



The Power of a Step: Piezoelectrics in action

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 - Study part 2: Comparison of other technologies
 - Study part 3: Non-energy related possible uses
- Conclusion



Introduction

With the increasingly urgent need to combat climate change, we explored how piezoelectricity may be able to generate clean energy and provide us with a more sustainable future.





Hypothesis

We believe that with our current development in new technologies, piezoelectricity may be able to become a reliable source of clean and environmentally sustainable energy.

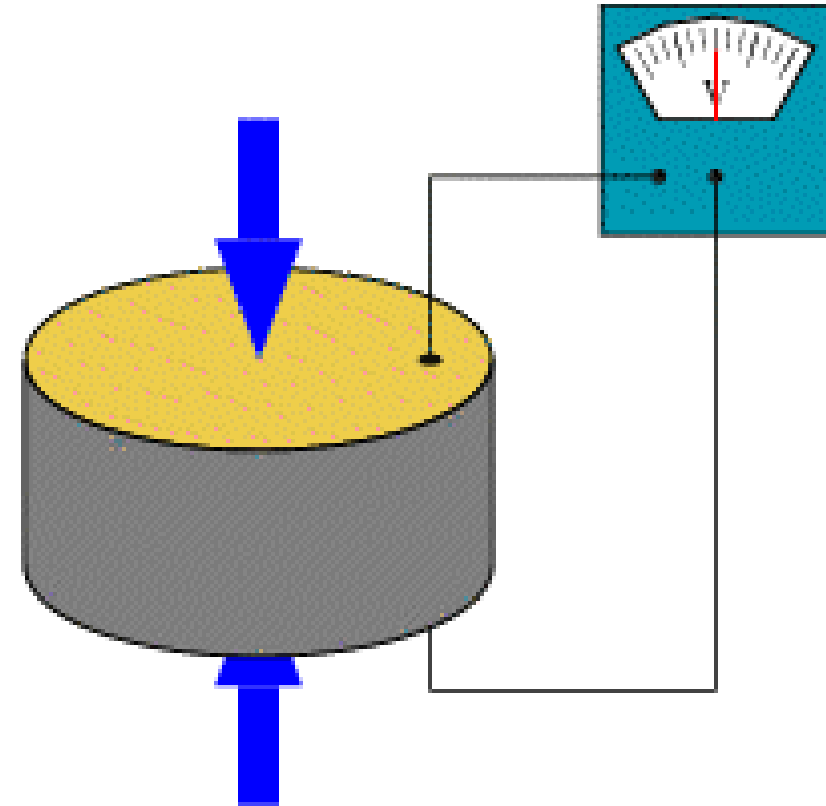


GETTY*



What is piezoelectricity?

Piezoelectricity is the electric charge that accumulates in certain solid materials when mechanical stress or pressure is applied.



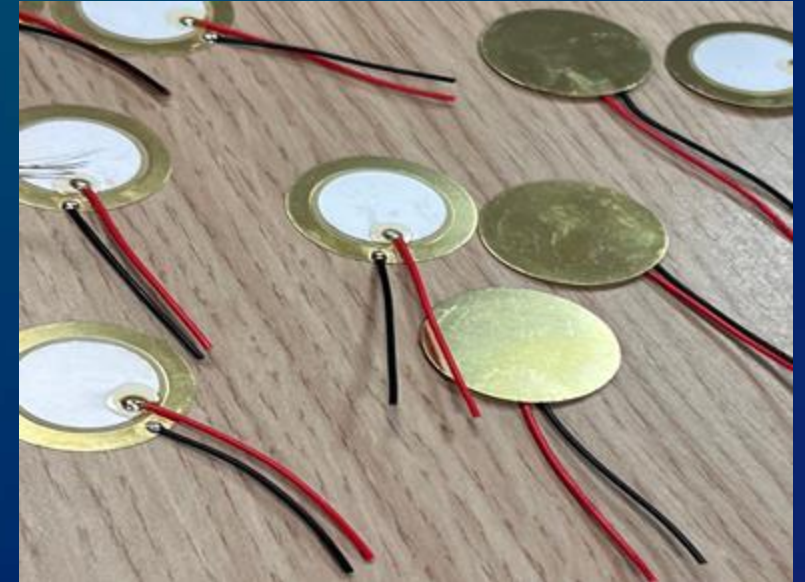
Wikipedia*



Why does Piezoelectricity occur?

In a piezoelectric material, such as Quartz, the effect occurs because of the slight difference in charge of the elements that make it up, in the case of quartz, silicon and oxygen.

The compression of those materials will cause partial negative and positive charges within the material inducing a potential difference.





How can piezoelectricity be used in real life?

Lighter
switches

Wikipedia



Guidance
systems

Shutterstock



Electronic
stethoscopes

Littmann





Do they already exist?

Do countries already implement similar technologies? If so, how can they be improved?

GETTY*



PaveGen electromagnetic plates

“The foundation of Pavegen’s kinetic energy floors, is using mechanical movement to generate electricity”*

- Pavegen’s plates have been able to generate 5 watts of power per step.
- These mainly use electromagnets.
- This proves our technology has real world applications.



Pavegen

(Links used in final slide)*

* <https://www.pavegen.com/blog/electromagnetic-vs-piezo>

Ultra-High Power Density Roadway Piezoelectric Energy Harvesting System



How is this different from our proposed study:

1. Only thinking about using ordinary plates, where they built composite piezoelectronics.
2. They only thought about using on roadways, whereas we were thinking about pavements as well.

Figure 2: An Artistic Rendering of Traffic Piezoelectric Energy Harvesting



Integration of the traffic PEHS with city utilities.

University of California, Merced

Their overall results:

1. Induced 300V under 1kN of applied force.
2. Was able to generate 73MWh of energy within one year.
3. The energy production in one year potentially reduced 24 tonnes of CO₂ emissions.



Huedaytour*

Other uses of this technology

Energy is not our only concern in the future. Increasing crime rates? Could it be a better way to estimate population data?



Tracking criminals

When walking, each person will apply movement onto the plates

Piezoelectric plates can use induced voltages to estimate the mass the of the person stepping on it

It may also estimate the velocity of person

Track mass of person (high accuracy because it can sense very small changes in movements)

Track travelling path of person



The conversation*



Estimating population in cities

- Every time a person steps over the plates, an electrical signal is induced
- This signal communicates with the database and increments the original population number
- People with the same mass and same shoe size will not be recorded again to make sure no same people are recorded
- Piezo-electricity can be used to constantly monitor the number of people
- Accurate results because the piezoelectric plates are sensitive.





Why piezoelectricity?

1. Improving Infrastructure
2. Medical Advancements
3. Few moving parts
4. Energy Harvesting
5. Low Maintenance Costs
6. Extended Battery Life
7. Applications in Multiple Industries

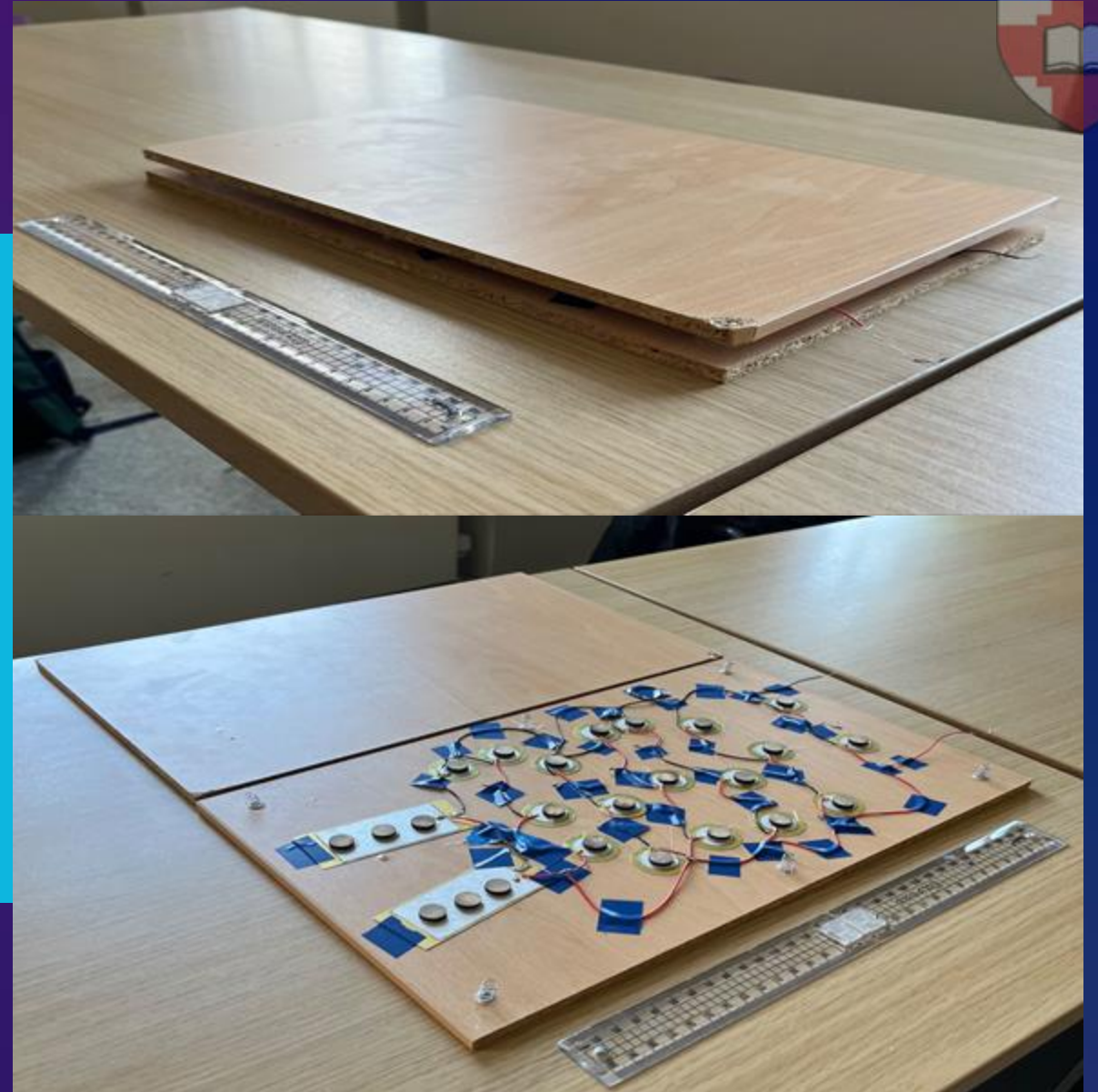


Limitations

1. Small amount of electric charge
2. Environmental conditions can affect performance
3. Energy output can be relatively low

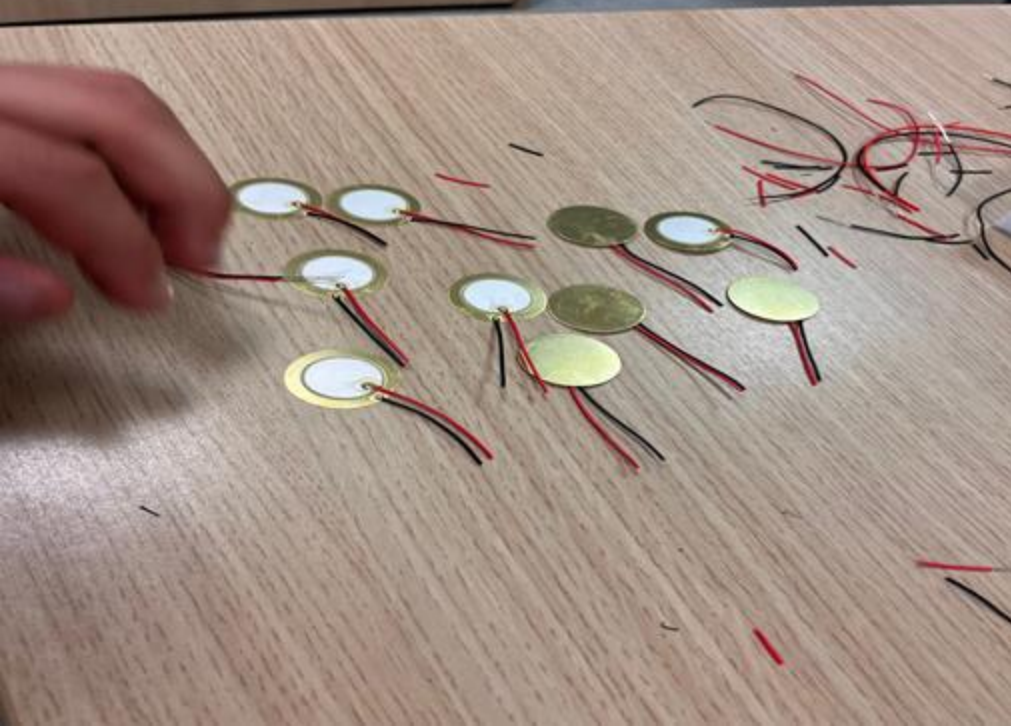


Overview of our device

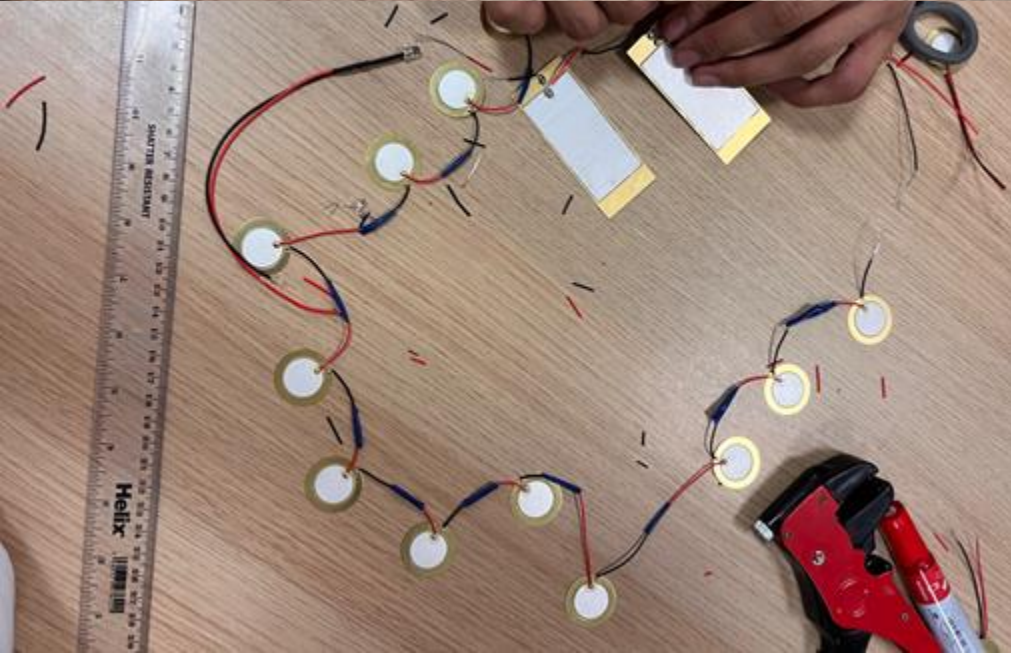




Manufacturing Diary 1



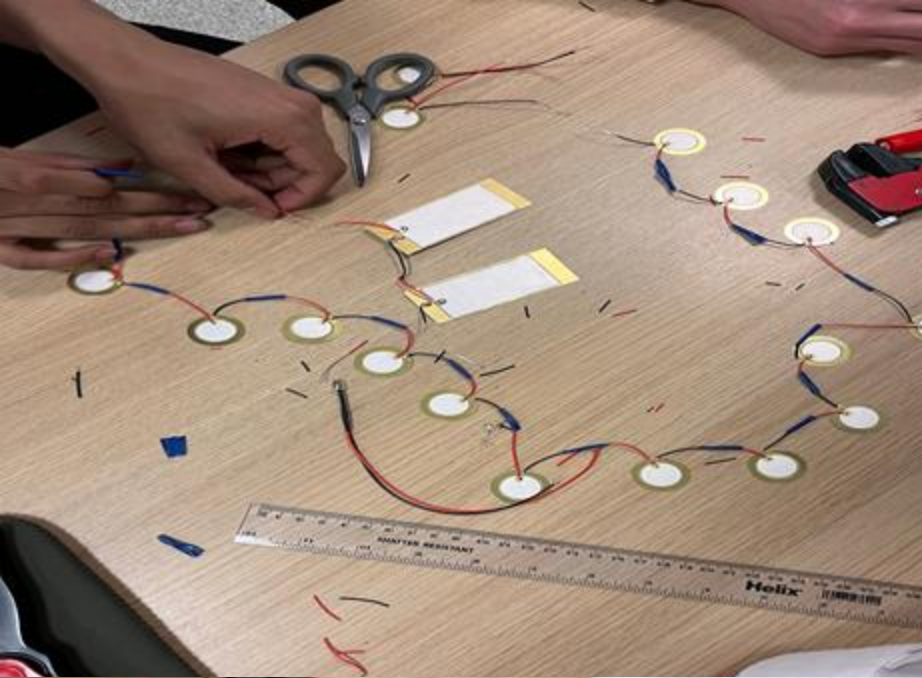
1: Before any manufacturing, we need to check that the piezoelectric plates and discs actually work. We used a multimeter and there was a voltage every compression



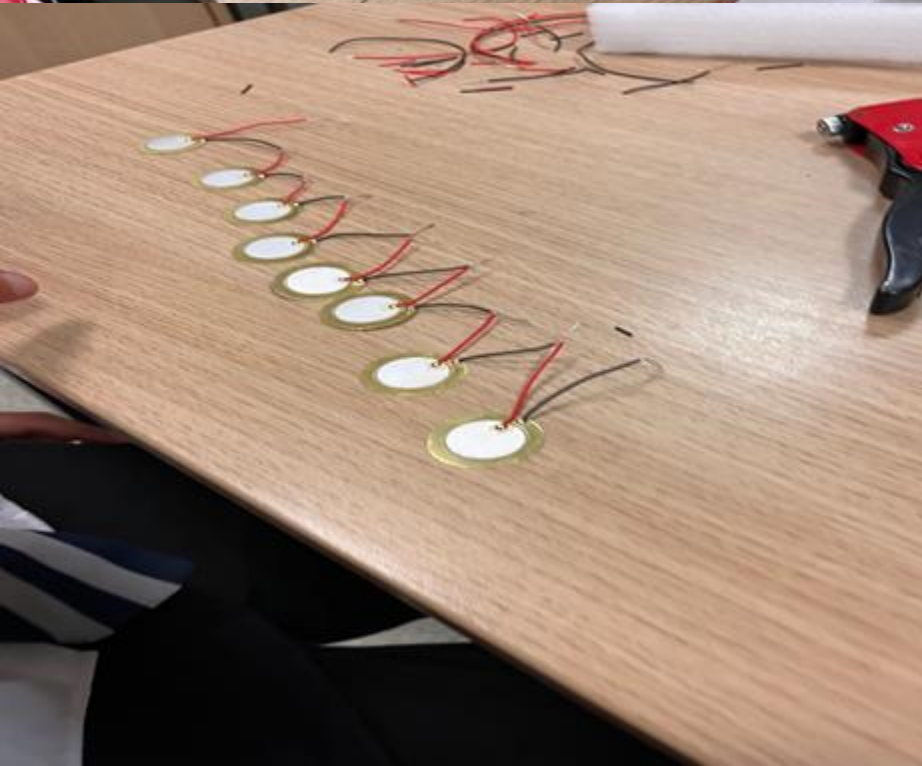
2: The first step of building was to connect the piezoelectric plates together so that they fit under one plate



Manufacturing Diary 2



4: Connecting the plates and discs together.

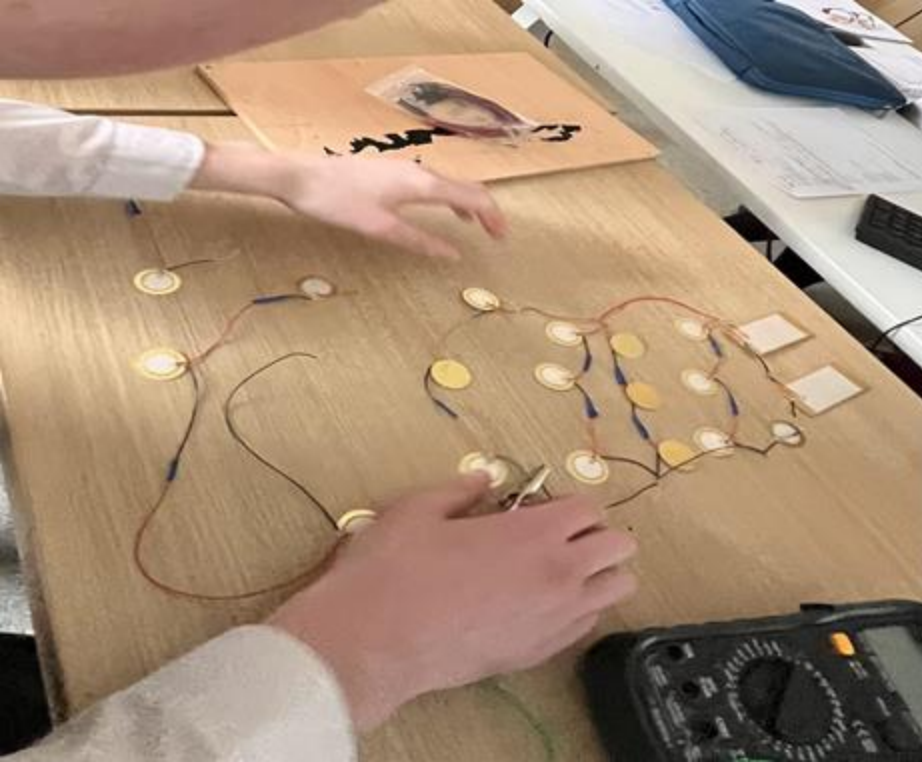


5: After testing, we noticed that the resistance is too high causing too low voltage output. We tried another way of connecting them.

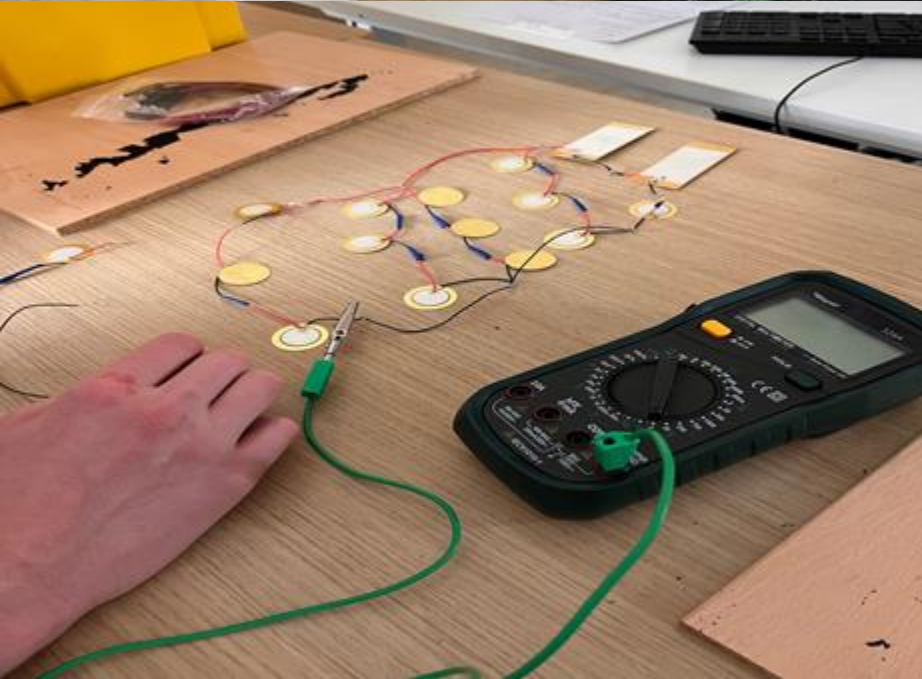


Manufacturing Diary 3

6: After trying some ways, we found out that the way to reduce resistance is by connecting them in parallel.



7: On the right shows us trying the new connection out. Consequently, it led to having a higher p.d..





Manufacturing Diary 4



We finished manufacturing process by taping it all down onto a plain wooden board to stabilise the plates and discs.

To allow the board to spring back up, we hot glued the springs onto the sides of the board.

Ultimately, the product is done and is ready to be tested out for study test results.

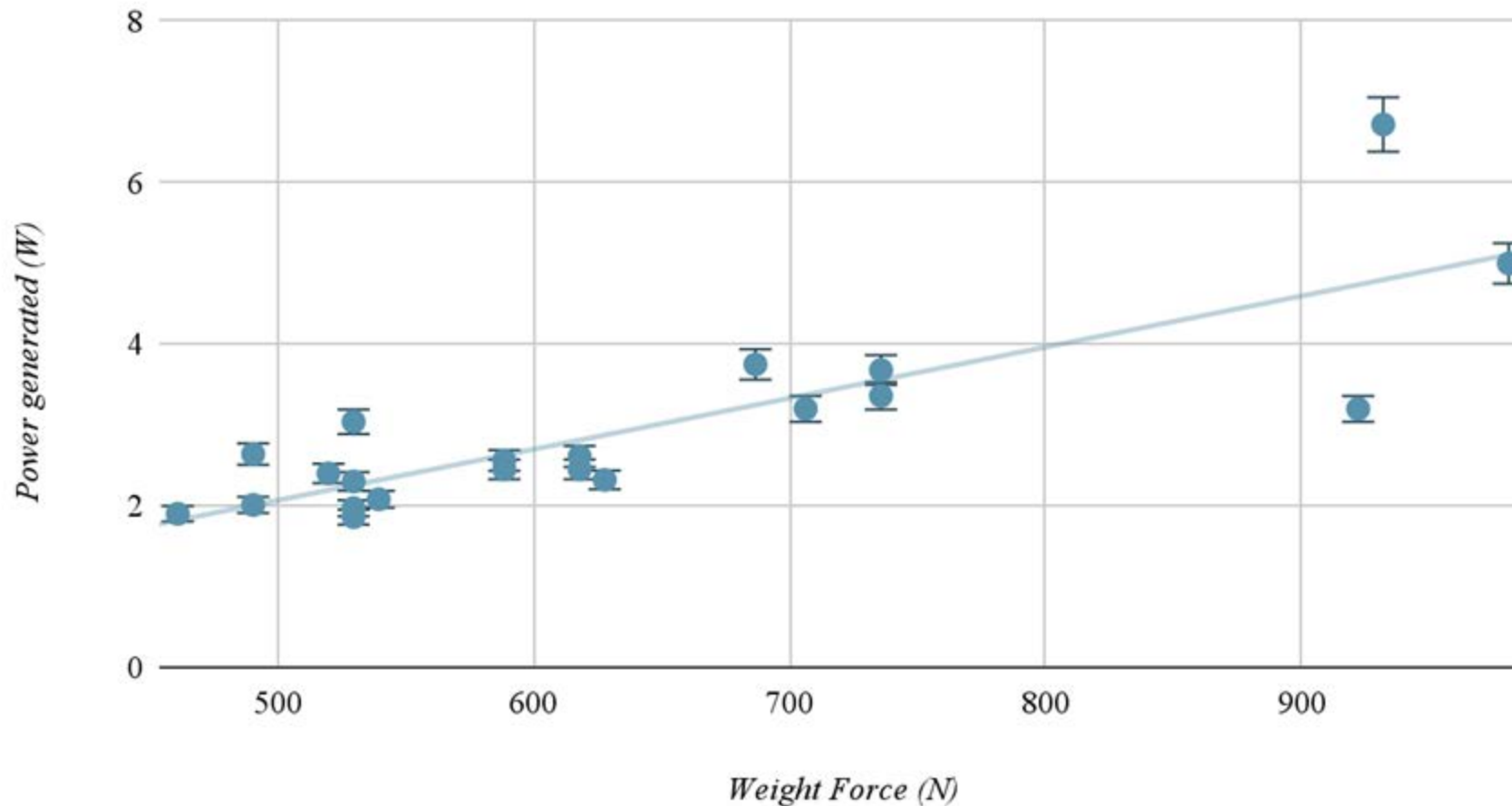




Experiment 1: force vs power



Power generated vs Weight Applied



This graph presents the proportional relationship between electrical power and force applied.

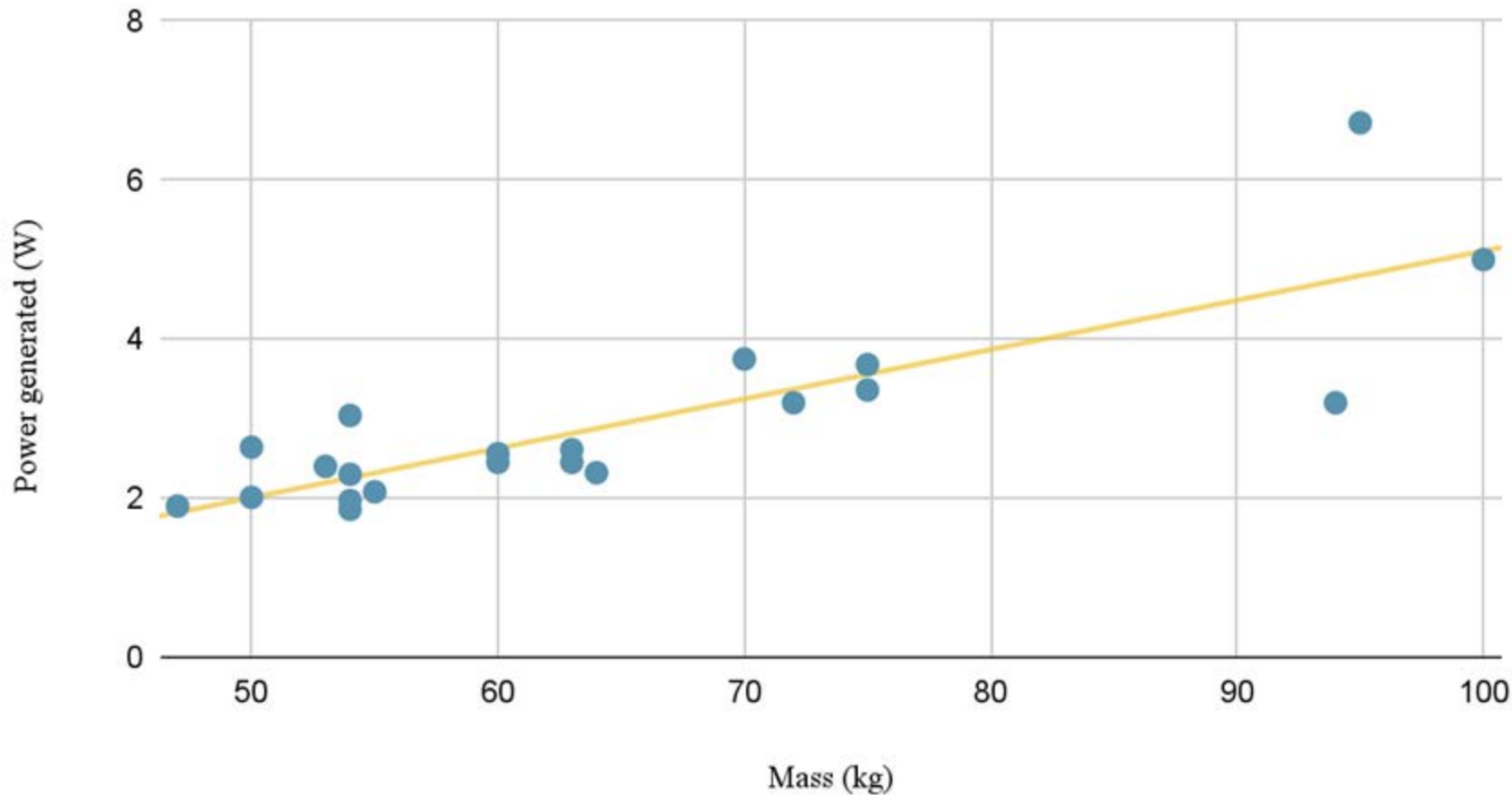
Conclusion:
We can deduce that the more force applied, the higher power output.

Maximum p.d. achieved during testing was 72V and 16W of power. This proves that the upper limit for power is very high.

Experiment 1: mass vs power



Power generated vs Mass



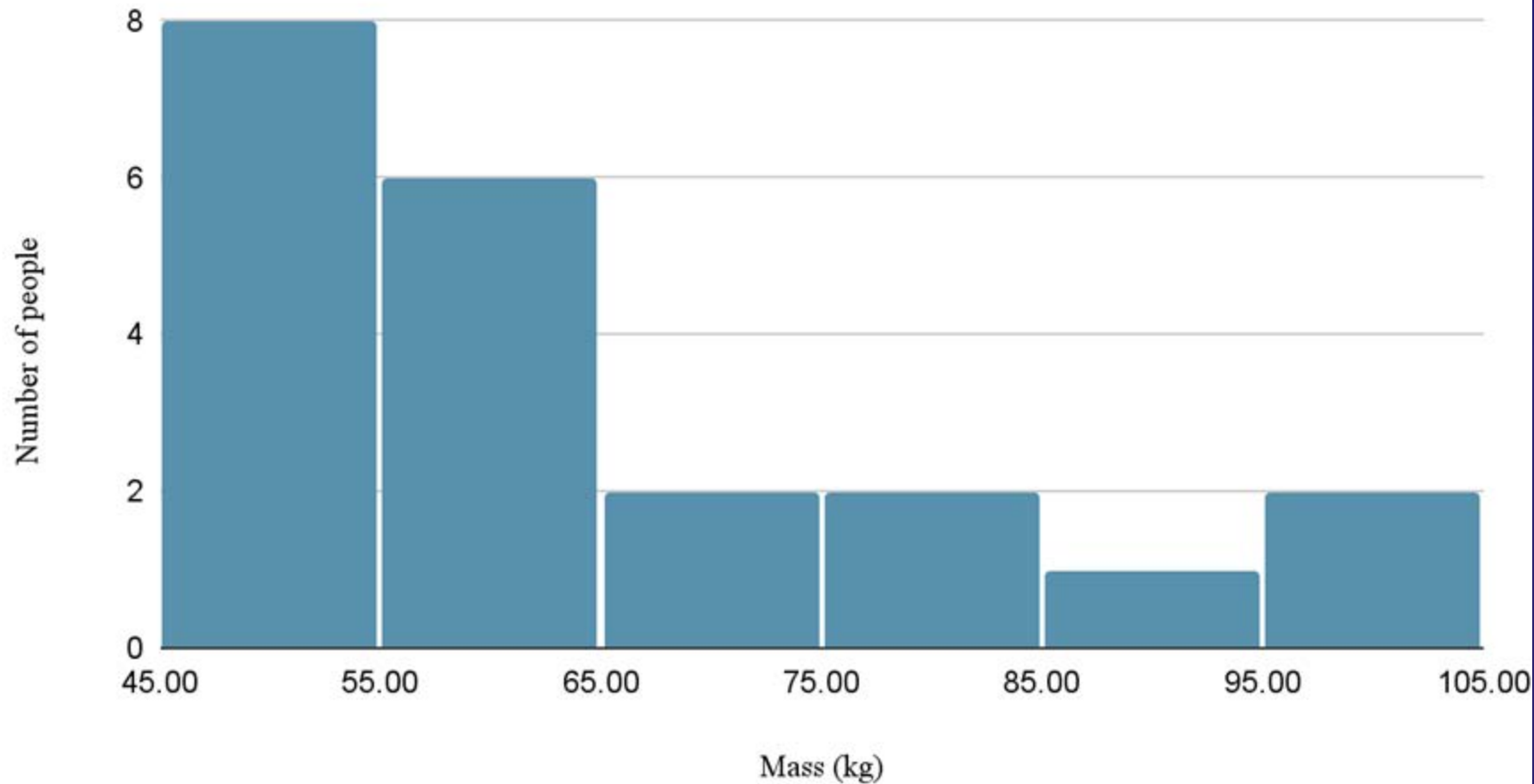
To achieve reliable results we randomly selected participants and instructed them to walk as if the plate was not there. We then recorded 3 results per person to find a mean.

Conclusion:
In public, the average weight is around 70kg, meaning the average power output per person should be around 3.2-3.5W.

Experiment 1: How representative is our data?



Masses of investigated people



The histogram shows the mass of different people we surveyed.

Conclusion:
The average results may be less accurate because fewer people have a higher mass.

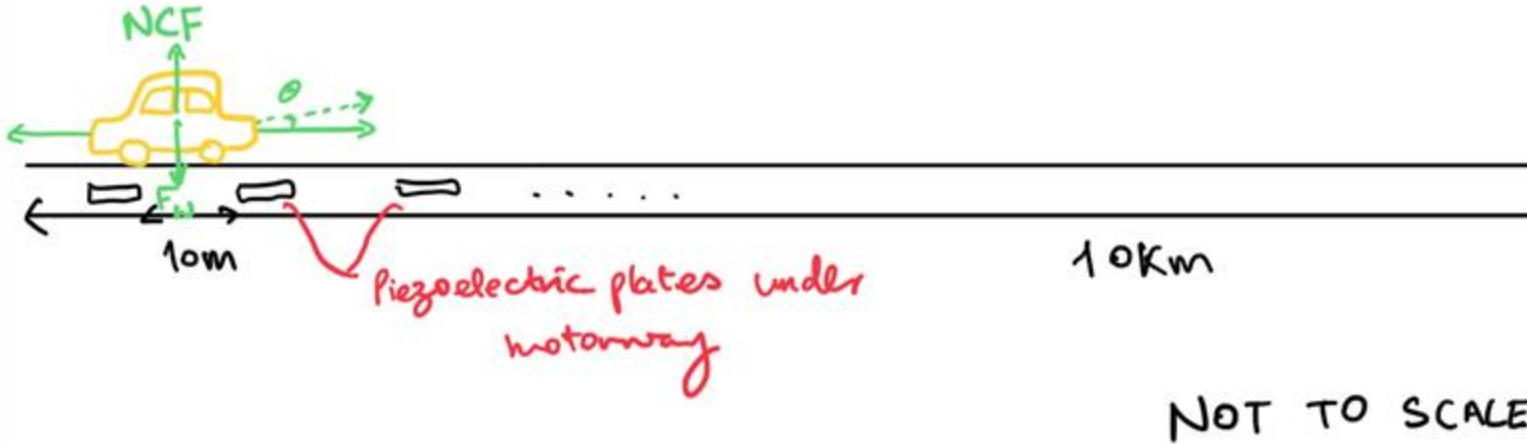


Hypothetical calculations

Those calculations are able to give us a rough understanding of the scale of this project in the future and the amount of energy it may generate

Pixabay*

Hypothetical Motorway Calculation



Numbers and constants:

C = capacitance

Q = charge

Weight of car (F) = $2000\text{kg} = 19260\text{N}$

Area of tyres = 0.02m^2

d = piezoelectric constant = $3\text{e-}10$

Calculation part 1:

$$F(\text{weight}) = 2000 \times 9.81 = 19,620\text{N}$$

$$p = F/A = 19260/(0.02 \times 4) = 240,750\text{Pa}$$

This is the weight of car divided by the surface area of 4 tyres

*Calculation part 2:

$$Q = d \cdot p \cdot A = 3.0\text{e-}10 \cdot 240,750 \cdot (0.02 \times 4) = 5.8\text{e-}6\text{C}$$

$C = 9.6\text{e-}12\text{F}$ (calculated from resonance frequency of piezoelectric discs)

$$\text{Energy} = Q^2/2C = 5.8\text{e-}6^2/2 \times 9.6\text{e-}12 = 1.74\text{J}$$

$$\text{Plates of 50 discs: } 50 \times 1.74 = 87\text{J}$$

$$\text{Road of 1000 Plates: } 87000\text{J}$$

Overall energy generated a day:

If one car passes one plate every 10 seconds:

$$1440 \times 87000\text{J} = 7.5\text{e}8\text{J} = 207\text{ kWh}$$

Energy in a year:

$$207 \times 365 =$$

$$75,555\text{kWh}$$



Conclusion

- Each disc produces a low p.d. which required many discs. connected in series and parallel to reduce resistance.
- Within a few weeks we managed to build a piezoelectric board at low cost, performed tests and collect a reliable and reproducible data.
- We proved that piezoelectricity can be used to generate p.d. up to 72V by applying a foot force.
- The max power achieved in our experiment was 10W.



Thank you for your attention