Towards a climate neutral water cycle

Jan Hofman, Kees Roest, Jos Frijns, Mark van Loosdrecht
COP15, 8 december 2009

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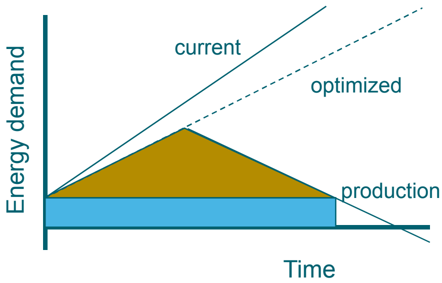
Energy demand water cycle

Creating an energy neutral watercycle:

- Optimize and reduce energy consumption for treatment
- Conserve water
- Recover heat from wastewater
- Create energy from wastewater



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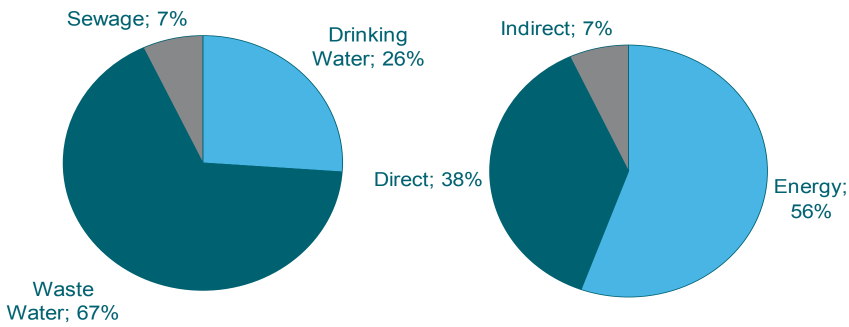
Climate and Energy

Green house gas emissions Dutch water sector



Carbon Footprint Dutch Water Sector:
1.67 million tonnes CO_2e per year, or 1.5 kg CO_2e per m^3 domestic water

Frijns, Mulder Roorda, KWR/STOWA 2008-17

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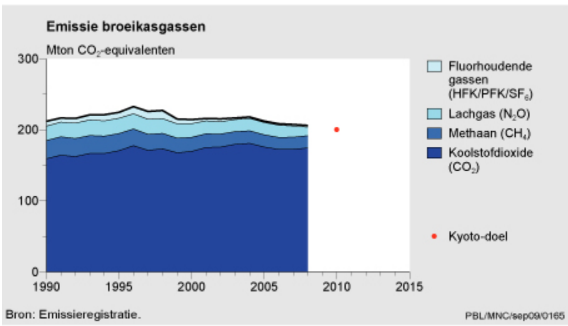
GHGs emission in The Netherlands



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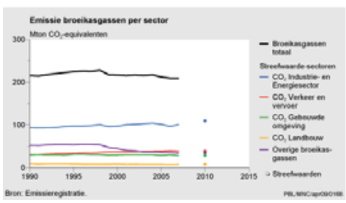

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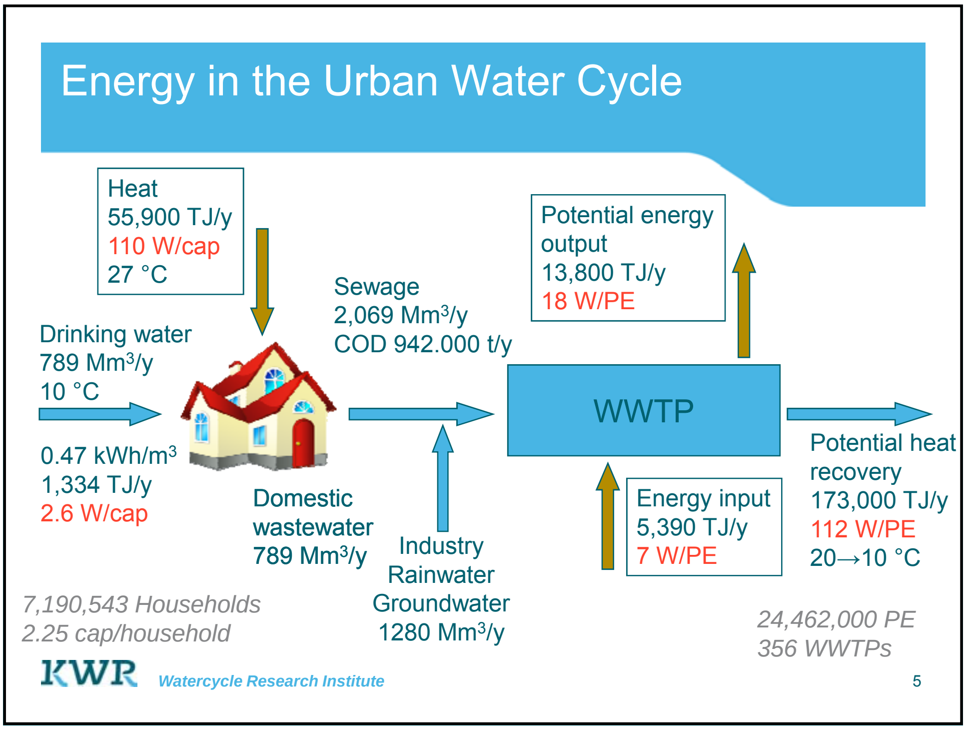
Energy in the Urban Water Cycle
Heat
55,900 TJ/y
110 W/cap
27 °C
Drinking water
789 Mm³/y
10 °C
0.47 kWh/m³
1,334 TJ/y
2.6 W/cap
Sewage
2,069 Mm³/y
COD 942.000 t/y
Domestic
wastewater
789 Mm³/y
Industry
Rainwater
Groundwater
1280 Mm³/y
Potential energy
output
13,800 TJ/y
18 W/PE
WWTP
Energy input
5,390 TJ/y
7 W/PE
Potential heat
recovery
173,000 TJ/y
112 W/PE
20→10 °C
7,190,543 Households
2.25 cap/household
24,462,000 PE
356 WWTPs
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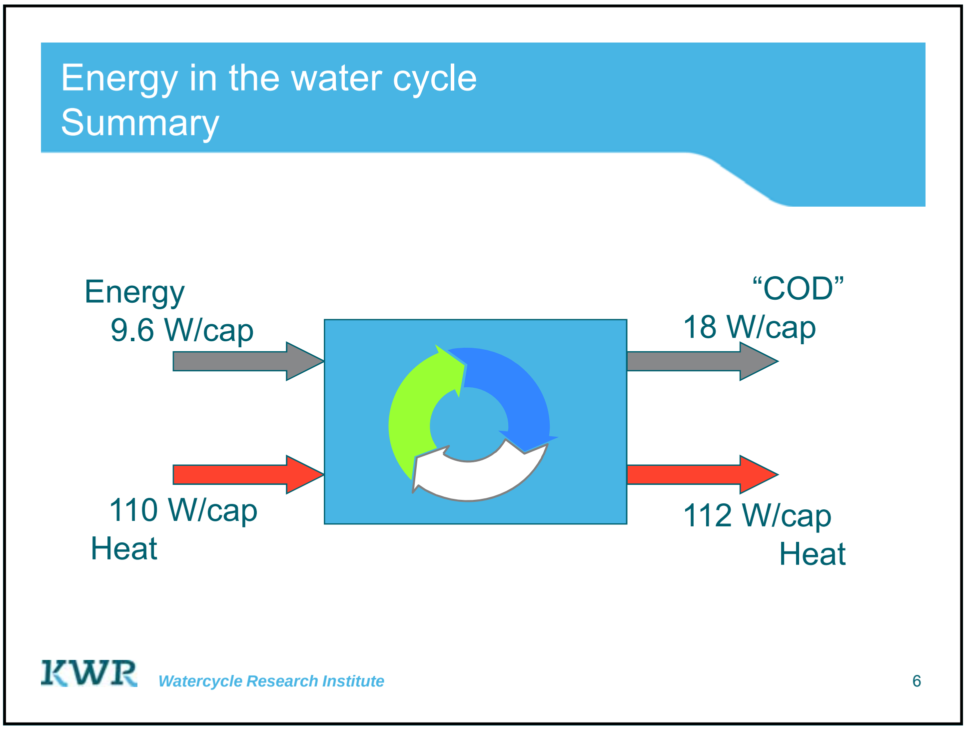
Energy in the water cycle
Summary
Energy
9.6 W/cap
110 W/cap
Heat
"COD"
18 W/cap
112 W/cap
Heat
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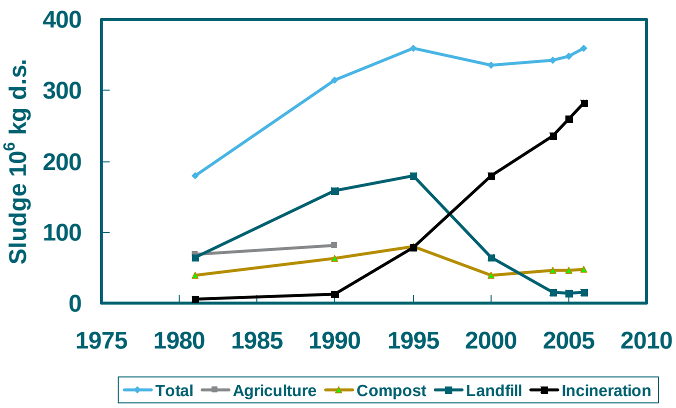
Energy from COD
Pathways

COD →
- MFC: mass transfer limitations at electrodes
  High costs, low power density (~4 W/m^2)
- Dark fermentation H_2: Only <1/3 COD is used
- Direct anaerobic; COD concentration too low
- Sludge digestion CH_4
- Sludge: drying, incineration, P-recovery

Best option according to *STOWA 2005-26 Slibketenstudie*:
- Pre-settling, no digestion, Bio-P
- Indirect thermal drying, co-incineration in cement oven

Final Sludge Destination



Options for Concentrating COD

Decentralized approach

- Separation at source, black water collection, vacuum toilets

Centralized systems

- Forward Osmosis
- Convert COD to suspended solids as much as possible and collect sludge

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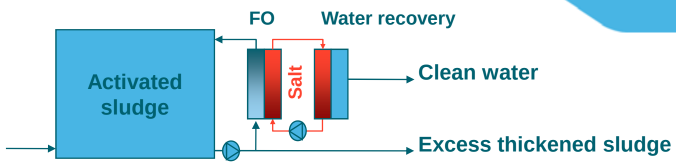
Forward osmosis



Advantages:

- **Less fouling**
- **Removal of Hormones and PPCPs**
- **Clean water production**
- **Energy production (PRO)**

But:

- **Energy consumption ?**
- **Membrane ?**
- **Water Recovery Technology**

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Optimized A-Stage

- High-load A-stage: Dissolved COD → Suspended material
- Flocculation with colloidal and suspended influent material
- Integration of chemical P-removal; if aluminium is used, incineration ashes can be used to recover P (Thermphos)

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Sludge collection

Existing AB-systems: settling tanks after each stage

- Works well, but large footprint

MF/UF membranes (MBR):

- Small footprint, but fouling and high energy demand

Dynamic membranes:

- Small footprint, low energy demand, but periodic low quality filtrate

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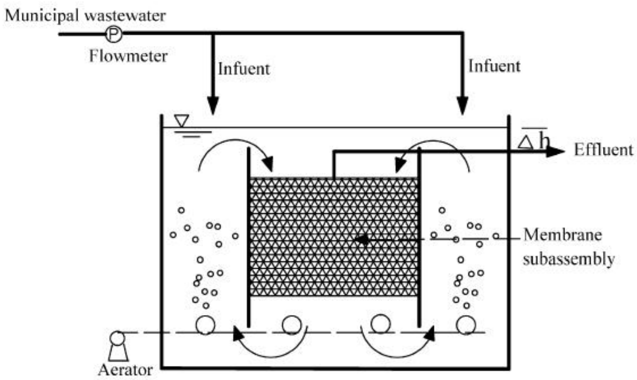
Dynamic membranes

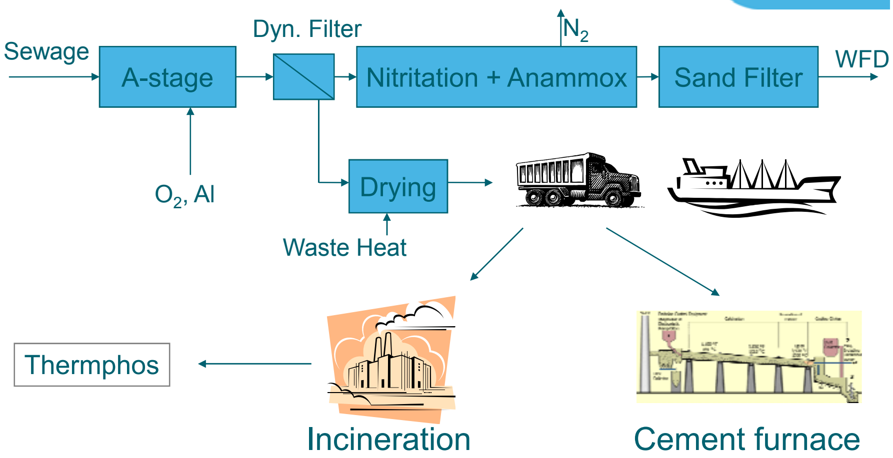


H. Liu, C. Yang, W. Pu and J. Zhang, *Chem. Eng. J.*, **2009**, *148*, 290-295

Dynamic membranes

Low cost porous substrate material
Dynamic membrane deposits on substrate
Periodic membrane cleaning
Gravity is driving force
Small footprint

Total Concept



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Deliverables and Research Questions

Deliverables:
- Clean Water (WFD)
- Energy: self-supporting water cycle
- Possibilities for P recovery

Questions:
- How much COD is converted to sludge?
- How much sludge can be removed effectively?
- What is the DS content of the sludge?

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Conclusion

- Energy: Self supporting water cycle is possible
- Increase energy efficiency
- Water conservation and heat recovery are important
- Reuse water and nutrients possible

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AB-Systems with dynamic filtration
a new way to produce energy

Jan Hofman, Mark van Loosdrecht

De RWZI als Energiefabriek II, 18 september 2009

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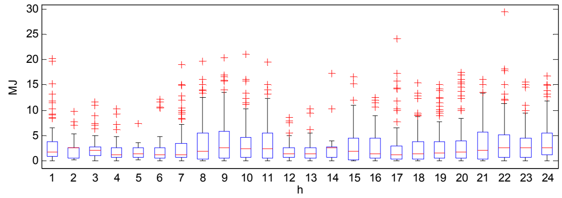
Heat from domestic waste water
Stochastic modeling SIMDEUM

Bath/shower: 38-40 ºC
Tap 10-55 ºC
Dishwasher/laundry 40 ºC
Garden tap, toilet 10ºC
300 demand patterns

Average: 21.3 MJ/home.d
109.6 W/cap

T_{ref} = 10 °C



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M. Blokker, 2009

Energy input wastewater treatment

Energy	**Amount (TJ/y)**
Electrical	2606
Natural Gas: 29,574 m^3; ΔH_c = -32 MJ/Nm^3	946
Own biogas: 73,527 m^3; ΔH_c = -25 MJ/Nm^3	1838
Total	***5390***
7,190,543 Households, 2,25 persons/household	***10 W/cap***
356 WWTP; 24,462,000 PE	***7 W/PE***

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Chemical energy from wastewater

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O \quad \Delta H_c = -2{,}808$ kJ/mol

COD: 941,736,000 kg O_2/y = 4.9×10^9 mol/y $C_6H_{12}O_6$

Potential energy: 13,800 TJ/y
27 W/cap
18 W/PE

Sludge drying: $\Delta H_e = +2{,}256$ kJ/kg

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