LIFE B2E4SustWWTP (LIFE16 ENV/GR/000298)

New concept for energy self-sustainable wastewater treatment process and biosolids management

Deliverable C.1.1. List of specific indicators

Specific indicators selected for the environmental assessment of the project actions

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1. OBJECTIVES

The aim of this guide is to define the indicators that allow the monitoring of the environmental impact of the actions developed by the Life B2E4SustWWTP project as well as developing the means and tools to monitor them.

The main objective of this project is the GHG emissions reduction in urban water sewage process, which it is intended to be achieved through two fundamental measures:

- Reduction of electricity consumption in the WWTP
- Increase in the generation / use of energy from renewable sources

This last aspect implies at the same time an additional environmental improvement, such as the reduction of organic solid waste (sludge) produced by the WWTP, since they are used for the energy generation.

Thus, measures foreseen for GHG reduction are linked to the lessening of energy consumption as well as the use of renewable resources. Therefore, indicators have been defined to allow the evaluation of this reduction in a reliable way. On the other hand, quantification of the reduction in waste production, this would be linked to its use as an energy resource.

Energy savings derived from changes in sewage process cannot be calculated simply as the difference between the consumption before and after the implementation of these changes, since in most cases energy consumption suffers variations due to external factors. Therefore, the approach adopted for the indicators definition is based on the application of a clear and rigorous methodology for the measurement and verification of energy savings.

The methodology used for the measurements and verification of energy savings is based on the International Performance Measurement and Verification Protocol (IPMVP), promoted by the Efficiency Valuation Organization (EVO).

2. BACKGROUND

The International Performance Measurement and Verification Protocol (IPMVP), developed by the Efficiency Valuation Organization (EVO), is a document that aims to establish the bases and procedures for the measurement and verification of energy consumption reductions achieved because of the implementation of energy saving actions (ESA).

The use of this type of procedure, sufficiently contrasted and bibliographically documented, serves as a guarantee for the parties as well as conferring greater credibility, even at the international level of energy saving reports.

Although the IPMVP is not a Standard, it has a similar application mode. To be able to benefit from this protocol, certain guidelines must be followed, and terminology adopted to achieve homogeneity among the different projects developed according to this protocol.

The IPMVP is developed with the idea of facilitating the measurement and verification procedures in several circumstances. Among them, those concerning the energy performance contracts signed between the service companies and their clients, or those derived from the implementation of efficiency programs, energy saving and efficiency measures, monitoring the maintenance of facilities, etc.

3. METHODS

Essentially, the application of the IPMVP requires the development of a Measurement and Verification Plan and the subsequent implementation of the corresponding measurements, verifications, calculations and adjustments necessary for compliance with the plan.

For the development of this measurement plan, the following steps must be followed.

3.1 Evaluation of the measurement and verification reports needs

Following the IPMVP, for the Life B2E4SustWWTP project, the European Commission could be adopted as a client. As needs, the fulfillment of the commitments established in the application proposal is established.

The first step was the identification of those areas of the selected WWTP affected by the project actions with the aim of highlighting the parameters to monitor in order to follow its evolution.

The parameters identified are:

- Electricity consumption from the WWTP
- Specific electricity consumption from the aeration of biological reactors and aerobic digestion
- Specific electricity consumption of the equipment proposed by the project (microscreen, dryer, gasifier).
- Dryer and the gasifier thermal energy consumption
- Cogeneration engine fuel consumption

- Cogeneration engine heat and electricity production
- Auxiliary fuels consumption needed for the start-up of thermal equipment (biomass, LPG, natural gas,...).
- Characteristics of treated water (COD, BOD, SST, NT, PT, $N\text{-}NH_3$, $N\text{-}NO_3$, $P\text{-}PO_4$).
- Solid waste production (organic sludge / gasification ash) and inmediate analysis.

In addition, independent variables are necessary been considered. These would be the ones that allow normalizing yields, so that the WWTP performance could be compared with other facilities. Among them, have been identified:

- Water influent flow
- Input water characteristics (COD, BOD, TSS, TN, TP, $N\text{-}NH_3$, $P\text{-}PO_4$).

All these variables must be quantified before and after the integration in the WWTP of the modifications proposed by the project. Nevertheless, a report will be issued with a minimum monthly periodicity.

3.2 Selection of the appropriate IPMVP option

One of the most important points facing the IPMVP application is the selection of the most appropriate measurement and verification option.

There are four options named A, B, C and D. The selection criteria will depend on the implemented ESA, the client's needs, the available budget for measurement and verification, the initial conditions of the system, etc.

- Option A. Isolated ESA verification: measurement of the key parameter. In this option, savings are determined by measuring key parameters on the installation. Measurement could be continuous or punctual. It will be necessary to estimate another parameter for savings assessment. This parameter must be justified by historical data, manufacturer specifications, etc.
- Option B. Isolated ESA verification: measurement of each parameter. In this Option, the improvements are obtained by measuring directly in the installation the energy consumption and waste generation of the whole system in which the ESA has been implemented. The measurement can be continuous or punctual, depending on the expected variation of improvements and the duration of the demonstration period of savings.
- Option C. Verification of the entire installation. The improvement is determined by measuring the energy consumption and waste generation of the entire installation. Measurement of energy consumption of the whole installation is carried out continuously during the demonstration period of savings.

- Option D. Calibrated simulation. The improvement is determined by simulating the energy consumption of the entire installation or part of it, as well as waste generation. The simulation has to be able to model the current energy performance of the installation. This option usually requires certain skills and specific knowledge to perform calibrated simulations.

Options A and B would be used for the isolated verification of the Savings and Efficiency Measures, since the effect of the improvement is measured exclusively within the measurement limit.

Option C, on the other hand, would be used in those cases in which it is interesting to verify the effect of the Savings and Efficiency Measures and, therefore, the savings in the whole installation.

Finally, option D could be used to verify the impact of the improvement measure on all or part of the installation.

The selection of one or the other option depends on the scope of the Savings and Efficiency Measures, the precision required and the budget available for measurement and verification. The option chosen for the Life B2E4SustWWTP project is Option C, although indicators have been defined to allow verifications based on options A and B to be made in order to evaluate the improvements introduced by each of the measures.

3.3 Measurement Periods

Within the IPMVP Protocol it is necessary to establish a reference and a demonstration period of the improvement, as well as the relevant adjustments for making the values obtained for both periods comparable.

For the reference period, the energy consumption and waste generation would be assessed before implementing the ESA envisaged in Life B2E4SustWWTP by using the last two years exploitation data. In addition, other variables that allow establishing the necessary adjustments, as well as expressing the results according to a functional and easy to compare unit would be gauged. This type of measurements is usually carried out continuously, as part of the normal operation of the WWTP, so they would be available.

In the demonstrative period, the same parameters as in the reference period will be measured once the ESA are implemented.

In order to make these values representative of the actual plant operation, they must cover the entire operating cycle. In the case of Life B2E4SustWWTP, this period will be one year, although for certain installations it may be one month, one week, one day or even hours.

3.4 Compilation of information

At this stage, all the information corresponding to the plant operation in the reference period would be gathered. This info is required for the characterization of the plant performance in terms of energy consumption and waste production, so that are registered for evaluation.

The information to be collected will correspond to the last two years of operation of the plant, and in particular:

- Electricity demand of the whole WWTP
- Electrical consumption of aeration in biological treatment
- Electrical consumption of aerobic digestion
- Electrical consumption of sludge dewatering
- Production and % of dry matter of dewatered sludge

All this information is currently available, since these measures are usually included in the exploitation activities of the WWTP, being necessary for the process' monitoring.

For making the reference period measurements and demonstration period savings comparable, it is usually necessary to carry out certain adjustments. Several variables affecting the energy efficiency of the installation should be considered. Hence, once the information has been analyzed, the indicators collected would be also defined in order to establish the influence factors on energy consumption. The main factor is the removal of water contaminants, calculated as the difference between the mass flow in inlet and effluent. By referring to the overall energy consumption of the plant, or the waste production for treated wastewater or the kg of BOD eliminated, for example, we will be able to compare the consumption of the reference and demonstration phases or compare the consumption of different facilities among themselves.

Like the variables indicated above, these are also available for their usual measurement in the WWTP, so they will be requested to the operator (DEYAR) for the characterization of the reference phase. The information to request would be:

- Treated wastewater flow
- Characterization of the WWTP inlet water (BOD, COD, TSS, TN, N-NH_3, TP, P-PO_4)
- Characteristics of WWTP effluent (BOD, COD, TSS, TN, N-NH_3, N-NO_3, TP, P-PO_4)

In the same way, the costs of energy supplies and waste removal will be collected, in order to relate them to the energy and sewage parameters.

- Electric power cost
- Dehydrated sludge removal cost

3.5 Settings. Base line

As described in previous sections, with the aim of compare the values obtained in the reference periods (before the implementation of B2E4) and the demonstration period (after its implementation) it is necessary to carry out the so-called routine settings, which are those that depend on the independent variables.

In the case of B2E4, the independent variables that condition the performance of the plant are basically two: 1) volume of treated wastewater, 2) concentration of pollutants in the wastewater (BOD, COD, $N-NH_3$, etc.). That is, the higher the daily flow of wastewater, the greater will be the consumption of electrical energy from the WWTP and greater the production of residual sludge. Similarly, the higher the concentration of contaminants in the wastewater, the greater the consumption and production of waste to achieve the treated water quality established by legislation. On the other hand, both independent variables could be unified in a single variable that expresses the load of entry to the WWTP of the pollutants to be eliminated (e.g. kg COD / day, etc.).

Therefore, the first step is to define the baseline corresponding to the reference period. To this end, measures must be taken of treated flows, energy consumption and waste production. With this, a proportionality relation could be stablished in order to predict the plant's performance as a function of these independent variables.

Similarly, with the aim of assessing the efficiency of the plant in the two considered periods, the consumption and generation of waste could be expressed with respect to the unit of mass of pollutant eliminated. Therefore, both the concentration of pollutants in inlet and outlet water, and the treated flow should be considered. In addition, a comparison of different WWTPs among themselves could be done. Hence, the typical indicators would be: kWh per treated m^3, kWh per kg of BOD eliminated, kg of MS produced per treated m^3, etc.

- For the reference period, the characteristics foreseen for the last two years of WWTP operation would be used referred to the electricity consumption and sludge production as a function of the volume of treated water and pollutants removed. This is the baseline to be used for the environmental impact’s analysis.
- In the demonstration period, the same procedure is followed, but expanded with the measurements made in situ to determine the consumptions / generations of the new equipment incorporated (microscreen, dryer, gasifier, engine-generator).

When emissions and consumption data of both periods are available, the derived CO_2 emissions will be obtained, and the environmental effects of the project would be checked in relation to GHGs, waste production, use of renewable energy sources, energy consumption from fossil fuels, etc.

3.6 Measurement equipment design, installation and commissioning

As discussed in previous sections, in order to achieve an effective monitoring, the followings indicator are established:

Variable (Functional cathegories)	Sym.	Uds.
Wastewater treated by the WWTP	M_a	m^3
COD of the wastewater affluent	COD_a	mg/L
BOD of the wastewater affluent	BOD_a	mg/L
TSS of the wastewater affluent	TSS_a	mg/L
TN or TKN of the wastewater affluent	TN_a	mgN/L
N-NH_3 of the wastewater affluent	$N\text{-}NH3_a$	mgN/L
TP of the wastewater affluent	TP_a	mgP/L
P-PO_4 of the wastewater affluent	$P\text{-}PO4_a$	mgP/L
Electrical energy consumption of the WWTP	$E_{e.WWTP}$	kWh
Electrical energy consumption of the aeration/mixing equipment	$E_{e.air}$	kWh
Electrical energy consumption of the aerobic digestion process	$E_{e.dig}$	kWh
Electrical energy consumption of the sludge dewatering	$E_{e.dwt}$	kWh
COD of the wastewater effluent	COD_e	mg/L
BOD of the wastewater effluent	BOD_e	mg/L
TSS of the wastewater effluent	TSS_e	mg/L
TN or TKN of the wastewater effluent	TN_e	mgN/L
N-NH_3 of the wastewater effluent	$N\text{-}NH3_e$	mgN/L
N-NO_3 of the wastewater effluent	$N\text{-}NO3_e$	mgN/L
TP of the wastewater effluent	TP_e	mgP/L
P-PO_4 of the wastewater effluent	$P\text{-}PO4_e$	mgP/L
Produced dewatered sludge (biosolids from the aerobic reactors)	M_{slg}	kg
Dry matter content of dewatered sludge	DM_{slg}	%
Wastewater treated by the microscreen	$M_{a.scr}$	m^3
Time of microscreen operation	t_{scr}	h
Electrical energy consumption of the microscreen	$E_{e.scr}$	kWh
Produced sludge from microscreen	$M_{e.scr}$	m^3
Dry matter content of sludge from microscreen (or sludge pre-dried in stage 1).	$DM_{e.scr}$	%
Electrical energy consumption of the dryer	$E_{e.dry}$	kWh
Heat provided by the cooling water coming from the syngas cooling. Calculated with flow and input/output water temperature	$H_{e.dry,\ w}$	kWh
Heat provided by the off gases coming from the engine. Calculated with off gases/air flows, input and output temperatures and relative humidity	$H_{e.dry,\ g}$	kWh
Dry matter content of dried sludge	DM_{dry}	%
Time of dryer operation	t_{dry}	h
Sludge/biomass consumption of the gasifier	$M_{a.gsf}$	kg
Electrical energy consumption of the gasification unit	$E_{e.gsf}$	kWh
Auxiliary fuel consumption – starting/operation/shut-down	$M_{f.gsf}$	kg
Solid waste production (ashes) from gasification	M_{ash}	kg
Time of gasifier operation	t_{gsf}	h
Engine syngas consumption	M_{syn}	kg
Available heat produced by the engine. Off gases flow and temperature	$H_{e.eng,\ g}$	kWh

Electrical energy produced by the engine	$E_{e.eng}$	kWh
Time of engine operation	t_{eng}	h
Electrical energy cost	$C_{E.E}$	€/kWh
Auxiliary fuel cost	$C_{f.gsf}$	€/kg
Dewatered sludge (biosolids) disposal cost	C_{slg}	€/ton
Solid wastes (ashes) from gasification disposal costs	C_{ash}	€/ton

The planned measurement procedure would collect part of the variables included in Annex. This annex specifies the variables included in the mentioned procedure, as well as the periodicity of the measurements. Part of the variables would be measured in situ during the demonstration period. WWTP operating company would provide the other part, which include the above mentioned variable for both the reference period and the demonstration period. These variables are usually monitored in the WWTP for the exploitation process control. This information is also specified in Annex I.

3.7 Monitoring system start-up

Once the installation of the monitoring system is completed, electrical and thermal measurements would be made to verify the correct functioning of the equipment for the monitoring system and to define the expected constants for the calculation of the indicators.

3.8 Compilation of information acquired during the demonstration period

The information needed for the development of energy savings and emissions reports will be compiled in digital format by the information system.

This information would be downloaded at least once a week from the system and stored on CETENMA servers.

This information will be completed with the information provided by DEYAR regarding the exploitation data from Rethymno WWTP, both during the reference phase and during the demonstration period.

3.9 Preparation of periodic reports

Once all the actions of the B2E4 project are launched, the demonstration period will begin, during which a report will be issued on a bimonthly basis where the main indicators would be collected following the format included in Annex. As far as possible, the frequency of reports would be extended.

4. FINAL CONSIDERATIONS

In order to carry out the evaluation of the emissions reduction and waste production of the Rethymno WWTP achieved with the actions developed by the B2E4 project, it is necessary to define and measure a series of indicators.

These indicators are related to the measurement of energy saving, waste production and the results of the conventional energy sources replacement by renewable energy sources.

The process energy evaluation is a fundamental part for calculating the environmental impact of the project. The indicators selected for the energy evaluation must meet two basic premises:

- Allowing the application of a measurement and verification methodology of energy savings based on the International Performance Measurement and Verification Protocol (IPMVP)
- Allowing a technical-economic evaluation of the different actions and technologies to be implemented in order to evaluate their replicability in other WWTP

The selected indicators are those included in Annex. In this annex, several information such as measurement equipment, registration periodicity, etc. are included. Part of the indicators are monitored by the staff of the WWTP, because these measurements are an integral part of the exploitation activities of the plant. The results of these measurements during the last two years of operation of the facility are used to define the reference period and adjust the baseline of the study. During the demonstration period, these variables will continue to be measured, as they are necessary for the characterization of the facility's performances. Finally, during the demonstration phase, the necessary variables will also be measured in situ to characterize the consumption and energy generation, waste production and emissions of the new treatment system implemented (microscreen, dryer, gasifier, moto-generator), previous to the installation in the system of the necessary measurement equipment.

For the compilation of the measurement of some variables measured during the demonstration period, a continuous monitoring system has been designed for the treatment facilities to be developed by B2E4. Therefore, the evaluation of the emissions reduction and the monitoring of the main operating parameters of the different technologies to be implemented could be carried out in an almost automatic way. Once the historical data collection has been carried out and the developed methodology has been applied, the baseline corresponding to the reference period is obtained, as well as the adjustment equation to verify the emissions reduction and waste production of the B2E4 project. Both reductions would be calculated as the difference between the values obtained during the reference period and during the demonstration phase, weighted with respect to the volume of treated water or pollutant removed. In the case of emissions, both the variation in the electrical energy consumption of the plant and the use / generation of energy from renewable sources, as well as the corresponding emission factors, would be considered.

ANNEX

INDICATORS							
Before B2E4 implementation (Baseline definition of Rethymno WWTP) – 1/2							
	Indicator	**Sym.**	**Uds.**	**Registration Periodicity**	**Report**	**Measurement equipment**	**Notes**
Independent Variables	Wastewater treated by the WWTP	M_a	m^3	Daily	One report collecting the data of the two last years of Rethymno WWTP exploitation	DEYAR's equipment, currently installed at the WWTP	From flow totalizer measures
	COD of the wastewater affluent	COD_a	mg/L	Variable (1 – 3 p. week)			Measured at laboratory from punctual samples
	BOD of the wastewater affluent	BOD_a	mg/L				
	TSS of the wastewater affluent	TSS_a	mg/L				
	TN or TKN of the wastewater affluent	TN_a	mgN/L				
	N-NH3 of the wastewater affluent	$N\text{-}NH3_a$	mgN/L				
	TP of the wastewater affluent	TP_a	mgP/L				
	P-PO4 of the wastewater affluent	$P\text{-}PO4_a$	mgP/L				
Parameters	Electrical energy cost	$C_{E.E}$	€/kWh	N.A.		N.A.	Contracted prize with electrical Co.
	Dewatered sludge (biosolids) disposal cost	C_{slg}	€/ton	N.A.		N.A.	Contracted prize with waste management Co.
Performance variables	Electrical energy consumption of the WWTP	$E_{e.WWTP}$	kWh	Daily		DEYAR's equipment, currently installed at the WWTP	Measured in situ. If it is no possible, it could be calculated from the power of the equipment and its functioning hours or production
	Electrical energy consumption of the aeration equipment	$E_{e.air}$	kWh				
	Electrical energy consumption of the aerobic digestion process	$E_{e.dig}$	kWh				
	Electrical energy consumption of the sludge dewatering	$E_{e.dwt}$	kWh				
	COD of the wastewater effluent	COD_e	mg/L	Variable (1 – 3 p. week)			Measured at laboratory from punctual samples
	BOD of the wastewater effluent	BOD_e	mg/L				
	TSS of the wastewater effluent	TSS_e	mg/L				
	TN or TKN of the wastewater effluent	TN_e	mgN/L				
	$N\text{-}NH_3$ of the wastewater effluent	$N\text{-}NH3_e$	mgN/L				
	$N\text{-}NO_3$ of the wastewater effluent	$N\text{-}NO3_e$	mgN/L				
	TP of the wastewater effluent	TP_e	mgP/L				
	$P\text{-}PO_4$ of the wastewater effluent	$P\text{-}PO4_e$	mgP/L				

INDICATORS								
Before B2E4 implementation (Baseline definition of Rethymno WWTP) – 2/2								
	Indicator	**Sym.**	**Uds.**	**Registration Periodicity**	**Report**	**Measurement equipment**	**Notes**
Performance variables	Dry matter content of dewatered sludge	**DM_{slg}**	%	Variable (1 – 3 p. week)	One report collecting the data of the two last years of Rethymno WWTP exploitation	DEYAR's equipment, currently installed at the WWTP	Measured at laboratory from punctual samples
	Produced dewatered sludge (biosolids from the aerobic reactors)	**M_{slg}**	kg	Daily			From flowmeter measurement and dehydrated amount of sludge picked by the waste management company

INDICATORS							
After B2E4 implementation – 1/3							
	Indicator	Sym.	Uds.	Registration Periodicity	Report	Measurement equipment	Notes
Independent Variables	Wastewater treated by the WWTP	M_a	m^3	Daily	Bimonthly	DEYAR's equipment, currently installed at the WWTP	From flow totalizer measurements
	COD of the wastewater affluent	COD_a	mg/L	Variable (1 – 3 p. week)			Measured at laboratory from punctual samples
	BOD of the wastewater affluent	BOD_a	mg/L				
	TSS of the wastewater affluent	TSS_a	mg/L				
	TN or TKN of the wastewater affluent	TN_a	mgN/L				
	N-NH_3 of the wastewater affluent	$N\text{-}NH3_a$	mgN/L				
	TP of the wastewater affluent	TP_a	mgP/L				
	P-PO_4 of the wastewater affluent	$P\text{-}PO4_a$	mgP/L				
Parameters	Electrical energy cost	$C_{E.E}$	€/kWh	N.A.	Bimonthly	N.A.	Contracted prize with electrical Co.
	Dewatered sludge (biosolids) disposal cost	C_{slg}	€/ton				Contracted prize with waste management Co.
	Gasification solid wastes (ashes) disposal cost	C_{ash}	€/ton				Contracted prize with waste management Co.
	Auxiliary fuel cost (gasification stage)	$C_{f.gsf}$	€/kg				Contracted prize with supplier
Performance variables	Electrical energy consumption of the WWTP	$E_{e.WWTP}$	kWh	Daily	Bimonthly	DEYAR's equipment, currently installed at the WWTP / CETENMA monitoring equipment	Measured in situ. If it is no possible, it could be calculated from the power of the equipment and its functioning hours or production.
	Electrical energy consumption of the aeration equipment	$E_{e.air}$	kWh				
	Electrical energy consumption of the aerobic digestion process	$E_{e.dig}$	kWh				
	Electrical energy consumption of the sludge dewatering	$E_{e.dwt}$	kWh				
	COD of the wastewater effluent	COD_e	mg/L	Variable (1 – 3 p. week)			Measured at laboratory from punctual samples
	BOD of the wastewater effluent	BOD_e	mg/L				
	TSS of the wastewater effluent	TSS_e	mg/L				
	TN or TKN of the wastewater effluent	TN_e	mgN/L				
	N-NH_3 of the wastewater effluent	$N\text{-}NH3_e$	mgN/L				
	N-NO_3 of the wastewater effluent	$N\text{-}NO3_e$	mgN/L				

INDICATORS							
After B2E4 implementation – 2/3							
	Indicator	**Sym.**	**Uds.**	**Registration Periodicity**	**Report**	**Measurement equipment**	**Notes**
Performance variables	TP of the wastewater effluent	TP_e	mgP/L	Variable (1 – 3 p. week)	Bimonthly	DEYAR's equipment, currently installed at the WWTP	Measured at laboratory from punctual samples
	$P\text{-}PO_4$ of the wastewater effluent	$P\text{-}PO4_e$	mgP/L				
	Dry matter content of dewatered sludge	DM_{slg}	%				
	Produced dewatered sludge (biosolids from the aerobic reactors)	M_{slg}	kg	Diary			From flowmeter measurement data and dewatered amount of sludge picked by the waste management company
	Wastewater treated by the micro-screen	$M_{a.scr}$	m^3	Daily	Bimonthly	Flowmeter installed at micro-screen	From flowmeter registered measurements
	Time of microscreen operation	t_{scr}	h	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time
	Electrical energy consumption of the microscreen	$E_{e.scr}$	kWh	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time or measure from portable analyzer
	Dry matter content of sludge from microscreen	$DM_{e.scr}$	%	3 measures p. week	Bimonthly	DEYAR's equipment, currently installed at the WWTP	Measured at laboratory from punctual samples
	Produced sludge from microscreen	$M_{e.scr}$	m^3	Daily	Bimonthly	N.A.	Calculated from $M_{a.scr}$, TSS_a, and $DM_{e.scr}$
	Electrical energy consumption of the dryer (stage 1)	$E_{e.dry1}$	kWh	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time or measure from portable analyzer
	Electrical energy consumption of the dryer (stage 2)	$E_{e.dry2}$	kWh	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time or measure from portable analyzer
	Time of dryer operation (stage 1)	t_{dry1}	h	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time
	Time of dryer operation (stage 2)	t_{dry2}	h				
	Heat consumption of dryer – (stage 1)	$H_{dry,1}$	kWh	Depending on measured parameters	Bimonthly	Punctual measurements	From sludge volume measurements after and before operation (silo 1 and 2) and dry matter content. From biomass consumption of gasifier. Direct measurement of flow and temperature of gases or estimation from fuels engine consumption (diesel and syngas). Direct measurement of flow and temperature of cooling water / air for drying.

Performance variables	Heat consumption of dryer – (stage 2)	$H_{dry,2}$	kWh	Depending on measured parameters	Bimonthly	Punctual measurements	From sludge volume measurements before operation (silo 2), gasifier sludge consumption and dry matter content. Direct measurement of flow and temperature of gases or estimation from fuels engine consumption (diesel and syngas). Direct measurement of flow and temperature of cooling water / air for drying.
	Dry matter content of dried sludge (stages 1 and 2)	DM_{dry}	%	3 Msrs. per week	Bimonthly	DEYAR's equipment, currently installed at the WWTP	Measured at laboratory from punctual samples
	Produced biosolids from dryer (stage 1)	M_{dry1}	Kg	Daily	Bimonthly	N.A.	Calculated from $M_{e.scr}$, $DM_{e.scr}$ and DM_{dry}
	Electrical energy consumption of the gasification unit	$E_{e.gsf}$	kWh	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time or measure from portable analyzer
	Time of gasifier operation	t_{gsf}	h	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time
	Heat consumption of the gasifier – fuel consumption		kWh	Daily	Bimonthly	Punctual measurements	From fuel consumption of steam boiler and auxiliary fuel for starting and shut-down periods
	Produced solid wastes (ashes) from gasification	M_{ash}	kg	Daily	Bimonthly	Measured by DEYAR at demo plant	Measured by weighing the produced ashes
	Engine syngas consumption	M_{syn}	kg	Depending on measured parameters	Bimonthly	Flowmeters or punctual measures	Measures from already installed gas flowmeter or estimated from fuel consumption
	Engine diesel consumption	M_{dsl}	kg		Bimonthly		
	Electrical energy produced by the engine	$E_{e.eng}$	kWh	Daily	Bimonthly	Portable analyzer (CETENMA)	Measures from portable analyzer
	Time of engine operation	t_{eng}	h	Daily	Bimonthly	Portable analyzer (CETENMA)	From registered equipment functioning time
	Available heat produced by the engine		kWh	Depending on measured parameters	Bimonthly	Punctual measurements	Measured from flow and temperature of combustion gases. Estimated from syngas, diesel and air consumption of the engine