A new wastewater treatment plant concept

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Image: Tom Fisk

Contents

Problem to solve

More than 4 billion people do not benefit from adequate sanitation services[1,2]

Some root causes

- Financial incapacity to cover the costs of construction, operation and maintenance;
- Increasing technical complexity and cost of wastewater treatment plants;
- Solutions developed for high income countries to not match the needs of middle and low income countries;
- Allocation of electricity to higher value activities;

1. WHO/UNICEF 2017
2. 2020, Hueso et.al, Eaux usées, eaux troubles

Mail&Guardian, South Africa

Solution

- A new system comprised of electro-mechanically simple units that optimize biological processes to deliver low-cost and robust treatment;
- Anoxic, Phototrophic and Anaerobic biological unit processes remove more than 90% of influent BOD5, more than 70% of N and 5% of P;
- Subsequent conventional membrane processes recover > 50% of the influent water for industrial, landscaping and agricultural uses;
- Final effluent polishing by a constructed wetland;
- Some of the biosolids are recovered for use as soil amendments. Some biosolids must be landfilled or incinerated;
- More than 50% of influent carbon leaves the system as biogas that is used to generate heat and power for autonomy and export (energy positive);
- An ownership model that benefits the public and private sector stakeholders.

Solution

Can a municipal wastewater treatment plant be energy positive ?

$$50'000\ p.e.\ \text{x}\ \frac{450\ mg\ TS}{l}\ \text{x}\ \frac{125\ l}{p.e.}\ \text{x}\ \frac{10{,}2\ MJ\ (TS{,}LHV)}{kg\ TS}\ \text{x}\ \frac{0{,}5\ MJ\_th}{MJ\_TS}\ \text{x}\ \frac{0{,}37\ MJ\_e}{MJ\_th}\ X\ \frac{1\ kg}{1'000'000\ mg}\ X\ \frac{1\ kWh\_e}{3{,}6\ MJ\_e} = \frac{1474\ kWh\_e}{day}$$

Raw Influent

Energy conversion

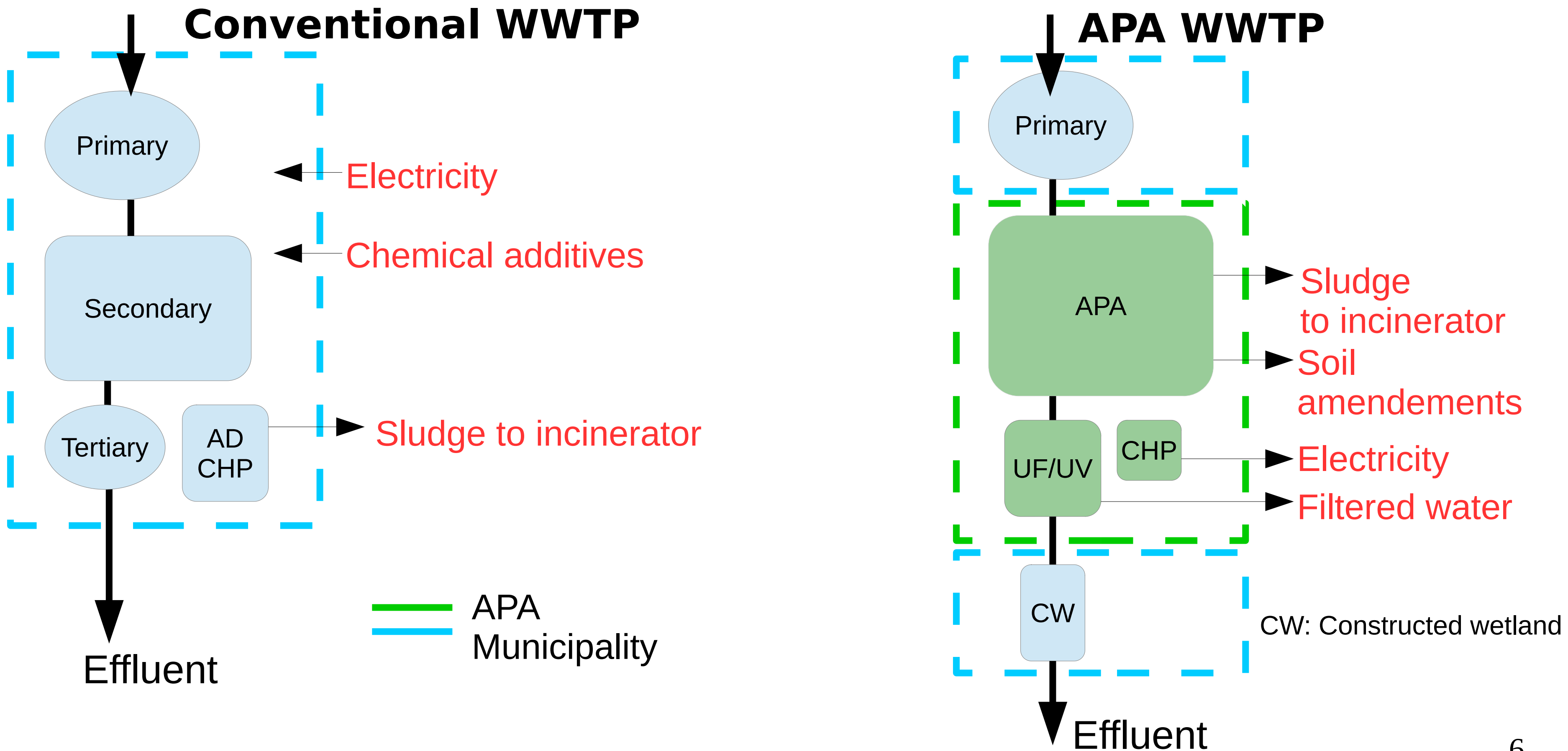
Proposed project

Constant power production potential :	61 kW_e	Expected energy yield from solids: 50% (65 % VS, 227 m³ CH4/tonne VS)
Constant power requirements :	34 kW_e	Constant pumping at the average influent flow rate, 30 meters dynamic head

61 kW > 34 kW =>

Yes, the wastewater treatment plant can be energy positive.
Replace the aerobic processes with anaerobic and anoxic processes.
Minimize pumping requirements.

Comparison to a conventional WWTP



Comparison to a conventional WWTP

Existing WWTP, Kondar, Tunisia

Tertiary aerobic treatment
Influent flow rate: 850 $m^3.day^{-1}$
Influent load: 500 kg $BOD.day^{-1}$ (25’000 PE)

Surface area (green box): 60m x 100m = 6000 m^2
Specific surface area: 6000/850 = 7 $m^2.(m^3.day^{-1})^{-1}$

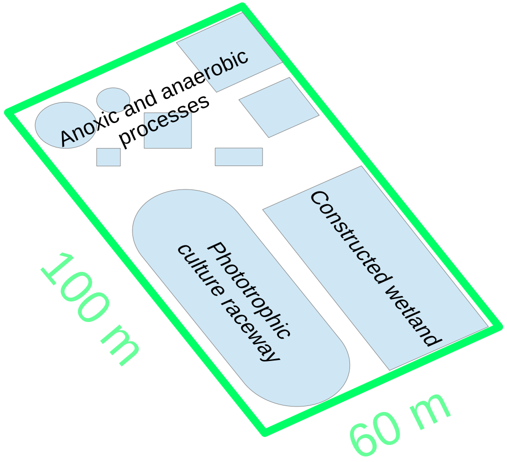
WGS84 : 35.9143955, 10.2754500

New WWTP, APA

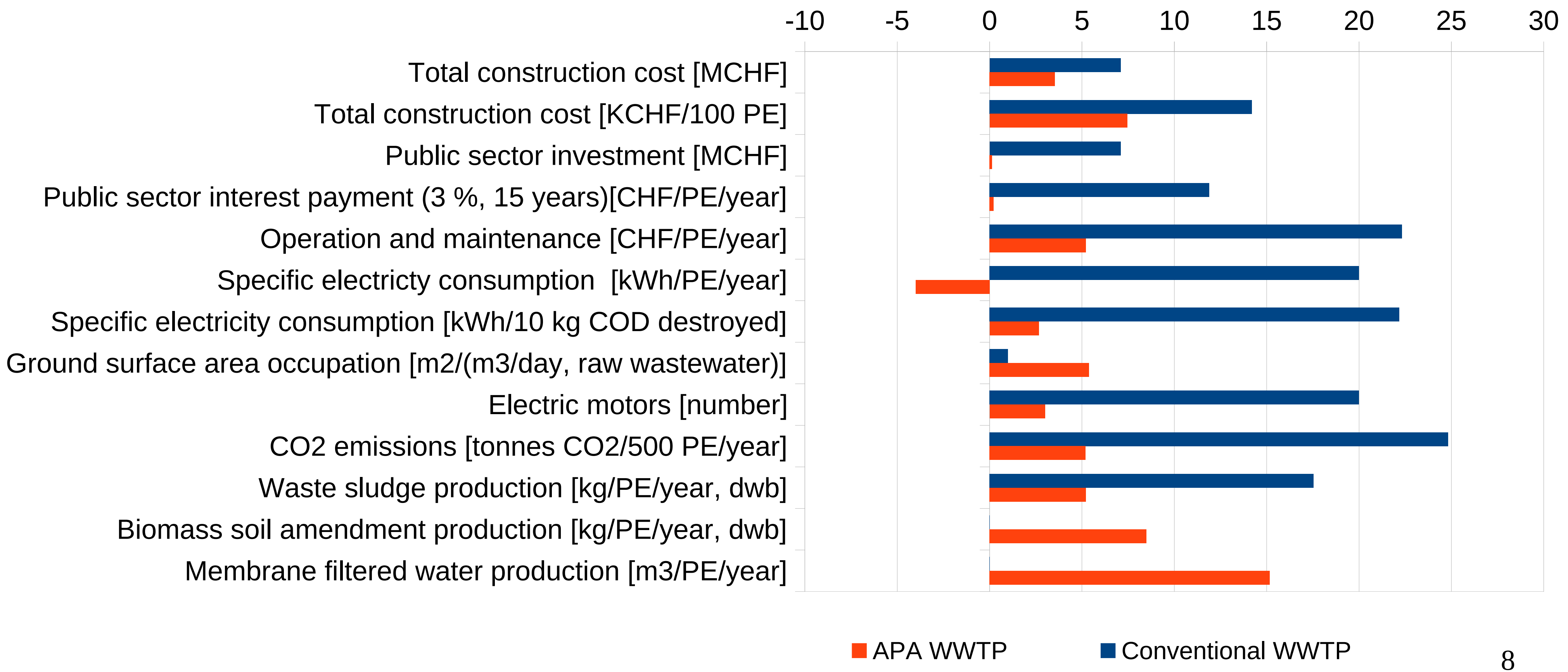
Anoxic, phototrophic, anaerobic treatment
Influent flow rate: 850 $m^3.day^{-1}$
Influent load: 500 kg $BOD.day^{-1}$

Surface area(green box): 60m x 100m = 6000 m^2
Specific surface area: 6000/850 = 7 $m^2.(m^{-3}.day^{-1})^{-1}$

Built surface area: 3600 m^2



Comparison to a conventional WWTP



Technology readiness

Anaerobic treatment: a non-conventional bioreactor that combines anaerobic filter and Imhoff tank type bioreactors. I have operated an anaerobic filter continuously for 9 months at a wastewater treatment plant (photos below).

Anoxic treatment: a novel attached growth, high rate, column bioreactor based on litterature reviews and stoichiometry. TRL2 (concept formulated). I do not have hands-on experience with anoxic treatment.

Phototrophic treatment: a conventional raceway, mixed culture of algae and cyanobacteria, design based on litterature reviews and stoichiometry. The culture and harvesting techniques are well known. I have supplied an influent stream to an algae bioreactor.

Membrane filtration: conventional UF or NF filtration followed by UV inactivation of microorganisms. I have some experience with membrane processes and UV treatment.

Biogas combined heat and power: conventional off-the-shelf equipment.

Constructed wetland: a conventional system based on litterature reviews.

Primary effluent

Primary effluent

Exploratory study of municipal wastewater primary sedimentation basin effluent treatment using an upflow anaerobic filter. https://doi.org/10.31224/osf.io/sm5qg

Work plan to build and operate a complete demonstration plant

Comprehensive data acquisition :

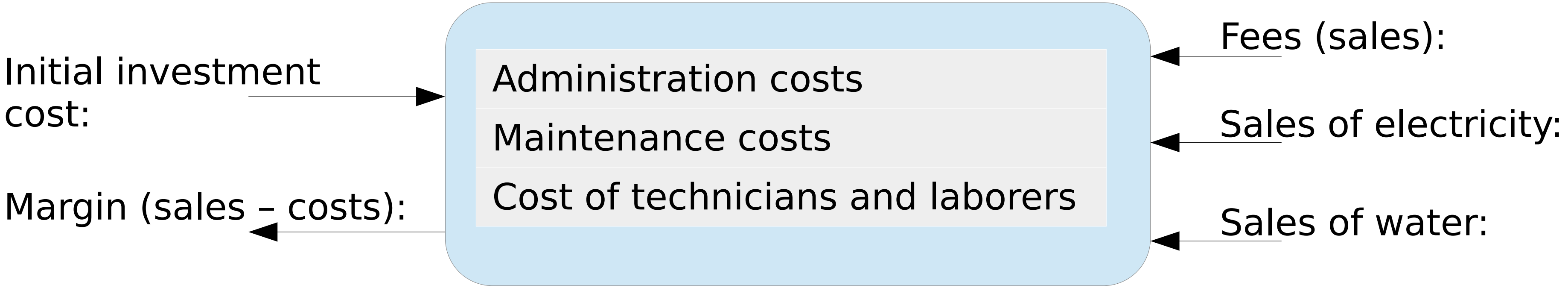
- Build a complete plant at demonstration scale (5’000 to 20’000 PE) ;
- Located at an existing WWTP, side stream influent ;
- Modular bioreactors (~ 100 m³, concrete, metal, plastic components) ;
- Automatic data acquisition over a wide range of experimental operating parameters using established sensor technology;
- Experimental plan : 15 factors, 2 levels, 16 experiments, 5 days per experiment => 80 days.
- Comprehensive analysis using data science tools ;
- Refine and repeat to obtain the optimal design specification of the unit processes of the system ;

Examples of concrete bioreactor type vessels

Revenue model

Ownership

Design, Build, Own, Operate: The core wastewater treatment processes are owned and operated by a private company. The **public sector pays a fee** for the operation service.



Cost to the public sector

The annual cost of the new WWTP concept to the public sector is less than 50% of the cost of a conventional WWTP and less than the cost of modern, collective non-sewered toilets[1].

[1]BM Gates foundation target: $0.05 per person per day = $18.25 per person per year (2021, Sutherland, et.al.)