Less is more: circular economy solutions to water shortages

Sustainable transitions | circular economy

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Executive summary

The circular economy could potentially save 412 billion m^3 of water in the regions covered…

Circular economy can significantly reduce water stress

The concept of a circular economy is much talked about in relation to the water sector, but it's potential to reduce water shortages is still unclear. This report finds that the circular economy - which aims to reduce, re-use and retain water - is not able to fully eliminate water shortages. It is, however, very capable of reducing water shortages. For example, in the very water stressed region of California, it has been shown to almost halve the number of years of anticipated water shortages. For the years for which shortages remain, these are reduced by more than 90%. As such, a circular economy could provide an alternative for desalination projects that come with high environmental and social costs. In the United Arab Emirates, however, water shortages are only slightly alleviated by the circular economy. As such, desalination will continue to play a crucial role in this region in addressing water shortages. For the six regions covered by our report, we believe the circular economy has the potential to save 412 billion m^3 of water a year, which is equivalent to 11% of annual global water demand, or almost the entire water consumption in the US.

Potential of a circular economy to reduce water stress

Region		Anticipated years with water shortages in 2017-2050 period	Average reduction of water shortage for years in which there remain shortages	Annual amount of water saved with circular economy measures in municipal, industrial and agricultural sectors
California	Without circular economy	30		
	With circular economy	17	93%	15.3 billion m^3
Ghana	Without circular economy	15		
	With circular economy	14	64%	0.117 billion m^3
Bangladesh	Without circular economy	34		
	With circular economy	34	46%	20.2 billion m^3
Northern India	Without circular economy	34		
	With circular economy	34	34%	376.0 billion m^3
The Netherlands	Without circular economy	34		
	With circular economy	34	26%	0.006 billion m^3
United Arab Emirates	Without circular economy	34		
	With circular economy	33	16%	0.373 billion m^3

Source: ING calculations based on Deltares modelling.

Executive summary

...and provide many new business opportunities

New business opportunities

Applying the principles of a circular economy requires transformative change from the current linear water systems. As such, it offers businesses in the water supply chain with a wide range of opportunities especially in the field of efficient irrigation techniques, sustainable water pumping, as well as water treatment and re-use. In already advanced water systems, such as in the United Arab Emirates where re-use of water is already widely applied, technology can only play a limited role and further improvement must come from behavioural changes.

Mind the pitfalls though

Circular economy measures can look appealing when viewed in isolation. However, the circular economy requires a system approach to assess whether measures are effective. For example, efficient irrigation systems could have a negative impact on ground water levels, calling for artificial recharge in order to prevent these measures aggravating water shortages. Furthermore, a reduction in water use from circular economy measures might be reduced by an increase in water demand (the so called rebound effect, see page 20). Last but not least, technology is available to treat and recycle highly contaminated water to drinking standards, but the so called 'yuck-factor' might limit its re-usability.

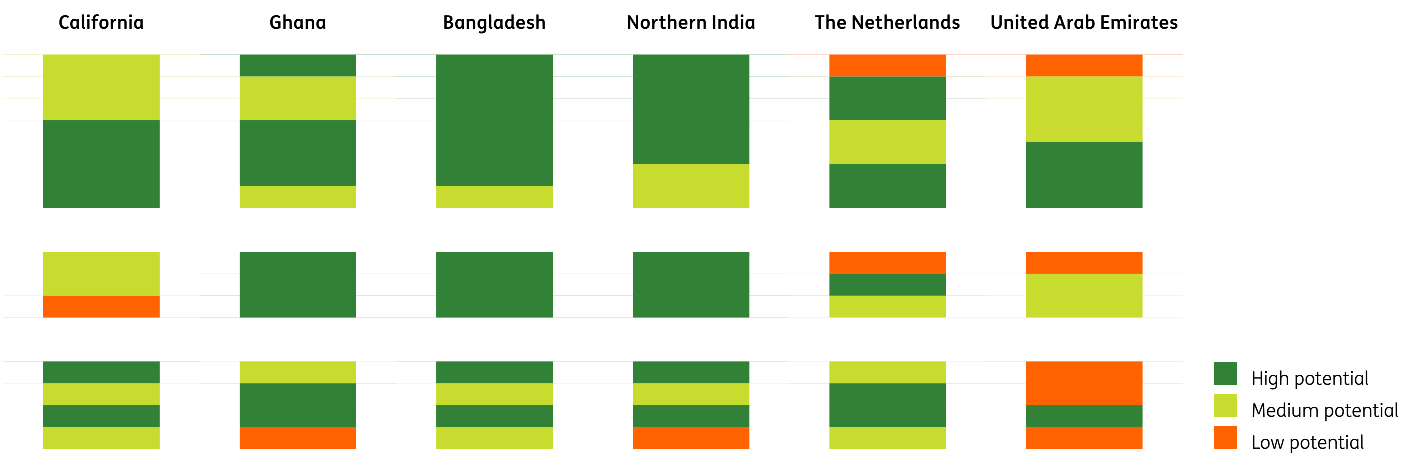
Heat map of circular water business opportunities

Qualitative assessment of the potential of circular water measures

Reduce water demand
- Reduce water losses through leakages
- Use more water efficient appliances
- Change to water efficient processes
- Use water efficient irrigation techniques
- Apply sustainable water pumping
- Crop refinement and changes
- Behavioural change toward using less water

Re-use of water
- Ecological treatment and re-use of waste water
- Industrial waste water treatment and re-use
- Sewage water treatment and re-use

Retention of water
- Rain water harvesting
- Enhance water retention of the top soil
- Aquifer storage and recovery
- Retention in natural reservoirs like lakes and wetlands



Content

Introduction

Shortages of fresh water require us to build more circular water systems

Increasing demand for water

Global fresh water demand is expected to grow by 2% per annum over the coming decades. Industrial water demand in particular is expected to grow fast. If no changes are made, global water demand is forecasted to outpace the sustainable water supply in 2040 by 35%. In fact, the World Economic Forum has identified water shortages as the biggest risk facing the planet. Our previous water report, Too Little, Too Much (ING, 2015), highlighted the significance of this.

The linear design of water systems is the root problem…

Many claim that water stress problems are the result of a linear model of water use in which water becomes more polluted and wasted as it travels through the system. For example, untreated water from many industrial processes cannot be used for agriculture or municipal use. In many countries the water cycle is extremely short and lasts only one to three cycles because the usability of water is lost as the quality deteriorates too quickly. For example, waste water from factories is often too polluted for any form of re-use. Without treatment facilities these factories simply discharge the waste water and use fresh water for their production.

> "The response to the risks of water stress can be threefold. You can live with it, insure it, or mitigate it. Living with water stress is not very appealing, insurance often impossible, so mitigation is the way forward. The circular economy opens up new ways to mitigate risks."
>
> Emilio Tenuta, Ecolab.

…but the potential of the circular economy on water systems is still unclear

The circular economy aims to close the loop and make the water system regenerative by design so water retains its quality and can be used for multiple cycles. Both McKinsey and the International Water Association have presented their views on circular water systems. While inspiring and promising, these views remained qualitative. Therefore, to what extent the circular economy can help solve water stress is still unclear.

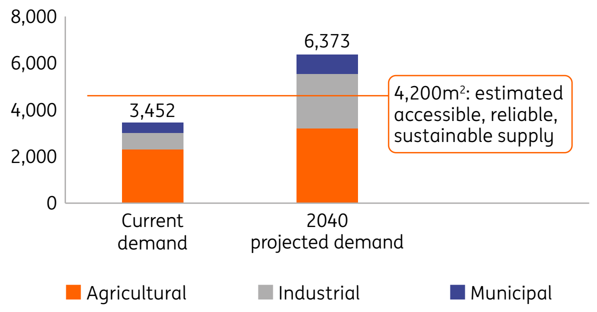
Reader's guide

This report considers the 'take, make and waste' approach to water use and seeks ways in which it could be turned into a circular 'reduce, re-use and retention' approach.

- Chapter 1 defines circular economy water measures and those that are not so circular yet.
- Chapter 2 presents the potential of the circular economy to reduce water shortages in the six focus regions of this report.
- Chapter 3 concludes and highlights some of the pitfalls of the circular economy in addressing water shortages.
- Lastly, the appendices provide information on the research method as well as more background information on the water systems utilised in the six regions covered by this report.

Freswater demand keeps on rising with fastest growth in industry

Billion m^3



Source: ING – Too Little Too Much, The diverse challenges of the water sector, 2015. Based on IFPRI and Aquastat.

Estimated compound annual growth rate of freshwater usage by sector towards 2040	
Industrial use	4.4%
Municipal use	2.2%
Agricultural use	1.2%
Total	**2.1%**

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Towards circular water systems

Assessing the potential of the circular economy to address water shortages

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Quantifying the potential of the circular economy requires a system approach

Modelling the water system

The water system is a delicate balance between supply and demand. This system is already circular by nature. Quantifying the potential of circular water measures therefore requires a system-wide approach, including the entire water supply chain and the main water users. Furthermore, it requires scenario analysis to take future social, economic and environmental developments and their interlinkages into account. The research method to capture these elements of the water balance is described in the appendix.

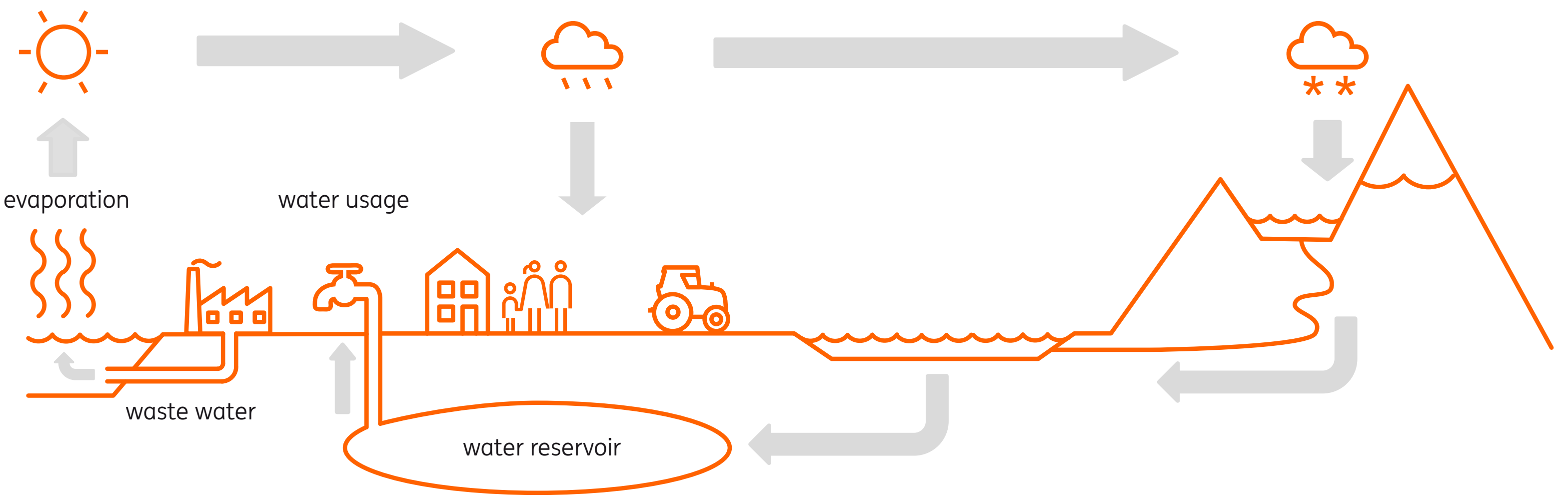
Quantity versus quality and impact

It is hard to determine what the impact of water shortages in a region is on the health of its people or on economic activities (think of reduced land productivity or a factory that is not able to grow as much as its owners would like). This report primarily looks at the potential of the circular economy in improving the local water balance in terms of supply and demand. In doing so it leaves aside the potential of the circular economy to recover resources from water. Think for example of slurry that can be used for energy purposes or to recover nitrogen and phosphorus components.

Definition of water shortage in this report

The purpose of this report is to quantify the impact of the circular economy on its ability to reduce water shortages. In this report water shortage is defined as the amount of fresh water that is demanded by the agriculture, industrial and municipal sectors, but which cannot be met by the available fresh water supply in that country. As such, water shortage is a form of unmet demand. Fresh water usage in a given sector or country would have been higher if the available fresh water supply had not been a limiting factor.

The water system; a delicate balance of supply and demand



"Water is fundamental to our business and our non-export, local manufacturing and sales business model. We not only look at water resource sustainability and circular water measures in our operations but also in the local community. This focus on shared water resources is essential when you operate in areas of high water stress."

Greg Koch, Coca Cola.

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Circular water measures: reduce, re-use and retention

There are many circular water measures that can improve a region's water balance and mitigate water shortages. These range from reducing water demand to increasing water availability through water re-use and water retention measures.

Reduce fresh water demand in agriculture

- Apply more efficient irrigation methods such as drip irrigation.
- Improve water efficiency of existing crops (crop refinement).
- Change to more water efficient crops.
- Use saline water for irrigation.

Reduce fresh water demand in industry

- Measures to prevent water leakages.
- Use of more water efficient equipment.
- Change industrial processes to become less water intensive.

Reduce fresh water consumption by households

- Use of water efficient appliances and technologies.
- Behavioural changes to reduce water demand.

Reduce water pollution

- Use water in such a way that prevents water pollution. For example, design industrial processes in such a way that dirty water streams remain separated from clean water streams.

Re-use and water purification

- Grey water re-use. Grey water is non-potable water that can still be used for many other purposes. Think of municipal water that can be used in irrigation.
- Black water treatment and re-use. Black water is heavily polluted water that can only be re-used after heavy treatment. Think of sewage water treatment or the treatment of toxic industrial waste water.
- Ecological water purification through natural processes, for example, through the use of wetlands (ecohydrology).

Water retention measures

- Upstream investment in natural infrastructure, such as wetlands and forestry projects, that is able to hold water for long periods.
- Water storage projects, such as aboveground water reservoirs or rainwater harvesting.
- Underground aquifer storage and recovery activities.
- Increase water retention of the soil so that agriculture needs less water for irrigation.

Source: ING and Deltares based on IWA, McKinsey and EMF.

Not so circular water measures (yet)

There are other measures that can substantially reduce water shortages. Think for example of desalination plants, the building of large water reservoirs through dams, or connecting water basins with each other. However, we do not consider these measures to be circular water measures.

Desalination not circular yet

Globally, 97.5% of the water on the planet is salt water, not fresh water. Desalination – the process of turning salt water into fresh water - could therefore be the answer to many water stressed regions in the world. However, desalination requires vast amounts of energy that rarely come from renewable sources. As such it has a large carbon footprint. Furthermore, dealing with the brine discharge can create environmental issues. Landfilling might reduce land productivity and putting it into oceans might impact sea life and the productivity of fertile deltas. This report investigates how the circular economy can reduce water shortages without desalination technologies. However, if shortages remain high, then desalination certainly has a role to play.

Dams create problems up- and downstream

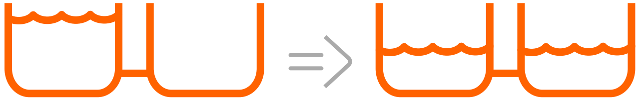
Building dams can be a very effective form of water retention. However, the impact on both the environment and societies that live up- and downstream is significant. Settlements may need to relocate and habitats are altered or destroyed irreversibly. As such we do not incorporate the building of dams as a circular water solution in our analysis. We do consider retention measures through man-made reservoirs, but only on a scale that does not involve social or environmental issues.

Connecting water basins often transfers problems from one basin to another

Connecting independently operating water basins can alleviate water stress in a region. This can be achieved over long distances through a network of pipes, as in Spain and California. We do not consider this a circular water solution as the building of pipes can have a significant impact on the local environment and society.

We look to assess the circular potential without including these more controversial measures, but they can be taken into consideration if the more conventional measures turn out to be ineffective.

Creating interdependencies



Assessing the circular potential in six regions

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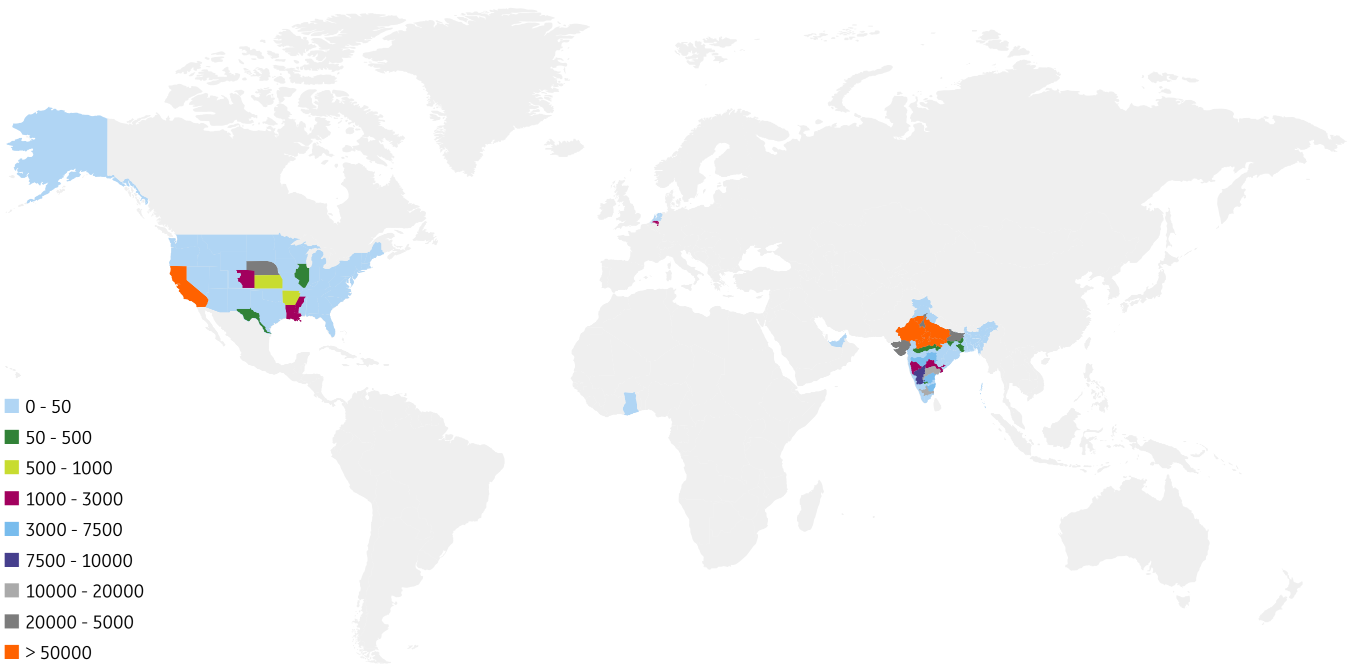
Country selection: water business is local business with diverse challenges

To help the various stakeholders in the water sector we focus on six regions, each facing a different water challenge, ranging from severe water shortage to dependency on large water consuming industries. We assess the circular potential for Northern India, California, Bangladesh, the United Arab Emirates, Ghana and the Netherlands for the following reasons.

HM^3/year



The **United Arab Emirates** ranks among the most water stressed countries in the world. It has a large oil industry that demands significant quantities of water. The United Arab Emirates is representative of water challenges faced by several Middle East countries, such as Saudi Arabia, Kuwait and Qatar.

Northern India is a very water stressed region that hosts a large burgeoning population. It also has a large water intensive agriculture sector.

California is a very water stressed region in one of the most developed countries of the world. It is the most populous State in the US and gets a lot of attention in the water sector. California already has experience of water retention measures that are pivotal in circular water systems and might serve as an example.

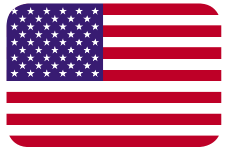
In **Bangladesh** both the water intensive textile and agriculture sectors are very large. In addition to water shortages the country has water pollution issues.

Ghana has multiple climate zones and hosts a water intensive mining industry. Furthermore, like India, it lacks sewage and water treatment systems making the current water cycle highly linear.

The **Netherlands** is a leading nation in both water solutions and the circular economy.

California

Circular economy can almost entirely eliminate water shortages



Introduction and outcome of ING assessment

- California's water supply fluctuates heavily from one year to the next due to droughts.
- Salt intrusion is a major risk due to declining water levels.
- Up to 2050 California is expected to experience water shortages in 30 out of the 34 years. According to our studies, the circular economy has the potential to reduce this considerably to 13 years. Water stress could be reduced by more than 90% as 12 billion m³ of water can be saved annually (four times the Dutch annual water usage).

Reduce

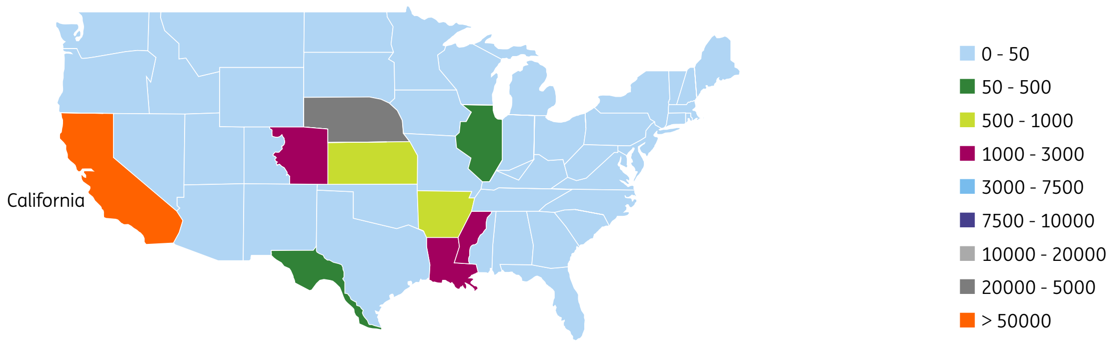
- Reduction of pollution is a high priority as many of California's groundwater aquifers are contaminated.
- Water efficient irrigation methods show high potential to reduce the region's water demand.

Re-use and retention

- The recycling of waste water is already an integral part of California's water supply. Further progress can be made by treating used water to drinking standards.
- Groundwater storage represents both a practical solution to the State's water shortages as well as a tool to help manage groundwater more sustainably.

California experiences the greatest water shortages in the US

Unmet water demand, million m³



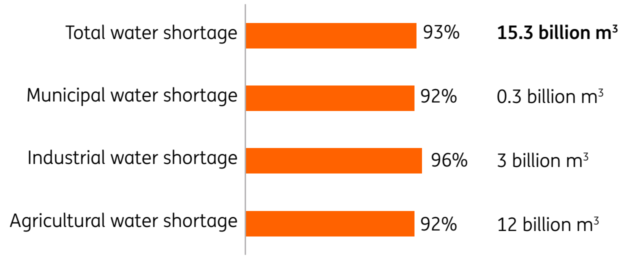
Source: Deltares.

Potential circular water measures identified for California

- Maintain water quality in ground water resources.
- Behavioural change and water efficient technologies introduced by industries and households.
- Apply water efficient irrigation techniques and increase the use of water efficient crops as well as drought tolerant crops.
- Water retention through aquifer storage and rain water harvesting coupled with water transfer possibilities between storage facilities.
- Re-use of grey water by businesses and households.

Agricultural and industrial sector show largest potential

Average yearly reduction of water shortage in m³, 2017-2050, %, and absolute savings



Ghana

Switching from water reservoirs to aquifer storage and recovery

Introduction and outcome of ING assessment

- Ghana can be divided into three regional climate zones. Circular measures and outcomes differ substantially for each region.
- Ghana's water system is currently heavily dependent on reservoirs created with dams.
- Up to 2050 Ghana is expected to experience water shortages in 15 out of the 34 years on a country level. According to our studies, the circular water economy will only eliminate shortages in one of these years. However, it has the potential to reduce water shortages by about two-thirds in the remaining years, which equates to 117 million m^3 annually.

Reduce

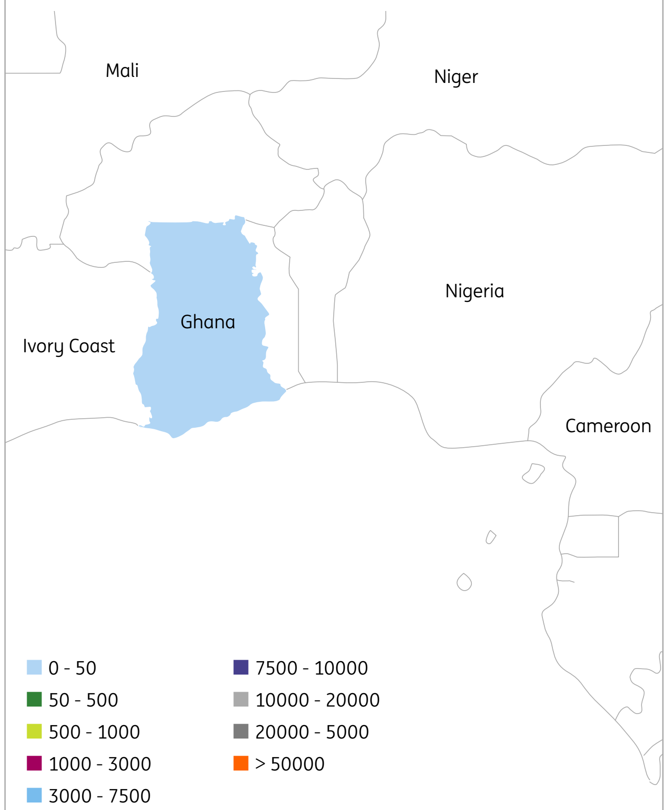
- Approximately 40% of Ghana's water is lost through leakages.
- Reduction of water pollution is key to Ghana's circular water economy.

Re-use and retention

- Little to no re-use is currently taking place. This has significant potential but a lack of qualified engineers to design and maintain the plants required is a major barrier to reap the full re-use potential.
- In terms of water retention in Ghana, aquifer storage has the most circular potential.

Relatively minor water shortages in Ghana

Unmet water demand, million m^3



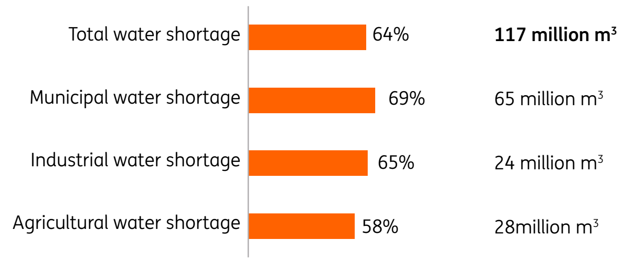
Source: Deltares.

Potential circular water measures identified for Ghana

- Reduce water pollution, especially in the mining sector, in agriculture (due to pesticides and fertilizers) and by households (sewage system).
- Aquifer storage and recovery.
- Wastewater treatment and re-use, both for municipal, agricultural and industrial use.
- Reduce water losses through leakages.
- Use more water efficient crops as well as drought tolerant crops.

Municipal sector shows largest potential

Average yearly reduction of water shortage in m^3, 2017-2050, %, and absolute savings



Bangladesh

Treatment technologies can trigger the re-use of water

Introduction and outcome of ING assessment

- The Bangladesh economy is highly dependent on water intensive sectors, agriculture (19% of GDP) and textiles (9% of GDP).
- Bangladesh's water system is currently heavily dependent on reservoirs created with dams.
- According to our studies, Bangladesh is expected to experience water shortages in every year up to 2050. However, the circular economy has the potential to almost halve the water shortages with a saving of 20 billion m^3 annually.

Reduce

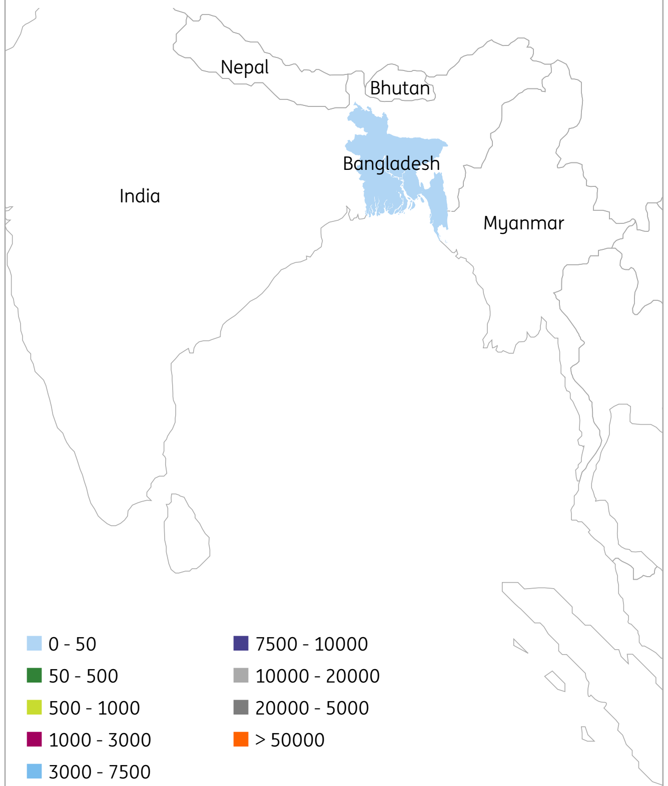
- Agricultural water demand can be reduced through water efficient irrigation methods. Industrial water demand can be reduced by 20% at relatively small cost.
- Up to 40% of water in Bangladesh is lost in the system due to leakages.

Re-use and retention

- Water pollution in Bangladesh is a barrier to the re-use of water. Treatment technology is crucial for the country to establish a more circular water system. This will require many more treatment plants as well as the knowledge and engineers to prevent system failure.
- Water retention in Bangladesh could come from increased rain water harvesting as well as new methods to capture flood water.

Water shortages in Bangladesh not as severe as in India

Unmet water demand, million m^3



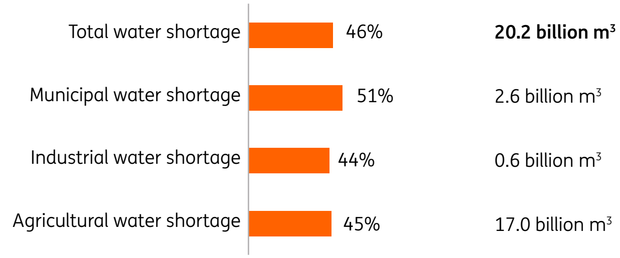
Source: Deltares.

Potential circular water measures identified for Bangladesh

- Prevention of water pollution and greater use of water treatment technologies.
- Increase reliability of treatment plants.
- Reduction of water leakages.
- Rainwater harvesting coupled with artificial groundwater recharge.
- Sustainable water pumping and more efficient irrigation techniques.

Agriculture and municipal sector show largest potential

Average yearly reduction of water shortage in m^3, 2017-2050, %, and absolute savings



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Large agriculture sector and seasonal patterns put irrigation and water retention at the forefront

Introduction and outcome of ING assessment

- Seasonal fluctuations in water levels are a significant challenge as most precipitation falls during the monsoon.
- According to our studies, Northern India is expected to face severe water shortages in every year up to 2050. The agriculture sector, in particular, will get far less water than it demands.
- The circular water economy cannot eliminate water shortages, but it can reduce them by a third and save 379 billion m³ annually. This equates to 10% of the water used globally, 80% of the water used in the US, or 100 times that used in the Netherlands.

Reduce

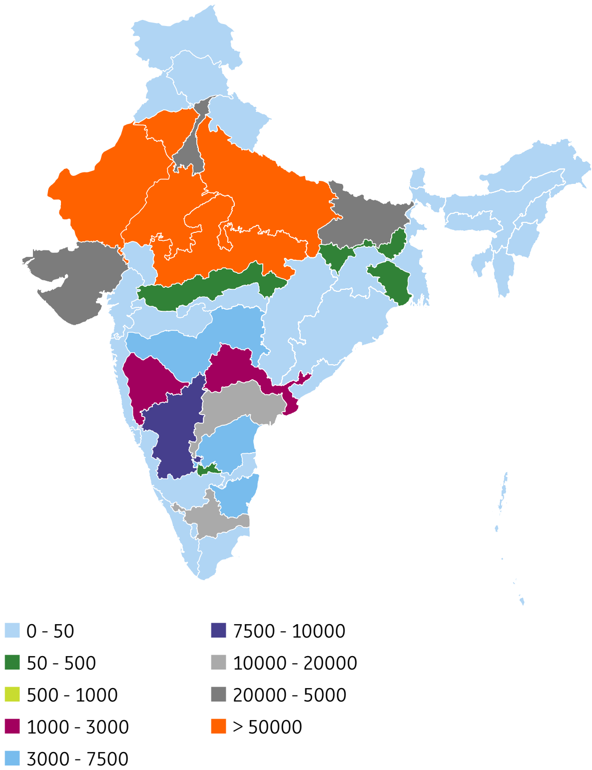
- On the demand side, switching to more efficient irrigation systems would generate the greatest potential saving as agriculture accounts for 84% of total water demand in Northern India.
- Leakages are a serious problem in the region. Up to 40% of water is lost as it flows through the system.

Re-use and retention

- Around 36% of the non-treated municipal waste water is currently re-used in agriculture. This could realistically be increased to 50% provided that the water quality does not deteriorate.
- Water retention shows great potential to address the seasonal fluctuations.

Water shortages most severe in northern part of India

Unmet water demand, million m³



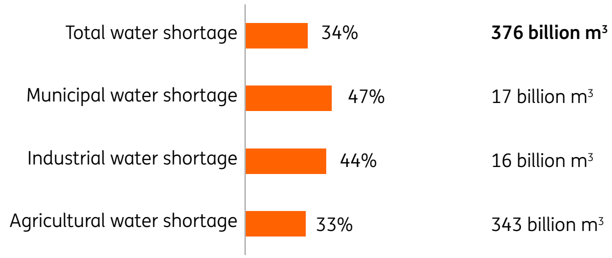
Source: Deltares.

Potential circular water measures identified for Northern India

- Reduce agricultural water demand through improved irrigation and sustainable water pumping.
- Water retention through aquifer storage and rain water harvesting.
- Reduce water losses through leakages.
- Re-use of grey water by businesses and households.
- Improve water quality especially by treating sewage water.

Northern India shows huge potential to save water

Average yearly reduction of water shortage in m³, 2017-2050, %, and absolute savings



The Netherlands

Making a highly efficient water system more circular: example 1

Introduction and outcome of ING assessment

- Around 80% of Dutch water demand is a direct result of its geographical characteristics, with fresh water used for water level management and flushing of its delta rivers and canals. Only 20% is related to 'real water use' by economic agents in the agriculture, industrial and municipal sectors.
- According to our studies, the Netherlands is expected to experience relatively limited water shortages in every year up to 2050, which will impact the agriculture sector in particular. However, this can be reduced by up to a quarter with circular water economy measures.

Reduce

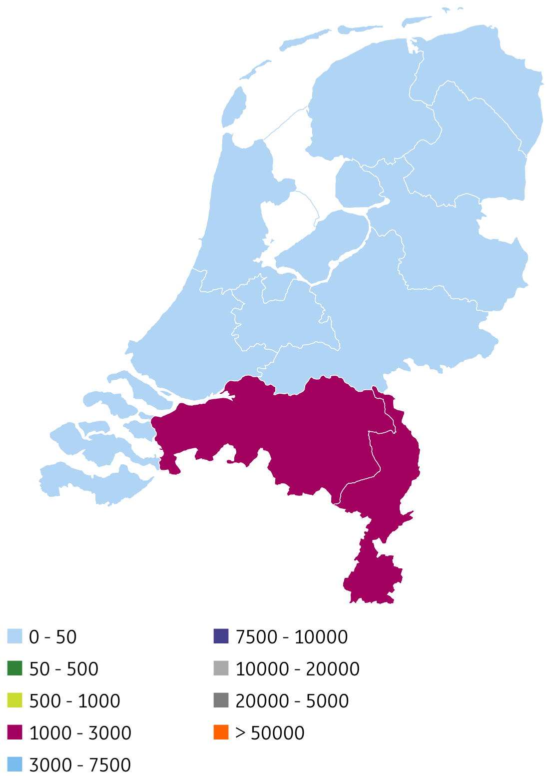
- Dutch irrigation efficiency ranks highest in the world but could be further improved with satellite data and the use of saline water to irrigate saline resistant crops.

Re-use and retention

- Waste water re-use is already high in the Netherlands but could be further improved through re-circulation systems that filter and recycle drainage water.
- Aquifer storage recovery shows great potential to retain water and prevent salt water intrusion in the western region of the Netherlands.

Unmet water demand relatively limited in the Netherlands

Unmet water demand, million m^3



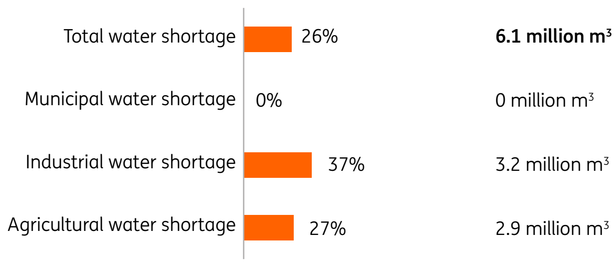
Source: Deltares.

Potential circular water measures identified for the Netherlands

- Aquifer storage recovery.
- Reduce water demand through the use of satellite data for irrigation methods, industrial process change and increased use of water efficient appliances by households.
- Use of saline water to irrigate saline resistant crops.
- Stimulate behavioural change to use less water.
- Reduce water pollution from hormones and antibiotics in drinking water, as well as from sewage overflows, factory accidents and agricultural nutrients that pollute surface water.

Impact circular economy

Average yearly reduction of water shortage in m^3, 2017-2050, %, and absolute savings



United Arab Emirates (UAE)

Making a highly efficient water system more circular: example 2

Introduction and outcome of ING assessment

- The UAE has acquired significant knowledge due to a long history in dealing with and reducing water stress. As a result, nearly all of the waste water generated in the UAE, about 550,000 cubic metres per day, is treated.
- Nevertheless, according to our studies, the UAE is expected to experience water shortages every year up to 2050. The circular water economy is expected to eliminate shortages in only one of these years. However, it has the potential to reduce water shortages by 16% in the remaining years. This saves 373 million m^3 water a year (8% of total water demand). As a result, desalination has to remain an integral part of the water system in the Emirates.

Reduce

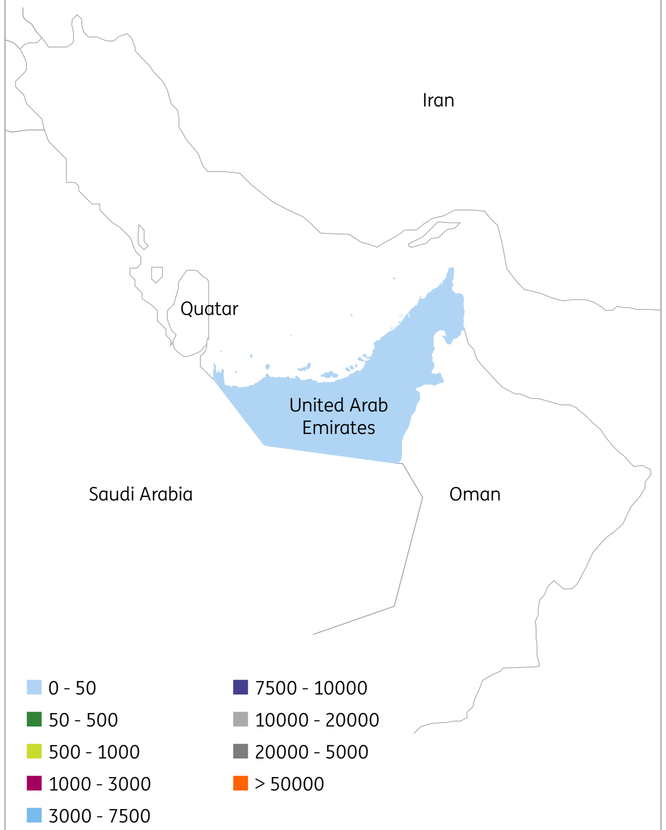
- Water consumption is high in the UAE. Given that the system is quite advanced (no leakages and plenty of saving technologies), further reductions need to come from lifestyle changes.

Re-use and retention

- Re-use is already high in landscaping and greening activities but limited in other activities.
- Salt water intrusion is threatening aquifers. Aquifer storage and recovery can be achieved through desalinated or treated waste water.

Relatively minor but structural water shortages

Unmet water demand, million m^3



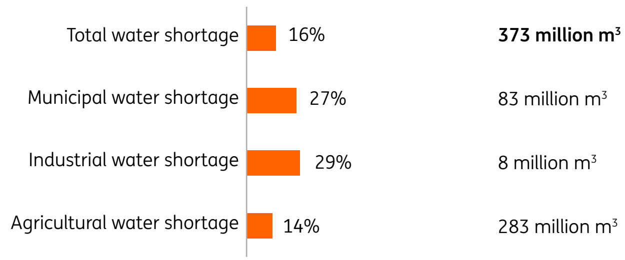
Source: Deltares.

Potential circular water measures identified for UAE

- Avoid overexploitation or contamination of aquifers through sustainable water pumping.
- Aquifer storage and recovery with desalinated or treated waste water.
- Re-use of treated water outside the domain of greening. This requires a change in mentality to overcome the 'yuck-factor'.
- Reduce water consumption through lifestyle changes.
- Change to more water efficient crops.

Impact circular economy

Average yearly reduction of water shortage in m^3, 2017-2050, %, and absolute savings



Concluding remarks

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Concluding remarks

The circular economy provides many business opportunities

Many business opportunities...

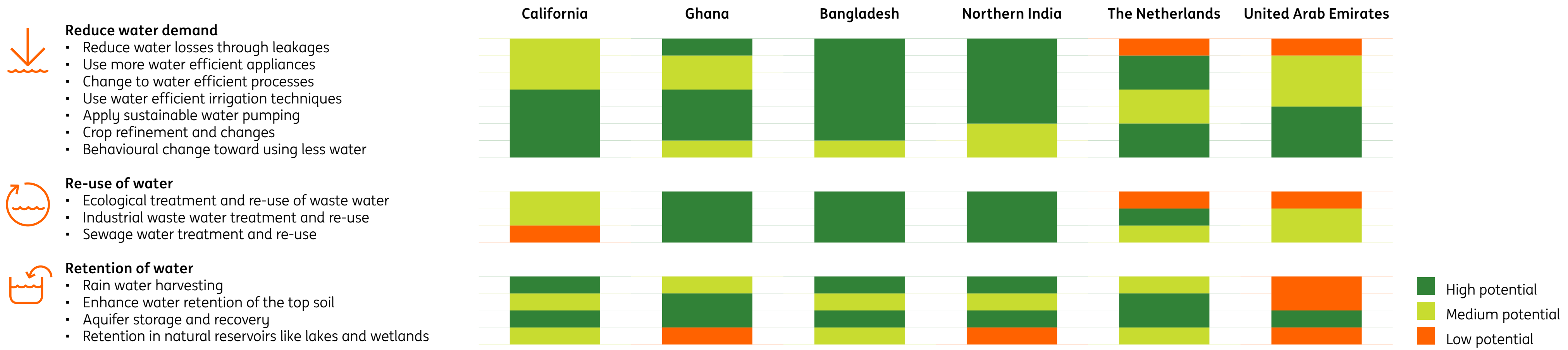
Applying the principles of the circular economy will require transformative change away from current linear water systems. As such, the circular economy will provide businesses with significant opportunities. For example, in every region, efficient irrigation techniques, crop refinement techniques, water efficient appliances and processes as well as sustainable water pumping will be important measures required to reduce water demand. As will techniques to re-use industrial waste water as well as technologies for aquifer storage and recovery. In regions with less advanced water systems, such as Northern India, Bangladesh and Ghana, technologies to prevent water leakages provide a quick win as they should make the current system much more efficient without transformational change towards circularity. In regions with more advanced water systems, such as California, the Netherlands and United Arab Emirates, technology already plays a large role in reducing water demand. In these regions behavioural changes will have to have a far more prominent role in the short term to reduce water demand further.

...throughout the supply chain

Business opportunities arise across the whole water supply chain. From research and consulting activities, through to engineering and construction activities, to maintenance activities. This involves skilled labour and therefore requires programmes to educate people. Without a qualified workforce the transition to circular water systems will be a difficult one that is highly dependent on imported technology and knowledge. In making water systems more circular, it is not only the water situation that needs addressing but also knowledge shortages.

Heat map of circular water business opportunities

Qualitative assessment of the potential of circular water measures



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Concluding remarks

The pitfalls of circular water solutions

Some circular economy believers present circular economy measures as a panacea to reduce water stress. While they may be right when measures are viewed in isolation the difficulty with sustainability in general and with water systems in particular is that individual measures impact the whole system. As such, circular water measures might create pitfalls that have rarely been discussed as yet.

> "With water everything is interconnected. Take agriculture; water influences agriculture, but agriculture influences the water demand. So, one must look at the whole water cycle to look for solutions to alleviate water stress."
>
> Ron Bohlmeijer, Heineken.

1. Implementing circular economy measures in isolation might be counterproductive

The circular economy stresses the importance of reducing demand. Take, for example, agriculture, which is the largest water user in many countries (globally it accounts for two-thirds of water demand). Reducing water demand through more efficient irrigation techniques therefore seems obvious. However, water used for irrigation also enters back into the ground thereby adding to ground water resources. These ground water resources can be very important. For example, around 70% of India's irrigation needs and 80% of its domestic water supplies come from ground water resources. Switching to drip irrigation without artificial ground water recharge measures can cause ground water levels to decline rapidly to unsustainable levels. In this respect, water systems with leakage of this nature may, on the face of it, sound like a circular economy curse but might also serve as unintended artificial recharge measures.

2. Mind the rebound effect

The counterargument against the above mentioned example is that, by being more efficient, one needs to use less ground water. This ignores the rebound effect; as water efficiency grows, more can be produced with less water, creating room for businesses to expand production. Instead of lowering withdrawal levels through efficiency measures, they are kept the same, or are even increased, because of higher demand. Therefore, just applying a circular water solution does not always yield the desired results in water stressed regions. The entire water cycle, from water supply, demand and behaviour needs to be improved before a circular water solution can be as effective as planned.

3. The hard to overcome yuck factor

Recycling water is an essential element of circular water systems. Treatment systems nowadays are so advanced that waste water can be purified beyond drinking standards. For example, NEWater is the brand name of treated sewage waste water. In addition to conventional water treatment processes it is purified through microfiltration and reverse osmosis (dual membrane technology) as well as ultraviolet technologies. The majority of this water is used by industries requiring very pure water. While the water is potable and could be consumed, most people instinctively reject it as repugnant to drink sewage water. This so called 'yuck factor' describes the instinctive responsive of consumers to new technology. It can easily be exacerbated by the media using terms such as 'recycled sewage' and 'toilet to tap water'. These technophobic sentiments are not easy to overcome in the transition to more circular water systems.

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Barriers must be broken down to reap full potential of circular water measures

Circular economy does make a difference...
Applying the principles of the circular economy to the water cycle has shown potential to reduce future water stress in the six regions examined in this report. The potential is highest in California where our assessment suggests the circular economy could reduce water shortages almost entirely. The circular economy can provide an alternative for desalination projects that often generate considerable carbon and ecological footprints.

...especially in a stronger climate change scenario
For all the regions we considered, apart from Ghana, the potential impact of the circular water measures appears to increase in a stronger global warming scenario than the scenario under the Paris Agreement. Under a stronger global warming scenario the years with anticipated water stress increase and circular water measures are more often able to reduce water shortages. Ghana and the Netherlands could be an exception as stronger climate change may result in an increase in precipitation in the north of Ghana.

So let's take away the barriers that prevent the circularity of water systems
Although there is potential for the circular economy to reduce water stress, there are also many barriers that prevent it from being introduced. For example, this report only assesses the potential of a circular economy, without considering the **cost** of implementing it. In addition to cost, conflicts between regulatory control and the **perception of free water rights** might be an even tougher nut to crack as people and businesses tend not to be in favour of attempts to regulate water usage or to increase water tariffs. Even in highly water stressed regions where the urgency to act is so apparent, tariffs are either absent or far too low to make a financially sound business case. Implementation critically hinges on **public support**, but many parts of the world have fragile democratic governments. Even where there is public support and money available, implementing circular economy measures is not easy. Many utilities, especially in developing countries, lack **qualified engineers** and mechanics to implement and maintain circular water solutions. These barriers should be taken into account when designing circular water systems. It is only then that the full potential of a circular economy to reduce water stress can be established and benefit so many people, businesses and the environment.

> "Man has no money to provide the driest areas with water, but does have money to see if there is water on Mars. Can we reprioritize and build more circular water systems that alleviate water stress?"
>
> As quoted by Waternet.

Appendices

Research method and country information

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Appendix 1

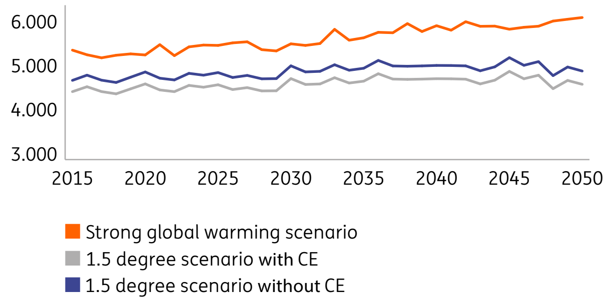
Research method

The impact of circular economy water measures is calculated using the Water2Invest model developed by Future Water, Utrecht University, Deltares, Carthago and Imperial College of London. This global water model resembles the local water balance anywhere in the world on a geographical grid of about 10 by 10 km. The following economic and climate scenarios from the International Panel on Climate Change (IPCC) are used to estimate future water demand:

- Strong global warming; high socio-economic growth coupled with ineffective climate policies (SSP5-RCP8.5 scenario).
- Global warming within 1.5 degrees Celsius; sustainable socio-economic growth combined with effective climate policies (SSP1-RCP2.6 scenario).

Examples of total water demand for different global warming scenario's

United Arab Emirates



For detailed descriptions of the Water2Invest model see Van Aalst (2015) and Brandsma (2015), for the NHI model see Ter Maat et al (2014) and www.nhi.nu.

The report shows the outcomes for the 1.5 degree Celsius scenario as the Paris Agreement has just been ratified. In the other scenario of high social-economic growth and ineffective climate policies, future water demand will be higher adding to more water shortages. In general, the circular economy has an even greater potential in the strong global warming scenario because there are more periods in which supply does not meet water demand. Ghana and the Netherlands are exceptions to this rule as climate change may lead to more precipitation which increases the fresh water supply.

A literature and water management plan review of the countries, together with the assessment of country experts from Deltares, lead to an overall assessment of the circular economy measures:

1. The current application of circular water measures in a country;
2. The potential application of circular water measures in the country;
3. The relevance of circular water measures in terms of impact on the local water balance.

In this study, desalination, dams and the connection of water basins over long distances are not considered circular economy measures due to their environmental and societal consequences and are therefore not incorporated in the model.

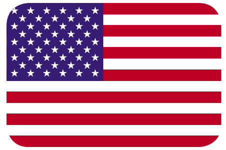
The Water2Invest model, unfortunately, does not allow for a gradual implementation of circular water measures. We could not alter the model due to cost and time constraints. Therefore, we model the full implementation of circular water measures as 'one big bang'. Of course water systems are not made circular overnight, but since our analysis focuses on the potential of circular water solutions rather than possible implementation paths, this is not so much of a problem.

We have captured the impact of the circular economy with a method that compares the model outcomes with and without circular economy measures for any given year in the 2017-2050 period, and does not include the changes caused by the climate or socio-economic scenarios.

The water system of the Netherlands is not well captured by the Water2Invest model alone. The Dutch situation is too specific as one third of the country is below sea level. As a result 80% of total water demand comes from activities to manage the ground water level as well as measures to flush the waterways in order to prevent salinization. The impact of circular economy measures is therefore assessed by combining the Water2Invest model with the 'Netherlands Hydrological Instrument' (NHI model), which is the 'official' water model in the Netherlands.

Appendix 2

Information on the water system in California



Highly interconnected water system in most populous US State

California is the most water stressed region in the US with many challenges. It can experience severe droughts, salt intrusion is a major risk for coastal delta areas, groundwater levels continue to decline, it is the most populous US State with a population that is expected to grow from 38 to around 50 million by 2050, and the region accounts for half of agricultural exports from the US. Due to the lack of reliable dry season rainfall, typically from June to November, water is limited. Around 75% of total precipitation (both rain- and snowfall) occurs north of Sacramento while water demand is highest in the south. As a result, California has an interconnected water system designed to store and capture runoff and to transfer it through pipelines and canals to areas with high water demand.

Reduce water demand

The agricultural, industrial and municipal sectors have room to reduce their water demand. The predominance of agriculture in California is controversial given that it uses so much water that is so scarce locally. For those agricultural products being exported from the US, the water used in their production is effectively being exported abroad. Half of the crops are currently grown with flood irrigation measures rather than more water efficient drip or micro sprinkler irrigation. There is potential to move to more water efficient crops although this would impact existing trade patterns. The introduction of drought tolerant crops, such as wine grapes and nuts, reduces demands on water, as evidenced by their widespread use in Mediterranean countries. Industry could reduce water demand through the introduction of water efficient equipment and change to waterless processes. California passed new laws in late-2014 that for the first time require the State to account for its groundwater resources and measure how much water is being used. This is expected to impact heavy industrial water users. Municipal water use has declined significantly, from 232 gallons per day per person in 1995 to 178 in 2010 and just 130 in 2015, in response to drought-related conservation requirements. Ideally, in a circular economy, these savings need to persist beyond periods of drought.

Water loss still averages 10% for California's water utilities and this does not currently get a high priority, so there is room for improvement.

Reduce water pollution

Reduction of water pollution is a high priority as many groundwater aquifers have been contaminated by outdated manufacturing and farming practices. The State Water Resources Control Board and the Department of Toxic Substances Control is taking action to prevent the continued spread of contamination, accelerate cleanup and protect drinking water in urban areas. Companies, however, can file petitions to change an aquifer's classification, arguing that it either has already been polluted or is too deep underground to likely be used. Even if water is relatively clean, once reclassified, an aquifer is no longer considered a "source of drinking water", and is no longer protected. Only "non-hazardous" substances are supposed to be pumped into aquifers but oilfield production waste, including chemicals and fracking materials, is not legally considered "hazardous," a term with a specific definition in federal environmental law.

Re-use of water

Recycled waste water is already an integral part of California's water supply. Further progress could be made by re-use of water in industrial processes and by treating used water to drinking standards.

Retention of water

California has a long history of implementing water retention measures. Wetlands, aquifer storage and recovery as well as the use of reservoirs are all widely used. However, rainwater harvesting by households is not yet in use on a large scale. The circularity of the system could certainly be further improved by harvesting water on roofs and terraces for gardening and flushing toilets. Unless these technologies are supported by government policies, few households are likely to implement them.

Groundwater storage represents a practical solution to the State's water shortages and can help manage groundwater more sustainably. This solution could be enhanced through the alignment of land use planning with groundwater recharge, streamlining of permits for on-farm recharge, and the identification of new opportunities, such as capturing and recharging storm water flows.

Appendix 3

Information on the water system in Ghana

Introduction

Ghana makes extensive use of reservoirs. It has nine (hydropower) dams, the majority of which are based in the Volta. Among them is the biggest man-made reservoir in the world, the Akosombo Dam, which covers approximately 3.6% of Ghana's land surface.

Reduce water demand

Switching to more efficient methods of irrigation has the potential to reduce agricultural water demand. Knowledge is already available and farmers have been experimenting with drip irrigation but so far have not scaled up. However, sprinkler and drip irrigation are not economically feasible for all crops and a switch of irrigation systems can require a change in crops. Ghana currently produces mainly cacao, palm oil, cotton, rubber, sugar cane, tobacco, yams, grains, kola nuts and timber. There is limited potential to use saline water to irrigate these crops, even in coastal areas. There is potential to save water through soil improvement practices that can increase crop yields and save water. However, developments in these areas are being driven by donor organisations, such as Development Banks, rather than national governments.

Reducing water losses will require high priority to make the water cycle more circular as up to 40% of the water is lost during transport. Municipal and industrial water demand could be reduced by more water efficient appliances.

Reduce water pollution

Water pollution is a big problem in Ghana. Reducing water pollution would have a significant impact in making Ghana's water cycle more circular. In agriculture, pollution from inorganic fertilizers is a problem, for households the issue is the lack of sanitation and, in industry, mining companies are heavy water polluters. Illegal small-scale mining has been identified as a major water polluter. In general, industrial pollution originates from dispersed medium- and small-scale industries. Many industries are located at the coast and, without government policies in place, can discharge effluent directly into the sea or rivers without any form of treatment while those located inland discharge their effluent into major streams and urban storm drains.

Re-use of water

Little to no re-use is currently taking place in Ghana. A lack of qualified engineers to design, implement, operate and maintain re-use technologies is a major barrier.

We believe there is significant long-term potential to re-use water in Ghana as currently almost no waste water collection or treatment infrastructure is available. Only in the big cities is there some water treatment infrastructure available, but its operation is not very reliable. Over the coming years, Ghana is set to determine how it will design its water treatment system. The opportunity exists to design and implement circular water measures from scratch, not limited by current linear systems. Little to no re-use is currently taking place by industrial companies although several large companies have recently installed water pollution abatement technologies. We see significant potential for the use of grey water in agriculture. Plants irrigated with grey water would benefit from increased water availability and added nutrients. More effective use of grey water could reduce human exposure to pathogens and insect breeding grounds that might otherwise be created by waste water disposal by industry (which could see a reduction in the prevalence of malaria). However, capturing these benefits will not only require significant investment but also a workforce that can operate and maintain water re-use facilities.

Retention of water

There is potential for more dams, mainly in the Black Volta, but these projects are very costly. Given the ecological impact and the requirement to resettle people, we do not consider these projects as circular water measures.

Aquifer storage has the most circular water retention potential. Current aquifer storage volume in Ghana is approximately 370 million cubic metres, which is four times the current annual ground water use. It should, however, be seen in close relation to water saving programmes in agriculture, as more efficient irrigation methods would increase the need for artificial recharge of aquifers.

Appendix 4

Information on the water system in Bangladesh

Large extremes between wet and dry seasons

Bangladesh has a very large and water intensive textile industry which accounts for 9% of its GDP. By comparison, the textile industry accounts for only 0.7% of the global economy. The water supply of Bangladesh shows large seasonal fluctuations as most of its annual precipitation occurs during the monsoon season. Bangladesh makes extensive use of large dams to retain the water for use during the dry season and to provide hydropower to meet the fast growing energy demand.

Reduce water demand

On average, up to 40% of water in Bangladesh is lost in the system because of leakages, but in some regions losses are even higher. The Dhaka Water Supply and Sewerage Authority (Dakha WASA) aims to reduce water losses to 11% by 2035.

Agriculture makes up 19% of the economy (compared with only 4% for the global economy). There are many government run canal irrigation projects in the country. Water demand could be reduced by applying sprinkler and drip irrigation techniques. The Northwest region is highly developed agriculturally and has the largest irrigated area among the regions supplied mainly by shallow tube wells. Groundwater levels are declining as a result. In the coastal zone, overexploitation of fresh water is causing salinization of the shallower aquifers. We believe that sustainable water pumping is a circular water measure with significant potential in Bangladesh. Crop changes in coastal areas could enable the use of saline water instead of fresh water for irrigation.

Industrial water efficiency measures have the potential to reduce both water demand and effluent treatment costs. In addition, efficiency measures could defer the significant investment that would otherwise be required to develop alternative water resources for the industry. Experts indicate that there are opportunities to reduce water use by up to 20% at a relatively small cost. However, authorities often fail to impose compliance on industries.

While most houses do not have access to tap water, the potential to reduce municipal water demand is large as a good deal of water is lost in the system due to leakages.

Reduce water pollution

Reducing water pollution is a key element in making the water cycle more circular. In the words of the Bangladesh Delta Plan: "Water quality and pollution is a one of the key issues in Bangladesh, causing not only health hazards but even contributing to casualties during floods. Sources of pollutants include municipal waste, dyeing industries, chemical plants, tanneries and refineries. The use of fertilizers, herbicides and pesticides also results in pollution of water in agricultural areas. In general, water quality of the surface water is within acceptable limits during the monsoon period. During long dry spells however, water quality deteriorates."

Re-use of water

Re-use of water is limited in Bangladesh. Poor water quality is often a barrier. As a result, water treatment is crucial to build a more circular water system. For example, only 10% of the total domestic sewage is currently treated. The main treatment plant operates at only about 30% capacity due to system failures. The remaining sewage is often discharged directly into open water bodies. Dhaka WASA is currently planning to construct six new surface water treatment plants by 2035.

Retention of water

Current water retention measures in Bangladesh are mostly related to the construction of big dams. More dams are being considered as a policy option but, due to their environmental impact, these are not considered circular water measures in this report. Rainwater harvesting shows great potential. Several forms are being considered, including managed aquifer recharge.

Bangladesh experiences flooding over at least 20% of its area in a normal year. In extreme cases the flood-affected area can be as high as 65%. Flood control drainage could provide opportunities to reduce flooding and take advantage of flood water for irrigation as it would drain and retain water in such a way that it can be used for irrigation. While not yet actively used, this measure offers circular water potential.

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Appendix 5

Information on the water system in Northern India

Large extremes between wet and dry seasons

India hosts 18% of the global population but only 4% of the world's fresh water resources. Water resources are unevenly distributed: 75% of annual precipitation occurs during the monsoon season (June to September) with up to 90% of the rainwater lost due to run-off. In some regions, half of the rainfall is seen in just 15 days.

Agriculture is very water intensive and shows largest water shortages

Agriculture accounts for 84% of total water demand. Up to 80% of agricultural water demand is met from ground water resources as rainfall is so limited outside the monsoon period. Farmers have been encouraged by the government to sink tube wells to access water with which to produce their crops. Power for pumping the water has been supplied almost for free or is heavily subsidized. This has led to over-exploitation of groundwater resources and irrigation is very inefficient as farmers more-or-less just flood their land for irrigation. This makes agriculture in the region very water intensive. Currently more than 2,000 litres of water is used to produce US$1 of economic value (GDP) in agriculture, compared with 910 litres globally and just 7 litres in both Germany and the Netherlands.

Reduce water demand

On the demand side, switching to more efficient irrigation systems shows the most significant potential. As does sustainable water pumping to reduce over-exploitation of ground water resources by farmers, in particular. Changing to more water efficient crops has not yet been encouraged in North India and, indeed, the potential is estimated to be limited as it would require investment that cannot be afforded by farmers. Behavioural changes by households to reduce water use are, in practice, often hard to bring about. Industry shows good potential to reduce water demand by changing to more water efficient equipment and the inspection of piping and hoses for leakages.

Leakage and water loss is a huge problem in India as outdated transportation systems lose up to 40%. A lack of metering and data is a problem, which if resolved would enable the management of water use more effectively.

Reduce water pollution

Reduction of water pollution is considered a high priority by the government as 70% of India's surface waters are polluted. The most significant source of water pollution is untreated sewage water, followed by agricultural runoff and waste water from unregulated small- and mid-sized industrial companies. An estimated 38 billion litres of sewage per day is generated in major Indian cities, but the sewage treatment capacity is limited to a quarter in larger cities and one-tenth in smaller cities. The rest is discharged into water bodies. In rural villages, sewage treatment does not exist.

Re-use of water

The potential for grey water re-use seems to be high, provided the water is clean enough to be re-used safely. Around 36% of non-treated municipal waste water is currently re-used in agriculture. We estimate this could be increased to 50% but would need to be accompanied by regulation for the safe handling, transport and disposal of waste water, without which risks of health issues, salination or crop contamination would be increased.

Retention of water

We believe circular water retention measures show great potential to address the seasonal mismatch in water supply in Northern India. The potential for natural water retention is limited as land for reforestation and wetlands would be in competition with the agricultural need to meet the food demands of a fast growing population. As a result, water retention must come from measures such as rain water harvesting and aquifer storage. Rooftop rainwater harvesting has been made mandatory for new buildings in 18 out of India's 28 states. Still this leaves the potential on existing rooftops untapped. There is potential for harvested rainwater to be stored in aquifers for use in the dry season.

Northern India has several large (hydropower) dams that act as water reservoirs. Multiple dams are currently under construction. After completion there will be limited potential for more reservoirs but we do not consider this a circular water measure.

Appendix 6

Information on the water system in the Netherlands

Dutch polders require fresh water for flushing and water level management

The unique polder landscape of the Netherlands requires vast quantities of fresh water. A quarter of the country's land surface is below sea level and 43% of the total water demand of 3.7 billion m3 per annum is required by water level management systems to prevent flooding and the infiltration of salt water. The country's many rivers and delta characteristics also require fresh water to guarantee a minimal amount of flushing, accounting for 38% of total water demand. Hence, around 80% of water demand is a direct result of the geographical characteristics of the Netherlands with the remaining 20% related to 'real water use' by the agriculture, industrial and municipal sectors. We assess the potential of the circular economy on water use by these three sectors. It is regulated by Dutch law that demand from the municipal sector is always met at the cost of water for the industrial and agricultural sectors.

The Dutch drinking water network is one of the most sophisticated in the world. Almost 100% of inhabitants are connected to the sewerage system, almost all water is treated (even water that is not directly being used) and leakages are low.

Reduce water demand

Dutch irrigation efficiency ranks highest in the world. On average, farmers require just 7 liters of water to produce US$1 of economic value (compared with an average of around 900 liters globally), but improvement is still possible. Satellite data could provide farmers with information to further optimize their irrigation methods. Municipal water use could be reduced by improving the efficiency of washing machines, toilets and dishwashers as well as the use of water saving showerheads. Behavioral change can further contribute to reducing water demand. There is still potential to reduce industrial water use. Since the 1970s, industrial groundwater use has been reduced by 60%. There are some frontrunners with ambitious water saving strategies, such as DOW Chemicals and Heineken. The technology is available but, in many cases, the financial business case is not feasible and implementation depends on intrinsic motivation.

Reduce water pollution

In the Western part of the Netherlands, salt intrusion is a big problem in dry years. Climate change will potentially increase this. Therefore, there is a steadily growing interest in salt tolerant crops that can be irrigated with saline water which would further reduce fresh water demand.

Since 100% of drinking water in the Netherlands is treated, most hazardous materials are removed but problems remain with substances, such as hormones and antibiotics, in the Dutch drinking water. Furthermore, sewage overflows and occasional factory accidents pollute the water system. In the agriculture sector the Netherlands needs to reduce its manure surplus as this pollutes the surface water.

Re-use of water

Waste water re-use in the Netherlands is high compared with other countries as all drinking water and most industrial water is treated so water quality is not a limiting factor. However, there is room for improvement. Currently, the use of rain and grey water for non-potable use (toilet flushing, washing machines, cleaning and gardens) is not very popular. Dual-reticulation or 'third pipe' systems are controversial following an incidence of cross-connection with the drinking water supply, which caused people to become sick from drinking tap water. There are circular systems available that make re-use of grey water possible but these are not frequently applied.

The Netherlands uses a lot of surface water for the irrigation of agriculture. Part of this water is effluent from water treatment plants. Re-circulation systems that filter and recycle drainage water are promising especially in the Eastern part of the Netherlands. An advantage of these systems is that the water is nutrient rich, saving fertilizers.

Retention of water

The development of aquifer storage recovery in the Netherlands would reduce salt water intrusion by creating a larger fresh water bell. Several large projects are being considered. There is much interest in soil improvement practices that can retain water. A large programme is due to start in the Eastern and Southern regions of the Netherlands (Lumbricus project).

Appendix 7

Information on the water system in the United Arab Emirates

Introduction

The United Arab Emirates (UAE) has a highly sophisticated water infrastructure. Up to two thirds of waste water is treated, which indicates the high quality of water infrastructure and sanitation. The UAE also makes extensive use of desalinated water.

Reduce water demand

The UAE makes huge efforts to preserve water resources, with emphasis on promoting the adoption and installation of modern irrigation systems to replace flood irrigation methods, which wastes significant amounts of water. Figures indicate that modern irrigation systems (sprinkler, drip and fountain irrigation) now account for more than 90%, compared with 32% at the turn of the millennium.

To date, water reduction has come from water saving technology and not from a change in crops, which leaves room for further circular potential.

Municipal water use is relatively high in UAE despite the use of water saving technologies. Further reductions in water use could be achieved through behavioral and lifestyle changes.

Reduce water pollution

One of the most significant water pollutants in the UAE is saline water. Due to the arid climate and physiography of the country, salt water intrusion is affecting the UAE's aquifers.

A deterioration of groundwater quality has also been observed as a result of the overuse of fertilizers and over-irrigation, as well as the intrusion of saline water in coastal regions.

Re-use of water

"Nearly all of the wastewater generated in the UAE, about 550,000 cubic metres per day, gets treated. It is treated to a very high standard with the intention of the treated effluent or reclaimed water being used for irrigation purposes," said Matthew Griffiths, wastewater manager at the Regulation and Supervision Bureau for water, wastewater and electricity sector. There is no plan to introduce policies to replace desalinated potable water with reclaimed water.

Recycled water is mostly used for landscape and greening, not for other uses. If a change in perception towards recycled water were to take place, recycled water could be used for many other activities and replace some of the demand for desalinated water.

Retention of water

The UAE has paid significant attention to the use of dams and rainwater harvesting projects. Dams contribute to protection from floods and flows risk, and improve the quality and quantity of water in aquifers by increasing the feed rates of groundwater. In addition, dams preserve the soil from erosion in agricultural areas. The UAE has around 130 dams and levees with a total storage capacity of around 120 million m^3 of water.

Pumping in excess of annual ground water feed rates has caused a reduction in the water in ground reservoirs because the rate of rainwater that feeds and renews groundwater reservoirs is no more than 10% of the withdrawn amount. Groundwater levels dropped by 10 metres per decade until the mid-1990s, and by 70 metres since then. Aquifer storage currently uses even desalinated water.

The already very arid climate is likely to become more so with global warming. As a result, limited potential is expected from water retention measures in the top soil or from rainwater harvesting from, for example, roofs and terraces.

<< Content

Colophon

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International Water Association (IWA)	Pritha Hariram
Netherlands Water Platform (NWP)	Lennart Silvis
	Joris van Oppenraaij
Waternet	Kenneth Comvalius
	Otto Ferf Jentink

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www.nhi.nu

Abbreviations

CE	Circular Economy.
mln	Million.
bln	Billion.
UAE	United Arab Emirates.

Disclaimer

ING joined the maximum of 100 global frontrunner corporations as an official Circular Economy 100 (CE100) corporate member of the Ellen MacArthur Foundation, the world's leading platform on circular economy. Through the Ellen MacArthur Foundation, ING aims to grow its knowledge and network on this topic, collaborating with experts, partners and other CE100 members to promote the circular economy and unlock related business opportunities.

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