



Operational lessons learned for a highly optimized water system in Denmark

WATER TECHNOLOGY ALLIANCE (WTA)



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DANISH WATER TECHNOLOGY ALLIANCE

Knowledge Sharing | Fact Finding | Collaborative Projects



Water Resource Management



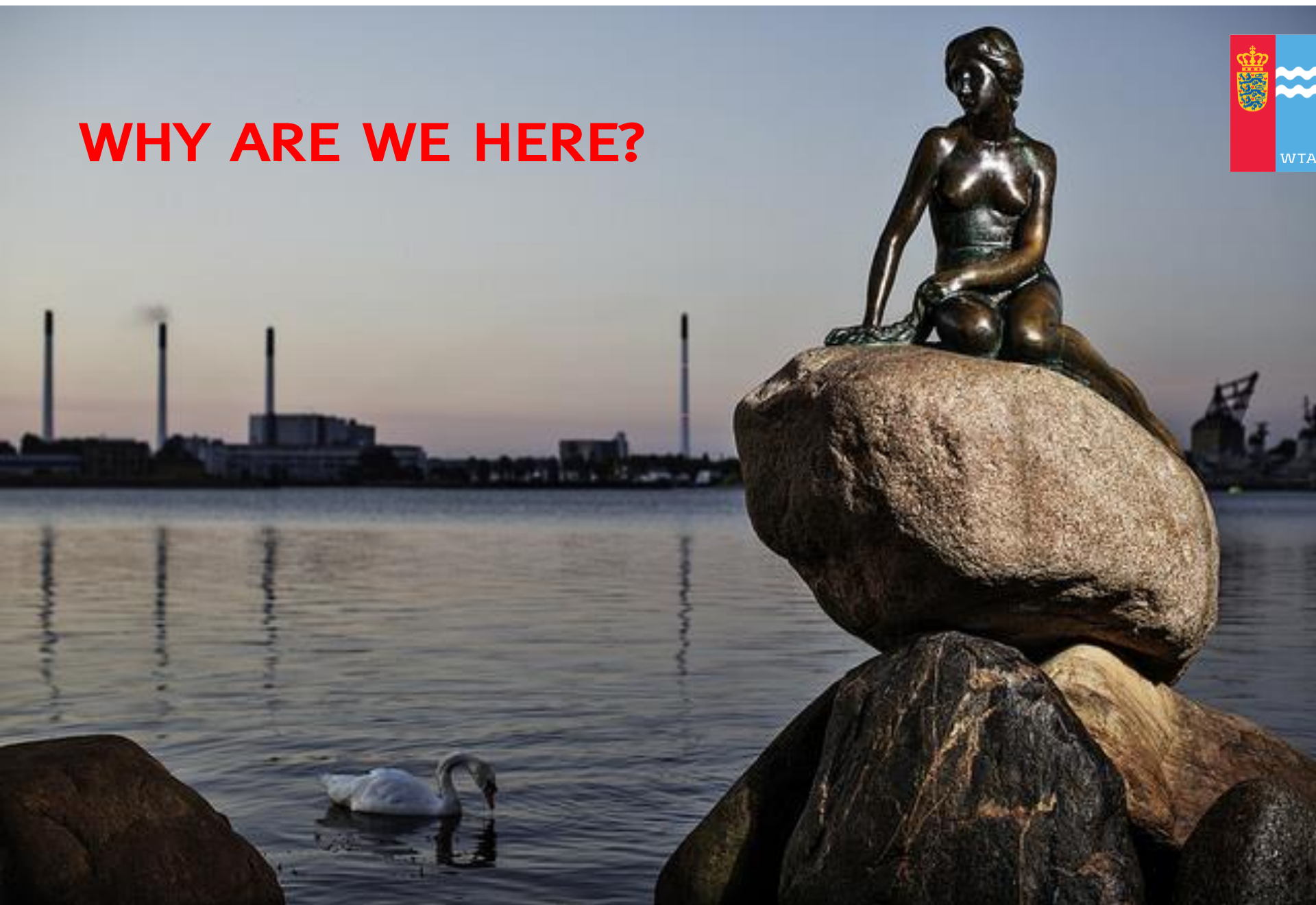
Smart Water Distribution



Wastewater & Energy Neutrality



WHY ARE WE HERE?





FACTS

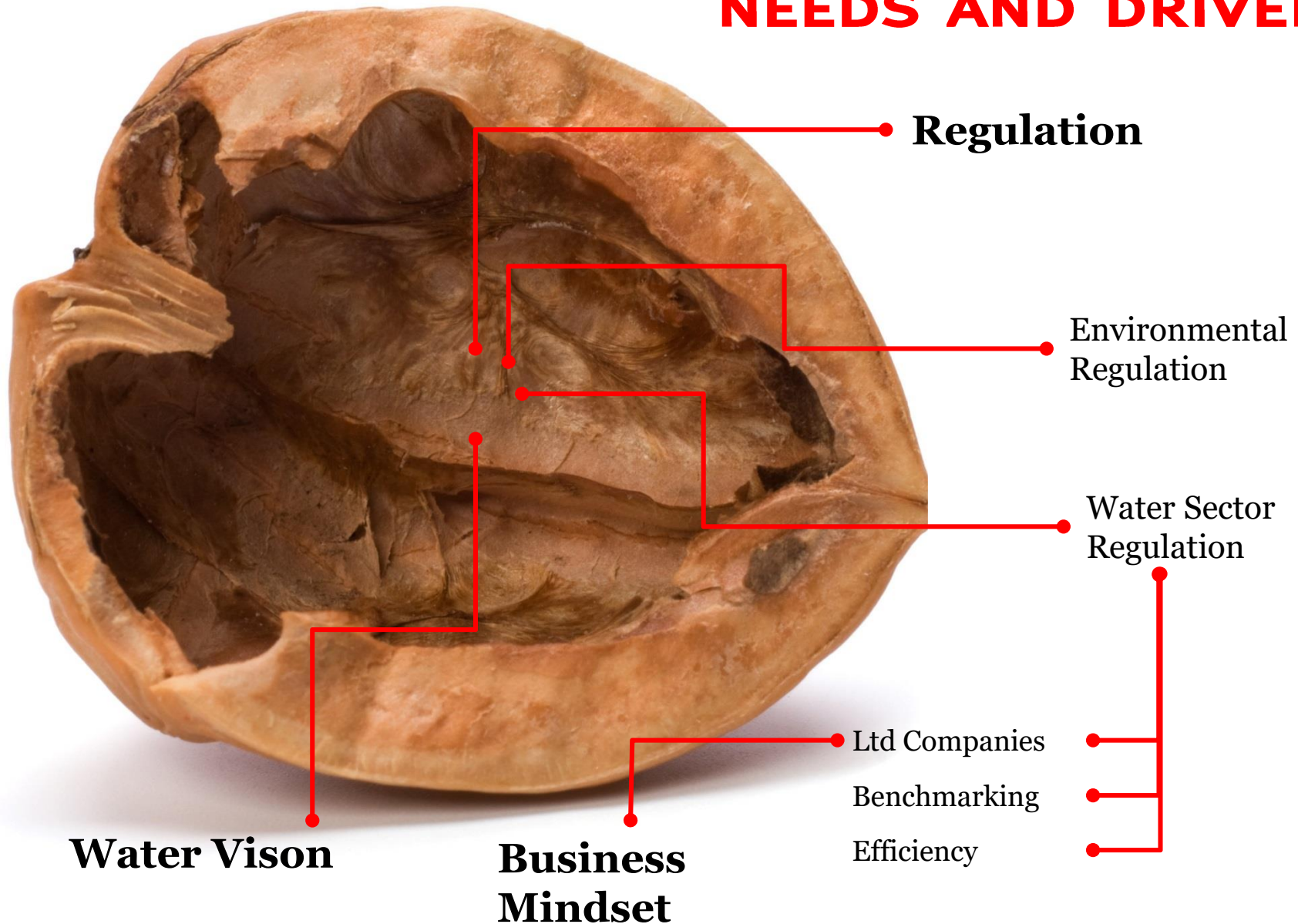
- 5.6M people
- 16.574 sq mi.
- 2/3 agriculture land
- 28M pigs
- 100% groundwater
- 28 gal./p./d.
- Water price 8-9 USD per m3
- Avg annual precipitation 29,5 inches.

DENMARK 20-30 YEARS AGO

- Decreasing water tables
- Saline water
- Lack of flows in streams in the summer time
- Water quality problems due to farming (P, NO₃, and pesticides), point sources, and over abstraction



NEEDS AND DRIVERS





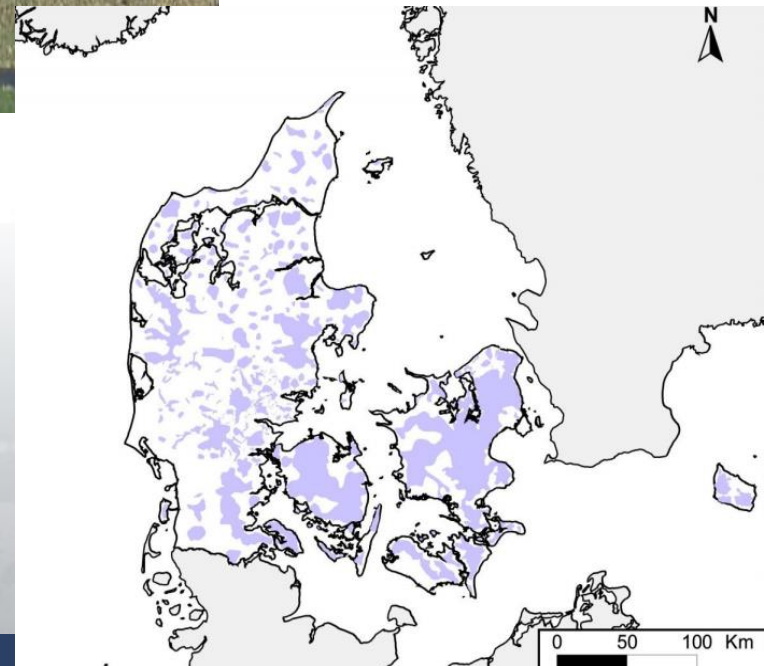
Sustainable Groundwater Management



- Regulated by permit since 1926
- Pollution pressures (nitrate, pesticides, industrial) in 80/90'es.
- National groundwater mapping 1999 – 2015



Water Supply in Denmark is all based on groundwater

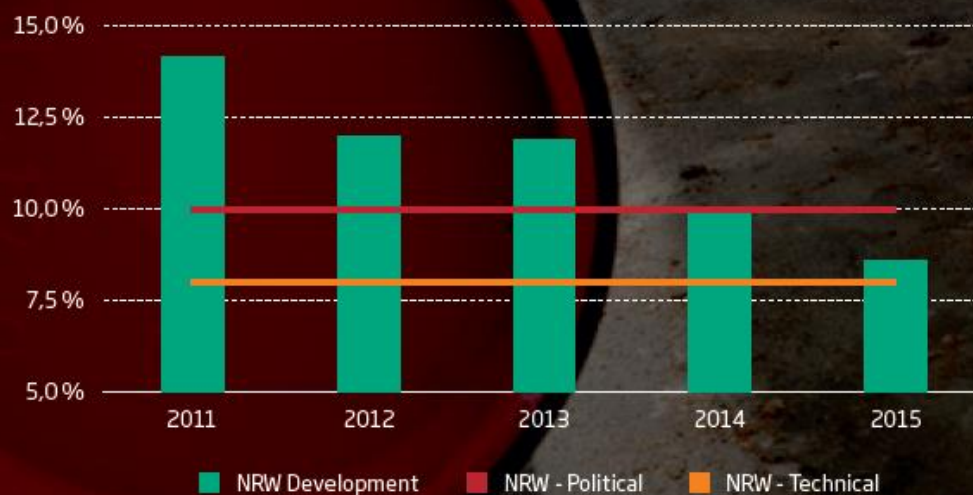


Resource
conservation
Motivating low
water loss

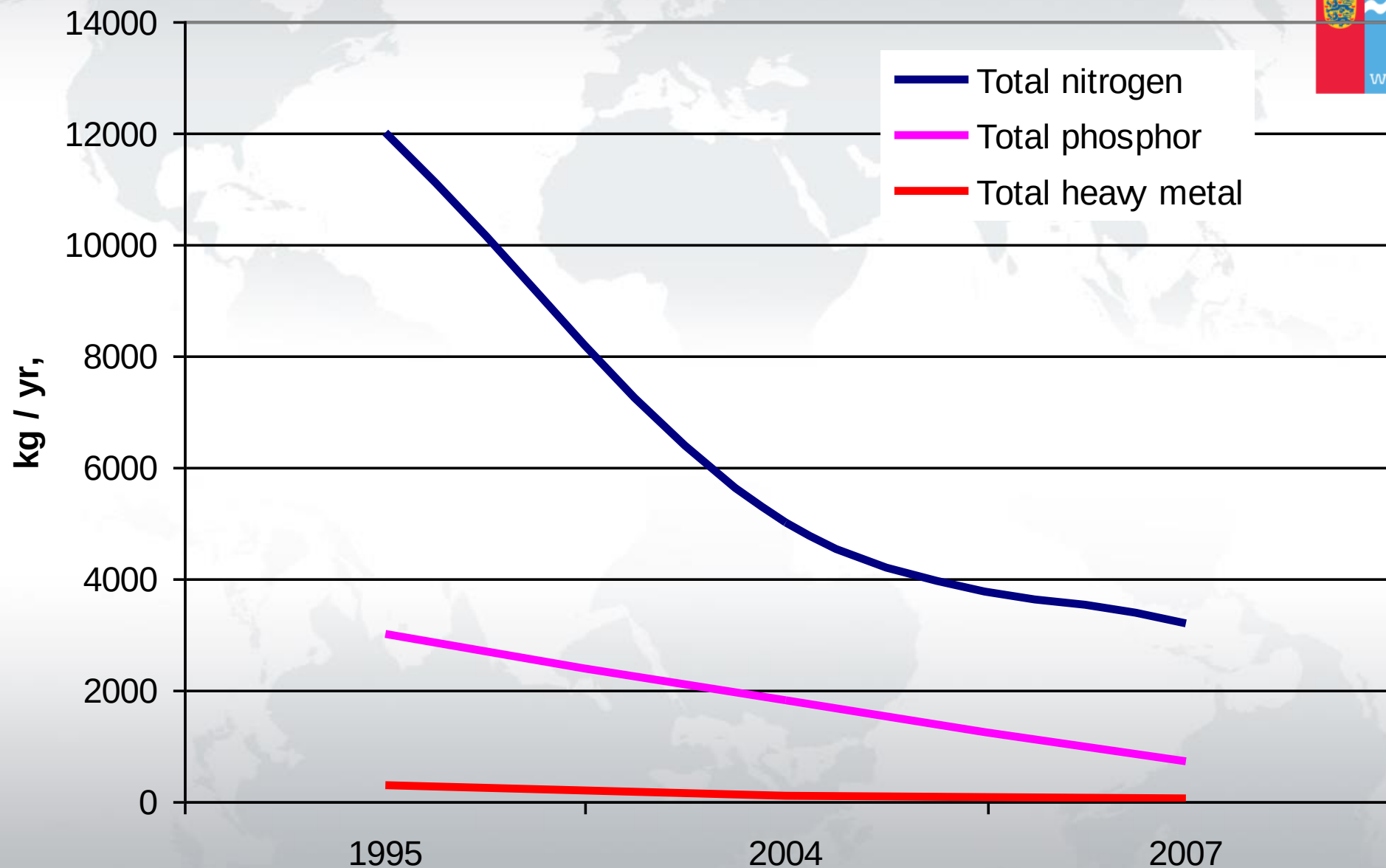
“Polluter Pays” –
principle

Penalty for water
loss above 10%

Yearly NRW Development



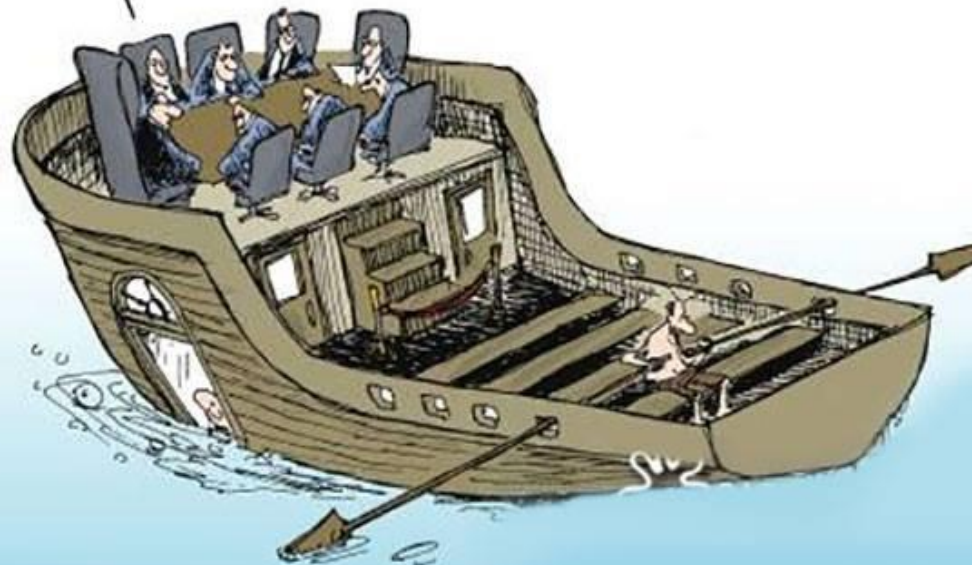
Regulation on wastewater discharge



BENCHMARKING AND REVENUE CAP



I DON'T GET IT... AFTER ALL THE BUDGET CUTS TO STREAMLINE THE WORK FORCE, WHY AREN'T WE MOVING FASTER?



Benchmarking (2010 – 2025)

- Governmental Utility Strategy 2025
- Economic regulation (Revenue Cap & 2% efficiency)
- Mandatory regulatory benchmarking (State Agency)
- Mandatory performance benchmarking (Danish EPA)

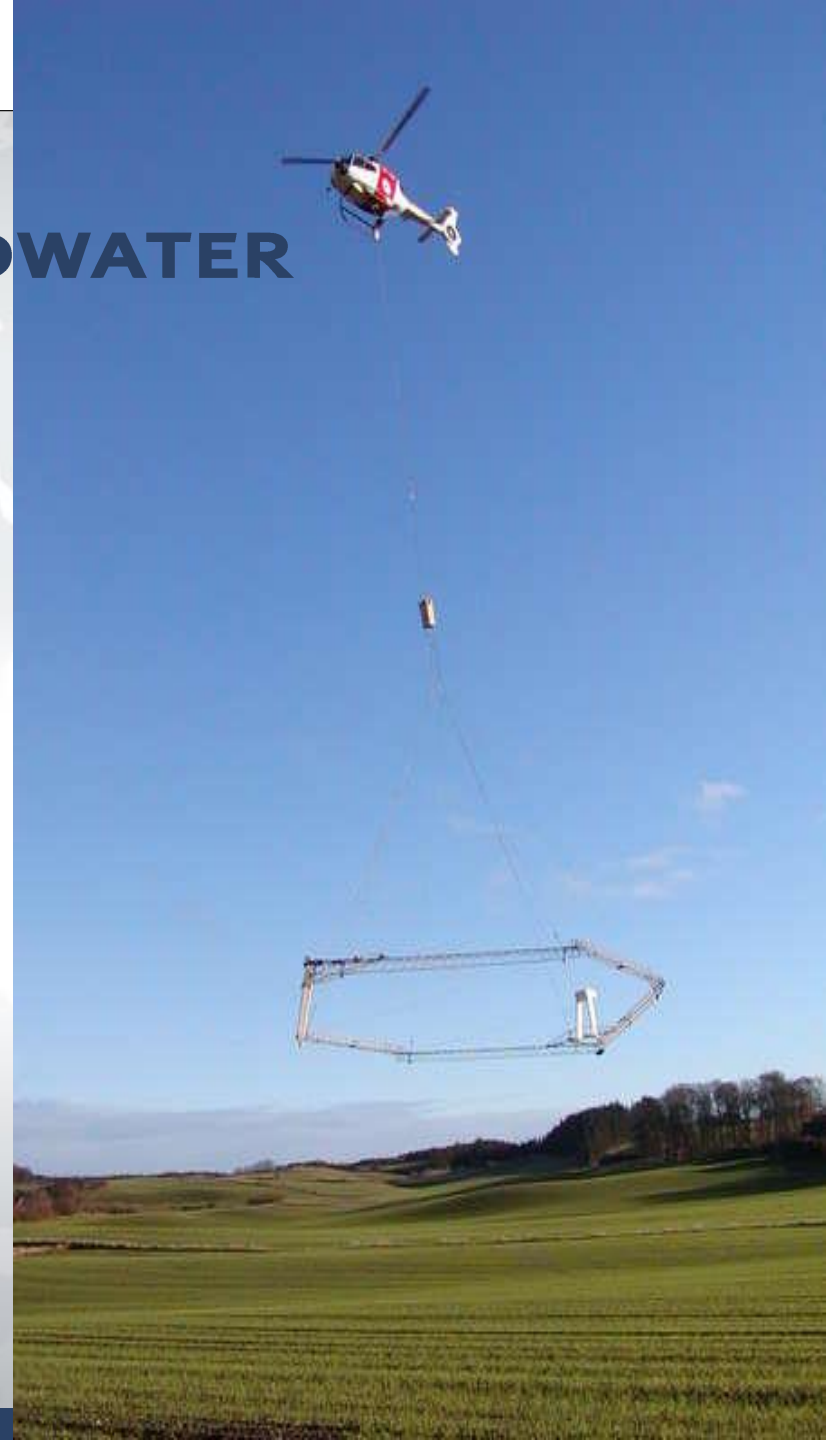
**Drivers for
efficiency and innovation**

ROADMAP FOR GROUNDWATER SUSTAINABILITY PLANS

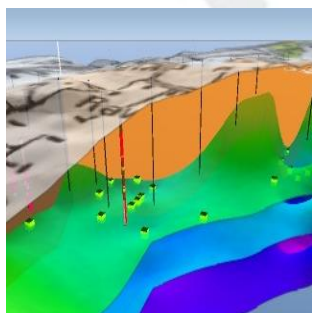
Experiences

National groundwater mapping 1999 –
2015. Financed by water consumers
8,2 cents/af

- Stakeholder management
- Mapping
- Data
 - Collection
 - Integration
 - Visualization



COLLABORATION - SUSTAINABLE WATER RESOURCE



Danish EPA

- Management
- Funding

Consultants

- Data
- Modelling
- GSPs

Municipalities and Utilities

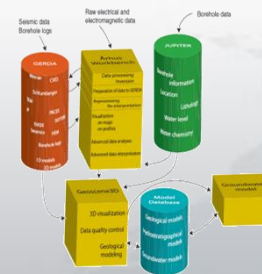
- Action plans
- Implementation

Universities

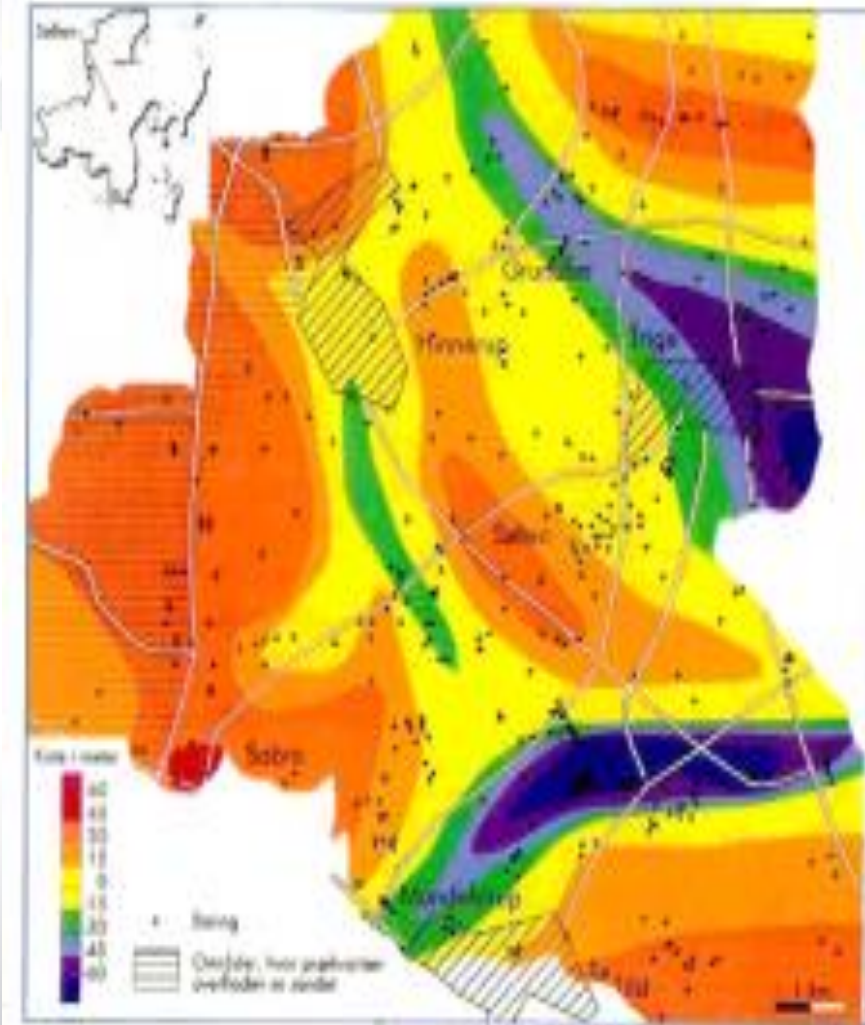
- Research
- Standards
- Candidates

GEUS - Geological survey

- Standards
- Databases



MORE DATA CREATES INSIGHT



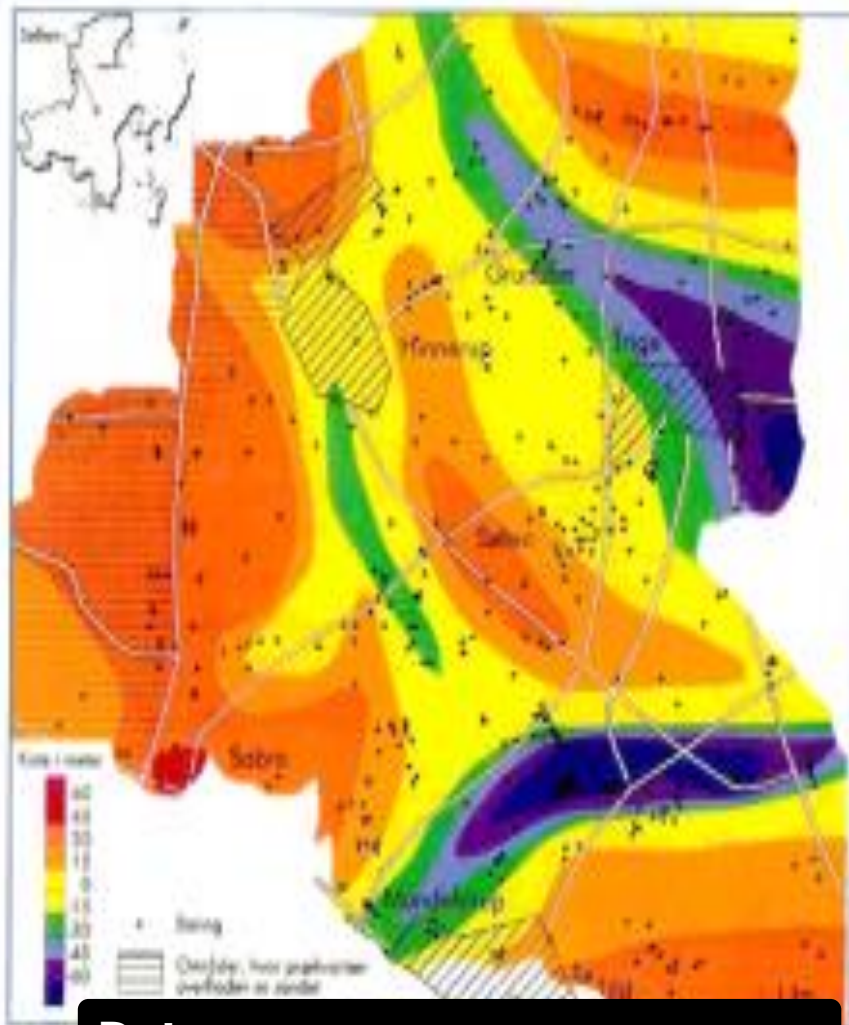
Data

- Information from 518 wells

MORE DATA CREATES INSIGHT

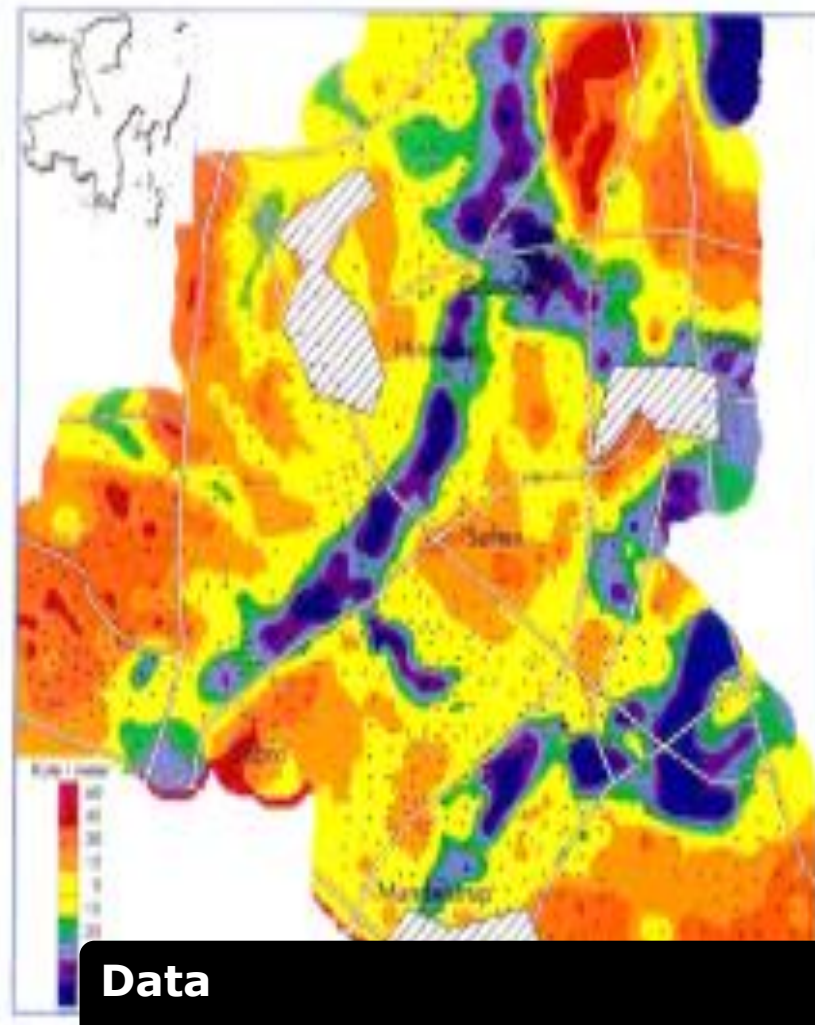


TA



Data

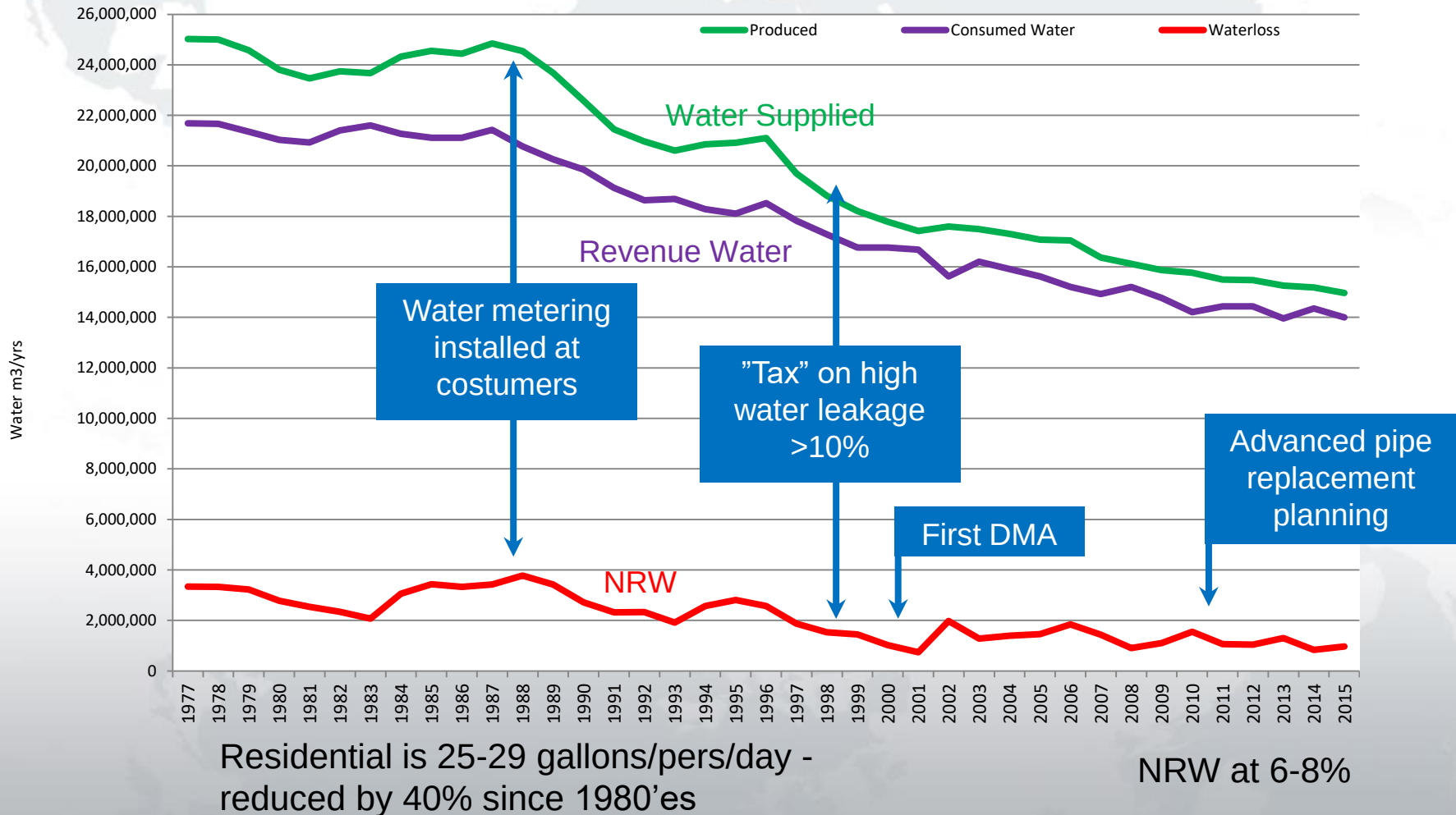
- Information from 518 wells



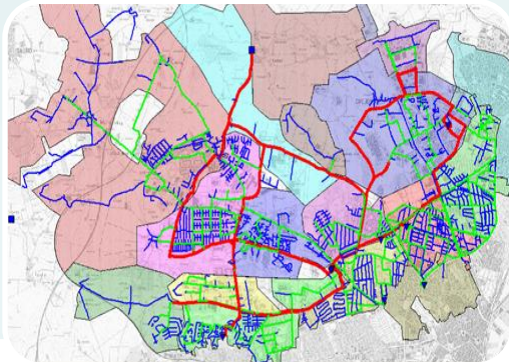
Data

- Information from 518 wells
- And 1400 TDEM soundings

WATERSAVINGS AND -LOSS DURING THE LAST 30 YEARS



PROACTIVE LOWERING LEAKAGE CONTROL



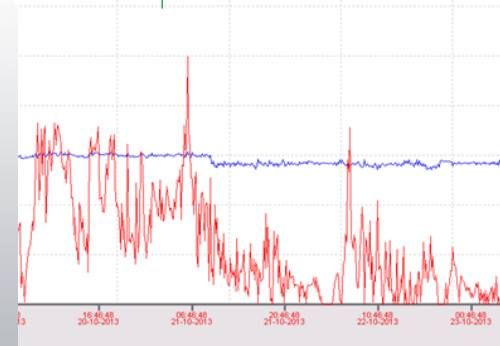
DMA construction
and monitoring
Water balance
Night time flow



Systematic
detection
Leakage location
(microphone,
correlator and gas)



Pressure
reduction
Service level:
28-35 psi



Leakage management – optimizing systems



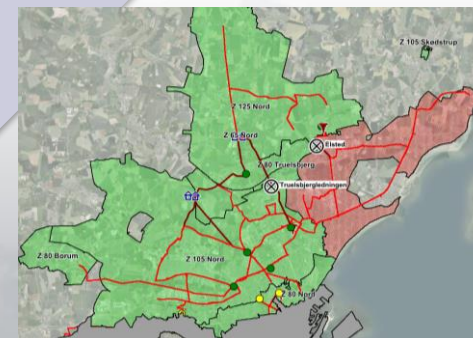
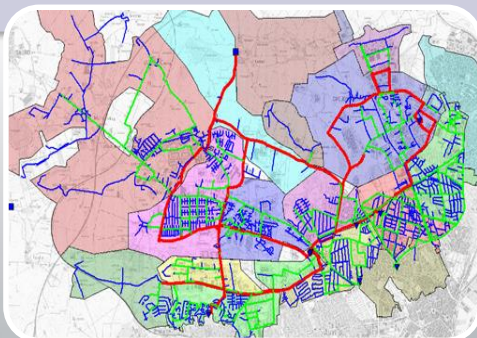
Water Metering

Proactive leakage control

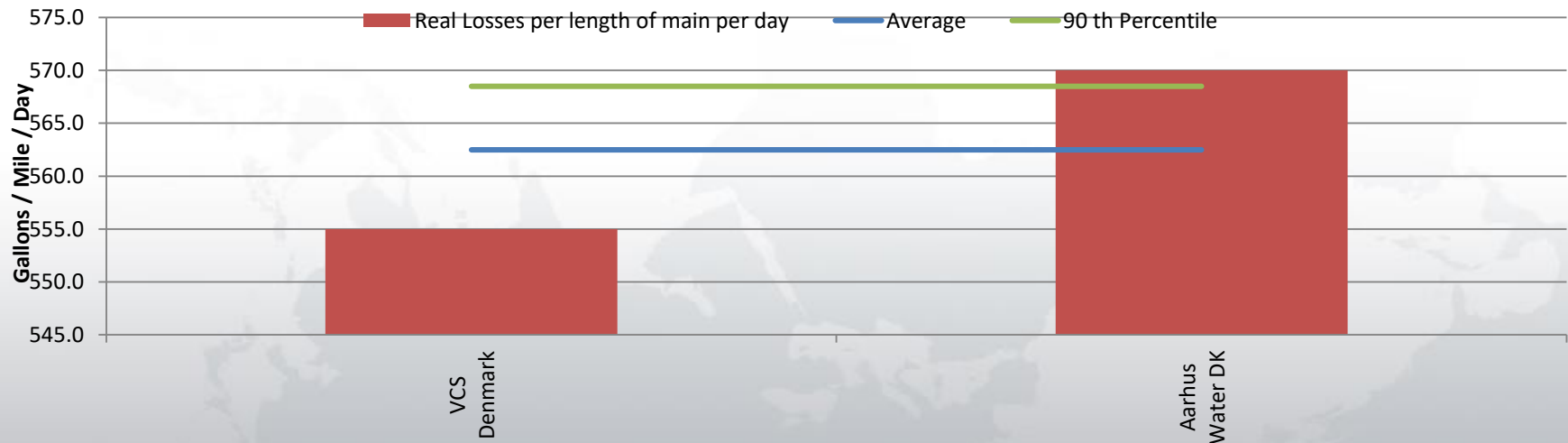
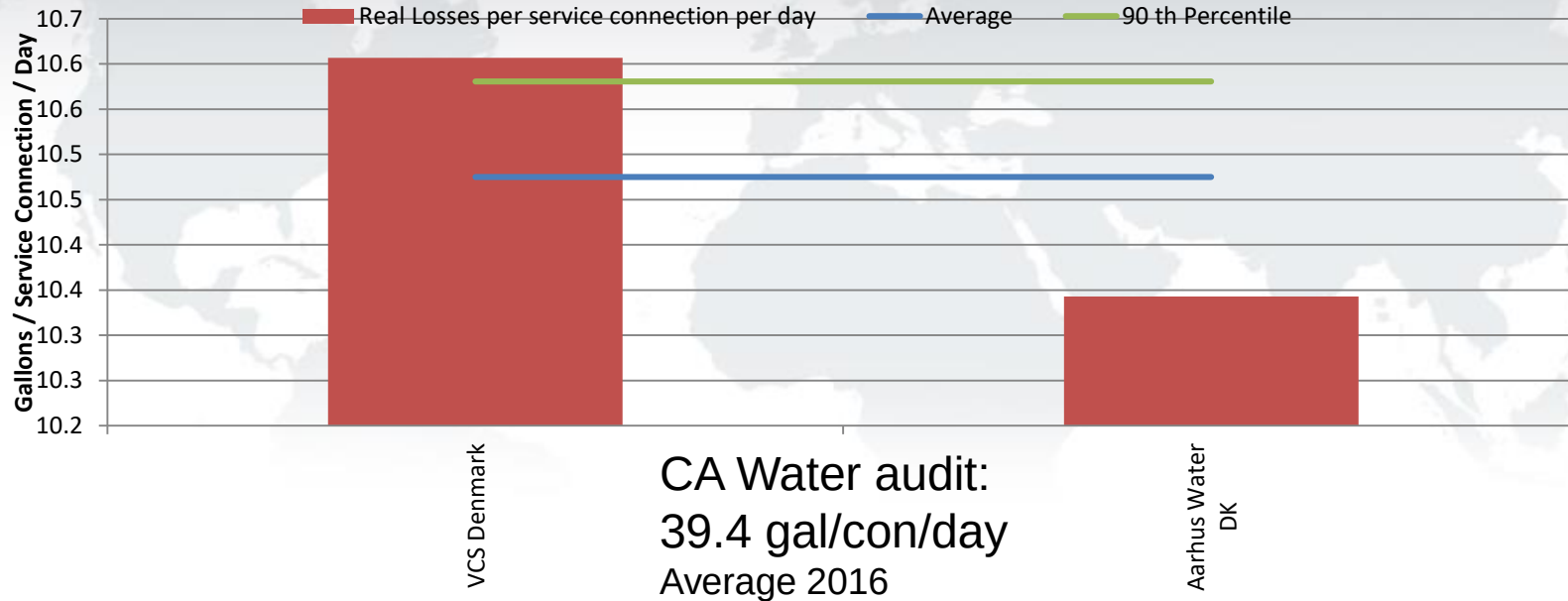
Pressure management

Asset Management

Data Management

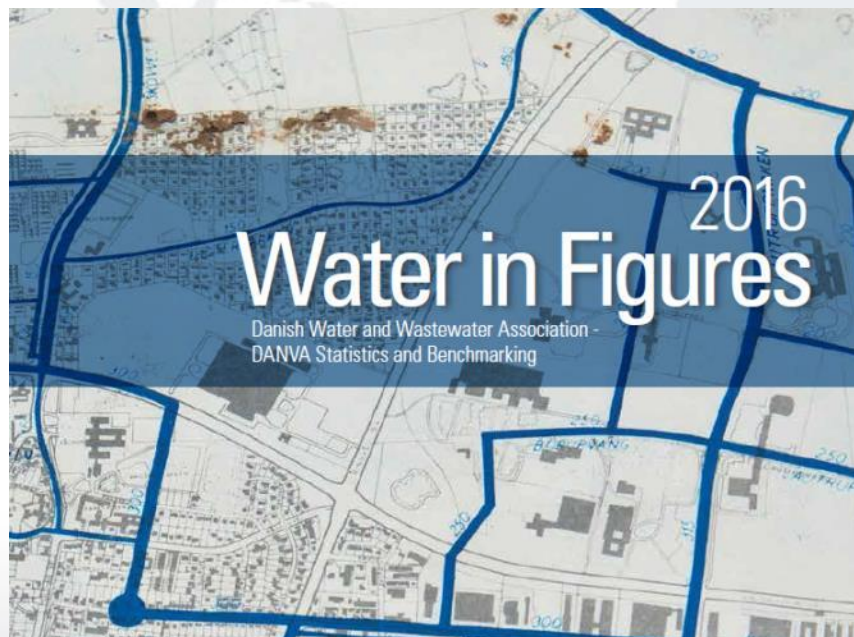


Specific water loss - Water Audit



PERFORMANCE BENCHMARKING

Danish Water and Wastewater
Association, DANVA



Key Performance Indicators
Danish average

OPEX	1.8 \$/ccf*
CAPEX	3.2 \$/ccf*
NRW	7.82 %
Specific water loss	552 gal/miles/day
ILI (CARL/UARL)	0.8
Energy intensity	1.2 kW/ccf*
Pipe replacement rate	0.95% (2015) 0.85% (10 year)
Breaks (excl. other factors)	8 per 100 miles/year

* Revenue water

DISCHARGE STANDARDS – DEVELOPMENT

Parameter	Unit	1960	1970-80	1990	2016 (sensitive areas)	EC Standards (1)
BOD ₅	mg/l	150	25	15	10	25
Total N	mg/l	-		8	8	15
Total P	mg/l	-		1.5	0.4	1
Treatment		M	MB	MBNP	MBNPS	

Legend:

M= Mechanical

MB= Mechanical-Biological

MBNP= Mechanical-Biological-Nitrogen-Phosphorus removal

MBNPS= Mechanical-Biological-Nitrogen-Phosphorus removal and sand filtration

(1) Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment

Tax Payment to Government on all three parameters

REGULATION BY "POLLUTION" TAX

Tax Rates – Pollution Discharge	Units	2016
Total N	\$/lb	2
Total P	\$/lb	11
BOD ₅	\$/lb	1

Aarhus Water
pays nearly
\$1 mill./year



Marselisborg WWTP – 220.000 PE / 18 MGD

Energy savings – Main activities



SCADA-System

N-removal
 NH_4 - and NO_3 -
online Control

Active control of

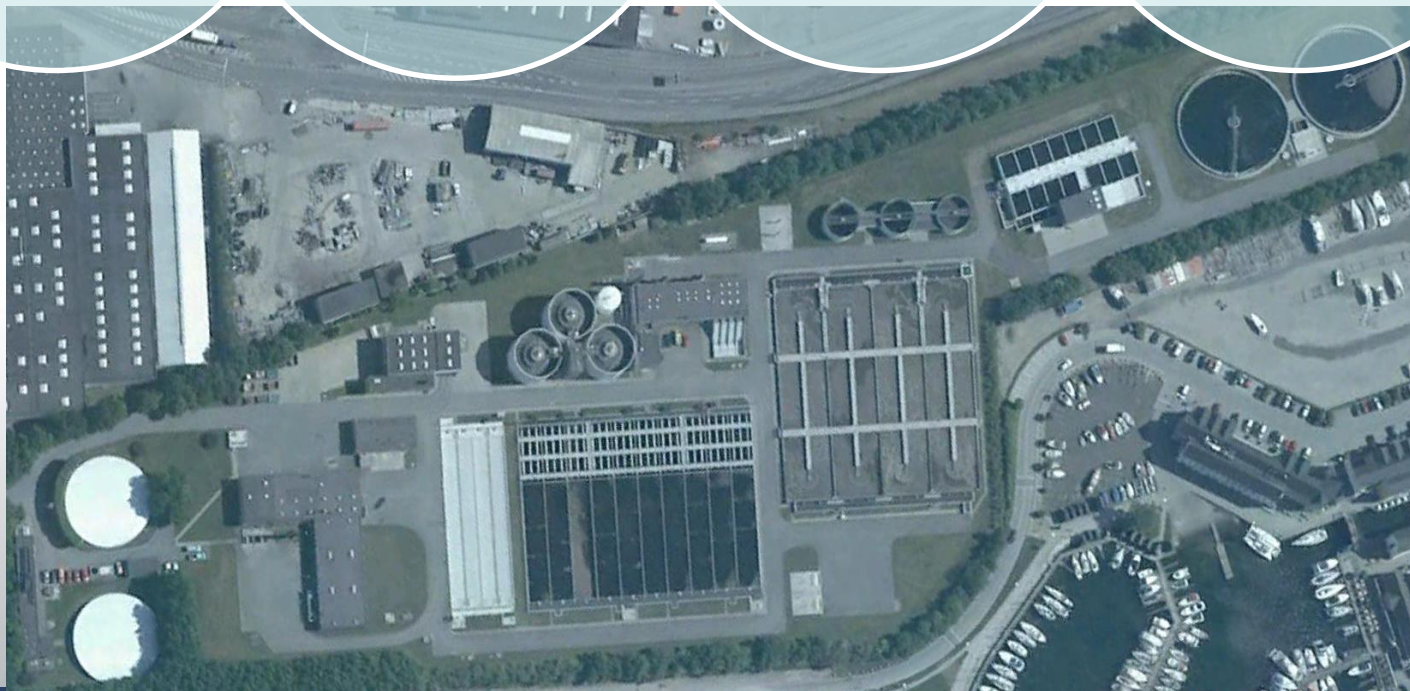
Sludge
Retention Time
(SRT)

New energy
efficient blowers

Bottom aeration

Sludge liquor
treatment

Side-stream
anammox



Improved efficiency of the aeration

aarhusvand

Replacement of 3 HV Turbo blowers

HV Turbo blowers - 1992



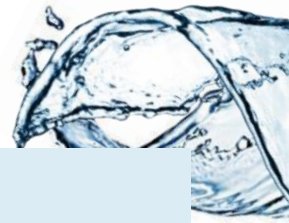
ABS HST Compressor



Key data for project:

- Reduction in power consumption:
300,000 kWh/year
- CO₂-reduktion: 153 tons/year
- Construction costs : US\$ 270.000
- Pay back time (ROI): 4-5 years
- Implementation: 2011-12

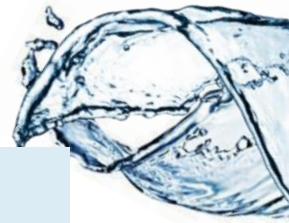
New membranes - fine bubble aeration



Optimized energy production

aarhusvand

Phase 1: Replacement of 3 old gas engines with two high efficiency - 2 pcs 250 kW - CHP units



Key data for the project

- Implementation: 2010-12
- Construction costs : 1,400,000 US\$
- Replacement of 2 biogas engines, incl. CHP
- Electricity production (additional production): approx. 1 mio. kWh/year
- CO₂-reduction: 426 tons/year
- Pay back time (ROI): 3 years



New gas engine

Power efficiency

38-39%

Surplus heat efficiency

50-55%

Total efficiency

88-94%

Optimized energy production

Phase 2: New CHP and gas treatment

aarhusvand



Gas engine installation:



Gas Treatment:



Key data for the project:

- Implementation: 2015
- Gas treatment - Activated carbon
- Power production (surplus production): 900,000 kWh/year
- Investment: \$ 510,000
- CO₂-reduktion: 376 tons/year
- ROI approx. 4 year

New gas engine

- 1 pcs. 358 kW CHP biogas motor
- Power efficiency 40%

MARSELISBORG WWTP – OPEX BENEFITS SUMMARIZED



Activity	Investment €	Savings/sales € per year
Process optimization	400.000	175.000
Improved aeration	250.000	26.000
Sludge liquor treatment	400.000	85.000
Replacement of old gas engines	1.271.000	154.000
New gas engine and gas treatment	430.000	139.000
Surplus heat for district heating	166.000	33.000
Total	2.917.000	612.000

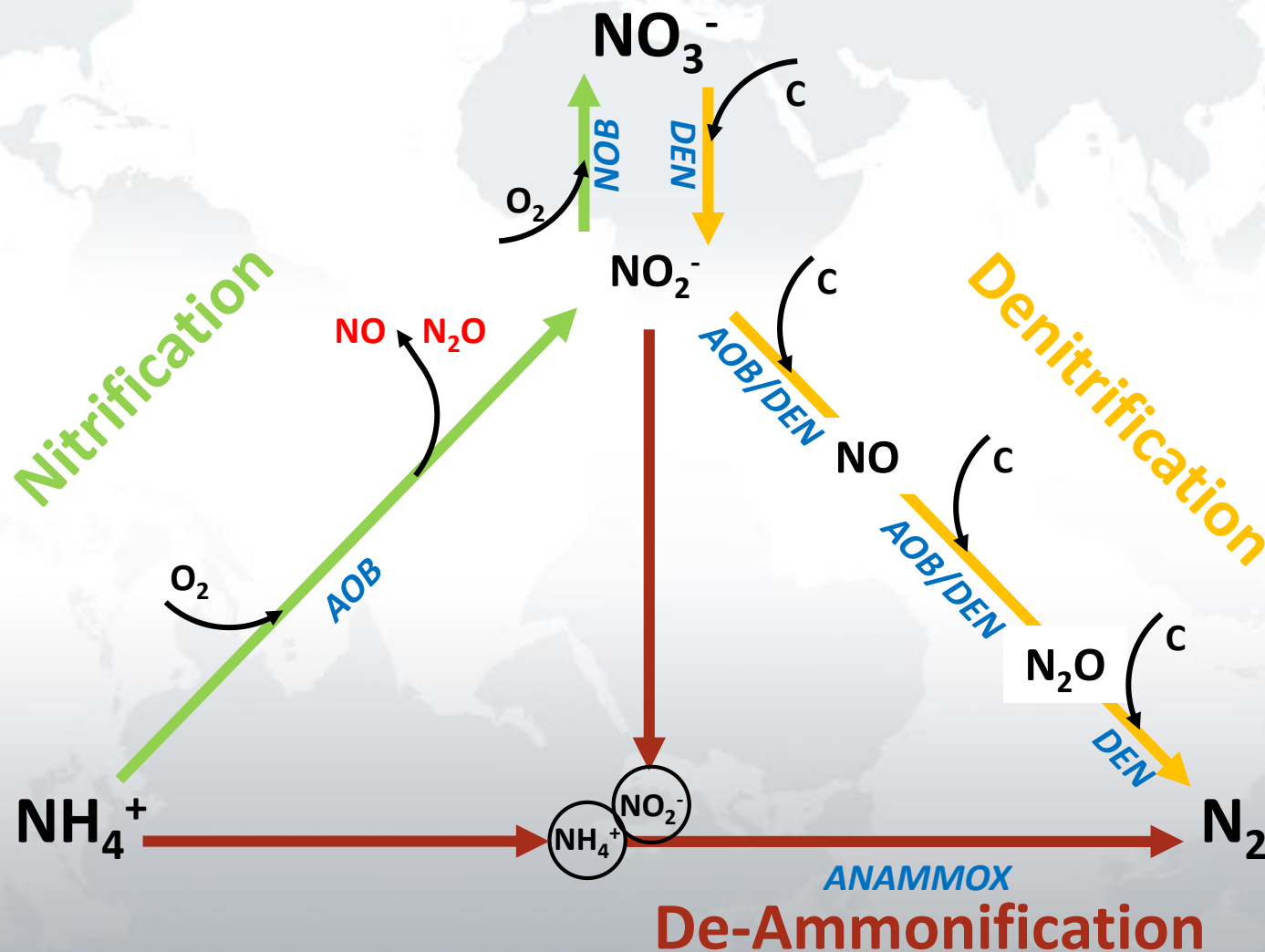
ROI in total: 4,8 years

OPEX for WW service in Aarhus Vand reduced: Savings/sales = 3,6 %

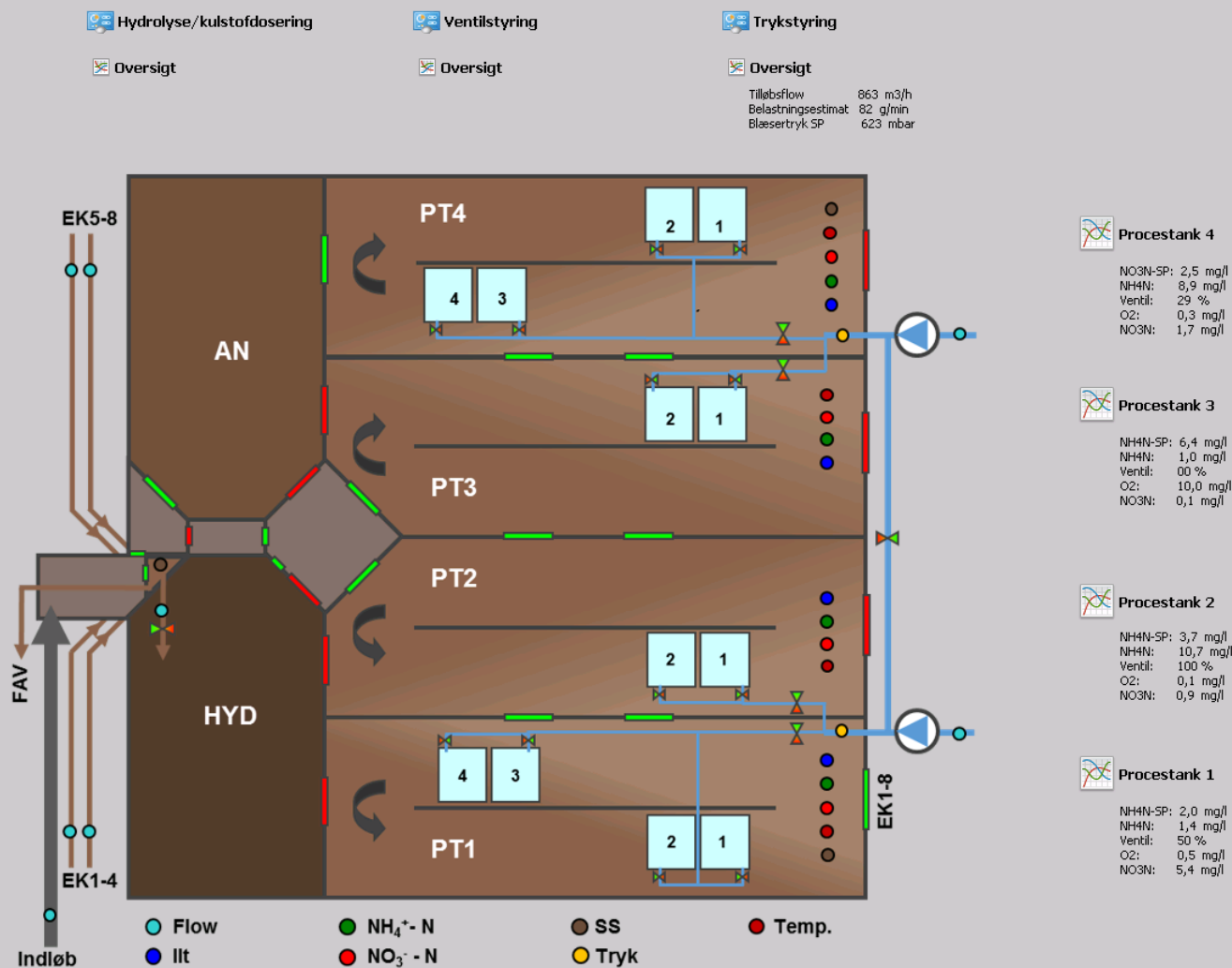
Savings = reduction of power consumption and waste water taxes

Sales = supply of power and excess heat to external power and district heating networks

PROCESSES FOR NITROGEN REMOVAL



Simultaneous nitrification/denitrification

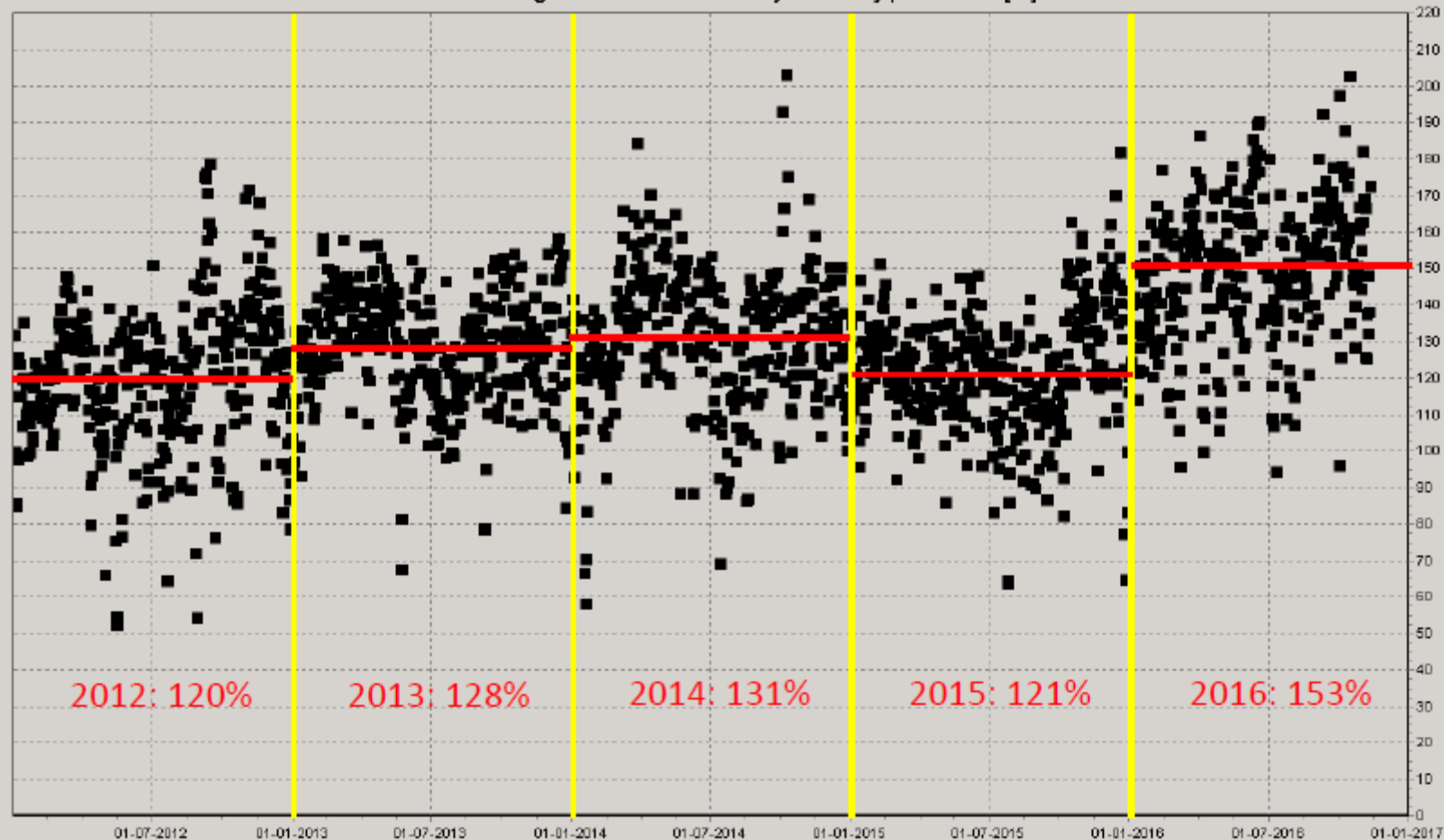


USING THE ANAMMOX PROCESS



- Side stream treatment of centrate
- Main stream – target now Nitrite shunt

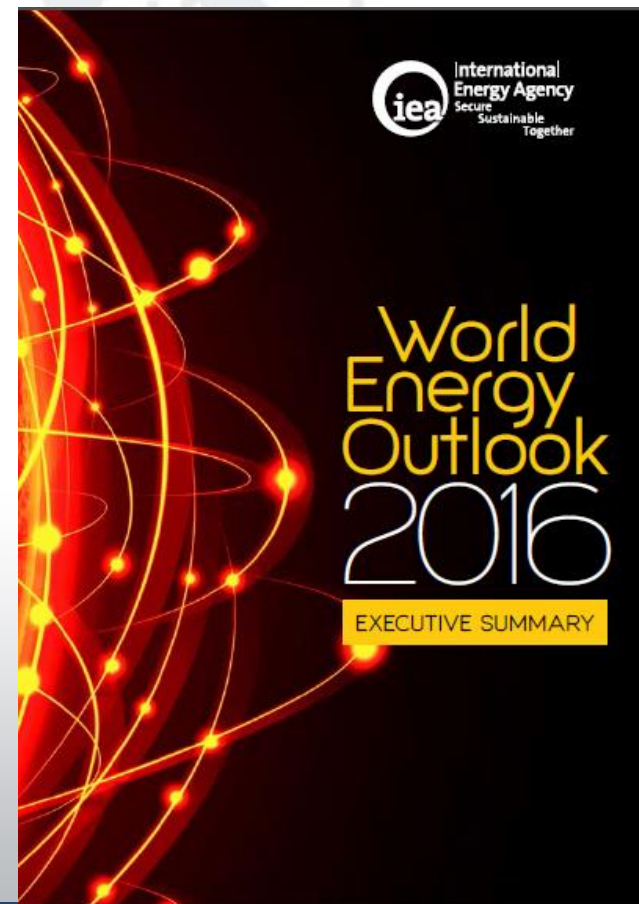
Marselisborg WWTP - Self sufficiency electricity production [%]



ENERGY+ WASTEWATER FACILITY

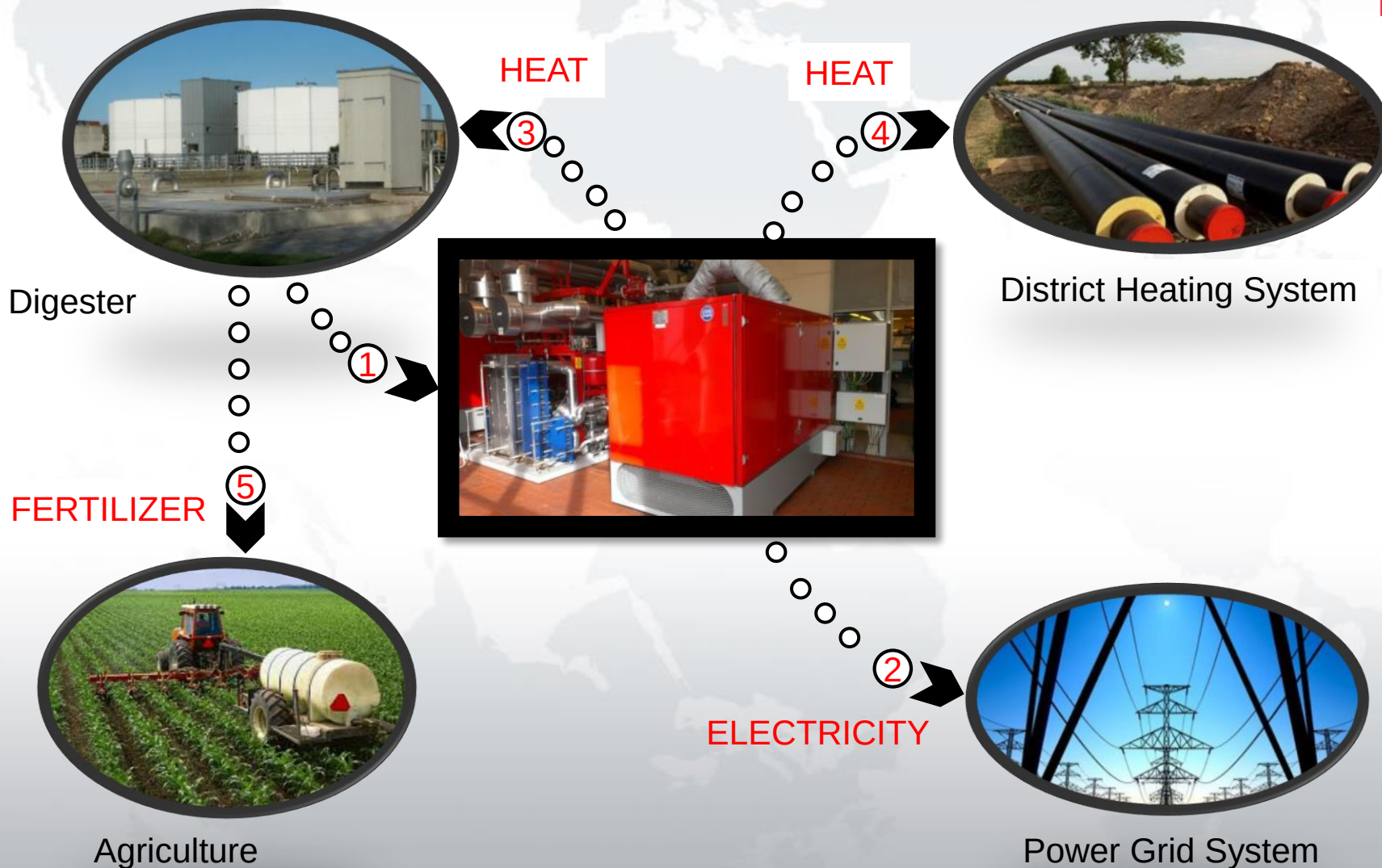
MARSELISBORG WWTP AARHUS WATER, DENMARK (2016)

- Size: 200.000 PE ~ Flow: 7,3 MGD (ave) and 50 MGD (peak)
- No external carbon sources
- 153 % electricity self-sufficient - 4,8 GW
- Excess heat ~2.6 GWh/year
- Total energy produced ~ 234 %



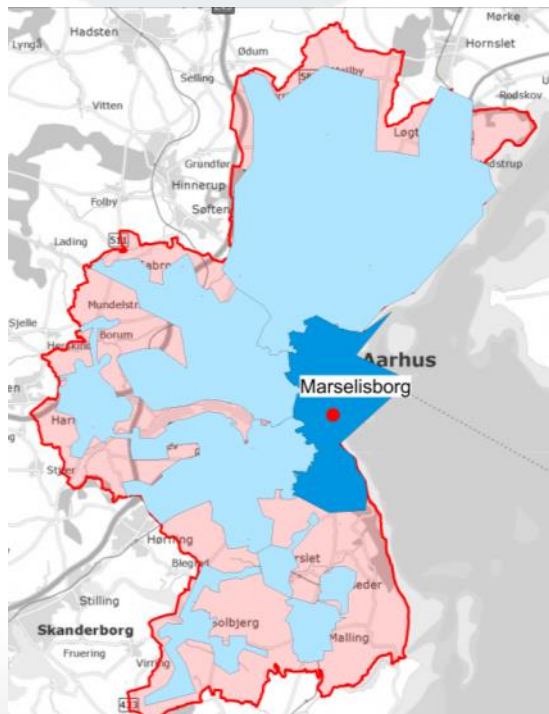
Optimized Energy Production

Improved Biogas Utilization



Energy Self Sufficient Water Circle

MARSELISBORG CATCHMENT AREA: 200,000 PEOPLE



ENERGY SELF SUFFICIENCY			2014	2015	2016
Amounts	Water Production	[MG]	1,532	1,585	1,611
	Wastewater treated	[MG]	2,774	3,170	2,959
Power Consumption	Water Supply	[GWh]	3,1*	3,2	3,6
	Wastewater Transport	[GWh]	0,7*	0,8	0,8
	Marselisborg WWTP	[GWh]	3,4	3,5	3,1
	Total	[GWh]	7,2	7,6	7,5
Energy Production	Power production	[GWh]	4,4	4,6	4,8
	Heat production	[GWh]	2,1	2,2	2,6
	Total	[GWh]	6,5	6,8	7,4
Energy self sufficiency	Marselisborg WWTP	[%]	192	194	234
	Catchment Area	[%]	90	90	99

AARHUS WATER – WATER PRICE 2016

Elements of the price	USD/ccf (af)
<i>Water consumption</i>	4.78 (2,084)
<i>State tax: water supply</i>	3.34 (1,455)
Water Supply (potable water)	8.12 (3,539)
<i>Waste water</i>	11.92 (5,193)
Water and wastewater	20.05 (8,733)
Total incl. 25% VAT	25.06 (10,916)

Household cost

Potable water:

53 ccf/year = 430 USD
(**0.121 AF/YEAR**)

Water & wastewater

(incl. storm water):

App. 89 USD/month
excl. VAT



MEMORANDUM OF UNDERSTANDING

- KICKED OFF SEPTEMBER 22ND 2017

- The MoU is intended to provide a general framework for cooperation on common water issues between California and Denmark*

Collaboration



Photo: Grundfos

WTA: Knowledge sharing & collaboration

In California and Denmark



WATER TECHNOLOGY ALLIANCE

A KNOWLEDGE SHARING INITIATIVE



Ministry of Environment
and Food of Denmark
Nature Agency

INNOVATION CENTER DENMARK
SILICON VALLEY



APPLIED BIOMIMETIC



RAMBOLL



Smith

kamstrup



LiqTech

I•GIS