Electrical Energy Planning in South Africa

A Case of Broken Systems Engineering?

Jörg Lalk
Department of Engineering and Technology Management
Graduate School of Technology Management
University of Pretoria
jorg.lalk@up.ac.za

Abstract. It is known that South Africa has slipped from a position of reliable, abundant and cheap electrical energy to that of a country plagued with endemic energy shortages and steeply rising energy prices. The only way to correct this is to embark on a large capital expenditure programme with an aim to rapidly enhance installed power generation capacity. The South African Government, through the Department of Energy, has responded to this challenge by publishing an Integrated Resource Plan, better known as the IRP2010. Although appearing to address different scenarios it has subsequently transpired that this plan falls short in many respects. It is not at all clear whether this plan resulted from a comprehensive and detailed techno-economic modelling and analysis effort let alone whether it addresses the obvious interrelationships with other national imperatives, such as South Africa's COP17 commitment to reduce its GHG emissions and national economic issues. This paper addresses the value of a systems approach to as a means to enhance South Africa's future energy security whilst also addressing environmental and macro-economic priorities. The paper suggests an integrated modelling approach that could be reasonably quickly implemented by using selected best-of-breed tools, making use of their respective strong points and integrating this into an overarching "Energy Modelling Cloud".

Keywords: Systems approach, energy security, energy policy, techno-economic analysis, energy modelling

Introduction

Until about 2006 South Africa was seen as a country with reliable, abundant and cheap energy resources – in fact, at the change to a democratic society in 1994 the country was seen as being blessed with the third cheapest electricity prices globally and Eskom, the national electricity utility, being counted as one of the most reliable utilities. Coal was seen as an almost infinite and cheap fuel for electricity generation. Although the country has some hydro-electrical resources and the only nuclear power station on the African continent, there was little reason to move away from coal as the dominant energy source. This changed by late 2007 when Eskom suffered a number of unplanned plant outages, together with a higher than expected economic growth rate. This created what one could argue was the "perfect energy storm". During 2008 the country suffered rolling blackouts (somewhat diplomatically referred to as "load shedding") that, at its worst, even saw the key mining industry being totally cut off from its electricity supply for long periods, forcing it to shut down operations. The effect on the economy was disastrous, and in some cases industries still have not fully recovered from the subsequent economic fallout. The economic impact on the Gross Domestic Product (GDP) of South Africa was in the order of R200 million per day while the loss to the mining industry during the time it was shut down was claimed to be R250 million per day, (Calldo 2008). Surprisingly, government sources stated at the time that these power blackouts will have no effect on the country's economic growth figures, (Calldo 2008). At the time government admitted that the loss in tax income over this period amounted to ca. R5.9 billion, (Calldo 2008). These events, together with increased pressures to substantially reduce greenhouse gas (GHG) releases, led to a fresh look at what the energy future of South Africa should look like.

During and after the blackouts of 2007 and 2008 a number of government policy and strategy documents were released that were clearly aimed at taking the country towards a more secure energy future, notably the Nuclear Energy Policy, approved by Cabinet during 2008, (DOE 2008d), and the Integrated Resource Plan. Of the latter, the first version, generally known as IRP1, was published in the Government Gazette during December 2008, (DOE 2008a), the second version was published in draft form for public comment during October 2010, and is now generally known as the IRP2010, (DOE 2010b) – this version has subsequently been approved by Cabinet and ratified by Parliament. Others included the Industrial Policy Action Plan, known as IPAP2, in force since April 2008, (DTI 2008), the Energy Efficiency and Demand Side Management Policy, also known as the EEDSM published in May 2010, (DOE 2010a), and the Nuclear Research, Development and Innovation Strategy, known as NERDIS, currently in draft form being reviewed by the Department of Science and Technology, with an approved version expected during 2013, (NECSA 2010), but which never materialised – its current status is unknown. All of these share the issue of energy security and its contribution to job creation, economic growth, research, human capacity building and skills growth. These are also underpinned by the Department of Economic Development's New Development Plan (better known as the "NDP"), a draft of which was released during November 2010, (NPC 2010) – *(Note: although regularly being referred to in speeches by politicians little real movement has been seen in enacting this plan).*

This rather impressive list of national plans creates a strong perception that South Africa's energy future is safe, provided of course that these plans will be timeously implemented. Delving deeper however leads one to suspect that the positive picture painted by such policies and plans does not quite match the current energy realities, with little indication that this energy "chasm" is converging towards a sustainable and environmentally-friendly future. Of course, with the re-appearance of load shedding during March 2014 and the subsequent admission by both Eskom and Government that since shortly after the 2008 load sheddings little attention has been paid to a preventative maintenance regime to ensure reliable power generation.

Today's Reality. Energy production in South Africa is generally viewed as the major contributor to the country's GHG emissions with particularly Sasol (synthetic fuel from coal) and Eskom (electrical utility responsible for almost 95% of South Africa, and 45% of the African continent's electricity generation) the main culprits, (Eskom 2012). It would thus stand to reason that both these entities, and the rest of the South African economy for that matter, would take their environmental impact seriously. This is borne out by many public statements over a number of years by both Government and industry. Trying to fulfil a leadership role the South African state also is generally seen as taking its environmental responsibilities seriously, most recently emphasised by the Minister of Planning's National Development Plan, (NPC 2012).

At the COP 17 meeting during December 2010 the South African Government, eager to demonstrate its willingness to contribute to the international climate debate, undertook to reduce the country's GHG releases by some 34% by 2020 and 42% by 2025 (DEA 2010). These targets are unrealistically optimistic and, unless a major intervention is affected (and there is little evidence to suggest this), probably impossible to achieve. The realities of South Africa's GHG problem is illustrated by the Yale and Columbia Universities' biennial Environmental Performance Index (EPI) published in collaboration with the World Economic Forum (Yale 2012). Figure 1 shows South Africa's slide in EPI ratings since 2006. According to these rankings South Africa is also ranked as 127th from 132 countries in terms of a CO_2 release per kWh and 112th of 132 countries in terms of its uptake of renewable energy resources (Yale 2012).

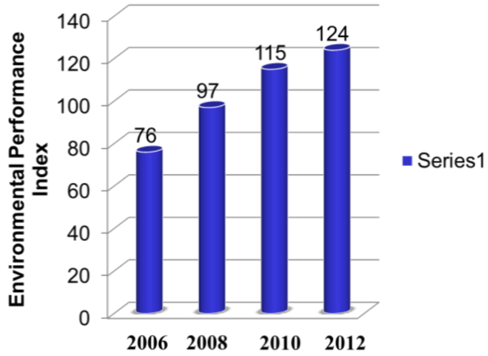

Figure 1. South Africa's slide down the EPI Rankings (Data: Yale 2012)

The slide down the EPI scale has accelerated to such a level that South Africa is now deemed one of the ten "worst sliding countries", (Yale 2012). As it stands, the only countries that are now deemed worse than South Africa are Kazakhstan, Uzbekistan, Turkmenistan and Iraq, in that order (Yale 2012). This illustrates a large gap between where South Africa claims it is heading and where it appears to be heading. Despite all the good intentions of the IRP2010 (DOE 2010) and the NDP (NPC 2012) South Africa is clearly not achieving its environmental objectives, nor is it showing any signs of doing so within the near future. This begs one to question the reasons for this. The answer perhaps lies in the large, seemingly disconnected number of Government policies and strategies that on face value appear to be quite acceptable, with some even deserving the label "good".Closer inspection reveals that many of these are in some instances diametrically opposing. For example the IRP2010 is quite clear in its support for nuclear energy whereas the NDP is not.

Perhaps the following words by Schendler (2009) are appropriate:

"The great flaw in the sustainable business movement today is that few are willing to admit that achieving sustainability is difficult, and maybe impossible, without big changes in the way the world operates."

Clearly major changes are needed in the way both energy security and climate change questions (the two are invariably linked) are addressed. Perhaps a first step in achieving the required big changes would be to change the way we think.

Systems Thinking and Energy Planning

Many researchers use the term “systems thinking” quite loosely without grasping what it really means. Simplistically stated, systems thinking can be seen as a way to address a complex problem from “cradle to grave”. That implies that the *whole problem* is evaluated. For example, when planning a new power station not only should the technical or engineering requirements be taken into consideration, but also all other dimensions as well, including impacts on the environment, population living in its close proximity, local and national economy, its eventual decommissioning, disposal and return of the site to greenfield status. The latter may be as far away as 20 years for most renewable plants, 40-60 years for a coal-fired plant, or even 100+ years for a nuclear plant.

For energy system planning the value of a systems approach is found in its appreciation of overall impacts when changing any aspect of the plan, regardless at what point in the plant’s life.

One needs to tread with caution however, as it is easy (and common) to confuse a systems thinking approach with a lateral thinking approach. Morgan (2005) states that the systems approach is much more than lateral thinking, it includes *“....vertical and horizontal and circular…….thinking”*, which focuses on *“....processes, patterns and relationships…”*.

Johnson and Suskewitz (2009) support this notion and state that in energy system planning

“Governments and businesses must consider projects that balance four components: An enabling <u>technological system</u> conceived in the context of an innovative <u>business model</u>, implemented through a careful <u>market adoption strategy</u>, aided by <u>supportive government policy</u>”.

They warn specifically against the use of existing business and planning models when devising long term energy plans that include a large proportion of renewable energy resources, exactly the type of problem South Africa is now facing.

Seeing the nature of a national energy system and its (complex) relationships with other systems, previously noted, one feels intuitively that a lack of a systems approach when planning such a system would result in expensive mistakes. Early indications of this seems to be evident in the IRP2010 and Government’s actions around this judging from recent statements by various Ministers and other senior public figures. For example, the DOE does not seem to know what the budgeted costs for the anticipated 9600 MW of nuclear power should be. In her February 2012 budget review Energy Minister Dipuo Peters mentioned a R300 billion budget (NT 2012:95), whereas general press reports use estimates in the order of R1.3 trillion (the latter probably closer to reality based on current nuclear project costs). University of Greenwich academic Steve Thomas (2012) went as far as calling the Department of Energy’s nuclear cost estimates *“an exercise in illusion, ignorance and delusion”*.

Viewing the energy picture on a national level then,it becomes evident that it is about much more than just energy security. Other aspects that play an important role in national energy policy should include:

- Resource depletion,
- Sustainability,
- Environmental and climate impacts,

- Economic and employment issues and
- Technology trends.

Analysing the IRP2010 in some detail it is evident that it only addresses a few energy resources, namely coal, hydro, nuclear, wind and solar with a small component of gas. The plan almost totally ignores other resources such as biomass, geothermal and wave/tidal energy. Admittedly some of these are still in the research space and a long way from commercial maturity. But taking into account that the IRP2010 supposedly addresses South Africa's longer term energy security one would expect that the plan also would provide for the achievement of maturity by some of these new resources. In this the IRP2010 fails. Interestingly the latest update of the IRP2010 released for public comment during 2013 (DOE 2013) is a much better effort and attempts to address a bigger picture, pity though that this update was not accepted by Cabinet leaving the original, and flawed, IRP2010 as the plan of choice.

Taking some of the previously mentioned aspects into account goes some way toward illustrating the complexity of the national energy picture (partially also shown by Figure 3). Even then it still remains a rather simplistic view as Figure 3 only focuses on electrical energy. When adding other energy sources such as liquid fuels for the transport industry this picture becomes substantially more complex. For the purposes of this paper, however, the focus will remain only on electrical energy.

There should be no doubt that a country's energy system is probably one of the most complex systems one can imagine. Perhaps one should rather refer to this as a system-of-systems (SoS), which, according to the definition by the International Council on Systems Engineering (Haskins 2011:6) can be defined as *"…a system-of-interest whose system elements are themselves systems; typically these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems*". Not only does a national energy SoS cut across economic and political domains, but it also is extremely complex from a technical perspective. To further complicate matters, the last few years has seen a growing focus on environmental issues. This has become such an issue that it now is almost impossible to focus solely on any energy technology without linking it in some way to climate change and thus to a space largely dominated by the United Nation's Intergovernmental Panel on Climate Change (IPCC), various environmental NGO's and environmental activist organizations such as Earthlife Africa and Greenpeace as well as relevant Government policies.

At the higher level the drivers of a national energy SoS include (at least) environmental, economical and (energy) security dimensions. This can typically be represented in the form of an "Energy Triangle", shown in Figure 2. This shows, as an example, a system that is selected to overwhelmingly lean towards economic performance. It is evident that this would be to the detriment of the other two dimensions.

Of course, should one decide that environmental issues outweigh energy security issues one could re-focus the system more towards the environmental point but this could then negatively impact on energy security. This simple example illustrates that, as in other application areas such as defence systems, a selected system is always the result of a compromise driven by rather complex interrelationships.

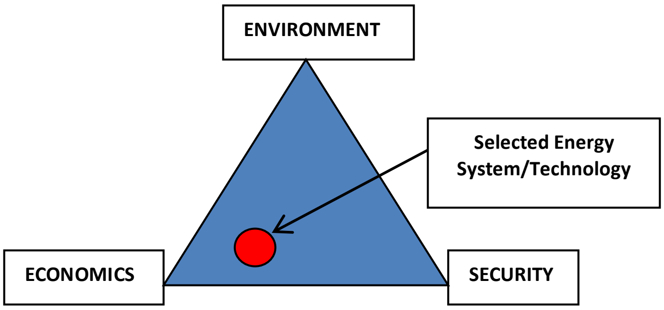

Figure 2. Energy trilemma

The World Energy Council (WEC 2011) views this "trilemma" somewhat differently by defining energy sustainability as based on three core dimensions, namely energy security, environmental impact and social equity. The latter includes the economic dimension shown in Figure 2 but also includes "accessibility and affordability of energy supply across the population", (WEC 2011:7).- *(Note: Very little of the social equity dimension is mentioned in any of the South African energy policy documents).*

Indicative of a lack of systems thinking in setting South Africa's energy policies and strategies is the country's slide in the WEC Energy Sustainability Index from 45th position in 2010 to a very poor 59th position in 2011, (WEC 2011: 18).

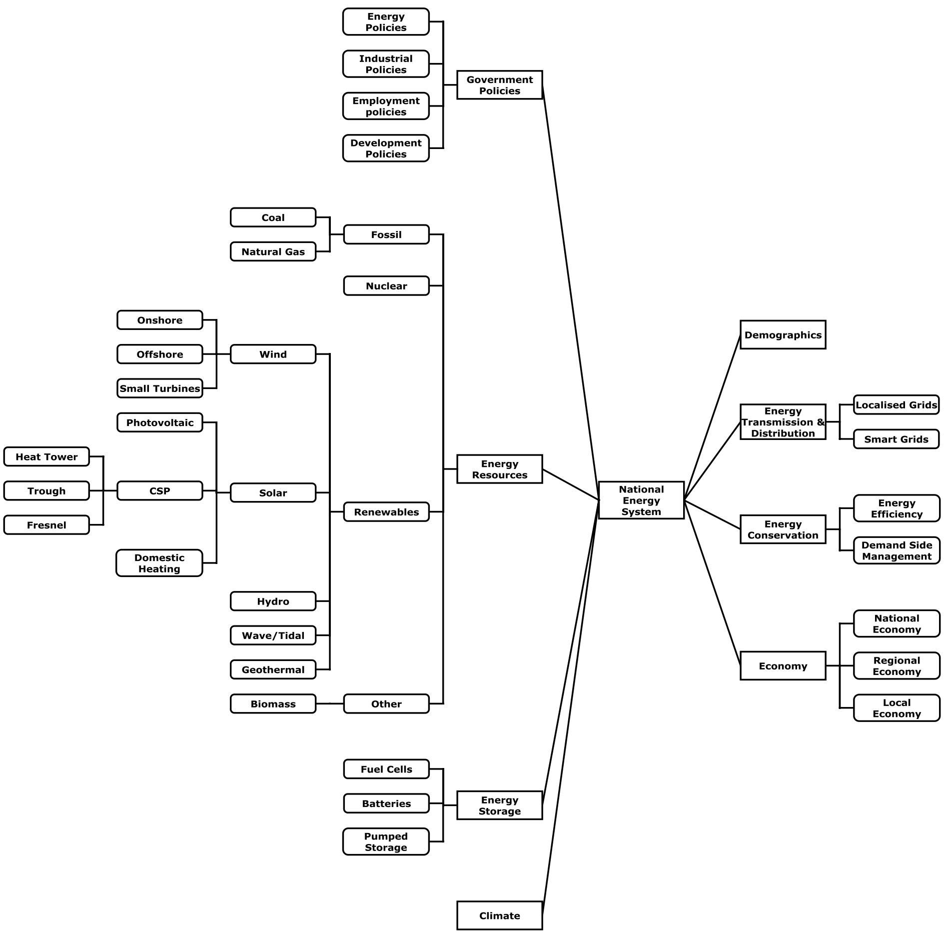

Figure3. Typical (partial) National Energy SoS

It is thus important to consider a national energy system holistically, especially when it comes to policy, investment and technology decisions. It would appear that the South African government's future energy decisions will be largely driven by the existing IRP2010 plan, but to some extent the importance of the IRP2010 seems to have been overtaken by the NDP- (*Note: there are also glaring contradictions between both these plans, yet both seem to enjoy solid Government support).* An open question that does remain though is how well, if at all, the systems engineering aspects were addressed during the development of these plans. On face-value these plans appear to provide for a reasonable mix of energy technologies, but when analysing them in more detail a number of questions arise.

Emergence of properties. Of particular concern when planning a national energy system is the phenomena of emergence. This has become a research focus in recent years and is particularly evident in a large complex SoS. Emergent properties of such a system do not arise from the individual components but are a result of the dynamics of the interrelationships between these components. These properties of a national energy system are difficult to predict as there exists so many complex interrelationships and permutations of such interrelationships. Figure 3 illustrates a typical complex national energy system. To complicate matters further each of the components shown (e.g. nuclear energy) is a highly complex system in own right with its own emergent properties. Current research by the author focuses on a systems engineering process model that can address such complex problems.- *(Note: this research extends substantially further than the issues with modelling tools also addressed by this paper)*

One way to (at least partially) predict such a system's emergent properties is found in complex techno-economic models. This is addressed in some detail later.

Benefits of a systems approach. There exists ample evidence from both literature and case studies demonstrating the benefits of a systems approach, particularly when dealing with a complex system, (Honour 2004). Within the energy domain some of the more obvious benefits include:

- Better insight and understanding of energy system interdependencies,
- Better selection of a correct energy mix to address a national, regional and local energy needs. In the case at hand it is well-known that South Africa has an energy intensive economy, mainly driven by the mining and mineral beneficiation sectors. This situation will not change in the foreseeable future and hence the country requires a reliable base-load solution (currently only supplied by coal, nuclear and limited hydro-power),
- Better policy making. This of course pre-supposes a good understanding by political decision makers of who the stakeholders are, factors influencing the economy, and so on,
- Accurate identification of key energy indicators and targets,
- Better understanding of geographic and regional peculiarities,
- The ability to do rapid and accurate "what if" analyses, and the ability to include the results timeously into national policies,
- Provided that the systems methodology followed is correct according to appropriate standards, such as the ISO/EIA 15288 standard, it provides for a common vocabulary making information exchange between stakeholders more accurate and less prone to costly misunderstandings.

Energy planning

Having stated that a proper systems perspective appears to be missing in the way South Africa's current longer term energy planning issues are being addressed, it begs the question as to how this should be addressed instead. The solution lies in a systems life cycle view.

The well-known systems life cycle (SLC), (Haskins2011:26), starts off by determining the system "need", in this case the "need" would allude to what the customer would require from a system. Here it is easy to confuse "need" and "requirement", the latter eludes to the technical specifications a perceived solution (or system) must comply to (in order to meet the customer need) whereas the former really has more to do with what the customer wants (in his or her own reference frame, and usually stated in non-technical language including many non-technical aspects such as standards, legal, financial, and so on) or put differently "understanding the problem". In order to achieve this one would attempt to answer, amongst others, the following questions, (Haskins 2011):

- Can we define the long, medium and short term national/regional/local energy needs? This is not a simple question as the answer is highly dependent on economic predictions (including the possible impact of international economic events on our own economy), population growth, and so on.
- Do we know what technologies will support our energy needs?
- How can we integrate these technologies into the existing energy system? And how do we identify future insertion points for technologies currently not mature but showing future promise?
- Where do we position new energy capacity? What about transmission and distribution infrastructure?
- Do we need new technologies, and for that matter any new capacity? When, and what about phasing out existing capacitythat reached end-of-life?
- How do we address future technology obsolescence?
- Do we know all the interfaces (and "outerfaces") with, for example existing plant, climate, externalities, policies, and so on.
- What about the likelihood of, and impact of, any incorrect planning decisions? Put differently, how do we intend to include risk identification and mitigation into our planning?

It is critically important to be able to address these questions. If this is not done it is easy to be pulled into popular arguments for and against specific energy technologies. This in itself appears to be well-understood systems engineering techniques, yet when it comes to national energy systems the choice of technologies is also largely driven by political considerations as well as socio-economic issues such as job creation. To illustrate the wider issues when it comes to these are described by way of two case examples:

- **Case Example 1:** It has long been believed that a resource such as wind together with wind turbines would contribute to lessening the effects of man-made climate change. Recently however, research by Liming Zhou, Research Associate Professor with the Department of Atmospheric and Environmental Sciences at the University of New York, found that according to satellite data large wind farms in Texas do in fact contribute measurably to local climate warming due to the turbulence caused by the large turbine blades. Temperature increases up to 0.72°C/decade were observed, (Zhou 2012). Furthermore, it is suggested that large wind farms would have a long term effect on local wind and weather patterns, (Gray 2012). Other aspects that come to the fore include transmission system instabilities caused by the random nature of especially wind generation. Point is, without a proper systems engineering effort, supported by relevant modelling actions, the new, supposedly environmentally friendly technologies such as solar and wind, could have unintended negative impacts on both efforts to stem climate change and the security of energy supply. Following this would be accompanying negative economic effects.

- **Case Example 2:** Meyer (2010) describes in some detail the visible impact due to a change in the Danish government's energy policies during the early 2000's which impeded quite dramatically (caused by ignoring the bigger picture)the growth in new installed wind energy capacity. This is illustrated in figure 4.

Many other examples (Liu 2007, Reddy et al 1995, Rad 2011 and Hoffman 1974) support the notion that without a proper holistic or big picture understanding of what a national energy system includes, what impacts on it, and on what it impacts in turn, it is almost impossible to achieve any notion of a realisticand accurate national energy plan.

Pierre Sellal (2012) stated that when a national energy policy is being formulated it needs to meet essentially three objectives, namely competitiveness, supply security and sustainability. The first objective, namely competiveness is usually the first area of focus of various pressure groups. Yu and Parsons (2009:4) found that (in 2007 US Dollars) the overnight cost of nuclear new-build in the USA is in the region of \$4000/kW and coal (excluding any carbon tax) \$2300/kW. The figures for nuclear new-build in South Korea seem to correlate well with US figures (Yu and Parsons 2009:11).

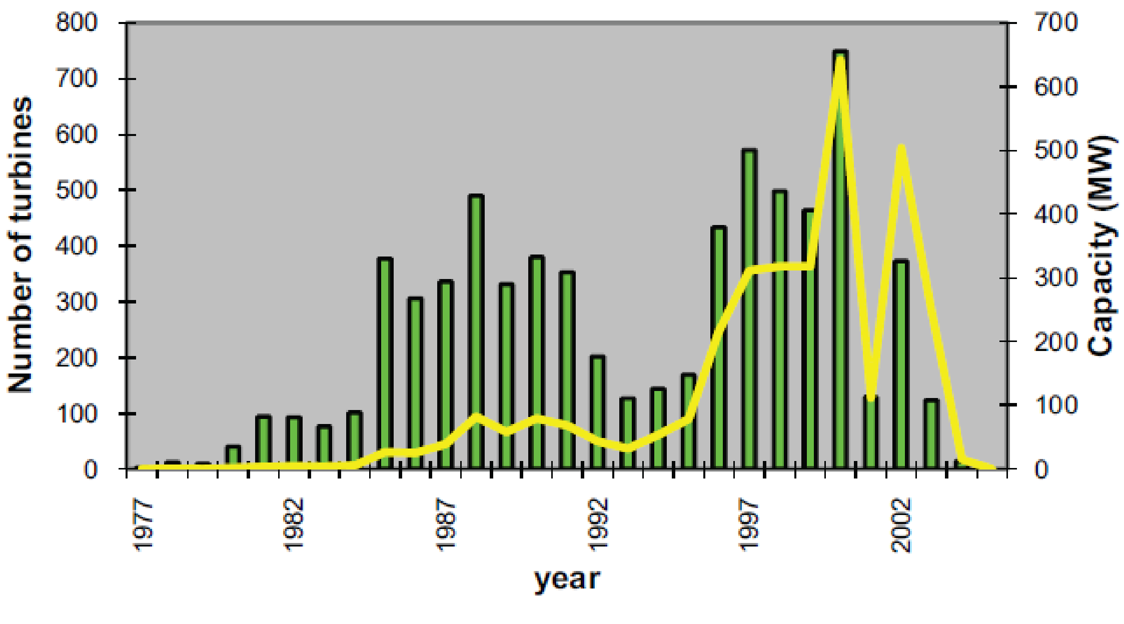

Figure 4. Unintended impact of policy changes (Source: Meyer 2010)

These values can be compared with the problematic nuclear projects under way in Finland (Olkiluoto project) and France (Flammanville project) where both the new EPR1000 reactors have been suffering from cost and schedule slippage. These new plants would now be expected to cost in the region of \$4000/kW (overnight) after increasing from the original projections of \$2800/kW. One should also note however that the Olkiluoto project's price increase includes a correction from 2005 monetary value to 2008 values. These two projects are popular with the anti-nuclear lobby as an instrument to "prove" that nuclear is impossible to accurately cost. The reality however is that both these projects are building the first plants of the Areva ERP1000 design which is a new design and should be regarded as "first-of-a-kind" (FOAK). In concert with experiences in other industries where a FOAK design is being built one should expect uncertainties in especially cost and schedule, and probably performance as well. This is conveniently ignored by those opposed to such projects.

Interestingly enough one finds a similar trend when examining some of the new renewable technologies. Good examples would be the Spanish Olmedilla de Alercon and US Agua Caliente projects. In the case of the former relatively old photo voltaic technologies are used to generate some 60MW. But at a project cost of some $530 million this equates to an overnight cost of $8800/kW. As is typical for plants of this nature availability is only typically 17%. In the case of the latter which is still under construction with completion aimed for in 2015 newer thin film technologies are used with project cost in the region of $1.8 billion for a plant capacity of 290MW. In this case the overnight cost is somewhat lower than that of Olmedilla de Allercon, namely $6200/kW, again at an availability factor of around 17% (First Solar 2012).

These examples lend further support to the case for a proper systems approach when planning energy systems.

Integrated Energy Modelling

As is the case in most instances where modelling and simulation is required, a plethora of different software tools are available. The selection of an appropriate tool is usually informed by specific modelling requirements. But in the main, modellers select a tool because of personal preference or previous experience (Banks 1991). This is also true when selecting a tool for modelling energy systems.

It should be emphasised that, for energy-related modelling,some 68 different tools are available, with most aimed at a particular aspect of the greater energy modelling effort. This may include Supply/Demand Models, Policy Models, Climate Models, and so on. The excellent paper by Connolly and his co-workers (Connolly 2010) describes most of the popular tools in substantial detail.

The large number of available tools leaves the modeller with the problem of selecting an appropriate tool. Banks (1991) found that some of the aspects that need to be taken into account when selecting modelling tools include development time, model control, output data formats, accuracy/fidelity, training requirements and the required tool runtime environment. What should be added to Bank's list are data management, access to meta-models and data as well as ease of integration with other tools (driven by the availability of open interface standards and access to meta- models). These latter aspects are critical going forward with an integrated modelling environment. Some researchers (GIZ 2011) have attempted to expand the use of available tools into an integrated modelling view.

This work by GIZ (2011) is valuable as it also attempted, seemingly for the first time, to include aspects of the national transmission problem. Furthermore this includes parts of the Southern African Power Pool (SAPP). This is in contrast to most local modelling efforts that, to date, focused only on South Africa.

The GIZ (2011) model is shown in Figure 5. This model also attempts to address transmission constraints (represented by the solid lines between the generating regions).

Although the work by GIZ (2011) provides a valuable step towards understanding the bigger issues of national energy planning, this work does fall somewhat short in that it does not include all of the SAPP members. Countries such as Zimbabwe, Botswana, Zambia, DRC, Tanzania, etc. seem to be excluded from the GIZ effort.

When, on a national level, energy modellers attempt to address the national energy view, all using different tools and each focussing on only specific areas of the larger energy picture it becomes almost impossible to build a holistic integrated model of South Africa's energy system. When different datasets and standards are used the problem is compounded.

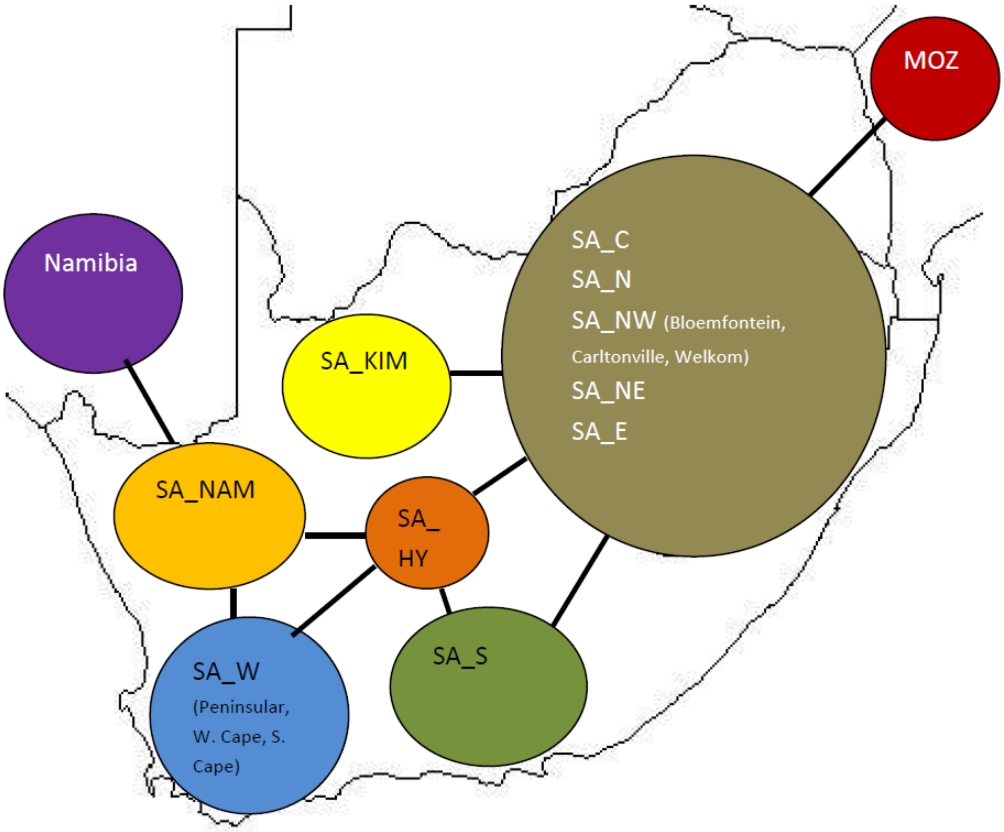

Figure 5. Expanding Energy Modelling Beyond South Africa (Source: GIZ 2011)

A possible solution would be the development of an integrated energy modelling environment which has sufficient flexibility for modellers to still use their preferred tools, but which allows for various models to exchange information/results in such a way that a national dataset is also being built over time, independent of specific modelling tools. A proposed architecture is shown by Figure 6.

The benefit of using such an integrative "cloud" lies in the fact that it allows users of various modelling tools to share their models and results with other users, even if they are using different tools. Furthermore this architecture would enhance the availability of a national energy database in support of ongoing national energy strategy development. This addresses one of the major shortcomings in energy modelling on a national level. Currently such an integration cloud is being developed, with the first beta testing scheduled for early 2017.

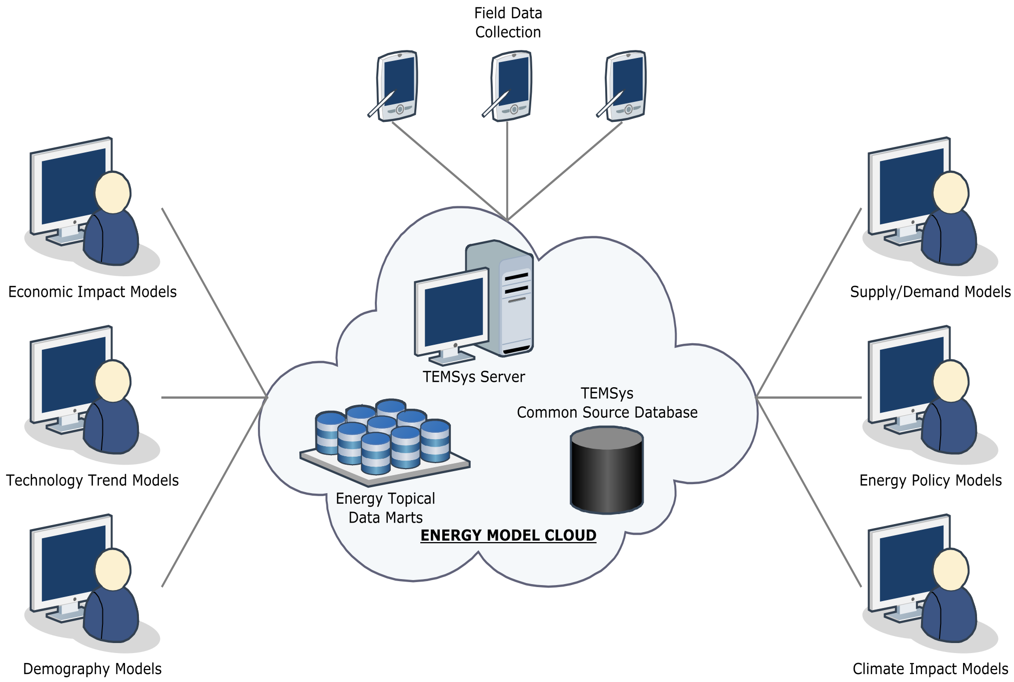

Figure 6. Proposed Integrated Energy Modelling System

Conclusion

Using a systems approach, the existing problems with integrating various activities and attempts to national energy planning in a coherent and efficient manner.

Almost four years after the IRP2010's publication and ratification by the South African government it is becoming evident that many questions regarding South Africa's energy future (and the underlying planning assumptions, datasets, processes and tools) remain unanswered. The newer National Development Plan (NPC 2012) complicates the issue even more. Much of this uncertainty can be traced back to what appears to be poorly integrated energy modelling efforts, and, in the bigger sense, a distinct lack of a systems approach to South Africa's longer term energy planning. This leads one to suspect that the IRP2010 is not correct and in fact contains many serious errors.- *(Note: as mentioned before some of these errors and incorrect assumptions seem to have been addressed by the updated version of the IRP2010, but this seems to have been discarded by political decision makers).*

On the energy modelling front no platform exists to support the integration of the various modelling activities (and tools). A suggested solution for this would be to develop a dedicated Energy Modelling Integration "Cloud" employing some of the basic principles of cloud computing, (Armbrust 2010). Although currently aimed at addressing the more pressing need of electrical energy shortages, the proposed solution can easily be expanded to also address other energy resources, for example liquid fuels, bio-fuels, and so on. Such an integrative platform would go a long way supporting the required systems approach when planning South Africa's energy future.

Failing this the only alternative would remain to attempt to manually integrate the outputs of many individual modelling efforts (and tools) that would lead to years of inefficient modelling, endless arguments as to which methodologies and tools are the best, and so on.- *(Note: A plethora of modelling tools are being used, OSYMOSYS by the Department of Energy, PLEXOS by Eskom, as well as various dynamic modelling tools also by Eskom, LEAP, TIMES-MARKAL, MATLAB and GAMS by various researchers at various universities, and so on; experience in other fields of modelling has shown that it would be almost impossible to convince various modelling interests to standardize on a single tool set).* In the mean time almost daily load shedding will continue unabated with typical crisis reactions being contemplated by Eskom but without addressing the real problem of a systems focused planning environment.

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