SOUTH AFRICANS WILLINGNESS TO PAY FOR RENEWABLE AND NUCLEAR ENERGY TO AVOID POWER OUTAGES

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Abstract

South African households like many households in developing countries, are faced with power outages. Household's welfare is negatively affected since electricity dependence has increased over the years. This paper uses a Contingent Valuation Method to investigate South Africans willingness to pay for renewable energy and nuclear to avoid power outages. A Heckman Selection Model and Cragg's Two Step Model models were used. The number of respondents who are not willing to pay slightly decreases as the duration increases. On average, households are willing to pay R75 more to their electricity bill to avoid power planned outages R61 to avoid unplanned outages. There is an overwhelming support for renewable and nuclear energy.

Keywords: Willingness to pay, nuclear, renewable energy, power outages.

1. Introduction

The number of South African households with access to electricity increased significantly, from 35 percent in 1990 to 81.5 percent in 2007 (StatsSA, 2007). The supply of electricity in South Africa has now reached an uphill as no new base-load plants have been built since the late eighties. Although Eskom[3] brought back some old mothballed stations, and has built about 2000 MW of gas/liquid fuel turbine stations since 2006, there remains a severe shortage of electricity generating capacity (Eskom, 2013).

At the end of 2007, South Africa started experiencing widespread blackouts as electricity demand surpassed supply. Given the threat this posed to the national grid, "load shedding[4]" was introduced. This proved not to be sufficient; hence power supply restrictions on mines and large industries were introduced in 2008.

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[3] Eskom is the state owned utility responsible for generating and distributing electricity in South Africa.
[4] Load shedding is a process where one area is supplied with power and the other cut off in order to save the national power grid from total collapse.

In an effort to address the electricity supply challenges, the government through Eskom commissioned the construction of two new coal fired power stations Kusile (in Mpumalanga province) and Medupi (in the Limpopo Province). Medupi power station (which will be the third largest power plant in the world) will not be fully online for next few years. Given that the power station was meant to be operational in 2011, it is clear that it is years behind schedule, and the delays have exacerbated the strain on the grid.

Medupi and Kusile will generate 4.8 gigawatts (GW) of electricity each. The current electricity generating capacity is at 44 GW. Eskom is committed to increasing capacity with 18.6 GW in 2017/18. This additional increase will come from Medupi and Kusile, refurbishment of old plants, renewable energy plants and the return to service of previously mothballed power stations (Msimanga and Sebitosi, 2014).

In addition to the 44 GW capacity, over 50 GW by will be needed by 2028 (IRP, 2010, Msimanga and Sebitosi, 2014). When Eskom delivers the additional 17 GW as promised, there will be a capacity shortage of 31.4 GW (50 GW-18.6 GW). The proposed nuclear power station is scheduled to be included into the grid in 2023. It will reduce the shortage to 21.8 GW (31.4 GW – 9.6 GW).

Moreover, more extreme weather such as extreme heat, extreme winter conditions, damaging winds, lighting, cable thefts and increased dependence on electricity will continue to put severe pressure on the electricity supply. Whatever the cause, it is most likely that the national grid will continue to be under pressure for the foreseeable future.

South African households like many households in developing countries, are faced with power outages. Power outages are a big problem, since the outages that the households experience are both frequent and long in duration. Despite all the efforts, South African households are likely to still face power outages for some foreseeable future. The fact that households are encouraged to invest in back-up options and conserve power suggests that the power system is severely constrained.

The objective of this study is to quantify household's willingness to pay (WTP) among South African households for the reduction of power outages with various characteristics such as the duration, frequency and whether the outage is known beforehand or not. In this study, respondents will be asked to state their WTP for avoiding different types of outages.

The outage scenarios will be two hours and five hours. Furthermore, the study will establish household's awareness, support and willingness to pay for renewable and nuclear energy.

2. South African energy mix

Eskom generates 96 percent of electricity used in South Africa, and about 45 percent of electricity consumed in Africa. Private electricity suppliers generate three percent while municipalities generate the remaining one percent. The power utility sells approximately 45 percent of its generated electricity to its main customers that include mining, commercial, agricultural, industrial and residential customers. The remainder is sold to redistributors, which then resell it to their customers (Eberhard, 2005; Eskom, 2014). An overwhelming proportion (83 percent) of Eskom's sales is derived from municipalities, big mining and industrial customers (Eskom, 2013).

Eskom generates 93 percent of electricity using coal. The remaining electricity generating sources are nuclear which accounts for 5 percent and renewables accounting for two percent (Msimanga and Sebitosi, 2014). The South African government like China, India and France are in favour of further investments towards more nuclear power stations. The government announced that it plans to build two more nuclear power stations in an effort to reduce the reliance on coal, as well carbon emissions.

Nuclear power has a large load factor as compared to the other power generating sources. Even though building a nuclear power station is costly, the cost of electricity generated from nuclear is low. Although nuclear is considered clean, there are concerns about its safety.

Improper management of the radioactive waste excreted by nuclear plants make them risky. The Fukushima Daiichi accident that occurred in 2011 in Japan that claimed many lives is an evident of the risks associated with nuclear plants. Since this accident, public views about nuclear have changed around the world. Public support for nuclear on average dropped to 49 percent from 57 percent. Countries such as Italy and Germany have decided to phase out nuclear power stations while others including China and India are still in favour of nuclear power (Hayashi and Hughes, 2012).

According to Eskom (2010) Bantamsklip and Duinefontein both in Western Cape (next to the existing Koeberg nuclear plant), and Thyspunt in the Eastern Cape were identified as potential locations for the planned nuclear power station. An environmental impact assessment concluded that Thyspunt was the most suitable location. The location is deemed more suitable due to relatively lower construction costs, the easiness of including nuclear

energy into the national grid (other locations require long transmission lines) and the fact that Thyspunt has lower seismic risk.

There is a strong opposition to nuclear power in this location. The Thyspunt community is concerned about nuclear waste and are worried that this would negatively affect their property prices. In addition, Thyspunt has a prominent fishing sector which exports to international markets. Chokka squid[5] from South Africa, which is sourced in this area, is rated second best in the world. Having nuclear power in the vicinity may result in negative perceptions towards supply from the area. This may result in the loss of foreign revenue and jobs for the local people. On the other hand, some residents in the nearby townships are in favour of the nuclear power station, saying it will make the place lively and create technical jobs for the community (Mail and Guardian, 2012).

The Fukushima accident influenced public opinions negatively; hence it is even more important for the governments to implement corrective measures and transparency during the process to regain the trust in nuclear power. This was successfully done in France by educating the public about the benefits and the risks of nuclear power (Sun and Zhu, 2014).

In South Africa, a survey about public nuclear attitudes that was conducted in 2011 by the Human Sciences Research Council (HSRC) showed that South Africans do not have enough information about nuclear energy. Around 40 percent of surveyed participants could not disclose whether they support nuclear power or not (HSRC, 2012).

In light of the growing recognition of the need for energy transformations, discussions among policymakers about renewable energy have gained momentum in recent years. Renewable energy is believed to be part of the solution to address global warming. It is expensive especially in terms of start-up costs when compared to traditional coal power stations. However, the operational costs are lower relative to the other two sources discussed above. The variable costs mostly consist of maintenance and operations contrary to coal power stations that need piles of coal to operate (Heal, 2009).

By the end of 2013, renewable energy contributed around 26 percent towards total global energy generation. The number of countries with renewable energy technologies increased from 138 in 2013 to 144 by 2014. Policies have been put in place to increase the contribution of renewable energy. The targets have been exceeded in some countries. In

[5] The Chokka Squid (also known as calamari) industry generates around R340 million foreign revenue per annum (South African Squid Management Industrial Association (SASMIA), 2014).

contrast, countries like South Africa have failed to meet their 2013 target of 10 000 GW renewable energy electricity generation (REN21, 2014).

To increase the private entities role in the electricity generation industry, renewable energy independent power producers (REIPP's) are contracted to provide renewable energy technologies of which there is already an agreement with the Department of Energy to supply 2 470 MW (IRP, 2013).

The introduction of these private investors eases the government's burden of having to fund such investments and provides the public with clean electricity supply (Msimanga and Sebitosi, 2014). The recent Integrated Resource Plan for Electricity 2010-2030 (IRP) outlines that 17.8 GW of electricity will be dedicated to renewables and the rest of the power generation will be catered for by other current traditional sources including coal.

3. Literature Review

The relevant literature has addressed several major issues concerning energy challenges. Studies have been conducted both in developed and developing countries and the focus is often on how power outages affect industries through the loss of output. Nonetheless, there are a few studies that recognize the significant welfare losses suffered by households due to unreliable power supplies (i.e. power outages).

Kufeoglu and Lehtonen (2014) classify outages into three categories (brief, sporadic and chronic outages). The first type of outage lasts for a very short period of time, often a few seconds. The second type stems from bad weather and lasts longer in duration. The third type is mostly from inadequate power generation or under performance of old power plants. It is usually of a longer duration relative to others. Chronic outages are the most common type of outages in developing countries as a result of insufficient resources. Outages can cause direct damages like broken appliances and indirect damages like theft due to non-operating alarm systems.

As stated by Lawton *et al*., (2003); Praktiknjo *et al.,* (2011); and Jha *et al*., (2012), welfare losses as a result of power outages are an inconvenience and loss of leisure. Schmidthaler (2012) also points out that welfare loss especially in a case where the outage is not communicated beforehand also leads to emotional stress. This is due to not knowing when the power will be restored again which may cause anxiety.

When an outage occurs, households are unable to carry out their normal activities. They now have to rearrange their activities to activities that don't require electricity, which is an inconvenience. The cost of the outage becomes even higher if there are no substitute

activities as they will have to wait until the power is back, which might take hours even days. Costs can be monetary and non-monetary.

Food spoilage is a direct cost in a sense that longer outages lead to food going off. Production can be lost during an outage for home-based businesses like knitting business using electrical appliances at home. According to Pasha and Saleem (2012), the cost of an outage differs with income levels. Higher income earners may lose more during an outage as a result of a higher dependence on electricity. For example, a low-income household will typically use a paraffin stove during an outrage. In contrast, a high income earner is more likely to use a gas stove or a generator, which is more expensive. In most instances high income households have expensive appliances that can be costly to fix or replace in a case of damages.

Non-monetary costs involve not being able to study for students when they are used to studying in the evenings. When a power outage occurs it deprives the student of the right to do so. According to Ibukunle and Emmanuel (2012) students benefit from electricity with regards to improved technology which makes it easier to access learning material from anywhere in the world through the internet which enriches performance in their studies.

Welfare losses can also include the inability to warm houses especially during winter, or to use air conditioners in summer. Heating water to bath also becomes a challenge especially if there are no back-up options. Loss of communication is also experienced in terms of phone batteries and laptops being low and not being able to charge because of the outage. As stated by Ketelhodt and Wocke (2008), financial costs from outages can also emanate from defects of electrical appliances which might need to be repaired or replaced.

- **Power outages literature**

Carlsson and Martinsson (2004) did a study in Sweden about households' WTP to reduce power outages. This came after the Swedish electricity market was liberalised in 1996, which brought about concerns on reliability and increased outages.

In Sweden, outages are usually prevalent in the evenings during January (Svenska and Elverksföreningen, 1994). The applicable study concluded that there is a positive relationship in WTP for longer outages. There is a low WTP among respondents who do not live in the big cities because in most cases those areas are not prioritized and tend to experience more outages hence they are usually prepared for them. WTP also has a positive relationship with income. Those with high incomes often have more electrical

appliances and are willing to pay more for a reduction in outages (Carlsson and Martinsson 2004).

A WTP study was done in Kenya to determine how much people are willing to pay to reduce unannounced electricity outages by using a choice experiment method. The survey was done in the rural Kisumu district with 202 household respondents who experienced long and frequent outages. A warning before hand was found to be a significant factor as it allowed users to make the necessary arrangements, especially for households with home businesses (Abdullah and Mariel, 2011).

The relevant findings show that older people and people who stayed in the area for longer periods lost confidence in government policies and are not willing to pay more for service reliability. However, those with bigger families and businesses are willing to pay more for increased reliability. Since confidence in the government decreased, respondents preferred to pay more for the reduction of outages only if funds were to be administered by a private company supplying electricity (Abdullah and Mariel, 2011).

Woo *et al*., (2014) conducted a study in Hong Kong estimating outage costs. Although the electricity supply in Hong Kong is one of the most reliable, outages would mostly occur during summer afternoons. These outages would last for five to 30 minutes. More than half of the respondents in the sample would rather trade some reliability for a lower electricity bill. On the other hand, about 23 percent of the respondents were willing to pay five percent more in their electricity bill to eliminate five minutes of outages, 13 percent were willing to pay 10 percent more for a 30 minute outage reduction while the rest were not willing to pay.

In the same way as Hong Kong, households in the Flemish region of Belgium were not willing to pay for the extra reliability of electricity supply. A choice experiment analysis showed how unimportant reliability of supply is to the relevant respondents. Only nine percent in the sample were willing to pay for increased reliability. More than half of the respondents would even welcome an extra outage per year while nearly 25 percent would not mind two more outages per year (Pepermans, 2011).

Pepermans (2011) argues that the reason for outage tolerance may be as a result of the rare power outages in the area. Around 75 percent of households experienced not more than two outages in two years. On average, outages would last for about 100 minutes per year. Contrary to Townsend (2000)'s analysis as cited by Abdullah and Mariel (2010), stating that when people are not accustomed to power outages, they tend to be willing to pay more for reliability. Pepermans (2011) also shows that the relevant households preferred outages in summer and during off peak periods.

Lim *et al*., (2013) estimated the value of electricity in the Republic of Korea by determining the WTP. The country experienced an electricity crisis in 2011 due to increased demand. To remedy the situation, policy makers had to know how much households were WTP so they could increase the electricity investments. On average, households value a reliable and consistent electricity supply and they were offering WTP for it. However, WTP went down as the bid went up meaning the respondents were only prepared to pay a base price which was 10 Korean won (KRW) per kWh than paying the highest bid of 60 KRW per kWh.

Another CVM study was done in South Korea calculating inconvenience costs from outages. There has been a major increase in electricity consumption in South Korea. The country was actually rated the 11th highest electricity consumer in the world in 2012. The reserve margin kept dropping since 2003 from the growing electricity demand coupled with electricity prices that were lower than their generation cost. On the other hand, supply was growing at a slower pace hence the pressure on the national grid. It was found that WTP was high for those households that consume more electricity and are also in the high income brackets. Respondents showed WTP, but were more sensitive to bid increases. It was concluded that WTP is higher for unannounced outages than it is for announced outages (Kim *et al*, 2015).

- **Renewable energy literature**

Renewable energy unlike coal and nuclear power is deemed an ideal source of generating electricity, because it is considered to be clean and safe. Park and Ohm (2013) made an interesting comparison to see what factors influenced support for renewable energy support before and after the Fukushima accident in Japan in 2011. It was found that the renewable energy cost was one of the reasons for reluctance to use renewables before the accident. However, the public's attitude towards renewable energy changed after the accident, and there was more trust in renewable energy because of the risks related to nuclear. The costs were no longer a major concern.

Zografakus *et al.*, (2009) found that households in Crete are well aware of other sources of generating electricity, and are in favour of increased investments in renewables. Furthermore, WTP for renewable energy increases as the number of outages increase. Households with electricity saving technologies were showing WTP for investments in renewable energy. Respondents living in large houses and with high incomes were also showing more WTP.

According to Mozumder *et al*., (2011), income is positively correlated to WTP. In a study undertaken in New Mexico (USA Southwest), affordability was taken into account since respondents were asked to take all expenses into account when answering WTP questions.

On average, there was a WTP of 10 percent more for renewable energy. In addition, around 40 percent of the respondents were willing to add 5 dollars more to the additional 10 percent which was initially agreed upon. Among those were people who are more concerned about the environment and being involved in environment initiatives. It was also found that reliability was also important when it comes to renewables hence people who did not have much faith in renewable energy sources in terms of reliability, were not willing to add more to the 10 percent bid. In addition, there was a very low WTP for those who think that the electricity price is too high.

Similarly, Stigka *et al.*, (2014) and Ertor-Akyazi *et al,* (2012) also found that WTP is high among people who are interested in environmental issues. Furthermore, those respondents prefer specific renewable sources more than others. Solar and wind power were the most preferred sources. Borchers *et al*,'s (2007) assessed WTP by power source in Texas. It was found that solar power was more preferred than wind power, followed by biomass powered energy.

In Italy, there is currently a commitment to increase the share of renewable energy in the total energy mix. Although every consumer pays for renewable energy in the form of feed-in tariffs, there was still a need to establish how many Italian households show WTP to increase their share of renewables. After surveying 1 019 households, Bigerna and Polinori (2014) found that age, education and income factors play a major role in WTP. Educated people and people with money show more WTP for renewable energy. The younger population also support renewable energy. Contrary to Mozumder *et al*., (2011) and Zografakus *et al.*, (2009) who showed a positive relationship between WTP and the household size; this study showed a negative relationship.

After the study of WTP to reduce outages in Kenya, Abdullah and Jeanty (2011) further went on with another WTP study on renewable energy in the same Kisumu district. A major portion of the relevant populated area has a very low electrification rate hence the Kenyan government's goal to increase the number of electrified households through renewable energy technologies. The study aimed at eliciting WTP for grid[6] and off-grid[7] energy systems.

Respondents that are involved in some kind of business and those with high incomes showed more WTP for the programme in general. Older people and those that have lived in

[6] *Electricity which is connected to the main supply system and is usually used in densely populated areas.*
[7] *This electricity system can stand in isolation and is mostly used for areas in remote locations, this can include solar power.*

the place for a long time are not showing WTP for the programme. On average, people are indicating more WTP for grid systems than off-grid systems (Abdullah and Jeanty, 2011).

The government trust issue that was discovered in Kenya was also evident in the USA. Wiser (2006) calculated WTP among 1 574 households. The aim of the study was to determine peoples' preferred supplier (between the government and private suppliers) of renewable energy technologies. The results show that respondents are showing more WTP if the money is paid to a private supplier than to the government. WTP is also high for compulsory payments than for voluntary payments. This can be ascribed to "free riding"; if people are not obligated to pay they would end up not paying while still enjoying the benefits.

Another aspect to take account of in both the Kenyan and American studies, is the fact that there is a participation expectation variable which is positive; showing that some respondents may be indicating WTP if they know other people are also showing WTP a certain amount for renewable energy (Wiser, 2006; Guo *et al*., 2014; Sardianou and Genoudi, 2013).

Longo *et al*, (2008) who conducted a study in England, argued that households need to know about the costs and benefits of the renewable source they chose to support. On average, a reduction in emissions was the most important factor, followed by WTP to increase renewable energy. The third most important factor was due to the desire to reduce black outs. Lastly, educated people who have kids and are involved in environmental activities are showing higher WTP while the WTP is lower for educated people without kids and having no involvement in environmental activities.

It is evident that determinants of WTP for renewable energy are similar across different countries. When respondents are well informed about the subject at hand, the results become more reliable. Education increases WTP in some countries. In addition, income also tends to be correlated with WTP in most countries. This also applies to the household size, with the exception of Italy. According to Jun *et al.*, (2009), renewable energy critics argue that it is not a long-term solution due to its intermittent nature and its high start-up cost.

- **Nuclear energy literature**

Over 400 nuclear reactors are in operation in 31 countries providing more than 11 percent of total electricity. There are currently more than 60 reactors under construction worldwide (World Nuclear Association, 2014). Nuclear power is cleaner compared to traditional energy sources such as coal power stations. Nonetheless, support for nuclear is mixed due to the risks associated with it.

According to Visschers et al., (2011), people's emotions have an impact in determining if something is beneficial or destructive. In the case of nuclear power, past experiences from accidents, incited negative ideas about nuclear. This is evident from the ever changing historical nuclear condemnation.

In the 1970's, public disapproval of nuclear was very low at about 20 percent but skyrocketed after the Three Mile Island in the US to over 60 percent and went up even more after the Ukrainian Chernobyl accident in the late 80's. It got worse with the Fukushima Daiichi accident in Japan in 2011, which resulted in other countries including Germany cancelling nuclear plans. This shows how destructive information can affect views of people who are in favour of nuclear hence the upward trend of nuclear resistance (Erto-Akyazi *et al*., 2012).

A study in Turkey by Erto-Akyazi *et al.,* (2012), found that more than half of the surveyed Turkish respondents are not in support of nuclear power. This negative outlook on nuclear can be attributed to insufficient knowledge since Turkey does not have an operative nuclear power station. Alternatively, the resistance might be attributed to the spill over effects of the Chernobyl accident which affected some parts of Turkey and affecting agricultural production negatively. Kovacs and Gordelier (2009) concluded that people who reside in countries with many nuclear plants tend to be in favour of them.

Public perceptions were analysed in China after the Fukushima Daiichi accident. Sun and Zhu (2014) estimated the WTP for nuclear power in China. Unlike other studies, this study analysed how much households are showing WTP for nuclear power plants to be constructed far from their residences, Respondents were showing higher WTP for the nuclear plants to be constructed away from them.

The study went further and split its sample according to those who are knowledgeable and those who are not. People with more knowledge were showing more WTP for the nuclear plant to be constructed far away than those with limited information. Accordingly governments need to ensure that the public is well informed regarding the subject at hand in order to make informed decisions (Sun and Zhu 2014).

Visschers *et al*, (2011) looked at the determinants of nuclear acceptance in Switzerland. Nuclear power contributes around 40 percent of Swiss total energy. It was found that Swiss people prefer nuclear power as it is deemed more reliable.

Liao *et al*, (2010) assessed people's perceptions and their WTP for nuclear power in Taiwan with the emphasis on ascertaining whether nuclear benefits outweigh its risks. Around 36 percent of the respondents believed the share of nuclear energy in the country should increase, while 33 percent of the sample wanted it to decrease. The remaining 31 percent felt the *status quo* should remain. However, only 21 percent of the people who wanted nuclear expansion were showing WTP for it. Among the ones that wanted the share of nuclear to decrease, only 23 percent were indicating WTP for the reduction.

The public is usually not in favor of nuclear power as a result of accidents that occurred in the past. However, this suggests knowledge gaps pertaining to the costs and benefits related to nuclear power. It is therefore vital that an assessment of people's perceptions about nuclear power and factors driving those factors are better understood to inform adequate policies and investments.

4. Methodology

A contingent valuation method is a generic method that attempts to put a value on an environmental good. In order to establish whether providing a good is beneficial or not, a certain monetary value has to be placed on it. To quantify the value of the non-monetary good, surveys are used.

The sum of what a consumer is willing to pay for a good and what the consumer is currently paying is defined as consumer surplus (Lim *et al*, 2014). Consumer surplus consists of willingness to pay (WTP) and willingness to accept (WTA). WTP is characterized by giving up a certain amount of money to enjoy a specific good or improve the state of the current good. WTA is whereby an individual is given a certain amount of money to forego a specific good (Brown and Gregory, 1999).

There have been major differences between WTA/WTP ratios. There are many contributors to this discrepancy. Income was found to be one of them. WTP respondents usually disclose what they would afford to pay taking into consideration their budget. Contrary to WTA of which any amount that is felt as a necessary compensation can be stated. It was also discovered that goods with no close substitutes have high WTA ratios. This is because, when there are no substitutes, it is almost impossible to replace a good hence the user may feel a high compensation is necessary (Venkatachalam, 2004; Viscusi and Huber, 2012).

Janneke *et al*, (2008) also indicated that being accustomed to a certain good is different to a good that is still to be introduced. There might be a connection or emotional attachment related to the good so if it is taken away, the loss may be bigger resulting to high WTA.

WTP is better suited for this analysis because it does not provide market related estimates like WTA but estimates that are more personal and within the user's means (Brown, 2005). WTA would be even higher since substituting electricity with other sources is almost impossible.

The superiority of CVM to other methods also stems from the fact of being able measure non-use values. Respondents are able to value goods that they do not use or goods which will be used by future generations. Critiques argue that respondents might be swayed during the interview when they are not too familiar with the product. However, with clear and well explained scenarios, uniformed respondents can be able to express their own opinions about the subject at hand (Veisten, 2007).

Another advantage of the CVM is that it gives researchers freedom to explore what might not be available in secondary data (Spash, 2008; Praktiknjo *et al.*, (2011). Surveys can be tailor made to display what is being researched; various scenarios can be explored which can include a change in public good or an introduction of a new good (Carson and Hanemann, 2005; Kjolle, 2008).

Like any other method, CVM also has shortcomings. One of the problems may be inaccurate estimations from improper construction of the questionnaire. However, well-designed questionnaires and well informed respondents can address this shortcoming.

Another shortcoming that has attracted attention is the fact that since it is a hypothetical situation, high or low bids may be placed on the responses. Low bids can come from the notion of having electricity as a human right, in a sense that some people may believe they are entitled to electricity or that electricity should be cheaper (Carlsson and Martinsson 2004).

The elicitation technique that was used in this study is the open ended method in order to elicit WTP for power outages. There are advantages and disadvantages for different methods. One of the advantages of open-ended questions includes the respondent's privilege to formulate their own answers. The response is not influenced by the interviewer, but the answer is based on what is more relevant to the respondent at that moment. It is free from starting point bias which can influence the respondent's answer especially when they

are not familiar or not have enough information about the good in question (Tisdell *et al*., 2008).

Open-ended questions do not restrict respondents to a few options to choose from but also caters for possibilities the interview did not anticipate that may be beneficial (Boyle, 2003). Contrary to closed ended questions where there are options which may not apply to the respondent resulting to a respondent settling for an answer that does not entirely represent what they believe in.

Open-ended questions also have disadvantages. The disadvantages involve respondents not being able to get relevant answers on the spot, but having to think about them for some time. Some people may even misunderstand the question and disclose other things that are not relevant to the question. In such cases, the interviewer can help the respondent by simplifying the question or by asking follow up questions that can help the respondent to think about relevant answers.

The surveys were conducted in Gauteng specifically in the Johannesburg suburbs and townships and specific parts of Eastern Cape. Johannesburg is the economic hub of South Africa. Households in Johannesburg are affected by outages since 84 percent households are connected to electricity (StatsSA, 2013). In Eastern Cape, four areas were chosen because of their proximity to the proposed nuclear plant which will be in Thyspunt. These areas include Humansdorp, St Francis Bay, Cape St Francis, Jeffreys Bay and Oyster Bay. The total sample from both surveys was 750.

5. The model

A Heckman model was used in this analysis together with Cragg's two-step model to cater for the selection bias and the heterogeneity in the scenarios. The chosen methodology makes it possible to determine the reason why households chose to pay and the reason for the stated amount. A standard Tobit model could have been since there are censored observations but due to the fact that is assumes determinants of WTP and the amount paid are the same; it was not preferred for this analysis.

According to Wooldridge (2013), the Heckman (1976) model has two stages. The stages include choosing to pay. A probit regression is used for this stage:

$$y_i* = X_i \beta + \varepsilon_i \quad (1)$$

$$\begin{aligned} y_i &= y_i* \quad if \quad y_i* > 0 \\ y_i &= 0 \quad if \quad y* \leq 0 \end{aligned} \quad (2)$$

Where X_i a vector of independent variables, β is a vector of coefficients and ε_i is the error term. y_i* is the censored variable which is greater than zero. When the respondent is WTP to avoid an outage a dummy variable with 1 for WTP and zero for not WTP was created.

An inverse Mills ratio ג is produced from the first stage obtained from calculating the ratio of the normal density function with the standard normal cumulative distribution function. The second stage is stating the amount a respondent is willing to pay. In this step y_i* is calculated with explanatory variables and the inverse Mills ratio. This step determines variables that explain the amount households are willing to pay taking into account the selection bias. This method was used for power outages.

A probit Heckman selection method was employed for WTP for renewable energy. The equation used in this section is comparable to equation 2 since responses where binary. Respondents had to answer yes or no to WTP for 20 percent extra in their monthly electricity bill and if they say yes, percentage went up to 50 percent.

For nuclear power, Cragg's two step model was used. A similar algorithm to the Heckman model is followed in the nuclear section. When households support nuclear energy, we run a probit model and get the determinants of the support. The second step is to run a truncated regression censored from below since there are also zero response. The regression is only performed for the sample that is willing to pay for nuclear energy.

The equation for the probit regression is as follows:

$$\text{P}\ (y_i* > 0) = \phi(\text{x}\,\gamma) \qquad (3)$$

6. Results

The results are based on 750 responses that were collected face to face from households. In the sample, there were 55 percent males and 45 percent females of all the race groups in South Africa. The population was between the ages 21 and 78, consisting mostly of the youth. 56.6 percent is between the ages of 21 to 35, 36.1 percent between the ages of 36 to 55 and 7.3 percent over the age 56. The distribution is similar to the official figures; the South African youth that is less than 34 years old is more than other age groups in the country's population (65.7 percent) (Stats SA, 2013).

The average household size is about 4 people while the largest household in the sample had 15 people. More than half (56.9 percent) of the respondents are employed full time with 43 percent of the respondents' salary bracket being under the less than R100 000 per

annum category. The education profile shows that most of the respondents' highest education is high school at 46.3 percent. This is in the same range as the Stats SA figures although slightly less than the 2013 figure of 64.2 percent for high school qualification (StatsSA, 2013).

When asked about the most disruptive time an outage occurs, 62.7 percent in the sample listed between 18:00 to 22:00. The most important activities occurring at that time are preparing for dinner (33 percent), general household disruption (20 percent) preparing kids for school and preparing for work (16 percent). Baarsma and Hop (2009) also discovered that households in Netherlands did not want outages in the evenings.

The minimum amount paid by households for electricity is R10 and the highest amount is R7000 per month. On average, households pay around R600 for electricity monthly and 78 percent of the respondents feel that electricity is costly. According to "A Survey of energy-related behaviour and perceptions in South Africa" 14 percent of households expenditure goes to electricity, this is higher than the international average of 10 percent (Department of Energy, 2012).

There were three outages on average over the previous month prior to conducting the survey. Households who experienced outages the most had about seven outages in one month and the households who were affected the least had one outage in one month. The shortest duration an outage occurred was one hour and the longest duration was 96 hours. Only 17 percent of outages occurred more than eight hours. The largest cost emanating from power outages is damaged electric appliances and food spoilage.

Description of independent variables for all scenarios

Variable	**Description**	**Type**	**Expected sign**
logbill_amount	Monthly electricity bill	Continuous	+
supply_satisf	Electricity supply satisfaction	Categorical	-
crisis_management	Is Eskom managing the power crisis as best as they can	Dummy	+/-
high_price	The current electricity price is high	Dummy	-
out_frequent	How many times did the outage occur in one month	Dummy	+/-
medical_equip	Electrical medical equipment present	Dummy	+
financial_costs	Incurred financial costs as a result of power outages	Dummy	-
avail_backup	Is there back-up available	Dummy	-
buying_backup	Planning to buy backup	Dummy	+/-
alt_clean_sources	Awareness of other clean energy sources	Dummy	+
carbon_emm	Does coal power stations contribute to carbon emissions	Dummy	+

location	Proximity to the nuclear power station (Eastern Cape = 1, Joburg = 0)	Dummy	+/-
gender	Gender (male = 1, female = 0)	Dummy	+/-
age	Age of respondent	Continuous	+/-
race_cat	Race categories	Categorical	+/-
hh_size	Household size	Continuous	+/-
kids_u18	Children under the age of 18 years old	Dummy	+
educ	Education categories	Categorical	+
logincome	Household income	Continuous	+/-
employed	Employed (yes = 1, no = 0)	Dummy	+/-
student	Student (yes = 1, no = 0)	Dummy	+/-
self-employed	Student (yes = 1, no = 0)	Dummy	+/-
retired	Student (yes = 1, no = 0)	Dummy	+/-

Power Outage Scenarios

In the table below, results of outage scenarios from a Heckman Selection Model are presented. Table 2 illustrates the selection results, Table 3 shows the outcome results of planned outages of two and five hours.

Table 2: Selection results – 2 and 5 hours planned outages

Variables	**2 hours planned outage**		**5 hours planned outage**	
Selection results				
	Coefficient	P-value	Coefficient	P-value
logbill_amount	-0.025	0.677	-0.042	0.478
supply_satisf	0.024	0.648	-0.040	0.451
crisis_management	0.150	0.165	0.188	0.083*
high_price	-0.331	0.006**	-0.286	0.017
out_frequent	0.169	0.121	0.211	0.054*
medical_equip	-0.010	0.939	-0.055	0.684
financial_costs	-0.177	0.082**	-0.129	0.205
avail_backup	0.017	0.908	-0.116	0.429
buying_backup	0.201	0.056**	0.070	0.506
gender	0.187	0.054*	0.116	0.230
age	-0.021	0.000*	-0.021	0.000*
race_cat	0.020	0.686	0.016	0.744
hh_size	-0.011	0.672	0.012	0.651
kids_u18	0.090	0.381	-0.043	0.676
educ	0.095	0.034*	0.115	0.001*
logincome	-0.087	0.140	-0.085	0.151
employ	0.002	0.964	-0.018	0.655
_cons	1.476	0.029	1.824	0.007

Significant at 95% *
Significant at 90% **

Six variables are significant for the two hours outage, these variables have the expected signs. Those that think electricity price is high have a lower WTP, this means that households are already overburden. Other people experience financial costs as a result of power outages, these people may not be WTP because they have experienced unexpected costs from outages. A positive or negative sign was expected from peole who are planning to buy backup. They may be WTP since they do not have back up yet or they may not be WTP with the aim of saving the additional money to invest in back up options.

The relationship between WTP and gender was expected to be positive or negative. Generally women are the ones doing most of the house chores so if there is not power they are inconvenienced since they can prepare food the conventional way and other things so they are expected to be willing to pay more to avoid power outages. In addition, it used to be men in the past that used to work and pay the household bills hence WTP could be expected to come from males but things have change over the past years since females are also active in the most economies bringing money into the household and more hands on in deciding where the money goes.

Age is also a contributing factor to the WTP. Older people may be loyal to the old ways of doing things like generating electricity through coal than adopting new ways of producing electricity like renewable energy (Borchers e*t al.*, 2014). In addition, they may not be WTP for the reduction of outages because of the lack of trust for the government (Kontogianni *et al*, 2013). They might feel that the government has made a lot of promises which were not fulfilled so nothing will change going forward (Abdullah and Jeanty, 2011). In this case, younger people are not WTP.

The level of education is also a determinant of WTP (Zhang and Wu, 2012). Educated people can understand the background of the current supply shortage and understand that in order to increase supply security, there has to be money available to increase electricity infrastructure. The money that will be used to increase the investments has to come from somewhere and usually it is the consumers' pockets hence the ones with higher education and knowledge will be WTP more than the ones without knowledge.

All the significant variables in five hours outages all have the expected signs. When households are of the idea that the government is not handling the electricity situation as

best as possible, WTP can be lower. People possibly will feel that if they pay more, their money will not go towards what it was aimed for.

The outage frequency was expected to be negative or positive because when people experience a lot of outages, they may be better prepared for them than people who do not experience them frequently. Those who experience them frequently may opt to use their back up options and wait until the power comes back. On the other hand, the ones who are not accustomed to power outages may be WTP to avoid them since they are not used to them (Abdullah and Mariel, 2010).

Table 3: Outcome results – 2 and 5 hours planned outages

Variables	**2 hours planned outage**		**5 hours planned outage**	
Outcome results				
	Coefficient	P-value	Coefficient	P-value
logbill_amount	16.624	0.014*	26.770	0.113
supply_satisf	-3.351	0.563	-6.053	0.675
crisis_management	-6.765	0.564	-30.010	0.308
high_price	-0.859	0.948	4.074	0.901
out_frequent	2.552	0.834	6.252	0.838
medical_equip	24.195	0.117	17.837	0.641
financial_costs	-2.964	0.797	7.940	0.778
avail_backup	19.424	0.253	12.962	0.756
buying_backup	5.485	0.645	20.658	0.466
gender	20.360	0.079**	46.867	0.091**
age	-0.997	0.142	-3.561	0.04*
race_cat	16.731	0.004*	26.074	0.063**
hh_size	-5.190	0.096**	-2.575	0.737
kids_u18	15.950	0.182	37.727	0.194
educ	-0.794	0.874	5.460	0.672
logincome	10.170	0.133	35.917	0.033*
employed	8.229	0.671	6.818	0.887
student	9.522	0.749	20.520	0.774
selfemployed	3.566	0.882	2.154	0.971
retired	84.351	0.067**	271.745	0.017*
_cons	-150.201	0.058	-427.636	0.030

The amount that a person is willing to pay to avoid a planned outage of 2 hours depends on the amount of electricity they pay monthly. Electricity consumption is one of the determinants of WTP (Guo *et al.,* 2014). Higher electricity consumption can indicate more dependence on electricity, which can result into higher WTP (Kim *et al,* 2015).

Similar demographics as the selection results significant also in the outcome results. In addition race is also significant, black people are WTP more to avoid a two hours planned outage. Retired and also WTP to avoid both outages. For 5 hours planned outages, similar demographics with the two hours outage significant and have the correct sign. Income is also significant. This means the higher the income, the higher the WTP (Kim *et al*., 2015; Schumacher, 2014). People with high income usually have a lot of appliances that work on electricity resulting in limited or no activity when there is an outage. Besides household appliances which can be damaged from frequent outages, there may be electric gates, of which, when not in operation can make them vulnerable to crime.

Table 4: Selection results – 2 and 5 hours unplanned outages

Variables	**2 hours unplanned outage**		**5 hours unplanned outage**	
Selection results				
	Coefficient	P-value	Coefficient	P-value
logbill_amount	0.008	0.890	-0.013	0.831
supply_satisf	-0.020	0.703	-0.077	0.144
crisis_management	0.321	0.003*	0.290	0.007*
high_price	-0.236	0.048	-0.187	0.117
out_frequent	0.101	0.354	0.127	0.242
medical_equip	-0.092	0.503	-0.089	0.515
financial_costs	-0.126	0.218	-0.057	0.573
avail_backup	-0.017	0.906	-0.070	0.631
buying_backup	0.211	0.045*	0.136	0.195
gender	0.159	0.102	0.068	0.482
age	-0.023	0.000*	-0.023	0.000*
race_cat	-0.023	0.651	-0.025	0.619
hh_size	-0.015	0.583	-0.003	0.915
kids_u18	0.113	0.276	0.016	0.875
educ	0.042	0.341	0.045	0.309
logincome	-0.072	0.223	-0.065	0.272
employ	-0.030	0.454	-0.019	0.636
_cons	1.526	0.025	1.813	0.007

Significant at 95%
Significant at 90%

Choosing to pay for both two and five hours unplanned outages depend on if the respondent believes Eskom is dealing with the power crisis as best as they can. Those who are planning to buy back-up are also WTP since they do not have back-up yet. Age is also significant in both durations.

Table 5: Outcome results – 2 and 5 hours unplanned outages

	2 hours unplanned outage		5 hours unplanned outage	
Outcome results				
	Coefficient	P-value	Coefficient	P-value
logbill_amount	16.522	0.003*	49.046	0.000*
supply_satisf	1.760	0.712	-6.628	0.519
crisis_management	-10.202	0.308	-25.658	0.227
high_price	-10.283	0.328	-20.961	0.345
out_frequent	-3.157	0.752	-10.973	0.606
medical_equip	10.624	0.422	4.072	0.882
financial_costs	-4.331	0.644	-9.687	0.619
avail_backup	22.677	0.115	34.865	0.243
buying_backup	2.699	0.785	-3.829	0.850
gender	13.112	0.169	27.803	0.154
age	-0.681	0.247	-1.285	0.298
race_cat	12.450	0.010*	10.735	0.293
hh_size	-3.015	0.239	-1.666	0.757
kids_u18	5.989	0.543	16.360	0.426
educ	-3.566	0.370	-1.665	0.845
logincome	8.567	0.140	15.174	0.221
employed	6.742	0.684	10.742	0.756
student	9.327	0.705	35.440	0.487
selfemployed	11.397	0.576	-1.891	0.964
retired	18.653	0.685	312.686	0.001*
_cons	-132.590	0.050	-303.248	0.034

The amount of electricity paid monthly, race and retired are significant in the outcome results of unplanned outages. In short, households would prefer not to have unplanned outages because the inconvinience is larger than planned outages (Kim *et al*, 2015).

Renewable Energy Scenarios

This section discusses the results from Probit model with a sample selection. Households had to state if there were willing to pay 20 percent more in their current electricity bill which is aimed for renewable energy, if the answer was yes then they were asked if they were willing to pay 50 percent more.

Table 6: Selection and outcome results of willingness to pay for Renewable Energy

Variables	**WTP 20%**		**WTP 50%**	
	Coefficient	P-value	Coefficient	P-value
alt_clean_sources	0.218	0.078**	-0.277	0.110

carbon_emm	-0.067	0.444	0.151	0.287
logbill_amount	-0.070	0.230	0.040	0.650
out_frequent	0.005	0.963	0.097	0.556
high_price	-0.472	0.000*	0.151	0.643
avail_backup	-0.023	0.873	-0.011	0.959
buying_backup	0.288	0.006**	-0.109	0.628
gender	0.100	0.298	-0.038	0.796
age	0.001	0.805	-0.029	0.226
hh_size	0.012	0.658	-0.019	0.620
kids_u18	-0.046	0.653	0.188	0.296
educ_years	-0.007	0.637	-0.032	0.405
logincome	0.002	0.976	-0.016	0.853
employed	0.047	0.787	-0.037	0.878
student	0.368	0.187	-0.516	0.173
selfemployed	0.052	0.803	0.171	0.643
retired	-0.272	0.459	-3.388	1.000
_cons	0.301	0.641	1.422	0.260

Significant at 95% *
Significant at 90% **

The selection results show that people choose to pay because they have knowledge about clean alternative energy source. In addition, those who think the electricity price is too high, are not to pay for renewable energy. The above variables do not explain willingness to pay 50 percent more for renewable energy.

Nuclear Energy Scenario

The results that will be presented in this section were obtained using Cragg's Two Step Model.

Table 7: Nuclear Energy Results

Variables	**Probit**		**Truncated Regression**	
	Coefficient	P-value	Coefficient	P-value
logbill_amount	-0.187	0.003*	1155.956	0.000*
supply_satisf	-0.124	0.020*	205.966	0.059*
crisis_management	0.109	0.310	236.345	0.365
high_price	0.037	0.756	364.546	0.214
out_frequent	-0.118	0.273	196.171	0.376
medical_equip	0.001	0.996	-202.090	0.466
financial_costs	-0.013	0.899	-1.168	0.996
avail_backup	-0.086	0.551	181.191	0.509

buying_backup	0.013	0.902	105.954	0.618
location	-0.276	0.014*	27.257	0.908
gender	0.026	0.786	-204.782	0.310
age	-0.001	0.850	-10.099	0.323
race_cat	-0.002	0.966	29.541	0.723
hh_size	0.023	0.401	115.785	0.080*
kids_u18	0.214	0.036*	-196.880	0.363
educ	0.026	0.564	26.181	0.771
logincome	-0.034	0.573	16.555	0.894
employed	0.001	0.998	798.732	0.196
student	-0.315	0.261	374.036	0.667
selfemployed	-0.040	0.849	1 078.814	0.116
retired	0.035	0.924	1 771.209	0.036
_cons	0.301	0.641	-11 419.050	0.001

Significant at 95% *
Significant at 90% **

The decision to pay for nuclear depends on the amount of electricity paid by the household monthly. Contrary to our expectation, households with high electricity bills, are not willing to pay for nuclear. The satisfaction with electricity supply shows the expected sign that if households are not satisfied with the supply of electricity, they are likely to not be willing to pay. The same applies to the payment decision, both the variables are significant.

The location is significant and negative, this means that households in the Eastern Cape are not willing to pay for nuclear energy. Studies that have been done in the past show that households are WTP to have nuclear plants constructed far away from them. (Sun and Zhu, 2014). In this study, most people cited employment as one of the reasons for endrsing nuclear. This can be an indication that they are not aware of other nuclear energy elements hence awareness programs are necessary.

The children variable is significant and positive as expected. Parents would are likely to pay more to increase the supply of electricity since most children are scared of the darkness and it also becomes difficult to prepare them for school. The household size is significant and positive in the truncated regression.

7. Discussion

It is evident that people are willing to pay more for longer outages than short ones. The results also show that planned outages are preferred because households can work around

their time table by moving activities to when there is power. There is lack of trust in the government since household feel that more can be done to manage the power outage problem. Households favour both renewable energy and nuclear. The survey responses from the Eastern Cape showed that renewable energy is favoured because of safety while nuclear energy is favoured because it will create jobs for people in the area. There is high unemployment hence respondents support the nuclear plan more since it will mean a better life for them. Awareness campains are needed so that households can be informed about all areas of renewable and nuclear energy in order to make informed decision.

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