Challenges Facing South Africa's Electricity Sector's Integrated Resource Plan

A Qualitative System Dynamics Approach

L Mqadi*
PhD candidate School of Public Leadership
Stellenbosch University

J K Musango
School of Public Leadership
Stellenbosch University

A C Brent
School of Public Leadership
Stellenbosch University

ABSTRACT

National electricity plans are policy approaches that provide opportunities for integrated, goal-oriented electricity transition management. This article provides a critical reflection of the challenges that face the Integrated Resources Plan (IRP) of South Africa, which include the misalignment of the electricity sector's long-term plan with other national strategic plans, and the minimal endogenisation of this long-term plan into existing sustainability transitions governance frameworks. The article argues that the use of qualitative system dynamics, particularly causal loop diagrams, can be useful in learning about the key feedback loops that relate to the IRP development process challenges in South Africa. The results show that resistance to IRP development, adoption and its overall implementation has contributed negatively to the electricity sustainability transitions agenda. Further, current solutions merely deal with symptoms rather than the root cause of the IRP challenges. An integrated sustainable electricity transitions framework is thus proposed, aimed at improving South Africa's electricity sustainability transitions agenda. The article finally argues the need to entrench the sustainability transitions-based framework in the existing IRP policy development process in South Africa.

INTRODUCTION

Countries make different governance choices as part of the highly complex and unprecedented process of enabling profound energy system transitions with the aim of ensuring affordable and secure energy services (Kuzemko, Lockwood, Mitchell and Hoggett 2016:97). In this instance, governance processes are used to ensure the provision of energy as a public good and to address the associated market failures (e.g. externalities), while policy governance structures specifically play a vital role in the security of energy supply (Morlet and Keirstead 2013:853). This in turn affects other sectors that rely on energy, such as residential, transportation and industry sectors (Markard, Raven and Truffer 2012:955–967; Edomah, Foulds and Jones 2017:476–485).

Edomah *et al.* (2017:476–485) define governance as a process of determining who can do what, and who would monitor it, including how rules are modified and changed over time. Governance includes any of the myriad processes through which a group of people can enforce the rules needed to enable that group to achieve desired outcomes. Furthermore, governance comprises rules, incentives and institutions that drive its successful implementation, while technological innovations and market actors remain the main drivers of change (Kuzemko *et al.* 2016:98). Kuzemko *et al.* (2016:97) further stress that governing for sustainability transitions is contingent upon both broader policy processes and related domestic policy institutions as well as on indigenous (energy) resources. Therefore, different configurations of policy processes, institutions and indigenous energy resources tend to influence the types of governance choices made and the nature of changes, including the related complex and unprecedented challenges encountered in electricity systems (Kuzemko *et al.* 2016:96–97).

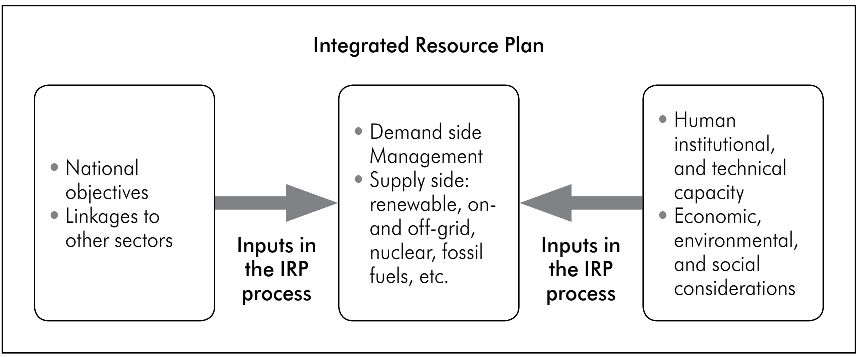
Within the electricity sector, long-term planning is one configuration entailing a complex process that often includes contradictory and complex sustainability objectives, all aimed at transitioning the sector. As such, traditional approaches to electricity sector planning have focused mainly on projections of future electricity demand and the expansion required in terms of electricity supply to meet the anticipated demand (Dixit, Chitnis, Jairaj, Martin, Wood and Kundu 2014:3); this is based on a stable monopolistic world without any competition, and therefore with little financial uncertainty (Dyner and Larsen 2001:1146). This has often resulted in excess capacity and higher-than-necessary energy costs, while far less attention has been paid to sustainability, such as social and environmental welfare, or what may be termed 'public benefits' (Dixit *et al.* 2014:4–6). Furthermore, how policies for planning have been developed have also affected how these approaches have eventually been implemented, sometimes leading to minimal integration of the plans into appropriate governance frameworks. This further has led to the need for sustainability transitions approaches to guide policies for planning (Dixit *et al.* 2014:3–14).

In the early 1970s, power utilities began to evolve owing to increasing public awareness of sustainability issues in relation to electricity demand and supply, energy planning complexities, including the role of various stakeholders and required processes, and electricity sector planning frameworks (D'Sa 2005:1271). The IRP was promoted as a policy development process approach for government's macro-strategic planning process, aimed at developing energy resource strategies and maximising related national benefits. It provided an integrated plan for the power system (Hu, Tan, Yang, Yang, Wen, Shan and Han 2010:6391). The IRP was also an approach intended to meet the estimated long-term requirements for electricity services during a specified period with a least-cost combination of supply and end-use efficiency measures while incorporating equity, environmental protection, reliability and other country-specific goals (D'Sa 2005:1272). Figure 1 provides an overview of the IRP as an electricity sector policy planning process (D'Sa 2005:1271–1285; Dixit *et al.* 2014:4).

By the late 1990s, the concept of an IRP had been introduced in most developing countries. However, only a few utilities in these countries developed comprehensive electricity plans based on an IRP (Malik and Sumaoy 2003:712). China, Brazil, South Africa, India, and Thailand each initiated a unique approach to developing an IRP (Hu, Tan *et al.* 2010:6391–6397; Hu, Wen, Wang, Tan, Nezhad, Shan and Han 2010:4635–4642; Dixit *et al.* 2014:6). Coincidentally, in these countries, transitions challenges of privatisation and deregulation influenced the IRP development. This prompted a modification of the respective IRPs to fit the new power utility business environment driven by various stakeholders with sometimes varying and competing sustainability objectives (Malik and Sumaoy 2003:712; D'Sa 2005:1274–1278).

It is in this context that this article examines the sustainability transitions agenda within South Africa's electricity sector, with a focus on long-term planning and its overall governance, and specifically the IRP as a policy planning approach.

Figure 1: IRP 2010–2030: The Approach



Source: (Adapted from D'Sa (2005:1271–1285 and Dixit *et al.* 2014:4)

SUSTAINABILITY TRANSITIONS, POLICY DEVELOPMENT AND POLITICAL DYNAMICS

Markard *et al.* (2012:956) describe sustainability transitions as a set of processes that lead to a fundamental shift in socio-technical systems with far-reaching changes along different dimensions. These include: technological, material, organisational, institutional, political, economic, and socio-cultural. Furthermore, these socio-technical systems change structurally over an extended period of time, thus involving a broad range of actors or stakeholders while typically unfolding over considerable time spans (50 years and more) (Kern and Smith, 2008:4094). Therefore, studies of complex problems are often aimed at understanding how sustainability transition evolves over time (Markard *et al.* 2012:956–957). Further, the sustainability transition management policies are not meant to replace regular policies, but rather complement policies with a strategic, long-term procedural, governance and transformational approach aimed at structural change (Kern and Smith 2008:4094).

According to Markard *et al.* (2016:216), despite the crucial role of policy development and political economy dynamics in sustainability transitions, circumstances that make the adoption and endogenisation of such policies possible are rarely considered. To illustrate this, Markard, Suter and Ingold (2016:216–217) highlight how the energy transition in Germany was closely linked to a variety of policies that included the deployment of subsidies for renewable energies and policy regulations targeting nuclear out-phasing; however, Germany still faced challenges in terms of its overall policy adoption and the required transformation processes (i.e. endogenous system processes). Meadowcroft (2011:71) further contends that politics are the constant companion of sustainability transitions, serving alternatively, and often at the same time, as context, arena, hindrance, enabler, intermediary and manager of repercussions. Meadowcroft (2011:73) also suggests political economy dynamics are driven by the three interrelated domains of 'interests', 'institutions', and 'ideas'. Even though studies (e.g. Kemp, Rotmans and Loorbach 2007:315–331; Kern and Smith 2008:4093–4103; Kern and Howlett 2009:391–408; Laes, Gorissen and Nevens 2014:1129–1152; Baker 2016:2–19; Markard *et al.* 2016:215–237) have attempted to incorporate political dynamics of the Dutch, British, German, South African, and Swiss energy transitions respectively, the focus on policy has been limited; that is, less attention has been devoted to the politics or related policy dynamics that makes the adoption and endogenisation of such policies likely (Meadowcroft 2011:73). This indicates that an understanding of policy development dynamics and political economy dynamics in terms of policy adoption, policy endogenisation and its associated transformation is crucial for sustainability transitions (Markard *et al.* 2016:216–234).

Ghaffarzadegan, Lyneis and Richardson (2011:24–27) identified five features that characterise public policy problems: (i) policy resistance from the environment, where a policy action generates feedback from its environment which mostly aggravates the initial problem situation; (ii) the need for experimenting and cost of experimenting, which is fundamental in public policy learning, is faced with policy resistance and long delays between action and consequences; (iii) the need to persuade different stakeholders, because diverse stakeholders have a role in developing and influencing the effectiveness of policies; (iv) overconfident policymakers, who often underestimate the limits of their knowledge when proposing reforms; and (v) the need to have an endogenous perspective, because policymakers tend to attribute undesirable outcomes to exogenous sources rather than to endogenous consequences of their earlier actions.

From the above discussion, one can underscore the need for an endogenous perspective to advance visions or insights into the political economy dynamics of policy development and action that can heavily influence sustainability transitions. This article applies a qualitative system dynamics approach, particularly causal loop diagrams, to identify sources of policy resistance, reveal insights to policymakers, contribute to policy discussions, and improve understanding of the need for an endogenous view for effective policymaking. The article focuses on the context of the challenges facing the strategic IRP development process in South Africa, including its adoption and subsequent implementation.

SYSTEM DYNAMICS APPROACH

The emergence of the system dynamics field can be dated to the 1950s and can be considered as "the study of the information feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise" (Forrester 1958:40). The system dynamics approach can simplify the endogenous structure of each particular system under assessment; identify the interrelationships of different elements of the system; and account for different alternatives for simulation (Sterman 2001:8–23; Musango and Brent 2011:87).

System dynamics models further allow for the understanding of the system structure, analyses of policies and strategies, the testing of theories, and system modelling and simulation to support public policy analysis and evaluation (Winz, Brierley and Trowsdale 2009:1305). Several studies have developed guidelines and strategies for the system dynamics modelling process, thus providing a range of steps; however, they all include similar iterative activities that involve both qualitative modelling and quantitative modelling (Winz *et al.* 2009:1305; Probst and Bassi 2014:41; Davies, Musango and Brent 2016:57). In this context, Probst and Bassi (2014:164) have proposed the following process or 'phases' for system dynamics modelling:

- Problem identification: In this phase, the problem or challenge is defined by identifying the causes and effects through definition of boundaries, which include political, environmental, economic and social dimensions. This is followed by the identification and analysis of causes and effects of key variables and actors directly linked to the problem. Once the root causes of the problem and their effects on the system have been identified and delimited, an analysis of future behavioural paths and impacts is also undertaken. In this instance, indicators and influence tables can be utilised as tools.
- System characterisation: In this phase, the mapping of complexity, including the assessment of the dynamic properties of the system, is undertaken. This phase includes the building or development of causal loop diagrams (CLDs), review of the system boundaries, overall understanding of the system, the identification of key feedback loops, and entry points for intervention, i.e., strategy or policy identification. In this phase, indicators, influence tables, CLDs and scenarios are suggested tools.
- Strategy/policy assessment: This phase focuses on the design potential of interventions, assessment of the interventions and the selection of viable options and indicators. Suggested tools for this phase include indicators, CLDs and scenarios.
- Decision-making and implementation: In this phase, a multi-stakeholder approach is promoted to assess roles and responsibilities, followed by an analysis (may include both qualitative and quantitative modelling) of the expected impacts across sectors and actors, and the overall definition of the strategy or policy. Again, the suggested tools for this phase include indicators, CLDs and scenarios.
- Monitoring and evaluation: In this phase, the strategy is implemented and the development of the system is monitored, while an analysis of the sectors and stakeholders is also undertaken. Also, lessons learned for the next decision-making process are utilised. Tools suggested in this instance also include indicators, CLDs and simulations (Pruyt 2013:46–47; Probst and Bassi 2014:164).

The above-mentioned process consists of both qualitative and quantitative modelling. Quantitative modelling enables visualisation of the effects of different intervention strategies through simulations (Sterman 2000:191–262). It requires explicit statements regarding assumptions about the underlying model and identification of uncertainties associated with system structure, including the identification of gaps in data availability, with the aim to promote transparency. Furthermore, quantitative modelling has been advocated because it uses mental models and structural elements of problems; identifies and integrates both soft and hard variables; simulates dynamic behaviour of the problem under assessment; and assists in greater problem understanding as well as an improved ability to further clarify, define and manage dynamic real-world issues (Sterman 2000:20–23).

Despite the advocacy of quantitative modelling, it has faced considerable challenges in the devising and quantification of soft and uncertain variables, as tackled by qualitative modelling (Davies *et al.* 2016:57). While mainstream system dynamics scholars like Wolstenholme (1999) agree that qualitative modelling is an essential aspect of system dynamics modelling, other scholars have emphasised the critical role of quantitative modelling as well in the pursuit of dynamic knowledge (Wolstenholme 1999:424; Coyle 2000:226). Coyle (2001:357–358) stresses that the early 1980s witnessed the development of purely qualitative modelling, which only consists of CLDs. The CLDs provide the conceptualisation and feedback structure at an aggregate level. CLDs can then be transformed into stock flow diagrams for simulation modelling. However, there is still an argument that a quantified simulation model is always superior to a qualitative model because it provides more insights (Pruyt 2013:40). However, in situations where the issue investigated mainly entails soft and uncertain variables, then qualitative system dynamics using causal loop diagrams becomes more relevant (Wolstenholme and Coyle 1983:569–581).

According to Probst and Bassi (2014:180), the creation of a CLD has several purposes and benefits: it combines ideas, knowledge and opinions; it highlights the boundaries of the analysis; and it allows stakeholders to achieve basic to advanced knowledge of the analysed issue's systemic properties. In this context, causal interrelationships are plotted for generating greater understanding of the nature of a problem with a view to gaining greater insight into potential interventions or problem solutions. Additionally, CLDs have the ability to represent a complex real-world problem that requires a long narrative explanation on a single diagram; the ability to stimulate discussion and understanding of the different relationships of a complex real-world problem being investigated; the ability to enable the identification of feedback loops that may assist in explaining behaviour or generating insights; and the ability to identify wider contexts of a modelling task. Despite these strengths, the effectiveness of the CLD is directly linked to the quality of the process, which in turn influences the conceptualisation of the CLD.

The building blocks of CLDs include the following:

- Variables: "They represent a condition, situation, action or decision that can influence and be influenced by other variables. A variable can also be quantitative or qualitative, since CLDs can incorporate both variables."
- Links/arrows: "They illustrate the relationship and the direction of influence or causation among variables."
- Direction of influence: "This is denoted by the symbol S / (+), meaning 'same direction', or O / (-), meaning 'opposite direction'. The arrows indicate the way in which one variable moves or changes in relation to another."
- Type of feedback loop: "There are two types of feedback loops: balancing feedback loops that pursue equilibrium and are represented by 'B' and

reinforcing feedback loops that amplify changes and are represented by 'R' (Probst and Bassi 2014:181; Davies *et al*. 2016:58).

CLDs can be utilised to support all the decision-making phases. In the problem identification phase, they help identify the causal chain that determines the problem to be solved, from an endogenous perspective. During the strategy/policy assessment phase, they facilitate the identification of the key entry points for interventions, where they also support the evaluation of selected interventions: short-term vs. long-term; and direct and indirect impacts, including responses. During the decision-making and implementation phase, and the monitoring and evaluation phase, CLDs can be utilised to bring together diverse stakeholders to promote synergies, coordination, and integrated strategies and action plans, and to identify unintended consequences of implemented interventions (Probst and Bassi 2014:105).

ENDOGENOUS PERSPECTIVE OF IRP POLICY PLANNING IN SOUTH AFRICA

Ensuring a reliable and affordable supply of electricity has been at the core of South Africa's development (Department of Energy 2009). National electricity planning, as part of energy policy, emerged internationally as the most effective way to shape the development of the electricity supply industry. The Department of Energy (DOE) is responsible for developing the Integrated Energy Plan (IEP), which is based on a general equilibrium model involving the economy and an energy component (Department of Energy 2013). This plan is relevant because of the inherent interaction among the components of the energy industry. As such, the main aim of the IEP is to incorporate the overall interaction within the energy industry, i.e., interactions between electricity, liquid fuels, coal fuels, gas fuels, etc. (Department of Energy 2009).

Additionally, the DOE is responsible for the development of the IRP, which is a subset of the IEP and is described in the Regulations for New Generation Capacity published on 5 August 2009 (Department of Energy 2009). In terms of long-term planning and related sustainability goals aimed at contributing to South Africa's sustainability transition path, the South African electricity sector is currently guided and driven by the IRP 2010–2030. The IRP has been described as a medium- to long-term plan that directs the expansion of the electricity supply over the given period (at least 20 years). Furthermore, the IRP was introduced to minimise the total cost of electricity (overall supply and associated losses or not supplied) to the consumer, given the constraints inherent in the technical aspects of the supply and non-technical considerations brought into the planning model.

The technical aspects are meant to flow directly from the planning assumptions, whereas the non-technical considerations are derived from the policy options and scenarios, including associated externalities. The IRP was proposed as a mechanism by which key electricity systems, sustainability and government policy requirements would be met so that the following questions would be answered: What are the electrical energy requirements for South Africa? When will the capacity be needed to provide for the electrical energy requirements? What is the appropriate mix of technologies to meet the needs that achieve the required policy objectives? (Department of Energy 2009).

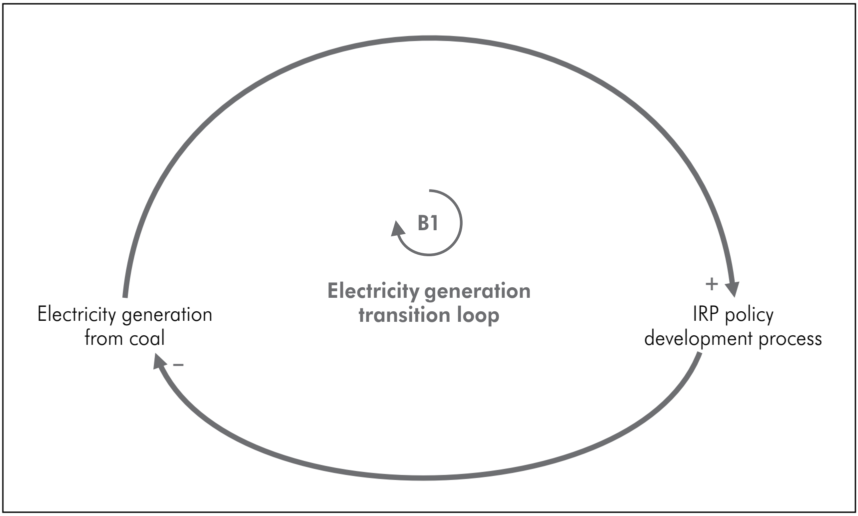
South Africa's first national IRP was completed by the National Energy Regulator of South Africa in 2002. The updated second national IRP was completed in 2004, and the third national IRP was completed in 2008. Eskom, the state-owned national utility, also used to develop integrated strategic electricity plans providing strategic projections of supply-side electricity options to meet Eskom's long-term electricity load forecasts (Calland and Nakhooda 2012:915). The current IRP 2010–2030 was promulgated in March 2011 (Department of Energy 2011). In 2013, a revised IRP was published for public comment in keeping with the expectation that the IRP be updated biennially; however, it was never approved by Cabinet. A process of updating the IRP was initiated in 2016 with stakeholder consultation commencing in December 2016; the finalisation of the IRP policy adjustments was approved by Cabinet in December 2017. The IRP has faced several challenges and the next sections focus on the problem identification and system characterisation phases of system dynamics to further examine challenges facing the strategic IRP development process in South Africa.

Characteristics of South Africa's Integrated Resource Plan policy planning process problem

The IRP was developed as a mechanism to facilitate electricity transition in South Africa, in particular, social development to promote job creation and localisation; economic development through increasing supply; and environmental sustainability through diversifying electricity supply sources. This was evidenced in the promulgated IRP 2010, where the proportion of renewable electricity capacity was planned to reach 17 800 MW by 2030, with 5000 MW to be operational by 2019, and a further 2000 MW operational by 2020. This was then followed with the Independent Power Producer Procurement Programme, which has been hailed as a success worldwide, where 102 projects were awarded in its four bids windows (IPPPP Office 2017).

Figure 2 shows the feedback loop of the initial objective of the electricity sustainability transition in South Africa, which entails a transition from mainly coal electricity generation to more renewable energy as driven by South Africa's IRP policy development process, represented as a balancing feedback loop, B1.

Figure 2: Electricity generation transition feedback loop



Source: (Authors' own conceptualisation)

However, the IRP policy development process was confronted with tensions, challenges and doubts, creating an uncertain environment regarding achieving its intended objectives. As an illustration, Baker, Newell and Phillips (2014:792) point out that the IRP implementation may result in "GHG emissions from electricity generation increasing from 237 million tons of CO_2 in 2010 to 272 million tons in 2030" owing to the flawed assumptions promoted during the IRP development process. In addition to this, IRP implementation may lead to increases in electricity prices estimated at 250% in real terms from the 2010 levels, while by 2020 they are estimated to be even higher owing to higher projected inflation rates. This increase in GHG emissions and electricity prices is attributed to the doubling in electricity capacity driven by "projected demand forecasts", specifically in the government-driven mining and minerals beneficiation programmes and coal-to-liquids technology programmes (Baker *et al*. 2014:802). It is in this context that some stakeholders raised concerns over the lack of transparency in gathering the technology costs data, decreasing renewable energy costs against coal costs and related externalities, assumptions made in terms of demand forecasts, and the role and influence posed by the traditional "mineral energy complex" players within the IRP development process. Additionally, in terms of technology diversification and options, especially concerning nuclear energy, stakeholders have highlighted the lack of consideration of capabilities of more flexible smaller modular nuclear reactors, which could be more suitable for South Africa given the uncertainty of demand and the large renewable energy resources (Energy Research Centre

2013:20). Furthermore, an integrated analysis linking the power and water sectors and the economy was lacking, proving that the electricity sustainability transition objectives were not captured in totality. For example, electricity production is closely linked to the water sector, and South Africa is expected to have a deficit of 234 gigalitres by 2025 as projected in national accounts (Hedden 2015:21; Pouris and Thopil 2015:2). As such, this is an illustration of the many gaps that need to be considered, aligned and endogenised in the IRP policy development process.

Other major IRP shortfalls are that environmental and social impact assessments on all advocated technologies notably have been missing. Also, the economic and financial impacts of the proposed electricity generation mix in the IRP could also have received more attention, while the contribution of the IRP and overall energy policy to the peripheral government objectives (social, environmental, and industrial) has been marginal (Montmasson-Clair and Ryan 2014:8–9).

Also, the increasing role of renewable energy driven by Independent Power Producers (IPPs) and small-scale embedded generation 'behind meters', which would eventually result in a more decentralised and intermittent electricity supply for South Africa, is currently lacking a clear governance process or framework to ensure overall alignment with the country's long-term strategic planning (Msimanga and Sebitosi 2014:420). The proposed IPP institutional and governance structures, including related existing barriers to renewable energy deployment in South Africa, are not sufficiently defined. Hence, enforcing implementation mechanisms or rules and regulations becomes challenging (Montmasson-Clair and Ryan 2014:13). While this is expected to affect various electricity sector actors, it is not explicitly considered in the IRP development process. Furthermore, IPPs have indicated continually that limited attention is given to grid planning in terms of where, geographically, future electricity will come from or who will produce it, including the geographical location of demand (Hedden 2015:2–18). These deficiencies further highlight the insufficiencies within the IRP policy development process and its misalignment with overall national strategic and integrated planning, such as the Transmission Development Plan for South Africa and the Strategic Grid Plan (Govender 2017:4).

Baker (2016:2–19) further underscores political planning dynamics and influences by various stakeholders in the way in which the IRP was negotiated, as this revealed the electricity sector's political economy dynamics driven by the "traditional minerals-energy complexity" in South Africa. This refers specifically to the technical advisory group that provided inputs into the modelling process, which was heavily criticised for consisting largely of representatives from coal miners, the Energy Intensive Users Group, Eskom (the national utility), and government. Therefore, this participatory nature of the IRP's public consultation process has been heavily criticised (Baker 2016:2–19).

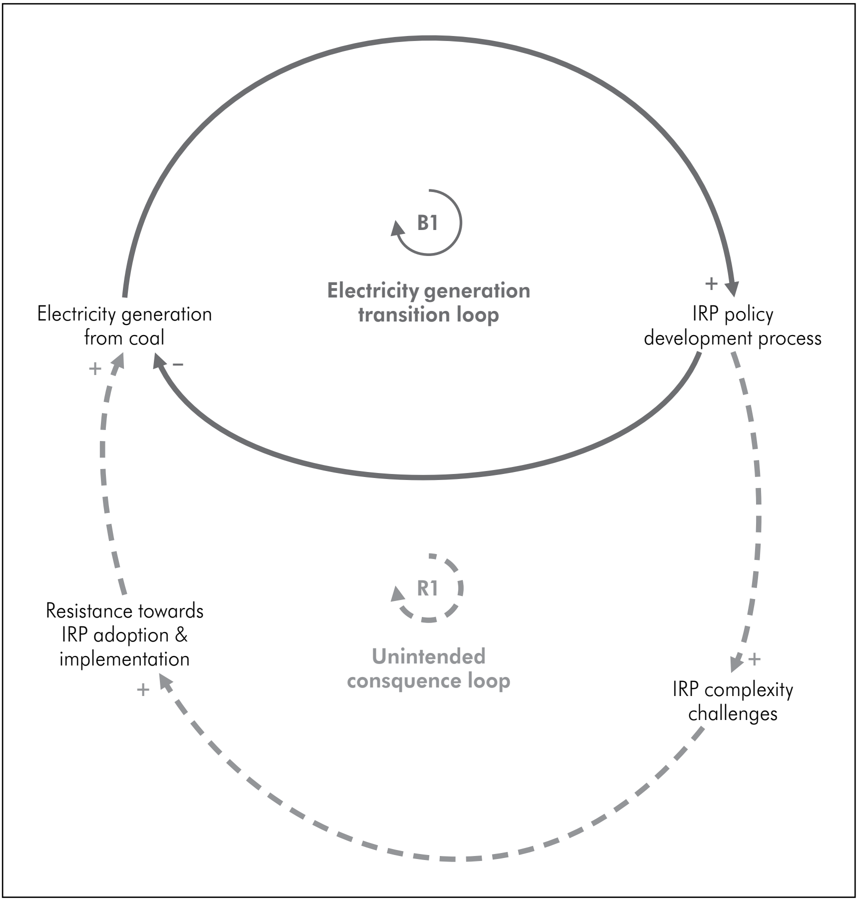
In the 2016 updated IRP (Department of Energy 2016), although the issues of load-centric distributed generation and short-term decentralised provision were addressed, there is still a lack of detailed studies on the subject. This is exemplified by the distributed generation definition, regarded as vague, while the long-term effects of short-term planning and short-term provision were not investigated (Rycoft 2017). In addition, the planning and impact of construction times of smaller plants (in particular distributed generation) were not considered. Questions relate to whether these plants will be centralised or localised, and whether a centralised planning for distributed generation would be required (Rycoft 2017). As such, this further highlights the lack of a governance framework within which the IRP development process and its subsequent updates can be undertaken to ensure transparency, alignment, endogenisation and overall contribution of the IRP as a policy-planning process for South Africa's transitions path.

Yelland (2016) notes the incorrect and inconsistent technology costs utilised in the Draft IRP 2016. He proposes an IRP process that starts with an unconstrained, least-cost, base-case scenario, using correct and up-to-date technology costs, to establish the associated least-cost, unconstrained, base-case technology mix to 2050, and the associated cost of this base-case scenario should be followed. Moreover, other scenarios using various imposed constraints (e.g. carbon constraints or water availability or electricity demand constraints) to establish the relevant energy mixes calculated in the IRP model for each of the alternative scenarios together with the associated additional costs up to 2050 will need to be considered (Yelland 2016). This would allow relevant stakeholders to understand the cost implications of the various constraints over and above the least cost, base-case scenario to obtain a meaningful view of the additional cost versus the resulting benefit or policy objective of the IRP (Yelland 2016). Additionally, the stakeholder consultation for the IRP 2016 was flawed and critiqued for only allowing the public 10 to 14 days' comment on the draft document. Only DOE policymakers had access to the costing of the various scenarios, including any new scenario information identified by stakeholders, affected parties and the public during the public participation process (Yelland 2016). Again, this further highlighted the lack of a framework to guide an inclusive process for the IRP development.

The complexity challenges facing the IRP policy development process created an uncertain environment for future energy development planning in South Africa. This has in turn created resistance towards IRP adoption and implementation, hence, reversing the effect of the initial IRP objectives to promote electricity sustainability transitions, i.e., reducing coal electricity generation in South Africa over time. This is endogenously captured as an unintended consequence in Figure 3, represented as a reinforcing loop, R1.

Figure 3 highlights that to facilitate electricity sustainability transitions the IRP was introduced as a policy planning process approach within the electricity sector (B1: electricity generation transitions loop). However, the IRP policy planning development process and its adoption and subsequent implementation faced

Figure 3: Unintended consequence feedback loop

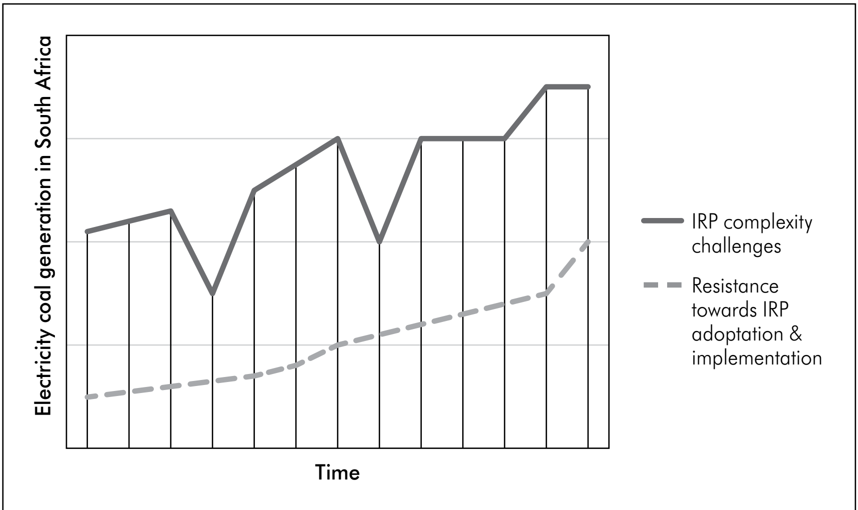


Source: (Authors' own conceptualisation)

various challenges due to the policy and political dynamics within the electricity sector in South Africa, leading to various unintended consequences – mainly resistance towards the IRP development process and its adoption – thus reverting South Africa's electricity to its initial situation of relying on coal electricity generation, or a slow electricity transition in South Africa (R1: unintended consequence feedback loop).

Figure 4 emulates "the fixes that fail system archetype", which illustrates that a quick-fix solution can have unintended consequences (i.e., resistance towards IRP development process, adoption and implementation) that can further aggravate the problem. It hypothesises that the problem symptom (i.e., IRP complexity

Figure 4: Fixes that fail system archetype: Electricity coal generation (i.e., slow transitions) over time in South Africa



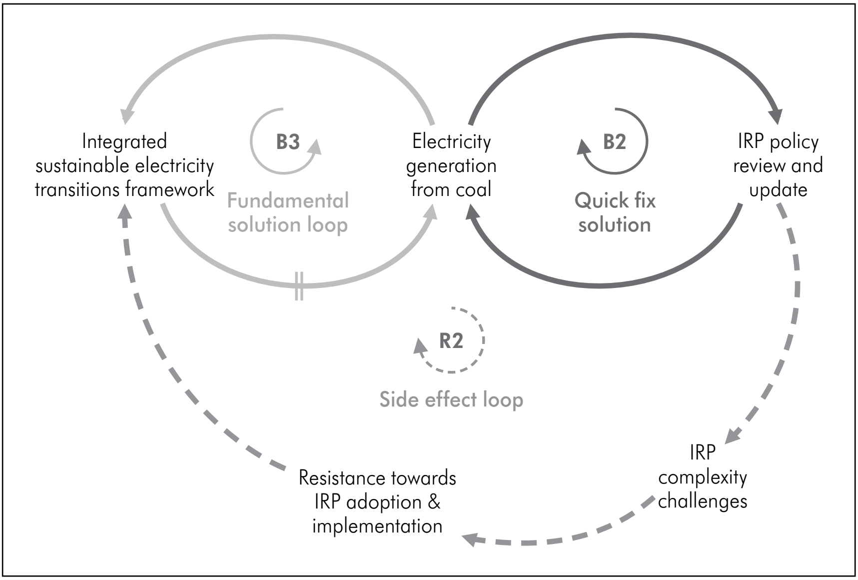
Source: (Authors' own conceptualisation)

challenges) will diminish for a short while and then return to its previous level or become even worse over time (Braun 2002:14–16).

Owing to the slow electricity transitions described in Figure 4, the DOE has continuously responded by reviewing and updating the IRP to transition electricity generation from coal, however, only some temporary improvement in performance is experienced. This is what can be considered a symptomatic feedback loop (B2 in Figure 5).

The quick-fix solution loop indicates that the DOE's review and update of the existing IRP is only a quick fix, which alleviates the problem symptom and reduces the pressure to seek a fundamental solution that will deal with the dominant challenges relating to resistance towards IRP development, adoption and implementation. As the initial objective of electricity transitioning worsens, there is a tendency to resort to the quick-fix solution instead of the fundamental solution that encompasses integrated sustainable electricity transitions. This is because the effects of the fundamental solutions occur after a longer delay, represented by a double line on the arrow of the fundamental solution loop (B3). The greater the reliance on quick-fix solutions, the worse the situation becomes, and thus over time the fundamental solution becomes indispensable. Hence, the fundamental solution feedback loop (B3) introduces the integrated sustainable electricity transitions framework aimed at electricity transitions from coal electricity generation. Figure 6 emulates the shifting the burden system archetype, which illustrates how

Figure 5: Shifting the burden characteristics of the IRP policy development process



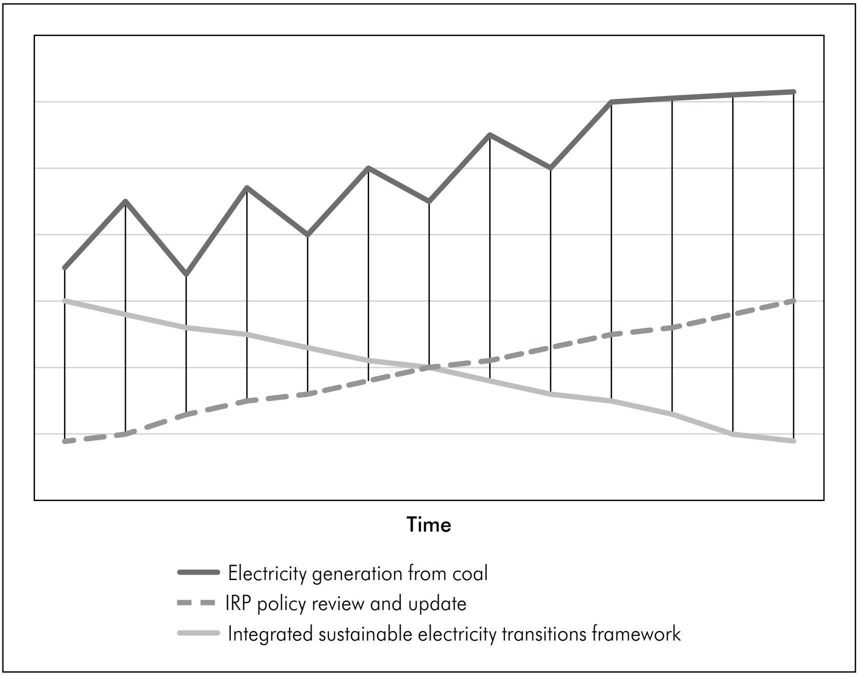
Source: (Authors' own conceptualisation)

management interventions work. Each time there is an intervention in the form of review and update of the IRP by the DOE to transition electricity generation from coal, only some temporary improvement in performance is experienced, until a fundamental solution is presented; in this case, an integrated sustainable electricity transitions framework, which assumes a well-planned intervention.

CONCLUSION

This article used qualitative system dynamics to examine challenges facing the IRP policy planning process in South Africa. The IRP policy plan is a complex system faced with several policy and political economy dynamics that have led to some resistance in terms of its implementation and even its development. The article has demonstrated the ability of causal loop diagrams to capture in a succinct manner the feedback structure of the characteristics of the IRP planning process problem in South Africa. By utilising causal loop diagrams, the IRP's current symptomatic solution, namely the review and update of the IRP by the DOE, and the fundamental solution, namely an integrated sustainable electricity transitions framework, each forms a 'balancing' loop with the problem symptom,

Figure 6: Shifting the burden system archetype: Management interventions and the impact on electricity transitions in South Africa over time



Source: (Authors' own conceptualisation)

as the main plan is to transition from primarily coal-based electricity generation. The resistance towards the IRP policy planning development process and the related IRP challenges, represented by a reinforcing loop, emphasises the system's inability to achieve its objectives with the quick-fix solution. Thus, there is the need to focus on a long-term fundamental solution, represented by the integrated sustainable electricity transitions framework. Future investigations will focus on the strategy/policy assessment phase where the focus will be on the design of an integrated sustainable electricity transitions framework and its application as part of the existing IRP development process.

NOTE

* This article is based on the ongoing PhD research entitled "Strategic Integrated electricity planning: A case of electricity transitions in South Africa" by Ms Lwandle Jackie Mqadi under the supervision of Proffs J.K. Musango and A.C. Brent.

REFERENCES

Baker, L. 2016. Post-Apartheid Electricity Policy and the Emergence of South Africa's Renewable Energy Sector. WIDER Working Article, No. 2016/15. Helsinki: United Nations University World Institute for Development Economics Research.

Baker, L., Newell, P. and Phillips, J. 2014. The political economy of energy transitions: The case of South Africa. *New Political Economy*. 19(6):791–818.

Braun, W. 2002. The System Archetypes, the Systems Modelling workbook, web articles presented at University at Albany, State University of New York. Albany. New York. USA. Available at: **www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf**. (Accessed 20 October 2016).

Calland, R. and Nakhooda, S. 2012. Participatory democracy meets hard rock of energy policy: South Africa's National Integrated Resource Plan. *Democratization*. 19(5):912–931.

Coyle, G. 2000. Qualitative and quantitative modelling in system dynamics: Some research questions. *System Dynamics Review*. 16(3):225–244.

Coyle, R.G. 2001. Maps and models in system dynamics: Rejoinder to Homer and Oliva. *System Dynamics Review*. 17(4):357–363.

D'Sa, A. 2005. Integrated resource planning (IRP) and power sector reform in developing countries. *Energy Policy*. 33(10):1271–1285.

Davies, M., Musango, J.K. and Brent, A.C. 2016. A systems approach to understanding the effect of Facebook use on the quality of interpersonal communication. *Technology in Society*. 44:55–65.

Department of Energy. 2009. Proposed IRP Planning Process. Pretoria: Department of Energy.

Department of Energy. 2011. Integrated Resource Plan for Electricity, 2010–2030. Pretoria: Department of Energy.

Department of Energy. 2013. Draft 2012 Integrated Energy Planning Report. Pretoria: Department of Energy.

Department of Energy. 2016. Integrated Resource Plan Update: Assumptions, Base Case Results and Observations. Pretoria: Department of Energy.

Dixit, S., Chitnis, A., Jairaj, B., Martin, S., Wood, D. and Kundu, A. 2014. 10 Questions to Ask about Integrated Resource Planning. Working Article. Washington, DC: World Resources Institute.

Dyner, I. and Larsen, E.R. 2001. From planning to strategy in the electricity industry. *Energy Policy*. 29(13):1145–1154.

Edomah, N., Foulds, C. and Jones, A. 2017. Policy making and energy infrastructure change: A Nigerian case study of energy governance in the electricity sector. *Energy Policy*. 102:476–485.

Energy Research Centre. 2013. Towards a New Power Plan. Cape Town: Energy Research Centre, University of Cape Town.

Forrester, J. 1958. Industrial dynamics: A major breakthrough for decision makers. *Harvard Business Review*. 36(4):37–66.

Ghaffarzadegan, N., Lyneis, J. and Richardson, G.P. 2011. How small system dynamics models can help the public policy process. *System Dynamics Review*. 27(1):22–44.

Govender, T. 2017. Keynote address and setting-the-scene. Presented at the Eskom Transmission Development Plan 2018 to 2027 (TDP 2017): Public Forum, Johannesburg, 19 October.

Hedden, S. 2015. Gridlocked: A Long-Term Look at South Africa's Electricity Sector. African Futures Article No. 15. Pretoria: Institute for Security Studies.

Hu, Z., Tan, Y., Yang, F., Yang, M., Wen, Q., Shan, B. and Han, X. 2010. Integrated resource strategic planning: Case study of energy efficiency in the Chinese power sector. *Energy Policy.* 38(11):6391–6397.

Hu, Z., Wen, Q., Wang, J., Tan, X., Nezhad, H., Shan, B. and Han, X. 2010. Integrated resource strategic planning in China. *Energy Policy.* 38(8):4635–4642.

IPPPP Office. 2017. The Independent Power Producer Procurement Programme. https://www.ipp-projects.co.za/ Accessed 31 December 2017.

Kemp, R., Rotmans, J. and Loorbach, D. 2007. Assessing the Dutch energy transition policy: How does it deal with dilemmas of managing transitions? *Journal of Environmental Policy & Planning.* 9(3–4):315–331.

Kern, F. and Howlett, M. 2009. Implementing transition management as policy reforms: A case study of the Dutch energy sector. *Policy Sciences*. 42(4):391–408.

Kern, F. and Smith, A. 2008. Restructuring energy systems for sustainability? Energy transition policy in the Netherlands. *Energy Policy.* 36(11):4093–4103.

Kuzemko, C., Lockwood, M., Mitchell, C. and Hoggett, R. 2016. Governing for sustainable energy system change: Politics, contexts and contingency. *Energy Research & Social Science.* 12:96–105.

Laes, E., Gorissen, L. and Nevens, F. 2014. A comparison of energy transition governance in Germany, the Netherlands and the United Kingdom. *Sustainability.* 6(3):1129–1152.

Malik, A.S. and Sumaoy, C.U. 2003. A case study of local integrated resource planning. *Energy*. 28(7):711–720.

Markard, J., Raven, R. and Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy*. 41(6):955–967.

Markard, J., Suter, M. and Ingold, K. 2016. Socio-technical transitions and policy change – Advocacy coalitions in Swiss energy policy. *Environmental Innovation and Societal Transitions*. 18:215–237.

Meadowcroft, J. 2011. Engaging with the *politics* of sustainability transitions. *Environmental Innovation and Societal Transitions.* 1(1):70–75.

Montmasson-Clair, G. and Ryan, G. 2014. Repositioning Electricity Planning at the Core: An Evaluation of South Africa's Integrated Resource Plan. Pretoria: Trade and Industrial Policy Strategies for the National Economic Development and Labour Council.

Morlet, C. and Keirstead, J. 2013. A comparative analysis of urban energy governance in four European cities. *Energy Policy*. 61:852–863.

Msimanga, B. and Sebitosi, A.B. 2014. South Africa's non-policy driven options for renewable energy development. *Renewable Energy.* 69:420–427.

Musango, J.K. and Brent, A.C. 2011. A conceptual framework for energy technology sustainability assessment. *Energy for Sustainable Development.* 15(1):84–91.

Pouris, A. and Thopil, G.A. 2015. Long-term Forecasts of Water Usage for Electricity Generation: South Africa 2030. Report No. 2383/1/14. Pretoria: Water Research Commission.

Probst, G. and Bassi, A.M. 2014. Tackling Complexity: A Systemic Approach for Decision Makers. Sheffield: Greenleaf.

Pruyt, E. 2013. Small System Dynamics Models for Big Issues: Triple Jump towards Real-World Complexity. Delft: TU Delft Library.

Rycoft, M. 2017. Mike Musings: Short Term Plans and Long Term Consequences. **http://www.ee.co.za/article/mike-musings-short-term-plans-long-term-consequences.html**. Accessed 15 February 2017.

Sterman, J.D. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Boston, MA: Irwin/McGraw-Hill.

Sterman, J.D. 2001. System dynamics modelling: Tools for learning in a complex world. *California Management Review*. 43(4):8–25.

Winz, I., Brierley, G. and Trowsdale, S. 2009. The use of system dynamics simulation in water resources management. *Water Resources Management*. 23(7):1301–1323.

Wolstenholme, E.F. 1999. Qualitative *vs* quantitative modelling: The evolving balance. *Journal of the Operational Research Society.* 50(4)**:**422–428.

Wolstenholme, E.F. and Coyle, R.G. 1983. The development of system dynamics as a methodology for system description and qualitative analysis. *Journal of the Operational Research Society.* 34(7):569–581.

Yelland, C. 2016. Analysis: The Draft 2016 Integrated Resource Plan – lightweight, superficial and downright dangerous, *Daily Maverick*, 30 Nov. 2016.Johannesburg.South Africa. Available at: **www.dailymaverick.co.za/article/2016-11-30-analysis-the-draft-2016-integrated-resource-plan-lightweight-superficial-and-downright-dangerous/#.WvM7RExuLDd**. (Accessed 20 April 2017).

AUTHORS' CONTACT DETAILS

Lwandle Mqadi
PhD candidate
School of Public Leadership,
Centre for Renewable and Sustainable
Energy Studies
Postal Address:
Post Net Suite 522, Private Bag X29
Gallo Manor, 2052

Professor Josephine Kaviti Musango
School of Public Leadership, Centre for
Renewable and Sustainable Energy Studies
Urban Modelling and Metabolism Assessment
(uMAMA) Research Group,
Centre for Complex Systems in Transitions
Stellenbosch University,
South Africa
jmusango@sun.ac.za
Postal Address:
Private Bag X1, Matieland
7602, South Africa
Tel: +27 21 808 4338

Professor Alan C. Brent
School of Public Leadership, Centre for
Renewable and Sustainable Energy Studies
Department of Industrial Engineering and the
Centre for Renewable and Sustainable Energy
Studies, Stellenbosch University
acb@sun.ac.za
Postal Address:
Private Bag X1, Matieland
7602, South Africa
Tel: +27 21 808 9530 and
Sustainable Energy Systems, School of
Engineering and Computer Science, Victoria
University of Wellington, New Zealand
alan.brent@vuw.ac.nz