

Performance vs Emissions of an Internal Combustion Engine.



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Abstract

According to critics, the transport sector accounts for 26% of the UK's greenhouse emissions rising by 2% since 2016 according to Josh Gabbatiss from the Independent. As Josh Gabbatiss stated, "The majority of Britain's greenhouse gas emissions now come from transport" (Gabbatiss, 2018). The Vehicle Certification Agency states that the UK government must reduce vehicle emissions by at least 34% by 2020 and 80% by 2050 (Vehicle Certification Agency, 2017). Global warming has become a visible effect and to combat this, the automotive industry are developing their compact, powerful engines to replace their larger, less economical engines. Engine downsizing is the reduction of engine capacity whilst providing the same performance output as that of a larger capacity. Ford and Mercedes are among many manufacturers to have taken this route, providing the needed power and reduced fuel consumption. This paper provides information on the current issues involving emissions and research into downsized engines.

As global emissions rise, emission regulations become more stringent. Currently, Euro 6 regulations state that vehicles must comply by the 130g/km CO₂ explains Frost and Sullivan Authors (Frost and Sullivan, 2016) but with Euro 7 standards looming, vehicle manufacturers are having to clamp down on their emission outputs. Frost and Sullivan predict that Euro 7 regulations, released in 2020 will drop the CO₂ emission output of vehicles by 35g/km down to 95. This is due to the increasing effect emissions has on human health and on global warming causing the increasing weather extremities throughout the world, especially in the last decade. Manufactures are tackling this by down scaling their engines and adding a forced induction system to compensate for the loss in engine capacity. This paper describes the gasses and problems cars currently produce as well as the global impact the transport sector on the natural environment.

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2.0 Introduction

This is a technical report discussing the impact of increased performance on emissions of an internal combustion engine. The significance of this question relates to manufacturers downsizing their engines with the addition of forced induction, as well as the upcoming stringent transition from Euro 6 to Euro 7 regulations. The aims of this project are as follows:

- Discover the impact increased performance has on vehicles emissions.
- Explore whether downsizing has solved the emissions complication.

There is a growing realisation worldwide that vehicle emissions are depleting the natural environment, but internal combustion engines have dominated the transport sector for decades. The legislations surrounding the formation of greenhouse gasses through exhaust emissions are leading vehicle manufacturers to reduce their carbon footprint and reduce global warming. Constant efforts are being made by manufacturers to reduce their impact on the environment through the reduction in fuel consumption and increase the efficiency of the powertrain; engine downsizing is considered the most effective strategy for this according to Chinmay Patil et al [5]. Euro 6 regulations in 2014 stated that gasoline passenger vehicle emissions must comply by the 130 g/km and the predicted Euro 7 regulations have dropped to around 95 g/km, this is a reduction of 27% states Frost & Sullivan authors (Anon, 2016). Manufacturers are tackling this by downsizing their engines and adding a forced induction system. Andy Goodwin from car keys explains that Ford have downsized their 81bhp, 1.25 litre Fiesta that produces 122 g/km of CO₂ to a 1.0 litre Ecoboost that produces 99bhp and 99 g/km of CO₂ (Goodwin, 2016); this almost complies with the predicted Euro 7 emission regulations and also provides an improvement in power. Euro 6 standards are very stringent on NO_x emissions due to their toxicity and have dropped 84% since Euro 3. NO_x regulations have dropped from 0.15 g/km down to 0.06 g/km, according to Chris Ebbs from Auto Express (Ebbs, 2018).

Many other manufacturers have downsized their engines much the same as Ford have. The latest Cayman from Porsche has had a reduction in engine capacity from a flat-six naturally aspirated 3.4 litre to a 2.5 litre turbocharged flat 4 says Antony Ingram. Mercedes has also followed the downsizing trend converting the naturally aspirated 6.2 litre V8 down to a 4.0 litre twin turbo which has proven to be just as powerful as the original engine (Ingram 2017). Jordan Katsianis states for Evo magazine, Toyota are taking a completely different approach with their Yaris; they're upsizing. Where the original 1.3 litre engine made 98 bhp, Toyota has decided to increase its capacity to 1.5 litres producing an extra 12 bhp whilst using a clever VVT-IE system that changes between the Otto and Atkinson cycle to produce the optimum efficiency and performance (Katsianis 2017).

Figure 6: Size difference between downsized and big block (Patil et al, 2017)



difference in size between a big block naturally aspirated engine and a downsized turbocharged engine.

This seminar paper discusses the future plans for my project along with the experimental procedure which is dependent on the equipment available. A literature review will be included discussing the papers and books already read.

Companies are focused on the use of forced induction to aid in the downsizing of their engines; turbocharging or supercharging. The same power can be maintained after downsizing by forcing compressed air into the cylinder along with additional fuel despite the lower displacement. Unlike a turbocharger that uses the exhaust gasses to compress the air, a supercharger will be driven mechanically by the power of the crankshaft explains Chinmay Patil et al (Patil, 2017). The image to the left demonstrates an example of the

3.0 Literature Review

3.1 Harmful Gasses

To reduce emissions, according to John H Johnson from Michigan Technological University, a more fuel efficient vehicle must be created using a 17:1 air fuel ratio to produce maximum fuel economy. An air fuel ratio of 17.5:1 can cause misfire and slow down the speed of the flame fronts causing an increase in Hydrocarbons (Johnson, n.d.).

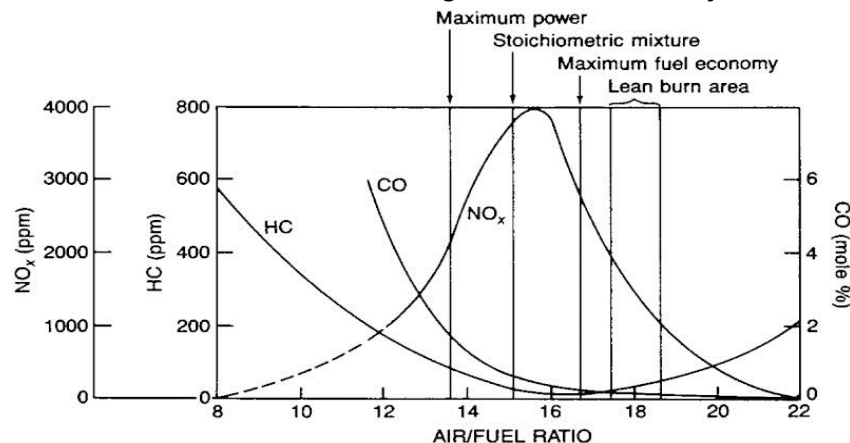


Figure 1: emissions at different air fuel ratios (Johnson, n.d.)

As seen in the graph above, it demonstrates what John H Johnson explained. As the air fuel ratio increases to around 16:1, the NO_x emissions are at their highest. This is close to the stoichiometric mixture. As the air fuel ratio increases NO_x emissions reduce but the Hydrocarbon and Carbon Monoxide begin to rise. For maximum fuel economy, 17:1 is the ideal mixture but for maximum power, 13.5:1 is the best mixture to use.

Nitrogen Oxide, known as NO_x, is one of the more toxic gasses exiting the exhaust causing near fatal side effects. NO_x is an irritant gas that causes inflammation of the airways if inhaled in high concentrations. NO_x is produced due to the reaction of nitrogen and oxygen in the air during combustion according to Icopal-noxite authors (Icopal-noxite, n.d.). As seen in the pie chart to the right, road transport equates to 40% of the EU's NO_x emissions as of 2011 due to the considerable health issues caused.

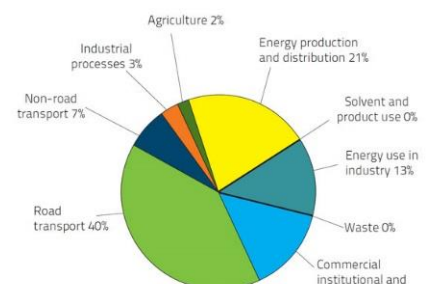


Figure 2: Share of emissions sector by group (Icopal-noxite, n.d.)

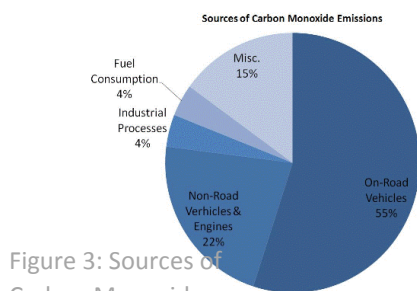


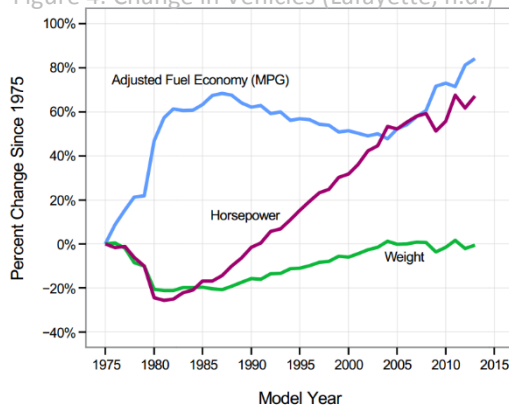
Figure 3: Sources of Carbon Monoxide (Dutton, n.d.)

(Dutton, n.d.).

Due to incomplete combustion, Carbon Monoxide is one of the most dangerous gasses emitted from a vehicle's exhaust. This is due to its lack of odour and lack of colour as well as its toxicity. It restricts the blood's ability to transport oxygen to the vital organs. The road transport sector equates to 55% of the carbon monoxide emissions nationwide states John A Dutton from the e-education institute

3.2 Performance

Figure 4: Change in Vehicles (Lafayette, n.d.)



The graph to the left demonstrates the dramatic decline in engine power and the sudden increase in fuel economy, this is due to the decline in big bore engines due to the safety concerns in the late 70's explains Lafayette authors. Due to the increase in safety regulations a couple of years later, vehicle performance began to rise again. Technology wasn't as sophisticated as it is today due to the decrease in fuel economy until 2005. Vehicles have begun to rise

steadily in weight since the 80's meaning power rises equally. (Lafayette, n.d.). According to Joann Muller from Forbes, since 2013, SUV sales have increased by 87% globally and car sales drop by 8% (Joann Muller, 2018).

Increasing performance can be acquired with the addition of a forced induction system to the engine. Turbochargers provide the engine with air at high pressure through the use of exhaust gasses spinning a turbine. This turbine is connected via a shaft to the compressor side of the turbo, where the air gets compressed and enters the cylinder. Higher the compression of the air, the more air can fit into the cylinder, where in turn, more fuel will be added causing a larger combustion explains Chris Woodford from Explainthatstuff.com (Woodford, 2018). Superchargers provide the same overall effect as that of a turbocharger except for the use of the engines power to compress the air rather than the use of the exhaust gasses (Mechstuff, n.d.).



Turbocharger

Supercharger

Figure 5: Forced Induction systems (Mishra, 2017)

The basic principles of increasing performance is to pump more air and fuel into the cylinder at a specific air – fuel ratio as well as having a free flowing path for the exhaust gasses to exit. A performance air intake will improve the volumetric efficiency of an engine due to the less restrictive path the air has to take reducing turbulence within the intake according to Jim Smart from Mobil (Smart, n.d.). Cylinder head porting can be a great way to increase volumetric flow according to Jim Smart. To increase airflow, valve and port sizes can be modified to provide a higher velocity path for the air to enter the cylinder (Smart, n.d.).

3.3 Mapping

The principle of remapping is overwriting the ECU's default configuration with a new software tailored to the improvement trying to be achieved. Remapping can improve engine performance and fuel economy. After remapping for performance, there will be a noticeable improvement in speed and power of the vehicle. According to Kevin Pratt, "Some remappers claim an increase in horsepower of between 30 and 40bhp and in torque of up to 80nm." (Pratt, 2017).

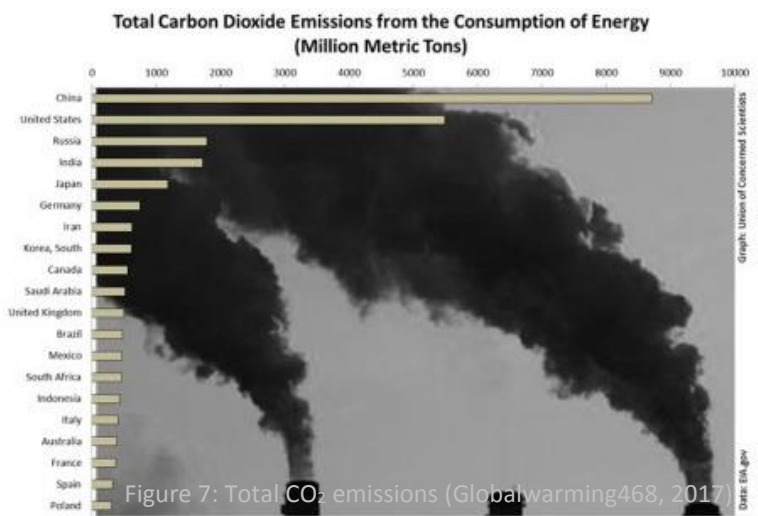
4.0 Experimental Procedure

A number of tasks will be undertaken on an engine to discover its emissions output as the power output increases. This will be undertaken by having a 1.5 litre Ford Ecoboost engine on the engine dyno, running it through a series of driving conditions; full throttle, constant speed and deceleration. These drive cycles will determine where the majority of the emissions come from at different powers. I will be using mapping software to adjust the power output of the car whilst using numerous other equipment to record the emissions output. The emissions results will be displayed in tables and graphs where each new power enhancement will be logged and the emissions recorded. After completing the procedure with the engine dyno, the ideal situation would be to put a downsized engine on the rolling road to acquire two sets of results. Graphs and tables through the use of excel will also be used to display these results after power enhancements have been made. The graphs will demonstrate the increase in power over the increase/decrease in emissions. The graphs will show how the two are related and how they correspond with each other.

Different maps will be added to both the engine on the dyno and the vehicle on the rolling. These maps will alter the performance of the car along with the side effect of emission change. The task will be to discover whether this increase in power increases or decreases the emission output of the engine in question.

5.0 Conclusion

To conclude, a number of tests will be conducted to acquire an accurate set of results to see if the increase in vehicle horsepower increases the emissions output. These tests will be completed due to the increasing concern for human and environmental health as a result of toxic vehicle emissions from the 31 million cars on UK streets (Dark, 2017). As seen in the image to the right, in highly populated countries such as China and the United States, the total CO₂ emissions skyrocket above the rest of the countries. Downsizing to smaller capacity engines would be extremely beneficial in these countries due to their already high emissions; especially America as it's renowned for its large capacity engines. After these tests, it will be discovering whether more power produced will increase the emissions of an internal combustion engine.



6.0 References

1. Anon (2016). European Emission Regulations – Will Stringent Emission Regulations Choke Automotive Industry Or Will OEMs Find Their Way Out? [online] Frost & Sullivan. Available at: <https://ww2.frost.com/frost-perspectives/european-emission-regulations-will-stringent-emission-regulations-choke-automotive-industry-or-will-oems-find-their-way-out/>.
2. Anon (n.d.). Nitrogen Oxide (NOx) Pollution - Health Issues - Icopal. [online] Icopal-noxite.co.uk. Available at: <http://www.icopal-noxite.co.uk/nox-problem/nox-pollution.aspx>.
3. Anon (n.d.). Performance and Fuel Economy Trends – Internal Combustion Engines. [online] Sites.lafayette.edu. Available at: <https://sites.lafayette.edu/eqrs352-sp14-cars/performance-and-fuel-economy-trends/>
4. Anon (n.d.). What are Superchargers? | Working, Types, Advantages, Limitations – MechStuff. [online] MechStuff. Available at: <http://mechstuff.com/how-superchargers-work-types-advantages-limitations/>.
5. Anon (2017). Car fuel and emissions information. [online] Carfueldata.vehicle-certification-agency.gov.uk. Available at: <https://carfueldata.vehicle-certification-agency.gov.uk/additional/aug2017/VCA-Booklet-text-Aug-2017.pdf>.
6. Anon (2018). What countries contribute the most to global warming? [online] GlobalWarming468. Available at: <https://globalwarming468.wordpress.com/2017/01/24/what-countries-contribute-the-most-to-global-warming/>.
7. Dark, M. (2017). Vehicles licenced for use on the road. [ebook] p.5. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/620223/vehicle-licensing-january-to-march-2017.pdf.
8. Dutton, J. (n.d.). Products of Combustion | EGEE 102: Energy Conservation and Environmental Protection. [online] E-education.psu.edu. Available at: <https://www.e-education.psu.edu/egee102/node/1951>.
9. Ebbs, C. (2018). Euro 6 emissions standards: what do they mean for you? [online] Auto Express. Available at: <https://www.autoexpress.co.uk/car-news/consumer-news/90816/euro-6-emissions-standards-what-do-they-mean-for-you>.
10. Gabbatiss, J. (2018). Transport is UK's most polluting sector as greenhouse gas emissions fall. [online] The Independent. Available at: <https://www.independent.co.uk/environment/air-pollution-uk-transport-most-polluting-sector-greenhouse-gas-emissions-drop-carbon-dioxide-a8196866.html>.
11. Goodwin, A. (2016). What is engine downsizing, and why should you care? - Car Keys. [online] Car Keys. Available at: <https://www.carkeys.co.uk/news/what-is-engine-downsizing-and-why-should-you-care>.
12. Ingram, A. (2017). Is engine downsizing finally falling out of fashion?. [online] Evo. Available at: <https://www.evo.co.uk/features/18753/is-engine-downsizing-finally-falling-out-of-fashion>.
13. Johnson, J. (n.d.). Automotive Emissions. [online] Ncbi.nlm.nih.gov. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK218144/>.
14. Katsianis, J. (2017). 2017 Toyota Yaris gets sharper looks and smarter engines. [online] Evo. Available at: <https://www.evo.co.uk/toyota/yaris/18820/2017-toyota-yaris-gets-sharper-looks-and-smarter-engines>.

15. Mishra, P. (2017). Difference Between Turbocharger and Supercharger. [online] Mechanical Booster. Available at: <http://www.mechanicalbooster.com/2017/03/difference-between-turbocharger-and-supercharger.html>.
16. Muller, J. (2018). The World's Most Popular Vehicles Of 2017: Cars Still Rule, But SUVs Coming On Strong. [online] Forbes. Available at: <https://www.forbes.com/sites/joannmuller/2018/01/10/the-worlds-most-popular-cars-in-2017-included-fewer-cars-more-suvs/>.
17. Patil, C., Varade, S. and Wadkar, S. (2017). A Review of Engine Downsizing and its Effects. [ebook] INPRESSCO. Available at: <http://inpressco.com/wp-content/uploads/2017/06/Paper75319-324.pdf>.
18. Pratt, K. (2017). What is 'remapping' - and is it worthwhile? [online] Moneysupermarket.com. Available at: <https://www.moneysupermarket.com/car-insurance/articles/what-is-remapping-and-is-it-worthwhile/>.
19. Smart, J. (n.d.). How to increase engine performance | Mobil™ Motor Oils. [online] Mobiloil.com. Available at: <https://mobiloil.com/en/article/car-maintenance/basic-car-maintenance-tips/how-to-increase-engine-performance>.
20. Woodford, C. (2018). How do turbochargers work? | Who invented turbochargers? [online] Explain that Stuff. Available at: <https://www.explainthatstuff.com/how-turbochargers-work.html>.