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Environmental Impact Assessment for an integrated microsieving-drying-gasification pilot plant for biosolids to electric energy in Rethymno, Greece

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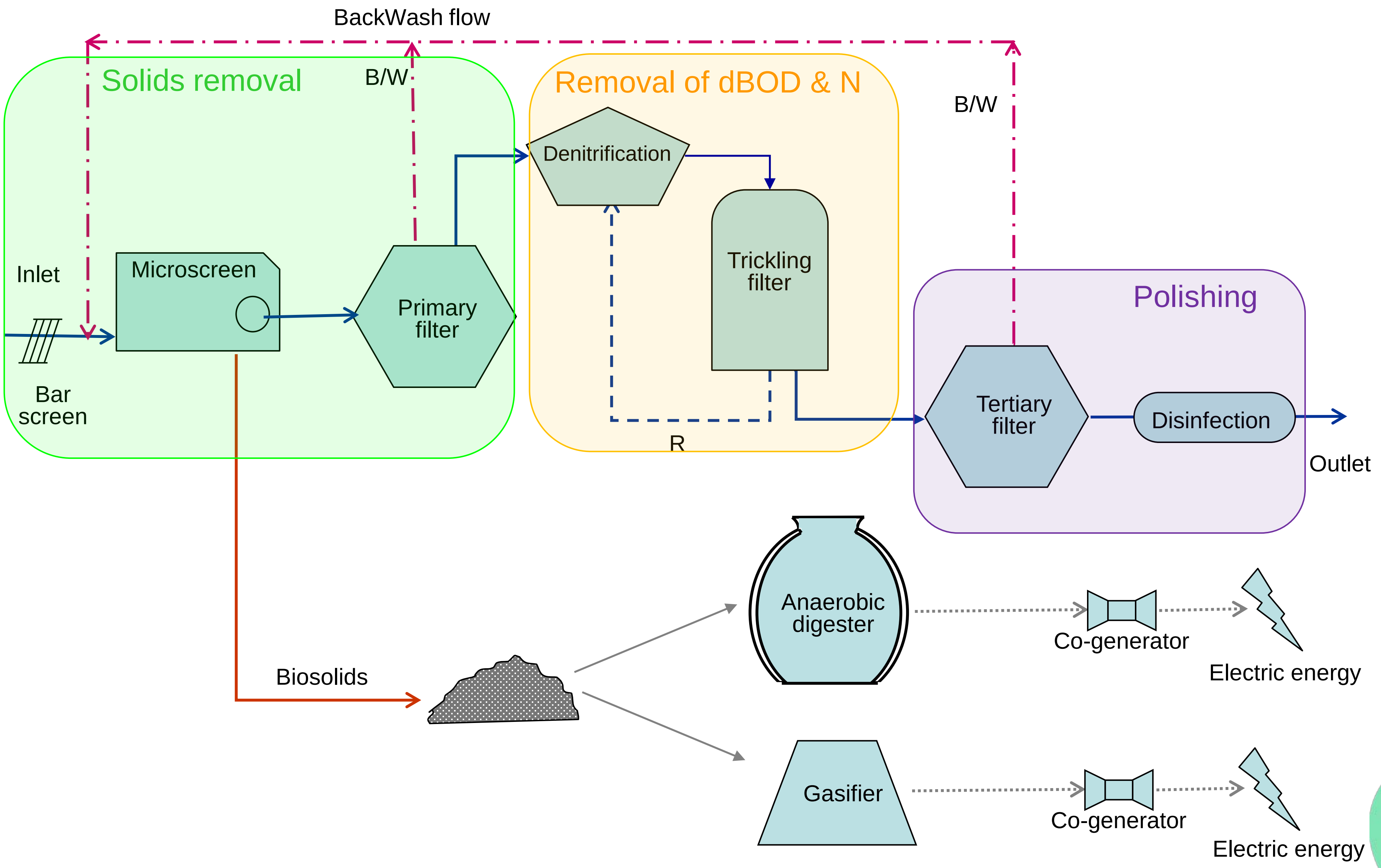
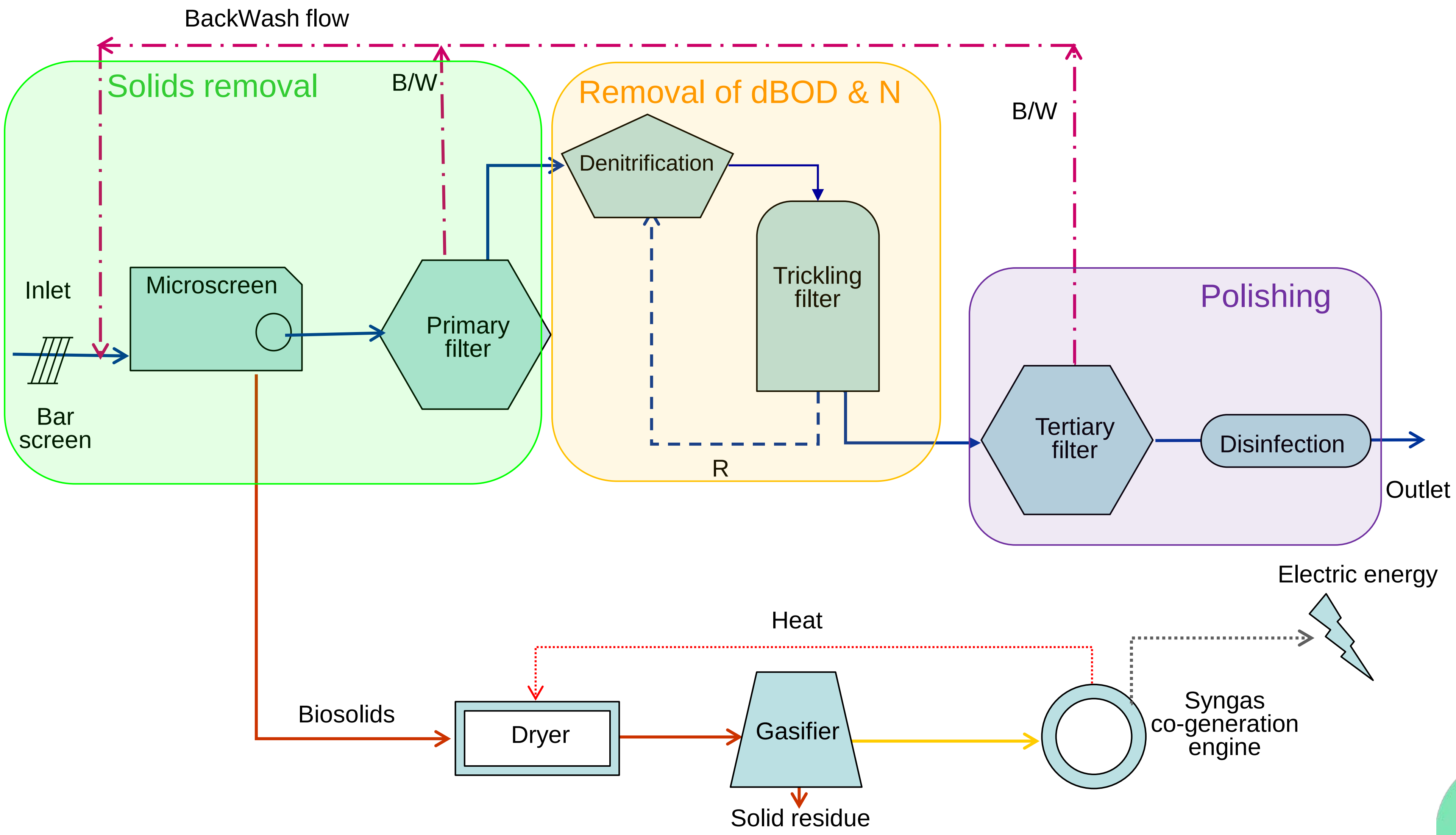
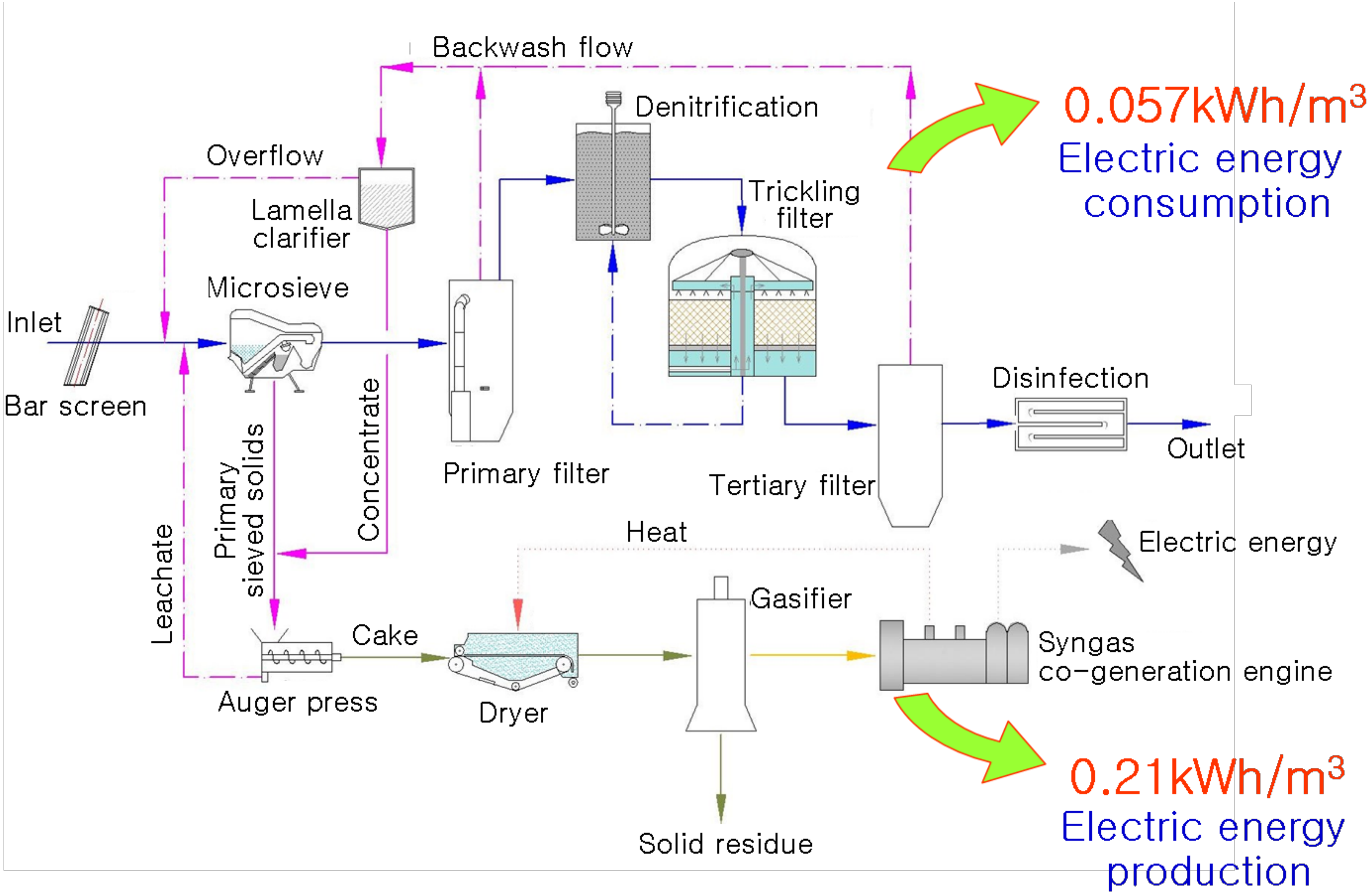
Upfront solids removal (USR) process



Upfront solids removal (USR) process with biosolids gasification



Electric energy production from primary sieved solids through gasification



biosolids 2energy

Project information

- **Title:** New concept for energy self-sustainable wastewater treatment process and biosolids management
- **Acronym:** LIFE B2E4sustainable-WWTP
- **Project duration:** 01/09/2017 – 31/12/2022
- **Total budget:** 1,993,855 €
- **EC co-funding:** 60% (1,162,004 €)
- **Website:** www.biosolids2energy.eu

Project co-funded by:

Life

GREEN FUND

- **Partners:**

Technical University of Crete

Δ.Ε.Υ.Α.Ρ. ΔΗΜΟΤΙΚΗ ΕΠΙΧΕΙΡΗΣΗ ΥΔΡΕΥΣΗΣ ΑΠΟΧΕΤΕΥΣΗΣ ΡΕΘΥΜΝΟΥ

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cetenma Centro Tecnológico de la Energía y del Medio Ambiente

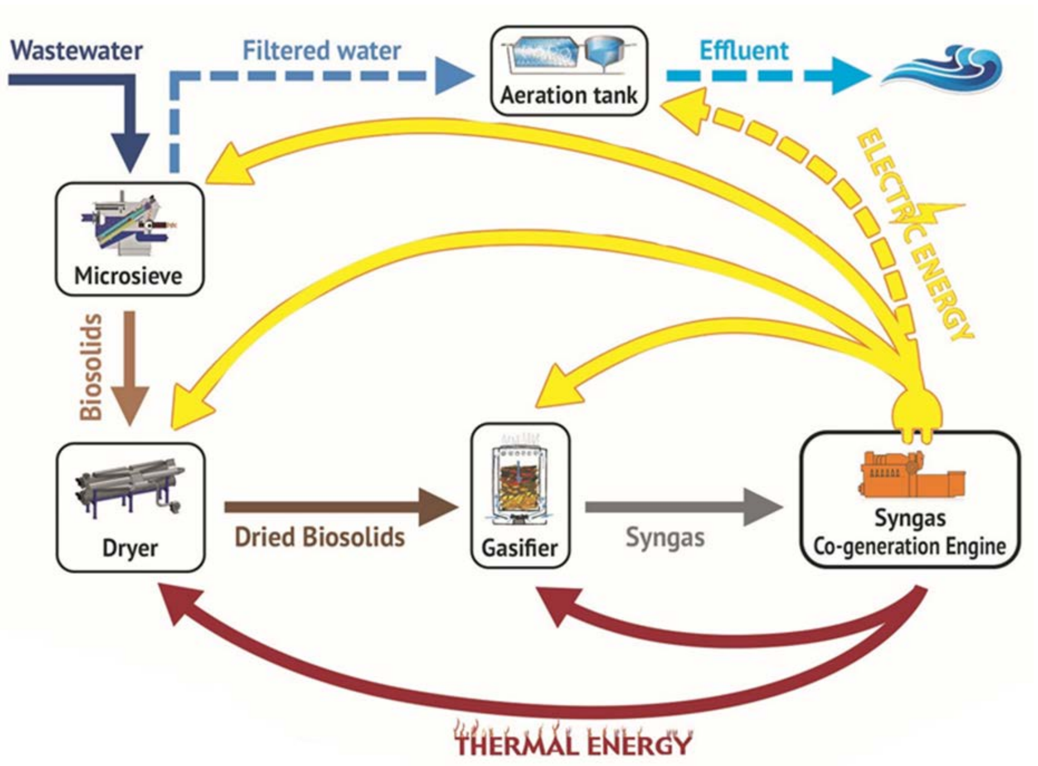
ENGINNOV CONSTRUCTION LTD

Coordinator

General description

OBJECTIVES

- Upgrade of overloaded (and thus, under-performing) activated sludge Wastewater Treatment Plants (WWTPs).
- Protection of aquatic environment against pollution caused by WWTPs effluent.
- Environmental management of biosolids.
- Energy production from biosolids.



PROJECT OUTLINE

- Microsieving → Removal of primary biosolids upfront of the aeration tank using a rotating belt filter.
- Drying → Moisture removal from biosolids.
- Gasification → Syngas production.
- Syngas combustion → Production of thermal and electric energy.

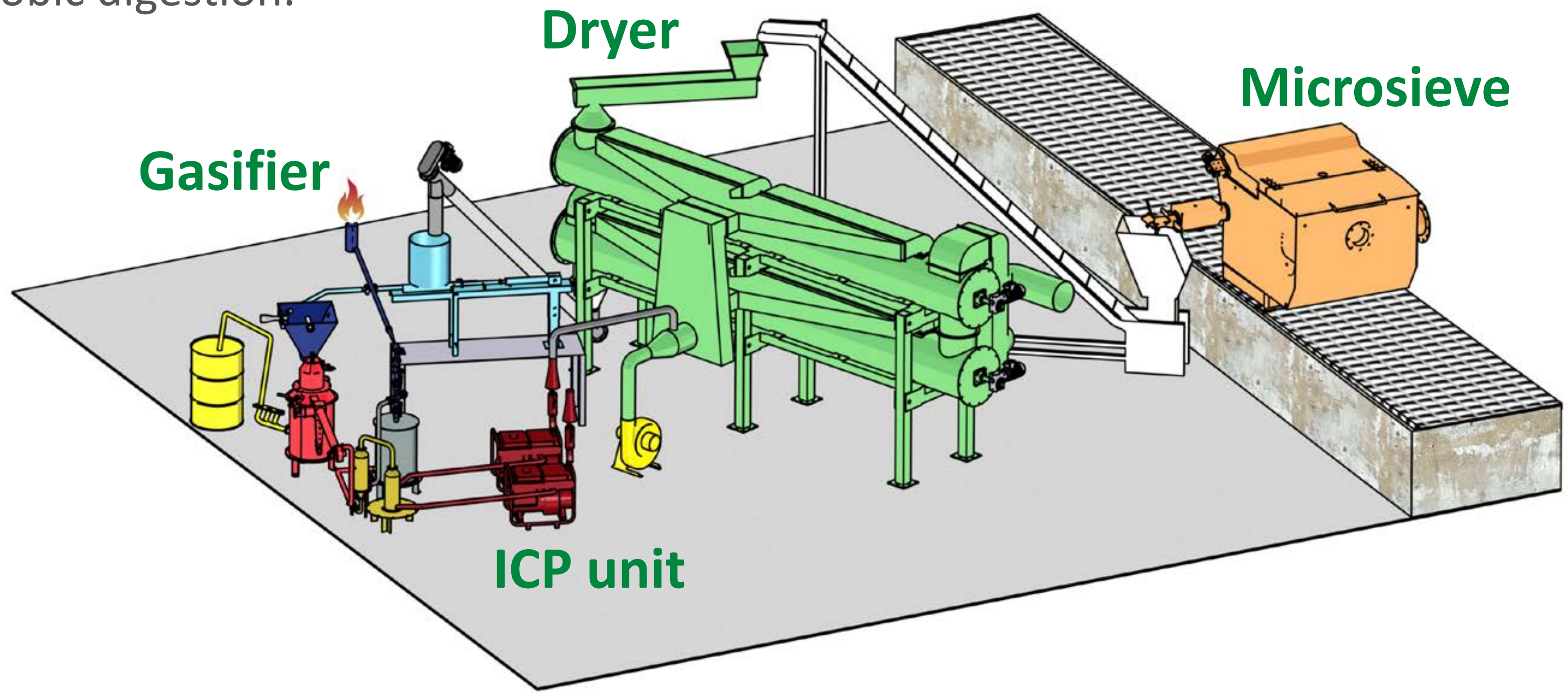
General description

FACTS

- Municipal wastewater contains 3-6 times the energy required for treatment.
- Biosolids produced through microsieving contain low moisture and high energy.
- Gasification has higher energy yield, compared to anaerobic digestion.

PROJECT FACTS

- Wastewater capacity: ~ 5,000 m^3/d
- Biosolids management: ~ ½ ton/d
- Biosolids Higher Heating Value: ~ 21.5 MJ/kg
- Syngas production: 1,800-2,400 Nm^3/d
- Target electric energy production: 30-50 kW



Location of the project pilot

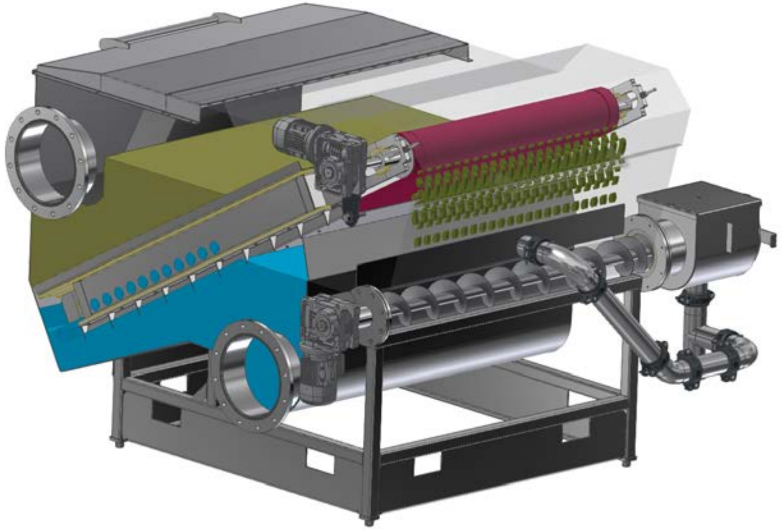
Municipal WWTP of Rethymno, Crete, Greece

- Population of about 35,000 inhabitants
- Daily wastewater flow between 10,000-15,000 m^3

Biosolids management

Biosolids removal by microsieving

- Fine mesh sieve produces biosolids with solid content up to **45%**, suitable to be used as gasifier feedstock.
- Requires **1/20** the area of an equivalent capacity primary clarifier.
- The biosolids have high **potential for gasification & production of syngas**.

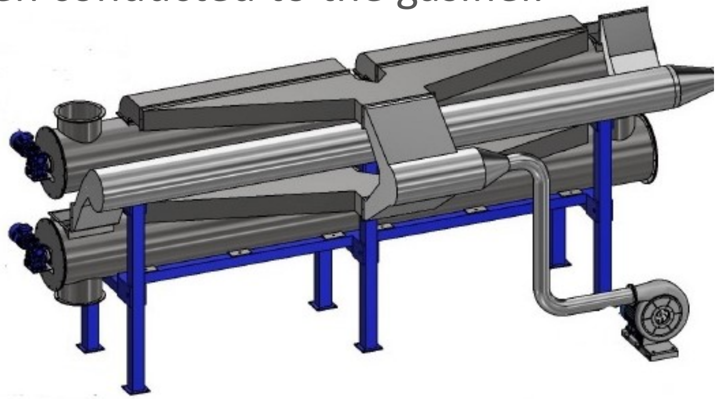


1st stage: Microsieving

Biosolids management

Stabilization & energy recovery from biosolids

- The dryer, bases its operation on the agitation of humid material in the flow of **hot air produced by the gasifier** as exhaust gases.
- Special conveying and simultaneous continuous **agitation augers**.
- Before the end of each module, humid air is sucked in from the **suction circuit.**
- In each module is introduced **hot and dry air** by the hot air distribution system.
- The suction circuit is discharged into a cyclone to catch **volatile and light particles**.
- The output of the second module that would be the final output of the treated material, is **mixed with the material captured by the cyclone**, and then conducted to the gasifier.



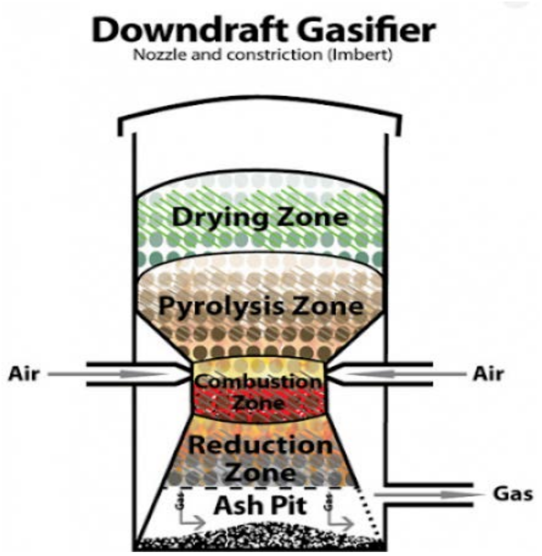
2nd stage: Drying

Biosolids management

Stabilization & energy recovery from biosolids

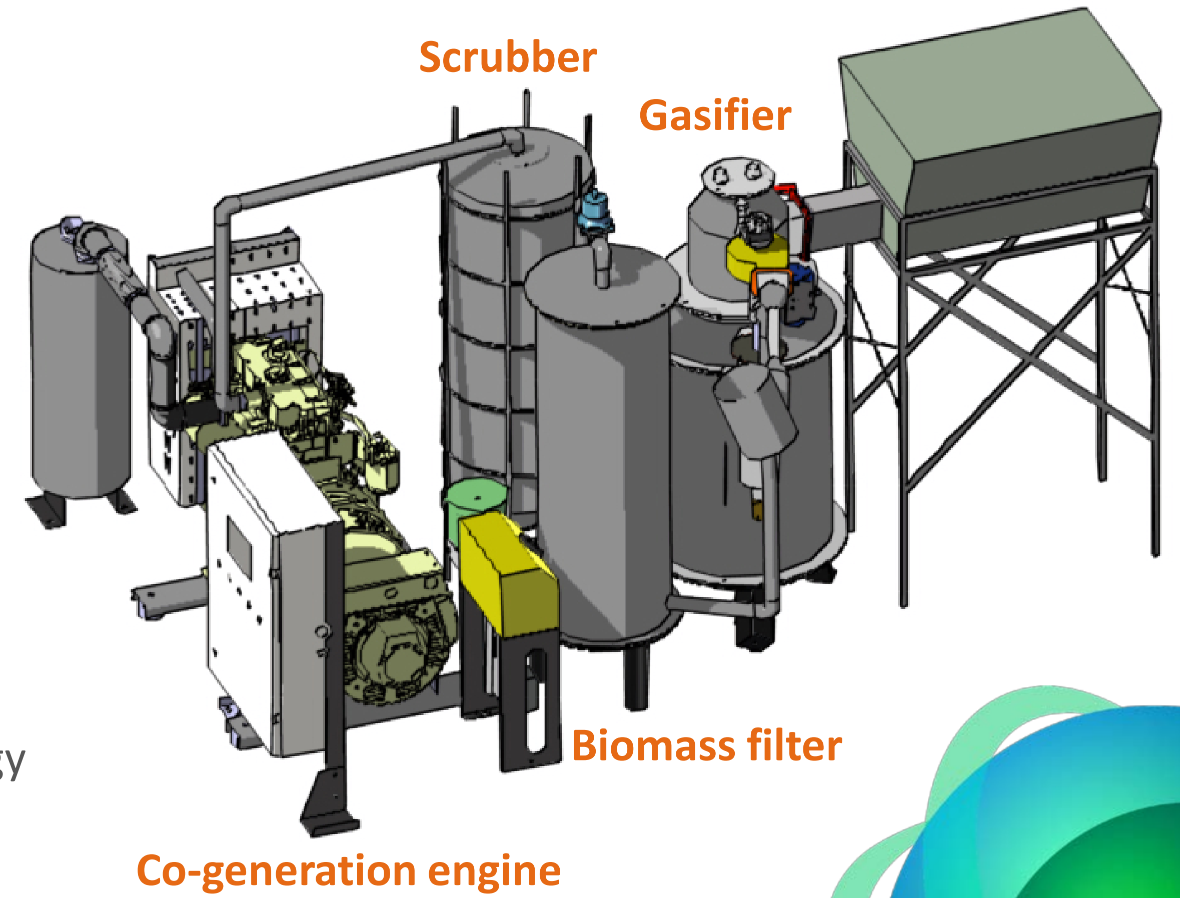
- **Syngas** (CO, H_2): fuel for the production of thermal & electric energy.
- **Thermal energy** will be recovered & used to partially dry the biosolids prior to gasification.
- Complete biosolids drying is not essential (optimum moisture content **10-15%**).

- **Gasification – Energy production system description:**
  - **Storage silo** for briquetted biosolids
  - **Downdraft gasifier** for syngas production



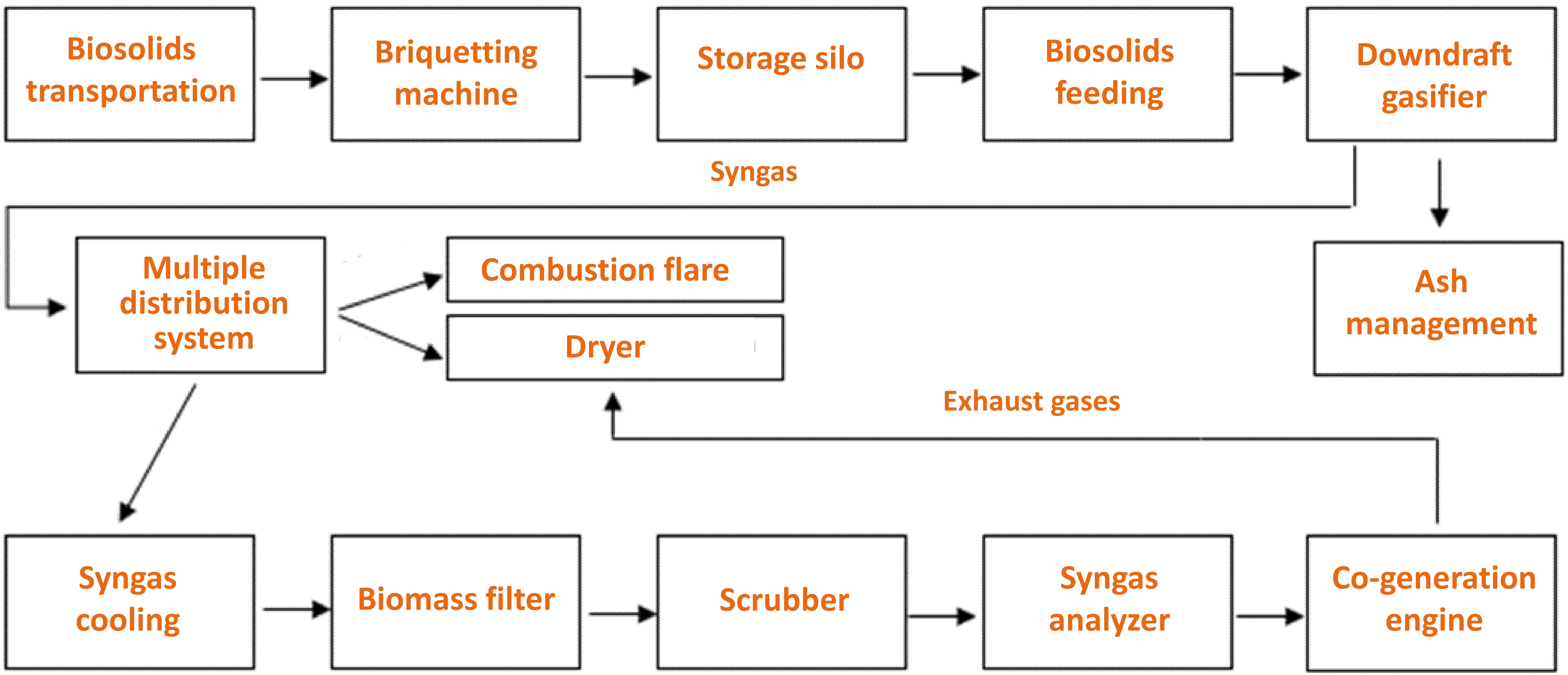
  - **Syngas cleaning and conditioning**
  - **Co-generation engine** for syngas combustion and energy production.

3rd stage: Gasification – Energy production



Biosolids management

Gasification – Energy production system description



Biosolids management

Syngas cleaning - conditioning

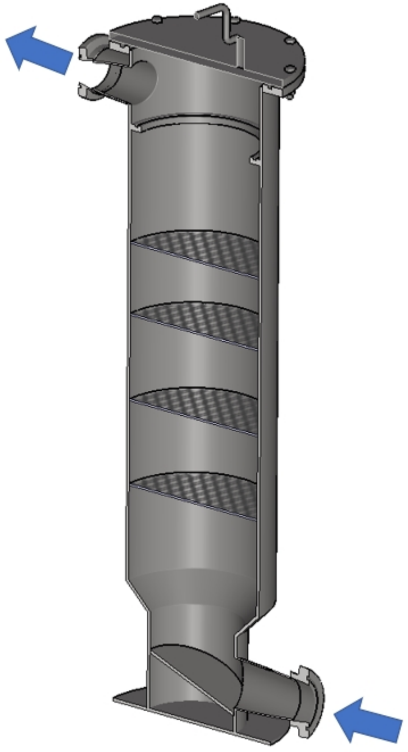
The main contaminants of the raw syngas are:

1. particulate matter
2. tar
3. sulfur
4. nitrogen
5. chlorine

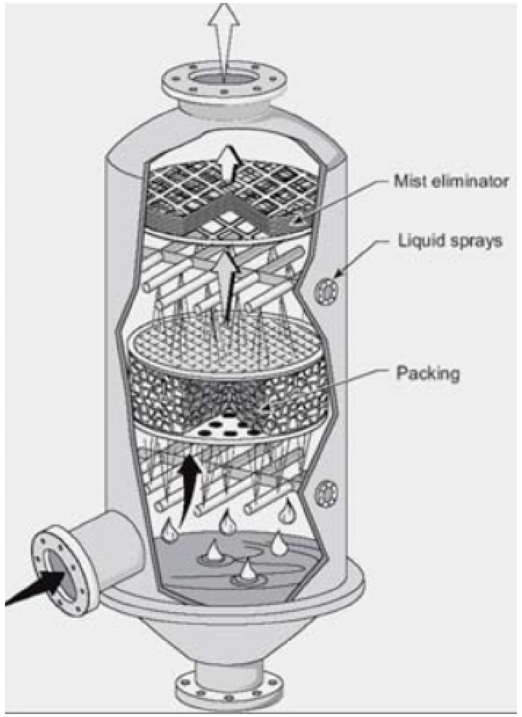
The proposed treatment for the syngas produced from the gasifier follows the “cold route” and it consists of the following parts in sequence:

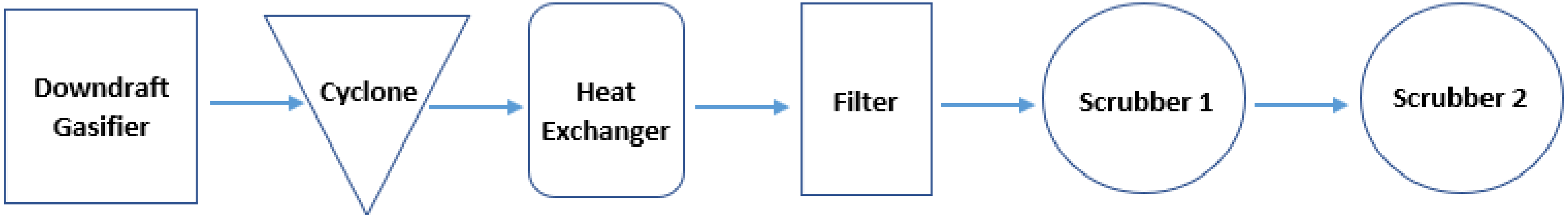
- **Cyclone** for the removal of particulate matter and tar.
- Straight tube **heat exchanger** for the cooling of syngas.
- **Granular filter** for the removal of particulate matter and tar.
- Caustic or limestone **scrubber** for the removal of sulfur and chlorine.
- Water **scrubber** for the removal of sulfur, ammonia and tar.

Biomass filter



Scrubber





Biosolids management
(laboratory analyzes)

Technical University of Crete

Mobile Environmental Lab

Design of Environmental Processes Lab

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Thermal energy balances

Table 1. Theoretical thermal energy demand for drying	Calculations	Comments
Biosolids produced from microsieve (kg/d)	920.0	
Biosolids produced from microsieve (kg/h)	38.3	
Moisture content (%)	70.0	Range: 60-70%
Dried biosolids (kg/d) *(0% moisture content)*	276.0	
Dried biosolids (kg/h) *(0% moisture content)*	11.5	
Moisture content at the inlet of gasifier (%)	10.0	Range: 10-15%
Dried biosolids (kg/h) *(10% moisture content)*	12.7	
Evaporated water (kg/h)	25.7	
Latent thermal energy demand for drying (MJ)	58.0	$\dot{Q}_l = m \cdot L$
Sensible thermal energy demand for drying (MJ)	12.8	$\dot{Q}_s = m \cdot C \cdot \Delta T$
Total thermal energy demand for drying (MJ)	70.8	$\dot{Q}_{total} = \dot{Q}_s + \dot{Q}_l$
Total thermal energy demand for drying (kcal)	16910.2	
Total thermal energy demand for drying (kW)	**19.7**	

Table 2. ENGINNOV dryer specifications	Calculations
Air supply (m^3)	95.8
Total thermal energy demand for drying (MJ)	105.4
Total thermal energy demand for drying (kcal)	25169.7
Total thermal energy demand for drying (kW)	**29.3**
Minimum temperature of air (^oC)	120.0

Thermal energy balances

Table 3. Thermal energy supply from TUC gasification system	Calculations	Comments
Higher Heating Value (HHV) of biosolids (MJ/kg)	21.5	
Energy content of biosolids (MJ/kg)	247.3	
Produced syngas (m^3/h) based on 1kg biomass: 2m^3 syngas	23.0	
Performance of gasifier	80%	Range: 70-80%
HHV of syngas (MJ/m^3)	8.6	
Energy content of syngas (MJ)	197.8	
Percentage of syngas to dryer	10%	
Energy from syngas to dryer (MJ)	19.8	
Energy from syngas to ICE (MJ)	178.0	
ICE performance (Electric energy)	20%	
ICE performance (Thermal energy)	50%	Range: 45-50%
ICE performance (Losses)	30%	Range: 30-35%
Electric energy from ICE (MJ)	35.6	
Thermal energy from ICE (MJ)	89.0	
Losses of ICE (MJ)	53.4	
Thermal energy from exhaust gases of ICE (MJ)	0.5	
Thermal energy from syngas cooling (MJ)	3.9	
Thermal energy from gasifier (MJ)	9.9	
Total thermal energy supply (MJ)	123.1	
Total thermal energy supply (kcal)	29401.4	
Total thermal energy supply (kW)	**34.2**	

Thermal energy balances

Table 4. Thermal energy balance	Calculations	Comments
Total **theoretical** thermal energy demand for drying (kW)	19.7	
Total thermal energy demand for drying from **ENGINNOV** (kW)	29.3	
Estimated losses of thermal energy transportation	20%	Range: 20-30%
Total thermal energy demand for drying from **ENGINNOV, including losses** (kW)	35.1	
Total thermal energy supply from **TUC** (kW)	34.2	
Net thermal energy (kW)	**-0.9**	

- The thermal energy balance is a function of several parameters some of which are not stable, such as:
  - the moisture content of biosolids produced from microsieve (60-70%)
  - the moisture content at the inlet of the gasifier (10-15%)
  - the performance of gasifier (70-80%)
  - the ICE performance (thermal energy 45-50%, losses 30-35%)
  - the estimated losses of thermal energy transportation (20-30%).
- To maximize the thermal energy recovery for the system, we have planned to place the gasifier and the ICE in insulated boxes with hot air recovery.
- The above tables show that the thermal energy is marginally sufficient for the system performance.
- We will focus on increasing the system performance (by insulation, reduced moisture content of biosolids, etc.), as possible, so to have a thermal energy positive process.

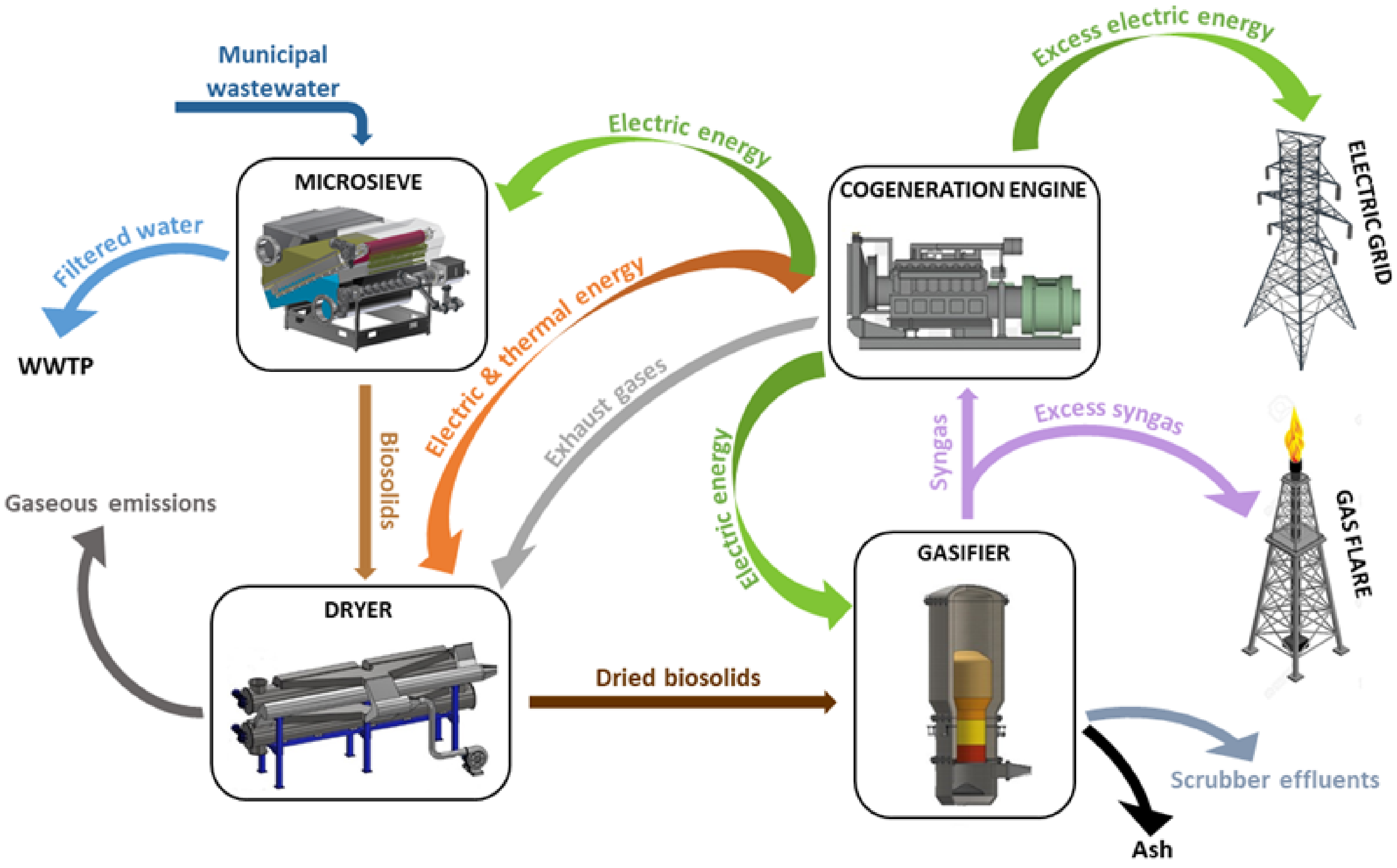
Environmental Impact Assessment (EIA)

- The construction and operation of such size demonstration plant requires the **issuing of Environmental Terms** → an EIA has been carried out.
- To the best of our knowledge, this is the first EIA for **exclusive gasification of biosolids** → the composition of such study posed a number of challenges.
- The project is characterized by **high innovation and originality** → no project with similar characteristics has been executed.
- The EIA follows the standard structure:
  - detailed **description** of the process and of the surrounding environment
  - **assessment**
  - **evaluation**
  - recommendations for the **mitigation** of environmental impacts
  - environmental **management** and **monitoring**.

Environmental Impact Assessment (EIA)

- Some special issues due to the magnitude, location and nature of the project, had to be assessed:
  - the lack of full characterization of the expected **by-products** (solid residue, liquid and gaseous emissions)
  - the **high temperatures** involved (above 1100 °C at the core of the gasifier)
  - the fact that **lethal intermediate products** will be formed (such as CO and H_2S)
  - the need for the continuous use of a **lighting flare** (for the combustion of excess syngas)
  - the potential **odor emissions** (from the biosolids drying system)
  - the fact that Rethymno is a city with very developed **tourism industry**
  - the location of the WWTP is near a **residential area.**
- The **Greek legislation** (Common Ministerial Decision No 2471/2016), in an effort to promote innovation, has enacted a special favorable procedure for issuing environmental terms, for research projects executed in the premises of existing industrial facilities, such as WWTPs.
- A special **less bureaucratic procedure** (compared to the usual one), has been followed.
- The said procedure required the submission of a full **EIA study.**

EIA – Inputs & Outputs



Mass and energy flows of the pilot plant

- The **input** to the demo plant is municipal wastewater (along with small quantities of industrial wastewater).

- The main **outputs** are:
  1) scrubber effluents from the gasifier
  2) solid residue (ash)
  3) exhaust gases from the ICE along with the evaporated water from the dryer.

EIA – environmental impacts & mitigation measures

- The demo plant will have an **overall positive environmental footprint**.
- The process will **enhance the performance of the WWTP**, due to the removal of a large fraction of SS and BOD from the wastewater, prior to the aeration tank.
  - About **30-50% of SS** and **20-30% of BOD** will be removed by the microsieve
- **Net electric energy will be produced**, so there will be a reduction of the energy requirements of the whole WWTP of Rethymno.
- The production of municipal sludge (a nuisance substance) will be **reduced**.
- A net reduction of about **140 kgCO_2/day** is expected.

EIA – environmental impacts & mitigation measures

- As for any industrial system, negative impacts are primarily related to the production of various by-products.
- In the studied case, the main by-products are:

By - product	Management
Scrubber effluents from the syngas cleaning process	They have been considered as industrial wastewater, and may be treated in the existing WWTP, along with the incoming wastewater.
Solid residue (ash) from gasifier	It will be analyzed and o if it will be classified as hazardous waste, it will be managed accordingly o if it will not be classified as hazardous waste, it may be disposed along with the secondary sludge.
Evaporated water from the dryer along with the exhaust gases from the ICE	These may generate unpleasant odors. In such case, an activated carbon filter will be installed to absorb potential odors.

- A tight inspection and maintenance program will be followed, for the early identification of leaks or failures, which will be instantly addressed.

Thank you for your attention!

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Technical University of Crete

Design of Environmental Processes Lab

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ΠΡΑΣΙΝΟ ΤΑΜΕΙΟ

1st International Environmental Engineering Conference

7th -10th September 2022, Rethymno, Crete, Greece

Info: www.biosolids2energy.eu/conference.html