Water and Energy

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Water and Energy/Water Loss
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„Our" actual energy environment

Mean continuous power in kW per inhabitant

Solar irradiation, our source of life:

- Total solar power reaching our globe (climate) 10,000
- Fresh water circuit (evaporation) 5,000

Power of **humans** and our **„Slaves"**

- Power of an adult person: 0.1
- Power of our brain 0.015
- Power behind a flash of genius ? <0.001
- **Total Primary power input (~50 slaves/P) ~5**
- Electric power at home including nutrition **0.7**
- Electronic equipment and communication >**0.1**

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Drinking water and energy requirements (pumping, treatment, recovery)

only orders of magnitude

Pumping energy for water supply

expressed in Wh/m³/m

- To lift 1 m³ of water by 1 m the theoretical energy requirement is 2,7 Wh
- Under practical conditions at a drinking water supply network ≥ 4,0 Wh
- „Hydro-power" production from 1m³ with a head-difference of 1 m ≤. 2,4 Wh

Drinking water supply

Energy requirement for **pumping per person (P)**

- **Supply from ground or surface waters** (example):
  Pressure requirement: 100 m, water consumption 70m³/P/a:
  Energy requirement : 100 * 70 * 4,5 32 kWh/P/a (~4 W/P)

Energy production by **hydropower stations** in the mains

- **Supply from alpine springs** (e. g. Vienna):
  70 m³/P/a, head difference 180 m 25 kWh/P/a (3 W/P)

Energy requirement for **drinking water treatment:**

- Depending on process: 10 to 300 kWh/P/a
  (Disinfection to sea water desalination) (1 to 35 W/P)

Energy from Hydropower

- It is definitely use of solar energy, therefore renewable, with very little influence on climate change
  Electric energy from hydropower on a global scale only little contributes to total energy supply
  - Even in Austria ~65% of electric energy comes from hydropower
- The relevance of hydropower will increase with increase of renewable energy supply from wind and sun (peak supply, energy storage)
- but there is no „free lunch“

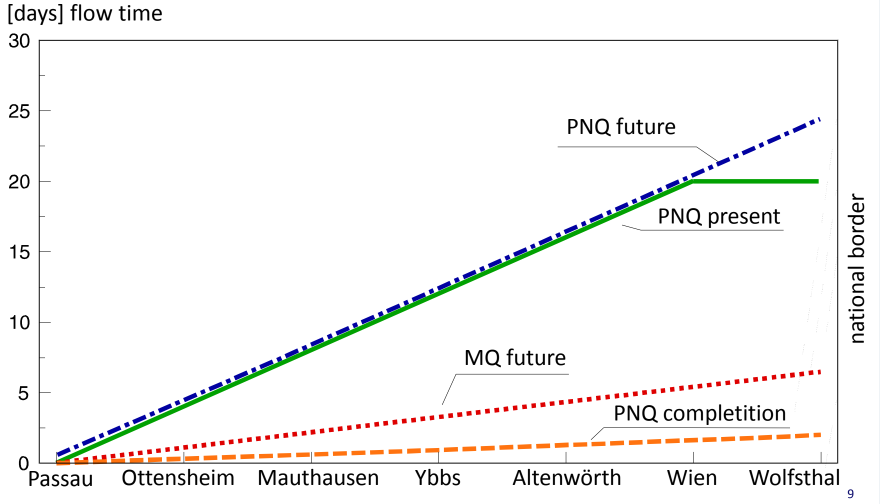
Problems with hydropower

- **Water quality problems:**
  - Morphology: Barriers in riverine ecosystems (e.g. fish)
  - Increased detention time of the water especially during low flow reduces biol. water quality (increase of eutrophication, temperature, anoxia, organic sediments)
  - Alteration of the water table and hence of the exchange between surface and ground water (DW supply)
- **Problems associated with sediment transport:**
  - Sedimentation of bed load, erosion (lack of sediments), high flow damages

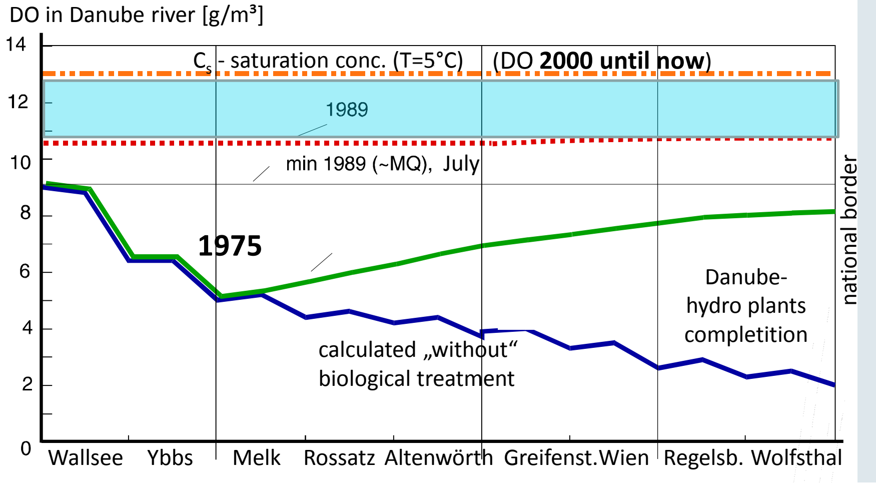
Hydro power stations are only compatible with water quality requirements if all relevant accompanying measures are implemented!

Detention time of water in river Danube

with and without river power stations



Influence of waste water treatment in the catchment on DO in river Danube with all hydropower stations along ~ 200 km



Energy and waste water

- Heat recovery from used water
- Energy recovery from organic pollution

Heat recovery from waste water

Energy consumption for heating our drinking water:
50 to 100 W/P (800 kWh/P/a) (low temperature heat)

- Heat recovery (<5 to 10%) from waste water for room heating and cooling is possible (literature data)
- Problems:
  - Low entropy energy requirement for pumping (factor HE/el.E >4)
  - Seasonal heat requirement is limited (economic problem)
  - Temperature variation curve in waste water is opposite to heat requirement (ΔT)
  - Increased temperature variation for wwt (negative!)
  - Scaling and fouling in pipes and heat exchangers (tech. problem)

☹ More relevant for research / media than for energy or climate
☺ Direct **heating of drinking water by sun or district heating**

Energy of waste water pollution

Organic Pollution (W/population equivalent):

- 1g COD is equivalent to energy of ~14 kWs (J)
- 40 kg COD/pe/a is equivalent to a
- „reclaimable" power of 18 W/pe (158 kWh/pe/a)
- or **36 W/P (~300 kWh/P/a)** (assuming ~2 pe/P)

Nutrients (only if replacing mineral fertiliser!):

Nitrogen: 1 kg N in mineral fertiliser needs ~11 kWh
- 4 kg TN/pe/a correspond to a power of 5 W/pe; (~8 W/P)

Phosphorus: 1 kg P in mineral fertiliser needs ~10 kWh
- 0.7 kg TP/pe/a corresponds to a power of 0,8 W/pe; (~1.4 W/P)

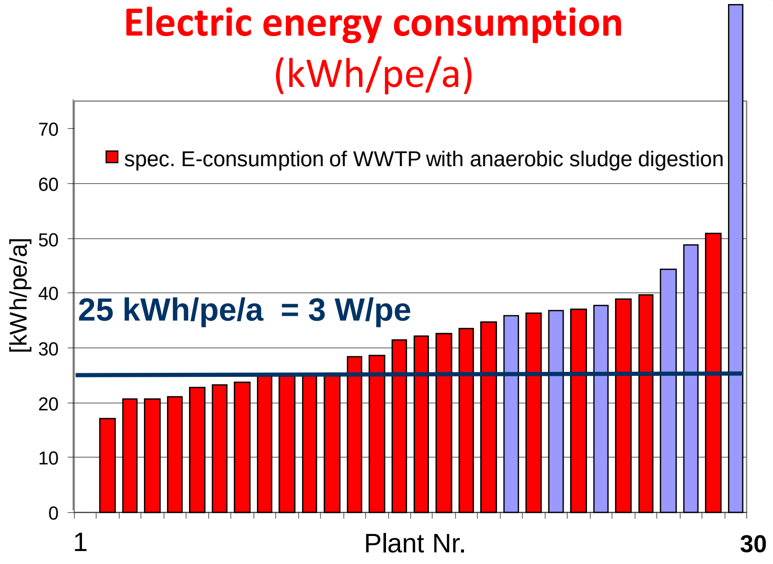
Nutrients have a potential to replace a power of **~ 10 W/E**

Municipal nutrient removal treatment plants with no external energy requirement

(without external substrate addition)

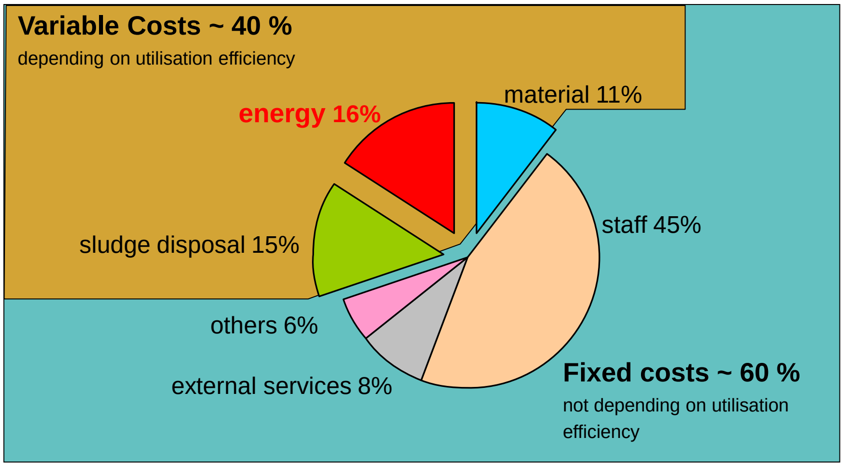
using the energy contained in organic pollution

Electric energy consumption (kWh/pe/a)



Benchmarking results from conventional nutrient removal plants in Austria

Operational cost distribution

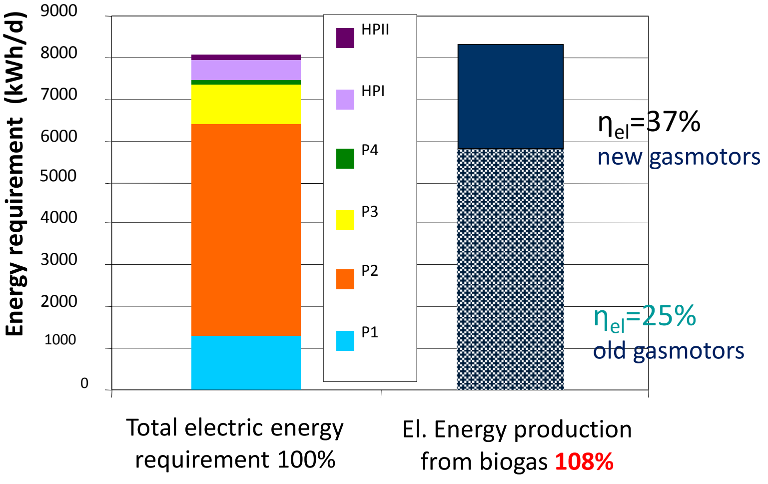


Austrian benchmarking results [Lindtner]

The first Austrian energy-self sufficient plant

Strass/Tirol (170.000 PE) [Wett, Lindtner]

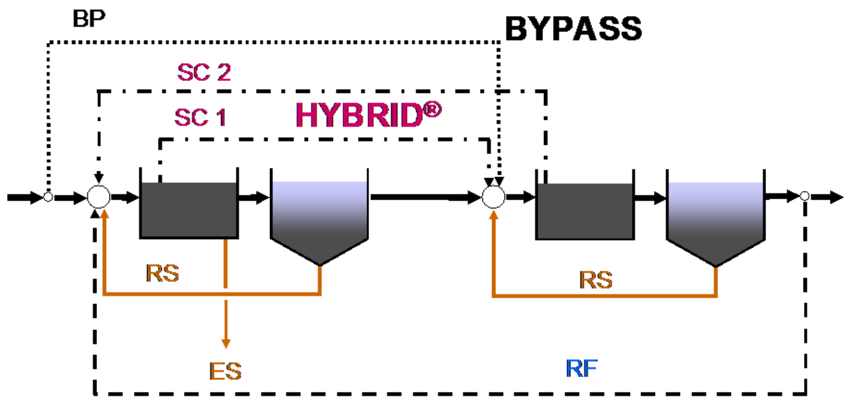
"AB" plant with reject water deammonification



Main Treatment Plant of Vienna (MTPV)

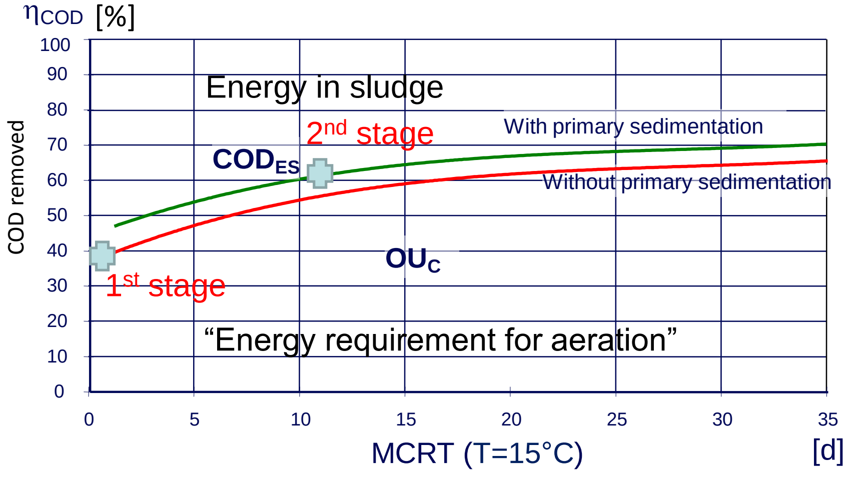
4 Mio pe

Process scheme of the 2- stage activate sludge treatment developed at TU Vienna



BP	Bypass line	***SC 1***	Sludge circulation line 1	**RS**	Return sludge
RF	Recirculation flow	**SC 2**	Sludge circulation line 2	**ES**	Excess sludge

COD (energy) balance concept



data have to be adapted to T = 30°C and specific waste water ?

Energy balance comparison

	Dim	1-stage η_N= 80%	MTPV/EOS η_N= 75%	HKA actually
"aeration efficiency"	*kgO_2/kWh*	*2,0*	*2,0*	*Raw sludge*
η_{el} gasmotor	*%*	*38*	*38*	*Incinera-tion*
Power for aeration	W/EW	1,6	1,25	2,26 to 2,33
Other power requirements	W/EW	0,80	1,10	
Biogas el. power prod	W/EW	1,9	2,75	-
Total el. power requ.	**W/EW**	**+ 0,5**	**- 0,4**	**2,3**
El. Energy requ.	**kWh/EW/a**	**+ 4,4**	**- 3,5**	**20,4**

EOS Project (2020): MTPV with digestion, 75 % N-removal, reject water nitritation+Deni in AT 1

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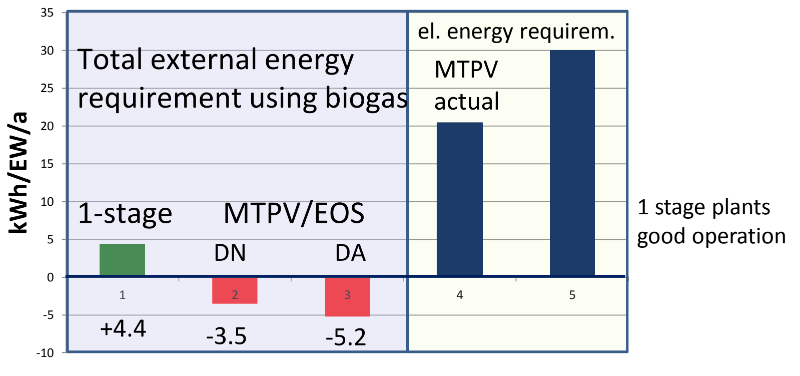
Energy requirements for nutrient removal plants in kWh/pe/a



DN Reject water Denitritation, DA Deammonification

Δ Energie DA versus DN for 3 Mio pe : 5,2 – 3,5 =1,7; 1,7 * 3 = 5 Mio kWh/a (~ 500.000 €/a)

Micro-pollutant removal with Ozone

Results from pilot investigations at MTPV

Goals:

- Efficient removal of most of the micro-pollutants (hormones, pharmaceuticals, personal care and household chemicals)
- Effluent can be discharged to bathing waters (hygienic aspect)
- Decolourisation of effluent

Energy requirement of effluent ozonation

- Effluent quality of MTPV 8 mg DOC/l
- O_3-Dosage 0,6 g O_3 /g DOC 5 g O_3 /m³
- Energy for ozone production 15 kWh/kg 75 Wh/m³
- Energy for 70 m³ effluent/pe/a **-5,2 kWh/pe/a**
- Excess energy from biogas (0.6 W/pe) **+5,2 kWh/pe/a**

Conclusions

- Energy considerations for water systems have to be based on 1st and 2nd law of thermodynamics (electrical, mechanical, biochemical, heat)
- Water infrastructure (transport and treatment) needs low entropy power in the range of 0 to about 400W/P. In most cases the power requirement is relevant for the municipalities but not for regional energy management.
- Local situation is more relevant for all energy considerations than e.g. treatment efficiency requirements for waste water treatment. E.g. primary power consumption varies between 2 and 14 kW/P (20 to 140 „slaves“ per person) and global solar irradiation is in the range of 10,000 kW/person.

Conclusions

- Power requirement for drinking water supply is strongly dependent on local morphology and the quality, availability and location of raw water sources.
- Hydropower, a renewable energy, will probably play an increasing role in energy management, but has to be linked to all necessary accompanying measures to avoid the associated negative impacts on water quality and sediment transport.
- The largest energy input into waste water is for heating (50 to 100 W/P). This high entropy energy can be recovered up to about 10% from the technological aspect, economic use for room heating and cooling is very limited. It can be recommen-ded to use solar irradiation instead of electric energy.

Conclusions

- Local situation again strongly influences total power requirements for waste water transport and treatment!
- The energy requirements for treatment of municipal waste water are in the range of 0 to 10 W/P and contribute to about 15 to 25% of the total operating costs (probably < 4% of fees)
- The electric power requirement of nutrient removal plants without aerobic sludge stabilisation can be reduced to less than 2.5 W/pe (5W/P) (20 kWh/pe/a) by optimising all energy consumers. The actual median in Austria is in the range of 4W/pe, there is potential for improvement. The largest influence is with the aeration efficiency.

Conclusions

- By using anaerobic sludge digestion and biogas conversion to electric energy the total external **energy demand** can be reduced to about **0.5 W/pe**. By using 2-stage AS treatment even a slight **excess power** can be produced (**0.6 W/pe**). High biogas conversion efficiency has a dominant effect.
- The contribution of energy minimisation at WWTP to climate change abatement is crucial: 5% loss of biogas and/or a slight increase of N_2O emissions to the atmosphere completely compensate for CO_2 emission reduction.

Conclusions

- There is no relevant good argument to reduce treatment efficiency for energy minimisation (e.g. increased NH_4-N effluent concentrations)
- There are no good arguments to waste energy and to increase costs without effect for water quality which has to be the main goal of WWTP design and operation.
- Removal of micro-pollutants will increase the energy demand but will not be the decisive factor for decision making.
- There is room for many innovations (which are in accordance with the basic laws of thermodynamics).

We cordially invite you all to the

IWA

WORLD WATER CONGRESS and EXHIBITION

Lisbon, Portugal

September 21 – 26, 2014

Thank you for your attention!

Helmut Kroiss