PROSPECTS OF WATERSAVING OPTIONS FOR COAL FIRED POWER PLANTS

Outcome of literature study & current EU developments

By: Ludwin Daal

Kind contribution: Eskom, ENEL, IEC & DNV GL
Acknowledgements: EC MATChING project GA 686031

VGB CHEMIE IM KRAFTWERK 2016

26./27. OKTOBER 2016 IN KARLSRUHE, GERMANY

Background – literature study

- Power industry (i.e. CF PP) consumes large quantities of water

  ➔ increase importance for water saving

- Global trend to adopt renewable energy resources

  ➔ current use of CF PP is still the main means of energy production

  – most affordable (and secure) ways to produce energy that will help fuel economic growth (APEC regions)

- Adoption of clean coal and environmentally friendly technologies ➔ further stress on water demand

Definitions:

Water use:	This term can be generally characterized as withdrawal, consumption and discharge
Water withdrawal:	Water **removed** from the ground or diverted from a surface water source—for example, an ocean, river, or lake—for use by the plant. This is a commonly used definition, although water *abstraction* would be more appropriate instead of withdrawal.
Water consumption:	The portion of the water withdrawn that is **no longer available** to be returned to a water source, such as when it has been evaporated, or bounded in by-products like waste water sludge or gypsum. Kenney et al., 2009 define it slightly different by stating that consumption is the amount of water that is evaporated, transpired, incorporated into products or crops, or otherwise removed from the immediate water environment.
Water discharge:	The **return** of water to its original source or a new source. Water discharge represents the difference between withdrawals and consumption. For many thermoelectric power plants, much of the water they withdraw is later discharged, although often at higher temperatures, for example cooling water.

Water pinch figures for China and USA

Description	Withdrawal (m^3/MW)	Consumption (m^3/MW)***	Sources
Once-through	86 – 138	0.39 – 0.95	USA: Macknick *et al*. 2012
	98	0.37	USA: Elcock & Kuiper, 2010
	80-100	0.23 – 0.29	?: Yang *et al*. 2011
		0.40 – 0.6	China: Liu, 2012
Cooling tower	2.3 – 3.8	1.87 - 2.6	USA: Macknick *et al*. 2012
	2.0	1.7	USA: Elcock & Kuiper, 2010
	2.3 – 2.6	1.95 – 2.1	?: Yang *et al*. 2011
		2.1 – 2.8	China: Liu, 2012
Pond	46 – 68	0.15 – 2.9	USA: Macknick *et al*. 2012
Dry-cooling	0.29 – 0.4	0.23 – 0.4	?: Yang *et al*. 2011
		0.6-0.8	China: Liu, 2012

To compare Dutch power station with once-through water pinch value (2008): 0.166 m^3 / MWh

Do the Dutch (water champions) do it right or do they measure with different parameters?

General water saving approaches

Main water consumers: cooling water (cooling tower), wet FGD and boiler make-up water.

Approaches to reduce water pinch:

- Dry cooling &/or re-localization along sea
- Wet vs Dry FGD
- Matching water quality for use
- Re-use of water and ZLD
- Cooling tower optimilization
- Membrane technologies

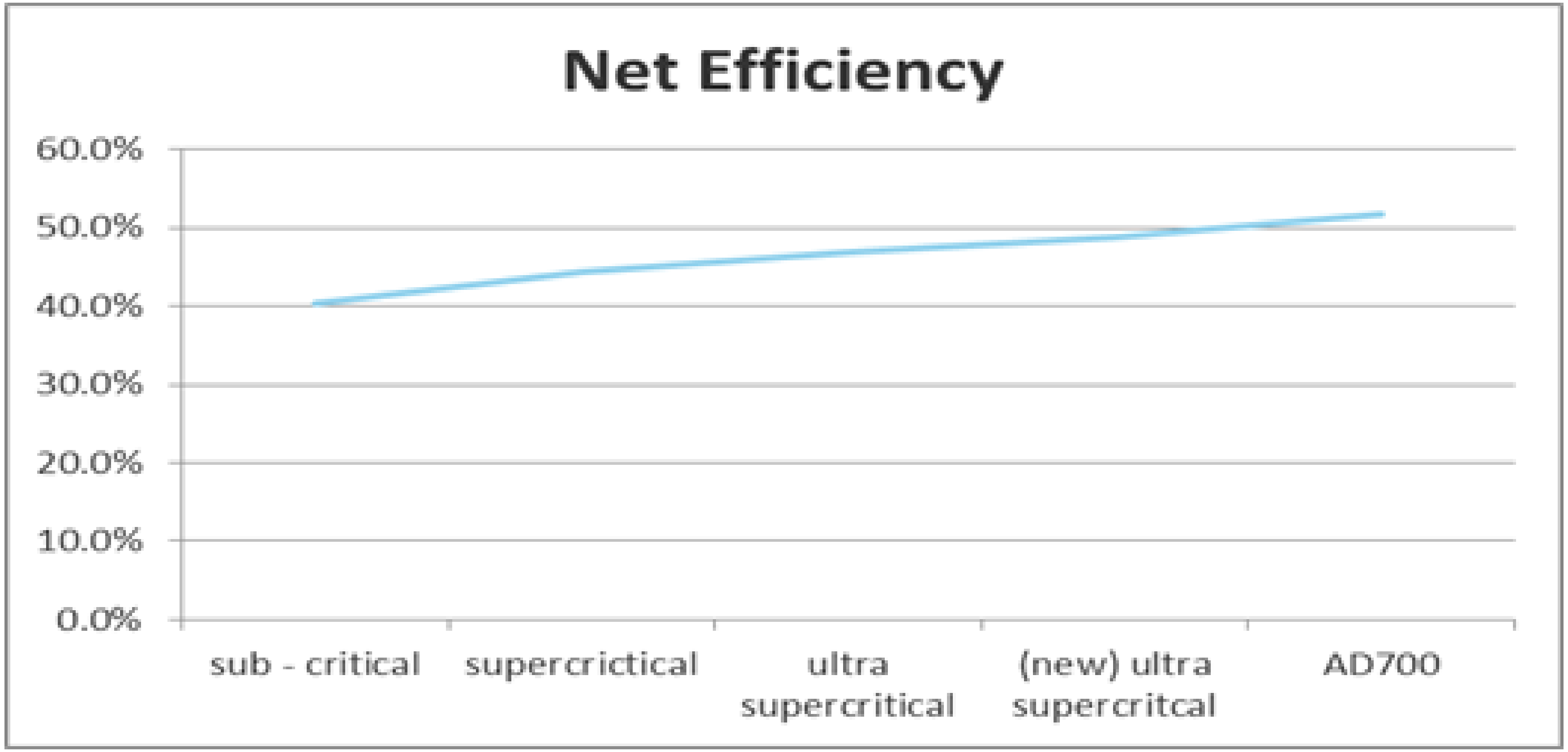
Developments:

- Climate change ➔ Clean coal techn.:
  - Wet FGD to be applied
  - Energy efficiency
  - Carbon capture

  ➔ Gas fired applications
- Water conservation policies to protect or allocate water resources

Clean coal anticipated energy efficiency improvements

Current plant efficiencies @ 43 – 46% ➔ potential improvements up to 59%



Courtesy of DNV GL

Energy penalty as a result of Dry Cooling

Courtesy of Eskom

Energy penalty: ±5.5%

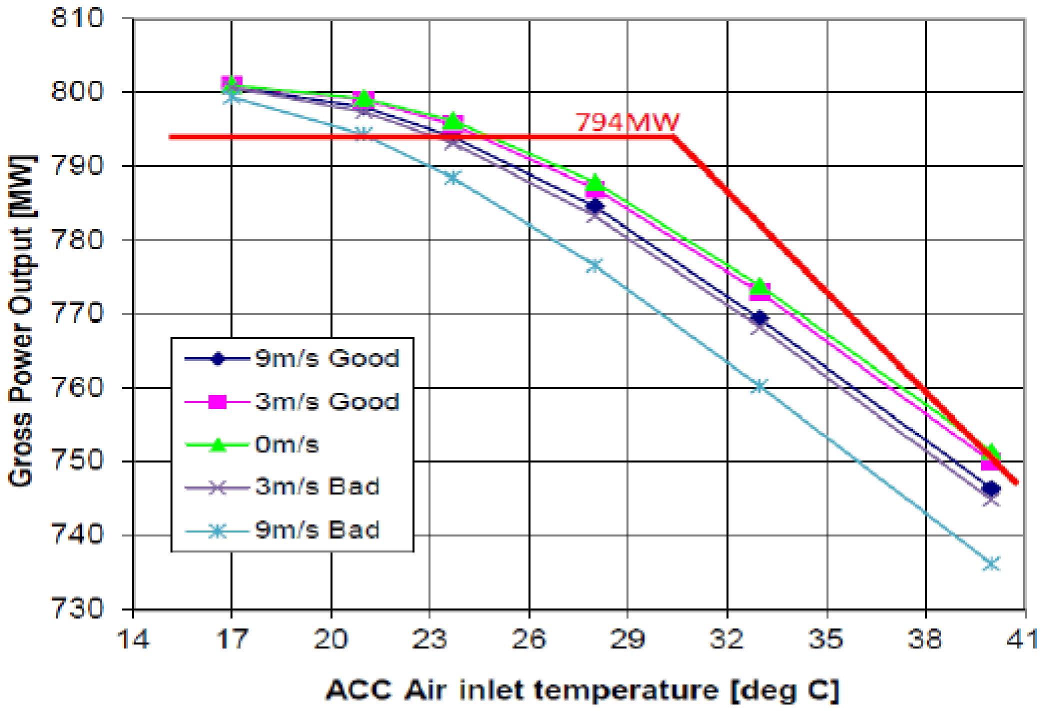


Exhibit 1: Medupi (design ambient 23.7°C, wind speed 9 m/s)

Energy penalty: ±3.5%

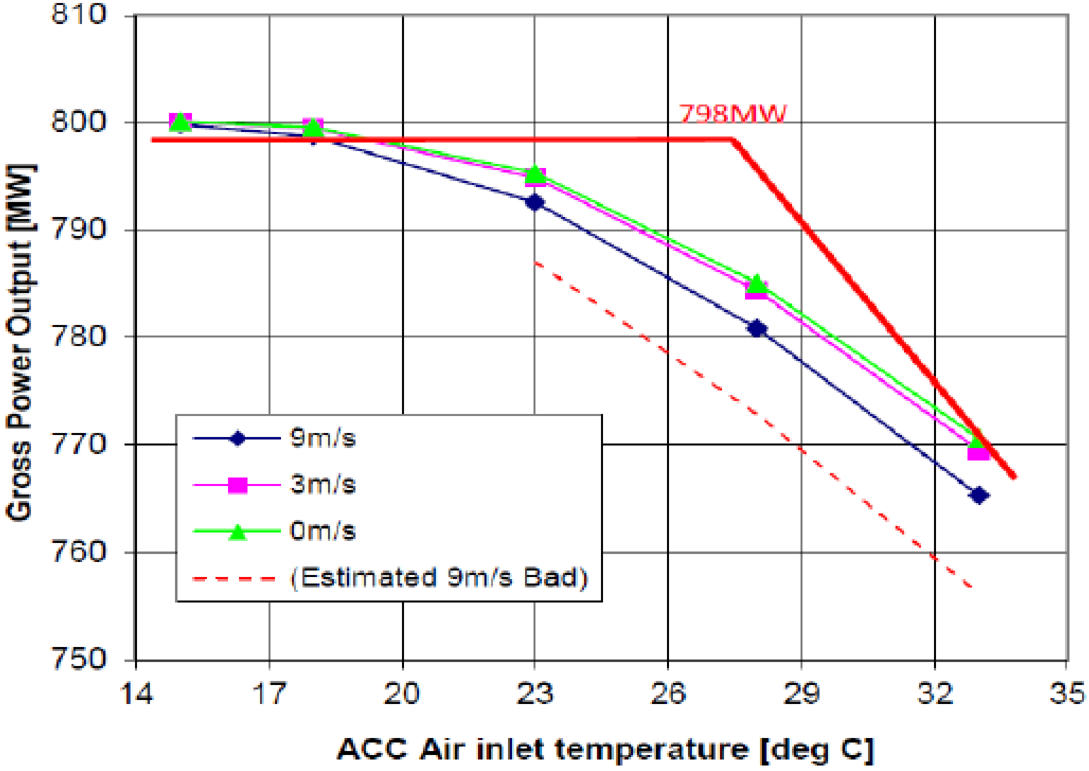


Exhibit 2: Kusile (design ambient 18C, wind speed 9 m/s)

Note: EPA study 2011 – states 7% penalty

Applying dry cooling ➔ extra attention W/S cycle

- (Alkaline) Oxygenated treatment: feedwater pH 9.8 ➔ aim control FAC
- Condensate polishing plant & stringent limit for make-up water ≤ 0.06 µS/cm
- Demineralization plant designed to reach these values:
  - Raw water source: river water (or mixture of storage waters)
  - RO and UF + multiple CEDI polishers

IX technology did not fit with raw water sources. Thus no comparison on cost made, likely more expensive. Demin plant operating as expected.

Dry cooling ➔ increase use of chemicals for conditioning W/S cycle & costs for energy (chemicals) for make-up production

Re-use of water (1 of 2)

- **Blow down water for (internal) re-use:** cooling tower blow down, treatment and re-use; Recycling of FGD waste water (MetCLEAN, ZLD, cold ZLD)
- **Operational improvements:** CT increase cycling rate; Anti-fouling and fouling release coatings (efficiency)
- **Other options for cooling:** cold underground storage; District heating
- **Third party waste water:** Paper industry secondary effluent; mine-water reuse; desalination plant boronic water ➔ applied in area's with ZLD or strong water conservation policies. ➔ *How does this affect chemical use to control process?*

Re-use (2 of 2)

- **Treated municipal waste water for**
  - Cooling tower make-up ➔ *What is effect of re-use water on cycling rate and thus make-up need?*
  - Wet FGD make-up ➔ *Similar question + how does it effect removal efficiency / composition of by-products?*
  - As raw water source for demin plant – example Eraring power plant Australia:
    - *Costs supplied but unclear; reliable performance?;* safety of personnel had to be addressed
    - To compare good experience at DOW Terneuzen - NED. *Why?*

Outcome ENEL literature search on ZLED systems

Utility	Power unit(s)	Location	Supplier	First operation	Process	State of operation
Enel	2,640 MW	Brindisi, Italy	Aquatech	2009	CT (Chemical Treatment) +BC (Brine Connector) +CRY (Crystallizer)	Running
Enel	960 MW	Fusina, Italy	Aquatech	2009	CT+BC+CRY	Lay-up
Enel	1,980 MW	Torrenord, Italy	Aquatech	2009	CT+BC+CRY	Running
Enel	600 MW	La Spezia, Italy	Aquatech	2008	CT+BC+CRY	Running
Enel	240 MW	Sulcis, Italy	Aquatech	2009	CT+BC+CRY	Running[1]
A2A	336 MW	Monfalcone, Italy	Veolia - HDD	2008	CT+BC+CRY	Running
Kansas City	850 MW	Iatan, USA	Aquatech	2009	BC+AS (Fly Ash Stabilizer)	Running
Vattenfall	410 MW	Vodskov, Denmark	Anhydro A/S	2005	SD (Spray Dryer)	Running
DoE	Pilot[2]	USA	GE-RCC	1995	BC	Out of Service
Springfield City	440 MW	Dallman, USA	Aquatech	2007	BC+SD	Out of Service
Transalta	1,376 MW	Washington, USA	Swenson	NA	CT+CRY	Out of Service
Matsushima	1,000 MW	West coast Japan	GE-RCC	1996	BC	Out of Service

Note: for Coal fired power plants with wet FGD

Different views on ZL(E)D

- ENEL: not water savings but limiting discharge (control chemical variability in the waste water composition)
- Eskom: dump brine (RO, regeneration) on ash dump sites. Purpose for dust suppression & irrigation of rehabilitation plant life for stabilization of the dumps. Eskom coal: ash content up to 45%. However 2021 co-disposal to be prohibited
- IEC adopted ZLD for cooling tower blow down; here make-up is treated municipal waste water

➔ abandoned ZLD as it was difficult to operate and expensive

➔ focus on use of boronic water from Desalination plant (largest ones in the world) as FGD make-up

ZL(E)D for gas fired power plants

Large number of articles describe in detail **ZL(E)D and re-use for Gas Fired Power Plants**

- ZL(E)D more mature in GF PP and also more applied
- GF PP optimized to use less water, thus small waste water streams to be treated with less complex chemistry composition
- Also GF PP have excess heat which can be utilized by crystallizers and brine concentrators
- GF PP can profit more on hot days when e-prices are high and water scarce. Assets are thus more compelled to make investments necessary for ZL(E)D

J. Martino interview with NV Energy Generation Executive Dariusz Rekowski –in Las Vegas:

"*The utility's plans to retire its coal-fired generation units will help the company reduce its water usage even more, Rekowski said, and keeps the company poised to not only preserve water resources but stay ahead of EPA regulations regarding water usage and emissions.*"

The Consortium

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

www.matching-project.eu

SWECO

Consortium: 4 Utilities, 5 Technology Providers, 6 Research institute & SWECO.

Partners from 6 EU Counties: 4 from Italy, 4 Belgium,3 Spain,3 Netherlands & 1 Denmark

User Group:
>10 additional
Global partners

R&D activities - MATChING

MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

SWECO

42 month project
Started: March 2016
Budget: 11.8 MEUR

RECOVER EVAPORATION

Water recovery from plume through membrane condenser

EVAPORATION

REDUCE EVAPORATION

Advanced Hybrid Systems

USE ALTERNATIVE WATER SOURCES

INTAKE WATER

Novel membrane based technologies for intake water pretreatment

Special materials / coatings to handle « dirty » fluids

CONDENSER

ENHANCE HEAT TRANSFER & EQUIPMENT ROBUSTNESS

Coatings / surface texturing to promote drop-wise condensation

Special materials / coatings to handle « dirty » fluids

RECOVER BLOWDOWN

Novel membrane based technologies for blowdown recovery

BLOWDOWN WATER

REDUCE BLOWDOWN

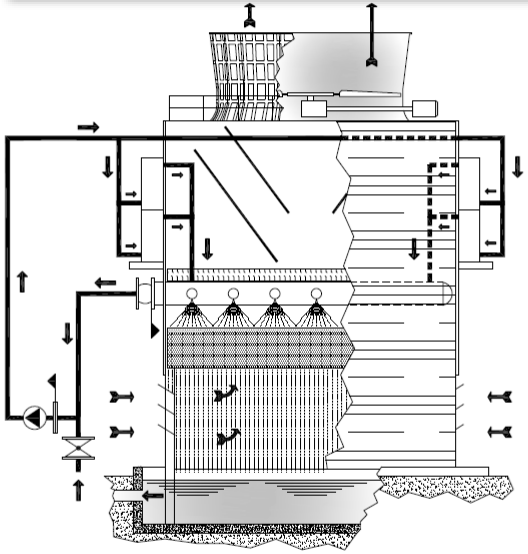
Special materials / coatings to handle « dirty » fluids in CT and condenser

Novel membrane based technologies to enhance intake water quality

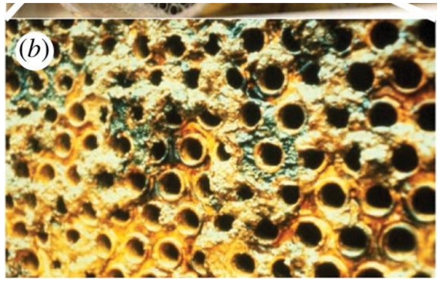
Novel circulating water conditioning systems

Technologies

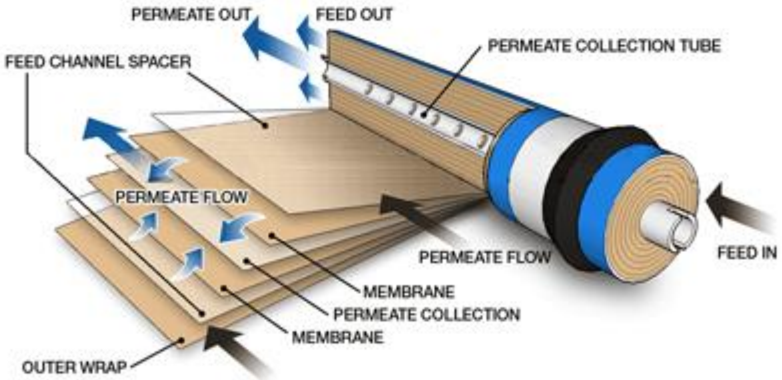
Hybrid CT for Geothermal application

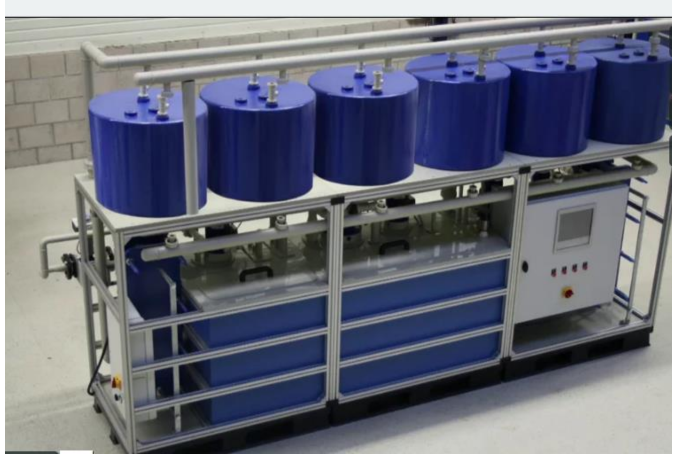


Materials for steam condenser& heat exchangers



Water treatment systems





Focus on water treatment

MATChING
MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Cooling Section

RECOVER EVAPORATE

EVAPORATION

Water recovery from

Membrane Condensor

ALTERNATIVE WATER SOURCES

INTAKE WATER

CONDENSER

Novel membrane based technologies for pretreatment

Pressure driven, MD, CDI

Recirculating water

RECOVER BLOWDOWN

BLOWDOWN WATER

REDUCE BLOWDOWN

Novel membrane based technologies for blowdown recovery

MD

Novel Circulating water conditioning systems

VPT

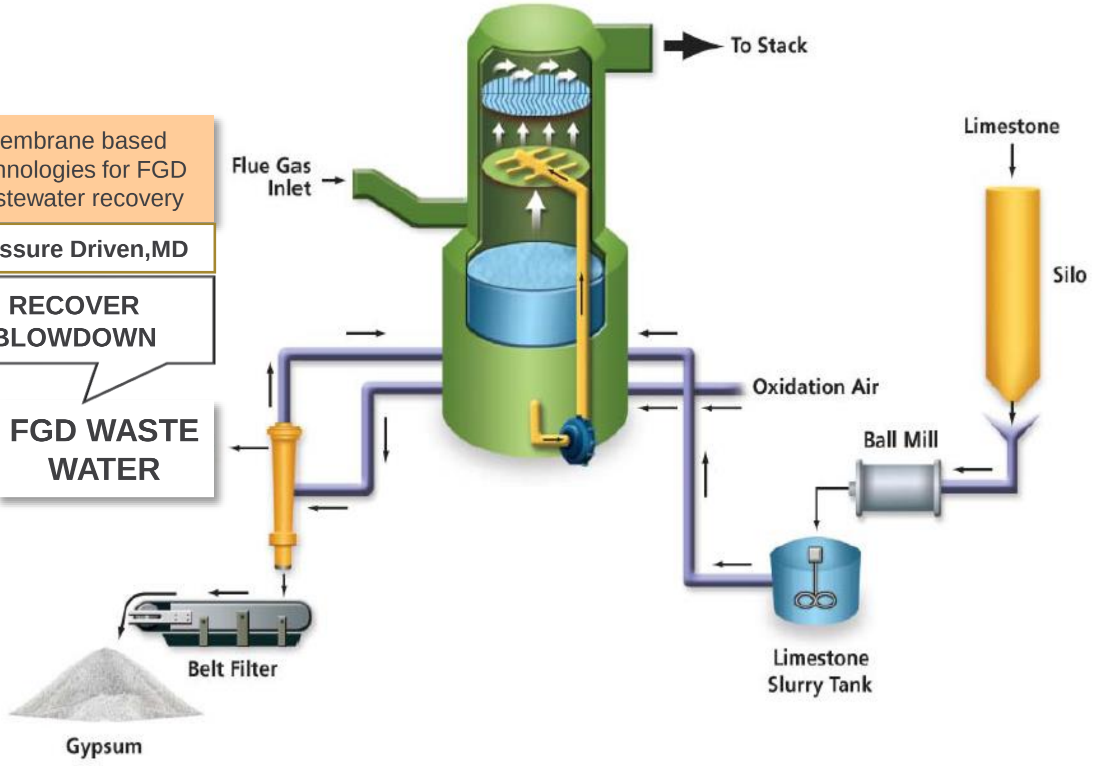
Flue Gas Treatment Section

Membrane based technologies for FGD wastewater recovery

Pressure Driven,MD

RECOVER BLOWDOWN

FGD WASTE WATER



Current developments, conclusions & outlook(?)

- Power plant operators from different countries can learn from each other
  - i.e. Dutch re-use strategies – matching water quality
  - i.e. USA – use of ponds
- Energy efficiency and dry cooling is best approach for coal fired power stations to reduce foot print, however
  - Location of power stations along the coast, energy efficiency improved + optimal use of water (consumption) *– But are we doing enough?*
  - Gas fired power stations with ZLED can also be preferred (in hot regions)
- In Europe there is an overcapacity: less efficient use of / mothballing of (gas) fired power plants
  ➔ Overall Dutch water pinch increased as a result
- Investigating different water re-use technologies
  - What is actual and real cost
  - Chemistry control very challenging
  - What is actual performance and effects on other matters (coc of CT, byproducts FGD)

Current developments, conclusions & outlook(?)

- CCS for CF PP has a clear increase in water pinch, fortunately water saving technologies under development – co-capture membranes
- Increase use of renewables will result in net decrease of water pinch
- Governmental policies
  ➔i.e. taxes on water consumption: not easily accepted *– or will it still come? In the 90's we (NED) anticipated a doubling of water price.*
  Only Israel and Australia experienced an increase in water prices as a result of governmental policies, ➔ adoption of water conservation practices @ CF PP
  ➔Countries with CF PP and (mothballed) GF PP. If water conservation policies are adopted, what is likelihood of ZLED adoption or a (revival) of GF PP ➔ and who is to pay?
  ➔Do we need policies to welcome adoption of innovative water saving technologies?

Questions?

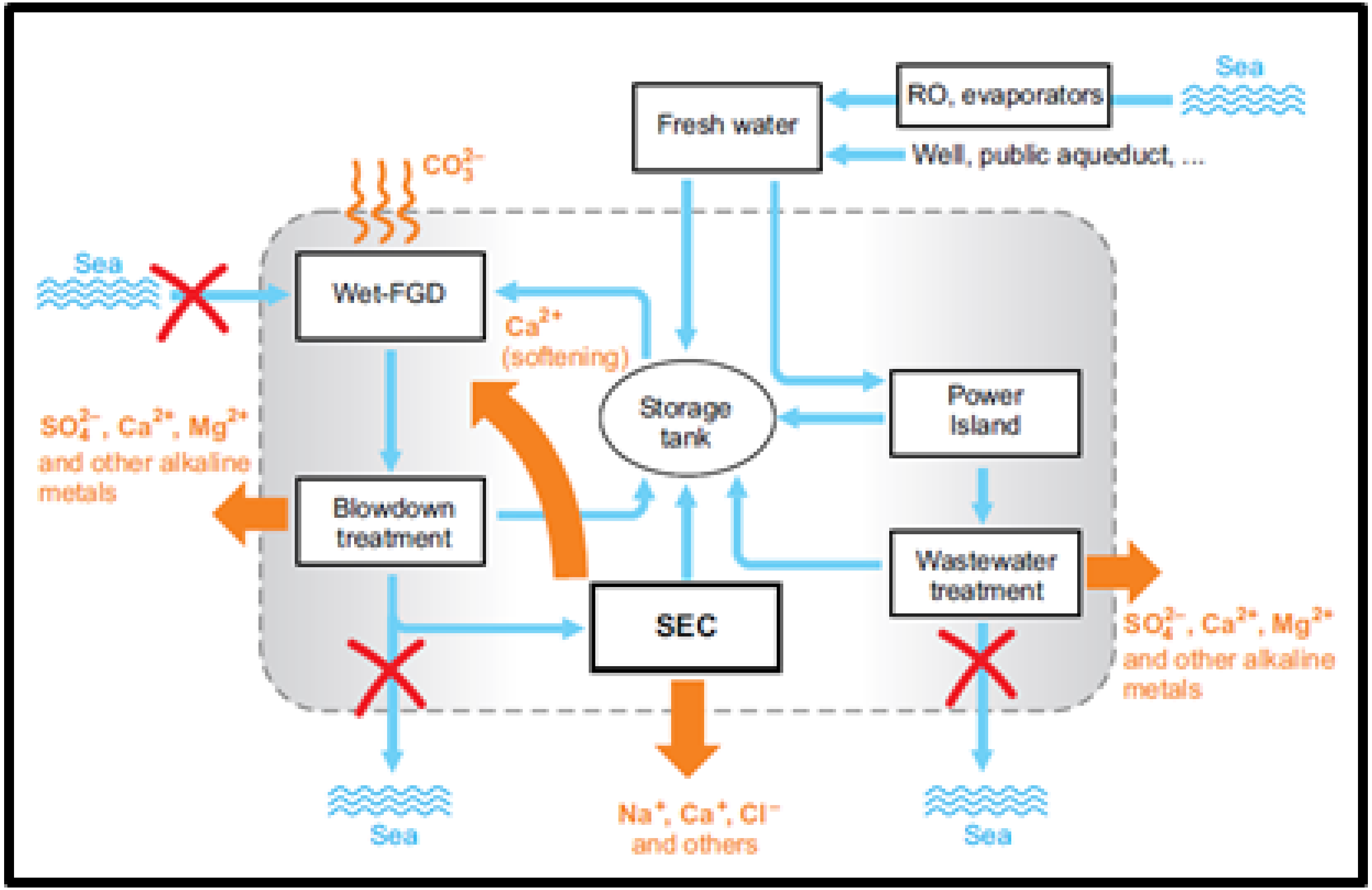
SWECO

Contact:
Ludwin Daal
Sr. Consultant

Ludwin.Daal@sweco.nl
Phone: +31 6 15 06 33 40 15

LinkedIN
www.sweco.nl

ENEL's ZLED approach



SEC: Softening Evaporation and Crystallisation

Water consumption / withdrawal when applying CCS

Water pinch values in m^3/MWh

Applying cooling tower	General power station*	Power station with CCS	IGCC	IGCC with CCS
Withdrawal	2.3 – 3.8	4.3 – 5	1.5	2.4
Consumption	1.9 – 2.6	3.2 – 3.5	1.4	2.0

Source: Water consumption and withdrawal comparison with carbon capture in m3/MW (Macknick et al., 2012)