AE6304-Course Benefit Analysis and The Environment

Singaporeans' Attitude Towards Nuclear Energy

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Abstract

The aim of this paper is to analyze the public opinions and the possibility of nuclear energy in Singapore through survey data and descriptive, inference analysis. Nuclear energy is an important component of energy security and global economic development. It is one of the pillars of the world's energy needs. With its numerous benefits, such as efficiency, low carbon emission, boosting economic growth, and reduce energy reliance on other countries, it is worthwhile to have a deep discussion. There are 110 respondents with overall 16 questions. From the data gathered, we see an overwhelmingly negative public perception of nuclear energy. A majority of our respondents agree that nuclear energy poses a threat to the public. Moving forward, Singapore may consider an energy mix, rather than a drastic shift to nuclear power.

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1. Introduction

1.1 Current global energy status

Currently, society largely relies on fossil fuels, and fossil resources are projected to cover 50% of the total global energy supply up to 2050. The dominance of fossil fuels in the global energy sector has generated significant pressure on the Earth's natural systems especially over the past five decades, during which it is estimated that 350 Gt C (gigatons or billion tones carbon) were released into the atmosphere (the other 55% was assimilated by the ocean and land areas), causing accelerated climate warming. Nuclear energy is a low-carbon technology, which is an important factor in the decarbonization of global economics.

1.2 Introduction of Nuclear energy

Nuclear energy is an important component of energy security and global economic development. It is one of the pillars of the world's energy needs, considering that in 2013 it covered an estimated 23234 TWh. Nuclear power is therefore a viable power source given increasing global energy demand, its high-power supply capacity, and the low fuel levels required for operation. However, more attention is being directed towards the relationship between nuclear energy and climate change, considering that the climate system's perturbation is probably the most pressing environmental problem today. Thus, nuclear energy presents a major opportunity to address some of these issues, by means of decarbonization and by stopping global warming at above pre-industrial levels.

There is, however, a notable downside to nuclear energy: safety issues and the radioactive waste it produces. Even though it is known that nuclear powerplants are safety systems, which have several built-in physical barriers conceived to prevent the escape of the radioactive isotopes into the environment, past decades have shown that nuclear accidents can happen. Such instances include the well-known Chernobyl (1986) and Fukushima Daiichi (2011) events that released high amounts of radioactive isotopes into the environment.

1.3 Nuclear energy in Singapore

The idea of using nuclear energy for the island state is not new. The late Lee Kuan Yew revealed back in 2008 that he once considered nuclear energy to be the best alternative to fossil fuels for Singapore, and it is easy to see why: situated in the tropics with high dependence on air-conditioning, the variability in Singapore's electricity demand is much lower compared to others, which makes the case for low-carbon baseload electricity supply typical of nuclear power generation. Bringing nuclear power

into Singapore would also boost the country's energy and engineering sectors while potentially creating thousands of high-skilled jobs.

Today, nuclear provides 10% of the world's electricity, but expansion has been slow as the technology faces many formidable obstacles. Nuclear power plants (NPPs) are costly to build, prone to construction delays and cost overruns, and endure exorbitant regulatory costs in addition to negative public perception. Indeed, fear of radiation is widespread, yet the truth is that much of this fear is unfounded. Taking a transcontinental flight, eating bananas or getting medical scans can expose a person to more radiation than living within a 50-mile radius of an NPP.

Despite sharply polarized opinions towards nuclear energy post-Fukushima, ASEAN Member States remain interested in it, given its strategic relevance in the region's energy and climate targets as concluded in a study by the Energy Studies Institute (ESI), the National University of Singapore in 2014. After all, nuclear is one of the cleanest forms of energy besides wind and solar, and is the second-largest source of low-carbon electricity in the world after hydropower.

Arguably, the upcoming hydrogen revolution alongside carbon capture technologies are among the more publicly acceptable approaches to decarbonization at the moment. However, Singapore faces unique adoption challenges, including a lack of land space. Considering the urgency of the global climate challenge, it would be unwise to exclude available technologies like nuclear power from decarbonization efforts.

A pre-feasibility study on nuclear energy conducted by the Singaporean government between 2010 to 2012 concluded that the then-available nuclear technologies were not suitable for deployment in Singapore. Nonetheless, the government remains open to the option of nuclear energy while focusing efforts on building up capabilities in nuclear safety.

In this first section, we introduced the background of nuclear energy and the current situation of nuclear energy in Singapore. In the next section, we will review the costs and benefits of nuclear energy. In the third section, we will introduce the methods used in our survey and also describe how the data is collected. The fourth section will summarize the results of our investigation. Finally, we conclude and consider some recommendations based on our findings.

2. Literature review

Nuclear energy and its use have been much discussed in the literature. In this section, we review selected recent studies that assess the costs and benefits of nuclear energy, as well as any other repercussions relevant to our field of interest.

2.1. Benefits

There are a huge number of papers discussing both benefits and the cost of NPPs. And the aspects expand to a lot of different topics, such as infrastructure, mechanism, energy, environmental impact, etc. We can see that from most of the papers that we read, lots of experts support the idea of building a nuclear power plant since it is efficient at generating electricity. However, in this part, we will discuss the benefits of the NPPs by going through the paper "The System Dynamics of Nuclear Energy in Singapore" written by Eng Seng Chia, Chee Kiat Lim, Adam Ng, and Ngoc Hoang Long Nguyen (2014). So we are going to discuss the aspects of the benefits in the below order: (1) Technology (2) Environment (3) Economics (4) Political.

Technology

In this aspect, the feasibility of a nuclear power plant depends on mainly three parts, which are its reliability, safety, and availability. It is clear that anything that could enhance the safety of NPPs is always the utmost important thing that we ought to factor in as it will reduce the chances of nuclear accidents such as nuclear leakage, meltdown, etc. and system failure. A study by Meshkati and Deato 2000, had indicated that this tragedy could have been avoided with better safety standards and quality.

Comparing the availability of nuclear energy with other renewable resources, we could tell that a nuclear power plant is much more efficient in terms of generating electricity. For other resources such as wind, in Singapore, it is hard to find a place to build wind-powered fans. Solar power may be an option. However, the efficiency of it is too low to support the electricity usage for the entire country. Thus, the low efficiency of other renewable technologies makes them hard to implement in Singapore. In addition, in order to maintain a nuclear power plant, it is estimated that at least 1400 employees would be needed. Nevertheless, since the nuclear power field requires professional manpower, both National University of Singapore and Nanyang Technological University could recruit experts in this field. The government could also acquire advice and expertise from other countries such as Taiwan, Japan, Korea, etc.

Environment

One of the main advantages of nuclear energy is its low carbon emission levels. According to Nuclear Energy Institute, building one nuclear power plant will reduce the level of carbon emission in producing electricity. This is vital to Singapore since 48%

of its carbon dioxide emission comes from electricity generation, which is according to the information in 2008 from the Minister for the Environment and Water Resource. This implies that Singapore could cut half of its annual carbon emissions by changing all its existing electricity generation facilities to NPPs.

Economics

A paper from Parameswaran (2008) had indicated the positive relationship between economic growth and energy consumption. Nuclear power could be considered a feasible action to deal with the rising demand for energy. On top of that, if we look at the source of the fuel for energy generation, we would know that 97% of the fuel and gas are imported to generate electricity, suggesting that Singapore is subjected to volatile prices of fuel and gas. As a result, introducing nuclear energy will be a viable solution to reduce its dependency on imported fuel. Additionally, Du and Parsons (2009) show that the cost per kWh of the nuclear power plant is cheaper than that from using gas and fuel. Also, the nuclear industry could also be a stimulus for Singapore's economy as it provides more jobs for building the nuclear power plant, boosting economic prosperity.

Another economic aspect is related to carbon tax. It is apparent that carbon tax would increase the cost of a business, and the implementation of carbon tax would indirectly increase the viability of nuclear power. Meanwhile, the reduction of carbon emission will enhance the image of Singapore as it shows that the government is willing to comply with the international obligation to curb carbon dioxide emission. Therefore, using nuclear energy would prevent significant incurred costs from the carbon tax and improve Singapore's international image as well.

Political

Energy security is one of the political issues in Singapore. It relies on geographical relationships with its neighbors. Roughly 80% of its natural gas comes from the pipes from Malaysia and Indonesia while the petroleum comes from the Middle East countries. Nonetheless, the option of nuclear energy provides Singapore with a way to diversify its energy portfolio. Besides, any argument or disagreement with Malaysia and Indonesia or social instability in Middle East countries would give rise to the disruption of energy sources. Consequently, nuclear energy ought to reduce Singapore's reliance on other countries, and at the same time, enhance its negotiation ability in the world.

2.2. Costs

In analyzing the risks and benefits of nuclear energy, a study conducted by the OECD Nuclear Energy Agency (NEA) specifies three main costs incurred as economic, environmental and social. We review these costs and include a political dimension.

Economics

NPPs bear high capital costs, contributing to about 70% of the total costs of nuclear-generated electricity, assuming a 10% discount rate (Grimston, 2005). This is largely due to long construction lead times and susceptibility to cost overruns. Long construction times are attributed to the capital-intensive nature of NPPs. In fact, they continue to be capital-intensive "at every stage of the fuel cycle" (Sovacool, 2010). The average construction period of 28 nuclear plants worldwide between 1995 and 2000 is approximately 116 months, which is higher than the 60-month average construction time of 48 nuclear plants between 1965 and 1970 (Kessides, 2009).

Furthermore, the construction of these plants are prone to cost overruns which may burden government budgets excessively. Ramana (2009) compares estimated and actual costs of construction from 1966-1977, when most American reactors were built, to find that plants cost at least twice as much as expected in every case. Factors contributing to the prevalence of cost overruns include: the lack of acknowledgement of nuclear waste, the exclusion of decommissioning, gaps and supply chain problems resulting in delays and shortages of trained staff. Additionally, these estimates were made by project sponsors and vendors, who often underplay issues associated with construction to present nuclear projects in the most favorable light (Flyvbjerg. et. al., 2003). Such cost overruns are highly risky and often deter private investors due to its time-consuming and expensive nature (Kessides, 2009). Hilliard (2014) highlights the trade-offs from renewable energy, citing that more funds and focus into nuclear energy would mean less resources put into other renewable energy sources.

The International Atomic Energy Agency (IAEA) identifies three cost drivers: technical, management and external. Technical cost drivers are associated with the cost of safety or performance enhancements which remain one of the more significant cost factors. Rose and Sweeting (2016) estimate the overall probability of a core-melt accident in a world with 443 reactors in the next decade to be 69.8%. However, this estimate does not consider the learning effect and assumes that all reactors in all countries have the same failure probability. Additionally, this result is subject to statistical uncertainty. Historically, almost two-thirds of all nuclear accidents have occurred in the United States, dispelling the notion that accidents are a thing of the past or only occur in countries with backwards technology or industry oversight (Sovacool, 2010). The

Japan Center for Economic Research estimated the clean-up costs of the 2011 Fukushima nuclear disaster to be $470-$660 billion.

Operation and management cost drivers include all expenditures essential for plant operation. These costs are estimated from the average capacity factor of the plant under normal operation conditions. Operational costs include wages, equipment, contractor services, nuclear insurance and licensing and regulatory fees (IAEA, 2018). They are relatively low compared to technical and upfront costs.

Cost of decommissioning consists of labor, energy and the transportation and disposal of waste materials. According to the OECD Nuclear Energy Agency survey (2016), the expected decommissioning cost ranges from $1.07-$1.22 million/MWe (megawatts electric). This is extremely costly compared to the decommissioning costs of wind turbines, estimated to be approximately 200,000 pounds/MW (Topham & McMillan, 2017).

Environment

An argument against nuclear energy is that NPPs produce extremely hazardous waste that can last for thousands of years. There has been no definite long-term waste solution. Before it was banned in 1983, radioactive waste was dumped into oceans. Buessler (2014) finds that radioactive elements can be absorbed by marine life and be transmitted up the food chain. Presently, countries are moving towards geologic nuclear waste repositories.

Radioactive leaks pose another source of concern. The environmental and social impact of nuclear waste can be minimized with proper waste management systems. This is harder with radioactive leaks. Watson et. al. (1999) found radioactive caesium and plutonium concentrations in seals and porpoises that ate contaminated fish. A report by IAEA (2005) documenting the environmental consequences of the Chernobyl accident reports that following the accident, vegetation and animals in forests and mountain areas have shown particularly high uptake of radiocaesium, and the presence of radionuclides in the soil. This led to the contamination of agricultural plants and the animals that eat them. There was an increase in mortality and a fall in reproduction in plants and animals exposed to high doses of radiation at relatively close distances.

Social

Social cost considers public health and perception. If nuclear waste is contained improperly, it can be harmful in two ways: direct, long-range external radiation, which

damages the cells of the human body from the outside, and internal radiation. The latter occurs if radioactive materials enter the body, where shortrange radiation can be damaging (Swedish Nuclear Fuel and Waste Management Company, 1995). In waste disposal, workers are protected against long-range external radiation. Even more insidious is shortrange radiation via ingestion of radioactive materials.

Sovacool (2009) finds evidence of elevated rates of leukemia and brain cancers at NPPs. Close proximity to NPPs has been blamed for causing 18,000 infant deaths and 6,000 childhood cancers over 20 years. Cardis et. al. (2006) find an increased risk of thyroid cancer in children in the most contaminated regions. They also discovered that time trends in cancer incidence and mortality in Europe do not indicate any increase in cancer rates that can be clearly attributed to radiation from the Chernobyl accident.

Institut de radioprotection et de sûreté nucléaire (IRSN, 2015) finds elevated concentrations of radionuclides in Tsukuba, an agricultural town located 170 km from the Fukushima nuclear power plant, five years after the accident. The study cites the suspension by wind erosion of particles from the soil and ash coming from biomass fires to be the cause. Radioactive particles and ash can be blown towards territories with lower deposits, resulting in temporary increased concentrations in the air. Hence, even those not in immediate proximity to NPPs could be exposed to radiation and radioactive substances, highlighting the threat of transboundary pollution.

A report commissioned by UNDP and UNICEF with the support of UN-OCHA and WHO (2002) identifies the consequences of human displacement due to the Chernobyl accident. The accident significantly disrupted the lives of those evacuated from their homes. Karácsonyi et. al. (2021) reports that mass displacement after a nuclear disaster has a higher impact on deteriorating health, natural reproduction and economic performance of the affected population than the radiation itself. Ashley et. al. (2017) predicts the economic costs of a hypothetical nuclear accident in the UK. They estimate the cost of displacement and resettling affected populations at 140 million pounds for high intervention levels. Similarly, they estimate the costs for those suffering from radiologically-induced health effects and corresponding countermeasures to be approximately 520 million pounds.

Hong et. al. (2013) establishes the association between public acceptance of nuclear energy and its excellent safety record in Japan. Uji et. al. (2021) did not find support suggesting that the respondents' proximity to Fukushima in 2011 affected their support for restarting NPPs in 2019. They also find that while some sections of Japanese people support nuclear energy for its local health benefits, they are less motivated to

support it for its global climate benefits. On the other hand, Wiegman (1995) reports a high level of risk perception and negative attitudes towards the use of nuclear power among French respondents, even though they are aware of its benefits. Corner et. al. (2011) finds that acceptance of nuclear power due to concerns about climate change and energy security will only increase under limited circumstances—specifically once other options have been exhausted. Conclusively, we see that public perception proves to be one of the main hurdles of a future fueled by nuclear energy.

Political

Nuclear energy appears to be the key to energy independence. This is especially true for countries lacking the natural resources to produce their own means of energy. Prior to the Fukushima nuclear disaster, nuclear energy made up 37% of total energy generation at its peak (Uji et. al., 2021). However, there are also "proliferation concerns" (Pretorius & Sauer, 2014) that nuclear energy may be used for weapons and terrorism (Bunn, 2006).

3. Survey Methodology

With regards to whether Singapore should use nuclear energy and build NPPs, public opinion is very important. Since Singapore has an area of only 724.4km^2, the shortcomings of any nuclear energy will be significantly magnified. At the same time, Singapore is also a multi-ethnic country of immigrants and a representative democracy. Therefore, the opinions of Singapore citizens should also be considered. Public opinion surveys can help the government assess Singapore's attitudes towards nuclear energy. We conducted an online survey through Google form designed to examine several key issues related to nuclear energy. The topics of our survey are as follows:

1. The relationship between the basic information of the citizens and the development of nuclear energy
2. The public's perception of nuclear energy
3. The public's general attitude towards nuclear energy construction

3.1 Research areas and survey objects

The subjects of the survey are Singapore citizens and permanent residents. We collected part of the data through social networking tools such as Facebook. The remaining data came from students or teachers in NTU. Among them, we received the replies of 110 respondents.

3.2 Survey design

This questionnaire is divided into four parts. Firstly, we ask for the basic information of the respondent. This information involves the following aspects: gender, age, race, parental status, education level, employment status, income, and household electricity bill. The purpose of these questions is to explore how personal information affects their views on nuclear energy development. For example, we predict that people with higher education who are between 18 and 30 years old may have a more positive view. However, parents would be more worried about the lasting impact of pollution and nuclear radiation on their children. For unemployed citizens, nuclear energy construction and operations will increase employment opportunities. For citizens with lower income and higher household electricity bills, they may prefer nuclear energy since the electricity bill per unit will be cheaper after the nuclear energy industry stabilizes.

Secondly, we assess the basic cognition and attitude of the citizens towards nuclear energy. This part includes asking citizens whether they are aware of the harmful effects of NPPs, whether they are worried about the future disposal of nuclear waste, their attitude towards replacing old fuels with nuclear energy, whether they agree that nuclear energy will become the main source in the future, and what kind of clean energy the citizens prefer. Most of these questions require to choose one of "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" to represent their attitude. The main purpose of these questions is to observe the general public's attitude towards global nuclear energy development. Thus, we do not specify a location.

Thirdly, we evaluate Singaporean attitudes towards the development and construction of nuclear energy in Singapore. We ask three questions: What do citizens think is the biggest benefit of nuclear energy development? What is the biggest cost to the development of nuclear energy? Do respondents support the Singapore government in using nuclear energy and building NPPs?

The last question requires citizens to choose between “yes”, “no” and “maybe”. These questions are to ensure that citizens can clearly express their attitudes on the problem of whether to support the nuclear energy development in Singapore after understanding the advantages and disadvantages of nuclear energy.

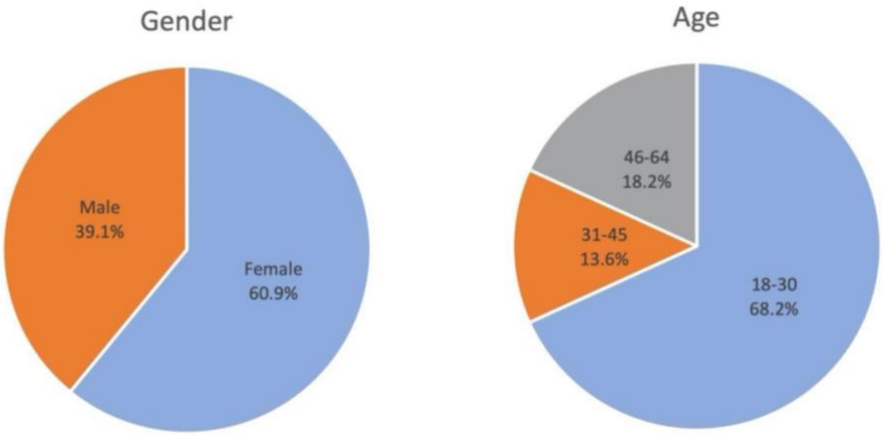
3.3 Limitations

The research will be restricted by the background of the person being investigated. Because this survey collects information through random sampling, and there is no age limit, most of the results are from people aged 18 to 65. There may be some younger or elderly citizens who are unaware of nuclear energy or misunderstand the

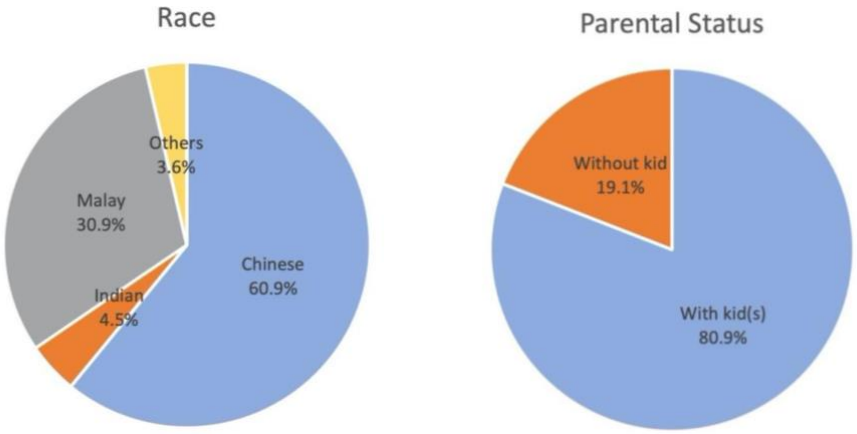
survey. At the same time, Singapore, as the country most plagued by aging population among ASEAN states, received no replies from the elderly people in this questionnaire. A possible reason is that most of the data comes from online responses, excluding people without Internet access. According to the results of the questionnaire, most of the people who participated in the survey had a bachelor's degree or diploma certificate. Citizens with higher education may have a vested interest in new energy, which affects the accuracy of the survey.

4. Result and Analysis

4.1 Demographic and other characteristics of respondents

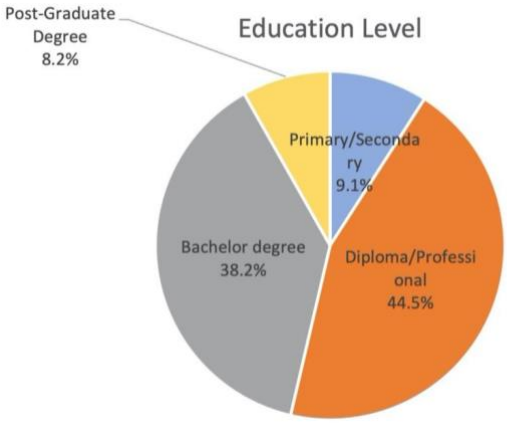


Out of 110 surveyors, there are 67 females and 43 males. The ratio of female to male is 1.56, with the ratio of females slightly outweighing the ratio of males. 68.2% are in the age group from 18 to 30. 13.6% are in the age group of 31 to 45, and 18.2% are in the age group of 46 to 65. Since the survey is distributed online, it could be much easier for the younger generation to access. Hence, the result may be more representative of the younger generation.

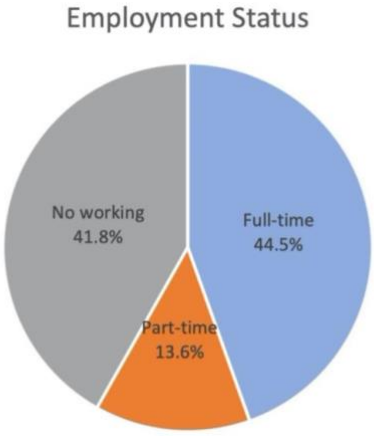


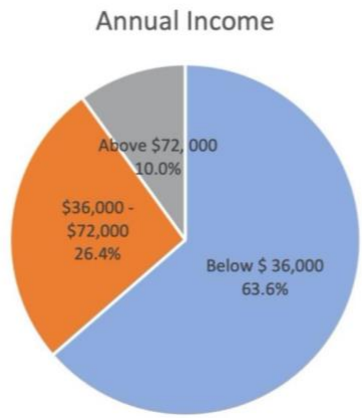
Respondents are well diversified by ethnic groups. Around 60% of them are Chinese, which makes up the majority population of this survey. 31% are Malay, 4.5% are

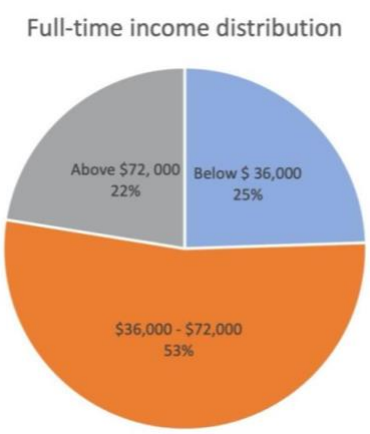
Indians, and there are still 2 Javanese, 1 Eurasian, and 1 Indian-Chinese. This is relatively similar to Singapore's race demographic. In the sample, 19% of them have children, and 81% of them do not have children.

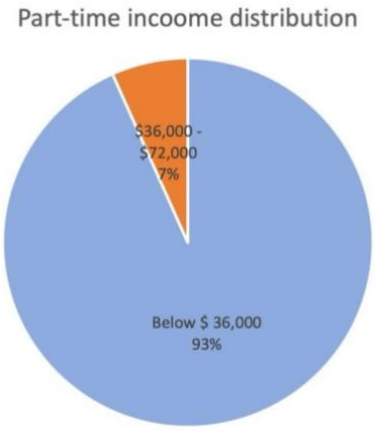


Given the sample data from the surveys, most of the respondents are well educated. 38.2% of them have achieved bachelor's degrees, and 8.2% of them have post-graduate degrees, which means nearly half of our survey responders have finished university education. However, almost 45% of them have diplomas or professional certificates. Only 9.1% of them are at primary or secondary school level.

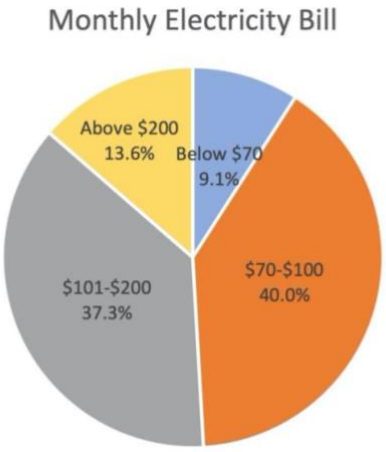






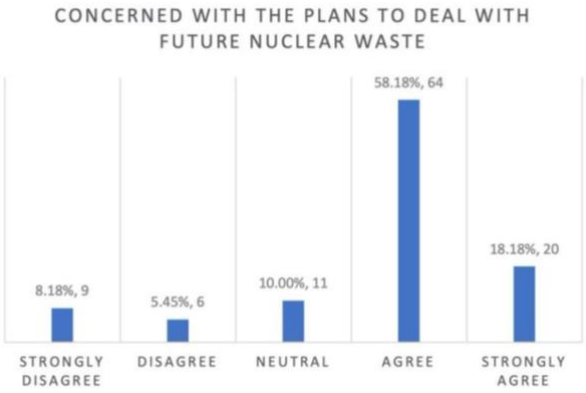


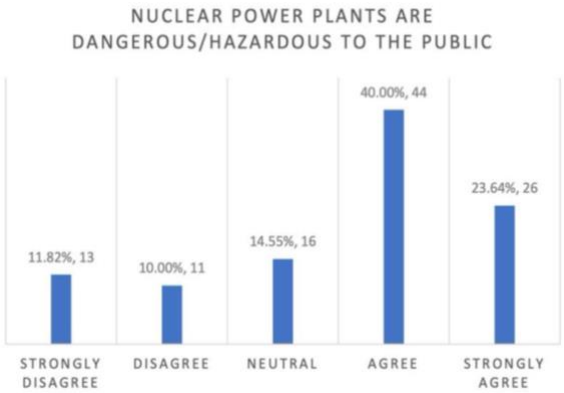
Almost 60% of the respondents are currently working either full-time or part-time. The rest of the respondents who are currently unemployed are mostly full-time students. Evaluating the income distribution more precisely, 53% of the full-time workers have an annual income between $36,000 and $72,000, which is close to the average salary of Singaporeans in 2019. 22% of them have an annual income above $72,000, and 25% of them have an annual income below $36,000. Speaking to part-time workers, the majority of them have an annual income below $36,000, and only 7% of them have an annual income between $36,000 and $72,000. Within this income bracket, 15 responders hold part-time jobs, and only one of them has a salary exceeding $36,000. However, a large portion of the part-time workers is full-time students. Therefore, we estimate that nearly 50% of the respondents are full-time students and have the ability to earn an average income after graduation.



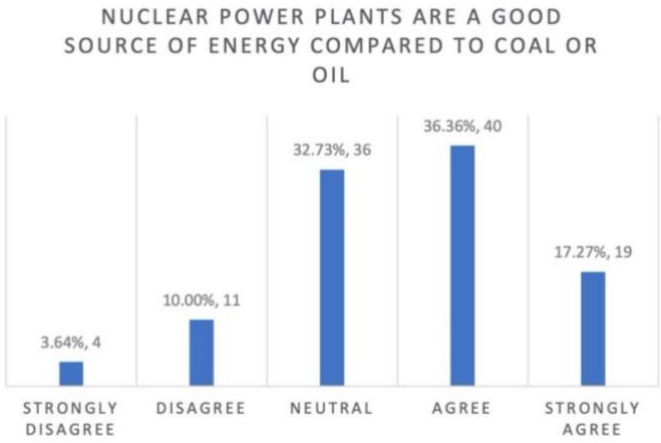
Regarding the monthly electricity bill of households, 40% of them are spending $70 to $100 monthly on their electricity bills. 37.3% are spending $101 to $200 monthly, 13.6% are spending above $200 per month and 9.1% are spending below $70 monthly. All of the above questions are designed to obtain the basic information of the respondents. This is to establish any relevant correlations between their backgrounds and their preferences towards nuclear energy.

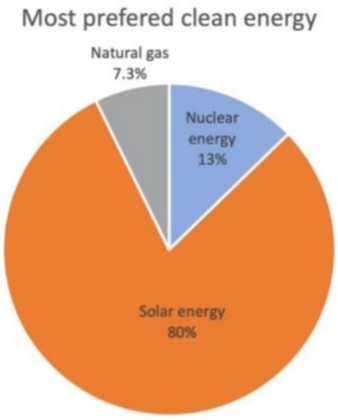
4.2 Opinions regarding nuclear energy



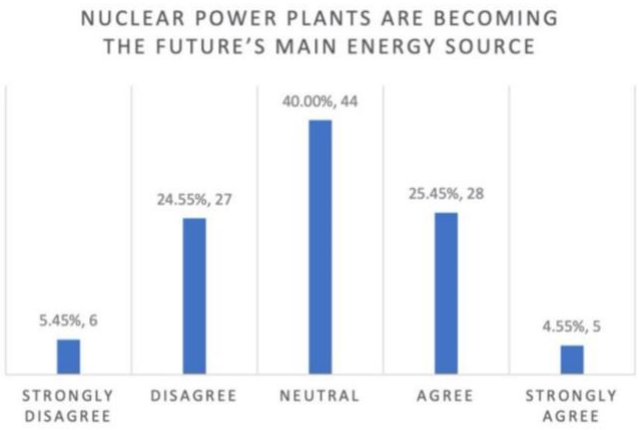


The survey result shows that nearly 60% of the participants are concerned with the plans to deal with future nuclear waste in Singapore. And 18.2% are strongly concerned with them, which means the majority of the participants worry about the nuclear waste in Singapore, and the result is consistent with our initial predictions. However, 10% hold neutral opinions regarding this question. 8.2% strongly disagree and 4.5% disagree. Similar to the results above, the majority of the participants hold an opinion that NPPs are dangerous or hazardous to the public, of which 40% of respondents agree and 23.6% of them strongly agree. 14.5% of them are neutral to this question, while only 22% of them do not worry about the dangers of NPPs.

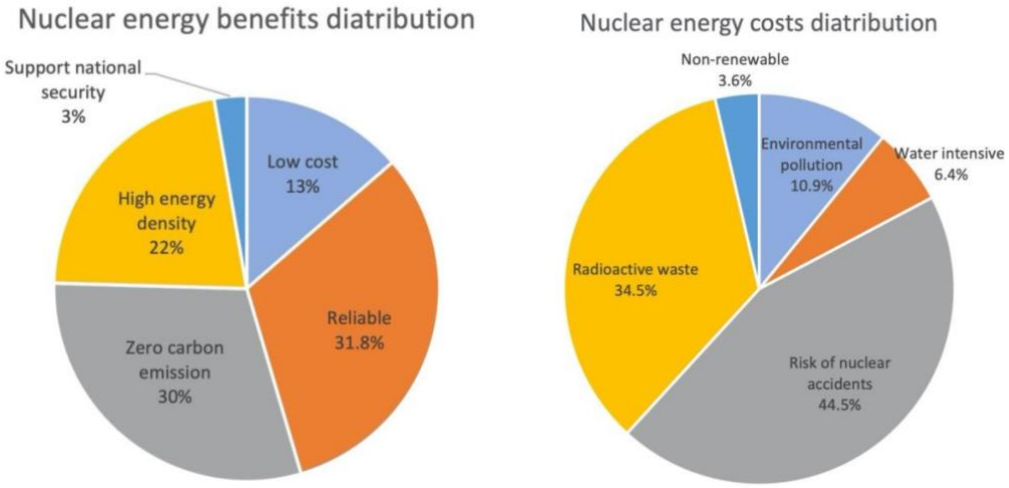




As aforementioned, nuclear energy is a type of clean and efficient energy that may be the key to decarbonization. Compared to coal or oil, above 50% of the participants think that it is a better source of energy, and 33% hold neutral opinions. 14% of them still prefer coal or oil as their energy source. Besides nuclear energy, solar energy and natural gas are alternative sources of clean energy. 80% of the respondents prefer to use solar energy. However, while solar energy is safe indeed, it has the obvious shortcoming of instability. Only 12.7% of participants prefer nuclear energy while 7.3% prefer to use natural gas.

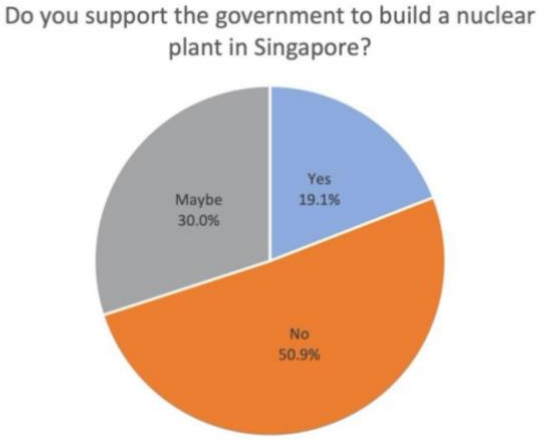


We asked the respondents another subjective question on whether they agree that nuclear energy will become the main energy source in the future. Faced with this question, the respondents' answers were divided into three equal parts. About 40% of the respondents were largely undecided. Half of the remaining 60% agreed that nuclear energy would become the main energy source, while the other half disagreed.



Because our survey is mainly aimed at understanding the citizens' attitudes towards nuclear energy development, these questions may form a premise upon which Singaporean governments can act on. Specifically, it highlights the areas of concern which the government can address, as well as the marketing strategies the government can adopt such that the people are more accepting of nuclear energy. Among the five benefits brought by nuclear energy, 31.8% of the respondents believe that nuclear energy is reliable; 30% of the respondents believe that zero-carbon pollution is the main advantage of nuclear energy; 21.8% of them pay attention to the high energy density of nuclear energy; 13.6% of people enjoy the lower cost of using nuclear energy; only 2.7% of the respondents believe that nuclear energy can help national defense. However, nearly half of the people are most worried about the risk of nuclear accidents caused by nuclear energy, 34.5% of the respondents are worried

about nuclear energy's radioactive waste; the remaining 10.9% believe that nuclear energy's environmental pollution is a cost; 6.4% are concerned about the large water consumption of NPPs; 3.6% are concerned about the non-renewable nature of nuclear energy.



Finally, the participants were asked about their willingness to support building a nuclear plant in Singapore. 50.9% of objects whereas 19.1% support this plan. Notably, 30% of respondents remain neutral. If the government plans to pursue nuclear energy, it should pay more attention to this 30% of the population. However, the government should also probe deeper into the reason for the disagreed group to appeal to them.

5. Recommendations

A possible approach may be to use the media to influence public perception. At its base level, the media serves as the main source of information on policies to the public. The media may also be used as a tool to 'guide' public opinion. Ideally, the government may use media platforms to present and disseminate official policies to the public while consolidating support. Furthermore, studies have shown that a high degree of transparency and efficiency in risk management may improve the public's trust in governments, which is crucial for the implementation of such policies.

Given Singapore's geographical limitations, we can seek to emulate the results of an experimental study done on respondents in Hong Kong by Kwok et. al. (2017) to study the impact of how one-sided information could influence public opinion. The study reveals that public attention could be directed to aspects of the issue for which public opinion is largely undecided and provide information favorable to the government's interests. A less obvious approach would be to draw the public's attention to aspects for which public opinion is rigid, leaving debatable issues untouched to ensure a favorable result. However, these methods may not align with Singapore's democratic

values. As such, we should put emphasis on the free flow of information and the importance of free press instead.

6. Conclusion

From the data gathered, we see an overwhelmingly negative public perception of nuclear energy. A majority of our respondents agree that nuclear energy poses a threat to the public.

Moving forward, Singapore may consider an energy mix, rather than a drastic shift to nuclear power. However, we do feel that a shift to nuclear is inevitable. Currently, Singapore is a hub for oil storage and refining facilities. An increasing global preference for nuclear energy would thus severely affect Singapore's economy and competitiveness if Singapore does not adapt. Moreover, a greater proliferation of nuclear weapons in neighboring countries poses a threat to Singapore's national defense and security. Public cooperation is especially vital for the Singaporean government, as a representative democracy, to tackle these issues effectively. Therefore, more research into the opinions of Singaporeans is warranted.

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Appendix A

Questionnaire

Public opinion survey "Nuclear energy"

1. What is your gender?

☐ Male

☐ Female

2. What is your age?

☐ Under 18

☐ 18-30

☐ 31-45

☐ 46-65

☐ Above 65

3. What is your race?

☐ Chinese

☐ Indian

☐ Malay

☐ Other

4. What is your parental status?

☐ With kid(s)

☐ Without kid

5. What is the highest level of formal education you have completed? (Please check only one)

☐ Primary/Secondary School

☐ Diploma/Professional Certificate

☐ Bachelor degree

☐ Post-Graduate Degree

6. What is your employment status?

☐ Full-time

☐ Part-Time

☐ Not working

7. What is your annual personal income?

☐ Below $ 36,000

☐ $36,000 - $72,000

☐ Above $72, 000

8. What is the monthly electricity bill?

☐ Below $70

☐ $70-$100

☐ $101-$200

☐ Above $200

9. I am concerned with the plans to deal with future nuclear waste, do you agree?

Strongly disagree

☐ disagree

☐ neither

☐ agree

☐ strongly agree

10. NPPs are dangerous/hazardous to the public, do you agree?

Strongly disagree

☐ disagree

☐ neither

☐ agree

☐ strongly agree

11. NPPs are a good source of energy compared to coal or oil, do you agree?

Strongly disagree

☐ disagree

☐ neither

☐ agree

☐ strongly agree

12. What kind of clean energy do you prefer use?

☐ Nuclear energy

☐ Solar energy

☐ Natural gas

13. NPPs are becoming the future's main energy source, do you agree?

Strongly disagree

- ☐ disagree
- ☐ neither
- ☐ agree
- ☐ strongly agree

14. What is the biggest benefit you believe nuclear power could provide?

- ☐ Low cost
- ☐ Reliable (can be generated at any time throughout the day)
- ☐ Zero carbon emission
- ☐ High energy density
- ☐ Support national security

15. What is the biggest cost you believe nuclear power could provide?

- ☐ Environmental pollution
- ☐ Water intensive (NPPs require a lot of water to produce energy)
- ☐ Risk of nuclear accidents
- ☐ Radioactive waste
- ☐ Non-renewable

16. Do you support the government to build a nuclear plant in Singapore?

- ☐ Yes
- ☐ No

Appendix B

Results of regression (Opinion on the respondents' personal information)

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	Do you support the government to build a nuclear plant in Singapore?		
	Support	Not support	Neutral
Gender			
female			
male	0.6557162(*)	-0.0098276	-0.6264759(**)
Age			
Young			
Middle	-1.13738	0.9673238(**)	-0.5374814
Race			
Others			
Chinese	4.845516	0.0847557	-0.6239311
Indian	4.898387	-0.0528935	-0.4780505
Malay	3.542695	-0.0244581	-0.1119422
Parental Status			
Without Kid(s)			
With Kid(s)	-0.7560362	0.2148845	-0.1183074
Education			
Primary			
Diploma	-0.1133517	1.540623 (**)	-1.187818(**)
Bachelor	0.068306	1.064392 (*)	-0.8345326
Post-graduates	1.286032	0.9757019	-1.675361(**)
Employment			
Not working			
Full time	0.6496715	0.7249011	-0.848071
Part time	0.0214811	0.2469757	-0.0344637
Income			
Below 36,000			
36,000-72,000	-0.8202559	-0.8457638(*)	1.09552(**)
Above 72,000	1.431526	-0.7975498	0.1010019
Eletrical Bill			
Below 70			
70-100	-0.5612349	0.6260032	-0.3428999
101-200	-0.8250354	0.5941624	-0.264191
Above 200	-0.5276088	-0.0612451	0.3614722
Intersect	-5.254615	-2.076504(*)	1.512566

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	I am concerned with the plans to deal with future nuclear waste, do you agree?	
	Agree	Disagree
Gender		
female		
male	-0.9147847(*)	1.036711
Age		
Young		
Middle	1.058275	2.24903
Race		
Others		
Chinese	0.8959002	0.3247514
Indian	0.6447284	-0.6004196
Malay	0.62021	-1.056762
Parental Status		
Without Kid(s)		
With Kid(s)	-2.575565	2.773301
Education		
Primary		
Diploma	1.427146	-3.122(*)
Bachelor	0.4013518	-0.3895162
Post-graduates	0.7409761	-1.534123
Employment		
Not working		
Full time	1.652441(*)	-3.624751(**)
Part time	-0.1682695	-6.625164(*)
Income		
Below 36,000		
36,000-72,000	-0.1364923	1.212508
Above 72,000	2.49928	-1.153803
Eletrical Bill		
Below 70		
70-100	-0.1632441	1.338331
101-200	0.1875874	-1.4558
Above 200	0.7596141	-1.21214
Intersect	-0.7743884	-0.6032986

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	Nuclear power plants are dangerous/hazardous to the public, do you agree?	
	Agree	Disagree
Gender		
female		
male	-0.4664	1.654162(***)
Age		
Young		
Middle	1.451174	-0.5744063
Race		
Others		
Chinese	-13.99017	13.97529
Indian	-13.62487	14.03014
Malay	-14.68383	13.63379
Parental Status		
Without Kid(s)		
With Kid(s)	-1.014755	1.599383
Education		
Primary		
Diploma	0.284288	-0.0850293
Bachelor	-0.2256407	0.7393679
Post-graduates	-1.104978	0.4419677
Employment		
Not working		
Full time	0.702664	-0.8130394
Part time	1.372657(*)	-2.020061(*)
Income		
Below 36,000		
36,000-72,000	0.3886804	-0.3297929
Above 72,000	0.9283394	-1.528005
Eletrical Bill		
Below 70		
70-100	1.092856	-1.315823
101-200	0.8057505	-1.887603
Above 200	0.5433446	-1.02123
Intersect	13.27787	-14.38742

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	Nuclear power plants are a good source of energy compared to coal or oil, do you agree?	
	Agree	Disagree
Gender		
female		
male	1.095944(**)	0.5332989
Age		
Young		
Middle	0.3656729	2.841288(*)
Race		
Others		
Chinese	-1.190154	16.46049
Indian	-2.231222	16.69341
Malay	-1.508396	15.88491
Parental Status		
Without Kid(s)		
With Kid(s)	-1.872691(*)	0.0051819
Education		
Primary		
Diploma	-0.3037447	-1.314205
Bachelor	-0.5882376	-1.209642
Post-graduates	-0.7785052	0.8902306
Employment		
Not working		
Full time	-0.2319742	-1.969212
Part time	-1.264778(*)	-1.803302
Income		
Below 36,000		
36,000-72,000	-0.4951364	0.046523
Above 72,000	2.77875(**)	-0.4378071
Eletrical Bill		
Below 70		
70-100	-0.5115687	16.14115
101-200	-1.363107	17.51955
Above 200	0.0081702	15.69643
Intersect	2.558163	-34.23648

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	Nuclear power plants are becoming the future's main energy source, do you agree?	
	Agree	Disagree
Gender		
female		
male	0.4973733	0.2811236
Age		
Young		
Middle	0.2262667	0.735199
Race		
Others		
Chinese	1.527595	16.07156
Indian	1.398519	16.02729
Malay	-0.0265239	16.40522
Parental Status		
Without Kid(s)		
With Kid(s)	-0.0868226	0.5439361
Education		
Primary		
Diploma	1.125993	-1.633228(*)
Bachelor	1.293047	-1.264042
Post-graduates	-1.273378	0.2058927
Employment		
Not working		
Full time	1.138259	-0.0121135
Part time	-1.16893	-0.3631446
Income		
Below 36,000		
36,000-72,000	-0.6293454	0.145935
Above 72,000	-0.9359143	-0.2664159
Eletrical Bill		
Below 70		
70-100	-0.9177959	0.678045
101-200	0.2262776	-0.4513872
Above 200	0.9171541	-1.119145
Intersect	-3.045759(*)	-16.27117

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	What kind of clean energy do you prefer using?		
	Nuclear Energy	Prefer Solar Energy	Prefer Natural Gas
Gender			
female			
male	1.333416(**)	-1.337384(**)	0.4877803
Age			
Young			
Middle	-0.5563715	16.6296	-1.707857
Race			
Others			
Chinese	1.587396	-17.2307	-0.3766073
Indian	1.747357	-17.0071	-0.6360848
Malay	-0.1672921	-15.87603	-0.4373347
Parental Status			
Without Kid(s)			
With Kid(s)	1.046843	-17.102	1.97032
Education			
Primary			
Diploma	1.839912	-1.409063	-0.9688854
Bachelor	2.176802	-1.682299	-0.8772957
Post-graduates	2.017896	-0.7467168	-1.430233
Employment			
Not working			
Full time	0.4746934	-1.129855	1.41841
Part time	-2.258422	0.1003031	2.048056(**)
Income			
Below 36,000			
36,000-72,000	-0.5043184	0.3126367	0.4143214
Above 72,000	-0.8161775	1.360513	-0.976693
Eletrical Bill			
Below 70			
70-100	0.1566302	1.054467	-1.578517
101-200	0.7415772	0.5759306	-1.328635
Above 200	0.8044348	0.5455653	-1.303396
Intersect	-5.600442(**)	19.72094	-0.6834646

(*) 10% significance level

(**) 5% significance level

(***) 1% significance level

Red words= Base

	Benefit				
	Reliability	Zero Carbon Emission	High Energy Density	Low Cost	Support National Security
Gender					
female					
male	-0.5676	0.100113	-0.0308525	0.038409	0.2724374
Age					
Young					
Middle	0.71521	-0.5620367	-1.959318	1.030449	-0.2956843
Race					
Others					
Chinese	-1.2081	-0.298017	13.19657	16.42904	-0.6573259
Indian	-1.4648	0.2493005	13.67964	15.86658	0.6191304
Malay	-1.1224	0.0258377	12.58498	16.61147	-0.9879582
Parental Status					
Without Kid(s)					
With Kid(s)	0.42275	0.6594161	-0.6484293	-0.191352	-0.3866128
Education					
Primary					
Diploma	2.10797	0.1164991	-1.221922	-1.59528	0.6707866
Bachelor	1.57292	0.0903561	-0.9460991	-0.712348	0.6470475
Post-graduates	2.20312	-1.31794	-0.0958114	0.363459	0.9274454
Employment					
Not working					
Full time	0.01149	0.7240506	-0.53337	-0.232035	-0.6837262
Part time	-0.2723	-0.4263606	0.1247867	1.562077(*)	0.2469773
Income					
Below 36,000					
36,000-72,000	0.53632	-0.4169945	-0.0557734	-0.558013	0.3203776
Above 72,000	-0.2761	-0.304704	2.220678	-0.568642	0.1797623
Eletrical Bill					
Below 70					
70-100	-1.0004	0.6399107	-0.5879292	16.052	-1.17183
101-200	-0.1183	-0.7193051	-1.582981	17.24714	0.7050038
Above 200	-1.5509	0.25019	0.1779662	14.81387	1.012561
Intersect	-0.9876	-0.912433	-12.28071	-34.20593	-2.344011

	Cost				
	Risk of Nuclear Accidents	Radioactive Waste	Environmental Pollution	Water Intensive	Non-Renewable
Gender					
female					
male	0.4011814	-0.7627259	-0.0342681	0.6990459	-0.2958206
Age					
Young					
Middle	-2.110918(**)	3.410916(***)	-1.100215	0.610163	-1.828897
Race					
Others					
Chinese	-1.354503	0.4511907	0.9492111	-0.7082573	-0.8244008
Indian	0.3882896	-0.4027225	0.1392678	-0.6474586	0.7984645
Malay	-1.337248	-0.0051923	1.312072	-0.6070209	-0.3198354
Parental Status					
Without Kid(s)					
With Kid(s)	0.9017836	-2.583222(**)	1.939431	0.8944129	0.0055258
Education					
Primary					
Diploma	-0.6093273	1.13938	-1.35581	1.21785	-0.044616
Bachelor	0.1293743	0.4846813	-1.170438	0.8868894	-0.3804661
Post-graduates	-0.1212918	0.0152008	-0.7383	2.018264	0.7745382
Employment					
Not working					
Full time	-0.518898	1.790179(*)	-0.9579967	-0.8241627	0.0160248
Part time	-0.9475975	0.2303316	1.400958(*)	-0.551058	0.8837347
Income					
Below 36,000					
36,000-72,000	0.6454036	-1.757833(*)	0.5693233	-0.6847098	1.437378
Above 72,000	-0.0622953	-0.1587621	1.389761	-1.929541	0.894166
Eletrical Bill					
Below 70					
70-100	-1.94735(**)	1.540449	0.5127822	0.7935297	-0.5916798
101-200	-1.611695(*)	-0.0860155	1.029878	1.508776	0.7848655
Above 200	0.3277823	-1.975294	0.7188607	0.6230578	0.3928485
Intersect	3.085522	-2.850729	-2.65524	-3.475431	-1.866371