

Alternative Power for Auxiliary systems due to increasing emissions regulations
Research Methods & Projects (M6X02206)

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1. Abstract

1.1 General Abstract

Current and future emissions changes in government regulations and testing procedures are leading manufactures to develop existing petrol vehicles to meet the requires. With innovative technology in the safety, comfort and convenience systems there is much gain to be had from improving the operation of these systems. The effect these technologies have on petrol vehicle emissions is provided through literature and data collection in this paper. Strategies to improve the operation of these technologies can prevent excess emissions production. Through discussion the technologies are refined to one system to be improved, the Air conditioning system.

The further progress and pathway of the project proceeding this paper is discussed and defined as the effect Air conditioning has on the emissions of a vehicle while warming up.

1.2 Technical Abstract

Euro 6 emissions regulations the WLTP and the RDET are discussed to how vehicle auxiliaries are becoming more relevant to reduce fuel consumption, power and subsequently emissions HC, CO, NO_x, CO₂. A/C system produces the highest fuel consumption of all auxiliaries at 9% hence is researched for paper. Different drive cycles of testing show large variety in emissions from A/C system hence the WLTP and RDET from (EU) 2017/1151 are selected to be analytical simulated to generate values for proposed savings in emission from the adoption of a KERS system.

The progression from the end of this paper to the viva and dissertation project are outlined for the future. Also, the application of qualitative and quantitative primary data is shown through live testing and a questionnaire.

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3. Abbreviations, Figures and Tables

<u>Abbreviation</u>	<u>Meaning</u>
A/C	Air Conditioning
CO	Carbon monoxide
CO ₂	Carbon dioxide
EC	European Community (1967-1992)
ECU	Engine Control Unit
EEC	European Economic Community (1957- 1967)
EU	European Union
EV	Electric vehicle
H ₂ O	Water
HC	Hydrocarbon (THC= Total Hydrocarbon)
KERS	Kinetic energy recovery system
N ₂	Nitrogen
NEDC	New European Drive Cycle
NMHC	Non-methane hydrocarbons
UI	User Interface
NO _x	Nitrogen oxides
PEMS	Portable Emissions Measurement System
PM	Particulate matter
PN	Particle number
RDE (RDET)	Real Driving Emissions (Real Driving Emissions Test)
WLTP	Worldwide Harmonized Light Vehicles Test procedure

Table 1: Abbreviations

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4. Introduction

This paper is a literature review for a project dissertation.

In this literature review a number of papers and sources outline the research undertaken to develop a more concise understanding of the project area. This area of study focuses on the emissions of a petrol vehicle along with the effect vehicle auxiliaries have on these emissions. Current and future technologies within auxiliaries which have an impact on the reduction of emissions are discussed as well as systems designed to supply alternative power sources to these auxiliaries. Through this literature review the number of possible pathways the project can proceed decreases refining the project. The final pathway of the project being, the effect Air Conditioning (A/C) systems have on the emissions of a vehicle during the warm up phase and the implementation of a system to reduce A/C system engine loading.

The decision to research this project topic comes from past experiences with an A/C system. Driving when the A/C system was turned on caused a noticeable difference in engine idle RPM audibly and seen on the dashboard. This experience became an interest and subsequently led to this project.

The relevance of this project is to demonstrate an understanding of the emissions, auxiliaries and engine loading in personal academia. For the general

public this paper introduces the relevance of how human factors can affect the emissions output via the A/C system. A questionnaire for the project to gather qualitative data is also introduced. This paper shows industries developments in technology now and in the future to reduce loading via auxiliaries, which contributes to reducing the emissions of a vehicle in line with government regulations.

Predictions-

The A/C system operation has a high effect on emissions output and fuel economy. The loading the A/C system has on the chosen engine is high. Replacing the A/C supply from belt driven from engine to electrical driven from an alternative source will improve emission as engine loading is removed.

Aims-

- Identify the extent the A/C system effects the emissions output and possible reductions from loading reduction.
- Collect primary practical data from an engine in workshop conditions and using analytical calculations from research data conclude possible emissions savings for implementing a loading reduction system.

5. Literature Review

5.1 Government Emissions legislation

Since the early 1970s the European Union (EU) has established emissions regulations for vehicles in relation to the pollutants they produced. One of the earliest of these was Directive 70/220/EEC which European Communities agreed to solely limit CO and HC in relation to the Weight of the vehicle (EU, 1970). Since then there have been amendments to the regulations, over the years most notable are the 91 /441 /EEC, 94/ 12/EC, 98/69/EC, 2002/80/EC and (EC) 715/2007 which put simply are Euro 1, 2, 3, 4 and 5-6 regulations respectively.

Euro 7 regulations are yet to be released however in 2017 the NEDC was replaced with the WLTP (EU) 2017/1151. The NEDC was an emissions test that was comparable as testing was undertaken within a lab however this became outdated as the results didn't reflect RDE. The new WLTP takes in to account RDE of a vehicle through a more thorough test. More importantly in the WLTP under the RDE testing *"The air conditioning system or other auxiliary devices shall be operated in a way which corresponds to their typically intended use at real driving on the road. Any use shall be documented. The vehicle windows shall be closed when the air conditioning or heating are use"* as stated in (EU) 2018/1832, an amendment

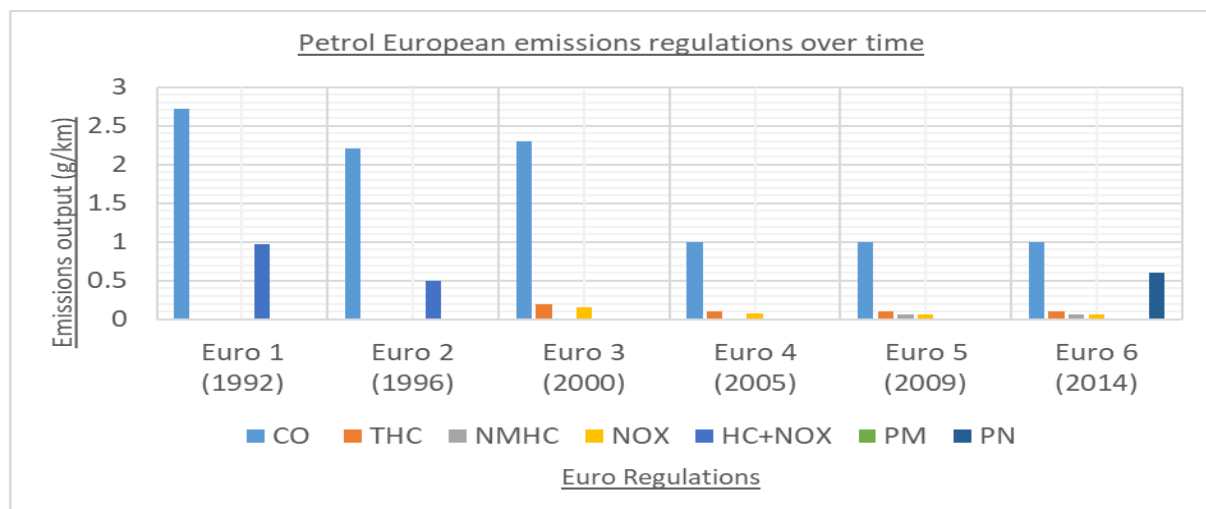
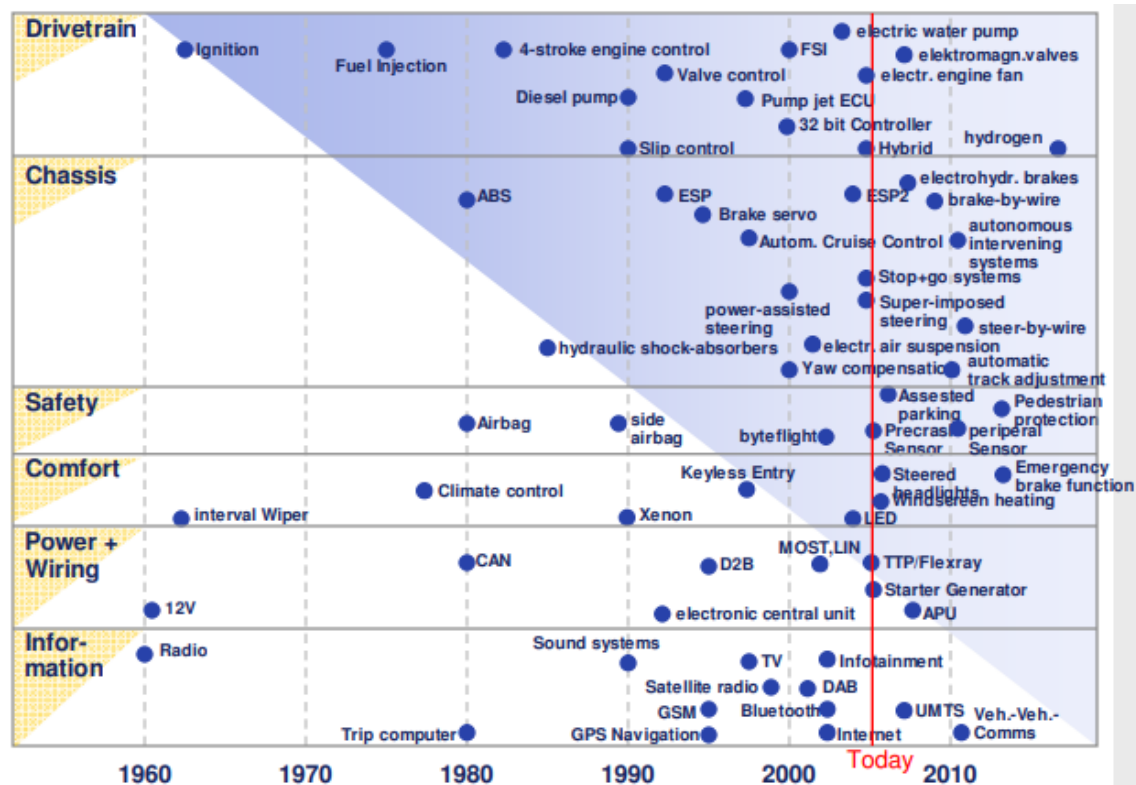


Figure 1, Petrol Euro Emissions Regulations source: EEA, 2016

As seen in Figure 1 the emissions limits through iterations of emissions regulations are becoming more controlled and limited. Quantity of each emission decreases overtime and the number of emissions being limited increases. The requirement for the car manufacturers to meet these regulations becomes more difficult with each iteration.

of (EU) 2017/1151. This is key for the project as the NEDC didn't not require the operation of Auxiliaries during testing hence weren't taken in to account when emissions were tested. With the WLTP testing the Auxiliaries there will be an increased incentive for manufacturers to reduce the emissions output caused by these systems.

5.2 Vehicle Auxiliaries



Quelle: ADL Research

Figure 2. introductions of new automobile technology over time. (ADL, 2015)

New technology is always being introduced to vehicles as seen in figure 2. Some of these new technologies are considered safety, comfort and convenience systems. These systems are critical in maintaining the full concentration of a driver especially with the ever-increasing demands of driving today (paraphrased from Bosch, 2016). Most of these systems can be characterized as vehicle auxiliaries. These auxiliaries are reliant on a supply either mechanical or electrical. This supply increases the loading on the engine hence causing an increased output in emissions.

“The use of auxiliaries requires an increased mechanical or electrical supply,

which in turn increases engine power demand and fuel consumption. The latter is estimated in the order of 9 % for the use of A/C, up to 4.5 % for the steering assist systems and up to 6.5 % for the other auxiliaries. Optimization and advanced technologies could provide benefits in fuel consumption by up to 2 % according to the literature. Purely mechanical auxiliary systems are losing ground to their electrical counterparts” (Zacharof & Fontaras, 2016)

As stated by Zacharof & Fontaras of the auxiliary systems A/C and Steering assist are the main contributors to the increased fuel consumption. A mechanical supply would be considered a belt or chain mechanical connection between the engine and auxiliaries. Whereas an electrical supply would be considered a draw from the battery/alternator and then would be recharged by the alternator via a belt drive

from the engine. Even though there is always a small amount of loading caused from the constant mechanical connection between the belts and engine.

As mentioned by Zacharof & Fontaras (2016) the supply increases the demand of engine power. This demand for power is increases the engine RPM, Injector on time and ignition angle (Bosch, 2007)

5.2.1 Steering Assist

Steering assist is the second most fuel consuming Auxiliary on a vehicle according to Zacharof & Fontaras (2016). *“During a typical highway drive, assistance from this power steering pump remains unused for majority (76%) of the time”* (Sonchal, et al., 2012).

As the steering assist is only used 24% of the time according to Sonchal, et al (2012) and has a lower fuel consumption than the A/C system it can be noted that the potential gain in reduced emissions is more favorable to the A/C system. While considering the auxiliary systems as a project the practical application of a steering assist emissions test would've become an issue as access to a testing rig was unavailable. For this reason, the steering assist will not be covered as part of a vehicle auxiliary in the project.

5.2.2 Air Conditioning

Since its application to passengers' vehicles A/C systems have become more common over the years. *“It is estimated that today (2011) around 85% of new cars are sold with air conditioning systems fitted as standard... increased from 10% in*

1993 to 55% by 2002 further to 70% by 2005” (DEFRA, 2011).

Being the main auxiliary to increase fuel consumption the A/C system has a good start to being a project. Practical application through primary quantitative data collection can be undertaken from an Audi A6 engine with an A/C and climate control system attached as standard. Through academia there is access to this engine in the form of a rig within an engineering workshop.

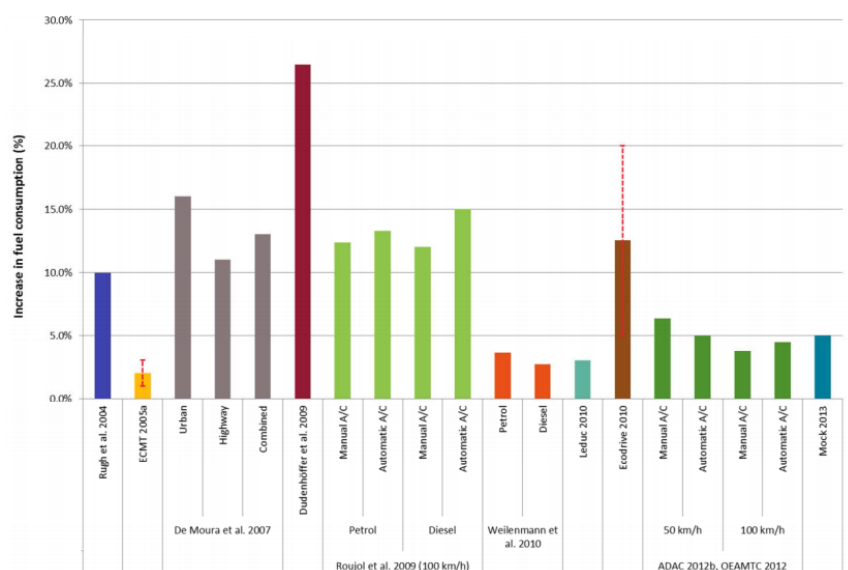


Figure 3, Zacharof & Fontaras 2016 Figure 3-4 “Estimated fuel consumption increase based on the findings retrieved from different sources.”

Figure 3 shows the variety of different studies of A/C systems Fuel consumption at various speeds and drive cycles. This shows the scale in contrasting values that can be achieved from different operations of the A/C system. Therefore, when looking in to a reduction system for the A/C the drive cycle specified is the WLTP cycle as of 2017 seen in (EU) 2017/115.

5.2.3 Other Auxiliaries

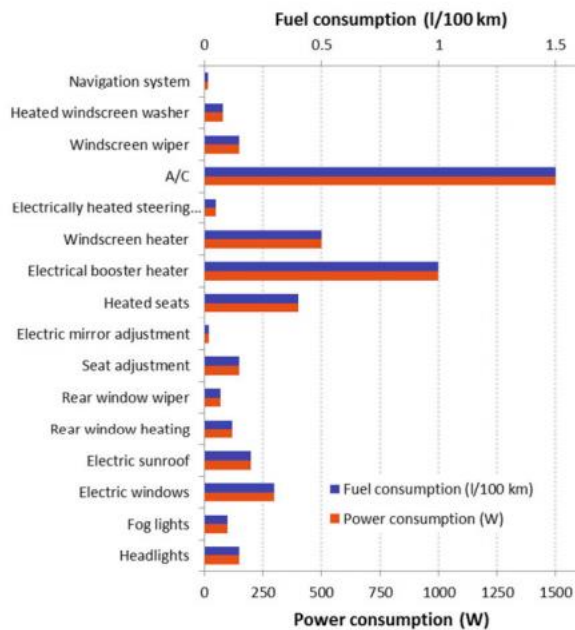


Figure 4, fuel and power usage between other vehicle auxiliaries (Zacharof & Fontaras, 2016)

Most notably seen in figure 4 is the A/C system showing in this particular drive cycle consumes 50% more fuel and power than the next highest auxiliary (Electric booster heater, which is technically part of the climate control system). Another clear indication is that the consumption of fueling (Liters /100km) and power (Watts) are equal to one another. From the other auxiliaries this figure (4) shows that the most predominant gain remains with the A/C system as seen before in Bosch, 2016.

5.3 Reduction Systems

A “reduction system” for the purpose of this project is a system added on to or improved on the vehicle to aid in the reduction of emission and or loading.

5.3.1 After-treatment Systems

After-treatment systems consist of the catalytic converter and the particulate filter. These systems don't focus of tackling the source of the engine emissions but rather deal with the aftermath of the emissions produced. In this example the catalytic converter is used to convert HC, CO and NO_x in to H₂O CO₂ and N₂ (Paraphrased from (Bosch, 2007)), which are less pollutant emissions. The Particulate filter reduces PM via exhaust gases travelling through a honeycomb structure and being deposited in pores then being burnt off in a passive or active process (Bosch, 2007). Other than reducing emissions as a volume these systems are used to convert the emission to a less harmful emission.

5.3.2 Smart Systems

Another example of a reduction system is a smart system. This system uses an ECU to control the operation of the A/C system allowing for operation under certain conditions. An example of this is an economy mode where the A/C system uses interior sensors in the passenger compartment to monitor the temperature and uses UI to maintain desired climate. The Economy side of this system refers to the alternating on and off time to maintain the temperature. The off time while alternating reduces the loading on the engine hence improving the emissions output overtime.

This system unlike the after-treatment systems is controlling the operation of the A/C unit and limiting it hence limiting the emissions produced. Then through this is an improvement from before the supply for the A/C still comes from a mechanical

connection of a belt from the alternator and pump to the engine.

5.3.3 Alternative sources

An alternative source for the A/C system in terms of the reduction systems removes loading from the engine as the electrical supply for the A/C system as the name suggests comes from an alternative source.

5.3.3.1 Kinetic Energy Recovery System

KERS is a system that generates energy while a vehicle is coming to a stop. The kinetic energy of the vehicle gets transferred to motors in the wheels in an EV and this in turn generates electricity. In HEV the same process is used however depending on the type of hybrid the electrical supply will be generated at the

wheel motors or at the generator through the drivetrain.

A similar system such as the KERS used in formula 1 could be used where kinetic energy is stored in a flywheel and released when required by the vehicle.

In terms of the project the electrical side could be used as the supply for A/C unit or the flywheel system could be used as an energy storage system to drive the engine hence removing the load.

Both of the electrical and mechanical systems have the benefit of reducing loading on the engine. However, storage of the mechanical flywheel KERS is finite. The electrical KERS can have long term (in relation to the mechanical KERS) storage of energy a battery/ management system for the A/C system.

6. Data Collection

To aid the project and support Secondary data, primary and secondary data will be collected in both quantitative and qualitative areas. Sections 6.1 and 6.2 outline the

6.1 Quantitative data

Some preliminary testing has been carried out to help develop an understanding of A/C systems and the emissions. These tests were carried out on a 3.2litre Audi A6 v6 adapted in to an engine rig by A.G. Block ltd. Current collected data from the Audi A6 rig regarding emission affected by A/C system can be seen in presentation viva 1. Test procedures and looking at controlling factors of testing in a workshop environment has been looked into via Martyr and Plint (2007)



Figure 5, Image of the Audi A6 Engine Rig within workshop, Standing. L 2019

6.2 Qualitative Data

Part of the project will be to look at the human impact on the emissions from A/C systems. To do this primary qualitative data is going to be collected and analyzed. This will be gathered in the form of a questionnaire which will follow practices shown in Silverman (1993). This data will be used to develop an understanding of how human factors can impact the emissions output from the A/C and develop a system that uses the data to negate some factors.

7. Conclusion

Emissions regulations limits are on a trend to decrease further with the introduction of Euro 7. The WLTP is a more thorough way for testing new cars and the RDET is key to testing the Auxiliary emissions missed by the previous NEDC. The Auxiliary emissions are predominantly produced by the A/C system and steering assistance. Due to limitations of testing and collection of live primary data for a steering assistance system the A/C system is selected to be the focused auxiliary for the project. The live data has and will continue to be collected from an Audi A6 engine rig in workshop conditions, to remain concise this data shall be shown at viva 1. Reduction systems have been reviewed and a Kinetic Energy Recovery System (KERS) has been the chosen for the A/C system. Further research is required for the calculations of a KERS to be theoretically incorporated on the Audi A6.

The continuation of this project will show an analysis of primary and secondary quantitative and qualitative data taken from workshop testing, Questionnaire and literature. This analysis will be used to develop and better understanding of the specific KERS system tailored for the Audi A6 engine. This KERS system will then be analytically calculated to see the Audi A6 possible decreased exhaust emissions.

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9. Appendix

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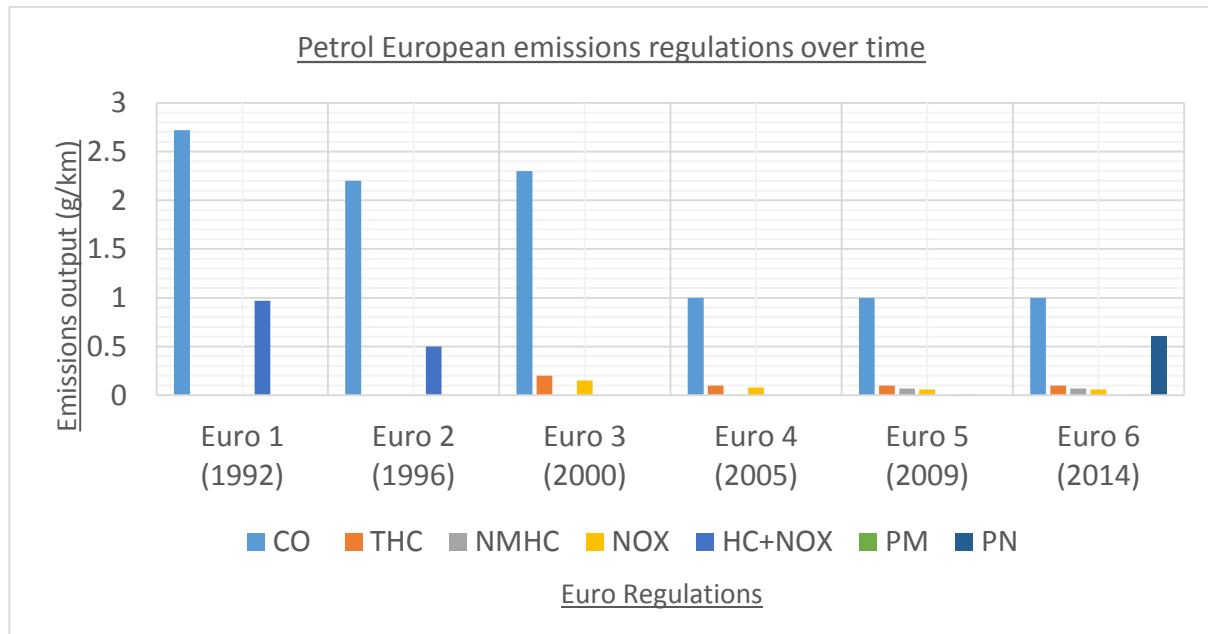


Figure 1

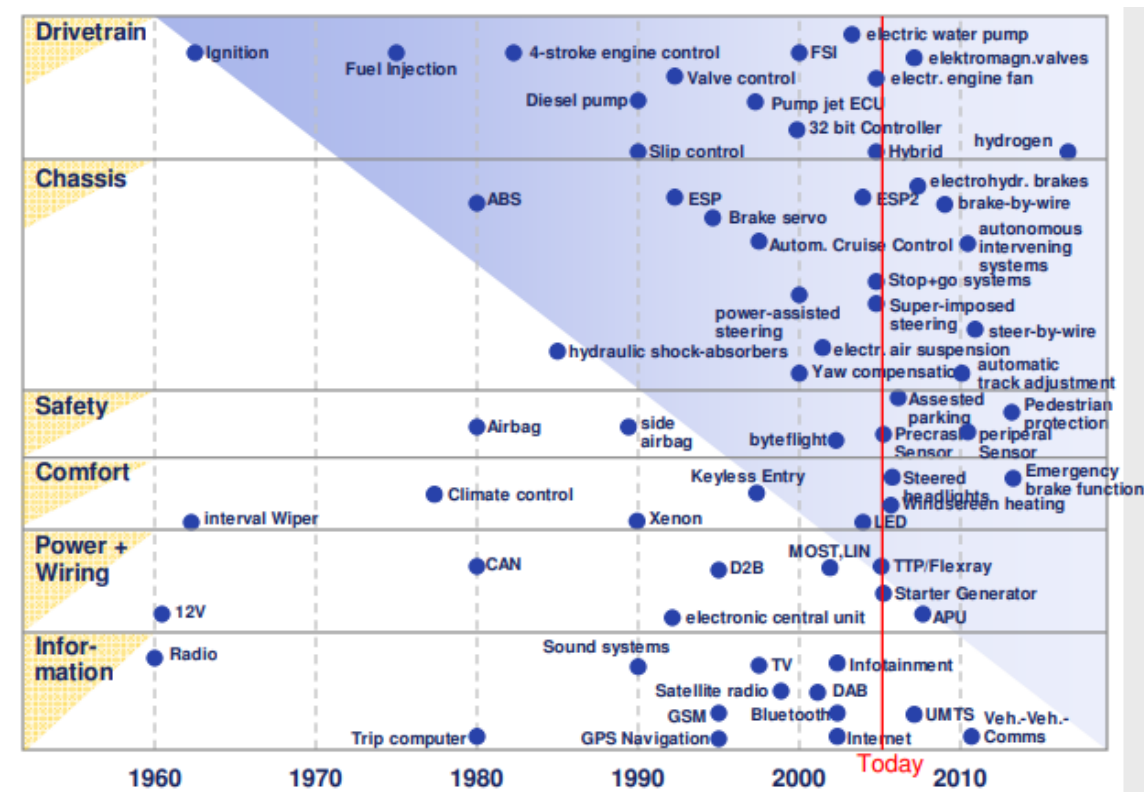


Figure 2

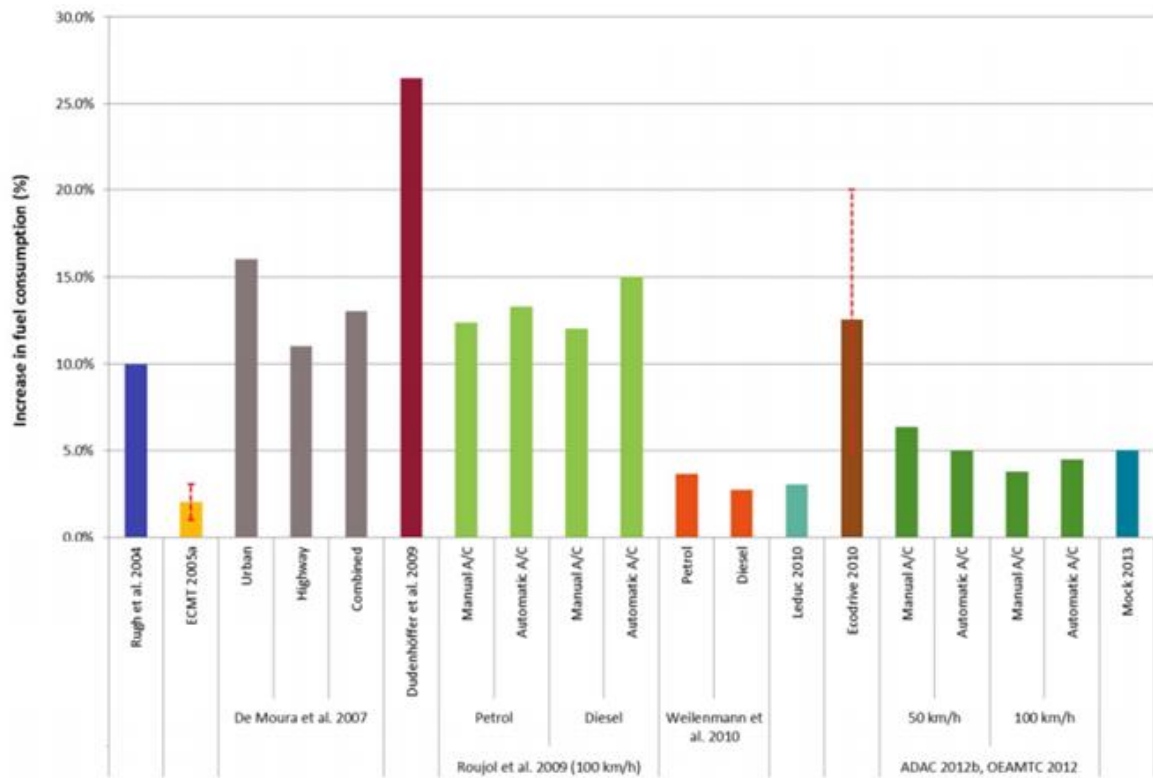


Figure 3

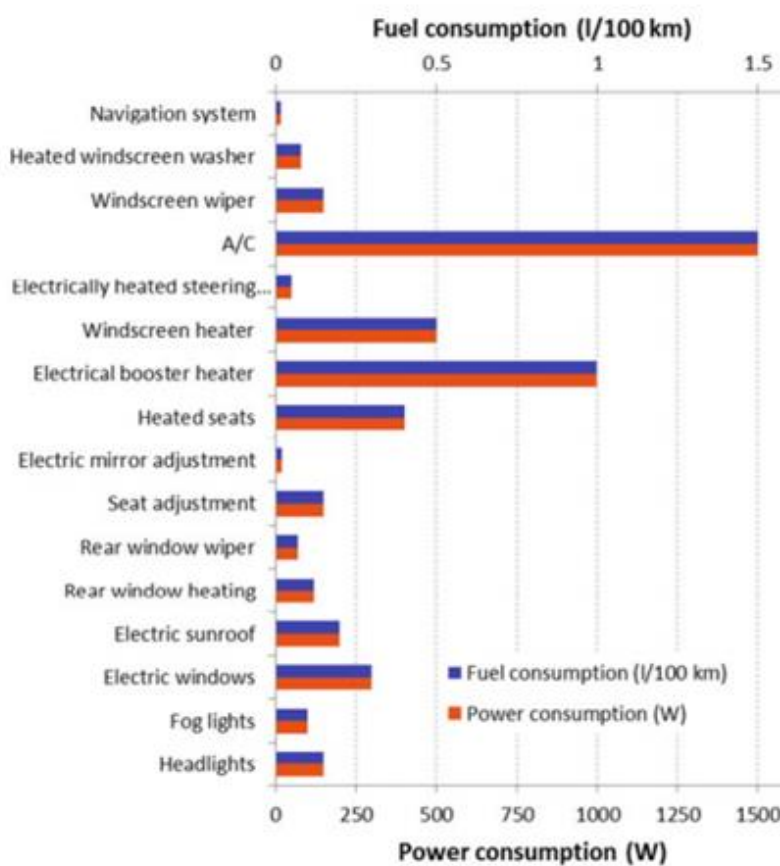


Figure 4



Figure 5