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Energy Transition in Malta: Understanding the Implications on the Environment and Public Perception

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Abstract - *In Malta, different sources of fuel have been used to generate electricity, including the traditional coal fired systems and the recent natural gas power station. This study will investigate the possible implications on the air and soil quality, as well as the social perception of the energy transition from heavy fuel oil (HFO) to liquified natural gas (LNG) in Malta. The implications of air pollutants emitted from power stations are well documented and whilst they may affect the local air quality due to the mobile nature of such substances, implications can be considered to be both regional and subsequently global. These pollutants may act directly on different environmental matrices since they can eventually end up in soil and water through precipitation. Understanding the public perception is important since it will help in identifying particular knowledge gaps and misinformation, as well as the willingness of the public to change the status quo on specific environmental issues. The parameters analysed for air quality were nitrogen oxides (NOx), carbon monoxide (CO), total suspended particulates (TSP) and sulfur dioxide (SO_2). The results show that the oldest power station emitted high quantities of emissions when compared to the other power stations. Soil samples, from the surface and from the bottom, were collected in close proximity (within a radius of 1km to 5km) to the power stations and two control sites were sampled over a period of one-year. Two sites that were near the power stations demonstrated a high concentration of sulfates in the soil. However, a control site that was far away from the power stations depicted a higher level of sulfates. This could imply other sources of sulfates in soil other than from electricity generation. When it comes to public perception and disposition, survey results showed that the public noted and acknowledged a change in air quality over time. According to the findings, the public is aware and has been well informed with regards to the advantages related to liquified natural gas as an energy source, yet the public seems not to be aware of the advantages related to heavy fuel oil.*

***Keywords*:** Environment, Energy, Heavy fuel oil, Liquified natural gas, Malta

1. Introduction

Electricity generation is the leading factor in social development. Due to rapid growth in population, technology and economy, electricity consumption is increasing. Electricity generation may affect the lifestyle of the individual, the economy for both the individual and the country, as well as the surrounding environment. Having affordable, abundant, safe, and clean energy is important for society, but the extraction processes and transportation involved in obtaining energy sources may influence both human health and the economy. The economic aspect may be affected since electricity prices incorporate the cost related to extraction, the transportation of fuel, the pricing of the fuel sold to the country, and the selling price to the consumer. Thus, a variation in energy pricing may eventually affect the lifestyle of the individual as one will spend more on energy costings and consequently less money on other goods [1]. Electricity generation can also affect the environment in various ways, primarily through excessive resource extraction without adequate time for replenishment or recovery and other implications associated with the combustion process, whose resulting emissions affect air, soil, and water. If there is an increase

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in the demand, there will be an increase in the combustion process whereby the resulting generated pollution affects the surrounding environment, leading to other human health and economy related issues.

This study aims to investigate the possible implications of emissions from two power stations (Marsa; MPS and Delimara; DPS) which ran on heavy fuel oil (HFO), and the emissions originating from the liquified natural gas (LNG) unit. Thus, this study focuses on the energy transition in Malta. This is done by evaluating the temporal variation in the air quality data of the MPS, DPS and LNG unit between 2010 and 2019. The air quality data is analysed in order to identify possible variations in emissions throughout the years. Soil is analysed for sulfates concentration (at the surface and at a depth of 30cm) over a period of one year. This approach enables the possibility to see whether there are any detectable alterations during the transitional period when the fuel source changed from HFO to LNG. This study also considers the social aspects of this transition and thus attempts to understand public perception on the air quality in the years following the transition. This is done by considering people from different localities in Malta. Through random sampling, this survey attempts to consider participants with different socio-economic backgrounds.

2. Related Work

Sources of energy are notorious due to their negative implications on both the environment and human health during extraction and combustion. Several electrical facilities are changing fuel source from oil or coal to natural gas, since the latter is considered to be cheaper in the long run, as well as producing less pollutants [2]. In Malta several fuels have been traditionally used to generate electricity, such as coal fired systems and the recent natural gas power station. Malta first acquired electricity in 1882 by using coal as an energy source and then switched to heavy fuel oil in 1995. In 2015, the interconnector between Malta and Sicily started to operate and the MPS was officially switched off. In 2017, the new LNG unit phase 4 started to generate electricity by using natural gas as an energy source. As a result, after several years of operation, the DPS was officially switched off from using heavy fuel oil as an energy source.

All systems and sources have their advantages and drawbacks on the surrounding environment. Heavy fuel oil and natural gas are both fossil fuels, making them non-renewable sources of energy. Oils have great heating and combustion values and characteristics, but the main drawback is that such substances tend to have a high sulfur content [3]. Just like heavy fuel oil, liquified natural gas also has its pros and cons; during the summer months, natural gas supply is found in abundance. Substituting to natural gas is more favourable not only due to sulfur emission reduction but also for sulfur deposition reduction [2]. However, during the extraction process, groundwater storage can become contaminated due to fracking fluid used during drilling operations as well as with gases such as volatile organic compounds (VOCs) and methane. The cause of this gas contamination of ground water storage can occur due to failing or improperly constructed wells which allow the gases to leak [4].

Heavy fuel oil has a vital practical constraint that one has to consider: storage. Storing such substances must be temperature controlled. To maintain a steady and constant temperature, steam is required to heat up the fuel, which would subsequently result in more emissions [3]. When compared to natural gas, storage of the latter provides added complications. For instance, in Malta, LNG is stored in a floating storage unit close to port which adds to the concern of potential water spills, something that was not present in previous operations [4].

The air pollutants which are emitted from any power plant may affect the local air quality as well as the global environment by increasing the level of greenhouse gases, thus further promoting the greenhouse effect [1]. The acidification and dispersion of metals from burning fossil fuels also have an impact on the environment [5]. The dry and wet deposition of such pollutants leads to environmental acidification. All these abovementioned phenomena affect the cultivated forests and destroy soil due to lack of oxide resistance from trees, especially during the vegetation period, in which leaves would wither and fall due to long exposure. Fossil fuel combustion emits several gases into the atmosphere which leave ashes behind and impose an adverse impact on the surrounding environment, such as nitrogen oxides and sulfur dioxide emissions which are both contributors to acid rain. The air pollution related to combustion affects multiple outcomes which include respiratory illness, birth outcomes, and cancer. The indirect effect of climate change caused by fossil fuel combustion can cause under nutrition and malnutrition, food insecurities, spread of infection disease vectors, illness caused by aeroallergens and mental illness, displacement, and political instability [6].

These implications will have a consequence on the public attitude and perception. Several surveys regarding the public attitude concerning the environment have noted that there is still a low level of awareness in terms of the issues on climate change and energy consumption [7]. Although research related to public acceptance has been associated with negative implications through the public understanding deficit, there is evidence to show that the more knowledgeable and informed individuals are, the more they will accept low carbon technologies. Empirical discovery showed that political beliefs correspond with social acceptance of several opinions in terms of how politics are responding to the situation [7]. The search for direct explanation for the public opposition to environmental harm and degradation yielded the NIMBY (*Not in My Back Yard*) concept. This concept explains public acceptance of issues resulting in environmental harm, except when it directly affects them. In other words, the public will only react and oppose such issues when environmental harm and degradation is taking place in 'their back yard'. Politically, studies have demonstrated that the NIMBY label can be positioned by pro-development organisations, meaning that land may be exploited with minimal governmental regulation in a social conflict situation as a disproval label used for lawful determination of the opponents' views [8].

3. Method

3. 1. Air Quality

The data was obtained from the Annual Environmental Reports (AERs) provided directly by the Environment and Resource Authority (ERA). Readings were obtained from the chimney stacks in MPS and DPS and the new LNG unit phase 4 (Figure 1) in accordance with the methodology specific to the parameter being analysed according to IPPC methodology. These parameters were nitrogen oxides (NO_x), sulfur dioxide (SO_2), total suspended particles (TSP) and carbon monoxide (CO).

3. 2. Soil Analysis

The concentration of sulfates in the soil was analysed since this parameter is one of the main pollutants generated from combustion of heavy fuel oil in power plants [9] [10].

The sampling locations (Figure 1) were chosen according to how near or far they are with respect to the two power plants, within a radius of 1km to 5km from source. Control sites were also considered in this study [11]. At each site, samples and replicates were collected from the surface and from the bottom; around 30cm depth from the surface [12] [13]. Samples were collected quarterly for a period of one year (Autumn 2017 – Summer 2018).

Sulfates were analysed using the turbidimetric procedure [14].

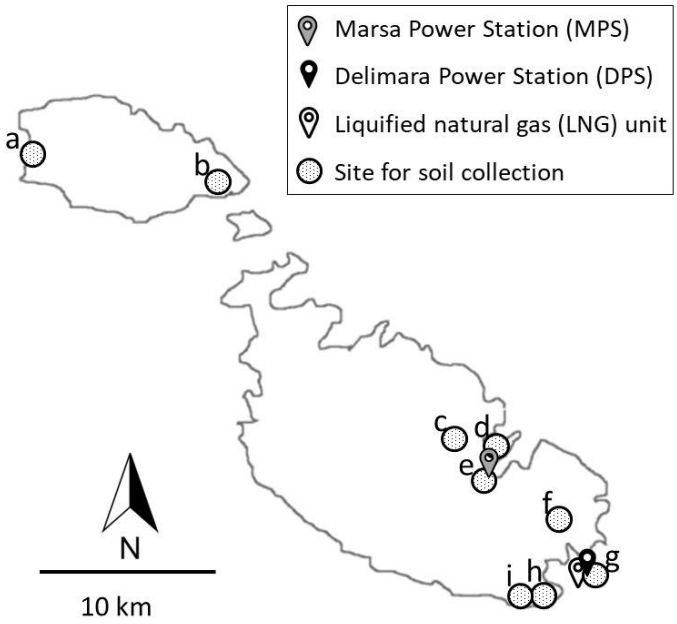

Figure 1. Locations of the two power stations and the LNG storage tanker as well as the sampling sites for soil collection. a: Dwejra (control site); b: Hondoq ir-Rummien (control site); c: Birkirkara, d: Floriana; e. Marsa; f. Zejtun; g. Delimara; h. Birzebbuga; i. Hal Far.

3. 3. Public Perception

Public opinion is important so as to identify the public's knowledge and willingness for a specific issue or subject. It is also vital to understand the respondent's opinion for changes and modifications to be carried out to improve the situation instead of ignoring it [15]. The approach for understanding public values include contingent valuation and utility elicitation. This was done by distributing a survey to the general public through different social media platforms. It was also sent to all local councils around Malta and Gozo for distribution and to different environmental stakeholders via email, including environmental Non-Governmental Organisations (NGOs), the environmental-regulating authority and monitoring companies. Hard copy distributions were also done in several localities around Malta. The survey consisted of 15 questions, including 1

open-ended question, 7 multiple choice questions, 2 tick down box questions and 5 linear scale questions.

The validity of the survey is an important criterion for test quality; this was done through face validity, by having the survey reviewed by a professional in the sector and through content validity since the questionnaire intentionally measured the public's knowledge and perception regarding change in energy source, air pollution, and social issues [16]. The test-retest reliability was used to ensure that the survey produces the same result on a repeated trial [17].

3. 4. Data Analysis

Temporal analysis for air quality was carried out by plotting line graphs to provide an overview of the situation using descriptive statistics. Line graphs can represent trends in various quantities over time, making it easier to observe change as well as making the overall trends and patterns clear. No statistical tools were used as the visual patterns through graphical representation allowed for an excellent comparison of emissions, and thus aligning with what was required to answer the research questions.

The data collected for soil analysis and public perception was coded and analysed using IBM SPSS Statistic 24, utilised by various researchers for complex statistical data analysis. Since the data collected for soil analysis violated the normality assumptions, the Kruskal Wallis test was applied to determine the statistically significant difference between two or more groups of independent variables. Spearman correlation was carried out to measure the strength of association between different variables attributed to public perception.

4. Results and Discussion

4.1. Air Quality

The MPS data collection stopped as of 2015, since this power station stopped generating electricity during the same year, after more than 60 years of electricity generation. The DPS was still being used for black start. When the LNG unit phase 4 and the interconnector between Malta and Sicily fail to send electricity to the main grid, these engines carry out a black start so as to generate sufficient energy for sectors which are of high importance. The LNG data starts from 2017 when operations commenced. The air quality results were analysed by identifying the change in emissions by each power station over a period of 10 years. All the data gathered was obtained from AERs provided by the local environmental authority.

As can be seen in Figure 2, the MPS and DPS, along with LNG unit showed different trends in air quality emissions throughout the years. Overall, the emission levels in MPS were quite high especially in NO_x, TSP and SO_2 when compared to the other two power stations. In 2010, NO_x emissions were relatively high. This was because the MPS was still running on heavy fuel oil as an energy source. A drastic increase in emissions was noticed in TSP and SO_2 during 2013. During that period the MPS was fully operational using heavy fuel oil as an energy source which is known to contain a high amount of sulfur content [3] and when combusted, it will generate a significant amount of particulate matter [18]. This may occur during incomplete combustion when the particulate matter and other substances are emitted into the atmosphere [19]. The SO_2 emissions are generated during conventional combustion of heavy fuel oil from the oxidation of sulfur contained in the fuel itself.

On the other hand, when observing NO_x, TSP and SO_2 for the LNG unit, the emission levels were much lower in comparison with MPS and DPS. The reason is that the LNG power station runs on natural gas which is cleaner when combusted than heavy fuel oil and diesel since the sulfur content in natural gas is relatively low, with a value of 5.5 mg/m^3; this will lead to low sulfur dioxide emissions [20]. Another factor may be because the energy source is in the gaseous state, thus, the filterable particulate matter is usually low in concentration.

The CO emission levels were quite constant throughout the years and the slight decrease noticed was due to the shutdown of the MPS. When observing the DPS emission levels, CO levels are quite high when compared to the other parameters, which are relatively constant throughout the years and decreased between 2017 and 2019. The increase in CO may be attributed to incomplete combustion [21], while the decrease in emissions between 2017 and 2019 was due to the fact that the DPS was shutting down several engines and switching to LNG as an energy source. The introduction of the interconnector between Malta and Sicily may also have contributed to this result. The high level of emissions of CO in the LNG unit in the first year occurred due to the start-up phase [22].

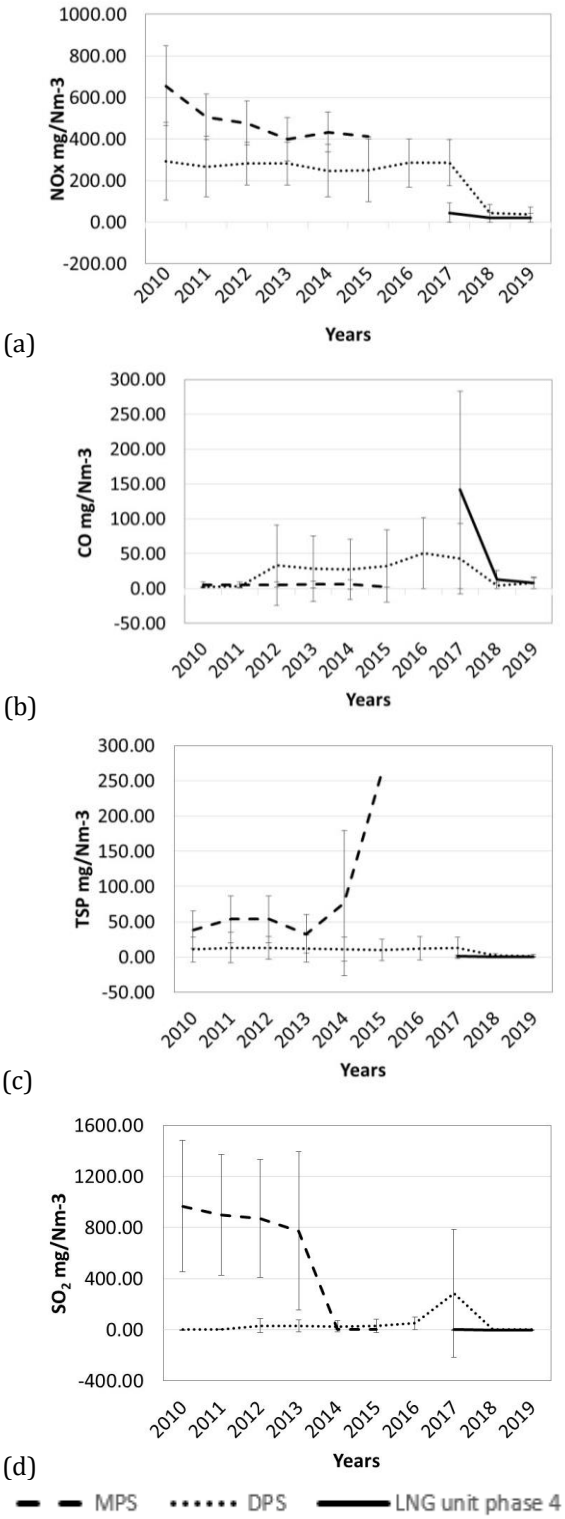

Figure 2. Graph showing the variation in the different pollutants emitted from the Marsa Power Station (MPS), the Delimara Power Station (DPS) and the Liquified Natural Gas (LNG) unit phase 4 from 2010 to 2019. (a) NO_x mg/Nm^{-3}; (b) CO mg/Nm^{-3}; (c) TSP mg/Nm^{-3}; (d) SO_2 mg/Nm^{-3}

Overall, the MPS shows the highest level of emissions, while the DPS and LNG unit phase 4 show much lower and relatively consistent emission levels for all parameters.

4.2. Soil Analysis

This study considered sulfates in soil with the premise that dry deposition, which usually occurs close to the source of emissions, and wet deposition, which can occur thousands of kilometres away from source [23], might have a major impact on soil from air emissions. This means that the high levels of sulfur dioxide emissions emitted from the power stations can influence soil due to wet deposition of sulfates several kilometres away from the source by precipitation [24].

Kruskal Wallis analysis demonstrated that when comparing different sampling sessions over a period of one-year, significant high concentration of sulfates were observed in Marsa and Hondoq ir-Rummien; sulfates concentration was especially high in autumn months and summer months respectively. Whilst Figure 3 provides an overview of the mean sulfates concentrations in all sites, when carrying out Kruskal Wallis analysis based on different depth, Birzebbuga showed a significant difference between the surface and bottom samples. Whilst high levels in Marsa and Birzebbuga might be attributed to the fact that they are near both power plants and their effect is immediate, this argument does not stand for Hondoq ir-Rummien.

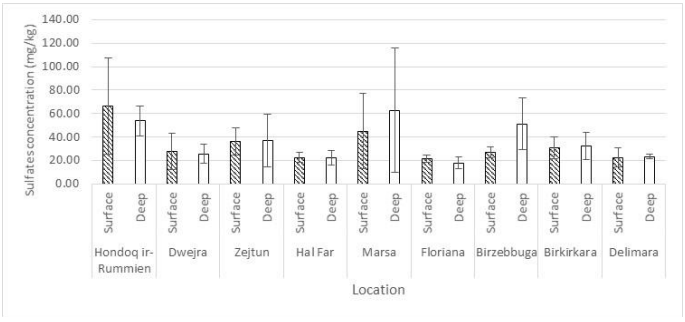

Figure 3. The mean sulfates concentration at soil surface and at 30cm below the surface (deep) over the entire sampling period. The error bars represent the standard deviation from the mean.

Overall, the highest levels of sulfates concentration were observed in Hondoq ir-Rummien, one of the control sites. Such an increase may be due to the soil collection point being surrounded by agricultural land, to which fertiliser containing sulfur in its chemical composition may be applied for crop support and health. Sulfur is

subject to leaching, therefore it can be easily transported from one point to another through soil [25]. This therefore shows that the presence of high concentrations of sulfates in the soil may be attributed to other anthropogenic activities not necessarily related to power generation.

4.3. Public Perception

A general overview of the public's perception with regards to the effects of both Marsa and Delimara power stations on the environment was obtained. 324 respondents participated in this survey and their responses were analysed using both descriptive analysis and statistical means. Spearman correlation was carried out to determine if and what type of correlation is present i.e., positive, or negative correlation.

The public opinion on the power plants was important to identify several aspects in relation to the topic, such as knowledge related to the source of electricity generation and perhaps certain misconceptions related to the subject. Each question was designated to obtain more information on several aspects to identify the knowledge of the public. The majority of the participants that answered the survey were between 18-29 years of age. Young people are well-placed to implement promotion on environmental awareness due to having available access of information and higher education regarding past and current environmental issues when compared to older participants [26]. The age of respondents makes a drastic difference in the way that they answer the question on observation of changes in air quality. Individual characteristics such as age is the key determinant of pro-environmental behaviour. It is indicated that younger and educated people are the most concerned regarding the environment [27] [28]. The people who will not engage in environmentally friendly actions have insufficient understanding of the impact of their own actions on climate change and environmental sustainability [29]. This can explain why there was a negative correlation between age and the observation in air quality change. On the other hand, a positive correlation was observed between age and the respondents' knowledge on the variety of globally available energy sources, meaning that older people are more aware of how Malta can be more sustainable with less emissions and better air quality by exploiting other sources of energy to generate electricity.

Even though the air quality data is clearly showing that emissions in relation to electricity generation are decreasing in terms of concentration, Figure 4 shows that the participants believe that in the last few years air quality is deteriorating. At a glance, this could be interpreted that the respondents see no improvement in the air quality as the country moves from HFO to LNG as an energy source. However, when asked to elaborate further, most of the respondents attributed this deterioration to an increase in cars and traffic which lead to car exhaust and also to construction and development, with a perceived increase in fine dust from quarries.

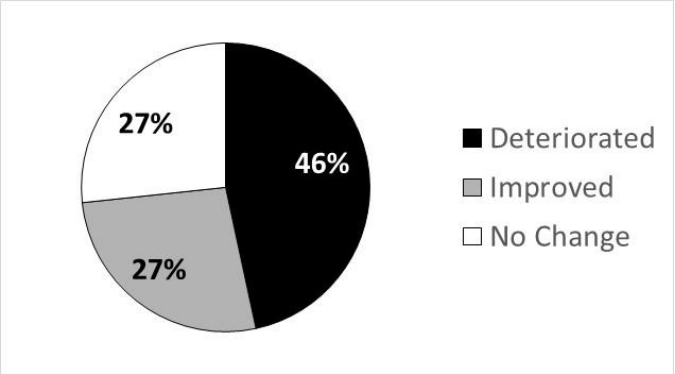

Figure 4. The feedback from 324 respondents when asked for their perspective with regards to air quality in the last two years.

The respondents who believe that air quality is improving associated this to the closing of the MPS and DPS, with the change of energy source from HFO to LNG. Going beyond electricity generation, the respondents highlighted that alternative, such as electric cars and improvements to the road's infrastructure could further improve air quality. Closing off the Malta dry docks could also be another improvement to the air quality according to some respondents. Obviously, one would have to understand the economic and social feasibility of such suggestions.

A survey is an established tool to acquire information on the participants' social characteristics, past and present behaviour, standards of attitudes and their beliefs for actions with respect to the topic under investigation [30]. The respondents expressed their knowledge and beliefs on what may be the advantages and the issues related to HFO and LNG. The social aspect is quite a vast factor which includes social lifestyle, attitudes and beliefs, social mobility, demographics, education, religion and ethics, historical issues etc. Attitudes towards the environment, health and career must also be taken into consideration. The cross-cultural and social factor communication play a vital role in

global and international markets, and the success will mostly depend on the depth of the research conducted in this area.

5. Conclusion

This research aimed to assess the temporal variation in air quality and the concentration of sulfates in soil in relation to the transition from the use of HFO to LNG for electricity generation in Malta. This study also assessed the public perception on such energy transition.

In the available air quality data, emissions varied according to the source of energy used. Overall, the MPS emitted high levels of pollutants when compared to the other power stations, especially with regards to NO_x, TSP and SO_2. The DPS was characterised with high levels of emission for specific pollutants when compared to the LNG unit. Even though only three years' worth of data were available, the LNG unit showed lower levels of emission. Whilst sites close to the power stations had high level of sulfates in the soil samples, one of the control sites transpired to have a higher concentration of this parameter. This implies that sulfates in soil may originate from other sources, example fertilisers, pesticides, and animal manure [25] by recent activities and can accumulate over time.

Assessing the public perception through surveys provided the opportunity to determine what the public thinks with regards to the implications of power stations and their overall perception of the air quality situation in Malta. Overall, the public noticed that the air quality in Malta has deteriorated within the last few years. However, interestingly enough, such deterioration was attributed to other sources rather than to power stations. The majority of the public showed that they are not aware of the advantages of HFO, therefore they lacked in knowledge on this energy source. On the other hand, the public seems to be well informed with regards to the potential negative implication that HFO can have on the environment and the economy. To mitigate the situation, most of the respondents were willing to pay more money in order to have a safe and healthy environment as well as overall health safety.

The public's opinion is a crucial explanatory factor such as the electorate's pro-environmental beliefs and policies which will impact the public's knowledge on certain environmental policies according to the political party's beliefs and approach [31].

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