

**ENERGY ACCESS AND GREEN
TRANSITION COLLABORATIVELY
DEMONSTRATED IN URBAN AND
RURAL AREAS IN AFRICA**

DELIVERABLE 5.1.

**Biogas Plant
Specifications**

(Component List and Ash Report)



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Deliverable Report

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Nature of the Deliverable		
R	Document, report (excluding the periodic and final reports)	R
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, etc.	
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Dissemination Level		
PU	Public, fully open, e.g. web	
CO	Confidential, restricted under conditions set out in Model Grant Agreement	CO
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

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1. PROJECT SUMMARY

Gathering 11 African-based partners and 17 Europeans with offices or subsidiaries in Africa, the ENERGICA project is ambitiously fostering the collaboration between partners of both continents on energy access and sustainable energy development. The main objective of the ENERGICA project is to demonstrate the efficient implementation of renewable energy technologies to match local contexts' needs. Three different demonstration sites will rely upon local Energy Transition Boards which will manage community-scale Integrated Community Energy Systems (ICESs). Based on these methodologies and respective innovative technologies, ENERGICA will demonstrate positive social, environmental, technical and economic impacts from the high energy-efficiency and low carbon emission RETs. Specifically, the project will develop innovative nano grids in rural Madagascar; low tech-efficient biogas systems in peri-urban Sierra Leone; and solar-powered e-mobility solutions in urban Kenya.

2. OBJECTIVE AND EXECUTIVE SUMMARY

The central theme of the WP5 is the development of low-tech and frugal technologies in both the biogas and water purification sectors. WP5 contemplates the design/redesign of quality products, services and systems making them cheaper and more basic but also adapted to local circumstances and cultures.

The first task of this Work Package (Task 5.1) consists of the development and testing of a low-tech innovative biogas digester. The Waste Transformers (TWT) is a private company that provides communities and companies with a turn-key product which uses small scale anaerobic digestion to convert organic waste into energy on-site at the source of the waste generation where the energy can be utilized continuously. Their technology converts what used to be waste, into biogas. The biogas can be used to heat water or create electricity. In addition, the technology provides a source of organic fertilizer ready for spraying.

An adapted version of the waste transformers modular turn-key community anaerobic digester will be designed in this task. The design will be tailored to the local technical and regulatory constraints and opportunities as found in WP1, WP2 and WP3 as well as to the need in lower CAPEX and OPEX and in increased yield. **Thus, three consecutive steps will be organised.**

Subtask 5.1.1: Setting-up of the local manufacturing of plant components: In this subtask, TWT together with local partners FWT and UAM will aim to source local fabricators and equipment manufacturers to build key components of the system in accordance with specifications supplied by TWT. A list of components previously sourced in Europe that can be replaced by components manufactured to specifications at lower cost in Africa will lay the groundwork for saving costs in equipment and component as well as providing an integrating action with the local economy.

Subtask 5.1.2: Optimising day to day operations: RISE together with TWT will reverse engineer the standard TWT-plant to simplify the design and control systems as much as possible and provide a balance between simplicity and production optimisation that is tailored specifically to emerging markets. One important part of this subtask, which ties back to subtask 5.1.1 is the simplification of the physical design resulting in less components and less functions to make up the complete plant. With a simplified design in hand, easy to understand process start-up manuals and operations manuals based on a “less-is-more” philosophy will be produced (D5.2) for use in local capacity building of educational capacity and integration into local training classes and programs (set up in T3.2), but also as day-to-day operations instructions for local plant operators.

Subtask 5.1.3: Testing and commissioning: In this subtask, RISE will conduct trials using its continuous laboratory reactors to benchmark the impact and test different types of locally available ashes. If successful in the laboratory, an ash trial will be added to the demonstration part of the project to showcase the strategy at full operational scale. Once the testbeds trials are completed, commissioning of the plants will be monitored by RISE and the biogas digesters provided for D5.5 alongside the agreed action plans from TWT and FWT.

Given this background, the objective of this document is to present the first Deliverable related to Task 5.1 which is a report providing the (re) designed Biogas plant specifications.

This report will only focus on providing a preliminary list of components for the modular turn-key biogas plant, previously sourced in Europe that can be replaced by locally manufactured components. In addition, it will also include results of the lab-scale ash trial.

3. Key Components of the biogas plant

The following components are identified in the preliminary design of the biogas plant as having a large impact on the system price:

- a) *CHP (Combined heat and power)*
- b) *The control system*
- c) *Containers and tank containers*
- d) *Pasteurization tank*
- e) *Flare system*



There are smaller components like valves, instruments and actuators that have a high discount possibility, but only have limited impact due to the relatively low cost (but could have high impact when there is a volume build). General information on these materials is included from paragraph 8 and 9.

A blue and silver industrial machine, likely a CO2 capture unit, with the brand name 'POWERBOX' prominently displayed. The machine features three circular icons: a CO2 molecule, a globe, and a power plug. Below these icons, the words 'CLEAN' and 'ENERGY' are visible. A yellow warning triangle is located on the lower front panel. The machine is situated in an industrial setting with other equipment visible in the background.

Figure 2. Combined Heat & Power Unit (CHP)

The biogas of the installation is converted to electrical and thermal energy by the CHP. The Waste Transformers have adapted and tested the CHP's from EC Power in Denmark. The following types are applicable:

<i>EC Power XGRi6 + IQ10 + Q20 + Modbus gateway</i>
<i>EC Power XGRi9 + IQ10 + Q20 + Modbus gateway</i>
<i>EC Power XGRi15 + IQ15 + Q80 + Modbus gateway</i>
<i>EC Power XGRi15 + IQ20 + Q80 + Modbus gateway</i>

b) The control system

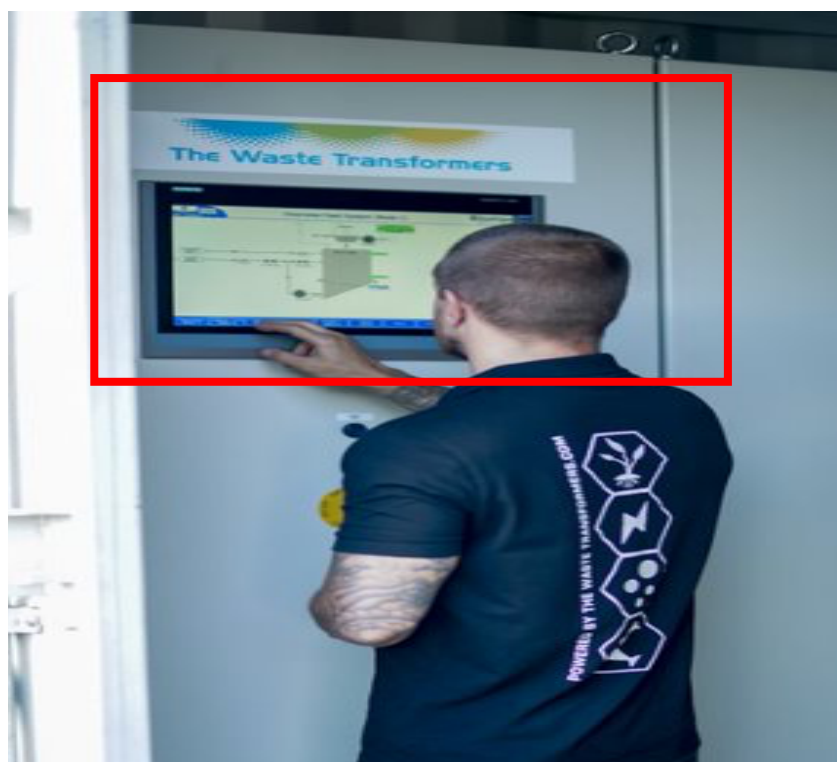


Figure 3. Control System

The installation is controlled by a central control cabinet and distributed control units per module of the installation. The components used in the control cabinet are, as much as possible, sourced from Siemens. This will allow us to locally service the systems all over Africa.

The following components are currently applicable.

<i>Main control cabinet</i>	<i>1 – 3 required (depending on installation size)</i>
<i>Digester remote cabinet</i>	<i>1-5 required based in number of digesters</i>
<i>Feed unit cabinet</i>	<i>1 when feed unit is required</i>

c) Containers



Figure 4. Tank Containers

The installation will consist of 1 - 3 x 20' freight container and 1 to 5 x 20' isolated (24.000 L) tank containers (depending on size). The tank containers may be new or used. The containers require close cooperation with The Waste Transformer team with regard to the modification of the containers/tanks, inspection and testing before delivery (this is also because the quality of the used containers varies substantially).

c.1.- ISO freight container for control containers

Type of containers	: 20 ft series 1CC Dry Storage Cargo/Shipping container
Configuration	: 2 doors at one short side
Materials	: Corten type steels
Design standard	: ISO 668:2013 & CSC Rules
Corner fittings	: ISO 1161:2016
Testing of containers	: ISO 1496-1:2013
Container coding	: ISO 6345:1995
Certification	: CSC plated/certified by DNVGL or LR (valid for more than 2 years)

Remarks

1. Design drawings/documents need to be available (structural calculations)
2. Original design appraisal document from notified body needs to be available
3. If any repairs, executed with "corten" type steels (with supporting documentation)
4. Class A containers. If class A, inspection required.

c.2.-ISO tank container for digesters

Type of containers	: IMO-1, 22T0, 22T1, 22T3 Shipping tank container
Tank configuration	: Isolated 24000 L stainless steel tanks
Fittings tank	: All fittings and manway from Fort Vale
Tank configuration	: Bottom valve and steam connection on same short side Manway and Pressure Safety Valve in the top middle of container

	2 Additional flanges near manway opening
Materials frame	: Corten type steels
Tank materials	: Grade 316L/UNS S31600/1.4404/X5CrNiMo 17-12-2
Fitting & valves	: Grade 316L/UNS S31600/1.4404/X5CrNiMo 17-12-2
Design standard	: ISO 668:2013 & CSC Rules
Corner fittings	: ISO 1161:2016
Testing of containers	: ISO 1496-1:2013
Container coding	: ISO 6345:1995
Certification	: CSC plated/certified by DNVGL or LR (valid for more than 2 years)

Remarks

1. Design drawings/documents need to be available (structural calculations)
2. Original design appraisal document from notified body needs to be available
3. New or used tank containers
4. If any repairs to the frame, executed with “corten” type steels (with supporting documentation)
5. If any repairs to the tank, executed with Grade 316L type steel (with supporting documentation)
6. Delivered with cleaning and hydrostatic/leak test certificate
7. Repairs to insulation require inspection
8. Should tank containers be adapted to our specification locally (i.e. not shipped), they do not require CSC certification

d) Pasteurization tank



Figure 5. Pasteurization Tank

The digestate exported from the installation needs to be pasteurized. The installation is equipped with an insulated stainless-steel tank, fitted with a heating spiral. Based on the number of digesters there are two sizes of pasteurization tanks:

Pasteurization tank 1000L	1 required per installation
Pasteurization tank 1700L	1 required per installation

e) Flare system



Figure 6. Flare System (top right)

The flare system burns the biogas in the situation of overpressure or when the system needs to be depressurized. The system is an autonomous safety system sized for the Waste Transformers systems.

Microflare 25-19	1 required per installation
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f) Piping & Valves

The piping of the installation consists of galvanized, stainless steel and PVC lines. The steel type lines are clamp type components. These materials are currently procured via the distributors in the Netherlands.

The PVC materials are combined with all valves and actuators of the installation and are procured in the Netherlands. The components were selected in such a way that we have the least number of different components. Limiting the number of spare parts.

g) Electrical & Instrumentation

The majority of the instrumentation is supplied in the Netherlands.

The electrical materials (such as electrical wires, cable trays, switch gears and the heating equipment like the heat exchanger and the expansion vessel) are currently procured from the Netherlands.

4. Local sourcing analysis

Below a table analysing the 5 key components and the groups of other components of the biogas plant with the individual percentage of cost contribution to the full plant and the general risk evaluation at the local availability.

Component	Cost fraction	Availability+Impact+Risk
CHP	13%	H
Control systems	8%	H
Containers (control and tank)	18%	L
Pasteurization tank	6%	H
Flare system	4%	H

Pumps	4%	H
Other equipment (including dewatering screw and frame)	4%	M
Electrical materials	2%	H
Instrumentation	7%	H
Piping	3%	M
Valves	8%	H
Fabrication	21%	M

H: high, M: medium, L: low

The biggest, low risk, opportunity for local production lies in the procurement of tank containers locally. One installation can hold as many as 5 tank containers, this could provide a new source of income and labour opportunities locally in the green economy. A second low risk option is to secure the frame that holds the dewatering screw locally. Sourcing additional items would mean that it would be extremely difficult to conduct an extensive Factory Acceptance Test (FAT) which would prove a wider risk to the success of the systems.

Criteria for assessing local tank container production capacity will include:

- Local competence with experience in Tank adaptations (for example from the transport sector)
- Local ability to source sufficient quantities and quality of tanks
- Ability to clean sourced tanks
- Ability to deliver with cleaning and hydrostatic/leak test certificate
- Ability to make adaptations to specification to the stainless steel internal tank executed with Grade 316L type steel (with supporting documentation)
- Ability to make adaptations to the stainless steel flanges on the top of the container
- Ability to pressure test the stainless internal tank after welding
- Ability to provide supporting documentation over all changes made
- Should additional sea travel be required, ability to re-certify with new CSC certificates
- Access to own quality management system
- Preferably ISO certified
- Able to work with independent quality control

The frames for the De-watering screw could be built by a local welding company.

In addition, some spare parts such as some piping, hosing, wiring and eventual extra pumps, could also be sourced locally.

5. Uses of Ash in the Biogas Process

Anaerobic digestion is the partial microbial decomposition of carbohydrates, protein and fat in several steps to methane and carbon dioxide (a gaseous mixture often called biogas when produced from biogenic organic residues). Each degradation step (hydrolysis, acidogenesis, acetogenesis and methanogenesis) is governed by its own set of biochemistry and optimal environmental conditions. Despite this, the whole process, including all sub-steps is most often run in a common complete-mix reactor. Sometimes, the hydrolysis can be handled as a separate step in its own reactor, but most

commonly the best total production economics are reached when achieving balanced conditions for all process steps in the same reactor. One common component to all four degradation steps is enzymatic reactions, which are in turn dependant on the availability of trace elements, or micronutrients, as they are often termed when discussing anaerobic digestion for biogas production. In practical application, the carbohydrates, protein and fat are supplied to a biogas production process in the form of complex organic residues, such as manure, food waste, food processing residues and crop residues (collectively called substrates). Different substrates inherently contain varying concentrations of micronutrients. Animal manure, and in particular dairy manure, naturally contains an abundance of the required micronutrients. Other substrates, such as food waste have much lower concentrations and are therefore often co-digested together with animal manure. However, the biogas production process envisioned in WP5 of the Energica project is based on food-waste as the only available substrate (no domestic dairy industry in Sierra Leone and no other manure of appropriate quality for continuous feeding). The need for external supply of micronutrients for high process stability and optimal biogas production when digesting food waste as a single substrate is a well-established (and easily replicated) scientific fact. The actual specific need of individual micronutrients is very complex and beyond the scope of this project, but in general single substrate food waste digestion will be low on substances such as iron, cobalt, molybdenum, manganese and selenium.

In subtask 5.1.3 empirical trials have been conducted to assess whether the needed additional micronutrients can be supplied by adding biomass ash (waste resource) instead of tailored chemical additives (purchased chemical products). Providing for this required external source of micronutrients through sophisticated tailored chemical additives is assumed to be a challenge in a western African context. At the same time, process stability and high biogas production are important factors that contribute greatly to achieving ease of operation and economic viability. This leads to our attempt to challenge state-of-art and see if we can provide these micronutrients by some other means, that may be easier to source locally. Biomass ash naturally contains many of the micronutrients that are needed and can hopefully be found locally in sufficient amounts.

A) Materials and method

The trials were conducted at RISE research facilities in Uppsala Sweden. Standard continuously fed 10 L complete mix reactor systems were used, which over the years have proven to represent real-life full-scale processes very well (figure 1).



Figure 7. Continuously fed 10 L laboratory scale complete mix anaerobic reactors in the RISE biogas laboratory.

In total 5 reactors have been used. After the initial start-up phase, the daily routine and methods for running the trials can be summarized as follows:

- we remove digestate (the finished slurry after digestion) from the reactors daily to make room for an equivalent volume of new feed
- daily feeding with a mixture of substrate (food waste) and dilution water (and where applicable, micronutrients in the form of chemical additives or biomass ash)
- produced gas volume is measured daily using a Ritter gasometer
- measurement of the gas composition:
 - Carbon dioxide (CO₂): saccharometer (daily)
 - Methane (CH₄), CO₂, Hydrogen Sulphide (H₂S) and Oxygen (O₂): handheld automatic gas analyzer Biogas 5000 (3 times/week)
 - CH₄: Gas Chromatography (GC, once a week)
- digestate analysis:
 - Alkalinity, Volatile Fatty Acids (VFA) and the ratio of Free Organic Acids to Total Alkaline Carbonate (FOS/TAC): titration (2-3 times/week).
 - VFA: High Performance Liquid Chromatography (HPLC, once a week)
 - Dry Matter (DM), Volatile Substance (VS): gravimetric (every two weeks)
 - pH: pH meter (daily)

All five reactors were run at 37 °C and the substrate was source-separated mixed food waste from a large restaurant for all parallel trials. The five parallel trials were named R1-R5 and set up in accordance with table 1.

Reactor	Description
R1	Blank (no additives)
R2	Control (Kemira-BDP)
R3	Ash 1 (1% of wet weight)
R4	Ash 2 (1% of wet weight)
R5	Ash 3 (1% of wet weight)

Table 1. Parallel trial set-up. R1 is receiving no additional external micronutrients. In R2 the external micronutrients were supplied via a tailored chemical product called BDP from the company Kemira. R3-R5 received micronutrients in the form of ash from three different biomass combustion plants.

Preceding the continuous trials, the ashes and digestate had been analyzed and screened for suitability and required dosing. This preparatory work will be presented scientifically as part of other deliveries in the Energica project, but the conclusion was that a suitable starting rate for dosing ash would be 1 % of the total ingoing feed based on wet weight.

From the screening trials, it was also determined that reasonable target values for the parameters organic loading rate (OLR) and hydraulic retention time (HRT) would be 3 g VS/m³, per day and 50 days respectively. For the substrate and biogas production system at hand, this represents a good and safe baseload that would not require advanced knowledge of biological production processes and continuous monitoring on the part of the operator. OLR is the “throttle” of the biogas production system, indicating a standardized measure of how much degradable organic matter (VS) is loaded per unit volume of reactor space during a specified time-period. HRT is the average time that a unit volume of substrate remains in the reactor, i.e. a measure of the time that the microbes have available to get at the organic matter. An anaerobic digestion system that can remain stable at high OLR and low HRT will be more economically efficient than a system that has to be run at low OLR and high HRT.

B) Results

The parallel trials were run for a total of 27 weeks including inoculation and start-up phase. This was enough time for an efficient start-up, process stabilization and achievement of theoretically expected yields at targeted organic loading rate. It was also enough time to note any dynamic and cumulative process problems and toxic/inhibitory effects.

In this report we will exemplify process stability by two of the most important parameters to follow when assessing a biogas production process – namely concentration of volatile fatty acids (VFA) and alkalinity measured as mg CaCO₃/L. Alkalinity can simplistically be explained as the ability for a process to deal with shifts in presence of acids without having it affect the pH. In short, it is a measurement of process robustness. VFA measures the presence of short chain fatty acids. These are, as the name suggests, acidic and will cause the pH to sink if there is too little alkalinity to counteract the effect. At the same time, VFA’s are a crucial biochemical precursor to methane. An appropriate balance between VFA and alkalinity is therefore one of the most important keys to a stable process. To simplify practical monitoring, the concentration of VFA and level of alkalinity is bundled into a relative parameter called FOS/TAC, which is essentially VFA divided by partial alkalinity. In figures 2 and 3 the development of these process stability indicators during the parallel trials is presented.

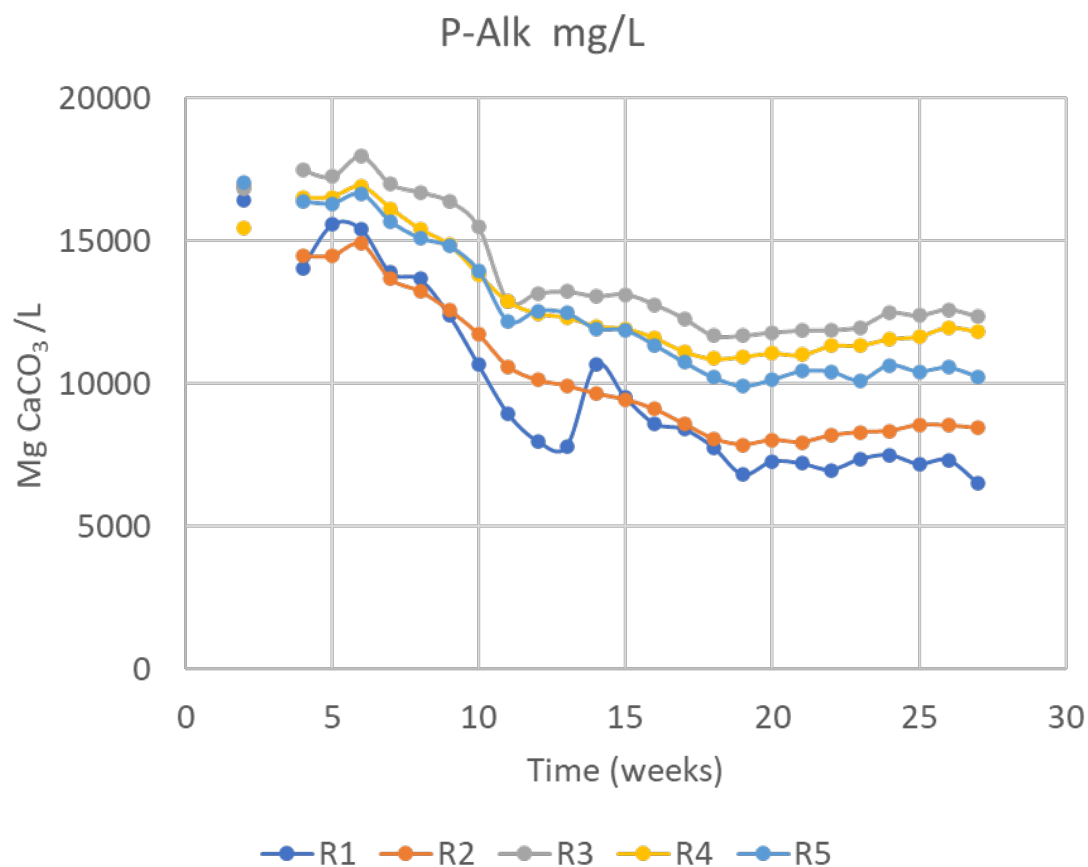


Figure 8 . Partial alkalinity of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5).

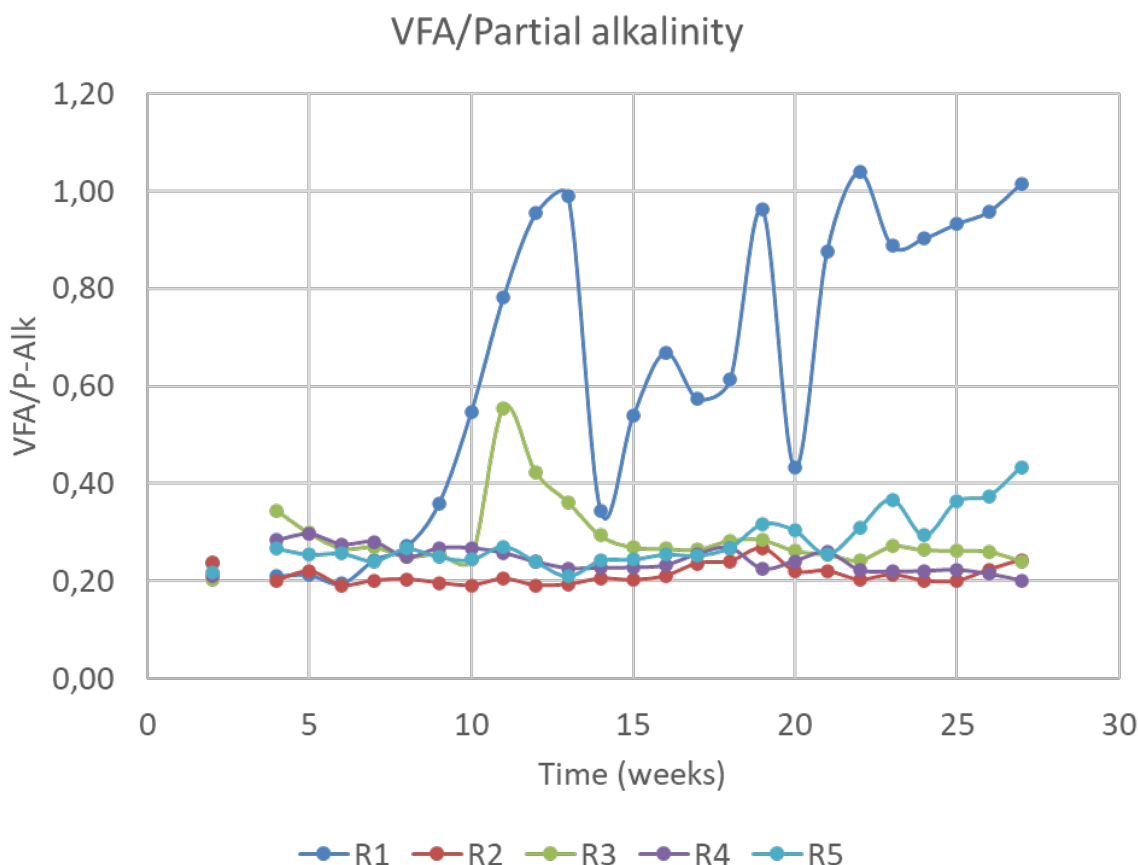


Figure 9. FOS/TAC (partial alkalinity divided by VFA concentration) of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5).

As a rule of thumb, stable biogas production processes based on food waste have values of partial alkalinity of $> 10\,000\text{ mg CaCO}_3/\text{L}$ and FOS/TAC values $< 0,3$ (dimensionless fraction). Led by these rules of thumb it is easy to see from the graphs (figures 2 and 3) that it is hard to achieve stability in biogas production processes based on food waste as a single substrate without the addition of external micronutrients. The control reactor (R1), that is not receiving any additional micronutrients quickly loses alkalinity and accumulates VFA leading to instability and a high maintenance process. R2, which is the process with the tailored chemical additive is also stabilized at slightly low alkalinity. At the same time, the added micronutrients allow the process to quickly convert any VFA to methane, preventing accumulating and, thus maintaining R2 at very low FOS/TAC values. The biomass ash (R3-5) provides enough alkalinity to the system and ensures quicker conversion of VFAs to methane than the control reactor. For R3 and R4 the composition of the biomass ash and the dosing is enough to ensure stable processes. The biomass ash added to the R5 reactor, on the other hand, is not good enough to maintain a stable process long term, which you can see by the alkalinity tipping downwards and the FOS/TAC turning upwards at the end of the trial period.

Based on alkalinity and FOS/TAC as well as some other parameters the pressure on the processes can gradually be turned up towards the target values for OLR and HRT. In these trials we have tried to push the processes towards full production potential quickly. This provides the added value of assessing practically achievable start-up time for the type of biogas production processes that are going to be demonstrated at full scale within the Energica project. The dynamic result of the process governance can be seen in figures 4 and 5.

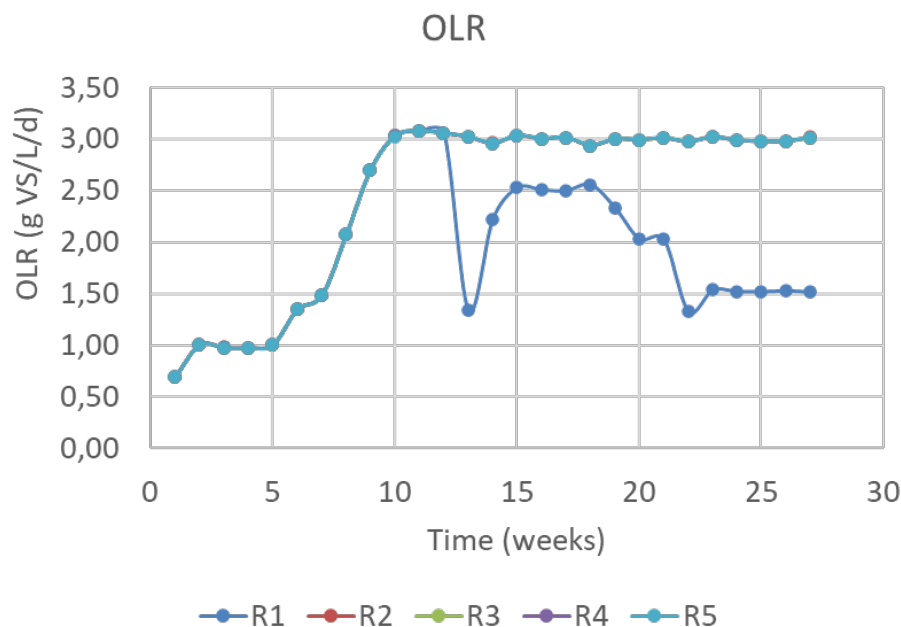


Figure 10. OLR (organic loading rate) over time of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5). The lines of R2-5 are hidden behind each other.

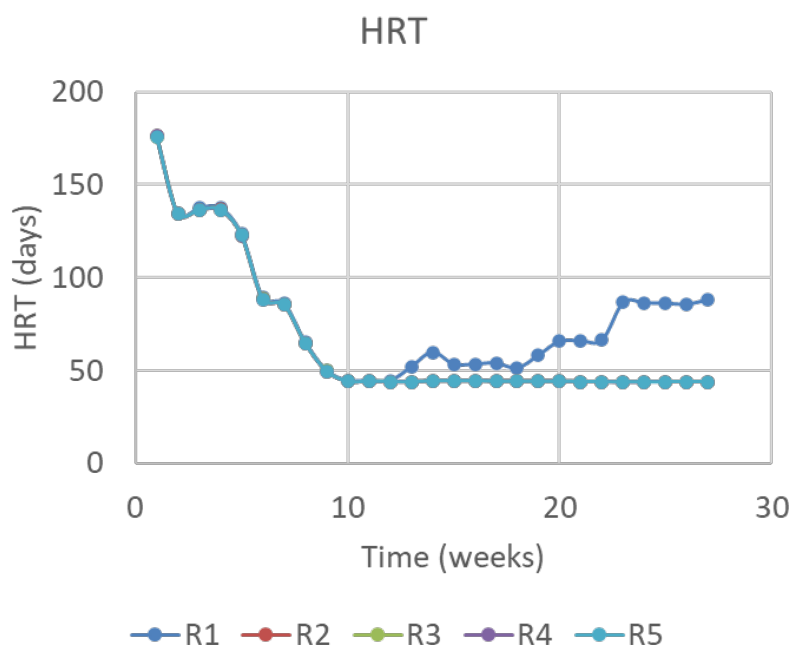


Figure 11. HRT (hydraulic retention time) over time of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5). The lines of R2-5 are hidden behind each other.

The target value for OLR, $3 \text{ g VS/m}^3 \cdot \text{day}$ was achieved within 10 weeks for all five processes, but as can be seen in figure 4, it was not possible to maintain target OLR in the R1 reactor that is not receiving any addition of micronutrients. Eventually R1 was stabilized at half the target OLR. Since OLR and HRT are connected variables the hydraulic retention time target of 50 days was also achieved after 10 weeks. Addition of external micronutrients allowed processes R2-5 to remain at target HRT while R1 had to be backed up to 80 days. Given the fact that both alkalinity and FOS/TAC take a turn towards

instability for both R1 and R5 towards the end of the trials, it is uncertain whether these reactors would have been able to be maintained at their finish values for OLR and HRT long term. For reactors R2-4, that are the most relevant for practical utilization, the processes show long term stability at the target values and most likely have the potential to be pressured towards even higher efficiency given sufficient time for microbial adaption.

Organic loading and hydraulic retention time are only part of the production efficiency picture. The other factor to keep an eye on is specific methane production. Specific methane production is a measure of how much methane per unit mass of loaded degradable organic matter that the process manages to yield. Lower than expected specific methane production can be caused by several factors including over loading, toxic process conditions and inhibitory effects. Lack of micronutrients is an inhibitory effect. Low pH caused by accumulating VFA combined with low alkalinity is an example of toxic process conditions. Specific methane production is measured as N mL CH₄/g VS (where N mL means that the measured gas volume is Normalized to standard pressure and temperature) and the achieved values for this parameter in each parallel trial can be seen in figure 6.

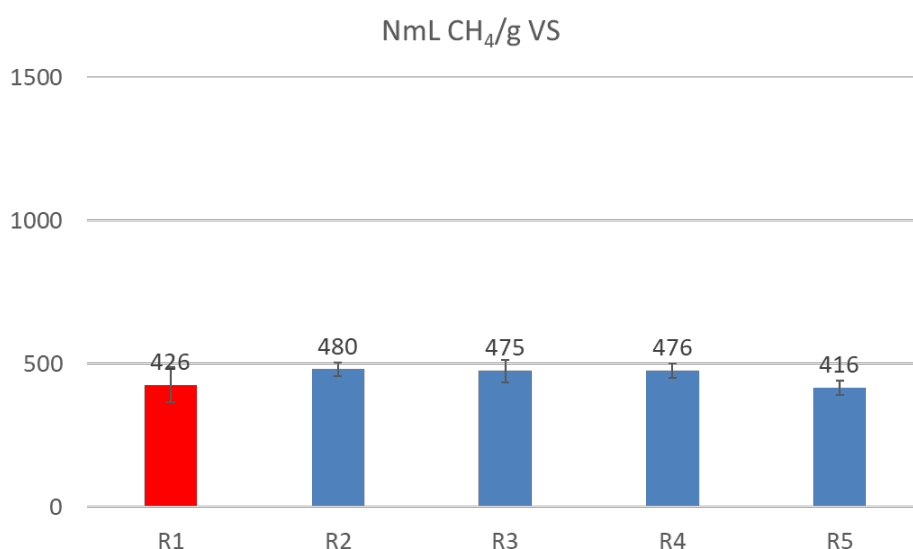


Figure 12. Specific methane production of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5). The smaller black bars indicate the standard deviation in the measured data. Overlapping standard deviation bars indicate no statistically significant difference between the processes. For processes where the standard deviation bars are not overlapping there is a significant difference in specific methane production.

As can be seen from the bar graph in figure 6, there is no significant difference in specific methane yield between two of the processes receiving external micronutrients in the form of biomass ash (R3-4) and the process receiving the same in the form of purchased tailored chemical additive (R2). As far as we know, this is the first time someone has provided empirical scientific evidence that the purchased chemical additive product could be replaced by waste biomass ash. The biomass ash dosed to R5 seem to lack some important components or contain some problematic compounds which results in (statistically) significantly lower specific methane yield than the other tested ash types. At half the organic loading rate compared to the other processes, the R1 process manages to achieve (statistically) the same specific methane production as the processes receiving external micronutrients.

Another factor of practical importance when operating a biogas production facility is the quality of the produced biogas. When utilising the biogas as a fuel for co-generation of electricity and heat via an

internal combustion engine the sulphur content of the biogas will affect the operational cost. High H_2S content in biogas that is injected into the engine will lead to high maintenance as it is corrosive and reduces the technical life span of gaskets and lubricants. The engine manufacturers typical requirement of (approximately) <200 ppm H_2S in the fuel to provide full warranties can serve as a practical rule-of-thumb target for this parameter. Figure 7 presents the hydrogen sulphide concentrations in the produced biogas for the parallel trials.

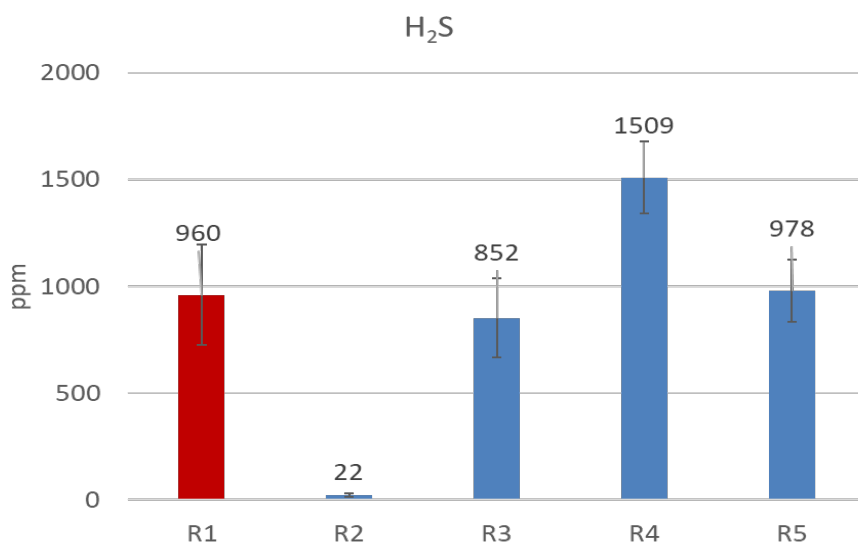


Figure 13. Hydrogen sulphide (H_2S) concentration of the different parallel trials without (R1) and with micronutrients added by means of tailored chemical additive (R2) and three variants of ash from biomass combustion (R3-R5). The smaller black bars indicate the standard deviation in the measured data. Overlapping standard deviation bars indicate no statistically significant difference between the processes. For processes where the standard deviation bars are not overlapping there is a significant difference in hydrogen sulphide concentration.

The tailored chemical additive that was dosed to R2 contains significant amounts of iron which is there specifically to chemically bind sulphates in the slurry to prevent formation of hydrogen sulphide. This is a real advantage of the purchased product over the biomass ashes added to R3-5. In addition, the biomass ash added to R4 seem to have contributed extra sulphur to the system and without the presence of enough iron this evidently compounds the problem. There is no significant difference in hydrogen sulphide concentration in the biogas between the control reactor and the reactors receiving low sulphur biomass ash. From this, we can deduce that the food waste substrate itself contains enough sulphur compounds to cause a problem and that additional iron needs to be added to the process from some other external source than biomass ash to achieve the target of <200 ppm H_2S in the biogas.

C) Conclusions

Addition of waste biomass ashes at a dosing rate of 1% of fed substrate (wet weight) enabled the same organic loading as purchased tailored chemical additives. Both types of additives ensured very stable and robust processes.

An organic loading rate of 3 g VS/L/d were easy to achieve in processes receiving additional external micronutrients through both chemical additive and biomass ash.

A food waste digestion process that is not fed any additional external micronutrients, is limited to about half of the otherwise achievable organic loading rate – 1,5 g VS/L/d.

The specific methane production was similar in all parallel trials except for one of the tested ash types, which caused a slight reduction.

A negative effect of the biomass ash compared to the purchased chemical additive is higher hydrogen concentration in the biogas. This is due to a lack of iron in the biomass ash. Some other source of iron or other form of H₂S abatement would be required if biomass ash is used as micronutrient additive.

The specific composition of the biomass ash impacts its performance as a process stabilizer. Based on the results of the trial it is now possible to estimate what quality of local biomass ash would be required. The composition should be as similar as possible to the biomass ash fed to the R3 reactor, which provided all the good effects (enabling high organic loading and process robustness) while avoiding higher hydrogen sulphide concentration in the biogas and loss of specific methane yield.

Biomass ash can be a workable cost-effective local alternative to purchased tailored chemical additives for enabling high yield biogas production processes based on food waste as a single substrate.

The work within subtask 5.1.3 now continuous with:

- Additional empirical trials to see if we can minimize the addition of biomass ash while maintaining the positive effects combined with adding some form of active iron compound that can be easily sourced locally.
- A search for a locally available biomass ash source with similar composition as the biomass ash added to the R3-reactor.

