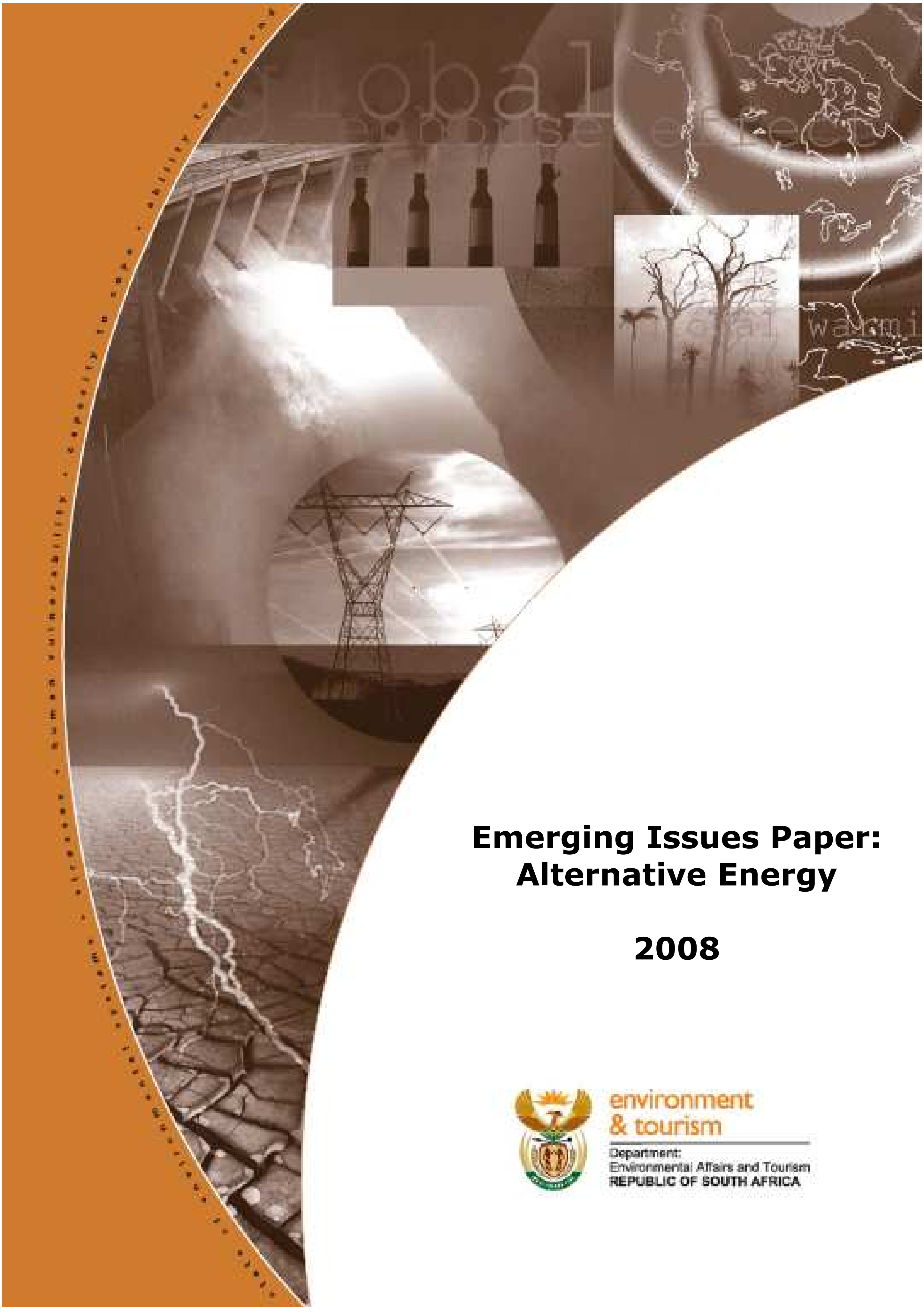

Emerging Issues Paper: Alternative Energy

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SUSTAINABILITY ASSESSMENT AND MANAGEMENT OF ALTERNATIVE ENERGY TECHNOLOGIES: TOWARDS POLICIES AND STRATEGIES TO ADDRESS THE NATIONAL SOE OUTLOOK AND OTHER GLOBAL CHANGE ISSUES

This document provides information on emerging issues that may affect the future state of the environment. The purpose of this paper is to draw attention to issues in preparation for the next state of environment reporting cycle.

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Introduction

The South African National Research and Development (R&D) Strategy (DST, 2002) states that for sustainable development to take place, rural and urban communities should have access to innovations that accelerate development and provide new and effective solutions compared to those utilised previously.

Energy is increasingly linked to the sustainable development paradigm (IPCC, 2007). Climate change is associated with use of energy whilst poverty is often linked to low access to energy. To this end, the challenge for NEPAD (2005) and the South African Energy R&D strategy (DST and DME, 2006) is to fully develop the available energy resources and to promote innovative, competitive, equitable and sustainable energy systems for various economic and social sectors across South Africa and the continent. Solutions to these sustainability problems may be achieved through the use of new technology that reduces pollution and, in some instances, provides development opportunities. The aim is to address the requirements of Agenda 21 pertaining to environmentally sound technologies (ESTs) (UN, 2005: 34.4):

"*There is a need for favourable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology cooperation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology. Technology cooperation involves joint efforts by enterprises and Governments, both suppliers of technology and its recipients. Therefore, such cooperation entails an iterative process involving government, the private sector, and research and development facilities to ensure the best possible results from transfer of technology. Successful long-term partnerships in* *technology cooperation necessarily require continuing systematic training and capacity-building at all levels over an extended period of time*".

Environmentally sound technologies (ESTs) are those that "*protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes*" (UN, 2005: 34.1; IETC, 2003).

In essence R&D efforts strive to render ESTs more affordable to all economic and social sectors through collaborative inter-country partnerships that address regional issues to minimise barriers and systems failures. In other words, partnerships working for local long-term energy security whilst also contributing to global issues such as climate change (Turton and Barreto, 2006). In response, policies in the Southern African Development Community (SADC) region place much emphasis on bio-energy and other renewable energy technologies (Motlhatlhedi, 2004). Table 1 provides an outline of the types of energy sources available, and the cross-cutting issues that face R&D.

Table 1: Classification of energy R&D requirements (adopted from Roos et al., 2004)

<table>
<tr><th>Category</th><th>Type</th><th>Resource</th><th>Generation</th><th>Distribution / Storage</th><th>Conversion</th><th>R&D requirements</th></tr>
<tr><td rowspan="3">Fossil</td><td>oil</td><td rowspan="3">Reserves, availability, extraction</td><td rowspan="3">Combustion heat</td><td>Road tanker, pipeline, shipping</td><td>IC engines, turbines</td><td rowspan="4">Energy efficiency:
• Residential;
• Commercial;
• Industrial.

Safety

Regulatory frameworks

Off-grid issues</td></tr>
<tr><td>coal</td><td>Road, rail, shipping</td><td>Rankine cycle with boiler, IGCC</td></tr>
<tr><td>gas</td><td>Bottles, pipeline, shipping</td><td>Combined cycle, OCGT</td></tr>
<tr><td>Nuclear</td><td></td><td>Fuel processing, enrichment</td><td>Nuclear heat: PWR, HTR, FBR</td><td></td><td>Rankine cycle, Brayton cycle</td></tr>
</table>

Category	Type	Resource	Generation	Distribution / Storage	Conversion	R&D requirements
Renewable	Solar	Insolation mapping	Photo-voltaic effect: PV	Use at source	PV cells	
Renewable	Solar	Insolation mapping	Solar heat: Thermal power generation (concentrated), water heaters	Heat stored in thermal oil and molten salts	Rankine cycle, Brayton cycle	
Renewable	Wind	Wind mapping	Mechanical motion	Use at source	Horizontal and vertical axis turbines	
Renewable	Hydro	Rainfall, terrain	Mechanical motion	Dams, rivers/waterfalls, pumped storage	Kaplan, Francis & Pelton turbines	
Renewable	Ocean	Wave, tide and current mapping	Mechanical motion	Use at source	Wave, current & tidal devices	
Renewable	Biomass	Climate, rainfall, soil	Combustion heat: Gasification, pyrolysis	Steam or electricity reticulation Use at source, reticulation or distribution	Rankine cycle	
Renewable	Geo-thermal	Geological mapping	Geothermal heat	Use at source	Rankine cycle	
Renewable	Municipal wastes	Arisings, quantity and composition, geographically	Combustion heat	Use at source, or transport over short distances	Rankine cycle	
Carriers	Electricity	Installed capacity	Mechanical motion to electric generator	Electric grid, no current feasible storage	Electric motor, induction heater, appliances	
Carriers	Hydrogen	Water, hydrocarbons	Electrolysis (H_2O), stripping, production of methane	Pressurised bottles, Cryogenic, pipelines	Fuel cell, gas turbine, IC engine	

Further studies have been undertaken to determine the feasibility of such alternative energy technologies (AETs) in SADC (Roos et al., 2004; Takavarasha et al., 2005). However, a number of important issues have been raised to ensure the sustainability of AETs in the SADC region (Takavarasha et al., 2005). One of these issues is the necessity of in-depth analyses of the appropriateness of the different technologies in a regional context, considering factors such as effective utilization of by-products, natural resource management that considers biodiversity conservation, ecology and pollution control, the management of supply and distribution chains, effective production and applications, and social adoption, to name but a few.

A number of statements have been made with regards to the development of relevant technology evaluation tools (Geisler, 2002):

- Technology is not judged by its existence alone, nor is its mere existence a sufficient condition for successful usage.
- We cannot evaluate technology unless and until we put it in the context of social (and environmental) and economic circumstances.
- Technology is not defined and evaluated by what it is, but by its actual and potential users.

The problem of assessing the recommending AETs can be ascribed to the complexity of the associated integrated technological, social, economic, environmental, and institutional systems in terms of:

- Time effects and the behaviours of interconnected systems;
- Multiple solutions and trade-off possibilities (technological and otherwise);
- Non-linear relationships between causes and effects in the systems, including scales from macro- to micro-levels; and
- Unintended consequences.

Results from various case studies (Mabuza et al., 2007; Brent and Rogers, 2007) indicate that the technical failure of technology systems can largely be attributed to:

- The complexity (and vulnerability) of social systems, which results in uncertainty for project planners and system designers; and
- The lack of resilience of the technology system to demands from social, economic and institutional systems.

In other words, the dynamic interaction between society, its energy-related technologies and management thereof, and the natural environment must be understood in a holistic and comprehensive manner. The regional capacities of resources, natural and social, must be taken into account when energy-related technologies are assessed and managed (Mapako, 2006), as the effective consideration of the sustainability of such resources must be incorporated in energy-related policies and strategies for AETs. Then AET-related policies and strategies would also be able to effectively address the themes of the National State of the Environment (SOE) Outlook (DEAT, 2006) and other global change issues.

Discussion

The alternative energy technology (AET) industry is advancing rapidly (Grasl et al., 2004) in response to policies such as the South African white paper on renewable energy (DME, 2003) and the South African biofuels industrial strategy (DME, 2007). AETs will all require tradeoffs between potential technical advantages, and socio-economic and environmental consequences. For example, the use of bio-energy will in most circumstances require a change in land use, thus presents both a threat to biodiversity and food production as well as an opportunity for rural development. A disproportionately high potential impact on the economy is likely (Brent et al., 2008). Land use change, in turn, may well lead to a net increase in climate change due to first-generation biofuel value chains (Searchinger et al., 2008).

Many of these sustainability aspects appear as fatal flaws in AET systems in that, despite technological advances, a number of project failures have been noted with the development, design and implementation of such systems in Africa (Mapako, 2006). Reasons for this include cost-effectiveness, market barriers such as inconsistent pricing structures, institutional, political and regulatory barriers, and social and environmental constraints (Painuly, 2001). Some sustainable development constraints may be specific to the technology, while others may be specific to the African socio-economic and political context (Ahmed, 2004). The risk of technology failures is therefore often enhanced by the inability of pre-feasibility and feasibility phases of a technology life cycle to understand the likely sustainable development implications after implementation of innovations, in a holistic and comprehensive manner (Brent and Pretorius, 2007).

The difficulty of integrating the paradigm of sustainable development and the reality of energy technology or innovation management practices has been argued (Coles and Peters, 2003). The literature on technology management and sustainable development increasingly deals with integrated strategies for the roadmapping, selection and transfer of technology across companies, sectors, regions and countries (Brent and Pretorius, 2007). However, moving AETs along the innovation chain from R&D to commercialisation, to facilitate maximum and sustainable market penetration, is a particular challenge (Foxon et al., 2005).

Most AETs are still found in the phases leading up to the pre-commercialisation phase of the innovation chain. To enable the progression of technologies along the innovation chain, multiple R&D efforts are required for each of the respective energy value chains (refer back to Table 1). Indeed, it has been noted that anywhere from seven to more than 300 years are required to diffuse energy R&D, with an average of 17 years (Moore et al., 2006).

Furthermore, it has been noted (UK DFID, 2006) that the constraining and enabling factors important to scaling-up of innovations, and the implementation of the new knowledge and technologies, are far less well understood than the technologies themselves. Technology management and marketing theory refers to 'chasms', or discontinuities, in the transfer and adoption phases of technology life cycles (Moore, 1999), which had traditionally been perceived as continuous. These chasms necessitate employing both top-down and bottom-up approaches for decisions pertaining to technologies (Mulder and Brent, 2006; Brent et al., 2007). This revised technology assessment and management approach for sustainable implementation has yet to be addressed by AET systems in the African context. It should however, be assist in:

- Prioritising and choosing from a range of AET options in relation to the robustness and resilience of complex systems, which require screening of technical feasibility, economic and financial viability, and social and environmental acceptance;
- Best implementing technically feasible solutions, in an integrated manner, within the country's prevailing political, socio-economic and social-ecological systems; and
- Monitoring and ensuring the sustainable adoption and operation of chosen AET options.

The main challenge is, therefore, how to ensure that policies and decision-making on AET options result in localised social-ecological advantages that outweigh disadvantages. The complex behaviours that both socio-economic and ecological systems exhibit exacerbate this problem, primarily because of the fundamental uncertainty associated with them. These behaviours must be recognised and approaches are required to assess and manage behavioural uncertainties in a sustainable way. If decision-makers of AET practices and policies consider in a holistic manner the complex interactions between future implemented AET systems and society, and the ecosystem services that will sustain them, then AET systems may be adopted and managed in a sustainable manner.

This challenge has provided the opportunity to link different bodies of knowledge, most notably sustainability science (Kates *et al*., 2001; Clark and Dickson, 2003) and technology management (see Figure 2), in terms of:

- The gap in knowledge of how technologies can be managed in a sustainable manner at sector and regional level in comparison with the management of technology at the enterprise level (Liao, 2005; Propp and Rip, 2006; Phaal et al., 2006).
- The identification of the real economic, social and environmental needs of the end-market, which enhance the probability of energy technology R&D project success (Potgieter, 2005; Singh, 2005).

	Sustainability Science	**Sustainable Technology Life Cycle Management**
Challenge	To extend sustainability science theory into practice.	To incorporate sustainability science theory into technology and innovation management practices, and associated tools, for AETs.
Objective	To promote understanding of the state of resilience and transformation potential of selected, potentially vulnerable, social-ecological systems affected by the transitions of such systems.	To promote understanding of the potential responses of selected social-ecological systems to AET and innovation strategies, interventions and management practices in Southern Africa.
Opportunity	To link to the region's social development priorities.	To link to the infusion of new technologies into the region, which are believed to be key long-term drivers for socio-economic development.
South African Competency	Established profile in the science of conservation planning, water resource management (and related policy development), integrated regional planning and urban settlement analysis, and environmental assessment.	Established profile in the sciences of engineering design and management, project management, and integrated environmental management. A major strength that can be utilised is the linkage between researchers in sustainability sciences, technology management and technology development.

Figure 1: Extension of the Sustainability Science field to Technology Management

Different modelling approaches from Sustainability Science and technology management bodies of knowledge may be utilised through an integrated modelling framework. A desired feature of such a framework is to dynamically represent change in technology adoption under various scenarios. In other words incorporate feedbacks and feed forwards, and the impacts of various policy measures on model outputs (Houghton, 2006). In this respect, ongoing behavioural modelling research is required to assist in integrated energy planning (Brent, 2008).

Conclusions

Technological research is viewed as one of the four branches of sustainability science (Kates *et al.*, 2001), one that concentrates on the design of devices and systems to produce greater social benefit with less environmental harm. The merger of these fields has led to concepts such as Environmentally Sound Technologies. The importance of alternative energy technologies has subsequently been recognised to address local, regional and global change challenges. However, challenges are recognised in the sustainability assessment and management of AET systems, and these are yet to be resolved.

Further research is required to strengthen the linkages between sustainability science and technology management, and promote joint problem solving by scientific, societal, economic and political stakeholders through a trialogue model (see Figure 3) (Turton et al., 2007) to:

- Systematically understand technological, sociological, ecological, economic, and institutional system complexity.
- Develop assessment frameworks and methods to assist decision-makers of AET systems to enhance the sustainability of associated management practices and policies.

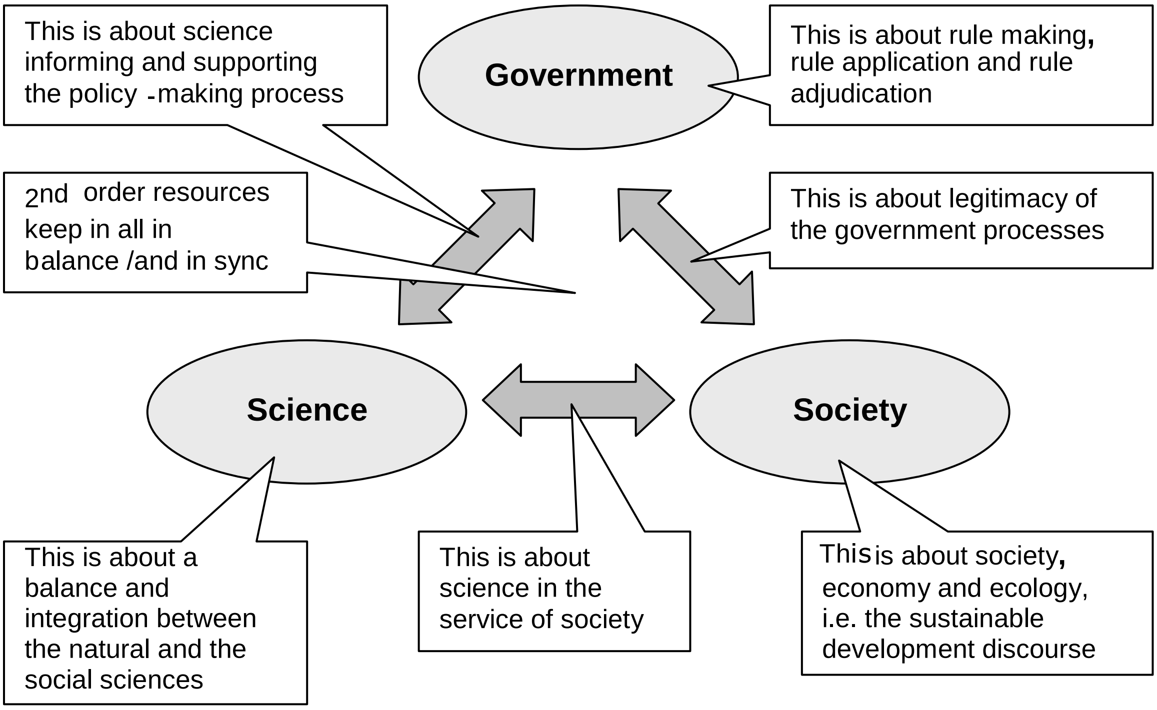

Figure 2: Schematic representation of the trialogue model (adopted from Turton et al., 2007)

Such a research approach will address two distinctive challenges:

- The challenge of effective and sustainable transfer and adoption of AETs: The general barriers for the successful transfer of AETs have been noted. Issues of environmental consequences of energy policies, energy supply inter-dependency, technology (and knowledge) transfer and capacity building must be addressed.
- The challenge of interaction of transdisciplinary research teams (Klein, 2004) which are required to reach truly sustainable technology management practices.

By addressing these challenges, the potential implications of AETs on the themes of the National SOE Outlook (DEAT, 2006) and other global change issues can be taken up in AET-related policies and strategies.

References

Ahmed, A. 2004. Making technology work for the poor: Strategies and policies for African sustainable development. *International Journal of Technology, Policy and Management*, 4 (1), 1-17.

Brent, A.C. 2008. Sustainability modelling aids integrated energy planning. *ScienceScope*, in press.

Brent, A.C. and Pretorius, M.W. 2007. *Sustainable Development: A conceptual framework for the technology management field of knowledge and a departure for further research*. Proceedings of the International Association for Management of Technology (IAMOT), Miami, USA.

Brent, A.C. and Rogers, D.E.C. 2007. *Sustainability science and the management of renewable energy technologies*. International Council for Science (ICSU) International Field Workshop on "Renewable Energy for Sustainable Development in Africa", Mauritius.

Brent, A.C., Rogers, D.E.C., Ramabitsa-Siimane, T.S.M and Rohwer, M.B. 2007. Application of the Analytical Hierarchy Process to establish Health Care Waste Management systems that minimise infection risks in developing countries. *European Journal of Operational Research*, 181, 403-424.

Brent, A.C., Fortuin, H., Wise, R. and Molapo, M. 2008. The viability of the South African biofuels industrial strategy. *International Journal of Environment and Pollution*, in press.

Clark, W.C. and Dickson, N.M. 2003. Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America*, 100 (14), 8059-8061. Online at: http://www.pnas.org/cgi/content/full/100/14/8059.

Coles, A-M. and Peters, S. 2003. Sustainable development, global innovation and advanced technologies: The case of fuel cells. *International Journal of Environmental Technology and Management*, Vol. 3, No. 3/4, 278–289, In: 2005. Alternative Energy Sources. *Fuel and Energy Abstracts*, 46 (1), 26.

DEAT. 2006. *South African Environmental Outlook*. Department of Environmental Affairs and Tourism, Pretoria.

DME. 2003. *White paper on renewable energy*. Department of Minerals and Energy. Online at: http://www.dme.gov.za/energy/documents.stm.

DME. 2007. *Biofuels industrial strategy of the Republic of South Africa*. Department of Minerals and Energy. Online at: http://www.dme.gov.za/energy/documents.stm.

DST. 2002. *South Africa's National Research and Development Strategy*. Department of Science and Technology. Online at: http://www.info.gov.za/otherdocs/2002/rd_strat.pdf.

Department of Science and Technology (DST), Department of Minerals and Energy (DME). 2006. *South African Energy Research and Development Strategy*. Confidential.

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A. and Anderson, D. 2005. UK innovation systems for new and renewable energy technologies: Drivers, barriers and systems failures. *Energy Policy*, 33 (16), 2123-2137.

Geisler, E. 2002. The metrics of technology evaluation: Where we stand and where we should go from here. *International Journal of Technology Management*, 24 (4), 341-374.

Grasl, H., Kokott, J., Kulessa, M. and Luther, J. 2004. *World in transition: Towards sustainable energy systems*. Earthscan, London.

Houghton, J. 2006. Introduction: Modelling technological change in climate policy analyses. *Energy Economics*, 28 (5-6), 535-538.

International Environmental Technology Centre (IETC). 2003. *Environmentally Sound Technologies and Sustainable Development*. Division of Technology, Industry and Economics, United Nations Environment Programme. Online at: http://www.unep.or.jp/ietc/knowledge.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The physical science basis: Summary for policy-makers*. IPCC, Paris, Online at: http://www.ipcc.ch/ipccreports/ar4-syr.htm.

Kates, R.W., Clark, W.C., Corell, R. Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grübler, A., Huntley, B., Jäger, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore III, B., O'Riordan, T. and Svedin, U. 2001. Sustainability Science. *Science*, 292 (5517), 641-642.

Klein, J.T. 2004. Prospects for transdisciplinarity. *Futures*, 36 (4), 515-526.

Liao, S-H. 2005. Technology management methodologies and applications: A literature review from 1995 to 2003. *Technovation*, 25 (4), 381-393.

Mabuza, L.O.K., Brent, A.C., Mapako, M. 2007. *The transfer of energy technologies in a developing country context: Towards improved practices from past successes and failures*. Proceedings of the World Academy of Science, Engineering and Technology, 22, 237-241, Prague, Czech Republic.

Mapako, M. 2006. *Renewable energy and energy efficiency delivery models*. Discussion paper presented at the ADB/FINNESSE Training Course on Renewable Energy and Energy Efficiency, Nairobi, Kenya.

Moore, G.A. 1999. *Crossing the chasm: Marketing and selling high-tech products to mainstream customers*. HarperCollins Publishers, New York. Summary online at: http://www.parkerhill.com/Summary%20of%20Crossing%20the%20Chasm.pdf.

Moore, M.C., Arent, D.J. and Norland, D. 2006. R&D advancement, technology diffusion, and impact on evaluation of public R&D. *Energy Policy*, 35 (3), 1464-1473.

Motlhatlhedi, F.O. 2004. *Strategies for biomass energy: The SADC programme for energy conservation (ProBec).* International Conference for Renewable Energies, Bonn, Germany. Online at: http://www.renewables2004.de/en/documentation/speeches_presentations.asp.

Mulder, J. and Brent, A.C. 2006. Selection of sustainable agriculture projects in South Africa: Case studies in the LandCare programme. *Journal of Sustainable Agriculture*, 28 (2), 55-84.

New Partnership for Africa's Development (NEPAD). 2005. *A summary of NEPAD Action Plans*. Online at: http://www.nepad.org/2005/files/documents/41.pdf.

Painuly, J.P. 2001. Barriers to renewable energy penetration: A framework for analysis. *Renewable Energy*, 24 (1), 73-89.

Phaal, R., Farrukh, C.J.P. and Probert, D.R. 2006. Technology management tools, concept development and application. *Technovation*, 26, 336-334.

Propp, T. and Rip, A. 2006. *Assessment tools for the management of new and emerging S&T; state of the art and research gaps.* Ta NanoNed Working Paper No1, Centre for Studies of Science Technology and Society, University of Twente, the Netherlands.

Potgieter, M.J. 2005. *Towards a requirements management process for the armaments corporation of South Africa.* Masters project, Graduate School of Technology Management, University of Pretoria.

Roos, T., Szewczuk, S., North, B., Hietkamp, S., Jeffreys, L., Engelbrecht, A., Strauss, K., Liphoto, L., McGonigal, S., Greben, J. and Zulu, T. 2004. *Techno-economic and environmental review of alternative energy resources*. CSIR report number PTC-05-032 (86DD / HTE44), Pretoria, South Africa.

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T-H. 2008. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change. *Science*, DOI: 10.1126/science.1151861.

Singh, N. 2005. *The development and application of a holistic lifecycle approach to managing products in the South African automotive industry*. Masters project, Graduate School of Technology Management, University of Pretoria.

Struyf, I.L.R. 2003. *Inter-organizational learning for sustained competitiveness and ecological sustainability – the case of beta-testing activities of alternative-fuel, fuel cell-driven public transport buses*. Doctoral research paper, Erasmus Centre for Sustainability and Management, Erasmus University, Rotterdam, the Netherlands.

Takavarasha, T., Uppal, J. and Hongo, H. 2005. *Feasibility study for the production and use of biofuel in the SADC region*. Southern African Development Community (SADC) Secretariat, Gaborone, Botswana.

Turton, H. and Barreto, L. 2006. Long-term security of energy supply and climate change. *Energy Policy*, 34 (15), 2232-2250.

Turton, A.R., Hattingh, H.J., Claassen, M., Roux, D.J. and Ashton, P.J. 2007. Towards a model for ecosystem governance: An integrated water resource management example. In: Turton, A.R., Hattingh, H.J., Maree, G., Roux, D.J., Claassen, M. and Strydom, W.F. (eds). *Governance as a trialogue: Government-Society-Science in transition.* Springer Verlag, Berlin.

United Kingdom Department for International Development (UK DFID). 2006. *Expressions of interest: Background document for energy for development research programme consortium*. Online at: http://www.dfid.gov.uk.

United Nations (UN). 2005. *Agenda 21*. Department of Economic and Social Affairs, Division for Sustainable Development. Online at: http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm.