BMv001

The Bumpy Road to a Greener Future

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Introduction – BMv001

Humanity has come a long way. On every step of our journey, we have faced and overcome seemingly impossible obstacles; from the very first cell, to the first spark of fire, to turning the first telescope towards the night sky. We sailed through the clouds with the invention of aircrafts. We sent probes to the universe. We created technology. Despite all that we have done, modern-day society is filled with problems. And now we're facing our biggest challenge yet: Global Warming.

Global warming has been the Earths foe since the dawn of the industrial evolution. Slowly the atmosphere surrounding our globe has had an increase in temperature, a trend which is unlikely to change anytime soon. Over the last decades the issue has gotten worse and worse. A report from IPCC[1] states that if the rise in temperature reaches 2 degrees Celsius, the world will sustain irreversible damage, such as an ice-free Greenland, lost ecosystems and flooded cities. We are already at 1.5 degrees Celsius. Considering that the global temperature is expected to rise by 4 degrees Celsius in the next 80 years[2], making it an annual rise of 0.05 degrees Celsius, we only have about 10 years until we lose the world we know today and have no possibility of going back.

The issue of global warming inspired us to take the next step towards a better future. Therefore, we decided to take matters into our own hands and tackle this problem by walking down the path of renewable and clean energy, thereby creating a device that could convert mechanical energy to electrical energy. This might sound like something that has been done before. Such as using waterfalls, thus mechanical energy, to drive a generator, thereby creating electrical energy. But the thing separating our device from generators commonly used in the society is that we want to convert something ladled as "wasted" mechanical energy into renewable electrical energy. The huge amount of wasted energy on highways, that could potentially be turned into usable power, stimulated our idea and led to the creating of our device: BMv001. But how does the device work?

When looking for sources of "wasted" energy, we noticed that cars and highways were a good place to start. Cars are moving all the time, and for the most part the energy used by cars is utilized to set and keep the car in motion, but not always. The pressure a car exerts on the ground combined with its movement forward, would make for a brilliant energy source. Therefore, we chose to make a machine that works almost like a button but looks quite similar to a speed bump. This "speed bump" would be placed across the road. A car moving over the device would press in into the ground using its own weight. Which would then result in the "button" being pressed, and this would so make the generator inside turn by using gears. Then the car would pass without being affected by the device and our generator would have created electricity. Soon after, the next car would come, and the process repeats again, creating a continuous energy source.

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[1] IPCC, 2018, s. 32
[2] Wang, 2018

Our idea soon turned out to be a lot harder to execute that we previously thought. Every step of the way we were met with hundreds of issues. Some were manageable, others required us to change our design or implement some other changes. Nevertheless, we ended up with a device that could turn mechanical energy into renewable electrical energy. This report contains how we worked with the project and how we created BMv001. This is our bumpy road to a greener future.

Figure 1: Car Counting Experiment

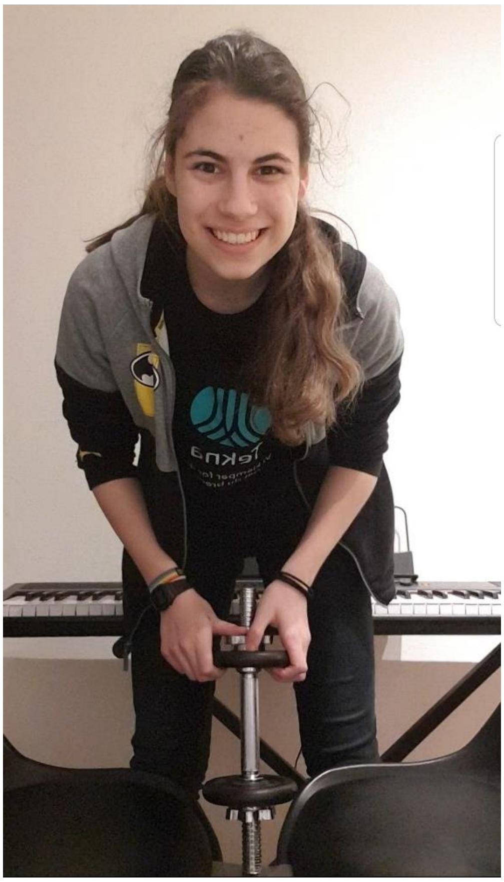


Figure 2: The aluminium plate test

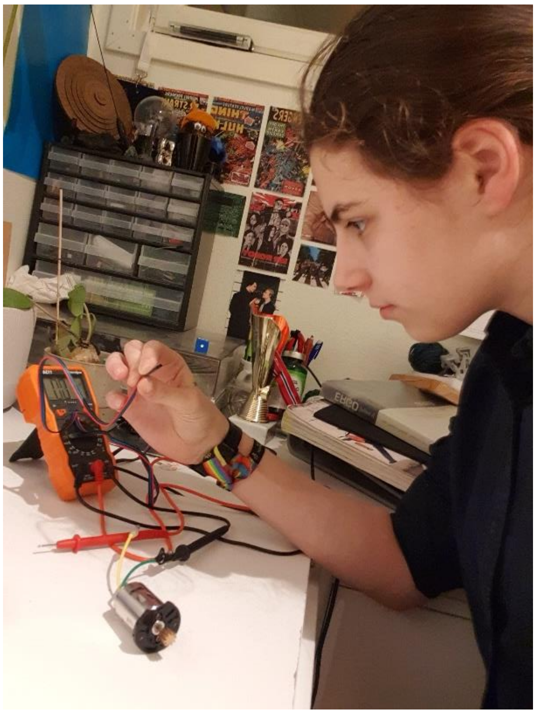


Figure 3:Testing different motors

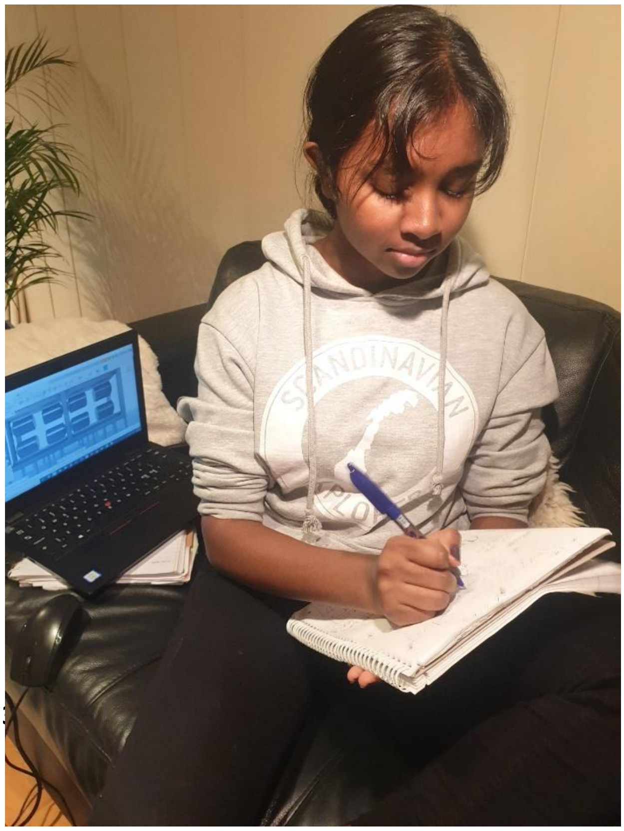


Figure 4: 3D prototype designing

Why keep it low-cost?

Throughout the project you will notice that we try to take measures to keep the parts of the device as cheap as possible. We do this with people in the developing countries in mind. If the project succeeds, getting this device out into the world and to the people in need would be a priority and our ambition. Energy is a necessity in the modern-day society and will be more and more important in the future. Therefore, the device would give people the opportunity to create and use energy that would otherwise be wasted, in an affordable manner.

Phase 1: Planning

Before beginning this extensive project, we needed a plan, so we would have something to keep us on track. After some thinking we ended up with this schedule:

1. Conduct research to choose a metal
2. Sketch
3. Make the outer/main frame
4. Research and create a generator
5. Test the different parts
6. Combine the main frame and the generator
7. Write a report

But as everyone knows, no matter how good the initial idea is, I hardly ever goes as planned. So quite a few detours were made.

Phase 2: Execution – Short Introduction

The execution phase is where all the fun begins. Here we report on how and what progress we made during our work with the project, and we mention every mistake, solution, problem and failure that came our way. After this phase we move on to the testing phase where we check how good our mathematical calculations are compared to the actual restraints of physical world, by testing it out.

Phase 2: Material Research

We quickly decided that the material for the main frame was supposed to be metal, due to no other material satisfying the criteria. The criteria were as follows:

1. Cheap
2. Strong
3. Weather resilient

4. Heat conducting

Plastic is cheap, but not strong enough to support a car, and not that environmentally friendly. Wood is not good for construction, can rot and is not too strong. And glass can easily shatter under the weight. Therefore, we ended up using metal. Now comes the question, what kind of metal?

There are 70 different pure metals, and many more variations of them, so it was overwhelming to try and choose the best metal type for our project. Logically we knew we could not use sodium, since it explodes when it comes in contact with water, gold and silver, since they are quite expensive, and pretty much every other metal except for iron, steel, copper and aluminium were excluded. We also decided to use some sort of alloy to increase the materials strength and thereby reduce the cost. After looking at the properties for each of the individual metals, we ended up with steel and aluminium alloy as our best candidates. Steel is much harder and stronger than aluminium and it cost less per kg. On the other hand, the density of steel means that the same amount of aluminium will weigh less, consequently costing less than steel. Lastly, aluminium is heat conducting, whereas steel is not. The generator can create quite a lot of heat, so having heat conducting walls can help keep the chamber with the generator from overheating. After considering both metals, to maximize the benefit of the material at the same time as we reduce the cost, we chose to go with aluminium. Again, there are many different types of aluminium alloys, but we chose aluminium alloy 6061 because its properties were rather good for its price.

Aluminium Alloy 6061 Properties[3]:

Density: 2.70 g/cm^3

Young's modulus (E): 68.9 GPa (9990 ksi)

Tensile strength: 124-290 MPa

Poisson's ratio (v): 0.33

[3] Wikipedia, 2020

Phase 2: Sketches

The first sketch (on the left side) was our initial blueprint. Here we have a main frame outside of the generator, with a pedal mechanism that turns the generator, when the pedal below the main frame is pressed (a car drives over). The second sketch (on the right) works by the same principles, but the pedal mechanism is beside the generator:

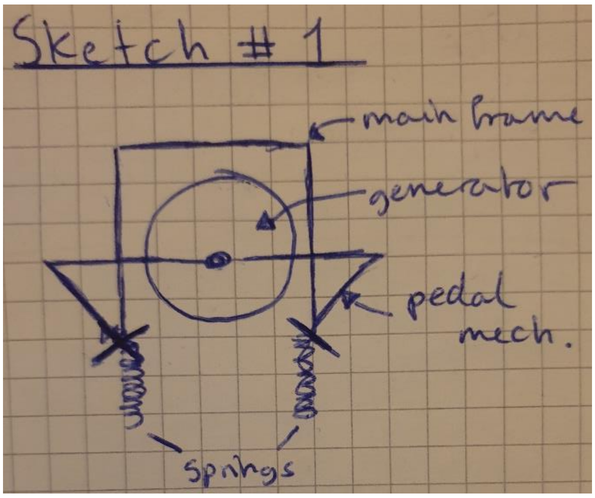


Figure 6: Sketch 1: Pedal Mech

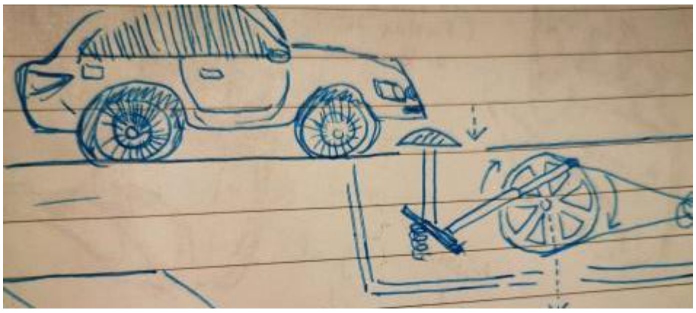
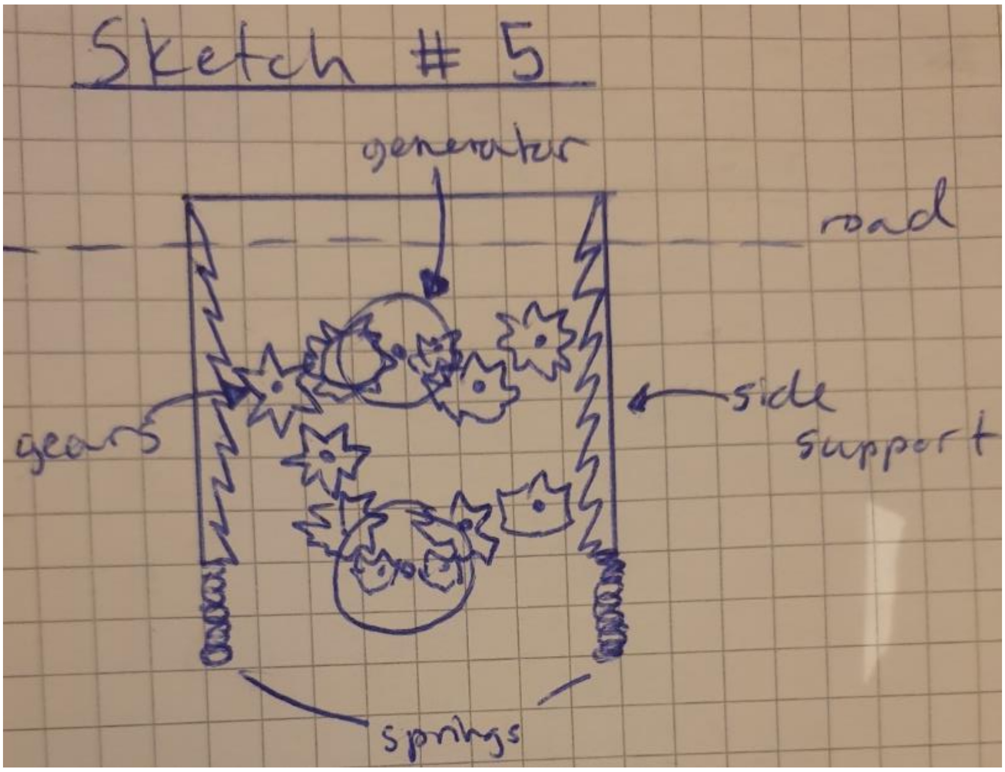


Figure 5: Sketch 2: Pedal Mech 2

Instead of using this design, which turned out to be a bit problematic, we decided to design a new device with this form:

Figure 7: Sketch 3: Gear Mech



The device would instead have a gear mechanism that turned the generators, both increasing the yield from each car passing and in return also producing more electricity.

Phase 2: Main Frame – Top Plate

Working on making the outer structure took much more time than planned, due to all the little details that had to be accounted for. The main frame consists of one top plate, two beams supporting it, and thin plates to close off the box. Before we even started making the frame, we ran into problems, such as: How big should the plate be? How much pressure does it need to withstand? How much will it take to break the plate?

To have a starting point, we checked how wide an average road in Europe is. According to Wikipedia[4] the answer is 2.5 meters wide, which meant that our plate had to be 2.5 meter wide. The average wheelbase of a car is about 2.5 meters long. Considering that we want to have only two and two wheels on the device at a time (since it gives us more electricity per car), we needed to give the device time to go down, and rise up again. Because of this, the length of the plate was set to 1 meter.

Now, we needed to calculate the force and the pressure that comes from one average car. The average weight of car is 1302 kg. To calculate the force, we used Newton's second law:

$$F = m * a = 1302 \cdot 9.81 = 12772.62 = 12.8\ kN$$

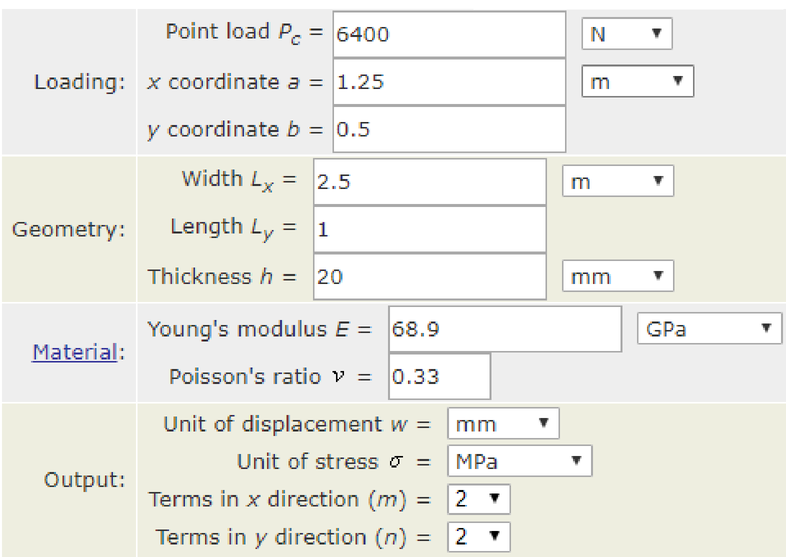
The pressure is:

$$P = F/A = 12800\ /\ (2.5 \cdot 1) = 5120\ Pa$$

Since the whole car puts 12.8 kN force on the plate, half a car (two wheels) will put 6.4 kN on the plate. The last thing that remained for the top plate was the thickness. Here we had to try out different values and calculate the stress and displacement to figure out if the thickness was too big or too small. We could make the plate very thick, just to make sure it does not break, but we also had to try to keep this project as low-cost as possible, so we calculated the thickness as well.

To determine the stress and the displacement of the plate with different thichnesses, we used Kirchoffs-Love theory[5]. This turned out to be quite a lot of calculation, so we used the online calculator at eFunda[6] to make this process easier. The inputs we had after trying many different possibilities were:

Figure 8: Inputs for top-plate



[4] Wikipedia, 2019
[5] Wikipedia, 2020
[6] eFunda, 2020

The output we got for these values gave us:

Displacement

$$w(x,y)=\frac{4P_c}{\pi^4 D L_x L_y}\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\frac{\sin\left(\frac{m\pi a}{L_x}\right)\sin\left(\frac{n\pi b}{L_y}\right)\sin\left(\frac{m\pi x}{L_x}\right)\sin\left(\frac{n\pi y}{L_y}\right)}{\left(\left(\frac{m}{L_x}\right)^2+\left(\frac{n}{L_y}\right)^2\right)^2}$$

$$w_{at\ loading} = w(a, b) = 1.5155943173 \text{ mm} \approx 1.52 \text{ mm}$$

Figure 9: Output for displacement of top-plate

Stress

$$M_x(x,y)=\frac{4P_c}{\pi^2 L_x L_y}\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\left(\left(\frac{m}{L_x}\right)^2+v\left(\frac{n}{L_y}\right)^2\right)\frac{\sin\left(\frac{m\pi a}{L_x}\right)\sin\left(\frac{n\pi b}{L_y}\right)\sin\left(\frac{m\pi x}{L_x}\right)\sin\left(\frac{n\pi y}{L_y}\right)}{\left(\left(\frac{m}{L_x}\right)^2+\left(\frac{n}{L_y}\right)^2\right)^2}$$

$$M_y(x,y)=\frac{4P_c}{\pi^2 L_x L_y}\sum_{m=1}^{\infty}\sum_{n=1}^{\infty}\left(v\left(\frac{m}{L_x}\right)^2+\left(\frac{n}{L_y}\right)^2\right)\frac{\sin\left(\frac{m\pi a}{L_x}\right)\sin\left(\frac{n\pi b}{L_y}\right)\sin\left(\frac{m\pi x}{L_x}\right)\sin\left(\frac{n\pi y}{L_y}\right)}{\left(\left(\frac{m}{L_x}\right)^2+\left(\frac{n}{L_y}\right)^2\right)^2}$$

$$\sigma_x\left(a,b,\pm\frac{h}{2}\right)=\frac{6}{h^2}Mx(a,b)= 5.6672395702 \text{ MPa} \approx 5.67 \text{ MPa}$$

$$\sigma_y\left(a,b,\pm\frac{h}{2}\right)=\frac{6}{h^2}M_y(a,b)= 12.1764690194 \text{ MPa} \approx 12.2 \text{ MPa}$$

Figure 10: Output: Stress on plate

We concluded that a thickness of 20 mm was more than enough to withstand the force from the car without bending (moves only 1.52 mm) or breaking (aluminium can withstand far more than 12.2 MPa of pressure).

The weight of the plate is:

$$225 * 100 * 2 * 2.7 = 121500\ g = 121.5\ kg$$

Considering that the price per kg of aluminium 6061 is about 3.5 dollars, which is equivalent to 31 Norwegian crones, the price for such a plate would be,

$$121.5 * 31 = 3766.5\ NOK$$

Which is a reasonable price so far.

Phase 2: Main Frame – Support

After figuring out the measurements for the top plate, we needed a way to support the plate, as well as make the side parts of the outer frame. To make this possible we required to know what we would have inside the frame. This took some thinking, but after a couple of different ideas, we decided to have eight generators inside of the frame, each with a diameter of 30 cm (more on this will come in the "Generator" section). Considering that the length of our box is 1 m (100 cm) we would stack the generators onto each other, leaving us with 70 cm of space (35 cm on each side).

If we go back to the top plate calculations, we see that they are calculated with the consideration that the plate is simply supported, which means that it has two beams (one on each side) holding the plate. Simply supported also means that the beams only cover a point, and not a big area. This again implies that if we make the beams thick, the stress and the displacement will be reduced further.

Having all this in mind, we chose to set the measurements of the support for the main frame to be 5 cm thick, 100 cm in length and 100 cm in width. Such a beam would weight,

$$250 * 100 * 5 * 2.7 \ = \ 337500 \, grams \ = \ 337.5 \, kg$$

Costing,

$$337.5 * 31 \ = \ 10\,462.5 \, NOK$$

This is significantly larger and pricier than we would have wished for. Therefore, we decided to cut some parts of the beam, hopefully without affecting its ability to hold the top plate.

To achieve this, we firstly divided the top plate into two parts. Since the top plate is 2.5 meters long, we need both support on the ends of the plate but also in the middle to make sure nothing breaks. The support would be constructed from four different parts. The bottom, the two sides and the middle. We decided that the bottom should be 10x5x250 cm. This would make the bottom quite thick and resilient to deterioration. Since the side plates will play a big role in driving the gear mechanism (more info in the "Gear Mechanism" part), as well as the generator, we had to make the middle and side parts wide. After seeing how much space we had left after placing in the generators, and how much space we would need for the gear mechanism, we came to the conclusion that the side-parts had to be 10 cm wide. In the end we had a support that looked like this,

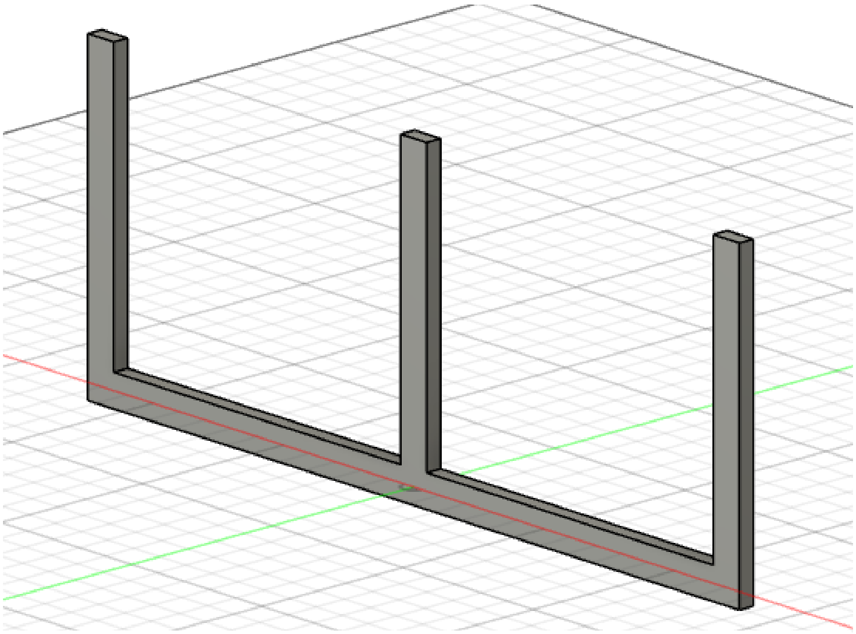


Figure 11: Side support beam

It weighted and costed,

	Bottom	Middle	Side
Weight (kg)	33.75	12.15	24.3
Price (NOK)	1046	376.65	753.3

The total price would then be approximately 2176 NOK per side-support, and with two of these the price would reach 4352 NOK. Being far more sensible than the last one.

Phase 2: Main Frame – Springs

The last part of making the outer frame consisted of finding a way to keep the whole frame from falling and breaking, at the same time as it has free movement upwards and downwards. For this task, we decided to use springs, due to their easy manufacturing and low price.

Springs have a beautiful ability to contract and retract, which would make for an ally in this device. To keep the device stable, we chose to use many springs spread evenly beneath the support surface. This resulted in a total of 20 springs (10 on each side). The total force on the top plate from the car is 6.4 kN. But we also have some force from the top plate itself and the side support as well. The main frame would then exert a total force of,

$F_T = F_{SIDE} + F_{TOP} + F_{CAR} = (70.2*2*9.81)+(121.5*9.81)+(6400) = 8965.315\ N \approx 9\ kN$

To simplify, we divided the force equally between all the springs. This gave us that every spring must tolerate,

$$9000/20 = 450\ N$$

Without the car, the spring would need to withstand about 130 N of force.

These results meant that the spring had to retract when the force is between 130 N and 450 N, and contract when the force is more than 450 N. We also knew that we needed at least 100 mm of travel to benefit the gear mechanism and get the generators to spin. The first thing we had to do, was to calculate the spring rate/spring constant, which is defined by the constant amount of force it takes for a compression spring to travel 1 mm of distance. Hooke's law[7] says that the spring constant is equal to the force divided by the distance travelled (k=F/x). The force in this equation is the force it takes to compress the spring a given distance (x). This mean that we needed more information about the material and the stiffness of our spring before we would be able to calculate the spring constant. After some research we realized that there were quite a few calculations to be made. To save time, we made our own spring calculator in Python.

Before using the calculator, we had to decide the material for the spring. With a bit of research, we decided to go for Stainless Steel grade 316, since it is a good material to use in springs (flexible, but strong). This material is a bit pricier than the aluminium we have been using, but since the springs require a small amount, the price would still be relatively low.

Stainless Steel 316 properties:

Density: 7.87 g/cm^3

Young's modulus (E): 190 GPa (9990 ksi)

Poisson's ratio (v): 0.265

Price per kg: 50 NOK

All the equations used are from eFunda[8]. Using the self-made calculator, we only needed the wire diameter, outer diameter, free length of spring and the number of active coils as inputs. From these inputs we got the:

- spring constant
- solid height
- max force
- max travel
- total wire length
- distance travelled under a specific load
- weight of each spring
- price per spring

Here is how the calculator looks:

Figure 12: Python Spring Calculator 1

```python
# -*- coding: utf-8 -*-
"""
Created on Sat Jan 25 22:55:25 2020

@author: Armina N.
"""
wd = int(input("What is the wire diameter?"))

od = int(input("What is the outer diameter?"))

Lfree = int(input("What is the lenght of the spring?"))

a_coils = int(input("How many active coils?"))

tot_coils = a_coils+2

E = 190*10**9 # Young's Modulus for Stainless Steel 316

v = 0.265 # Poison's Ratio of Material for Stainless Steel 316

D = od-wd # Mean Diameter
G = E/(2*(1+v)) # Shear Modulus of Material
k_mm = ((G*(wd**4))/((D**3)*8*a_coils)) # Spring Constant (N/mm)

k_m = k_mm/1000 # Spring Constant (N/m)

solid_height = wd*((tot_coils)+1)
```

[7] Wikipedia, 2020
[8] eFunda, 2020

```python
coil_wire_length = D*(3.14)

wire_length = coil_wire_length*(tot_coils)

max_travel = Lfree-solid_height # Max travel for the spring

max_force = (k_m*(Lfree-solid_height))/1000 # Max force the spring tolerates

weight_spring = 7.87*(wire_length/10)*((wd/10)**2)*3.14 # Weight in g

price_per_spring = (weight_spring/1000)*50

load = int(input("What is the load on the spring?"))

if load > max_force:
    travel = 0
    print ("The sping can't withstand this force")
else:
    travel = (load/k_m)*1000 # Distance traveled (mm)

print ("")
print ("The Spring Constant is: "+ str(k_m) + " N/m")
print ("The Solid Height is: " + str(solid_height) + " mm")
print ("The maximum force is: "+ str(max_force) + " N")
print ("The maximum travel is: "+ str(max_travel) + " mm")
print ("The total wire lenght is: "+ str(wire_length) + " mm")
print ("The distance traveled under a load of " + str(load)+ " N is: " + str(travel) + " mm")
print ("The price per spring is: " + str(price_per_spring) + " NOK")
```

Figure 13: Python Spring Calculator 2

After trying different values, a couple of times, we realized that a larger outer diameter, more coils and a thinner wire makes the spring tolerate less force, and vice versa. At the same time, less force gives us less travel, so we had to try and find a balance between these factors. Many tries later, we discovered that a spring with these values gave us a good result:

Figure 14: Output+Input for 450 N

```
What is the wire diameter? 5

What is the outer diameter? 50

What is the lenght of the spring? 250

How many active coils? 14

What is the load on the spring? 450

The Spring Constant is: 4598.937771240509 N/m
The Solid Height is: 85 mm
The maximum force is: 758.8247322546841 N
The maximum travel is: 165 mm
The total wire lenght is: 2260.8 mm
The distance traveled under a load of 450 N is: 97.84868210526314 mm
The price per spring is: 69.8355468 NOK
```

From the calculations, the spring would move 97 mm if the load is 450 N, which is around what we desired. At the same time, a load of 130 N, would give acceptable result:

```
What is the wire diameter? 5

What is the outer diameter? 50

What is the lenght of the spring? 250

How many active coils? 14

What is the load on the spring? 130

The Spring Constant is: 4598.937771240509 N/m
The Solid Height is: 85 mm
The maximum force is: 758.8247322546841 N
The maximum travel is: 165 mm
The total wire lenght is: 2260.8 mm
The distance traveled under a load of 130 N is: 28.267397052631576 mm
The price per spring is: 69.8355468 NOK
```

Figure 15: Output+Input for 130 N

The travel would be about 3 cm at all times, which is suitable for the gear mechanism. The cost is also fine, 70 NOK per spring would result in,

$$20 * 70 = 1400 \, NOK$$

for all 20 springs.

To summarize, the properties of the spring would end up being:

Wire Diameter	5 mm	
Outer Diameter	50 mm	
Free length	250 mm	
Number of active coils	14	
Load	450 N	130 N
Spring Constant	4598.9 N/m	
Solid Height	85 mm	
Max Force	758.8 N	
Max Travel	165 mm	
Total wire length	2260.8 mm	
Distance Traveled under load	97.8 mm	28.3 mm
Price per spring	70 NOK	

Using the spring creator at Acxesspring[9], we were able to make a blueprint for the spring.

[9] Acxessprings, 2020

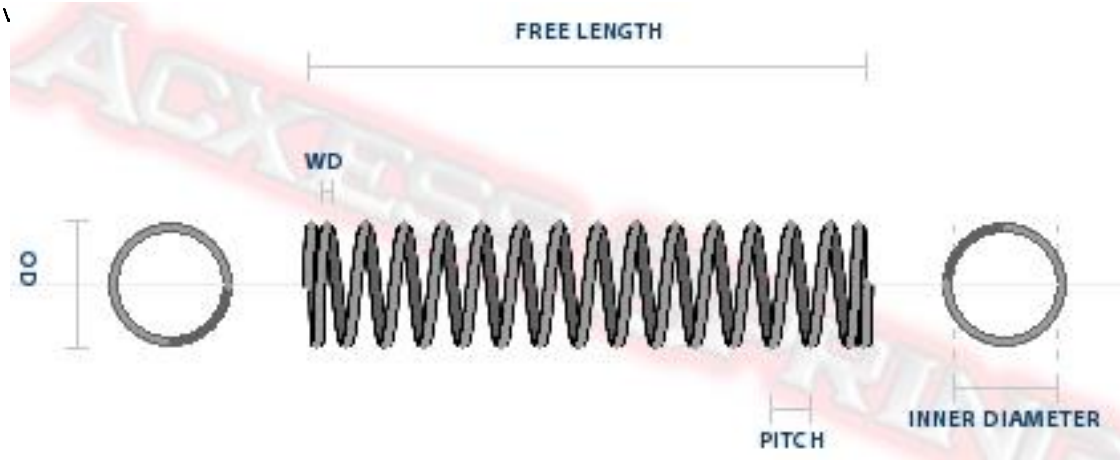


Figure 16: Spring design

Phase 2: Main Frame – Finished Design

In the end, the main frame would look somewhat like this (excluding the springs):

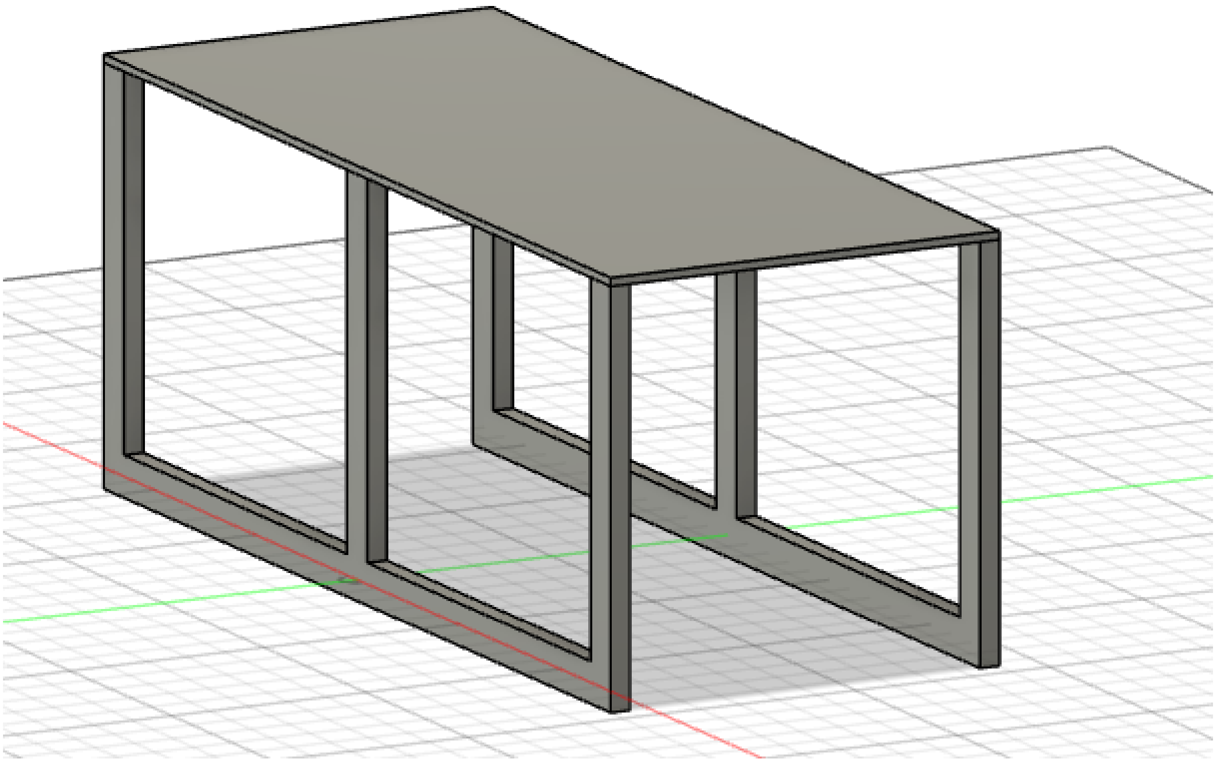


Figure 17:Complete Main Frame

The gear mechanism would be placed on the sides, and the generators inside the main frame. To make sure that dirt and other unnecessary substances don't interfere with the generators, very thin aluminium plate will cover up the sides. Their purpose will be only to shield the device.

The total cost of the main frame would end up being around,

$$3767 + 4352 + 1400 = 9520\ NOK$$

This is quite a high price tag, but we will look for ways to make this cheaper in the "Debugging" section.

Phase 2: Generator – Gear Mechanism

Our first prototype of the BMv001 was planned to convert the mechanical energy from the downwards force of the mainframe by using a "pedal", as demonstrated in one of the sketches. The pedal resembled a lathe, by using two pipes, which would slide against each other to rotate a giant wheel, which would then be connected to the generator. The problem with this concept was that this mechanism would create huge amounts of friction and generate unnecessary heat. The pedal would also be unreliable, as the first 3D printed prototype proved that it, 20% of the time, spun the wheel in the wrong direction, or didn't spin at all, which resulted in undesired force at one point. As the main frame would be travelling downwards at 6,4 kilo Newtons, we didn't want to risk breaking our whole mechanism (especially since the procedure of repairing it would be a touch costly). Since our pipes for the pedals were too weak and fragile, and the larger wheel took up a vast amount of space in the main frame. So, the pedal idea was not a good fit for this project.

By the time we decided to use gears instead of the previous pedal system, we had already thought of basing the generator system on a windmill. The windmill is a classic example of producing pure electrical energy (which could be sent to the power stations) from the rotational mechanical energy, which is achieved through the wind moving the blades.

The design for the gear was tricky. So far, we had a very basic idea on how we wanted the device to move the gears, but we didn't know how to execute it. We needed something that could give the generator sufficient torque, while converting downward linear motion from the car pressing down on our "speed bump" to rotational movement. In addition, we couldn't have the gears switching direction on every upward/ downward motion of the device. This would be problematic, as we needed the rotor of the generator to spin in one direction. After a while of intense brainstorming and scouring through pages on the Internet, we found a video[10] that had a similar construction of gears to what we needed. The following images are of the files from the video that we downloaded, before opening them up on the 3D modelling software Autodesk Fusion 360.

[10] Youtube, 2013

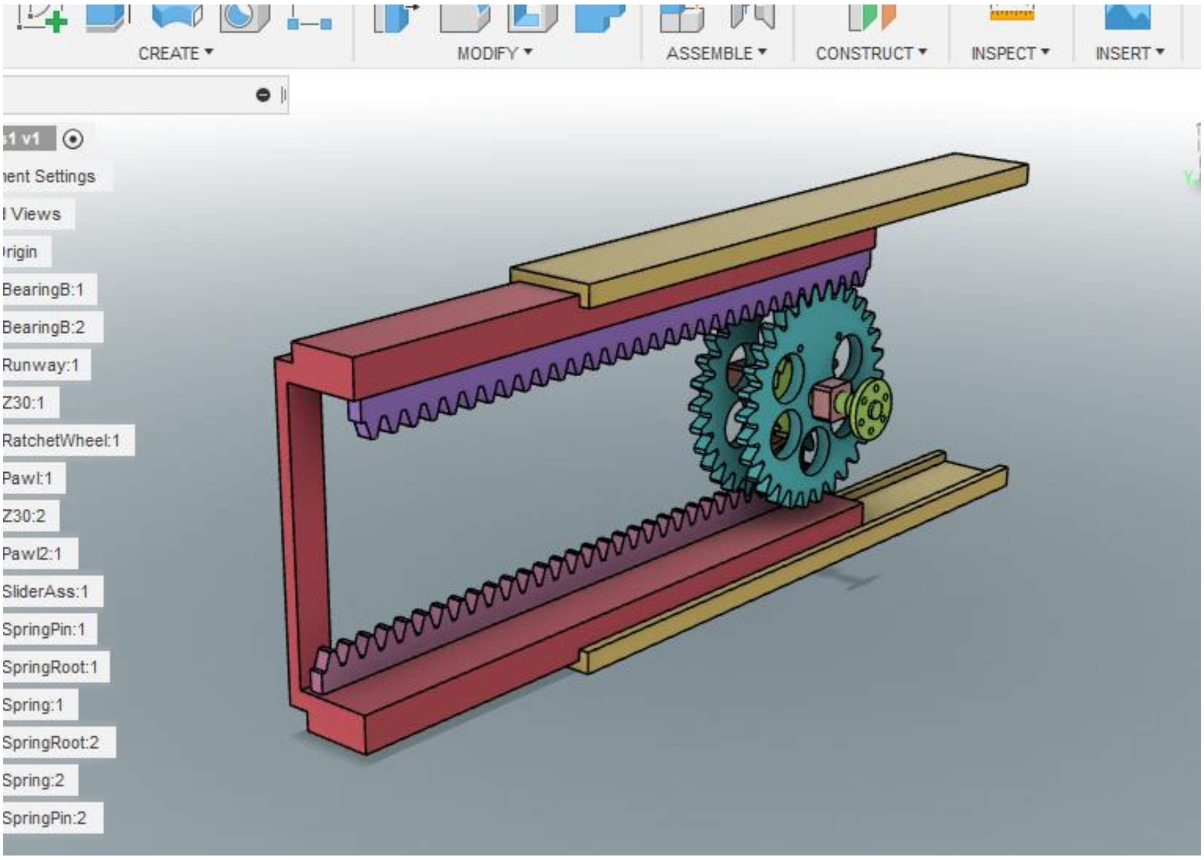


Figure 18: Two-way linear motion to one-way rotation, gear assembly

As you can see, the major elements of the gear assembly consisted of a pair of rack gears and some standard spur gears. Although the model was laying horizontally, the plan was for the assembly to be fastened vertically, along the beams of the mainframe.

With the mechanical energy of the car driving across the plate, or the “speed bump”, the mainframe would get pushed downwards. The rack gears would be mounted across each other on the sides of the frame. Amidst this we would have two big spur gears. One of the gears would be linked to one of the rack gears, and the other gear would be linked to the rack gear on the other side. By doing this, we had made two gear assemblies, which would rotate in opposite directions to one another. When the mainframe was pushed, spur gear 1 would rotate clockwise, and spur gear 2 would rotate counterclockwise. In the same way, when the frame bounced back up after being pushed, spur gear 1 would rotate counterclockwise and spur gear 2 would rotate clockwise. This way, we could take advantage of the counterclockwise rotation from both gears, or formulated differently, we could take this as a basis to turn two-way motion to one-way rotation.

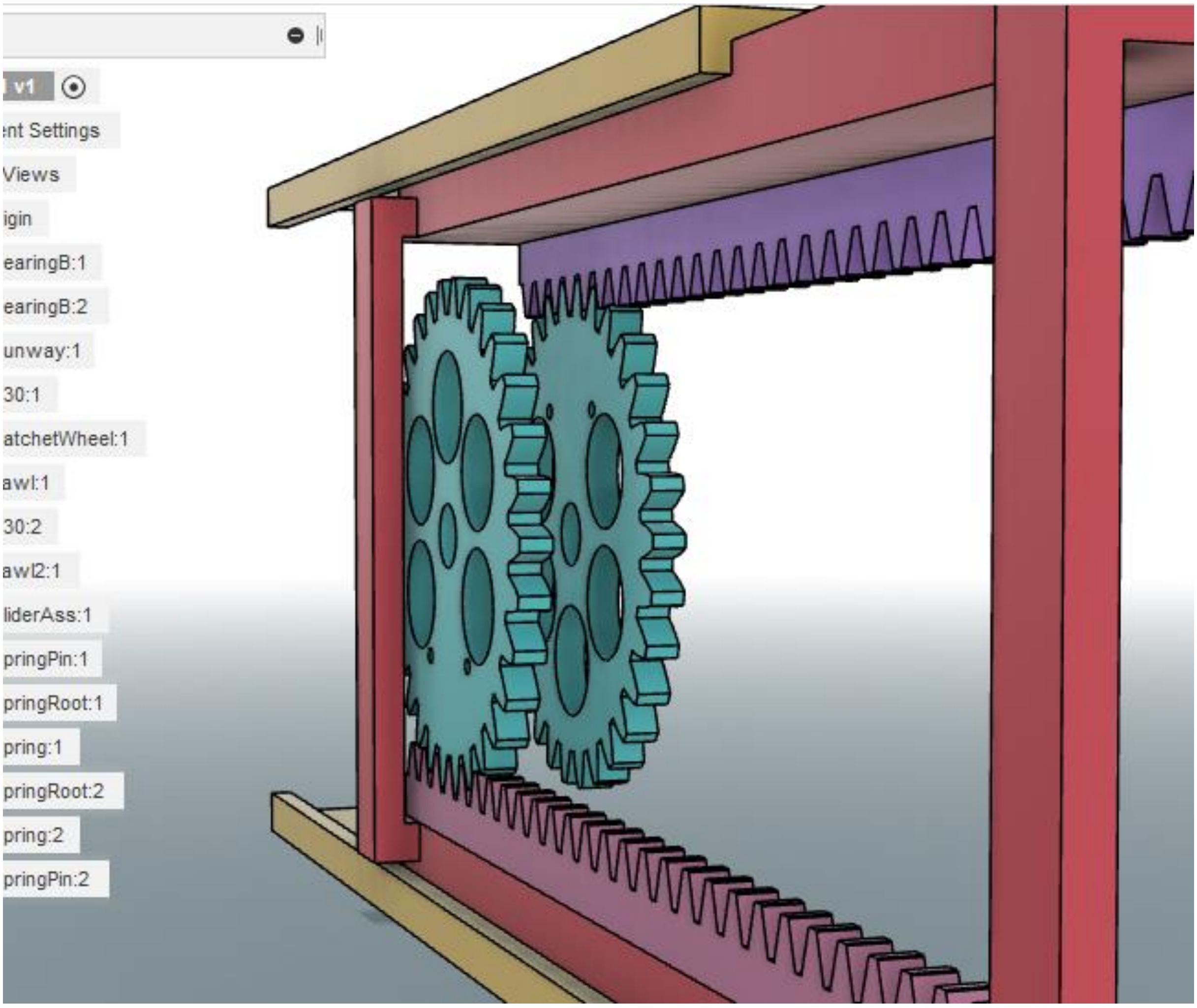


Figure 19: Two spur gears on rack gears

Between these two large spur gears was attached a ratchet system. One of the larger spur gears would have a pawl attached to it, which would be forced down by a leaf spring, also attached to the same spur gear with the help of a pin. The pawl would be caught between the teeth of the ratchet wheel when spun the right way, only allowing it to spin in the counterclockwise direction. If spun clockwise, the pawl simply glides over the wheel. However, by this point, we were facing the problem of turning the upward linear motion into rotational movement as well, since we only had the rotation from the downward linear motion. This is where having two spur gears came into play. Instead of having one ratchet gear we would connect two ratchet gears and maximize the total output rotation. In the same way the previous ratchet gears were assembled, a pawl and a leaf spring was attached to the second spur gear, only allowing the ratchet wheel to rotate counterclockwise. These two ratchets sandwiched between the spur gears were then connected to the primary gear that would be a part of the gear mechanism that would amplify the input torque. We now had a gear assembly that would convert two-way linear motion into one-way rotation.

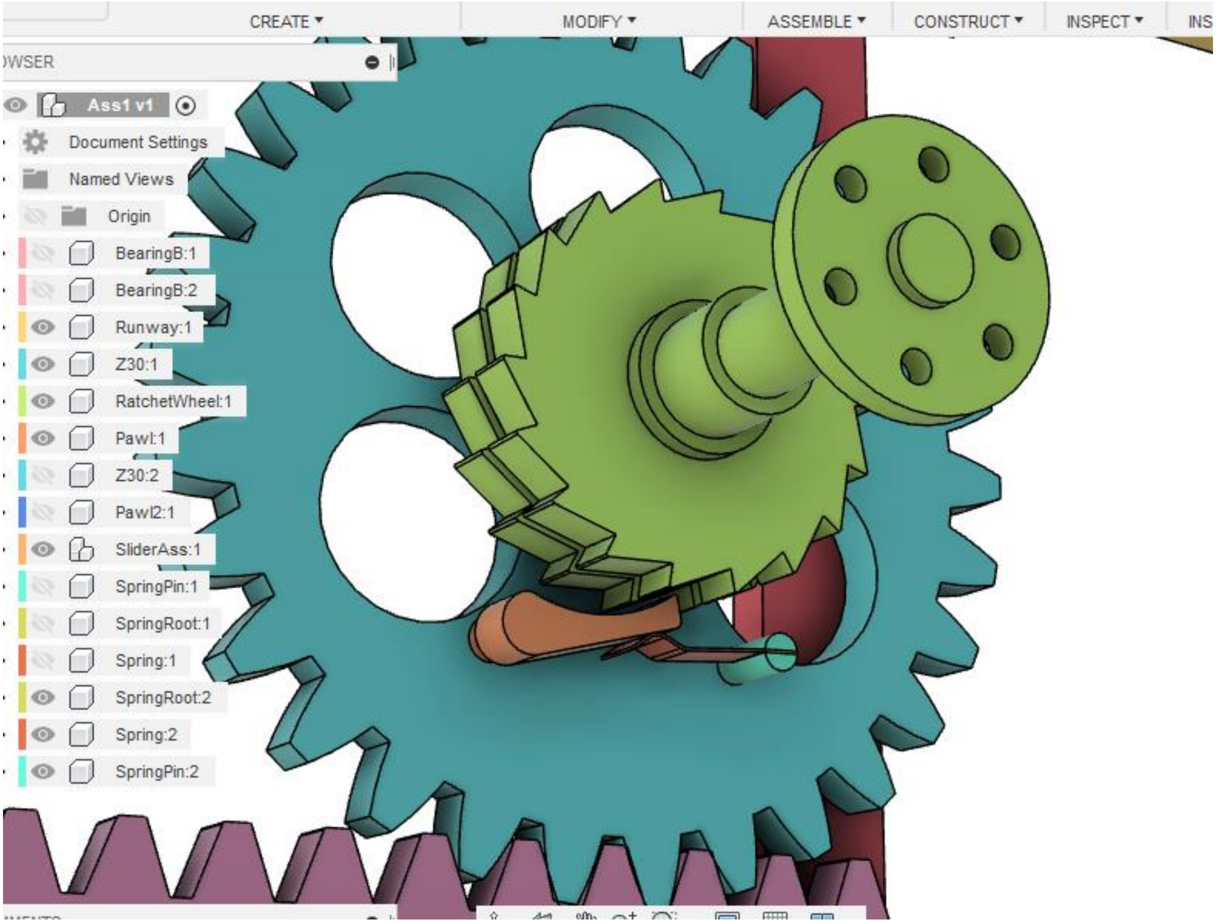


Figure 20: Spur wheels with the ratchet and pawl

The next step was to figure out how to convert the low torque from the gear attached to the ratchet wheel to a higher torque. As mentioned previously, we wanted to base our generator on the wind turbine and take inspiration from it. One factor we didn't take into account was how fast we wanted the rotor of the generator to spin. We needed the maximum amount of voltage with the lowest loss of energy, in the form of heat, building up in the gear system. After a while, we concluded that it would be possible to use a simple planetary gear box (also called the epicyclic gear train or assemblies).

The final step of the gear mechanism was to calculate the amount of torque the assembly as a whole and the planetary gear box would need to generate. We had much of the information and measurements needed to figure out how to do so. The goal would be to get enough torque to achieve an RPM of 1540. How we got to this number will be discussed later in the report. Using the formula: HP = (T * RPM) / 5252, where HP was the rate of work, measured in horsepower, and the T was torque, we could start working out the numbers. Our bare minimum goal on the wattage was 10kW (to be at least somewhat beneficial), and we could convert this into horsepower. Multiplying the value by 1.34 (to convert from watts to horsepower), we got to 13.4 HP. We could now plug the values into our formula,

$$13.4 = T * \frac{1540}{5252}$$

$$T = 13.4 \cdot \frac{5252}{1540} = 45.7\ Nm$$

The torque needed to be produced by the gear assembly for the induction generator to generate 10kW was about 46 Nm. Now that we had one number, we had a few more to go, namely, how much torque would be produced from the rack and spur gears, and the specifications on the planetary gear set, such as the number of modules and size of the individual gears.

Our rack gears would travel 10 cm downwards, which meant that we could get 20 cm of linear motion by the main frame travelling down and up. But here we must remember that due to the top-plates weight, we lose 3 cm of motion. This leaves us with 14 cm of linear motion.

Now to the speed of the plate's vertical movement. In a 60 km/t zone (16.7 m/s), the car would only be at the plate for approximately,

$$t = \frac{s}{v} = \frac{1}{16.7} = 0.06\ sek$$

Assuming that the plate would go down 7 cm in that time period, we would get a speed for the vertical movement of,

$$v = \frac{s}{t} = \frac{0.07}{0.06} = 1.167\frac{m}{s}$$

The speed would be about 1.167 m/s. The linear speed of the rack gears would need to be converted to angular velocity. As we determined that the size of the spur gear would be 15 cm in diameter, we used the formula for linear velocity: v = (2π/60) · r · RPM. The radius was 7.5 cm. Rearranging the formula we got: RPM = v/((2π/60) · r), where a linear velocity of 1.167 m/s would produce an angular speed of about 150 RPM.

$$RPM = \frac{1.167}{\left(\frac{2\pi}{60}\right) \cdot 0.075} \cdot 0.075 \ \approx 150\ RPM$$

Next, we could figure out the torque, simply by using: Torque = Force * Distance, where distance was the radius of the spur gear and the force was newtons exerted upon by the weight of the car. As we had established further upwards in the report, the main frame would travel downwards with the force of 6.4kN. Plugging in the correct values, we got,

$Torque \ = \ 6400 \ \cdot \ 0.075$, resulting in 480 Nm.

This was a pleasant surprise, the output torque we had established was way lower than the input torque. We had aimed a little low.

We now had the values for the starting torque and the torque we needed to end up with. The original plan involved planetary gears, but after looking at these numbers we decided to scrap them, as too many gears and assemblies in our mechanism would create a leak in energy in form of heat. This was important, because we needed to all the electrical energy we could get.

Now we could re-use one of the formulas from earlier to calculate the exact wattage our mechanism would generate: HP = (T * RPM) / 5252[11], where HP was the rate of work, measured in horsepower, and the T was torque.

$$HP = \frac{(T \cdot RPM)}{5252} = \frac{480Nm \cdot 150RPM}{5252} = \frac{72000}{5252} HP = 14.7\ HP$$

Converting this to wattage would give us: 104919.97 W, or about 104kW for a continues push of the box. But since the car is on the box for only 0.06 seconds, the wattage produced will be,

$$104\ kW \cdot 0.06 = 6.3\ kW\ per\ downward\ push$$

This is still a lot, and considering that there are eight generators the total amount of power produced will be,

$$6.3 \cdot 8 = 50.8\ kW$$

Again, giving us,

$$50.8 \cdot 2 = 101.6\ kW\ per\ car$$

This was roughly 10 times more wattage produced than our goal!

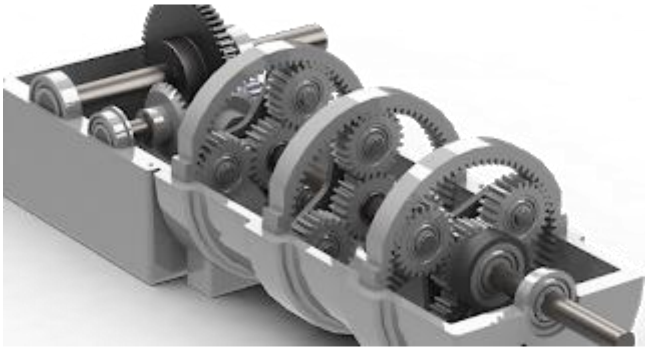


Figure 21: Planetary Gears

The original plan for increasing the produced electricity involved planetary gears. A reasonable ratio for the gear box would be 20:1d as it wouldn't be too high to let heat out, and it wouldn't be too low as to create unnecessary work and do nothing. The planetary gears inside the gear box would work by being connected to the sun gear in the middle, which would then be the driving force behind the motors. The epicyclic gears consist of the sun gear (middle spur gear), the planetary gears which reside around the sun gear, and the ring gear that encircles the assembly. The spur gear from the first assembly would be connected to the planetary gears in the epicyclic gear set, making them travel around the ring gear, which would again rotate the sun gear. This would then be the output. In our case, amplifying the rotational movement by 20 would give the preferable outcome. Next, we'd have to multiply the previous power output by the ratio we had chosen; 20.

$$101.6\ kW * 20 = 2032\ kW$$

As shown above, the outcome would be an astounding 2032 kW of power. Of course, we hadn't yet factored the inefficiencies, and how much power we would lose. The more gear assemblies we attached to our mechanism, the more inefficient the contraption as a whole would become.

[11] Wikipedia, 2020

Phase 2: Generator – Motors

One of the most important players in our product was the generator itself. As mentioned in the subsection above, we wanted to base our generator on the wind turbine. The turbine's components matched for the most part to what we needed, including the planetary gearbox (as we discussed in the previous portion) and an electrical generator. And induction generator would be used. Our electric generator would be a brushless AC induction motor, as motors essentially are the same as generators, only the generator produces electric energy, and the motor reacts to supplied voltage. We will prove this later in the report.

The most used earthing system in Norway is the IT-grid. This means that the most common voltage supply is 230 Volts, 50Hz. A typical four-pole motor, with the efficiency of 80%, operating on a 50 Hz grid will have the synchronous speed of 1500 RPM. A capacitor system could be connected to the induction generator, to generate sufficient power to operate on its own.

Since we wanted to produce 50 Hz power, we could use the following formula to find out the rotation speed needed for the rotors of the induction generator.

$$Ns = \frac{(120 \cdot f)}{P}$$

Where Ns was the synchronous speed of the shaft, or the speed we wanted for the rotors, f was the frequency of the generated power, and P was the number of poles, in this case 4. Hereby we could plug in the correct values for the variables.

$$Ns = \frac{120 \cdot 50}{4} = 1500\ RPM$$

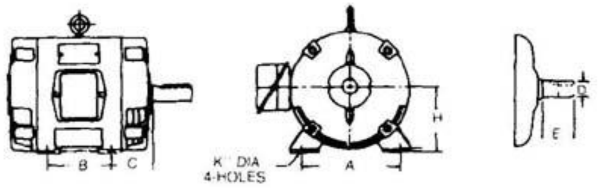
Unsurprisingly, our four-pole induction generator would need 1500 RPM to produce sufficient energy, just as an asynchronous four-pole motor would spin with 1500 RPM connected a 50 Hz grid. We could also include the slip between the rotor rotational speed and the stator rotational speed. Since Ns = 1500, and we took the slip into account, N = Ns + 40 RPM. This would mean that the required prime mover speed for our rotor would be 1540 RPM.

The next step for the generator was to calculate how much power it would generate, since at this point, we had all the information we needed to find our wattage. Finally, after working back and forth between all the dimensions and the numbers involved for the mechanism for the gear assembly and the specification for the motors, we had come to the conclusion that the BMv001 would produce 104kW for each downward push of the main frame.

All the calculations, however, only accounted for one induction generator in the "box". With the size of the box, we could fit multiple generators inside of it. The dimensions for the electrical generator were about 25 cm across in diameter and a length of approximately 50 cm. We got these measurements from IEC, which is the standard for electrical motors in Europe:

IEC FRAME DIMENSIONS*
FOOT-MOUNTED THREE-PHASE MOTORS

*Letters in parentheses are NEMA equivalent to IEC.



FRAME	H	(D)	A	(2E)	B	(2F)	C	(BA)	K	(H)	D	(U)	E	(N-W)
	mm	IN	mm	IN	mm	IN	mm	IN	mm	IN	mm	IN	mm	IN
56	56	2.2	90	3.54	71	2.8	36	1.42	5.8	.228	9	.354	20	.787
63	63	2.48	100	3.94	80	3.15	40	1.57	7	.276	11	.433	23	.905
71	71	2.8	112	4.41	90	3.54	45	1.77	7	.276	14	.551	30	1.18
80	80	3.15	125	4.92	100	3.94	50	19.7	10	.394	19	.748	40	1.57
90S	90	3.54	140	5.51	100	3.94	56	2.2	10	.394	24	.945	50	1.97
90L	90	3.54	140	5.51	125	4.92	56	2.2	10	.394	24	.945	50	1.97
100L	100	3.94	160	6.3	140	5.5	63	2.48	12	.472	28	1.1	60	2.36
112M	112	4.41	190	7.48	140	5.5	70	2.75	12	.472	28	1.1	60	2.36
132S	132	5.2	216	8.5	140	5.5	89	3.5	12	.472	38	1.5	80	3.15
132M	132	5.2	216	8.5	178	7	89	3.5	12	.472	38	1.5	80	3.15
160M	160	6.3	254	10	210	8.27	108	4.25	15	.591	MANUFACTURERS DO NOT AGREE BEYOND THE 132 FRAME.			
160L	160	6.3	254	10	254	10	108	4.25	15	.591				

Figure 22: Table of measurements from IEC

We chose A to be 254 mm (diameter of motor), which is the biggest possible size. That gave us a value of 245 mm for B, and 108 for C, which ended up as a total of,

$$254 + 2 \cdot 108 = 470\ mm$$

The mainframe would be 1 m * 2,5 m * 1m. This meant that a total of 8 generators would fit inside the mainframe, allowing more energy to be expended on each of the generators, producing more electrical energy.

The last step of this subsection was to find the price for each of the generators. The cheapest one we could find that was still optimal was at a 100$. Multiplying the number by 8 would give us a 800$ for the motors, which was a sufficient price

Phase 3: Testing

The third phase is our practical phase, where we put all our math and theoretical findings out in the real world to see how much of what we calculated actually relates to the physical restraints in our world.

Testing – Car Counting

Before being able to determine how much the electricity our device would produce, we needed an estimate for how many cars pass on a road on average. To get to this number, we counted how many cars passed three different roads on three different times of the day and repeated this experiment on 7 different days to get a very averaged estimate.

The first road we chose was a very busy highway(E6), the second was a lesser busy highway that came after a roundabout, and the last street was a smaller road that had little traffic. We then counted cars on each of those roads for one minute at different times and wrote the result in the table below:

Busy Highway: Road 1	Morning (7:00-7:30) (cars in one minute)	Daytime (16:30-17:00) (cars in one minute)	Evening (19:00-20:00) (cars in one minute)
Monday	83	129	72
Tuesday	93	106	86
Wednesday	66	98	59
Thursday	94	128	51
Friday	98	81	77
Saturday	35	104	92
Sunday	24	95	60
Average	70.4	105.9	71

Highway after a roundabout: Road 2	Morning (7:00-7:30) (cars in one minute)	Daytime (16:30-17:00) (cars in one minute)	Evening (19:00-20:00) (cars in one minute)
Monday	50	39	11
Tuesday	46	67	39
Wednesday	58	33	64
Thursday	65	59	29
Friday	31	44	20
Saturday	17	21	43
Sunday	6	31	19
Average	39	42	32.1

Figure 24: Road 2

Inactive street: Road 3	Morning (7:00-7:30) (cars in one minute)	Daytime (16:30-17:00) (cars in one minute)	Evening (19:00-20:00) (cars in one minute)
Monday	7	13	22
Tuesday	5	8	11
Wednesday	14	20	16
Thursday	12	13	21
Friday	9	10	7
Saturday	1	9	3
Sunday	3	2	12
Average	7.3	10.7	13.1

Figure 25: Road 3

The average number of cars per minute for road number 1 ended up being,

$$(70.4 + 105.9 + 71)/3 \ = \ 82.4 \ cars \ per \ minute$$

Average for Road 2,

$$(39 + 42 + 32.1)/3 \ = \ 37.7 \ cars \ per \ minute$$

And the average for Road 3 is,

$$(7.3 + 10.7 + 13.1)/3 \ = \ 10.4 \ cars \ per \ minute$$

Figure 26:Motor left untoutched

All of this gave us an estimate for the average number of cars per minute on roads to be,

(82.4+37.7+10.4)/3 = 43.4 cars per minute on average driving at the Norwegian roads.

Sources of errors for Car Counting Experiment:

The biggest source of error is probably that we did not do the calculations at the same time each day, we did it within a timeframe, but not at the exact same time.

Counting for just one minute is a recipe for error, since the number of cars on a road will differ a lot during such short time intervals.

We also might have missed or counted one too many cars sometimes.

Figure 28: Motor at 99 mV

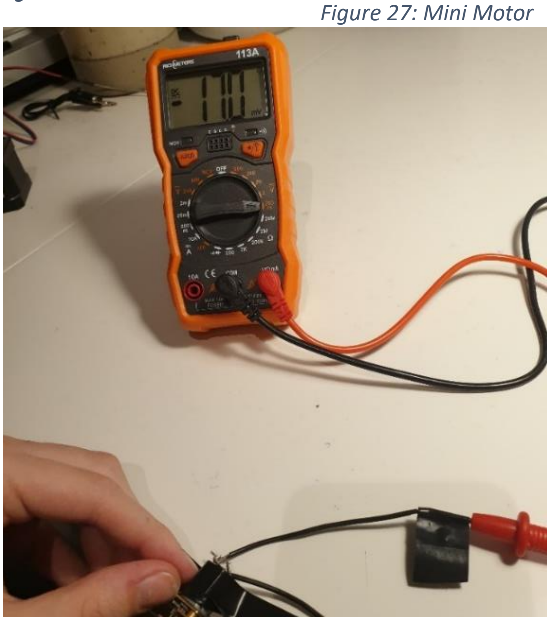
Lastly, we did only choose three different roads, so an average of cars on those three can not speak for the whole country, or for other places in the world (so our result is not global/universal).

Testing – Generator

Since we base our theoretical generators on the assumption that motors work as inverse generators, we had to put this to the test. To see if a motor could indeed be made into a generator, we took a simple DC motor and connected it to a multimeter (we used the mV setting).

If the motor was left untouched the value on the multimeter read 0.0 mV, which was as expected.

Figure 27: Mini Motor



When we started moving the motor shaft the voltage levels remained quite low, at about 1.5 mV. But with some effort we got the value up to a steady 99 mV (= 0.098V). The specifications for this particular motor was 12V and 100 RPM. Which meant that we had to rotate the shaft 100 times in a minute to create such voltage, something our hand speed limit does not reach. Instead to try to understand this concept, we tried the same experiment with a very small motor and a 1.7 A Stepper motor to see if we could get any different answers.

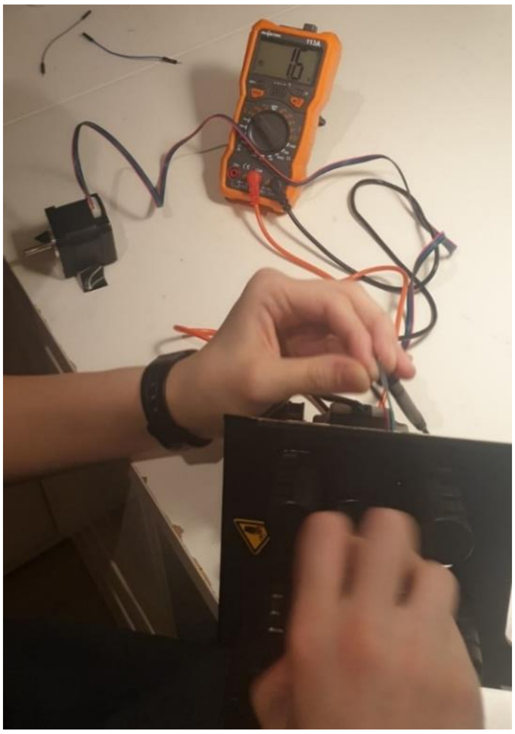


Figure 29: Stepper motor at 1.6 V

Mini Motor: We got quite lower results with the smaller motor, which is logical. The smaller the motor the less induction per round and therefore the less electricity is produced. The highest reading we got was 17 mV, but the value that was holding steadily the most was 3.3 mV.

Stepper Motor: Here we quickly realized that a stepper motor produces AC, not DC, voltage, so we had to switch up the multimeter setting to get some results. The stepper motor required more force to be turned, but in return it gave us a lot higher voltage output. At the same time, being able to turn it both ways made it easier to get higher voltages, so that is a big plus for AC voltage. The easiest, most steady value to get was 0.4 V, but the highest we were able to achieve was 1.6 V.

In conclusion we now know that a motor can be used as a generator. The fact that AC voltage produced more electricity per round, and can be turned either way, strengthens our decision to use AC motors as generators for our device.

Sources of error:

All in all, we did prove that a motor could be used as a generator, which was the objective of this experiment. Despite this, we made errors along the way.

Our biggest issue was that our hand-power was not enough to spin the motor to the highest of its capacity, since a 12V motor should in theory produce 12V when used as a generator, something we did not achieve.

The highest values we attained were only lasting for a couple of seconds, which means that the constant values we got were far lower than the greatest value we were able to get.

Testing – Plate

Our whole main frame is based on calculations, so testing how good the math is compared to the world is a must. To do this properly, we decided to downscale the top plate 20 times. So, the measurements for the top plate would now be 12.5x5x0.1 cm. If our math is correct, this plate of aluminium should be able to withstand a force of 320 N (which is equivalent to about 33 kilo) and the displacement would be around 0.076 mm (which should be unnoticeable). Having this in the back of our minds we started testing.

Figure 30: Aluminium Plates for testing

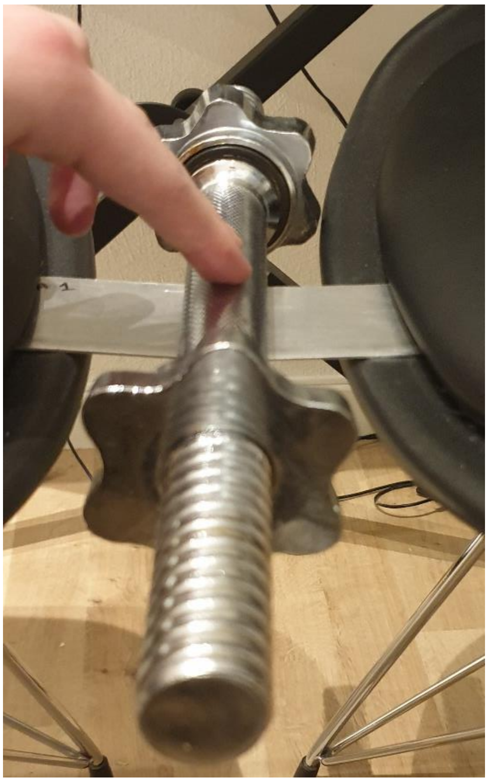


Figure 31: 1.3 kg on test plate #1

First, we cut out a piece with the correct measurements from an aluminium plate (we made four pieces to make sure we could verify the results). This aluminium is not the same as we use in our theoretical device, but it will do for in this experiment.

Then we placed the piece between two chairs, so that the middle had no support, and began placing weights on top to see when it would break.

To test the waters, we began with a small weight of 1.3 kg. This worked very nicely, since no displacement was shown.

Then we added a lot more weight, 14.3 kg. Here we started to notice a slight amount of movement. The displacement measured about 0.4 cm, which is already more than we were supposed to have.

Figure 32: 14.3 kg on test plate #1

Afterwards we increased the weight even more. Now the weight was at 24.3 kg. Logically, the displacement here was even more, and came to about 1.1 cm.

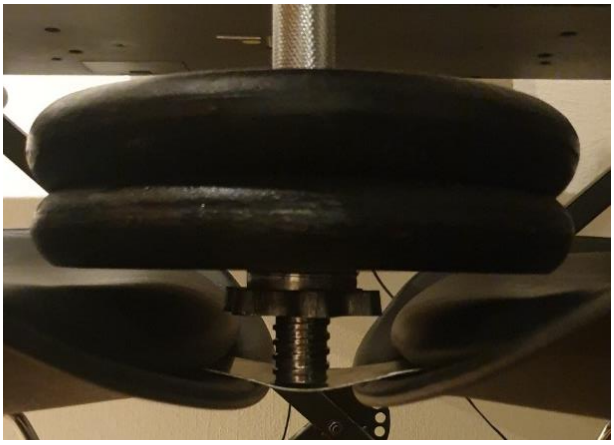


Figure 33: 24.3 kg on test plate #1

(Side note: At this point we realized that we made quite a few errors when executing this experiment. Like the weight not being in the middle, or the chairs not having the same distance between them at all times. Such mistakes could be a potential source of wrong results in this experiment.)

Figure 34: 65 kg on test plate #3

After reaching 33 kg without the plate breaking, we continued putting on more and more weight until the plate finally bended too much, which was at the weight of 65 kg. Here we used ourselves as weights, and got a displacement of 2.1 cm. Which is still impressive for such a small aluminium plate.

To be sure our results were correct, we tried this experiment with three more plates with the exact same measurements. Here the displacement values were somewhat similar, but there were some differences. Although they were so insignificant that we chose to exclude them

from the experiment. This is the final averaged outcome:

Weight (kg)	Displacement (cm)
1.3	0
4.3	Very close to 0
11.8	0.2
14.3	0.4
21.8	0.9
24.3	1.1
34.3	1.5
65	2.1*

This leads us to confirming that our calculations are indeed similar to what would happen in the real world. The only thing that did not act the same way on paper as in real life was the displacement. There was about 1.5 cm of displacement already at 30 kg, which should not have happened, and is something we have to keep in mind as we move forward. (This also means that our top-plate will have to be far thicker than the 20 mm we initially calculated).

Sources of error:

As mentioned previously the weight distributions was not even, and we did miss to place the weights in the middle some of the times, which would have affected the results.

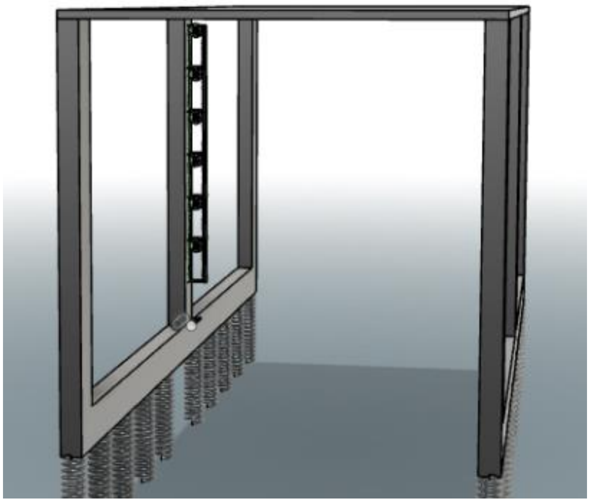
We were also uncareful with the distance between the chairs, so the support for the plate varied for each weight, which affected how much the displacement of the plate was.

Another thing worth mentioning is that when we tried the 65 kg weight on two of the plates, they fell through the chairs, mostly due to the support not being good enough. The plates did not break, and even thought they reached a displacement of around 8 cm, we think that with sufficient support they would tolerate far more, and since the support failed, we choose to exclude these results from the experiment (that is why the displacement for 65 kg is written with a star *).

Testing – 3D Prototype

In this section, we made a 3D model in Fusion of all the components assembled and jointed together. To achieve this, we had to find a way to combine and physically assemble the components, since up until this point we only looked at each of them individually. Assembling the main frame components was easy, because the making of them was based on the measurements proportional to each other. It was when the generators and gear mechanism came into play that it became difficult. We need a way to benefit the gearbox, connect the gear mechanism to the main frame, and fit all the generators inside the device in a systematic and efficient manner. Our initial build was based on our first idea to connect the gear assembly to the side support bars, as planned. But upon further inspection, we noticed that this would not work, since the gear assembly was both facing the wrong direction and had not possibility for contact with the motor shafts (which is essential to produce electricity). This is how the model looks so far (Figure 35):

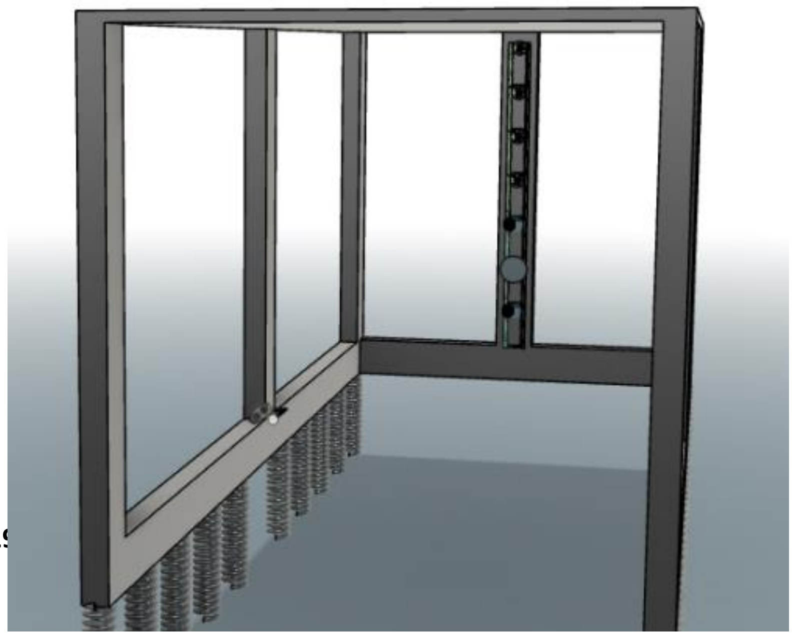
Figure 35: Model with G.A. on side beam



Therefore, we chose to add beam on each side on the top-plate, which we then connected to the gear assembly. Here is how the main support looks after we solved the problem involving the gear assembly (Figure 36):

(We will add the same thing on the other side later).

Figure 36: Model with G.A. on back beam



Now that this was in order, we had to incorporate both the gearbox and the generators. After adding one generator (surrounded by the gearbox), we realized that they were far smaller that we assumed, and looked quite ridiculous in the gigantic main frame:

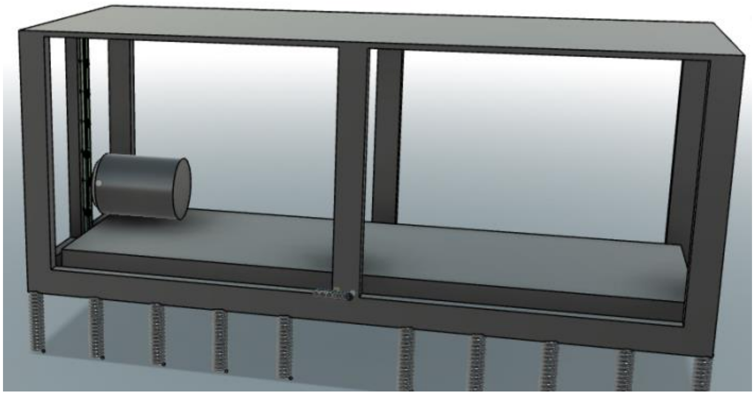


Figure 37: one generator inside the main frame

The reason for this was that we initially planned on using a wheel with one enormous generator, similar to this:

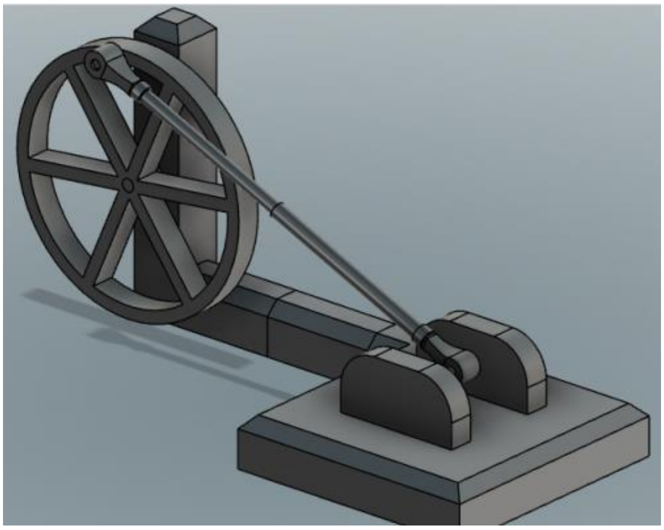
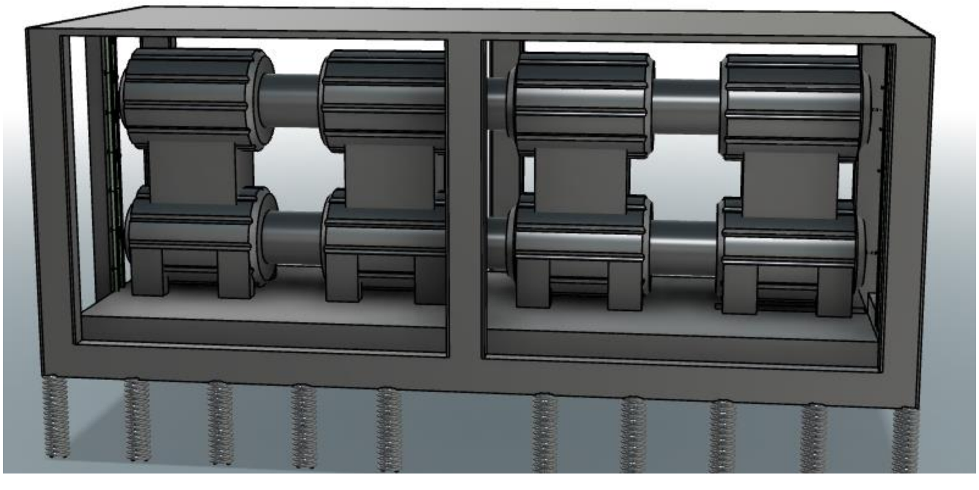


Figure 38: Pedal Mech

Side note: If we had figured out that we would use the gear mechanism instead of the pedal mechanism, we would had made the main frame quite smaller, which would have reduced the cost and incremented the amount of force the top-plate tolerated. But since we had come so fra in the project, it was too late to make those changes. So, one should keep in mind that the device would have turned out better if we had though this detail through.

The last thing we did was to place all the generators inside the main frame, which ended up looking like this:

Figure 39: Finished Model



The bottom motors will be placed on a concrete plate to keep them stationary. While the springs will be lowered into the ground. There is a difference of around 150 mm between the top generators and the top-plate, which means that the main frame will be able to move without a problem. So, when a downwards force is applied to the device, the gear assembly on the end will turn the motor shaft, which will then activate the gearbox, that will amplify the power outcome by 20. This will then create a ripple effect to the next generator which connected to the initial generator through a smaller gearbox.

Phase 4: Debugging

The "Debugging" phase is where we look at the project and reflect on all the issues with it, as well as look at some possible solutions that could resolve these problems.

While working with the project and trying to design a somewhat workable device, we encountered hundreds of issues. The more we tried to solve them; the more problems we encountered. So instead of trying to fix up everything (considering that this is only the first draft of the device) we decided to discuss the theoretical solutions.

The biggest issue of all was making this device functional. It is no question that it does indeed produce electricity, but some question arises. Is this an effective way of making energy? How much energy is wasted (through heat)? How resilient is this device? How much does it interfere with the traffic on the highways? How cost efficient is it? So, on and so forth. Let us take one and one question at a time:

How good will it do in the real world compared to what we calculated?

To make our math easier we decided to simplify things and work only with certain types of objects and situations. We, for example, assumed that all cars weight about 1500 kg, so that we could calculate the top-plate thickness and design the springs. Although in the real world we have very many different cars that would weight more or less. This could potentially lead to the top-plate breaking, the device not working properly (or at all) since it is dependent on weight, or the springs not tolerating the weight and bending. Considering that most highway trucks weigh way more that 1500 kg, this would be a big problem.

A possible solution to this would to make the device less weight dependent. The plate thickness could be made thicker (of course also increasing the price, but this is another problem) to tolerate more. In general the whole system would have to be redesigned to function properly in the real world. Our proposal would be to make a system similar to the model in Sketch 2, but we would replace the pedal mechanism with the gear mechanism (The small area where the cars would have to press would be much more resilient to the weight).

Won't the device overheat?

There are eight generators inside a metal box underground, so the risk for overheating is vast. Even though we chose a metal that conducts heat well it will not be enough to keep the device from overheating, so some sort of a ventilation system needs to be in place. We want to place some on each end, where one fan will pull the cold air in, and the other fan will draw the hot air out, thereby creating air flow and pressing the the hot air out through openings (that lead to the surface) in the sides of the device. The ventilation system would look somewhat close to this:

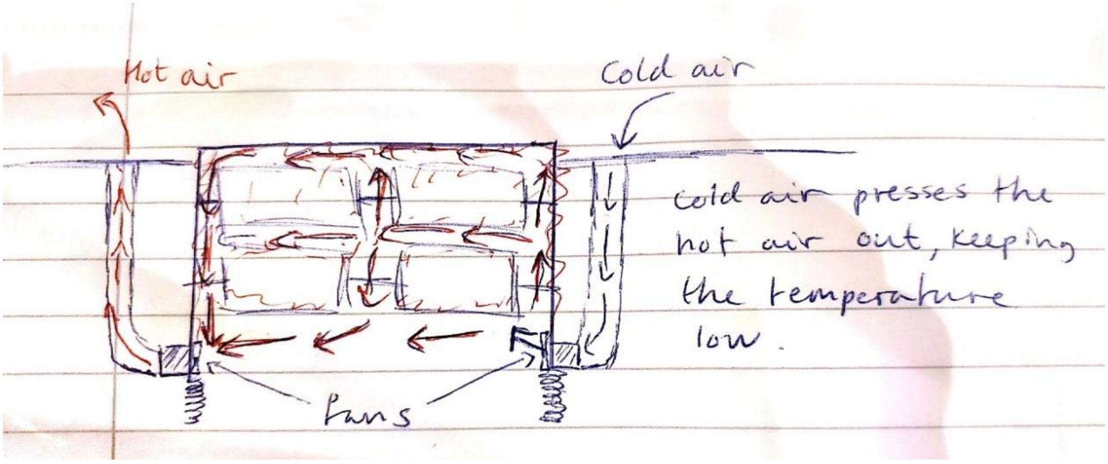


Figure 40: Ventilation System Sketch

Another thing to keep in mind is that the heat conducting characteristics works both ways. So, in the warmer seasons of the year, the heat inside the device might increase due to the weather.

How would we get the device from sinking into the ground over time?

Since the device would be placed underground, several measures must be taken to prevent the ground from collapsing. The spring movements also had to be accounted for. What we were thinking is to use thin aluminium plates to surround the device. These would both keep dirt and other unwanted substances away from the device and support the ground from collapsing in on itself. Because such plates are quite inexpensive the total price will not change much. We could also take away the same thin plates from the side-supports, since they will not be required anymore. The springs would be placed lower into the ground than the rest of the device, so we would have to make a "box" surrounding the spring as well. Due to our free length divided by the mean diameter being greater that four, we run the risk of the spring buckling when being compressed. To make sure this does not happen, we can place the springs on shafts. To make sure the side support is not affected, we will need to make holes in the side support so that

Figure 41: Zoomed in on the spring shaft sketch

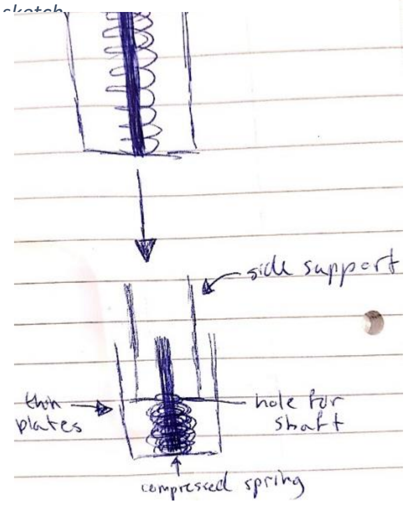
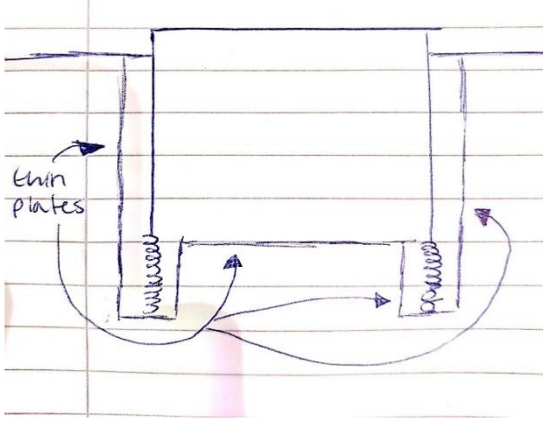


Figure 42: Thin plates surrounding the device sketch



the shaft can pass through when the spring is compressed (Figure 42).

How much does it interfere with the traffic?

The device could initially be compared to a speed bump and would be sticking about 10 cm up from the ground. These road irregularities would of course interfere with traffic, making it illegal to place on road with a lot of traffic or high speeds, such highways (due to its nature to cause accidents). This would in turn be bad for the electricity producing abilities of the device, since it requires many cars driving past it preferably at high speeds to produce a lot of electricity.

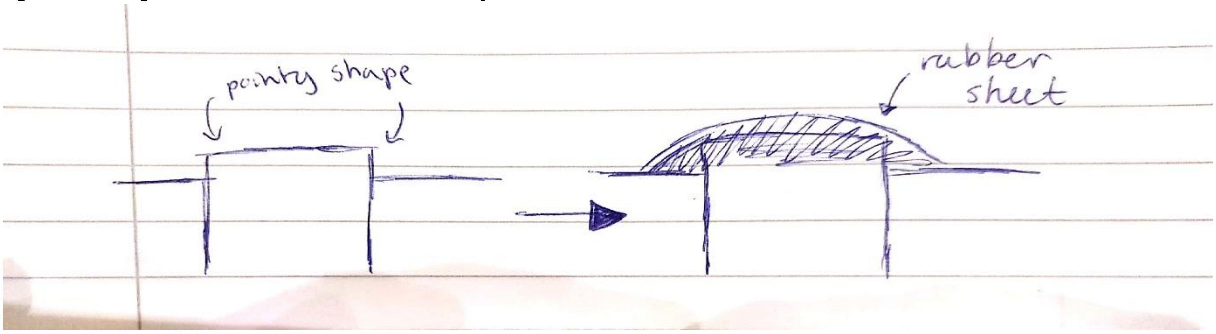


Figure 43: Sketch of rubber sheet on device

To counter this issue, we could place the device lower in the ground. But this would still be problematic, since the displacement is the same, and the car would end up going below the ground level, which is just as bad. We could also make the springs tolerate more force and have a smaller travel distance, but that would result in the device making less electricity, since the gear mechanisms need movement to work. Another potential solution could be to replace the speed bump with these devices, so that drivers would be prepared for them when they come, although this still results in less electricity being produced (since speed bumps are generally placed on less busy roads). We could also place a thick sheet of rubber on top to create more of a "bump" shape instead of a rectangular "pointy" shape.

How much usable energy does the device produce?

Even though we came to the conclusion that each generator produces about 200 kW of electricity, we did not consider the efficiency of the generators and the gearbox in this calculation. For most wind-turbines, the efficiency hits its peak at 50%. Considering all factors about our device, such as the huge amount of both friction and heat produced, the efficiency will be significantly smaller, at about 20-30%. Because of this, the generator will create approximately less than half of the calculated power, which could then be turned into useable energy. This is still considered to be a somewhat good result, although, it would not be the best result for the effort and money that would be invested into this project. The only way to solve for this issue is to make a system with a lot less friction (our gear mechanism has a lot) and make more efficient generators.

How to store the energy produced?

Our idea is to store the energy temporary in a battery, and then transfer it to a power grid (so it could distribute the power further). This, of course, would not be easy, since new underground wiring has to be laid out to achieve this (which is very expensive).

But one could also connect it directly to a house (or some other medium that requires energy), which already has measures to store electricity, and the possibility to use it when needed.

Could we make it less expensive?

Even though we tried to keep a low-price tag, the cost of just the parts (excluding manufacturing and installing costs) required for this device is very high. Luckily there are many ways to make this device less expensive (at the expense of the amount of electricity produced of course).

The first and foremost thing one could do is downsize the device and have only one or two generators instead of eight. This would make the device much cheaper, since most of the cost comes from the generators. Although such a change would result in much smaller amounts of electricity produced. Another way of reducing the cost is to use other available materials instead of aluminium. Aluminium is somewhat expensive and trading this metal for some other material (with the same characteristics) that is less expensive and more locally available in your area may make the device cheaper. One could also use scrap metal or reuse metal from other objects, which is generally cheaper than buying the material from a vendor. A more home-made solution that fits each individual need, such as a redesign, could make for a cheaper alternative that the industrial produced device.

Phase 5: Conclusion

The goal for this project was to develop a device that could produce electricity from wasted energy on highways, as our need for ways to produce pure energy grows stronger for every day. We achieved this by making a device with many different components such as gears, springs, generators and infrastructures. It was a huge challenge on its own to do the calculations and the manufacturing. On top of that, making the device affordable was an immense struggle. The problem with affordability is that the cutting down on cost will cut down on the performance and quality of the device as well, so we had to find the perfectly balanced middle between the two. When both the cost and the parts were complete, we moved on to the real-life model and functionality. This is where we encountered a diverse spectre of issues.

The manufacturing of the device was far more difficult than envisage from the drawings and the calculations due to, among others, unforeseen external factors having impact on the device. It was the conducted experiments that led to the discovery of how outside factors played a bigger role than initially expected, which therefore gave a mismatch in the theoretical and physical calculations. Although there is a difference between our theoretical and physical findings, the device proved to be workable and able to produce electricity, which is a victory on its own.

Even though there is a lot of room for improvement and redesigning, we believe that the idea of such a creation and demonstration of a device that could make unused energy into useable electricity is a big step in our endeavors to combat "climate changes.

BMv001 is the very first version of a device that could make unused energy into useable electricity. While the device itself is far from efficient and functioning, the idea of such a creation is the most important part. With more time invested into finding the best possible solution for our future, we think that this device has the potential to turn into something useful for humanity and beneficial to the world. To make this a reality it will take a very long and far bumpier road, but we believe that in the end everything will pay of, and the device BMv001 could be used to create the affordable greener future we are all hoping for.

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