Introduction

Without electricity the global modern economy would not be able to provide millions of people with the quality of life that they possess or strive towards. It is the backbone of our economy and is fundamental to every aspect of life, both in the aid of production, in the pursuit of leisure, and everything in between. It is so important that mankind will often engage in destructive means of producing electricity without hesitation or consideration of the effects of such activities. This was especially true in the industrial era when electricity was generated by means of environmentally destructive processes.

Background

Water Limitations and Consumption

Water is an abundant resource on the planet. The problem that humanity faces is that a very small quantity of that water is fit for human consumption. It has been estimated that 40% of the world population is dependent on water that is extracted from water stressed areas. By 2025 this figure will have increased from 40% to 50% by 2025 (Revenga, Brunner, Henninger, Kassem & Payne 2000: 8). This figure is alarming seeing as that the world population is constantly increasing at an ever more rapid rate than ever before.

Similar problems exist in South Africa which has historically been a water deprived nation. According to Eberhardt and Pegram (2000 :vi) the current water demand in South Africa is equivalent to about 60% of the maximum available water within the country. It is estimated that by 2030 South Africa's water demand will be equal to all of the available water within the country.

The South African government is aware of this problem and have created several policies which serve as a means of protecting our water supply, not just at the present but in the future as well. However, the mere fact that the South African government created policies and have tried to implement them does not mean that they will make a significant difference to the problem at hand. Claassen, Funke &

Nienaber (2013: 147-148) created scenarios which were initiated by the Water Research Commission which suggests that the most probable scenario is one in which government recognises the need to implement strategies that will turn around the current problem.

However, the chances that these policies have the ability reverse the current trend effectively still have to be seen. Three problems face the government with regard to this issue. The first is whether the policies created are sufficient and encompassing enough to ensure that there they can work effectively, secondly whether these policies can be implemented correctly so as to have the desired effects. The third problem is whether the trade-off between energy generation and water conservation can be managed in such a way so as to ensure the security of both goals. All three problems that have been highlighted are of importance, only the latter will be discussed in this article.

The third problem holds within it a contradiction in the sense that the current means of energy generation is dependent on water, namely coal generation. The country therefore faces a trade-off between power generation and water conservation. Both of which are crucial to the well-being of the people of the country and the economy. The problem is further compounded by the fact that there is currently immense pressure on government to secure the countries energy supply.

Current Means of Generating Energy

Currently the majority of the South African electricity supply is created through coal burning power stations. According to Newberry & Eberhard (2008) over investment in coal power generation in the 1970’s and 1980’s led Eskom to massive infrastructure development. This, paired with an abundant supply of coal, has led South Africa on a path of massive reliance on coal. Alternative means of generating energy using renewable sources has only been dappled with as side projects and has never truly been incorporated into development plans as a serious replacement for coal. They argue that due to the cost effectiveness and availability of coal it would be unwise to focus too much on renewable energy.

Even though coal is a cheap form of power it is not a silver bullet and does have several problems. For one, the amount of estimated coal available has been downgraded over the last decade at an alarming rate (Hartnady, 2010). They predict that coal production will reach its production apex in the Southern African region by 2020. After which it will start declining. Using data from the growth rates between 1988 to 2007 Hartnady (2010: 2) predict that southern Africa's coal resource will be depleted to 90% by the year 2062.

This figure is alarming seeing as that at that point it might not be cost effective to extract the remainder of coal within the geographical region. As a result of the existing infrastructure of coal based power generation stations it is likely that South Africa would become dependent on importing coal, which would severely compromise their ability to maintain "energy security" in the future.

An Input and Output analysis done by Nieuwoudt, Backeberg (2011: 704) suggests that one cubic meter of water generates an economic output of R157.40 in the industrial sector. Even though the above figure is not wholly representative of power generation and includes general industry, it isn't completely accurate of the benefits of using water, but it still shows our dependency on water as a means to economic growth.

Research Question

This article will attempt to measure the effect that traditional coal powered stations, have on the water supply of the country using a conflict model. In doing so it will try to determine whether the alternative policies put in place by the energy producer has been sufficient enough to limit water consumption by the major energy producer and/or whether the rate of improvement in water reducing dry cooling power stations are sufficient. Both of which have been heavily promoted as a means of reducing water consumption by the major energy producer.

It is important to note that the model used on this article does not show the point at which water "runs out", but rather show how this precious resource will shift between the two parties that seek to consume the product. It is therefore not a projection that water has run out or that it is in abundance, but rather it shows how water much control each of the two parties have on the water source.

Contribution of the Study

One of the problems that the South African government face is that current means of energy generation is dependent on water, namely coal generation. The country therefore faces a trade-off between power generation and water conservation. Both of which are crucial to the well-being of the people of the country and the economy. The problem is further compounded by the fact that there is currently immense pressure on government to secure the country’s energy supply.

With this in mind this article will analyse the affects that traditional coal generation has on the water supply. This will be done by using a conflict model to determine who has control of the water supply, the “energy producer” and the “water consumer”. It will also look at the effects that our current coal dominated power stations have had on the country from 1970 to 2012.

The data that will be used within the conflict model is unique in the sense that it does not use secondary data to determine the amount of water consumed but focuses rather on direct consumption of water. Put differently, water consumed by the energy company is the actual amount of water consumed by the power plants of the energy company. Similarly, water consumed by the water consumer is the estimated amount of water that the average person consumes which then takes population growth into account.

Litterature Review

(This section is incomplete)

Claim

Power generation is a vital component of modern society. Unfortunately South Africa’s means to power generation are at odds with global and local environmental concerns. The reason for this is that the methods used, namely coal power plants, consume a lot of water. The problem is that this is not a resource that the country has in abundance.

Alternative means of power generation must thus be looked at much more intensity. It should become a serious concern rather than a point which is given lip service. Policy should be directed so as to lead South Africa to a situation where there is a mixture of different means of electricity generation, with renewable energy being the primary source. This would stand in contrast to our current mixture in which the majority of power is created by means of coal with only a small proportion being renewable energy.

The reason for this radical shift lay in what this article will set out to show. That power generation by means of coal negatively effects the amount of water available for normal consumption. This will be shown by means of a CSF model, which will show that the two parties, namely the water consumer and the energy producer, have consistently increased their demand for water. As a result demand will eventually lead to shortage for both parties.

Support

An increasing demand for water, both globally and locally, are well documented. There is a massive body of research which examines how populations' demand for water are outstretching what can be supplied. According to Eberhardt and Pegram (2000 :vi) the current water demand in South Africa is equivalent to about 60% of the maximum available water within the country. It is estimated that by 2030 South Africa's water demand will be equal to all of the available water within the country. It therefore makes sense for South Africa to limit water consumption where it is possible to do so.

Seeing as one cannot limit water consumed in order to live, one has to look at other avenues such as power generation. Currently the energy producer uses coal burning power stations as its means of generating electricity. Water is an essential part of the process as it spins the turbines, which generates electricity. This is a process which should be converted to alternative means of energy generation which does not use water at all.

Historically, Eskom has been aware that their water consumption is a major concern. As early as (GET DATE) Eskom have been looking for ways in which to decrease the amount of water that they consume. (GET REF) Eskom states that “”. This has often been done by making the coal systems used more efficient.

Even though it is good to see that Eskom have made steps to improve water consumption from their plants. Water per unit of power might have decreased, but the amount of units of power has increased. Therefore in order for the energy producer to reduce the amount of water consumed per unit with faster than the increase in demand for electricity.

Logic behind the data used

The data used to gauge what effect of power generation has had on water consumption is fairly direct to the claims made. This is because all of the data, regarding water consumption and energy product, are actual figures extracted from Eskom’s annual reports from 1969 till 2012. Data used in this section therefore doesn’t contain many assumptions but is instead directly related to the issue at hand.

One of the assumptions made in the dataset is with regards to power consumption of the state and water consumption of Eskom itself. Data is readily available as to how much power is consumed in the country, as well as how much water is consumed and power is generated by Eskom. However Eskom is not the only supplier of electricity in the country, but have a vast majority of the market share. As a result exact data on the amount of water used by other producers are not documented in this dataset. In order to estimate how much water is consumed by the state, in terms of power generation, it is assumed that all other producers consume water at the same rate as Eskom.

Like most data sets this one does have some errors and omissions. In the years of 1978 and 1979 no information is available as to the amount of water that Eskom consumed. Similarly, in the years from 1997 to 2000 Eskom withheld their annual reports, meaning that no information is available. In all of these cases arithmetic smoothing techniques were used to ensure a continuation of the dataset.

In terms of human water consumption this article uses figures set out by the Free Basic Water policy which according to (GET REF) state that the basic human need for water is 25 litres of water per day. This figure is used for several reasons, one of which is because the right to water is a human right set out in the South African constitution. The figure of 25 litres is also used because there are several problems measuring historical and present water consumption of the whole population.

Another problem with other sources of water information is that it often measures consumption which includes agriculture and mining activities. It is acknowledged that agriculture is a vital human component, but all produce generated in South Africa is not consumed in the country. Therefore to avoid the positive and negative externalities created between international food sales agriculture is excluded from this article.

In order to estimate the minimum amount of water that a person may consume as a human right the 25 litres per day is multiplied by the amount of days in a year. This simple calculation gives 8900 litres of water a year for each person. The total is then multiplied by the year on year population increase of the country from 1969 to 2012.

According to (GET REF) the problems regarding population data has been discussed at length in several academic papers. While researching historical population data problems did arise due to several geographical areas of the country being excluded from official estimations of the past. To circumvent this problem estimates of population data are used in which is derived from the above article from the years of 1960 to 2001. After which data is extracted from official government estimates.

Against

According to Newberry & Eberhard (2008) over investment in coal power generation in the 1970's and 1980's led Eskom to massive infrastructure development. This, paired with an abundant supply of coal, has led South Africa on a path of massive reliance on coal. Alternative means of generating energy using renewable sources has only been dappled with as side projects and has never truly been incorporated into development plans as a serious replacement for coal.

It is argued by Newberry & Eberhard (2008) that due to the cost effectiveness and availability of coal it would be unwise to focus too much on renewable energy. They argue that switching to renewable energy would not make any financial sense as we have abundance of coal and a lot of our infrastructure is already based on coal power generation.

The problem with coal is that even though it is a cheap form of power the amount of estimated coal available has been downgraded over the last decade at an alarming rate (Hartnady, 2010). They predict that coal production will reach its production apex in the Southern African region by 2020. After which it will start declining. Using data from the growth rates between 1988 to 2007 Hartnady (2010: 2) predict that southern Africa's coal resource will be depleted to 90% by the year 2062.

Therefore to urge that South Africa should keep in relying on coal because it is cheap, one has to adopt a narrow standpoint that is only focused on the medium term. It doesn't take long term factors into account. It doesn't ask the question, "what do we do when the coal runs out?" It is therefore a good idea to start building a much more aggressive mixture of coal and energy power stations.

Conflict Model

This article will make use of a Conflict Success Function in order to determine what the current state of fresh water resources are in South Africa. The CSF takes two opposing forces that vie for control of a specific resource, in this case fresh water, and measures their relative success in controlling that resource (HIRSHLEIFER). For the purposes of this model the fresh water supply will be fixed. This is in contrast to the actual water supply which is not constant but rather fluctuates depending on precipitation, runoff and several other factors (2001: 1029)[i].

--------lit review end------

-------possible research design---- (old section)

Conflict Model from 1970 to 2012

Historically South Africa has been heavily dependent on tradition coal power stations. The conflict model shows the effects of this type of energy.

The net loss in water to produce energy according to (GET REF) is 1.35 litres of water for every one kWh of electricity that their coal power stations generate. Most of this water is lost through evaporation while the rest is used in the industrial process of generating electricity.

Within the conflict model there are two major players namely, the “energy producer” and the “water consumer”. The “energy producer” represents Eskom which is responsible for the majority of South African electricity generation. While the “water consumer” represents the South African populace who consumes water as a means to survival.

----research design (newest section)

Research Design

The Question

The aim of this paper is to determine what the effects are of coal power generation on water. With severely limited water resources in the country every drop of water counts. Therefore, even though coal power generation consumes only about two percent of the country’s water supply that two percent could have gone towards other means. Especially seeing as that there is an ever increasing population that consumes the water.

Even though it might not be a problem now, one should be mindful of the fact that Eskom has recently cleared and implemented policies which will lead to a considerable increase in coal power generation. As more and more coal generation plants become operational it leads to higher and higher amount of water consumption as well as a fairly homogenous energy mix. Since the 1960’s Eskom has put a considerable amount of resources into making coal power stations less water dependent. As a secondary point of interest this paper will try to determine whether these technological improvements have made any difference within the conflict model. As well as trying to determine whether alternative energy has led to a reduction in water consumption.

Delimitations

As a result of pitfalls within the data, namely a grey area between 1997 to 2001 in which Eskom didn’t release their Annual Reports, this paper has two different case studies of two periods. The first period from 1969 to 1997 and the second period is from 2001 till 2012. The period between 1997 to 2000 will therefore be excluded from the data set as it was felt the using arithmetic smoothing techniques would not be conducive to the accuracy of the data.

As a result of the creation of two graphs the second graph will move to the state of the end of the first graph almost instantly. This does not mean that the second period was marred with rapid deterioration, or improvement, but rather that it continues with the previous trend with a structural break within it.

Another exclusionary delimitation within the data is smaller energy producers during the period of study. The cumbersome process of trying to find data from all of these smaller companies, many of which doesn’t to exist anymore, it was considered best to remove them from the findings all together. In order to accommodate for the lack of information brought forth, it their proportion of control over the energy market will simply be given to the major energy producer. It is also assumed that they were as efficient in water technology as the major energy producer.

The question at hand has many points which are highly subjective. It is impossible, for example, to determine what pressure the major energy producer has been put under which led to any changes. Trying to determine such subjective points and then relating then converting them into quantifiable data would not be lead to any accuracy.

As a result many such variables where excluded from the model and was simply left as constants. It is assumed that these components would be exposed when one observes total water consumption or the rate of water consumed by the energy producer. If any of the above has did alter one could safely assume that public pressure has been effective.

Justification for the Data used and the Conflict Success Function

The variables used are the year on year changes in population which is added up (Ma). This is done to show what the effects are of the on total growth of the population since from 1970 and onwards. It therefore excludes growth the population before the starting period.

The second variable used is energy generated by the major energy producer (Mb). All of these variables are appropriate for the model since Ma consumes water and Mb, since water is consumed to generate power.

As noted by Hwang (2009: 1) conflict success functions have made significant contributions in economics as well as in political sciences and evolutionary biology. The flexibility of the model means that it can be used in many different fields. Few requirements for using the model is that there has to be two groups that fight for control of a set resource. Therefore this is a good model to try and answer the question set forth if one stylise it as a conflict between two groups fighting for control over water.

The other benefit of this model is that it doesn't make the claim that if the "fight" is lost water would run out. It simply reveals whether the major energy producer has been effective in its various water conservation policies. As a result the finding cannot lead to any claims, such as a date at which water will run out, which lays completely outside of the scope of this paper and the model.

Critical Analysis of the Design

One of the weaknesses of the design lays within the water consumer side. It is assumed that all of the population consumes exactly the same amount of water and therefore water consumption isn't properly represented in the data. Similarly water scarcity is showcased as a whole but doesn't target specific areas where water extraction for power generation effects local water supply.

One of the benefits of this model is that can clearly expose how sensitive water is to power generation using traditional coal power stations. Without making productions as to state when our water supply would run out. This model merely reflects the state in which our water supply is in.

Origin of the Data

All of the data gathered regarding water consumption comes directly from Eskom's annual reports over the last couple of decades. Due to the accuracy and great details which was encountered during the research one could safely assume that the data is accurate and does not contain within it many flaws. For this reason it was decided that two graphs would be constructed, to compensate for the four year gap, so as to ensure that the information set out would as accurate as possible.

========end of research design ========

Analysis

What follows is a preliminary analysis of the raw data without using the CSF. This done to highlight how efficient the major energy producer is so that it one can measure the effects of that efficiency when getting to the CSF. After which the CSF in logistics form is showcased.

Preliminary Analysis

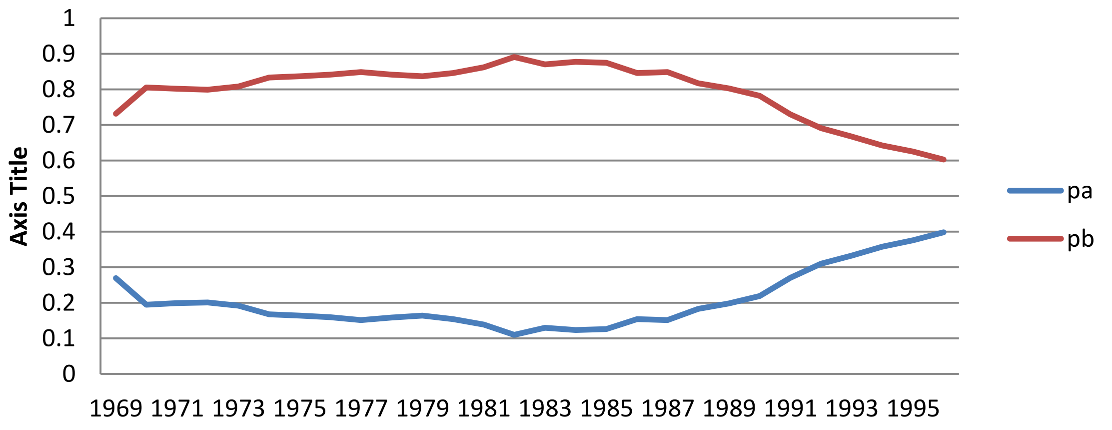
(Insert chart)

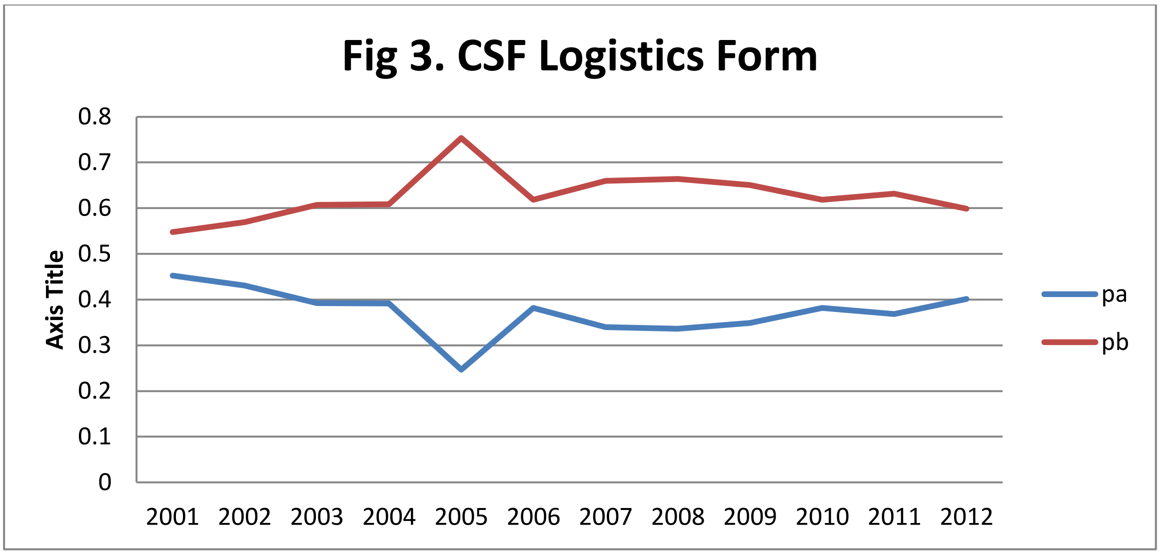
From the above chart one can see the effects of improvement in technology. Even though output constantly increases water consumption does start to decline.

Conflict Success Function

What follows are the Conflict Success Function model of water consumption for power generation.

Fig 2. CSF Logistics Form





Projected Conflict Model Using Proposed Energy Policies

Less water dependant forms of coal energy, namely dry-cooled power plants serves as an alternative to the current wet-cooled power plants. The technology promises to reduce water consumption and is a step in the right direction for the "energy producer". With regards to the conflict model one can see that this move by the "energy producer" will lead to an improved position for the "water consumer".[ii]

The IRP (GET REF) included dry-cooled coal power plants in scenarios for power generation in the future. One scenario estimated that water consumption could be reduced from 336 420 million litres in 2010 to 266 721 million litres in 2030, which is an estimated decrease of 20.8% in water consumption.

Even though this is a considerable decrease in water consumption by the energy producer one has to take into account the fact the demand for water from the water consumer will increase drastically by 2030. This is due to projected increase in the country's population from (GET VALUE) to (GET VALUE). What this entails is that the water "saved' by this scenario of has to cover the percentage increase in the country's population in order for the country to be in the same position that it is in in 2010.

Conflict Model Using IRP Most Environmentally Friendly Scenario

The problem with coal based power generation is that the limited water supply is consumed in order to meet electricity demands from an ever expanding water population. From what has been shown in the conflict model it can be observed that the demand for energy, in the short-run, out way the demand for fresh water in the long-run.

From the model one can observe that the energy producer is more effective and therefore gets more water than the environmentalist. As a result the environmentalist systematically losses more and more resources until they would eventually be left with no resources at hand.

It is clear that the environmentalist cannot win this battle and at the end the energy producer would control all of the fresh water available. This, however, is not a victory for the environmentalist because the moment that the environmentalist controls no water is the moment when the energy producer would have nobody to supply power to.

The conflict model highlights a problem that water is needed in both energy generation and normal consumption. Both parties seek to fight for control over the resource. The solution is therefore to remove one of the two players that are dependent on water from the model.

The only way that this could be done is by means of moving the energy producer away from its water dependency through the use of alternative energy generation. When this is done the (FIND VARIABLE) systematically becomes less as the proportion of electricity generated by means of coal, which consumes water, becomes less. The resultant effect of this is that there is a shift in water from the energy producer to the environmentalist.

The IRP recognized this problem and have created scenarios in which renewable energy is an important factor in future energy production. The scenario that is most environmentally friendly is called “the carbon tax scenario”. This strategy included a carbon tax which causes a shift from the intense reliance on coal power generation technology to more renewable technology.

The technologies that will be focused on in this strategy include nuclear power generation, and hydroelectric energy that will be imported. The resultant effect of this is a decline in water consumption from 336 420 million litres in 2010 to 238 561 million litres in 2030. That is a 29.1% drop in water consumption. Again the same problem arises when one takes into account the amount water that the estimated populace would consume by 2030.

----- Possible Part of the conclusion-----

Alternative Energy as a Viable Economic Solution

Even though renewable energy plants have a high initial cost it should be remembered that after the plant has been built very little input costs are required. This is unlike traditional coal power stations which consumes coal in order to be productive.

It can be argued that coal is a cheap form of energy do to its abundance within Southern Africa. However, according to (Hartnady, 2010), Southern Africa's coal supply is increasingly found in more difficult terrain which makes extraction of the raw material all the more harder to do. Even though coal is currently an abundant form of energy it has a dwindling supply. It will eventually become uneconomical to extract or simply run out.

The exact cost of coal production and the input costs of coal versus alternative energy lay outside of the scope of this article. However it seems prudent to take note of the issues around using energy sources that rely on a constant supply of a raw material in order to generate electricity. Not just in the fact that there is a cost involved in the extraction but also the opportunity cost in consuming the raw material ourselves instead of exporting the raw material to other countries.

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[i] Water in a changing world is the reference.
[ii] Elaborate once the data has been created.