# A new source of *demin* water

When can industry become net water producers and save energy

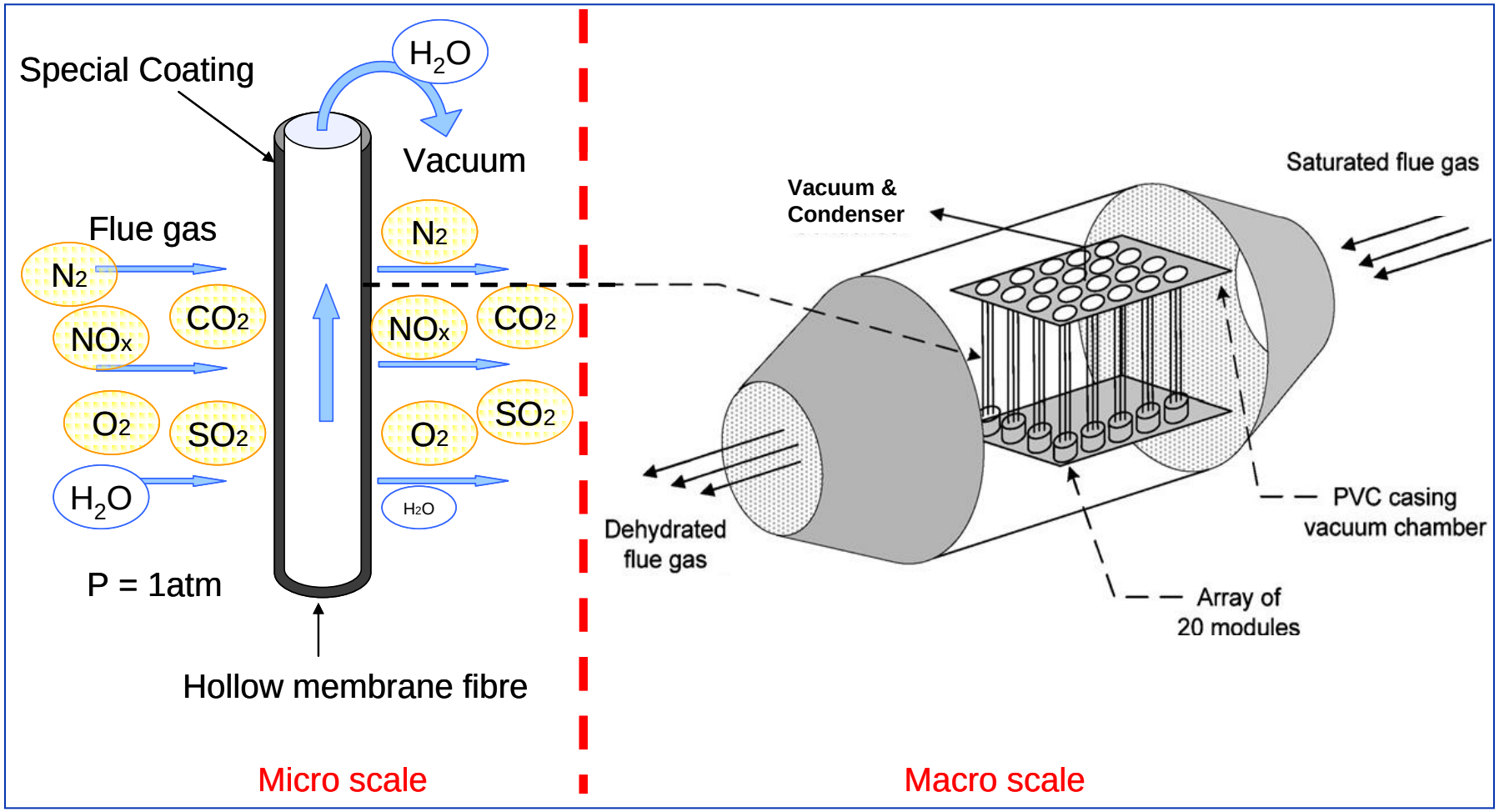
EU project: CapWa
By: Ludwin Daal – projectmanager

Version: 7th December 2012

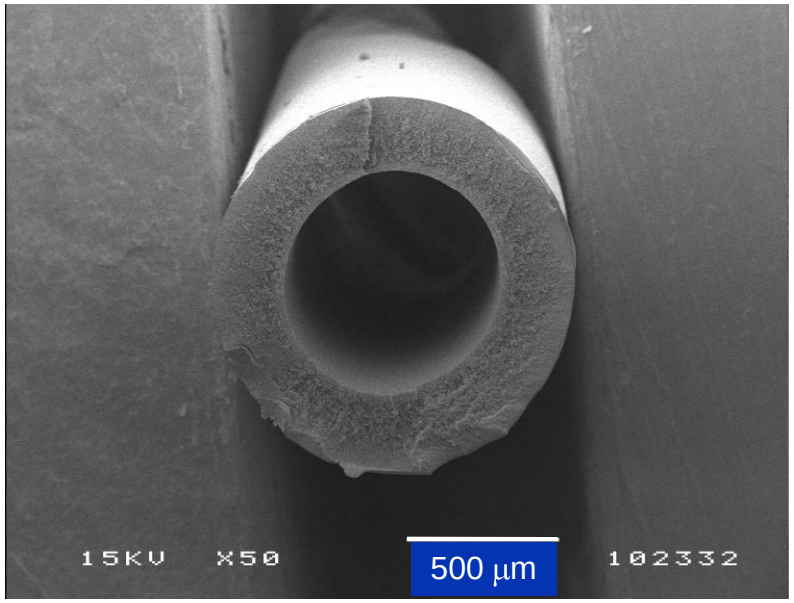
# Content – a new source of *demin* water

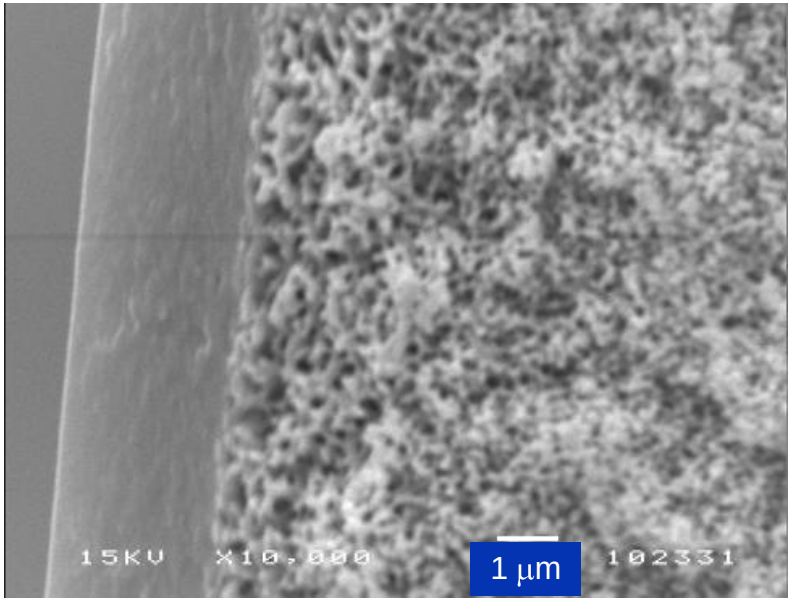
- Working principle
- Technology development path
- EU funded CapWa project
  - First prototype
- Energy calculation
- Benefits technology
- What does the technology enable

# Working principle



# Membrane materials: visually




Micrometer-scale selective material coated on porous support fibre

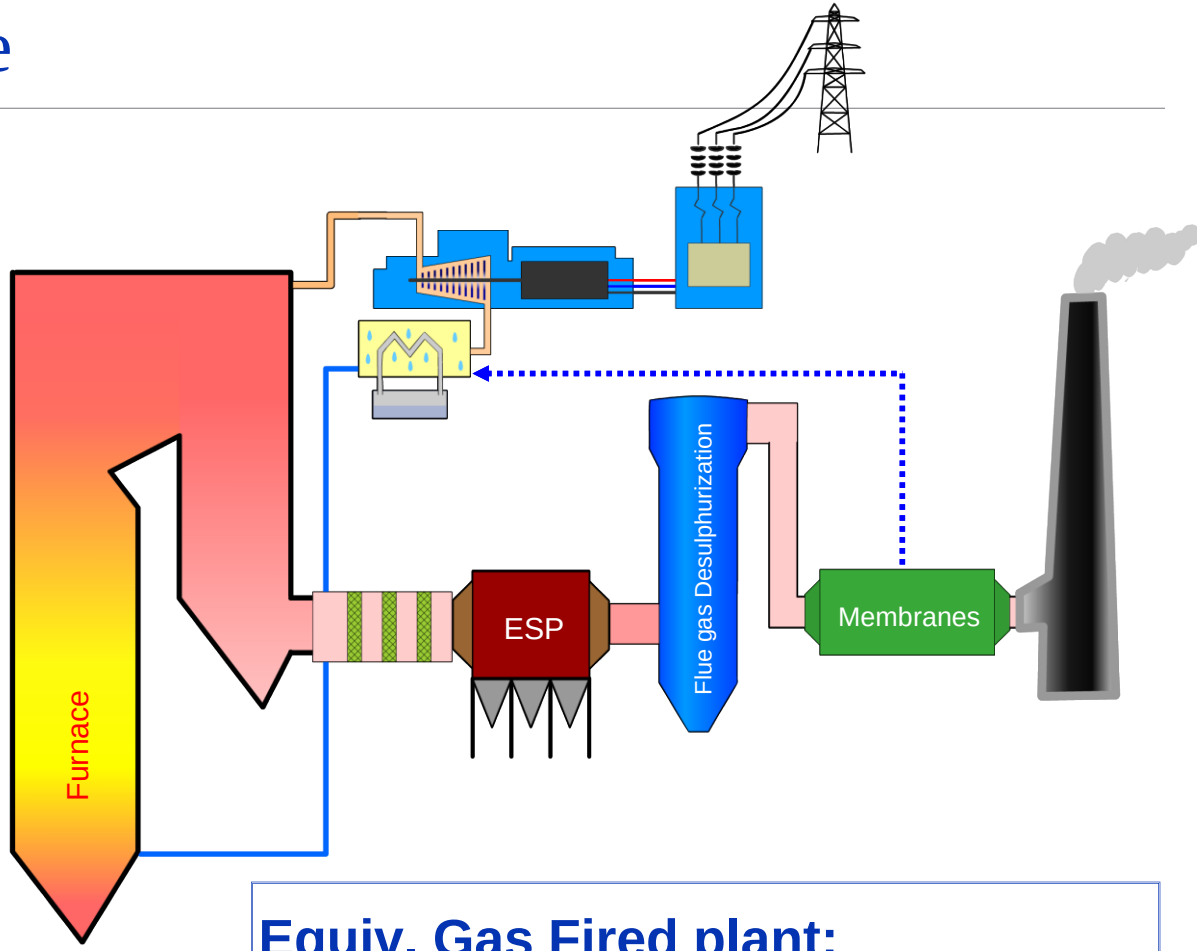
# Principle water capture

**400 MW coal fired power plant with FGD:**

- Emits 150 $m^3$ water per hour to the atmosphere
- Needs 30 $m^3$/h water ➔ 20% capture

No FGD in place:

- 90-120 $m^3$ water per hour




**Equiv. Gas Fired plant:**

- Emits 90 - 120 $m^3$ water per hour
- Needs about 1 $m^3$/h water

# 12 year preliminary research

## Background:

- Power companies expected doubling of water tariff in the ’90’s
- Surface water needed extensive water treatment steps
- Research by KEMA, University of Twente & Dutch Power industry

## Overview of general technology development:

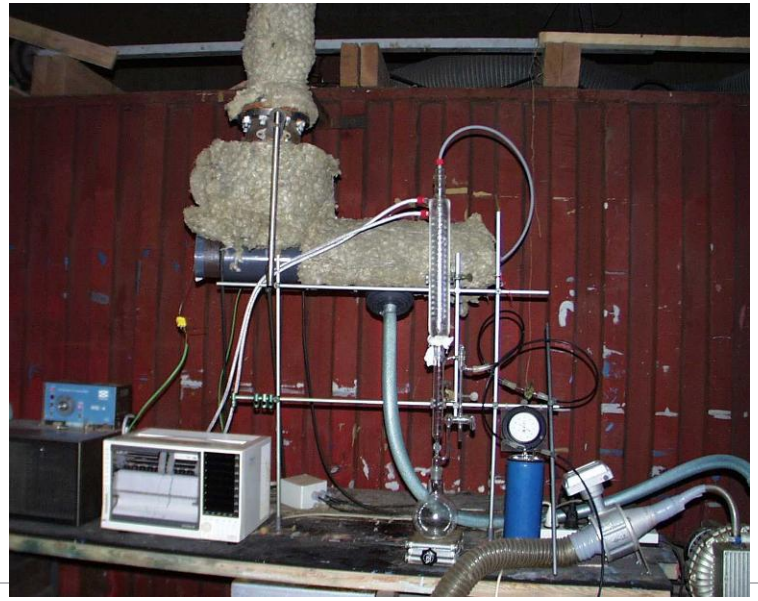
| Field tests – flue gas | Relative humidity | Duration | Results (1) | Year |
|---|---|---|---|---|
| Coal fired power plant after reheat max. 60 °C | 95-99% | 32 weeks | 0.2 L/m$^2$.h 500 – 1000 µS/cm | 2003 |
| Coal fired power plant after FGD 46 -48 °C | 100% | >5000 hours | 1.4 L/m$^2$.h 20 µS/cm | 2006 |
| Waste to Energy max. 65 °C | 100% | Exposed: 6000 Oper. 2000 hrs | 3-4 L/m$^2$.h 40 µS/cm; | 2007 |
| Gas burner at 40-50 °C | 70% | 20 hours | ~1 L/m$^2$.h | 2009 |
| Gas burner at 80-90 °C | 10% | 100 hours | ~0.03 L/m$^2$.h | 2010 |
| Cement Kiln 55 – 62°C | 100% | >1100 hours | 3-6 L/m$^2$.h 15-20 µS/cm; | 2012 |

**>40% water capture, results warrent a follow up!**

(1) water flux in litre liquid water per m$^2$ membrane area per hour; water purity in specific conductivity

# Proof of principle at CF PP

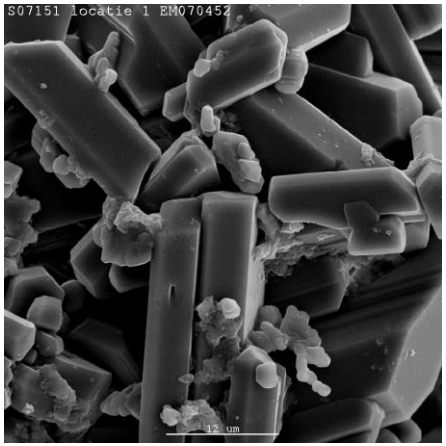
- Started with commercial available dehumidifiers modules
- At KEMA facility, flue gas generator
- Additional tests carried out at CFPP
- Proof of principle successful
- Results basis for project subsidized by Dutch government (2001 – 2008)



# Field test Waste to Energy plant

# Setup permeate recovery

# Fouling after 10 months before CIP

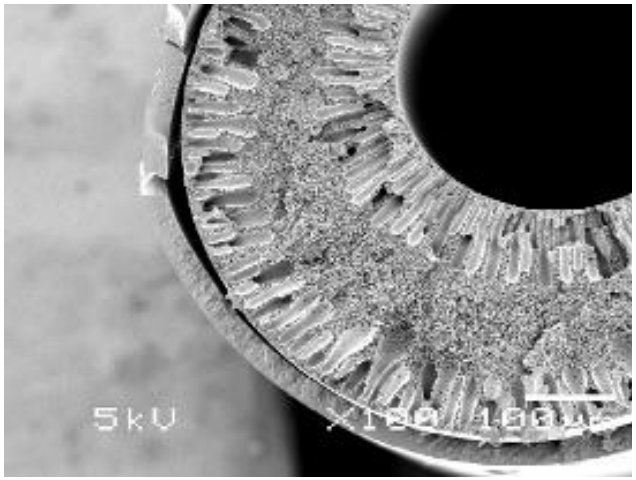



Gypsum particles

Cleaning in place units placed

# Membrane improvement UT

- At high sulfonation degree dissolution possible
- Good distribution of sulfonic acid groups necessary
- No clusters
- UT produced a few hundred meter hollow fiber membrane
- New modules built by KEMA and tested at KEMA



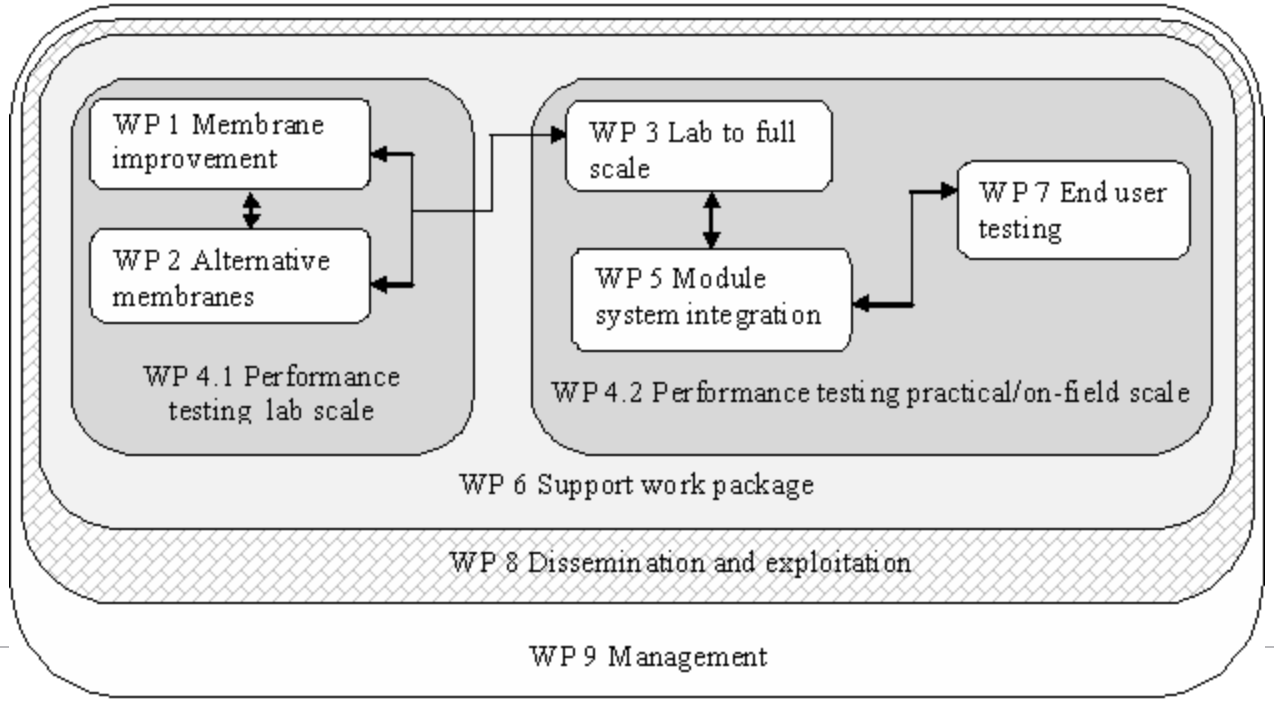

Delamination because of insufficient adhesion between coating and support.

# Goal / ambition of EU project: Capture of evaporated water - CapWa

produce a commercially available membrane modular system suitable for industrial applications **within 3-4** years. The produced demin water from this system should be competitive with existing demin water technologies. The starting point will be the water vapour selective composite membranes that are developed in the proof of principle project.

# Work packages in 3 year project

| | YEAR 1 | | | | YEAR 2 | | | | YEAR 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WP1 Membrane improvement | | | | | | | | | | | | |
| WP2 Alternative membrane | | | | | | | | | | | | |
| WP3 Lab scale to full scale | | | | | | | | | | | | |
| WP4 Performance testing | | | | | | | | | | | | |
| WP5 Module system integration | | | | | | | | | | | | |
| WP6 Support work package | | | | | | | | | | | | |
| WP7 End user testing | | | | | | | | | | | | |
| WP8 Dissemination & exploitation | | | | | | | | | | | | |
| WP9 Management | | | | | | | | | | | | |



# Applicability

- Power generation – flue gases
  - Coal-fired power plants
  - Gas-fired power plants
  - Waste to energy plants
- Industrial processes
  - Paper mills; wood drying & similar drying processes
  - Petrochemical plants; offshore
  - Cement factories
  - Glass production
- … under investigation *cooling towers*

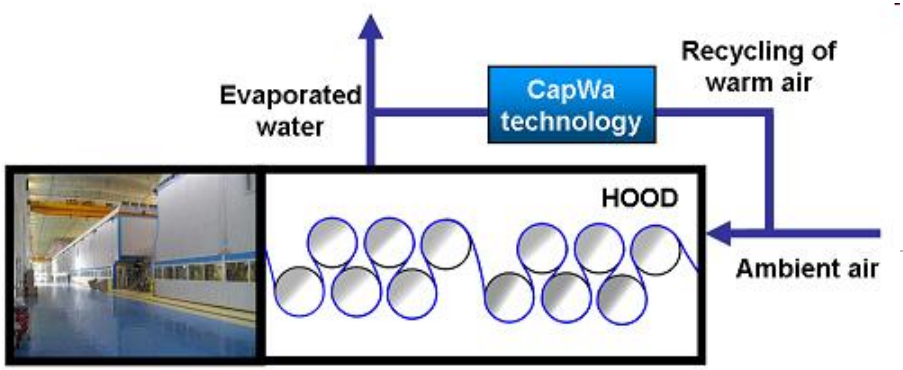
# Prototype membrane module installed at Sappi Nijmegen end 2011



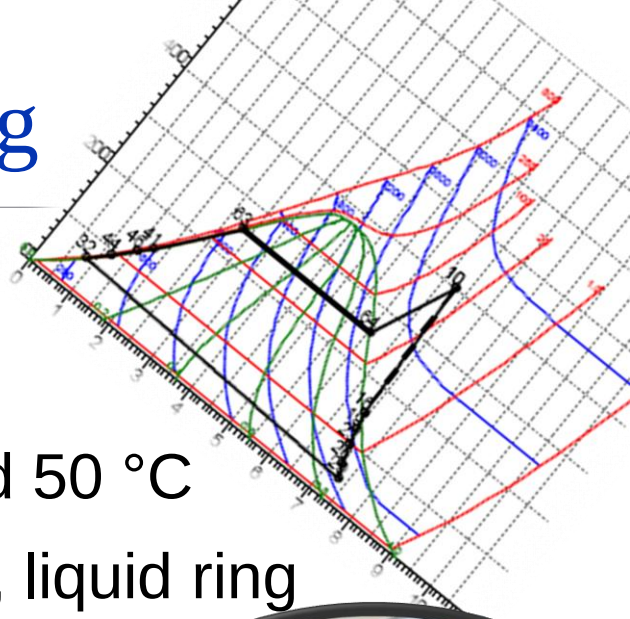
# CapWa – aim demonstrations

Aim EU funded international project (9 EU & 3 African partners):

- **Automation of hollow fibre membrane production – milestone reached!**
- Construct a module system for flue gases (coal and **gas fired plants**)
  - the system is capable of producing 0.1 $m^3$/h water
  - roughly the size of a 22 ft container – *based on a curtain shaped 1 stage separation system*
- A smaller system is envisaged for:
  - (forced draft wet) **cooling tower with Tunisian geothermal well**
  - ***under the hood of a paper/board factory***

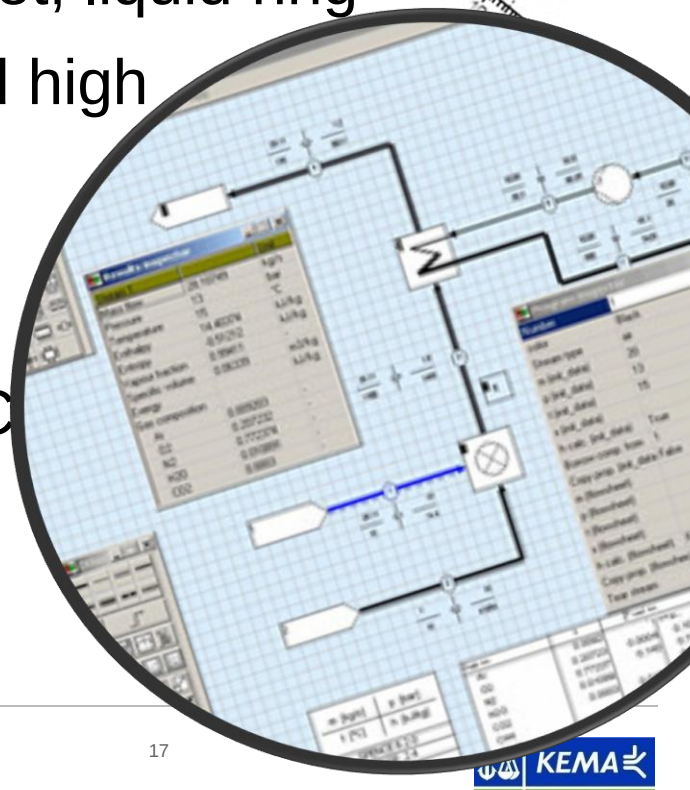


# Case summary, Energy modeling



- Number of cases:
  - 2 applications — coal, gas
  - 2 cooling temperatures — 20 °C and 50 °C
  - 2 vacuum methods — steam jet, liquid ring
  - 2 recoveries — low and high

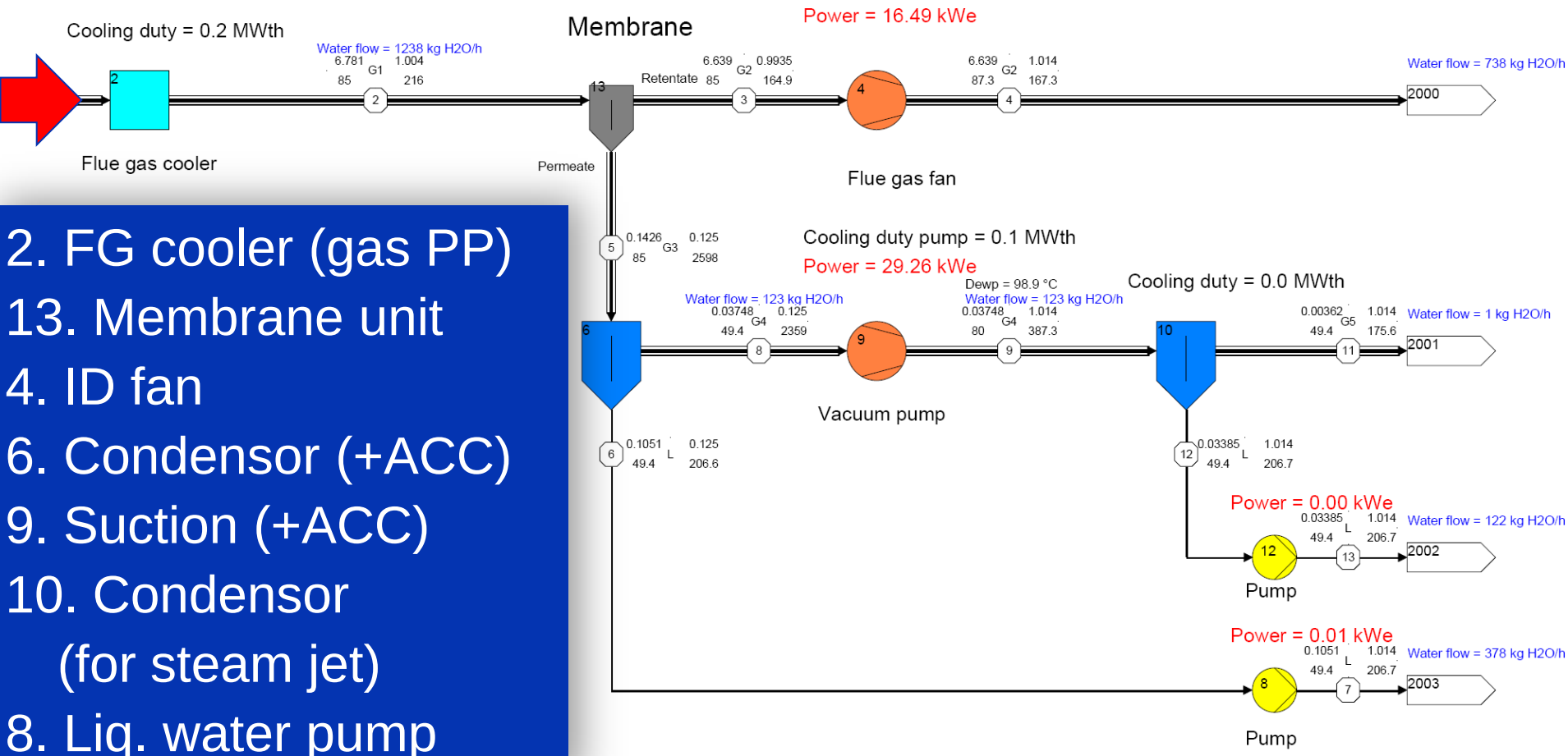
➔ 2 x 2 x 2 x 2 = **16 cases**



- Note: ‘worst case’ scenarios
  - Reference case: water cooling to 12 °C
- Model: KEMA’s proprietary SPENCE®

  process modelling software package

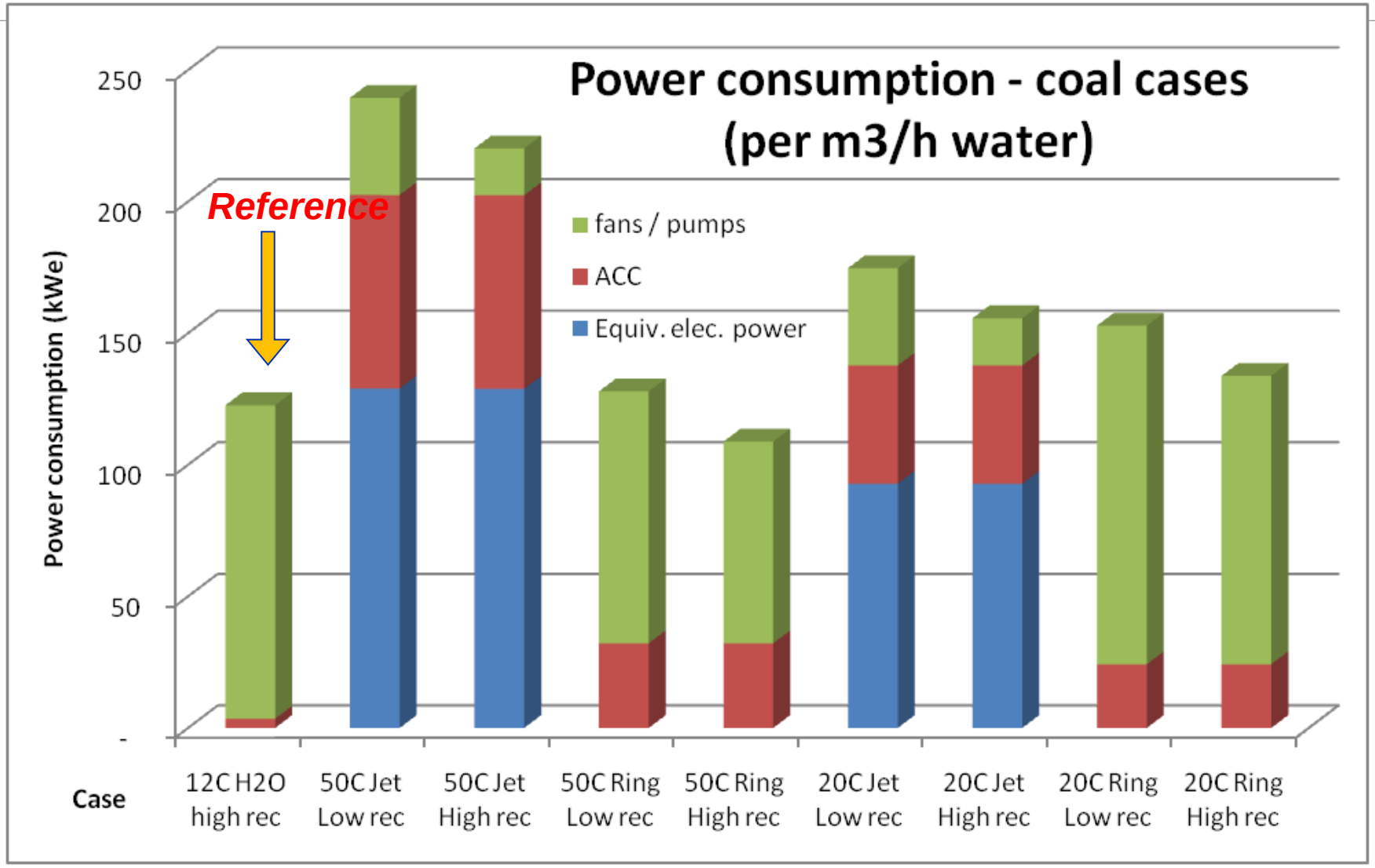
# Example SPENCE CapWa model scheme




2. FG cooler (gas PP)
13. Membrane unit
4. ID fan
6. Condensor (+ACC)
9. Suction (+ACC)
10. Condensor
    (for steam jet)
8. Liq. water pump

*Slide is not for reading every number, but for 'the big picture'*

# First results Coal cases – Trend is important..



# Further improvements in modeling work

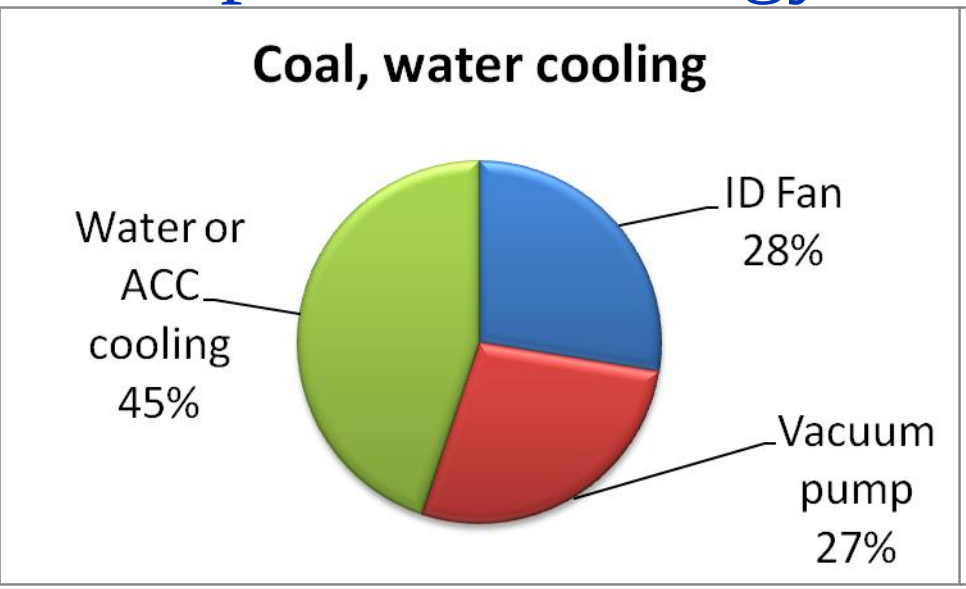
Coal cases: reference & ACC (50°C); Gas case: ACC (50°C )

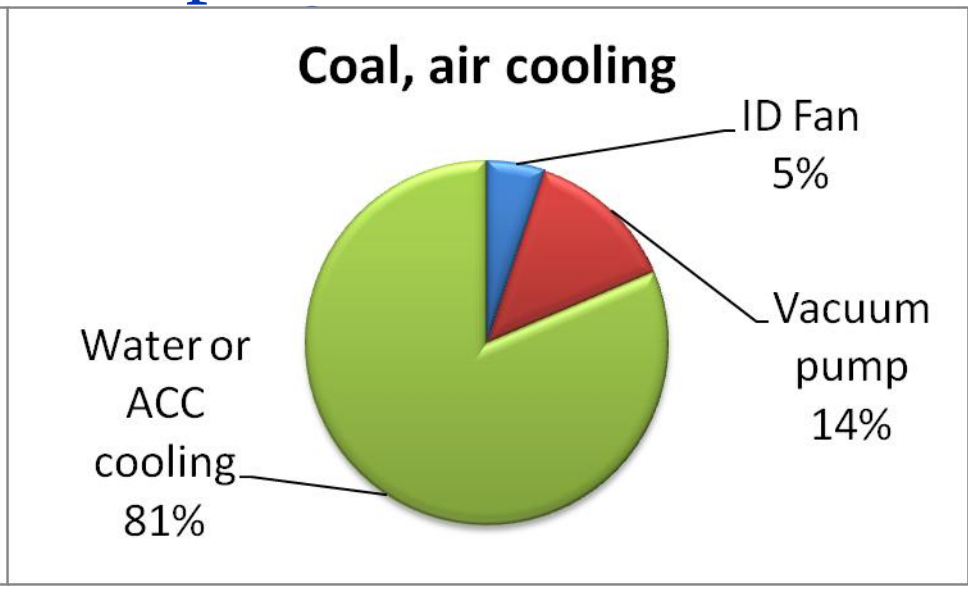
→ 3-step recompression of vacuum system

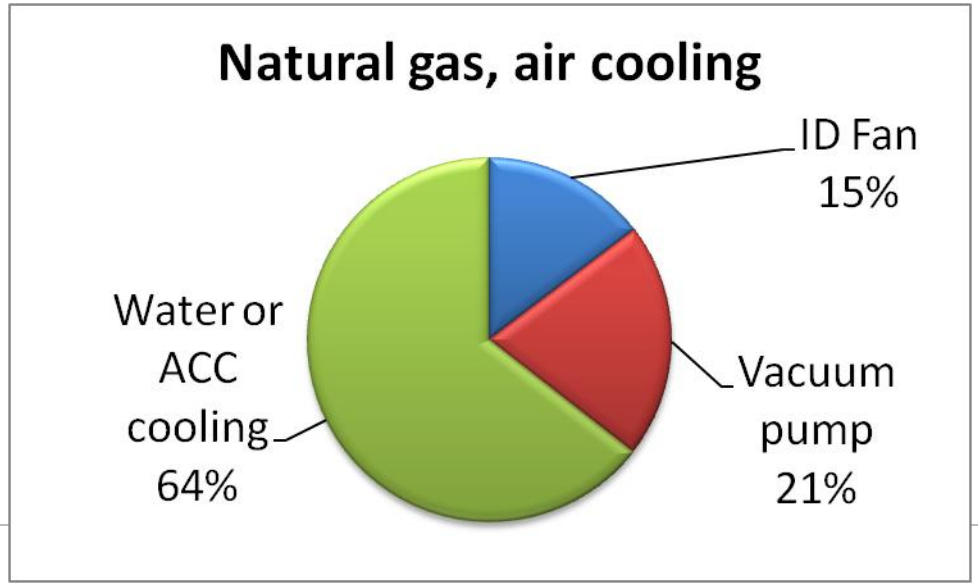
→ determined Δp for fibres placed in row with 20% water recovery

| Case | Velocity | Δp ID fan | Energy consumption | | |
|---|---|---|---|---|---|
| | | | Coal | | Natural gas |
| | | | water cooling | air cooling | air cooling |
| - | [m/s] | [mbar] | [kWh/m³] | [kWh/m³] | [kWh/m³] |
| Reference | - | 10.00 | 14.01 | 44.18 | 37.22 |
| 1 | 1.0 | 0.31 | 5.31 | 35.48 | 20.96 |
| 2 | 3.5 | 2.13 | 6.94 | 37.10 | 24.06 |
| 3 | 4.5 | 3.35 | 8.03 | 38.20 | 26.10 |

# Proporionate energy consumption



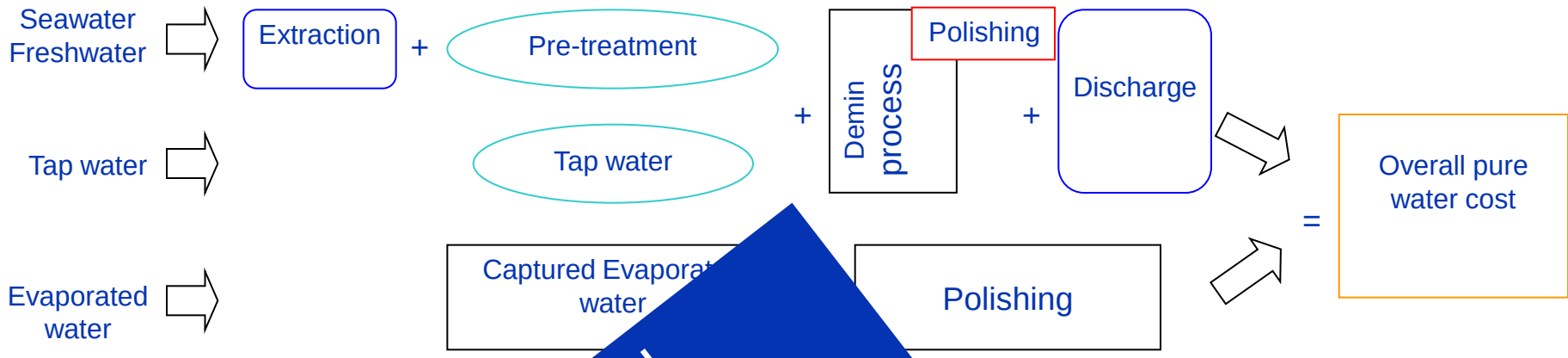



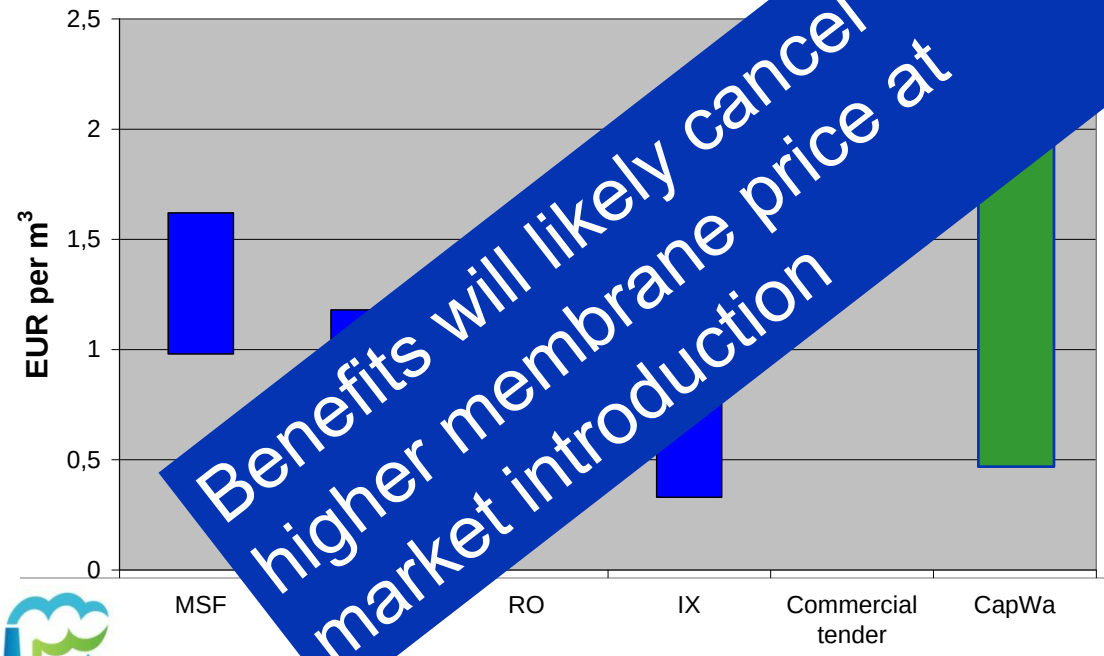
# Energy savings achievable for Coal units

| Description | Saved [kWe] | Capture rate | Remarks | Likelihood |
|---|---|---|---|---|
| No reheating of flue gas by low pressure steam | 3300 | >70% | Additional water loss at FGD due to high inlet temperatures | NO, hardly any cases like this, increase use of wet stack |
| Energy recovery before FGD - 3rd condensate preheater | 6960 | 70%? | High CapEx and OPEX for plastic / ceramic heat exchanger | NO, new power plants are not built this way due to poor payback time |
| Removal of reheaters in flue gas stream | 1200 | >30% | Efficiency increase of ID Fan | SOMETIMES, retrofitting needed and appropriate stack needed |
| Condensate preheating | 924 | >12% | In wet cold areas – access to cooling water, if accessible by piping | YES, if piping can be reached. Also savings combined with the savings described here |

Consumption: 7 kWh per $m^3$ ➔ for a 600 MW unit = 240 kWh

# Capture technology versus traditional demin technologies – basis 400 MW CF PP in Wet Region




Benefits will likely cancel higher membrane price at market introduction

Be aware: low membrane price of 20-50 EUR/m$^2$ used comparible with RO. However total cost does not include benefits like:

- flexibility - transport
- corrosion mitigation
- energy

# Benefits of this technology

- Technology aims to be competitive with current demin water production
- At least five business cases identified for end users:
  - **Water:** availability and raw water source quality
  - **Energy:** at least 0.2% for CF PP with cooling water
  - **Corrosion mitigation:** reduction of water condensation in stack
  - **Sustainability(1):** Large social impact in dry regions - preservation and conservation of natural resources
  - **plant flexibility:** ability to locate plant or enlarge existing asset in dry area's & save on transport without extra water consumption; no shut-downs due to recurring environmental catastrophes like algae bloom
- the membranes used to capture water also capture $CO_2$ (www.NanoGLOWA.com)

(1) Global media attention www.watercapture.eu or also http://ec.europa.eu/research/industrial_technologies/success-stories_en.html

# What does this technology enable? – Example China

1.There is an actual 600 MWe Coal fired power plant which can now operate

- additional profit EUR 14 MLN yearly(1)

  ➔Corresponds to demin water(1) value: 162 EUR/$m^3$

2. Expansion or New Build in WET or DRY region:

- Saving by placing plant in DRY region (on top of coal): EUR 3-5 MLN yearly versus coal transport to WET regions

  ➔True value demin water 18 EUR/$m^3$

  ➔congestion of rail infrastructure can result in higher value

Amount of plants with these issues are increasing worldwide due to stringent regulations and water shortages

(1) Assuming 4500 lost operation hours, a water need of 37 $m^3$/hr and a loss margin of EUR 10 per MWh (profit & effective use of CAPEX)

# What does the technology enable? Ex. Algae bloom

- Red Tide – algae bloom causes desal plant shut down
  - Temporarily no water available for power plant
  - Growing risk in Australia, M.E. and elsewhere
    - Occurrence Gulf of Oman about 1x a year

    ➔YES power plant shut downs occurred here

Implications 380 MWe Gas fired power plant

- Loss of income + penalties ±EUR 850.000 per day!

  ➔True value demin water(1): 82 EUR/$m^3$
- Industry accepts worst case – water truck: 10 EUR/$m^3$

  ➔Is equivalent to a plant shut due to Red Tide, once every 10 years....

(1) Assuming 8000 hours operation, E-price of EUR 50 per MWh and demin water need of 1 $m^3$/hr

Thank you for your attention

Ludwin.Daal@DNVKEMA.com

# 13 Dutch Regional Newspapers

*Provinciale Zeeuwse Courant*

## Drinkwater uit rook

ARNHEM – Kennisbedrijf K
nen uit de rookgassen var
hergebruiken, maar het w
het onderzoek samen uit
enkele energiebedrijven.
wordt met membranen, e
De techniek wordt in div
briek in Nederland.

BN DeStem.nl zaterdag 26 februari 2011

IO | economie

### Kema kan drinkwater maken uit rook

Kennisbedrijf Kema heeft een manier bedacht om water te winnen uit de rookgassen van fabrieksschoorstenen. De fabrikant kan dit water hergebruiken, maar het is ook prima geschikt om te drinken. Kema gaat de technologie op grote schaal testen.

LEEUWARDER COURANT

25 februari 2011 , pag. 2

## watraakt Water uit rook

Noordhollands Dagblad

## Drinkwater uit rook fabrieken

ARNHEM - Kennisbedrijf Kema heeft een manier bedacht om water te winnen uit de rookgassen van fabrieksschoorstenen. De fabrikant kan dit water hergebruiken, maar het water is ook prima geschikt om te drinken. Dankzij een miljoeninjectie vanuit Europa gaat Kema de technologie op grote schaal testen. Kema voerde het onderzoek samen uit met onderzoekers van de Universiteit Twente en enkele energiebedrijven. Het water dat normaal in de lucht verdwijnt, wordt met membranen, een soort minuscule filters, uit de rook getrokken. De hoeveelheid water die bij een gemiddelde energiecentrale opgevangen kan worden, komt overeen met het gemiddelde waterverbruik van ongeveer 3500 gezinnen.

# International websites

# Populair technical publications

MEMBRANEN HALEN WATER UIT KOLENROOK

Zuiver schoorsteenmat

11 MAART 2011 • DE INGENIEUR • 4

tops op te laden. (i

Technisch Weekblad, voorpag

Meer water uit rook

MEMBRAANTECHNOLOGIE Uit

een langlopend onderzoek

water van een derge

latie is voldoende

Water Recovery From Flue Gases

Ludwin Daal, KEMA, The Netherlands

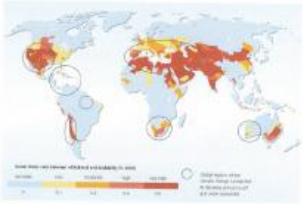
How the power industry can contribute to reducing the global water shortage

Dutch engineering consultant KEMA's investigation into recovering significant quantities of clean water from flue gas surpassed expectations. Ludwin Daal, process & cooling water consultant at KEMA, discusses the implications of this technological development on the global power industry.

One of the major challenges of this century is the provision of safe drinking water for a growing population. The shortage in water resources in arid areas requires the availability of more efficient and cheaper potable water production processes. In order to make drinking water out of groundwater, it is often sufficient to aerate and disinfect.

However, in large parts of the world, the use of groundwater from aquifers is not possible because of excessive use and global climate change that allow penetration of seawater into the aquifers. Population growth, not surprisingly, leads to greater pollution of aquifers, rendering the water quality unsuitable for drinking water purposes without excessive treatment. In some arid areas there is almost no water available or no water at all.

Interestingly, air can contain large quantities of water vapour. Based on statistics provided by UNESCO, it appears that annually



Water uit schoorsteen

erugwinnen

UTILITIES

nr. 02 - 2011

CapWa

# Feedback in China – July/Aug 2011

- Over 50 websites
  - Incl. top 8 media
  - 4 published