Towards carbon neutral water utilities

Reducing greenhouse gas emissions: experiences of Waternet

Prof. Jan Peter van der Hoek

waternet
waterschap amstel gooi en vecht
gemeente amsterdam

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Delft University of Technology

Content

- Global and local ambitions
- Possibilities for water utilities
- Aquathermal energy
- Conclusions

UN targets

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

UNITED NATIONS
PARIS CLIMATE AGREEMENT
SIGNING CEREMONY
22 APRIL 2016

- **Keep global temperature rise well below 2 °C**
- **Pursue efforts to limit temperature increase to 1.5 °C**

EU targets 2050

Dutch targets

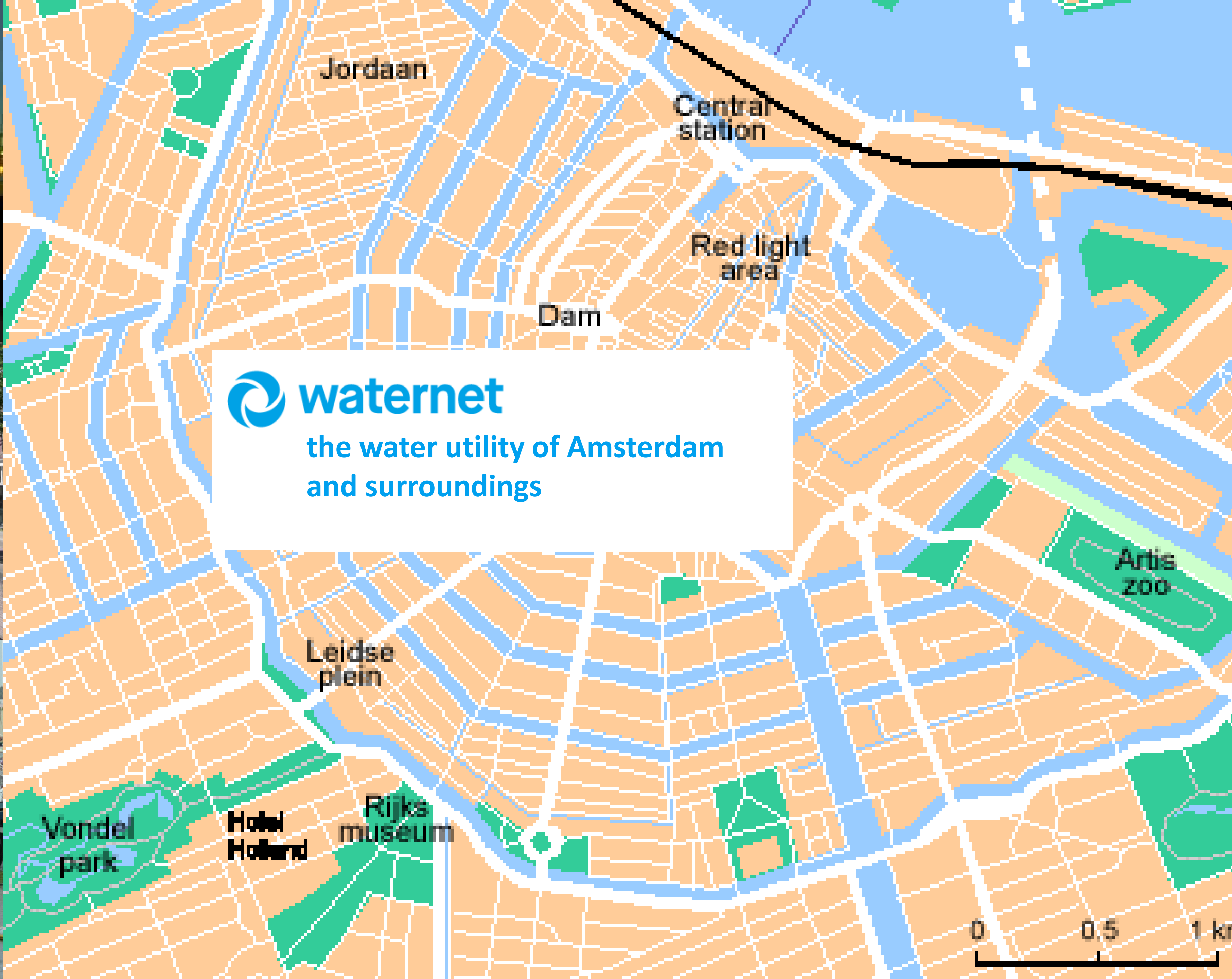
Dutch Ministry of Economic Affairs and Climate Change

"Towards a CO_2 low energy supply" →

No use of fossil fuels in 2050

Amsterdam targets

Goal:
Reduce CO_2 emissions in Amsterdam by 55% in 2030 and by 95% in 2050



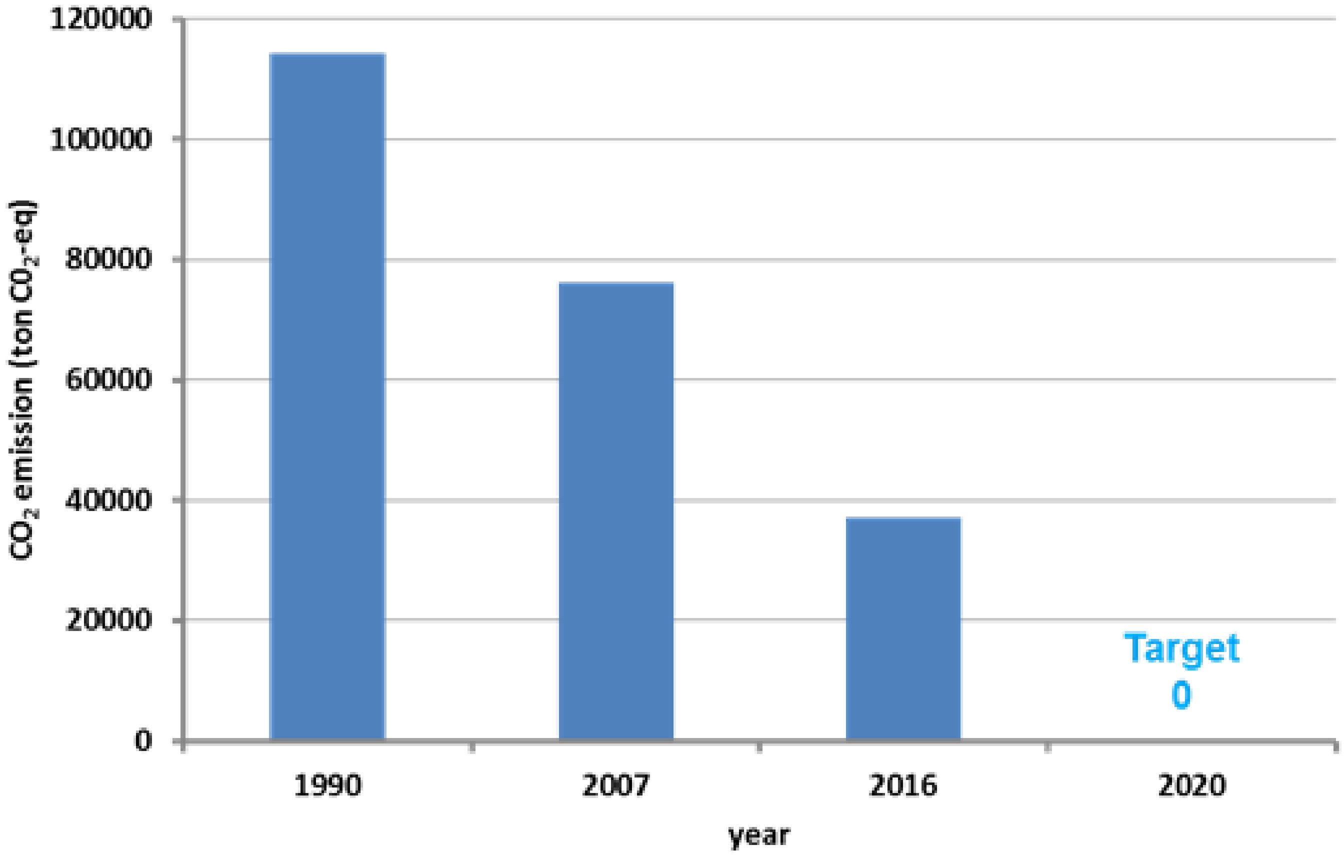
waternet

the water utility of Amsterdam and surroundings

Waternet: some key figures

• Customers	1.2 million
• Municipalities	20
• Employees	1,770
• Annual budget	€ 383 million
• **Drinking water**	90 million m³/y
• Drinking water connections	100%
• Drinking water treatment plants	2
• Drinking water pipelines	3,100 km
• Leakage	2-3%
• Non-revenue water	0%
• **Wastewater**	125 million m³/y
• Sewage connections	100%
• Wastewater treatment plants	12
• Sewerage system	4,200 km
• **Dikes**	800 km
• **Nature** (resources)	4,200 hectares

Waternet target



Climate neutral operation

=

Operation without a net GHG emission

Possibilities for water utilities

Environmental Science & Technology

pubs.acs.org/est Policy Analysis

Low-Carbon Urban Water Systems: Opportunities beyond Water and Wastewater Utilities?

Ka Leung Lam* and Jan Peter van der Hoek

Cite This: *Environ. Sci. Technol.* 2020, 54, 14854–14861 Read Online

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Selection and prioritization of mitigation measures to realize climate neutral operation of a water cycle company

Jan Peter van der Hoek, Stefan Mol, Theo Janse, Enna Klaversma and Joost Kappelhof

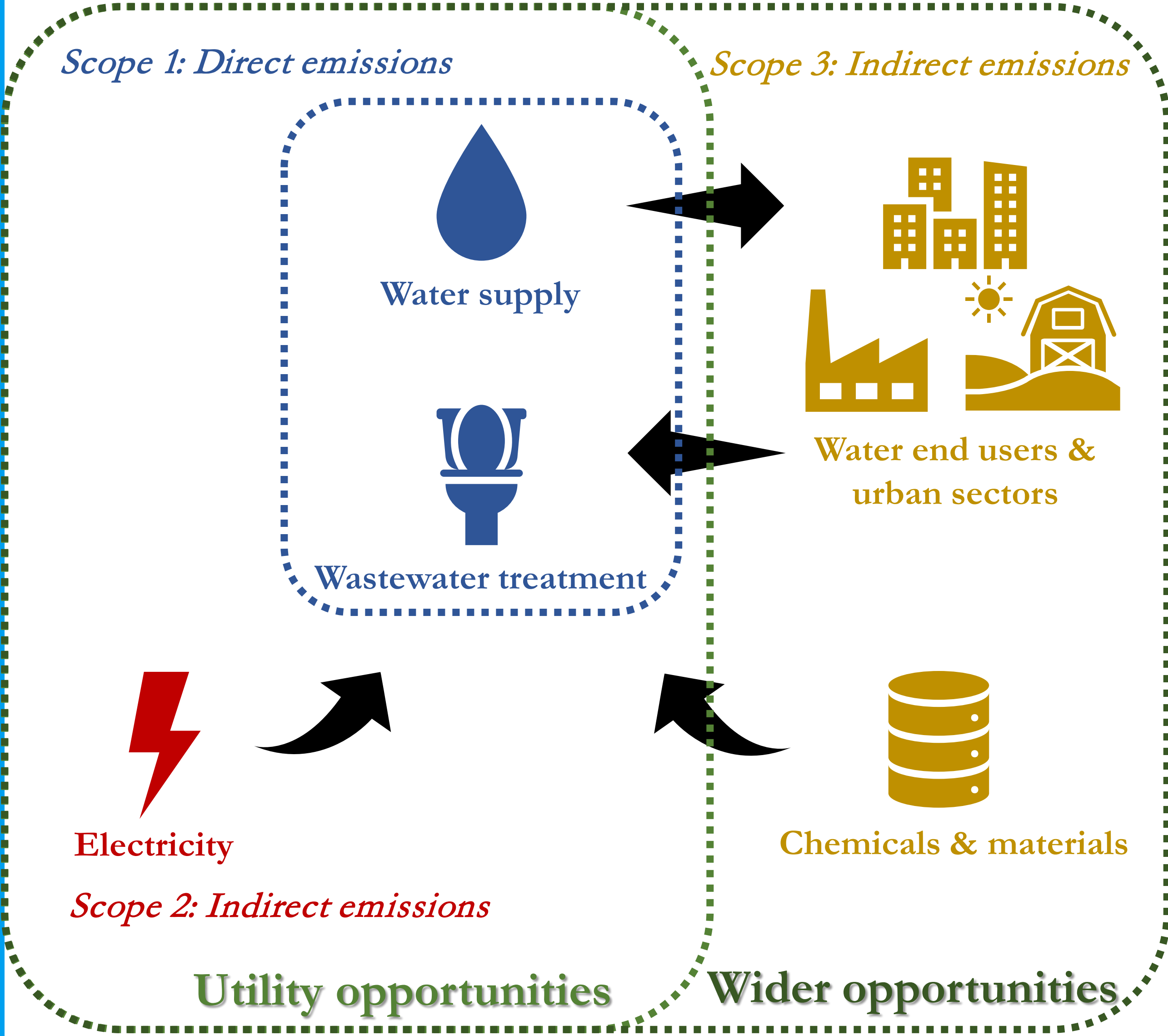
Possibilities for water utilities

- **Utility opportunities**:

  opportunities within the jurisdiction of a water utility, directly related to the operations

- **Wider opportunities**:

  opportunities on which a water utility has no direct influence and/or has to cooperate with others



Ka Leung Lam

LEaDing Fellows Postdocs Programme

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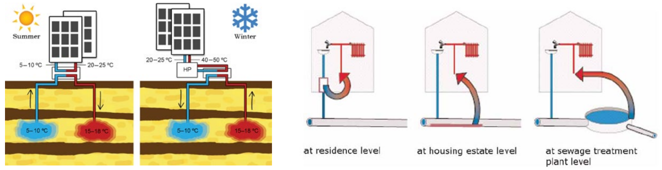
Wider opportunities

- Thermal energy opportunities:
  - Energy recovered from the water cycle
- Water end use opportunities:
  - Opportunities related to the end use of water
- Life cycle opportunities:
  - Taking into account the upstream and downstream impact



Thermal Energy

Recovery, storage and supply

Water End Use

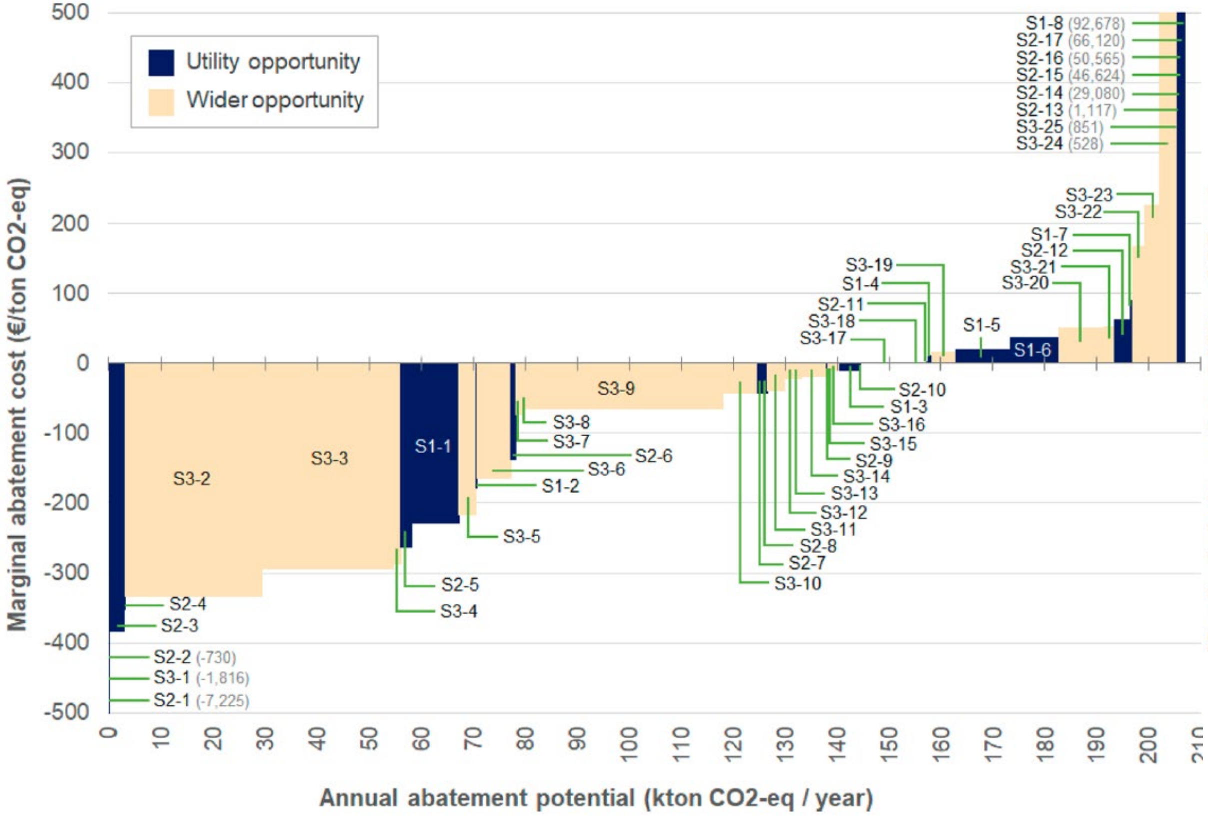
Household water-related GHG

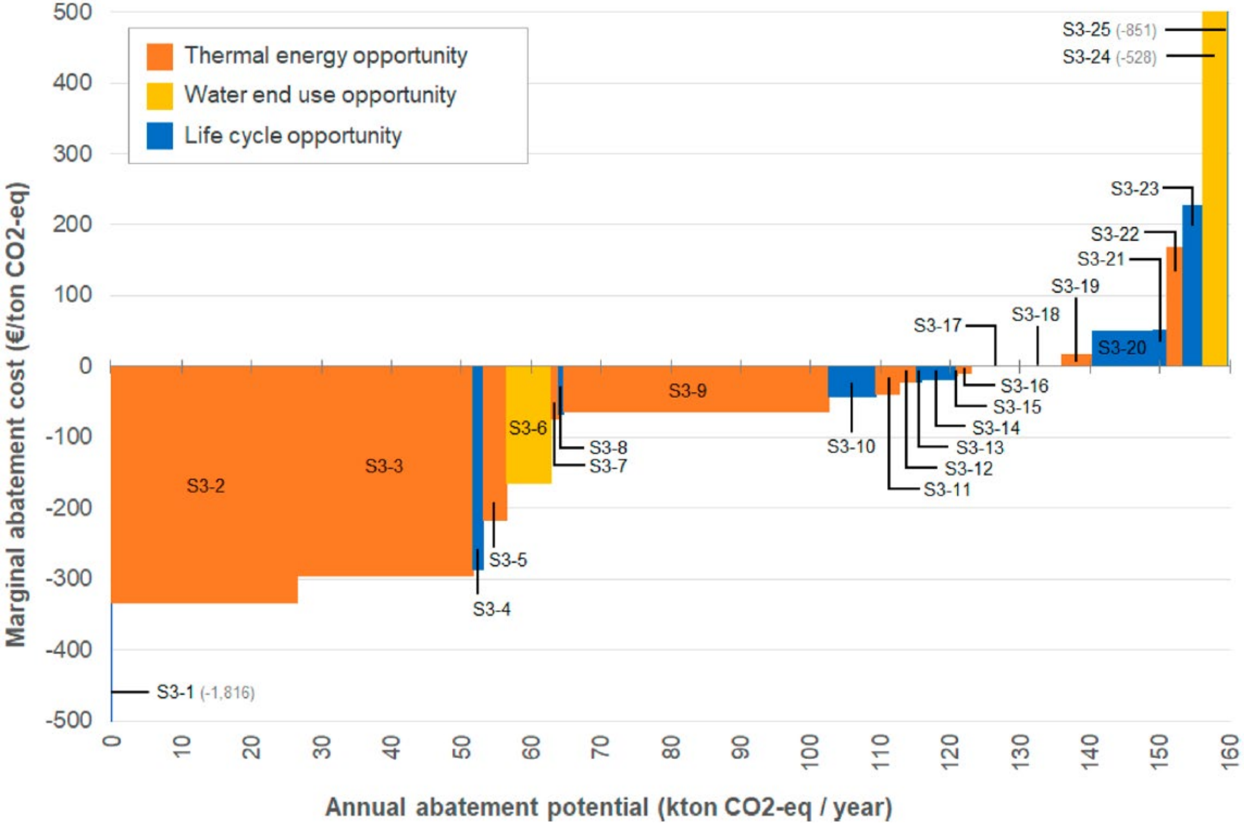
Life Cycle

Externalities: upstream, downstream

Marginal abatement cost curves

- Each box: an opportunity
- Width: reduction potential
- Height: marginal abatement cost (cost-effectiveness)
- Prioritised from most cost-effective (left) to least cost-effective (right)

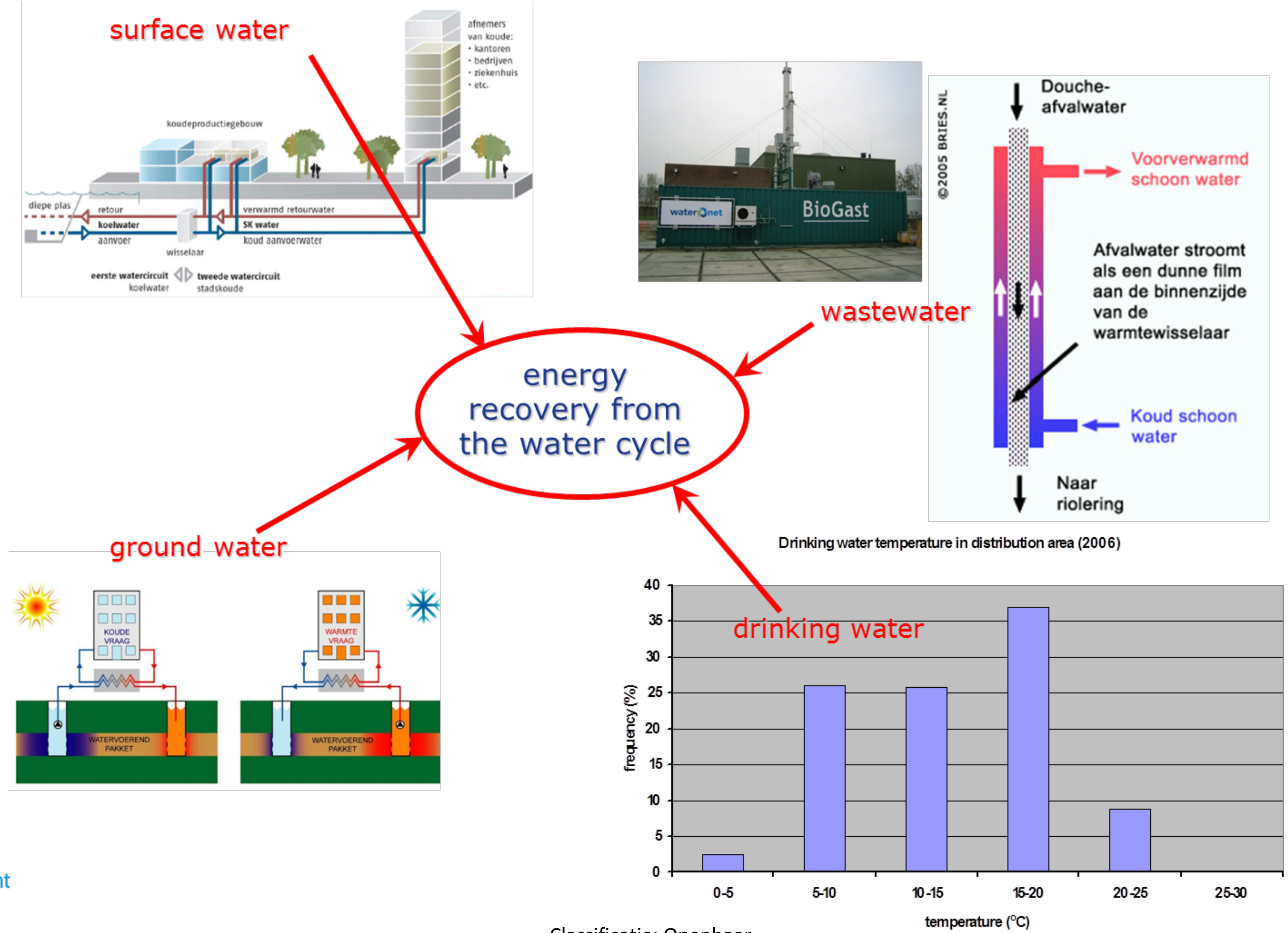




Wider opportunity >> Utility opportunity

Thermal energy opportunity >> Water end use opportunity
Thermal energy opportrunity >> Life cycle opportunity

Aquathermal energy (and chemical energy from wastewater)



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Aquathermal energy

Heating demand & supply in The Netherlands:

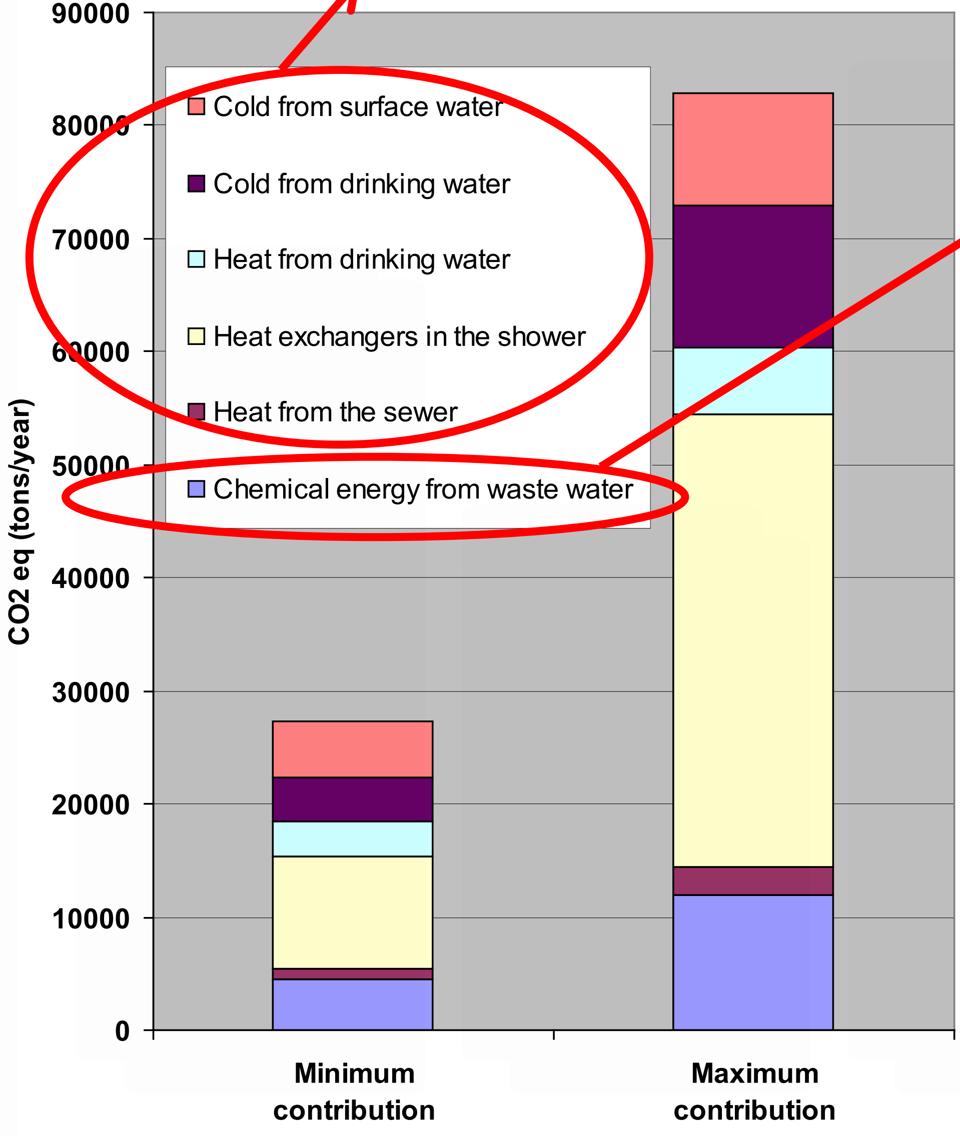
- Heating demand in the urban environment: 350 PJ/year
- Potential thermal energy from surface water: 150 PJ/year
- Potential thermal energy from wastewater: 56 PJ/year
- Potential thermal energy from drinking water: 4-6 PJ/year

(surface water + wastewater + drinking water): 212 PJ/year

Cooling demand & supply in Amsterdam:

- Cooling demand for space cooling: 2161 TJ/year
- Potential thermal energy from drinking water: 2800 TJ/year

Aquathermal energy from the water cycle >>> chemical energy from wastewater



Contributions of the water cycle

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Coping with climate change in Amsterdam – a watercycle perspective

Jan Peter van der Hoek, Paulien Hartog and Eilard Jacobs

Case 1
Thermal energy recovery from drinking water

Cold from drinking water

Sanquin

waternet
regional public water authority
amstel gooi en vecht
city of amsterdam

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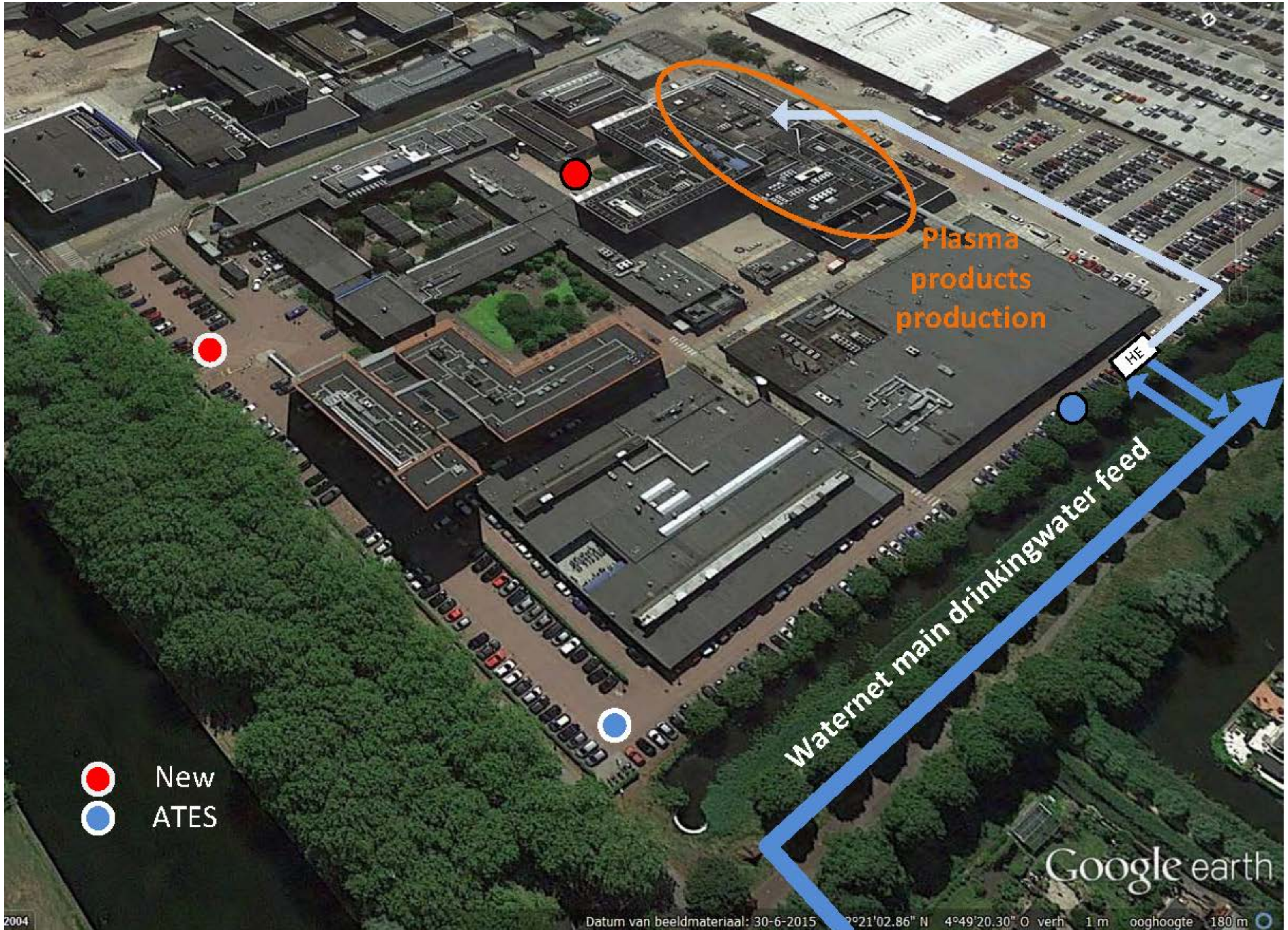
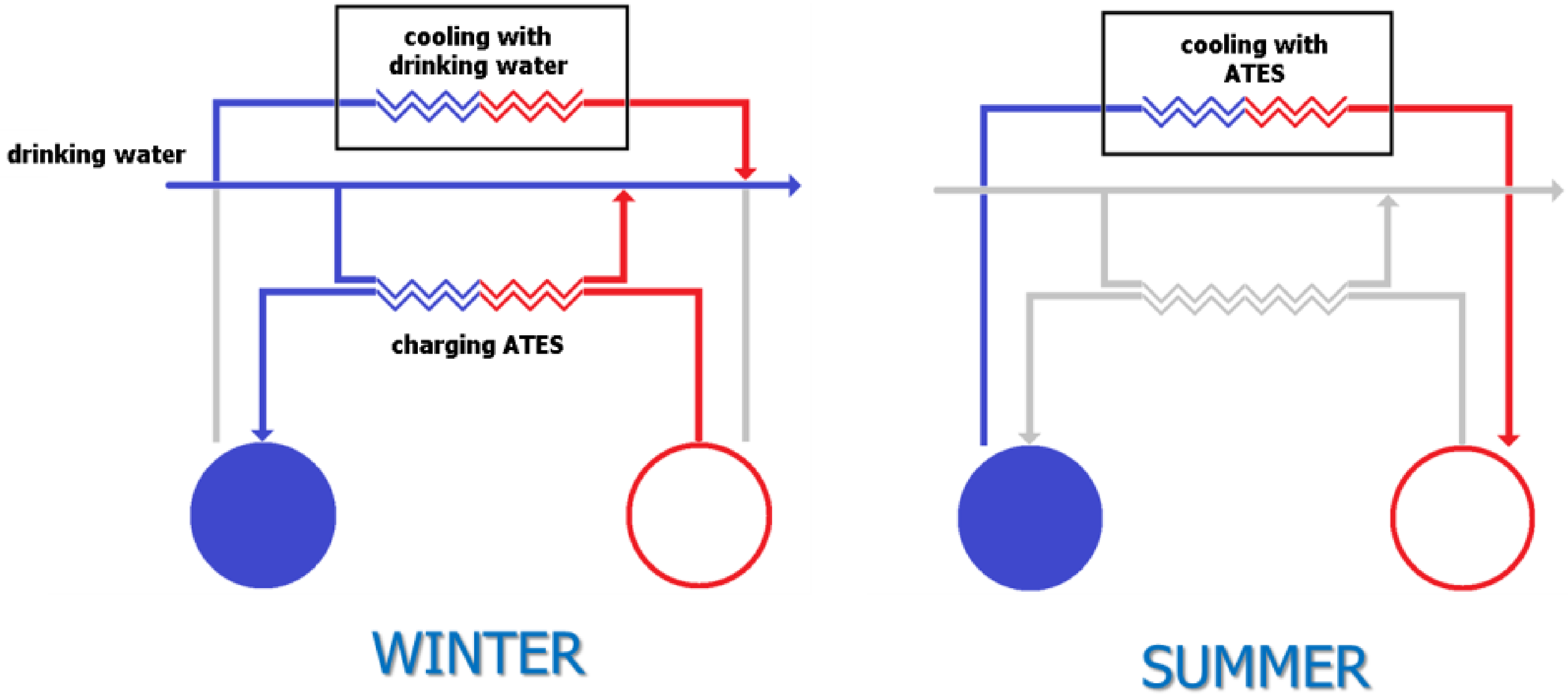
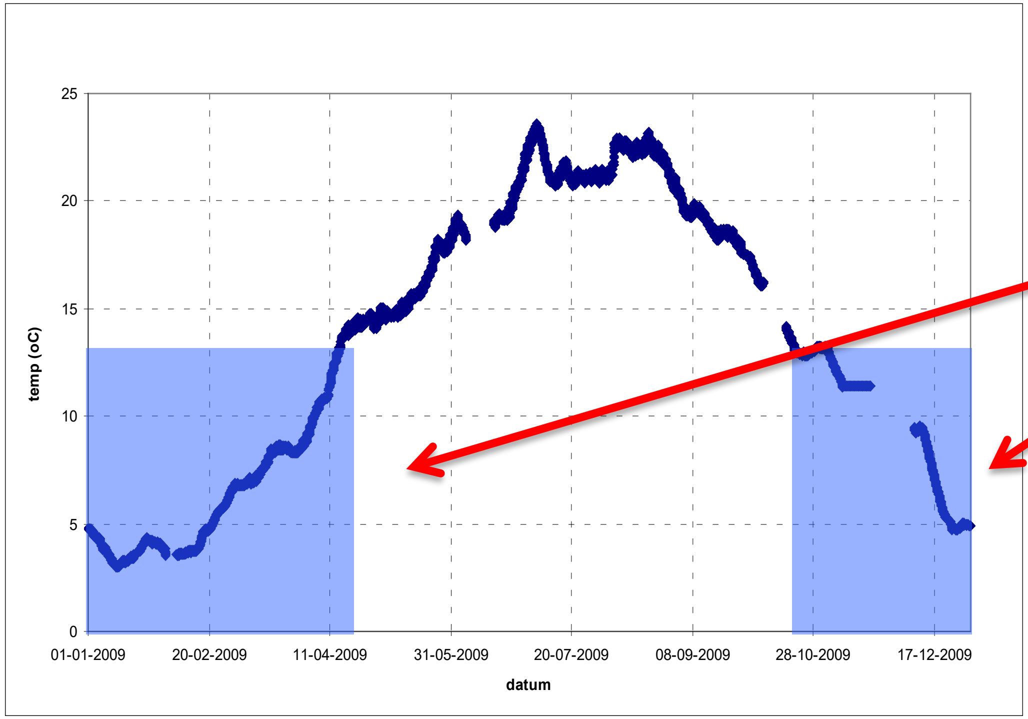


TOPSECTOR WATER & MARITIEM

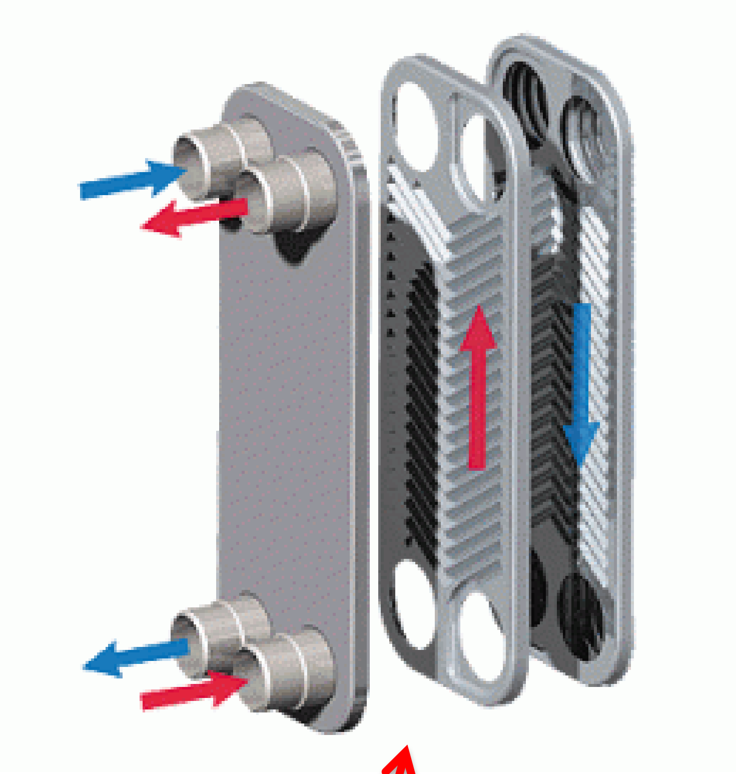
CITY-zen

The principle



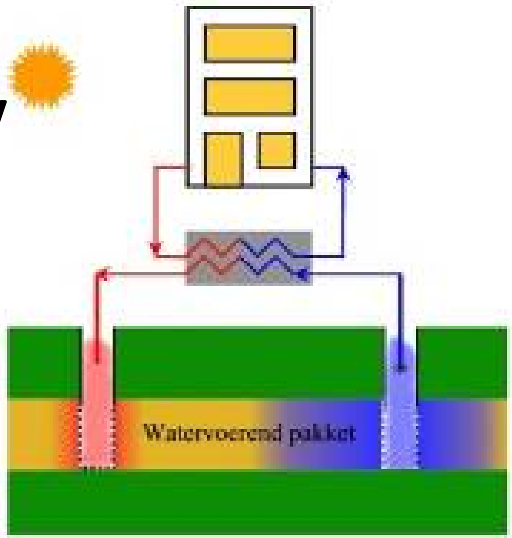


Cold



Heat exchanger

Aquifer thermal energy storage



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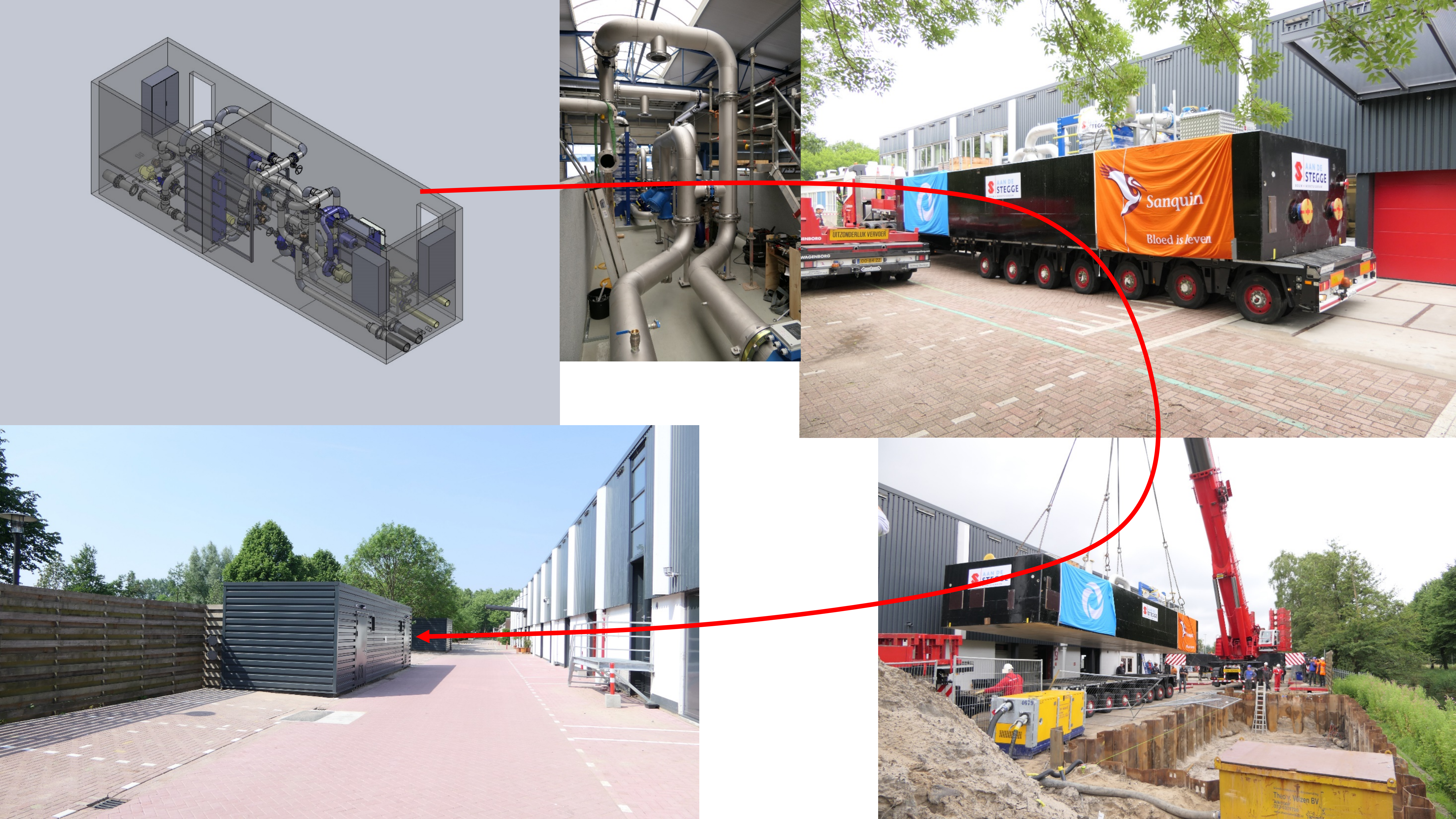

AAN DE STEGGE
Sanquin
Bloed is leven
UITZONDERLIJK VERVOER
WAGENBORG

Benefits

1. Reduction of GHG emissions

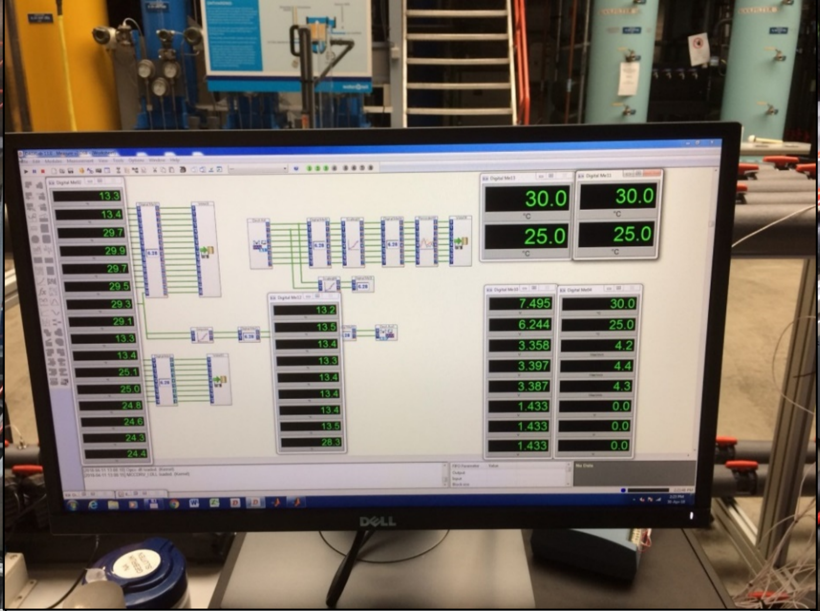
	Energy use (MWh/year)	GHG emission (ton CO_2-eq/year
Traditional cooling machines	1725	966
Cooling with drinking water	172.5	97

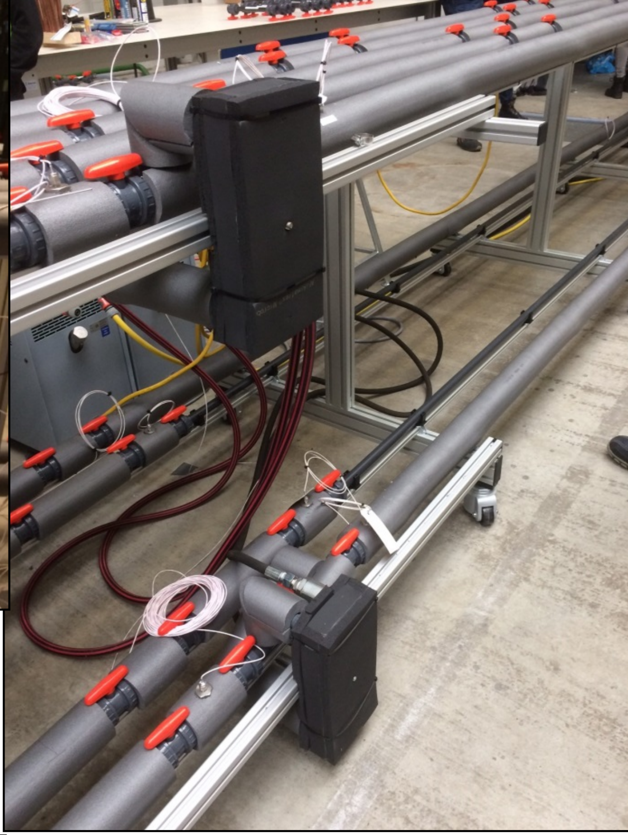
2. Financial benefits

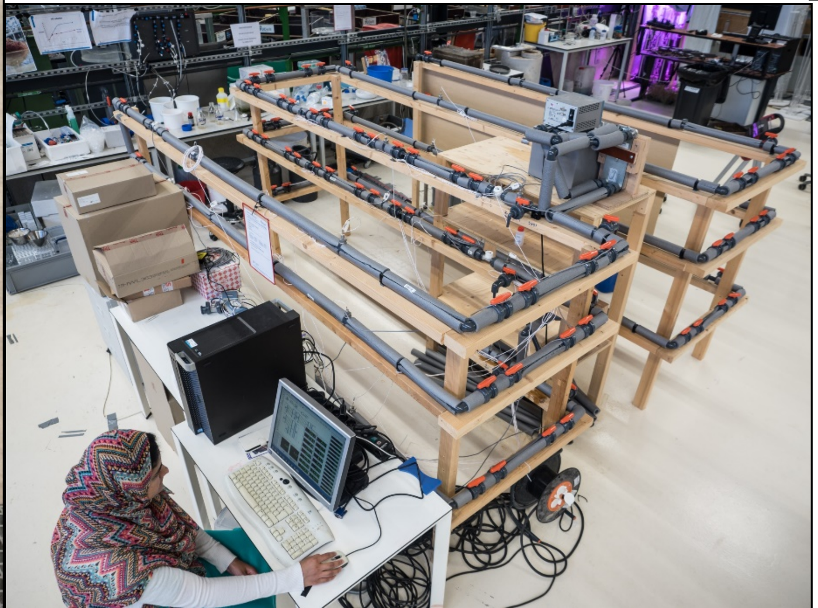
	Total Cost of Ownership (million €)
Traditional cooling machines	8.2
Cooling with drinking water	6.8

Simple technology, but……

- Cold recovery: temperature increase drinking water
- Effect on microbiological drinking water quality?
- Effect on biofilm development on the pipe wall?
- Maximum acceptable temperature T_{max} after cold recovery?







TOPSECTOR
WATER &
MARITIEM

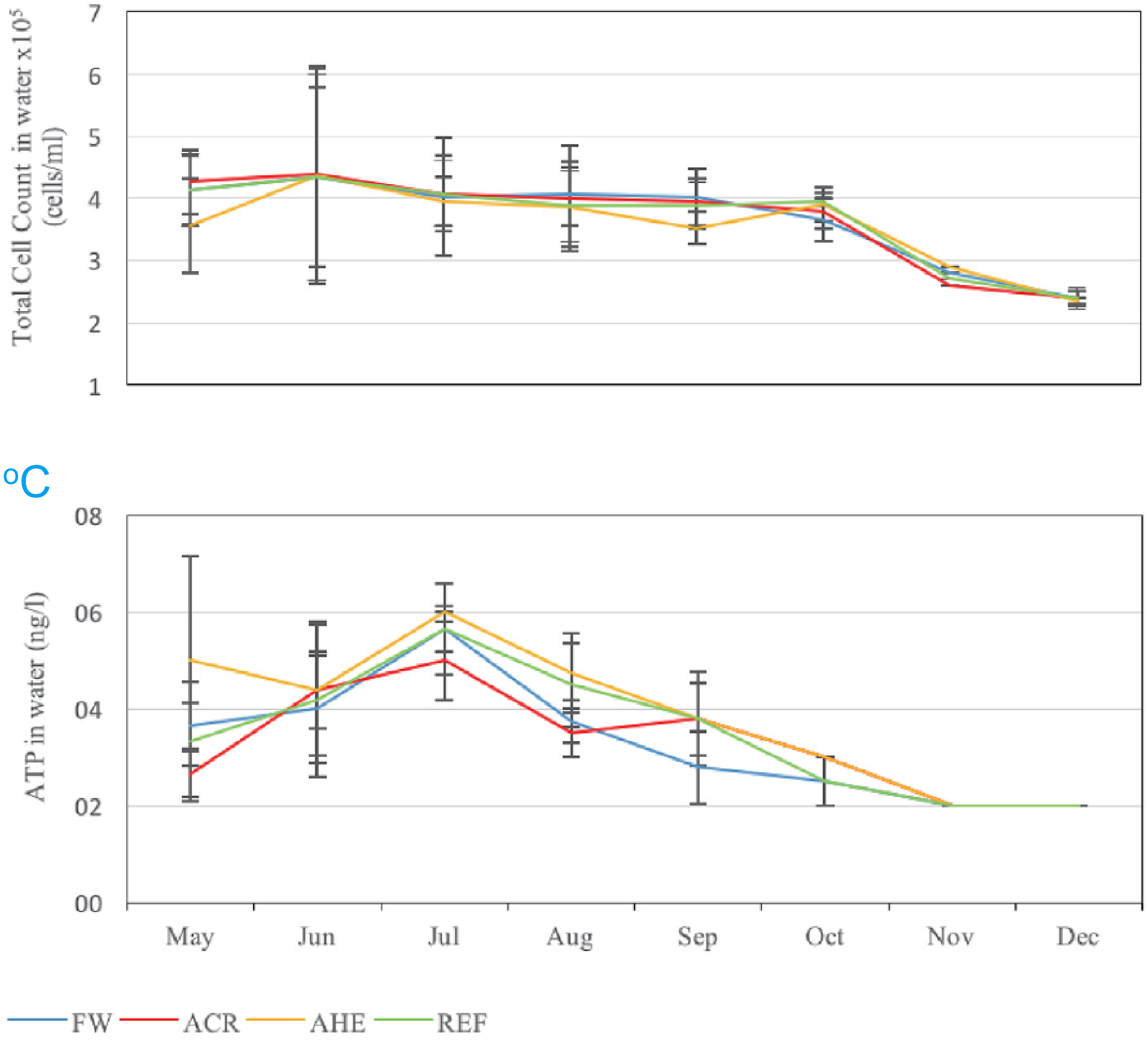
Effect T_{max} on microbial drinking water quality

— FW = feed water

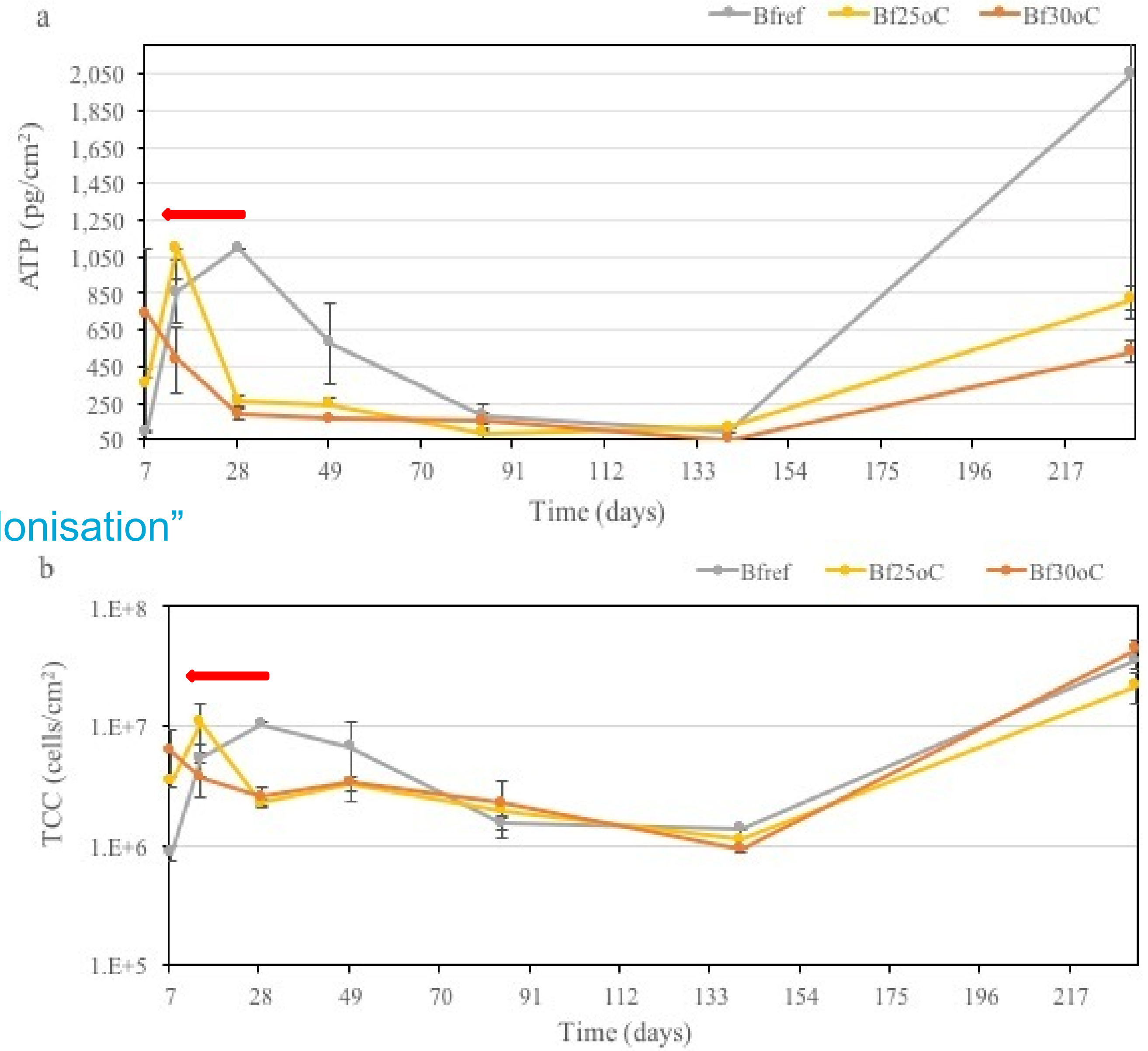
— ACR = after cold recovery T_{max} 25 °C

— AHE = after (non operational) heat exchanger

— REF = reference



Effect T_{max} on biofilm development



"Faster colonisation"

Energy 162 (2018) 977–987

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Energy recovery from the water cycle: Thermal energy from drinking water

Jan Peter van der Hoek [a, b, *], Stefan Mol [b], Sara Giorgi [b], Jawairia Imtiaz Ahmad [a, c], Gang Liu [a, d], Gertjan Medema [a, e]

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Problems solved!

Environmental Research 187 (2020) 109655

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Thermal energy recovery from chlorinated drinking water distribution systems: Effect on chlorine and microbial water and biofilm characteristics

Xinyan Zhou [a,b], Jawairia Imtiaz Ahmad [b,c], Jan Peter van der Hoek [b,d], Kejia Zhang [a,*]

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Effects of cold recovery technology on the microbial drinking water quality in unchlorinated distribution systems

Jawairia Imtiaz Ahmad, Gang Liu [a,b,*], Paul W.J.J. van der Wielen [c,f], Gertjan Medema [a,c,g], Jan Peter van der Hoek [a,d]

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Environmental Research 194 (2021) 110648

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Changes in biofilm composition and microbial water quality in drinking water distribution systems by temperature increase induced through thermal energy recovery

Jawairia Imtiaz Ahmad [a,c,*], Marco Dignum [b], Gang Liu [a,d], Gertjan Medema [a,e,f], Jan Peter van der Hoek [a,b]

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energies

MDPI

Article

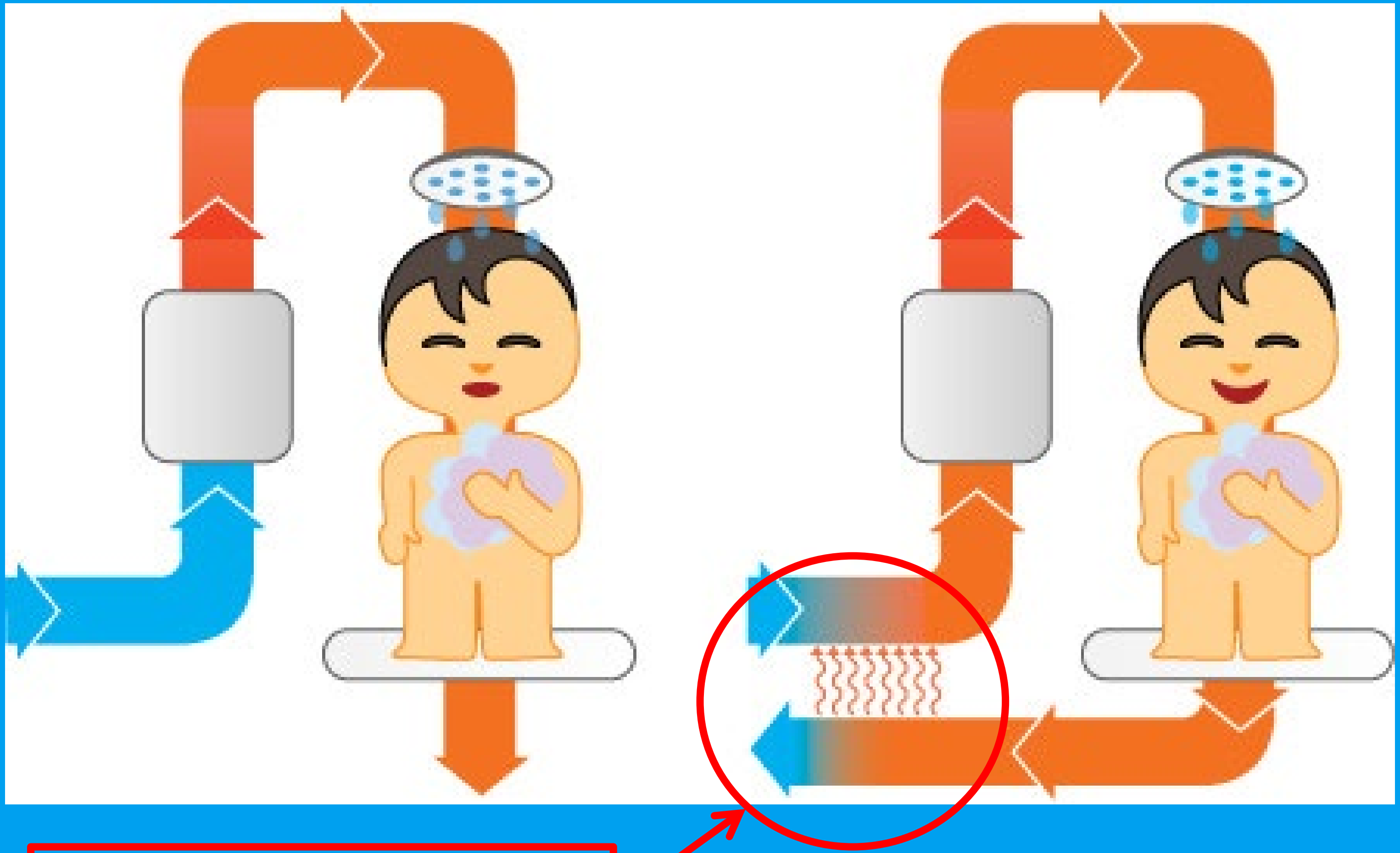
Maximizing Thermal Energy Recovery from Drinking Water for Cooling Purpose

Jawairia Imtiaz Ahmad [1,2,*], Sara Giorgi [3], Ljiljana Zlatanovic [1,4,5], Gang Liu [1,6] and Jan Peter van der Hoek [1,3,5]

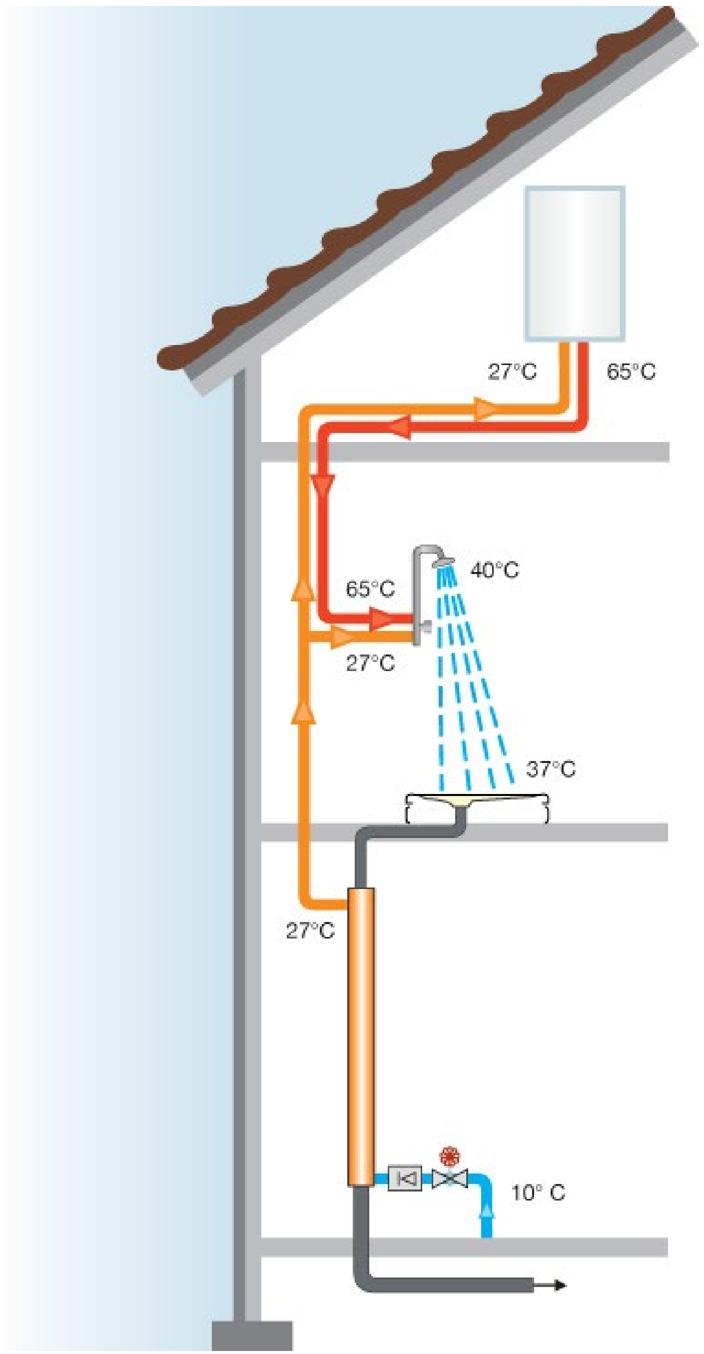
Lessons learned

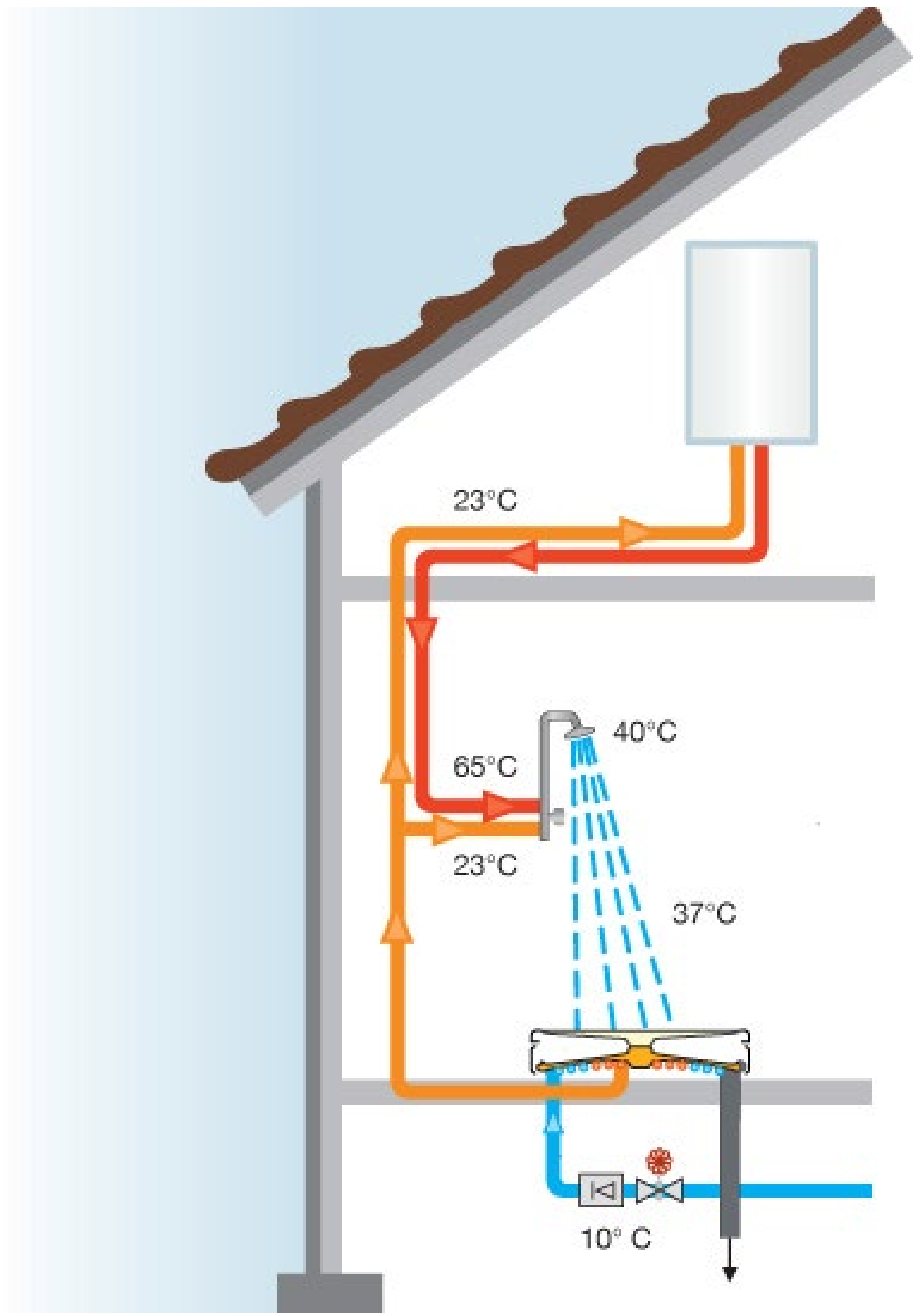
- Drinking water utilities can contribute to reduction of GHG emissions
- Innovative approaches are required: thermal energy recovery from drinking water
- Positive business cases are feasible
- The drinking water quality is not affected

Case 2
Heat exchangers in showers



Reuse of the heat


27°C
65°C
65°C
40°C
27°C
37°C
27°C
10° C


23°C
40°C
65°C
23°C
37°C
10° C

Introduction shower HE in an existing house

old situation without shower HE

new situation with shower HE

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Research in Amsterdam Uijlenstede

- Use of shower heat exchangers and the effects in student apartments
- Experimental set-up in laboratory

Drink. Water Eng. Sci., 9, 1–8, 2016
www.drink-water-eng-sci.net/9/1/2016/
doi:10.5194/dwes-9-1-2016

Drinking Water
Engineering and Science
Open Access

Shower heat exchanger: reuse of energy from heated drinking water for CO_2 reduction

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Correspondence to: Z. Deng (zdeng2014@outlook.com)

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Energy and efficiency calculations

Equation 1

$$Q_{recovered} = \Sigma\{q_{cold} * \rho(T_{cold}) * [h(T_{pre\,heated}) - h(T_{cold})] * dt\}$$

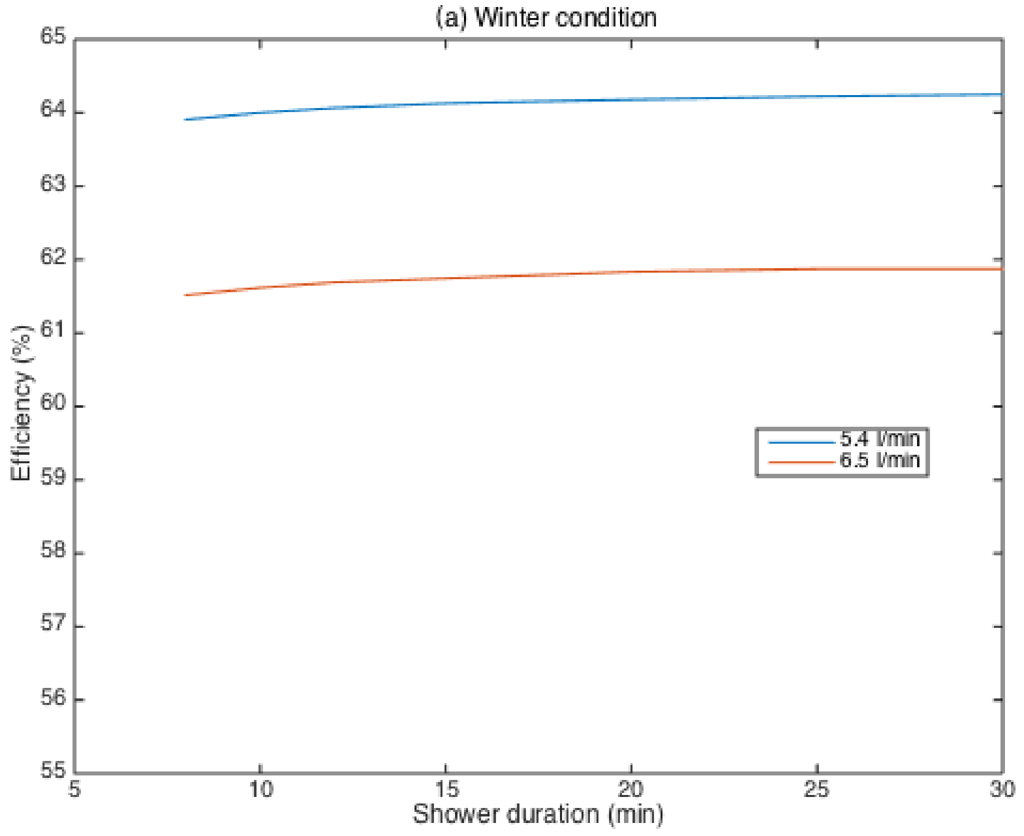
Equation 2

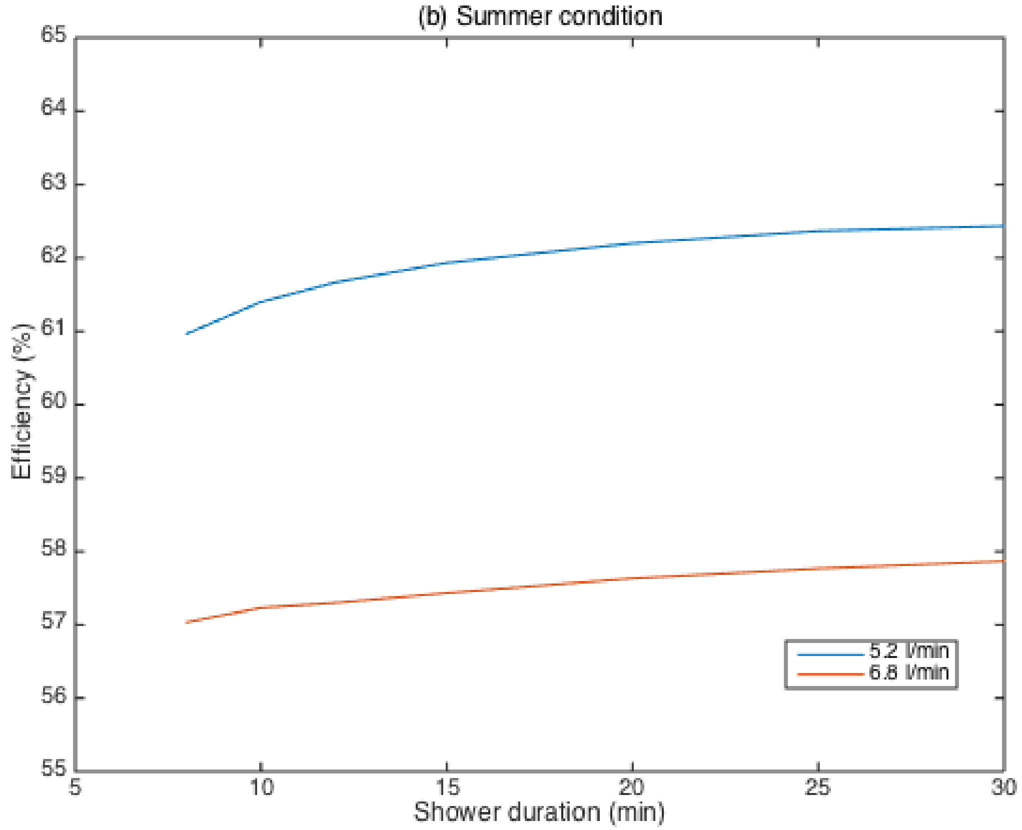
$$Q_{waste} = \Sigma\{q_{shower} * \rho(T_{shower}) * [h(T_{shower}) - h(T_{cold})] * dt\}$$

Equation 3

$$\eta_{recover} = \frac{Q_{recovered}}{Q_{waste}}$$

Efficiency shower heat exchanger





Estimation of energy recovery and CO_2 emission reduction

- A shower heat exchanger installed at 412,000 apartments in Amsterdam
- 2 persons per household

Annual energy saved by shower heat exchanger	kWh	260,000,000
Electricity consumed in households	kWh	740,000,000
Gas consumed in households	kWh	5,800,000,000
Annual total consumption	kWh	6,540,000,000
Saving compared to electricity	%	35.0
Saving compared to gas	%	4.5
Saving compared to total energy	%	4.0
CO_2 reduction	kton	54

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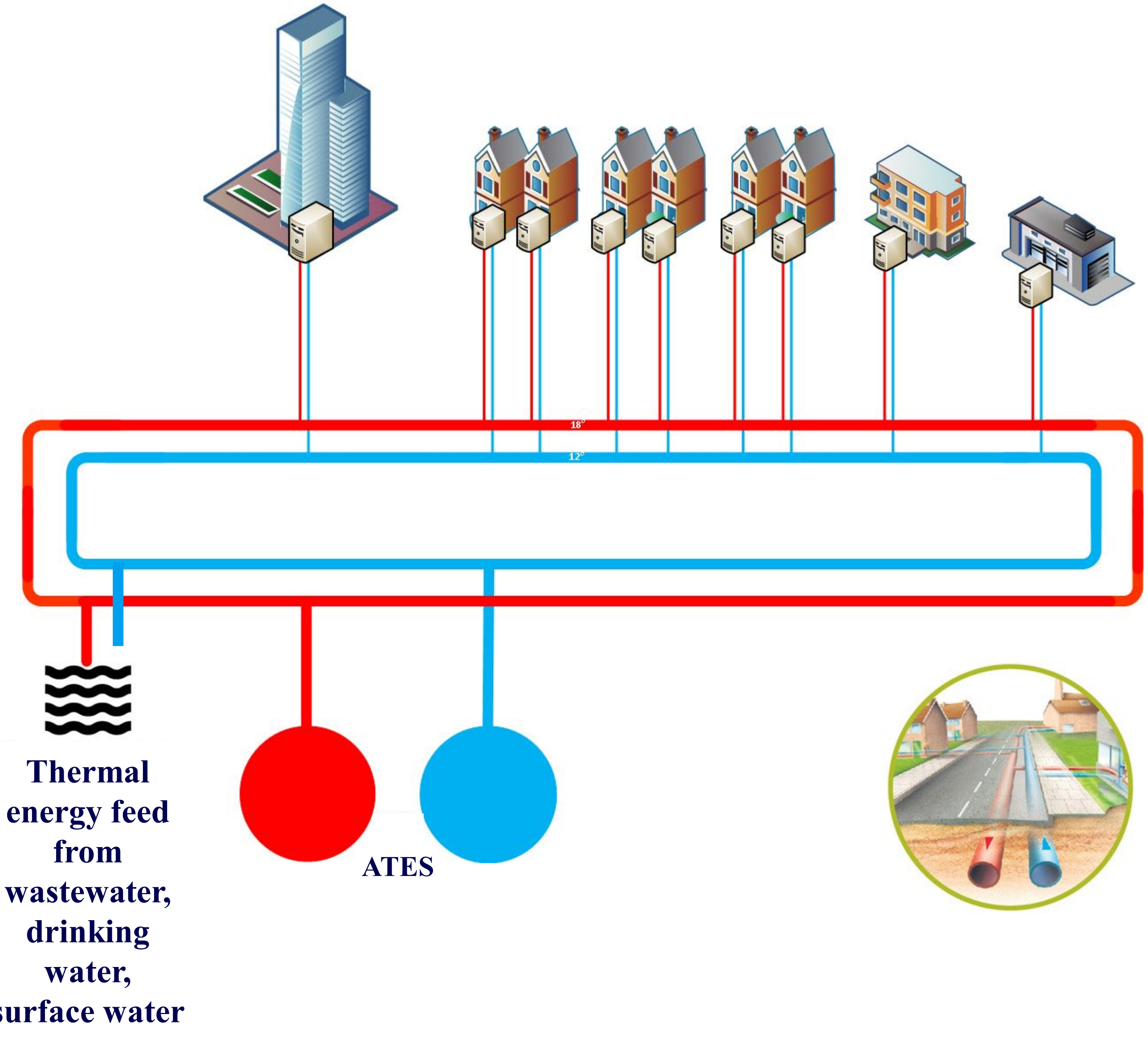
Future perspective aquathermal energy



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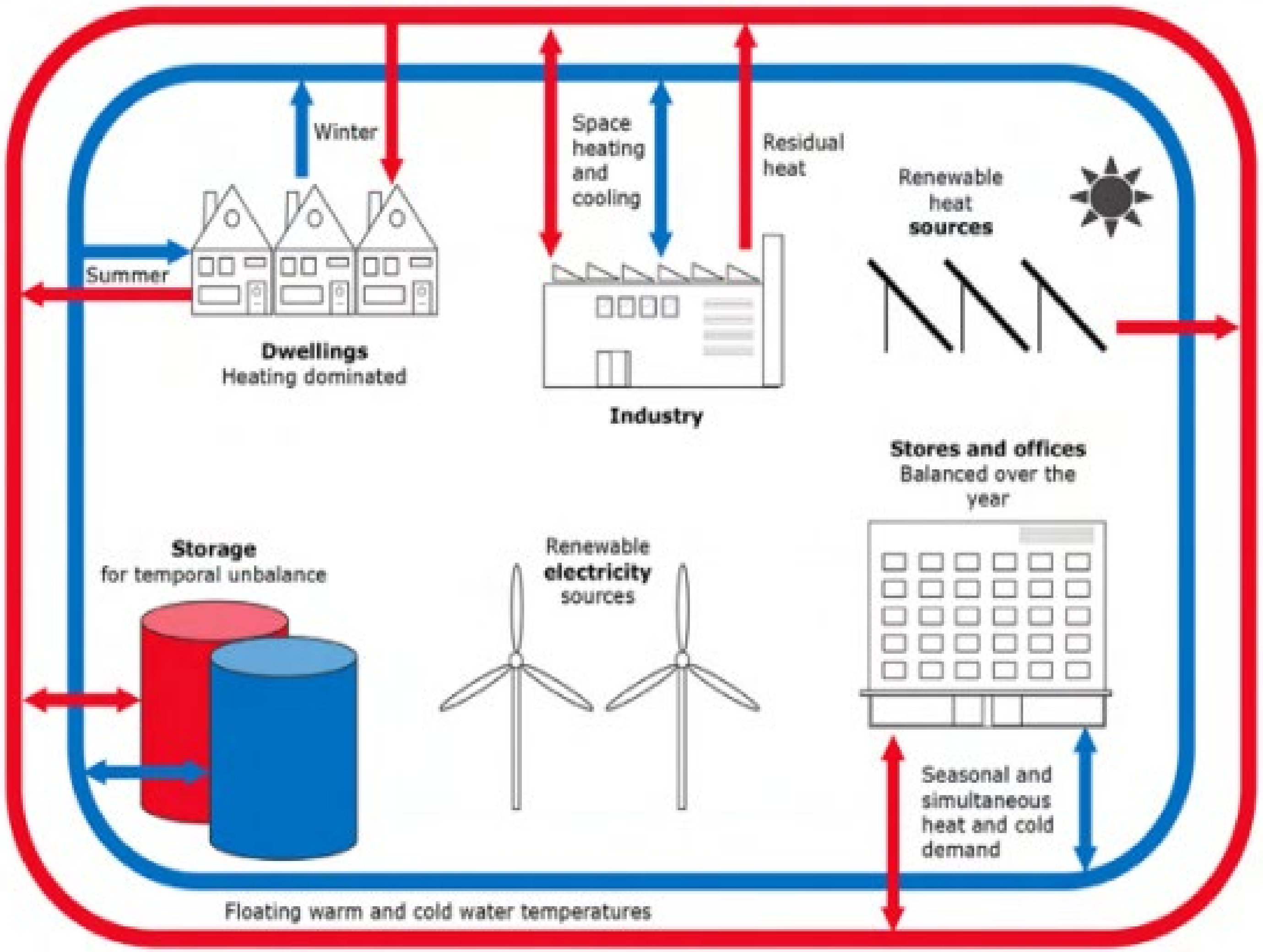
Future perspective renewable energy



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Towards carbon neutral water utilities

Reducing greenhouse gas emissions: experiences of Waternet

Thanks for your attention!

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jan.peter.van.der.hoek@waternet.nl