Securing a sustainable water future through inter-basin water transfer

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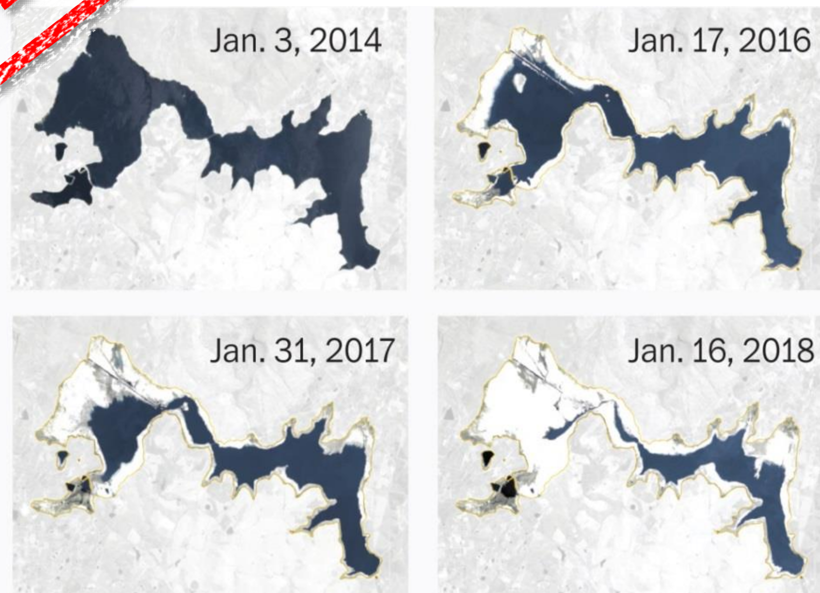
26/3/2019

The problem

'So, what is the problem? The answer is simply that water, although plentiful, is not distributed as we might wish. There is often ***too much or too little****, or what exists is too polluted or too expensive. A further problem is that the overall water situation is likely to further deteriorate as a result of global changes.'*

Daniel P. Loucks


DAY ZERO


Jan. 3, 2014
Jan. 17, 2016
Jan. 31, 2017
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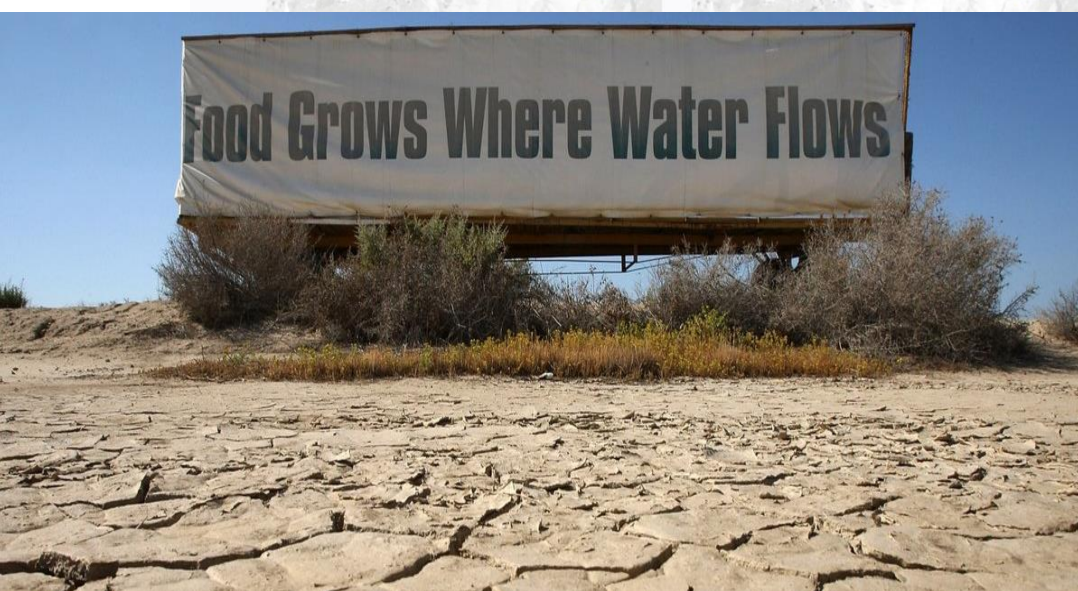

Food Grows Where Water Flows

The 11 cities most likely to run out of drinking water - like Cape Town[1]

[1] https://www.bbc.co.uk/news/world-42982959

The extent of flood in Carlisle following Storm Desmond in 2015

Submerged vehicles in the Heaton district of Newcastle after the ‘Thunder Thursday’ flood in 2012

‘There may also be further opportunities for development of greater linkages between existing water company systems, and sharing of water resources to gain some of the same benefits expected of large-scale transfers.’

Environment Agency, 2011

‘In the face of rapid urbanisation, population growth, and climate change, the organisations tasked with securing our water supply must tackle bigger challenges than ever. Water transfers and interconnections are vital elements of these strategies.’

Institute of Civil Engineers, 2015

‘The water resource planning process does not include an independent analysis to identify strategic options such as transfers between regions.’

National Infrastructure Commission, 2018

Existing inter-basin transfer (IBT) projects:

Project name	Country	Water transfer quantity (billion m^3 /a)	Length of canal/tunnel (Km)
California North-to-South Water Transfer Project	USA	5.2	900
Central Arizona Project	USA	3.7	800
Quebec Water Transfer Project	Canada	25.2	861
West-to-North Water Transfer Project	Pakistan	14.8	662
Snowy Mountains Scheme	Australia	1.13	80
Great Man-Made River	Libya	2.5	4500
The National River Linking Project	India	-	4440
South-to-North Water Transfer Project	China	44.8	3833

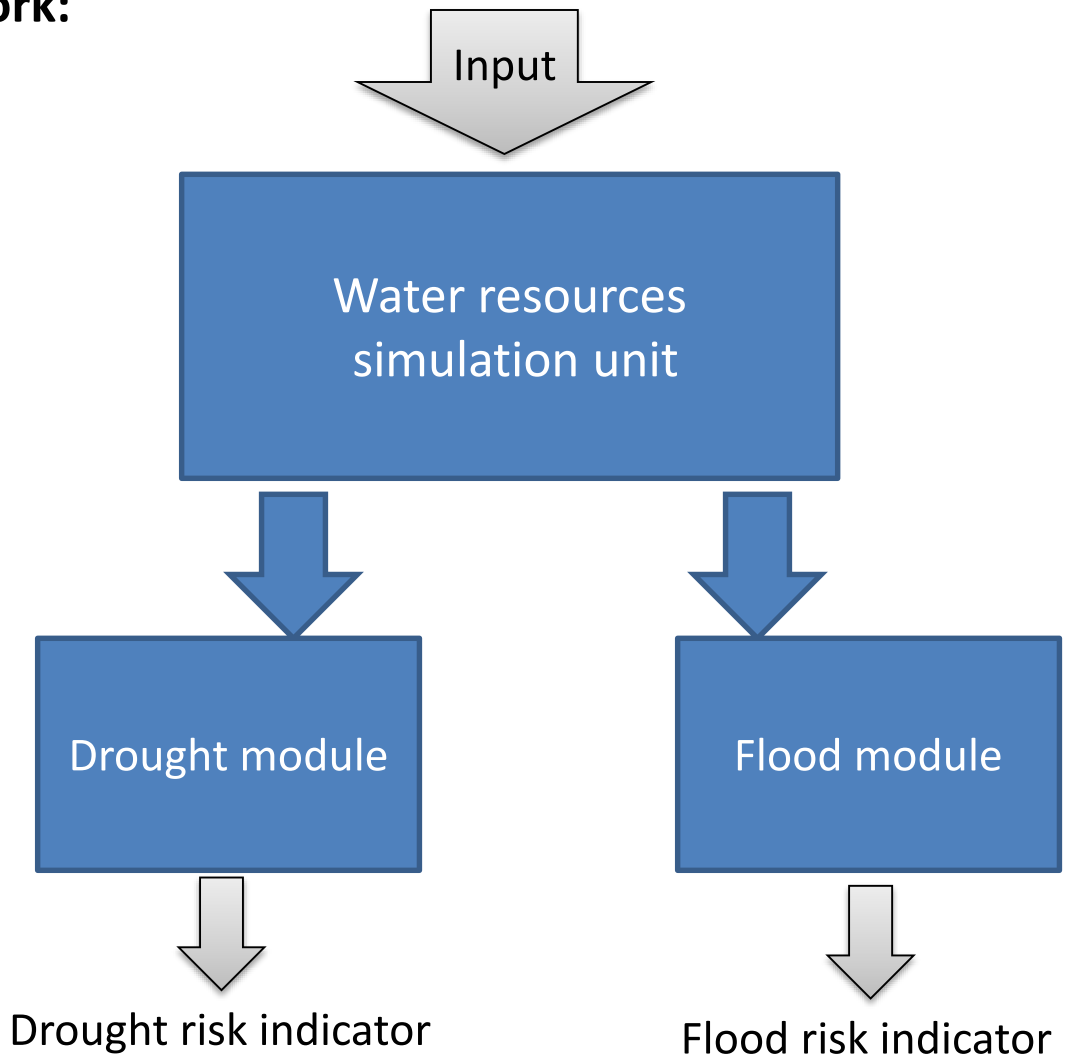
Contribution of inter-basin transfers (IBTs) to all water withdrawals of the world:

Region	Water withdrawals (billion m^3/a)		
	Total	Through IBTs	
South America	182	3	2%
North America	705	300	43%
Asia	2357	146	6%
Europe	463	79	17%
Africa	235	11	5%
Australia and Oceania	32	1	3%
World total	3974	540	14%

The aim

- We aim to provide a methodological framework to carry out the first step in IBT projects: feasibility study.
- The framework is used to assess the potential negative impacts that IBTs might have on the donor (exporting) basin.
- These include hydrological, environmental, and social impacts.
- It is important to note that we only consider negative impacts that come from conveying a certain quantity of water outside of its basin regardless of type and condition of the transfer.

Modelling framework:



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Water resources simulation unit:

$$Max\ Z = \frac{\sum_d DSR_d P_d}{\sum_d P_d} + \frac{\sum_r (maxS_r - S_r)}{\sum_r maxS_r} - \frac{\sum_r (targetS_r - S_r)}{\sum_r targetS_r}$$

Subject to

$$I_i + \sum_{j|link(j,i)} (1 - l_{j,i}) Q_{j,i} - \sum_{j|link(i,j)} Q_{i,j} = DSR_i td_i \quad \forall i \in d$$

$$I_i + \sum_{j|link(j,i)} (1 - l_{j,i}) Q_{j,i} - \sum_{j|link(i,j)} Q_{i,j} + initS_i = S_i \quad \forall i \in r$$

$$minS_i \leq S_i \leq maxS_i \quad \forall i \in r$$

$$minQ_{i,j} \leq Q_{i,j} \leq maxQ_{i,j} \quad \forall i,j \in link$$

DSR=demand satisfaction ratio
P=demand priority
S=Storage volume
I=net inflow
l=losses
Q=flow
td= target demand
targetS=target storage volume
initS=storage at the end of previous timestep
minS =minimum allowable storage
maxS=maximum allowable storage
minQ=minimum allowable flow
maxQ=maximum allowable flow
d=set of nonstorage nodes
r=set of storage nodes

Drought module:

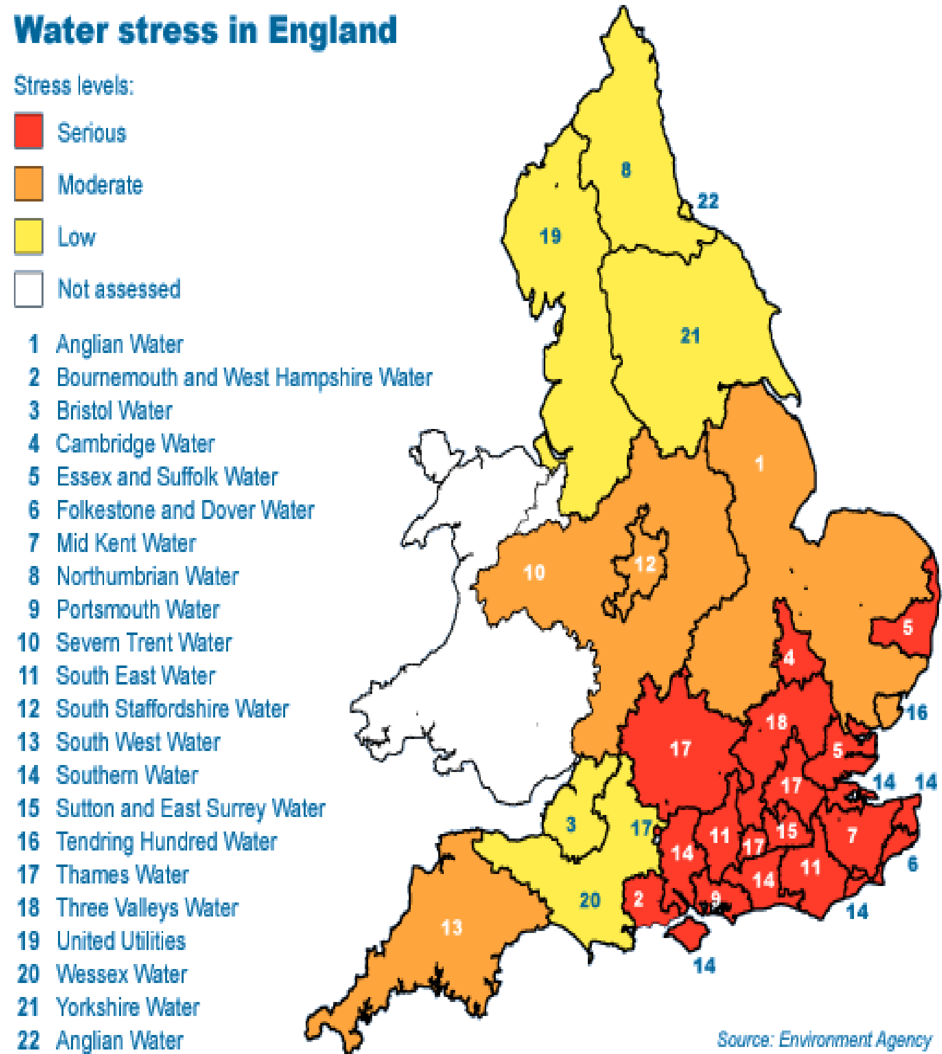
This module looks at DSR in all demand nodes over the planning horizon and reports magnitude and number of times that target water demand was not fully met.

Flood module:

This module evaluates flood risk by calculating storage headroom in each reservoir. If there is no occurrence of reservoirs being completely full (which leads to spillage and increases flood risk), this module reports the smallest value of storage headroom over the planning horizon.

Application

- We consider a hypothetical IBT case from UK's North East to South East.
- Kielder reservoir has the largest artificial lake in the United Kingdom by capacity of water.
- Northumbrian Water reported in their WRMP19 that they predicted water surplus until 2060.



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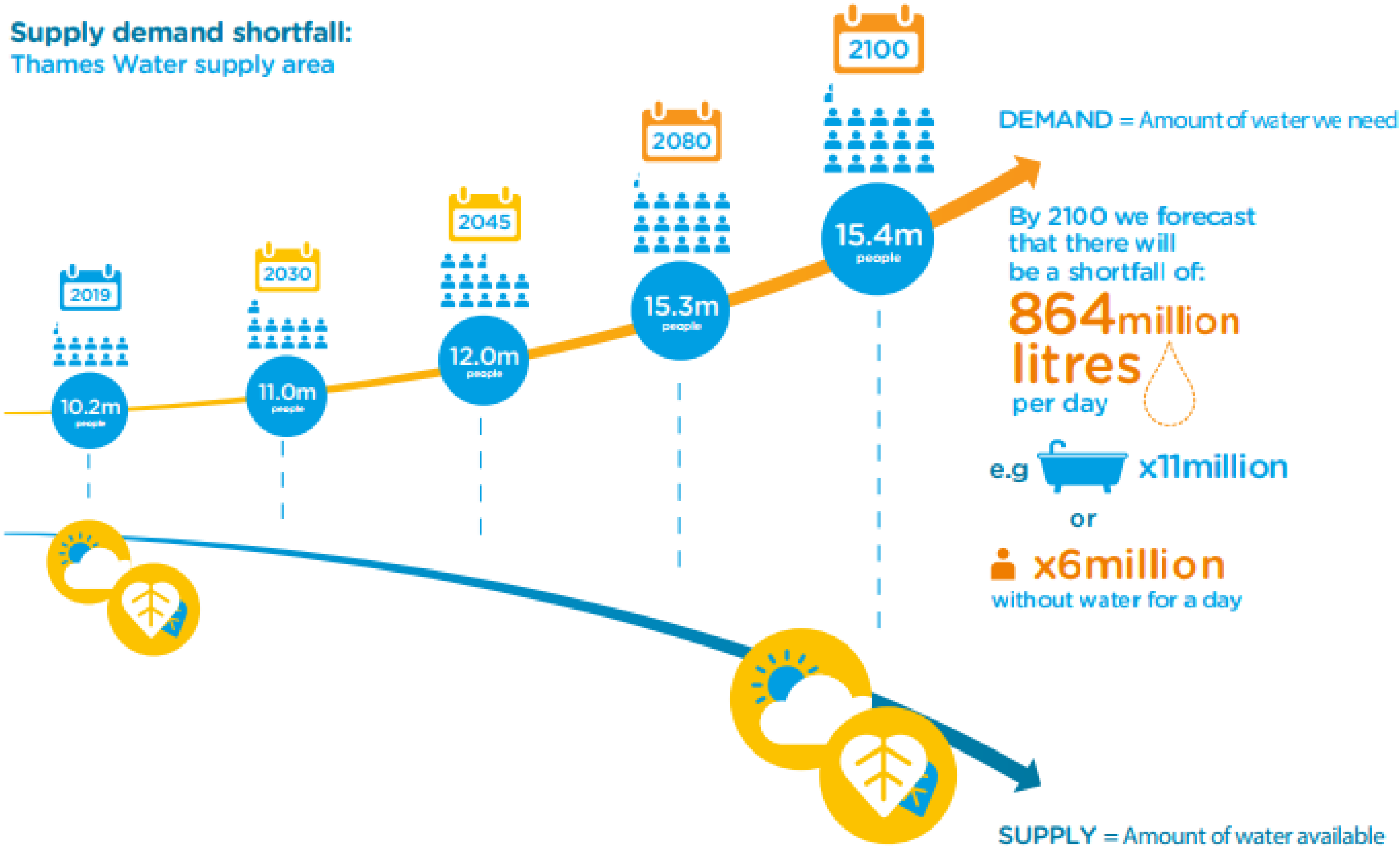
Thames Water supply shortfall forecast:



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Inputs and assumptions:

1) Climate scenarios

We consider three climate scenarios. A baseline scenario which contains inflow of normal years, i.e. created by bootstrapping from historical inflow data. A dry year scenario which includes bootstrapped historical inflows from years with annual inflow below the annual average inflows. And a wet year scenario which, opposite to the dry year scenario, is created by bootstrapping from historical years with above average inflows.

2) Transfer operating rule

Two transfer options are considered. Transferring the shortage volume reported by Thames Water throughout the year, or transferring the same volume only during wet season.

3) Planning horizon is 2020-2100 (80 years) and historical data cover 1992-2017.

4) Each scenario contains 100 realisations.

Naming of scenarios:

	Normal Year Climate	Dry Year Climate	Wet Year Climate
Transfer only in wet season of each year	NYWM	DYWM	WYWM
Transfer throughout each year	NYAM	DYAM	WYAM

Results

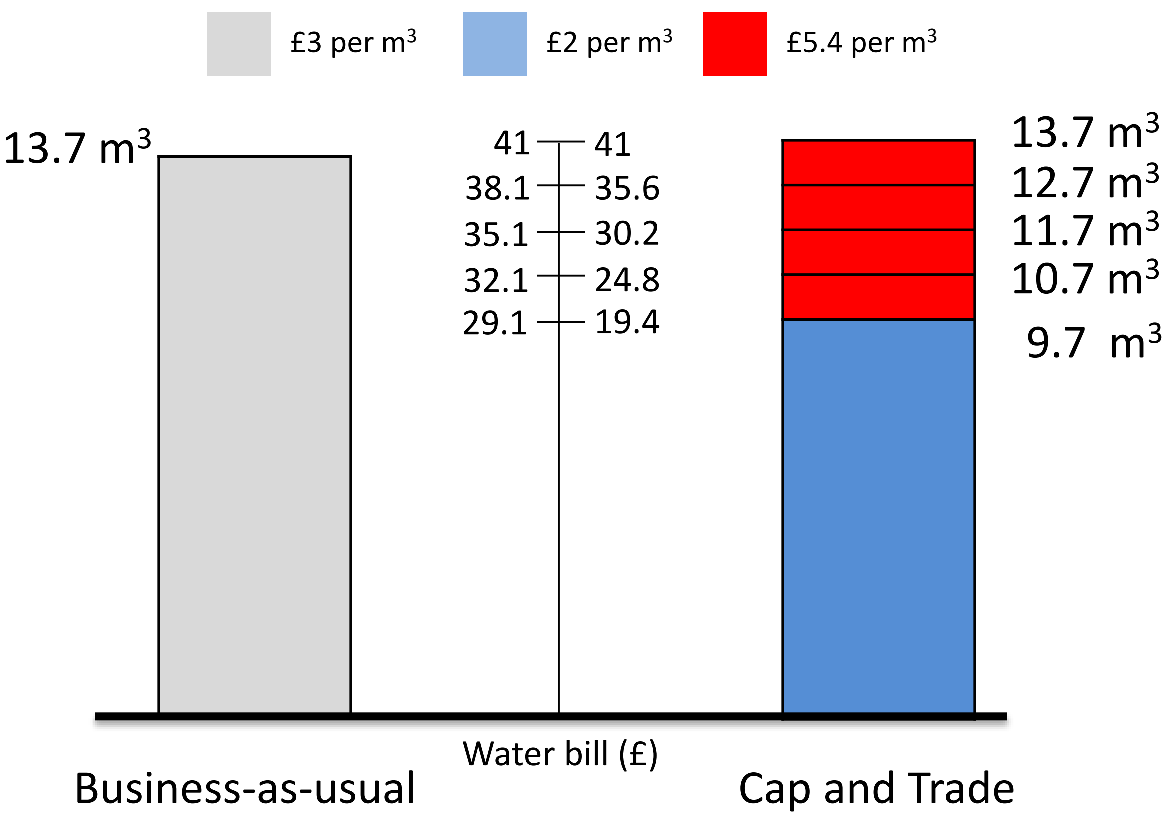
Percentage of times that drought or flood risk indicators were triggered (any demand node experienced water shortage or spillage occurred at least once over the planning horizon):

	NYWM	NYAM	DYWM	DYAM	WYWM	WYAM
Number of realisations where drought risk was triggered	-	-	-	1	-	-
Number of realisations where flood risk was triggered *	-	3	-	-	7	9

* Another model run, the benchmark scenario (business-as-usual), using historical inflows and no IBT was carried out. This also shows that under normal climate and with no transfer, flood risk was triggered several times over the planning horizon.

Social impacts:

The negative social impact of IBT is that people in both importing and exporting regions might change their consumption behaviour. We propose a dynamic water tariff similar to ‘Cap and Trade’ which helps in preventing such behaviour change and can lead to increased water supply in both regions.



The average water usage for a standard household in the UK is about 13.7 m^3 per month. One cubic metre costs around £3.

Consumers can sell their unused allowance to each other at a lower price (<£5.4 per m^3) or buy any extra allowance from the water company (£5.4 per allowance).

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Concluding remarks

- Water resources are not evenly distributed. Too little water can cause sever droughts and too much water results in more frequent flood.
- IBTs have long been appreciated by many countries as a solution to the above problem. Over the past recent years authorities in the UK encouraged water companies to consider IBT as one of the strategic options.
- We proposed a methodological framework that carries out the first step for IBTs, i.e. feasibility studied.
- The framework indicates how IBT changes flood and drought risk.
- A hypothetical case of IBT between UK's water-rich North East and water-demanding South East was considered.
- Results showed that with IBT, the exporting region will experience less flood risk while not being threatened by drought.
- In order to prevent change in consumption behaviour due to IBT, we propose a dynamic water tariff, similar to 'Cap and Trade' to be used for both importing and exporting regions.

What are the next steps?

- Evaluating different transfer options: permanent long range infrastructure (canal or pipeline), transferring as a cascade of water resources zones, transferring using water tankers, etc.
- Finding the best timing and choice of set of actions to be taken in order to implement IBT.
- Assessing how other demand management options such as rainwater harvesting can help IBTs.

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Questions?