GRENOBLE INP UGA Génie industriel

Deliverable 3

Open Source Plastic Recycling Machine

Date : 22/03/2022

Groupe N° : 14

Names : BIANCIOTTO Tom / CLAVEL Maxime / GASTON Louis / LEGARDEUR William / LENNE Margaux / WILLIE Nsongurua Innocent

SUMMARY

A/ Context of the study - Main objective of the project

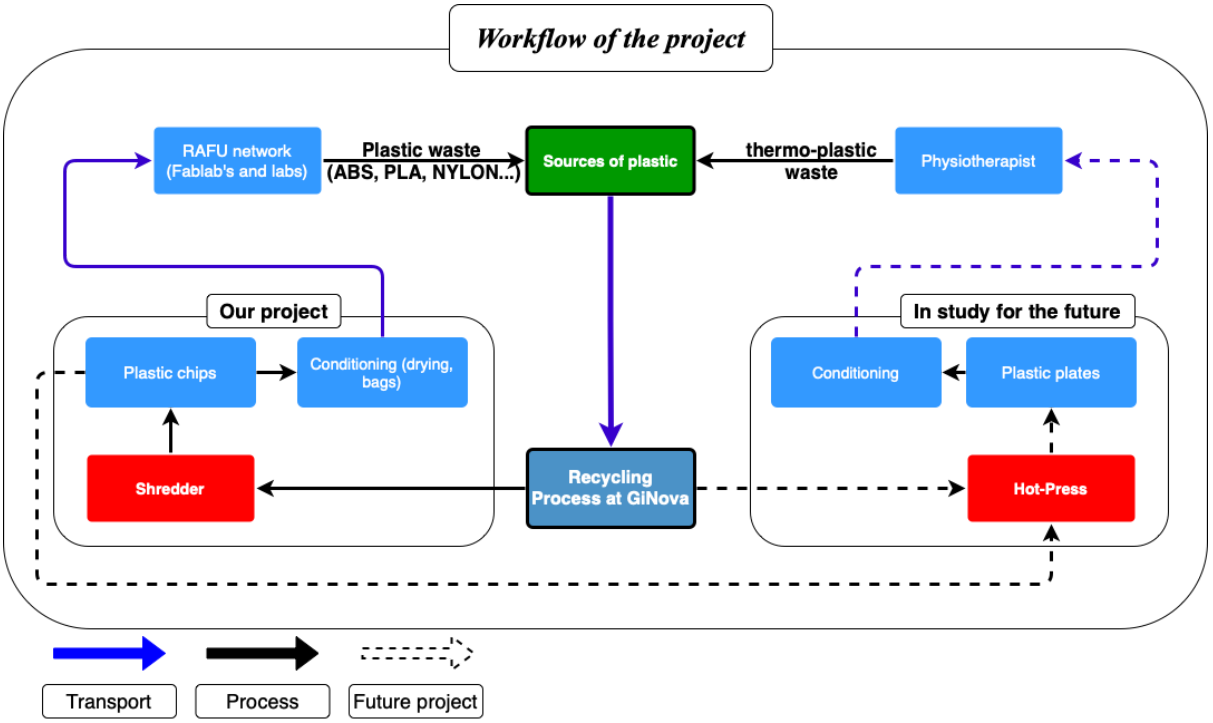


Figure 1 : Context of the project

The objective of our project can be summarized by finding an open source solution to recycle different kinds of plastic waste. In our more specific situation the objective is to first provide a plastic recycling solution to the **RAFU network**. This network gathers the **labs** and **Fablab of the UGA.** The research and the craft made there, create plastic waste especially with the 3D printing process. It would be a huge improvement if it became possible to recycle these plastics. In the future this solution could be extended to other kinds of actors who use plastics such as **physiotherapists** who make splints with thermoplastic or industrial materials (such as **Chabloz company** with nylon waste).

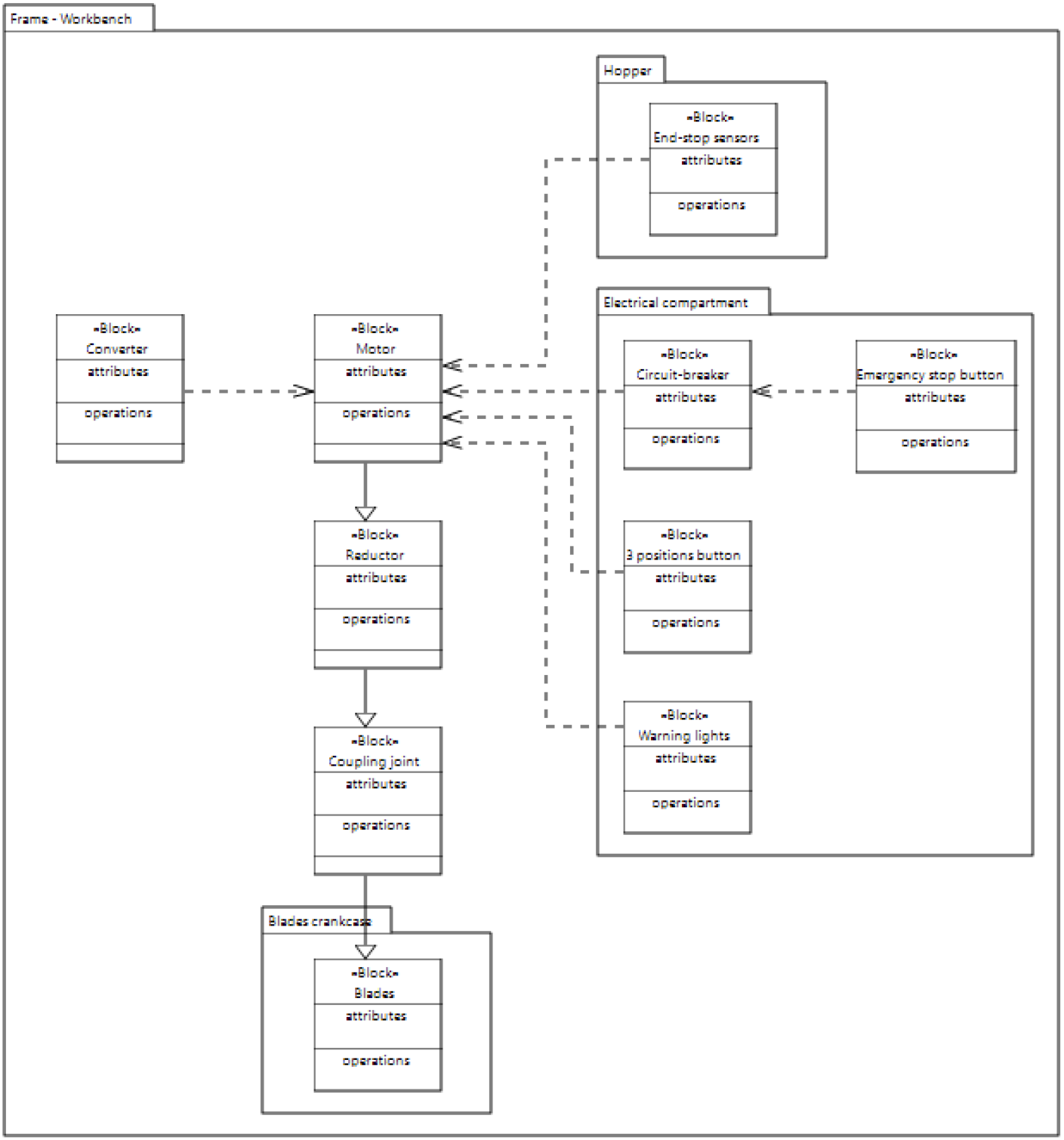
The objective of the group was to find a way to make the creation of 3D printing filament easier with the professional recycling machine available in the **fabMSTIC**. The main point of improvement is to work on the size of the pieces of plastic that had to be recycled. Another important phase is to organize the collection and the travel between the different recycling spots and users. Another point that could be developed is the creation of plastic plates to give a new life to the plastic collected.

To work on this project, the group was given a prototype of a plastic shredder and a hot-press. These two prototypes were not fully finished and need to be improved in a matter of capacity and mostly about safety to be used properly.

Since the first deliverable the work was focused between a fine study of the way to recycle plastic, the design of the prototypes improvement, and the creation of the Open source documentation on a Github repository.

B/ Architecture

To have a better view of the products of our project, we made an Internal block diagram for both the shredder and the compactor. It allows to represent the connections between components but also, and especially, the exchanges of matter, energy and information with the notion of ports.



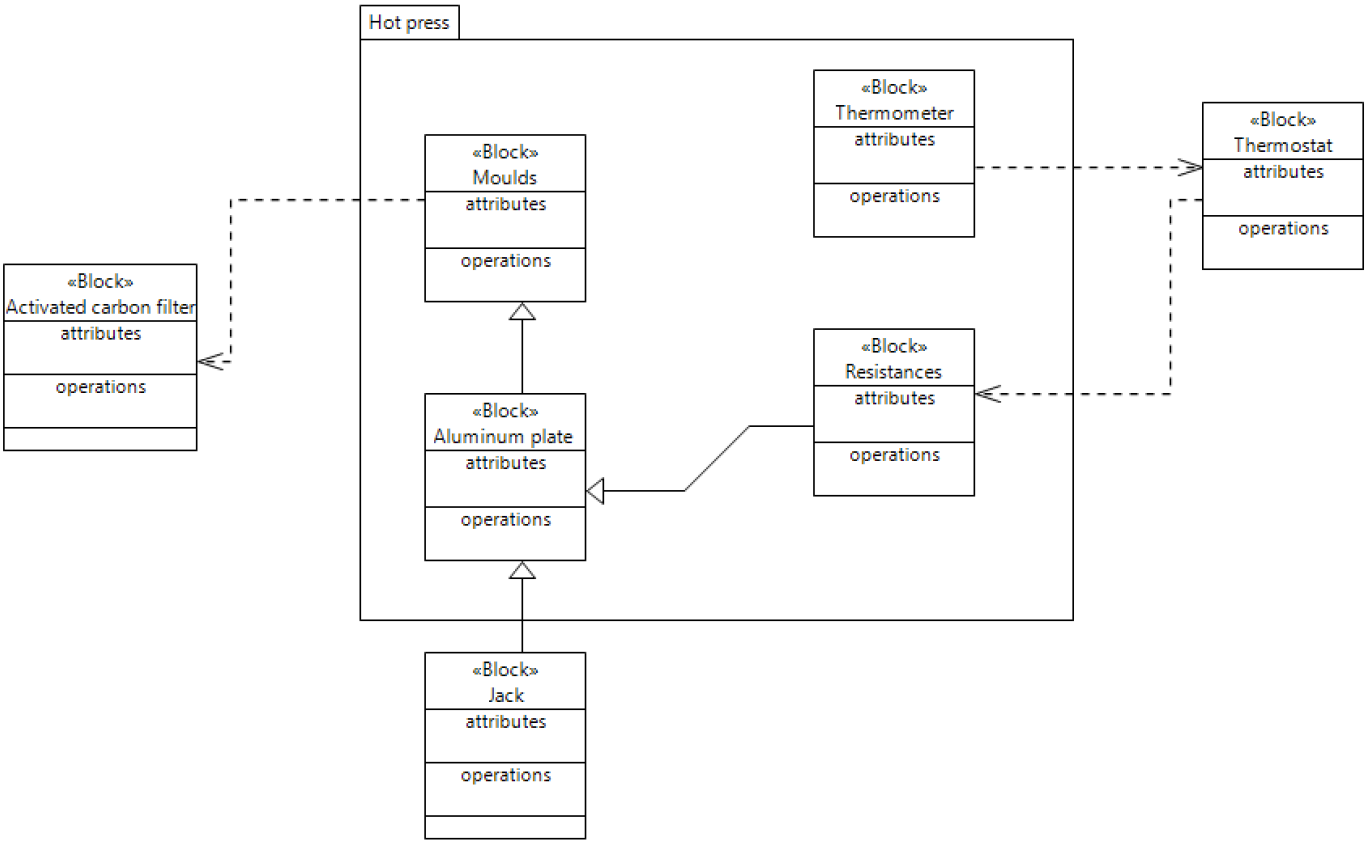
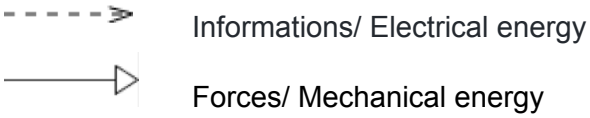


Figure 2 : Internal block diagram Shredder & Compactor



C/ Verify plan

In order to follow the requirements requested by the customer, we list them in a table *[figure 3]* and for each of them we assign one of three levels:

- Not verified: meaning that we have not yet been able to verify this requirement. However, verification plans exist and will be implemented as soon as possible.
- In progress: meaning that we are currently working on the mill to validate this requirement.
- Verified: everything has already been implemented to validate the requirement.

ID requirement	Name	Level of verification
FR1	The shredder needs to work on a standard 220V 50Hz EU plug.	Verified: use of a converter
FR2	The shredder needs to respect the 1m50x1mx1m50 maximum volume to avoid cluttering the space.	Verified
FR3	The shredder needs to shred plastic into chips with a surface inferior to 15 mm² with a tolerance of 5%.	Not verified: requires a test phase when the shredder will be operational
FR4	The shredder needs to stop in case of emergency in less than 3 seconds.	Not verified: requires a test phase when the shredder will be operational
FR5	The shredder must be secured to prevent injury on contact (against moving parts and projectiles).	In progress: a hopper and a cover have been installed. Lack a protective cover for rotating parts and the installation of an end-stop button to switch off the engine if the cover is opened
FR6	The shredder needs to have a power-on and/or operation indication that the operator can see	In progress: provided on the electrical diagram but not connected yet
FR7	The shredder must not exceed the maximum accepted noise level.	Not verified: requires a test phase when the shredder will be operational
FR8	The shredder should not transform one of the labs and fablabs of the RAFU network into a storage place for all the plastic chips.	Verified: use of kanban labels to track each bag of chips
FR9	The shredder needs to have a reverse function in case of blocking or any other mechanical problem.	Verified: thanks to the converter
FR10	The shredder and its installation should be stable and strong.	Verified: through structural calculations

Figure 3 : Monitoring of the requirements

So we have three requirements that are not yet verified at the time of writing this deliverable. Let us detail the verification plans for these:

- **FR3** *"The shredder needs to shred plastic into chips with a surface inferior to 15 mm² with a tolerance of 5%."* :

For the test phase, we will cut different types of grids with different holes in steel using the water jet cutter *[see figure 4]* (plexiglass is impossible to use because it is brittle and the grate is right under the teeth of the rotating grinder. This grid will be placed under the shredder, just below its blades. Thus, if the chips are too large, they are recovered by the blades and returned to be crushed until they reach the size desired by the customer.

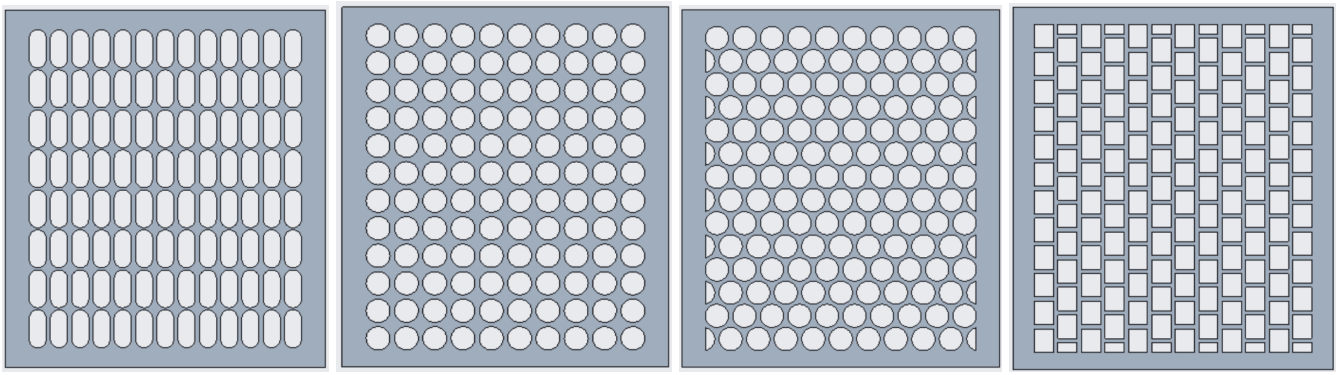


Figure 4 : Different kind of grid to test

- **FR4** *"The shredder needs to stop in case of emergency in less than 3 seconds".* :

  In order to verify this requirement, we plan to use the blocked week to have two people from the group work on the converter ramp study. Indeed, by choosing the right parameters on the one we already have we will be able to configure the new ordered converter correctly once we receive it.

- **FR7** *"The shredder must not exceed the maximum accepted noise level.* :

  This requirement will be verified once the prototype is completed. Potential noise sources are mainly from :
  → From the engine
  → From the shredding of the plastic, but the first shredding test we did with the old engine showed us that the noise emitted was still acceptable.
  → From the workbench

D/ Simulation (new)

In the previous deliverables, we were talking about reinforcing the support structure of our workbench, supporting the shredder assembly and the motor, actually made of a **30 mm** MDF wooden plate. This idea was quite rushed and our professors asked us to prove the necessity of changing this plate, so now we do :

The system we have, transmits high torque by the upper plate of the table, the reason why is that the motor and the shredder are two independant parts so they must necessarily be attached to a common support : the wooden plate. We would not want it to break under the effect of the engine torque so we decided to make a small simulation of the situation, described on *[figure 5]* below :

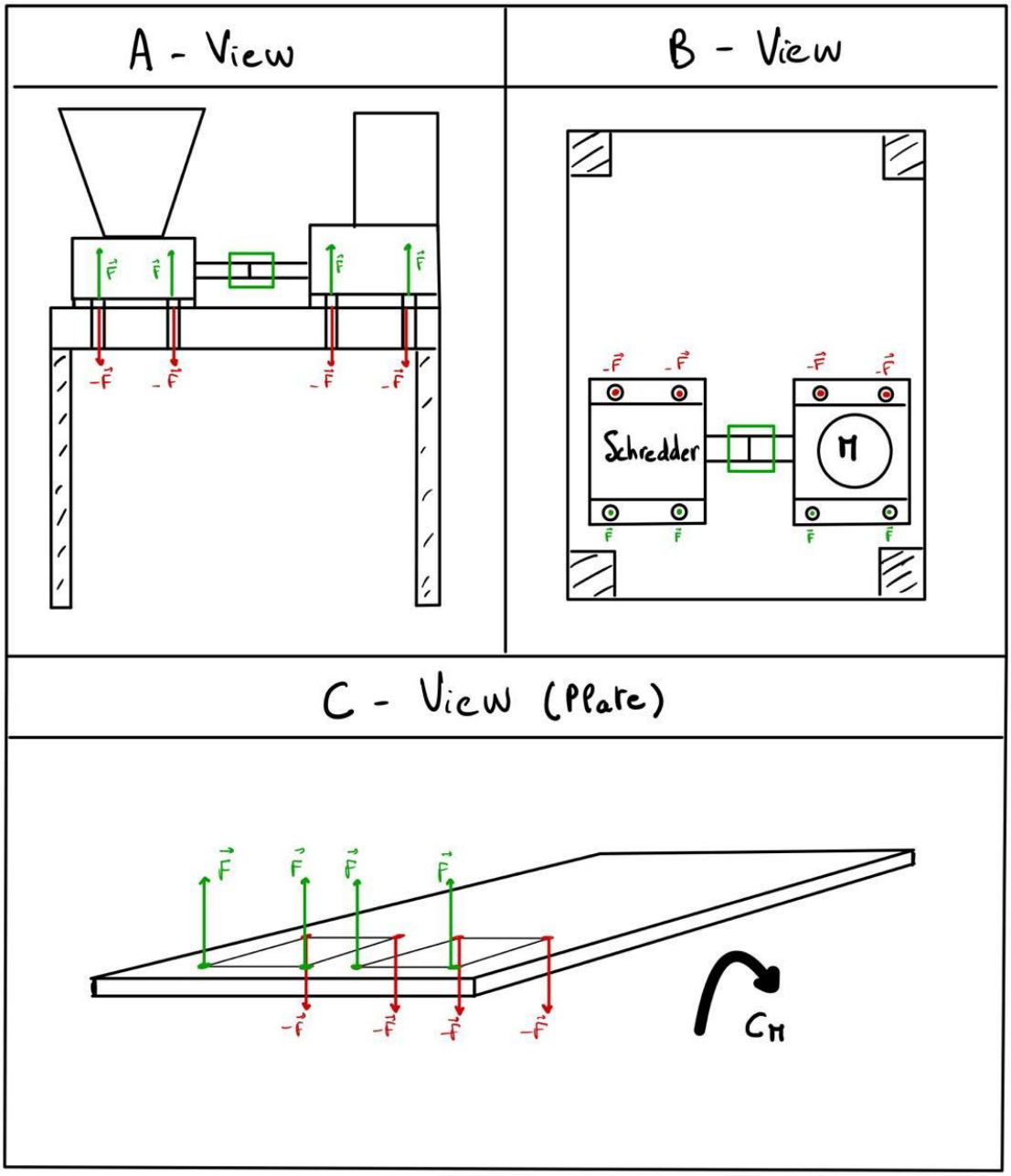
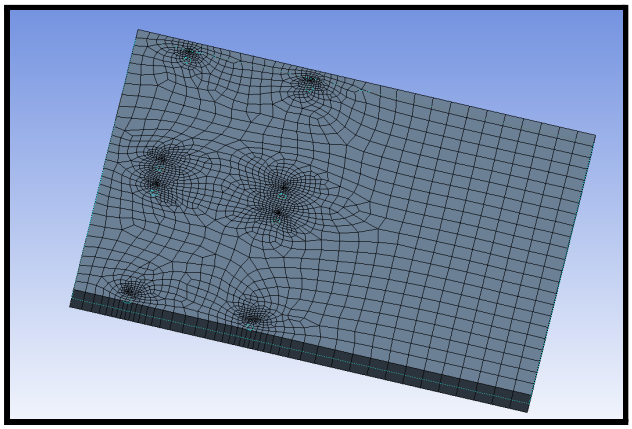
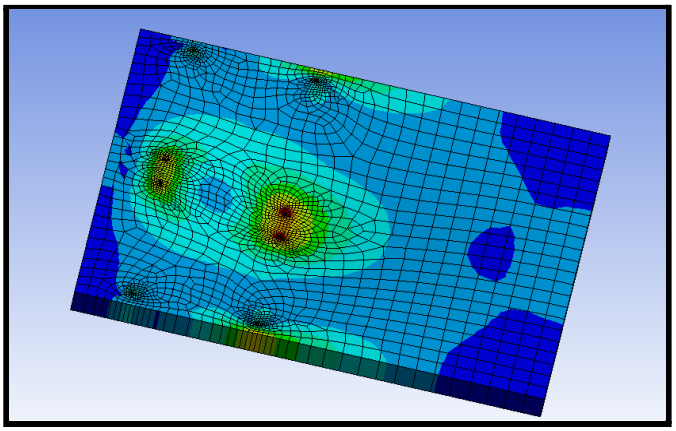


Figure 5 : Representation of the efforts due to engine torque

Now we have a simple but realistic schematic of what will really happen on the plate. We can get further into it by modeling this schematic on a structural calculation software, here we will use ANSYS Workbench.

By assumption, we are considering that the torque is equally distributed in the **8** fixation points, we also make the hypothesis that the radius of the blades is about **8 cm**. If we take a torque of **300 N.m** (maximum transmitted torque), we obtain ***(300/0,08)/8 = 470 N*** on each hole of fixation.





Caractéristiques techniques (valeurs moyennes des panneaux)			MDF
Spécifications	**Norme**	**Unité**	
Densité *	EN 323	kg/m³	570 - 720*
Résistance à la flexion	EN 310	N/mm²	15 - 23
Résistance à la traction, surface	EN 311	N/mm²	1,0
Module d'élasticité	EN 310	N/mm²	1500 - 2400
Teneur en humidité	EN 322	%	4 - 10
Émission de formaldéhyde	EN 120		E1
Tolérance épaisseur	EN 324-1	mm	± 0,2
Tolérance dimensionnelle	EN 324	mm	± 5
Conductibilité thermique λ	EN 12524	W/m.K	0,15
Teneur en PCP	EN 13986	ppm	< 5
Classe incendie	EN 13501		D
Résistance à la traction, perpend	EN 319	N/mm²	0,45 - 0,70
Gonflement après 24h. (18 mm)	EN 317	%	< 16

* Densité différents types de panneaux MDF: 560-620 = L-MDF / 650-670 = MEDIUM MDF / 720 = ST

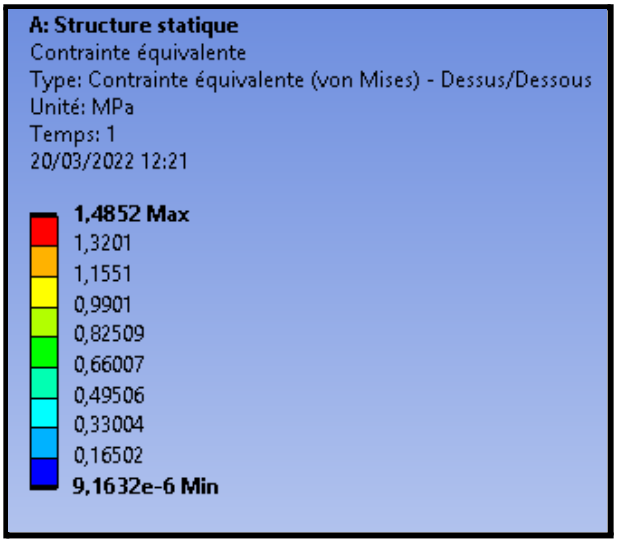


Figure 6 : Resistance of MDF wood [decopan.com]

As we can see, the maximum constraint is about 1.5 Mpa on the wooden plate, regarding [Figure 6], MDF can absorb around 20 Mpa of bending so the plate seems solid enough to support all these efforts.

E/ Prototype

While waiting for our new adapted gear motor we tried to make as much progress as possible on the structure of our shredder, two important things were missing:

- A chip collection tray
- An electrical compartment

To put these elements in place, it was necessary to add a floor to our frame, so we prepared the structure and welded square steel profiles of **30x30 mm**.

We then fixed a wooden plate for the shelf and a plexiglass plate as a front for the different switches: emergency stop, forward/backward/off switch, potentiometer, circuit breaker. A separating sheet has also been installed to prevent people from electrical injuries putting their hands in the electrical part. For safety reasons, all the metal elements will be connected to the ground.

We obtain the following structure (still incomplete) [Figure 7]:

Figure 7 : Structure of the shredder

We also installed our hinges and the opening sensor on the hopper [Figure 8]:

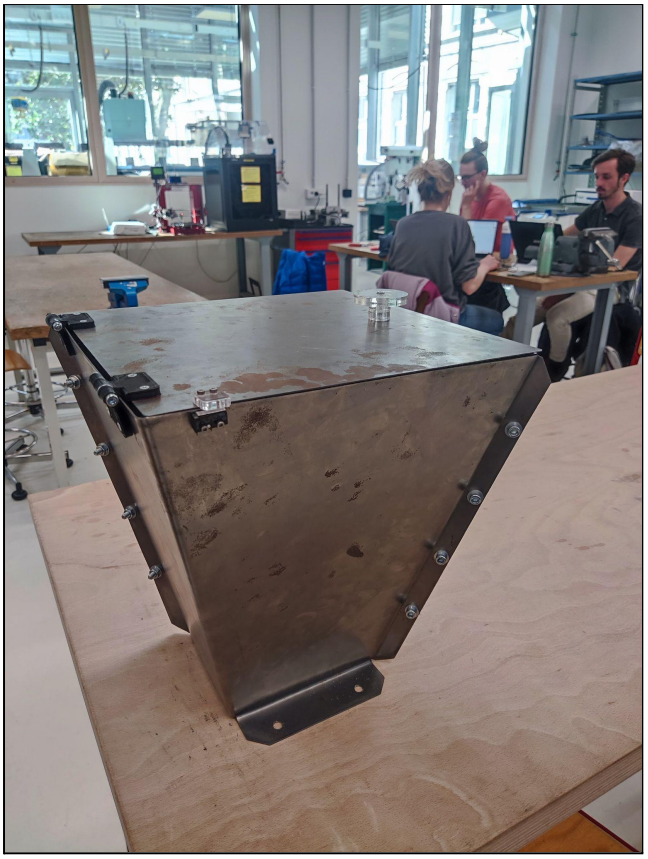


Figure 8 : Hinges, handle and opening sensor on the hopper of the shredder

We now have to make the various attachments for the transmission according to the specifications of the new gear motor ordered, cut a steel sheet for the shelf (currently made of a poor wooden plate) and an aluminum sheet for an enhanced rigidity of the front panel (currently made of plexiglas).

As explained above (Part C/ Verify plan), we also need to cut out different backflow grids for the chips to determine their optimal size. We therefore go to ENSE3 to make all our cut-outs [Figure 9] :

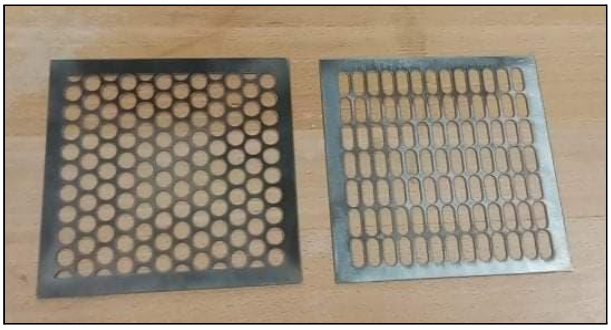


Figure 9 : Backflow grids for the shredder

Now, the next step for these grids will be to create a sheet metal forming die to form the sheet into a cylinder.

F/ Project tasks advancement and achieved work plan

Since the last audit, the tasks have gone according to the Gantt chart. We only had a one week delay on task D "Systems Engineering" because we had not finished the SysML part of the hot press on papyrus. However, this delay does not have a big impact on our project as it is not on the critical path.

For the next few weeks, we have to pay close attention to task I "Improvement of the shredder" which is a critical path task. Indeed, as planned, this task must be finished by week 15 (11 April - 17 April) in order to make room for the last task of the critical path: "Tests" *[see annex 1]*. However, if we look at the subtasks of I, we notice that many of them are on stand-by *[see figure 10]*. The reason for this is that the motor given by Guillaume MARIN (the engineer who gave us a first prototype of the shredder at the beginning of the year) had insufficient torque, as did the second motor we found in Ginova. This necessitated a calculation phase in order to find the torque we needed for shredding plastic. We are now waiting for this new motor and a new converter, as the old one is not suitable for the future motor. *[See G/ Risk analysis for more details]*.

I- Improvement of the shredder			
Tâche I.1	Securise the shredder with a hopper		
Tâche I.2	Install a cover		Hinges in printed. Make a wrist
Tâche I.3	Install the electrical box		Connections to be made
Tâche I.4	Install the end/stop button on the hopper		
Tâche I.5	Make the front of the electrical box		CAO in progress
Tâche I.6	Realise the housing (carter)		Waiting for the engine
Tâche I.7	Install the geared motor		Waiting for the engine
Tâche I.8	Adjust the modes on the converter		Waiting for the new converter
Tâche I.9	Make the engine support		Waiting for the engine
Tâche I.10	Install a grid under the shredder to make big plastic chips		
Tâche I.11	Design a bin (bac) for the big ships of plastic		
Tâche I.12	Make the bin		Water jet cutting machine

Figure 10 : Details of task I - Improvement of the shredder
(red = task not started, orange = task in progress, green = task finished)

While waiting for this new engine, we will take advantage of the week blocked for the project activities to make as much progress as possible on the prototype of the shredder. When we receive the motor, all we have to do is install it and connect it to the shredder shaft.

We also made an update of the project cost estimations *[appendix 3]* where we mainly add the engineering price and the new gearmotor quote with its new converter.

G/ Risk analysis

At the period of the last deliverable, the group got some issue with the engine which was not powerful enough for the shredding task. This possibility was considered in the Risk analysis but the criticality was clearly under-estimated. To not make the same error the group had decided to reconsider all the severity and occurrence levels of the previous Risk Analysis document to create a new revision of the document. This revision number 2 is focused on two main points. First reconsider all the critical levels as said before with the experience we had gained during the first phases of the project in order to highlight all the major risks for the end of the project. The second part of the work in the Risk Analysis is to think about the new issues that could occur in the prototyping and testing phase.

For the new evaluation of the risk levels, we can take the example of the risk of an engine that is too weak to shred that passed from a Criticality 1 to 4 that is clearly more reasonable after experiencing this problem. Some other risks were re-evaluated : to finish the prototyping, we need to receive a new engine with enough torque, a problem in the order could compromise the end of the project. We can also talk about the fact that the lab might be occupied by other students, that could prevent us from working on the prototype. At this period this risk is more important because first year students have some project that needs the lab. The access to the tools and equipment could be pretty difficult during these phases.

Risk family	Risk	ID	Description	Severity	Occurence	Criticality (F*F)	Action taken to avoid the risk	Solution identified if risk is encountered
Performance	The motor is of a low torque, therefore not enough to shred the plastic	11	Shredder jams, runs at too low a speed	1	1	1		To find a new motor/reducer

Figure 11 : Motor risk in REV1

Performance	The motor is of a low torque, therefore not enough to shred the plastic	11	Shredder jams, runs at too low a speed	2	2	4		To find a new motor/reducer

Figure 12 : Motor risk in REV2

About the New risks that were added they are mainly related to the prototyping and testing phase. A very obvious risk in this kind of phase could be to break a component while mounting it or while testing it. To find a solution to this problem or to try to limit at maximum the chance of this happening, the group had made a list of all the components of the prototype. In this list the group will define what components are the more fragile or the most difficult to replace. This could help to be more careful when we manipulate the more critical parts of the prototype. Another risk could be about the shredding module which could possibly not work as expected. We never saw it work because of the engine issue and we completely do not know how it will shred the plastic parts.

Organization	Breacking parts of the prototype	19	A group member breack a coponent of the prototype during the mounting or testing phase	3	2	6	List of critical component to handle with care	
Performance	Cahotic working of the shredding module	20	With a proper motor the shredding module that was given do not work as expected	3	1	3		Make a problem finding demarche fix is it possible or propose a way to fix the problem

Figure 13 : Risks added in REV2

H/ Work Plan - objective, Key elements, difficulties

As compared to the first few months when we started, we can boldly say that we have a clear work plan and end goal now. In the first few months of our project, we were solely focused on the global perspective of our project, instead of being specific on a particular area (functional shredder). We had indeed underestimated the demand of the work. Thanks to several educating sessions with the professors, we are more focused on the specifics and now have a clear goal.

The objective of our work, in correlation to the topic, is to deliver a functional plastic shredding machine, with detailed documentation on GitHub, as it is an open source project. With this objective in mind, our shredder should be able to shred plastics to the desired fineness, for other usage. The key elements of this machine are the motor, blades, torque and the electrical components of the shredder. To determine the performance of our shredder, different tests will be carried out on the shredding machine. For example, the ratio of the output mass to the input mass will be determined and a high percentage indicates a good shredding process.

So far, we have had a fair share of difficulties in the course of this project, especially as stated above concerning the global and specific objective of our project. We had underestimated the demands of the project and tried to fulfill the global objective in such a short time, which is clearly impossible. Another major difficulty has been with the motor of the shredder. It had a lower capacity and therefore could not power the machine. We finally made a new order but now there is a delay. Also we did not follow completely accurate procedures, this could have been the cause. In the first two deliverables, we did not include SysML diagrams and we had ignored a lot of engineering aspects in our presentations, especially to aid in communicating effectively our project. All these have been rectified. We are gradually but clearly working on delivering a finished prototype.

As regards the documentation on GitHub, as a team, we have made commendable progress. We have clearly defined the task for everyone, and had to redefine roles, so as to get everyone involved in the project and deliver on time. The report takes this format, a weekly update of tasks carried out by each member of the team and their progress, this is done by the project advancement manager. The gantt manager updates the gantt regularly, each member also has a part to update on the platform. The project manager oversees.

Therefore, at the end of the project, we should be able to deliver a functioning shredder, able to shred plastics to the desired fineness, thanks to the grid. And also make it an open source project, thanks to GitHub.

APPENDIX 1: GANTT chart

Link to go to the drive with the gantt chart (to see the sub-tasks):
https://docs.google.com/spreadsheets/d/1zl9KApmCFzgjy7fXfSUUbfGAa_7RfqJYZSNwacTICsc/edit?usp=sharing

You can also see directly a sample below :

GANTT REV.3

Open source plastic recycling machine

		Durées	Ressources	S38	S39	S40	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S1	S2	S3	S4	S5	S6	S7	S8
				20/09 - 26/09	27/09 - 03/10	04/10 - 10/10	11/10 - 17/10	18/10 - 24/10	25/10 - 31/10	01/11 - 07/11	08/11 - 14/11	15/11 - 21/11	22/11 - 28/11	29/11 - 05/12	06/12 - 12/12	13/12 - 19/12	20/12 - 26/12	27/12 - 02/01	03/01 - 07/01	10/01 - 14/01	17/01 - 21/01	24/01 - 28/01	31/01 - 04/02	07/02 - 11/02	14/02 - 18/02	21/02 - 25/02
Infos		NA	NA						Exam 28/10		Exam 8/11	Exam 19/11														
Deliverable												L1 : 16 Novembre											L2 : 1 Février			
A	Reading of technical documents	2	Team																							
B	Meeting/mail with Germain LEMASSON	5	Team																							
C	Project management	3	TB/ML																							
D	Systems Engineering	7	LG/MC/ML																							
E	Connecting the converter	2	ML/MC																							
F	Organisation of the collect/routing of plastic	9	Willie/ML																							
G	**Shredder supply chain**	8	WNI/ML/MC																							
H	Study of the current engine and the engines available	3	MC/ML																							
I	Improvement of the shredder	21	TB/WL/ML/MC																							
J	Tests	7	Team																							
K	Write open source document on Github	16	Team																							
L	Write the deliverables	4	Team																							
M	Hot press research phase	6	LG/MC																							
N	**Hot press state of the art**	7	LG/TB/MC																							
O	Calculation of costs	7	LG																							

TOUSSAINT | NOEL | NOEL | PARTIELS S1 | !! REMANIEMENT ORGANISATION !! | HIVER

GANTT REV.3

Open source plastic recycling machine

		Durées	Ressources	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
				28/02 - 06/03	07/03 - 13/03	14/03 - 20/03	21/03 - 27/03	28/03 - 03/04	04/04 - 10/04	11/04 - 17/04	18/04 - 24/05	25/04 - 29/05	02/05 - 06/05	09/05 - 13/05
Infos		NA	NA				semaine bloquée							
Deliverable							L3 : 23 Mars			L4 : mid may		L5 : end may		
A	Reading of technical documents	2	Team											
B	Meeting/mail with Germain LEMASSON	5	Team											
C	Project management	3	TB/ML											
D	Systems Engineering	7	LG/MC/ML											
E	Connecting the converter	2	ML/MC											
F	Organisation of the collect/routing of plastic	9	Willie/ML											
G	**Shredder supply chain**	8	WNI/ML/MC											
H	Study of the current engine and the engines available	3	MC/ML											
I	Improvement of the shredder	21	TB/WL/ML/MC											
J	Tests	7	Team											
K	Write open source document on Github	16	Team											
L	Write the deliverables	4	Team											
M	Hot press research phase	6	LG/MC											
N	**Hot press state of the art**	7	LG/TB/MC											
O	Calculation of costs	7	LG											

PAQUES

Code couleur	
Late	
In time	
Advance	
Past	
	Semaine bloquée

Revision date : 25/01/2022

Last modification : 16/03/2022

APPENDIX 2: Risk analysis

Risk family	Risk	ID	Description	Severity	Occurence	Criticality (E*F)	Action taken to avoid the risk	Solution identified if risk is encountered
Communication	Mistakes on client requirements	1	The customer expected something different than what we produced	3	1	3	Maintain regular contact with customers (not just virtually)	
Communication	Additions of requirements by the customer after the prototype is finished	2	The client changes his mind in the middle of the project, adds fundamental requirements, has expressed himself badly beforehand/ Misunderstanding of expectations	2	1	2	Maintain regular contact with customers (not just virtually)	
Security	A user is injured by the shredder	3	Cutting, plastic splashes, risk of electric shock...	2	1	2	Protective covers, precise rules of use, safety contactors, emergency stop...	
Security	A user is injured by the compactor	4	Risk of burns, steam release, electric shock	3	1	3	Smoke evacuation system, increased electrical safety, sufficient heat shields, comprehensive user regulations with appropriate PPE	
Environment	The compactor must not emit toxic gases or consume excessive energy	5	Evacuation of toxic fumes	2	2	4	Drainage system complying with specific standards	
Communication	Lack of plastic from collection	6	People are not or no longer involved and do not give us a sufficient amount of plastic	3	2	6	Establishment of an active communication network, acronyms and explanations	
Communication	Disengagement of some group members	7		2	1	2		
Organization	Work overload some weeks with midterms, other projects, audits...	8	Delays in planning due to bad forecasts, forgotten events...	2	2	4	Organise our schedule well and take into account any impediments as much as possible	
Organization	Access problem to the GINOVA platform	9	Provide for possible overloads of GINOVA (project platforms, first years....)	2	1	2		
Communication	Lack of communication within the group	10	The group is not united and not everyone is up to date on the work done	2	1	2		
Performance	The motor is of a low torque, therefore not enough to shred the plastic	11	Shredder jams, runs at too low a speed	2	2	4		To find a new motor/reducer
Organization	Delayed orders	12	Necessary parts ordered too late	3	2	6	We design our products well in advance and take into account the maximum number of parts to be manufactured, ordered...	
Performance	Porosity in the plastic when compressed	13	Presence of pores in the plastic plates, poorly fused particles	1	2	2	Use the same type of plastic for a plate, dry the plastic, put enough material to make the plate	
Organization	COVID-19 outbreak	14		2	2	4		Create a New workflow which will allow remote work (mail / cloud /zoom meetings)
Organization	Long-term absence of a group member	15		1	2	2		reorganize the ressources if the member couldn't work / organize a workflow which permit work to continue despite the absence (mail / cloud /zoom meetings)
Performance	Plate thickness after compression not as expected by the physio	16	The plate is too thick, too thin	2	2	4	Be aware of the amount of material needed before compression, design our moulds accordingly	
Performance	Size of plastic chips too large	17	The chips are too big, the customer cannot use them to make filament	2	1	2	Use a properly sized recycling grid	
Design	Errors in CAD	18		1	2	3	Share the work between members to check for errors	
Organization	Breacking parts of the prototype	19	A group member breack a coponent of the prototype during the mounting or testing phase	3	2	6	List of critical component to handle with care	
Performance	Cahotic working of the shredding module	20	With a proper motor the shredding module that was given do not work as expected	3	1	3		Make a problem finding demarche fix is it possible or propose a way to fix the problem

APPENDIX 3: Cost table

Parts		1 879,23 €
	Mechanical parts	217,63 €
	Electric parts	774,41 €
	Motorisation	887,19 €
Machining		147,05 €
Ingeneering		24 480,00 €

Description	Material	Price	Details	Quantity	Where to get it
Machine parts					
3mm pieces	Steel	- €		1	IUT Joseph Fourier - G
5mm pieces	Steel	133,28 €		1	http://www.oxytemps
6mm pieces	Steel			1	
Screw	Steel	- €	M6 x ??	8	
Nut	Stainless	- €	M6	8	
Washer	Stainless		M6	8	
Hexagonal bar	Steel	6,92 €		1	https://www.acier-det
Bearing		22,01 €	UCFL204 Ø20m	2	https://www.123roule
Screw	Stainless	3,10 €	M10 x 60	4	Neton
Nut	Stainless	2,17 €	M10 6 pans	4	Neton
Threaded shaft	Steel	1,95 €	Ø10 - 25cm	2	Mon brico
Nut	Stainless		M10 6 pans	4	
Motor/Shaft connector	Steel	2,50 €	Ø60mm L60mm	1	https://www.acier-det
Screw	Stainless	- €	M8 x ??	2	
Structure	Steel	- €		1	Ancien portail
Angle profile	Steel	- €	30*30*3mm	2	
Washer	Stainless	- €	M10	16	
Screw/Shaft	Stainless	- €	M10 x 50	4	
Nut	Stainless	- €	M10	8	
Screw	Stainless	- €	M8 x ??	3	
Nut	Stainless	- €	M8	3	
Washer	Stainless	- €	M8	3	
Mesh sheet	Steel	0,50 €	1<Ep<2mm	1	Arc-en-ciel
Sheet metal for hopper	Steel	35,20 €	1<Ep<2mm	2	https://www.leroymer
Plastic filament	Plastic	10,00 €	200 gr		
Structure		Récup		1	
Gear Motor					
Gearmotor		839,53 €		1	
Coupling		- €	d = 56mm, l = 78r	1	https://fr.rs-online.cor
Electronics					
3 Poles male plug + Earth		14,75 €		1	https://www.leroymerlin.fr/v
3-position switch contactor		7,32 €	on-off-on 15A/2	1	https://www.manomano.fr/p
Female flat terminal		- €	6,3 x 0,8mm	6	
Electrical Cable		- €			
Electronic box		- €			
~~Permanent capacitor~~		~~10,32 €~~	~~20 µF à câble~~	~~1~~	~~https://www.condensate~~ ~~https://www.astuces-prat~~
End-stop sensor		24,23 €		1	https://fr.rs-online.com/web/
Yellow LED flashing light		225,15 €	24 V CA CC -l	1	https://www.se.com/be/f
Emergency stop button		23,60 €		1	https://fr.rs-online.com/w
Potentiometer		10,00 €		1	
Circuit breaker		81,68 €	2 poles C60N	1	https://fr.rs-online.com/w
Converter		377,36 €		1	https://fr.rs-online.com/w
Machining					
Screw head		- €			GENOVA Phiphi
Bearing spacer 3mm	Plexiglass	- €			GENOVA Phiphi
Hexagonal bar		- €			GENOVA Phiphi
Motor/Bar connector		- €			GENOVA Phiphi
Drilling Motor/Bar/Connector		- €			
Tapping (Thread)		21,25 €			Mon Brico
Grinding structure		- €			
Welding structure		50,00 €			Remorque mandrinois
Water jet cutting hopper		-			ENSE3 Fablab
Hopper folding		-			GInova
3D printing		-			FavLab
Finishing					
Sanding + Disc		- €			
Rustproof paint		14,50 €			
Machine costs:					
Water jet cutting		4,00 €		20min	
3D printer		1,30 €		2h	
lathe		16,00 €		20min	
Operator costs		40,00 €		1h20 (trémis découpe + pliage + tour)	
Ingeneering costs		24 480,00 €		408	
TOTAL PROJECT		26 458,62 €			
TOTAL (without ingeneering cost)		1 978,62 €			