D.T1.3.1 – INSTRUCTION GUIDE FOR CHECKING THE SOUNDNESS OF REEF 2W IN TERMS OF EE-RES SOLUTIONS TO BE INVESTIGATED

30/11/2017

Table of content

1. Content 2

2. EE TOOL – ENERGY EFFICIENCY IN REEF 2W PLANTS 3

2.1. EVALUATION OF ELECTRIC ENERGY CONSUMPTION 4

2.2. EVALUATION OF THERMAL ENERY CONSUMPTION 4

3. RES TOOL – RENEWABLE ENERGY SOURCES IN REEF 2W PLANTS 5

3.1. ELECTRIC AND THERMAL ENERGY FROM SAWAGE GAS..... 6

3.2. THERMAL ENERGY POTENTIAL FROM WASTEWATER HEAT RECOVERY 6

3.3. ADDITIONAL SOURCES..... 7

3.3.1. Hydropower 7

3.3.2. Solar energy 7

4. LITERATURE..... 9

1. Content

This deliverable describes the intended methodological/calculation approach for evaluating potentials for energy efficiency (EE) as well as energy generation from renewable energy sources (RES) at REEF 2W plants.

2. EE TOOL – ENERGY EFFICIENCY IN REEF 2W PLANTS

The EE tool can be used to identify optimisation potentials for the use of (1) electric and (2) thermal energy at WWTPs. Herby both, the energy demand of wastewater treatment as well as the operational infrastructure can be considered.

The basic principle of the evaluation a comparison of current electric and thermal energy demand parameters of a related wastewater treatment plant (WWTP) with standard ranges from literature (Lindtner, 2008). Table 1 and 2 display the standard ranges for electric and thermal energy consumption of different WWTP processes and structures.

Table 1: Standard ranges for electric energy consumption (Lindtner, 2008, adapted)

		standard range	
WWTP total	**kWh/PE_{120}/a**	***20***	***50***
1) inflow pumping station and mechanical pre-treatment	**kWh/PE_{120}/a**	***2,5***	***5,5***
1.1 pumping stations	kWh/PE_{120}/a	***1,5***	***3,5***
1.2 screening	kWh/PE_{120}/a	***0,5***	***1***
1.3 sand trap and primary clarifier	kWh/PE_{120}/a	***0,5***	***1***
2) mechanical-biological treatment	**kWh/PE_{120}/a**	***14,5***	***33***
2.1 aeration	kWh/PE_{120}/a	***11,5***	***22***
2.2 stirrers	kWh/PE_{120}/a	***1,5***	***4,5***
2.3 return sludge pumps	kWh/PE_{120}/a	***1***	***4,5***
2.4 miscellanious (sec. clarifier)	kWh/PE_{120}/a	***0,5***	***2***
3) sludge treatment	**kWh/PE_{120}/a**	***2***	***7***
3.1 thickening	kWh/PE_{120}/a	***0,5***	***1***
3.2 digestion	kWh/PE_{120}/a	***1***	***2,5***
3.3 dewatering	kWh/PE_{120}/a	***0,5***	***3,5***
4) infrastructure	**kWh/PE_{120}/a**	***1***	***4,5***
4.1 heating	kWh/PE_{120}/a	***0***	***2,5***
4.2 misc. infrastructure	kWh/PE_{120}/a	***1***	***2***

Table 2: Standard ranges for thermal energy consumption (Lindtner, 2008, adapted)

		standard range	
WWTP total	**kWh/PE/a**	***0***	***30***
sludge heating	kWh/PE/a	***8***	***12***
transmission loss, digester tower heating	kWh/PE/a	***0***	***4***
generation, storage and distrivution loss	kWh/PE/a	***0***	***2***
heat for buildings	kWh/PE/a	**0**	**2**
heat for supply air unit	kWh/PE/a	***0***	***10***

The standard ranges refer to population equivalents (PE) of 120 g COD per capita (P) and day.

2.1. EVALUATION OF ELECTRIC ENERGY CONSUMPTION

Input data required:

- Q_{WW}: daily average of wastewater flow at the WWTP in m³/d
- COD_{conc}: daily average of COD inflow concentration in mg/l
- $EC_{el,tot}$: total electric energy consumption of the different consumers mentioned in table 1 (as detailed as possible) in kWh/a

Applied formulas:

- $COD_{load} = COD_{conc} * Q_{WW} * 0,001$
- $PE_{120} = COD_{load}/0,12$
- $EC_{el,PE120} = EC_{el,tot}/PE_{120}$

Calculated outputs:

- COD_{load}: COD inflow load at the WWTP in kg/d
- PE_{120}: Population equivalent connected to the related WWTP in the analysis period
- $EC_{el,PE120}$: electric energy consumption per population equivalent and year

2.2. EVALUATION OF THERMAL ENERY CONSUMPTION

Input data required:

- $EC_{th,SH}$: total thermal energy consumption of sludge heating in kWh/d
- A_{DT}: Surface digestion tower(s) in m²
- T_{DT}: Temperature in the digestion tower(s) in °C
- T_{Amb}: Ambient air temperature in °C
- k: k-value digestion tower(s) in W/m²*K (default values also applicable)

- $A_{building}$: Surface of heated buildings in m²
- $EC_{building}$: Building heat demand in kWh/m²*a (default values also applicable)

Applied formulas:

- $EC_{th,THL} = A_{DT}*(T_{DT}- T_{Amb})*k*24/1000$
- $EC_{th,GSDL} = (EC_{th,SH}+ EC_{th,THL})*0,1$
- $EC_{buildings}$: $A_{building}* EC_{building}/365$
- $EC_{th,PE120} = (EC_{th}/PE_{120})*365$ (calculation of PE_{120} compare electric energy evaluation)

Calculated outputs:

- $EC_{th,TML}$: loss for transmission, digester tower heating in kWh/d
- $EC_{th,GSDL}$: loss for generation, storage and distribution in kWh/d
- $EC_{buildings}$: heat demand for buildings in kWh/d
- $EC_{th,PE120}$: electric energy consumption per population equivalent and year (applicable for $EC_{th,SH}$, $EC_{th,TML}$, $EC_{th,GSDL}$, $EC_{buildings}$)

3. RES TOOL – RENEWABLE ENERGY SOURCES IN REEF 2W PLANTS

The RES-tool can calculate the energy generation potential of the following sources:

- 1) electric and thermal energy from sewage gas
- 2) thermal energy recovered from wastewater (and electric energy needed for)
- 3) additional sources:
    - electric energy from hydropower
    - electric + thermal energy from solar (PV, solar thermal and hybrid collectors)

Furthermore, wind power could also be mentioned as an additional source. However, due to very specific and local data requirements it will not be considered at the current stage of tool development.

The tool requires separate input data for each month and calculates monthly balances and aggregates them to an annual balance.

3.1. ELECTRIC AND THERMAL ENERGY FROM SAWAGE GAS

Input data required:

- SG_{total} = monthly amount of sewage gas in m³/mo (default values also applicable)
- c_{CH4} = methane content in % (default values also applicable)
- e_{cont} = energy content of methane in kWh/m^3 (default values also applicable)
- SG_{grid} = monthly part of sewage gas fed into the grid in m³/mo (default value 0)
- eff_{el} = electric efficiency of the CHP unit in % (default values also applicable)
- eff_{th} = thermal efficiency of the CHP unit in % (default values also applicable)

Applied formulas:

- $E_{el} = (SG_{total} - SG_{grid})*c_{CH4}* e_{cont}*eff_{el}$
- $E_{th} = (SG_{total} - SG_{grid})*c_{CH4}* e_{cont}*eff_{th}$

Calculated outputs:

- E_{el}: monthly generated electric energy from sewage gas available at the WWTP in kWh/mo
- E_{th}: monthly generated thermal energy from sewage gas available at the WWTP in kWh/mo

3.2. THERMAL ENERGY POTENTIAL FROM WASTEWATER HEAT RECOVERY

Input data required:

- Q_{WW}: monthly average of wastewater flow at the WWTP in m³/mo
- f_{TW}: monthly part of dry weather wastewater flow in % (default values also applicable)
- T_{WW}: monthly average of wastewater temperature at the WWTP in °C
- T_{min}: technical minimum temperature of wastewater after heat recovery in °C (default value 5)
- T_{heat}: temperature needed for the supply (to be reached in the heat pump circuit) in °C (default values also applicable)
- CF: Carnot grade: factor between real COP and maximum possible COP at given temperatures (carnot cycle) (default value 0,45)

Applied formulas:

- monthly available thermal potential from wastewater heat recovery: $P_{th} = 1{,}16*Q_{WW}*f_{TW}*(T_{WW} - T_{min})$
- coefficient of performance per month of the heat pump: $COP = CF*(273+T_{heat})/(T_{heat} - T_{WW})$ (default values also applicable)
- monthly needed electric potential: $P_{el} = P_{th}/(COP - 1)$
- monthly available total thermal potential from the heat pump system: $P_{total} = P_{th} + P_{el}$

Calculated outputs:

- P_{th}: monthly thermal potential recovered from wastewater available at the WWTP in kW
- P_{el}: monthly electric energy needed for heat pump(s) in kW
- P_{total}: monthly available thermal energy supply available at the WWTP in kW (sum of thermal energy from wastewater and electric energy for the (compressor) heat pump)

3.3. ADDITIONAL SOURCES

3.3.1. Hydropower

Input data required:

- Q_{WW}: monthly average of wastewater flow at the WWTP in m^3/mo
- h: drop height at the effluent of the WWTP in m
- eff_{hpp}: efficiency of turbine and generator in % (default values also applicable)

Applied formulas:

- $E_{el} = Q_{WW}*h*eff_{hpp}*9{,}81/3600$

Calculated output:

- E_{el}: monthly generated electric energy from hydropower available at the WWTP in kWh/mo

3.3.2. Solar energy

Input data required (all types)

- W_{sol}: solar irradiance per month in kWh/m^2*mo (default values also applicable)

<u>Photovoltaics:</u>

Additionally needed inputs:

- A_{PV}: PV collector surface in m²
- $eff_{el,PV}$: electric efficiency of the PV plant in %

Applied formulas:

- $E_{el,PV} = W_{sol} * A_{PV} * eff_{el,PV}$

Calculated output:

- monthly electric energy generated by the PV plant at the WWTP in kWh/mo

Solar thermal:

Additionally needed inputs

- $A_{sol.th}$: solar thermal collector surface in m^2
- $eff_{th,sol.th}$: thermal efficiency of the solar thermal plant in % (default values also applicable)

Applied formulas:

- $E_{th,sol.th.} = W_{sol} * A_{sol.th.} * eff_{th,sol.th}$

Calculated output:

- monthly thermal energy generated by the solar thermal plant at the WWTP in kWh/mo

Hybrid:

Additionally needed inputs:

- A_{hyb}: applicable PV surface in m²
- $eff_{el,hyb}$ electric efficiency of the solar hybrid power plant in %
- $eff_{th,hyb}$ thermal efficiency of the solar hybrid power plant in %

Applied formulas:

- $E_{el,hyb} = W_{sol} * A_{hyb} * eff_{el,hyb}$
- $E_{th,hyb} = W_{sol} * A_{hyb} * eff_{th,hyb}$

Calculated output:

- monthly electric energy generated by the solar hybrid power plant at the WWTP in kWh/mo

- monthly thermal energy generated by the solar hybrid power plant at the WWTP in kWh/mo

Solar total:

Applied formulas:

$$E_{el} = E_{el,PV} + E_{el,hyb}$$

$$E_{th} = E_{th,sol.th} + E_{th,hyb}$$

Calculated output:

- monthly electric energy generated by the solar power plants (of all 3 types together) at the WWTP in kWh/mo
- monthly thermal energy generated by solar power plants (of all 3 types together) at the WWTP in kWh/mo

4. LITERATURE

Lindtner, S. (2008): Leitfaden fuer die Erstellung eines Energiekonzeptes kommunaler Klaeranlagen (Guideline for the development of an energy concept for municipal wastewater treatment plants). Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management (BMLFUW), Vienna.