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SCIENCE, TECHNOLOGY AND INNOVATION POLICYMAKING, ADVICE AND EVALUATION CAPABILITIES IN POST-APARTHEID SOUTH AFRICA: AN ASSESSMENT

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ABSTRACT

This paper examines the configuration of South Africa's science, technology and innovation (STI) policymaking, advisory and evaluation capabilities in the post-apartheid era, responding to calls for deeper analysis of evidence-in-use. The research question probed is: How have institutional histories and sector-specific developments shaped the country's ability to generate, mobilise and apply evidence in support of policy learning? The analysis is structured around four case studies – institutionalisation of STI measurement, policy advice and evaluation; the HIV/AIDS crisis; the Square Kilometre Array (SKA); and the Pebble Bed Modular Reactor (PBMR) – each refracting strengths, weaknesses, opportunities and risks within the national system of innovation. The cases reveal a system characterised by both resilience and fragmentation: strong indicator and evaluation infrastructures coexist with uneven advisory autonomy, variable political commitment to evidence, and inconsistent cross-domain learning. The paper argues that strengthening South Africa's STI policymaking, advisory and evaluation capability nexus requires more autonomous advisory bodies, milestone-based review and evaluation ("decision gates") for major projects, and institutional mechanisms that enable knowledge brokerage across sectors. These findings offer lessons for countries seeking to balance expertise, politics and public accountability in STI governance.

Keywords: *Evidence-in-Use, Assessment, Science, Technology, and Innovation, Policymaking, Advice, Evaluation, South Africa, National System of Innovation.*

1. INTRODUCTION

Evaluation scholars have called for deeper analysis of *evidence-in-use* in Africa's public policy contexts (Goldman & Pabari, 2021). Such calls recognise the complex, context-specific, interactive, and iterative nature of evidence-informed policy making. They also challenge earlier linear models (science-push, or science-pull for example), recognising change processes occurring at individual, interpersonal, organisational and system levels, and in the context of several constraints, such as resources, ideological, data-related, and use-informed constraints (Cloete, 2009, 2017). In the South African context, the evidence ecosystem has been found to be characterised by growing institutionalisation of evidence use (Stewart et al., 2019). However, scholars have also warned of the dangers of performative scientism (e.g. Muller, 2021) and emphasised the critical role of knowledge-brokers in bridging the gap with policy (Strydom et al., 2010). Deeper contextual analyses, for example by sector or policy domain, are key to provide indications of strengths, weaknesses, opportunities and risks in the broader enterprise of evidence-in-use to inform policy learning.

In part as a response to Goldman and Pabari's injunction, this contribution focuses on the nexus of South Africa's science, technology and innovation (STI) policymaking, advice and evaluation capabilities. The mandate for STI falls under the same ministerial umbrella in South Africa, as do the human and institutional capabilities for STI policymaking, advice and evaluation. Policymaking, advice and evaluation capabilities, however, reflect distinct competencies and communities of practice, and the first analytical step of this paper is to historicise their evolution. Critically, where these capabilities do or do not converge at different "moments" of policy decision-making in and beyond the remit of the ministry – that is, in which key personalities or organisations mobilise resources and pursue strategic visions – unique insights may be gleaned about the resilience of these evidence-in-use capabilities and, equally so, their points of fracture or contestation. In a second analytical step, this paper draws on four case studies of such moments of policy decision-making that can be instructive to inform the future(s) of STI policymaking, advice and evaluation.

2. HISTORICISING SOUTH AFRICA'S STI POLICYMAKING, ADVICE AND EVALUATION CAPABILITIES

The South African National System of Innovation

A conceptual starting point is the innovation systems perspective, which South Africa has formally adopted as both analytic concept and development tool (Freeman, 1987; Kuhlmann & Arnold, 2001; Lundvall, 2002, 2007; DST, 2019). In this perspective, innovation is more than the net result of the R&D-performing firm. It is rather a function of a broader set of organisations, interactions, conditions and, critically, institutions. In recent decades, several scholars have developed important analyses of aspects of South Africa's national system of innovation (NSI) (e.g. Kahn, 2006; Scerri, 2009; Lorentzen, 2009; Walwyn & Cloete, 2016). In this paper, we start from a recent model of NSI contained in Akoojee, Kahn and Letseka (2021) (Figure 1), which moves beyond the box and stick model of innovation systems and offers a sextuple helix. This model emphasizes the complex, open, self-organising nature of innovation activities (centre of Figure 1). The model also eschews straight lines, proposing curved linkages that speak to the multiple connections that well-functioning innovation systems are predicated upon.

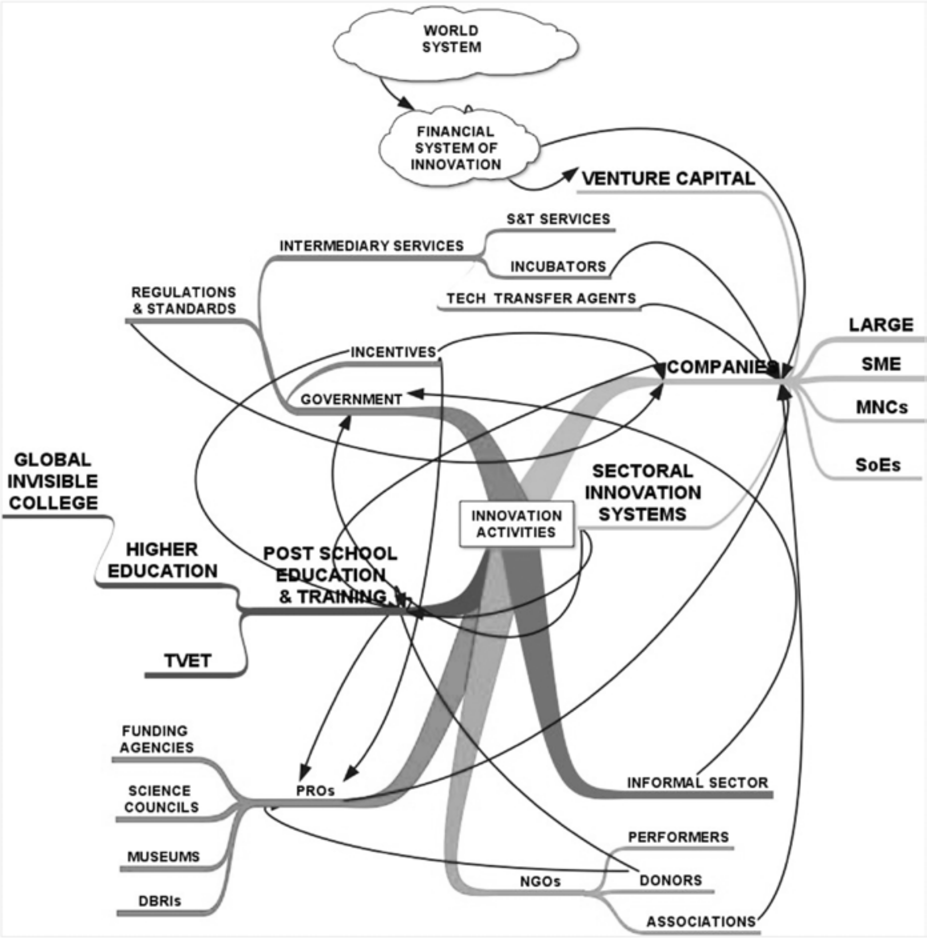

Figure 1: "Spaghetti" model of the SA innovation system

Notably, the left-hand side of the model includes the public sector, including Technical Vocational Education and Training (TVET) and Department Based Research Institutes (DBRIs); the right is the set of market facing actors; the bottom-right includes the third sector and the informal sector; while the top reflects the state and its regulatory institutions. Should all linkages be shown, the graphic would resemble a plate of cooked spaghetti. The development of the spaghetti model is informed by complexity science; its present use value lies in the way that it may highlight system failures, such as disarticulation, that characterises innovation systems of emerging economies.

Policymaking capabilities

Explicit science and technology (S&T) policy formulation dates from the First World War period during which the Union of South Africa played a major role as a logistics and *matériel* production hub. Based on this experience, the Department of Mines and Industry under Minister JP Malan promoted the equivalent of mission-oriented research and development (R&D) and industrial policy in the 1920s, deepening and expanding state control of the commanding heights of the economy. The Second World War saw further industrial diversification, and the growth of a military-industrial complex that in 1945 birthed the Council for Scientific and Industrial Research (CSIR). From the 1960s the country slid into low-intensity civil war, with the CSIR playing the roles of research performer, organisational incubator, weapons laboratory, and seat for S&T policy advice to government alongside the office of the Chief Science Advisor and the Scientific Advisory Council (CSIR, 1964, 1970). Academia enjoyed the state's support to function much like Polanyi's (1962) Republic of Science.

By the 1980s, the Republic of Science was being compelled to reckon with fast-swelling anti-apartheid resistance. It was also facing strategic choices about its orientation towards neo-liberalism (Garrett & Clark, 1992; Lutjeharms & Thomson, 1983). Indeed, neo-liberalism informed the granting of "framework autonomy" – a form of conditional independence for research institutions to govern their own research agendas, internal policies, and operational structures, while remaining accountable to national authorities and developmental goals – to the Science Councils[1] as part of the agenda of corporatisation (CSIR, 1986). By the time of the

1 Science Councils refers to several research-performing, mostly state-funded entities established at different points in the twentieth century, such as the CSIR, the Human Sciences Research Council, the Medical Research Council, Agricultural Research Council, Council for Geoscience, and the like.

democratic transition, corporatisation saw the privatisation applied to telecommunications, air transport, steel, forestry, and chemicals.

Post-1994 redress and modernisation came through a range of sectoral policies including the White Paper on Science and Technology (DACST, 1996), the subsequent National R&D Strategy (DST, 2002), and the establishment of a dedicated Department of Science and Technology (DST). The White Paper advocated for the adoption of the innovation system approach alongside the establishment of new institutions – the National Research Foundation (NRF), Academy of Science of South Africa (ASSAf), and National Advisory Council for Innovation (NACI). A notable achievement of the period was the National Research and Technology Foresight study (DACST, 1999).

Curiously, the subsequent R&D Strategy and Ten-Year Innovation Plan (TYIP) (DST, 2008) promoted the linear model of change in contradiction to that of a self-organising national system of innovation. In addition, the heuristic device of the "innovation chasm" was advocated to explain the lack of – or difficulties associated with – commercialisation of R&D. These assertions exerted a powerful influence on the evolution of STI policy and organisational strategies, notably that of the DST, CSIR and the new Technology Innovation Agency (TIA). A key recommendation of the R&D Strategy was to abolish the coordinating mechanism of the parliamentary grant to the Science Councils, known as the "Science Vote". This took place alongside re-arrangement of their reporting lines, with CSIR moving to the DST. By contrast, the apartheid-era publication subsidy, researcher rating system, the Technology and Human Resources for Industry Programme (THRIP), and the Support Programme for Industrial Innovation (SPII) were maintained. Also, DST introduced five new supply side incentives, namely the South African Research Chairs Initiative (SARChI), Centres of Excellence, Centres of Competence, the National Intellectual Property Management Office (NIPMO) with support for technology transfer offices, and the enhanced R&D Tax Incentive. The TYIP was given substance through the development of sectoral roadmaps.

Evaluation and assessment capabilities

Following the Organisation for Economic Co-operation and Development (OECD) review of South Africa's innovation policy (OECD, 2007), three Ministerial reviews were initiated and published (DST, 2012, 2017; HESTIIL Ministerial Committee, 2020). As noted in the independent review of the National R&D Strategy and TYIP (NACI, 2020a), notwithstanding successes in radio astronomy (Case Study B below) their various recommendations led to new institutional modalities, but resulted in little systemic change. The White Paper on STI (DST, 2019) and the STI Decadal Plan 2022-2032 (DSI, 2023) continue to advocate basic research with efforts toward innovation-driven socio-economic impact. These two instruments give substance to the recommendations of the Ministerial Review (DST, 2012) in advocating government-industry cooperation, and a re-capacitation of an autonomous NACI.

Other assessments include Kaplan (2010), who argued that skills constraints would limit the attainment of the TYIP; while Cooper (2011) drew attention to the related problem of sub-optimal personality-driven research groups. The NRF commissioned an external evaluation of its five grant programmes, finding that:

> "The chance of socioeconomic impact ... is enhanced when eight interconnected factors work in synergy ... grouped into two sets of factors that reflect (i) leadership in science and innovation ... and (ii) the character and quality of the context for science and innovation ... by a policy environment cognisant of economic, environmental and sociocultural trends, and by the interface between the producers and users of the capacities and knowledge the NRF grants and scholarships helped to develop." (NRF 2015, p. 3)

While an evaluation function is institutionalised in the Presidency, and while bodies such as NACI, CeSTII and SciSTIP perform such evaluation routinely, it is debatable as to whether STI evaluation is institutionalised in as complete or coherent a manner as it should be (see Case Study A below).

Kahn (2019, 2013) described the pre-1994 social contract as one in which the South African science system marched on two legs[2] – that is, through the Republic of Science (one leg) and state-driven technology missions (the other leg). Kahn avers that the social contract *continues* to walk on two legs – the Republic of Science as the one and flagship science projects as the other. This bifurcation, accompanied by the dominance of supply-side measures, and weak university-industry links would limit policy socio-economic impact.

Advice capabilities

On the one hand, in terms of institutionalised advice on STI policy, NACI was established in 1997 to advise the Minister and, thereby, Cabinet. Prior to its establishment, the Mandela administration created the Ministerial Council on Science and Technology. Its deliberations and achievements are not in the public domain, and it was quietly abandoned in 1999 when the Mbeki administration took office. In contrast to its sister organisation, the Council on Higher Education, NACI plays a subordinate role to its parent, the DSTI, functioning as a sub-division.[3] Even though its advisory notes are unclassified, these are not in the public domain, and its visibility is constrained (DST, 2012, p. 75). The ASSAf, established in 2001, plays a limited advisory function through its consensus reports, but its impact on STI policy has not been evaluated. There is no office of Chief Scientific Advisor; in effect this role is played by the Science Council presidents who may initiate or respond to the need for specialist advice.

On the other hand, South Africa's highly diversified biomedical science system (Glanzel, 2000) acts as both a formal and informal source of discipline-specific scientific advice. Disciplinary excellence, as measured by category-normalised citation index scores is high across most of the Essential Science Indicator categories, implying the capability to provide state-of-the-art advice on request or by volition. This represents

2 The reference here is to the Altendorff et al. (1974) report China: Science Walks on Two Legs.

3 Currently, the Department of Science, Technology and Innovation. Previously, the Department of Science and Technology (2002 to 2019) and the Department of Arts, Culture, Science and Technology (1994 to 2002).

the Republic of Science at its best, as attested to by its response to understanding the aetiology of HIV (Kahn, 2016) (Case Study B).

The timeline of STI policy, advice and evaluation outputs is summarised as Table 1 that illustrates the involvement of stakeholders in policy formulation.

Year	Document	Type	Process
1996	White Paper on Science and Technology	Policy	Stakeholder-based through the Department
1997	National Advisory Council on Innovation (Act 55 of 1997)	Legislation	Internal to Department; Parliament
1999	National Research and Technology Foresight	Foresight	Generated by 12 panels appointed by Department
2001	Academy of Science of South Africa (Act 67 of 2001)	Legislation	Internal to Department; Parliament
2002	R&D Strategy	Strategy	Internal to Department
2008	Ten Year Innovation Plan (TYIP)	Plan	Internal to Department
2011	Science Amendment Act	Legislation	Internal to Department; Parliament
2012	Ministerial Review Committee	Review	Committee; selected interviews; international consultants
2017	A Review of the South African Science, Technology and Innovation Institutional Landscape	Review	Committee; selected interviews
2019	White Paper on Science, Technology and Innovation	Policy	Internal to Department; public consultation
2020	A Review of South Africa's Higher Education, Science, Technology and Innovation Institutional Landscape	Review	Committee; selected interviews
2020	South Africa Foresight Exercise for Science, Technology and Innovation 2030	Foresight	International and local consultants

2021	Review of the R&D Strategy and TYIP	Review/ Evaluation	National consultants to NACI
2023	Decadal Plan	Plan	Internal to Department

Table 1: Summary timeline of key policy, strategy and evaluation instruments (1996 – 2023)

3. CASE STUDIES INFORMING STI POLICYMAKING, ADVICE AND EVALUATION CAPABILITIES

This section provides high-level insights into South Africa's STI policymaking, advice and evaluation capabilities, which are drawn from empirical examples. Four cases are storied to reflect a SWOT analysis: strengths, weaknesses, opportunities, and threats (replaced with risks) (Puyt et al., 2023). The utility of a SWOT lens in analysing the case studies, is to be able to present a synthetic assessment of important policymaking, advice and evaluation events. The significance of choosing these specific cases requires a qualification: each case study represents a significant development in South Africa's post-apartheid STI trajectory from which insights into how STI policymaking, advice and evaluation capabilities cohered or fractured, including, and critically, in which the role of evidence is implicated. The systemic importance of each case study cannot be over-stated and their illustrative value for different capability dimensions mentioned above (policymaking, advice, evaluation) is clear.

By way of structure, Case Study A is oriented to strengths, B to weaknesses, and so on. Methodologically, the availability of a diversity of case study data in the public domain – that is, non-embargoed public reports, articles, and scholarly literature – that could be used for document analytical purposes (Bowen, 2009), formed an important part of the selection rationale.

3.1. BUILDING STRENGTH: INSTITUTIONALISATION OF STI MEASUREMENT, POLICY ADVICE AND EVALUATION

Purpose and contextualisation of the case

This case study aims to highlight the inherent strengths of three South African organisational entities active in the production and use of evidence to inform STI policy decision-making. While their organisational stories exhibit overlaps, each has a distinctive mandate and function, which point toward a state of institutionalisation of STI measurement, policy advice and evaluation.

The meaning of "institutionalisation"

For the institutionalisation STI measurement, policy advice and evaluation to be durable and effective, several interrelated characteristics must be established. First, formal, legally or policy-recognised institutional bodies should be designated to carry out measurement, provide policy advice, and undertake independent evaluation; such recognition anchors mandates and accountability within the state framework (OECD, 2015). Second, measurement activities must be routinised rather than episodic, requiring stable funding lines, dedicated staff and organisational infrastructure so that data collection, indicator development and reporting occur as sustained functions (OECD, 2015; UNESCO, 2015). Third, empirical evidence produced by these measurement systems must be integrated into decision-making processes: scientific evaluation should inform policy formulation, priority-setting and allocation decisions, with formal mechanisms linking evidence producers and recognised decision-making bodies (Nutley, Walter & Davies 2007). Fourth, evaluation and advice functions should be institutionalised so they persist beyond the tenure of individual office-holders; organisational continuity, clear procedures and statutory safeguards for independence help ensure that bodies continue to operate when senior officials or ministers change (OECD, 2018). Finally, investment decisions by funding agencies and partners – for example to establish national entities for STI indicators and policy analysis – should reflect and reinforce these institutional features, aligning resources, mandates and governance to create an enduring ecosystem of measurement, advice and evaluation (UNESCO, 2015). How has South Africa fared considering these broad criteria?

Institutionalising STI measurement

In the three decades since its democratic transition in 1994, South Africa invested in the institutionalisation of STI measurement and indicator production to inform its national STI policy development, implementation, and monitoring and evaluation (DACST, 1996; DST, 2019; Kruss & Ralphs, 2021). If the 1996 White Paper on Science and Technology, in effect, marked the starting point of post-apartheid STI institutionalisation, it explicitly positioned STI measurement and indicators as essential for rebuilding the NSI after apartheid. It did this by linking evidence to democratic accountability and developmental policy goals, and framing measurement as a strategic public investment necessary to move from fragmented science governance to a coordinated, evidence-based STI policy regime. This investment ensured the production of national R&D and innovation indicators according to OECD guidelines.

R&D surveys had been conducted by the CSIR since 1968 (Blankley & Kahn, 2005). This function was transferred to the Foundation for Research Development (FRD) in 1990. FRD conducted R&D Surveys 1991/92 and 1995/96, after which the series terminated for various reasons (the survey was given lower priority during the transition to a democratic government, the National Research and Technology Audit took the place of the R&D Survey, and the surveys being moved between different bodies resulting in a loss of expertise and weakened institutional memory among respondents). The DST then decided to resuscitate the series and commissioned Human Sciences Research Council (HSRC) to perform the survey for 2001/02, that laid the basis for the 2003 establishment of the Centre for Science, Technology and Innovation Indicators (CeSTII). CeSTII grew the competencies needed to conduct various STI surveys (Kruss & Ralphs, 2021).

CeSTII's strengths lie in conducting national R&D and innovation surveys, producing analysis informing policymaking, and development of new measurement frameworks, including informal sector innovation

(Mustapha et al., 2022). CeSTII has shared its expertise across the Southern African Development Community (SADC), and more broadly across the African continent through its support to the African STI Indicators Initiative (ASTII), a flagship programme of the African Union. CeSTII works with the UNESCO Institute for Statistics and the OECD committee of National Experts on STI Indicators.

Institutionalising policy advice

NACI is mandated to provide advice on a range of issues related to STI to government, through the Minister of Science and Technology. NACI plays a strategic role by commissioning and coordinating STI indicators reports and policy-related research. It operates through collaboration with local and international experts, organisations and institutions (NACI, 2020b) and aims to foster engagement across sectors to improve transparency, accountability, and effectiveness, and in order to synthesize evidence on investments, research outputs, human resources, and digital competitiveness in innovation (see Table 1). Another main goal is to monitor progress against national innovation plans (Cele, 2020).

Institutionalising evaluation

The Stellenbosch University Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy (SciSTIP), established in 2014 as part of the DSI-NRF Centres of Excellence Programme and jointly held with the Institute for Economic Research on Innovation at Tshwane University, developed from the earlier work of the Centre for Interdisciplinary Studies (CENIS) that morphed into the Centre for Research on Evaluation, Science and Technology (CREST). The Centre of Excellence has two mandates: scientometrics – to monitor and measure the performance of the South African STI system – and STI policy – to conduct research and analysis that contributes to national policy debates on STI (CREST, 2026). Its research focuses on R&D performing institutions and their funding; science and innovation for socio-economic development; the expansion and transformation of human resources; and science-society interactions.

SciSTIP provides evaluation of the STI ecosystem in part through the NSI Monitoring and Evaluation Framework. The 2019 White Paper noted certain weaknesses in strategic monitoring and evaluation (M&E) of STI, including poorly institutionalised policy learning mechanisms; fragmented and non-coherent evaluation practices; weak data, indicators, and analytical foundations; and limited system-wide and multi-stakeholder integration. To address these weaknesses, NACI partnered with SciSTIP to produce the NSI Monitoring and Evaluation Framework (NACI, 2020b).

Key lesson: Long-term investment in capabilities matters

The above mentioned should not be taken to imply that these three entities entirely and fully address system needs (Cele, 2020). Collectively, they strengthen evidence-in-use for policy learning but are subject to limitations. CeSTII produces robust empirical indicators, yet despite extensive longitudinal datasets and indicator systems, its outputs are still not fully embedded in policy processes at all levels of government decision-making. NACI acts to synthesize strategic policy evidence with institutional coordination, yet its advisory role is still constrained by fragmented evidence inputs from multiple institutions and limited authority to coordinate across departments and agencies. SciSTIP indeed helped in the design of an STI M&E framework and has performed work on several major evaluations, but the full transition from framework design to operational system implementation is incomplete, particularly in terms of a fully institutionalised, national STI M&E architecture.

That the goals of each of these bodies is not fully realised is not an indication of failure. South Africa has made crucial foundational investments in STI policy capabilities, and these are cumulatively valuable even if the system is not fully integrated. Capabilities have been successfully built but not cohesively coupled into a high-functioning system, as effective STI policy learning systems emerge only after sustained investment in underlying analytical and institutional capabilities. Once these separate entities have matured, deeper integration, feedback loops, and policy learning can be institutionalised.

An important step toward tighter integration of empirical STI indicators with high-level policy advice is the relocation of CeSTII into NACI announced to Parliament in 2026. Embedding CeSTII's robust longitudinal datasets and indicator systems within NACI's advisory and coordination remit, the move aims to improve evidence flow into strategic decision-making, reduce fragmentation of inputs, and strengthen institutional linkages across departments. This can help assimilate CeSTII outputs into policy cycles, enable more coherent synthesis of quantitative evidence with sectoral strategy, and create clearer feedback loops for monitoring and learning.

3.2. COUNTERING WEAKNESS: CONFRONTING THE POLICYMAKING AND ADVICE CRISIS DURING THE HIV/AIDS EPIDEMIC

Purpose and contextualisation of the case

This case study examines crisis response in the hands of the Republic of Science that mitigated State weakness in dealing with the HIV/AIDS epidemic. The case study describes how NSI actors confronted the HIV/AIDS crisis and why political failure – rather than technological or scientific limitations – allowed the epidemic to spiral catastrophically. It examines the country's contradictory record: a global pioneer in medical research (think, the first successful heart transplant performed by Christiaan Barnard), yet the site of one of the most destructive AIDS epidemics. The central purpose of the case study is to explain how state denialism emerged and persisted, why it constituted a "political market failure," and how a coalition of civil society actors, scientists, courts and business – a quadruple helix – mitigated the failures.

Analytic frameworks to interpret the case

To interpret the crisis, two analytic frameworks are drawn on. First, Dependency Theory (Frank, 1967; Wallerstein, 1974) that helps to explain the ideological terrain on which AIDS denialism took root. South Africa's political leaders, especially President Thabo Mbeki, increasingly viewed Western biomedical science with suspicion, interpreting it through a postcolonial lens that emphasised exploitation, pathologisation of

Africans, and multi-national pharmaceutical company profiteering. The epidemic's spread was also amplified by structural features long rooted in the country's colonial and apartheid political economy – most notably the migrant miner labour system that fragmented families and intensified infection pathways, this being amplified by long-distance trucking across international borders.

Second, the NSI approach avers that innovation capacity depends not only on firms and research institutes but on interactions across the whole system. As argued above earlier, the innovation system continues to "walk on two legs". Post-1994 policy sought to democratise and expand the NSI, but R&D funding stagnated, Big Science projects dominated priorities, and HIV research remained marginal in official strategy. The once-powerful civil society movement that mobilised against apartheid became weakened during the transition, as donors redirected funding to the new democratic state and many activists entered government. Deficiencies in service delivery soon re-activated activism, and the courts became the arena where citizens asserted "second-order constitutional rights" such as access to housing, water and healthcare. This set the stage for the rise of a new form of social entrepreneurship. The key actor on HIV mitigation was the Treatment Action Campaign (TAC), founded in 1998 (Heywood, 2009).

Despite stagnating investment, the Republic of Science – the academic and research community enjoying significant autonomy – continued to produce world-class research, especially on infectious disease. It was this institutional robustness, as noted earlier, that later allowed scientists to work effectively with civil society against denialist policy.

The emergence of a policy vacuum

HIV cases had first appeared in the mid-1980s, to which the apartheid government offered limited response. By the mid-1990s it was clear that the virus had spread among sexually active adults (Sharp & Hahn, 2011). While life expectancy had been improving for decades, the 1990s marked an abrupt reversal: by 2005 it had fallen to levels last seen in the mid-20th century. Although tuberculosis appeared as the leading cause of death in official statistics, the exclusion of "AIDS" as a notifiable category obscured the true impact of HIV. Mortality doubled within a decade, hitting poor black South Africans hardest. This decline occurred despite impressive economic growth that reached 5%, rising incomes for millions, and an increasingly capable democratic state. Yet health policy and interventions stagnated.

Despite a national strategy of awareness promotion, the Mandela administration emitted inconsistent signals, including a remedy sold as Virodene based on an industrial solvent. Under Mbeki's leadership, scepticism hardened into new orthodoxy. Convinced that HIV was not the main cause of AIDS, Mbeki convened an advisory panel of mainstream scientists and denialists. He increasingly viewed Western biomedical discourse as racist and conspiratorial, asserting that poverty – rather than a virus – was driver of AIDS. His health ministers supported this; provincial health departments and the Medicines Control Council became conflict zones; and the official response offered incoherent messages about nutrition, lifestyle, traditional medicine and abstinence. Research institutions studied the aetiology of the disease, but in silence. The Medical Research Council and other scientific bodies expanded research on HIV and opportunistic tuberculosis, but government neither championed nor funded these thrusts aggressively. Private companies, recognising the economic threat, began offering antiretrovirals (ARVs) to their employees, but unemployed citizens remained without access to ARVs.

Role of the Quadruple Helix in addressing system failure

It was in this policy vacuum that the TAC emerged as the country's most influential social movement since the anti-apartheid era. Its strategy combined activism, scientific evidence, litigation and international alliance-building. TAC: exposed failures in mother-to-child transmission prevention; challenged drug patents by importing generic medicines; joined the state as *amicus curiae* against pharmaceutical companies defending monopolies; sued the government itself to compel it to provide ARVs to pregnant women, and mobilised mass protests, hunger strikes and media campaigns.

South Africa's independent judiciary repeatedly found in TAC's favour, compelling the State to provide life-saving treatment. After a series of public embarrassments – including the international outcry when the health minister promoted garlic and beetroot as treatments – for AIDS, the political tide turned. For a variety of reasons President Mbeki was removed from office, and the subsequent administration expanded ARV access rapidly. By the mid-2010s, South Africa operated the world's largest ARV programme, with more than 2.4 million ARV beneficiaries and the near-elimination of mother-to-child transmission.

This transformation was possible because the emergence a Quadruple Helix of civil society (TAC), universities and researchers, public research organisations and regulators, business and the pharmaceutical sector had come into being: The quadruple helix emerged organically in response to crisis and political failure (Kahn, 2016).

Key lesson: Value of coalitions of and for evidence-informed policymaking

The case study shows that South Africa's innovation system was resilient enough to withstand political interference: its scientific institutions, legal system, and activist traditions collaborated to restore evidence-based policy. The TAC's achievements exemplify how social entrepreneurship, backed by evidence and legal recourse, can overcome even ideologically entrenched political resistance. Yet future work is needed to examine TAC's knowledge networks, the sustainability of donor-funded research, and how South Africa can maintain its innovation capacity as external funding declines as a consequence of US isolationism. In effect, evidence-based political mobilisation was successful in bringing about a change to policy. A single interest coalition emerged to pressurise a government that was then at its peak of political power. Nothing of similar magnitude has since emerged. From a political economy standpoint, a diffuse set of interests coalesced independent of structural form or change.

3.3. PURSUING OPPORTUNITY: SOUTH AFRICAN ASTRONOMY'S MUSKETEERS AND THE SKA PROJECT

Purpose and contextualisation of the case

South African STI policymaking, advice and evaluation capabilities converged meaningfully in the decision to compete as a site for the Square Kilometre Array (SKA) and, not least, in the commencement of its construction. Not without its governance complexities (Binneman & Davis, 2021; Chinigò, 2025; Walker & Chinigò, 2018), this case study highlights the pursuit of opportunity by "personalities" working at the nexus of international, longstanding fields of scientific exploration and policy, with the backing of South Africa's national infrastructure development ambitions.

Emergence of astronomy in South Africa

The emergence of astronomy in South Africa, as a scientific field within an active community of scholarly practice, has a history spanning more than two centuries (Dubow, 2019). Coinciding with the 1820 arrival of British settlers to what is now the Eastern Cape, the Royal Observatory in Cape Town was established as an extension of the Royal Observatory at Greenwich in England, serving for some time as "the Cape's premier scientific institution" (Dubow, 2019, p. 664). Owing to favourable geographical positioning in the Southern Hemisphere, over the next two hundred years astronomy in South Africa became institutionalised through interactions between metropolitan scientists, colonial administrators and South Africa's nascent scientific institutions, such as its universities and, from the mid-1940s onward, its CSIR (Dubow, 2019; Twidle, 2019). Additional observatories in Johannesburg, Durban, and Sutherland, and the formation of the South African Astronomical Observatory (SAAO) and the Hartebeeshoek Radio Astronomical Observatory (HartRAO) were some outcomes of this sustained attention. Additionally, the field of theoretical cosmology, which had as its local pioneer in the person of George Ellis (2004 Templeton Prize winner) at the University of Cape Town from the 1970s onward, represented another outcome, and indeed served as a "notable example" (Dubow, 2019, 683) of South African astronomy's resilience.[4]

It is important to situate the emergence of *the idea* for an SKA as a consequence of international scientific and political developments. For example, writing in a preface to their comprehensive history of the SKA project from 1990 to 2012, Schilizzi et al. (2024, p. xi) recount:

> "The concept of a collecting area of one million square metres, one hundred times more sensitive than the most powerful telescope in the world, did not come out of the blue; it built on decades of radio telescope development after the Second World War. Not surprisingly, the idea proved attractive for a much wider community and the science case expanded, as did the requirements for innovative supporting technology to make it affordable and to service the other observing frequencies and modes of operation involved."

However, in the preface to the same project history, Womersley also writes of the tension between this scientific ambition (foresight), policy, investment and the "element of luck" that characterised the decision by the UK's government to support the SKA (Schilizzi et al., 2024, p. vii). In that context, political timing was critical and, indeed, the UK – a major player, in that it now hosts the SKA headquarters at Jodrell Bank – was the last country to ratify the convention for the SKA to be "recognised as an intergovernmental organisation" (Nordling, 2020). For South Africa, the element of luck would come into play both in its strategic geo-location and in the persistence and alacrity with which its scientists and policymakers pursued the opportunity it presented.

Advocating for the South Africa SKA site co-hosting

In the early South African involvement in the SKA, several key personalities emerged, who have since shaped the direction of astronomy in post-apartheid South Africa in profound ways. One of these was Rob Adam, a nuclear theoretical physicist who would become DACST's second director general. Promotion of astronomy was a key feature of the 1996

4 Indeed, one of the authors of this paper was a student of Ellis in the UCT Applied Mathematics department.

White Paper developed under the leadership of the first director general, Roger Jardine. On the side of public administrators, Jardine and Adam are widely regarded as having played key roles, alongside the FRD's vice-president, Khotso Mokhele, and leading astronomers, Bernie Fanaroff, George Nicholson and Justin Jonas (Schilizzi et al., 2024). It was largely in the personalities of these prime movers or "musketeers" (Schilizzi et al., 2024, p. 88), who, combining policy and advice, and working project by project, built and sustained the business case for the South African science mega-project in its early years.

The South African Large Telescope (SALT) project was authorised in 1998, when the South African government committed USD $10-million in funding for it; it was completed and opened in 2005, starting full scientific operations in 2011 (Campbell, 2025). After ground was broken in 2000 for the SALT, several moves were made by the "musketeers" – to whom others would later be added, such as science administrator Adrian Tiplady and science diplomat Daan du Toit – to convince the South African government to get behind a bid to host the SKA site. "This proposal was taken up by the DST in November 2002," write Schilizzi et al. (2024, p. 86), "and as, Adam describes, the *case was made outside science*." (emphasis added) They continue:

> "The appeal was the prospect of a world-class scientific and engineering project on the African continent, the big data challenge, and the potential to use the SKA project to attract and retain young people in science and technology in Africa."

Fanaroff was selected as the project manager and a South African SKA Steering Committee was formed with Adam as its chair (Schilizzi et al., 2024). The law followed suit, through the Astronomy Geographic Advantage Act of 2007 that created an electromagnetic quiet zone across 120 000 square kilometres of Karoo desert (SARAO, 2026).

The SKA builds on the expertise in dish receiver design and construction embodied in the KAT-7 array and its successor MeerKAT with 64 dishes (McMullin et al., 2020). Both complexes use a low noise detector that was designed and built by a company based in Stellenbosch Technopark (Kahn

2021). After the successful construction and launch of the MeerKAT, work on the first phase (SKA1) commenced for the period 2021 until 2030. In SKA1, there are two components: SKA-Low, located in Western Australia, will be made up of "131,072 log-periodic dipole antennas distributed across 512 aperture array stations of 256 antennas each"; and SKA-Mid, consisting of "133 15-m SKA dishes and 64 13.5-m MeerKAT dishes" in the Northern Cape of South Africa (SKAO, 2026). A second phase of the SKA project (SKA2), yet to be fully specified, envisions "increasing both the number of receptors (stations/dishes) and baseline lengths for each telescope (extending to other African countries in the case of SKA-Mid), and perhaps the addition of other telescopes (survey dish array, mid-frequency aperture array)" (SKAO, 2026). Expected to be completed in the 2030s, the SKA would then be the world's largest radio telescope.

Evaluation capabilities for steering signals

The positioning of evaluation capabilities within the context of the case requires some further context. The SKA project is designated, in South African governance parlance, as Strategic Integrated Project 16 (SIP 16) – one of two "Knowledge SIPs" – under the Presidential Infrastructure Coordination Commission (PICC, 2012). This means that, at the highest level, its progress is tied to national infrastructure targets, requiring a specialised overarching evaluation framework that links the Big Science of the SKA project: to national economic developmental goals. At the level of project implementation, then, several evaluations or assessments have been undertaken to address different aspects of the SKA, notably its strategic environmental impact assessment comprising several domain specific sub-assessment reports (CSIR, 2016); routine performance and accountability audits; and scholarly and policy-oriented analyses assessing the socio-economic impact of the SKA on local communities in the Northern Cape (Adams, Tiplady & Sgard, 2023), on capabilities and skills (Gastrow, Kruss & Petersen, 2016) and on the role of the SKA within the broader public imagination (Twidle, 2019; Gastrow, 2016). Expenditure on R&D within space science has also been a question added to the South African R&D Survey from 2016/17 onward (Case Study A).

Key lesson: Going far, together

The case of the SKA refracts an image of state-backed, flagship science in South Africa as internationally networked, ambitious and forward-looking. For South Africa's part, this case study highlights the opportunities that arise when policymaking, advice and evaluation capabilities come together. It particularly highlights the role of personalities in advancing South Africa's science agenda. However, it also highlights the importance of alignment to national planning as a route to ensure comprehensive evaluation and assessment as well as broader political support.

3.4. FACING RISKS: THE RISE, DEMISE, AND POTENTIAL REBIRTH OF THE PEBBLE BED MODULAR REACTOR

Purpose and contextualisation of the case

This case illustrates how weaknesses in South Africa's STI policymaking, advisory and evaluation capabilities, particularly the lack of any institutionalised evaluation architecture, allowed the PBMR project to advance despite accumulated evidence of technical, financial and governance risks.

Background and evolution of the PBMR programme

On 17 November 2025, South Africa's Nuclear Energy Corporation (NECSA) announced the re-commissioning of the Pebble Bed Modular Reactor (PBMR), a project mothballed in 2010 after consuming more than R8 billion (approximately USD 1.1 billion) in public funds, primarily from the Department of Public Enterprises (Biyela, 2025; Research Professional News, 2010a, 2010b; Thomas, 2011).[5] This decision, driven by soaring energy demand and potential fuel commercial opportunities, reopens critical questions about the governance of large-scale technology projects. The original PBMR venture, this case study suggests, exposes how governance failures such translate directly into risks for STI policymaking, offering stark lessons on democratic accountability, transparency, and resistance to regulatory capture.

5 Calculated using an average exchange rate for 2010 of 0.137 USD per ZAR.

The PBMR project, initiated in 1999, aimed to develop "small-scale, high-temperature reactors in an effort to provide cheap electricity" (Research Professional News, 2010a). It represented "the most determined recent attempt" to commercialise a High Temperature Gas-cooled Reactor (HTGR) design, a pursuit with a 50-year global history of failed attempts across Germany, the USA, the UK, and France (Thomas, 2011, p. 2431). Despite this, the PBMR became South Africa's largest R&D project. However, Thomas (2011, p. 2431) notes that, by 2010, the programme was "running decades late and the costs were many times over the original budget".

The project was terminated in February 2010. Then Public Enterprises Minister Barbara Hogan announced the cessation of state funding, stating: "The problem with the project is that it has not been able to get a long-term investor and a customer" (Fig, 2010, p. 1). The government revealed that a staggering further R30 billion (approximately USD 4.11 billion)[6] was needed to achieve commercial status (Thomas, 2011), and it only had R1 billion (approximately USD 135 million) remaining funds (Research Professional News, 2010a). Consequently, over 75% of its 800-strong workforce was dismissed (Fig, 2010). The withdrawal of Exelon in 2002 – whose CEO called the project "three years behind schedule and… too speculative" (Fig, 2010, p. 16) – dealt a critical commercial blow in that it eliminated the partner needed to navigate US safety approval, thereby undermining the PBMR's export ambitions (see also Thomas, 2011). At the same time, PBMR CEO Dave Nicholls publicly expressed confidence in Exelon's continued involvement (Fig, 2010, p. 16), highlighting starkly contradictory assessments between investors and project leadership.

Policymaking capability failures

Despite this well-documented international poor track record of HTGRs, particularly the failure of Germany's THTR-300, proponents instead championed the AVR (Arbeitsgemeinschaft Versuchsreaktor) prototype as a success story. However, a 2008 safety re-evaluation of the AVR revealed

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6 Same exchange rate used as in note 5.

dangerously high fuel temperatures that massively contaminated the reactor vessel, raising generic safety questions for all pebble-bed designs (Moormann, 2008, cited in Thomas, 2011). The US Nuclear Regulatory Commission had identified the fuel temperature issue as early as 2001, yet the South African National Nuclear Regulator (NNR) granted approval in principle in 2003 with no mention of it (Thomas, 2011). Furthermore, the PBMR's key innovation – a helium-driven gas turbine – was an unproven technology. Development struggles led to the replacement of contractor Alstom with Mitsubishi Heavy Industries, and the gas turbine was ultimately abandoned in a 2009 redesign in favour of a conventional steam cycle, undermining a core claimed economic advantage (Thomas, 2011).

Advisory capability failures

Despite early assurances that nuclear policy would be handled transparently – Finance Minister Trevor Manuel famously remarked that such decisions would not be left to "experts in dark, smoke-filled rooms" (Fig, 2010, p. 8) – the PBMR quickly became characterised by closed, centralised decision-making. In practice, authority over the programme was tightly concentrated within the Department of Minerals and Energy and the Department of Public Enterprises, with little room for broader participation. As Fig (2010, p. 9) observes, decisions about the direction of the nuclear industry were largely confined to these two departments, leaving stakeholders and the public firmly on the margins. He further notes that what ultimately emerged as government policy had been shaped without meaningful debate in formal policy spaces or within ANC structures themselves (Fig, 2010, p. 9).

The policy process was dominated by executive branch capture, vulnerable to industry lobbying. Fig (2010, p. 2) argues this pattern "raises broad questions about the relationship between mega-projects and development, about public policy making, about the special pleading of small lobby groups and about shaping democratic governance in a young democracy". Specifically, "the executive branch of government has come to dominate national policy making... Cabinet has become susceptible to the special pleading and some of the false claims of the industry"

(Fig, 2010, p. 9). The organised nuclear lobby, including the PBMR company itself as a founder member of the Nuclear Industry Association of South Africa (NIASA), effectively promoted its interests at the expense of rigorous independent evaluation (Fig, 2010).

Evaluation capability and evaluation architecture failures

The PBMR's trajectory illustrates a fundamental absence of an institutionalised evaluation architecture. Unlike the STI evaluation entities described earlier in Case Study A (e.g., NACI, CeSTII, SciSTIP), the nuclear governance domain lacked equivalent institutionalised evaluation architecture, leaving no dedicated body with the mandate to impose systematic evaluative requirements across the project lifecycle.

This weakness appeared in several ways. First, there were no mandated milestone reviews or decision-gates requiring the PBMR to demonstrate technical feasibility or risk reduction before advancing. As a result, the project continued despite long-standing warnings – most notably those arising from the AVR re-evaluation, which identified dangerously high fuel temperatures and generic design risks (Moormann, 2008, cited in Thomas, 2011). Second, the governance system lacked standardised evaluative methods. There was no requirement for comparative international benchmarking, independent technical audits, or structured scenario-based assessments. This allowed project advocates to override or ignore extensive international evidence on HTGR failures. Third, institutional mandates were fragmented, with no entity empowered to integrate evidence, enforce review cycles, or halt the project pending evaluation. Regulatory oversight was not tied to formal evaluative procedures, leaving accountability for risk appraisal diffuse and inconsistent.

Collectively, these gaps reveal that the PBMR advanced without the mandated processes, evaluative methods, milestone checkpoints, or the necessary decision-gates needed.

Transparency and accountability failures

Thomas (2011, p. 2438) observes a critical failure of accountability: "It is unclear why the South African government should have had such total faith in a project that... was, so blatantly, going badly wrong." Eskom and foreign investors (Exelon, BNFL/Westinghouse) stopped contributing after 2004, leaving the government as the sole funder, yet it lacked representation on the PBMR Ltd. board (Thomas, 2011). This opacity directly contradicted constitutional norms. Fig (2010, p. 18) observes the lack of openness "flies in the face of the culture of transparency established by the South African Constitution and the Promotion of Access to Information Act". The industry maintained a "global reputation for secrecy, opacity and impunity," which Fig (2010, p. 26) argued did "not bode well for... a young democracy like South Africa".

The 2025 recommissioning: renewed promise or reproduced risks?

The PBMR's demise resulted in significant opportunity costs, workforce displacement and a loss of public trust. Thomas (2011, p. 2439) argues that investment in energy efficiency, renewables or gas could have produced a "cheaper, more reliable and 'greener'" energy system for South Africa. Yet, the 2025 recommissioning takes place amid global energy shifts driven by AI-related data centre demand. PPPs are promoted to share risks and expertise (Croucamp, 2025), situating the PBMR within a hybridity model (Reissner, 2017; Sadri, Aristidou & Ravasi, 2024). Yet unresolved safety issues, historical cost overruns, market uncertainty, nuclear waste challenges and South Africa's greylisting by the Financial Action Task Force (FATF) raise questions about governance readiness (Gungor & Sari, 2022; Croucamp, 2025). Thomas (2011) argues that any renewed attempt requires clear evidence that earlier technical and governance failures have been fully addressed.

In contrast to the institutionalised measurement and evaluation structures in Case Study A, the PBMR case shows that the energy/nuclear domain operated outside these established mechanisms, illustrating significant fragmentation in national evaluation capability. The analysis underscores the absolute necessity of several reforms to ensure robust governance. These include establishing an independent advisory capacity insulated from undue influence, implementing transparent and rigorous milestone-based evaluations with clear decision gates along dimensions of technical complexity barriers and economic return on investment, whilst guaranteeing meaningful stakeholder participation throughout the policy process.

Key lesson: Avoiding capability path dependency

Although the PBMR sits formally within the nuclear energy policy domain, the technical nature of HTGR development and its status as South Africa's largest publicly funded R&D project place it squarely within the STI system. However, unlike entities in the STI evaluation ecosystem, nuclear governance lacked an institutionalised evaluation architecture.

The PBMR was not halted due to effective STI oversight but because it collapsed under cumulative failures in policymaking, advisory and evaluation systems. The 2025 recommissioning represents a critical test: whether South Africa can build the institutionalised governance and evaluation architecture needed to avoid repeating past mistakes. Without such reforms, the PBMR risks becoming an even more costly replication of its earlier demise.

4. CONCLUSION: BUILDING SOUTH AFRICA'S STI POLICYMAKING, ADVICE AND EVALUATION CAPABILITIES FOR THE FUTURE

Using a series of case studies as a lens, this paper has traced how South Africa's a distinctive, if uneven, ensemble of STI policymaking, advisory and evaluation capabilities has emerged in the post-apartheid period. Historically, the system has oscillated between a Republic of Science grounded in academic autonomy and a mission-oriented, State-driven technology project. Post-1994 reforms expanded the institutional repertoire – new councils, agencies, policies and foresight exercises – but did not fully resolve this dualism. The four case studies show that the key question is no longer whether evidence exists, but how it is mobilised, contested and institutionalised in practice.

Returning to the question posed earlier, the strengths of the system lie above all in the institutionalisation of measurement and evaluation. The emergence of NACI, CeSTII and SciSTIP has created a durable backbone for producing STI indicators, synthesising evidence and experimenting with monitoring and evaluation frameworks. These institutions illustrate how "evidence-in-use" can be stabilised through routines, standards and long-term investments in capability, even within a resource-constrained setting.

The HIV/AIDS case exposes the converse: the catastrophic consequences when political leadership actively resists evidence and when advisory and evaluative capacities lack the autonomy or positional power to correct course. Yet it also demonstrates systemic resilience. The bottom-up formation of a quadruple helix of activism, science, business and courts shows how alternative pathways for evidence use can emerge when formal advisory structures fail, and how constitutional mechanisms can be mobilised in defence of scientific reason.

The SKA case illustrates the opportunities that arise when policy vision, scientific excellence and institutional entrepreneurship converge around a mega-science project. Here, a small group of "musketeers" leveraged South Africa's astronomical tradition, crafted a compelling international scientific development agenda, and secured legislative and fiscal commitments. This success underscores the importance of personalities and networks, but also of strategic foresight and credible evaluation of benefits and risks over long time horizons.

By contrast, the PBMR case exemplifies systemic risk: technological over-optimism, regulatory weakness, opaque decision-making and failure to learn from international evidence. Its possible rebirth under new public–private configurations raises difficult questions about whether the underlying governance pathologies have been addressed, or merely repackaged. The case warns that mega-projects can hollow out evaluation, crowd out alternatives and erode public trust when accountability is weak.

Taken together, these cases suggest that South Africa's STI policymaking, advisory and evaluation capabilities are best understood as a dynamic, contested assemblage rather than a coherent design. Capabilities are uneven across domains; they depend on institutional histories, leadership, and wider political economy conditions. Advisory councils and expert bodies matter, but they are embedded in broader constellations that include social movements, courts, international partners and private actors.

Looking ahead, building a more robust nexus of policymaking, advice and evaluation will require: strengthening the autonomy and transparency of advisory bodies; institutionalising milestone-based evaluation for large projects; enhancing cross-domain learning between health, energy and astronomy and indeed on a broader scale beyond the cases described in this paper; and protecting spaces where dissenting evidence can be voiced without political sanction. For African and other transitional contexts, South Africa's experience shows both the possibilities and perils of striving to locate science policy "between expertise and relevance" – where evidence is neither technocratically insulated nor wholly subordinated to short-term politics, but negotiated through institutions capable of learning from both success and failure.

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