

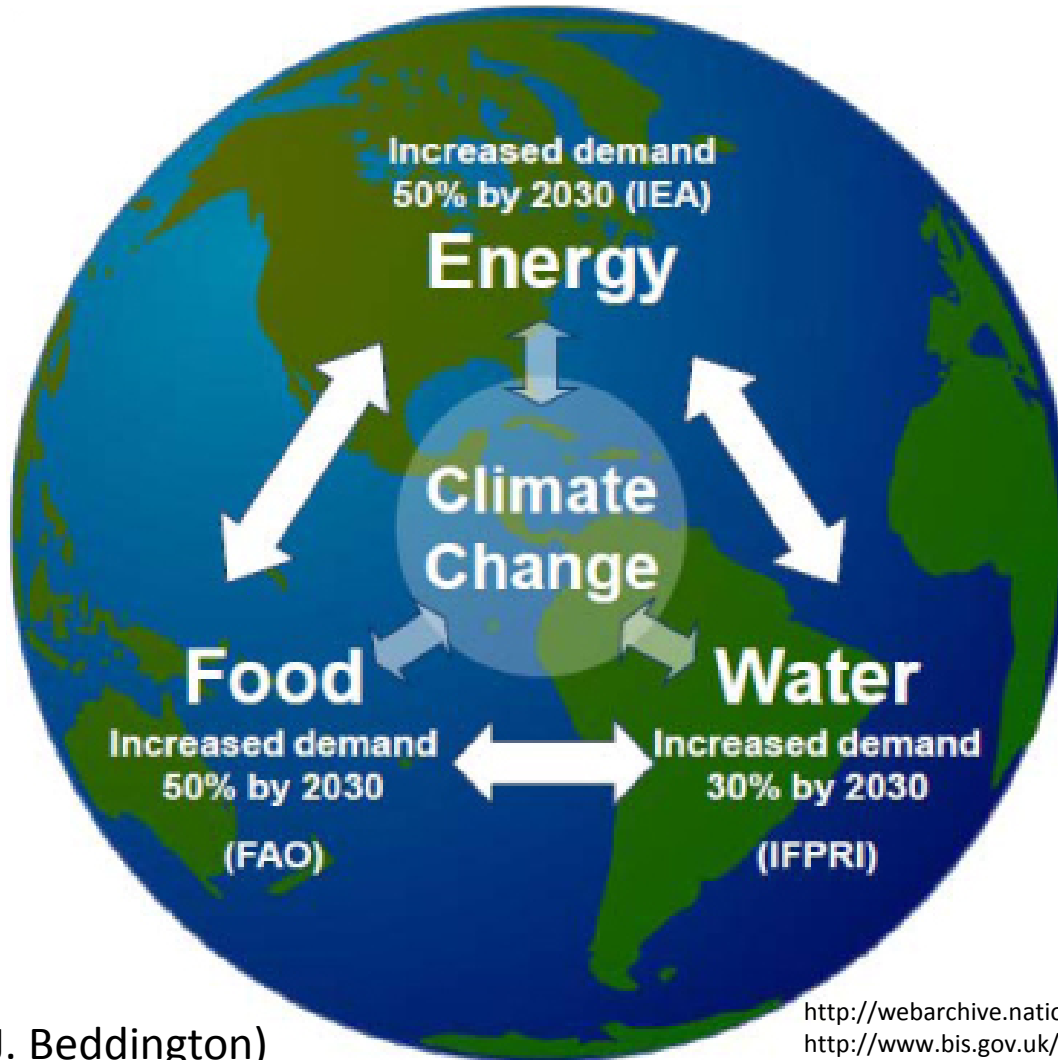


Water Treatment with Aquaporin Inside™ Forward Osmosis

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CTO Aquaporin Group**

Dairy Research Day March 2, Billund Denmark

Water-energy-food nexus



The perfect storm (J. Beddington)

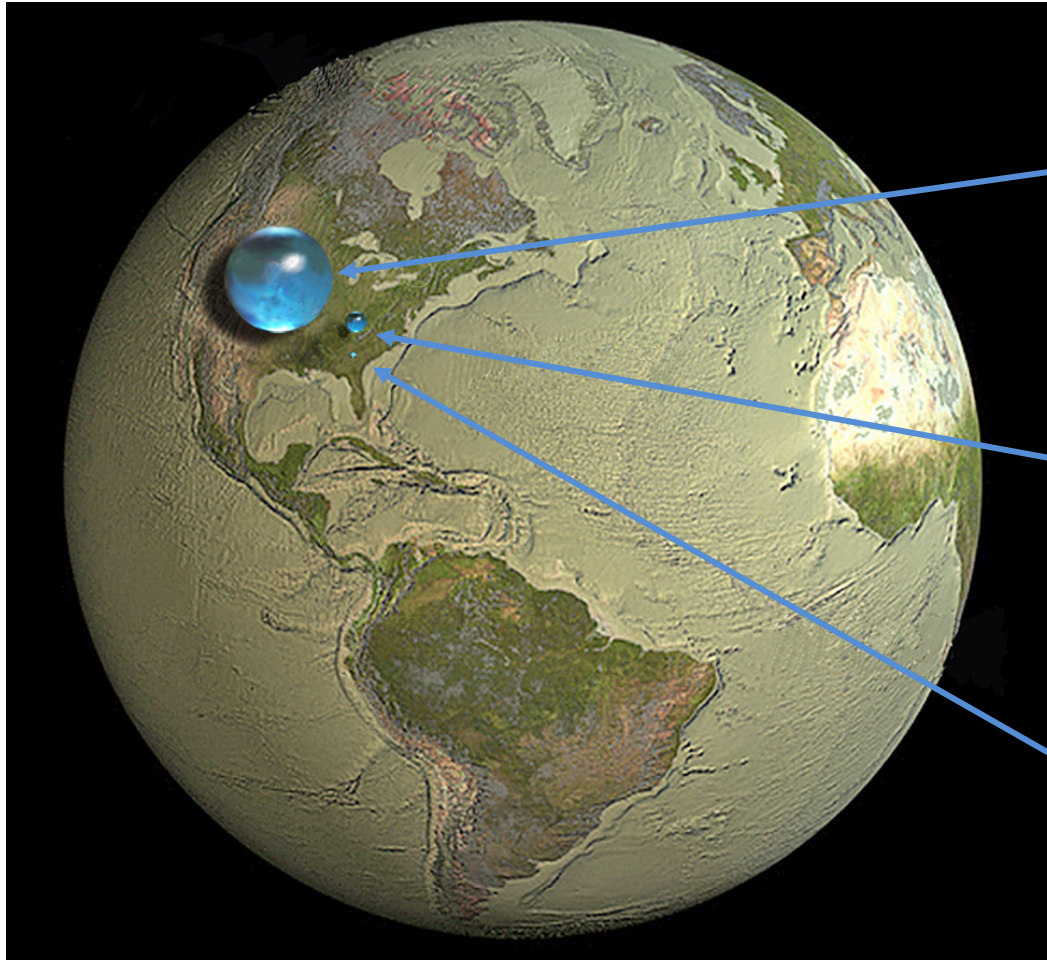
<http://webarchive.nationalarchives.gov.uk/20121212135622/http://www.bis.gov.uk/assets/goscience/docs/p/perfect-storm-paper.pdf>

But don't we have enough water?



Planet Earth/ colourbox.dk

Well, water is not just water...



All of Earth's water
(1375 km ø sphere)

Liquid fresh water
(273 km ø sphere)

Surface water
(56 km ø sphere)

H. Perlman, USGS & J. Cook, Woods Hole Oceanographic Institution

Danish export is relying on superior water quality to secure food safety



- The food industry accounts for 25% of Danish export.
 - The dairy industry present 11% of this.
- Multiple partnerships have been initiated to develop the future's state of the art water treatment solutions based on Danish technology
 - Water Efficient Dairies
 - DRIP
- Denmark has to be on the forefront with state of the art solutions due to high costs levels and regulatory demands.



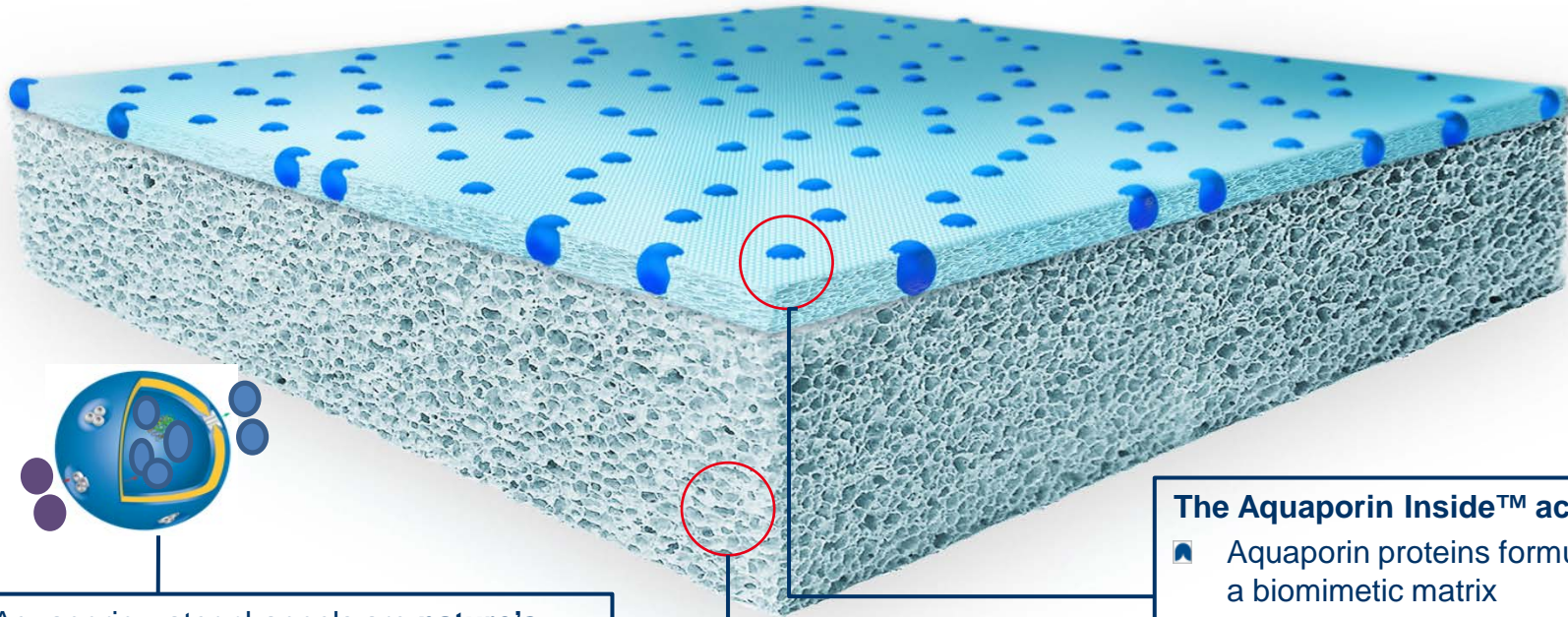


Aquaporin is a **global cleantech** company with a ground-breaking biotechnology to **separate** and **purify water** from all other compounds based on **Nature's own (biomimetic) technology**:

Aquaporin Inside™

Our **vision** is to become the **leading company** in **membranes for water treatment.**

Aquaporin proteins are integrated into robust industrial membranes



- Aquaporin water channels are **nature's water filters**
- Can be found in all living cells – from bacteria to plants to humans
- Aquaporin water channels **only allow water (H₂O) to pass** through the channel, while blocking all impurities

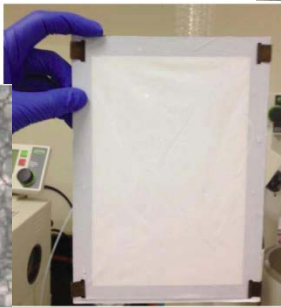
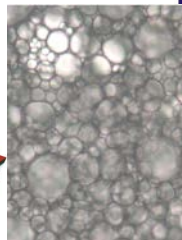
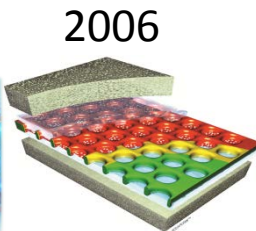
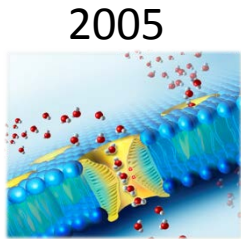
The Aquaporin Inside™ active layer

- Aquaporin proteins formulated into a biomimetic matrix
- Embedded on the surface by an immobilization matrix

- Customized support substrate
- Suitable for different membrane types

Milestones in Aquaporin A/S Timeline

- 2005 Aquaporin A/S founded
- 2006-2017 basic R&D in Public Private Partnerships
- 2010 First mm² sized membranes
- 2011 Aquaporin Asia Singapore subsidiary incorporated.
- 2011 First cm² sized membranes
- 2013 First pilot production of FO membranes
- 2014 First hollow fiber module developed
- 2014 Equity financing for InterChina Wate, Poten Env. Group and Danica Pension
- 2015 First RO membranes produced
- 2016 RO tap water modules
- 2016: First brackish water RO prototype membrane
- 2016: Golgi ApS founded.
- 2017: Start of industrial production at DK HQ



2015



Aquaporin production line



High Rejection Water Treatment

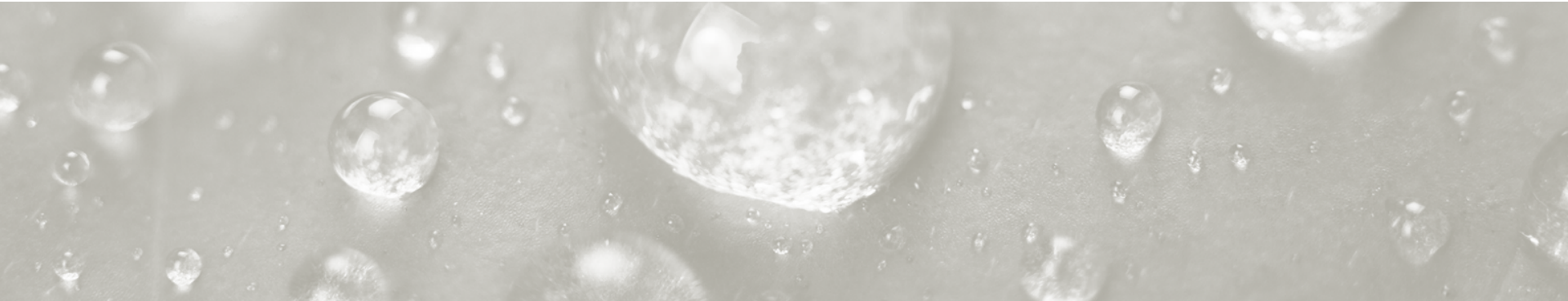


High Rejection Forward Osmosis Membrane

- **High rejection** of all compounds, e.g. trace organics, micro pollutants
- **Low energy** consumption
- Low fouling propensity

Products

- Flat sheet rolls in R&D quantities
- 2.3 m² (25 square feet) hollow fiber (HF) elements
- Single tubular membranes and small modules for R&D purposes



Reduction of Process Water at Dairy Plant



Pilot study of Aquaporin Inside™ Forward Osmosis membrane to treat water in whey processing plant:

- Lower costs of dewatering the whey which contains 95% water.
 - Increase lifetime of RO membrane.
 - Reduce volumetric RO reject water to wastewater treatment plant.
- Increase purity of final permeate compared to conventional RO treatment.
 - Enable more reuse of water.

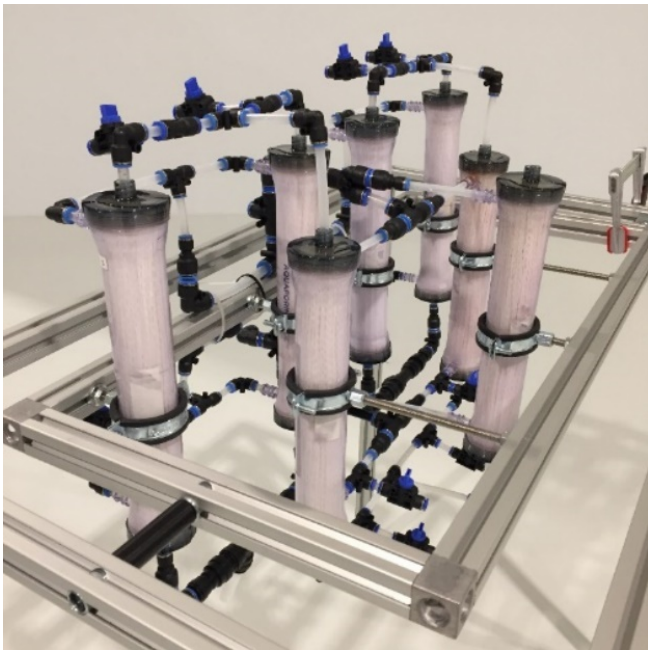


- IBISS Project funded by the Innovation Fund Denmark.
- Partners: Aquaporin, Arla Foods, Tetra Pak Filtration and Process Solutions, Danish Technical University, University of Copenhagen.
- Pilot unit located at Danmark Protein where they producing concentrated whey protein, lactose, and functional milk proteins.

Reduction of Process Water at Dairy Plant



- Capacity of pilot setup is up to 250 L/h
- Treats ultra filtration permeate containing 170 mg urea/L
- Test set up with Aquaporin Inside™ Forward Osmosis 16.1 m²



Reduction of Process Water at Dairy Plant



- Lab-scale FO filtration tests have been performed with 2.3 m² FO AIM modules, treating Arla Foods' RO and UF permeate samples with a 1M NaCl draw solution. Water fluxes of 5-6 L/(m²h) and urea/TN rejection rates of up to 80% have been measured.
- FO-RO process was tested at semi-pilot scale at DTU Environment, using 20 L RO permeate as a feed solution and 1 M NaCl as a draw solution. Two 0.6 m² HF FO AIM modules and a 4" BW30 RO element was used to recover the draw solution. After ca. 99% feed up-concentration, TN levels in the resulting RO permeate were on average 5 mg/L with a maximal 8 mg/L i.e. slightly exceeding discharge TN limits.
- Exposure to a standard RO membrane cleaning procedure with Ultrasil 78 and Ultrasil 115 does not harm standard performance of the FO AIM modules.
- Process optimization and OPEX/CAPEX calculations in progress.



Thank you for your attention!

www.aquaporin.dk