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Research article

Operationalizing transformative capacity: State policy and the financing of sustainable energy transitions in developing countries

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Abstract: We explored the capacity of the state to facilitate financing for sustainable energy transitions in a developing country context. We responded to the critical challenge of financing in developing and emerging contexts where significant financing gaps contribute to the inequitable deployment of renewable energy technologies. A critical realist case study design explored South Africa's transition to green hydrogen as an instrumental case to understand how policy instruments—regulative, economic, and informational—interact with financing social structures to enable or constrain transformative change in financing the energy transition. The conceptual framework drew on sustainability transitions literature and integrated insights from finance, policy, and institutional theories to operationalize the state's transformative capacity in modifying financing rules through policy interventions. Data was collected through semi-structured interviews with key stakeholders and analysis of academic and grey literature, including policy documents and government publications. The findings illustrated how policy instruments can reinforce, disrupt, transform, or displace structures, embodying varying degrees of the state's capacity to engender structural change. Critically, the findings support transition scholars who advocate for experimental policy engagements by offering opportunities to challenge fundamental values, norms, beliefs, and cognitive models.

Keywords: energy transition; finance; green hydrogen; policy instruments; structural change; South Africa; transformative capacity

JEL Codes: G38, P48, O38, O55

1. Introduction

It is widely recognized that government interventions are needed to catalyze and direct sustainable energy transitions (WCED, 1987; United Nations, 2015a). This multi-faceted role includes setting research agendas, collecting data, developing regulations, markets, and infrastructure, and ensuring access to finance (IRENA, 2020; Farrell, 2023). In developing countries, support must also address systemic inequalities to ensure that the benefits of technological advancements are inclusive and equitable (Newell and Bulkeley, 2017; IEA, 2022). Studies indicate that government support and policy interventions significantly benefit renewable energy deployment (IRENA et al., 2018). Conversely, the sustained competitiveness of fossil fuels has also been attributed to inadequate support and ineffective incentives for integrating renewables into the energy system (Abdmouleh et al., 2015). The capacity of the state to drive energy system transformation thus emerges as a critical analytical dimension.

We aim to explore this capacity, focusing on the contemporary challenge of financing energy transitions. This challenge is particularly acute in developing and emerging countries, many of which have yet to realize sustainable economic development. Studies find that resource allocation to renewable energy remains geographically uneven, especially in countries where fiscal constraints limit government spending and undermine policy commitments (IEA, 2021). IRENA and CPI (2023) report that the disparity in renewable energy investments between developed and developing countries has grown significantly from 2017 to 2022. Strikingly, "In 2022, more than 50% of the world's population, mostly residing in developing and emerging countries, received only 15% of global investments in renewables" (IRENA and CPI, 2023). This disparity underscores a broader issue of the capacity of the state to use policy to address inequalities in financing renewable energy deployment.

Exploring this capacity thus necessitates a closer examination of public policy. Vedung (1998) asserts that public policy instruments are how governments exercise their power to facilitate social change. Scholars have used qualitative and quantitative methods to explore this relationship, including policy's effectiveness, impact, and resource mobilization potential (e.g., Polzin et al., 2015; Migendt et al., 2017; Corrocher and Cappa, 2020; Polzin and Sanders, 2020; Isah et al., 2023; Omri and Ben Jabeur, 2024). These studies provide valuable empirical insights into how policy instruments relate to contemporary financing flows and patterns, mechanisms such as risk and return, and critical barriers and constraints. However, researchers primarily focus on the financing outcomes of policy interventions without sufficiently addressing how these policies shape the underlying financing structures that generate and condition these outcomes. This oversight limits our understanding of the deeper structural changes needed to finance energy system transformation. This gap in understanding highlights a critical area for further research.

We aim to address the gap by utilizing the concept of transformative capacity, which has been used in various disciplines to explore the potential of transformation in response to external pressures (Garud and Nayyar, 1994; Weiss, 1998; Folke et al., 2002; Walker et al., 2004; Dolata, 2009; Polzin et al., 2015). Following Wolfram (2016), we define *transformative capacity* as emerging from empowered actors who can modify the rules governing the interpretation of and access to human and non-human resources. This understanding provides a conceptual basis for exploring how the state is empowered, through policy instruments, to modify financing structures for system transformation. Accordingly, the central research question guiding this inquiry is: *How does policy facilitate changes in financing structures for sustainable energy transitions?*

The conceptual framework adopts a multi-disciplinary approach grounded in a critical realist understanding of causation to focus on structures (financing rules) and mechanisms (policy instruments) (Danermark et al., 2005). The framework integrates concepts and theory from policy literature, finance literature, and institutional theory to analyze and theorize interactions between policy and finance (Strange, 1990; Vedung, 1998; O'Sullivan, 2006; Fabozzi and Drake, 2013; Scott, 2014; Anyebe, 2018; UNIDO, 2018; Browne et al., 2019; Melicher and Norton, 2020; Suaste Cherizola, 2021). Critical realist principles underpin the hypothesized modes of interaction that emerge from analysis, informed by broader sustainability transition concepts such as transition pathways, directionality, and empowerment (Geels and Schot, 2007; Geels et al., 2016).

The empirical research is designed as a critical realist instrumental case study in the empirical domain of South Africa's transition to green hydrogen. In this type of study, the case is of secondary interest, playing a supportive role in exploring the underlying phenomenon of transforming finance through policy (Stake, 1995; Ridder, 2017). South Africa was selected as a developing country with high greenhouse gas emissions and significant transition financing needs (Presidential Climate Commission, 2021, 2022; The Presidency, 2022). Significant financing challenges are compounded by deep-rooted poverty and inequality, where economic power keenly reflects Apartheid-era distributions (World Bank Group, 2018; World Bank, 2022). The state has pursued a green hydrogen strategy for over two decades, aiming to harness mineral and natural resource endowments to support industrialization and decarbonization and "tackle the triple challenges of poverty, inequality and unemployment" (DSI, 2021). Primary data was collected through semi-structured interviews with key policy stakeholders, including financiers, innovators, and public and private research institutions. Secondary sources comprised academic and grey literature, online and print media, government publications, and confidential documents provided by interview participants.

This study advances our understanding of the state's capacity to facilitate financing for sustainable energy transitions through several critical contributions. Its novelty lies in its focus on finance social structures and methodological approach to developing pathways to structural change in finance. Conceptually, it develops a novel model for explaining how policy impacts financing structures for systemic transformation in finance. Methodologically, the study offers a method for conducting focused analyses of the interactions between mechanisms and structures. Empirically, the study provides insights into financing structures and the pathways of policy action to transform finance. These contributions advance sustainability transitions theory and our knowledge on 'greening' financing for sustainable system transformations while offering practical insights for policymakers in developing contexts.

The remainder of this paper is structured as follows: In Section 2, we discuss the literature on financing energy transitions, policy to support financing, transformation in finance, and transformative capacity. In Section 3, we build on this literature to develop the conceptual model. In Section 4, we present the research design and methodology, detailing case selection, data collection, and analysis. In Section 5, we present the findings, and in Section 6, the discussion. We conclude in Section 7 by summarizing findings, contributions, and future research avenues.

2. Literature review

2.1. Financing energy transitions

In their narrative analysis of finance's role in energy transitions, Pathania and Bose (2014) found that "innovations in finance were crucial, arguably playing the most important part at the point of inflexion." For example, they argue that recognizing intellectual property as an asset facilitated the transition to the steam engine in the late 18th century. Similarly, they suggest that developing futures markets was critical for diffusing crude oil technologies and expanding oil exploration and refining. The scale, scope, and rapid pace required to meet a 1.5°C target suggest that novel financing structures and mechanisms could play a similarly pivotal role in transitions to sustainable energy systems (IRENA, 2023).

Recent research underscores the challenges inherent in aligning finance flows with the low-carbon, climate-resilient pathways mandated by Article 2.1 of the Paris Agreement (United Nations, 2015b). This alignment depends on robust policy frameworks that promote, regulate, and guide green finance initiatives to ensure that financial flows support broader sustainability targets. However, despite reaching a record USD 1.3 billion in energy transition technology investments in 2022, IRENA (2023) highlights a significant shortfall in meeting the 1.5°C target. Their 1.5°C Scenario requires redirecting ≈ USD 26 trillion away from fossil-based coal and oil technologies by 2050. The financial resources needed for an effective energy transition span the supply chain, including research, development and demonstrations, infrastructure and skills development, minerals extraction, component manufacturing, and technology installation and operation (IEA, 2021; IRENA, 2023; UNCTAD, 2023).

Critically, the scenario for financing transitions in developing countries is particularly concerning. Europe represented nearly three-quarters of all global renewable energy investment projects in 2022 (including intra-European flows) (UNCTAD, 2023). The least developed countries depend on external sources for approximately 75% of their energy investments; however, they face costs up to seven times higher than those of developed countries when accessing international capital markets (UNCTAD, 2023). An extensive list of financing challenges in such contexts includes revenue risks, market volatility, regulatory uncertainties, existing debt burdens, and strict local content requirements (IEA, 2021; IRENA and CPI, 2023). Notably, developing countries rely more on development and philanthropic finance, although they primarily depend on public debt for renewable energy investments (IEA, 2021; UNFCCC, 2022; IRENA and CPI, 2023).

In this context, green finance emerges as a critical response to bridging investment gaps, broadly defined as "financing of investments that provide environmental benefits" (IFC, 2017). Bhattacharyya (2021) suggests that green finance can be understood as strategies and methods for acquiring, raising, and allocating public, private, and philanthropic funds to address this gap. As such, the term may include, for example, climate, ecological, sustainable, environmental, and transition finance (Zhang et al., 2019; Bhattacharyya, 2021; Sikka et al., 2023; Dziwok and Jäger, 2024a; Tavares et al., 2024). Specific mechanisms that build on existing financing structures include impact bonds (e.g., green, social, sustainability-linked), carbon financing mechanisms, climate-for-debt swaps, and blended finance (Yang and Luo, 2020; Bhattacharyya, 2021; Rahman et al., 2022; UNFCCC, 2022; Tavares et al., 2024).

Encouragingly, the uptake of green finance has grown significantly over the last decade. Bloomberg (2024) reports that new impact bond issuance totaled almost US$ 1 trillion in 2023, with

record sales from governments and corporations. By comparison, in 2014, Bloomberg reported a total issuance of just under US$ 37 million (Spector, 2015). However, research suggests that this growth is neither sufficient nor consistent across regions and economic sectors, primarily focusing on the energy sector and concentrated in China, the United States, Europe, Brazil, Japan, and India (UNFCCC, 2022; IRENA and CPI, 2023). These financing patterns have been attributed to several factors in developing contexts. These include misjudged short-term adaptation needs, low or uncertain returns, institutional capability gaps, and inadequate funding mechanisms for developing countries (UNFCCC, 2022). Critically, this phenomenon suggests a misalignment between green financing mechanisms and the needs of these economies. This misalignment underscores the importance of examining the underlying financing structures that underpin these mechanisms while suggesting a key area for policy intervention to support novel financing mechanisms and structures.

2.2. Policy for financing energy transitions

The scale and scope of financial resources needed for the energy transition underline advocacy for strong international and public-private collaboration and comprehensive policy frameworks to deploy renewable energy technologies (IRENA, 2023). Researchers have identified key challenges for policy to address, including the availability and cost of financing, capital intensity, the absence of suitable financial instruments, limited institutional knowledge, and a lack of suitably priced risk mitigation instruments (IRENA et al., 2018; Polzin et al., 2019; IEA, 2021; Monaca et al., 2024). Transition scholars also advocate for policy to foster new financing mechanisms and structures that embody qualities such as consistency, responsiveness, and inclusivity (e.g., Naidoo, 2020; Penna et al., 2023).

However, current financing patterns suggest that policy has yet to address these challenges, particularly in developing contexts. Studies indicate that policy uncertainty, a lack of policy support, and ineffective policy design may be critical factors stymying finance flows to developing countries (Wüstenhagen and Menichetti, 2012; Polzin et al., 2019; Hafner et al., 2020). Alternatively, policy inefficacy could stem from how policy problems[1] are framed, which may overlook deep structural impediments in the global financial system (see Knuth, 2018; Dziwok and Jäger, 2024b). According to a Bank of America economist, the recent increase in flows to some emerging markets "suggest[s] that investors are rewarding certain [developing] countries as they implement reforms that are painful to citizens, such as currency devaluations and subsidy cuts, in an effort to shore up state finances" (George, 2024). This perspective suggests that without structural reform, even if policy meets the demands of finance, interventions may not yield sustainable, just transitions. Promoting reform of international finance institutions has been a key objective of the cooperation between BRICS countries to be more responsive to developing economies and emerging markets (Ngwu et al., 2017; Shahrokhi et al., 2017; Larionova and Shelepov, 2022).

The capacity of the state to effect structural change is realized through public policy instruments, which Vedung (1998) describes as "the set of techniques by which governmental authorities wield their power in attempting to ensure support and effect or prevent social change." Vedung (1998) proposes a threefold, mutually exclusive typology, which aligns with conceptions of coercive, remunerative, and normative power, described as regulatory, economic, and informational instruments, respectively

[1] Dunn (2018) defines a policy problem as "an unrealized need, value or opportunity for improvement attainable through public action".

(Table 1). Although studies such as those by Migendt et al. (2017), Polzin et al. (2019), UNIDO (2018), and others may categorize policy mechanisms differently, they refer to a similar set of instruments to explore and explain the relationship between policy and finance in renewable energy transitions.

Table 1. A typology of policy instruments.

Instrument	Description	Examples
Regulatory instruments (Coercive power)	Authoritative directives that compel compliance. Defined by their authoritative nature rather than by associated punitive measures.	- Licensing requirements - Emission regulations - Grid preferences - Sustainable finance standards and guidelines
Economic instruments (Remunerative power)	Manipulate material resources to incentivize or disincentivize actions. Provide choices without mandating specific behaviors.	- Grants - Subsidies - Tariffs - Taxes - Government vouchers
Informational instruments (Normative power)	Exert influence through knowledge transfer, reasoned argument, and persuasion. Includes mediated and interpersonal transmission.	- Demonstrations - Exhibitions - Conferences - Workshops - Printed media - Press releases

Source: Summarized from Vedung (1998, pp. 41–50)

States select policy instruments for renewable energy based on various factors, including national objectives, economic conditions, fiscal capacity, resource endowments, political context, and administrative traditions (Newell and Bulkeley, 2017; Carfora et al., 2018; Isah et al., 2023; Fields et al., 2023). For example, in their panel study on the determinants of renewable energy policy selection in 56 countries, Carfora et al. (2018) illustrated that preferences in developing and developed countries differ. Governments in developing countries play a more active role, favoring a multi-instrument approach of economic and regulatory instruments. Critically, they also found that developing countries' green policies may be counterproductive in promoting renewable energies. External influences, such as the conditionality imposed by multilateral organizations like the World Bank and the International Monetary Fund, may further limit policy options in developing countries (see IMF, 2023).

The policies countries select and implement can also shape the financing mechanisms available (Kern et al., 2015; Ragosa and Warren, 2019; Mirzania et al., 2020; Moura and Soares, 2023; Isah et al., 2023). For instance, Isah et al. (2023) found that the Brazilian Development Bank has been instrumental in using instruments like long-term contracts and auctions to foster a conducive investment environment in Brazil. In contrast, Nigeria's reliance on external debt funding from bilateral and multilateral development banks reflected underlying policy uncertainties and limited catalytic public financing.

Establishing the efficacy of policy instruments in mobilizing finance for energy transitions has thus received considerable scholarly attention. Scholars have used quantitative and qualitative methods across different analytic levels to assess and evaluate policy impacts on financing mechanisms such as debt, equity, and grants (Abdmouleh et al., 2015; Polzin et al., 2015; Newell and Bulkeley, 2017; Ragosa and Warren, 2019; Moura and Soares, 2023; Isah et al., 2023; Fields et al., 2023; Omri and Ben Jabeur, 2024). For example, in a systematic review of policy's impact on investment risk and return, Polzin et al. (2019) find that effective policies address both metrics simultaneously; they

advocate for policies to be designed accordingly. Abdmouleh et al. (2015) use case studies to assess renewable energy policies in Europe, China, Australia, and Nepal, highlighting critical successes and failures. They show, for example, how Spain's abrupt changes to its feed-in tariff scheme created market instability to discourage long-term investments in renewable energy and how robust partnership frameworks and targeted subsidies underpin Nepal's successful Biogas Support Programme. However, while these studies provide critical insights into how different policy instruments can impact financing flows, a key gap remains in conceptualizing and theorizing how such interactions relate to the underlying financing structures of financing mechanisms.

2.3. Transforming finance for sustainable energy transitions

The intractability of financing challenges in developing countries underpins calls for the radical transformation of the global financial system from various scholarly disciplines, including economic, political, and accounting sciences (e.g., Lütz, 2005; Zademach and Dichtl, 2016; Ryszawska, 2018; Kemfert and Schmalz, 2019; Franz and McNelly, 2024). In sustainability transitions literature, such *transitions* are conceptualized as radical shifts in the social structures of a vital societal system (such as mobility, energy, or food) toward more sustainable outcomes (Schot and Geels, 2008). Accordingly, structures emerge as a primary unit of analysis, often operationalized in transition studies using institutional theory and Scott's (2014) institutional pillars. These pillars are delineated as regulatory, normative, and cultural-cognitive and include regulations, standards and laws, behavioral norms and values, belief systems, problem definitions, and guiding principles (among others).

However, despite the extensive study of whole-system change within this field, research on the transformation of finance—both as a system and as a critical set of governance structures in other societal systems—remains limited. Notable contributions to this literature include Geddes and Schmidt (2020), Seyfang and Gilbert-Squires (2019), and O'Connell (2024), who identify critical financing structures underpinning financing dynamics in sustainability transitions. They provide examples such as centralized decision-making, profit-maximizing, the importance of trust, and perceptions of the state's de-risking role. Transition scholars have also proposed new principles and philosophies to align financing with the demands of sustainable transitions (Ryszawska, 2016; Loorbach et al., 2020; Naidoo, 2020; Schot et al., 2022; Penna et al., 2023). For example, Schot et al. (2022) propose twelve principles for transformative investment practices, strategies, and processes. Similarly, Penna et al. (2023) advocate for an expanded definition of fiduciary duty, prioritizing returns from investment in system change and mapping unquantifiable system uncertainties. However, a critical gap remains in understanding how policy can change financing structures to integrate such transformative principles.

Transition scholars advocate for policy experiments as important mechanisms to develop alternative social structures and steer transition trajectories toward preferred outcomes (Schot and Geels, 2008). In sustainability transitions literature, structural changes are framed as transition pathways, signifying the routes to system transformation (Geels and Schot, 2007; Geels et al., 2016). Policy interventions could, therefore, propagate new financing structures alongside existing institutional arrangements, modify existing rules for incremental or substantial changes, or displace and replace them entirely. For example, in South Africa, the government introduced the Broad-Based

Black Economic Empowerment [2] (B-BBEE) regulatory framework, which provides voluntary transformation guidelines and incentives for the financial sector (DTI (Department of Trade and Industry), 2012, 2017).

Transition studies also highlight the role of policy in reinforcing financing structures that perpetuate unsustainable financing patterns. Dziwok and Jäger (2024b) draw attention to epistemological foundations, neoliberal cognitive models, and financialization as critical structural challenges. Further, they argue that current policy initiatives in green finance may serve to stabilize these structures rather than transform financing for sustainable transitions. Similarly, Gibson (2022, p. 372) proposes the notion of a "*financial pathology of institutions* (emphasis in original)" to describe the detrimental cycle where local governments prioritize financial metrics over their core mission and shape the priorities of policymakers.

These critiques also highlight the pervasive impact of *financialization*, described as "the increasing role of financial motives, financial markets, financial actors and financial institutions in the operation of the domestic and international economies" (Epstein, 2005). Further, they underscore the importance of understanding the state's capacity to effect much-needed structural change in finance through policy interventions. This study addresses this gap using the conceptual lens of transformative capacity, as explored in the subsequent section.

2.4. The transformative capacity of the state

In academic literature, transformative capacity has been used to denote the ability or potential of an entity or object—be it an individual, an organization, a technology, a city, a sector, or a state—to adapt and transform in response to new circumstances, pressures, or disruptions (Garud and Nayyar, 1994; Weiss, 1998; Walker et al., 2004; Dolata, 2009; Wolfram, 2016). Scholars have applied this concept to explore various dimensions, such as the transformative capacity of technology (e.g., Arocena and Sutz, 2002; Dolata, 2013), state-level capacity for industrial development (Weiss, 2000; e.g., Bakir, 2006), system-level capacities for socio-ecological resilience (e.g., Folke et al., 2002; Walker et al., 2004), and urban capacity for socio-technical transitions (e.g., Wolfram et al., 2019; Peris-Blanes et al., 2022). These diverse approaches all aim to provide policymakers with insights into key intervention points to foster transformative change.

For example, using Weiss's (1998, 2003) approach, Bakir (2021) analyzed Turkey's post-2001 economic and financial restructuring, finding that the supranational governance structures, such as the European Union, World Bank, and International Monetary Fund, could largely account for (then) emerging policy outcomes for the country's financial system. In transition studies, Kuhmonen and Siltaoja (2022) use this lens to identify constraints to the transformative capacity and resilience of farmers in Finland, while Omann et al. (2020) were able to identify critical factors for scaling novel sustainable technologies, including the need for new finance models and public subsidies.

[2] The Broad-Based Black Economic Empowerment (B-BBEE) Act (2003) and its subsequent amendments encourage businesses to address significant social challenges, such as gender and income inequality, developing critical skills, and promoting socio-economic development (DTI (Department of Trade and Industry), 2012). Companies are invited to voluntarily comply by tying a company's access to public expenditure budgets to a B-BBEE score calculated using industry-developed scorecards. Economic sectors have developed sector-specific codes which reflect and respond to sector transformation challenges, such as the Financial Sector Code, 2012, 2017).

Wolfram (2016) makes a significant conceptual contribution to sustainability transition literature, synthesizing the early approaches of Dolata (2009), Weiss (1998), Folke et al. (2002), and others to explore urban transformative capacity. Wolfram (2016) adopts Avelino and Rotmans's (2011) approach to power in the context of sustainability research as "*the capacity of actors to mobilize resources to achieve a certain goal* (emphasis in original)." Accordingly, transformative capacity represents this power to change, arising "from (empowered) actors that can modify the rules governing the interpretation of and access to human and non-human resources" (Wolfram, 2016). Their perspective homes in on the dynamics between structure (rules) and agency (actors) and the necessity of collective empowerment to drive systemic change.

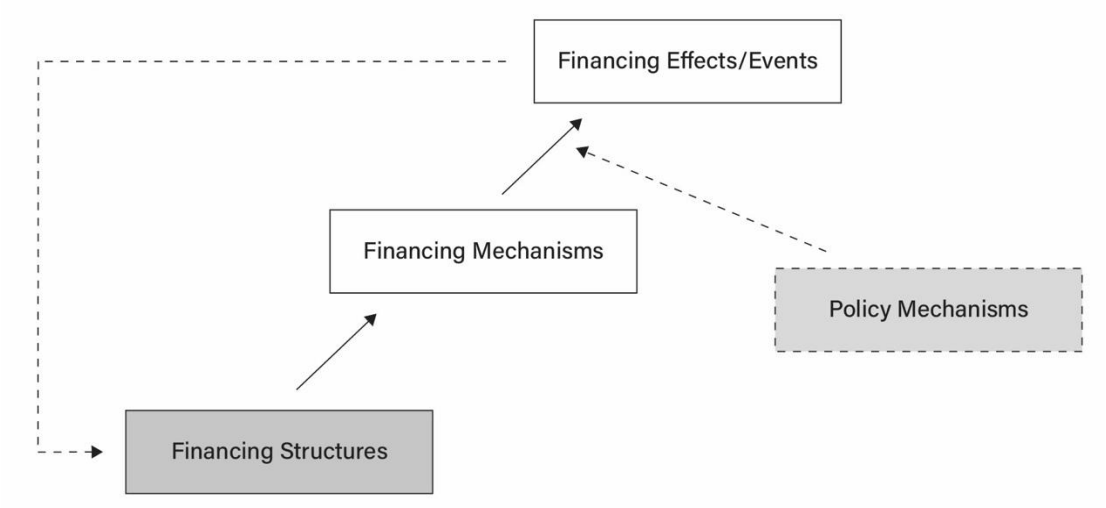
Wolfram (2016) uses this understanding to develop a comprehensive conceptual framework for understanding, analyzing, and developing transformative capacity in urban contexts, outlining ten interdependent critical components related to governance and leadership, social engagement and learning, processes and innovation, and multi-scalar and multi-actor agency. However, we contend that Wolfram's (2016) conceptualization—drawing as it does on various traditions—has broader utility, particularly in studying the redirecting of financial resources for sustainable transitions. Foremost, it facilitates a shift in framing—from ensuring the availability of financial resources for transitions to modifying the resourcing rules within transition processes. Second, it explicitly recognizes the power that underpins the mobilization of resources for social change. Consequently, we believe it provides a powerful theoretical basis for examining the state's role as an actor in modifying financing structures for sustainable transitions.

3. Conceptual framework

One strength of Wolfram's (2016) conceptualization of transformative capacity is its clear articulation of the causal relationships between actors, structures, and change. In this study, the concept underpins a focused analysis, theorizing a critical juncture between two powerful governance structures: policy and finance. This approach allows us to address the research question: *How does policy facilitate changes in financing structures for sustainable energy transitions?*

The proposed framework is underpinned by critical realist principles, which posits a reality that is stratified and differentiated "between the real structures and mechanisms of the world and the actual patterns of events that they generate" (Bhaskar, 2008). In this view, *objects*, which could include people, things, and ideas, have *structures*, imbued with causal influence, and realized through mechanisms (Sayer, 2000; Danermark et al., 2005; Bhaskar, 2008). Critical realists argue that events are concrete phenomena brought about by the causal powers of structures, where generative mechanisms interact to reinforce, weaken, or neutralize each other (Danermark et al., 2005). Mechanisms interacting under specific conditions (including other mechanisms) generate effects or events.

Figure 1 illustrates the causal interactions conceptualized for this study, where financing structures are realized through financing mechanisms that interact with policy mechanisms (amongst other contextual conditions) to generate financing effects or events. Effects could include changes in observed financing flows or the emergence of new financing structures.



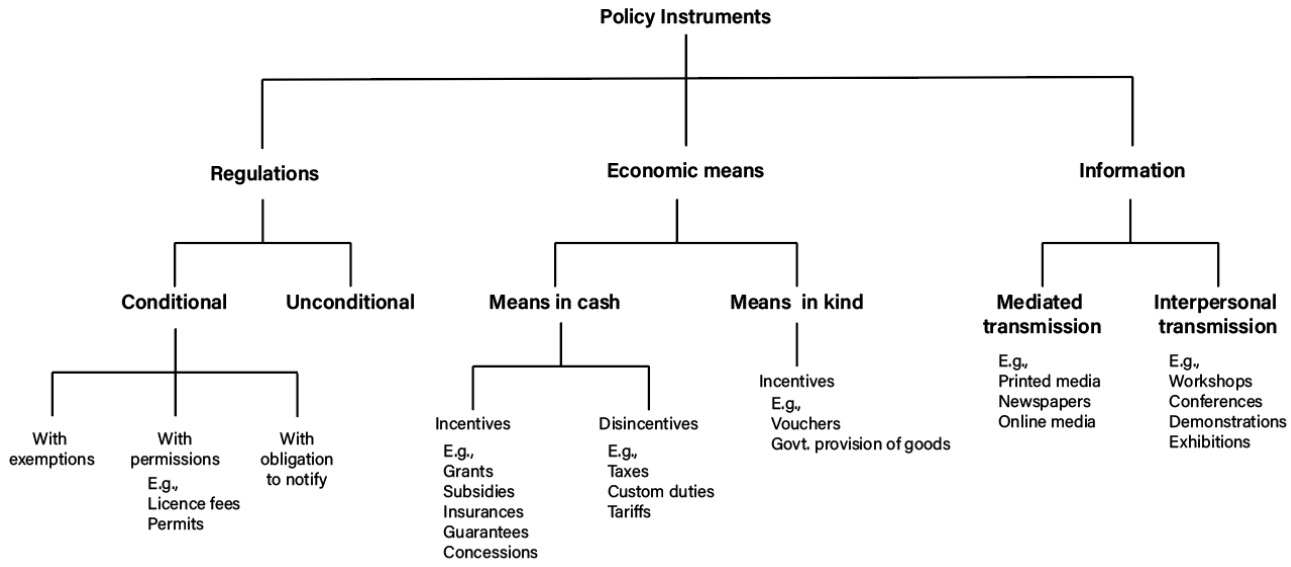
Source: Adapted from Sayer (2000, p. 15)

Figure 1. Policy and financing structures, mechanisms, and effects.

The conceptualization of this framework demands a multidisciplinary approach, drawing on policy, finance, and institutional theory to analyze and theorize how policy interacts with financing structures. Policy literature informs the categorization, functions, and tendencies of policy instruments as mechanisms (Vedung, 1998; Anyebe, 2018; UNIDO, 2018; Browne et al., 2019). Finance literature informs financing structures' dimensions, scope, role, and causal influence (Strange, 1990; O'Sullivan, 2006; Fabozzi and Drake, 2013; Melicher and Norton, 2020; Suaste Cherizola, 2021). Institutional theory operationalizes structure as regulative, normative, and cultural-cognitive rules (Scott, 2014). The ensuing sub-sections explain how scholarly works from these literatures were employed to operationalize mechanisms and structures for data analysis.

3.1. Operationalizing policy mechanisms

In this study, policy instruments are analytically resolved as mechanisms, understood as "the ways of acting of things" (Bhaskar, 2008). "Mechanisms are regarded as tendencies which can be reinforced, modified or suppressed in a complex interaction with other mechanisms in an open system" (Danermark et al., 2005). As discussed in the literature review, varying typologies have been used to classify policy instruments that policymakers can deploy. This study adopts Vedung's (1998) threefold typology to identify and classify policy instruments (Table 1). Critically—and in contrast to other approaches in the literature—it offers distinct categories with several analytical advantages (Vedung, 1998). Specifically, it provides a clear primary classification, facilitates systematic and comparative analyses, and supports deductive approaches for statistical generalization (Figure 2).



Source: Compiled from Vedung (1998, pp. 41–50)

Figure 2. A taxonomy of policy instruments.

3.2. Types of financing structures

In critical realism, structures represent "a set of internally related objects or practices" of a natural or social object or entity (Sayer, 1992). Sustainability transitions literature designates social structures (referred to as rules) as a primary unit of analysis, while transitions represent structural (rule) change (Geels and Schot, 2007). Transition scholars have often looked to Scott's (2014) three institutional pillars—regulative, normative, and cultural-cognitive—that constitute social structures. In this seminal text, Scott (2014) clarifies critical dimensions for understanding how each pillar creates, sustains, and legitimizes rules (Table 2).

Table 2. Critical dimensions of the three institutional (rule) pillars.

	Regulative	Normative	Cultural-cognitive
Basis of compliance	☙ Expedience	☙ Social obligation	☙ Taken-for-grantedness
Why actors comply			☙ Shared understanding
Basis of order	☙ Regulative rules	☙ Binding expectations	☙ Constitutive schema
Underlying structure			
Mechanisms	☙ Coercive	☙ Normative	☙ Mimetic
How rules are enforced			
Logic	☙ Instrumentalism	☙ Appropriateness	☙ Orthodoxy
Reasoning framework			
Indicators	☙ Rules	☙ Certification	☙ Common beliefs
Measures to assess	☙ Laws	☙ Accreditation	☙ Shared logic of action
compliance	☙ Sanctions		☙ Isomorphism
Affect	☙ Fear Guilt/ Innocence	☙ Shame/Honour	☙ Certainty/Confusion
Induced psychological response			
Bases for legitimacy	☙ Legally sanctioned	☙ Morally governed	☙ Comprehensible
Source of validity			☙ Recognizable
			☙ Culturally supported

Source: Summarized from Scott (2014, p. 60)

Finance theory informs the scope and causal influence of financing rules (Strange, 1990; Fabozzi and Drake, 2013; Melicher and Norton, 2020; Bhattacharyya, 2021; Suaste Cherizola, 2021). In this study, regulatory structures include financing regulations, standards, and laws; normative structures include behavioral norms and values that govern financing actors; and cognitive structures encompass, amongst others, belief systems, problem definitions, guiding principles, and search heuristics. These structures, in turn, underpin financing mechanisms that facilitate the transfer of financial resources, such as financial instruments, adjudication processes, use of proceeds covenants, and sustainability criteria (O'Connell, 2024). Exploratory research of these principal dimensions for each pillar of financing structures is included in Appendix A, Table A.1.

4. Research design and method

The research is designed as an instrumental case study to explore how the state, as an actor, is empowered to modify financing structures for sustainable energy transitions. In this design, the case of green hydrogen is secondary and "serves to help us understand phenomena or relationships within it"—in this case, finance and policy (Stake, 1995). Critical realist research that seeks to understand how structures and mechanisms give rise to events is also best suited to intensive (case study) research (Bygstad et al., 2016). This "involves investigating one or a small number of social entities or situations about which data are collected using multiple sources of data and developing a holistic description through an iterative research process" (Easton, 2010).

4.1. Case selection

In instrumental case study designs, case selection is purposive, selected to explore the phenomena under study – in this case, finance and policy in energy transitions. South Africa provides a compelling empirical domain as a developing country with significant energy transition financing needs (Presidential Climate Commission, 2021, 2022). After conducting mini-case studies on emerging renewable energy technologies in South Africa, the study was further delimited to green hydrogen. Sampling criteria included data availability, public domain visibility, national strategy and policy prioritization, historical development, global relevance, and financing demands. This delimitation facilitated a more manageable and focused in-depth examination of policies and impacts while recognizing green hydrogen's position within a renewable energy portfolio in finance practice and within economic sectors in policy practice.

For over two decades, the South African government has supported and prioritized green hydrogen as a critical pathway to much-needed environmental, economic, and social benefits (CSIR, 2006; DSI, 2021; DST, 2007; DTIC, 2023; The Presidency, 2022). As a presidential flagship initiative and prioritized area of investment, the state aims to capitalize on the country's significant platinum group metals reserves (PGM), land availability, natural resources, and technology base to support industrialization, decarbonization, and sustainable economic development (CSIR, 2006; DSI, 2021; DTIC, 2023). The Hydrogen Society Roadmap for South Africa (DSI, 2021) positions South Africa as a major exporter of green hydrogen and derivative products while stimulating local demand.

The financing demands that underpin this strategy are significant: In the short term (2023-2027), the Department of Trade, Industry, and Competition (DTIC) (2023) estimates ZAR5.51 billion will be needed for project development (pre-feasibility and feasibility studies), with a further ZAR313.5

billion estimated for project capital costs. This includes catalytic projects in sustainable aviation fuel, e-methanol, green steel production, fuel cell manufacture, infrastructure, and hydrogen mobility. The bulk of the funding during this period will be directed to green hydrogen and ammonia production (ZAR113 billion) and port infrastructure (ZA151 billion).

4.2. Data collection and analysis

The case study design uses a mixed methods approach in data collection and analysis, drawing on primary and secondary data. Primary data was collected using a semi-structured interview instrument. Ethical clearance for this research was approved and granted in writing by The University of Johannesburg's Research Ethics Committee. The sampling framework was based on inclusion criteria where actors had to participate in or support financing approval, allocation, or disbursement processes for renewable energy, including policymakers in renewable energy in South Africa. Purposive sampling and snowball sampling techniques identified key actors to yield a sample size of N=24 (Table 3). Interviews were conducted for approximately one hour each from July 2022 to July 2023. Interviews were recorded and transcribed on conditions of anonymity.

Table 3. Expert participant list.

#	Role/Designation*	Sector
1	Head: Fixed Income Research	Private
2	Director: GH Entrepreneur	Private
3	Portfolio Manager: Equity	Private
4	ESG Analyst	Private
5	Multi-asset trader	Private
6	Director: GH Research	RI Public
7	Managing Director. GH SME	Private
8	Project Manager: GH Research	RI Public
9	Portfolio Manager: Equity	Private
10	Portfolio Manager: Debt/Equity, RE	Private
11	Head: RE Research	RI NGO
12	Director: Hydrogen and RE	Public
13	Director: Energy Research	Private
14	RE Entrepreneur	Private
15	Industry Strategist: GH	Public
16	Portfolio Manager: Energy Unit	Public
17	Venture Capitalist. Angel Investor	Private
18	Head: Equities	Private
19	Head: Sustainable Finance	Private
20	Chief Director. DFI	Public
21	Head: Sustainable Finance	Private
22	Head: Power, Infrastructure	Private
23	Head: Just Transition (MNC)	Private
24	CEO: GH SME	Private

Note: DFI: Development Finance Institution; GH: Green Hydrogen; RE: Renewable Energy; RI: Research Institute; NGO: Non-governmental organization MNC: Multinational corporation; SME: Small or Medium Enterprise

Secondary data collection methods included desktop research, documents from participation in workshops and webinars, and confidential documents shared by interview participants. Sampling was purposive to select grey and academic literature, including government documents publications, meeting reports and summaries, speeches and addresses, press releases, conference and webinar proceedings,

Hansards, and news articles on financing South Africa's energy transition to green hydrogen.

Data analysis applied critical realist techniques using a phased approach (Danermark et al., 2005; Easton, 2010). In the first phase, content analysis identified policy mechanisms, and coding categorized financing rules as regulative, normative, or cultural-cognitive. A second phase identified instantiations of rule changes and resistance to change, and a third phase used thematic analysis to discern impacts developed from the participant's perspectives and the extant academic and grey literature. Finally, retroductive techniques were used to theorize modes of interaction through which policy exerts a causal influence. Results were then synthesized to explore and conceptualize relationships between policy and finance, using the theoretical lens of sustainability transitions literature and the philosophical paradigm of critical realism.

5. Results

5.1. The renewable energy policy environment in South Africa

The South African government has developed a comprehensive policy framework to support a just energy transition that "focuses on managing the social and economic consequences of [climate mitigation and adaptation policies] while putting human development concerns at the center of decision-making" (Presidential Climate Commission). The policy environment for renewable energy in South Africa is informed by several legislative and regulative instruments, including the National Energy Act 34 of 2008, the Climate Change Bill 2021, and the National Environmental Management Act (NEMA).

In addition to tax incentives and various funding instruments, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) emerged as a key economic instrument pivotal to accelerating renewable energy adoption (DMRE, 2024b; Eberhard and Naude, 2016). This program is designed as a competitive tender process to attract private investment into grid-connected renewable energy projects. As at 31 March 2024, procured projects have provided 13 422 MW of electricity capacity to the grid (DMRE, 2024a). As a member of the Green Hydrogen Panel recounted: "a lot of lessons in the REIPPPP and public-private partnerships we've established, [Power Purchase Agreements], quite intricate ones, and mechanisms of derisking, etc. All those lessons are quite valuable". Informational instruments of significant import in the renewable energy landscape include the Just Transition Framework and Integrated Resource Plan: "Whatever energy we invest in, it needs to be shown in that resource plan" [Interview 9].

Various instruments are being deployed to support the transition to green hydrogen specifically. Regulatory instruments, such as permits, licenses, and certificates, are being developed, such as the need to amend the Gas Act No. 48 of 2001 (DSI, 2021; DTIC, 2023). Economic instruments, such as the Hydrogen South Africa (HySA) RDI Programme, were fundamental in ensuring early funding to sustain innovation before commercial interest (DST, 2007). Similarly, informational instruments such as the *Finding the Fuel Cell Niche for South Africa* seminar and the *National Fuel Cell Strategy Workshop* in 2003 were instrumental in developing early networks and galvanizing private sector interest (CSIR, 2006; DST, 2007). These efforts were later supported by a slew of technology demonstrations in fuel cells and mobility applications, as well as new fora for collaboration, such as the Green Hydrogen Panel led by the DTIC and the Africa Green Hydrogen Alliance (see DTIC, 2023).

A more detailed list of key policy instruments in the South African context, organized using Vedung's (1998) threefold typology, is included in Appendix B. Table B.1.

5.2. Policy impacts on financing structures

Table 4 below summarizes the findings from our data analysis on the impacts of the respective policy instruments on regulative, normative, and cultural-cognitive financing structures in the context of green hydrogen development. These impacts were largely derived from the primary data using thematic analysis. Critically, as green hydrogen has not yet been commercialized, and its development is evolving, participants needed to reflect and draw upon wider experiences. For example, participants discussed policy impacts in the context of green hydrogen as part of their renewable energy portfolios, asset class portfolios, and economic sectors or as part of their line function within the organization (e.g., innovation, sustainability, project finance, infrastructure, industrial development, research).

The sub-sections that follow elaborate on these impacts. Tables C.1–C.3 in Appendix C further provide substantiation by presenting additional representative quotes for each type of policy instrument interaction.

Table 4. Summary of policy impacts on financing structures.

	Regulative Structures	Normative structures	Cultural-cognitive structures
Regulatory Instruments	New instruments demand regulatory compliance, compelling actors and financiers to align practices with evolving standards and frameworks.	Regulatory instruments establish norms about the governance of financing activities, shaping expectations about the state's role in market regulation and intervention.	Through compliance processes, actors must internalize new structures and adapt to regulatory constraints and opportunities.
Economic Instruments	New standards, frameworks, and processes emerge to maximize benefits or minimize the costs of economic instruments.	Economic incentives and disincentives inform expectations about economic feasibility and shape beliefs about the government's role in the economy.	Economic interventions reinforce cognitive models that underpin economic decision-making and frame policy problems as economic.
Informational Instruments	Stakeholder engagement provides feedback to align the resources and strategic objectives of policymakers and stakeholders.	Strategic communication informs expectations of development pathways and shapes beliefs about the government's role in market development.	Informational instruments can shape cognitive models and decision-making frameworks, providing certainty (or uncertainty) to financing and market actors.

5.2.1 Regulatory instrument impacts

Introducing new regulatory instruments signifies a shift in the overarching regulatory framework, which includes regulative financing rules. In South Africa, regulative financing structures encompass national legislation and regulation for financing activities, such as The Banks Act of 1990, private regulation, such as the King Code of Governance and the Johannesburg Stock Exchange Sustainability Disclosure Guidance, and standards derived from international and multilateral frameworks like the Sustainable Development Goals (Bank for International Settlements 2024; IFRS Foundation 2016; Institute of Directors in Southern Africa 2017). Critical aspects of finance governance are distinctly global, as one head of sustainability in banking explained: "Given the Basel [III] regulations, it's really,

really hard for us to take anything, it's hard to take equity risks, just because it costs us a fortune" [Interview 21].

Notably, the global nature of regulatory frameworks in finance constrains the extent to which the state can reconfigure or propagate alternative financing structures through regulatory mechanisms. For example, South Africa's recent greylisting by the Intergovernmental Financial Action Task Force demanded a robust response to strategic deficiencies in anti-money laundering and combatting the financing of terrorism (National Treasury, 2024). Critically, finance favors stable, shared rules to facilitate transactions: "All the funders want to see that you're reducing emissions at a rate that's aligned to the Paris Agreement" [Interview 24]. Conversely, novelty represents uncertainty and instability, which contribute to risk.

New regulatory instruments can also incur significant compliance costs, for example, for licenses, permits, and certifications: "Even if the technology has been proven to work. If there are things that do not meet the requirements of government, yes, then you have to hold that back until […] you have the necessary certifications for you to put that into the market" [Interview 16]. Regulatory compliance is deeply embedded in all financing contexts: "So we won't advance one cent in cash until we have finished our due diligence process […] we would have done technical DD [due diligence], we would have done insurance DD, will have done the legal DD, the financial DD, the model audit" [Interview 22]. Regulatory instruments may also reinforce the market dominant actors due to increasing transaction and friction costs: "But the smaller funds, they don't want to spend [those] transactional costs, so they need some support" [Interview 11].

New regulatory mechanisms may catalyze the development of new networks and specialized expertise, such as in the case of the broad-based black economic empowerment (B-BBEE) regulations [Interview 9,10,22,23]. As one veteran project financier explained: "You have BEE requirements. BEE guys need funding; the funding requirements can add a potential premium. So, there are a whole lot of nuances in South African project finance that you maybe don't necessarily have elsewhere". Interventions can also prompt innovation and adaptation, leading to new strategies that circumvent regulatory demands [Interview 9]. Conversely, evidence was found of financing actors developing informal standards with their peers to address the lack of regulatory guidance on sustainable finance in South Africa [Interview 20].

5.2.2 Economic instrument impacts

The deployment and uptake of economic instruments suggest the development of new standards, guidelines, and decision-making frameworks to guide practice. For instance, an innovation funder's development of an online grant management system to manage the inflow and proper use of grants illustrates how such procedural innovations are necessary [Interview 16]. Critically, they are also mechanisms for international engagement to inform shared rules and practices: "Look when REIPPP rounds 1-4 happened, and when we saw a lot of the international legal firms coming in and getting involved, there was a severe lack of skills in the country […] But there was a skill transfer and the skills, a lot of those skills, did remain" [Interview 22].

Economic instruments also facilitate innovation that might not otherwise secure funding [Interview 6,7,14,18,17,22,24]. Innovation is critical in sustainable energy transitions, and the government is perceived as the primary driver, particularly in the absence of a well-developed venture capital industry in South Africa [Interview 17,18,22]. Critically, efforts to de-risk investments reinforce

normative beliefs and cognitive models about the responsibility of the government to drive sustainable economic development: "Because what [de-risking] boils down to is that government will need to take some risk either directly financially or indirectly as in guarantees" [Interview 15].

The government's use of economic instruments influences the financial sector's perception of new opportunities and markets, particularly when de-risking high-risk projects. For example, long-term government offtake agreements offer security to encourage investments in areas like renewable energy [Interview 9]. Economic instruments thus clarify the government's position to finance actors shaping perceptions about long-term economic viability: "And then having this framework to negotiate these [Power Purchasing Agreements], which are bankable, which were government guaranteed, that also really helped" [Interview 21]. Critically, the efficacy of economic instruments is necessarily constrained by the wider economic landscape: "To be completely honest, and I mean, really, this isn't an indictment on policy, but if we had growth in this country, we would find a way to [increase investment in renewable energy assets]. Because banks couldn't actually hold on to all these assets, and they would need to sell down" [Interview 1].

5.2.3 Informational instrument impacts

Data analysis suggests that interpersonal processes are critical mechanisms for aligning financing structures with available resources and the strategic objectives of policymakers and financing actors. Informational instruments facilitate the diffusion of knowledge and provide opportunities for knowledge co-creation and second-order learning. For example, interviewees who participated in developing the Hydrogen Society Roadmap for South Africa (DSI (Department of Science and Innovation), 2021) recounted instances of shifts in normative and cognitive dimensions, underscoring the transformative potential of informational instruments [Interview 6,12,13,23,24].

The scope and inclusivity of stakeholder participation emerged as pivotal factors in the effectiveness of informational instruments. Participants recounted varying perspectives on what kind of participation is warranted, the appropriate avenues for participation, and whether participation was meaningful [Interview 1–4,6,9,14–16,23]. One interviewee who participated in the stakeholder consultations for the Hydrogen Roadmap recounted: "And, actually, [CEO of an international South African energy company] really enjoyed [the interaction]. Because I felt, oh my god, this is going a little bit beyond what I'm allowed to do. Because I was being purposefully provocative" [Interview 13]. Conversely, exclusions can undermine this efficacy by limiting the diversity of input and perspectives. "That [Hydrogen Roadmap] process itself was quite limited in terms of consultation, and that's actually one of the issues to which our research responds, is that there was no civil society consultation" [Interview 2].

Informational instruments embed knowledge within decision-making frameworks, aligning policymakers' and stakeholders' resources and strategic objectives. Limited capacity among stakeholders to absorb information thus emerges as a critical constraint. As one head of sustainable finance explained: "But the people facing clients and seeing the real impact of those policies are like on the ground, sitting in meetings in client meetings, and just don't have the time capacity to read these policies" [Interview 21]. One fund manager explained that policy coherence is critical: "I think our biggest problem is that [ideologies] are not aligned in the government. [They are] saying something on the one hand, and then they're pursuing something else" [Interview 9].

The widespread adoption of similar informational instruments across different regions, such as those used in green hydrogen initiatives, helps to foster a shared understanding that facilitates international cooperation and trade (IRENA, 2020; World Energy Council, 2021). This uniformity was discussed at a green hydrogen workshop at Utrecht University, where scholars from Latin America, Africa, Europe, and Asia reflected on the commonalities in policy language and strategy (see Gevaert et al., 2023). While such consistency supports the alignment of national strategies with global norms, it also raises concerns about the influence of global North actors, potentially imposing a form of soft power that could limit transformation.

5.3. Modes of policy mechanism interactions

To address the research question of *how* policy facilitates changes, the final analysis phase aimed to clarify the modes of interaction through which instruments can induce change. This iterative analysis process drew on the understanding of causation in critical realism, and in particular, how mechanisms interact as contextual conditions to generate events and emergent outcomes (see Figure 2). Thematic analysis proposes four modes of interaction, as described in Table 5 below, supported by contextual examples in the South African context. A more detailed matrix of the findings on policy impacts on financing structures is included in Appendix D, Table D.1.

Table 5. Theorizing modes of interaction between policy mechanisms and finance structures.

Influence	Mode of Interaction	Contextual example(s)
Reinforce	- Reinforce and strengthen existing financing structures.	- Adopting international financial reporting standards in South Africa aligned recording and verification processes to global standards (IFRS Foundation, 2016). - Using Special Economic Zones to support green hydrogen development (DTIC, 2023)
Disrupt	- Weaken existing financing structures for constructive/destructive outcomes.	- The impact on financing decision-making after South Africa's credit rating downgrade due to deteriorating fiscal policy (Fitch Ratings, 2020). - Renewable energy subsidies direct funding away from fossil-based technologies to support green hydrogen (DTIC, 2023).
Transform	- Transform or reconfigure existing financing structures.	- The gazetting of the Financial Services Sector Code (part of the Broad-Based Black Economic Empowerment regulatory framework) provides voluntary transformation guidelines and incentives for the financial sector (DTI, 2012, 2017). - The stakeholder consultation process for South Africa's Hydrogen Roadmap transformed normative beliefs about the feasibility of green hydrogen as a viable transition pathway (see DSI, 2021).
Displace	- Existing structures are replaced or displaced with alternatives.	- South Africa joined BRICS for an alternative governance framework "to create an alternative world order in favor of multi-polarization" (Duggan et al., 2022, p. 475).

Our analysis finds that economic instruments primarily interact with the regulative and normative dimensions by inducing new standards and guidelines to accommodate instruments and shaping normative preferences of future economic opportunities. These interactions disrupt or weaken existing financing structures for constructive (or destructive) outcomes that favor (or prejudice) unsustainable technologies. For example, in South Africa, policymakers have been cautious about using economic disincentives to support green hydrogen development because of the risk of negative socio-economic

impacts (DTIC, 2023). Critically, economic instruments reinforce both the underlying cognitive models and philosophical paradigms of economic decision-making and the framing of the policy problem as economic.

Regulatory instruments can also transform regulative structures and frameworks to foster sustainable outcomes. The B-BBEE Act, for instance, led to the promulgation of voluntary sectoral codes, such as the Financial Sector Code, aiming to broaden the economic participation of historically disadvantaged groups in the financial sector. These instruments can also reinforce or disrupt normative beliefs about the state's role and impact cognitive models and frameworks that underpin compliance and risk management, prompting adaptation and innovation among financing actors to align with new regulations. While regulations are often perceived as constraints, they are also understood as essential measures to ensure stability and reduce uncertainty.

Interpersonal informational instruments are pivotal in transforming all three dimensions—regulative, normative, and cognitive—by disseminating knowledge and fostering stakeholder dialogue. For example, developing South Africa's Hydrogen Roadmap involved public consultations, workshops, seminars, and policy updates, providing critical platforms for knowledge creation and co-creation. These interactions facilitated adaptation processes to update regulatory frameworks and develop new standards and guidelines (DSI, 2021; DTIC, 2023). Critically, they provided opportunities for second-order learning to challenge underlying assumptions, values, norms, and beliefs for new cognitive models and knowledge frameworks. In contrast, mediated transmissions, such as press releases that communicate new partnerships or strategies (e.g. Sasol Limited, 2021), were typically parsed through participants' pre-existing cognitive frameworks. This suggests that these types of mechanisms are likely to either reinforce or disrupt existing structures and, at best, transform normative beliefs, depending on how the new information aligns or conflicts with internalized norms and expectations.

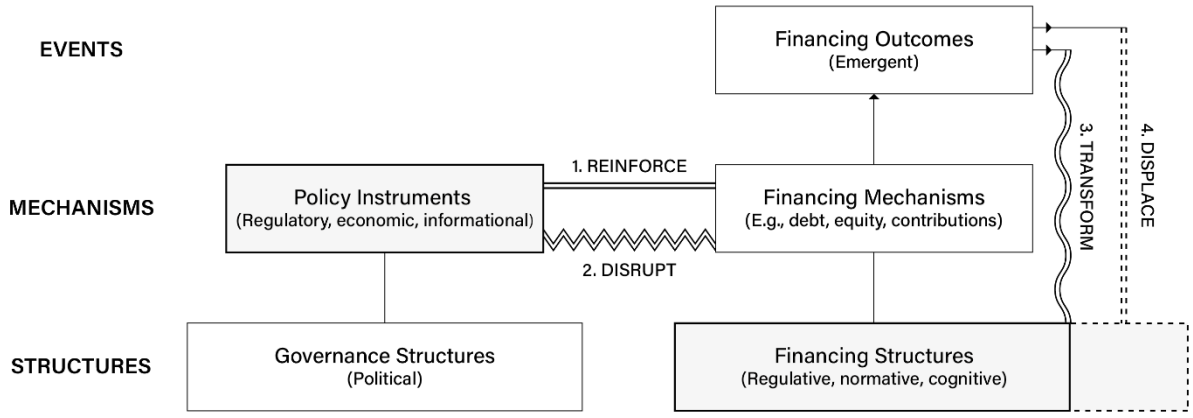
The primary data did not provide any evidence of where policy mechanisms displaced financing structures in the specific context of green hydrogen development. The conclusion drawn here is that financing structures are highly diffused, shared globally, and universally embedded, which both facilitates and constrains how resources are allocated. Powerful actors, such as international development banks, can exert significant influence, coercing compliance with existing financing norms and standards in developing contexts (e.g. IMF, 2023). This reality points to the need for stakeholders to consider appropriate governance levels and strategic points of intervention to support structural change.

6. Discussion

The findings in section 5 show how policy instruments have directly and indirectly facilitated changes in financing structures for South Africa's transition to green hydrogen. These instruments are the mechanisms through which the state, as an actor, can exercise its transformative capacity to modify financing rules. The discussion in this section will focus on addressing the research question and reflecting on areas where this study contributes new perspectives on policy for transforming finance for sustainable energy transitions. In Section 6.1, we present a novel conceptual model of how policy facilitates changes and reflect on how different modes of interaction impact system transitions (as structural change). Section 6.2 considers the importance of governance levels and the role of policy experiments in driving transformative change. Section 6.3 concludes by presenting insights and implications for greening finance in sustainable energy transitions.

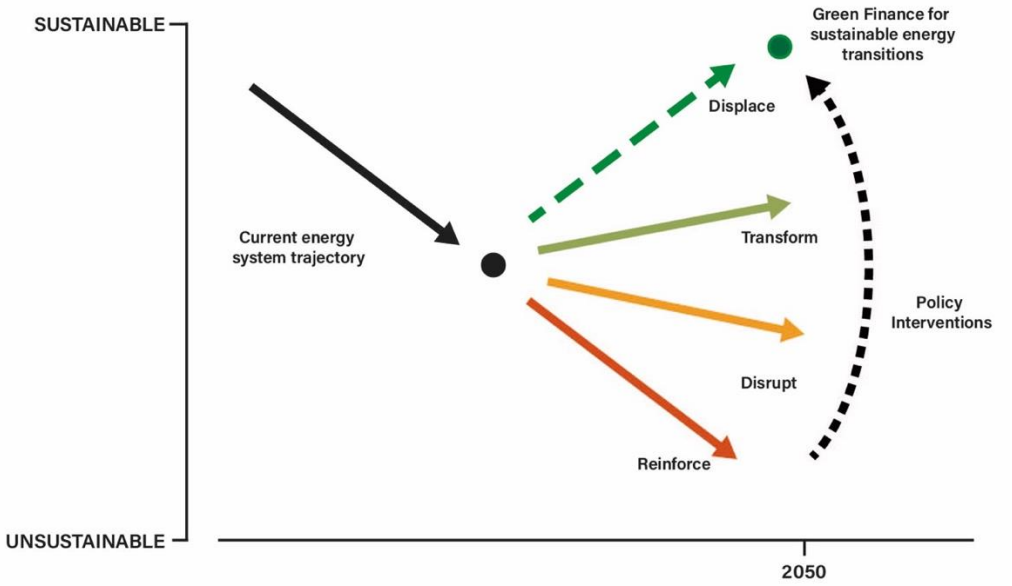
6.1. Modes of interaction and transformative capacity

The conceptual framework in Section 3 developed a focused lens to guide the research design and data analysis of the interactions between policy mechanisms and finance structures. Figure 3 below expands this lens to develop a model that incorporates the four modes of interactions and hypothesizes how they affect financing outcomes and structural change. Interventions that reinforce or disrupt financing mechanisms can change patterns in financing flows without inducing structural change in finance. In contrast, new structures can emerge from interventions that interact to transform and displace. While green hydrogen in South Africa provided the empirical domain for this study, we found that the data supports, at the very least, its wider applicability to renewable energy in South Africa.



Source: Authors' own

Figure 3. A conceptual model of policy and financing interactions for structural change.



Source: Developed and adapted from Wigboldus et al. (2021, p. 22).

Figure 4. The potential of policy mechanisms for financing sustainable transitions.

To address the research question of how policy facilitates changes *for sustainable transitions*, we propose that the different modes of interaction reflect varying degrees of transformative capacity as they pertain to the transformation of finance (Figure 4). Policy mechanisms that interact to reinforce structures are the least transformative by maintaining unsustainable trajectories in financing transitions. In the literature reviewed, Knuth (2018) provides an apt example, revealing how financial innovations are often products of financialization, entrenching the influence and power of financing actors. Similarly, Dziwok and Jäger (2024b) argue that current policy initiatives in green finance may stabilize epistemologies and cognitive models rather than transform financing for sustainable transitions.

Conversely, displacement involves replacing existing structures with new governance regimes. These interactions represent the highest level of transformative capacity and the opportunity for significant systemic change—whether sustainable or not. An unsustainable outcome could include the destabilization of the financial system arising from policy intervention. Nonetheless, displacement strategies may offer greater opportunities for *radical* structural change. Notably, the lack of evidence of displacement in this study underscores the stability and widespread diffusion of financing structures and their inherent resistance to radical change.

6.2. Governance levels and policy experiments

Analysis suggests that the interactions between policy and financing structures span multiple governance levels. Policy instruments can directly affect operational practices and strategic decision-making by individuals and organizations. The national context, especially regarding legislative and executive actions, shapes the national and sectoral environments within which entities operate. International and global governance structures play a dominant role in shaping the parameters within which national policies can operate.

Real limits of the state's capacity emerge from international organizations and structures. As Bakir (2006) found, organizations like the International Monetary Fund and the World Bank—key actors in development finance for developing and emerging economies—can (and have) placed considerable restrictions on the state's capacity to exercise its power for sustainable development. For example, conditionalities imposed may limit the size of the government or the levels of public debt to invest in renewable energy infrastructure (IMF, 2023). These constraints exemplify notions of finance as a system of governance that codifies control and embodies structural power (Strange, 1990; Walter and Wansleben, 2020; Suaste Cherizola, 2021). Bakir (2006) refers to this phenomenon as *governance by supranational interdependence*, where "policy outcomes can be understood in terms of the pressures emanating from the international political economy and efforts to harmonize national monetary governance and financial governance arrangements".

Two key governance levels emerge for policy interventions to propagate radical structural change. First, at the level of the state, states can collaborate to displace financing structures. In the South African context, the emerging alternative governance framework that BRICS represents may provide opportunities for collective international action by developing countries. By forming alliances that advocate for and implement new financial governance frameworks, these collaborations can consolidate power to develop the necessary autonomy and flexibility to enact transformative policies.

Second, the findings support transition scholars who advocate for transformative innovation policy experiments as informational instruments that can facilitate learning and adaptation. Given the limitations of economic and regulatory instruments in challenging cognitive models, such experiments

could be instrumental in reshaping the foundational ideas and assumptions of policymakers, financing actors, and energy stakeholders. In particular, experiments could prove useful in co-creating mechanisms that transform or displace financing structures across governance levels for radical transformation. Critically, in a financing context, experiments offer opportunities for ring-fencing interventions to assume greater uncertainty while controlling for unsustainable outcomes such as destabilizing the financial system.

6.3. Insights and implications for greening finance

Our findings also suggest that understanding the responses from financing actors to policy interventions could enrich policymaking processes for more responsive, informed, and effective interventions to finance sustainable energy transitions. We propose three responses by financing actors: *adaptation, innovation, and resistance*.

First, financing actors may adapt to interventions, aligning their cognitive models with new standards and norms. This adaptation is observed in actors' compliance with national and international regulations. For instance, implementing the Carbon Tax Act in South Africa has compelled financing actors to consider the operational efficiencies and emissions profiles of energy companies (Environment, Forestry and Fisheries Portfolio Committee, 2021).

Second, in response to new challenges and opportunities, financiers may innovate within the system by developing new products, services, or approaches that comply with or capitalize on new interventions. Examples include the proliferation of green bonds and sustainable investment funds, which allow investors to participate in sustainability transitions while achieving competitive returns. However, as Dziwok and Jäger (2024b) argue, these innovations may sustain and stabilize existing financial structures.

Finally, powerful actors may resist changes that threaten established interests or practices, leading to bottlenecks, inertia, and coercive measures. This resistance may stem from the perceived risks of deviating from established financial practices, the implicit dilution of power and control, or the direct costs of implementing new technologies or processes. Given these dynamics, enhancing regulatory autonomy at the international level is essential, as such autonomy could allow for imagining and developing innovative, context-specific solutions. For example, the New Development Bank of BRICS offers financing for sustainable infrastructure projects in member countries without the stringent conditions typical of Western financial institutions such as the IMF (see Ngwu et al., 2017; Shahrokhi et al., 2017; Larionova and Shelepov, 2022; IMF, 2023).

7. Conclusions

We explored the state's capacity to address the contemporary challenge of financing a sustainable energy transition in a developing context. The question to frame this research was formulated: *How does policy facilitate changes in financing structures for sustainable energy transitions?* A single-case study design, underpinned by critical realist principles, drew on primary and secondary data to conduct empirical research in South Africa, using the unfolding transition to green hydrogen as an instrumental case. Its novelty lies in its focus on financing structures and its unique methodological approach to interrogating policy impacts and conceptualizing pathways to structural change in finance.

Our study proposes that policy instruments can reinforce, disrupt, transform, or displace financing

structures to maintain or transition an energy system. In response, financing actors may adapt, innovate, or resist policy interventions to limit the transformative capacity of the state. In the face of powerful actors, interventions that reinforce or disrupt may fail to address the needs of developing countries and emerging markets. Consequently, policy experiments emerge as critical interventions that can challenge normative beliefs and cognitive frameworks to reimagine green finance that responds to developing countries' challenges.

As a single-case study, the research design limits the generalizability of the findings as they pertain to system-specific impacts and modalities of change. However, critical realist approaches consider the generalization of causal mechanisms as tendencies. As such, the results may be of wider interest in contexts where similar policy mechanisms are deployed. Further, while we find that the data supports its validity in the wider renewable energy transition in South Africa, future research could consider comparative studies across different geographic and economic contexts to refine the proposed model and validate its recommendations.

The research contributes to academic discourse and offers practical frameworks for policymakers to develop strategies for transforming finance. Future research should explore other developing countries to compare policy impacts in other regulatory and financial contexts. Investigating the longitudinal impacts of these instrument interactions will also help understand their sustained effects and conceptualize their interactions as part of an evolving transformative policy portfolio.

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Author contributions

O'Connell, Amanda-Leigh: Conceptualization, development of the methodology and conceptual framework, data collection and analysis, visualization, and preparation and presentation of the manuscript; Schot, Johan: Critical review and commentary, supervision of the research process, conceptual development.

Use of AI tools declaration

During the preparation of this work, the first author used OpenAI's ChatGPT to streamline the manuscript, specifically to address issues of tautology, redundancy, and superfluity in the text. After using this tool, the authors reviewed and edited the content as needed and can confirm full responsibility for the publication's content.

Conflict of interest

The authors declare no conflict of interest.

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