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LEARNING SCENARIO	BIOGAS
MODULE 4	MAINTENANCE

COLOPHON

Authors

This module is part of the Learning Scenario *Biogas*. It is developed in the frame of the European project "BioComp".
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PREFACE

The learning scenario Biogas has been developed as part of the Erasmus+ project BioComp. In that project, the most relevant competences for professions in the sector BBE are analysed, described and ranked. See https://navigator.biocompetences.eu/. Based on these competences this learning scenario has been developed for EQF-level 3-4. The focus is on technical competences.

Nr	Competences, ranked according importance	Modules
B1	Management - Identifying needs and mechanisms of the overall management of the biogas production process.	1, 2
B2	Operate biogas plant - Operate equipment, which treats energy crops and waste from farms, called anaerobic digesters. Ensure the equipment functions correctly in the transformation of biomass to biogas, which is used for the generation of heat and electricity.	1
B3	Resolve equipment malfunctions - Identify, report and repair equipment damage and malfunctions; communicate with field representatives and manufacturers to obtain repair and replacement components.	4
B4	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the types of bio-waste, the recovery routes (composting, digestion, incineration).	5
B5	Recycling - Identifying needs and technological responses - To know the circular economy, compost processing and the use of fermentation.	1, 3
B6	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the chemistry and biological processes of composting.	1, 5
B7	Bioconversion process - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	3, 5
B8	Composting of organic waste and management - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	5

These 8 most relevant competences are covered by the following 6 modules:

1. Circular economy
2. Introduction
3. Health and Safety
4. **Maintenance**
5. Malfunctions
6. Composting and disposal

Apart from these 6 text documents, the scenario also has a trailer and a WIKI with background information. To support the teacher, didactic guidance is available. It can be used for all scenarios and also includes suggestions for learning activities to develop personal

and transversal competences. For this guidance, see the *Pedagogical Guidelines* in the Navigator.

CONTENT

Module 4 contains the following topics:

1. Introduction to the module

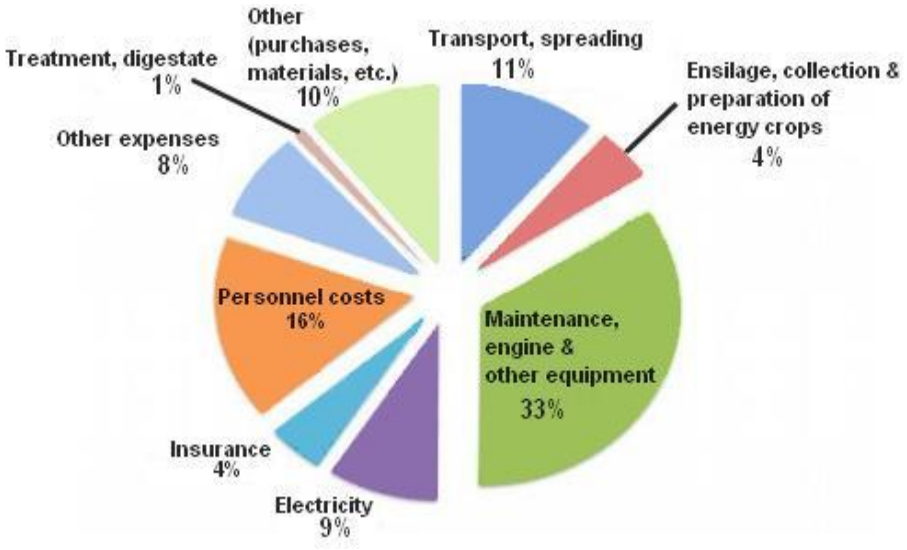
The maintenance of a biogas plant is an essential step in its management connected with the production capacity. For example, if the fermenter is not cleaned regularly, its yield is reduced. Also, the cogeneration unit needs maintenance for stable performance.

Source: https://youtu.be/U3zXQL9OTLE

Maintaining a biogas plant means doing minor repairs to the equipment, changing its oil as needed, removing debris from organic matter that falls to the bottom of the tank, solving problems in the process, and many other actions [2]. The basis is the monitoring of the current state and regular revisions. It is estimated that for a farm scale biogas plant, with an electrical power capacity (equivalent) of up to 75 kWel, the labour time (net) for operating and maintenance is usually approx. 1.8 hours per day [7]. Most of the controls may be done continuously by control and monitoring systems (like the temperature of the reaction, the amount of substrate, the quantity of gas/electricity/heat produced, etc.) but others might require expert support or can be done by the farmer himself (e.g., resolving liquid leakage at pumps, oil changing at CHP, small repairs, etc.) [1].

The proper control of the biogas production process and its optimization requires regular and systematic recording of different parameters. These measurements require the supply of the necessary measurement equipment, which adds costs. As a result, often – especially on small-scale installations – it is attempted to skip the use of this equipment during implementation [1]. The costs for installing equipment is part of the disposable investment during the building phase, however, investment for maintenance must be included in the operational costs of the biogas plant as well. Maintenance equipment costs account for about one third of the total annual costs of operating a biogas plant (Picture 1).

Picture 1. Maintenance costs



Source: [Maintenance of a Biogas Plant - energypedia.info]

However, paying attention to aspects such as the equipment, anaerobic digestion, and safety ensure several advantages connected with the good operation of a biogas plant, such as [2]:

- Prevention of technical failures or problems in the process,
- Increase in the life cycle of the equipment,
- Prevention of accidents and safer plant environment,
- Optimization of a plant operation or biogas production.

As previously mentioned, maintenance is not only prescribed operations at a fixed time or operating intervals but is based on daily monitoring of the current state and compliance with operating rules. Therefore, in order to keep all devices in optimal condition, it is necessary to:

- Use the same feed rations (size, composition),
- Not provide/supply too much material (in the ratio), as this leads to a shorter retention time which prevents fermentation from being completed (lower ration content leads to lower productivity, but does not harm or reduce quality),
- Ensure smooth flow to the fermenter,
- Not add soap, oil, chemicals, insecticide, and/or pesticide,
- Not have open flame or fire at the biogas pipes, beware of the possibility of sparks,
- Maintain well-covered silage and slurry reservoirs. Silage should undergo milk fermentation, which stabilizes it and takes place in an anaerobic environment. Exposed slurry bothers with odour and abundance of flies.

To do this, it is necessary to keep track of the indicators which monitor the processes and the status of the devices in use and respond adequately if necessary.

The actual maintenance then takes place with the intentions of the project documentation and based on the regulations of the manufacturers of the equipment used. The farmer (or operator)

must ensure the maintenance and observe the maintenance intervals (important for warranty of plant parts) of the biogas plant and the downstream equipment [1]. Some maintenance can be done by the farmers themselves (e.g., scheduled replacement of worn parts such as filters, seals, and replacing or replenishing supplies or consumables like engine oil or water) or by certain service providers (e.g., general overhaul of CHP unit).

However, it is necessary to realize that biogas is produced even in conditions that are very far from our carefully designed biogas plants, which are laced in by European Union directives. In that case, the maintenance instructions can be unbelievable. What do you think about these rules?

Biogas Development and Training Centre, which operates at Tamil Nadu Agricultural University, India (http://ecoursesonline.iasri.res.in/mod/page/view.php?id=2851) and organizes many courses for users of biogas plants informs, that:

Weekly: The burners and lamps are to be cleaned; long bamboo may be inserted in the digester through the outlet gate and stirring is done to prevent the accumulation of scum;

Monthly: Valves and mantles of gas lamps may be checked and replaced if necessary; If the manure pit by the side of the gas plant is full, the outlet slurry may be diverted to the next pit;

Yearly: For protecting the gas holder from corrosion, the outer surface needs to be painted once a year. When the gasholder is full of gas, the main gate valve may be closed, entire outer surface visible above the slurry level is thoroughly cleaned with water. A wire brush may be used for cleaning the rusted portion, if any. Black enamel paint is applied over the entire surface.

2. Safety during maintenance

In 1992, **the Directive 1999/92/EC** of the European Parliament and of the Council of 16 December 1999 was enacted which regulates **the minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres** (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC). Additionally, to this Directive, the Non-Binding Guide to Good Practice was created for implementing the European Parliament and Council Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres. Due to the potentially risky environment within a biogas plant, it is good to remember part 4.6.

Maintenance of this document [3, p. 44]:

Maintenance comprises repair, servicing, and inspection. Before maintenance work begins, all concerned must be informed and the work must be authorized, for example, by means of a permit-to-work system (see above). It may be carried out only by competent persons.

Experience shows that a high accident risk attaches to servicing work. Before, during, and after completion of the work, care must therefore be taken to ensure that all necessary protective measures are taken.

When maintenance involving a risk of ignition is carried out in a hazardous place, it should be reliably ensured that it will be free of hazardous explosive atmospheres for the duration of the work and if necessary for some time thereafter (for example, to allow cooling).

Except in exceptional circumstances, when other appropriate and adequate precautions have been taken, the items of plant on which work is to be carried out must as necessary be emptied, depressurised, cleaned, purged and must be free of flammable substances. While work is in progress, such substances must not reach the place where it is being carried out.

Where work may give rise to flying sparks (for example, welding, flame cutting, grinding), suitable screening should be provided and a fire sentry posted, if necessary.

Note: During servicing, items of equipment or plant which could cause an explosion if inadvertently switched on during the work must, if possible, be mechanically and/or electrically isolated. For example, if open flame operations are carried out in a container, all pipes from which a hazardous explosive atmosphere may be emitted or which are connected to other containers where such an atmosphere could be present must be separated from the container and blinded off or closed by some comparable means.

3. The reality of maintenance in a smaller agricultural biogas plant

Fachverband Biogas e.V., the largest European interest group in the biogas industry which represents manufacturers, system builders, agricultural and industrial biogas plant operators, and institutions, has published a lot of documents to support them. One of these documents also contains the phases of safe maintenance. These nine steps are suggested to do if maintenance should be realized:

1. Determination of the maintenance and repair requirements on the system
2. Determination of the scope of work
3. Completion of the guideline on the cornerstones of safe maintenance and repair
4. Obtaining offers based on the guideline
5. Coordination with service companies
6. Comparison of offers/selection of the service company
7. Preparation of the measures (place / time / system preparation / supervisor ...)
8. Carrying out safe maintenance/repairs
9. Completion of maintenance/repairs

The first three steps should be decided during the creation of the contract for the construction of the biogas plant and must certainly be part of the operational documentation. But before each maintenance and in the determined time intervals, they should again be taken in mind. A lot of companies skip points 4-6. They use the same company for the whole duration of the biogas plant life. While this has some advantages (the service company knows the specific biogas plant; it is time-saving), there are also disadvantages (over time, there may be more effective and cheaper companies, new technologies, etc.). The last three points (7-9) are always realized everywhere. However, proper maintenance is not only cleaning the fermenter or replacing the plugs of the cogeneration unit. Next, you can read not only about what regular maintenance looks like but also about actual daily care in a specific biogas plant.

The **Krásná Hora nad Vltavou biogas station in the Czech Republic** is a small agricultural biogas station. Its output is 526 kW, thermal output 580 kW. The input raw materials are manure (50 t per day) and corn silage and grass silage (20 t, ratio 70:30). It was put into operation in 2008 and the supplier is the Farmtec, a.s. company.

The stirrers in the fermenter are fixed, only the mixing time and speed can be changed. They are in operation for about 8-10 hours per day. The cogeneration unit uses a gas spark ignition engine with 12 spark plugs, originally designed for natural gas. Biogas consumption is 280 m^3 per hour.

The dosing of the fermenter takes place automatically every hour, the dose size depends on the fullness of the biogas, but the size is decided by the plant operator. Shortly before inserting the batch, stirrers that work for a specified period are switched on so that the newly inserted batch is well distributed in the fermenter content. The stirrers are then shut down because the energy for their movement is taken from the biogas plant's generated energy and is, therefore, a de facto loss. The usual energy consumption for mixing is 6-7 %, depending on the composition of the dose (in case of a larger share of grass, the consumption of technological energy can increase up to 10-12

%). However, mixing is also necessary as a prevention against the formation of crusts on the surface of the liquid in the fermenter. Although the mixing time and its interval are set, it is checked daily by the plant operator and, if necessary, the mixing time is extended. By default, the mixing takes up about a third of the operating hours. However, it is specific to this biogas plant and its feed dose to the fermenter. Other plants may have a different strategy chosen, depending not only on the composition of the dose (silage, grass, slurry) but also on the size of the fermenter, type and number of stirrers, etc. For another type of biogas station (a wastewater treatment plant using municipal waste, or, e.g., waste from poultry farms), the mixing conditions are completely different.

Although it is stated in the literature that chemicals do not belong in the fermenter (except for chemicals to pH correction), in this station they dilute the slurry by flushing it from the milking room, thus getting a certain smaller amount of chemicals into the fermenter. However, water mustn't be mixed with the one used for rinsing hooves containing potassium permanganate, which is a larger amount and would negatively affect bacterial colonies in the fermenter (once this happened to them and caused problems).

Also, the temperature is not necessarily adhered to at a very narrow interval. This biogas plant operates in the temperature range of 38-42°C, but they have experimentally verified that even a short-term (several hours) rise in temperature to 50 °C does not matter.

Once a month, the fluid in the fermenter is analysed. In case of deviation from the standard, the station operator consults with the technology of the equipment supplier (Farmtec). As part of the monitoring of indicators, it measures pH, nitrogen, phosphate, dry matter, and organic solids, as well as lower fatty acids. When starting a biogas station (after shutdown), it is measured twice a month. The optimal pH is at an interval of 7.6-7.8. The **increased proportion of acetic acid** is a problem, but it is not essential and can usually be solved by adjusting the ration. Like everything else, the proportion of acetic acid has a standard in the form of an interval that does not have completely strictly defined boundaries. According to the chief technologist, the amount of 300 mg is fine, but the amount of 2,500 mg or more is already a reason to intervene. An increased proportion of propionic acid is a more serious problem than an increase in acetic acid production. However, the processes in the fermenter are quite slow, so when, for example, biogas production decreases and, after increasing the ration it equalizes within 3-4 days, it is considered a solution to the problem, with no additional maintenance or remediation taking place. If necessary, it is possible to compare the proportions of ingredients in the fermenter with another fermenter, but this is already a solution to the problem and not routine maintenance.

More complex analyses are done once a year. They may also result in the need to supply micro-elements, but this is not necessary for this station because they use slurry and, therefore, the necessary minerals get into the fermenter as a result of being commonly added to the cattle feed.

An important aspect of maintenance is the monitoring of water condensation, which can cause corrosion of the cogeneration unit. In the case of this biogas plant, biogas is so far away from the cogeneration unit that the water condenses in the pipes and therefore does not enter the unit. It would cause problems especially in the fuel mix cooler, so the temperature in it must not get below

the dew point. Therefore, the water cannot condense. This means a minimum temperature of 44-48°C.

Another potential problem **is sulfone (H_2S),** which, as already described in the health and safety module, not only has toxic effects but is also highly corrosive. In this station, thanks to the materials used, little is produced and the rest is removed bacterially. Air is controlled into the fermenter space, the amount of which is controlled by the oxygen content (O_2) in biogas. It can only be enough so that the O_2 concentration does not exceed 0.4-0.6 vol. % in biogas. At a concentration of 0,8 vol. % O_2 in biogas is already worse in quality, but is still a quantity well below the explosive limit.

Machine service is provided by the equipment supplier (Farmtec) and is governed by the total life of the oil. Due to different oil quality and recommendations of the manufacturers, the intervals may be different. Here is stage 1 after 2,000 operating hours, and maintenance requires 2-3 hours of downtime of the CHP unit. During this time, the gas accumulates in the reservoir, and there is no need to significantly reduce the feed dose. Further maintenance is carried out after 10,000 operating hours and then every additional 10,000 hours. The manufacturer's manual states what is to be checked, adjusted, or replaced, and is an increasingly comprehensive list. Logically, it also requires a longer downtime associated with the liquidation of excess biogas with a flute.

According to the contract, only the manufacturer can provide service of the engine of the CHP unit, partial interventions can also be carried out by the plant operator with the help of a call centre. Separately, they can perform, for example, the replacement of candles in the engine. In their case, it is a set of 12 spark plugs that should work at a defined voltage interval. After several years of operation, they found that if the optimal voltage is exceeded by 0.2 (with the allowed interval being up to 0.3), the candles wear out more. Therefore, it is necessary to maintain the voltage as accurately as possible. Thanks to the chief technologist, they also have other cost savings in this biogas plant. He found that there is a certain distance between the components in the plugs to ensure their optimal performance. However, wear leads to loss of performance. To avoid this, after several thousand hours of plug operation, they reduce this distance. They'll do it twice again later. Thanks to this, they can extend the life of the spark plugs from about 10,000 to 12,000 operating hours without losses of machine power. At the end of their life, they will use an additional set of back-up spark plugs available to them at all times in case of a defect.

4. General rules for maintenance - fermenter

Regular monitoring and control of the biological process of biogas is an essential part of the maintenance of a biogas plant. Indeed, problems in the biological process are the fifth most frequent cause of malfunctions of the plant [1].

Therefore, the project developer must equip himself with technologies to monitor the biological process, detect deviations from the desired characteristics and those obtained, and solve them.

These technologies can be automated, and it could be possible to control them and implement corrective activities remotely. Specialized staff in a biogas plant are not necessary, but they are more expensive. As you know from the practical case before, parameters of the biological process to monitor and control are [2]:

- The rate of biogas production: The amount of gas produced per unit of time is important to evaluate the efficiency of the biological process and adjust it as needed.

- Formation of floating mud layers or moss: Floating mud layers sometimes form on the surface and must be removed manually as they accumulate. The foam can plug the pipes or escape through the safety valves.

- The composition of some gases: A significant drop in methane concentration, for example, may indicate a problem in biogas production. For certain, oxygen and sulfone ratio are also very important.

- A wide variation in temperature: The optimum temperature varies according to the process. Sometimes the temperature is regulated by legislation (e.g., in the Czech Republic [4], for anaerobic digestion of bio-waste in all types of facilities with expected sanitized output, a minimum temperature of 55 ° C of treated bio-waste must be maintained and held for at least 24 hours without interruption).

- pH value: This variable has a strong impact on the biological process. In the case of methane, it must be between 7 and 7.5 (however, *as you know from the previous practical case, it does not actually have to be*).

If you enter the words "biogas plant maintenance" into Google's search engine in the Czech language, you will get almost exclusively links to fermenter cleaning. The contents of a fermenter should be completely removed (along with sediment and accumulated non-degradable components) once every 2 years. Depending on the type of station, very seldom every year (e.g., ASB Dětřichov [5]), in some places every three years. However, in the biogas plant Úpice (the Czech Republic) it is every 8 years, for example.

The most advanced technologies for cleaning tanks and cleaning biogas plants allow the use of wet and dry cleaning methods. For professional teams that clean biogas plants, a high level of work

safety during cleaning work is a matter of course. That's why they have gas monitoring systems, a specialized ventilation system, and fresh air breathing systems.

It is common to use a combination of a suction dredger (see Picture 5) and wet or high-pressure cleaning to remove stickers from tank walls.

Picture 2. A suction dredger

Source: 1. HUTIRA - BRNO, s.r.o. - čištění bioplynové stanice mobilním sacím bagrem - YouTube

The process of fermenter cleaning can be seen here: Údržba bioplynové stanice - Biogas station maintenance - YouTube

Generally, maintenance of agitation, pumping, and flushing equipment should always be performed above ground level. If this is not possible, a forced ventilation system must be permanently installed in order to counteract the risk of asphyxiation and poisoning in the event of an escape of gas [6].

5. General rules for maintenance – cogeneration unit, etc.

It is a bit strange that when using Google's search engine for maintenance in English, it offers us mainly maintenance of a cogeneration unit. One illustrated example is in this video (in German but with English subtitles): What does the maintenance of a biogas plant consist in? - Videos | Biogas Channel | Biogas Channel.

Certainly, cogeneration units are a subject of maintenance also in the Czech Republic. Regular annual inspections of refrigeration units are carried out. Revision of refrigeration equipment is required by Decree No. 257/2012 and subsequent updates in accordance with EU Regulation No. 517/2014

Together with the inspection, the necessary maintenance, cleaning of evaporators, repairs of leaks, and the cooling circuit of the cogeneration units, etc. are performed. Every 2,000 hours the gas filter must be checked, and the air filter of the cogeneration unit should be cleaned.

Gas Storage Tanks

These are very important facilities and their construction is regulated by many regulations. But, they are maintenance-free to a very large extent.

Flare System

This is also a very important device that is used to burn any excess biogas. Again, it is necessary to meet many conditions during its construction, but afterwards is maintenance-free to a very large extent.

6. Checklist

At the end of this module, you can be **inspired** by a checklist for maintenance created by the Fachverband Biogas association. **Would you add something?**

Safe Maintenance Guide	Comments
What maintenance work is necessary?	
The maintenance work is carried out by: ☐Internal staff ☐External staff	
☐Supervisor necessary (Executing companies must, for dangerous work processes or with hazards, name the supervisors who are familiar with the measures and the legal requirements to be observed[2]) ☐Coordinator necessary (Special hazards[3] can arise when employees from several employers work together. Therefore, a coordinator with authority to issue instructions must be appointed by the parties involved[4]) ☐These are activities in Ex areas	
Exact description of the work:	
Name of possible hazards: ☐Risk of explosion ☐Fire danger ☐Gas hazard (suffocation) ☐Mechanical hazards ☐Working at height ☐Heat / warmth ☐Hazardous work equipment ☐Electrical hazards ☐Hazardous substances / substances (chemical / biological hazards) ☐Further:	

Requirements for the time execution depending on the work to be carried out: □When should the work take place? (Start end) □How urgent is the measure, possibly due to other hazards? □Which staff are available during this period? □Is the necessary safety equipment available? □Are the necessary spare parts available?	
Determination of important cornerstones for the tender / request for offers: □Description of the work and the necessary material (spare parts) or any relevant material requirements □Description of the possible hazards □Note on the execution / sequence of the work □Necessary equipment □Notes on the appointment of a supervisor[2] / coordinator[4] □Notes on the specialist knowledge of the maintenance company (certificates of specialist knowledge in accordance with TRAS 120 / references, etc.) in the offer. The specialist company must provide evidence (e.g. internal risk assessment for his specific activities, "welding appear ", suitability for work, e.g., with respiratory protection, qualified electrician, etc.) he is authorized to do so. □Clarification as to whether a specialist company obligation according to AwSV applies (work on safety-relevant parts according to AwSV) □Obtain instructions for safe implementation (procedure of the specialist company, briefly explain) □If necessary, gas-tightness test according to TRGS 722 / TRBS 2152 or test according to § 15 BetrSichV, if necessary afterwards □If necessary, leak test of the maintained substrate or heating cables, etc. in Follow-up, if necessary □Etc:	
Evaluation of the offers regarding the following points: □Concept of maintenance taking into account safety / proof of more secure working method □Consideration of certificates of qualification / references □Provision of specially qualified staff (possibly coordinator, specialist knowledge according to TRAS 120, specialist according to company, etc.) □Provision of safe work equipment □Reliability in terms of quality of work, time compliance, and costs	
Commissioning the selected company: □Determination of the tasks defined in the offer, taking security into account □Written or verbal order confirmation according to the offer □Coordination of the schedule or necessary work steps (preparation of the documents / appointment of supervisors, etc.) □Determination of the contact person (possibly coordinator) on both sides	

Preparation of the work: □Determine the date / time of the work □Make preparations on the biogas plant by the operator □Information of relevant people in the system and, if necessary, the rescue services; Coordination of a rescue concept for dangerous work □Provision of tools, necessary machinery and equipment, spare parts, i.e, safety-relevant aids (e.g., inert gas, additional fire extinguishers, etc.) □Provision of personal protective equipment (clean, serviced ...) □Prepare / fill out the instruction protocol or the risk assessment	
Maintenance day: □Preliminary discussion with all those involved / on-site coordination of the measure □Coordination of powers and appointment of supervisors / if necessary coordinator (written!) □Filling out the instruction protocol or the risk assessment and permission document + signature □Clarification of all safety-relevant measures (if necessary, rescue concept, fire extinguisher, Escape routes, ...) □Safe implementation in compliance with the agreed measures	
Follow-up and documentation of maintenance: □As far as sensible, creation of a recommissioning / test report with information on materials used, setting values, test methods, test sequence, etc. □Handover by the specialist company to the operator with information on consequences / functionality (if necessary, handover of assembly declaration, CE declaration of conformity, instruction manual, etc.) □If necessary, documentation of the maintenance measures in accordance with TRAS 120 (Section 2.6.4 (4.)) □Determination of the further procedure for restarting the component / the biogas location based on the manufacturer's documentation □Determination of normal operation, e.g., by leak test or test in accordance with § 15 BetrSichV (by person responsible for examination) □Adaptation of all safety-relevant documents (risk assessment, R&I) □Flow diagrams, circuit diagrams, software ... ...) of the system, if necessary	

7. Quiz

This module contains a quiz. The quiz can be answered on-line, by using QR code below. The student receives per question an answer of either **correct** or **incorrect** and has to correct each wrong answer before proceeding to the next question.

(Scan with your Smartphone camera / QR Code reader app to access the quiz)

1) Maintenance of a biogas plant is a professionally demanding activity performed exclusively by specialists:

a. Yes
b. No

Answer: b

2) The most important part of maintenance is the fermenter (digester):

a. Yes
b. No

Answer: b

3) A lot of maintenance diagnostics is automated:

a. Yes
b. No

Answer: a

4) Maintenance intervals are the same for all biogas plants of the same kind and size:

a. Yes
b. No

Answer: b

5) Well-performed maintenance increases productivity and safety of biogas production:

a. Yes
b. No

Answer: a

8. Sources

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