Addressing energy problems in South Africa

Dr Jörg Lalk

During 2008, the South African economy suffered massive losses due to a steadily growing shortage of electrical energy, which reached a peak when widespread blackouts – also known as "load shedding" – became common. Most areas had to deal with at least four hours of load shedding a day.

As a result, the South African Department of Energy (DoE) developed a long-term roadmap, commonly known as the Integrated Resource Plan 2010 (IRP 2010). The IRP 2010 captured the government's vision of electrical energy capacity growth between 2010 and 2030 and envisaged an increase of installed capacity from approximately 42 GW in 2010 to approximately 85 GW by 2030 (Department of Energy, 2010).

During the development of the IRP 2010, which was a first for the South African government, some energy forecasting and modelling was conducted. An open-source tool, the Open Source Energy Modelling System (OSeMOSYS) (Howells et al., 2011) was used for this. After the publication of the IRP 2010, it became clear that the anticipated installed capacity of 85 GW by 2030 may not be realistic, as the economic growth figure of 4 to 6%, which was assumed during the initial modelling, will probably not be achieved. According to data that has been collected since 1994, it seems more reasonable to assume a growth figure of approximately 2.5%. This is further supported by the latest figure of only 1.9% for 2013. Forecasts for 2014 were in the region of 2.1% (see Figure 1).

With the latest prediction of only 1.5% by the South African Reserve Bank, it is evident that the South African economy is not growing nearly as much as anticipated. This scenario is affected by much higher electrical energy prices and an increased awareness of how South Africa's largely coal-based energy economy affects climate change.

A closer inspection of the complexities of energy analysis and planning at a national level reveals that one is not only dealing with the direct complexities of energy systems, but also with the impact of other factors, such as the national economy and climate change. Briefly, one is dealing with what can be classified as a "wicked problem". Such problems are difficult to formulate, have only "good" or "bad" solutions, have limited opportunities to learn by trial and error, and are essentially unique (Rittel and Webber, 1973, in Camillus, 2008). This explains why different analysis studies tend to show opposing results. It remains problematic to develop models of what is essentially a multidisciplinary and complex environment.

As part of the University of Pretoria's pursuit to produce world-class research, a number of Institutional Research Themes (IRTs) were identified, of which Energy is one. In order to expand research on the IRT on Energy, the Energy Analysis Research Group was established in the Graduate School of Technology Management. The Group attempts to address many of the problems related to national energy issues. An important aspect of the Group's research is that a proper systems approach, which makes it possible to deal with the wicked problems of energy analysis, is being followed. Since its inception, the Group has attracted some 23 postgraduate research students and two postdoctoral researchers, who are working on a number of subtopics in the energy analysis domain.

Two of the Group's research focus areas, system modelling and analysis and climate/energy system interaction, are particularly important. The latter is concerned with the impact of climate change on energy systems, as opposed to studying the benefits of so-called environmentally friendly energy systems, such as wind and solar power. The Group is focusing on studying the influence climate change has on renewable energy systems, as well as coal, hydro- and nuclear power systems.

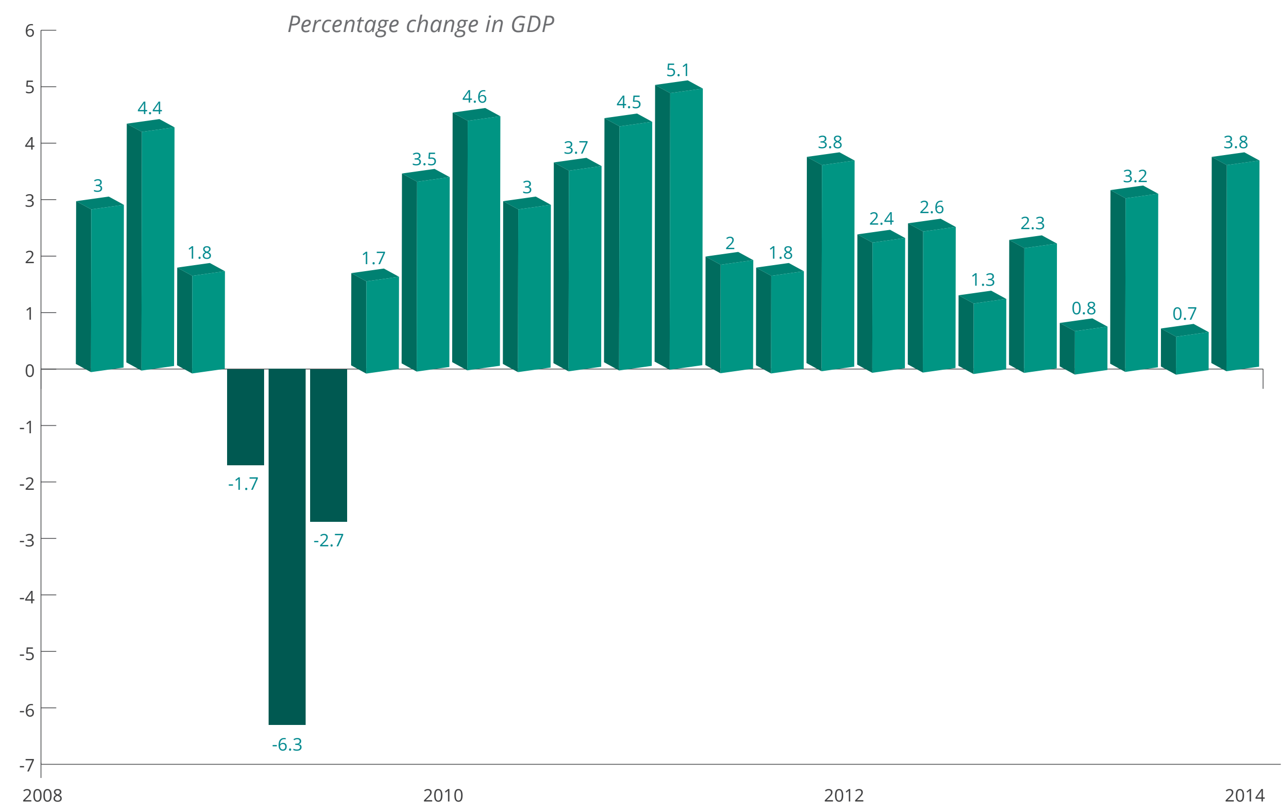


Figure 1: Historical data of South Africa's gross domestic product (GDP) growth rate. (Source: www.tradingeconomics.com.)

The starting point of the research is that climate change is a certainty, irrespective of how much human activity contributes. Ignoring this fact may lead, for example, to wind farms being positioned in areas where, in a few decades, the prevailing wind patterns shift so much that they can no longer effectively produce electrical energy.

Studies that analyse the impact of climate change on wind resources usually only model changes in wind speed. The Group's study took this a step further by determining how different wind speeds affect annual energy production (AEP) and power density. The research provides a more accurate description of how altered wind speeds could affect the most important factor of a project's feasibility: the electrical energy output.

When determining the AEP in the Wind Atlas Analysis and Application Program (WAsP)™ software simulation tool, the power curve, of whichever turbine(s) occur in the area-assessed resource grid, is determined (Herbst and Lalk, 2013). For this study, only wind speed was

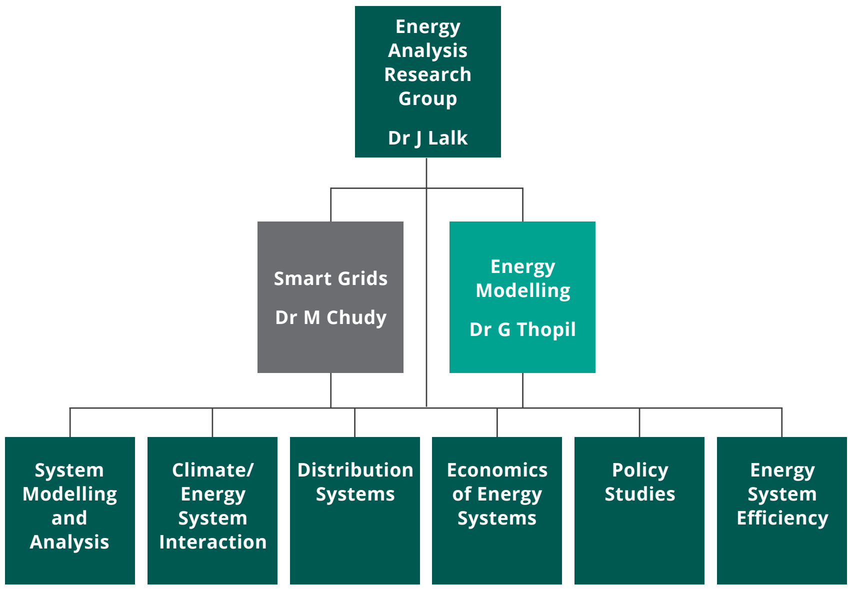
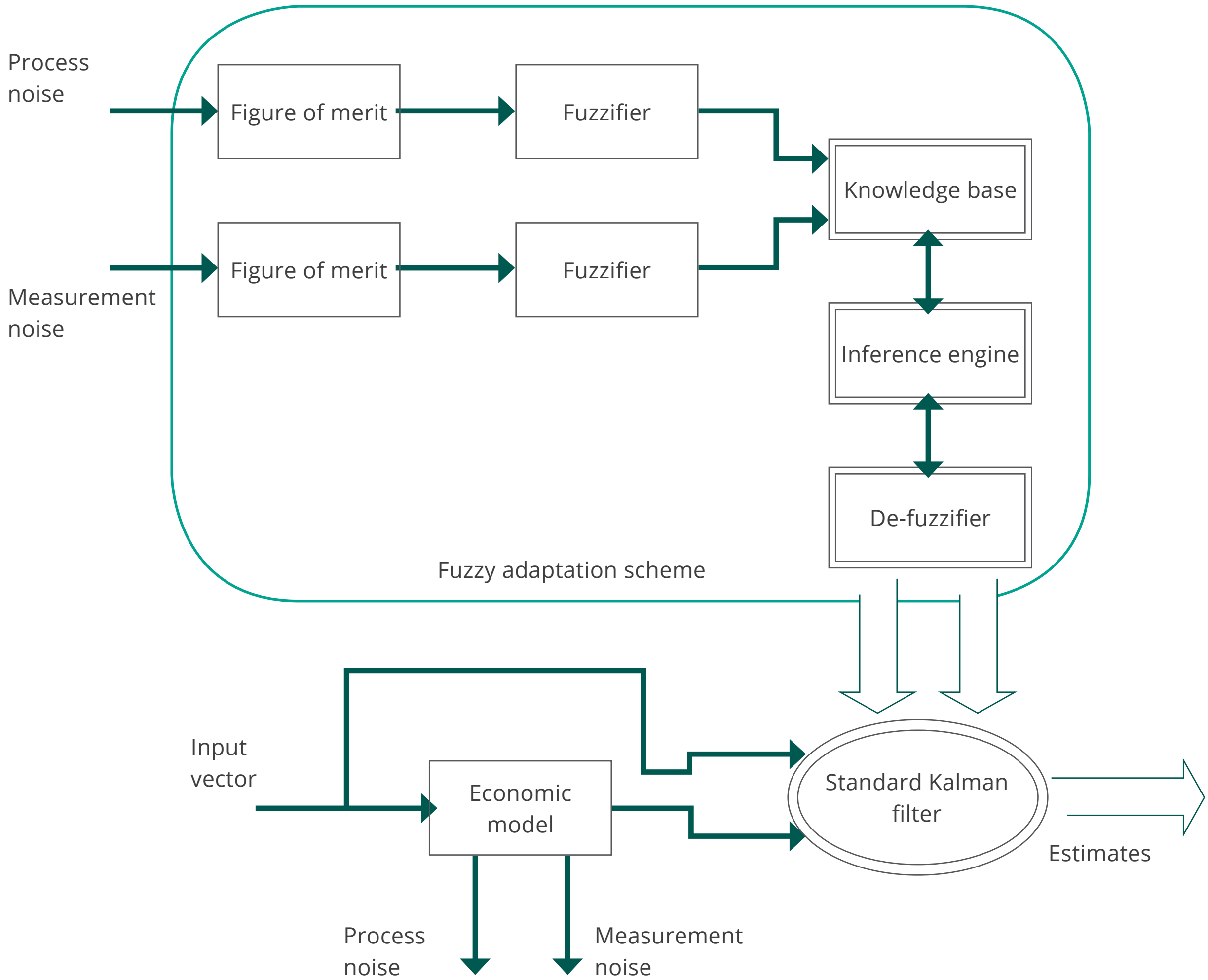


Figure 2: Subtopics being examined by the Energy Analysis Research Group.

modified. If the climate changes, a number of other factors may also be affected, possibly also influencing electricity output from individual wind turbines and/or wind farms. During this project, an initial study was completed that used information from existing wind sensor masts operated by the Council for Scientific and Industrial Research (CSIR) (Herbst and Lalk, 2013).

In 2014, this research has been extended in collaboration with the University of Stuttgart and the CSIR to cover other energy resources.

System modelling and analysis involves advanced modelling techniques applicable to the analysis and long-term forecasting of energy needs.



→ *Figure 3: A fuzzy adaptive Kalman filter (KA-KF). (Adapted from Lalk, 1994a; Lalk, 1994b.)*

There are two main types of forecasting techniques: qualitative and quantitative methods. The qualitative technique is subjective and relies mainly on the "opinions" of expert individuals using the well-known Delphi method (Dalkey, 1969). The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method that relies on a panel of experts. Although this method is useful when little historical data exists, it is open to individual manipulation and individual bias. The quantitative method is more common and is especially useful where historical data exists.

In conjunction with a (statistical) forecasting model, this method identifies trends in the historical data and uses these to forecast a certain future (using the forecasting model embedded in the forecasting tool).

Although a number of forecasting tools are available, the trend is to use an advanced estimator such as a Kalman filter. The Kalman filter is a set of mathematical equations that provides an efficient computational way of estimating the state of a process in a way that minimises the mean squared error. In statistics, the mean squared error (MSE) of an estimator measures the average of the squares of the "errors"; that is, the difference between the estimator and what is estimated.

The Kalman filter was initially used widely in weapon systems, in particular anti-aircraft systems, where it is critical to predict a target's position in space at a certain future time to ensure a direct hit on the target aircraft or missile.

Some of the Group's current work focuses on a type of Kalman filter that is particularly well suited for so-called wicked problems, such as South Africa's national energy system. Artificial intelligence techniques, such as fuzzy logic, are used in this research. Previous experience and research has illustrated that such an estimation scheme not only allows for more accurate estimation results, but provides the ability to dynamically adapt to changing economic parameters by using fuzzy logic schemes as adaptation schemes for a standard Kalman filter.

The underlying work for such a scheme was performed by Lalk (1994a, 1994b). This work has shown that the application of fuzzy logic has a number of benefits. A typical scheme is illustrated in Figure 3. Of course, the actual estimation scheme is substantially more complex than shown in Figure 3. Although a standard Kalman filter is being used, the scheme's complexity lies in the setup of the fuzzy adaptation scheme, including the design of a workable figure of merit algorithm.

Many of these details will be covered by future publications as the research progresses.

References

Camillus, JC. 2008. Strategy as a wicked problem. *Harvard Business Review*. [Online]. Available at http://hbr.org/2008/05/strategy-as-a-wicked-problem/ar/1. Accessed: 6 May 2014.

Dalkey, NC. 1969. *The DELPHI method: An experimental study of group opinion*. RM-5888-PP. RAND Corporation.

Department of Energy. 2010. *Integrated Resource Plan 2010*. Pretoria: Department of Energy.

Herbst, L & Lalk, J. 2013. The effect of climate variability on wind resources in South Africa (submitted to the *Journal of Energy in Southern Africa*, awaiting review).

Howells, M, Rogner, H, Strachan N, Heaps, C, Huntington, H, Kypreos, S, Hughes, A, Silveira, S, De Carolis, J, Bazillan, M & Roehrl, A. 2011. OSeMOSYS: The open source energy modelling system: An introduction to its ethos, structure, and development. *Energy Policy* 39(10): 5850–5870.

Lalk, J. 1994a. Novel expert system strategies for Kalman filter adaptation. PhD thesis. Bedford: Cranfield University.

Lalk, J. 1994b. Intelligent adaptation of Kalman filters using fuzzy logic. *Proceedings of the Third IEEE International Conference on Fuzzy Systems*, Orlando, June 1994, pp. 744–749.

Statistics South Africa. [Online]. Available at www.tradingeconomics.com.

***Dr Jörg Lalk** is associated with the Graduate School of Technology Management in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria.*

World's top solar thermal specialists share their expertise

South Africa is making increasing advances in the field of solar thermal energy. During the past few years, more plans for concentrated solar power (CSP) plants have been seeing the light. One such project is the Karoshoek project near Upington in the Northern Cape. Solar thermal experts from across the world have recognised South Africa's potential to develop sustainable solar thermal energy plants because of the country's high solar radiation levels.

In response to this realisation, some of the world's top solar thermal experts offered a specialist workshop on solar heat for industrial applications at the University of Pretoria in February 2014. The workshop was presented by the Southern African Training and Demonstration Initiative (SOLTRAIN), a three-year project to enhance solar thermal technology in Southern Africa.

The aim of the project is to support Southern African Development Community (SADC) countries to develop sustainable renewable energy plants. The 36 delegates were limited to persons who had attended previous SOLTRAIN courses, or who have experience of large solar-heated water systems in Lesotho, Mozambique, Namibia, South Africa and Zimbabwe. This train-the-trainer workshop was sponsored by the Austrian Development Agency and was coordinated by the Sustainable Energy Society of Southern Africa (SESSA).

"South Africa and the SADC region urgently need this expertise," says Prof Dieter Holm, regional SOLTRAIN coordinator for Southern Africa, "and this is a cost-effective way of creating decent long-term jobs." The Austrian project leader of SOLTRAIN, Werner Weiss, concurs: "Southern Africa has twice Austria's sunshine."

The University of Pretoria is the SADC leader in the use of solar water heating in its student residences. The University is also building a thermal demonstration unit for practical experiments by students. The Hatfield Campus falls in SOLTRAIN's Solar Thermal Flagship District, where various installations can be visited by technical tourists and political decision-makers.

Southern Africa boasts 59% of the world's best winter sunshine areas, but does not rank among the global solar thermal power leaders. "Not yet," says Prof Holm, "but, given enabling legislation and leadership by example in government buildings, we could create a sustainable and competitive solar water heating industry in the region. A strong local solar water-heating industry will earn forex, decrease our chronic regional electricity problem, reduce pollution and contribute to achieving our environmental commitments."