Industrial Water Recycling
- Challenges and Limitations

Department of Environmental Technology

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Wastewater = Waste

Yes!

1. Wastewater contains recalcitrant and hazardous substances even after treatment

   → heavy metals, salts, COD composition?
2. Generates costs
3. Generates energy consumption


Ozone generator

1. Wastewater contains recalcitrant and hazardous substances even after treatment

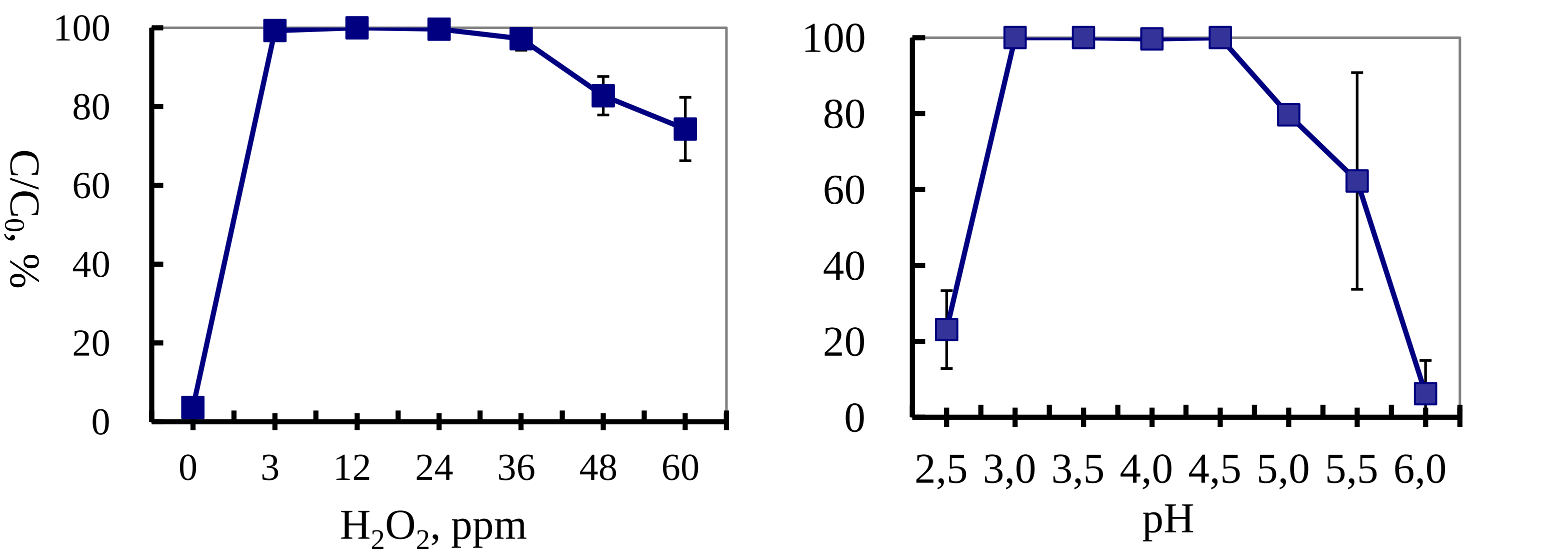
Removal by oxidation, adsorption, membrane filtration or advanced biological processes

Example: White Rot Fungi

- The primary decomposer of lignin in the ecosystem.
  - Lignin is hardly biodegradable by other microorganisms.
- Unique lignin degrading enzymes
  - lignin peroxidase, manganese peroxidase, laccase.
- Degradation of recalcitrant pollutants.
  - PAH, chlorophenols, dyes, pesticides and some emerging pollutants like diclofenac, ibuprofen, EE2, etc.
- The enzymes can be produced under nutrient limited conditions

Example: White Rot Fungi

– Diclofenac as a pollutant example
  - A widely detected PhAC. Low removal in STP.
  - Complete elimination by LiP (acidic condition, proper H_2O_2)



Wastewater = Waste

2. Generates costs

Example Brewery:

4 hL fresh water/hL SB incl. 2.5 hL wastewater/hL

Production capacity: 1 Mio hL/a → 250,000 m^3 wastewater/a

Water purchase and wastewater treatment costs in Germany:

4 €/m^3 → **1 Mio. €/a**

3. Generates energy consumption

Carbon concentration: 1.5 g DOC/L → 375 t DOC/a

Aerobic treatment:

500 t/a O_2 for aeration → 2 kg O_2/kWh

→ **250,000 kWh/a** (3% of brewery consumption)

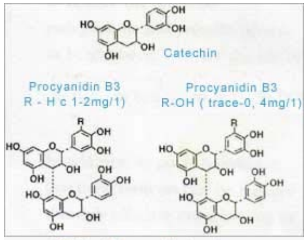
Wastewater = Waste

No!

Wastewater contains

1. Water

2. Valuables



Critical flavanoid structures adsorbea PVPP

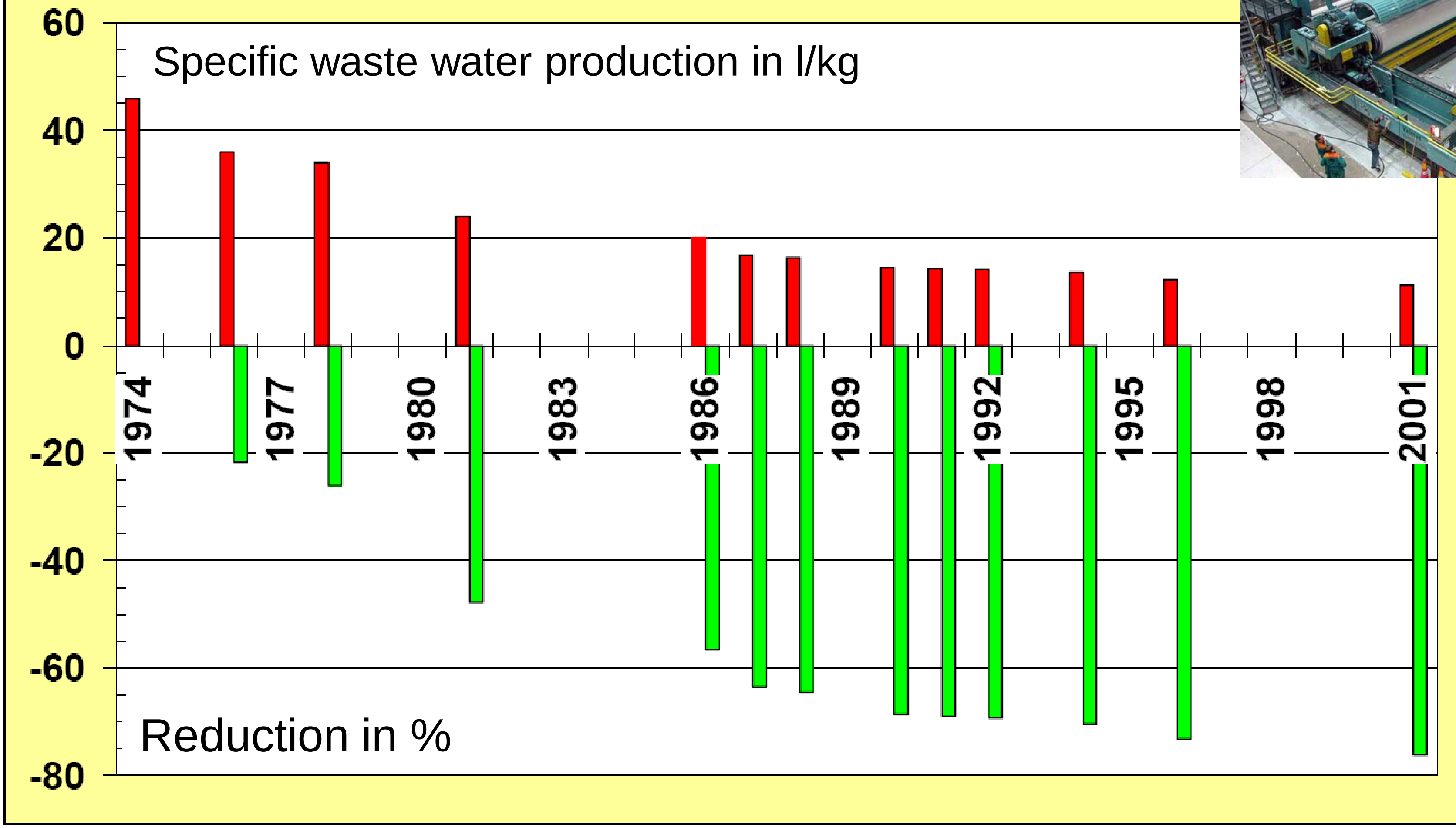
3. Chemical Energy & Heat

1. Water

- Reclaimed water volume about 2.2 billion m^3/a (2001/2002, Worldbank)
- Israel, Australia and Tunisia will use reclaimed water to satisfy 25, 11 and 10 % of their water demand (Lazarova et al.)
- Middle East countries are planning to reuse 50 to 70 % of waste water

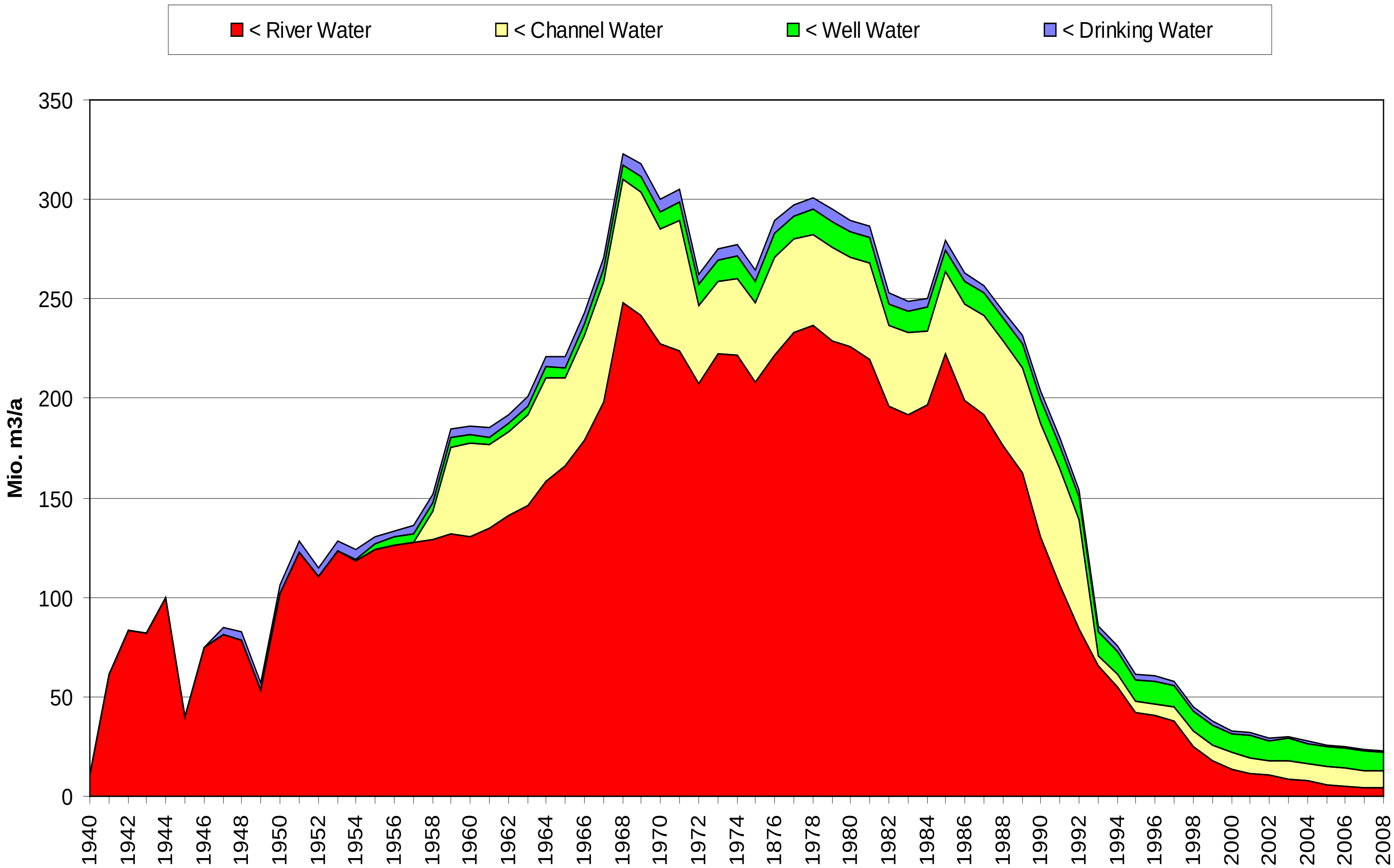
- And Industry?

The United Nations World Water Development Report; www.unesco.org



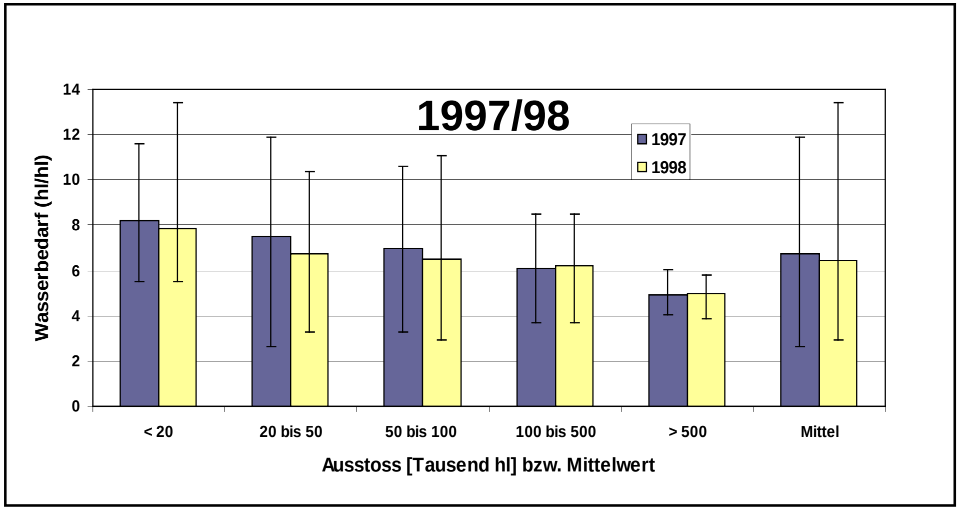
Development of the water use in German paper industry (Pfaff, Dietz, Götz)

Water Use of Chemical Industry Park Marl, Germany

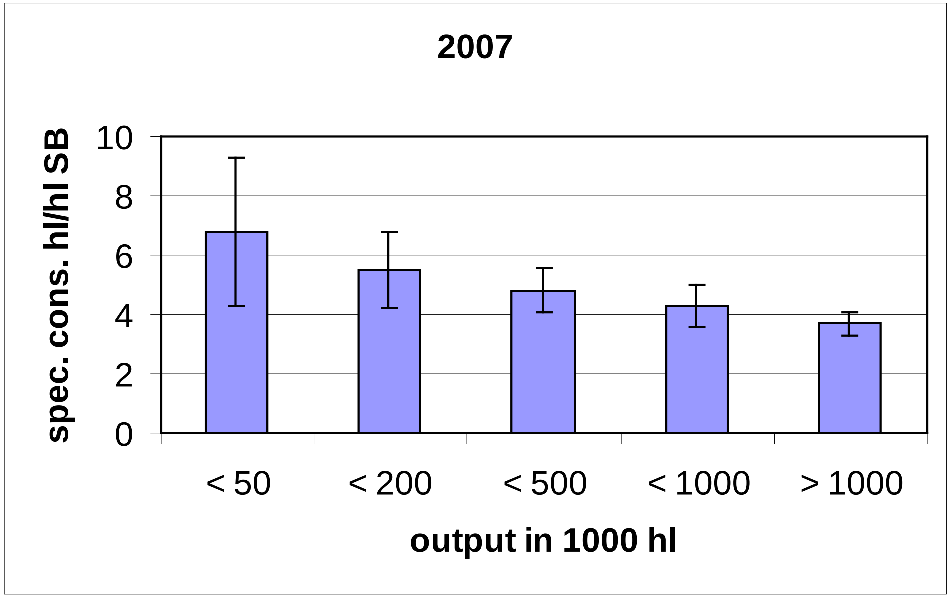


by courtesy of Dr. Bernd Guenzel, Infracor GmbH, Marl, Germany

Development of water use in breweries



Source: Schu, Stolz, Jordan: Brauwelt Nr. 26 (1999)



✓ approx. 1 hl/hl SB reduction for large breweries

2.5 hl/hl discharged

Data: Nieroda: Deutscher Brauer Bund e.V, Evaluation 2007, 94 Breweries

www.goldcoast.qld.gov.au/attachment/edmp/is3_fosters.pdf

Industrial Water recycling

Yatala Brewery, Australia

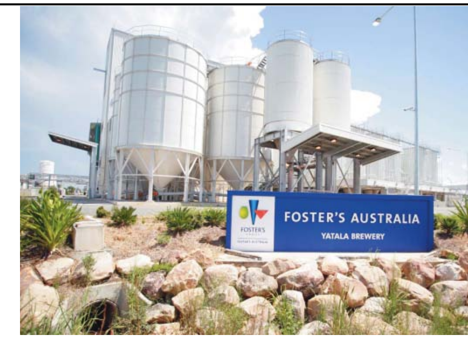
– Reuse for non-product related applications

external keg washing, washdown hoses, cooling towers and boilers, toilet flushing, vacuum pumps

– 2.2 hL water used/hL SB beer www.fosters.com.au/about/water.htm and http://www.sirfrt.com.au/sirf_pages/download.php?id=126

– 0.9 hL wastewater/hL SB beer http://www.sirfrt.com.au/sirf_pages/download.php?id=126

→ **Reduction of water use by approx. 45 %**



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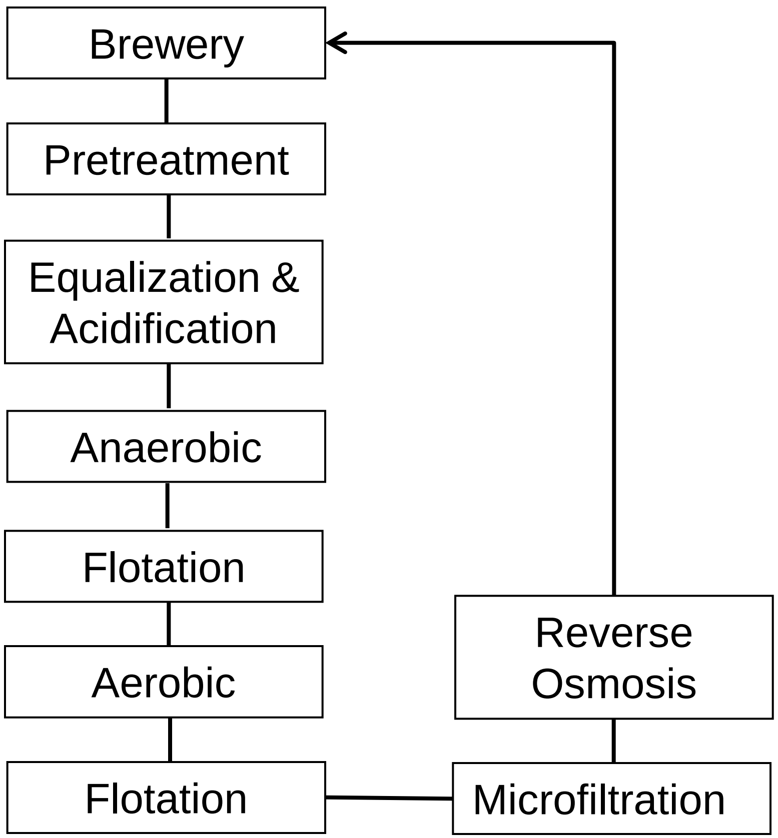
Industrial Water recycling

Yatala Brewery, Australia



4,000 m^3/d Reverse Osmosis

www.osmoflo.com/project/15/Polishing-of-process-wastewater-enabling-reuse.aspx

Industrial Water recycling

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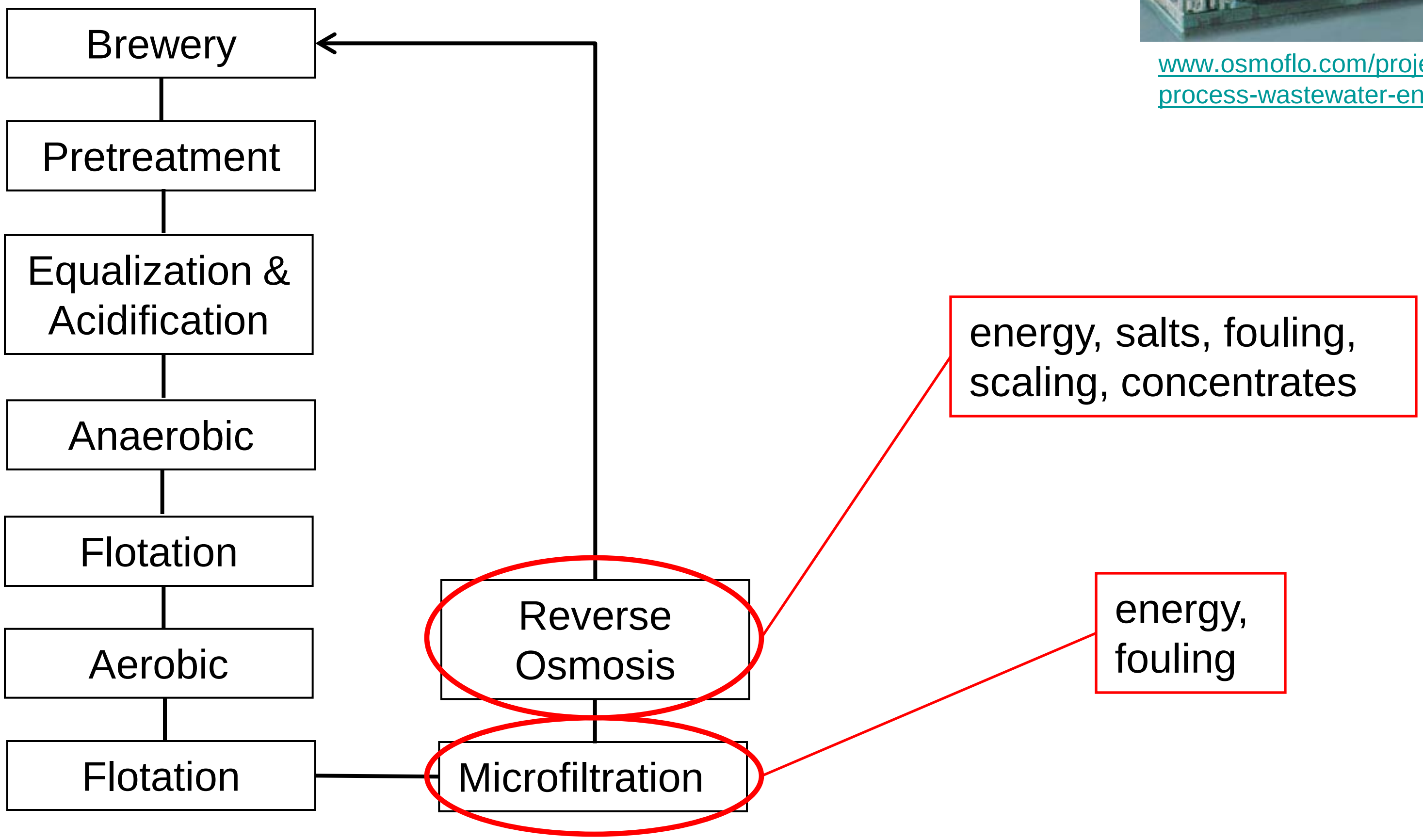


Industrial Water recycling

www.osmoflo.com/project/15/Polishing-of-process-wastewater-enabling-reuse.aspx

- → Water recycling is feasible even in sensitive industries
- → Membrane processes are applicable for water recycling, but disadvantages have to be considered
- → Production integrated technologies will increase the efficiency of water recycling

2. Valuables

Olive Mill Wastewater, Tunisia 2005

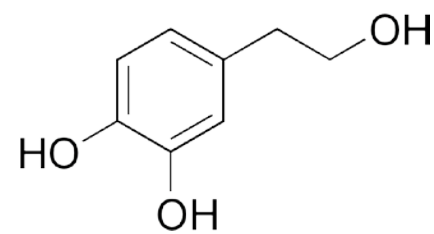
Olive Mill Wastewater (OMW)

Reduced anaerobic degradability due to high concentration of polyphenols:

e.g. 1-3.5 kg Hydroxytyrosol per m^3 Wastewater

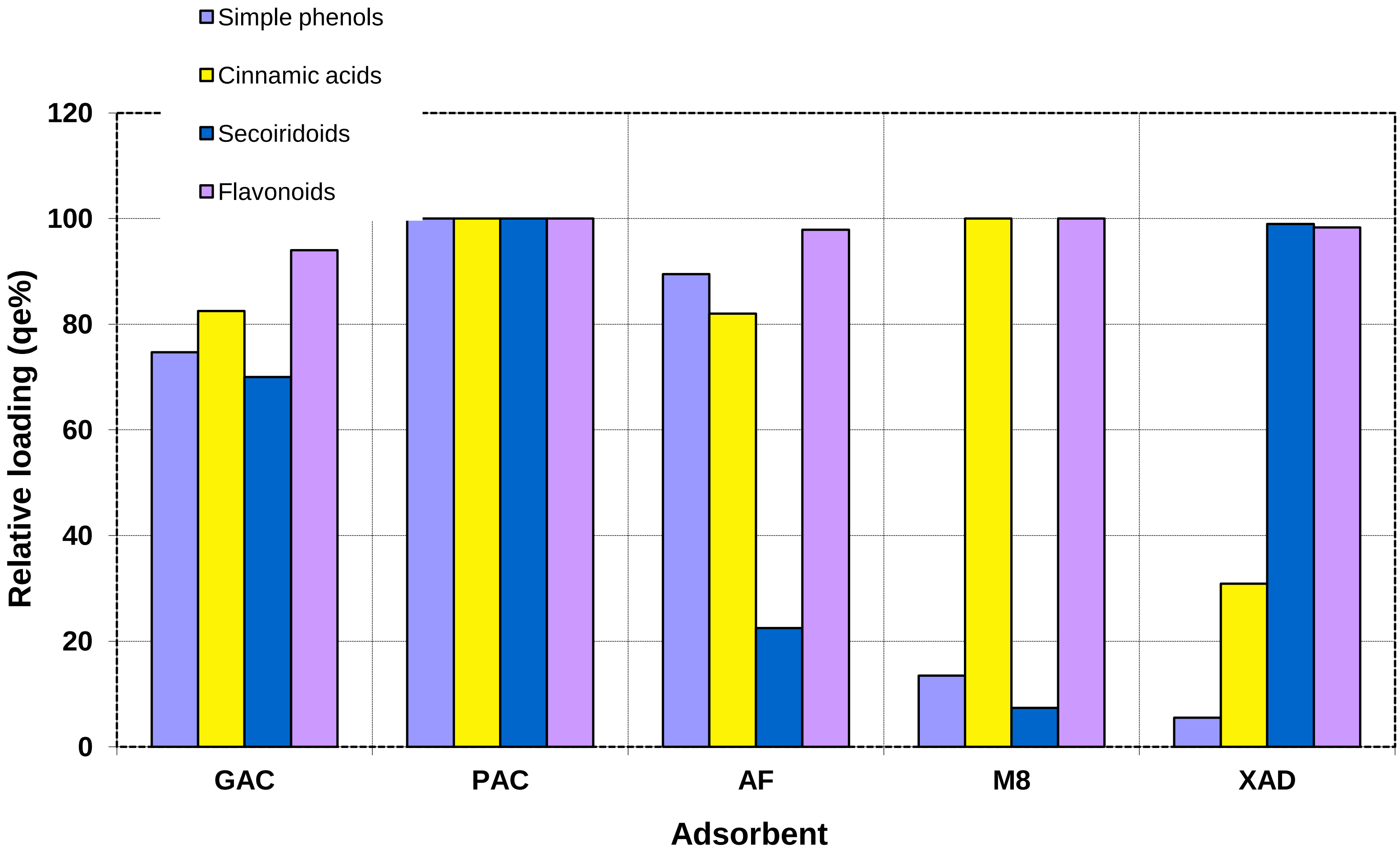
Price approx. 50 € per g

→ Selective separation of polyphenols



Wastewater = Valuables

Polyphenol uptake by different sorption materials



GAC: granular activated carbon
PAC: powdered activated carbon
AF, M8, XAD: resins

→ Selective uptake is possible but requires multi-step treatment

3. Heat & Energy

– Chemical energy (brewery effluent)

2.5 hL wastewater/hL SB → 250,000 m^3/a

DOC = 1.5 g/L → 375 t DOC/a

Anaerobic treatment

Removal eff.: 80%, Biogas production: approx. 0.75 kWh/kg $DOC_{elim.}$

225,000 kWh/a ≈ 21,000 L fuel oil/a (**1.2%** of brewery consumption)

+ energy savings against aerobic processes

→ **Anaerobic treatment recovers energy from wastewater and saves energy, but only minor overall energy benefit**

Under development: e.g. H_2 production, Algae, Bio-Fuelcell

3. Heat & Energy

– Heat energy (brewery effluent)

1 Mio. hL sales beer (SB) per year

4 hL fresh water/hL SB

2.5 hL wastewater/hL SB → 250,000 m^3/a

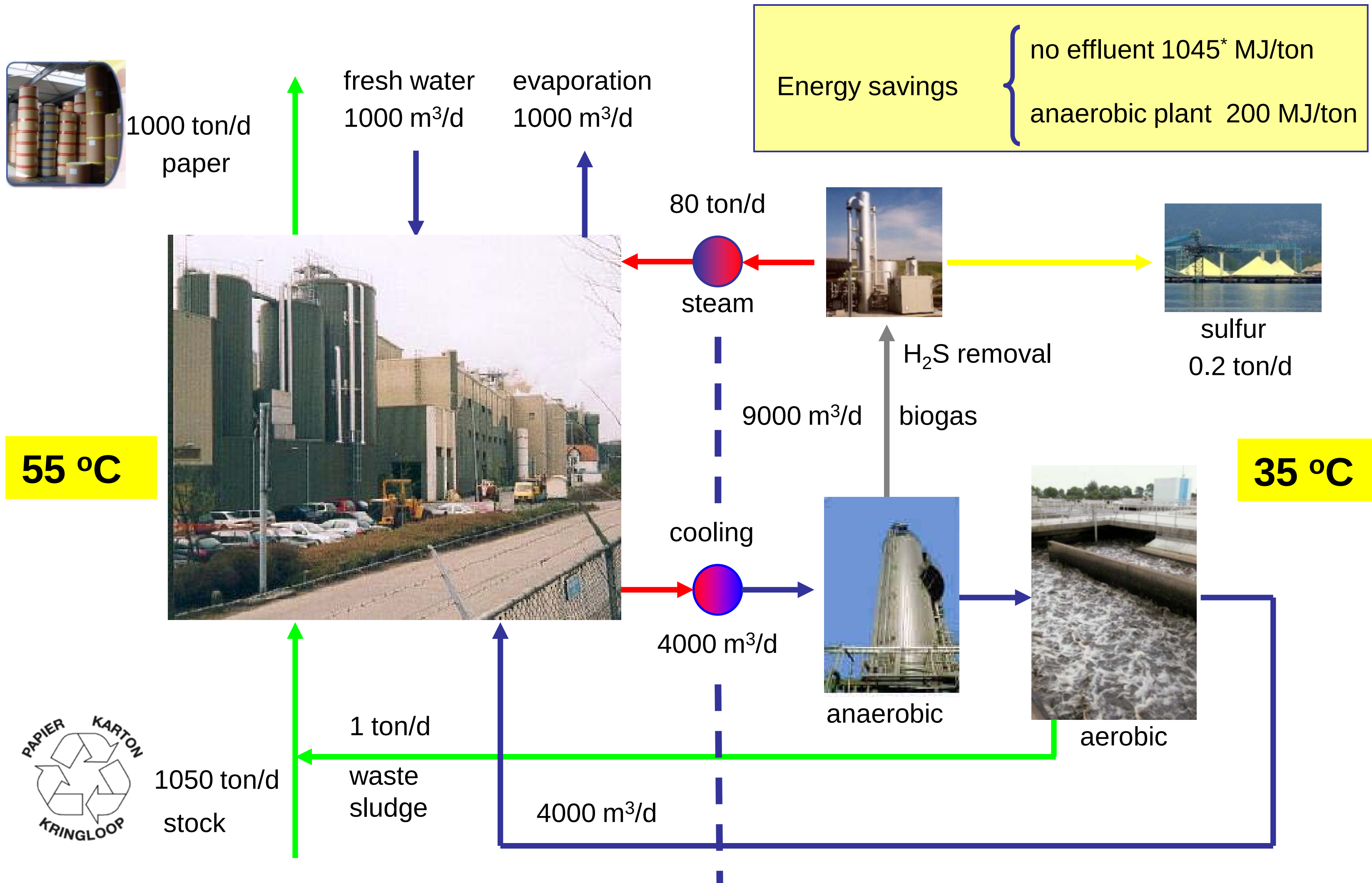
Well water ≈ 12°C → wastewater ≈ 30 °C

ΔQ = 5.2 Mio. kWh/a ≈ 0.5 Mio. L fuel oil/a (**28 %** brewery consumption)

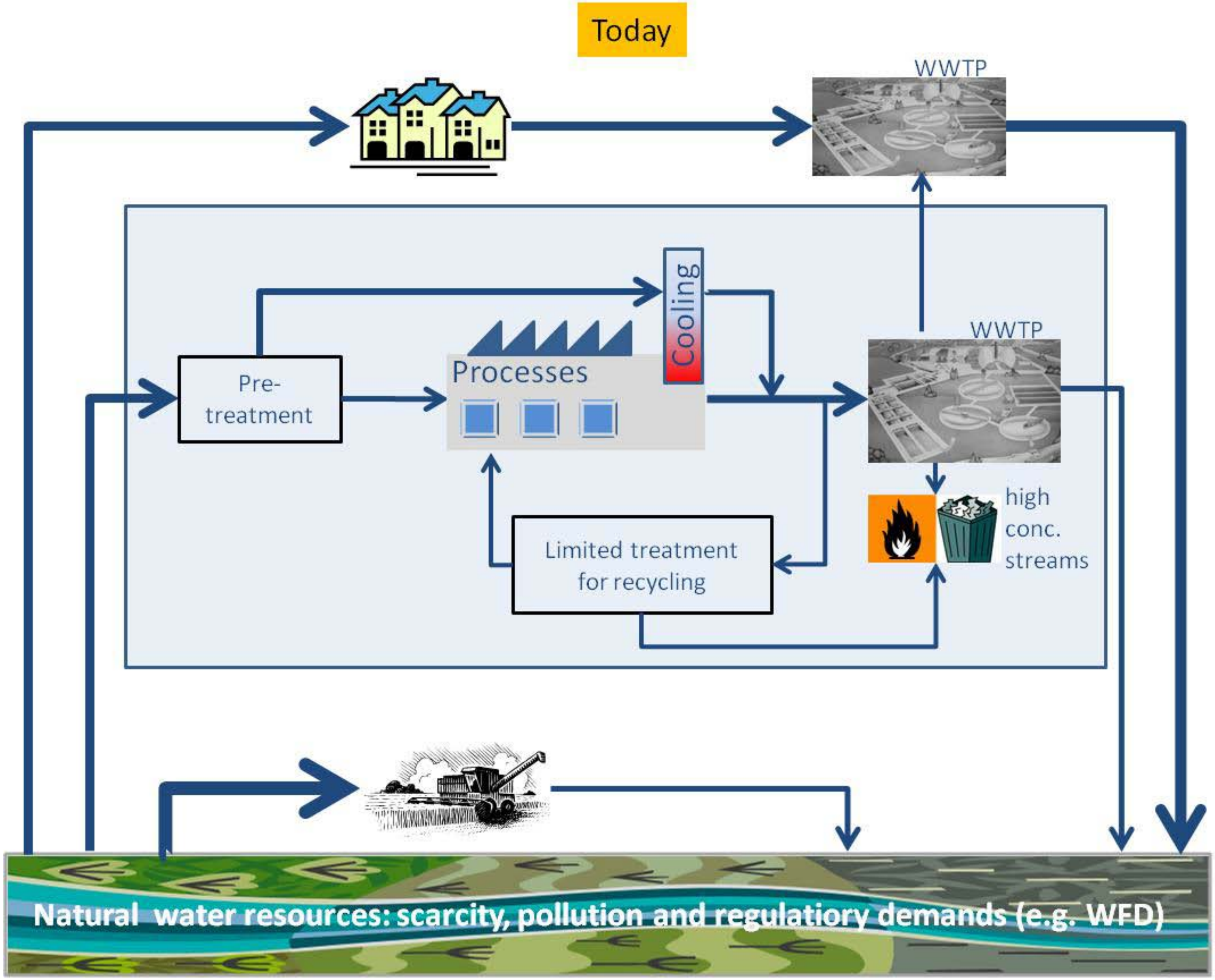
→ **Water recycling reduces energy demand for heating**

Note: efficiencies of heating and heat transfer are not considered

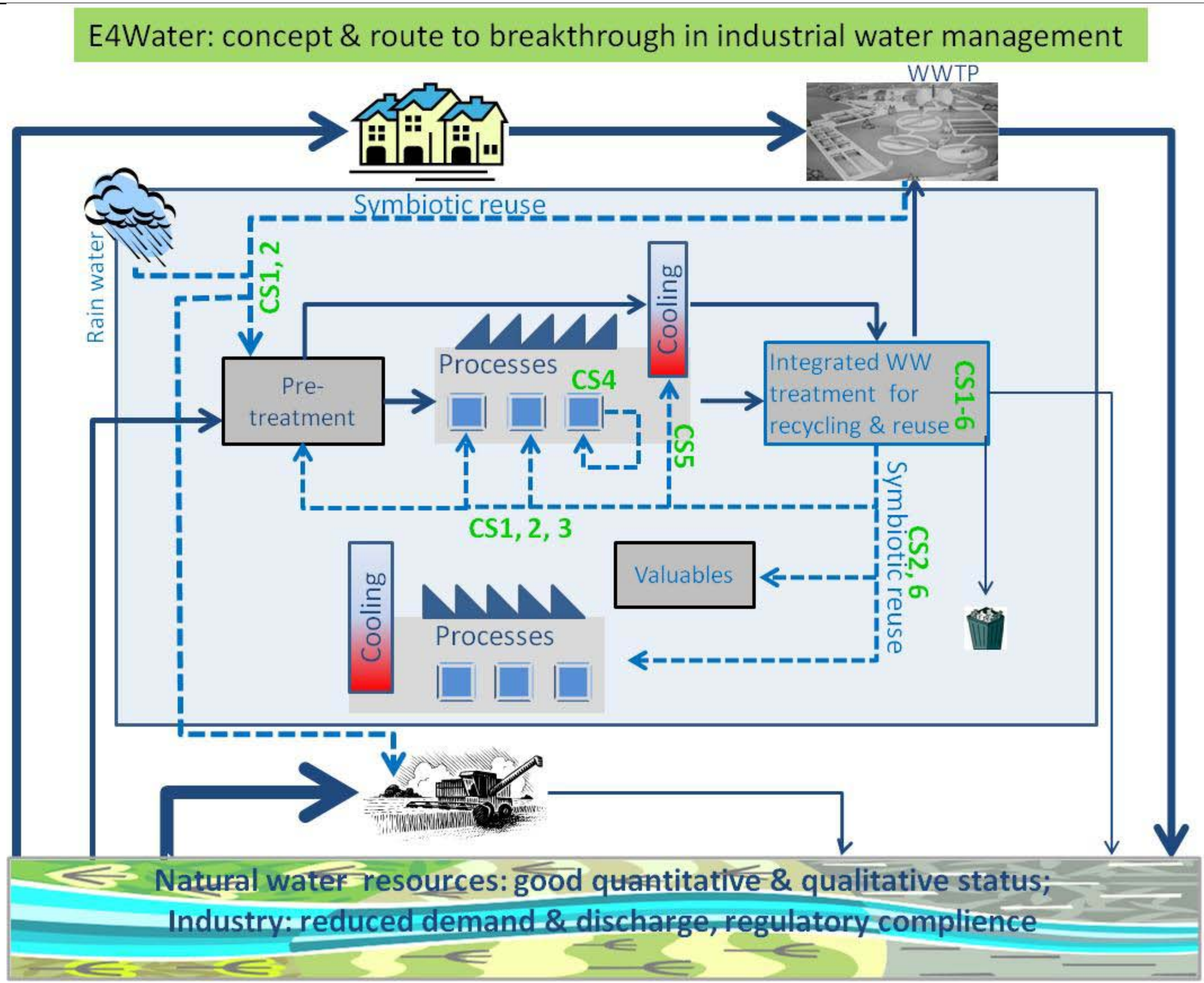
“Zero-discharge” corrugated card board industry



Transparency from J. Van Lier, Lettinga Associates Foundation, Netherlands, 2007



Today
WWTP
Cooling
Pre-
treatment
Processes
WWTP
high
conc.
streams
Limited treatment
for recycling
Natural water resources: scarcity, pollution and regulatiory demands (e.g. WFD)



E4Water

Economically and Ecologically Efficient Water Management in the European Chemical Industry

EC FP7

Chances

1. Process optimization saves water
2. Valuables can be extracted
3. Wastewater recycling recovers water and heat
4. Production integrated technologies will decrease the costs

Limitations

Management tools have to be applied

Cost effective selective separation technologies

Applications limited

Implementation necessary


Thank you for your attention!
Prof. Dr.-Ing. Sven-Uwe Geissen