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Title:

Sustainability Analysis of Alternative Fuel Vehicles by using Life Cycle Assessment and Optimisation

Abstract

In recent years, there has been an increasing interest in alternative fuel vehicles (AFVs), such as electric vehicles (EVs), fuel cell vehicles (FCVs) and compressed natural gas (CNG) vehicles, as a promising option for mitigating global warming and reducing energy consumption. Most studies in this area have been conducted on only a few types of powertrains, e.g. EVs and gasoline vehicles; to fill this gap, this study will cover FCVs, CNGs, hybrid electric vehicles, diesel hybrid electric vehicles and liquefied petroleum gas (LPG) vehicles. Moreover, most of the papers focus on the use phase of those vehicles and disregard the manufacturing part, which is energy and emission intensive. The indirect effects of emissions production include severe health problems such as chronic asthma or even mortality. Automakers and policy makers need to investigate the lifecycle emissions of vehicles in different regions. It is crucial to decide if governments should invite EV production into their country, or whether it would be more appropriate to import vehicles.

This research is novel because it includes energy security aspects, uses multiple scenario analysis, and investigates FCVs and various stages of AFV's lifecycle in different regions. The objective of the thesis is to systematically assess the sustainability of AFVs. Firstly, the economic pillar of sustainability is being investigated by carrying out optimisation. The optimal AFV portfolio, based 3 on different scenarios to sustain energy security in light of gas and petroleum restrictions until 2030, is being calculated. The Polish market is considered as a case for demonstrating the optimal model. Secondly, environmental and social pillar of sustainability is explored. Life cycle assessment (LCA) has been applied to this research in order to quantify greenhouse gas (GHG) and non-GHG emissions and health impacts of air pollution connected with AFVs. We assessed air pollution from vehicles in Japan, China, and the United Kingdom (UK) and additionally health impact for Poland.

This research help automakers and policymakers recognise investment possibilities and it provides numerical findings for multiple stakeholders such as governments, energy, and automotive companies. The findings from scenario analysis can be used to create government

policies and proposals, which was already studied in conventional studies. The results from LCA are crucial for strategic decision making on investment in EVs.

Chapter 1 presents the background and subject of the research, previous studies deliverables, originality, motivation, and objective of the study. In Chapter 2 methods of the thesis are briefly described. Chapter 3 provides qualitative analysis of AFV and insights into automotive industry and energy sectors of the case studied country. The results from interviews suggest that environmental issues are neglected in Poland; the price of the vehicle is the most important reason influencing the purchase. Moreover, the introduction of incentive system for AFVs for both companies and private entities might spur the sales of the cars again.

Chapter 4 elucidates the optimization model, and constraints, variables, and results for vehicle portfolio analysis. The results indicate that it is crucial to introduce all types of powertrains to achieve both economic and energy security objectives. The projected diffusion of FCVs will be more pronounced than that in previous studies, owing to the expected rapid decline in the cost of 4 both infrastructure and purchase price of cars.

Case study for shale gas revolution and vehicle portfolio analysis is illustrated in Chapter 5. The results of this study suggest that due to shale gas revolution and decrease of gas prices, the portfolio of AFVs improves. Moreover, the results show that increased use of shale gas engenders the high consumption of water. Even though shale gas might improve the AFV portfolio the drawbacks of high water consumption and safety threads might hinder the positive aspects of implementing it in a long run. Water safety measures such as water recycling, reusing and disposal; technology choice; establishing the plants in low-density areas; are crucial while considering investment in shale gas.

Chapter 6 explains the LCA method, scenarios, and data used in the calculations for two case scenarios. Government and automotive companies can use created a model to make crucial decisions while setting up the location of the production plant. The results of the LCA simulations are provided in Chapter 7. Results for the LCA: GHG and non-GHG emissions indicate that EVs do not necessarily decrease pollutant emissions. Only in the UK the environmental cost of GHG and non-GHG emissions for EVs is lower than for GVs. EVs are more environmentally intensive than GVs. The substantial difference between those two is attributed to battery manufacturing EVs produce less CO2 during use phase, but other emissions are still high. However, a high decrease of the cost is projected in the Technological Advancement Scenario, especially for China. The results of the second case study LCA: Health effects imply that the total cost of health issues is lower when import of EVs is from the nearby countries, which generate electricity from clean energy resources or when it is produced in a low emission country locally. Surprisingly, maritime transportation accounts for a substantial portion of the total emissions, because ships use diesel oil. That is why one of the recommendations is to switch from diesel oil ferries to LNG ships. Moreover, in 2025, the monetary cost of health diseases drops dramatically due to significant 5 technology improvements such as increases in energy efficiency and production, increase in the share of renewable sources in the electricity mix, stricter air emission standards. Finally, conclusions and limitation of the study are presented in Chapter 8.

Key Words
I alternative fuel vehicles, policy, automotive, sustainability, air pollution