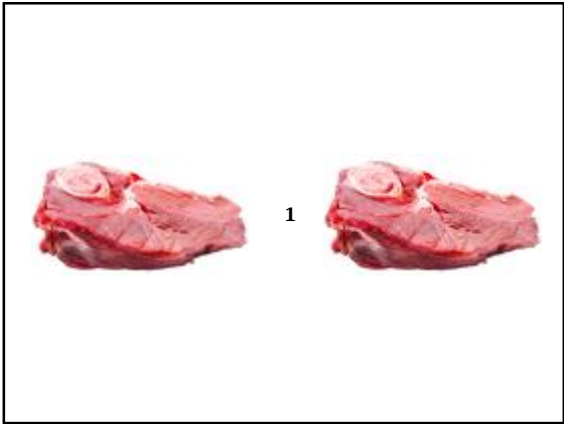
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<p>Grazing systems</p> 	<p>Water footprint: •mostly green •local</p>
<p>Mixed systems</p> 	<p>Water footprint: •green &amp; blue •local</p>
<p>Water footprint: •green &amp; blue •partly imported</p>	<p>Industrial systems</p> 

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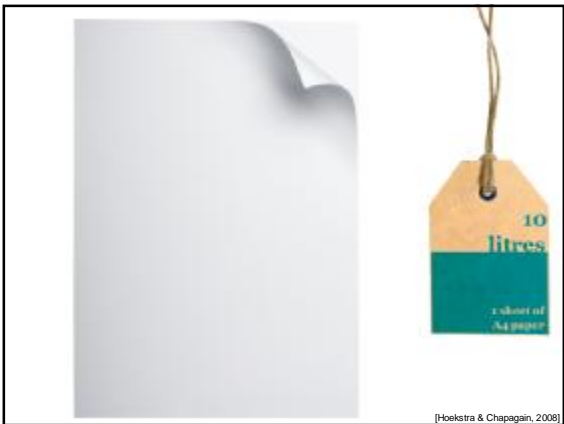
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[Hoekstra & Chapagan, 2008]

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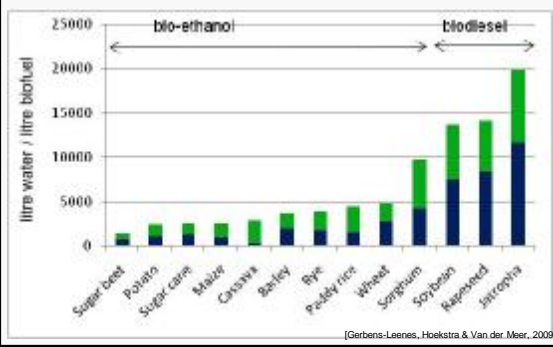
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Water footprint of biofuels from different crops [litre/litre]




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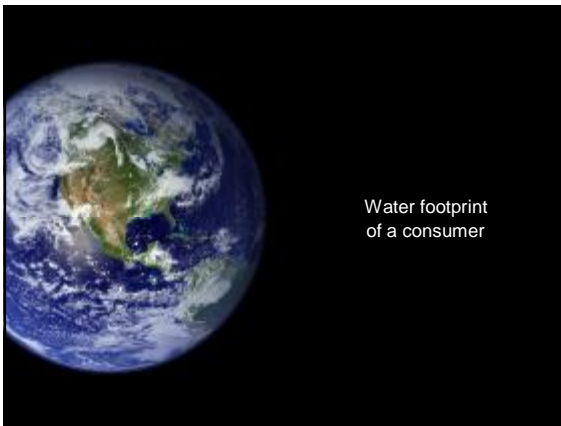
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**Water footprint of a consumer**

- ▶ the total volume of water appropriated for the production of the goods and services consumed.
- ▶ equal to the sum of the water footprints of all goods and services consumed.
- ▶ dimensions of a water footprint
  - volume
  - where and when
  - type of water use: green, blue, grey

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**The total water footprint of a consumer in the UK**

- ▶ about 3% of your water footprint is at home.  
150 litre/day
- ▶ about 97% of your water footprint is 'invisible', it is related to the products you buy in the supermarket.  
3400 litre/day for agricultural products  
1100 litre/day for industrial products
- ▶ about 60 to 65% of your water footprint lies abroad.

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**Meat versus vegetarian diet**

	Meat diet	kcal/day	litre/kcal	litre/day	Vegetarian diet	kcal/day	litre/kcal	litre/day
Industrial countries	Animal origin	950	2.5	2375	Animal origin	300	2.5	750
	Vegetable origin	2450	0.5	1225	Vegetable origin	3100	0.5	1550
	Total	3400		3600	Total	3400		2300
Developing countries	Animal origin	350	2.5	875	Animal origin	200	2.5	500
	Vegetable origin	2350	0.5	1175	Vegetable origin	2500	0.5	1250
	Total	2700		2050	Total	2700		1750

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**National water footprint accounting**

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### Water footprint of national consumption

- ▶ total amount of water that is used to produce the goods and services consumed by the inhabitants of the nation.
- ▶ two components:
  - internal water footprint – inside the country.
  - external water footprint – in other countries.
- ▶ water footprint of national consumption =  
 water footprint within the nation + virtual water import  
 – virtual water export

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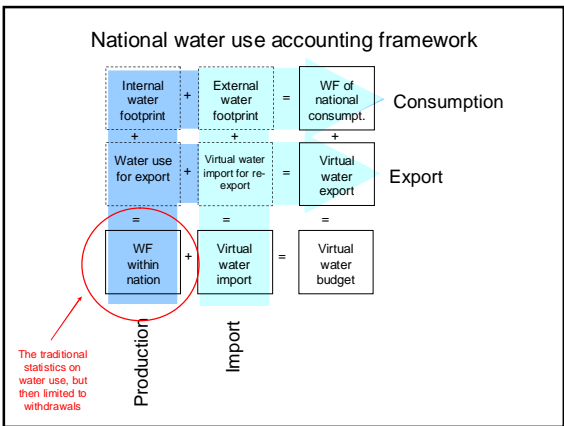
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Country/region	National water footprint (Gm <sup>3</sup> /year)	
	from the perspective of production	from the perspective of consumption
Australia	91	27
Canada	123	63
China	893	883
Egypt	59	70
EU25	559	744
India	1013	987
Japan	54	146
Jordan	1.8	6.3
USA	750	696

Traditional statistics on water use, but then restricted to water withdrawal

WF within a nation

WF of national consumption

[Hoekstra & Chapagain, 2008]

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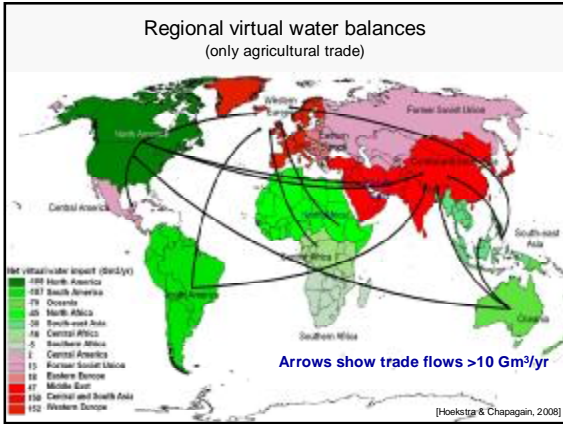
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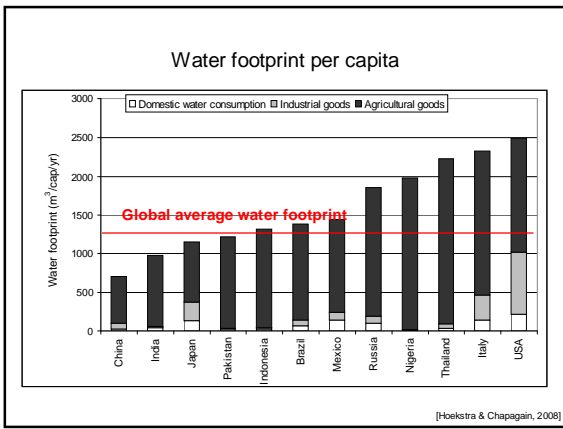
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**Major determinants of the water footprint of national consumption**

1. Consumption characteristics
  - n Consumption volume
  - n Consumption pattern
2. Production circumstances
  - n Climate: evaporative demand at place of production
  - n Agricultural practice: water use efficiency

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 Water footprint:  
why businesses are interested

Water risks for business

- Physical risk
- Reputational risk
- Regulatory risk
- Financial risk

Water opportunity for business

- frontrunner advantage
- corporate image

Corporate social responsibility



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 Water footprint of a business

Operational water footprint

- the direct water use by the producer – for producing, manufacturing or for supporting activities.

Supply-chain water footprint

- the indirect water use in the producer's supply chain.

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**Water footprint:**  
what's new for business

- From operations to supply-chain thinking.
- Shifting focus from water withdrawals to consumptive water use.
- From securing the 'right to abstract & emit' to assessing the full range of economic, social and environmental impacts of water use in space and time.
- From meeting emission standards to managing grey water footprint.

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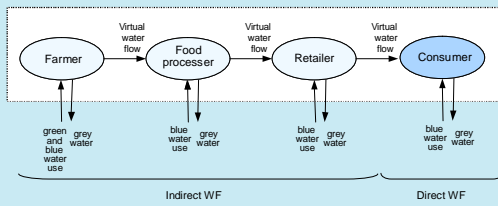
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**The water footprint of a consumer**



[Hoekstra, 2008]

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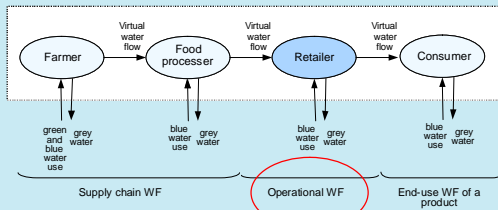
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**The water footprint of a retailer**



The traditional statistics  
on corporate water use

[Hoekstra, 2008]

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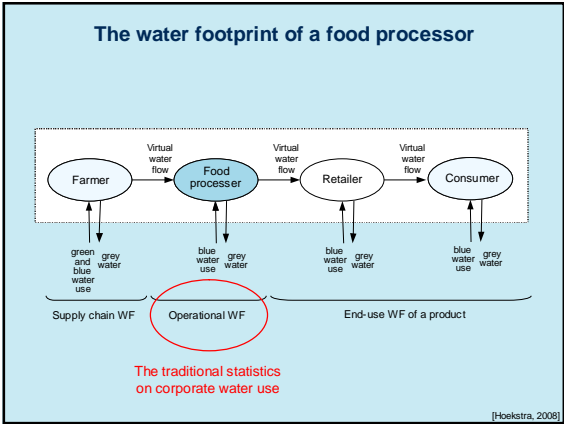
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### Water footprint of a business

- total volume of freshwater that is used directly and indirectly to run and support a business.
- temporal and spatial dimension:  
when and where was the water used.
- three components:  
green: volume of rainwater consumed.  
blue: volume of surface or groundwater consumed.  
grey: volume of polluted water.

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### Water footprint of a business

Operational water footprint		Supply-chain water footprint	
Water footprint directly associated with the production of the business's product(s)	Overhead water footprint	Water footprint directly associated with the production of the business product(s)	Overhead water footprint
<ul style="list-style-type: none"> <li>Water incorporated into the product</li> <li>Water consumed or polluted through a washing process</li> <li>Water thermally polluted through use for cooling</li> </ul>	<ul style="list-style-type: none"> <li>Water consumption or pollution related to water use in kitchens, toilets, cleaning, gardening, or washing working clothes.</li> </ul>	<ul style="list-style-type: none"> <li>Water footprint of product ingredients bought by the company</li> <li>Water footprint of other items bought by the company for processing their product</li> </ul>	<ul style="list-style-type: none"> <li>Water footprint of infrastructure (construction materials etc.)</li> <li>Water footprint of materials and energy for general use (office materials, cars and trucks, fuels, electricity, etc.)</li> </ul>

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**Water footprint – Carbon footprint**

<p><b>Water footprint</b></p> <ul style="list-style-type: none"> <li>• measures freshwater appropriation</li> <li>• spatial and temporal dimension</li> <li>• actual, locally specific values</li> <li>• always referring to full supply-chain</li> <li>• focus on reducing own water footprint (water use units are not interchangeable)</li> </ul>	<p><b>Carbon footprint</b></p> <ul style="list-style-type: none"> <li>• measures emission GH-gasses</li> <li>• no spatial / temporal dimension</li> <li>• global average values</li> <li>• supply-chain included only in 'scope 3 carbon accounting'</li> <li>• many efforts focused on offsetting (carbon emission units are interchangeable)</li> </ul>
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*Water footprint and carbon footprint are complementary tools.*

[Hoekstra et al., 2009]

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**Water footprint – Life cycle assessment**

<p><b>Water footprint</b></p> <ul style="list-style-type: none"> <li>• measures freshwater appropriation</li> <li>• multi-dimensional (type of water use, location, timing)</li> <li>• actual water volumes, no weighing</li> </ul>	<p><b>LCA</b></p> <ul style="list-style-type: none"> <li>• measures overall environmental impact</li> <li>• no spatial dimension</li> <li>• weighing water volumes based on impacts</li> </ul>
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*For companies, water footprint assessment and LCA are complementary tools.*

- *WF assessment is a tool to support formulation of a sustainable water management strategy in operations and supply chain.*
- *LCA is a tool to compare the overall environmental impact of different products.*

*WF is a general indicator of water use; application of WF in inventory phase of LCA is one particular application.*

[Hoekstra et al., 2009]

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**Water footprint sustainability assessment**

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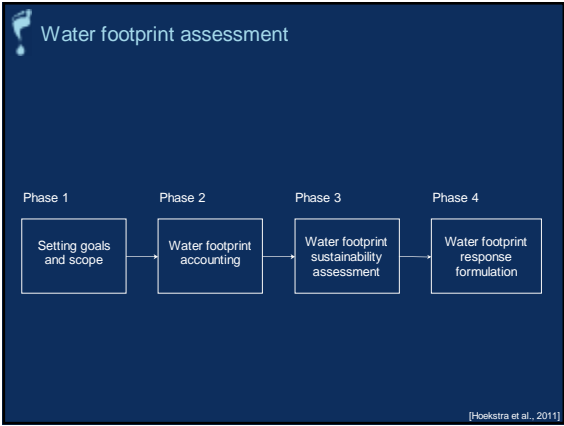
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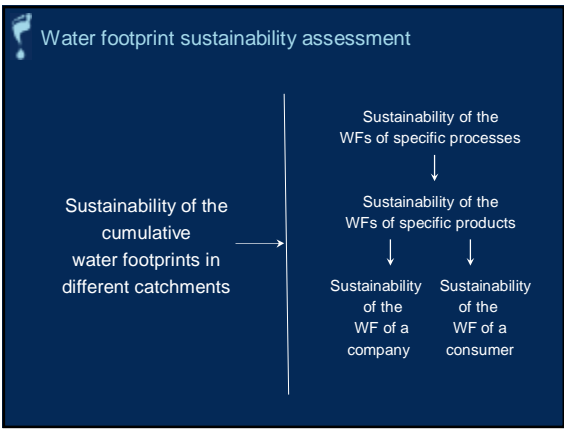
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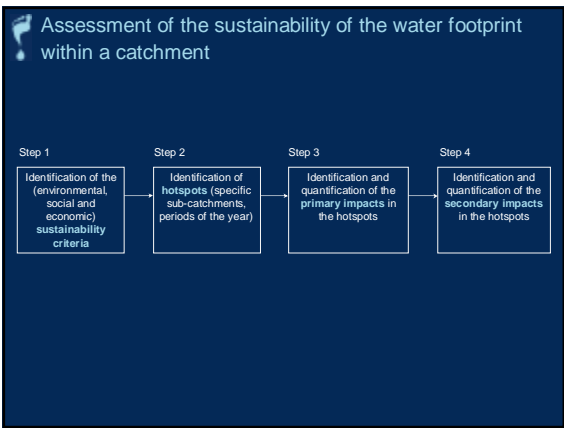
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### Step 1 - Sustainability criteria

**Environmental**

- Environmental flow requirements
- Environmental green water requirements
- Ambient water quality standards

**Social**

- Basic human needs – min. drink-water, food security, employm.
- Rules of fairness – fair allocation, water user & water polluter principle

**Economic**

- Efficient allocation and use of water

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### Step 2 - Hotspots

Environmental sustainability criteria:

- Green water footprint < available green water
- Blue water footprint < available blue water
- Grey water footprint < available assimilation capacity

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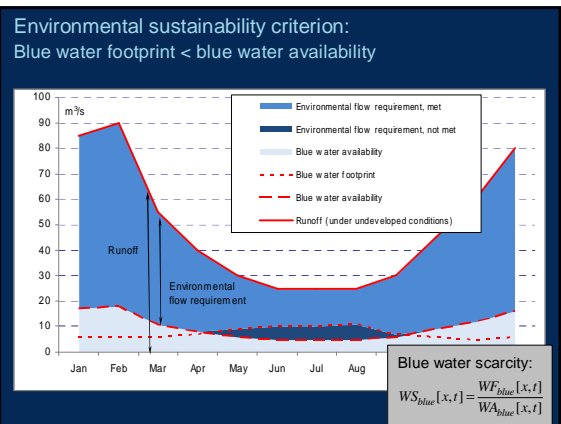
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### Environmental flow requirements

1. Catchment level
2. Monthly basis
3. Generic rule of thumb:

EFR = 80% of natural runoff, on a monthly basis.

4. Use data from generic global methodology, but replace when better studies give better local estimates

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### Environmental sustainability criterion: Grey water footprint < available assimilative capacity

Grey water footprint < runoff → Assimilative capacity not fully used

Grey water footprint = runoff → Full assimilative capacity of the river used

Grey water footprint > runoff → Pollution exceeding the assimilative capacity of the environment



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### Steps 3-4 Primary and secondary impacts

#### Primary impacts

- Changes to hydrology
- Changes to water quality

#### Secondary impacts

- Effects on abundance of certain species
- Effects on biodiversity
- Effects on human health
- Effects on employment
- Effects on distribution of welfare
- Effects on income in different sectors of economy

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**Shared responsibility and an incremental approach**

- n Consumers or consumer or environmental organizations push businesses and governments to address water use and impacts along supply chains.
- n Some businesses act voluntarily in an early stage, driven by consumers or investors.
- n Governments promote businesses in an early phase and implement regulations in a later phase.
- n Governments, companies, consultants and accountants use same standard definitions and calculation methods.
- n International cooperation, through UN and other institutions.

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**The ultimate perspective**

	Agriculture	Industry
Green WF	Decrease green water footprint (m <sup>3</sup> /ton) by increasing blue water productivity (ton/m <sup>3</sup> ) in both rain-fed and irrigated agriculture. Increase total production from rain-fed agriculture.	Not relevant.
Blue WF	Decrease blue water footprint (m <sup>3</sup> /ton) by increasing blue water productivity (ton/m <sup>3</sup> ) in irrigated agriculture. Decrease ratio blue/green water footprint. Decrease global blue water footprint (e.g. by 50%).	Zero blue water footprint: no losses through evaporation – full recycling – only blue water footprint related to the incorporation of water into a product cannot be avoided.
Grey WF	Reduced use of artificial fertilisers and pesticides; more effective application. Grey water footprint can go to zero through organic farming.	Zero grey water footprint: no pollution – full recycling, recapturing heat from heated effluents and treatment of remaining return flows.

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**Priorities in water footprint reduction**

	Non-hotspots	Hotspots
Little reduction potential	0	+
Large reduction potential	+	++

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**Water footprint reduction and offsetting**

Reduce:

- Reduce by avoid: do not undertake water-using activities altogether.
- Reduce by improved production: replace one technique by another technique that results in a lower or even zero water footprint

Offset:

Compensate the residual water footprint by making a reasonable investment in establishing or supporting projects that aim at a sustainable, equitable and efficient use of water in the catchment where the residual water footprint is located.

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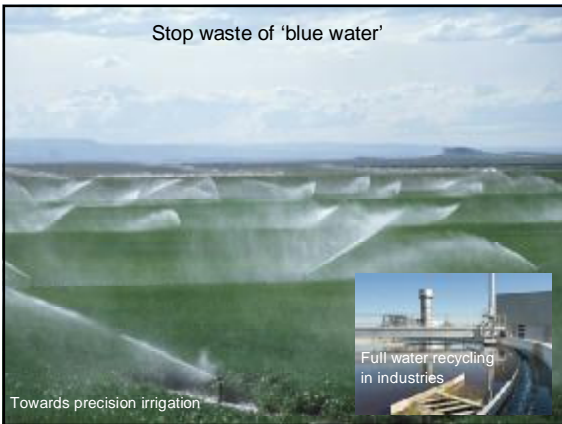
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 Reducing humanity's water footprint – Consumers

Reduction of the direct water footprint:  
n water saving toilet, shower-head, etc.

Reduction of the indirect water footprint:  
n substitution of a consumer product that has a large water footprint by a different type of product that has a smaller water footprint;  
n substitution of a consumer product that has a large water footprint by the same product that is derived from another source with smaller water footprint.

Ask product transparency from businesses and regulation from governments

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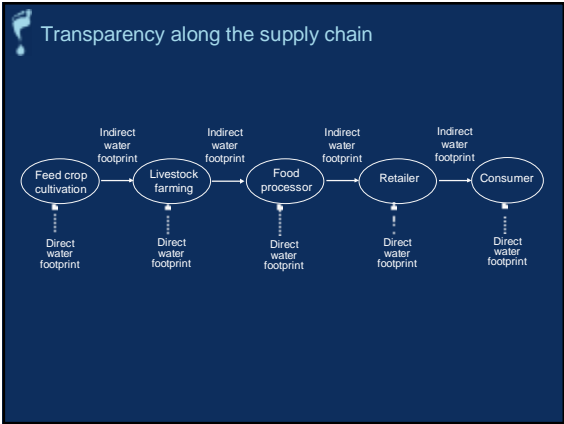
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### Reducing humanity's water footprint – Companies

- Shared terminology & calculation standards →
- Product transparency
  - water footprint reporting / disclosure
  - labelling of products
  - certification of businesses
- Quantitative footprint reduction targets
  - benchmarking

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### Reducing humanity's water footprint – Companies

Reduction of the operational water footprint:

- water saving in own operations.

Reduction of the supply-chain water footprint:

- influencing suppliers;
- changing to other suppliers;
- transform business model in order to incorporate or better control supply chains.

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 Reducing humanity's water footprint – Investors

Reduce risk of investments:

- physical risk formed by water shortages or pollution.
- risk of damaged corporate image
- regulatory risk
- financial risk

Demand accounting and substantiated quantitative water footprint reduction targets from companies.

[Morrison et al., 2009; Pegram et al. 2009; Hoekstra et al., 2011]

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 Reducing humanity's water footprint – Government

Embed water footprint assessment in national water policy making.

Promote coherence between water and other governmental policies: environmental, agricultural, energy, trade, foreign policy.

Reduce the own organizational water footprint:

- n reduce the water footprint of public services.

Promote product transparency

- n support or force businesses to make annual water footprint accounts and to implement water footprint reduction measures.
- n e.g. through promoting a water label for water-intensive products;
- n e.g. through water-certification of businesses.

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International cooperation

- n international protocol on water pricing
- n minimum water rights
- n tradable water footprint permits
- n water-labelling of water-intensive products
- n water-certification of industries and retailers
- n international nutrient housekeeping
- n shared guidelines on water-neutrality for businesses

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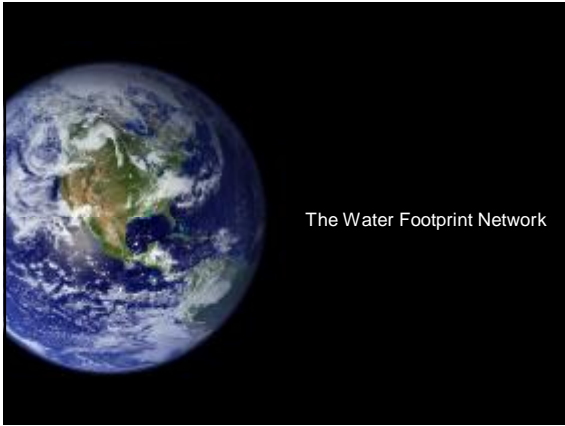
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 The Water Footprint Network

Mission: Promoting sustainable, equitable and efficient water use through development of shared standards on water footprint accounting and guidelines for the reduction and offsetting of impacts of water footprints.

Network: bringing together expertise from academia, businesses, civil society, governments and international organisations.

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 The Water Footprint Network

Founding partners (16 October 2008):

- International Finance Corporation (World Bank Group)
- Netherlands Water Partnership
- UNESCO-IHE Institute for Water Education
- University of Twente
- Water Neutral Foundation
- World Business Council for Sustainable Development
- WWF-the global conservation organization

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 **The Water Footprint Network**

Current partners

partners from six continents

- universities & research institutions
- governmental institutions
- non-governmental organisations
- large companies
- medium and small companies
- branche organisations
- consultants
- accountants
- international institutions

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 **Work programme Water Footprint Network (1)**

- n **Technical work programme**
  - n Water footprint assessment methodology
  - n Data and statistics
  - n Tools and materials, incl. Water footprint assessment tool
- n **Policy work programme**
  - n National, regional, local & river-basin WF pilot projects
  - n Corporate and sector WF pilot projects
  - n Product WF studies
  - n Incorporation of the WF in reporting, standards, certification and regulations for the corporate sector
  - n Integration of WF data and statistics into existing global databases

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 **Work programme Water Footprint Network (2)**

- n **Training**
  - n Face-to-face training courses
  - n E-learning training course
- n **Partner forum**
  - n Annual face-to-face forum Stockholm
  - n Online partner forum
  - n Webinars
  - n Working groups
- n **Website**
  - n Water footprint calculator
  - n Statistics
  - n Publications

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The Water Footprint Assessment Manual

Manual Nov. 2009      Manual Feb. 2011

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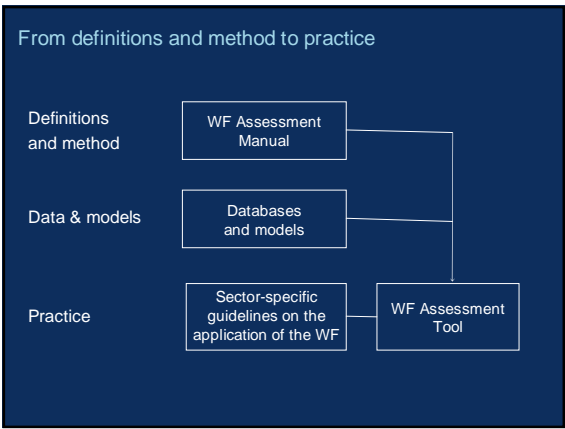
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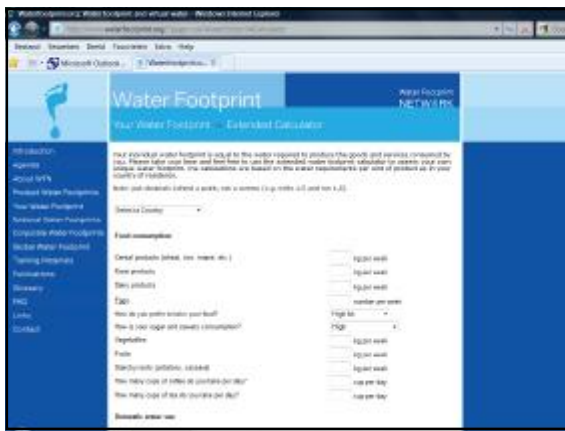
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