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| AECENAR TECDA<br>Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region | **NLAP Supplement Final Report 2021-2024 Supplement** |

## Contents

# 1 Project 22/5: Biogas (ICPT - Biogas) (to be put into NLAP-WEDC Final Report 21-24)

## 1.1. Position of biogas project

This project was proposed to produce methane gas for later use in the burner. This project is divided into two parts: a theoretical section and an applied (executive) section. Work on the biogas project started this year. Emphasis was placed on theoretical and applied aspects, as the project was studied, and the proposed design was manufactured without commissioning it.

## 1.2. Méthanisation: Processes, conditions, étapes, …

(Anaerobic digestion: process, conditions, steps, …)

### 1) Model size

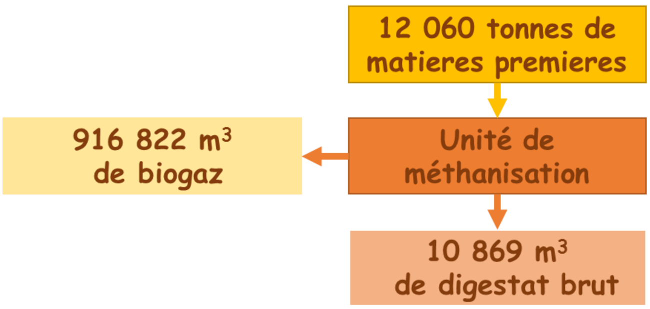
Operation: 91% approximately 8000 hours per year.

Quantity of raw materials: 12,060 tons.

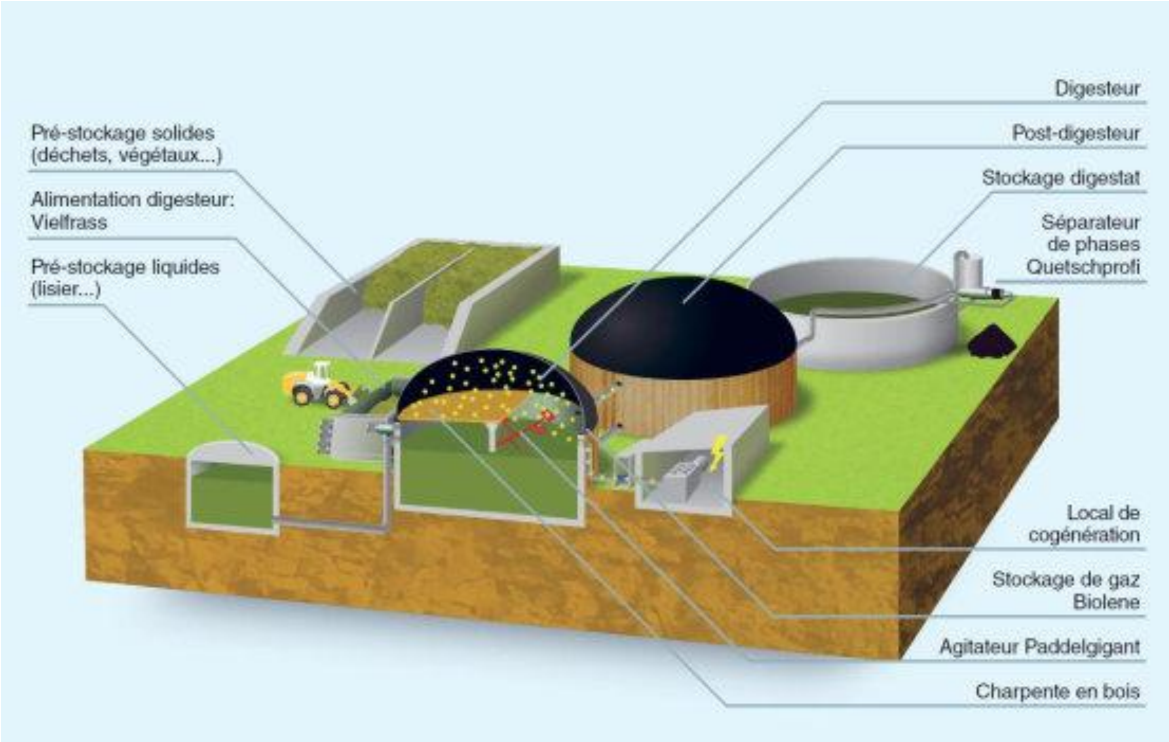
Quantity of biogas produced: 916,822 $m^3$/year (54.3% methane).

Quantity of digestate: 10,869 $m^3$.

### 2) Bilan des matières




### 3) Systèmes de production du biogaz




**a) Input**

Inputs can be of two types:

- EVEB liquid inputs
- Solid inputs (manure, plant matter)

Liquid inputs are pumped to the digester and must be agitated.

Solid substrates are introduced into the digester using a specially designed device.

This device has sufficient capacity to contain the equivalent of one to two days of inputs.

Insulation of the walls reduces the heating needs of the system.

The substrates are finely mixed to avoid the formation of crusts and to favor the expulsion of gas.

**b) Digester**

Pumping system to introduce liquid materials into the digester. A 160 mm diameter polyethylene pipe will be connected to the pump and the digester to introduce the solid inputs.

**c) The stirring system: paddle stirrer**

4 blades placed on a rotating axis generate currents in different directions with a high content of dry matter and thus prevent the formation of a surface layer.

The low rotation speed preserves the bacterial population.

***Brewing system; 4 blade agitators***

**d) Membrane**

Membrane for biogas storage: 2 mm thick EPDM

In high quality EPDM rubber, elastic, resistant (to UV and Ozone).

***Rubber membrane to maintain the biogas***

**e) Digestion pit heating system**

Network of tubes in composite material fixed on the internal wall of the pit.

The passage of hot water keeps the digestate at the right temperature.

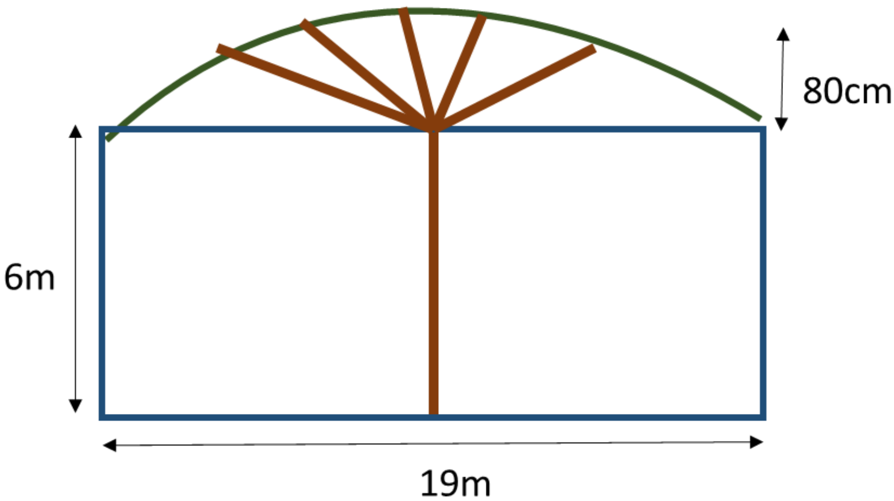
***Digester heating system***

**f) Digestion pits (digester)**

Reinforced concrete pit with a central pillar supporting a wooden frame (supports the EPDM biogas storage membrane, and offers a large colonization surface for bacteria that transform hydrogen sulphide $H_2S$ into sulfur which is deposited on the wooden frame).

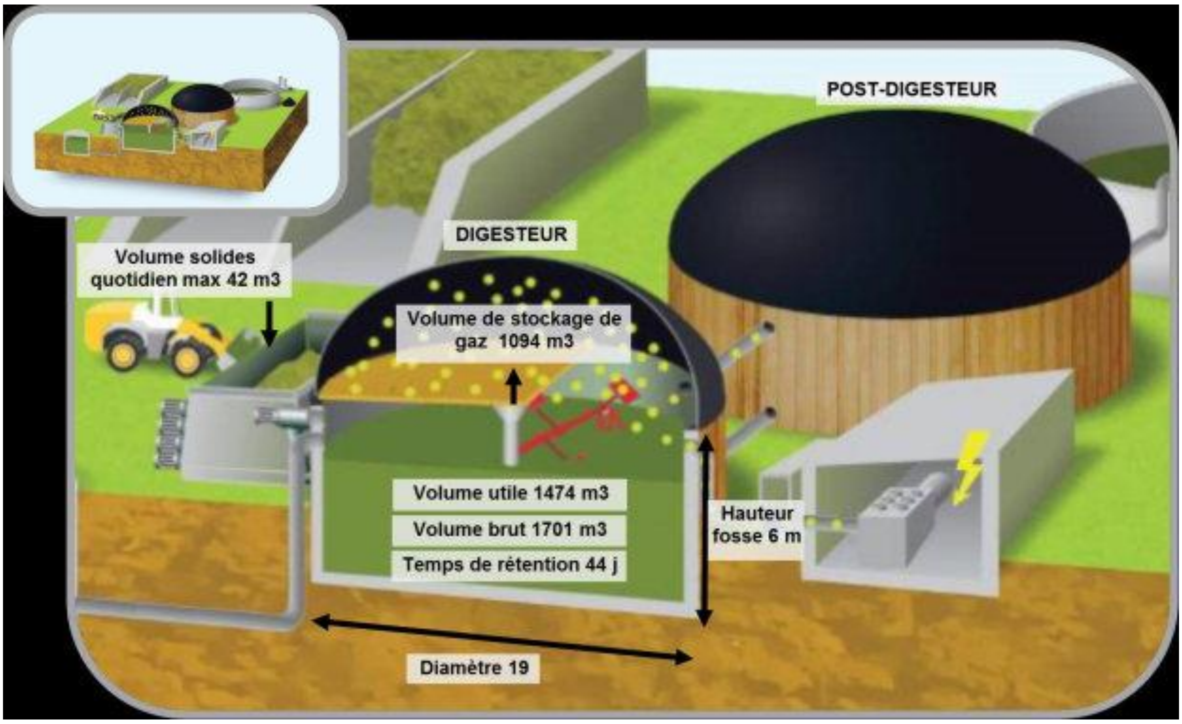
***Wood frame***

## 4) Biogaz dimensions




A digester diameter of 19 m allows a hydraulic retention time of 44.1 days

- Duration of methane production: Diameter= 19m => 44.1 days.
- Maximum load = 3.7kg MO/m³/day

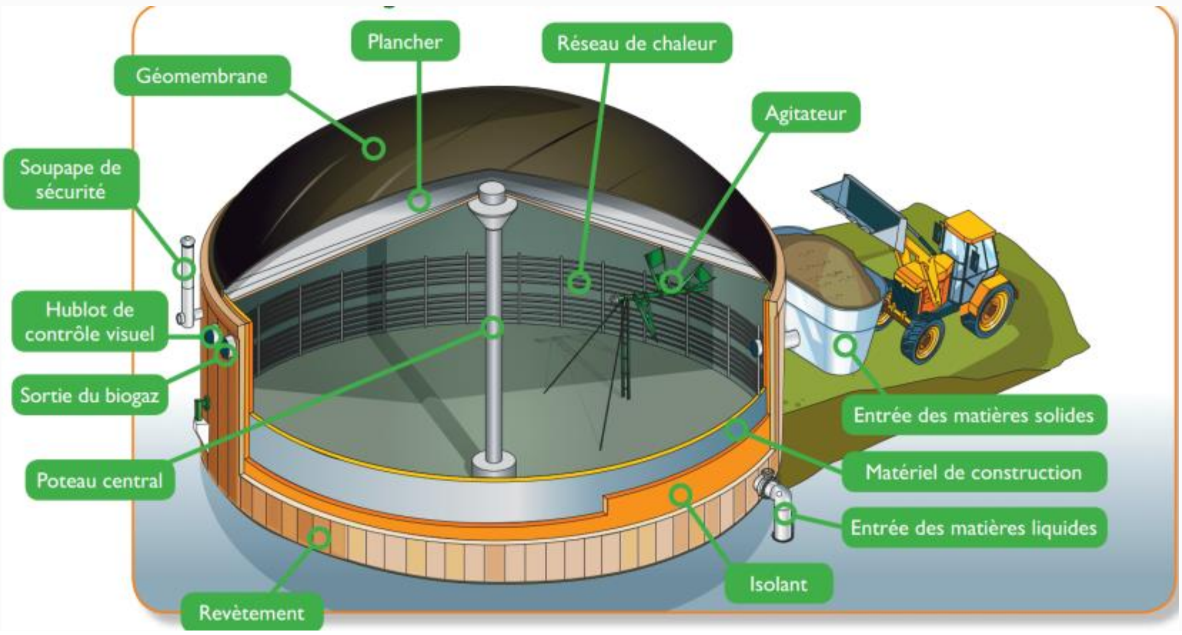



- **Dimensions :**

Φ=19m, h=6m

Gross volume: 1701m³

Net volume = 1,474 m³




## 5) Biogas steps

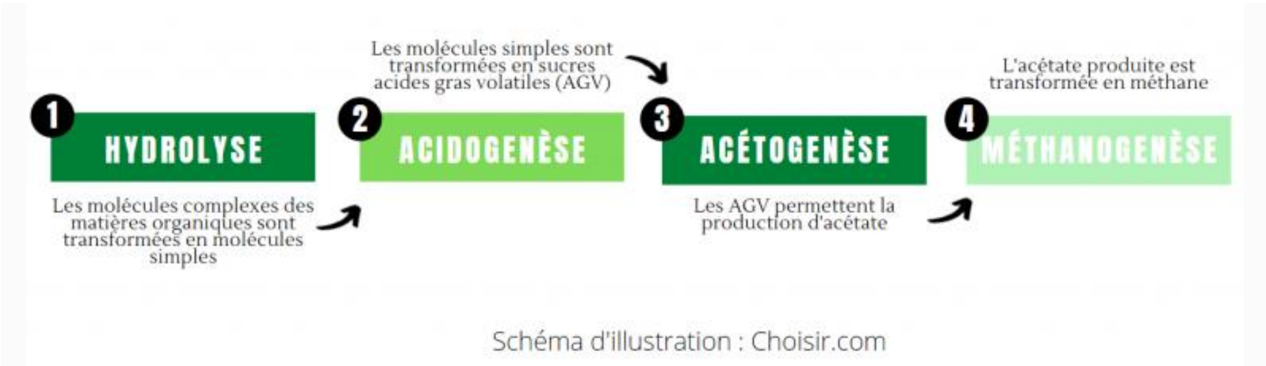



Schéma d'illustration : Choisir.com

## a) Hydrolyze

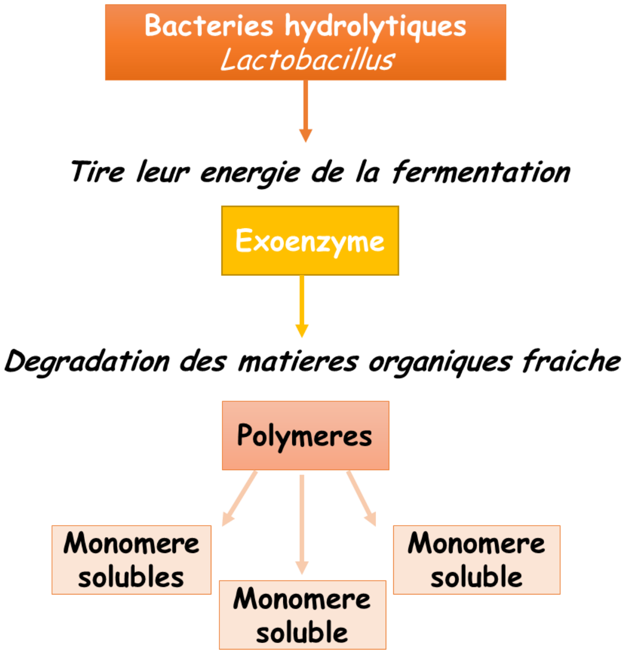



TABLEAU 1 : CARACTERISTIQUES DES BACTERIES HYDROLYTIQUES

| Bactéries hydrolytiques | |
|---|---|
| caractéristiques | bactéries relativement résistantes, tolérantes à $O_2$, production d'exo-enzymes |
| gamme de pH optimal | [4,5 – 6,3] |
| temps de division | quelques heures (reproduction rapide) |
| sensibilité | lignine (pas dégradable, ralenti la réaction) |

## b) Acidogenesis

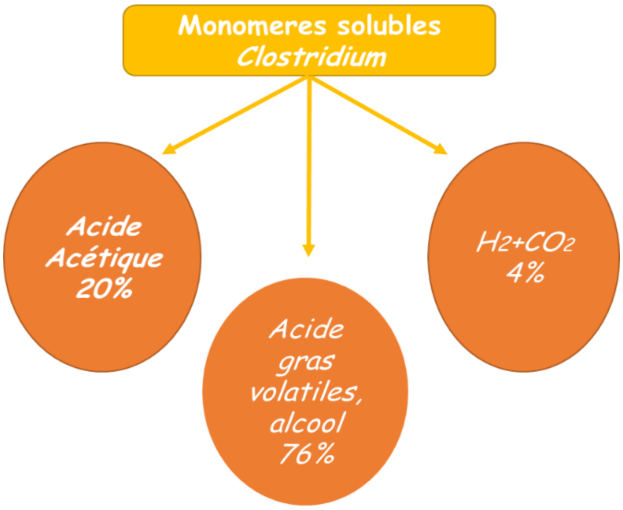



TABLEAU 2 : CARACTERISTIQUES DES BACTERIES ACIDOGENES

| Bactéries acidogènes | |
|---|---|
| caractéristiques | bactéries sensibles à $O_2$, participent en général également à l'hydrolyse |
| gamme de pH optimal | [4,5 – 6,3] |
| temps de division | quelques heures (reproduction rapide) |
| sensibilité | $H_2S$, $NH_3$, sels, antibiotiques |

## c) Acetogenesis

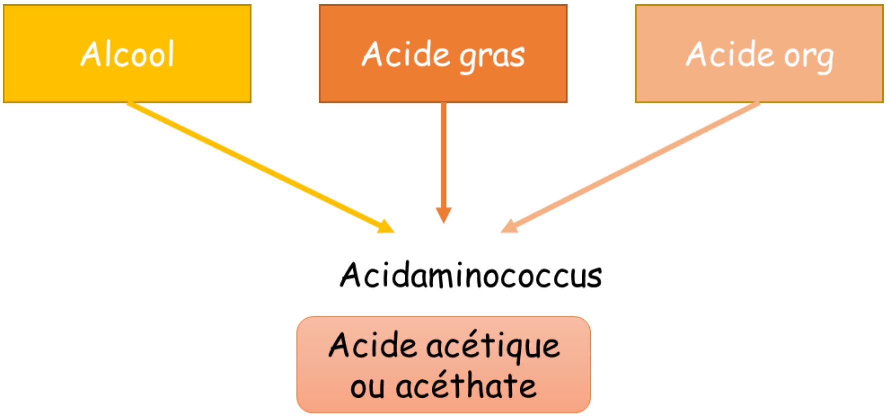



TABLEAU 3 : CARACTERISTIQUES DES BACTERIES ACETOGENES

| Bactéries acétogènes | |
|---|---|
| caractéristiques | bactéries relativement fragiles, sensibles à $O_2$, production de $H_2$ |
| gamme de pH optimal | [6,8 – 7,5] |
| temps de division | quelques jours (1-4 jours ; reproduction lente) |
| sensibilité | $H_2$ en excès, $H_2S$, $NH_3$, sels, antibiotiques, variations de température |

## d) Methanogenesis

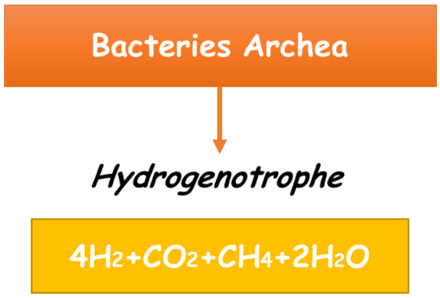



TABLEAU 4 : CARACTERISTIQUES DES BACTERIES METHANOGENES

| Bactéries méthanogènes | |
|---|---|
| caractéristiques | archaebactéries très fragiles, très sensibles à $O_2$, besoin de Ni, plusieurs substrats possibles |
| gamme de pH optimal | [6,8 – 7,5] |
| temps de division | quelques jours (5-15 jours ; reproduction lente) |
| sensibilité | $O_2$, variations de pH et température, Cu, sels |

| Type de gaz | Proportion |
|---|---|
| Méthane – CH4 | 55 – 75% |
| Dioxyde de carbone – $CO_2$ | 25 – 45% |
| Hydroxyde de souffre – $H_2S$ | 500 – 8000 ppm |
| Dioxygène - $O_2$ | 0 – 1% |
| Vapeur d'eau – $H_2O$ | Saturation |

It is necessary to heat methane:

- Mesophilic zone: 35°
- Thermophilic zone: 55 to 60°C

**N.B.:**

**Biogas reduces the greenhouse effect. Limits environmental damage**

## e) The digestate:

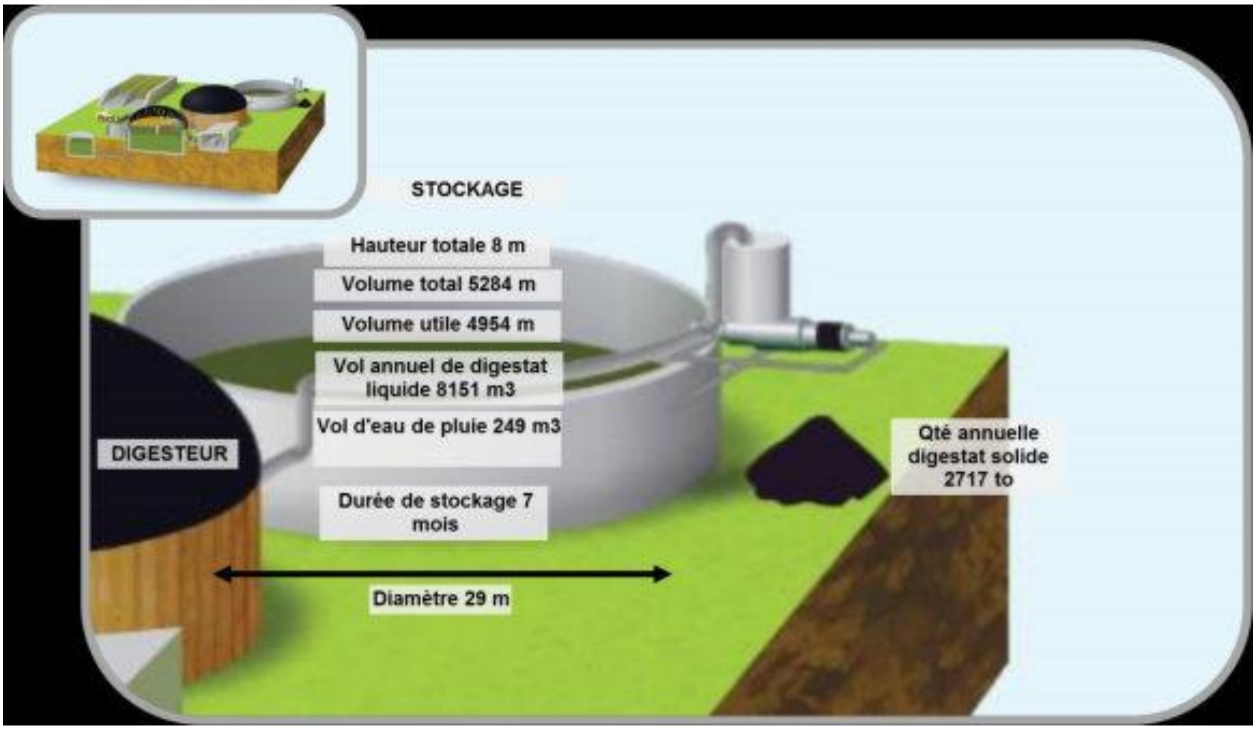
Deodorize, olfactory nuisance is destroyed in the digester.

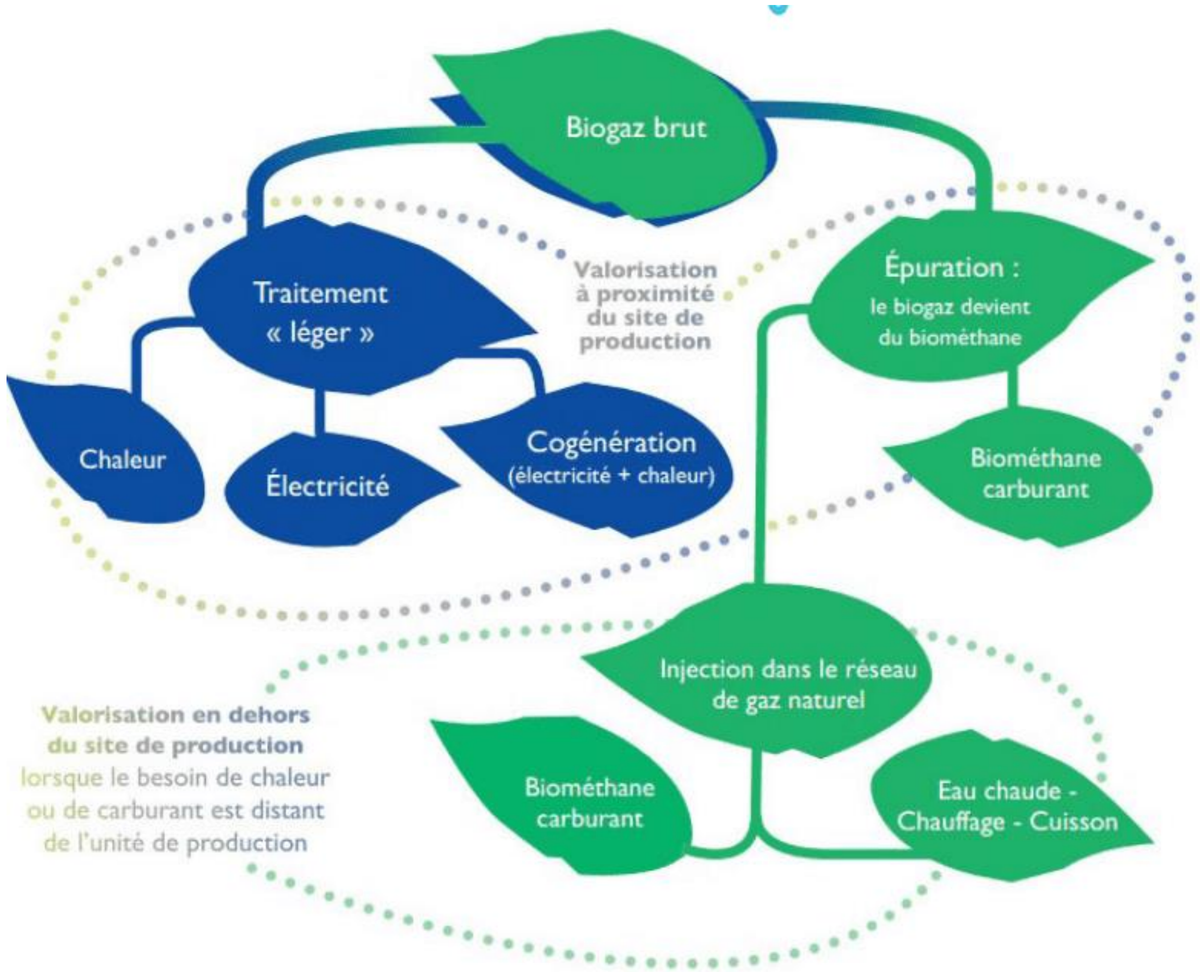
Its fertilizer value is improved, the quantity of nutrients is preserved but the initially organic nitrogen is found in ammoniacal form.

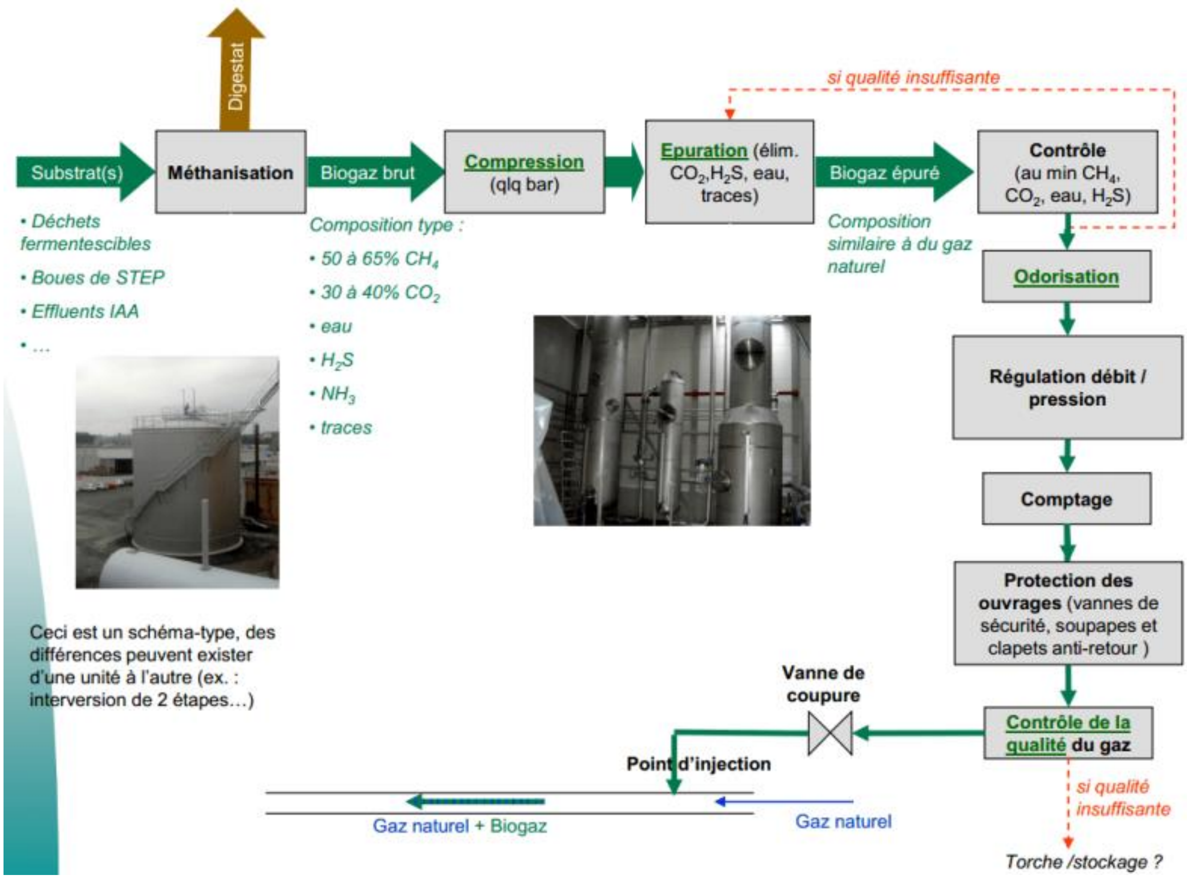
It is therefore assimilable for plants.

This spreading improves microbial activity and soil respiration compared to spreading manure or slurry.

Spreading is carried out using a dropper.


STOCKAGE
Hauteur totale 8 m
Volume total 5284 m
Volume utile 4954 m
Vol annuel de digestat liquide 8151 m3
Vol d'eau de pluie 249 m3
Durée de stockage 7 mois
DIGESTEUR
Qté annuelle digestat solide 2717 to
Diamètre 29 m


Biogaz brut
Traitement « léger »
Valorisation à proximité du site de production
Épuration : le biogaz devient du biométhane
Chaleur
Électricité
Cogénération (électricité + chaleur)
Biométhane carburant
Injection dans le réseau de gaz naturel
Valorisation en dehors du site de production lorsque le besoin de chaleur ou de carburant est distant de l'unité de production
Biométhane carburant
Eau chaude - Chauffage - Cuisson


Digestat
si qualité insuffisante
Substrat(s)
Méthanisation
Biogaz brut
Compression (qlq bar)
Epuration (élim. $CO_2$,$H_2S$, eau, traces)
Biogaz épuré
Contrôle (au min $CH_4$, $CO_2$, eau, $H_2S$)
• Déchets fermentescibles
• Boues de STEP
• Effluents IAA
• …
Composition type :
• 50 à 65% $CH_4$
• 30 à 40% $CO_2$
• eau
• $H_2S$
• $NH_3$
• traces
Composition similaire à du gaz naturel
Odorisation
Régulation débit / pression
Comptage
Protection des ouvrages (vannes de sécurité, soupapes et clapets anti-retour )
Ceci est un schéma-type, des différences peuvent exister d'une unité à l'autre (ex. : interversion de 2 étapes…)
Vanne de coupure
Contrôle de la qualité du gaz
Point d'injection
si qualité insuffisante
Gaz naturel + Biogaz
Gaz naturel
Torche /stockage ?

$1\ m^3 = 9\ Kwh$

$V_{total} = \pi \times (r)^2 \times H = \pi \times (1500)^2 \times 2000 = 14.130$

$\rho_{eau} = \frac{m}{V}$

$m = \rho . V = 1 \times 7065 = 7.065\ kg$

$\rho_w = \frac{m}{V}$

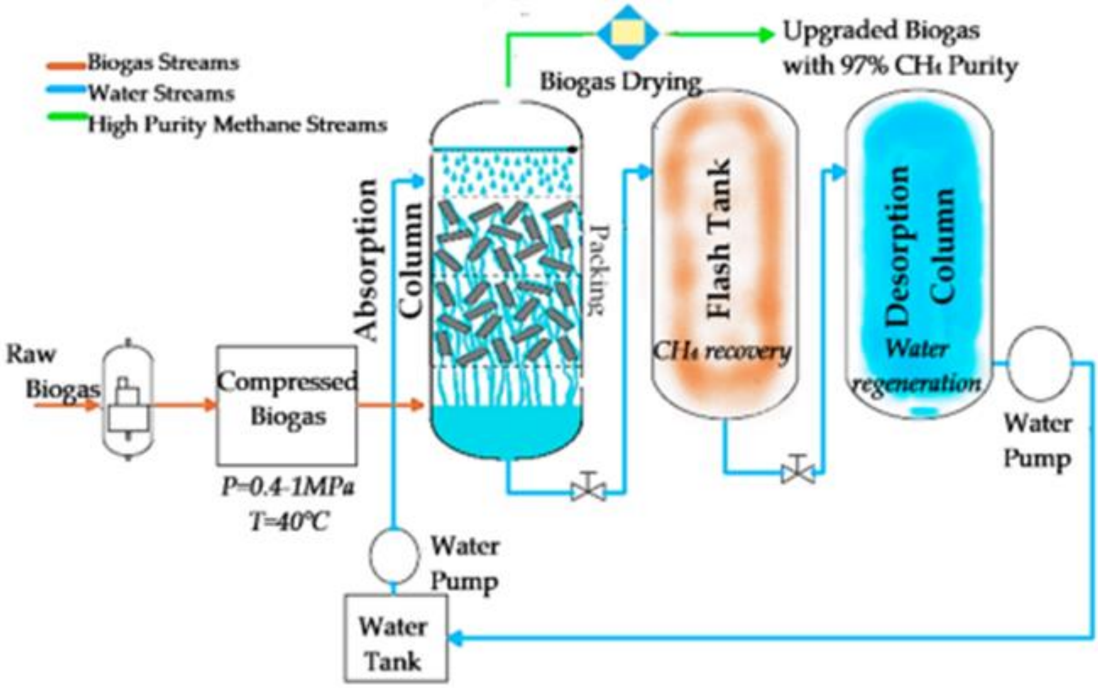
$m = \rho \times V = 1.5 \times 6065\ kg$

$m_t = m_{water} = m_{liquid} = 7065 = 10600 = 17.665\ kg$

| Flygt 4460 | Puissance nominale 50 Hz | Diamètre de l'hélice | Poussée 50 Hz | Installation |
|---|---|---|---|---|
| Semi rapide | 7,5 kW | 1,25 m | 2860 N | Système de support biogaz (BIS-1) |
| | 12 kW | 1,25 m | 3650 N | |
| | | 1,0 m | 2800 N | |
| Vitesse lente | 5,7 kW | 2,5 m | 3850 N | Tripode |

## 6) <u>Features of the agitator</u>

## a) Gas separation




## b) Physical Scrubbing

- Working Principe

- $CO_2$ is more soluble than $CH_4$ according to Henry's law.
- Raw biogas flow through a counter flow of a liquid in a column.
- Liquid absorb $CO_2$ leaving biogas with high content of $CH_4$.

- Type of liquid

- Water for water scrubbing.
- Polyethylene glycol (PEG) / selexol and Genenrob for organic scrubbing.

- System upgrading

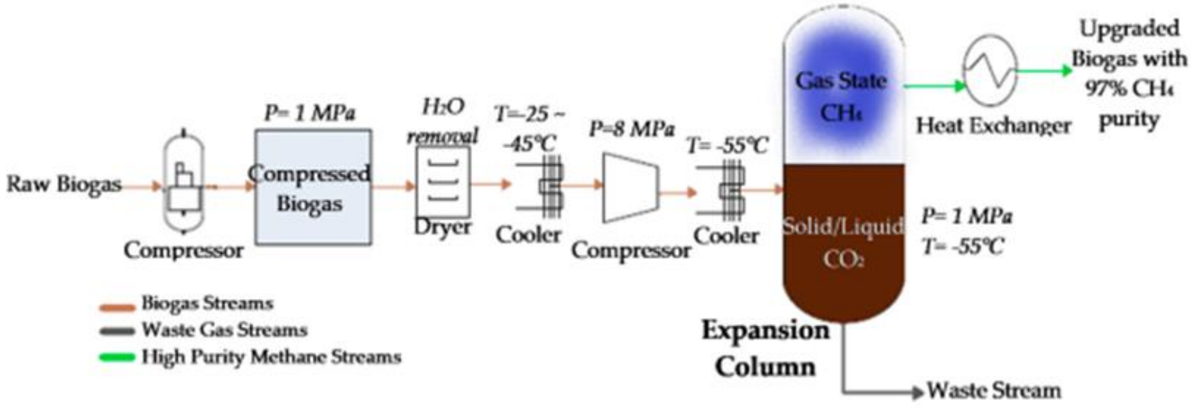
- Absorption column filled with packing material to increase mass transfer.
- Flash tank installed to recover trace of $CH_4$.
- Water/PEG regeneration to remove $CO_2$ for reuse purpose.

- Advantages

- Simple process
- High methane purity
- Less methane loss.
- Low operation and maintenance cost.

- Disadvantages

- Required huge amount of water.
- High energy needed
- Chances of biological contamination.
- Required external heat.




**c) Cryogenic separation:**

- Working Principe

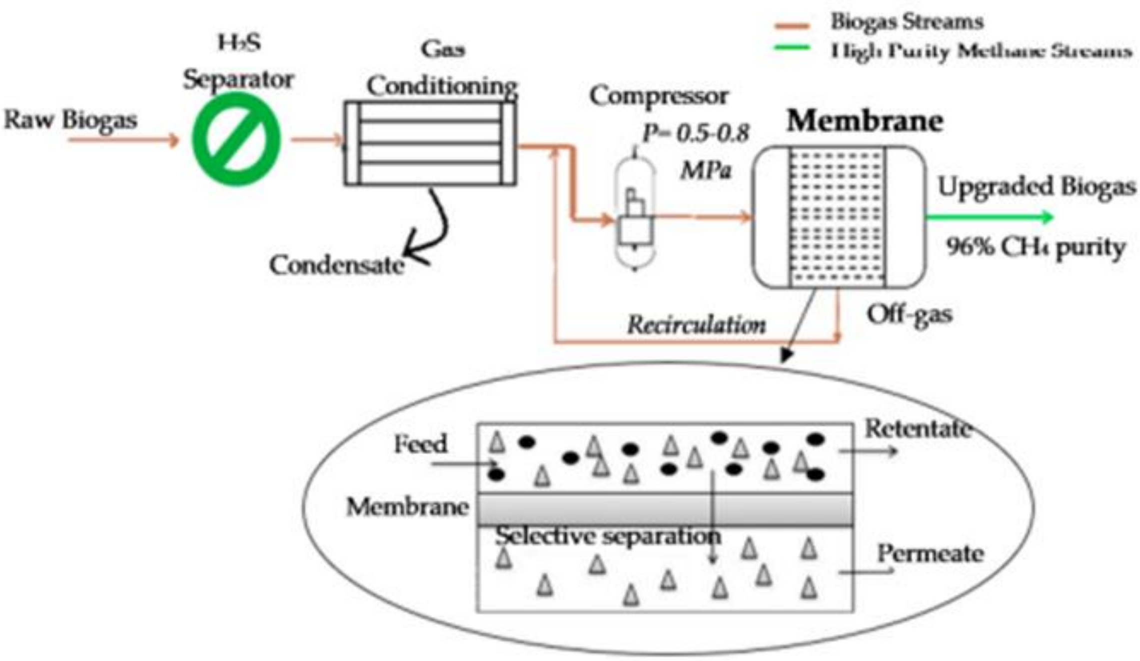
- Different gases condense at different temperature-pressure domains.
- Boiling point of $CO_2$ was higher than the $CH_4$ thus allowing the separation.
- Biomethane produced by graduand decrease of temperature and compressing the biogas.
- Equipment: compressor-turbine-heat exchanger and cooler.

- Post treatment

- Final product is in accordance with the quality standards gore liquified natural Gas (LNG).
- Further cooling for purification will produced liquid Biomethane (LBM).

- Advantages
- High gas quality
- Low methane losses
- Environmentally friendly
- Produce LBM with low extra-energy

- Disadvantages
- High investment operational cost
- Pre-treatment needed
- High energy required for cooling
- Technology is still under development.




d) Membrane separation

- Working Principe

- Separation of biogas components using membrane as permeable material.
- The selection of permeability properties of membrane is crucial.
- Ascending order of permeation rate: $CH_4$, $CO_2$, $H_2S$, $N_2$ and $H_2O$.

- Separation techniques
    - Gas-gas separation(dry)
        - $H_2S$ and oil vapors were first removed.
        - Biogas is pressurized and injected into membrane.
    - Gas-liquid separation (wet)
        - Liquid and gases separated by membrane.
        - Impurity is the gases absorbed by the counter current flows of liquid.

- Increasing efficiency

- Enhanced the $CH_4$ purity by using two or three stage performance.
- Ideal membrane must have high permeability difference between $CO_2$ and $CH_4$.

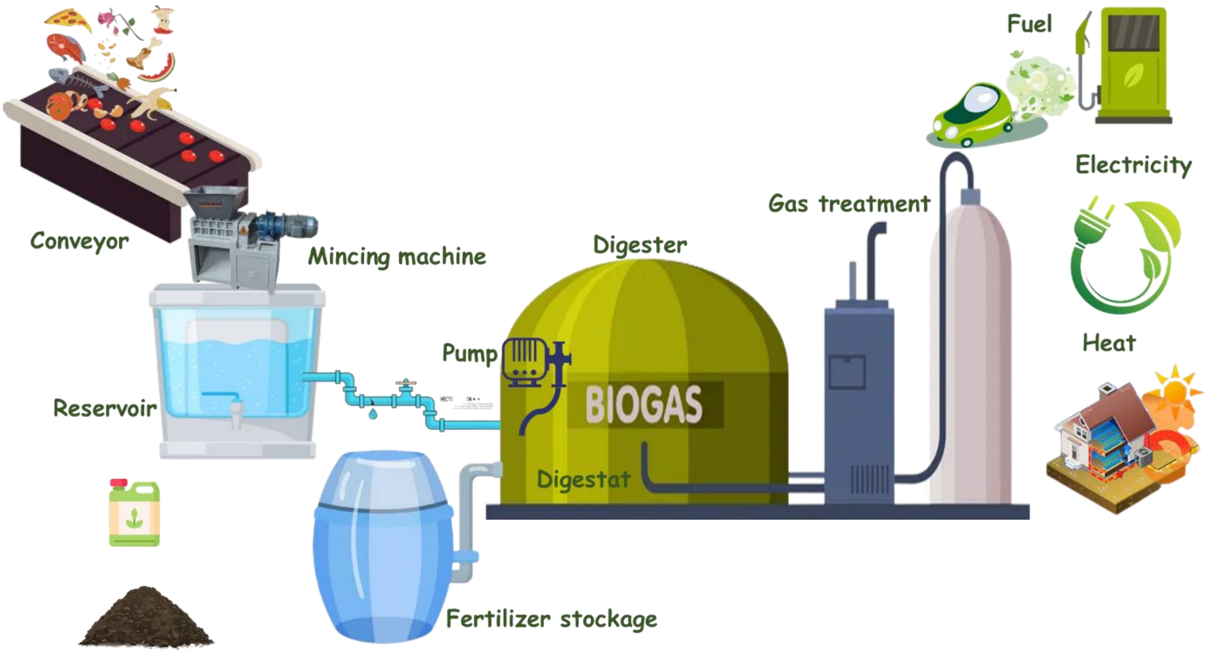
- Advantages

- Environmentally friendly
- Low energy consumption
- Low cost

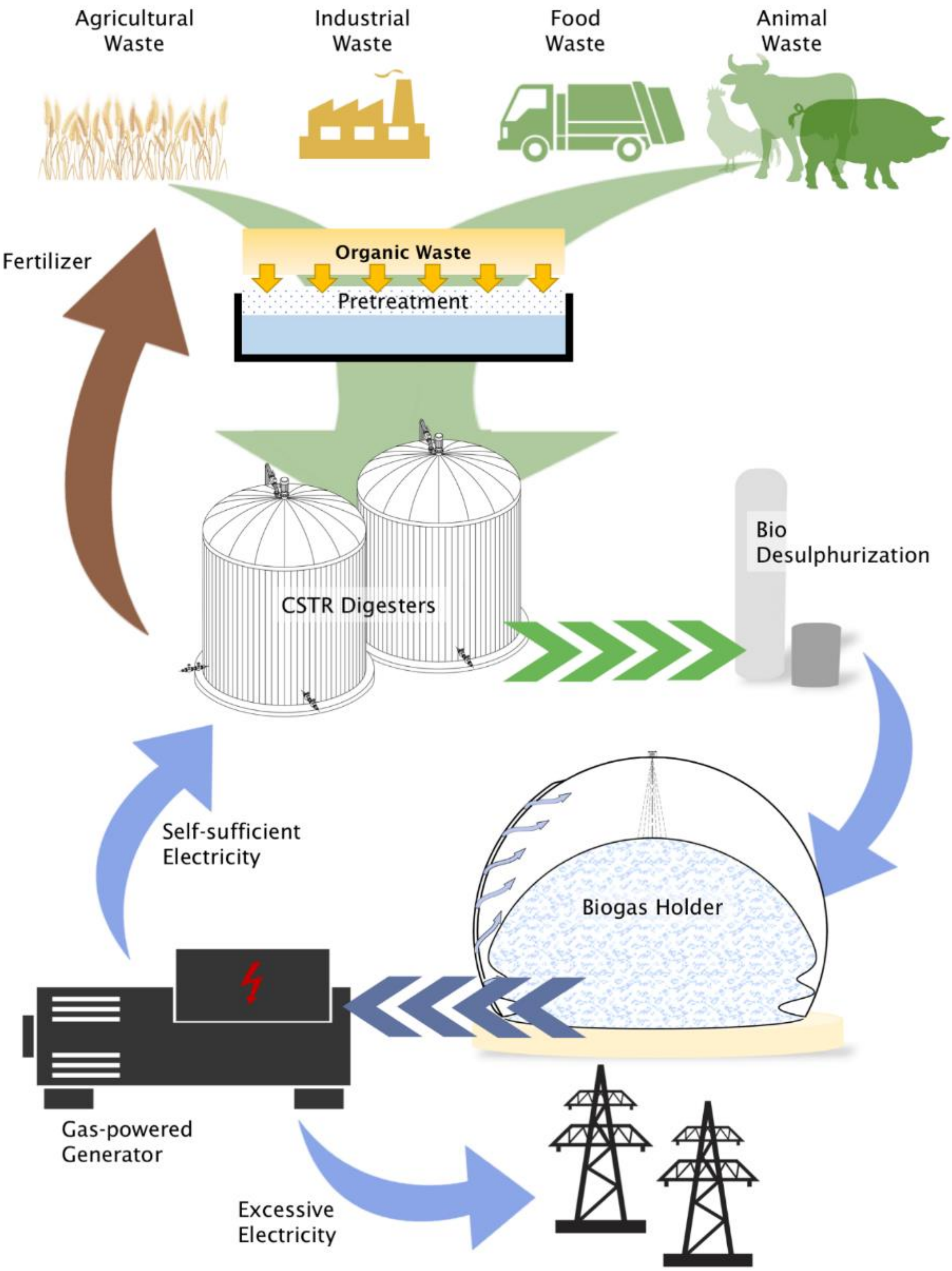
- Simple process

  - Disadvantages

- Low membrane selectivity
- Pre-treatment necessary
- Low $CH_4$ purity



## 1.3. Biogas production from municipal waste

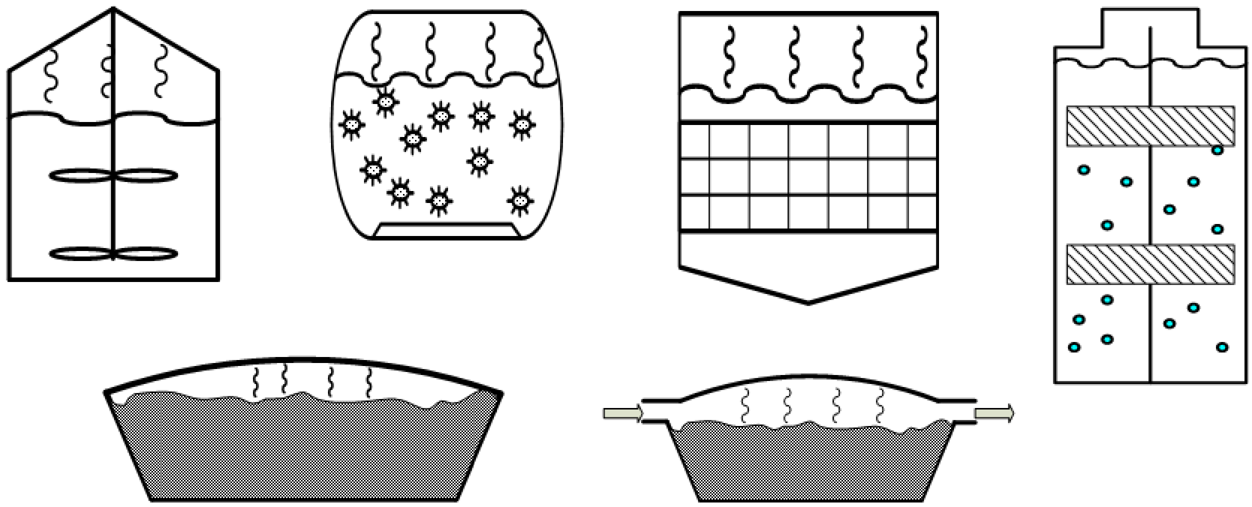



### 1.4. WET DIGESTION

The process is considered wet digestion when the content of the digester is pumpable. That means that the material inside the digester has a consistency of approximately 10% dry matter or less (90% water).

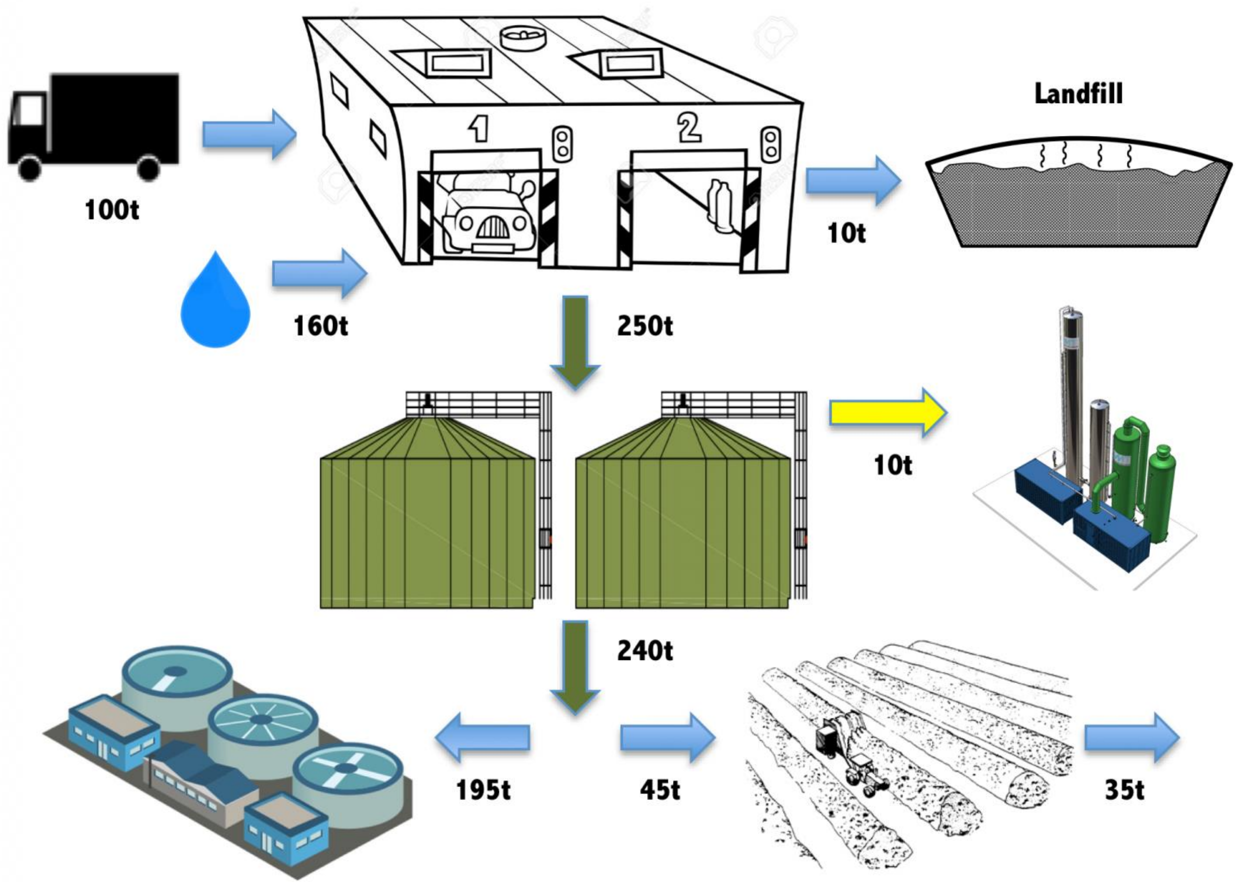
There exist many configurations of **wet digesters**:

- Complete mix or Completely stirred tank reactor (CSTR)
- Plug-flow
- Upflow Anaerobic Sludge Blanket (UASB)
- Fixed film reactor
- Floating films reactors
- Sludge bed reactors
- And more.



These configurations have been designed to optimize the process for various feedstock conditions and market applications.

The mass balance of a typical wet digestion process looks like this:




For example, 100 tons of solid municipal residential source separated organics (SSO) arrives at the biogas plant using wet digestion (complete mix). This feedstock needs to be pretreated to remove potential contaminants (plastics, metal, sands, etc.). Approximately 10 tons will be removed as contaminants and will probably be landfilled.

In order to be pumpable (10% TS), the feedstock will be diluted with water that may come from a fresh source or from a mixed of fresh and recycled water from the wastewater portion of the biogas plant. The liquid feedstock going to the digester will be approximately 250 tons.

In the digesters, the bacteria will consume the majority of the volatile solids in the feedstock and will convert them into biogas. Approximately 10 tons of gas will come out of the digesters. The more liquid digestate will represent approximately 240 tons.

At this point, the digestate may be applied to land directly. Please note that 100 tons of solid material turned into 240 tons of liquid and land applying the digestate in this form will present significant transportation costs.

The digestate may also be separated into a solid fraction (45 tons) to be land applied (or composted down to 35 tons) and a liquid fraction (195 tons) to be returned the sanitary sewage or directly back to nature.

One may be tempted to use the treated wastewater as dilution water for the input feedstock and limit the amount of water consumed and rejected by the process. It is possible only if the wastewater plant removes almost all nutrients (salts and ammonia/ammonium) in the water. Without this removal, there will be a rapid buildup of nutrients in the water and this will inhibit and/or kill the anaerobic digestion process.

The digester must meet the following requirements:

**Requirements**

No matter which design is chosen, the digester (fermentation tank) must meet the following requirements:

• **Water/gas-tightness** - watertightness in order to prevent seepage and the resultant threat to soil and groundwater quality; gas-tightness in order to ensure proper containment of the entire biogas yield and to prevent air entering into the digester (which could result in the formation of an explosive mixture).

• **Insulation** - if and to which extent depends on the required process temperature, the local climate and the financial means; heat loss should be minimized if outside temperatures are low, warming up of the digester should be facilitated when outside temperatures are high.

• **Minimum surface area** - keeps cost of construction to a minimum and reduces heat losses through the vessel walls. A spherical structure has the best ratio of volume and surface area. For practical construction, a hemispherical construction with a conical floor is close to the optimum.

• **Structural stability** - sufficient to withstand all static and dynamic loads, durable and resistant to corrosion.]

بغض النظر عن التصميم الذي يتم اختياره ، يجب أن يفي الهاضم (خزان التخمير) بالمتطلبات التالية:

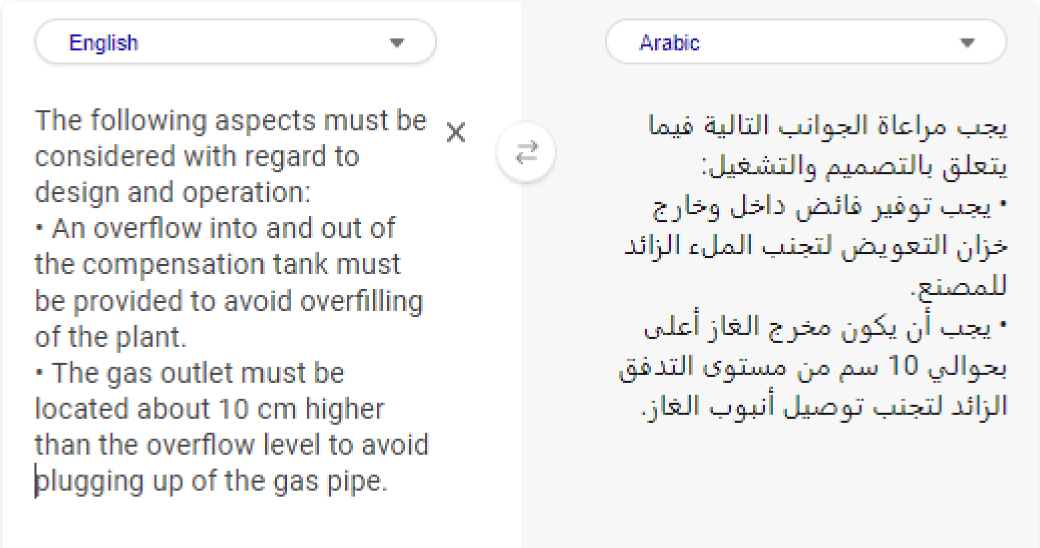
● **المياه / النفاذية** - مقاومة الماء من أجل منع التسرب وما ينتج عن ذلك من تهديد لنوعية التربة والمياه الجوفية ؛ مقاومة النفاذية من أجل ضمان الاحتواء المناسب لكامل محصول الغاز الحيوي ولمنع دخول الهواء إلى الهاضم (مما قد يؤدي إلى تكوين خليط متفجر).

● **العزل** - إذا كان وإلى أي مدى يعتمد على درجة حرارة العملية المطلوبة ، والمناخ المحلي والوسائل المالية ؛ يجب تقليل فقد الحرارة إلى أدنى حد إذا كانت درجات الحرارة الخارجية منخفضة ، ويجب تسهيل تسخين الهاضم عندما تكون درجات الحرارة الخارجية مرتفعة.

● **الحد الأدنى من مساحة السطح** - يحافظ على تكلفة البناء إلى أدنى حد ويقلل من فقد الحرارة عبر جدران الوعاء. يحتوي الهيكل الكروي على أفضل نسبة من حيث الحجم ومساحة السطح. بالنسبة للبناء العملي ، فإن البناء النصف كروي بأرضية مخروطية يكون قريبًا من المستوى الأمثل.

● **الاستقرار الهيكلي** - كافٍ لتحمل جميع الأحمال الساكنة والديناميكية ، ودائم ومقاوم للتآكل.

The following aspects must be taken into account in terms of design and operation (يجب مراعاة الجوانب التالية فيما يتعلق بالتصميم والتشغيل)




## 1.5. System concept / system design

### 1) Raw materials for biogas production

Although, cattle dung has been recognized as the chief raw material for bio-gas plants, other materials like night-soil, poultry litter and agricultural wastes can also be used.

### 2) Advantages of biogas production

- It is a eco-friendly fuel.
- The required raw materials for biogas production are available abundantly in villages.
- It not only produces biogas, but also gives us nutrient rich slurry that can be used for crop production.
- It prevents the health hazards of smoke in poorly ventilated rural households that use dung cake and fire-wood for cooking.
- It helps to keep the environment clean, as there would be no open heap of dung or other waste materials that attract flies, insects and infections
- Availability of biogas would reduce the use of firewood and hence trees could be saved.

### 1) Components of biogas plants

- **Mixing tank** - The feed material (dung) is collected in the mixing tank. Sufficient water is added and the material is thoroughly mixed till a homogeneous slurry is formed.

- **Inlet pipe** - The substrate is discharged into the digester through the inlet pipe/tank.
- **Digester** - The slurry is fermented inside the digester and biogas is produced through bacterial action.
- **Gas holder or gas storage dome** - The biogas gets collected in the gas holder, which holds the gas until the time of consumption.
- **Outlet pipe -** The digested slurry is discharged into the outlet tank either through the outlet pipe or the opening provided in the digester.
- **Gas pipeline -** The gas pipeline carries the gas to the point of utilization, such as a stove or lamp.

**2) Points to be considered for construction of a biogas plant**

**a) Site selection**

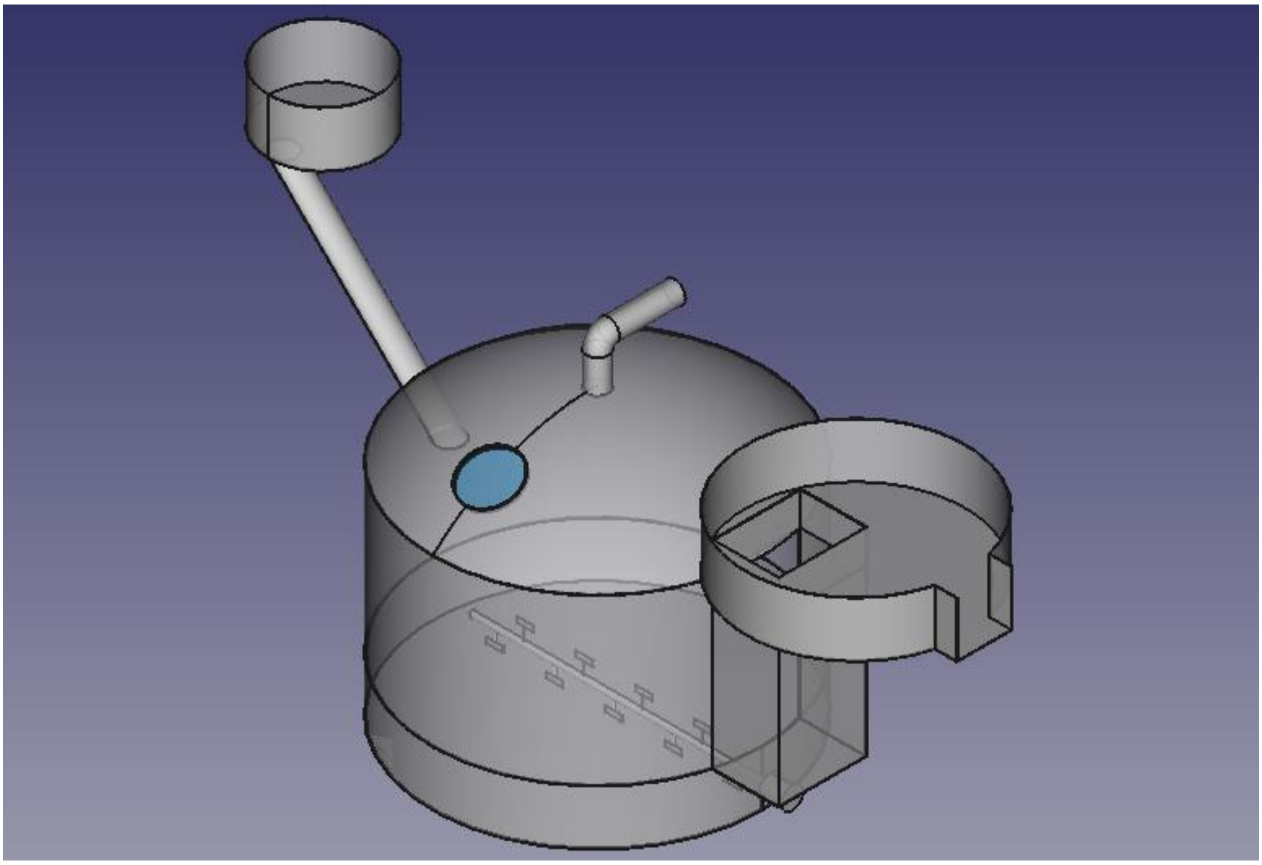
- While selecting a site for a biogas plant, following aspects should be considered
- The land should be levelled and at a higher elevation than the surroundings to avoid water stagnation
- Soil should not be too loose and should have a bearing strength of 2 $kg/cm^2$
- It should be nearer to the intended place of gas use (eg. home or farm).
- It should also be nearer to the cattle shed/ stable for easy handling of raw materials.
- The water table should not be very high.
- Adequate supply of water should be there at the plant site. The plant should get clear sunshine during most part of the day.
- The plant site should be well ventilated.
- A minimum distance of 1.5m should be kept between the plant and any wall or foundation.
- It should be away from any tree to prevent root interference.
- It should be at least 15m away from any well used for drinking water purpose.

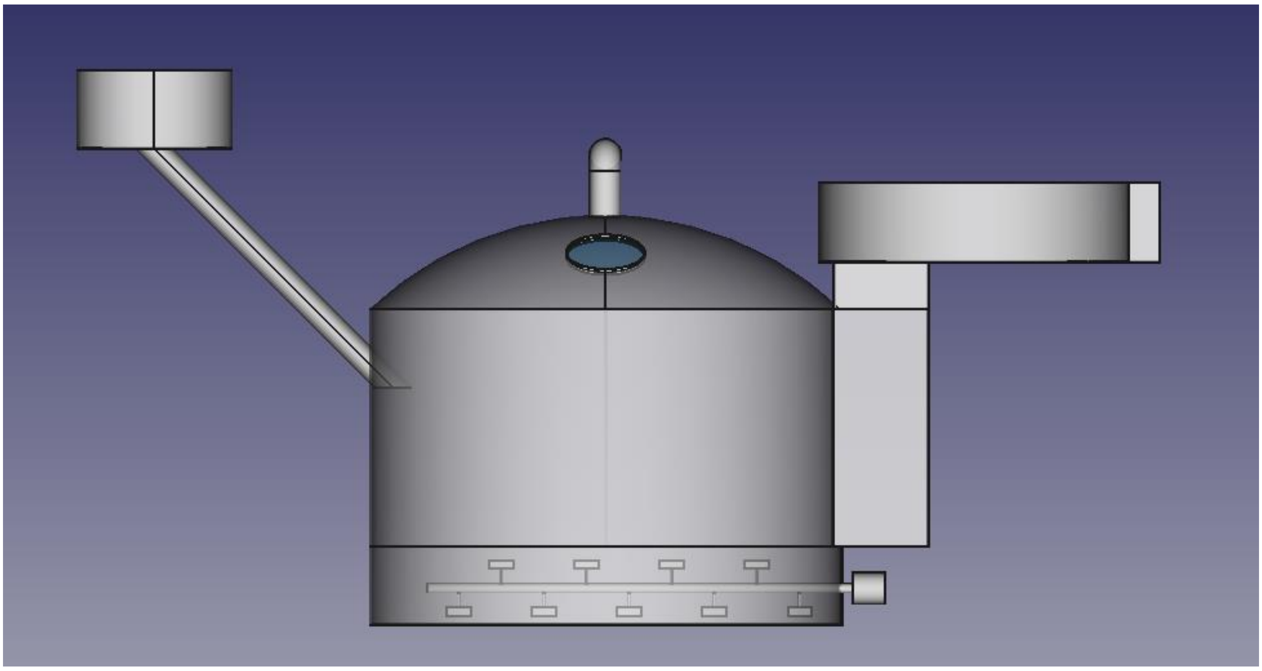
**b) Availability of raw materials**

The size of the biogas plant is to be decided based on availability of raw material.

## 1.6. 18.10.2022 – Proposal FreeCAD design

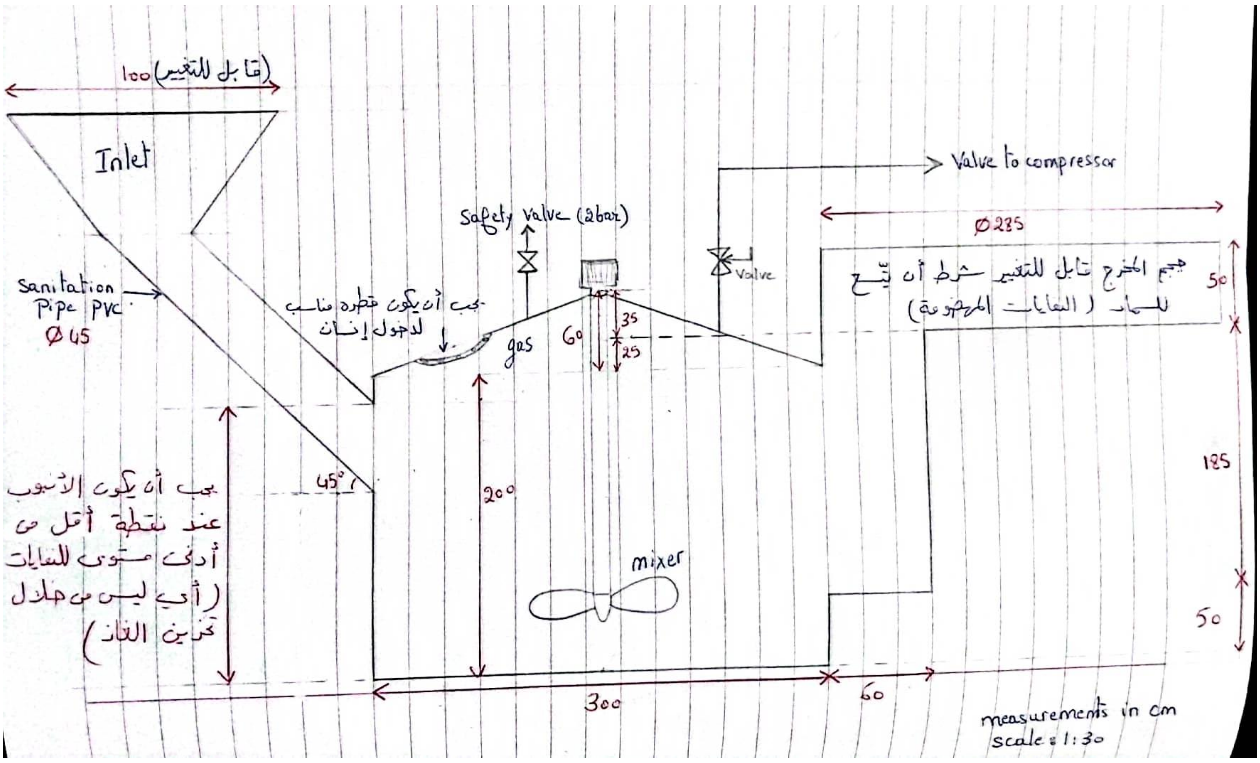
18102022_Biogas plant prototype des



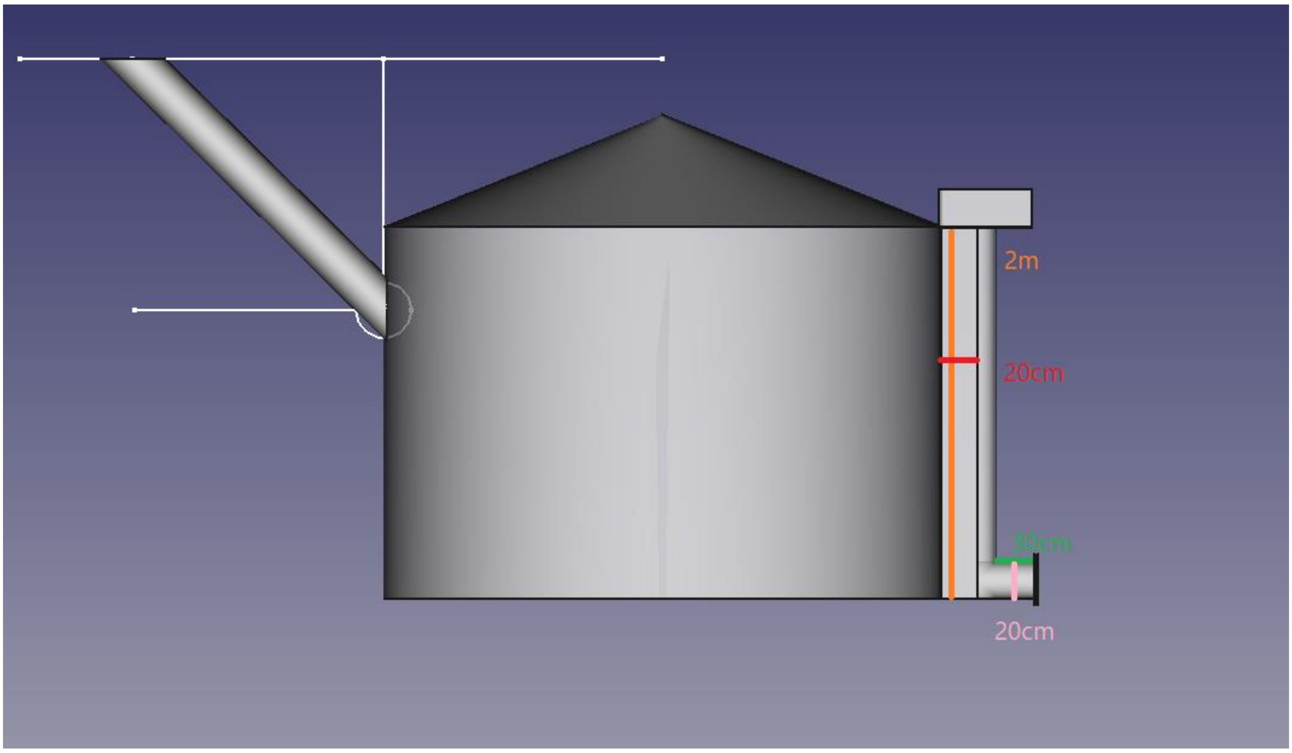


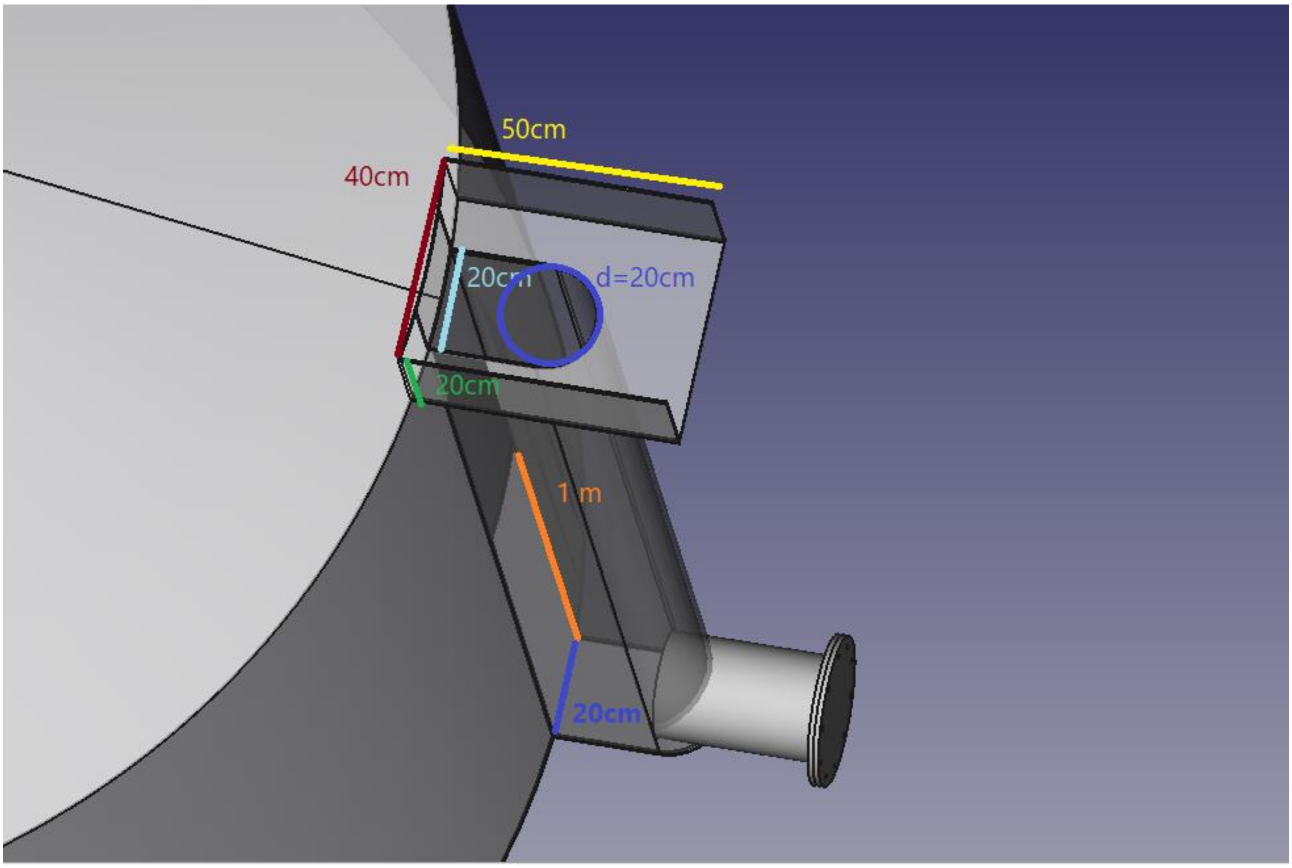
## 1.7. Design notes

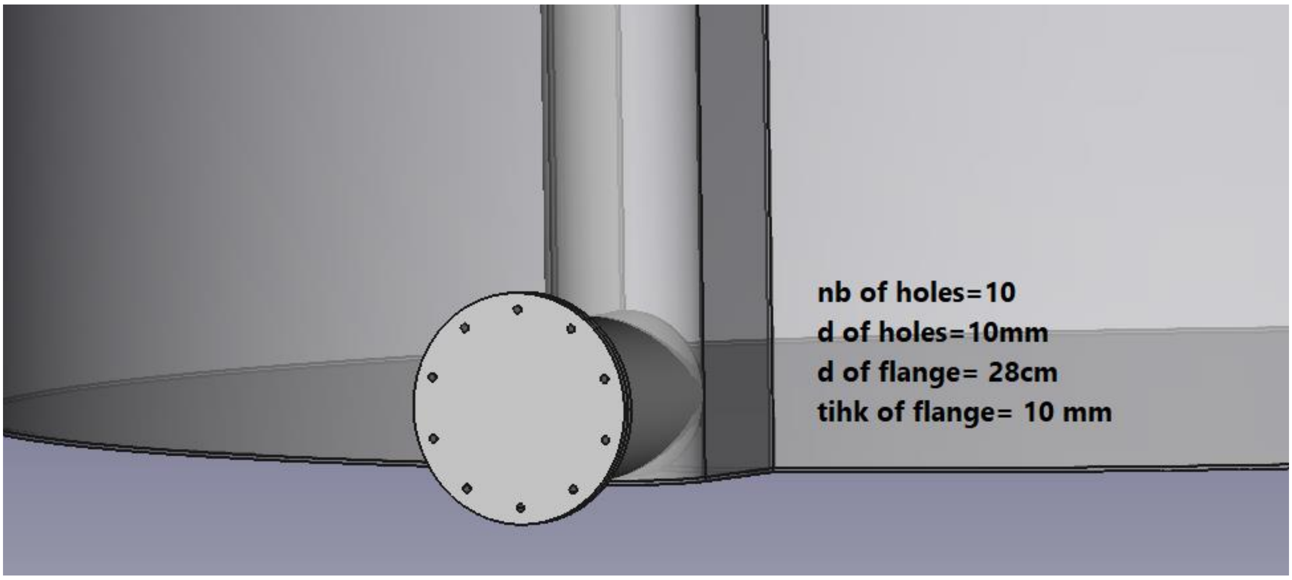
- [ ] The inlet pipe lead straight into the digester at a steep angle.
- [ ] يجب أن يخترق أنبوب المدخل جدار الهاضم عند نقطة أقل من أدنى مستوى للنفايات(أي ليس من خلال تخزين الغاز).
- [ ] يجب إغلاق نقاط الاختراق جيداً منعاً للتسرب.
- [ ] ينتهي أنبوب المدخل أعلى في الهاضم من أنبوب المخرج.
- [ ] يمكن أن يكون خزان النفايات المهضومة مفتوحاً أو مغلقاً و متصلاً بحامل الغاز لالتقاط إنتاج الغاز المتبقي.
- [ ] يمكن تجنب مشاكل التآكل إذا تم استخدام خزان من stainless-steel. سمك اللوح لخزان الغاز الحيوي أقل من 5mm.
- [ ] يمكن تشغيل النظام ذاتياً من خلال عملية الهضم الطاردة للحرارة( the exothermic digestion process )، على الرغم من أنه عادة ما يتم توفير حرارة إضافية عن طريق حرق بعض الغاز الحيوي.
- [ ] يتم تحسين الهضم عن طريق الحفاظ على درجة الحرارة عند حوالي 40 درجة مئوية، و مستوى PH بين 5.5 و 8.5.
- [ ] يمكن أن يساعد الموقع المشمس في تدفئة المحتويات قبل إدخالها في الهاضم لتجنب الصدمة الحرارية بسبب مياه الخلط الباردة.
- [ ] يؤدي تشغيل أنظمة الهضم اللاهوائي ذات الحالة الصلبة في الظروف المحبة للحرارة(thermophilic conditions) (55-65°C) إلى تسريع عملية الهضم اللاهوائي و توفير فائدة إضافية تتمثل في زيادة قتل مسببات الأمراض خلال مرحلة اللاهوائية.
- [ ] the digestion process will stabilize more quickly if the slurry is agitated frequently and intensively. Only if the process shows extreme resistance to stabilisation should lime be added in order to balance the PH value.
- [ ] No additional biomass should be put into the biogas plant during the remainder of the starting phase.
- [ ] Optimum stirring substantially reduces the retention time. If agitation is excessive, the bacteria have "no time to eat". The ideal is gentle but intensive stirring about every four hours.
- [ ] يجب أن يتكون الملء الأولي لمصنع جديد للغاز الحيوي، إن أمكن، إما من ملاط مهضوم من مصنع آخر أو روث الماشية.
- [ ] عمر و كمية المدخلات لها تأثير كبير على مسار التخمير. من المستحسن البدء في جمع روث الماشية خلال مرحلة البناء من أجل الحصول على ما يكفي بحلول الوقت الذي يتم فيه الانتهاء من المصنع.
- [ ] يجب تنفيس أول حشوتين من حامل الغاز دون استخدام لأسباب تتعلق بالسلامة، لأن الأكسجين المتبقي يشكل خطر الانفجار.
- [ ] عندما يتم ملء الهاضم لأول مرة، يمكن تخفيف الركيزة بماء أكثر من المعتاد للسماح بملء كامل للهاضم.

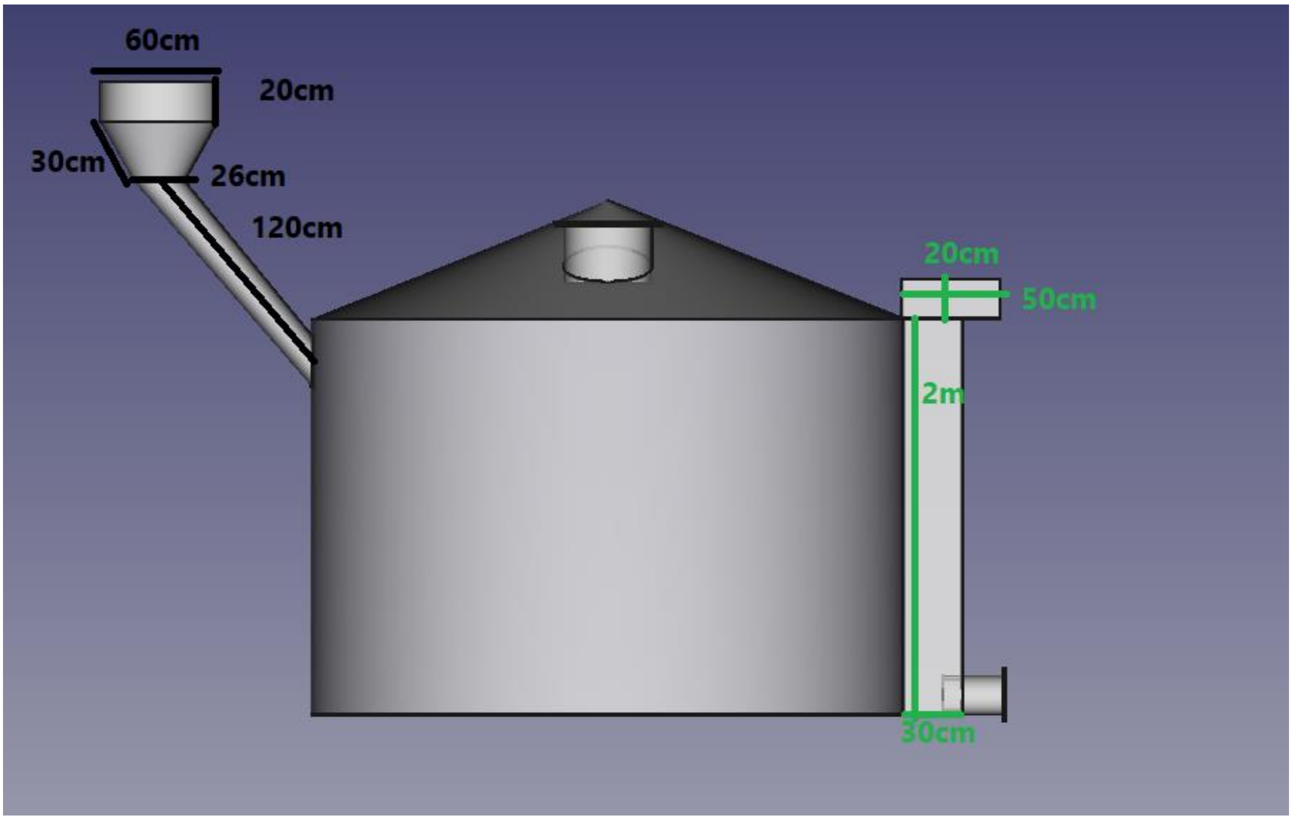


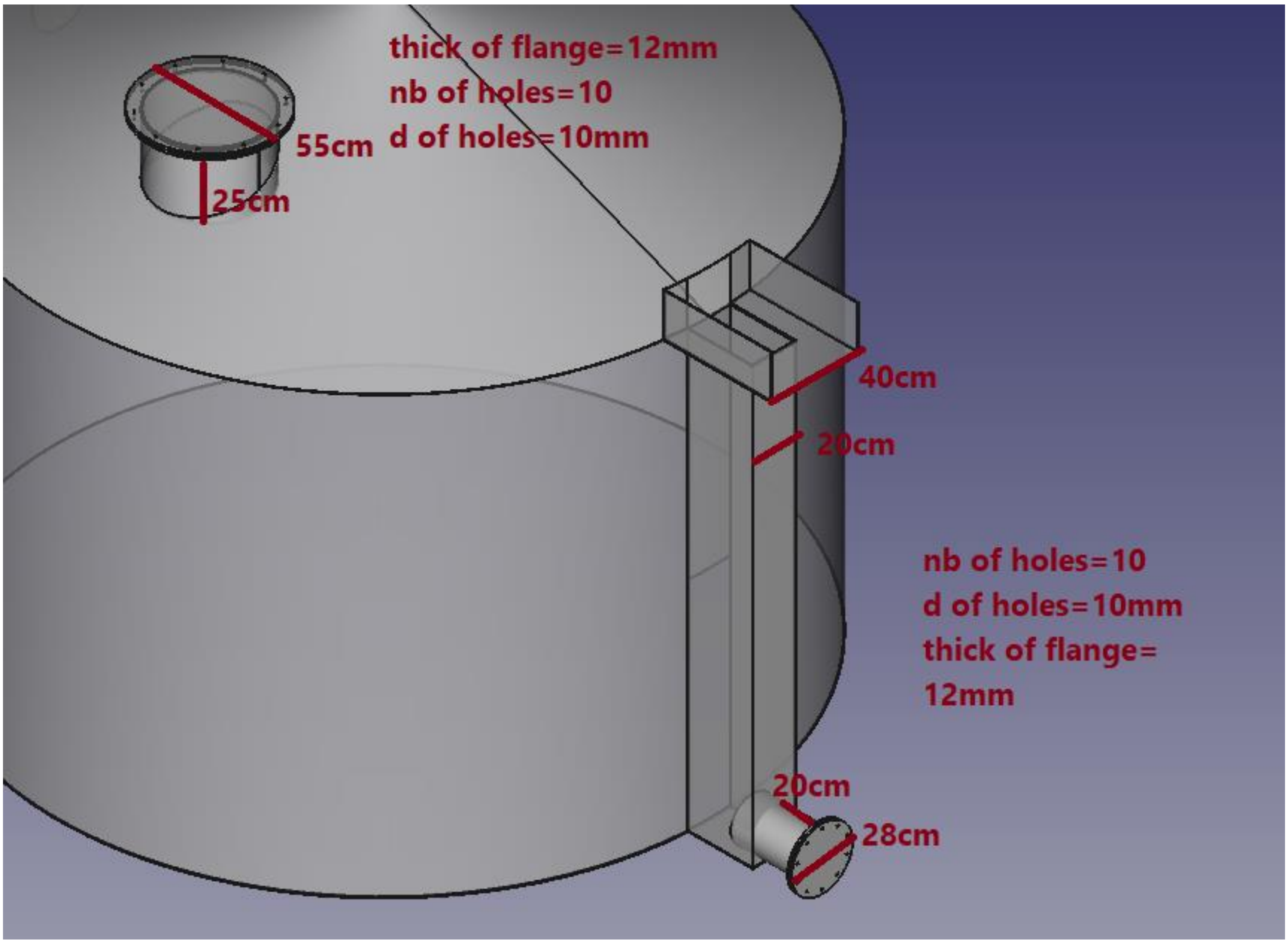

## 1.8. Update design - Version 11-12.11.22




50cm
40cm
20cm
d=20cm
20cm
1 m
20cm


nb of holes=10
d of holes=10mm
d of flange= 28cm
tihk of flange= 10 mm


60cm
20cm
30cm
26cm
120cm
20cm
50cm
2m
30cm


thick of flange=12mm
nb of holes=10
d of holes=10mm
55cm
25cm
40cm
20cm
nb of holes=10
d of holes=10mm
thick of flange=
12mm
20cm
28cm

## 1.9. Mechanical Realization

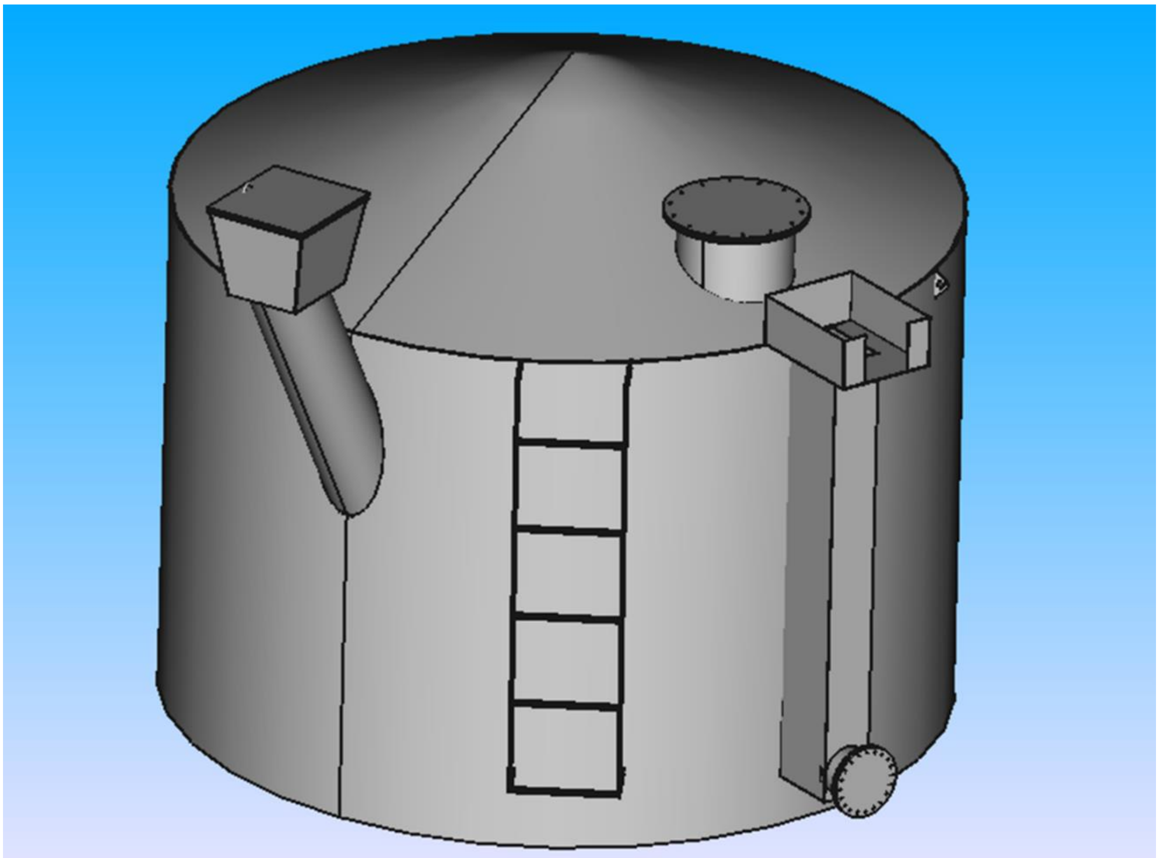
### 1) Main Fermenter

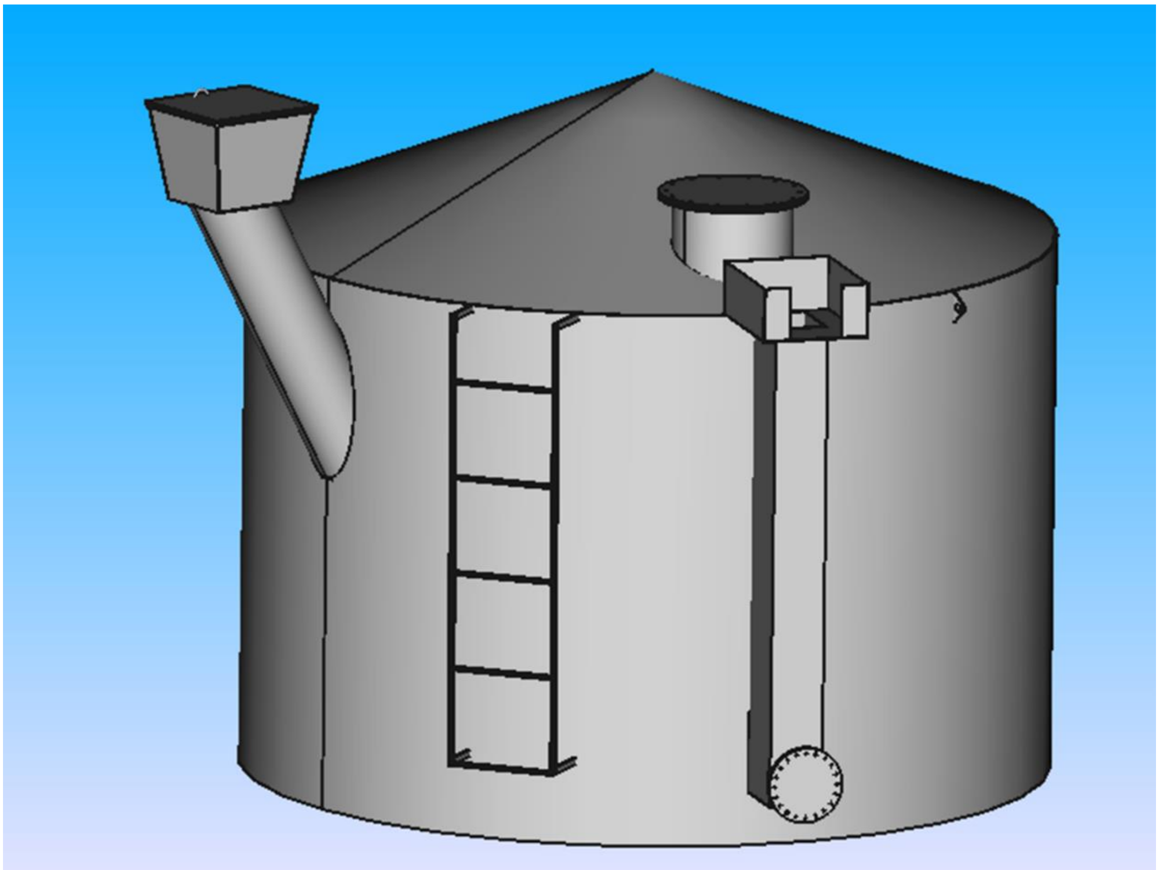
## 2) Outlet

### 3) Flanges

## 1.10. Real design

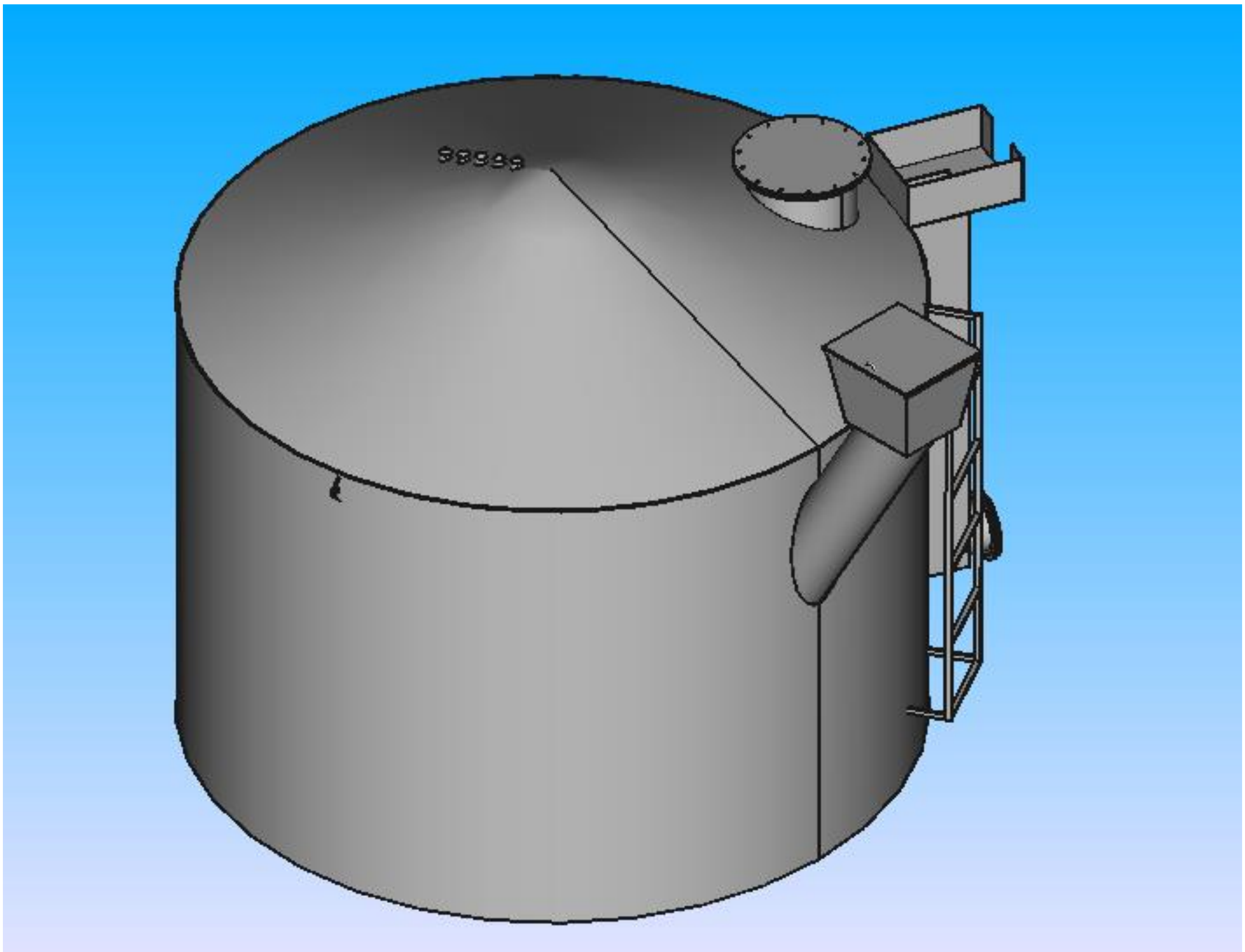
The final design of the biogas prototype

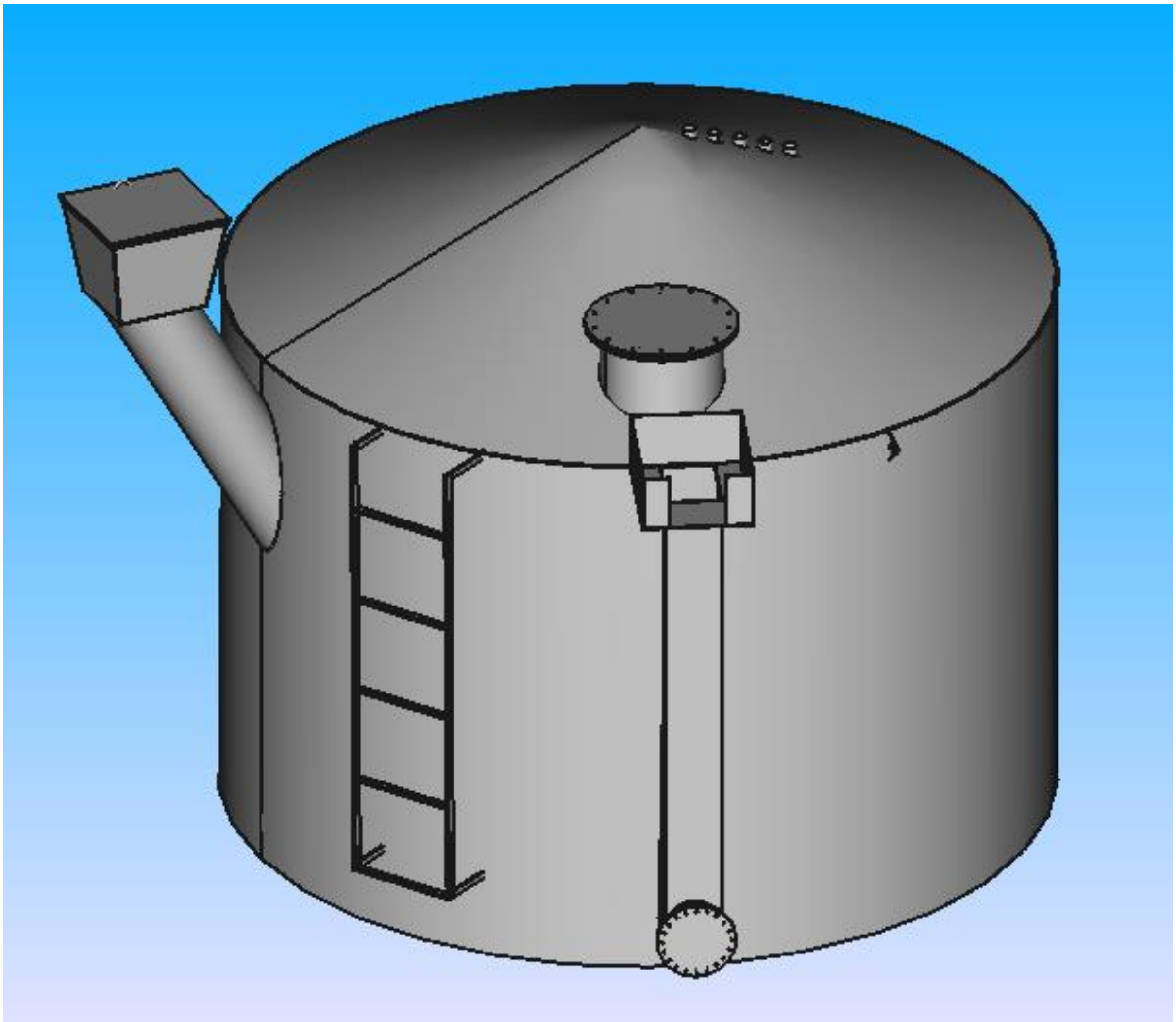




- With sensors holes:

30122022_Bio Gas FreeCAD design.FCS





## 1.11. What's next

In this project, after completing the installation of the sensors, we will start with the necessary procedures for operation.

# 2 Project 22/6: Gas Turbine for Methane gas (ICPT - GTM) (to be put into NLAP-WEDC Final Report 21-24)

## 6.1. Position of Gas turbine project

This project is divided into two parts: the fuel burner and the gas turbine. Work has been done on the fuel burner section in the past years, this year the stand was manufactured for the burner only. While the focus was on the gas turbine, the project was studied theoretically, and a preliminary design of the gas turbine was developed.

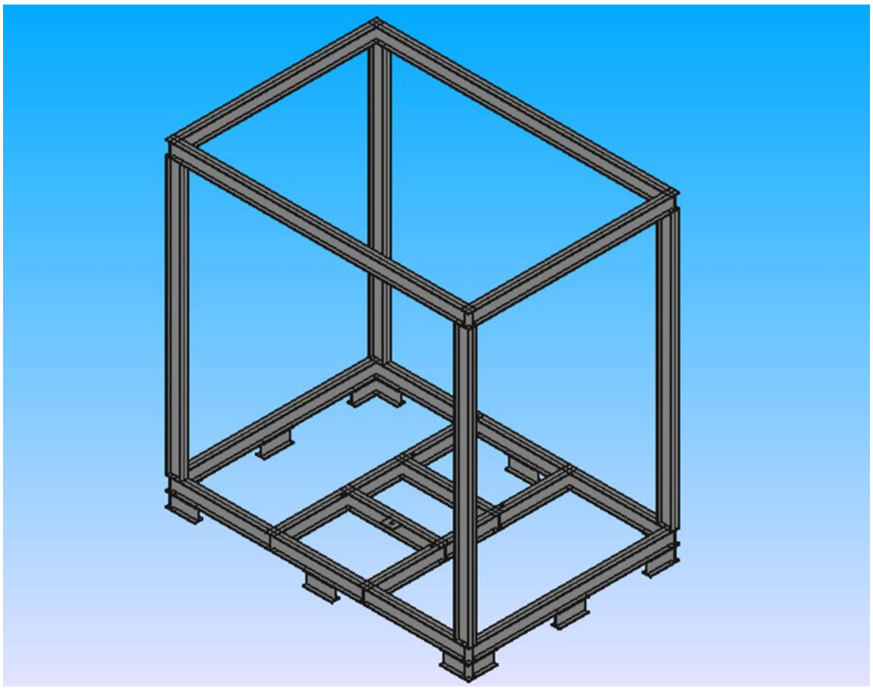
## 6.2. Relationship between gas turbine and fuel burner

The burner burns gases (hydrogen, natural gas, ...) with oxygen. At the exit of the burner, a gas turbine will be installed in order to adjust the path of the flame formed as a result of combustion. The gas turbine also seeks to regulate combustion and thus regulate the flame.

## 6.3. Fuel Burner Testrig

### 1) FreeCAD design of fuel burner stand

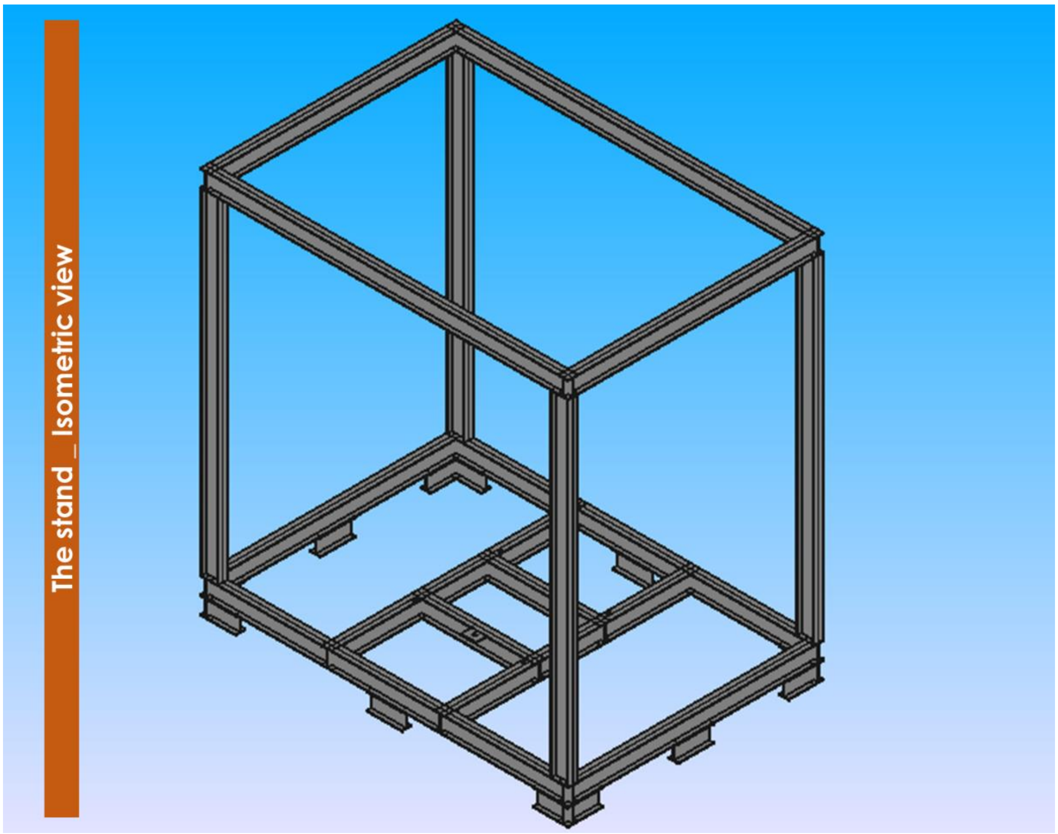
21112022_FB - stand.FCStd

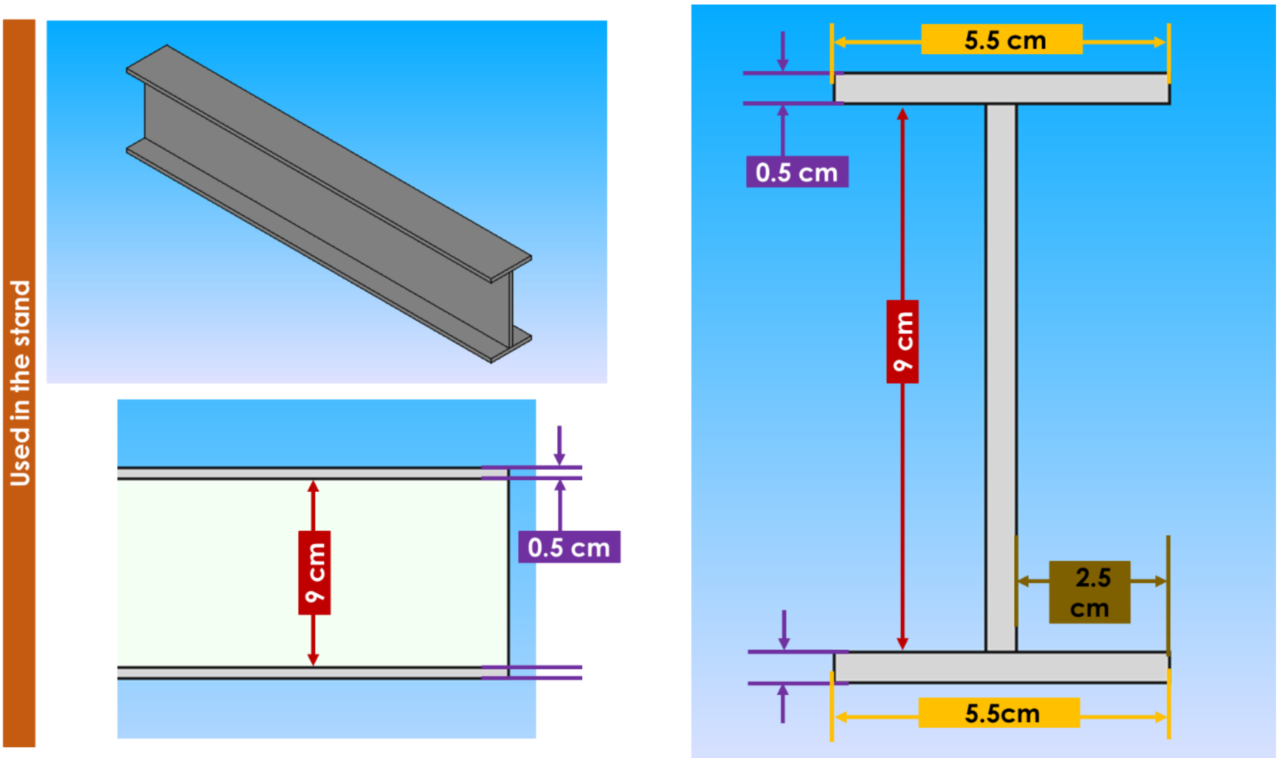


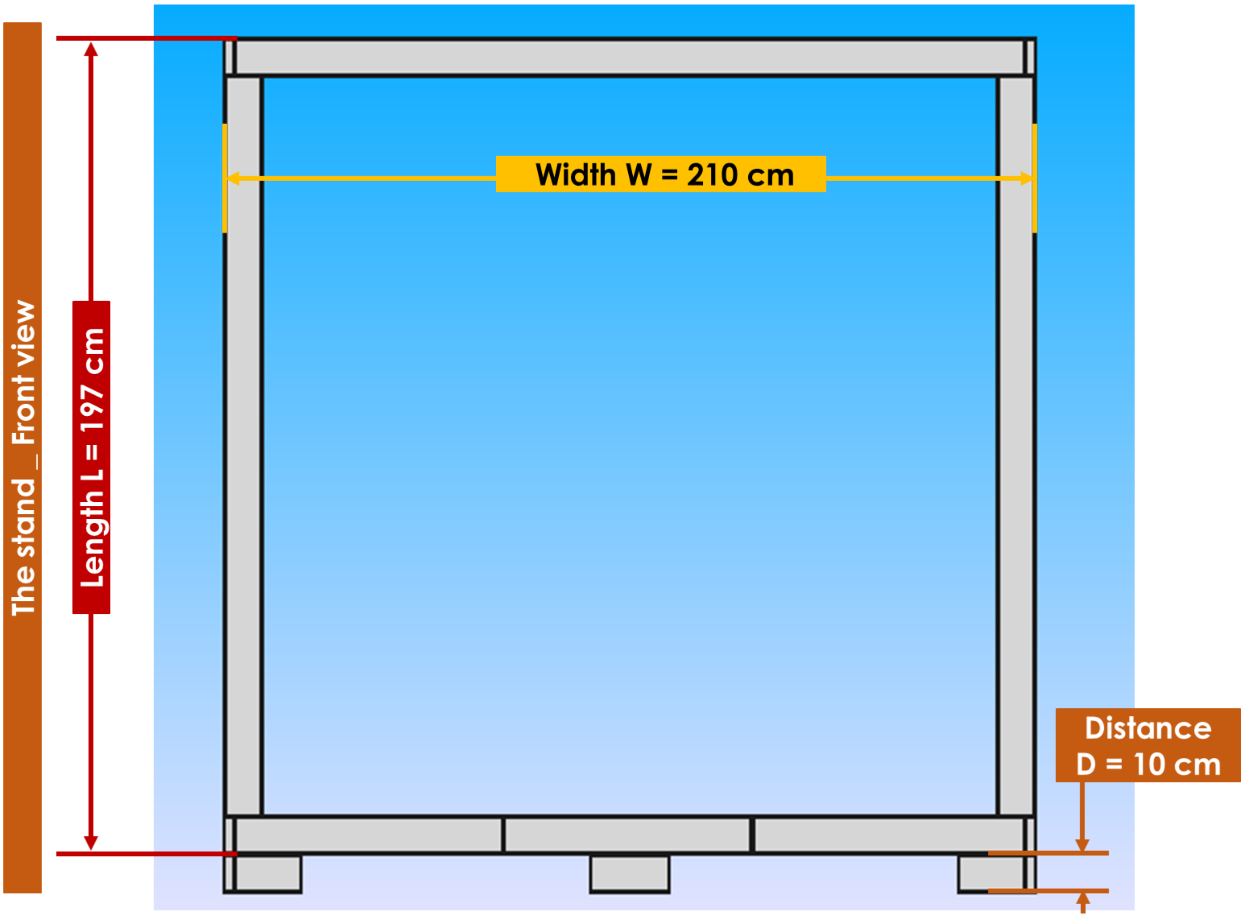
### 2) Design of fuel burner stand

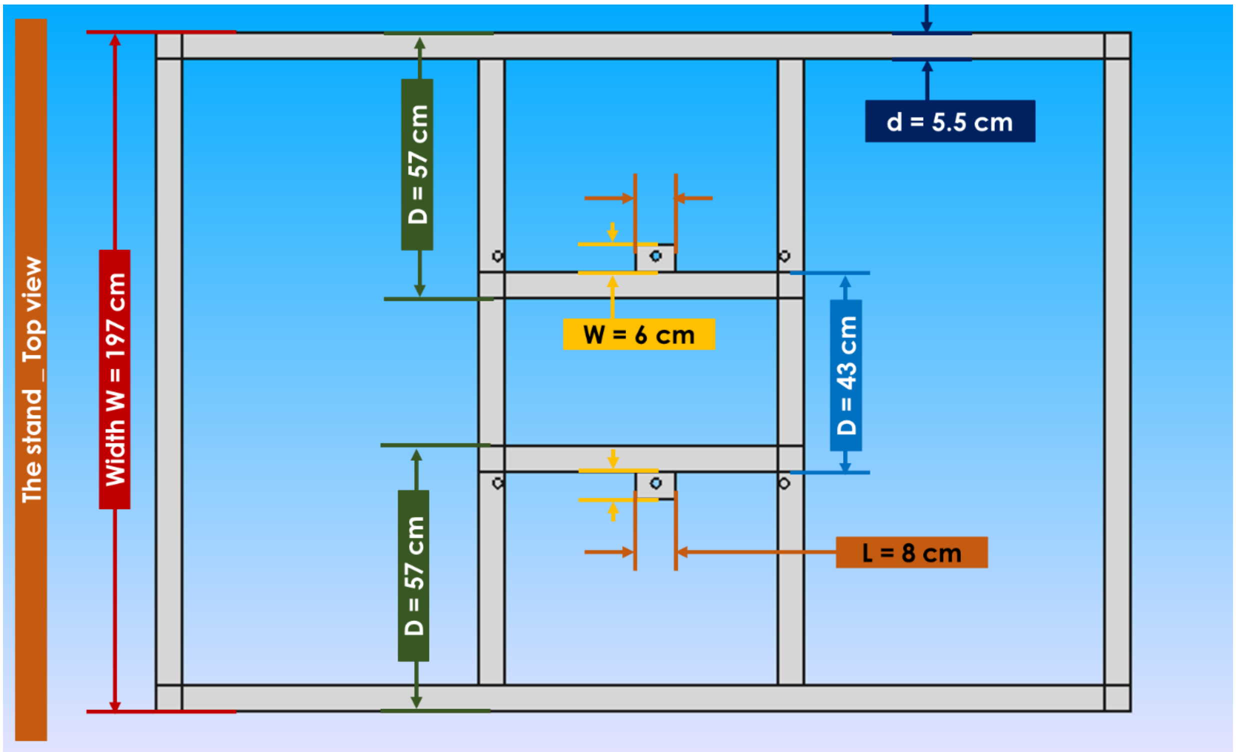
Fuel burner stand – Design and sizing (.pptx)

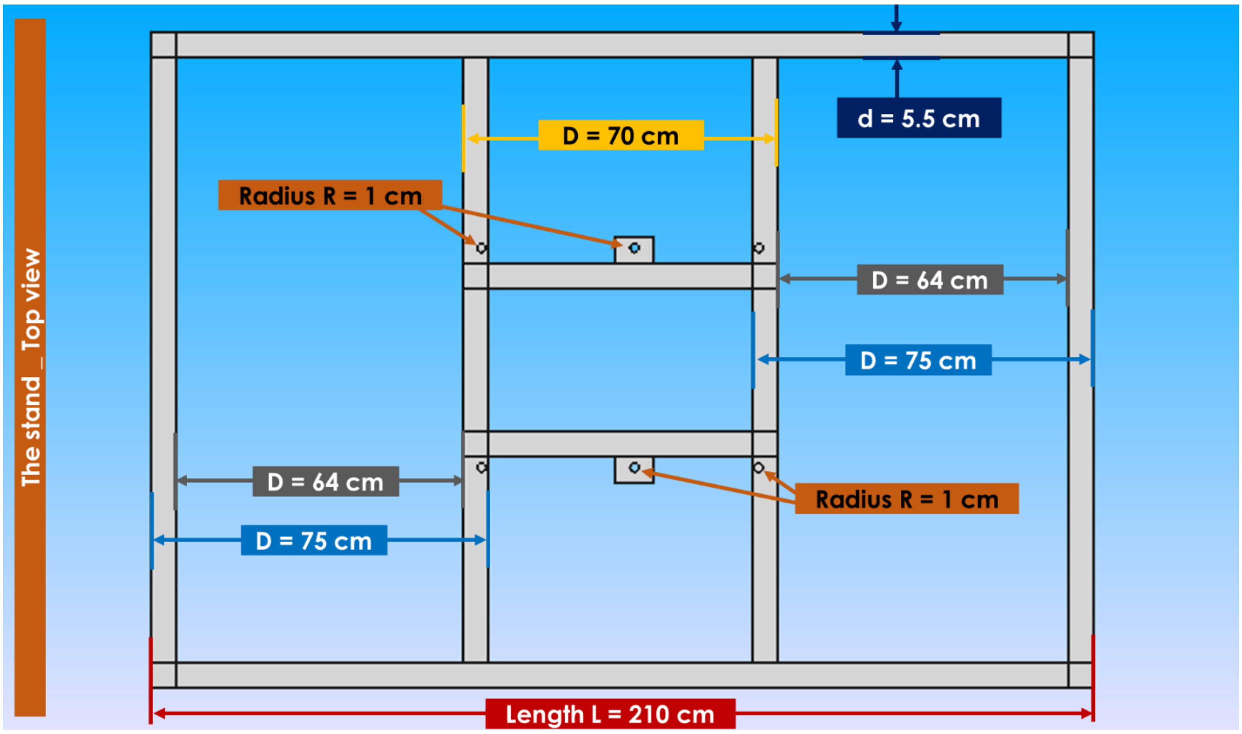
26112022_Sizing -
Fuel Burner with Sta

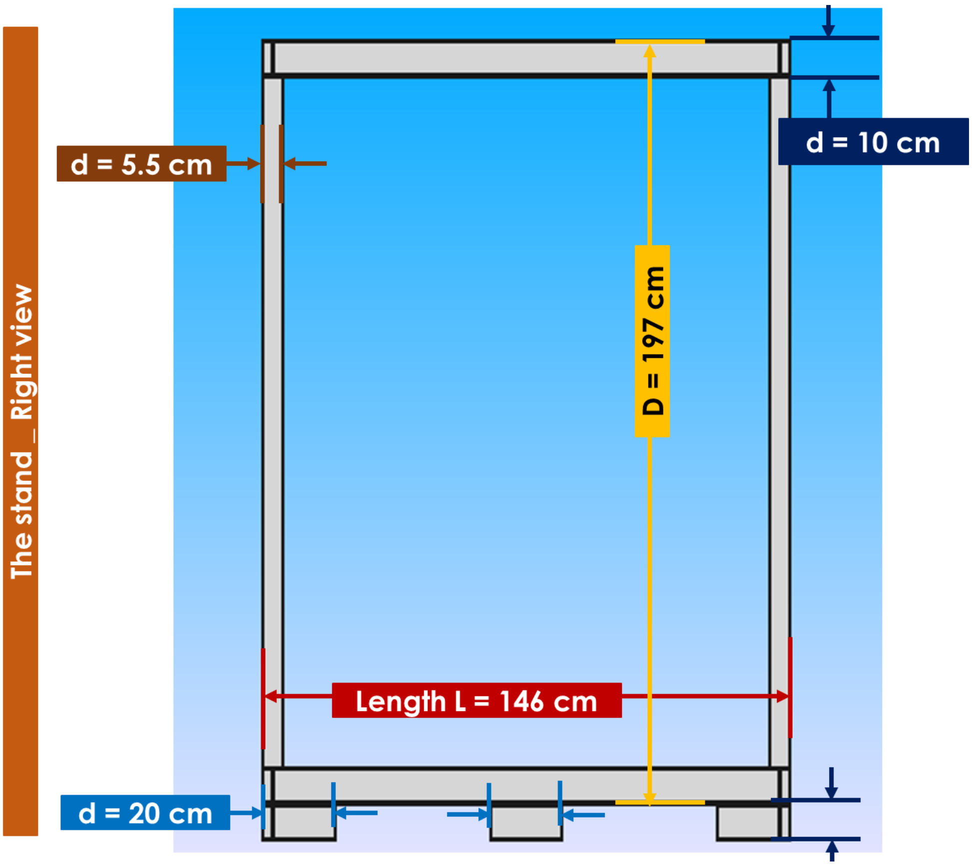


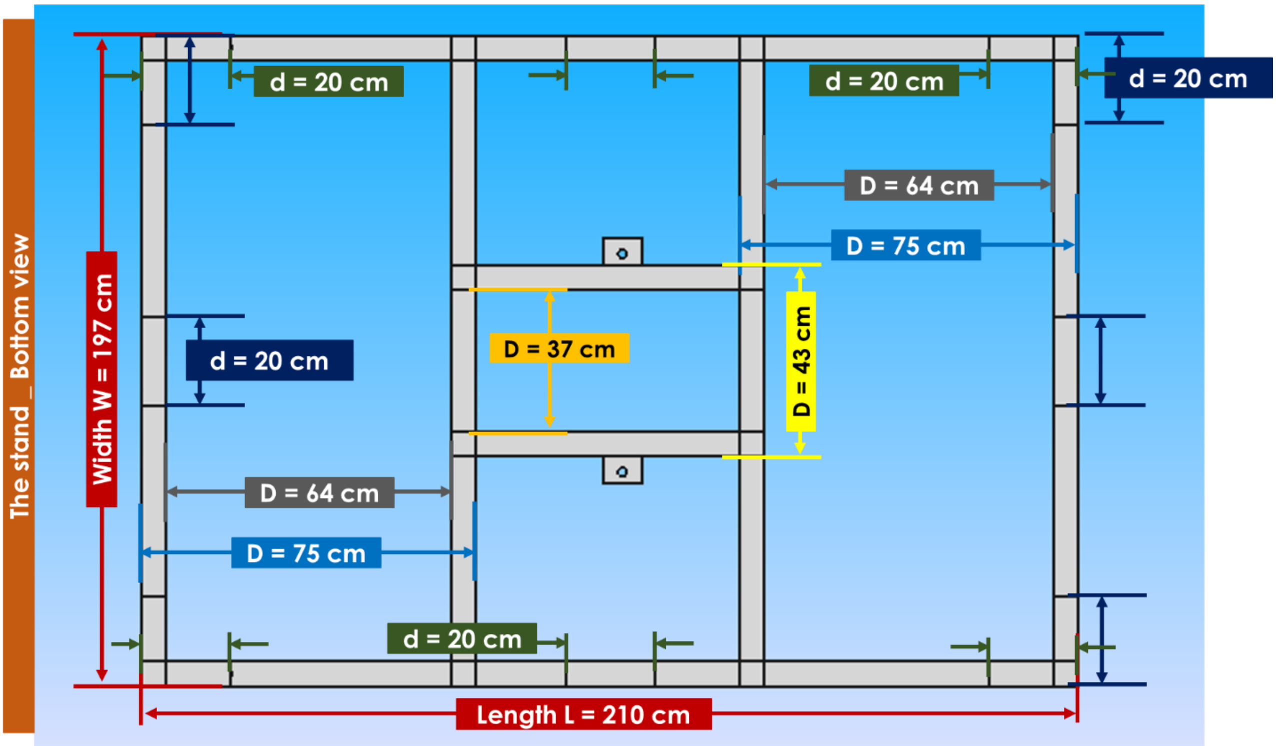



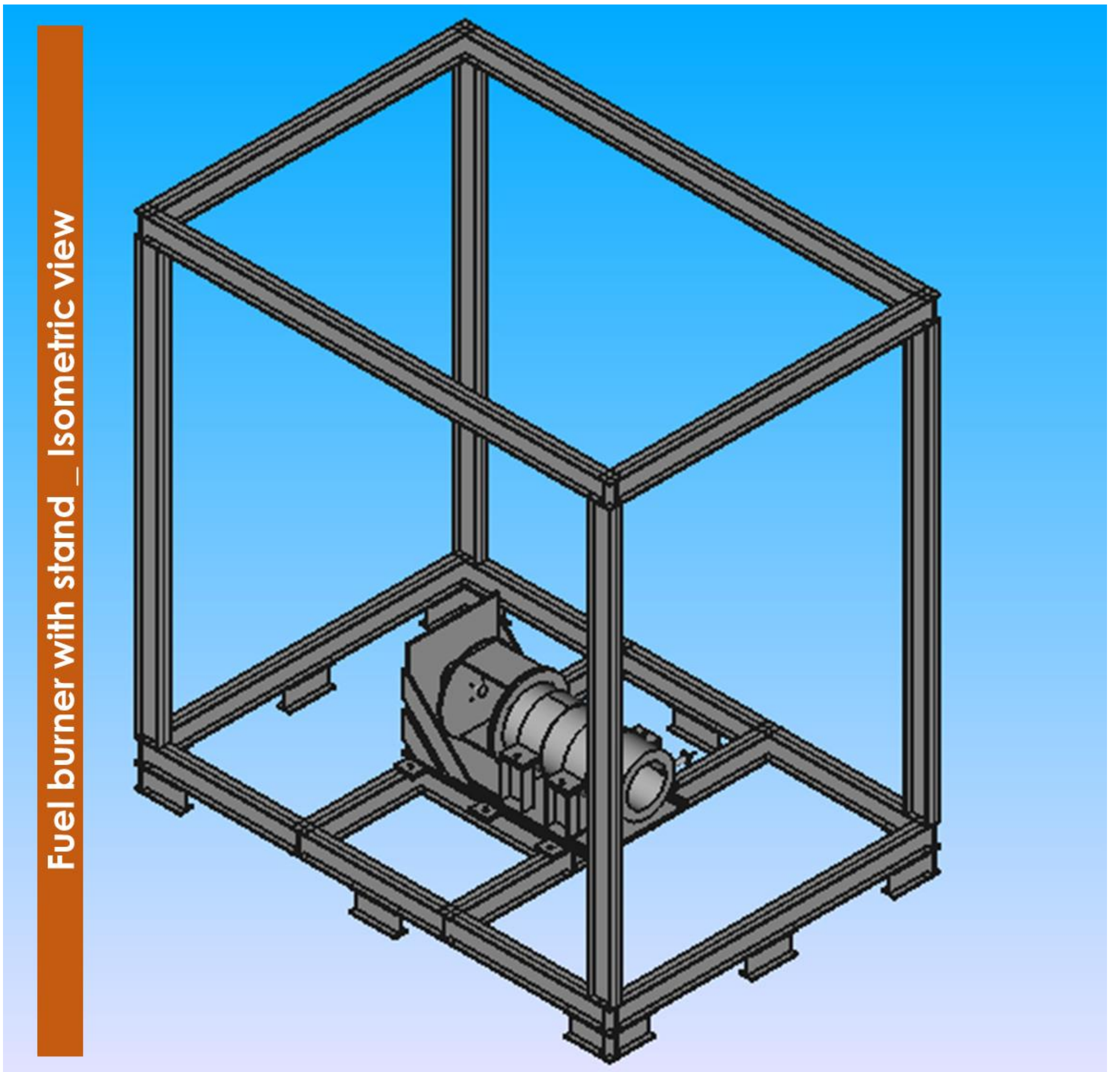

The stand _ Front view
Length L = 197 cm
Width W = 210 cm
Distance D = 10 cm


The stand _ Top view
Width W = 197 cm
D = 57 cm
d = 5.5 cm
W = 6 cm
D = 43 cm
D = 57 cm
L = 8 cm


The stand _ Top view
d = 5.5 cm
D = 70 cm
Radius R = 1 cm
D = 64 cm
D = 75 cm
D = 64 cm
Radius R = 1 cm
D = 75 cm
Length L = 210 cm

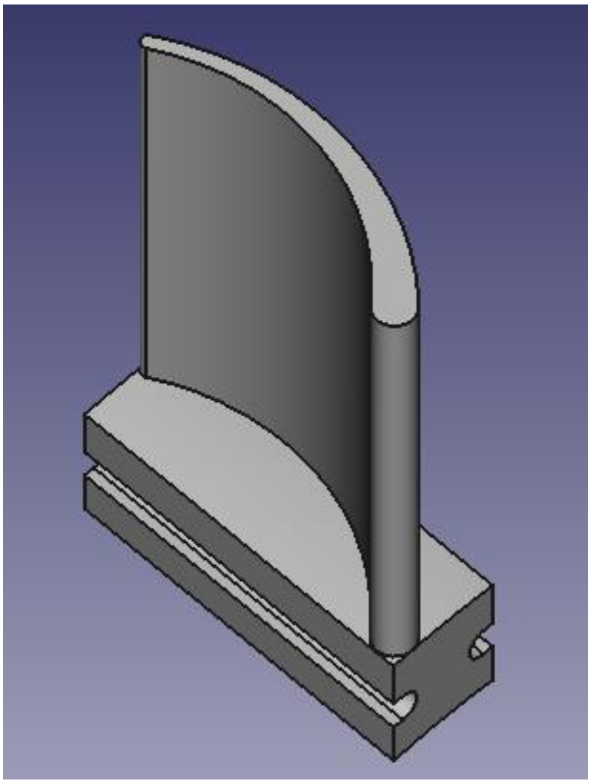

The stand _ Right view
d = 10 cm
d = 5.5 cm
D = 197 cm
Length L = 146 cm
d = 20 cm


The stand _ Bottom view
Width W = 197 cm
Length L = 210 cm
d = 20 cm
d = 20 cm
d = 20 cm
d = 20 cm
d = 20 cm
D = 64 cm
D = 75 cm
D = 37 cm
D = 43 cm
D = 64 cm
D = 75 cm

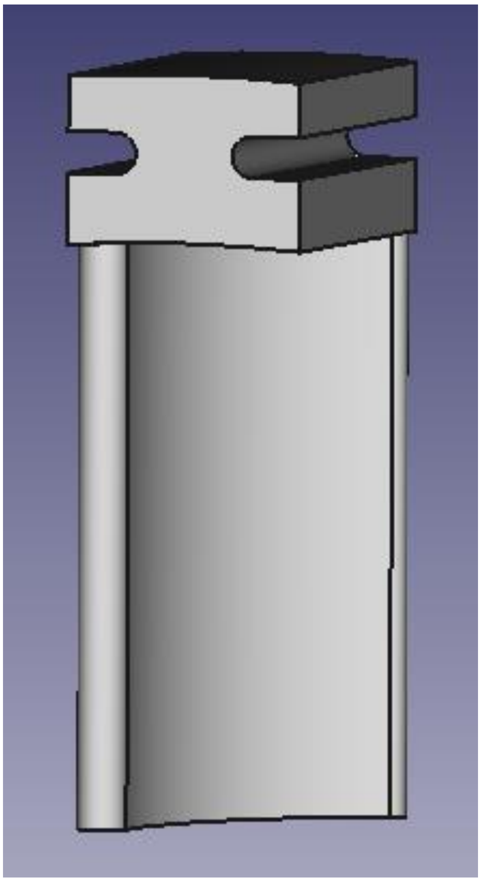

Fuel burner with stand _ Isometric view


## 6.4. Gas turbine pieces

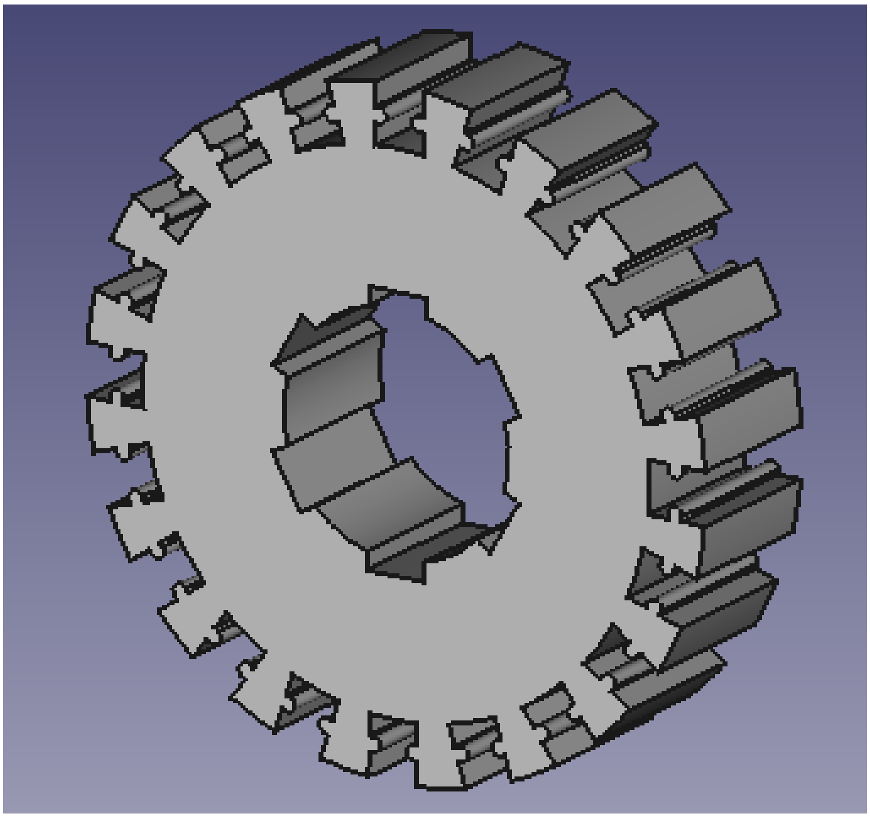
1) **Moving blade piece**



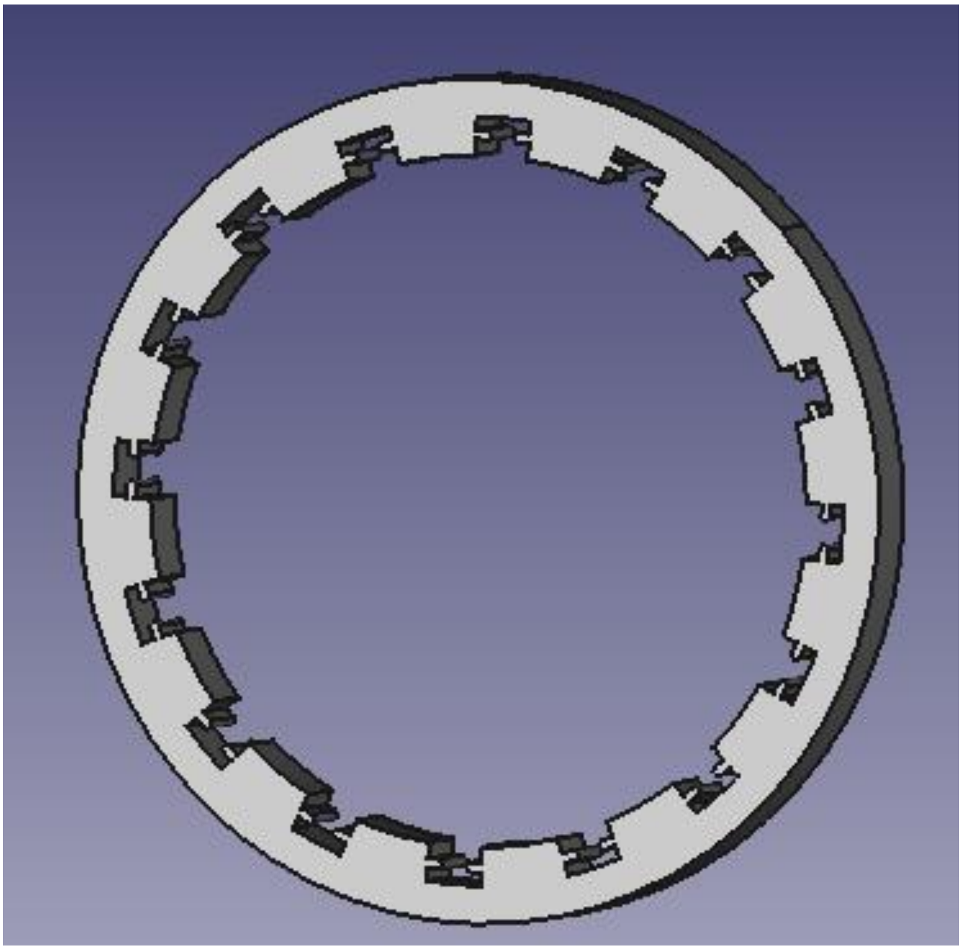
2) **Stator blade piece**



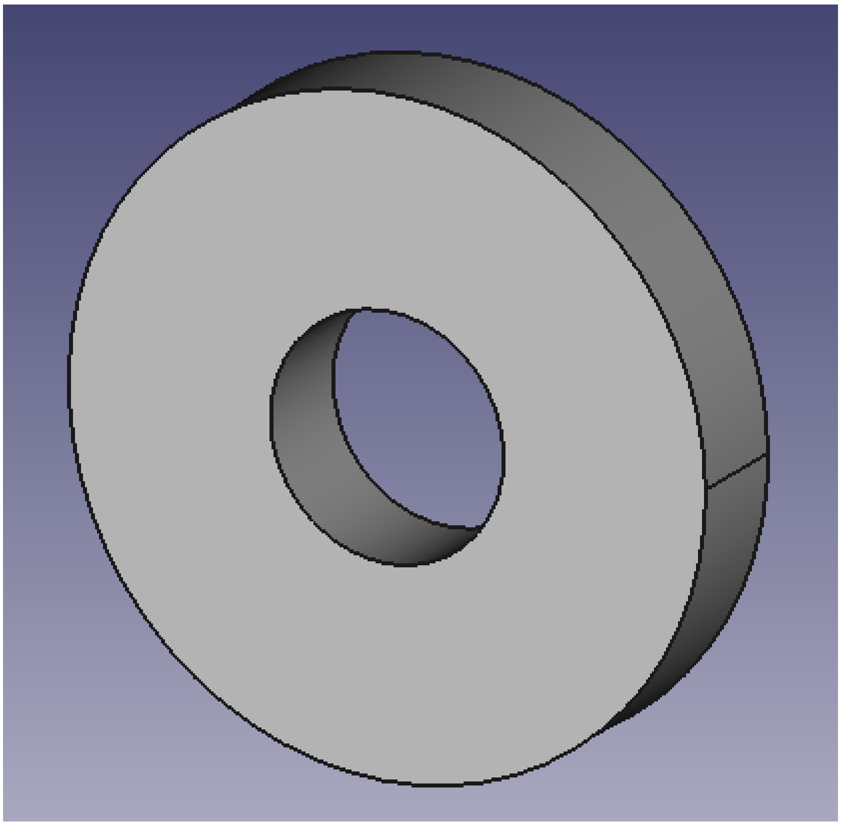
3) **Moving blade holder**



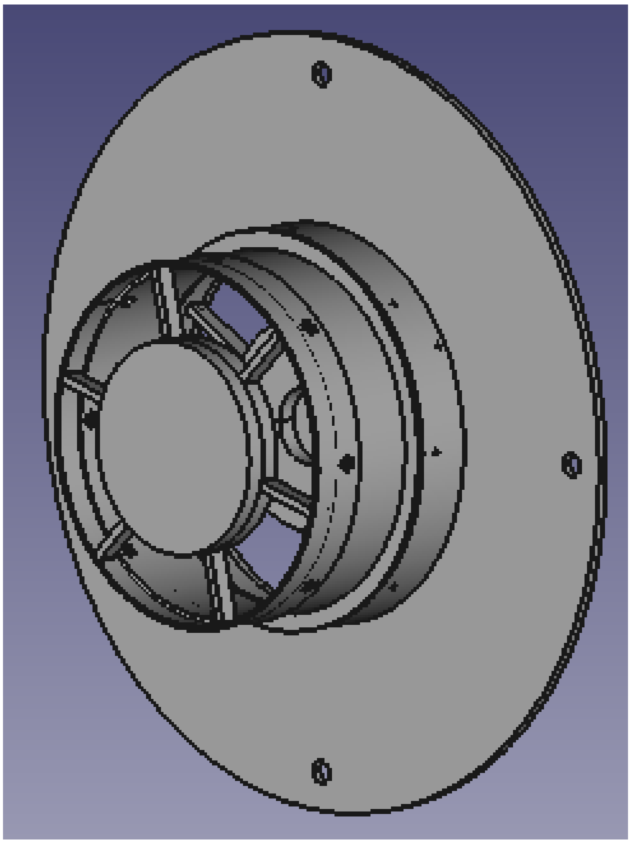
4) **Stator blade holder**



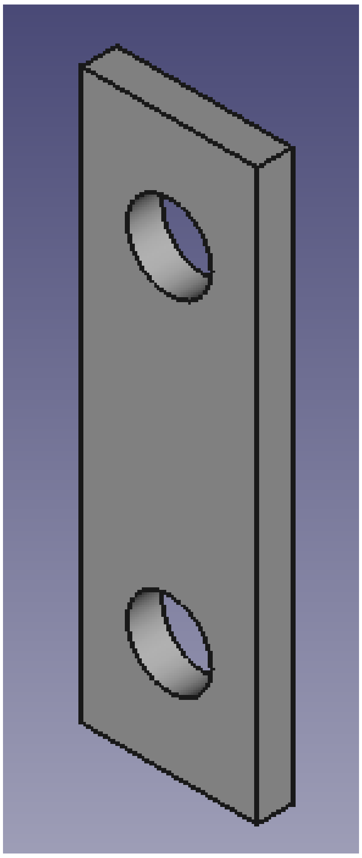
5) **Spacer ring**



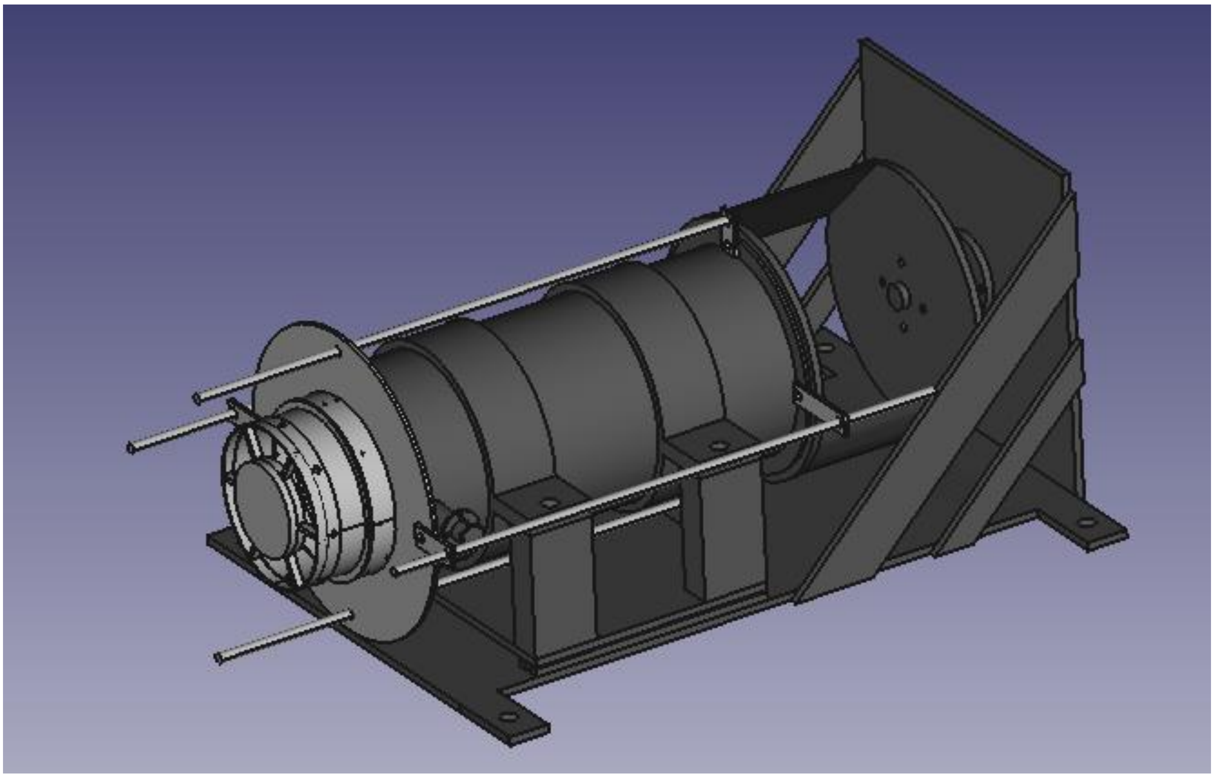
**6) <u>Cover</u>**



**7) <u>Bridge</u>**



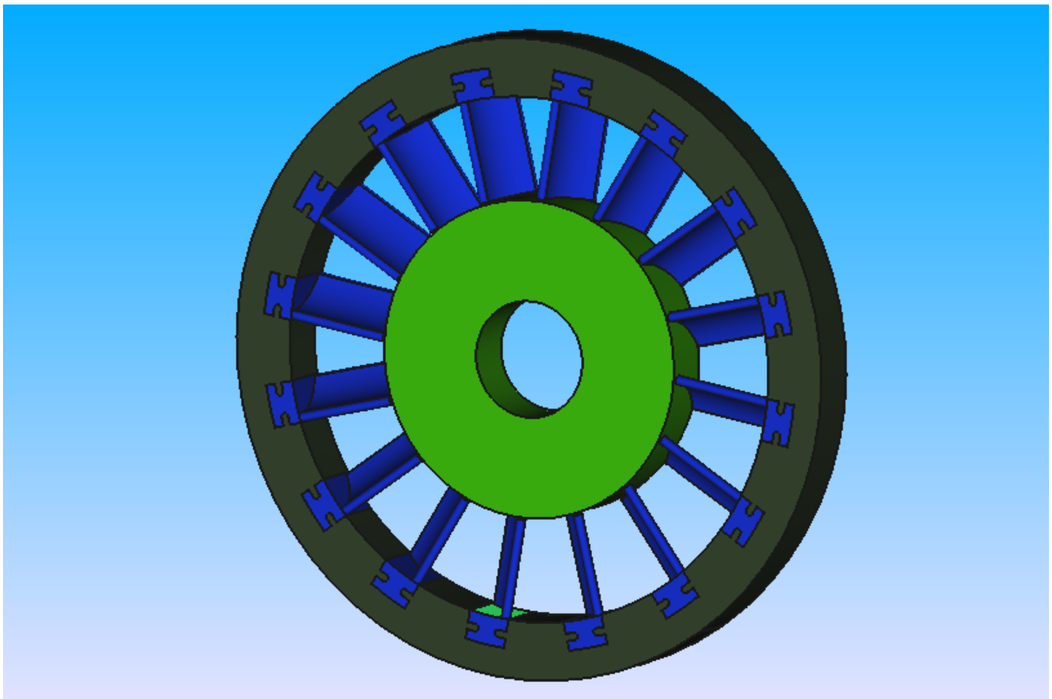
8) **Gas turbine integrated with fuel burner**



## 6.5. Gas turbine pieces - FreeCAD design

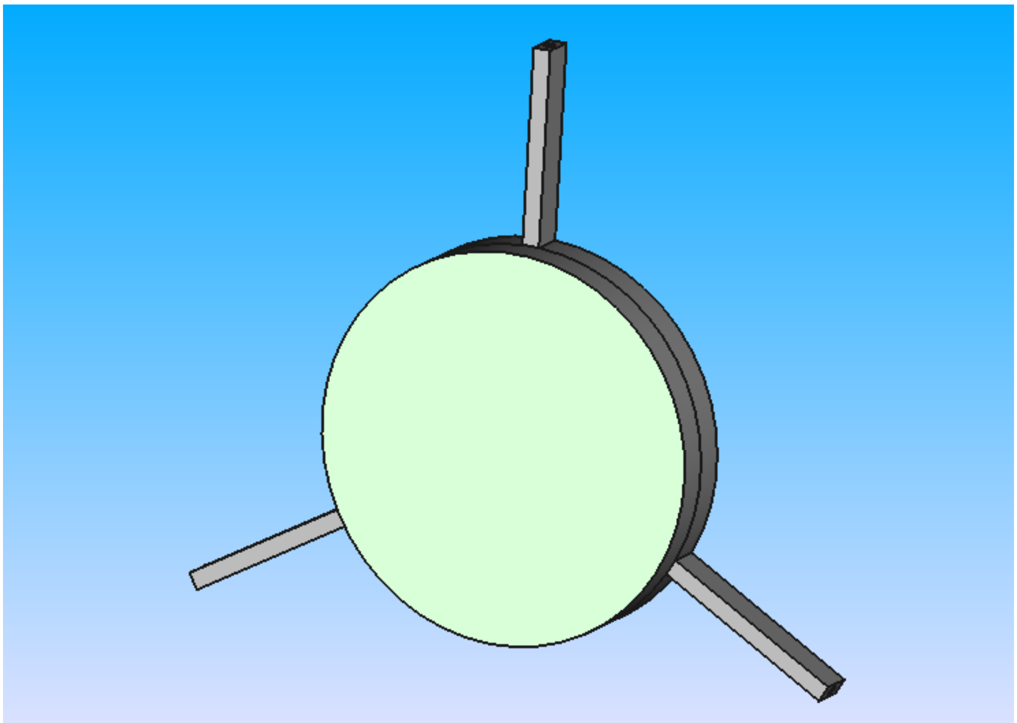
1) **Stator**

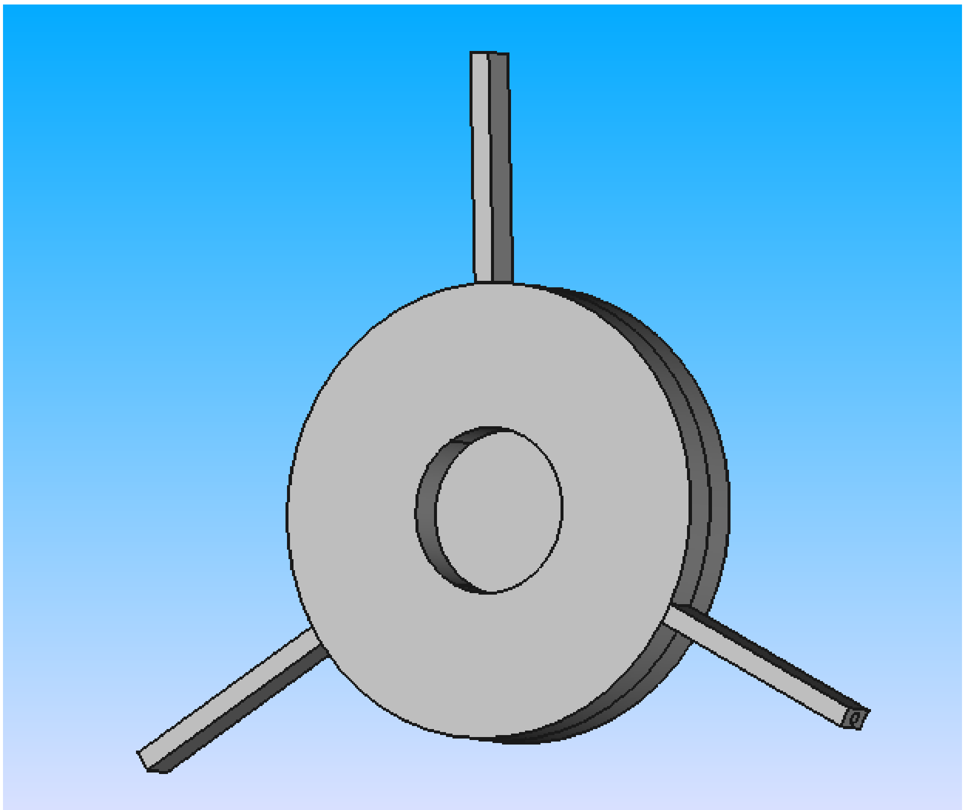
02102022stator.FCStd



## 2) Turbine cover A

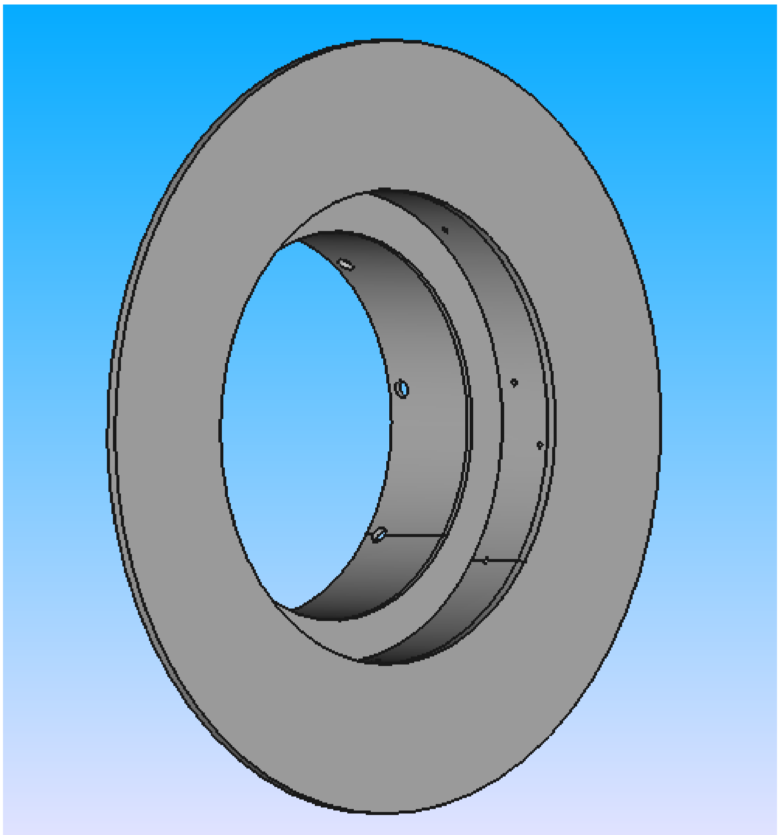
02102022tb cover a.FCStd





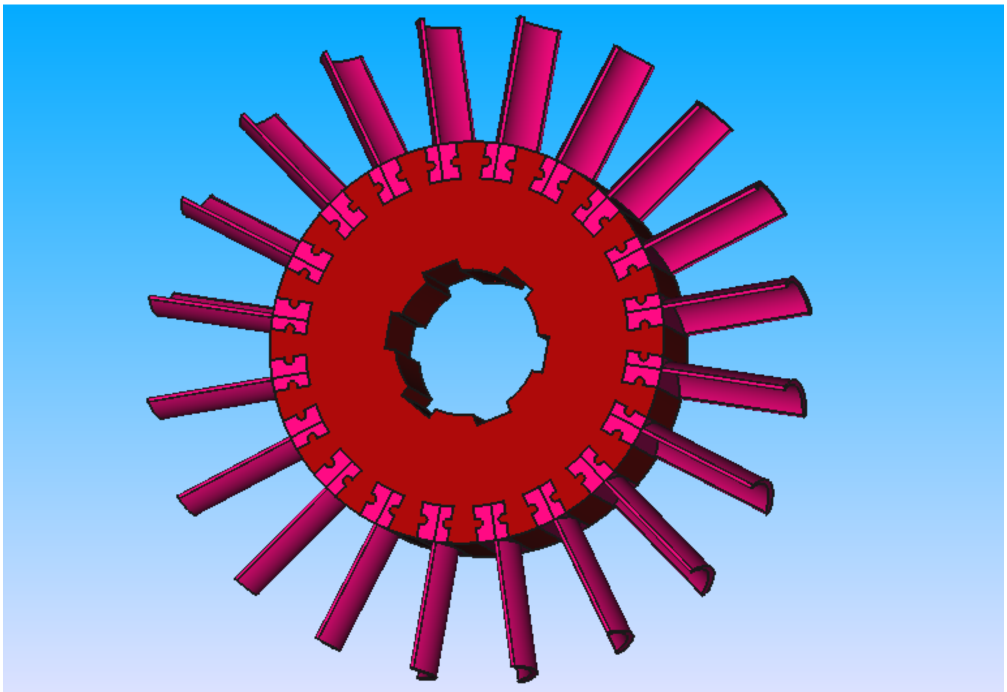
## 3) Turbine cover B

02102022turbine
cover b.FCStd



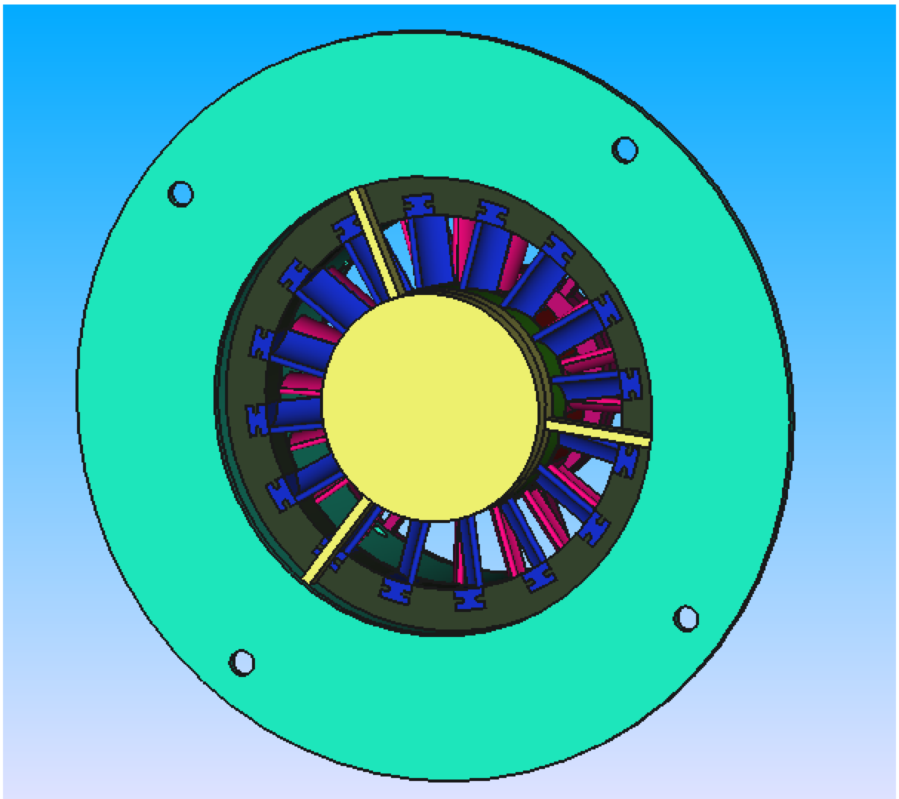
## 4) Turbine

03102022turbine.FC
Std



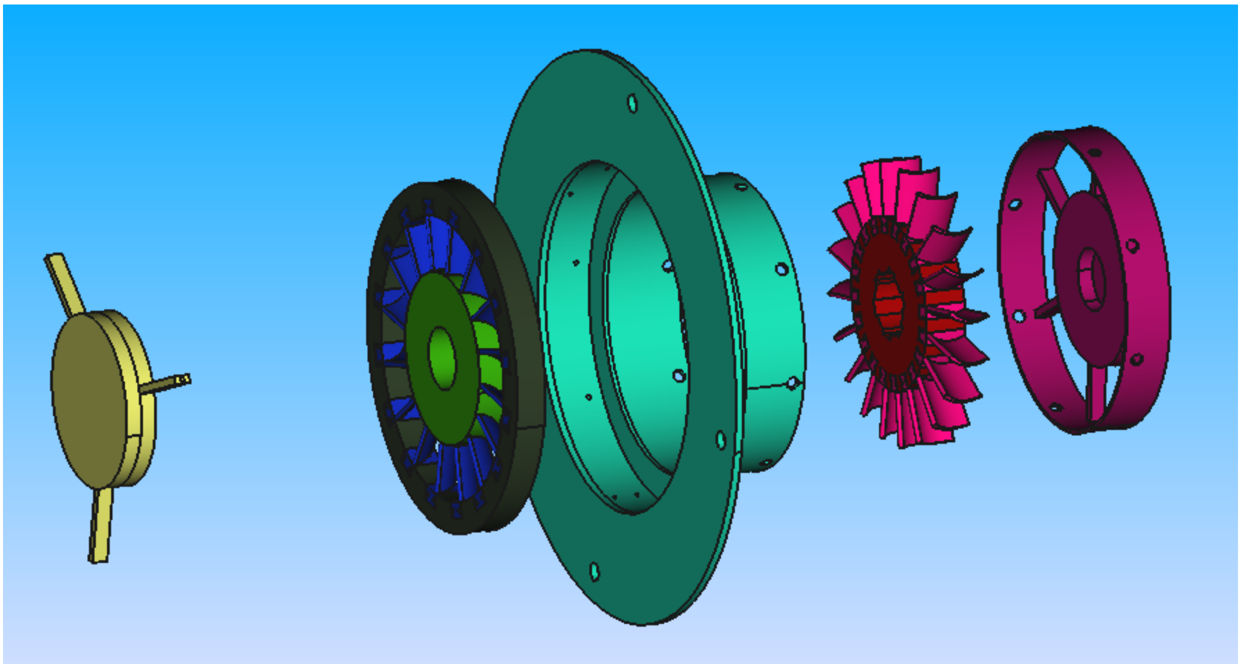
## 5) Complete turbine

04102022complete-
turbine.FCStd



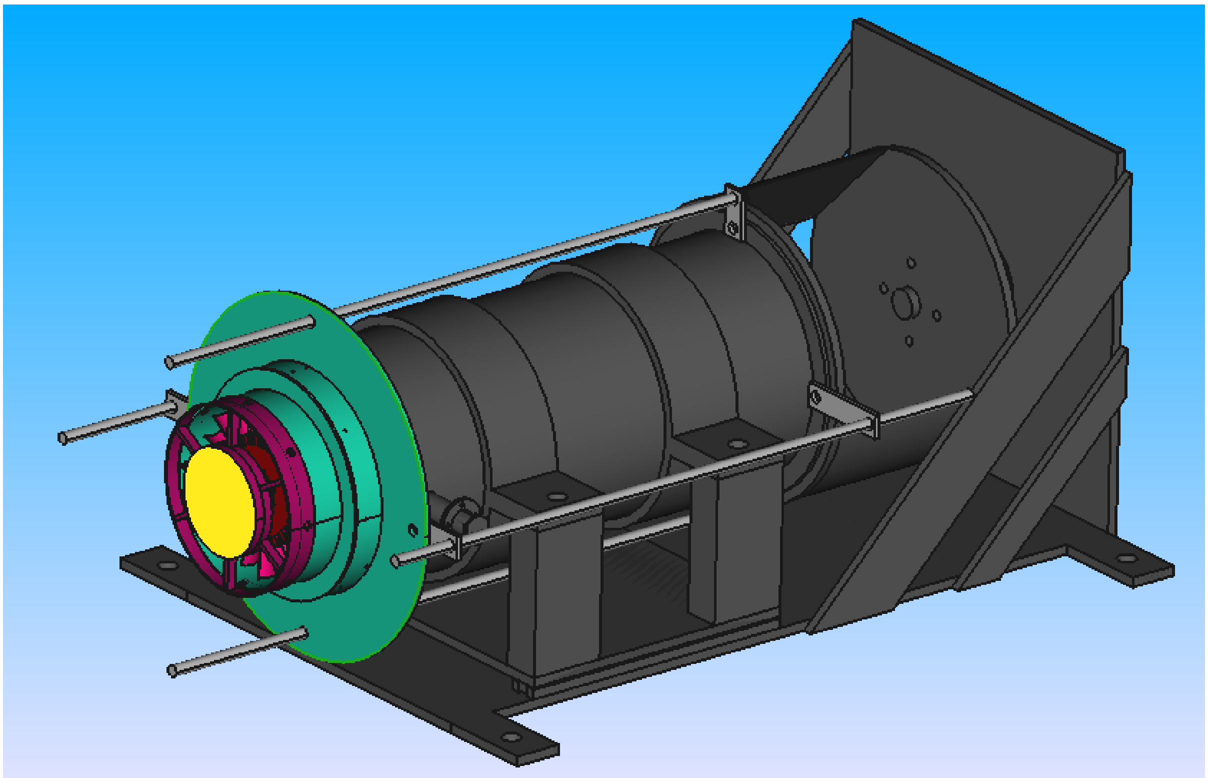
## 6) Complete turbine expanded

04102022complete-
turbine-expanded.F



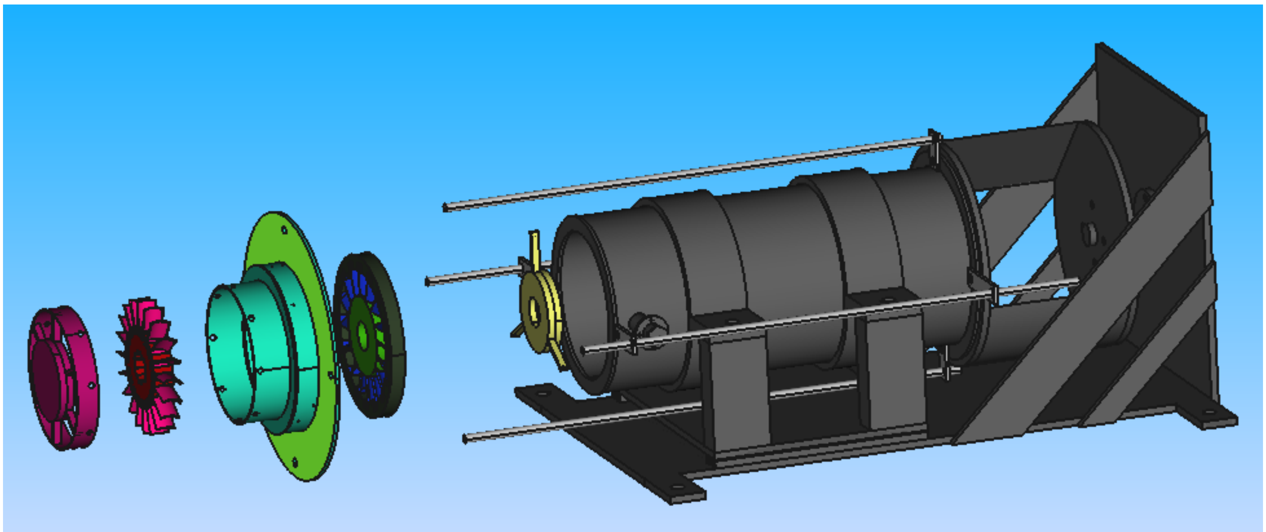
## 7) Assembly

05102022assembly.
FCStd



## 8) Assembly expanded

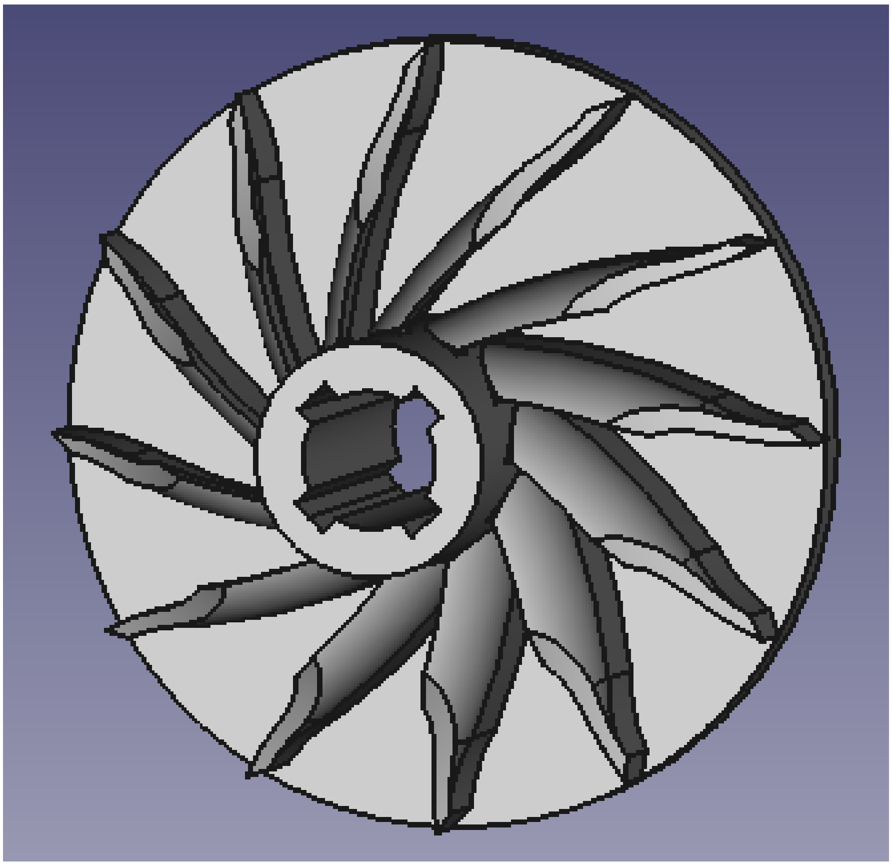
05102022assembly-expanded.FCStd



## 6.6. Gas turbine compressor

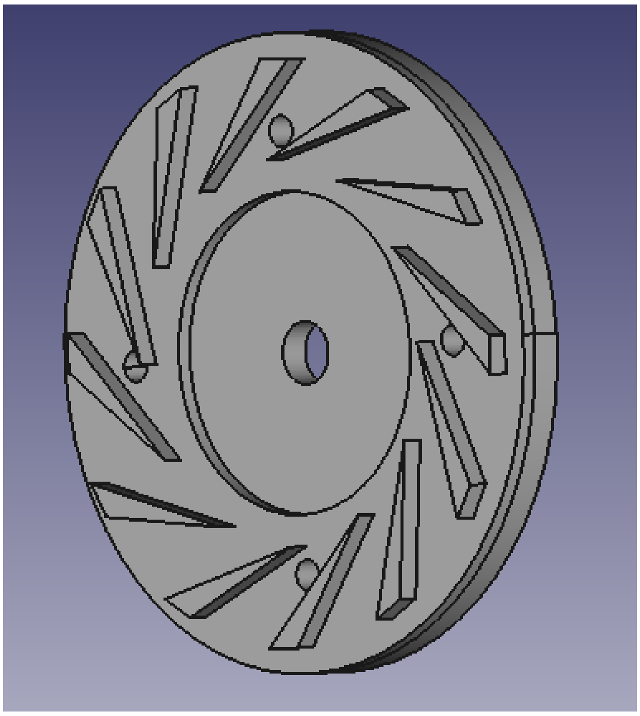
### 1) Compressor impeller

compressor.FCStd



### 2) Compressor diffuser

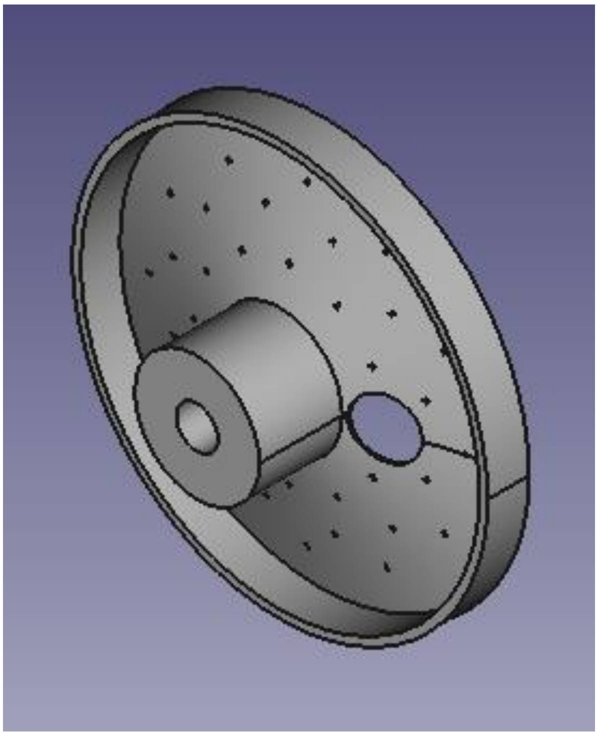
diffuser.FCStd



## 6.7. Combustion chamber parts With FreeCAD design

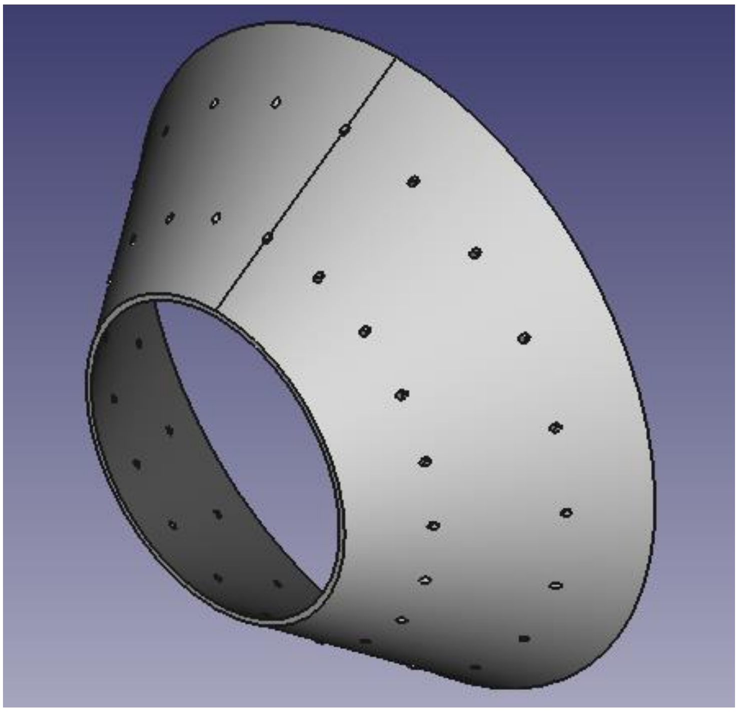
### 1) Cap

combustuon
cap.FCStd



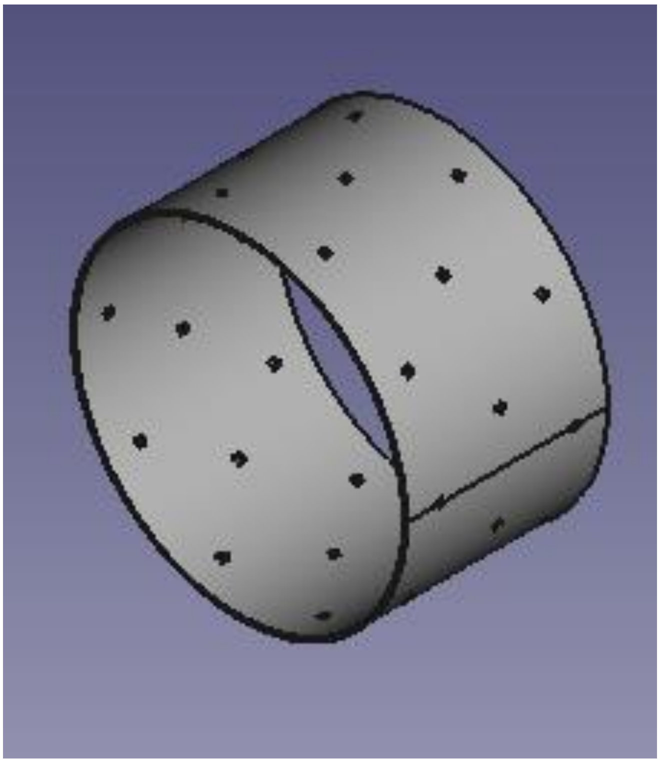
### 2) Primary zone

combustion primary zone.FCStd



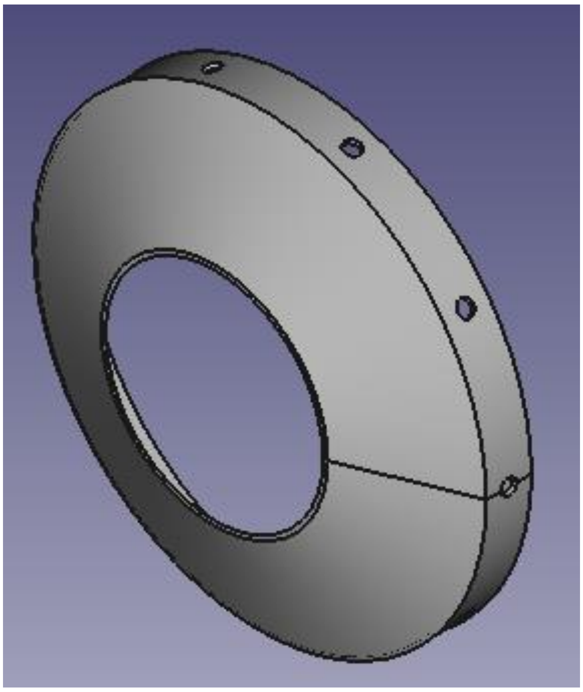
### 3) Intermediate zone

combustion intermidiate zone.F(



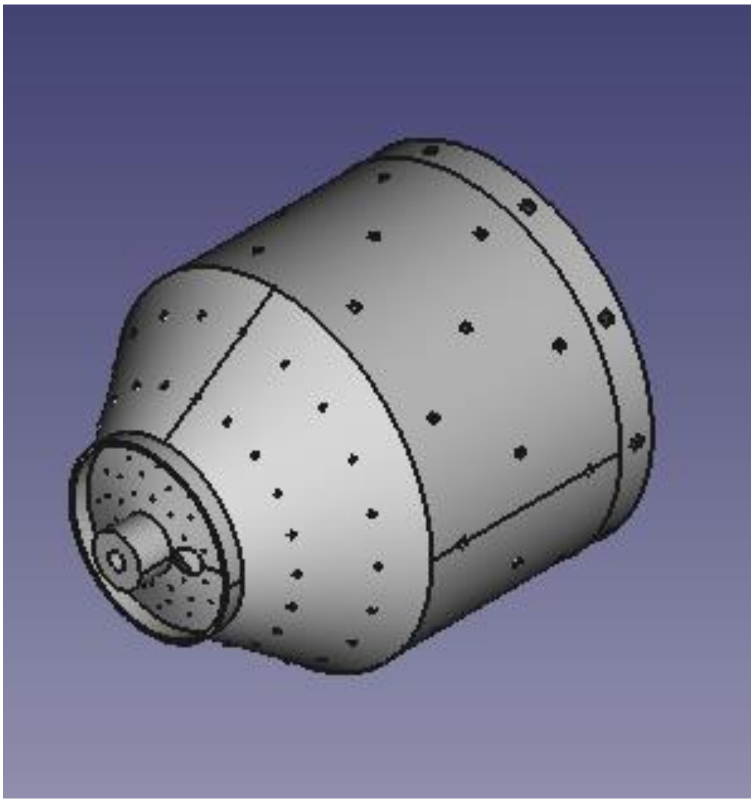
### 4) Dilution zone

conbustion
dilution.FCStd

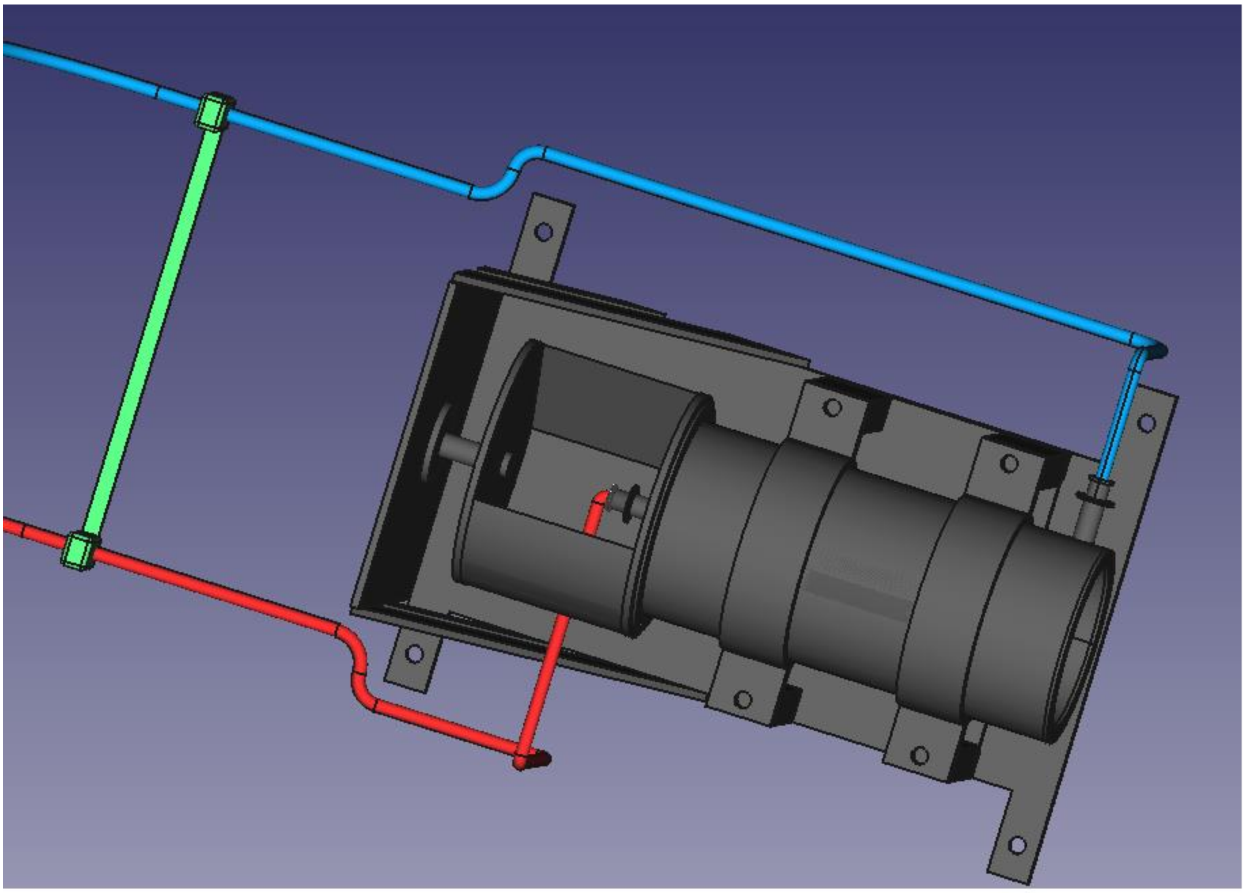


## 5) Combustion chamber

comb-chamb.FCStd



## 6) Alternative Fuel burner combustion chamber



## 6.8. What's next

**To complete this project, we must select the type of metals and sensors suitable for the model, after that we can start manufacturing the turbine.**

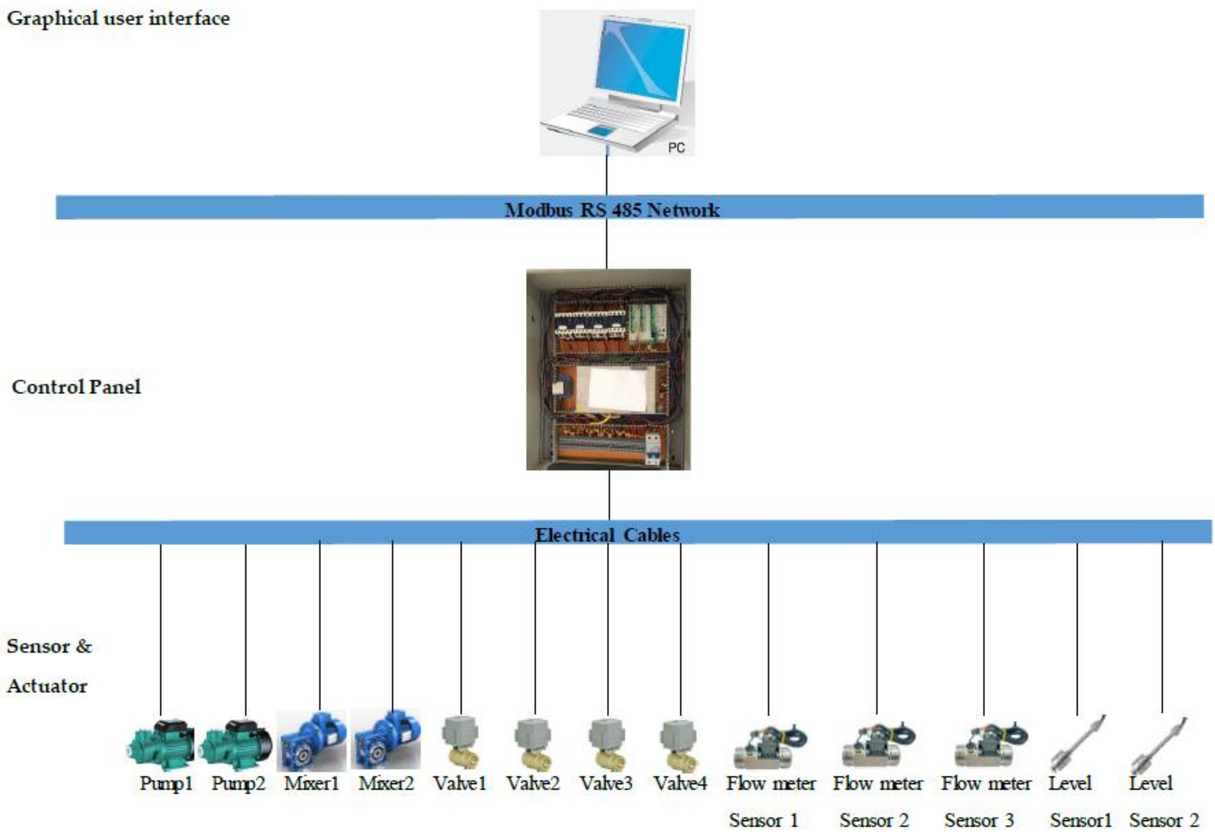
## 3 Project 22/7: Ashes Recycling (ICPT - AR) (to be put into NLAP-WEDC Final Report 21-24)

### 3.1 7.1. Position of Ashes recycling project

Work on this project began in the past years. In this year (2022), the focus was on the control, as the PLC was added and operated on the project.

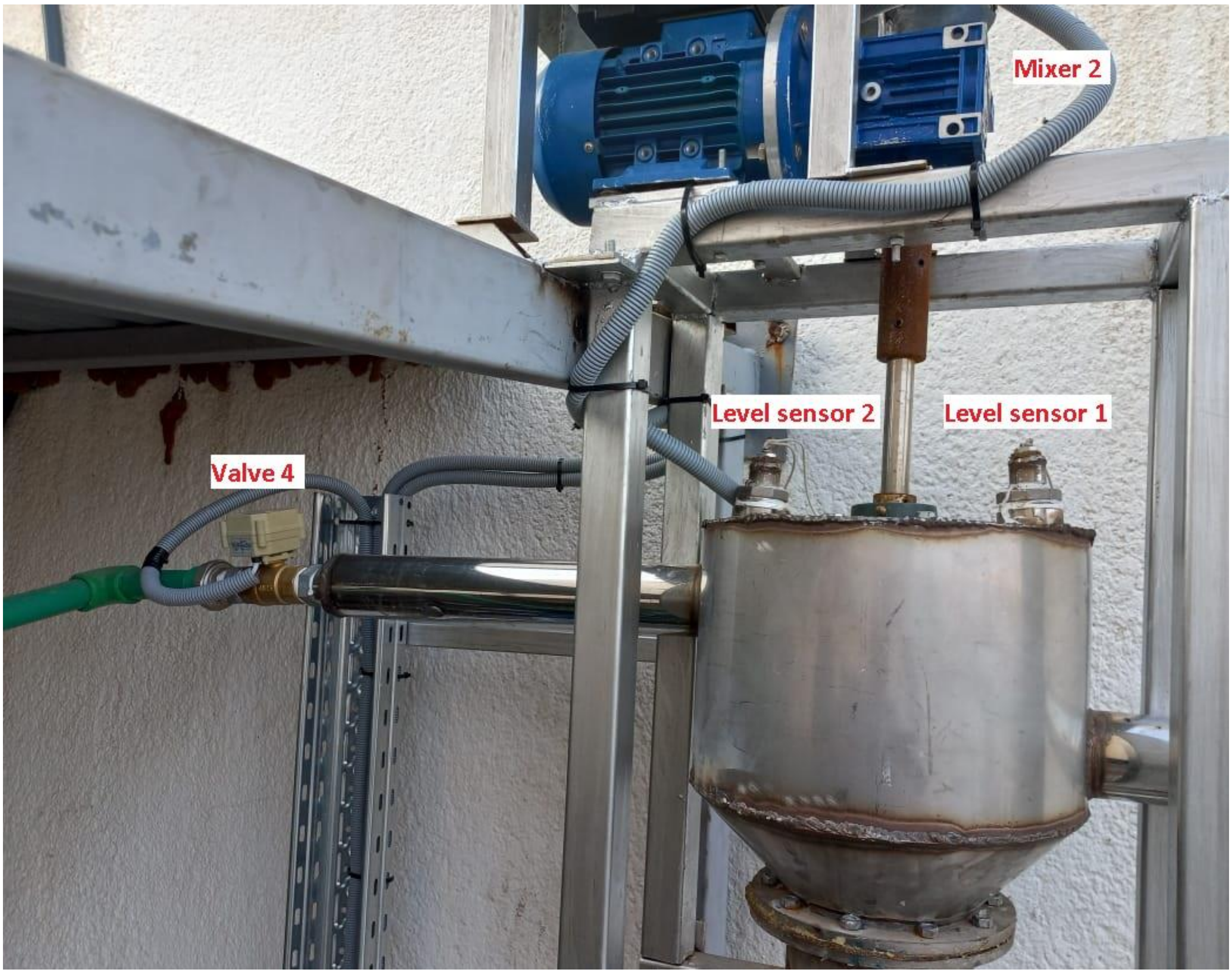
### 3.2 7.2. Ashes Recycling PCS Implementation

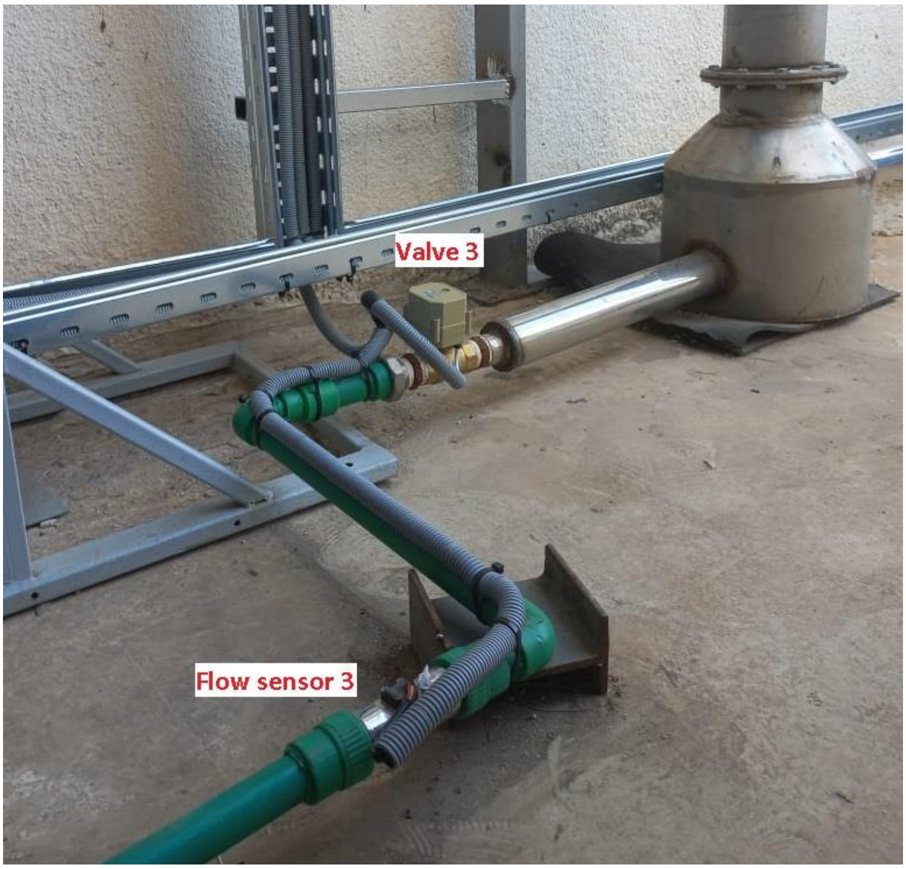
**1) The process control system for the Ashes Recycling system**




**2) The Ashes Recycling system**


Mixer 1
Valve 1
Flow sensor 1
Pump 1
Valve 2
Flow sensor 2
Pump 2


Mixer 2
Level sensor 2
Level sensor 1
Valve 4


Valve 3
Flow sensor 3


### 3) The Material Used

1-Proportional 2 way valve A20-M25-B2-C and Proportional 3 way valve A20-M25-B3-C (24VDC; input 0 to 10v) [1][2]

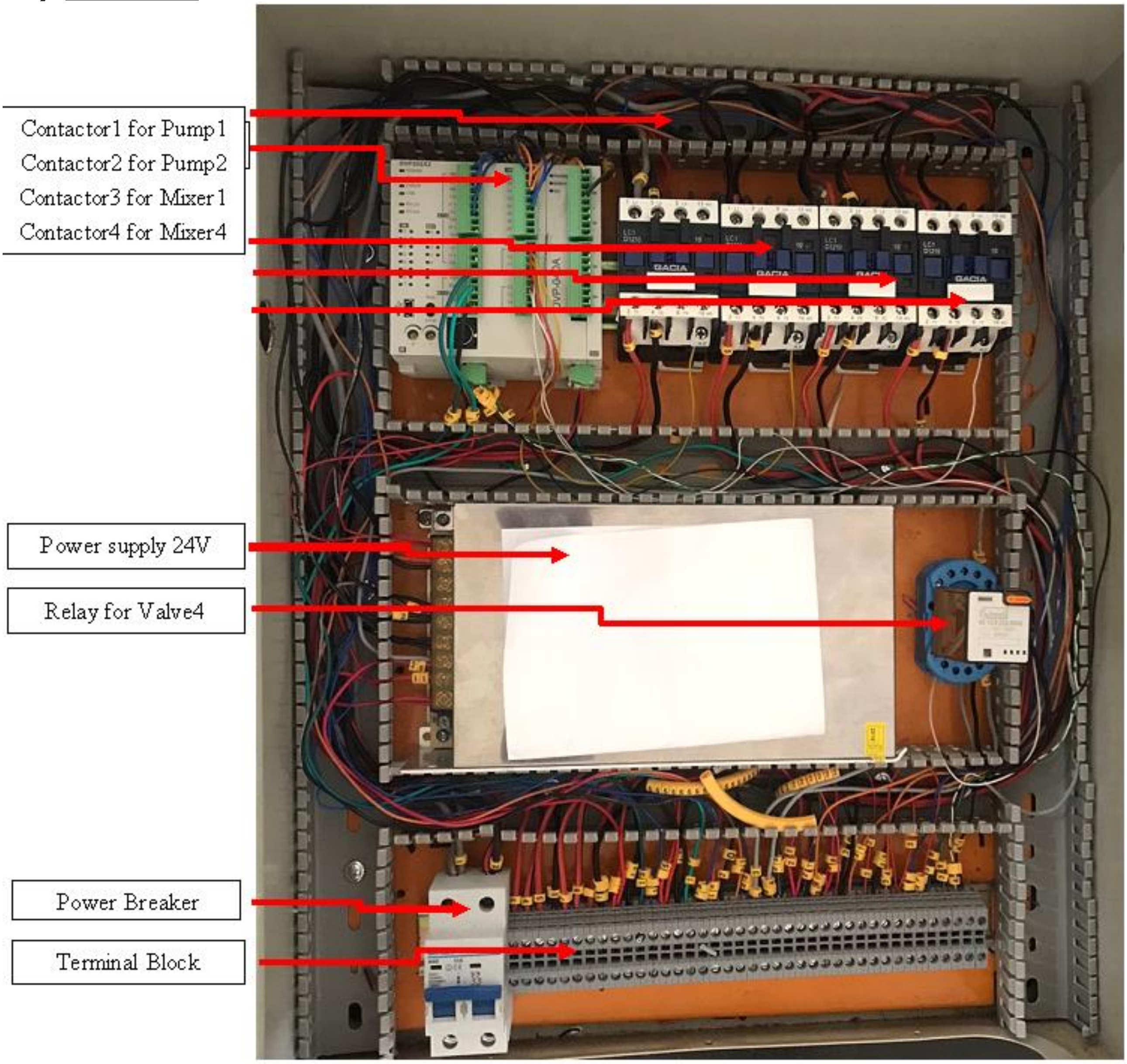
2-Motorize Valve A20-T25-B2-C (24VDC; CR301) [3][4]

3- Delta PLC DVP20SX211R [5]

4-Delta Module DVP04DA-S [6]

5- Water Flow Sensor USS-HS43TB (2-45L/M G3/4") [7]

## 4) PLC Panel

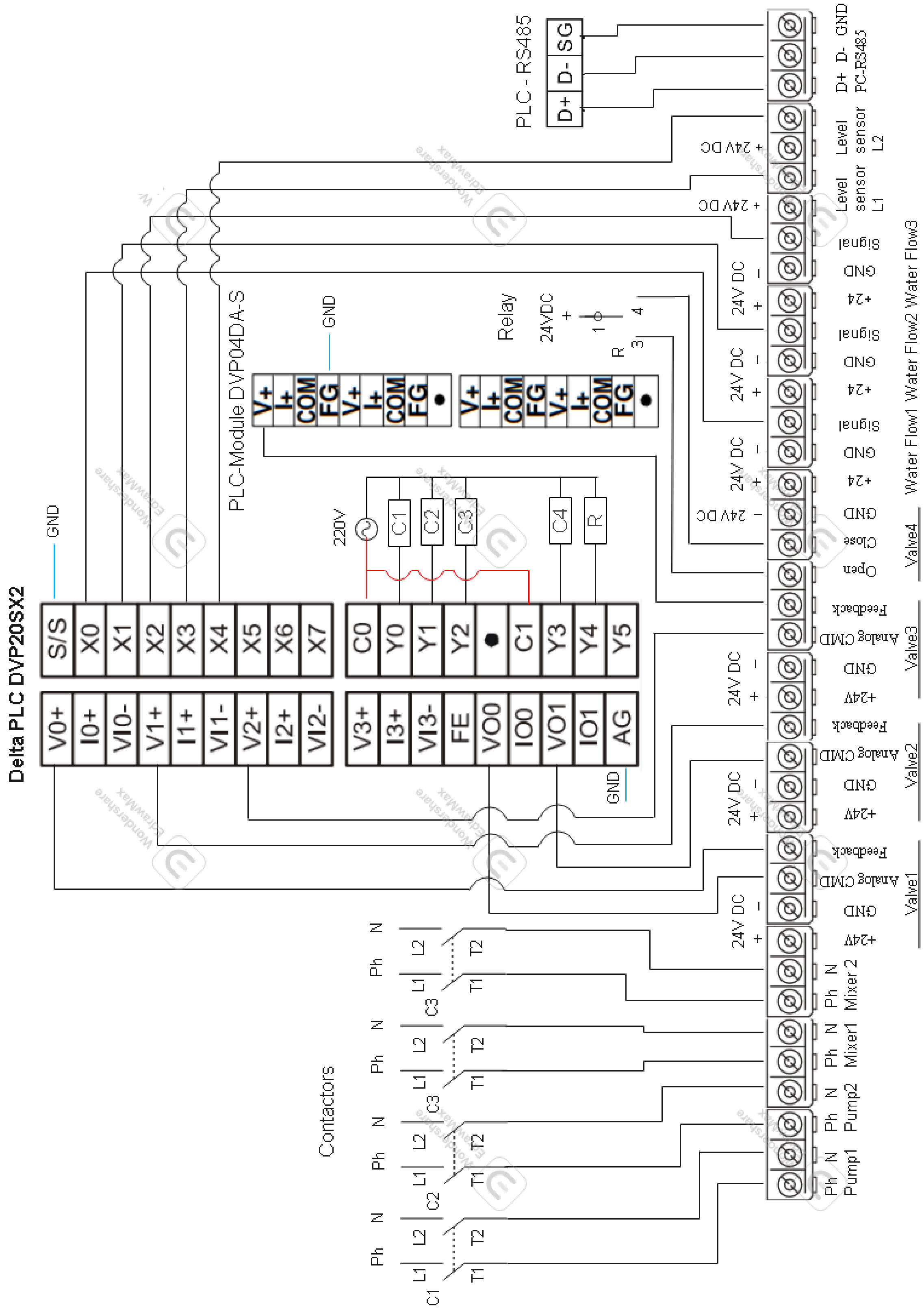



## 5) Terminal Block of Panel

| | |
|---|---|
| 1-Breaker | Power - Phase |
| 2-Breaker | Power - Neutral |
| 3-Terminal Block | Pump 1- Phase |
| 4-Terminal Block | Pump 1- Neutral |
| 5-Terminal Block | Pump 2- Phase |
| 6-Terminal Block | Pump 2- Neutral |
| 7-Terminal Block | Mixer1- Phase |
| 8-Terminal Block | Mixer1- Neutral |
| 9-Terminal Block | Mixer2- Phase |
| 10-Terminal Block | Mixer2- Neutral |
| 11-Terminal Block | Valve1- 24VDC + |
| 12-Terminal Block | Valve1- 24VDC – (GND) |
| 13-Terminal Block | Valve1- Analog Command (0 to 10V) |
| 14-Terminal Block | Valve1- Feedback |
| 15-Terminal Block | Valve2- 24VDC + |
| 16-Terminal Block | Valve2- 24VDC – (GND) |
| 17-Terminal Block | Valve2- Analog Command (0 to 10V) |
| 18-Terminal Block | Valve2- Feedback |
| 19-Terminal Block | Valve3- 24VDC + |
| 20-Terminal Block | Valve3- 24VDC – (GND) |
| 21-Terminal Block | Valve3- Analog Command (0 to 10V) |
| 22-Terminal Block | Valve3- Feedback |
| 23-Terminal Block | Valve4- Open 24VDC + |
| 24-Terminal Block | Valve4- Close 24VDC + |
| 25-Terminal Block | Valve4- 24VDC – (GND) |
| 26-Terminal Block | Water Flow1- 24VDC + |
| 27-Terminal Block | Water Flow1- 24VDC – (GND) |
| 28-Terminal Block | Water Flow1- Signal |
| 29-Terminal Block | Water Flow2- 24VDC + |
| 30-Terminal Block | Water Flow2- 24VDC – (GND) |
| 31-Terminal Block | Water Flow2- Signal |
| 32-Terminal Block | Water Flow3- 24VDC + |
| 33-Terminal Block | Water Flow3- 24VDC – (GND) |
| 34-Terminal Block | Water Flow3- Signal |
| 35-Terminal Block | Level sensor 1- 24VDC + |
| 36-Terminal Block | Level sensor 1-Status |
| 37-Terminal Block | Level sensor 2- 24VDC + |
| 38-Terminal Block | Level sensor 2- Status |
| 39-Terminal Block | RS485 Serial + |
| 40-Terminal Block | RS485 Serial - |
| 41-Terminal Block | RS485 Serial GND |

## 6) Control Panel Wiring

200822Ashes Recycling - Control I

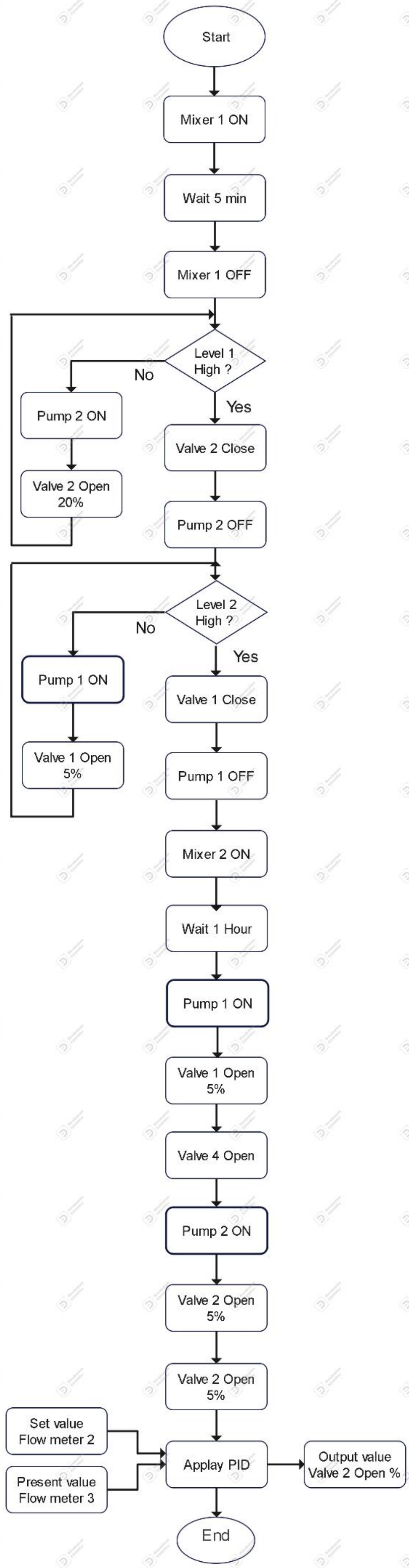



## 7) Operating steps

1. In the mixture put 338 Kg of Ashes with 1690 L 0f acid of 15.8 mol/l of concentration
2. Turn on the mixer (M1)
3. Open the Valve 2 and ON the pump (P2) to reach the column to the level (a) of ash mixed with nitric acid
4. When thelevel of liquid in the column reaches the top left nozzle (a), Turn Off the Pump (P2) and Close the Valve 2.
5. Turn on the mixer (M2)
6. Open the Valve 1 and Turn on the pump (P1) to put the solvent (LIX : LIX® 984N )
7. When the level of liquid reahes the top lef nozzle (b), Turn Off the Pump and Close the Valve 1.
8. Wait Time ... min. Allow the interface to form between the top mesh (a) and the top left nozzle (b). The interface appears as an immiscible layer between acid and extractant with droplets
9. Turn On the Pump (P1) and Open the valves (V1) and (V4) to set the extractant (Solvent) flow rate (equal between the inputs and the output).
10. Turn On the Pump (P2) and Open the valves (V2) and (V3) to set the aqueous phase flow rate (equal between the inputs and the output).

**3.2.18) <u>Algorithm</u>**

030922Ashes Recycling_PCS_Algo


Start
Mixer 1 ON
Wait 5 min
Mixer 1 OFF
Level 1 High ?
No
Yes
Pump 2 ON
Valve 2 Open 20%
Valve 2 Close
Pump 2 OFF
Level 2 High ?
No
Yes
Pump 1 ON
Valve 1 Open 5%
Valve 1 Close
Pump 1 OFF
Mixer 2 ON
Wait 1 Hour
Pump 1 ON
Valve 1 Open 5%
Valve 4 Open
Pump 2 ON
Valve 2 Open 5%
Valve 2 Open 5%
Set value Flow meter 2
Present value Flow meter 3
Applay PID
Output value Valve 2 Open %
End

## 9) Graphical user interface

- PLC code :

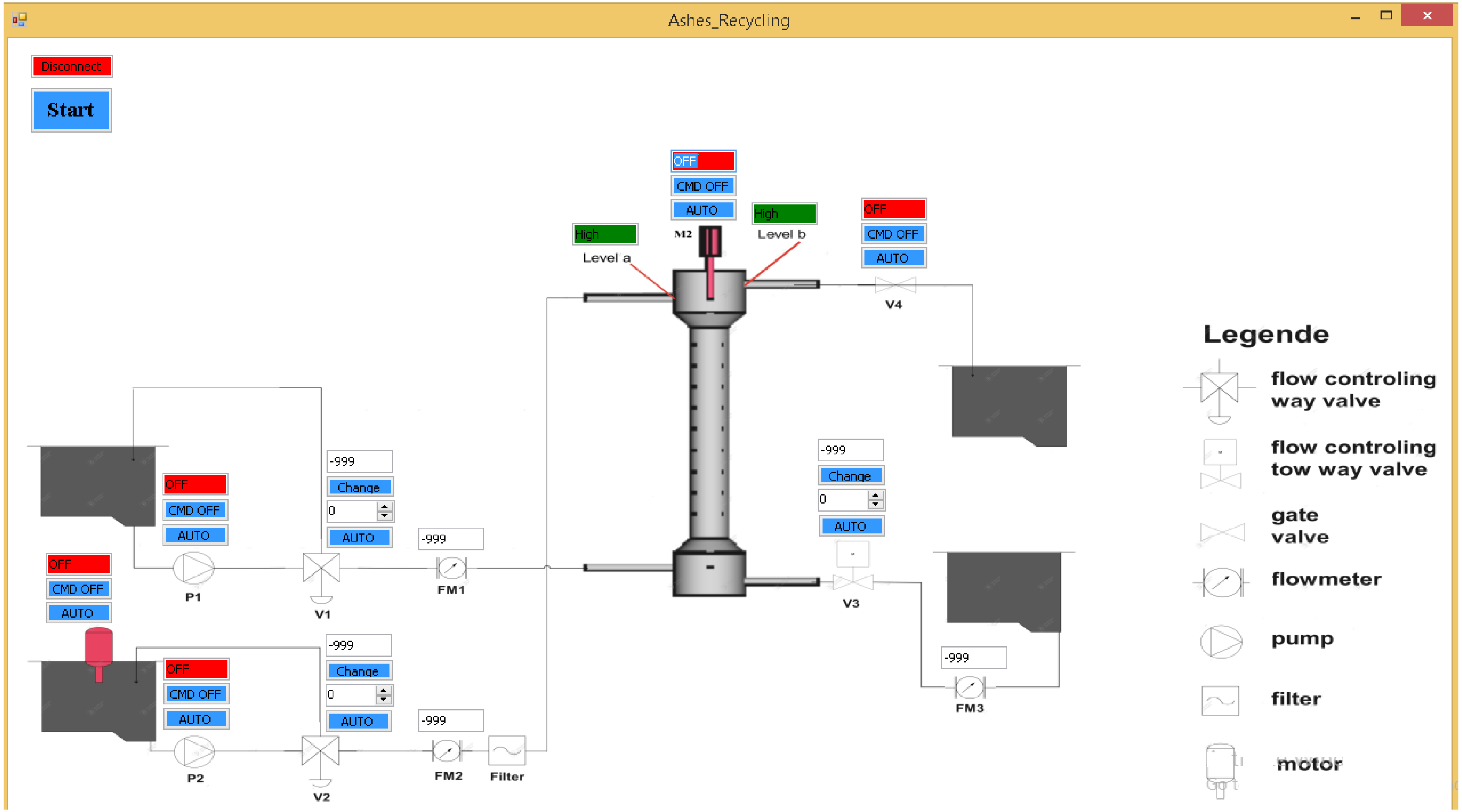
021222_ICPT-Ashes Recycling_PCS_PLC C

- Graphical User Interface code (C#) :

ICPT-Ashes Recycling_PCS_GUI_(

- PLC Modbus Addresses :

090922_ICPT-Ashes Recycling_PCS_PLC M

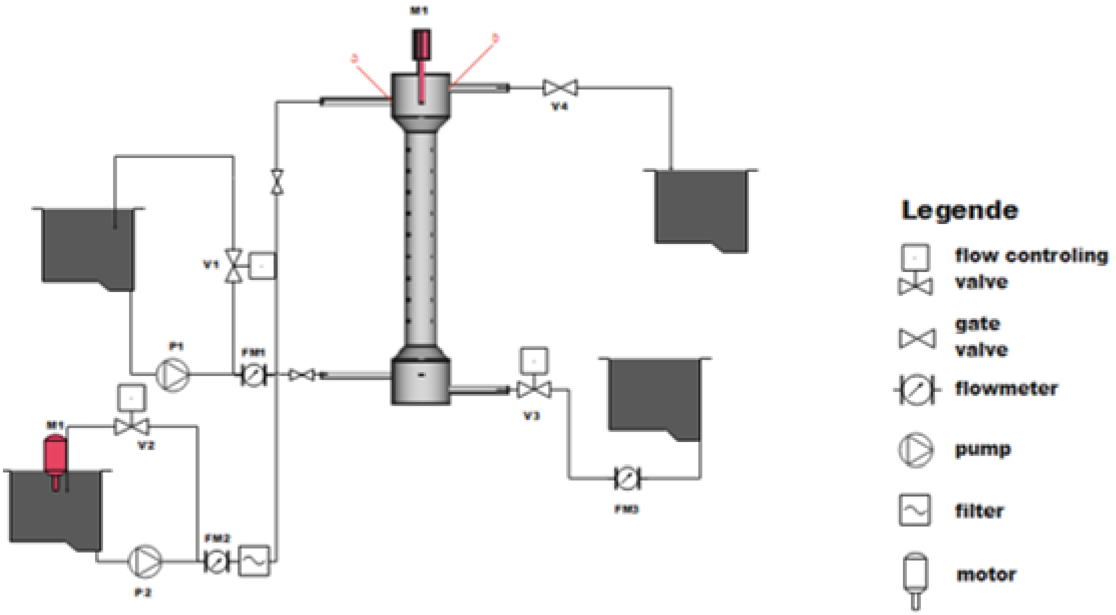

Ashes_Recycling
Disconnect
Start
OFF
CMD OFF
AUTO
M2
High
Level a
High
Level b
OFF
CMD OFF
AUTO
V4
OFF
CMD OFF
AUTO
P1
-999
Change
0
AUTO
V1
-999
FM1
OFF
CMD OFF
AUTO
OFF
CMD OFF
AUTO
P2
-999
Change
0
AUTO
V2
-999
FM2
Filter
-999
Change
0
AUTO
V3
-999
FM3
Legende
flow controling way valve
flow controling tow way valve
gate valve
flowmeter
pump
filter
motor

## 3.3 7.3. Ashes Recycling System Test Specifications

ICPT_WEDC-Testrigs_PCS2021_190122.zip

### 1) Before using

- All valves are turned off
- The motor is turned off




### 2) Follow these steps

1. Turn on the motor (M1)
2. In the mixture put 338 Kg of Ashes with 1690 L 0f acid of 15.8 mol/l of concentration
3. Turn on the motor (M2)
4. Open the pump (P2) to reach the column with 44 l of ash mixed with nitric acid
5. When the level of liquid in the column reaches the top left nozzle (a) . Turn on the valve (V2) to set the flow rate of the mixture
6. Turn on the pump (P1) to put the LIX (LIX® 984N )
7. When the level of liquid reaches the top left nozzle (b). Turn on the valve (V1) to set the extractant flowrate
8. Allow the interface to form between the top mesh (a) and the top left nozzle (b). The interface appears as an immiscible layer between acid and extractant with droplets
9. Once the interface is formed in the desired location, close the valve (V1) slowly until there are flowrates out of the column
10. To keep the flowrates equal between the inputs and the output 2, adjust the valve (V3) to set the output flowrate

## 3.4 7.4. Operation of ashes recycling system

List of Consumables for one batch run:

| Consumable | Quantity | Price |
|---|---|---|
| Extractant | 10L | |
| Nitric Acid | 44L | |

## 3.5 7.5. Requirements

A-Z : system requirements
1,2,3... : product requirements

A. The column system must be able to transfer the metallic salts from the solution to the solvent.
A.1. The rotator must be able to mix the two phases well enough to transfer the metal ions from the aqueos phase to the organic phase.
A.2. The solvent used shall be able to extract a specific ion from the solution (e.g. LIX® 984N for copper ions).
B. The mixer must be able to dissolve all solubles in the ash into the acid
C. The inflows and outflows of the fluids must be able to harmonise with each other.
C.1. The mixer shall rotate in x rpm

## 3.6 7.6. What's next

After completing the control of the applied model, in the future, this part must be started, and accordingly the required mixture – purchase or manufacture – must be provided to operate the model.