# FUTURE OF FORESTRY

**Team 1: Amanda Barnard**
María Jover Tarancón | Oriol Juanhuix Sieira | Ruth Mota Villalobos | Uttara Kumar

CBI Challenge Based Innovation

CERN Ideas

# PROJECT TREEPLICATE

one tree, three products

Project Treeplicate is an innovative solution to bring a circular, sustainable, and regenerative economy to the forest community, resulting in an increase in forest health & biodiversity.

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# PART I: UNDERSTANDING THE PROBLEM

# Introducing the Challenge

*"Guiding change together"* is the slogan of Pioneers of Our Time, a dynamic forest community space located in the Eastern Pyrenees area known as the Muga Valley. The co-founder & CEO of Pioneers, Stef van Dongen, started the project in 2018 with 250 hectares of private forest land. The primary goal of the project is to reinvent the forestry industry to ensure healthy & resilient forests for long term sustainability. This includes rejuvenating thriving wildlife and ensuring a prosperous economy & lifestyle for the surrounding community.

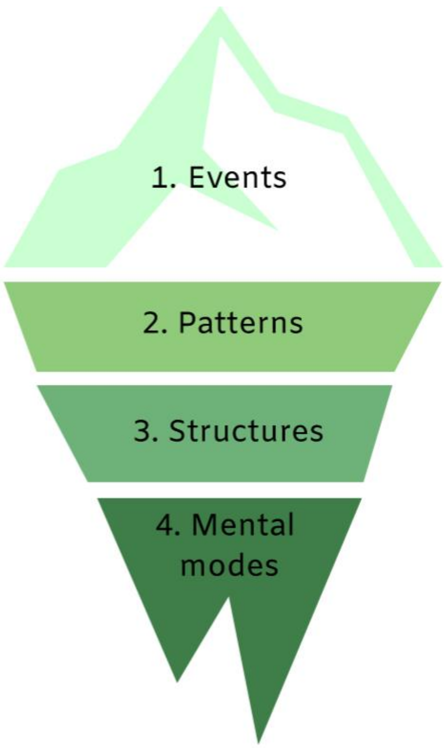

As the primary stakeholder of *Challenge 1: The Future of Forests & Forestry* as part of the Challenge Based Innovation (CBI) course, Stef met with our team to explain in detail his initiative at Pioneers, the current challenges he is facing, and the opportunities he sees for greater impact through systemic change. As of last year, Stef owns 400 hectares of private land. His team is passionate and eager to build a structure that contributes to the project's goals to guide change towards a dynamic, climate-positive forest environment in the coming years.


## Evaluating the Systemic Issues

We continued to research forests in Catalunya and found trigger points for why some of the issues are present and persistent. The iceberg model was beneficial in understanding the deeper concerns and systemic issues at hand. Once we deep-dived into the underlying causes and effects, we were able to uncover and pinpoint the structures at hand that we could tackle in our potential solutions. We realized that maintaining the forests, especially controlling the pine tree infestation, is not profitable for the forest teams, due to the low market value of pine wood as a raw material. The lack of maintenance then is the primary cause of uncontrolled forest fires, an increase in invasive species, and a reduction in forest biodiversity. The vulnerable forests are more prone to the effects of climate change and unable to withstand the changes in nature. For example, the soil is more likely to erode and lose its high nutrient qualities when floods happen.

As a consequence, there is a major crisis of rural abandonment where the surrounding forest community is moving to work in the cities at an increasing pace, leaving the forest lands even more under-managed. The government, on the other hand, does not view forests as a priority and is not investing efforts to protect them and prevent further degradation. The dominant underlying driver of these cycles is the structure of capitalism where profits drive the economy and the mindset that the forest is self-regenerative, which stems from a lack of education by the common public.

From a first instance, these seem like overwhelming topics to understand, let alone try to solve. However, our team was determined to gain more insights into *why* these issues are persistent in the context of the Pioneers, and where our backgrounds and expertise can best help in finding a solution.




Events

- Non existent or low profit related to forestry - eg wood & wood products
- Increased forest fires - in number & affected areas
- Lack of infrastructure or investment in protecting the forests and surrounding community
- Rural communities are struggling with their livelihood due to a failing economy
- Biodiversity of forests is rapidly reducing, giving space to invasive species and increasing vulnerability of the ecosystem

Patterns

- Consequences of climate change
- People have been leaving rural ares due to poverty or lack of infrastructure
- There is a growing interest in nature by locals and it's intrinsic value
- Wild fires have grown exponentially
- There are not any innovations in forestry

Structures

- Low priority to maintain forests
- As most of the forests in catalunya are private property, it's difficult to monitor the use of the land from a governing perspective.
- Enterprises only focus on revenue, and larger trees are valued more. so there is no market for small trees or smaller projects
- There is not much public investments in maintaining forestry
- People want to live connected with nature, but only do so for a short while (or as tourists), so huamn invasiveness has become an issue as we don't know how to apply regenerative practices

Mental Modes

- Profits are what drive the economy (capitalist mindset)
- The mindset that the forest is self-generating and will "take care of itself"
- The common citizen is unaware that there is a problem with the forests

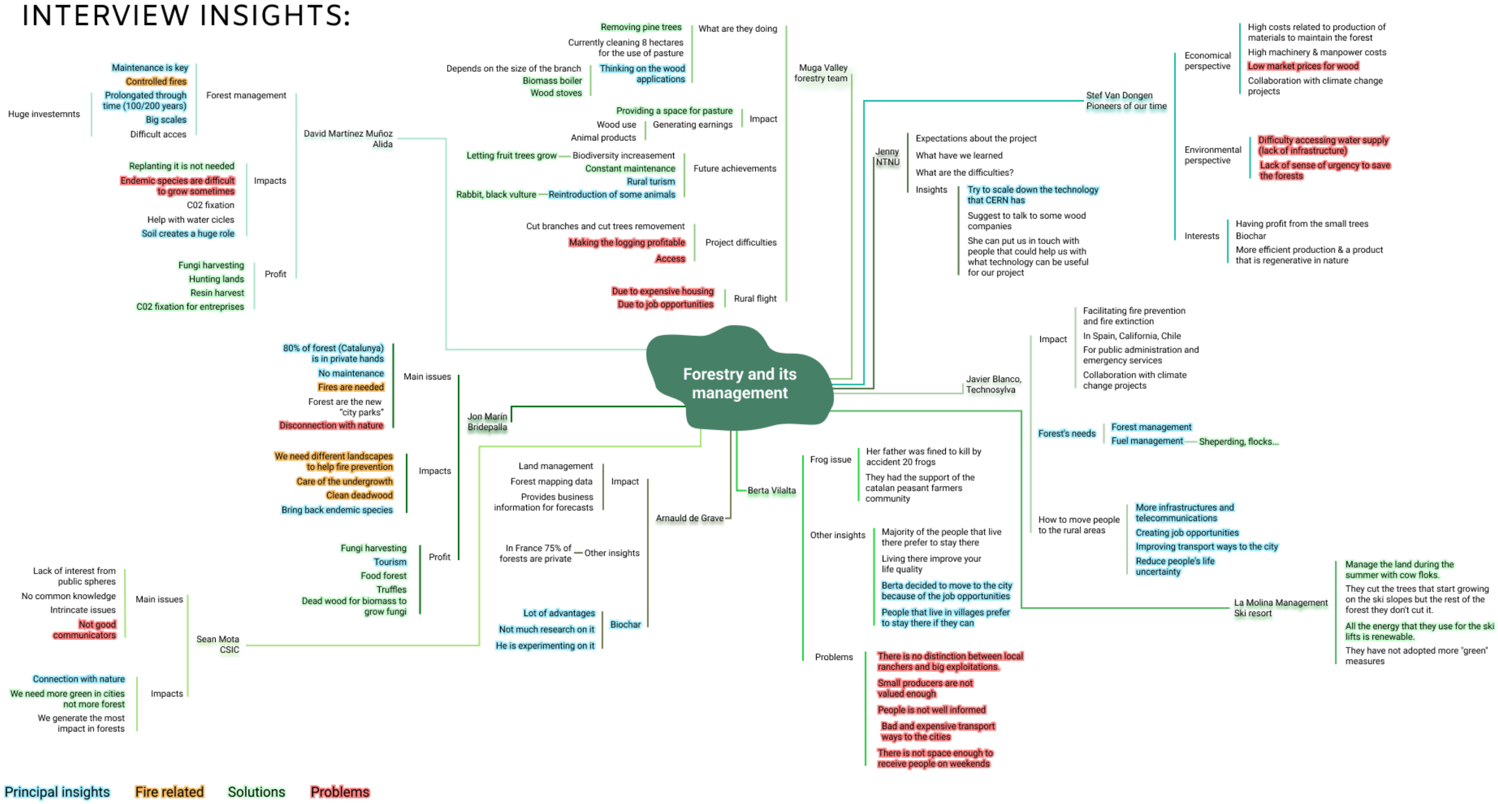
## Contextualizing the Challenge

After our initial conversation with Stef, our CBI team thought it would be best to pay a visit to the Muga Valley for face-to-face conversations with the team of forest engineers at Pioneers. After all, the first step of the ideation process is to understand and empathize with the situation and related collaborators. Their team was happy to welcome us and speak to us about the current operations in the area and were able to deep dive into the pain points & barriers the team is currently facing in generating income and preserving the wildlife landscape.

Then we spoke to other stakeholders who gave us more information on the forest situation, what's being done at the moment, and what are still revolving problems.

Firstly, we understand that regeneration in nature is a long-term challenge. A typical cycle in the forest lasts 10 to 20 years, sometimes even 100 years to see changes implemented today. With this, since a human generation lasts 20-30 years, and government parties rule for 4-5 years, forestry communities find it extremely difficult to carry on sustainable forestry practices.

## INTERVIEW INSIGHTS:




On the topic of forest fires, we learnt that fires from natural origins are necessary for forest health here in the Mediterranean territory. The issue is fires caused by human intervention, such as climate change, are rampant & cause wider spreading and damage to forests. That being said, there are plenty of resources at the moment focused on fire management & prevention.

Another insight from the interviews is that in Catalunya, where our project is based, 80% of the forests are private property. This is important to consider as governing laws do not offer subsidies or assistance to private forests. This means forests are not streamlined in their maintenance, leading to unsustainable practices & depletion of soil health.

However, this also offers an opportunity for entrepreneurs to launch pilot projects for forest conservation & regeneration, while engaging the local rural communities, such as flood management, biochar planting, and rural tourism.

## Mapping the Challenges, Solutions, and Gaps

From the insights of the interviews, we started to map the challenge and identify existing gaps. The table below outlines the work we did in understanding the issues with forests in Catalunya, along with current solutions both at a local & global scale. We also highlighted the gaps in impact, where the solutions fail to solve the challenges at hand.

We understand that there is a mismanagement of the forest ecosystem, along with infrastructure & governing issues. This leads to a struggling economy for the rural population, and ultimately a lack of understanding of how to maintain forest biodiversity while also sustaining life & work for the foresters. There are some solutions in place, in a local & national setting. They include various biodiversity projects in the Muga Valley estate, as well as fire prevention and other solutions that exist in the forestry context but are not applied to our target stakeholders.

The gaps we identified were: a solution that is high impact and scalable, also multi-faceted. Another important gap was an opportunity to use aspects of the forest itself, instead of bringing in foreign elements.

| Challenge Mapping | Impact Gaps | Solution Mapping |
|---|---|---|
| • Mismanagement of forest ecosystem<br>• A struggling economy for the local rural population mismanagement of the forest ecosystem<br>• Infrastructure issues, such as restricted access to water & essential resources<br>• Laws that favour bigger logging companies, with no consequences<br>• Lack of understanding of how to maintain forest biodiversity while also sustaining life & work for the foresters | • A solution that is high impact & scalable<br>• Multi-faceted, with high impact, short term & long term benefits<br>• Using aspects of the forest itself, instead of bringing in foreign elements<br>• Different economic activities that could help the forest and the rural population | On-site projects:<br>• Biodiversity project: reintroducing various types of vultures into the forest<br>• Ecological & regenerative egg farm<br>• Using animal flocks (cows, sheep) to keep the forests clean<br><br>Other related, third-party initiatives(not implemented on-site, but exists in other forests in Spain)<br>• Fire management/prevention database<br>• Using forest wastes to produce bio-charcoal<br>• Smart soil sensors |

During the first few weeks of the project, our team went back and forth with the critical issues at hand and tried to focus on one that was approachable, but also when tackled, created enough change to make a tangible impact. The key issue we directed our attention on was rural abandonment in the forests. There is a trend among people living in rural areas not being able to make enough profit to continue justifying living in these areas. Consequently, they migrate to cities due to the lack of infrastructure and economy in the rural areas. In Spain, 90% of the population lives on

30% of the land. The remaining 70% of the land is abandoned. Our unkempt forests are an example of this abandoned land, of which the lack of maintenance increases the risk of wildfires and reduces the range of biodiversity as invasive species such as pine trees infiltrate the terrains. This creates a vicious loop, as there is a reduced effort from the government to maintain the land, due to a lack of incentive to maintain the forests, which continues the rural abandonment. This is why we aren't seeing innovative solutions in this area. We would like to focus our efforts on finding a solution that benefits Stef & the Pioneers of Our Time. We note that this issue is pertinent throughout the forests of Catalunya and Spain, and aim to build a solution that is scalable to the wider community.

## Reframing Our Insights Into Opportunity Areas

Finally, we developed some "how might we's" to make the problem more focused & approachable. As we spent time defining the problem, we reframed our insights into opportunity areas.

| |
|---|
| How might we help the Muga Valley forest community create a circular, sustainable, and regenerative economy? |
| How might we create opportunities for the Pioneer research center to have more revenue streams and engage more of the community? |
| How might we help the Pioneer forest engineers utilize forest databases & algorithms to improve forestry management? |

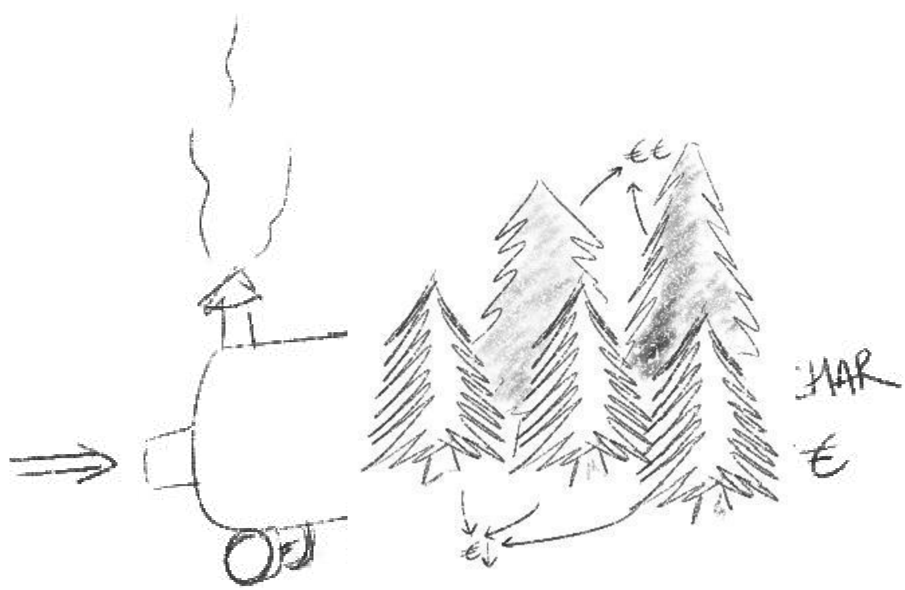
# PART II: FINDING A SOLUTION

## Breaking Down the Problem

| | | |
|---|---|---|
| **Who** | Who has the problem? Who are the stakeholders? | 1°: Pioneers of Our Time workers<br>2°: Pioneers of Our Time management team & investors |
| **What** | What is the problem? What has been done to solve it? | A struggling economy for the Pioneers, due to a lack of sustainable revenue from small trees & wood waste |
| **When** | When did the problem occur? When should it be solved? | This problem started during the 1970s agriculture revolution & rural flight. It needs to be solved now! |
| **Where** | Where is the problem occurring? | The Pioneers' estate in the Muga Valley (although the larger context is forests in Spain) |
| **Why** | Why is it a problem? Why is there no solution? | **Logistical issues:**<br>1. Difficulty in the cutting & transporting small trees/wood waste<br>2. Difficulty accessing the pine trees deep into the forest<br>**Little to no value for wood** |
| **How** | How did the problem come about? How did the stakeholders try to solve the problem? | Refer to the iceberg model & impact gap analysis |

*The problem: the workers of the Pioneers' estate in the Muga Valley are currently facing the issue of a struggling economy, due to a lack of sustainable revenue from small trees & wood waste. This is due to 2 pain points: logistical barriers, and low market value for raw materials*

## Initiating & Validating the Ideation Process

Once we defined the

problem, we were ready to ideate and think of potential solutions. After researching & discussing the current solutions, we shortlisted three potential ideas to move forward with:

| Idea | Details |
|---|---|
| **Biochar Processing** | • Biochar has multiple nutritional properties in the soil, to improve soil quality<br>• The forest engineers can sell the physical product and also claim carbon |
| **Application of AI prediction using the forest mapping database** | • Predict the occurrence of truffle on the property, for processing & selling (high-value commodity)<br>• Flock management to maintain the health of forests |
| **Expanding the research & community center** | • Long term project<br>• On-site work/learn program for students/young professionals<br>• Start-up incubator<br>• Forest data collection & management |

We had the following questions about each potential solution, which warranted another chat with Stef to validate our ideas and give us feedback on the process so far.

- How do we scale this up (as the property grows, and also for other forest communities)?
- How do we obtain the initial capital to get the project running?
- What is the profitability and unit economics of the project?
- How do we measure/track progress in terms of economical & environmental benefits?

- What are the main functions of each solution & how do we ensure that it is environmentally sustainable?

Stef expressed enthusiasm for our three ideas and while he mentioned he sees potential in the AI solution, he considered the biochar opportunity a priority. He also shared some helpful resources and insights on biochar and its production process. With this, we had a clear idea of how to proceed and worked towards building a viable solution that tackled the defined problem.

# Expanding the Chosen Solution

## The Impact Model Canvas

Designed for: Project Treeplicate | The Future o

Designed by: Team 1

**Key partners, donors, contributors or stakeholders**

- Key Stakeholder: **Pioneers of Our Time**
- Key resource: **CERN**

**Key activities**
What has to happen to deliver value?

1. Production of biochar: creating a machine that is small-scale, mobile, & self-sufficient
2. Carbon credits: receiving carbon credit certification to be able to sell credits to corporations
3. Energy management: redirecting the biogas created back to continue running the machine, and selling excess as energy

**Key resources**
What resources are needed to make your idea work?

1. Human resources: Forest workers to process the wood & engineering expertise to build & maintain the machine
2. Corporate resources: Companies in the area who are potential clients
3. Monetary resources: Initial investment to fund capital

**Value propositions**
What impact will you make in the lives of those you help?

1. Making the biochar production process small scale, mobile, self-sufficient - Providing access to those who have previously not had it
2. Boosting the economy by triplicating the revenue sources - physical product, carbon credit, Eexcess biogas from production
3. Clearing the forests of wood waste - ensuring increase in forest health & biodiversity

**Customer relationships**
What new relationships will you create and facilitate?

- Small land owners who are keen to boost the rural economy & facilitate in enhancing forest health
- Clients of the small land owners - agriculture & gardening companies

**Channels**
How are you going to reach each segment you serve?

- Contacting individuals & companies from the supply chain, we believe word of mouth is the most relevant and effective mode of communication for the time being

**Impacted segments**
Who are you helping? Describe your target audience in a couple of words.

- 1°: Pioneers of Our Time team
- 2°: Small land owners in the Catalunya area
- 3°: Purchasers & users of biochar/carbon credits/biogas in their applications

**Costs and outgoings**
What will cost money or other resources?

| | | | | |
|---|---|---|---|---|
| Machine parts acquisition & maintenance | Transport of biochar | Certification of carbon credit | Cutting & processing pine trees & wood waste | Overhead costs |

**Funding**
What will support the activities needed to make an impact

| | | | | |
|---|---|---|---|---|
| Kickstarter.org | Gofundme | VCs: Climate Tech, 0Waste PreAccelerator program | grants: Funding & tenders (europa.eu) | Revenues generated by the project |

## Strengths

- Machine is mobile in multi-terrains
- High usability of biochar
- High profitability by multiple revenue sources
- Carbon negative project

## Weaknesses

- Impact only as large as the capacity of land owner & team
- Machine needs to be customized to terrains & capacity

## Opportunities

- Growing market for biochar with exponential growth rate
- Scalable project to make a larger impact
- Sustainability & ESG is forefront of corporations now, high market opportunity

## Threats

- Fierce competition from other emerging companies for sale of biochar

# PART III: ENTER PROJECT TREEPLICATE

## A further look into biochar

Biochar is a charcoal-like substance made by burning organic material from agricultural and forestry wastes (also called biomass) in a process called pyrolysis. Although it looks a lot like common charcoal, biochar is produced using a specific process to reduce contamination and safely store carbon. During this process, organic materials, such as wood chips, leaf litter or dead plants, are burned in a container with very little oxygen or none at all. As the materials burn, they release little to no contaminating fumes. The organic material is converted into biochar, a stable form of carbon that can't easily escape into the atmosphere. The energy or heat created during pyrolysis can be captured and used as a form of clean energy. In this project, the biomass used to produce biochar is wood waste and small trees that have low market value.

The characteristics of biochar are influenced mainly by the preparation temperature and biomass. Higher pyrolysis temperature often results in the increased surface area and carbonized fraction of biochar leading to high sorption capability for pollutants.[1]

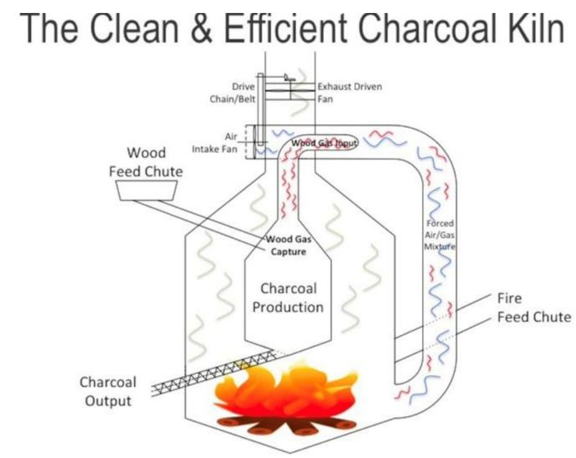
## Designing the Machine

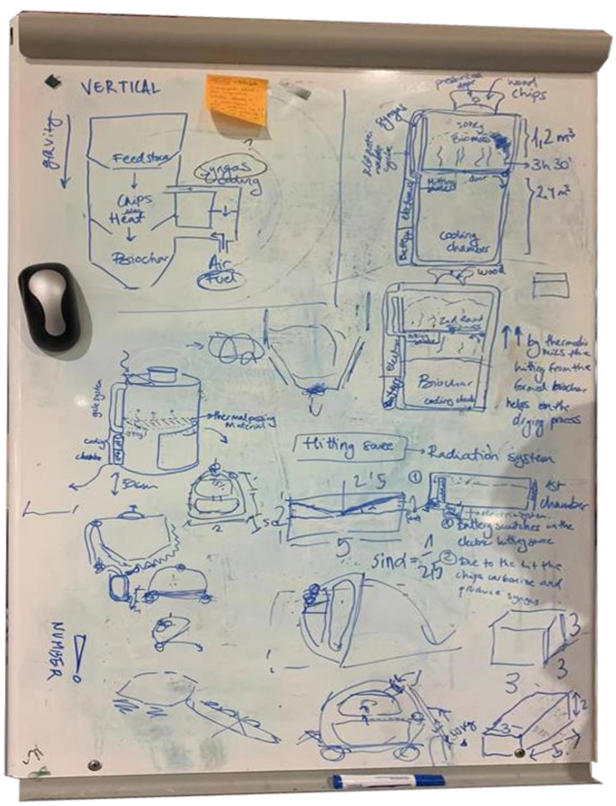
The choice to develop a biochar machine that could be transported was the option chosen because it tackles the main problems that landowners face: creating value from small trees & wood waste and reducing logistical costs. Biochar is made from biomass, and its valuable properties fetch a high price in the market. On the other hand, creating a machine that would be mobile would solve the issue of transporting the wood

[1] Characteristics of biochar and its application in remediation of contaminated soil, Journal of Bioscience and Bioengineering, Volume 116, Issue 6, 2013

products in and around the forest area.  Another advantage is that being a fairly simple process, almost any type of organic matter can be used. The previous processing of the wood is almost null, any leaves, branches, and pinecones can be included in the process without an additional step of preparing the raw materials. Consequently, this machine can be used for any vegetation cleanup (without reaching optimal performance, but with benefits).

When we decided on the design of the biochar machine, we chose a vertical design. Gravity itself helps to pass the matter from one chamber to another, while in horizontal designs a rotation movement has to be added to the process, making the system more complex. We wanted a simple, compact and functional design.



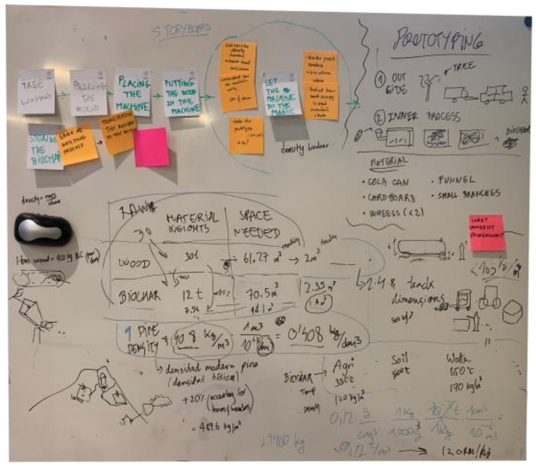



The number of chambers was clear from the beginning, as well as the general aspects that the machine should have. This includes the inlet hole, furnace chamber, cooling zone, material extraction, gas collection and distribution.

Apart from the verticality of the machine, an important factor to maintain was the use of shapes that were as rounded as possible. Having corners in this kind of design can create several problems such as excessive accumulation of material, which can generate buildup and would require more tedious maintenance.

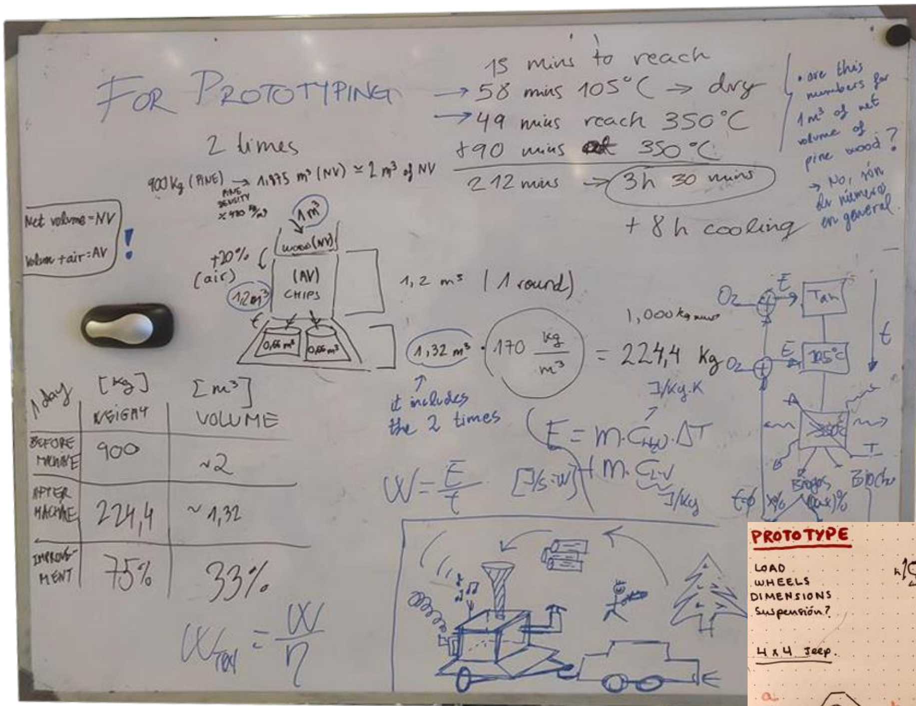
Another thing to take into account is the fact that, being transportable, the machine has to maintain a certain point of stability since the terrain which it is going to move over is quite uneven, so the machine's center of gravity has to be kept as low as possible.

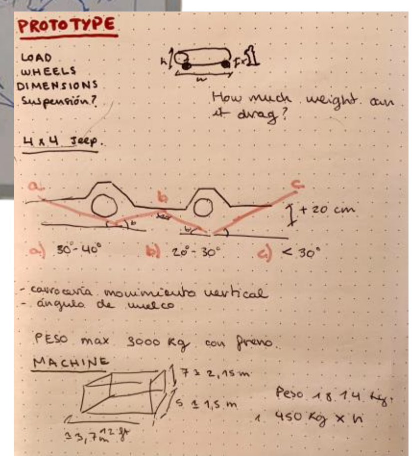
We worked on some first approximations of how the machine should work and what external appearance could be adapted better. To know the measurements that our machine had to have, we calculated the maximum volume of material that the workers collected per day thanks to the data that they provided us in the Muga Valley. This would be the volume that the machine would have to process.



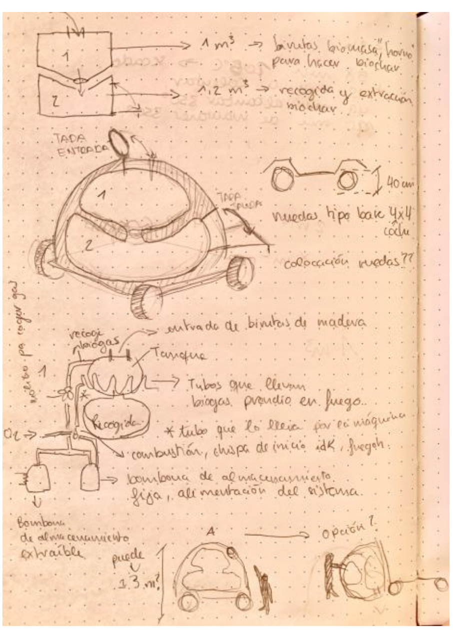

At the same time, we managed to find out the maximum amount of time that can be reached in the production of biochar (production at a lower temperature) and we calculated the maximum that a process would take to be carried out.

Since we wanted the machine to be as small and light as possible to remain mobile, the production process would last less than four hours (excluding the cooling process). With this, we decided that the machine was going to carry out two processes in the same day, considering a workday of 8-9 hours. Thus, our oven chamber size would reduce by half. Although the cooling chamber has to store the result of two batches of material, the volume of biochar produced is 30% of the volume of the input materials, due to loss of water. Due to this, the size that we initially thought our machine would have to have, after making these inquiries, was divided in half, allowing us to have a much more realistic approach to the machine that could become transportable with a car.



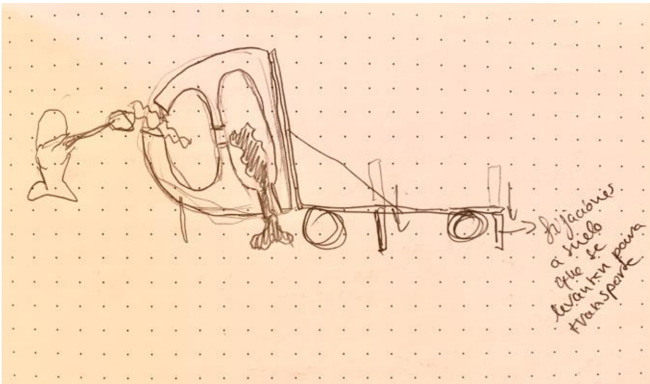




For its transport, we took as a reference the placement of the wheels of all-terrain cars since they are most used in the forest environment. We also took into account the maximum weight that the machine must be so that it can legally be towed, giving a maximum weight of three thousand kilograms, as long as it has a brake.



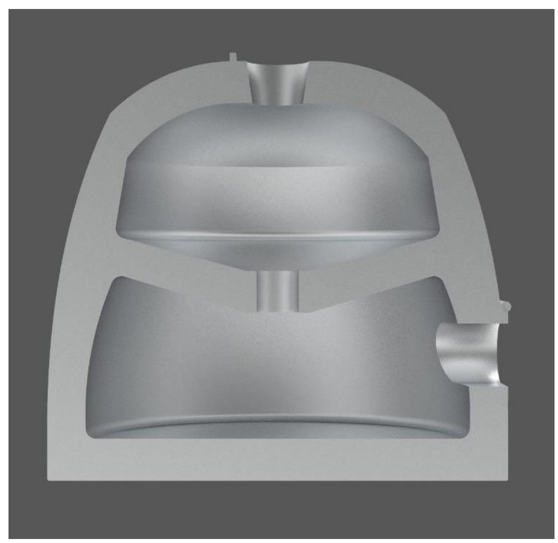
The approach to the final shape took all of these previous steps into account, and we settled on an igloo shape as it kept the shapes rounded but allowed the center of gravity to be reduced.

There are slopes in the upper chamber as they help decant the material in the lower chamber, which is key to the correct operation of the machine. Likewise, the lower chamber, which is where the material is collected, has a large area shared with the upper chamber since the residual heat of the material can help the drying process of the second firing.




Due to the large dimensions of the machine, the hole to introduce the material was too high. Wanting to minimize the need for extra machinery, we opted for a system similar to those used by trucks on-site, which allows the worker to access the lid more easily, saving us from adding a process to the system.

The cooling process is planned to be done overnight, so the next morning, while the worker is emptying the biochar produced, they can start loading up with material to start the process again, optimizing time as much as possible.



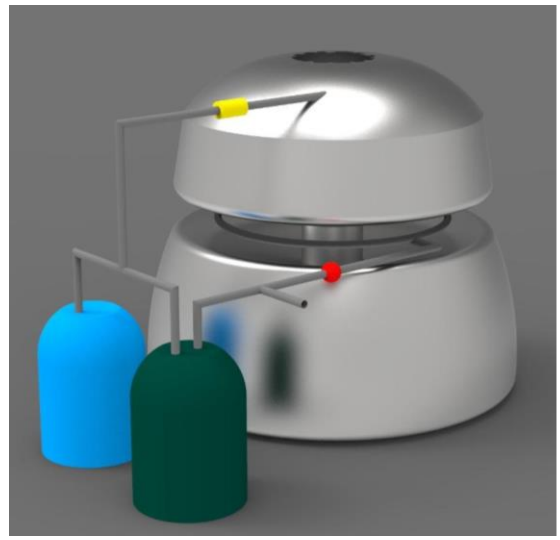
## Processing the Biochar

To explain the machine this section is going to be divided into two parts, the inside and the outside.

#### Inner process

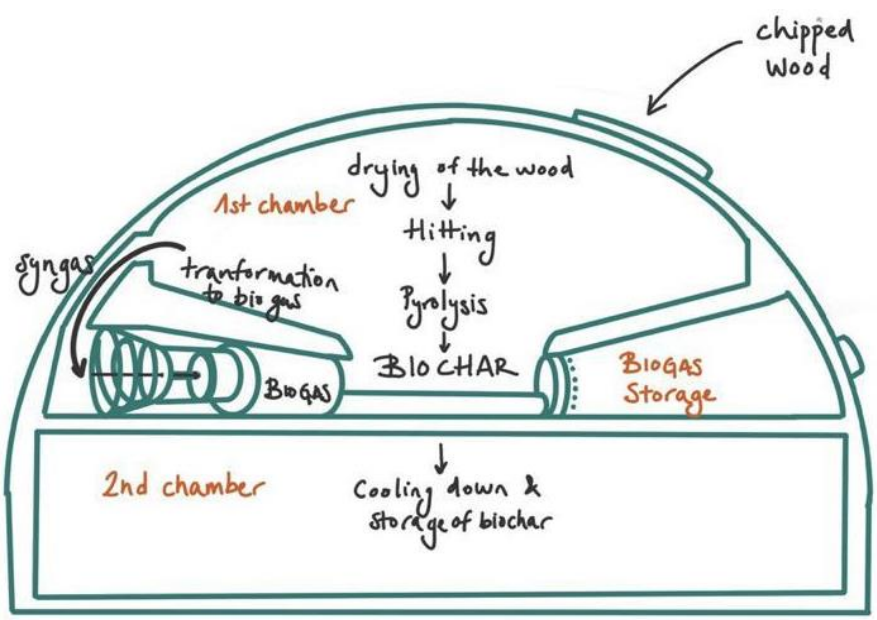
As we can see the Treeplicate machine has two main chambers. The upper one is where the wood chips are fed in and dried. Once this process is completed the pyrolysis starts. As explained before, this process takes different time spans so the final product can have different characteristics.

Once the pyrolysis is completed, the biomass that now is converted into biochar, with the passing door from one chamber to the other, is deposited on the lower part.
Then, a cooling and settling process starts. The calorific energy helps in the next drying process of the first chamber. And once the biochar is at room temperature it can be removed from the chamber with the lateral door.



The gases produced in the first chamber are channelized and pressurized to generate biogas. As it can be seen in the picture below, with two different cylinders the gas is stored. One of the cylinders, the green one, will be used to power the machine. And on the blue one, the surplus will be kept to sell it afterwards. In this way, the Treeplicate machine is self-sufficient and reuses energy as much as possible.

In this last diagram, the whole process is explained.



## External features

The Treeplicate machine is designed to meet really specific needs. The mobility through the forest terrain is a must and the functionality for the forest workers too. With this in mind, the external features of the machine can be better understood.


To begin with, all-terrain wheels and the possibility to attach them to a pickup truck or a similar car answers the need for mobility.

For the workers' functionality, the Treeplicate machine has a hydraulic pulling system. As explained in the last section. The wood will enter through the upper door. But it is out of reach. Thanks to this system the chipped wood can be easily fed to the machine. And on the other hand, when the process is finished it allows the removal of the biochar from the lower chamber in a user-friendly way.

All the pulling and the control system of the machine will be powered with the biogas converted into electricity. In this way, a 100% self-sufficient functioning is guaranteed.

# Creating the Business Proposition

In order to estimate the economic impact of our project, we needed to compare the current situation (business as usual) with our proposed solution from a monetary perspective. We compared the costs & revenues of selling wood (raw material) to those of Project Treeplicate.


The above graph shows the estimated costs and revenues (profits are highlighted in dashed lines) comparing the two processes. Breaking down the items, under Costs we have:

- Cutting & processing wood
    - Each month, the forest engineers cut and process 20 tons of pine wood. This figure was given to us by Stef, who has 2-3 engineers on sight and stated that this was their monthly capacity. Stef pays the engineers 20€ per ton of wood processed.

    - Yearly cost: 20 tons x 20€/ton x 12 months = 4800€

- Transporting wood
    - One trip from the site where the pines are cut to the base of the mountain is 2km long, with many sharp twists and turns on the path down. A large truck transports this wood once a month, the minimum it can carry is 15 tons of wood to be profitable. Stef pays 15€/ton to transport the wood to the base where it is sold.
    - Yearly cost: 20 tons x 15€/ton x 12 months = 3600€ (12 trips)
- Transporting biochar
    - The carbonization rate (percentage of wood turned in biochar yield) is 30%. This is an estimate from literature sources, so from the 20 tons of wood processed by the engineers, 6 tons of biochar is produced. Although the cost would differ since there are fewer tons of material being carried, the biochar pieces would have to be placed in sacks and arranged on the truck. Considering these extra steps we decided to consider the same cost as we used for transporting wood as an estimate.
    - Yearly cost: 3600€ (12 trips)
- Carbon credit certification
    - To be able to claim carbon credits from the process, we need to get the process certified. The Fair Trade organization charges a 15€ per ton CO2 premium. From literature research, we found that 1 ton of biochar sequesters 2 tons of CO2.
    - Yearly cost: 15€/ton CO2 x 2 ton CO2/ton biochar x 6 ton biochar/month x 12 months = 2160€
- Building the Machine
    - Upon researching how much such a machine would cost, we considered size, capacity, technology use, and estimated the machine to be around 60000€
    - Yearly cost: None. The machine is a one-time cost of 60000€, with a lifespan of 5-8 years.
- Electricity (cost saved)
    - Since the Project Treeplicate machine process generates its own energy to run, the cost savings are high enough to consider in our model. To run the

machine per day, we would theoretically use 48€ of electricity, which we save as the machine creates its own biogas to run on .

    - Yearly cost (saved): -48€/day x 30 days/month x 12 months/year = -17280€

- Overheads & Total costs
    - We considered 20% overhead in addition to costs mentioned above, for both the selling wood model & Project Treeplicate's model. This figure was verified by Stef who considers 20% in his costs as well.
    - Yearly costs:

| **Model** | **Subtotal cost** | **Overhead** | **Total cost** |
|---|---|---|---|
| Wood | 8400 | 1680 | **10080** |
| Project Treeplicate | 10560* | 2112 | 12672 + 60,000 - 17280 = **55392** |

*Does not include one-time machine cost, this is included in the total cost box

For Revenues, we have:

- Wood
    - One ton of wood fetches a market price of 50€, this was conveyed by Stef
    - Yearly revenue: 50€/ton x 20 tons wood/month x 12 months = 12000€
- Biochar (physical product)
    - The market price of biochar is currently 1000€/ton, based on market research
    - Yearly revenue: 1000€/ton x 6 tons biochar/month x 12 months = 72000€
- Carbon credit
    - 1 ton $CO_2$ sells for 100€ in the current market, based on market research
    - Yearly revenue: 100€/ton $CO_2$ x 2 ton CO/2ton biochar x 6 ton biochar/month x 12 months = 14400€
- Biogas as energy
    - During the production process, only 10% of biogas produced is used back in the system as energy. The remaining 90% can be collected and sold as a renewable energy source.

- 40 liters of excess biogas is produced, which is approximately 9480 kWh. Estimating a 33% efficiency conversion, 2844 kWh is actually used as energy. This converts to 80€ worth of electricity generated per day .
- Yearly revenue: 80€/day x 30 days a month x 12 months a year = 28800€

In summary:

| Annual Figures | Selling wood model | Project Treeplicate model |
|---|---|---|
| Costs (€/year) | | |
| Cutting & processing wood | 4800 | 4800 |
| Transportation | 3600 | 3600 |
| Building the machine | - | 60000 |
| Certification of carbon credit | - | 2160 |
| Energy (saving) | | -17280 |
| Overheads | 1680 | 2112 |
| Revenues (€/year) | | |
| Wood | 12000 | - |
| Biochar (product) | - | 72000 |
| Carbon Credit | - | 14400 |
| Biogas as energy | - | 28800 |
| **Profits (€/year)** | **1920** | **59808** |

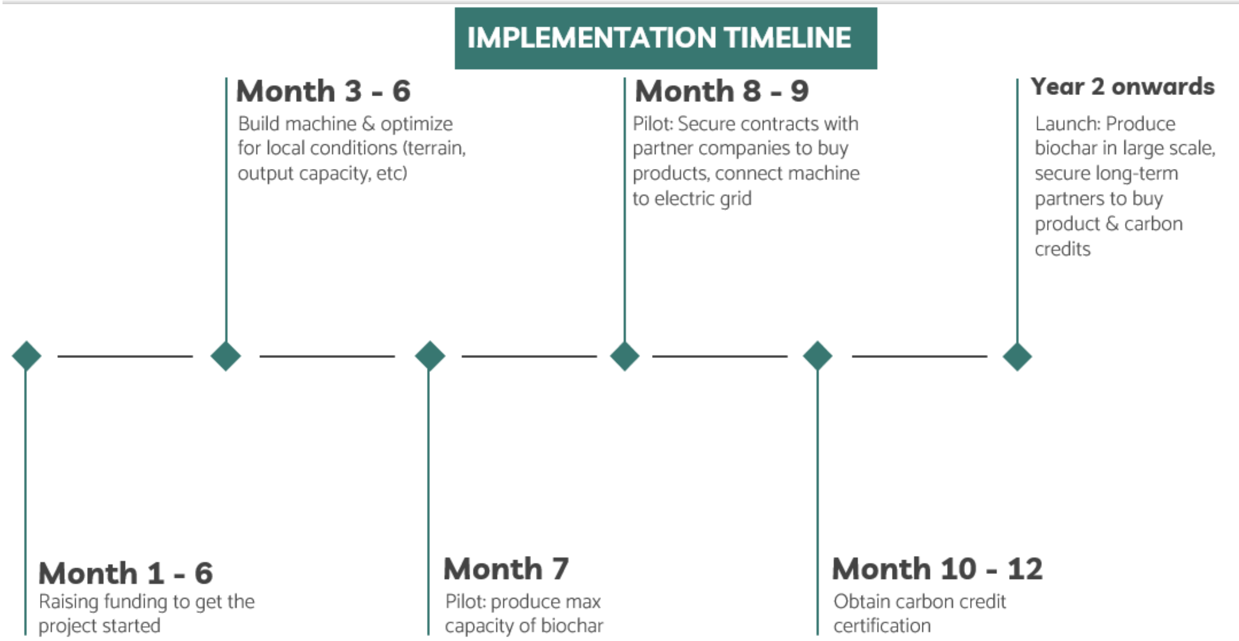
As you can see, the profit made from implementing Project Treeplicate is 30 times the current business of selling wood as a raw material. This is one order of magnitude!!

## Forecasting the Expected Impact

With the estimated revenues just from biochar from the first year, Stef can hire 3 new forest engineers, considering a salary of 24000€ per person per year. The short term impact of this is job creation in the rural area, the long term impact is a circular economy and a lower rate of rural abandonment.

The biogas produced can power 3 homes in the community, meaning reduced reliance on fossil fuels, giving back to the community.

The carbon credits offset makes the process carbon negative, on a larger scale it absorbs $CO_2$ from the atmosphere so helping mitigate climate change, keeping the micro-community healthy & thriving. The growing interest from not only individuals, but enterprises that volunteer & are mandated to remain carbon neutral or negative (so they invest in certified projects in order to not pay carbon dioxide taxes), and also global institutions that are realizing the vital role that forestry has in our system (helping reduce increasing temperatures, creating more humid environments, etc.) as well as a social recognition of nature intrinsic value (as we have seen with the doubling number of people moving to the countrysides after the pandemic).




## MEASURING THE SUCCESS OF OUR PROJECT

- Number of new employees onboarded as a part of Project Tree-plicate
- Projected budget vs actual budget
- Tons of biochar sold & rate of production vs distribution, with price
- Efficiency of machine - output rate, energy reuse rate
- Return on Investment (ROI) - by measuring value of project against the initial investment
- Tons of $CO_2$ offset & rate at which carbon credits are sold
- Portfolio of partner companies

The future we envision: circular, sustainable, regenerative economy in the Muga Valley - we achieved it!

# PART IV: APPENDICES

# OUR TEAM


**María Jover Tarancón**
Bachelor's in Telecommunications
UPC'23

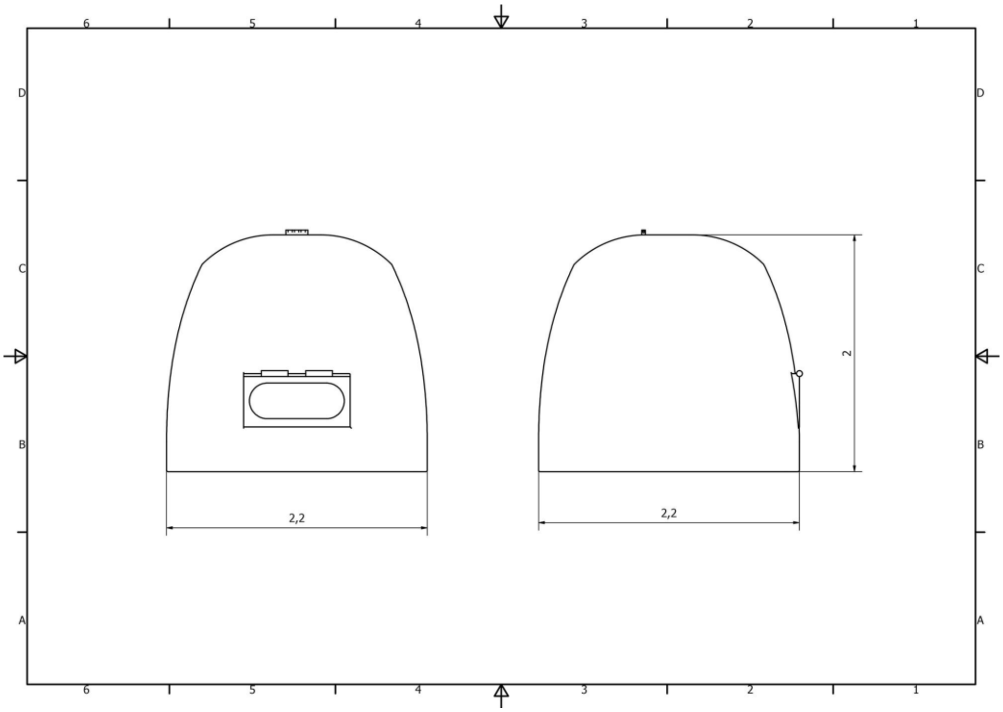
**Oriol Juanhuix Sieira**
Bachelor's in Telecommunications
UPC'23

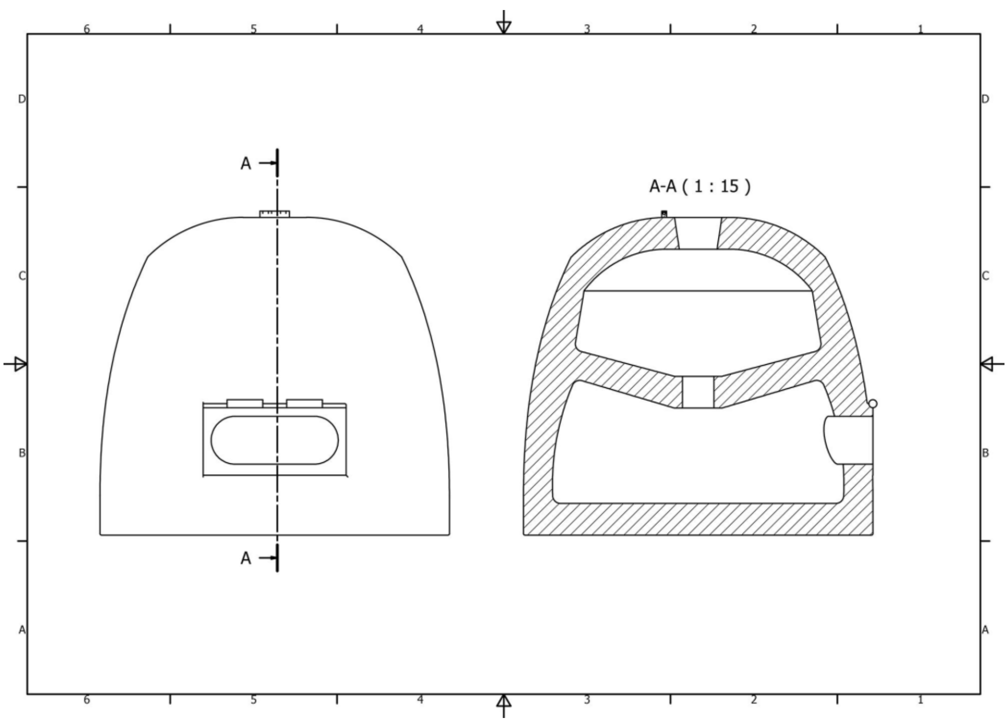
**Uttara Kumar**
Master's in Business Administration
ESADE'22

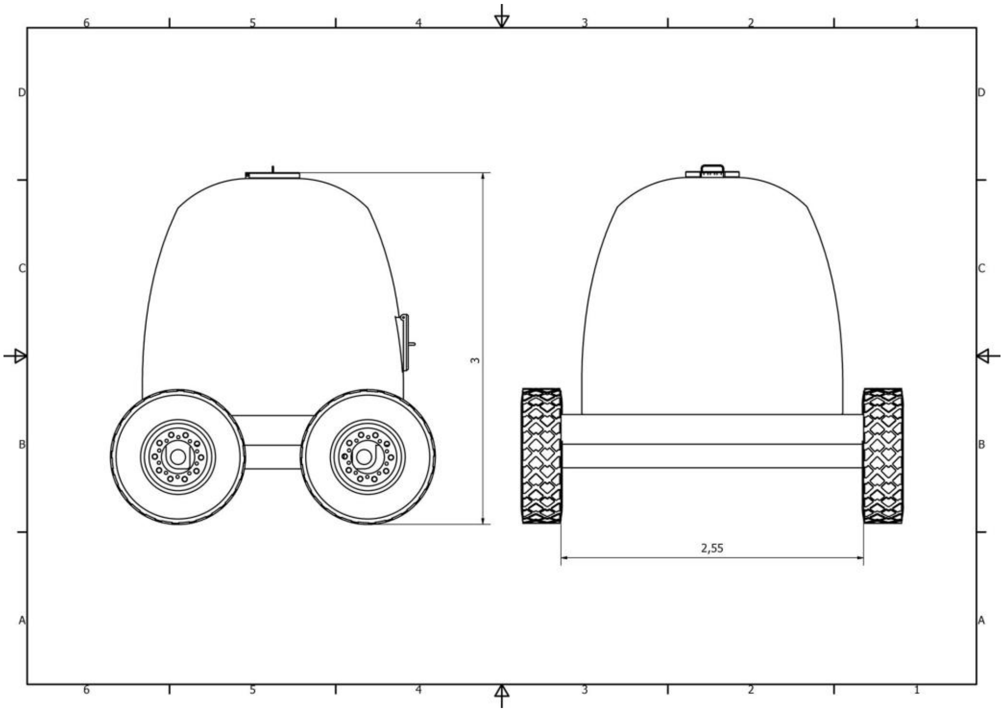
**Ruth Mota Villalobos**
Master's in Sustainable Design
IED'22

## General Measurements

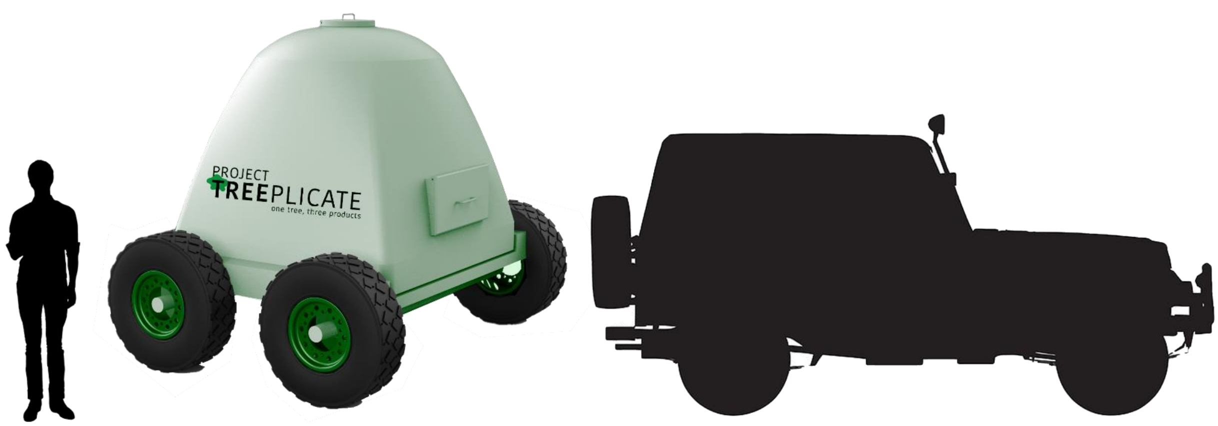
All measurements are in meters.

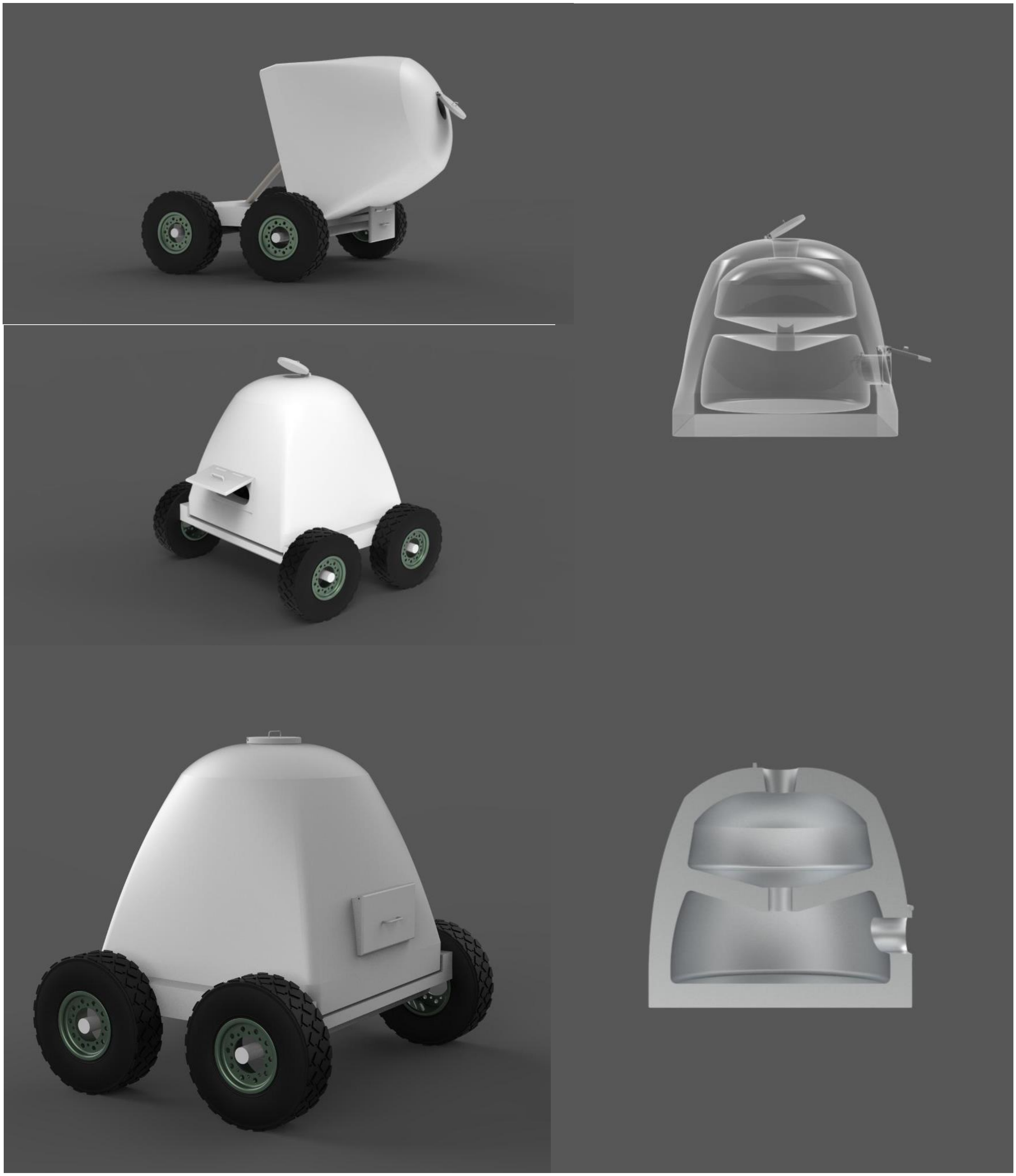


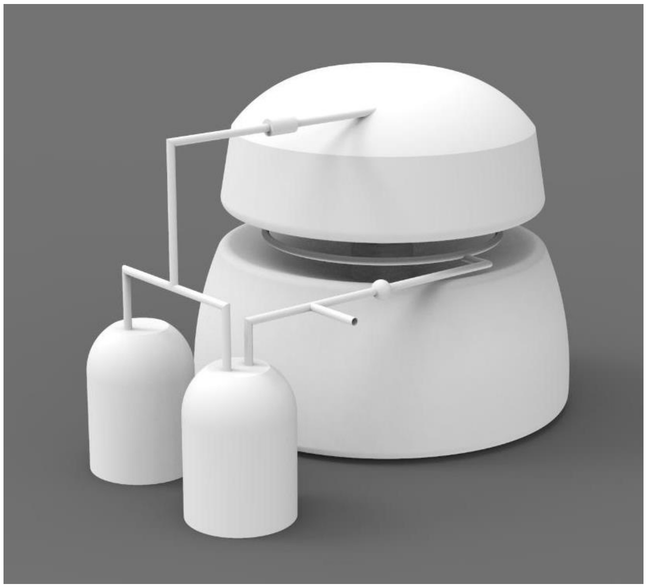



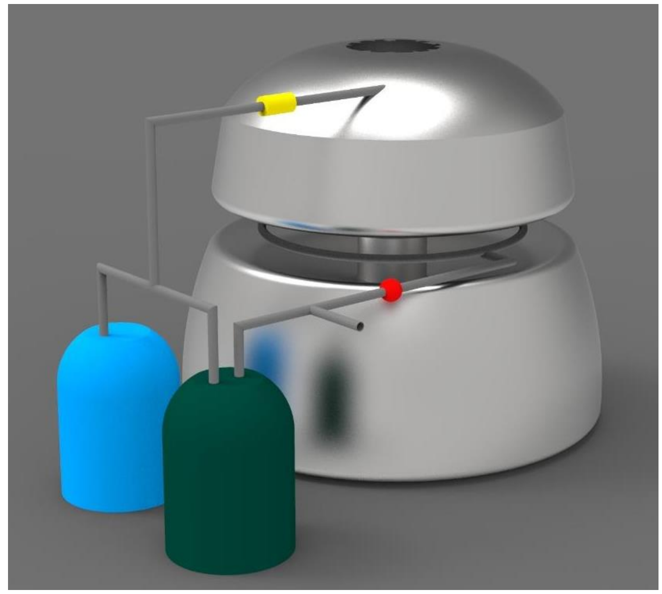



## 3D Modeling










PROJECT
TREEPLICATE
one tree, three products

## Energy Calculations

Calculations are for one cycle, please note each day runs two cycles.

1. Some initial figures
   a. Every day processed mass: 900kg
   b. Each machine cycle process 450kg.

2. Energy to dry the wood. It is the energy to increment the temperature of a certain quantity of water plus the energy to change of state.

$$E_1 = m_{H2O} C_{H2O} \Delta T + m_{H2O} \cdot C_{L-V}$$

$$m_{H2O} = 25\% \cdot m_{total} = 0.25 \cdot 450kg = 112.5\ kg$$

$$C_{H2O} = 2.08 \cdot 10^3\ J / kg \cdot K$$

$\Delta T$ = 105° - 20° = 85°

$$C_{L-V} = 2251\ kg/K$$

$$E_1 = 112.5kg \cdot 2.08 \cdot 10^3\ J / kg \cdot K \cdot 85K = 19.89MJ + 0.2532MJ = 20.14\ MJ \simeq 20\ MJ$$

$$P_1 = E_1/t_1$$

$$t_1 = \Delta T/5 = 17\ min$$

$$P_1 = \frac{20\ MJ}{17\ min \cdot 60\ s/min} = 19.6\ kW$$

3. Energy to reach the necessary temperature to produce the biochar.

$$E_2 = m_{wood} \cdot C_{dry\ wood} \cdot \Delta T$$

$$\Delta T = 400 - 105 = 295º$$

$$m_2 = 75\% \cdot 450\ kg = 337.5\ kg$$

$$C_{dry\ wood} = 0.49\ J/\ g \cdot K$$

$$E_2 = 337.5kg \cdot 0.49\ J/\ g \cdot K \cdot 295K = 48.78\ MJ \simeq 50\ MJ$$

$$P_2 = E_2/t_2$$

$$t_1 = \Delta T/5 = 60\ min$$

$$P_2 = \frac{50\ MJ}{60\ min \cdot 60\ s/min} = 13.88\ kW$$

4. Energy that can be produced by combustion with the biogas
   a. Assumptions

i. 20% of the dry wood mass is the biogas mass

$m_{biogas} = 20\% \, m_2 = 67.5 \, kg$

ii. Half part of the biogas is methane

$$m_{CH4} = 33.75 \, kg$$

b. Specific heat capacity

i. Calculations

$$C_{CH4} = \frac{806 \, kJ/mol}{16 \, g/mol} = 50.375 \, kJ/g$$

c. Energy produced in the combustion

i. Calculations

$$E_3 = m_{CH4} \cdot C_{CH4} = 33.75 \, kg \cdot 50.375 \, kJ/g = 1.7 \, GJ$$

5. Percentage of energy that is needed for **one** cycle from the energy produced with the biogas

a. Assumptions

Half percent of the energy is lost so it is necessary to do this calculation by multiplying the numerator by two.

b. Calculations

$\frac{E_1 + E_2}{E_3} = \frac{2 \cdot (20MJ + 50MJ)}{1.7 \, GJ} = 8.23\% \simeq 10\%$

6. Energy in terms of money

a. Assumptions

`Price for the kWh = 0.4 €.`

$E_1$ is needed for 17 minutes (0.25h approx).

$E_2$ is needed for one hour.

b. Calculations multiplying by two due to the losses

$$P_1{}' = 2 \cdot P_1 = 39.2 \, kW \simeq 40 \, kW$$
$$M_1 = 0.4€/kWh \cdot 40 \, kW \cdot 0.25h = 4.00 \, €$$
$$P_2{}' = 2 \cdot P_2 = 27.76 \, kW \simeq 28 \, kW$$
$$M_1 = 0.4€/kWh \cdot 28 \, kW \cdot 1h = 11.20 \, €$$

c. Summary

i. Money saved per day = $(4€ + 11.2€) \cdot 2 cycles/day = 30.4€$

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