ENGINEERING TOMORROW

# Turning the Water Industry into Energy Neutrality + low water leakage

**Water New Zealand Conference & Expo, 21 of Sept. 2017**

**Global Director & GKAM, Mads Warming, Water & Wastewater**

# Danfoss headquarter in Nordborg, Denmark

**25.000 people, sales in >100 countries, production in 20**

**Turnover 5,3 bn. €; Cooling, Power Solutions, Heating and**

**Danfoss Drives**

# Danfoss Drives has global presence




## Danfoss VSD centers

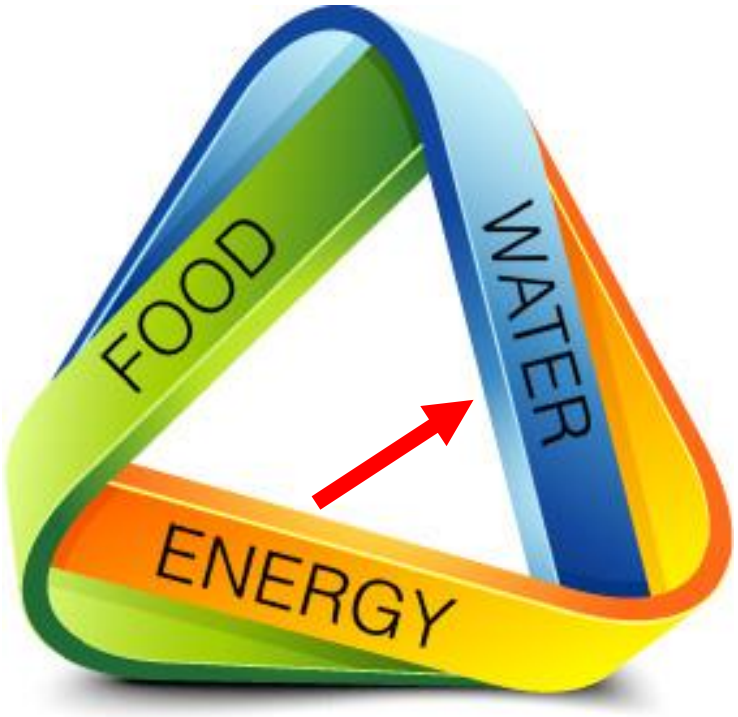
- USA (Rockford)
- Denmark (Graasten)
- Finland (Vaasa)
- China (Haiyan)
- India (Chennai)
- Germany (Flensburg)

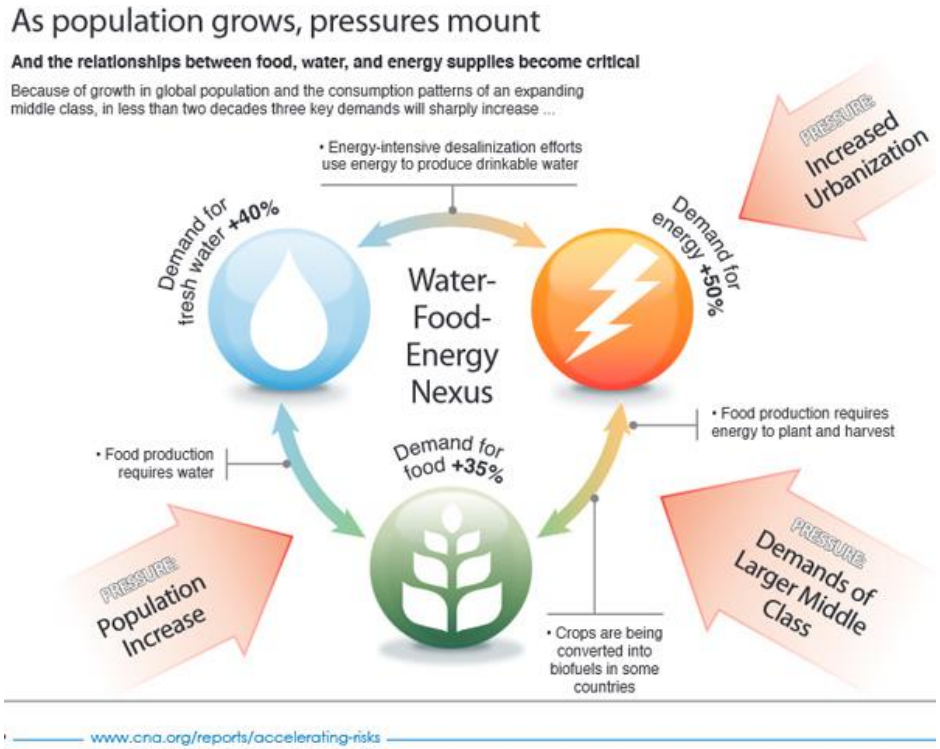
## Danfoss Drives globally:

- ~ 4500 people
- Sales & service in > 80 countries
- 20 mill VSD supplied
- TS 16949

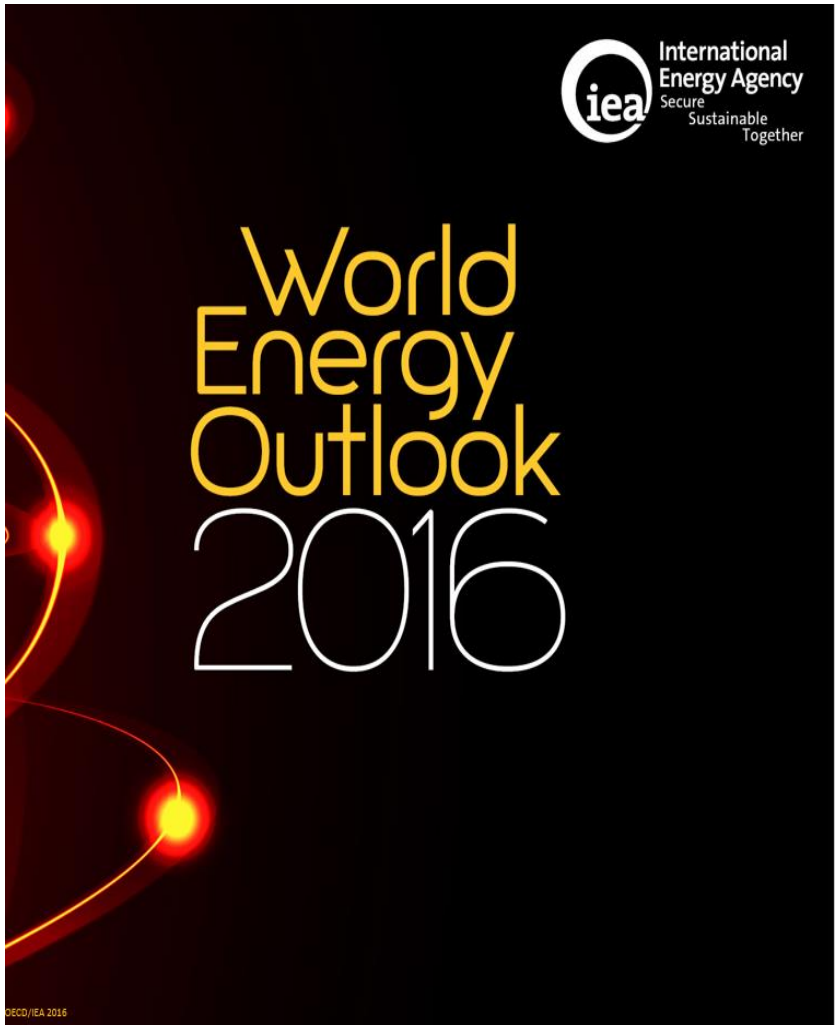
**First to introduce dedicated VSD for W&WW**

# The Water – Food – Energy - Nexus



# A few statements from WEO 2016




## Chapter 9: Water - energy nexus:

- Water counts for **4 % of global electricity ~ Russia** (+ gasoline)
- Electricity consumption **expected to double** next 25 years
- The energy saving in "450 Scenario" is ~ **70 larger coal fired** power plants
- Leakage reduction to **6 %** as Denmark ~ 130 TWh saved ~ **Poland's** entire electricity need
- Water provision and wastewater treatment ~ **30 – 50 %** of **municipal electricity bills**
- The Aarhus Marselisborg WWTP facility in Denmark produces **~ 100 % more energy** than is consumed
- **VSD** mention multiple places as a key component for obtaining these benefits

# A case - Ontario Municipal Energy split

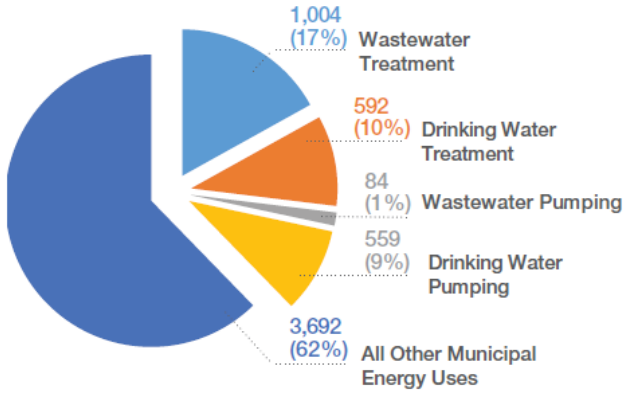



**Figure 1.1. Ontario municipal energy co**
**by facility type (eGWh), 2011**


Municipal water and wastewater systems are typically the largest energy uses reported by Ontario municipal governments.

**Table 1.1. Ontario Municipal Energy Use by Facility Type (2011)**

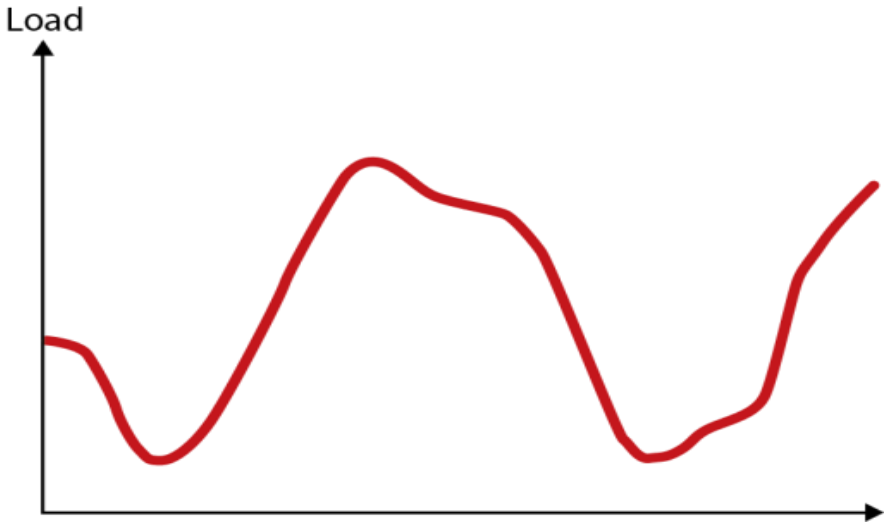
| Municipal Energy Use | eGWh | % of Overall |
|---|---|---|
| Water & wastewater treatment & pumping | 2,235 | **38%** |
| Administrative offices | 765 | **13%** |
| Ice arenas | 599 | **10%** |
| Indoor recreation facilities | 579 | **10%** |
| cilities | 462 | **8%** |
| centres | 348 | **6%** |
| ons | 243 | **4%** |
| | 193 | **3%** |
| Fire stations | 193 | **3%** |
| Swimming pools | 155 | **3%** |
| Cultural facilities | 92 | **2%** |
| Ambulances | 64 | **1%** |

Note: Energy use reported in equivalent gigawatt-hours (eGWh), combining multiple energy sources.

Source: Ministry of Energy, O. Reg. 397/11, 2011 normalized data.

In Aarhus Denmark this wastewater treatment plant have net production of energy (234%) and still complying with the very strict outlet permissions.

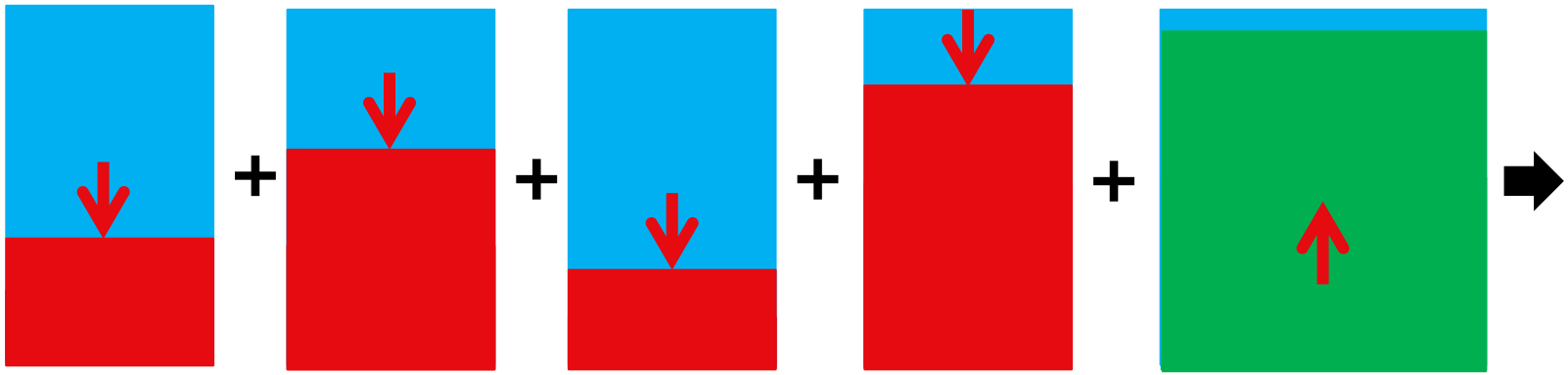
# Why use VSD drives in the water and wastewater business? ..




## The benefits are typically:

- Better water quality
- Better asset protection
- Less maintenance cost
- Reduced energy cost
- Higher plant reliability/capacity

# The energy neutrality concept is a lot more than optimizing the wastewater facility

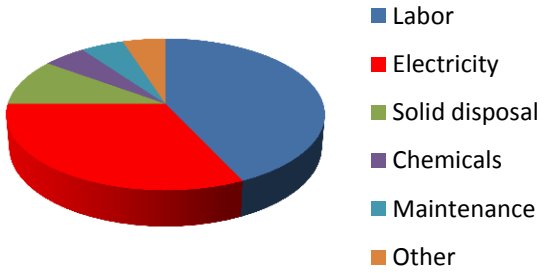


| Water Production | Water Distribution | Wastewater Pumping | Wastewater Treatment | Energy Production |
|---|---|---|---|---|
| Energy reduction: **20-45%** | Energy reduction: **20-40%** Leakage reduction: **30-40%** | Energy reduction: **5-25 (50)%** | Energy reduction: **25-60%** | Energy production increase: **20-60%** |
| *Energy-optimizing raw water pumping* | *Optimized pressure management/zones* | *De-ragging, prevent clogging, save energy* | *Real on-line computer control* | *High-efficiency CHP (Combined Heat & Power) facility* |
| *Pumps which fit demand* | *Reduce leakage, also active leakage* | *Optimal pump and pump station design* | *High Speed Turbo blowers* | *Carbon harvest* |
| *Reservoir filling at night* | *Adjust pressure to service level* | | *Energy-optimal "bottom" aeration* | *Insulation of digester* |
| *Avoid energy burners* | *Avoid energy burners* | | *Sludge age control* | *Production when prices are high* |
| | | | *Avoid burning carbon* | |

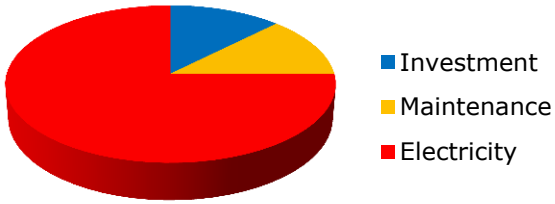
**Energy neutrality**

**Highly efficient components and VSDs in all process step is a precondition**

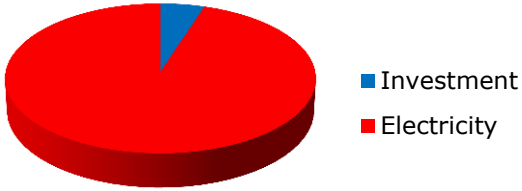
# High efficient components – means focus on Installed energy efficiency ….




**Wastewater OPEX split**

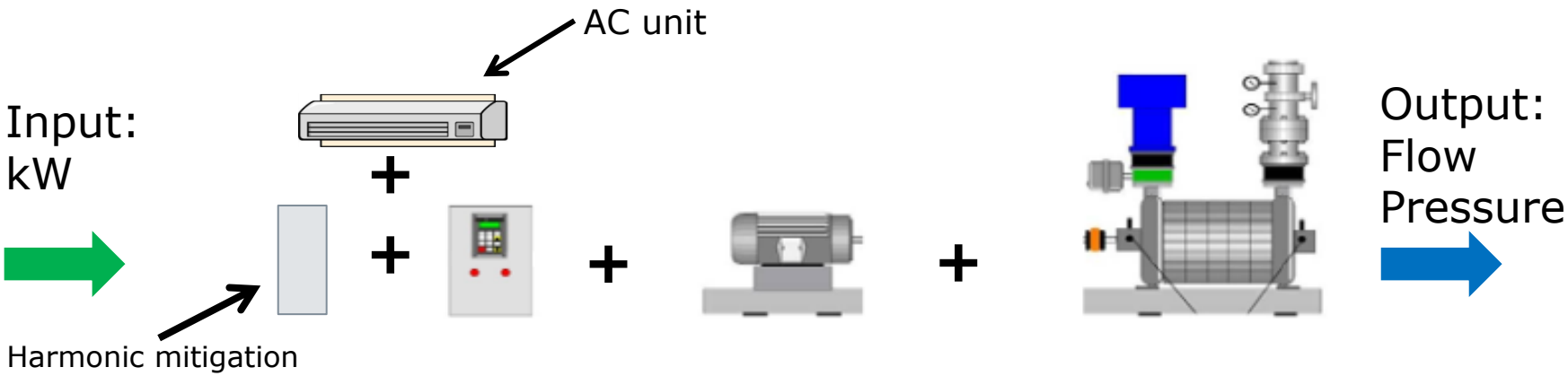



**Blower CAPEX/ OPEX split**

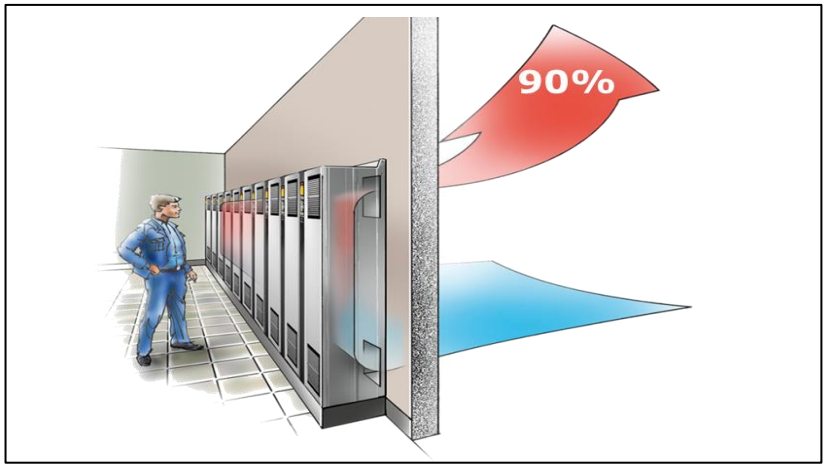



**Motor/VSD CAPEX/OPEX split**

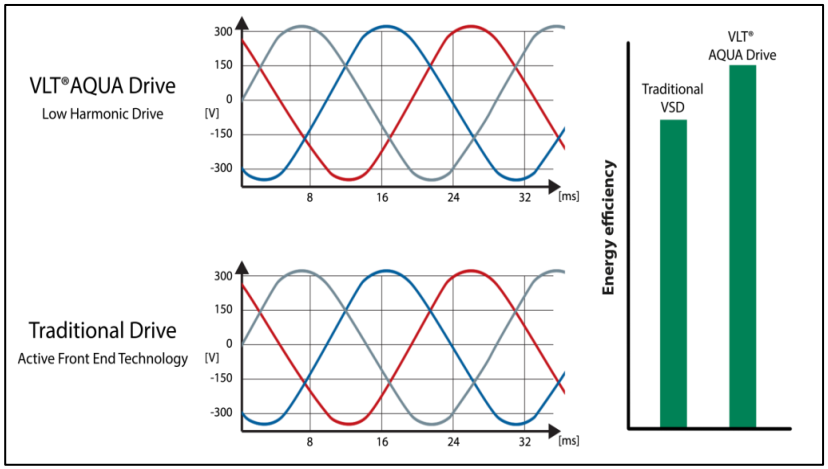
## Installed or ”wire to air” efficiency is the trend (ASME PTC 13)



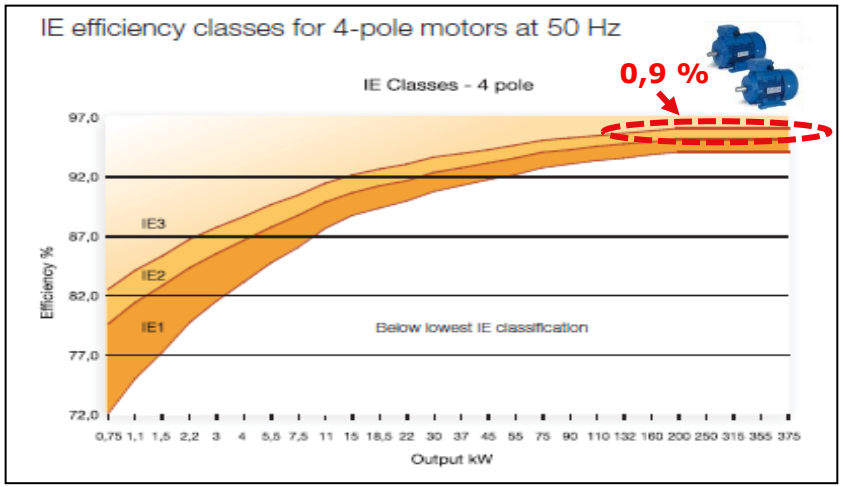
# Installed efficiency the important point ….




**Backchannel cooling vs tradition air-condition**




**AAF vs AFE harmonic mitigation solution**



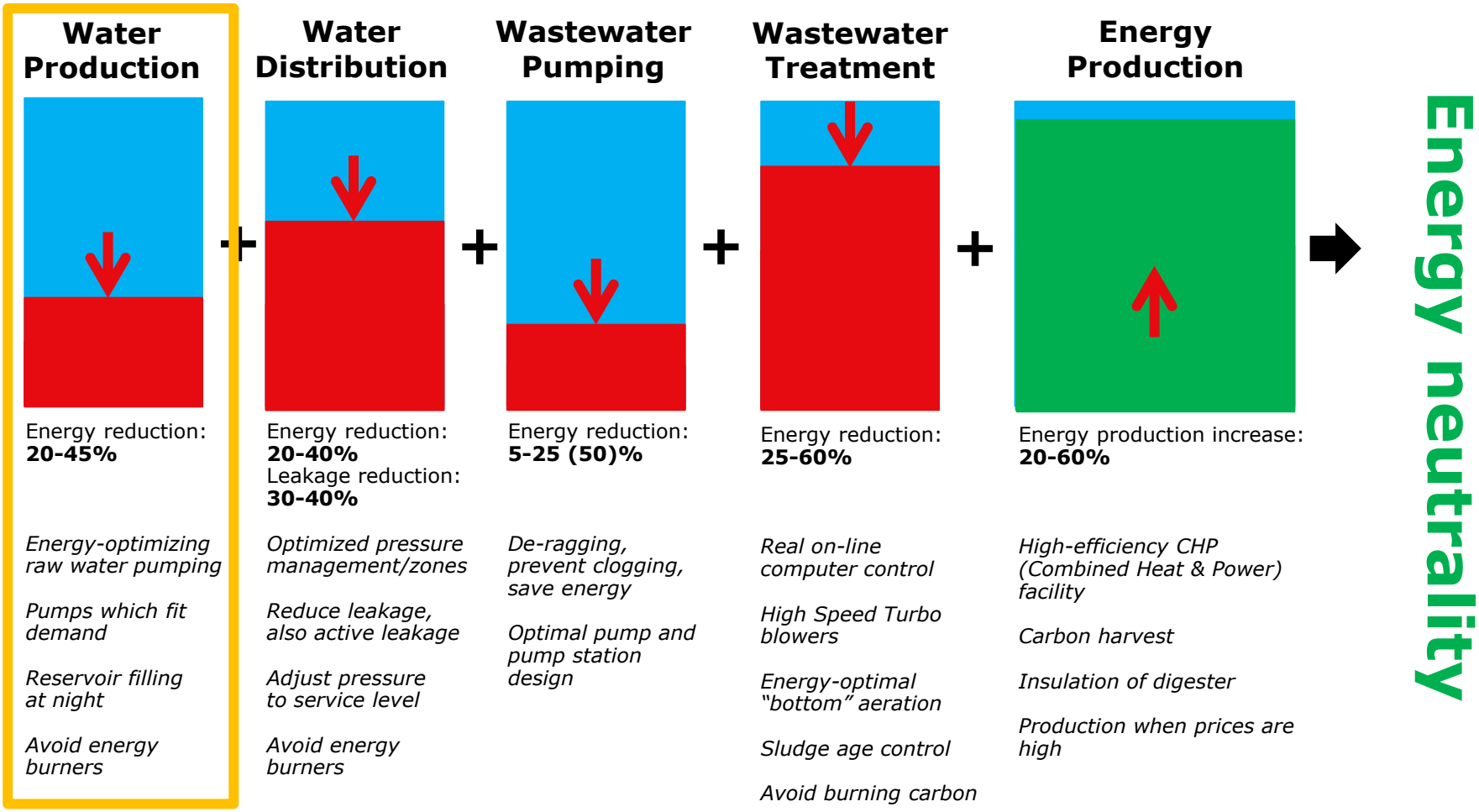

| Options | Efficiency gained |
|---|---|
| IE 2 to IE 3 motor | 0,9 % |
| Backchannel cooling | ~ 2,5 % |
| AAF vs AFE | 1,6 – 3,0 % |

**2–4 %**

| Options | Savings % of Inv. of VSD |
|---|---|
| Backchannel cooling | 12 – 20 % |
| AAF vs AFE | 7 – 23 % |
| Total | 20 – 43 % |

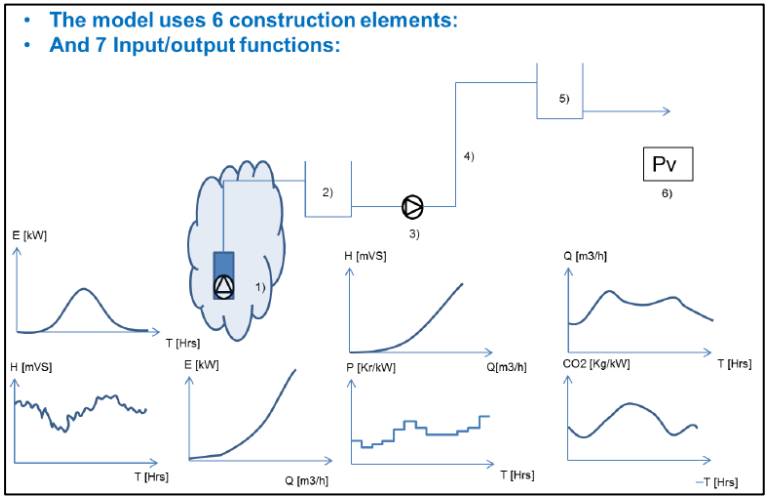
**Basis for calculations**: LHD AC Drive, 0,1 €/kWh, 60 % load, 24/7 operation, 0,4 W AC/W removed

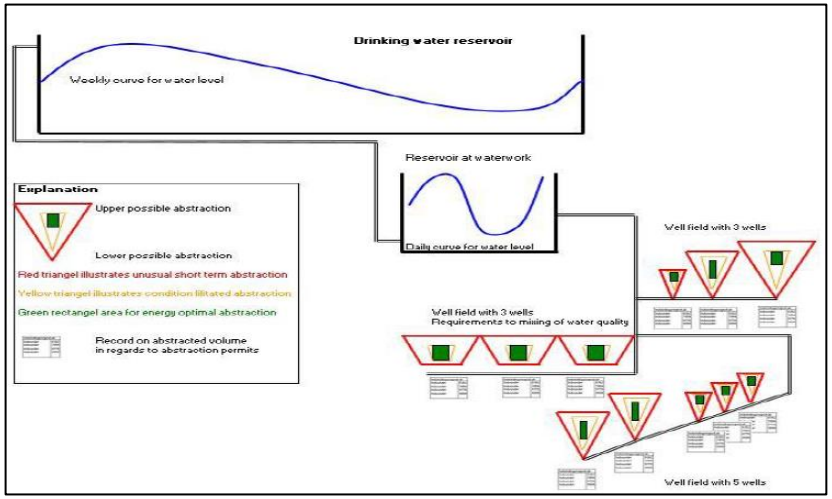
# The energy neutrality concept is a lot more than optimizing the wastewater facility

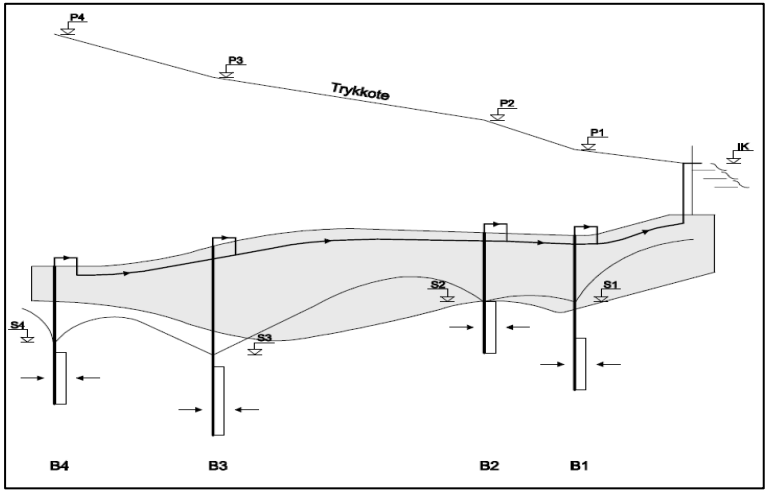


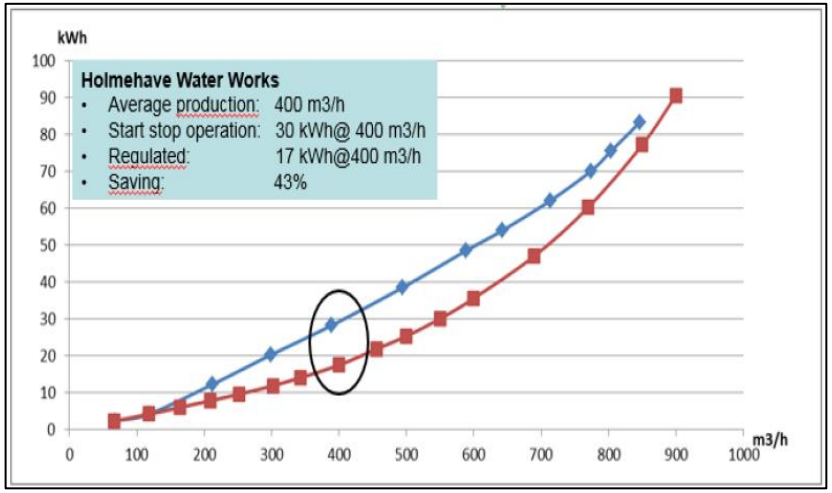

**Highly efficient components and VFDs in all process step is a precondition**

# Well Field Model – VCS Odense DK > 40 % savings



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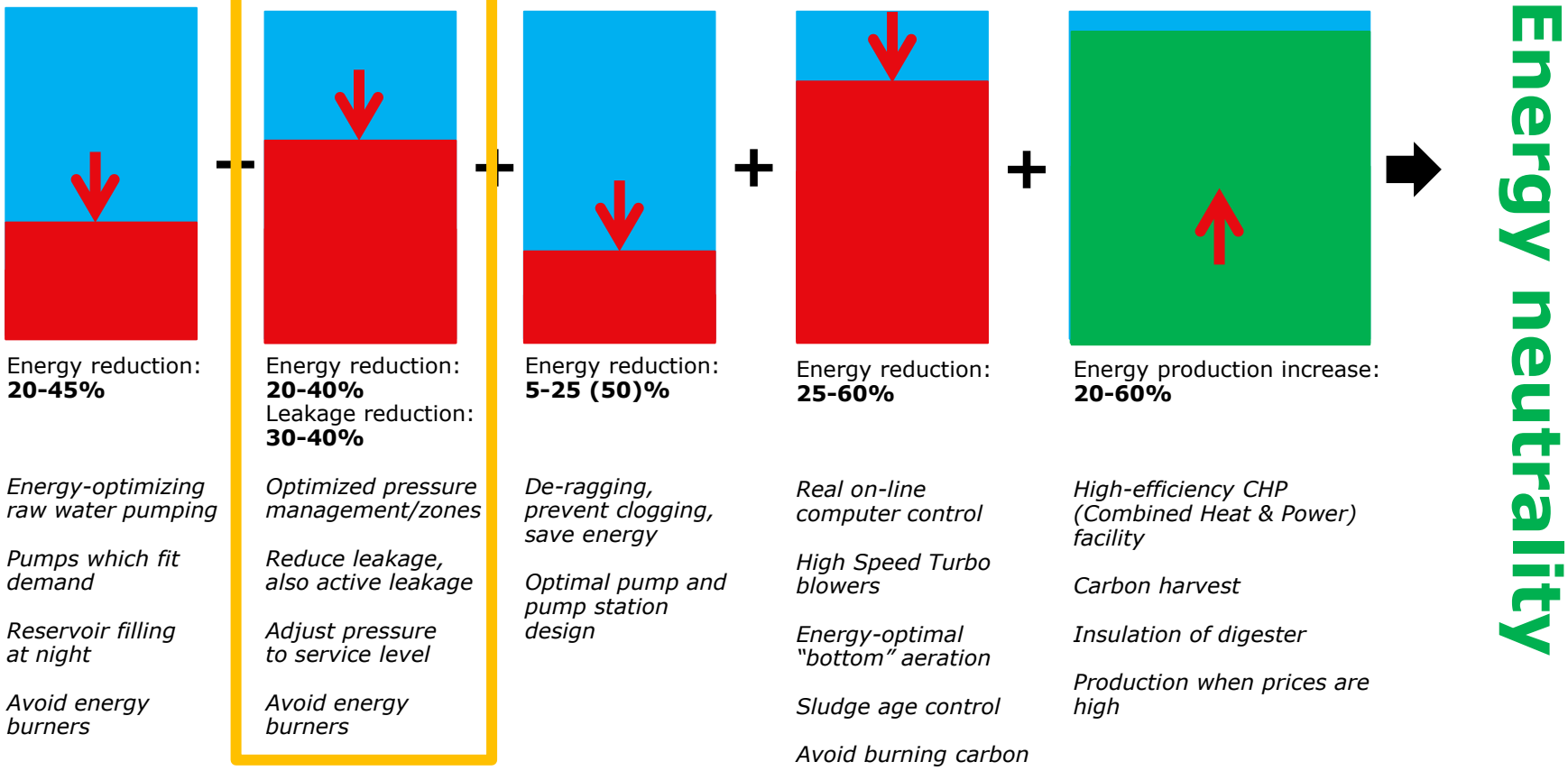
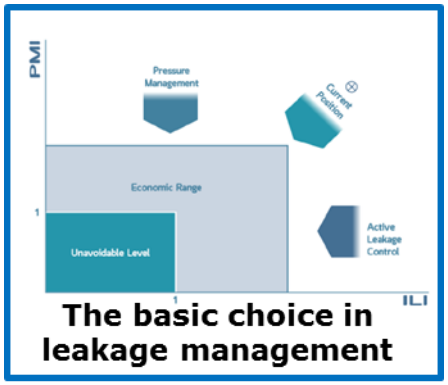



**Highly efficient components and VFDs in all process step is a precondition**

# The pressure management/reduction concept




**The basic choice in leakage management**

Original hydraulic grade line

Reduced input pump head

Optimized hydraulic grade line

Supply zone boundary

Input energy saved

Optimized boosted subzone

Optimized boosted subzone

Target level-of-service pressure—*20 m*

Pumping station

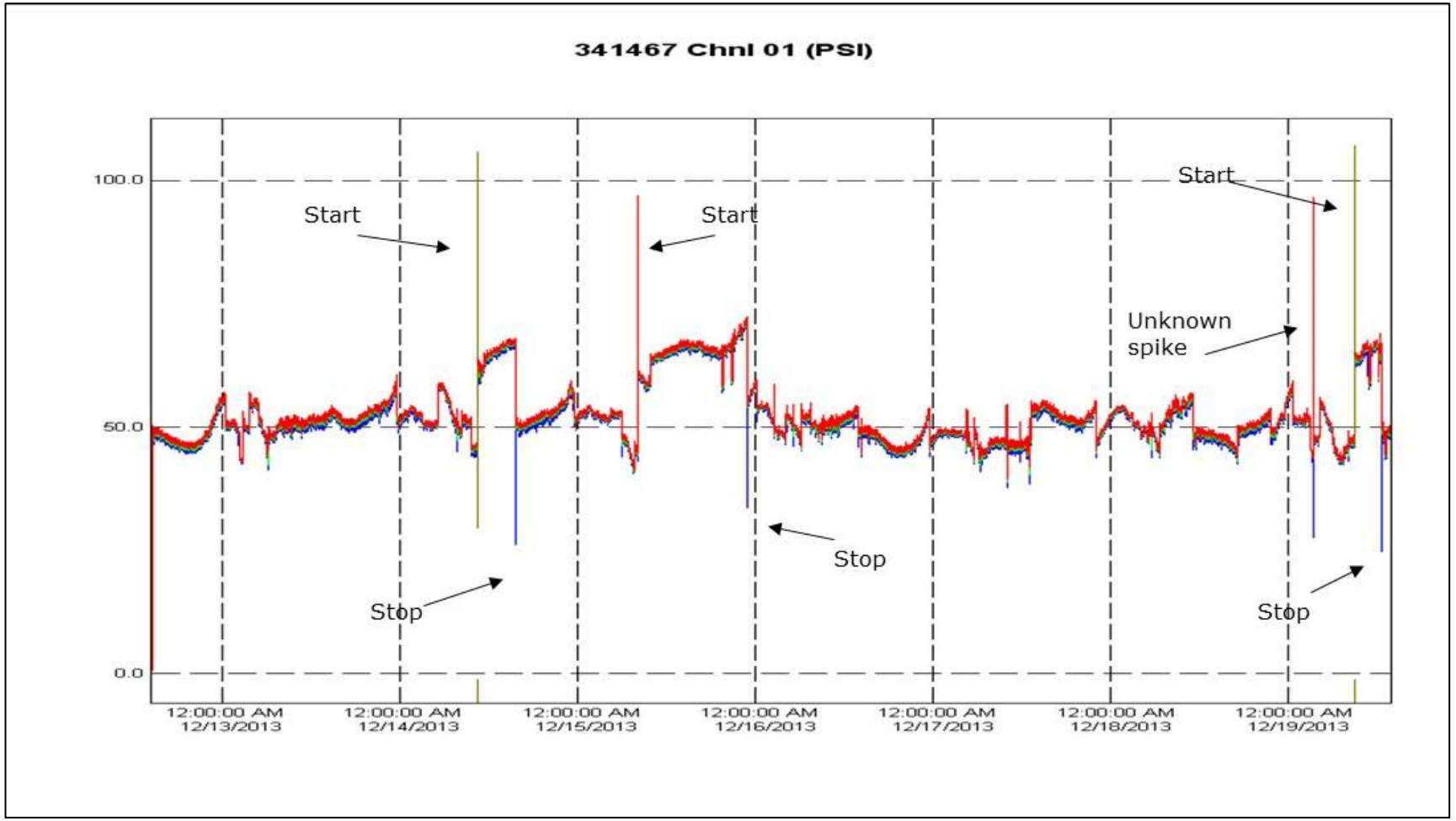
Treated water pumping station

City

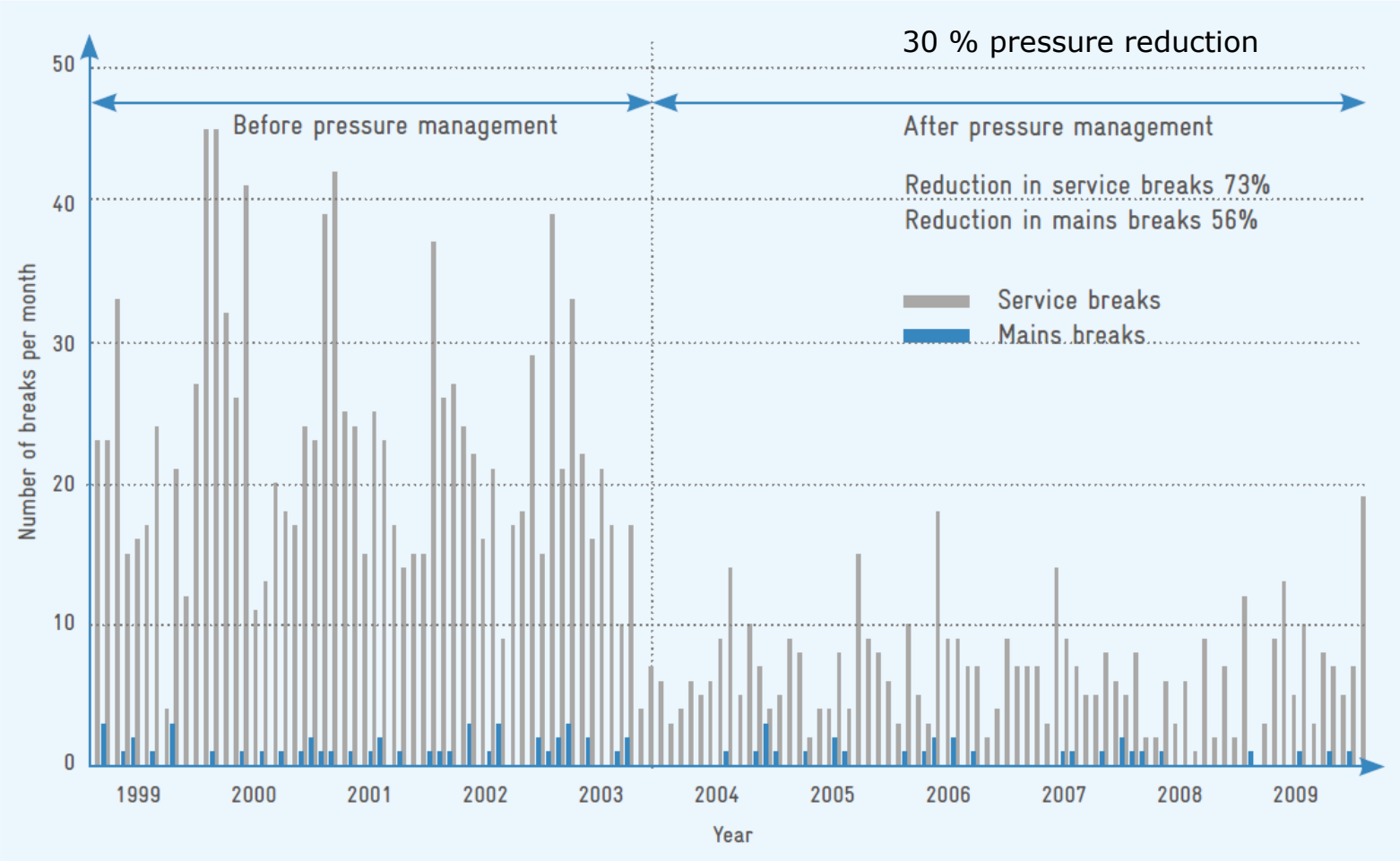
River

Treated water pumping station

# Recent case from the US - Emerald Coast Utilities Authority



# The effect of pressure management, Gold Coast Water, Australia




Ref.: Guidelines for water loss reduction giz

On behalf of Federal Ministry for Economic Cooperation and Development

# Pressure management experience

**Experience from:**

- 112 systems
- In 10 different countries

**Average result:**

- 38 % reduction in pressure
- New breaks reduced by 53 %

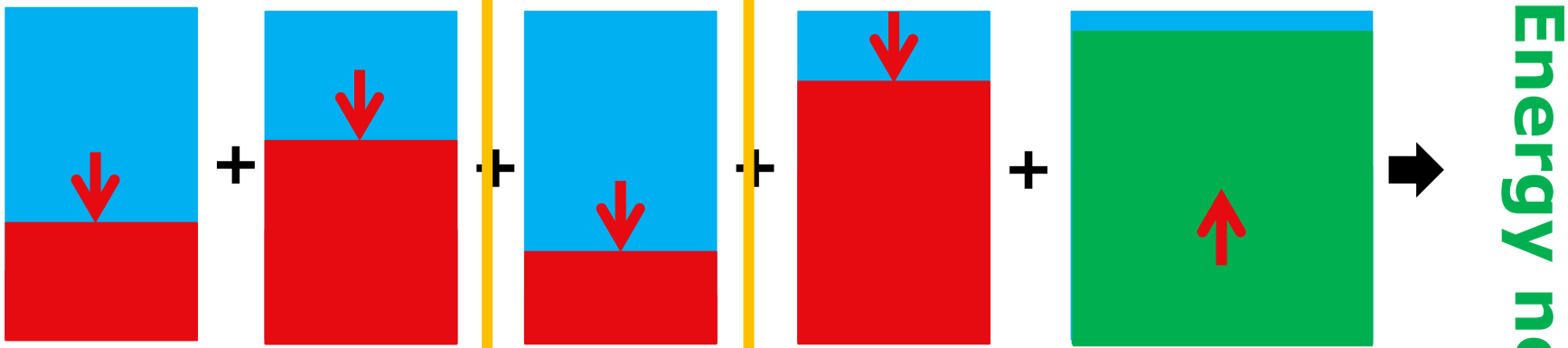
**Other benefits:**

- **Typical 38 % water leakage reduction**
- **Energy consumption reduced by 20 – 40 %**
- Extended asset lifetime
- Fewer network related complains

| Country | Water Utility or System | Number of Pressure Managed Sectors in study | Assessed initial maximum pressure (metres) | Average % reduction in maximum pressure | Average % reduction in new breaks | Mains (M) or Services (S) |
|---|---|---|---|---|---|---|
| Australia | Brisbane | 1 | 100 | 35% | 28% | M,S |
| | Gold Coast | 10 | 60-90 | 50% | 60% | M |
| | | | | | 70% | S |
| | Yarra Valley | 4 | 100 | 30% | 28% | M |
| Bahamas | New Providence | 7 | 39 | 34% | 40% | M,S |
| Bosnia Herzegovin | Gracanica | 3 | 50 | 20% | 59% | M |
| | | | | | 72% | S |
| Brazil | Caesb | 2 | 70 | 33% | 58% | M |
| | | | | | 24% | S |
| | Sabesp ROP | 1 | 40 | 30% | 38% | M |
| | Sabesp MO | 1 | 58 | 65% | 80% | M |
| | | | | | 29% | S |
| | Sabesp MS | 1 | 23 | 30% | 64% | M |
| | | | | | 64% | S |
| | SANASA | 1 | 50 | 70% | 50% | M |
| | | | | | 50% | S |
| | Sanepar | 7 | 45 | 30% | 30% | M |
| | | | | | 70% | S |
| Canada | Halifax | 1 | 56 | 18% | 23% | M |
| | | | | | 23% | S |
| Colombia | Armenia | 25 | 100 | 33% | 50% | M |
| | | | | | 50% | S |
| | Palmira | 5 | 80 | 75% | 94% | M,S |
| | Bogotá | 2 | 55 | 30% | 31% | S |
| Cyprus | Lemesos | 7 | 52.5 | 32% | 45% | M |
| | | | | | 40% | S |
| England | Bristol Water | 21 | 62 | 39% | 25% | M |
| | | | | | 45% | S |
| | United Utilities | 10 | 47.6 | 32% | 72% | M |
| | | | | | 75% | S |
| Italy | Torino | 1 | 69 | 10% | 45% | M,S |
| | Umbra | 1 | 130 | 39% | 71% | M,S |
| USA | American Water | 1 | 199 | 36% | 50% | M |
| Total number of systems | | 112 | | | | |
| | | Maximum | 199 | 75% | 94% | All data |
| | | Minimum | 23 | 10% | 23% | All data |
| | | Median | 57 | 33.0% | 50.0% | All data |
| | | Average | 71 | 38.0% | 52.5% | M&S together |
| | | Average | | 36.5% | 48.8% | Mains only |
| | | Average | | 37.1% | 49.5% | Services only |

Ref:Thornton and Lambert 2007, Water Service Association of Australia Asset Management 2011 ** 16th January 2013, Coombe Abbey, Warwickshire

# The energy neutrality concept is a lot more than optimizing the wastewater facility



**Water Production**

Energy reduction:
**20-45%**

*Energy-optimizing raw water pumping*

*Pumps which fit demand*

*Reservoir filling at night*

*Avoid energy burners*

**Water Distribution**

Energy reduction:
**20-40%**
Leakage reduction:
**30-40%**

*Optimized pressure management/zones*

*Reduce leakage, also active leakage*

*Adjust pressure to service level*

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**Wastewater Pumping**

Energy reduction:
**5-25 (50)%**

*De-ragging, prevent clogging, save energy*

*Optimal pump and pump station design*

**Wastewater Treatment**

Energy reduction:
**25-60%**

*Real on-line computer control*

*High Speed Turbo blowers*

*Energy-optimal "bottom" aeration*

*Sludge age control*

*Avoid burning carbon*

**Energy Production**

Energy production increase:
**20-60%**

*High-efficiency CHP (Combined Heat & Power) facility*

*Carbon harvest*

*Insulation of digester*

*Production when prices are high*

**Energy neutrality**

**Highly efficient components and VFDs in all process step is a precondition**

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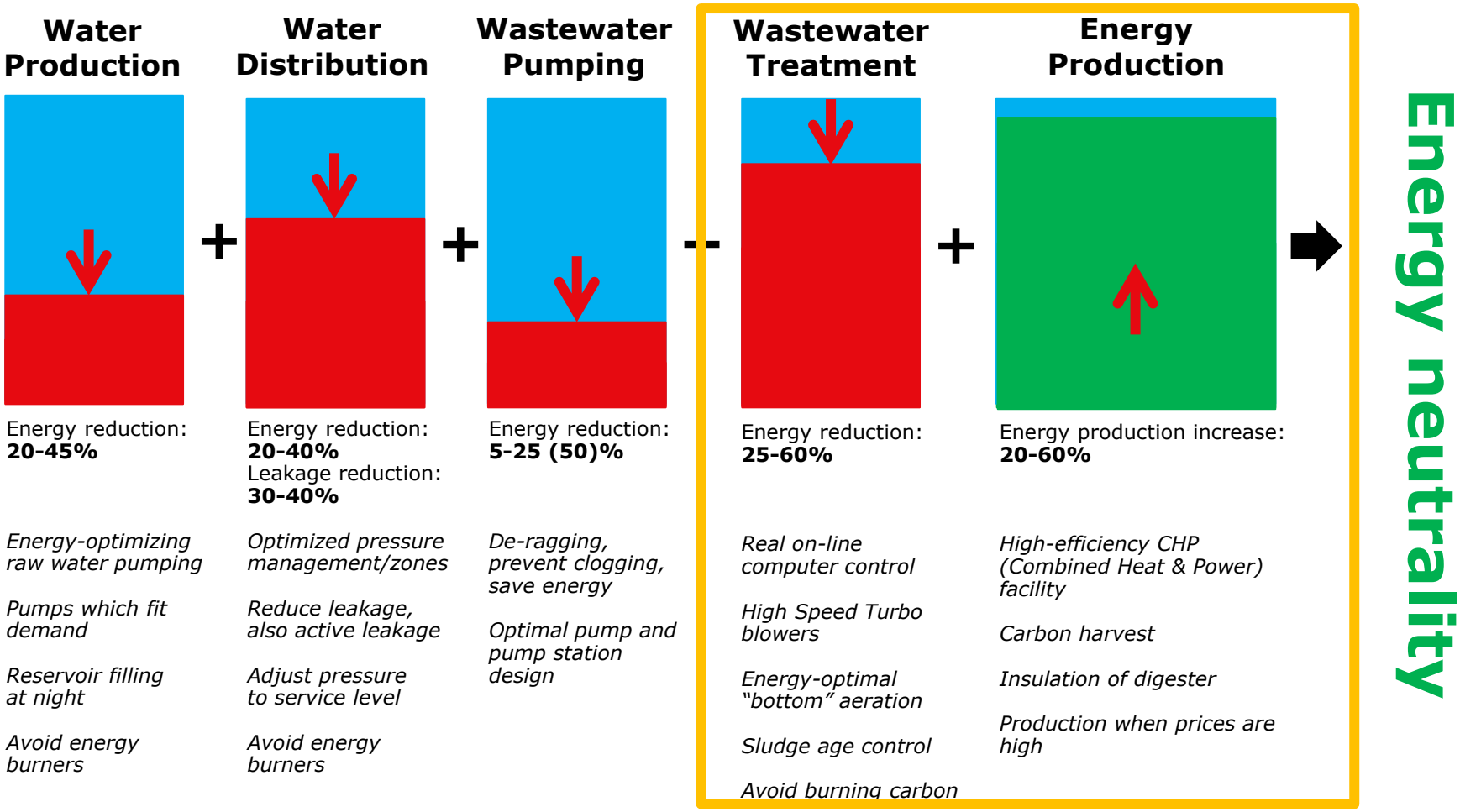
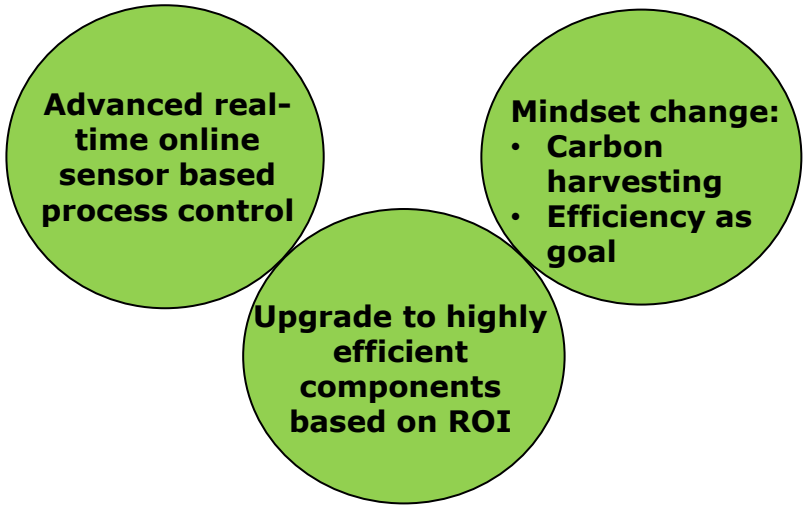



**Highly efficient components and VFDs in all process step is a precondition**

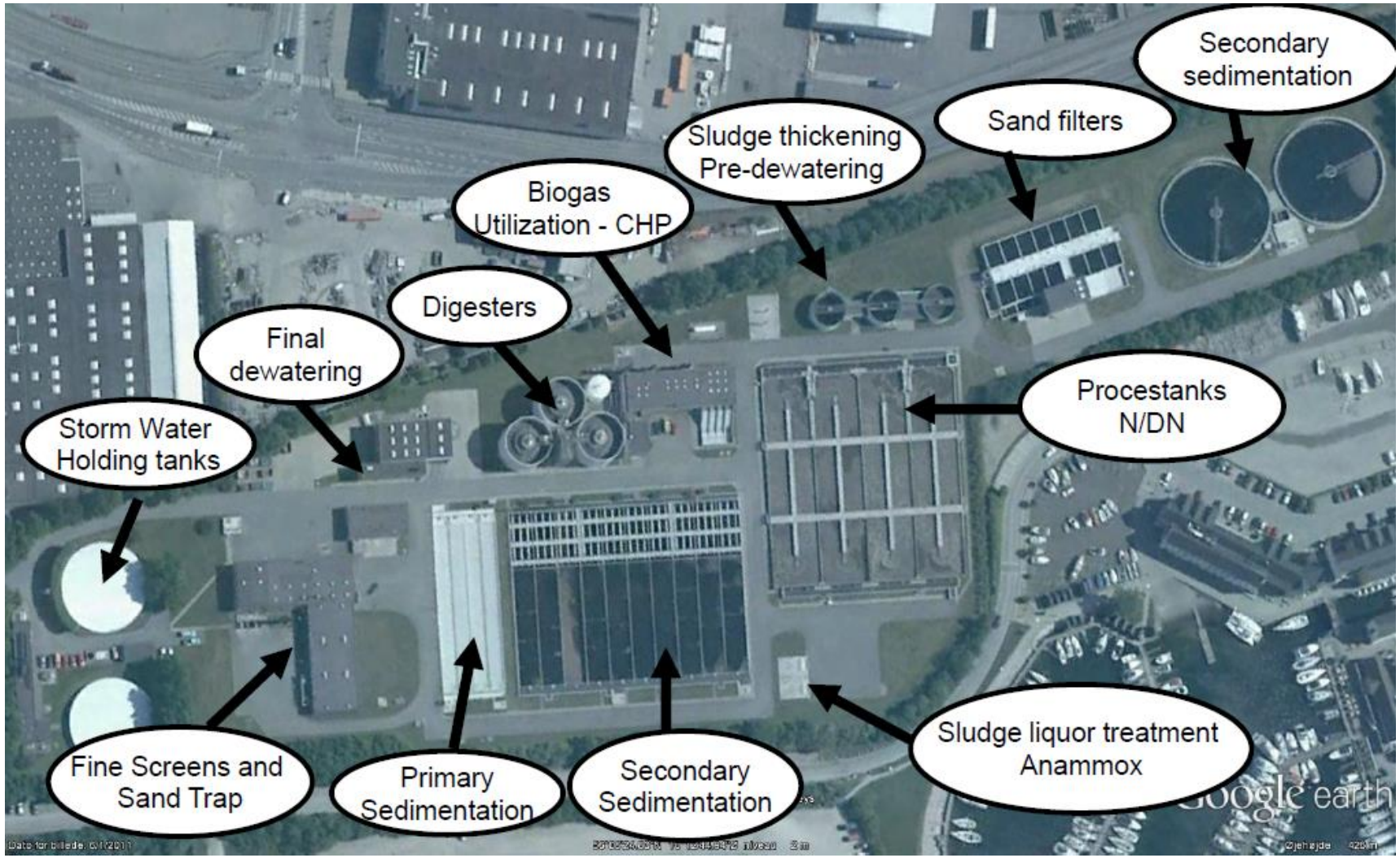
# Energy surplus producing wastewater facility
## Marselisborg WWTP Aarhus Denmark

- Size: 200.000 PE ~ 26.000 m3/d
- No external carbon sources
- 142 % electricity in 2014
- Excess heat ~2,1 GWh/year in 2014
- Total energy produced ~ 192 %




**SCADA fallback process control strategy**

# Layout – Marselisborg wastewater facility



# The World Wide first energy-neutral catchment area – Marselisborg, Aarhus Water, Denmark

**Fact box**

- Energy neutrality for the whole water cycle *(water supply + wastewater)*
- Catchment area for 200,000 people. No wind, solar or heatpump energy is produced
- Based on energy savings & household wastewater energy production *(no external carbon)*

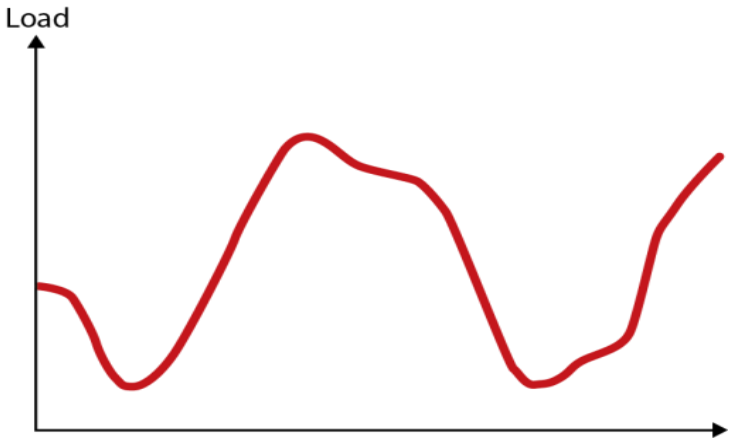
| Marselisborg catchment area | Status 2014 | Status 2016 |
|---|---|---|
| **Energy consumption** | | |
| Water treatment, distribution [kWh] (avg. 0.51 kW/m³, high) | 3,1 mill | 3,2 mill |
| Wastewater transport [kWh] | 0,7 mill | 0,8 mill |
| Marselisborg WWTP [kWh] ($BOD_5$ = 2,4/TN= 6,0/TP = 0.2) | 3,4 mill | 3,2 mill |
| ***Total energy consumption [kWh]*** | ***7,2 mill*** | ***7,2 mill*** |
| **Energy production** | | |
| Electricity production [kWh] | 4,4 mill | 4,8 mill |
| Heat production [kWh] | 2,1 mill | 2,6 mill |
| ***Total energy production [kWh]*** | ***6,5 mill*** | ***7,4 mill*** |
| **Own energy supply degree** | | |
| Wastewater treatment process, electricity and heat [%] | 192 % | 234 % |
| Wastewater treatment process, electricity [%] | 142 % | 150 % |
| ***Total Marselisborg catchment area [%]*** | ***94 %*** | ***103 %*** |

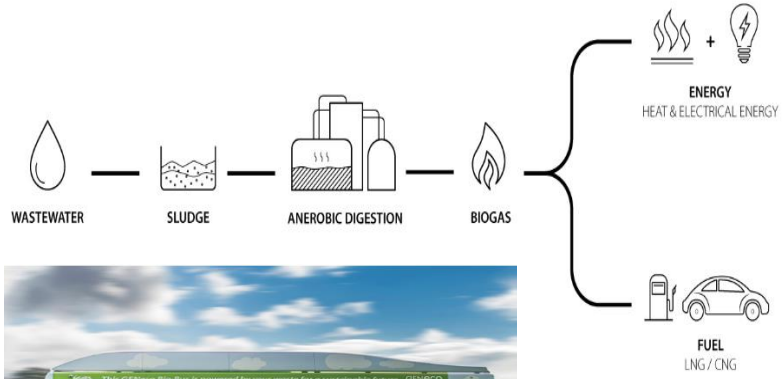
**290 VFD's installed in catchment area**

# What has been done to achieve these results?

## Key elements for obtaining beyond Energy Neutrality:

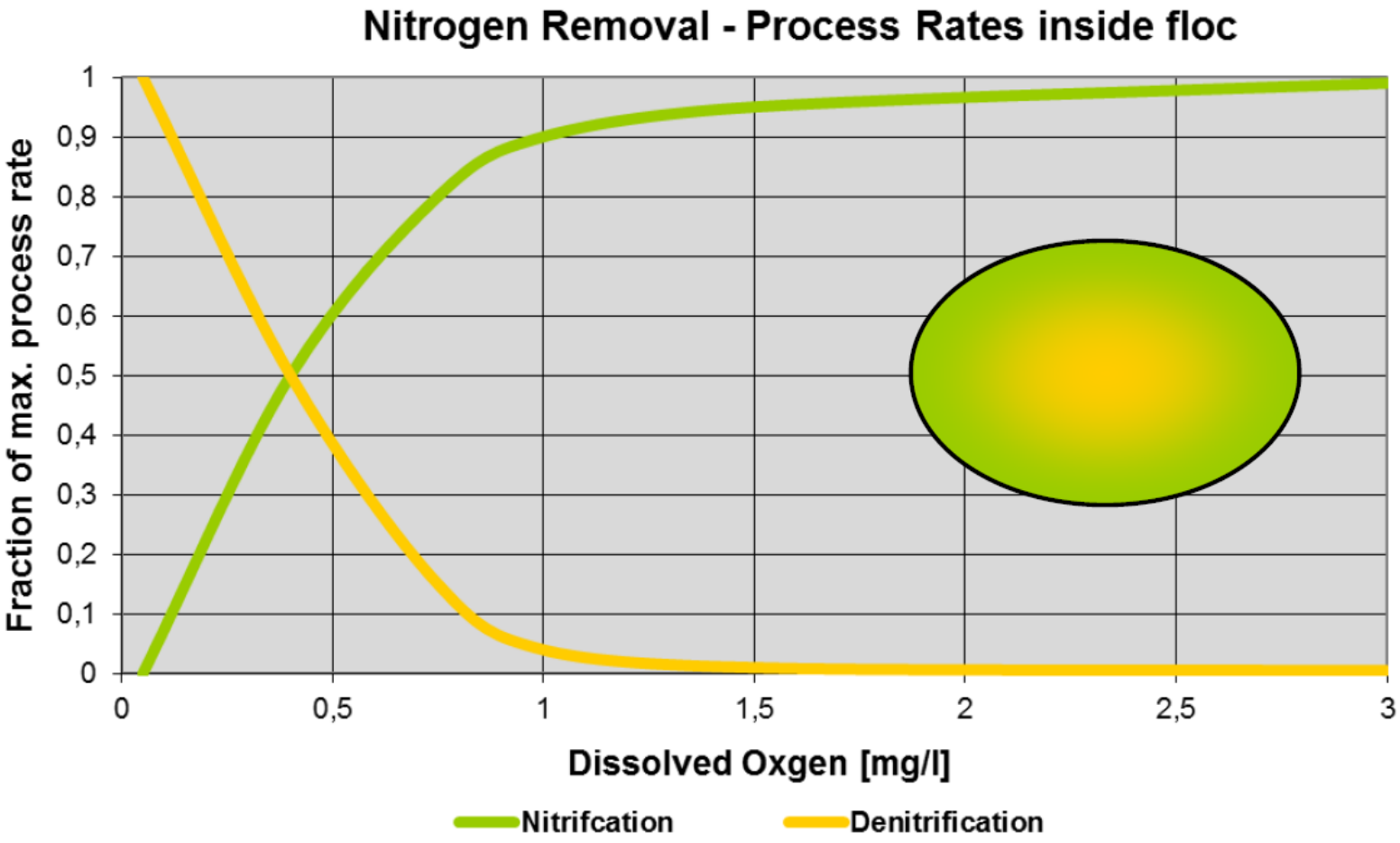
- Process control based on online sensors (RAS, N & P, fall back strategy)
- VSD drives on all rotating equipment (from 40 % to 100 %)
- Carbon harvesting
- Highly efficient components (Bottom aeration, High Speed blowers ..)
- Deep process knowhow
- CHP installation (electricity & heat)




Bio-bus - showing where the fuel comes from
Source: Wessex Water/Julian James Photography.

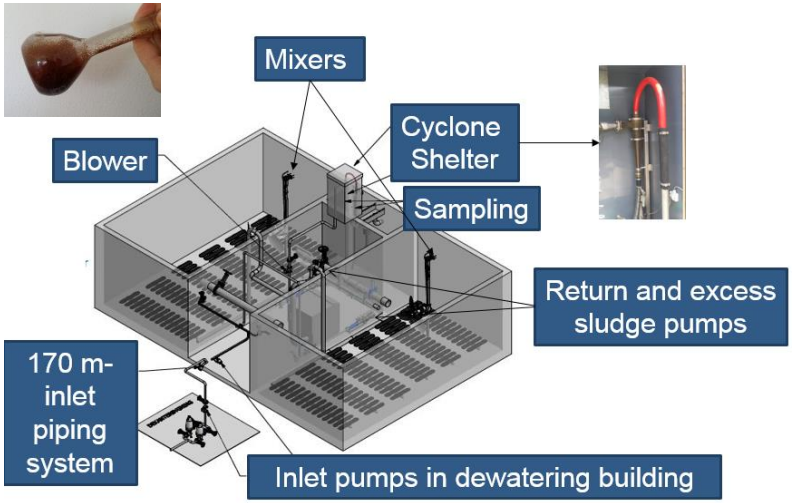
# Simultaneous Nitrification/Denitrification




**Oxygen uptake increase dramatic**

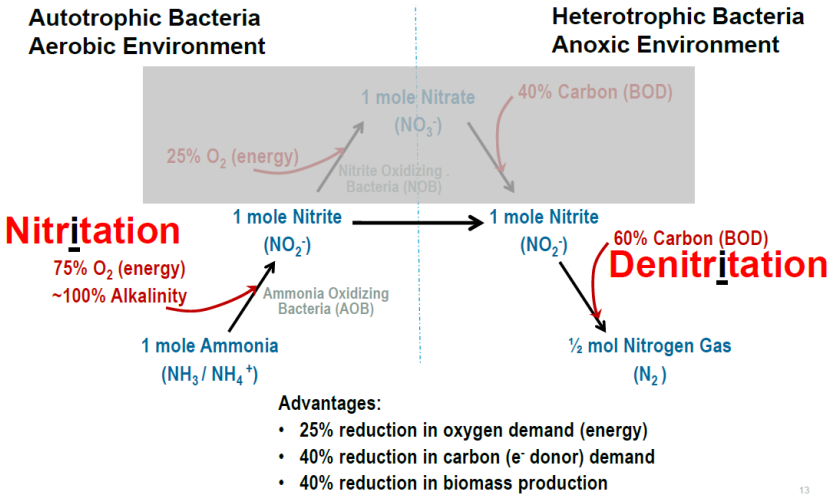
# Anammox on side-stream and partly nitrite shunt

## Side-stream Anammox

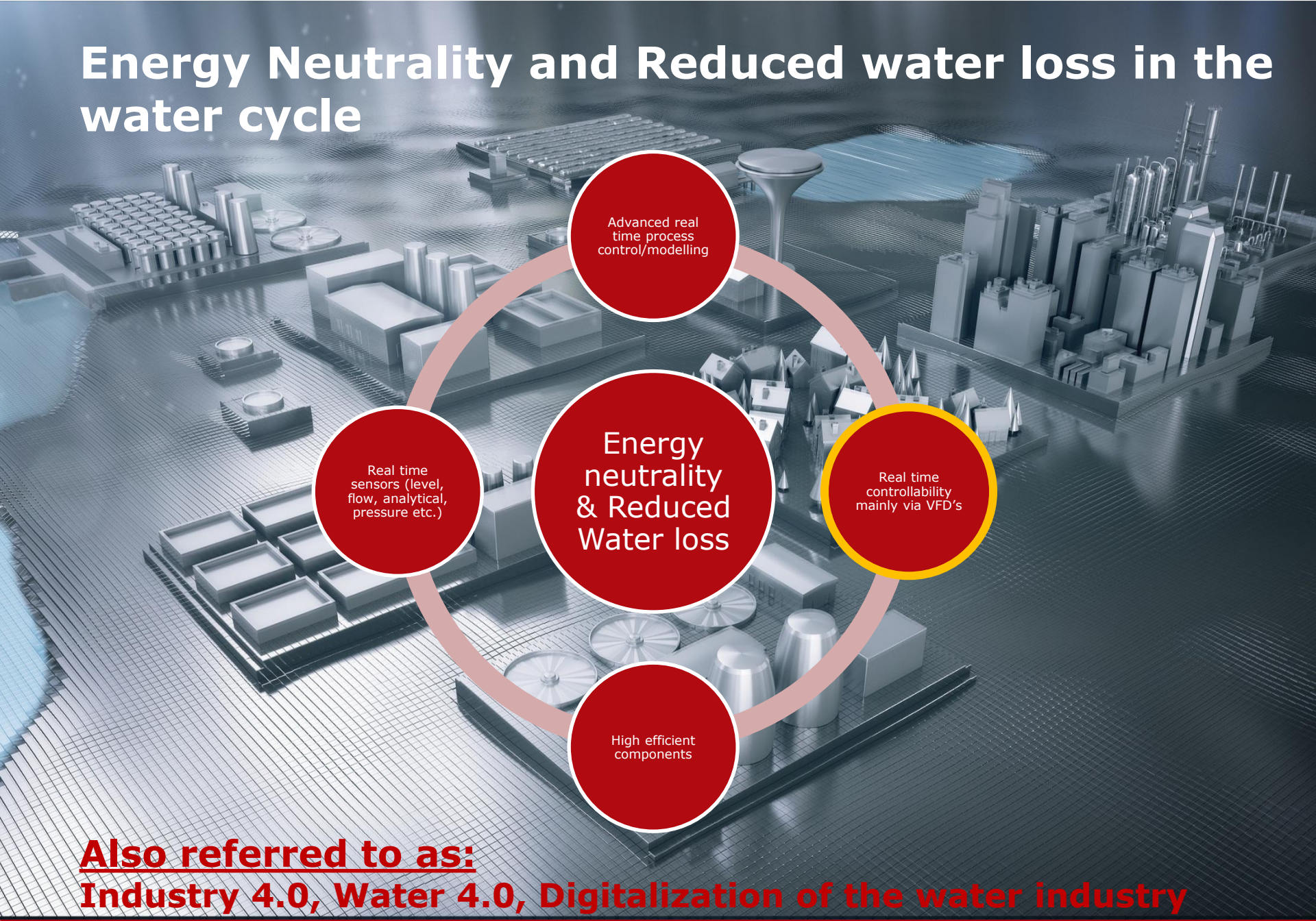



## Partly active Nitrite shunt

(Due to an out selection of the Nitrite Oxidizing Bacteria)



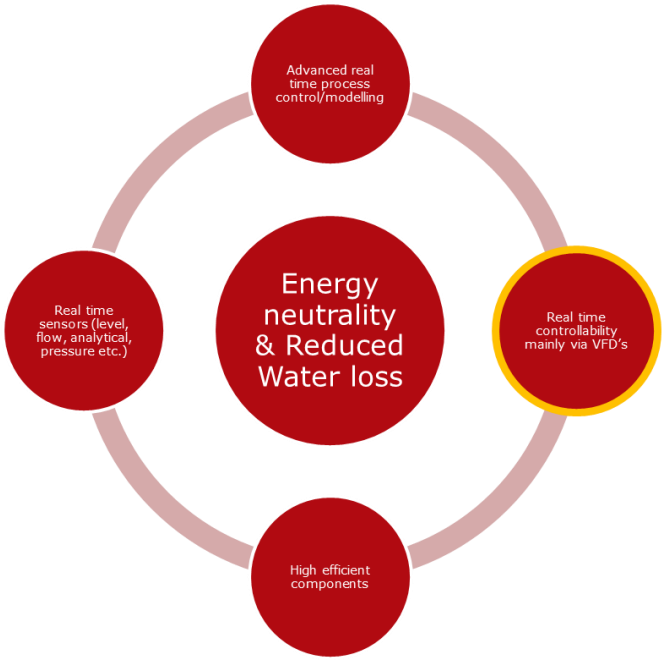
# Energy Neutrality and Reduced water loss in the water cycle




**Also referred to as:**

**Industry 4.0, Water 4.0, Digitalization of the water industry**

# How does the concept fit the big agendas……




Energy savings – **the energy reduction agenda**

Water savings – **the water scarcity agenda**

GHG savings – **the $CO_2$ agenda**

Longer assets life time

Higher facility capacity

} **the asset inv. agenda**

OPEX savings

Good ROI

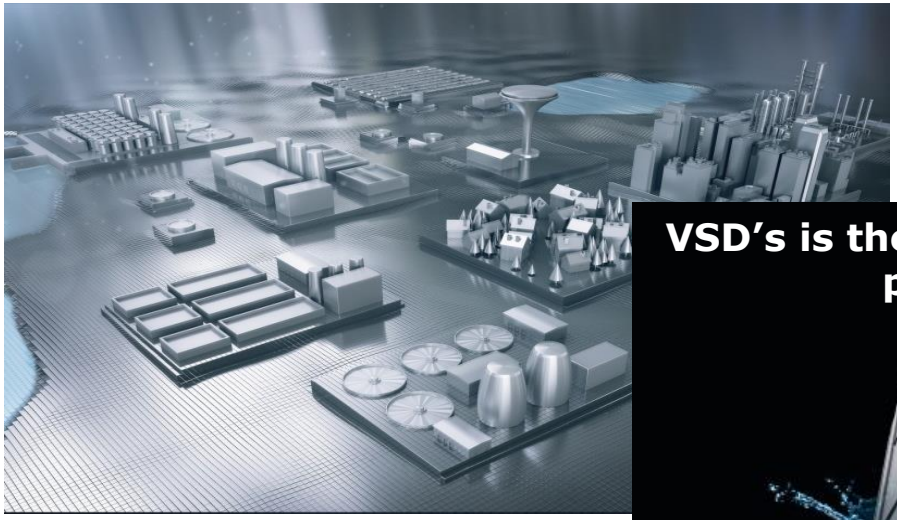
Less maintenance

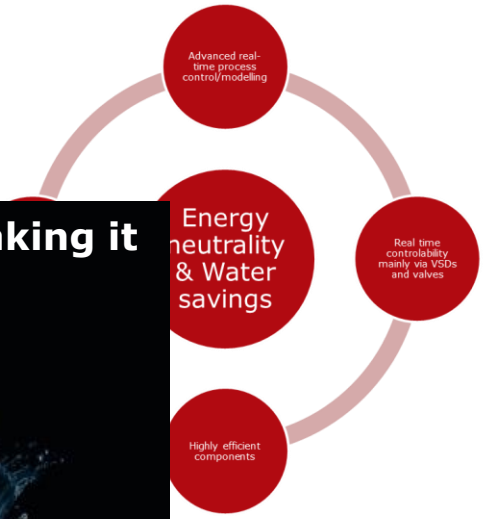
} **the water cost agenda**

Less customer complaints

More stable processes/higher controllability

# Turning the Water Industry into Energy Neutrality + low water leakage





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