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Interactions between energy security and climate change: A focus on developing countries

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ABSTRACT

We briefly consider the tensions between climate change and energy security policy imperatives, and highlight some concepts that may bring additional clarity to decision-making at the nexus of the two areas. We focus on developing countries and use the case of the Medupi supercritical coal plant in South Africa. The justification for the plant's construction stemmed from an Integrated Resource Planning process informed by South Africa's national utility. Often, as in the case of South Africa, there are tensions not easily captured in quantitative algorithms between, *inter alia*, a lack of access to electricity by millions of people (and associated welfare losses) and greenhouse gas emissions from electricity generation. It is difficult to identify any formal processes that have prioritised climate change considerations over those of energy access. Thus, it becomes imperative to have a clear understanding of the consequences of this reality when considering power system expansion. We find that the processes often employed do not provide an entirely satisfactory precedent for future planning analyses, and the justifications do not adequately reflect the complexity of the decision space. Finally, we highlight some options by which these tools might be enhanced in areas including explicit and formal consideration of risk.

Economic man is a clod, heroic man is a fool, but somewhere between the clod and the fool, human man, if the expression may be pardoned, steers his tottering way. *(Boulding, 1970)*.

1. Introduction

Energy security and climate change are both increasingly critical drivers affecting policies, regulations and investment in the energy sector.[1] While there are many potential synergies between the two issues, they can also result in conflicting recommendations. Bazilian et al. (2010a), argued that climate change should be treated as a subset of energy (and other sectoral) policy rather than *vice versa* in order to be most effective and influential, and noted that, "… many ways of reducing greenhouse gas emissions are alien to traditional energy sector "core" objectives, such as reliable electricity supply, and can be inconsistent with its well-established financial, technical and risk perspectives". In this paper, we consider how the relative prioritisation of energy security vs. climate change mitigation objectives can directly impact large-scale investment decisions.

We briefly consider the case of the Medupi supercritical coal plant being built in South Africa to illustrate the potential trade-offs between these two factors for energy policy.[2]

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[1] Energy security is an overused and poorly defined term, for the purposes of this paper we define it as, "… the uninterrupted physical availability of energy products on the market, at a price which is affordable for consumers (EU, 2000)". Helm (2002) augments this by categorising electricity security of supply into three discrete areas: supply (contracting) security, network (wires and delivery) security and as a function of diversity of fuel supply (or generation). (See Bazilian et al. (2006) for several definitions and associated metrics.) We note that in many developing countries, the starkest energy security issue is a lack of access to energy services – in terms of both poor service and resource constraints (Bazilian et al., 2010b). Sovacool and Rafey (2011) use a much wider framework for energy security when considering Medupi that encompasses environmental considerations. We use the more bounded security definition in order to clearly distinguish its relative influence on policy making.

[2] Levi (2009) also considered tensions between these issues using the case of the Canadian oil sands. He assesses the interaction between the areas through a qualitative framework considering areas such as price volatility, wealth transfers and market barriers. The study concludes that, "A healthy balance is possible".

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Pielke described the interaction of these two issues bluntly,

> "When GDP growth comes into conflict with emissions reduction goals, it is not going to be growth that is scaled back … when rich countries wanting emissions reductions run into poorer countries wanting energy, it is not going to be rich countries who get their way. When energy access depends upon cheap energy, arguments to increase energy costs or deny energy access are not going to be very compelling (Pielke, 2010)".

While this accurately depicts the current situation, changes in the policy boundary conditions are likely in the future. In addition, it is not just policy, but the specific tools guiding energy planning such as regulation, the architecture of electricity markets, and the specific analytical tools that underpin decision-making that have to be more closely evaluated.

Despite the difficulties in pricing damages (or benefits) from climate change and energy security, it is clear that the direct short-run benefits of energy security (including improving energy access) will ensure that it is almost always given more emphasis than other concerns (including climate change mitigation). While this outcome may be appropriate, given the alternatives available and the country's priorities, the rationale for the decision and the associated processes can often lack transparency and/or rigour. A careful and open examination of tradeoffs and the value judgments involved might yield different recommendations in like situations. To this end, Blyth and Lefevre (2004) highlighted, "the need for more sophisticated tools to evaluate energy policy drivers and their interactions, taking into account national circumstances and the expected patterns of evolution in energy markets and energy consumption trends." Blyth's work attempted to quantify (see also IEA, 2007[3]) aspects of the intersection between these two drivers using proxies.[4] Such an approach is one available tool to utilise at the national level.

The potential to create wealth by expanding access to electricity for households and businesses in an energy-constrained country is usually the principal motivator for decisions to provide additional large-scale power generation, especially when they can also make use of locally available fuel sources.[5] However, decision-making processes that focus primarily on such immediate drivers run the risk of excluding risk factors which may come to dominate the plant's economics later in its life, especially in the case of large, long-lived and high-emission capital stock such as coal-fired power generation. As Victor and Morse (2009) note, "Because coal is ubiquitous, its future depends on dozens of policy decisions taken by many governments. 'Global' coal policy will arise from the bottom up rather than through some grand strategy". Furthermore, South Africa is setting a precedent for other sub-Saharan African countries.[6] Perhaps a better precedent could have been set by more clearly articulating competing criteria—even if the decision remained the same. Given that these types of decisions are being faced by countries throughout the world, improved processes matter. The balance between climate and security considerations is a dynamic one, and optimal outcomes could very well be different in the circumstances in place in other countries.

[3] One result from a scenario found, "Achieving a 5% reduction in emissions through a switch from coal to gas, on the other hand, has a negative impact on both security indicators".

[4] Namely, geopolitical energy security and power system reliability.

[5] A few privately owned coal companies supply most of the 125 million tons of coal to Eskom, which is used to generate some 90% of South African electricity (IDASA, 2010).

[6] Levi and Michonski (2010) add, "The Bank's shareholders should thus say yes … [but] Shareholders should emphasise that this is an exceptional circumstance". While we generally agree; this case is unlikely to be unique.

2. Big coal

In April 2010 the World Bank Group (through the IBRD) approved a USD 3.75B financing package to South Africa's electricity utility, Eskom Holdings Ltd. (Eskom).[7] The Bank's decision attracted a large amount of public attention. Most of the financial package (USD 3.05B) is for the Medupi coal plant in Limpopo province, one of two such supercritical plants being built by Eskom—each at the scale of 4800 MW (World Bank, 2010a). The other elements of the World Bank loan will go to support wind, concentrating solar power (CSP), and energy efficiency projects. According to the Loan Agreement (2010), the project objective is formally to, "enable the Borrower to enhance its power supply and energy security in an efficient and sustainable manner so as to support both economic growth objectives and the long term carbon mitigation strategy of the Guarantor". In the Medupi case, the impetus for the investment comes primarily from the results of a generally well conducted Eskom IRP process (Eskom, 2009), and was the subject of a review by an expert panel report commissioned by the World Bank (Davidson et al., 2010).[8]

The justification for the loan ultimately stems from the need to increase generation, assertedly in-line with a long-term low-carbon growth trajectory outlined in the country's Long-Term Mitigation Scenarios (Scenario Building Team, 2007). The former objective was clearly articulated by Obiageli Ezekwesili, the World Bank Vice President for the Africa region: "Without an increased energy supply, South Africans will face hardship for the poor and limited economic growth". Potentially it is also the first large coal plant to be built in South Africa for around 20 years—this represents a new decision paradigm.

The expert review panel proposed, by way of navigating this difficult terrain, a "third option … reflecting its strong belief that environmental and development objectives must be pursued together" (Davidson et al., 2010). Despite the diplomacy of this vocabulary, the panel clearly endorsed Medupi, but also recommended a long-term partnership between the World Bank Group and the government, "to introduce a portfolio of additional sustainable energy technologies and practices as part of a strategy of investing in an eventual low carbon future". Developing countries are not the only ones struggling with these difficult tradeoffs.[9] In most cases, the desire for increased supply (especially with a "job-intensive" domestic energy source[10]) overshadows climate considerations. Still, it has been interesting to note the increased public and political concern with new coal plants in some countries, to the extent that the realities of large public protest of coal plants, associated litigation, and resultant raised project costs are proving to make further investment in

[7] Reviews of the process can be found in: Nakhooda (2010), Sovacool and Rafey (2011), and World Bank (2010a, b, c, d, and e). In addition there was a large media attention on the project (see e.g. BBC (2010), Guardian (2010), and Reuters (2010)).

[8] Earlier modelling studies of the South African power sector also see coal-fired generation as the "most cost effective" under a range of scenarios (Rogner et al., 2006).

[9] A regulatory decision in the Republic of Ireland sheds light on a similar process. The Moneypoint coal plant was slated for closure as envisaged in the country's original climate change mitigation plans, but after a further consideration by the regulator – along with requirements to be met under the Large Combustion Plant Directive – this decision was not taken, and in fact the plant was retrofitted in order to keep operating for an extended period. It emits a significant share of the country's GHGs and is Ireland's largest single point source. See also Doherty (2008).

[10] See, for example, Tuohy et al. (2009). However, most studies of job creating potential for renewable resources do not consider how its costs, if higher than traditional energy sources, can reduce jobs elsewhere in the economy by reducing net consumer income.

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that technology difficult—despite IRP processes indicating the optimality of such outcomes.[11]

Rather richly, the US (along with The Netherlands, UK, and Italy) abstained from the vote on the basis of the climate impacts of the project.[12] The US Treasury Department explained: "We also recognise that, if South Africa's base load power needs are not met, the country's economic recovery will suffer, adversely impacting electrification, job creation, and social indicators". This decision clearly shows how difficult it is to resolve tradeoffs in such projects. As an example, the 100 MW of wind energy and 100 MW of CSP are among the largest planned grid-connected RE projects in sub-Saharan Africa. Yet their relatively small size only illustrates how difficult it might be to ramp up RE production to approach anything resembling the 9600 MW being brought on-line with the coal plants, at least in the very short-term.

Medupi's planned construction cost of USD 17.8B represents 10% of South Africa's current GDP. Whether or not this expenditure is recovered by South Africa will depend, in large part, on whether Medupi facilitates sufficient acceleration of economic growth over a long enough time horizon. In normal circumstances (if the future were a continuation of the past), this hardly seems in doubt: if Medupi were to operate normally over 20 years or more, the economic growth rate would need to be accelerated by at least 0.25% point to recover the initial investment.[13] Given that the plant adds 10% to South Africa's total electricity generation capacity, and current supply–demand imbalance, it might not be hard to make the case that it would meet this requirement. However, the future technical and political landscape is rapidly changing, and is unlikely to mirror the conditions of the past few decades.

From a strictly financial perspective, for Medupi, there may be enough time to recover capital costs before the risks of disruption to normal operation from policy and technology changes increase substantially. But the calculus for subsequent plant may well prove different (due in part from significant learning curves of competing technologies). For example, if Medupi proved to have only a period of 10 years in which to recover investment before facing substantial technical and policy risks, then the additional growth generated by the investment would need to be close to one percentage point per year. The option value of waiting until risks are resolved then becomes much higher.[14] This value reflects the additional risks of building coal in uncertain circumstances, and may be manifested not as an actual delay in building, but in increased costs required to cover the associated risk premium (i.e. to cover the need for a more rapid return on investment). Consideration of these risks therefore raises the effective cost of electricity from coal-fired generation, leading to a smaller gap between coal and alternatives such as renewables than would have been included in the economic justifications for Medupi.

2.1. *And a bit on nuclear*

It is useful to briefly consider nuclear power and its relationship to the climate-security nexus. The IAEA (2010a) cites 60 nuclear plants under construction (as of August 2010), many in developing countries; and the explicit link between nuclear energy and development is made in IAEA (2010c). South Africa has one nuclear power plant, Koeberg, completed in 1984 and supplying around 6% of SA's electricity needs. Until recently, South Africa had significant plans for expansion and was also pioneering a novel Generation IV Pebble Bed Modular Reactor (PBMR) design. In late 2007 Eskom still hoped to have over 3000 MW of nuclear generation under construction by the end of 2010. Whilst acknowledging it would have significantly higher costs than Medupi, the Eskom CEO noted that the company had to assume that it would, at some point in the future, have to pay carbon 'taxes' for its emissions (Hill, 2007). These nuclear construction plans were cancelled by Eskom in 2008 and the PBMR programme was cancelled in 2010 after over USD 1B in public expenditure without successful demonstration or commercialisation of the technology (Thomas, 2009).

A number of states with very limited domestic energy sources and hence significant energy security challenges have seen nuclear power as a key electricity industry option. The implications of nuclear power for energy security and climate change are markedly different from the use of local fossil fuels.[15] Nuclear power, of course, has no direct operational greenhouse emissions and relatively low life-cycle emissions. However, it raises other sorts of energy security concerns including the possibilities of accidents, natural disasters, terrorist attacks and the reliability of the plants themselves (MacGill et al., 2006). In some ways, this kind of externality (security, as opposed to, say, emissions) is even more difficult to treat in an IRP process.[16] In addition, the requirement for robust governance structures, and thus capacity development, is even more important for nuclear than coal (IAEA, 2010b).

3. Making plans

Generally in power system planning, there is investment in some mix of a limited range of large-scale (lumpy) capital intensive assets with enormous externalities (both positive – contribution of secure energy supplies to welfare and economic development; yet also negative – particularly with respect to environmental impacts). The costs and benefits of these externalities may outweigh the direct costs of building and operating these technologies but are very difficult to value, and fall across different jurisdictions from the local (local environmental impacts but also jobs) through to global (notably climate change).[17] What sort of process might be able to deliver useful assessments across all of these challenges?

IRP has a long history as a process and an associated set of analytical tools for expanding the traditional concept of least-cost utility planning (Swisher et al., 1997). The essence of IRP is to consider the full range of demand-side management (DSM), supply, and transmission alternatives for meeting demands for energy services while explicitly recognising uncertainties as well as

[11] The case of the Xcel's Comanche 3 supercritical coal plant (also informed by an IRP (least-cost resource planning)) in Colorado is illustrative (Xcel, 2004). While the plant (750 MW) was built, the ensuing consumer outcry over rate increases and emissions has certainly affected the decision-making process in Xcel.

[12] We write 'richly' both because of the high per capita emissions of the USA as well as the conflicting nature of the statement and the influence of an abstained vote. It is also interesting to note that the funding by the US Export–Import Bank for the Kusile coal plant is still under consideration.

[13] A 50-year operational life is cited by Eskom.

[14] It could also be argued that the Government of South Africa and Eskom already waited too long and that this partially resulted in the power crisis in 2007–2008.

[15] IAEA (2010a) notes, "In the context of growing energy demands to fuel economic growth and development, climate change concerns, and volatile fossil fuel prices, as well as improved safety and performance records, some 65 countries are expressing interest in, considering, or actively planning or nuclear power".

[16] In addition, getting accurate and up to date estimates of levelised or overnight costs for nuclear plants is very difficult (see e.g. OECD/IEA/NEA (2010), Nogee (2011), or Koplow (2011)). In addition, there is a complex relationship with subsidies; on this topic (and related to Australia) Outhred (2006) notes, "Nuclear power stations have a broad set of implications that make them essentially incompatible with the design philosophy of the National Electricity Market, in which an individual investor is assumed to bear most if not all investment risks".

[17] And range across many expertise areas from environmental to social to economic.

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tradeoffs among multiple objectives and stakeholder perspectives. Generally, at the core of the exercise is a linear programming-based optimisation tool highly dependent on a series of constraints formulated to reflect national policy priorities. In many cases, alternative scenarios, along with sensitivity analysis, allow for a richer picture than offered by a simple least-cost optimisation—as can utilising tools of multi-objective optimisation.[18] Additionally, we note that there are limitations in how well these processes can consider "cumulative impacts" of multiple projects on the environment or local populations. As an example, this is especially important in the Medupi case, because both the proposed Kuseli 4800 MW coal plant and the proposed Sasol Coal-to-Liquids (CTL) plant are to be built in close proximity.

The Eskom (2009) IRP utilised several scenarios—some of them specific to the climate constraint. The Eskom IRP also implicitly addressed the security aspects of having domestic coal; it is not an explicit objective in the optimisation analysis, but can be reflected in the assumed long-term price.[19] The Eskom IRP does consider a suite of alternatives including DSM and renewable energy (also to be financed by the World Bank in part[20]) to deliver the required energy services, but it is difficult for these options to provide full solutions in a country with such large infrastructure development requirements.[21] A separate government IRP process (GoSA, 2010) utilised aspects of portfolio theory, by deriving "risk factors" for each generation portfolio considered.[22] It also used a multi-criteria decision analysis (MCDA) framework as part of the process of weighting criteria (such as regional development and impacts on water use) in the various portfolios considered.[23] In addition, there were several academic studies focused on power system expansion options in South Africa.[24] As an example, Heinrich et al. (2007a,b) consider the South African electricity supply under conditions of uncertainty and uses a "value function MCDA" approach, as well as considering multi-objective frameworks and stochastic programming. Their explicit treatment of various uncertainties is especially useful. This type of framework, if fully implemented, would likely offer an improved approach for informing policy options.

Diversification of generation types and their associated fuel sources can be a tool to mitigate energy security risks—however there are complex interactions to consider.[25] They often have different characteristics that can be synergistically operated to meet fundamental power system requirements for frequency stability, voltage, etc. in addition to the value of a mix of different capital/operating cost characteristics for meeting varying demand. Portfolio theory and other related financial tools can often help energy planners characterize and manage the financial and other risks in IRP (Vithayasrichareon et al., 2010). In many cases, renewable energy technologies can play a more pivotal role in system operations and in reducing costs than once recognised (Bazilian and Roques, 2008). Three relatively recent developments make this even more clear: RE technology cost reductions have become significant, investment in RE is now of a scale to positively affect risk perception and thus cost of capital, and electricity market studies are showing that RE can have a downward pressure on price. None of these factors are normally treated accurately in IRP work. Additionally, more analysis of inputs (including explicit acknowledgment of the weaknesses of relying solely on levelised cost methodology) and parameters (such a load growth), would allow policy options that are not obvious to emerge from these IRP processes.

Other tools that consider uncertainty and risk can also be employed such as real options (see, e.g. Yang et al. (2008) and Blyth et al. (2007)). Real options refers to the options that companies have regarding the timing, type and modification of investment decisions. Faced with an uncertain future, there may be additional value to making investments after information has been gained which can improve financial and other outcomes. In the case of coal plants (or even individual turbine and boiler contracts), such information might for example relate to the speed of international action on climate policy, the technical and cost characteristics of carbon capture and storage (CCS) plant, and the costs of competing technologies. The shorter the period of time before such risks affect the normal running of the plant, the more companies will have to worry about them, and the higher the option value of delaying construction until the risks are resolved. Admittedly, where there are enormous gaps between demand and supply, coupled with the immediacy of issues of poverty and equity, the usefulness of these techniques is diminished to a certain degree.[26]

4. Wealth creation

The huge pressures presented by a large population without access to electricity services (approximately 20% in the case of South Africa[27]) or with unreliable service create an enormous impetus for both generation and infrastructure (transmission and distribution) development not found in similar planning exercises in OECD countries.[28] The same can be said for South Africa's industrial policies for wealth creation. As a prime example, the country's renewables initiative (SARi) is an important precedent for linking cost-effective renewable energy and "green" industrial growth (Government of South Africa, 2010).These economic and social development drivers also weigh heavily on the politics of South Africa and sub-Saharan Africa more generally.

President Zuma made South Africa's priorities clear, saying that, "achieving energy security will be a critical factor for restoring economic growth, both in South Africa, and the wider

[18] See, e.g., Cohon (1978), Belton and Stewart (2002), Mendoza and Martins (2006), Figueira et al. (2005), Hobbs and Centolella (1994), or Hobbs and Meier (2000).

[19] We note that this assumption of low-cost domestic coal can represent a very significant economic loss to a country—they can potentially earn far more by exporting the coal at international prices and (assumed and real) local prices should really reflect this.

[20] USD 260M for RE vs. USD 3.08B for the coal plant.

[21] While it is challenging for governments to assess these issues given uncertainties associated with, *inter alia*, technical progress and potential discovery of new resources; it is potentially beyond the capabilities and remit of a state owned electricity utility requiring broader energy, economic, environmental and societal perspectives.

[22] The Eskom IRP assumes that Medupi will be built, and the South African Department of Energy IRP assumes, as an input, the full Eskom Coal build programme.

[23] IRP is generally a process for governments or publicly owned or highly regulated monopoly utilities. In restructured electricity industries with market driven generation investment there is no utility to do the studies—instead governments often undertake them at the sectoral-level to inform policy and regulatory settings that guide private investment—this helps inform the interface between the two IRPs referred to in the main text. (See Rodrik (2004, 2008) for a clear justification of the need for government intervention in this type of sector—especially in developing economies.)

[24] Howells and Laitner (2003) consider efficiency investments and their impacts on GHG emissions.

[25] As an example, tensions between domestic supply and fuel diversity. In South Africa, the bulk of the electricity generation is comprised of coal and

(*footnote continued*)
nuclear—this is not the ideal mix from an operational perspective. However it is a suitable foundation for introducing intermittent renewable energy (RE).

[26] Witness that the use of some of these tools in the case of SA made very little impact on the optimal choices.

[27] IEA (2010), using 2009 data, show electrification at 75%, equating to 12.5 M people without access. Eskom's figure from (World Bank, 2010d) is 81%. GoSA (2005) also shows 5131 schools and 184 health clinics with no access to electricity services.

[28] See IEA (2010) for a detailed account of the scale of the energy access issue.

southern Africa sub-region".[29] The World Bank project document (2010b) cites the historic racial divide as an impetus for delivering fast, cheap energy supply, noting that, "... self-employment has been hampered not only by the lack of capital and more recently energy, but also the vast spatial barriers erected by the geography of apartheid". Eskom is also the key player in the South African Power Pool and is critical for supply in a region that suffers greatly from a lack of access to electricity (IEA, 2010).

While one can put costs for climate change damages or future taxation into an IRP model, it is very difficult to cost the lack of electricity services for the rural poor. If we utilise the economic concept of discounting,[30] even at a very low discount rate, it is quite possible that the immediate needs of the poor in gaining access to electricity services will be put ahead of the impacts of climate change on future generations.[31] Of course this has to be balanced with the reality that there do exist lower-carbon options for providing electrification (especially for the rural poor) that may be superior to coal in terms of overall delivery in some contexts.[32]

The goal of wealth creation through industrial development is a strong impetus for this type of large-scale generation in addition to the poverty issue (see, e.g Rodrik, 2004, 2008). Indeed, there is now greater appreciation that electrical energy is a necessary but not sufficient condition for such economic progress, particularly in the context of rural development (Cabraal et al., 2005). Not only does South Africa have a huge demand/supply gap, but it is a country of large inequality between the various populations. The need to bridge both gaps is clearly a powerful pressure point on decision-makers and politicians. Whether the Medupi decision will prove to be the societal optimal result is, of course, still questionable.

Some of the criticism of the Eskom plan had to do with the lack of transparency of the process (Nakhooda, 2010).[33] This type of governance flaw, however, is fairly common in utility planning—a highly technical area that is not easily communicated to lay audience. One way of hedging against such issues (and augmenting IRP practices) is presented by Hobbs and Meier (2000) in the form of multi-stakeholder MCDA. This process allows for careful and explicit consideration of tradeoffs among stakeholder objectives, as embodied in the full range of alternatives considered. This is then followed by evaluation, negotiation, and recommendations that reflect multiple stakeholder perspectives, sometimes aided by the quantitative weighting of objectives from various points of view. Still, the transparency (and governance) of the process is only one important aspect of moving to a final set of decisions.

Finally, the issue of supercritical (or ultra-supercritical) coal plants being eligible for Clean Development Mechanism (CDM) credits under the UNFCCC precedes the Medupi case. (CDM is predicated on developed countries with emissions targets achieving emissions reductions by supporting projects that reduce emissions from business-as-available progress and support sustainable development—the fact that supercritical plant is even contemplated for CDM highlights the complexity of the situation.) The methodology for calculating the credit has been approved (UNFCCC, 2010). The Tata Power plant in Gujarat (which received money from the Bank through the IFC) was turned down by the CDM Executive Board in August 2010. However, other supercritical plants (including the Adanis plant located very close to the Tata plant) have been approved (Reuters, 2010). How this will impact on Medupi is, as yet, unclear.

5. Towards clarity

The final decision on Medupi is clear—it is being built. What remains less than clear are how to use the processes and the justifications for that decision as a precedent for future projects and plans at the nexus between energy security and climate concerns. Rather, those precedents – in the form of abstained votes, articulation of a "third way", critiques of transparency, results of an IRP, and commentary about the complexity of the decision space – provide insufficient guidance. Clearly, South Africa is not alone, the Medupi plant provides a microcosm of the issues facing a large number of countries, with coal users all over the world facing similar dilemmas. As we have argued, part of the answer lies in clearly evaluating the risks of different energy sector options, and showing explicitly the trade-off between these risks in the decision-making process. Taking advantage of available refinements in analytical tools (e.g. MCDA, real options, innovative and explicit treatment of uncertainties, portfolio theory, and alternative valuation techniques) and adopting them at an early stage in a comprehensive IRP process can add significantly to the provision of policy options and understanding of their tradeoffs.

In addition, demand-side issues are not often treated well in analytical work conducted to look at power system expansion. But it is clear that with smarter planning and early investments (not solely in response to fighting short term shortages), South Africa may have already been on a lower emissions trajectory and "bought" time to consider other new, developing low-carbon options. Distributed generation is likewise often difficult to consider in IRP processes. But lessons like those emerging from the Moroccan experience, which relies on complementary centralised and decentralised electrification programmes, shows the importance of these 'hybrid' approaches. Thus, we need not only more visionary investments, but clear signals from the international community. Still, will likely see more international investment in coal, often for the 'right reasons'.

Another part of the answer is to separate the risk of lock-in to coal generation plant *per se*, from the risk of lock-in to unsustainable industrial structures in the wider economy. The risk of creating stranded assets in the energy sector may be dwarfed by the risk of creating stranded assets in the wider economy.[34] Using cheap electricity to grow energy-intensive industry at the expense of more value-added economic activities may be unwise given the costs of industrial re-structuring this might imply in the future. The alternative is to capture the rents associated with cheap electricity sources such as Medupi through state taxes. These funds could be

[29] This was the first major lending engagement with South Africa since the end of apartheid (World Bank, 2010a).

[30] See Stern et al. (2006) and the ensuing criticisms from several economists (e.g. Tol and Yohe, 2006; Nordhaus, 2006) for a discussion of discounting in light of climate change.

[31] The Scenario Building Team (2007) notes that, "Developing countries are currently not constrained under the Kyoto Protocol. However in the upcoming international negotiations there is increasing pressure on the larger developing country emitters to demonstrate their plans for achieving emissions reductions". Thus, the future nature of the constraint on climate change is made explicit.

[32] Indeed, Eskom undertook some highly innovative solar home system deployment programs in the early 2000s that highlighted some of the opportunities yet also challenges of such approaches (Lindiwe et al., 2006).

[33] IDASA (2010) provides a full evaluation of the governance issues in the SA power sector. They focus on the process of policy and regulatory decision-making and find that in South Africa, "... a systemic lack of clarity concerns roles and responsibilities ... with an associated extended period of policy opaqueness. Despite an initially clear vision for policy ... a sense of drift ... has characterised policy development".

[34] As an example, South Africa's dependence on the mining sector is critical in this regard—the minerals are there, and have been offering very high profits in the current commodities boom. Those benefiting could likely pay more for electricity especially if it was associated with improved supply security (and quality of service).

used to promote green growth priorities and a longer-term more sustainable industry structure, whilst building financial reserves to help tackle future energy-sector de-carbonisation.

Finally, and although we have espoused the use of improved analytical methods, we recognise that the results of any analysis require some considerable level of interpretation and translation in order to appropriately inform design and implementation of government policy.[35] Underscoring this need, Weyant (2001) notes that analysis conducted to support policy making is, "… rich and extensive, but widely divergent in results". At the same time, Munson (2004) adds that there is also a disconnect between the questions policy-makers want answered and the results provided by modelling exercises. This is often due to "communication gaps" inherent in the dialogue between environment, economic, and energy experts and "silo thinking" in government departments.[36] Thus, along with refined analytical tools, and bridging communication gaps between technical experts and policy-makers, there is the essential need for capacity building at all points along the continuum (Bazilian, 2009). This is an especially clear priority in developing countries.

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[35] Laitner (2006) poses the risks of relying too heavily on existing analytical tools and methods, "… such models provide biased estimates that tend to reinforce the *status quo*, inadequately inform policy-makers about new market potential, and serve to constrain the development of innovative policies". And Koomey (2008) notes, "One purpose of analysis is to support public or private choices; in this context, it cannot be value-free. It can, however, illuminate the *consequences* of choices so that the people and institutions making them can evaluate the alternative outcomes, using both their values and the analysts' best estimates of the consequences for each choice".

[36] New institutions like the Joint Institution for Sustainable Energy Analysis (JISEA) are recognising this issue and designing research agendas accordingly.

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