DM2120

Project Research

Case Study

How can electric vehicles be modified or redesigned to reduce non-exhaust emissions in London?

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2092 Words (Excluding Front Page, Contents, Diagrams, References and Appendices)

Contents

Introduction

London is one of the most polluted places in the UK. London's pollution problem is exacerbated by high population density and tightly-packed buildings which trap toxins at low level. Policy Exchange (2016) found that air pollution puts nearly 3500 people in London hospitals annually, and that if pollution levels (at the time of publishing) stayed the same, those born in the Capital in 2010 would each lose an average of 2 years from their life expectancy.

Most airborne pollutants are either gases or particles. It is pollutants like carbon dioxide and ozone that most people are aware of due to the increased recognition of global warming in the last few decades. While such gases do have a negative impact on the health of both people and the planet, fine airborne particulate matter causes more direct damage to humans. An article in the *Journal of Thoracic Disease* starkly states that 'PM2.5 (particles less than 2.5 micrometers in diameter) can penetrate deeply into the lung, irritate and corrode the alveolar wall, and consequently impair lung function' (Xing *et al*., 2016:69). Figures from the Greater London Authority (2019) show that not a single area of London fell within World Health Organisation guidelines for PM2.5 concentration. The report also determined that the single largest contributor to particle pollution in London is road traffic. Combustion also contributes highly, which encompasses any burning, from household heating to commercial cooking. Combustion will not be the focus of this study as the sources are so varied and firmly established in the country's infrastructure. Conversely, the automotive market is fast-paced, consumer driven and has the potential to undergo substantial changes in a short timescale.

One proposed solution gaining traction in the UK is the adoption of battery electric vehicles (BEVs). Compared to ICE (internal combustion engine) vehicles, BEVs offer the advantage of zero tailpipe emissions. This does not mean 'zero-emissions' however, since all road vehicles also produce non-exhaust emissions (NEEs) regardless of their method of propulsion. NEEs are created through tyre wear, brake-pad wear and resuspension of road particles. NEEs contain the fine particulates discussed previously, making them particularly dangerous to human health. There is currently no legislation in place that regulates NEEs. This study investigates if electric vehicles are a suitable solution to combat air pollution in London, and if so, how we can redesign or modify them to reduce NEEs.

Aims & Objectives

Aim 1: Determine the key sources of non-exhaust emissions in London
Objective: Collate and analyse secondary research data

Aim 2: Determine if electric vehicles are a solution to air pollution
Objective: Analyse secondary research data and gather primary data though an online survey

Aim 3: Understand the public's perception of vehicle emissions and their relationship with electric vehicles
Objective: Source data from my primary research survey

Aim 4: Suggest how non-exhaust emissions could be reduced
Objective: Utilise primary and secondary data to produce a design solution to combat NEEs

Methodology

I gathered data from several secondary sources such as Government publications and journal articles. The data gathered here is mostly scientific in nature and compensates for the fact that I didn't possess the resources to collect my own air pollution data which would require specialist equipment. Reliable secondary research is essential to this type of study because it allows analysis of data collected over a wide time period, such as historic air quality readings. Government-published data was particularly useful as the studies are typically repeated year-on-year to establish trends.

I also collected primary source data through an online survey using Google Forms, which helped me gauge public opinion on air pollution and electric vehicles. It also gave me the opportunity to see how people might respond to my design proposal. The usual caveats of online surveys apply – the respondent might not interpret the question as the author intended or answer it truthfully. For the data to be in any way representative of the public's opinion I needed as large a sample size as possible, so I shared it on social media and sent it to my family in London.

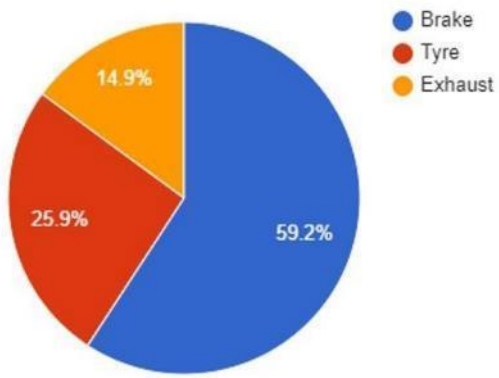
I have sorted my findings into groups which represent my case study aims. This allowed me to compare small selections of primary and secondary research side-by-side to establish trends without being overwhelmed, which might be expected if it was not split into groups. The complete set of survey responses can be found in Appendix A.

Findings

Aim 1: Determine the key sources of non-exhaust emissions in London

The single greatest resource that facilitated this research was the Greater London Authority's *London Atmospheric Emissions Inventory* (2010, [online]), recently updated with 2020 data. I focussed on the road traffic sources of PM2.5 in the whole of London and discovered that in 2020, out of the 1285.8 tonnes-per-annum emitted by road vehicles, less than 15% originated from the exhaust [Fig 1].

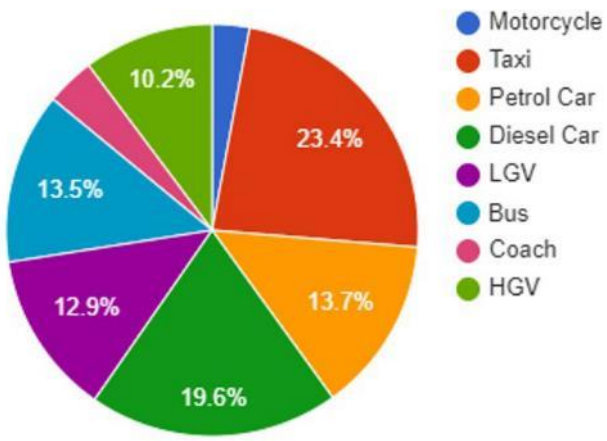
[Fig 1] Origin of vehicle-emitted PM2.5 in London in 2020, measured in tonnes per annum



Data from GLA's *London Atmospheric Emissions Inventory*

The same dataset also detailed each type of vehicle's contribution to these emission figures. I found that in Central London, the vast majority of PM2.5 emissions came from passenger cars. This category can be broken down further into taxis, petrol cars and diesel cars [Fig 2]. Unfortunately, BEVs were not mentioned in this dataset.

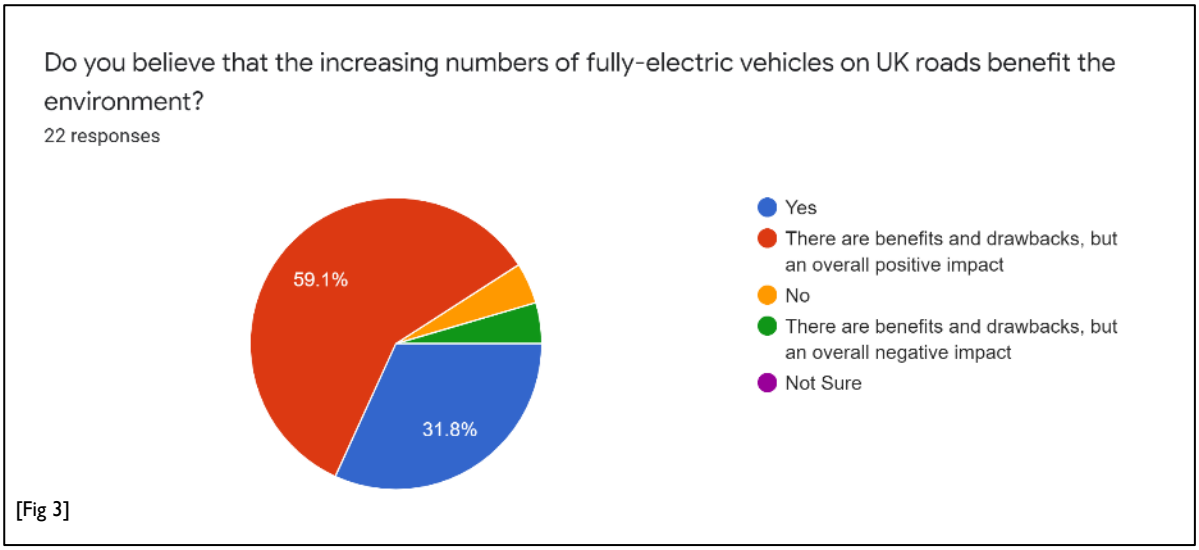
[Fig 2] PM2.5 emissions in Central London by vehicle, 2020



Data from GLA's *London Atmospheric Emissions Inventory*

Aim 2: Determine if electric vehicles are a solution to air pollution

Pollution is a complex issue with no single solution, but most experts agree that fossil-fuel ICE vehicles will soon become obsolete. BEVs are considered the ideal replacement by many since they produce zero exhaust emissions, so sales in the UK have skyrocketed in recent years. Figures published by The Society of Motor Manufacturers & Traders (2020) show that BEVs had a 6.7% market share in 2020 compared to just 2.2% in 2019. The results from my primary research survey showed that most respondents felt BEVs have an overall positive effect on the environment [Fig 3].

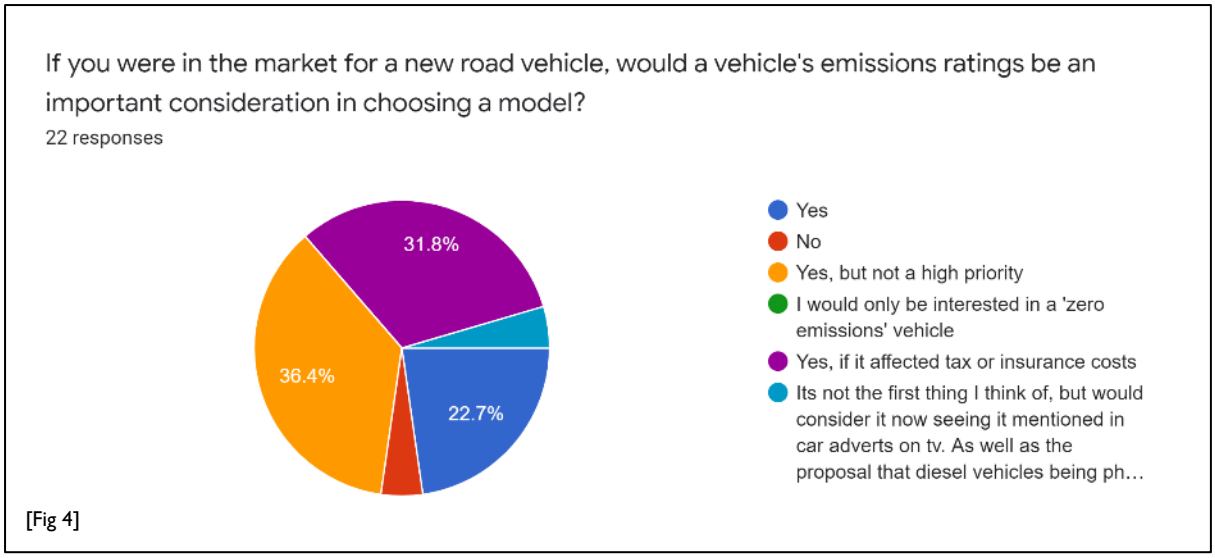


[Fig 3]

Electric vehicles still emit NEEs. My research indicates that an equivalent BEV can emit more particulate matter than a similar ICE vehicle due to their weight. Vehicle weight is a main factor in NEE levels due to increased friction between the wheels and the road, and because the brakes must be applied more heavily to overcome the vehicle's momentum. I researched several vehicles and found that in every comparison I made, the BEV was heavier than the comparable ICE vehicle. For example, I compared the specifications of the Volkswagen Golf (ICE) to the Volkswagen ID.3 (BEV). Despite very similar size and performance between the two, the BEV weighs approximately 35% more than the petrol car (*Parkers*, 2020).

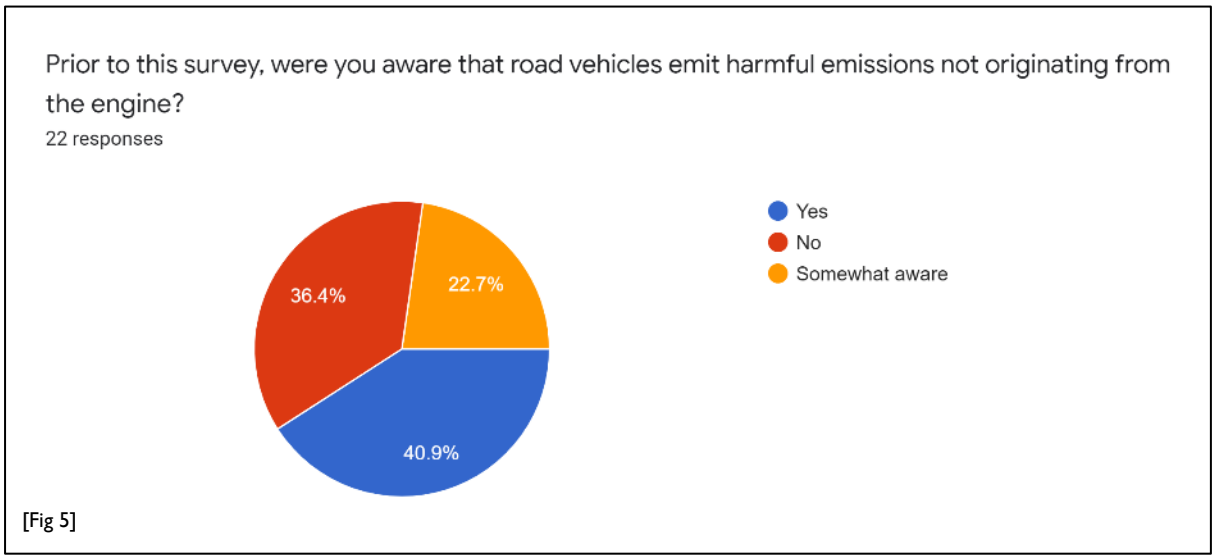
Aim 3: Understand the public's perception of vehicle emissions

Much of my survey was designed to gauge the public's relationship with vehicle emissions and how this linked to their perception of electric vehicles. I established that 17 of my 22 respondents regularly drove a motor vehicle. Next, I wanted to examine if emissions were a consideration to them when choosing a new vehicle. The answer was an overwhelming 'yes', although 8 respondents did not consider it a high priority and 7 others said they would only consider emissions if it affected tax or insurance costs [Fig 4]. See Appendix A for full set of survey responses.



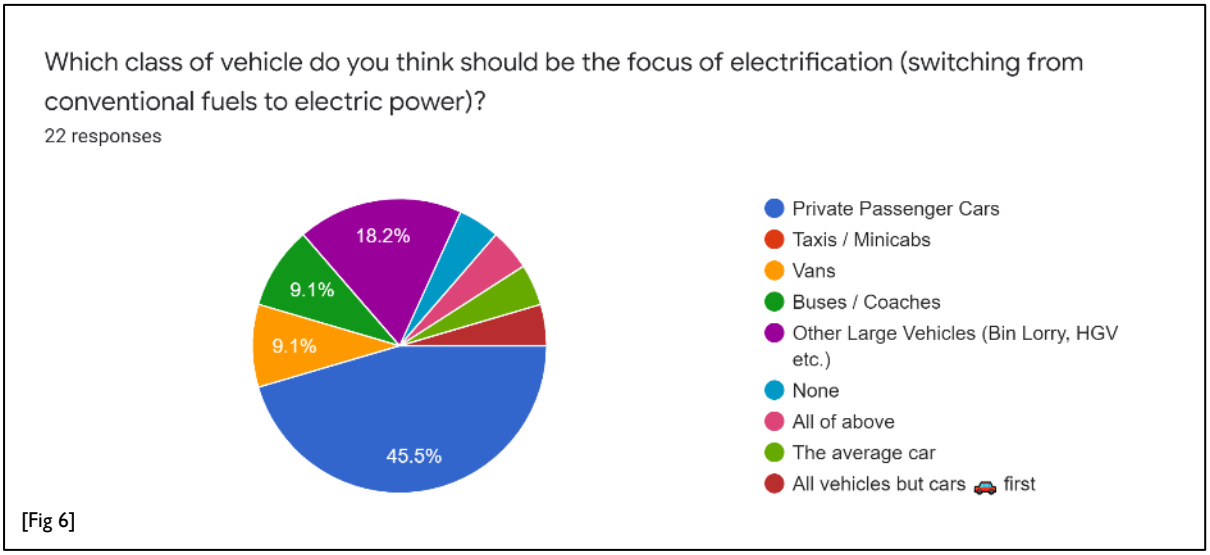
[Fig 4]

I was surprised to find that most respondents were already aware of non-exhaust emissions when I posed the question to them [Fig 5].



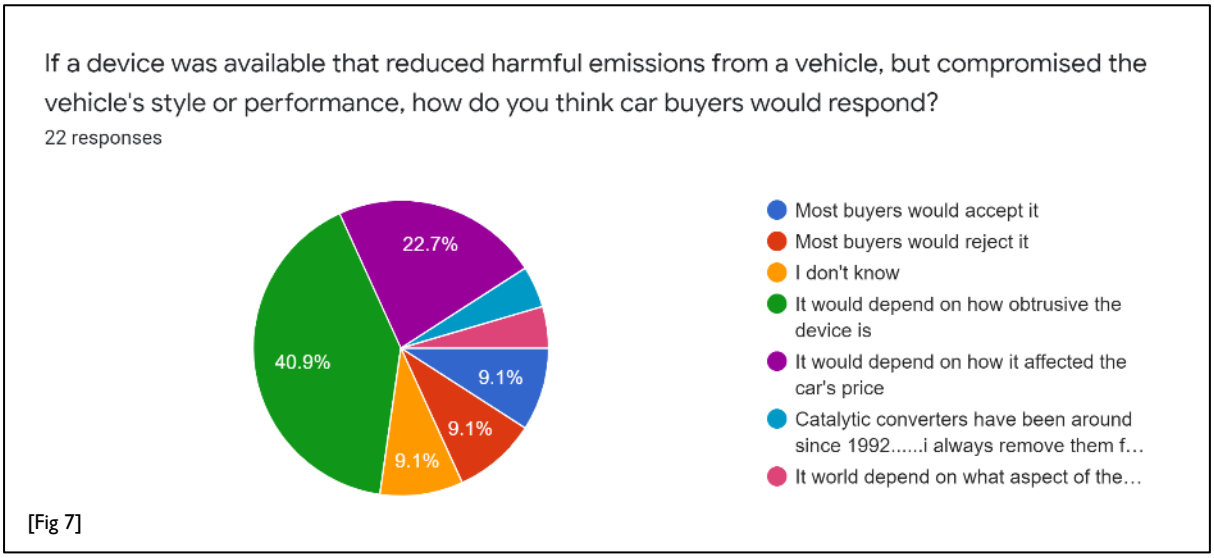
[Fig 5]

I wanted to know which vehicles the public thought should be the focus of ‘electrification’. 10 of 22 respondents suggested that the focus should be on passenger cars [Fig 6]



[Fig 6]

My final question was designed to gain some understanding of whether a new NEE-reducing product could be viable to the public. Responses were mixed, and most respondents said their answer would depend on how obtrusive the product was [Fig 7].



[Fig 7]

Analysis

The combination of my primary and secondary research showed clear trends. Firstly, it was overwhelmingly clear that passenger cars, whether taxis or personal vehicles, were the leading cause of fine particle pollution in Central London. An important finding was that although some vehicles like Buses and LGVs are individually 'dirtier', it is the sheer volume of passenger cars that make them the key NEE contributor. Interestingly, most survey respondents felt that private passenger cars should be the focus of electrification but not taxis. I believe this is because most respondents did not live in London and therefore encounter far less taxis on the road. This would also explain why most respondents were not concerned about air pollution in their locality. Despite this and the fact I only received 22 responses, I still consider the survey a success as some of the answers provided were very detailed and there were clear trends to the data.

My interpretation of the data is that while vehicles are becoming cleaner and meet current exhaust emission standards, NEEs remain unchallenged and are becoming a much larger proportion of a vehicle's total emissions. This is especially true of electric vehicles which, due to their weight, will typically emit more NEEs than an ICE car. There is a positive correlation between the numbers of electric vehicles on the roads and the proportion of emissions that are non-exhaust. Despite this and the other problems associated with BEVs such as the issue of lithium mining for batteries, I believe they do have an overall positive effect, and this is something my survey respondents also recognised. My research led me to make the following recommendations: NEEs from all vehicles should be measured and regulated in the same manner as tailpipe emissions. ICE vehicles should be phased out and replaced with BEVs, but these electric vehicles should be modified or redesigned in some way to reduce NEEs. As my primary research indicated, I suspect that most consumers are not interested in emission-reducing technology if it compromises the luxuries of modern motoring, such as negatively affecting performance or cost. Any product aimed to combat NEEs would have to be integrated as unobtrusively as possible.

Solution Proposal

Aim 4: Suggest how non-exhaust emissions could be reduced

Having identified an area for improvement in the automotive market, I investigated how I could create a true 'zero-emission' vehicle. This could be achieved by reducing the number of particles produced by a vehicle or capturing them after emission. A solution to the former could be a new material that sheds less particles, or even a completely new wheel design. Since tyre manufacturers are already perusing this, I focussed on a design that actively collects particles while on the move. The air flow around a wheel means that the addition of a collection filter into the wheel arch could be very effective, I estimate 80-90% of particulates could be captured before diffusing into the air. It was challenging to design an unobtrusive system that didn't add too much mass to the vehicle. Refer to Appendix B for details of my design process and solution.

Conclusion

To conclude, the aims I hoped to achieve in this study have been met successfully. I determined that the main sources of NEEs in London are taxis and private passenger cars, and made recommendations to combat the problem. My investigation into BEVs found that they have great potential for reducing emissions in London but are hampered by their weight. Since reducing weight would also improve vehicle range, I predict manufactures will continue to develop lighter BEVs which would also help reduce NEEs. I have proposed that NEEs are measured and regulated in the future to ensure that BEVs have a positive effect on cutting pollution in cities. My survey was successful by showing trends in the way people perceive electric vehicles, which had a big impact on my own design solution. The survey responses reinforced my idea that most people would like to drive a cleaner vehicle, but many aren't willing to make compromises to their driving experience. This valuable information guided the design of my proposed solution.

If I was to redo this case study, I would try and increase the reach of my survey through more aggressive sharing through different outlets. Considering the study focussed on London, only receiving two responses from the capital was disappointing. I would also have liked to establish a dialogue with key players. I messaged several prominent tyre and vehicle manufactures for comment on whether NEEs are something they take into consideration and opinions on my design proposal [Appendix C]. As of writing this study, no responses have been received. Regardless, my detailed research led me to develop a design solution that I believe could reduce NEEs dramatically, meeting my goal. I intend to develop this idea further and present the project to the RSA.

References

Greater London Authority (2019) *PM2.5 in London: Roadmap to meeting World Health Organization guidelines by 2030*. London: Greater London Authority.

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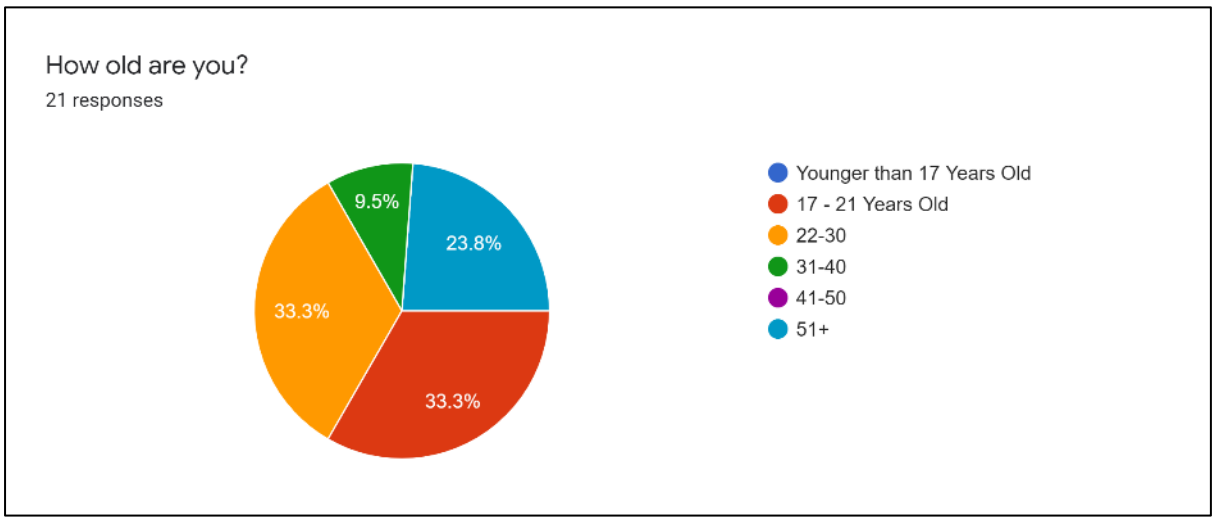
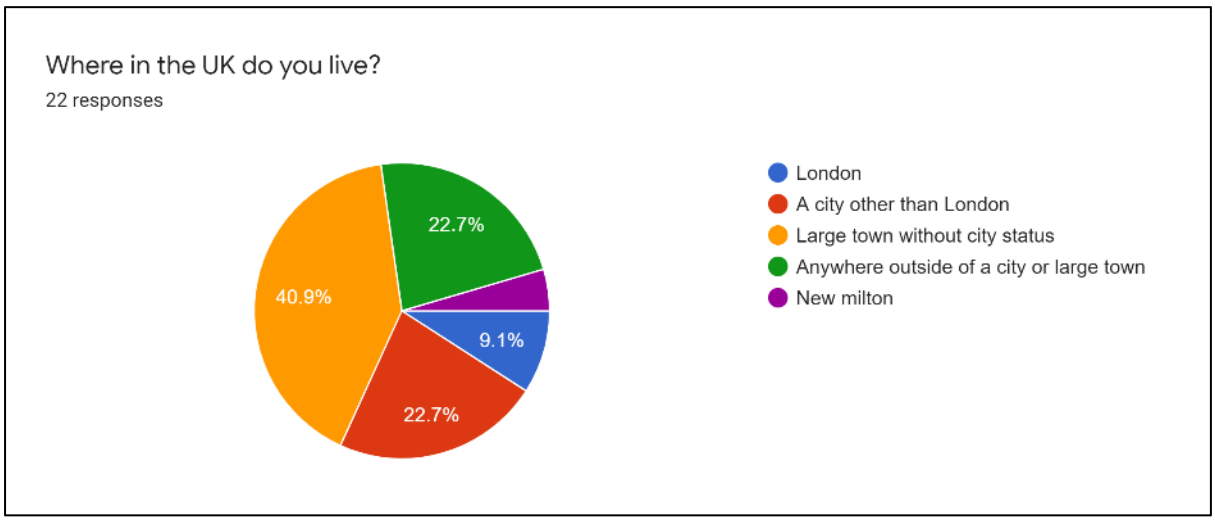
Appendices

Appendix A

Here you can view my survey results in full. The survey was open for responses from the public between 16 November 2020 and 1 January 2021. The survey was posted on various social media platforms. I did not restrict the survey to a specific location because I know this would lower the number of respondents considerably, and fewer respondents means that the information gathered is less representative of public opinion. The majority of the 22 respondents live in either Hampshire or Dorset, representing acquaintances from my university, hometown and workplace. Please note that the written answers are presented exactly as the respondents submitted them. Most questions gave the respondents the option of adding their own answer.

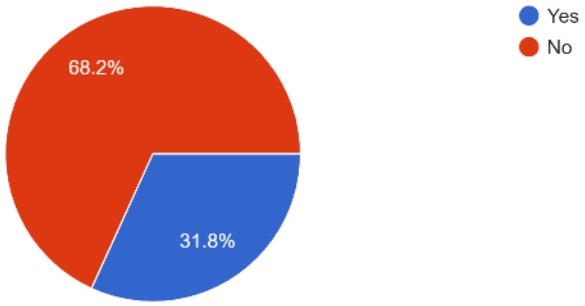




Appendix A (continued)

Does the air quality in your area worry you?

22 responses



If you answered Yes to the last question, what worries you about the air quality in your area?

6 responses

That it'll harm my health/the health of others

I'm not worried about the air quality in my area specifically as it might not be too bad compared to some areas - I'm more worried about air quality overall across the country/world.

It bad

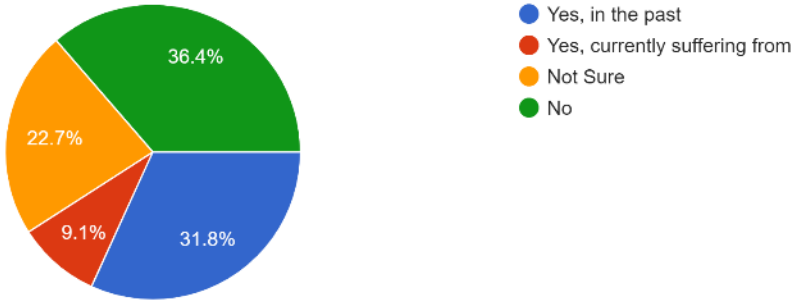
Its smells funny

Chemicals in the air, toxins that drift

The possible health implications from constant exposure to exhaust fumes from walking past heavy traffic on a regular basis.

Have you, or a family member living in the same area, suffered from any breathing problems such as asthma?

22 responses



Appendix A (continued)

If yes to the above, please provide some more information

8 responses

asthma

My son had pneumonia and sometimes displayed other breathing problems when he was young.

Father, mother and grandfather, but not myself

Had athsma in the past

Mother had asthma from a young age

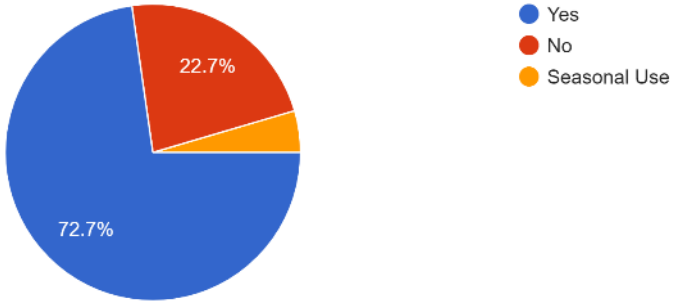
My eldest son was prescribed an inhaler for asthma symptoms in primary school.

Pet allergy

My brother suffered from minor issues when younger but it hasn't been serious.

Do you drive a motor vehicle regularly? (once a week or more)

22 responses



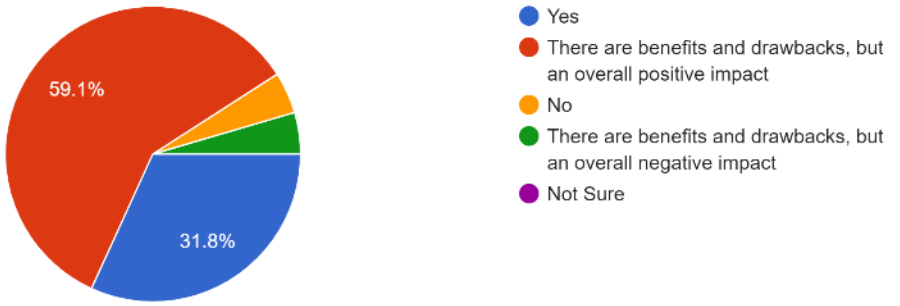
If you were in the market for a new road vehicle, would a vehicle's emissions ratings be an important consideration in choosing a model?

22 responses

Appendix A (continued)

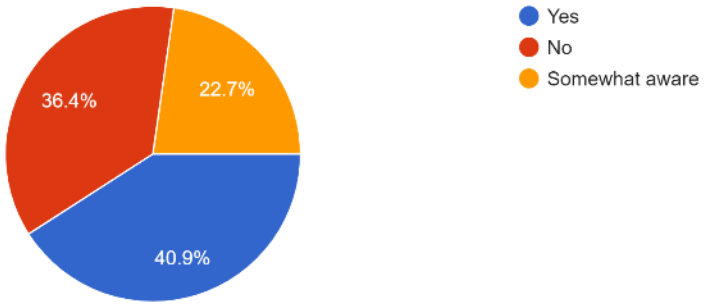
Do you believe that the increasing numbers of fully-electric vehicles on UK roads benefit the environment?

22 responses



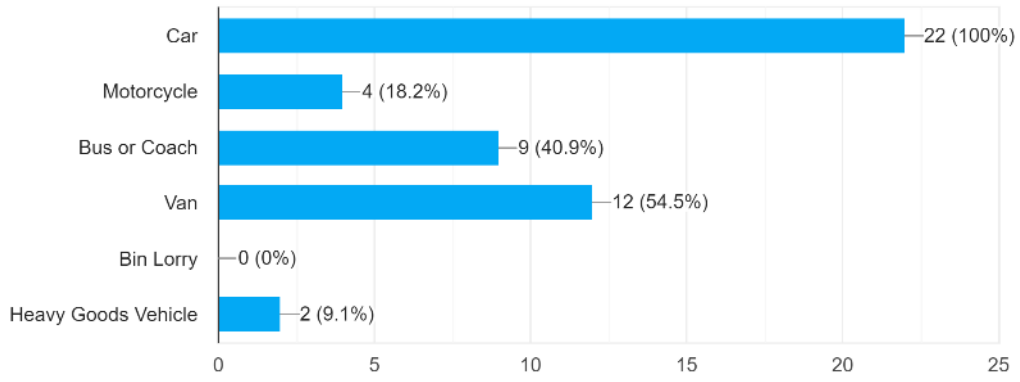
Prior to this survey, were you aware that road vehicles emit harmful emissions not originating from the engine?

22 responses



What type of road vehicles do you encounter most frequently in your area? You can select up to three if you encounter equally high numbers of more than one type.

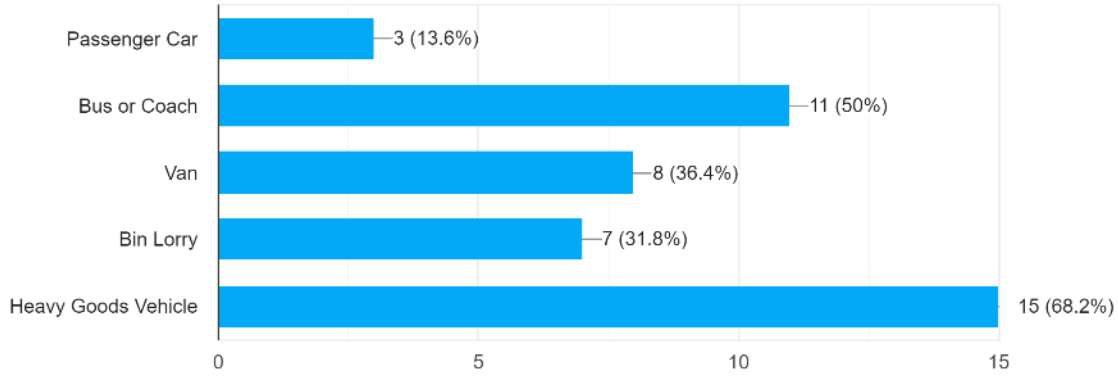
22 responses



Appendix A (continued)

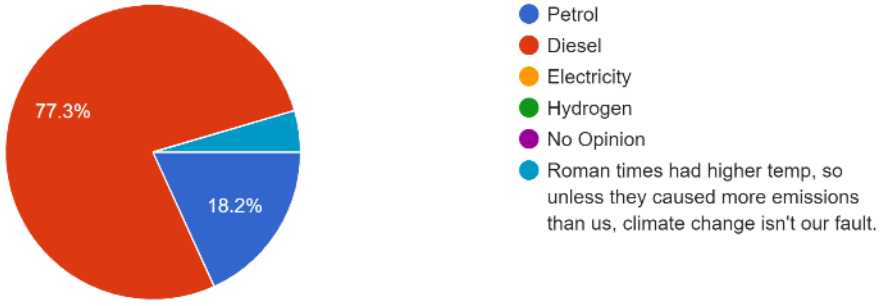
In terms of emissions, which of the following types of vehicle do you perceive to be the 'dirtiest'? Please select 2.

22 responses



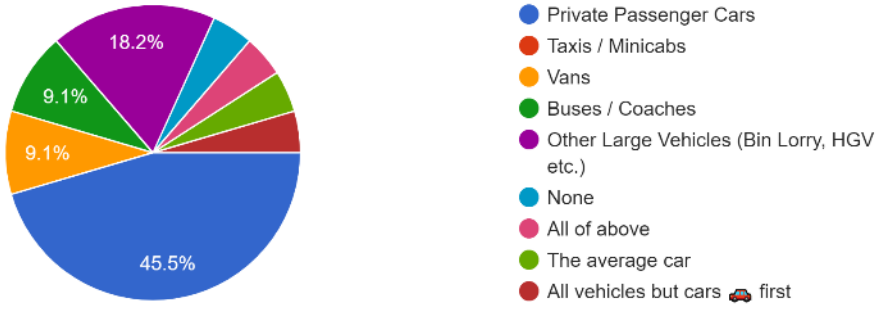
Which of the following vehicle propulsion methods do you believe to be the most damaging to the environment?

22 responses



Which class of vehicle do you think should be the focus of electrification (switching from conventional fuels to electric power)?

22 responses



Appendix A (continued)

Please explain your response to the above question

19 responses

Possibly the dirtiest and cannot be as easily replaced by trains, cycling, walking etc

Because they see the most use

the environmental impact of mining for elements such as lithium, added to the manufacture of the electric vehicle.....far outweigh the environmental impact of running a petrol powered vehicle

There are more private passenger cars than any other vehicle and having a small percentage impact on them will have a larger overall effect

More on road

There is a high density of ban use in London. Plus they tend to be driven faster and under hard ecceleration

Because they're in the majority.

All are already in process of switching if not already switched.

I just feel that buses should be electric, I think it would encourage more people to use those vehicles

Used more regularly

They emit the most I think

Sheer volume of them

I believe tackling the most popular form of transport first will influence other forms of transport to follow suit.

Because there are more of them on the road

As cars would be the largest road user target them first then the next class of high polluting vehicles

There's more cars on the road than any of the other vehicles.

In my opinion, vans are one of the most commonly used vehicle types across all manner of industries and uses. Now, with almost everything available online and the popularity of UK high streets declining, the current and future use of vans (especially for deliveries) is yet to decrease.

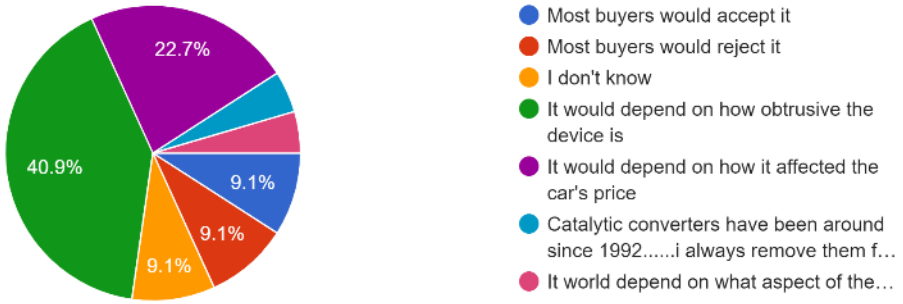
To make a real impact to help the environment, you need to induce mass change. Therefore, the change would need to be aimed at private cars.

higher quantity

Appendix A (continued)

If a device was available that reduced harmful emissions from a vehicle, but compromised the vehicle's style or performance, how do you think car buyers would respond?

22 responses

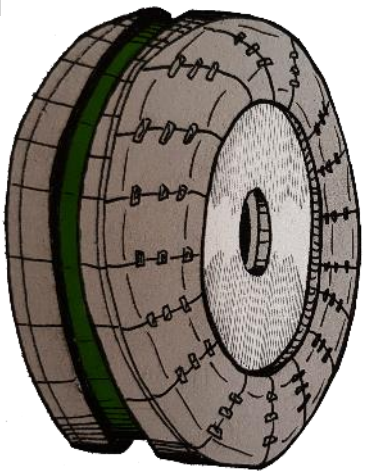


Appendix B

Here you can find the origins and evolution of my proposed solution to the non-exhaust emission problem. Note that all images are original, produced by me.

Appendices B1/2/3: A selection of annotated diagrams displaying three of my initial design ideas

B1

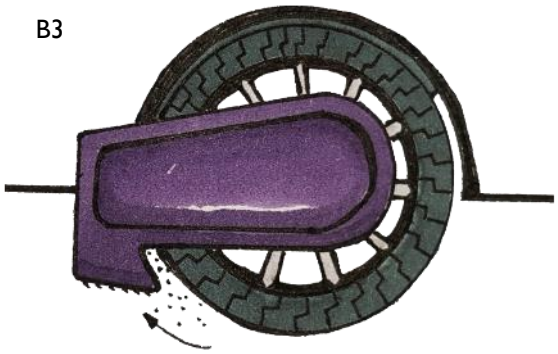


A NEW WHEEL DESIGN OR TYRE MATERIAL THAT EMITS LESS PM

B2

DESIGN A WAY OF REDUCING THE WEIGHT OF ELECTRIC VEHICLES

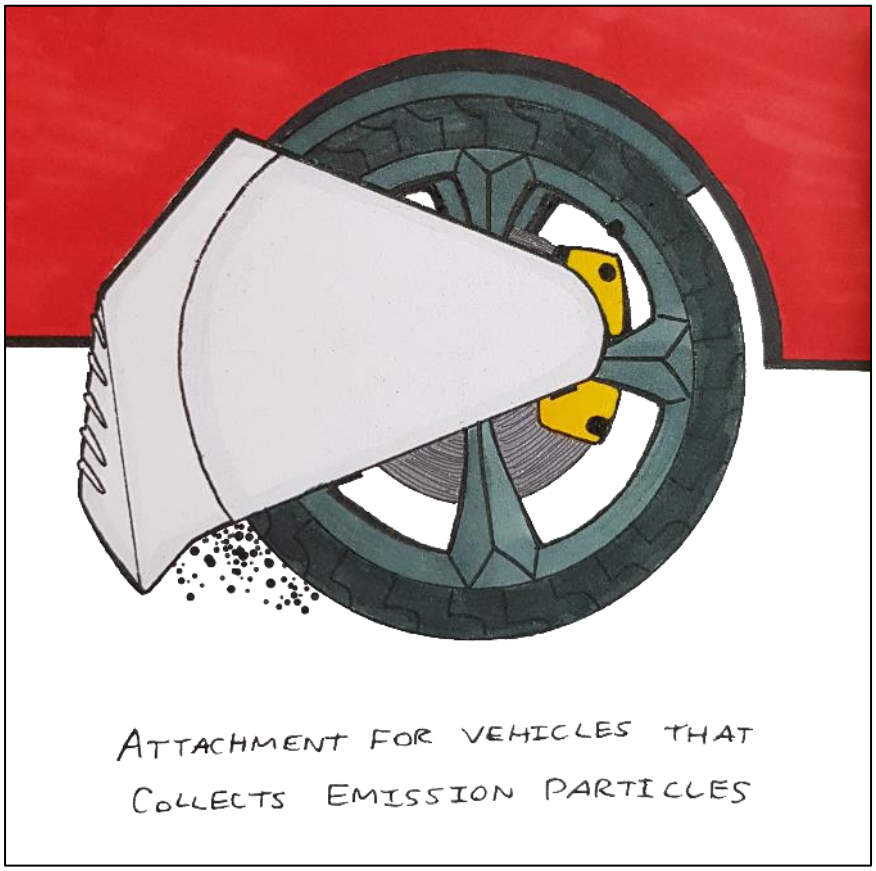
B3



ATTACHMENT FOR VEHICLES THAT COLLECTS EMISSION PARTICLES

Appendix B4: This illustration (fine-line and coloured marker pens) shows further development of design concept B3. This design features a collection tray positioned behind the vehicle's wheel that could utilise the wheel's air flow or self-generated suction combined with electrostatically-charged filters to capture particulate matter as they are shed from the brakes and wheel. A typical car would require 4 of these devices to be effective. Effects on the vehicle's performance and the driving experience should be minimal. Construction should be of lightweight alloys and polymers to minimise any increase to vehicle mass. Vehicle appearance would be affected, this could be an issue for some consumers.

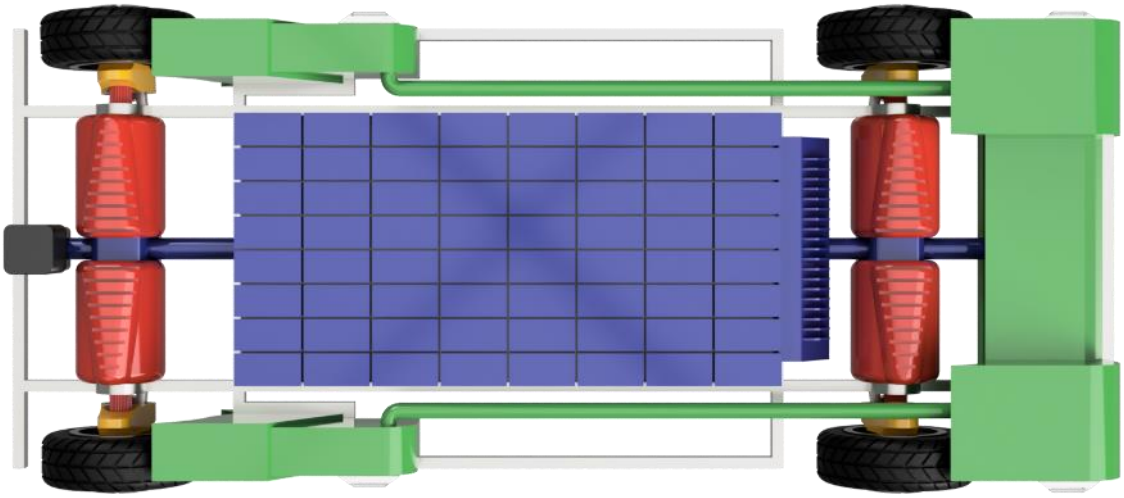
B4



Appendices B5/6/7: Part-way through the evolution of the design shown in B4, I encountered a very similar product currently being developed by a group of students. The Tyre Collective's concept won the *James Dyson Award* UK Prize in 2020 and is fundamentally the same product as my solution, being a wheel attachment that collects particles through use of electrostatically-charged plates (James Dyson Award, 2020). Although one could be mistaken for thinking my design was influenced by this product, it was simply a case of two unrelated parties coming to the same conclusion independently. This discovery took me back to the drawing board, but I was sure that the concept could be improved on. Looking back at my survey results, I concluded that a well-integrated system that had less impact on the aesthetics of a vehicle would have more success on the consumer market. I began developing a new design solution based on the concept of complete integration, meaning that the idea had changed from a vehicle attachment to a substantial vehicle redesign. My new solution is still in the early stages of development, but I have finalised the chassis layout which can be seen in the CAD renders below (B5/6/7).

B5

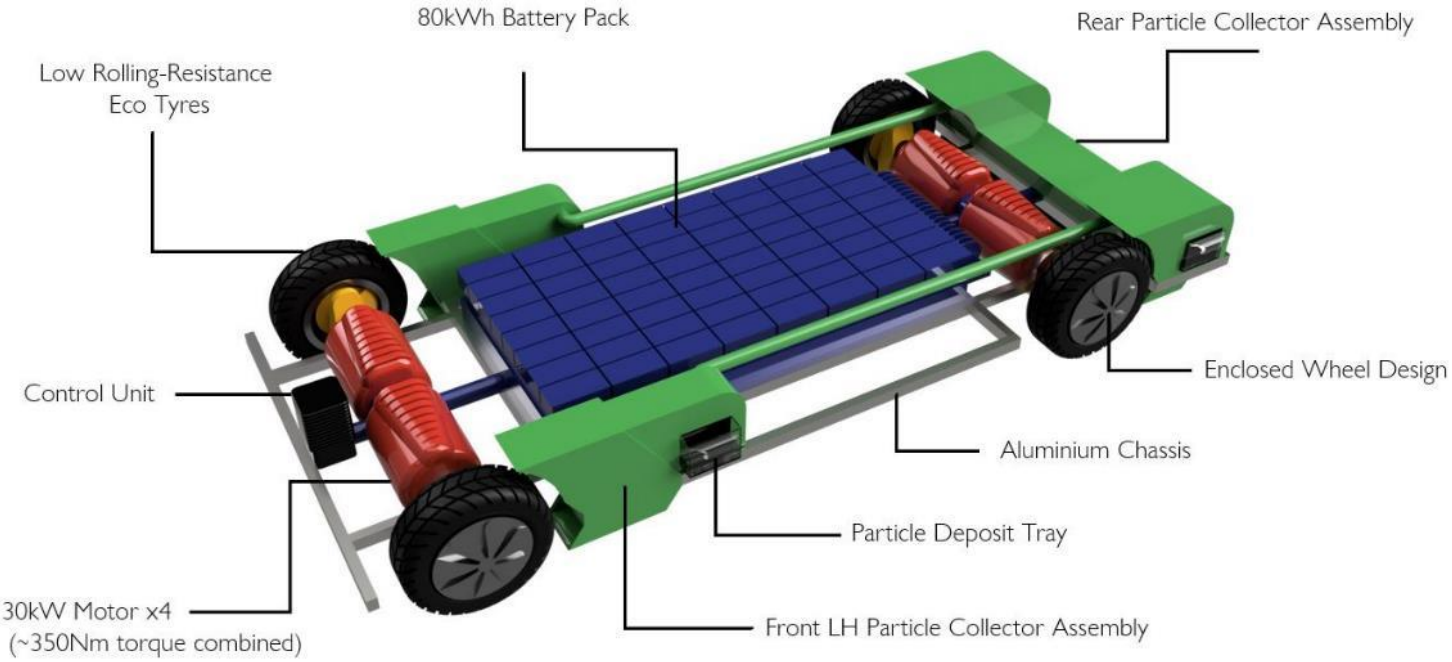
B6



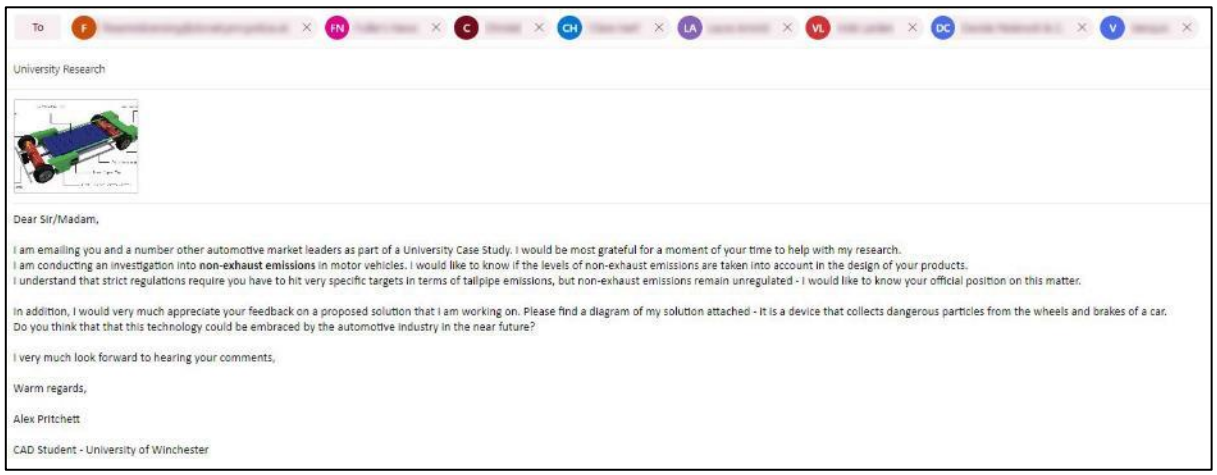
B7

Appendix B8: Annotated diagram of my zero-emission vehicle chassis. Project is still in progress at the time of writing this report.

B8



Appendix C: Screenshot of an Email that was sent to multiple key players in the automotive industry. My goal here was to understand if manufactures take non-exhaust emissions into consideration when designing tyres/brakes or complete vehicles. I also took this opportunity to propose my design solution to these key players, hoping for feedback. As of writing this report, no responses were received.



To

University Research

Dear Sir/Madam,

I am emailing you and a number other automotive market leaders as part of a University Case Study. I would be most grateful for a moment of your time to help with my research.
I am conducting an investigation into **non-exhaust emissions** in motor vehicles. I would like to know if the levels of non-exhaust emissions are taken into account in the design of your products.
I understand that strict regulations require you have to hit very specific targets in terms of tailpipe emissions, but non-exhaust emissions remain unregulated - I would like to know your official position on this matter.

In addition, I would very much appreciate your feedback on a proposed solution that I am working on. Please find a diagram of my solution attached - it is a device that collects dangerous particles from the wheels and brakes of a car.
Do you think that that this technology could be embraced by the automotive industry in the near future?

I very much look forward to hearing your comments,

Warm regards,

Alex Pritchett

CAD Student - University of Winchester