Geoforum 161 (2025) 104244

Contents lists available at ScienceDirect

Geoforum

journal homepage: www.elsevier.com/locate/geoforum

Governance of future-making: Green hydrogen in Namibia and South Africa

Britta Klagge [a,*], Benedikt Walker [a], Linus Kalvelage [b], Clemens Greiner [c]

[a] University of Bonn, Department of Geography, Meckenheimer Allee 166, D - 53115 Bonn, Germany
[b] University of Cologne, Department of Geography, Otto-Fischer-Straße 4D - 5ß674 Köln, Germany
[c] University of Cologne, Global South Studies Center, Classen-Kappelmann-Str. 24D, 50931 Köln, Germany

ARTICLE INFO

Keywords:
Expectations
Bindingness
Path creation
Green hydrogen
Regional development

ABSTRACT

The green-hydrogen sector has created considerable expectations in the Global South about export-oriented development and industrial path creation. However, whether and how these expectations are really materializing requires further scrutiny. This article develops a conceptual approach that we call governance of future-making. Thereby, we want to understand how actors try to coordinate their expectations about future economic development in different contexts and across scales over time. We conceptualize the emergence of new regional development trajectories as resulting from the use of governance instruments with an increasing bindingness, which reflect the interplay between governance of and by expectations. Based on this approach, we analyze and compare green-hydrogen activities in Namibia and South Africa. We find that future-making is becoming more binding in both countries but has not resulted in path creation yet.

1. Introduction

Green hydrogen is an energy carrier made from renewable electricity and water in electrolyzers, which can replace fossil fuels in industrial processes, transport and heating. Although green-hydrogen production and use face technological challenges and are still far from being cost-competitive with fossil fuels (IRENA, 2020), green hydrogen has become an object of future-making, and focus of new path creation in various countries around the world (Scholvin & Kalvelage, 2025). As an emerging field of innovation and economic activity, green hydrogen is an interesting case for studying the associated governance structures and how they develop over time.

Whereas expectations are high, the green-hydrogen industry has not effectively resulted in path creation in the form of large-scale production yet.[1] So-called grey hydrogen, produced from natural gas and other fossil fuels, still accounts for more than 99 % of hydrogen production today and is primarily used in the (petro-)chemical industry (IEA, 2023b, p. 14). Moreover, most green-hydrogen production projects worldwide are in early stages of development and only few projects, which account for 4 % of expected hydrogen production capacity by 2030, have reached a final investment decision (FID) (IEA, 2023b). The development of large-scale projects, from feasibility and engineering studies to operation requires four to eight years (Engelmann & Rohrmeier, 2022). This means that FIDs are an insufficient indicator for analyzing the development of the green-hydrogen industry, in contrast to associated future-making practices i.e., activities that aim to turn visions and expectations into matters of fact (Müller-Mahn, 2020).

While green hydrogen has become the preferred solution to decarbonize hard-to-abate industrial sectors in Europe and elsewhere, domestic production is unlikely to deliver the required quantities in some countries in the Global North where demand for green hydrogen is expected to be large, such as Japan and Germany. At the same time, it is widely acknowledged that green hydrogen produced in suitable Global South locations is going to be cheaper than production in most northern countries. Therefore, green hydrogen and its derivatives are envisioned as internationally traded commodities produced in various locations across the globe (van de Graaf et al., 2020). This raises the question of how the supporting multi-scalar governance structures are developing.

Green-hydrogen futures have gained traction in Namibia, South Africa and other Global South countries, because they promise foreign direct investment (FDI) and economic development, e.g. through green industrialization (Dorn, 2024; Eicke & De Blasio, 2022; Scholvin & Kalvelage, 2025). At the same time, there are already discussions on how international green-hydrogen trade might lead to green extractivism and

* Corresponding author.
E-mail addresses: klagge@uni-bonn.de (B. Klagge), benediktwalker@uni-bonn.de (B. Walker), linus.kalvelage@uni-koeln.de (L. Kalvelage), clemens.greiner@uni-koeln.de, clemens.greiner@uni-koeln.de (C. Greiner).

[1] For an analysis of already-operating small-scale production projects see Schwabe (2024) and Walker and Klagge (2024).

https://doi.org/10.1016/j.geoforum.2025.104244
Received 14 June 2024; Received in revised form 29 January 2025; Accepted 19 February 2025
Available online 28 February 2025

neocolonialism (Gabor & Sylla, 2023; Kalt et al., 2023), and also land-use conflicts, and water scarcity (Tunn et al., 2024). However, it is still uncertain whether the industry will materialize in the first place, given the increasing implementation gap between project announcements and investment decisions (Odenweller & Ueckerdt, 2025). Especially against the background of past hydrogen hypes (Bakker & Budde, 2012) and disappointed expectations about the emergence of an export-oriented biofuels industry in Africa (Gasparatos et al., 2015; Ponte, 2014; Ponte & Birch, 2014), the disparity between visions and expectations on the one hand, and their materialization and path creation on the other hand, deserves particular scrutiny.

Against this background, this article focuses on what we call governance of future-making, meaning the coordination of actors, interests and institutions to turn expectations into path creation. We argue, first, that future-making leads to path creation when its governance becomes (more) binding over time, especially when investments are being realized. We therefore propose to scrutinize future-making governance instruments in regard to their bindingness to gain insights into the relationship between future-making and path creation. Second, following the literature on path creation, we argue that governance of future-making is contingent upon contextual conditions and the agency of actors in multi-scalar governance structures.

Focusing on future-making and path creation provides an interesting starting point that adds new insights into two – so far not connected – literatures. While the impact of visions of, and plans for, the future has long been neglected in literatures on new path development (Hassink et al., 2019, p. 1638), there are now various calls to integrate the role of expectations, imaginaries and other ideational concepts, or more generally "futures" and forward-looking perspectives, into past-oriented research on regional economic development (Benner, 2024; Gong, 2024). In our view, the future-making perspective is particularly well-suited for this purpose because it focuses on the actors and practices that aim to turn future possibilities into path development (Purwins, 2022). Furthermore, very few authors have yet applied the path creation concept to the Global South context (Mlilo et al., 2024). Therefore, we explore these issues by looking at South Africa and Namibia, two countries pioneering green-hydrogen futures and production with similar visions, but different contexts for, and experiences with, hydrogen, and address the following empirical research question:

How is the governance of green-hydrogen future-making in Namibia and South Africa developing over time and moving towards path creation?

To answer this question, the article is structured as follows: In the next section, we develop the governance of future-making approach. In the methodology section, we present our case-study contexts and explain the empirical methods, before three analytical sections follow. First, we analyze the governance of green-hydrogen future-making in Namibia and then in South Africa. Afterwards, we compare the two cases and examine how they are related. In the conclusion, we discuss our arguments and point out future research directions.

2. Governance of future-making: conceptual thinking and the case of green hydrogen

To develop our understanding of the governance of future-making, we introduce the distinction between governance of and by expectations as first conceptual element (2.1). Governance instruments of varying bindingness are the second conceptual element, and we argue that future-making leads to path creation when the used governance instruments become (more) binding over time (2.2). To sustain our argument that governance of future-making is contingent upon contextual conditions and the agency of actors in multi-scalar governance structures, we then reflect on the contexts in which path creation takes place (2.3).

2.1. The governance of and by expectations

Governance of future-making includes the coordination and politics of expectations and underlying imaginaries among various actors (Eaton et al., 2014; Hielscher & Kivimaa, 2019; Longhurst & Chilvers, 2019). Empirical research on future-making practices often focuses on specific actors, such as global consultancy firms (Müller-Mahn, 2020), urban communities (Bunnell et al. 2018), entrepreneuring practitioners (Thompson & Byrne, 2022) or digital platforms (Schneider & Lösch, 2019). These actors have different capacities to change – or establish new – expectations and institutions, and hence contribute to future-making and path creation. Since governance can occur at different levels or scales, from local to international, an analytical distinction can be made between top-down and bottom-up forms of governance. While the former are driven by, and serve the interests of, actors at higher scales (such as the national and international), the latter work in reverse (Gong, 2024).

In the literature on expectations, Konrad and Palavicino (2017) distinguish between governance of and by expectations. Governance of expectations refers to "how expectations are … coordinated among individuals, organizations, communities and arenas" (2017, p. 192). By contrast, governance by expectations focuses on how expectations "contribute to coordinating actors, and shaping strategies and institutional arrangements" (2017, p. 192), thereby directing attention to how "expectations channel efforts into certain directions and contribute to the emergence and stabilisation of socio-technical structures, institutional arrangements and paths" (2017, p. 194). However, as Konrad and Palavicino (2017, p. 189) argue, "governance of and governance by expectation reflexively relate to and build on each other; a dynamic which leads to governance patterns evolving over time".

Both the governance of and by expectations have a geographical dimension when the expectations of actors become associated with certain places or regions, e.g., actors need to agree about the question where development should take place. In this regard, future-making also includes the development of "spatial imaginaries" (Chateau et al., 2021) as outcomes of the governance of expectations. Spatial imaginaries assign certain qualities or challenges to places, as the terms "green hydrogen valley"[2] or "rust belt" exemplify. Once actors associate qualities or challenges with certain places, spatial imaginaries become part of the governance by expectations and can, for example, have an impact on investment decisions.

2.2. Binding decisions and governance instruments in green-hydrogen future-making

We argue that the governance of future-making moves towards path creation when enough actors make binding decisions, because they increase the likelihood of associated expectations becoming reality (Konrad et al., 2016; Konrad & Palavicino, 2017). Decisions are binding when alternatives are costly for the decision maker and other actors involved in the governance of future-making. Binding decisions can become costly financially, such as when sunk costs occur. The costs can also be political, for instance when publicly proclaimed goals and targets need to be fulfilled to avoid loss of reputation due to failed expectations (Bakker & Budde, 2012). Moreover, expectations become increasingly realistic once they are integrated into institutions, such as spatial development plans or subsidy schemes (Konrad & Palavicino, 2017). The more expectations are institutionalized, gain collective acceptance and credibility, the more they bind actors, create a governance by expectations, and, eventually, the creation of a new path becomes realistic

[2] Hydrogen valleys are envisaged to "include a complete hydrogen ecosystem – a micrography of the hydrogen-economy vision; ranging from renewable energy and hydrogen production to hydrogen transportation and enduse" (Bampaou & Panopoulos, 2025, p. 2).

(Konrad et al., 2016; van Merkerk & van Lente, 2008).

Binding decisions can be made by buyers and suppliers, infrastructure developers, financiers, domestic and foreign government entities, financial institutions and international organizations. To further examine the bindingness of decisions, as well as to understand the associated interplay between governance of and by expectations and its impact on path creation, we scrutinize different governance instruments of future-making. As citizens and civil-society often lack the agency and capacity to imagine desirable hydrogen futures as well as the implications of large-scale energy projects (Crootof et al., 2021; Eltham et al., 2008), our overview focuses on governance instruments employed by state and market actors and whether they represent more or less binding decisions (Table 1).

Important governance instruments employed by state actors to support the realization of green-hydrogen futures are roadmaps, requests for proposals, subsidy schemes and public contracts with investors as well as supportive legislation, spatial development plans and zoning (Cidell, 2011). Roadmaps as governance instruments with a low(er) bindingness are policy documents, often developed top-down, that outline a desired future development path and its benefits, and often include spatial imaginaries in the form of annotated maps (cp. Fig. 1). They intend to inform, and gain support from, the public, raise the interest of market actors and include suggestions for future action (McDowall, 2012; McDowall & Eames, 2006). In contrast, requests for (investment) proposals and, as more binding governance instruments, subsidy schemes and development funds directly address market actors, especially firms and innovative entrepreneurs. Legal institutions (incl. legislation, contracts and zoning) are among the most binding governance instruments of future-making. Especially contracts over subsidies or investment, when fulfilled, actually turn possibilities into final investment decisions and thus matters of fact.

In addition to state actors, expectations can also be expressed by business and other market actors, using additional governance instruments, such as market forecasts, business plans, technology projections (Thompson & Byrne, 2022), scientific prediction and forecasting methods (Knappe et al., 2019), environmental and social impact assessments (Strömmer & Ormiston, 2022), newspaper articles, feasibility and engineering studies, or in public and stakeholder participation, such as workshops, and group discussions (Bal et al., 2021; Stemerding et al., 2019). Some of these instruments have or gain more authority than others, and, hence can shape expectations and resulting governance structures (Hielscher & Kivimaa, 2019). For example, market forecasts, business models, technology and scientific projections are important bases for, and governance instruments of, business and eventually investment decisions. Public and stakeholder participation processes, e.g., in environmental and social impact assessments, give voice and, if mandatory, power to citizens and civil society, thus integrating them into the governance of future-making.

2.3. Path creation and the role of expectations and context

Future-making offers a perspective on how expectations, visions, or imaginaries are not only constructed, but also put into practice, thereby – potentially – leading to the creation of new development paths. In comparison, path creation refers to "the emergence of new development trajectories in a region based upon the growth of new industrial sectors or new products, techniques and forms of organisation" (MacKinnon et al., 2019, p. 3). Green-hydrogen production and associated green industrialization are prime examples of path creation, because the green-hydrogen industry represents an industry that is new to the world, as reflected in its miniscule contribution to global hydrogen production (Njøs et al., 2024).

While path dependency and windows of locational opportunity are important concepts in the literature on path creation and development (Hassink et al. 2019), the role of visions and expectations of the future has only recently been introduced by Steen and Hansen (2018; also see Steen 2016). They argue that shared expectations and visions create legitimacy and can be "generative" as they can attract stakeholders "to a new path" and motivate them to invest in it (Steen, 2016, p. 1611). Furthermore, Steen emphasizes that the "particularities of new paths will … be context specific" (2016, p. 1608) and discusses the dynamics between path creation and established paths. While "old paths may provide assets and resources relevant to different paths" (2016, p. 1608), their institutions and incumbent actors can also constrain path creation. Context thus refers to the "legacy of actions undertaken in the past" (R. Martin & Sunley, 2006, p. 403), and to the organizational and institutional environment of places (Steen, 2016).

Contexts, like the organization of the state or existing industrial assets, are often place-specific and shape local development (R. Martin, 2010). However, as Hassink et al. (2019) argue, research on path dependencies often over-emphasizes local endogenous sources of development, while it plays down influences on local development originating from larger scales, such as demand at the national or international scale (H. Martin et al., 2019). To develop a more comprehensive understanding, they argue for a multi-scalar view of path development, highlighting specifically "(1) non-local flows of knowledge and other assets; and (2) the impact of national and supranational institutional environments" (Hassink et al. 2019, 1639). Scale and scalar relations are particularly relevant for the emerging international green-hydrogen economy in the Global South, since green-hydrogen imaginaries often express hope for regional development based on foreign direct investment (Dorn, 2024).

Building on these ideas and findings, we argue that understanding the governance of green-hydrogen future-making and associated path creation requires sensitivity to economic and political context. A distinction can be made between contexts where green-hydrogen activities can build on existing institutional structures and industries (like in South Africa) and contexts where this is not the case (like in Namibia). With respect to the first, "historically grown structural preconditions produce probabilities for certain future paths" (Grillitsch & Sotarauta, 2020, p. 705), whereas "peripheral areas find fewer opportunities for diversification or the creation of completely new growth paths" and "[u]nrelated diversification is less likely but may have a greater transformative power" (Grillitsch & Sotarauta, 2020, p. 705). Against this background, we explore and compare the governance and governance instruments of green-hydrogen future-making in Namibia and

Table 1
Important governance instruments of green-hydrogen future-making by their bindingness and (mostly) involved actors *Own compilation.*

Actor Bindingness	Market actors	State actors
Low	Market forecast; Technology projection	Request for proposals; Roadmap; Spatial imaginary
Medium	Business plan; Engineering study	Subsidy scheme; Development Fund; Spatial development plan
High	Investment decision	Legislation; Public contract with investor (e.g. over subsidies, investment); Zoning regulation

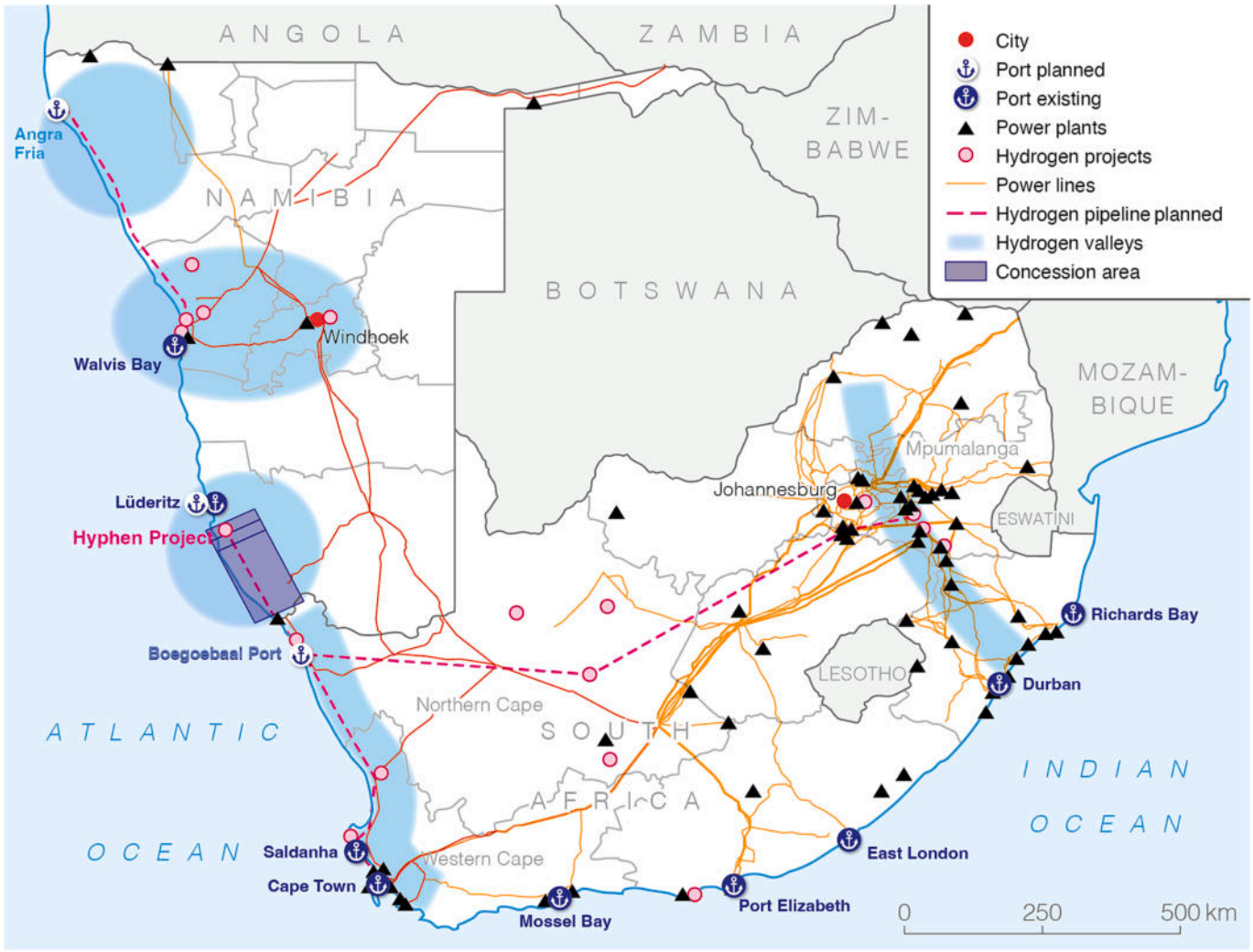

Fig. 1. Map of Namibia and South Africa with locations of envisioned and planned green-hydrogen projects and valleys Own design based on policy documents and web research (Design: Martin Gref and Irene Johannsen). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

South Africa, and how they are related to each other. More specifically, we analyze whether governance of and by green-hydrogen expectations has led to binding decisions and thus new path creation in the two countries.

3. Research context and methodology

Our empirical focus lies on Namibia and South Africa, two neighboring countries in the Global South. Both countries, especially at their Atlantic coasts, have a high natural potential for renewable-electricity generation at their Atlantic coast (IEA, 2019) and have engaged in developing green-hydrogen projects with the aim to export green hydrogen to the EU. We chose the two countries following a diverse-case comparison approach (Seawright & Gerring, 2008), particularly to understand how different political and economic contexts influence future-making. Compared to South Africa with around 60 million inhabitants on 1,200,000 km^2, Namibia has a small population (2.5 million) but large area (820,000 km^2), resulting in one of the lowest population densities worldwide (Worldbank, 2024). Whereas South Africa has a diversified economy with a comparatively strong industrial sector, Namibia's economy is dominated by mining, agricultural and tourism activities, but both countries have well-developed financial sectors. While South Africa has a multi-tiered political system with strong provinces and large cities as economic centers beside the industrial and political heartland around Johannesburg and Pretoria, political and economic power in Namibia is concentrated in the capital. At the same time, both have a colonial history and shared legacy of apartheid, and are upper middle-income countries characterized by large socioeconomic disparities and high unemployment rates, especially among young people.

Regarding hydrogen activities, South Africa has a much longer history than Namibia. South Africa started to engage with hydrogen technologies, particularly synthetic fuels, to enable the production of fuels from coal instead of oil already during Apartheid, to gain independence from oil imports.[3] More recently, both the national and provincial governments support green-hydrogen projects all over the country with various initiatives, policies and partnerships (Table 2, Fig. 1).

By contrast, Namibia's engagement with hydrogen began only in 2019/2020 and mainly focuses on green-hydrogen production and export thus far (Table 2). To this end, the government issued a request for project proposals in 2021, to develop a large-scale export-oriented green-hydrogen flagship project in the South, near the town of Lüderitz, which has been awarded to the German-British Hyphen consortium

[3] Synthetic Fuels have very similar technical properties as fossil fuels and, hence, can substitute fossil fuels in conventional applications such as automobiles with internal combustion engines or airplanes.

Table 2
Timeline/History of (not only green) hydrogen institutions in South Africa and Namibia Sources: Referenced articles, policy documents and web research.

	South Africa	Namibia
2007	**Hydrogen South Africa** (HySA), a technology innovation program – extended for 10 years in 2021 (Bessarabov et al., 2017)	
2013	Energy partnership with Germany	
2020		President appointed **special advisor for green hydrogen**
2021	Department of Science and Innovation (DSI) publishes first version of **Hydrogen Society Roadmap (HSRM)**, following extensive stakeholder consultations led by KPMG (Department of Science and Innovation, 2021a); DSI and partners launch **Hydrogen Valley Feasibility Study Report** (Department of Science and Innovation, 2021b); **International Just Energy Transition Partnership** with France, Germany, UK, US and EU (Vanheukelom, 2023); **Northern Cape Province** launches its Green Hydrogen Strategy (NCEDA, 2021)	Launch of **Inter-Ministerial Green Hydrogen Council (GHC)** (GH2 Organisation, 2023); Request for project proposals to develop large-scale green-hydrogen project near Lüderitz (NIPDB, 2021); University of Namibia establishes **Green Hydrogen Research Institute** (Kangootui, 2021)
2022	Department of Trade, Industry and Competition releases **Green Hydrogen Commercialisation Strategy for South Africa** for public comment (Department of Trade, Industry and Competition, 2022); National government starts to subsidize transformation of coal power plants into hydrogen power plants; **MoU between Northern and Western Cape Province** to develop a hydrogen corridor (Smith, 2022); 20 hydrogen projects are awarded **Strategic Integrated Projects status** (Planning instrument to prioritize projects; according to Infrastructure Development Act) (Department of Public Works and Infrastructure, 2022)	**Hydrogen Partnership** with Germany at COP 27: GHC launched its **Green Hydrogen and Derivatives Strategy**, sponsored by the German government (Ministry of Mines and Energy of Namibia, 2022); Launch of **SDG Namibia One sovereign wealth fund** (Climate Fund Managers, 2022)
2023	Launch of SA-H2 Fund with Danish and Dutch support (DBSA, 2023)	**Feasibility and Implementation Agreement (FIA)** for Hyphen project; Special Advisor (see 2020) promoted to **Green Hydrogen Commissioner** with his own office of experts, the Implementation Authority Office (Hyphen & Government of Namibia, 2023)
2024	Strategic Environmental Assessment for Boegoebaai Project started (CSIR, 2024); First green-hydrogen projects receive environmental authorization (Alesbury, 2024; Enertrag, 2024)	National government starts advocacy initiatives to increase public awareness of green hydrogen's benefits; Feasibility Study Namibia-South Africa Pipeline underway (Namibia Green Hydrogen Programme Office, 2024)
2027 (planned)	Boegoebaai project production start (PRDW, 2022)	Hyphen project production start (Hyphen & Government of Namibia, 2023)

(Kalvelage & Walker, 2024).

We collected data about the context of, and activities in, the green-hydrogen industry in South Africa and Namibia through explorative web research, (online) participant observation of industry conferences, and analyses of political documents. To study the governance of future-making, we employed additional methods. After mapping important actors and institutions (Table 2), we conducted interviews with these actors and other stakeholders in Namibia and South Africa between February and April 2023. In total, we conducted 43 semi-structured interviews with stakeholders from government agencies, both national (I_gov-nat) and local (I_gov-loc), financiers (I_finance), consultants and other companies (I_comp-cons), business associations (I_bus-ass), civil-society organisations and NGOs (I_cso-ngo), and researchers (I_research) in Namibia (29) and South Africa (14). The data collection approach also included site visits along the West Coast of South Africa and Namibia, where the largest green-hydrogen projects of South Africa and Namibia are being planned, and in the South African region Mpumalanga, the industrial heartland of South Africa, where demand for grey hydrogen is currently concentrated. In addition, we participated in a German business-delegation trip to Johannesburg and Windhoek organised by the Economic Development Agency of the German state of Brandenburg.

To enhance the reliability and validity of our findings, we employed both data and methodological triangulation (Flick, 2017). For data triangulation, we interviewed a diverse range of stakeholders, representing various positions and perspectives within the field, to get a comprehensive view. We increased reliability by using semi-structured interviews and repeating key questions across different stakeholders to identify consistencies and discrepancies in their responses. Additionally, we validated the information obtained by cross-referencing data across multiple data sources (websites, interviews, grey literature), ensuring congruence and reinforcing the robustness of our results.

Reflecting on our positionality as German researchers within the hydrogen sector in general, as well as the post-colonial context of Namibia, in particular, we are aware that Germany – or rather parts of German industry – could potentially benefit from the development of export-oriented green-hydrogen projects in the Global South. However, we are sceptical about the feasibility of export-oriented green-hydrogen projects and believe that due to the high transport costs, the local (industrial) use of renewable energy (and potentially also) green hydrogen should be prioritized (Samadi et al., 2023). Despite our scepticism, our positionality facilitated access to key stakeholders, particularly German stakeholders. We hope that the empirical insights we derived from these stakeholders can provide the basis for further deliberation about the desirability of developing export-oriented green-hydrogen projects and associated governance structures that can ensure the sustainability of the industry.

4. Green-hydrogen future-making in Namibia

The following three sections focus on future-making in Namibia. First, we describe the associated visions and strategies (4.1). Then we analyze which actors within the country (4.2) and internationally (4.3) have agency in green-hydrogen future-making.

4.1. On the path towards green industrialization: Visions and strategies

In Namibia, the national government views green hydrogen as a "strategic bet" (I_gov-nat) to help diversify the economy and initiate the "desperately needed … economic recovery", especially because the government "can't see that coming from any other industry at this point" (I_bus-ass). It is "definitely high up [on the] government agenda" (I_bus-ass) as it seems to promise new jobs, income from abroad, electricity for the domestic market, as well as, in the longer run, (green) industrialization.

Geographically, the Namibian national government envisions three "potential hydrogen valleys" with complementary projects and infrastructure (Fig. 1; Ministry of Mines and Energy of Namibia, 2022).

However, although several small projects are being developed across the country, governance of future-making focuses on the large-scale, export-oriented green-hydrogen project Hyphen, which is under development in the Southern Corridor Development Initiative (SCDI), the southernmost hydrogen valley.

The Hyphen project is portrayed as an "amazing experiment" (I_gov-nat), which is expected to create 15,000 direct jobs during the first four years of construction and further 3,000 permanent jobs, with 90 % to be filled by Namibians (Hyphen, 2023). Due to its size (estimated investment of 13 billion US$), the project is expected to transform the Namibian economy. It is to be realized in the first two of several concession zones of the SCDI (Fig. 1). The SCDI spatial imaginary refers to an area which ranges from Lüderitz to the South African Border and could host up to 10 projects the size of Hyphen. The Hyphen project should comprise of wind and solar energy plants (5 GW in total), seawater desalination facilities, a green-hydrogen (3 GW) and an ammonia production plant as well as a port designated for the export of the green-hydrogen derivative ammonia and other commodities. These include agricultural products, which the town council envisions will be produced from excess water supplied by the desalination facilities (I_gov-loc).

The national government has created a dedicated governance structure for the project, consisting of various working groups that coordinate expectations and address different challenges from regulation to infrastructure and urban development, the latter involving also local government actors. Representatives of Namibia's national government are particularly active in promoting Hyphen and have high hopes for the "secondary and tertiary effects of this industry" and associated path creation "from the primary sector driven economy to secondary […] sector driven economy" (I_gov-nat).

While the current focus of green-hydrogen future-making in Namibia lies on the Hyphen project, the inclusion of (already existing) local businesses is deemed difficult due to the thin industrial base (I_bus-ass; Scholvin and Kalvelage, 2025). Nonetheless, innovative industrial activities based on green hydrogen are already envisioned or even implemented in some of the smaller projects, which provide more suitable opportunities for bottom-up initiative. These pilot projects include the production of food and fertilizer (Daures Green Hydrogen, 2023), green fuels for trucks and locomotives (CMB, 2023), green iron (HyIron, 2023), power generation (HDF Energy, 2023), and a hydrogen refueling station (Cleanergy Solutions, 2023).

4.2. Key role and (pro-)active engagement of national government

In Namibia, green hydrogen governance is mostly driven by the national government. This encompasses, first and foremost, Namibia's Green Hydrogen Commissioner, his Office and the Inter-Ministerial Green Hydrogen Council consisting of high-ranking representatives from several ministries and other important organizations (Central Bank, National Planning Commission). The Commissioner, together with his Office, has been marketing Namibia as a suitable location for FDI in the green-hydrogen industry. At the same time, his office is tasked with identifying and addressing regulatory hurdles and gaps to enable green-hydrogen projects legislatively, and governing the expectations of different stakeholders related to Namibia's green-hydrogen industry.

While large parts of the Namibian business sector so far lack agency in green-hydrogen future-making due to missing experiences and expertise, Namibia's financial sector is actively involved in putting green-hydrogen expectations into matters of fact. It is motivated and supported by the Namibian state which wants to create domestic investment opportunities in green hydrogen for Namibian investors, especially for its well-developed, but small financial industry, including the Government Institutions Pension Fund (The Brief, 2023b). Moreover, the Environmental Investment Fund (EIF) of Namibia, together with (development) finance partners from the Netherlands and the US, has launched the SDG Namibia One Sovereign Wealth Fund, which raises capital from domestic and international sources to finance green-hydrogen projects across the country (EIF, 2023).

Due to a centralized government structure that is dominated by the independence party SWAPO, the local level lacks agency and barely takes part in the governance of expectations. At the time of the interview, several members of Lüderitz' town council, a town of about 15,000 inhabitants, saw the Hyphen project as an economic opportunity, especially for jobs (I_gov-loc). Nonetheless, concerns regarding environmental, social and urban-development challenges were raised, especially the necessary expansion of housing and infrastructures to cater for an influx of more than 10,000 workers during construction. Although stakeholder engagement workshops in the region are well documented, our interviewees in Lüderitz, who participated in the workshops, stated that they feel not fully and/or timely informed, and that decisions are taken in Windhoek, i.e., in a "top-down approach" (I_gov-loc, I_bus-ass). Overall, the interviewed town council members were in cautious support of the project, but their reported lack of information reflects their difficulties of imagining the future of the region and shows limited opportunities to participate proactively in its making.

However, at least two Namibian civil-society organizations are more sceptical. The Institute of Public Policy Research has criticized the transparency of the request for proposal process, highlighting the risk that the hydrogen industry furthers corruption in Namibia (IPPR, 2022). Responding to these criticisms, the Namibian government published additional information about the tender process (The Presidency of Namibia, 2022). Moreover, Hyphen and the Namibian government even agreed on explicit anti-corruption measures, and Hyphen's CEO declared that if corruption cases become public, they would stop the project (Donald, 2024). Hence, civil-society organizations provoke reactions and thus participate in the governance by expectations.

Furthermore, the Namibian Chamber of the Environment has raised concerns over the development of the Hyphen project in a national park (NCE, 2024). The Tsau Khaeb national park was established under the South African Apartheid regime to protect an industrial diamond mining site. Today, it is a category II area according to the International Union for Conservation of Nature and Natural Resources (IUCN). At the international level, the development of green-hydrogen projects in such protected areas is contentious, while national environmental groups are more concerned with protesting the emergence of a fossil-fuel industry, after considerable reserves have been found along the coast of Namibia (I_cso-ngo). Land in the park is state-owned, but given Namibia's colonial history and related unresolved issues of land redistribution, local stakeholders have expressed land claims and fear potential impacts of the green-hydrogen project on the site of a former German concentration camp (Angula, 2024; Forensic Architecture, 2024).

The role of the local level and civil society will increase once the Hyphen project applies for environmental approval. As part of Namibia's environmental and planning regulations, the Hyphen Consortium is obliged to conduct environmental and social impact assessments (ESIAs) at multiple stages of project implementation, which include various forms of engaging local stakeholders (SLR Consulting, 2022, 2024). The extent to which the ESIA process – which has not started yet – will be governed by the negative expectations and concerns voiced by civil society and local actors will provide insights into the agency of these actors in the governance of future-making. So far, both environmental and local groups have only started to take part in the governance of expectations.

4.3. Dependence on international demand, technology and capital

Green-hydrogen future-making in Namibia was originally initiated around 2019/2020 by Fortescue Future Industries (FFI), a green-hydrogen company which proposed the Namibian government to develop the first (export-oriented) green-hydrogen project in Namibia (I-gov-nat). Inspired by this proposal, Namibia's government began to engage in the governance of expectations. It signed a hydrogen

partnership with Germany in 2022 and, with support of the German government, developed its hydrogen strategy (Table 2). Since Namibia's main focus is currently on the expected green-hydrogen demand in Europe and East Asia, the progress of green-hydrogen projects depends on reliable offtake agreements – and, thus, on international actors' expectations that imports from Namibia will be cost-efficient and reliable. So far, Hyphen has secured memorandums of understandings for offtake agreements with German, South Korean and Japanese energy multinationals RWE, Approtium and ITOCHU respectively, which, however, are not binding.

Namibia also requires capital as well as technology expertise and skills from abroad to develop green-hydrogen projects, which makes the country even more dependent on international support.

> "The skill set needed, I think, they're going to be so vast, it's going to feel to be a little bit like Dubai and Qatar. Namibia will not be able to fill that […] with just the Namibians. So … we are going to have to import skills from somewhere." (I_gov-nat)

Considering these various needs, the Hyphen project consortium represents itself as a suitable investor because it brings both technological know-how (by the German renewable energy company Enertrag) and capital (by the British holding, investment and project development company Nicholas Holdings). This is complemented by various types of support by Germany's government (Kalvelage & Walker, 2024), which not only sponsored the development of Namibia's Green Hydrogen Strategy and four of the five smaller green-hydrogen projects mentioned above, but also finances an urban development plan for the city of Lüderitz (German Embassy Windhoek, 2023).

Overall, the Green Hydrogen Commissioner is optimistic that green-hydrogen projects will develop in ways which benefit both Namibia and international actors, also beyond Germany. With this message, the Namibian government actively approaches potential foreign investors and supporting governments, in particular at the Conference of the Parties (COP), the annual meeting of the decision-making body of the UN Convention on Climate Change (Table 2). The Green Hydrogen Commissioner explicitly highlights the importance of COPs for advertising and financing Namibia's green-hydrogen activities:

> "You have to use COP well, you have to use it very, very strategically. […] You might use COP to showcase an opportunity in progress and use that presence to raise awareness and raise funding for a project. […] So COP […] is massively important […]. I mean, today I'm already developing a strategy for COP 28 that involves the showcasing of a green industrialization agenda in an emerging market." (I_gov-nat)

5. Green-hydrogen future-making in South Africa

The following three sections focus on future-making in South Africa. First, we describe what kind of path development actors envision (5.1). Then we analyze which actors within the country (5.2) and internationally (5.3) have agency in green-hydrogen future-making.

5.1. On the path towards a net-zero carbon economy and green (re)industrialization: Visions and strategies

Visions and strategies around green industrial development in South Africa build on the existing industrial context and regard green hydrogen as a "game changer […] to move towards a net-zero carbon economy" (Department of Science and Innovation, 2021a, p. 13). The geography of South Africa's green-hydrogen vision and strategy comprises of two hydrogen valleys or corridors and numerous projects of different types, such as green-hydrogen production for domestic use and export, technology innovation and manufacturing, as well as the greening of existing industries. In addition to revaluating existing places and industries, for example, through green-steel production in the mothballed (2020) steel plant in Saldanha, the South African government and various multinationals, like Sasol, imagine the industrialization of new places and regions, such as the Port Nolloth municipality and the Northern Province.

Close to Port Nolloth and the Namibian border, the Boegoebaai special economic zone is planned to become the largest domestic green-hydrogen export hub, including large facilities for renewable-energy (10 GW) and green-hydrogen production (5 GW) as well as a new port. This greenfield development would constitute the northern end of an emerging corridor across the West Coast reaching from Cape Town over Saldanha to the Namibian border, as envisioned by the Northern and Western Cape province governments (NCEDA, 2023). Another green-hydrogen valley, essentially a logistics corridor with hydrogen fueling stations for heavy-duty trucks, is planned from the mining regions (Limpopo, Mpumalanga) through the industrial heartland around Johannesburg, to Durban and Richards Bay (Fig. 1).

5.2. Heterogeneous domestic actor constellations with a strong role of industrial players and state actors at various levels

In contrast to Namibia, key drivers of the green-hydrogen industry in South Africa are not only state actors, but also established industry multinationals. For example, mining multinational Anglo American and the national government hope that hydrogen technologies, like certain types of electrolyzers and fuel cells, will provide demand for platinum-group metals, of which South Africa has 80 percent of worldwide reserves. Against this background, South Africa created a research and development program for hydrogen technologies in 2007 (Bessarabov et al., 2017) and aims to become not only a green-hydrogen producer and exporter, but also a technology and green-industry leader.

The government and South Africa's multinationals want to leverage their existing knowledge and assets to enter future-oriented markets. In addition, the multinationals are governed by the expectation that they will experience competitive disadvantages in export markets, such as the European, if they do not reduce the carbon footprint of their products (see 5.3). Moreover, beyond these multinationals, a myriad of small and medium-sized enterprises develop green-hydrogen projects in South Africa. There are several independent project developers with professional backgrounds in the energy and chemical industry, who hope to sell their projects to investors eventually (I_pro-dev). As a result, both large and small green-hydrogen projects exist across the country and range from technology development and manufacturing, to (planned) green-hydrogen production, transport and use in various industries. The South African national government has engaged in the governance of expectations of these project developers by designating 20 large-scale, mostly export-oriented hydrogen projects as Strategic Integrated Projects (SIPs). Their planning permits are being prioritized and can be accelerated by the administration (Department of Public Works and Infrastructure, 2022), but the national government has not chosen which of the projects should be developed first:

> "There actually is no clear path as to which projects should be invested in. I think every project is listed on the SIP list […] There is literally no clear pipeline. And that is why the risks are still too high at this point in time." (I_finance)

The missing prioritization of projects by the government is one of the key problems holding back the South African green-hydrogen industry (I_finance). It is a result of competing interests and different visions of a desirable future within the government, which are described in greater detail in Kalt et al. (2023). In short, the coal industry, one of the most labor-intensive and well-unionized sectors in the country, is not interested in advancing the energy transition. Fractions of the ruling party ANC and the government are close to these unions and the coal sector, and have blocked advancements of renewable energies successfully in the past years. To appease this political fraction, the national government of South Africa started to subsidize the transformation of coal

power plants into hydrogen power plants in 2022 (FuelCellsWorks, 2022). Thereby, it hopes to foster legitimacy and public support. Moreover, the presidency tries to circumvent these blockades by coordinating the national hydrogen industry itself, rather than leaving it to the Ministry of Mineral Resources and Energy, which is (too) closely aligned with the coal industry. Instead, a green-hydrogen working group in the Investment and Infrastructure Office of South Africa's presidency reports directly to the president. Whether this governance structure will be able to coordinate the positive and negative expectations of different political fractions in regard to the green-hydrogen industry is controversial:

> "I am cautiously optimistic that we will have a transition, but it will be very bumpy. I think the export part could drive some things because it doesn't take away anything from South Africans. The domestic part will be tough given that our industry is so fragile that we cannot punish it with taxes." (I_comp-cons)

To make matters more complex, provincial governments pursue their own green-hydrogen strategies. This includes the Northern and Western Cape Provinces along the West Coast but also other provinces with coast lines and/or favorable conditions for renewable-electricity generation or existing industrial assets.

Local communities and civil-society organizations in South Africa have mixed experiences with the South African energy transition and the associated spatial planning regulation (McEwan, 2017), and have started to protest against the development of hydrogen projects (Kalt et al., 2023). Local discontent exists, for example, about South Africa's largest green-hydrogen project, the Boegoebaai project, as it is located in an area of spiritual importance to the local community. Furthermore, local fishermen fear that the industrial scale of the project and the port development will ruin their livelihoods (I_research). They express their fears in social and environmental impact assessments as well as public consultations but the national government tries to govern these negative expectations by sending supporters to public hearings which express positive expectations (Nzo & Mahabir, 2023).

As is the case in Namibia, water supply is currently not highlighted as a concern by (local) stakeholders but regarded as an opportunity, as the projects could over-size desalination and water treatment plants to provide water to local communities (Roos & Wright, 2021). Projects across the South African shoreline plan to use desalinated seawater and inland projects a combination of wastewater and freshwater from underground aquifers (I_comp-cons). However, the phase-out of South Africa's fossil-fuel industry would decrease water use more than the envisaged green-hydrogen economy would require (I_gov-nat, for cross-validation see: Beswick et al., 2021).

5.3. *Importance of international climate policies and EU markets for green products*

International interest in South Africa's energy politics is particularly high because South Africa's economy is powered by coal, which is why the country has higher CO_2 emissions per capita than Germany or China (Ritchie et al. 2023). As an important step to curb those emissions and result of its agency, the South African national government has signed a Just Energy Transition Partnership (JET-P) with France, Germany, the United Kingdom and the United States of America, along with the European Union in 2021. Through the partnership, the Global North countries want to support South Africa by financing energy-transition projects. In total, the partners want to provide 8.5 billion US$ to South Africa, parts of which should be used to develop green-hydrogen projects (Department of Trade, Industry and Competition, 2022). Denmark and the Netherlands want to provide another billion US$ (Energy&Capital, 2023).

The EU's legal definition of what it considers to be "green" hydrogen also constitutes another binding legislative governance instrument, since it defines what can be exported to the EU as green hydrogen and receive EU subsidies. In particular, the EU only considers hydrogen as green if it is produced from additionally installed renewable-energy facilities and does not increase transmission-grid shortages (Walker & Klagge, 2024). Therefore, developers of export-oriented green-hydrogen projects plan new purpose-built renewable-energy installations for their projects and will not use electricity from the national grid (I_comp-cons). This aspect is particularly important in the South African context, since the energy transition there has been challenged by electricity shortages and transmission-grid bottlenecks (IEA, 2023a; Kalt et al., 2023). Hence, although the projects will not exacerbate electricity shortages, they will neither contribute substantially to advancing electricity transitions in South Africa or Namibia, except for feeding excess electricity into the grid and possibly serving local communities.

Furthermore, the European Union does not only provide funding for green-hydrogen projects in South Africa, but also regulatory incentives for the export of climate-neutral goods to the European market. The EU will introduce the Carbon Border Adjustment Mechanism (CBAM) in 2026, which will require importers to pay a carbon tax equal to the difference between the European carbon price and the carbon price that is charged in the country from which the commodity originates. Currently, around seven percent of South African exports would have to pay the carbon tax. In the 2030s, the tax could eventually concern around 19 percent of all South African exports, particularly primary resources and basic materials like iron, steel and aluminum (Monaisa & Maimele, 2023). Expectations about the implications of the CBAM on the South African economy differ, but it is clear that local use of green hydrogen can help to mitigate its effects on exports from South Africa and also from Namibia, whose main exports to the EU – minerals and fish – are not yet included in the CBAM (The Brief, 2023a).

> "When the EU first announced the CBAM, the BRICS countries issued a statement expressing their concern, where I thought, South Africa made a mistake to join that statement because China and Russia have a lot more to lose than we have. We have an opportunity to decarbonize and actually charge a premium on our steel." (I_comp-cons)

6. Governance of future-making – comparative analysis

Both Namibia and South Africa are eager to develop their green-hydrogen activities into viable business cases and thereby create new industrial paths to tackle problems like high (youth) unemployment, lacking economic development in peripheral regions, as well as meeting energy- and climate-policy goals. Thus, their visions and strategies are similar and include, for example, the development of spatial imaginaries such as "green hydrogen valleys" and support for large-scale export projects. However, there are significant differences in the associated governance of green-hydrogen future-making (Table 3). To understand these differences, we first analyze how they can be explained by different industrial and political contexts (6.1), then we look at how the bindingness of governance instruments of green-hydrogen future-making in both countries is increasing in different ways (6.2), and lastly explore the roles of international actors in green-hydrogen future-making and path creation as well as cooperation within Southern Africa (6.3).

6.1. *The role of industrial and political contexts*

Despite its thin industrial base, the Namibian government aims to make Namibia a "green hydrogen superpower". The future-making focus lies on one large export-oriented flagship project (Hyphen), while several smaller pilot projects receive lesser attention. The strong role of national government actors and the resulting top-down governance, together with the focus on a single project, have enabled the Namibian government to move fast from the governance of expectations to the governance by the expectation that the Hyphen project will be realized. Therefore, Namibia will possibly benefit from first-mover advantages,

Table 3
Governance of green-hydrogen future-making and the role of context conditions: South Africa & Namibia compared (Own compilation).

	South Africa	Namibia
Visions and strategies	**Hydrogen regarded a "game changer"** towards net-zero carbon economy, with focus on energy transition & green (re-) industrialization, plus green-hydrogen export; Many & different types of projects all over the country plus two valleys: West Coast Corridor & Hydrogen Valley	"**Green hydrogen superpower**" with focus on export first, and green industrialization later; Three green-hydrogen valleys with smaller projects plus the Hyphen flagship project in the "Southern Corridor Development Initiative" (SCDI) valley
Governance	**Distributed governance** involving industrial players and state actors at different levels Ambiguous support by national government due to strong coal sector, strong support by provincial governments and some multinationals; Emerging governance of & by expectations: Diversified project pipeline	**Top-down (national-state) governance** aiming at fast realization in cooperation with international partners; Strong commitment by national state; Strong governance of & by expectations: First-mover advantages
Beneficial context conditions	Domestic industrial and mining firms; existing hydrogen market; Technology expertise and skills; Broad international support for country's climate policies	State-ownership of SCDI land; Centralized political system
Challenges and risks	Complex governance structure; Competing interests & conflicts at national state level > Missing prioritization of projects	Offtake agreements & Financing; Technological expertise and skills > Dependency on international partners & dominance of one large-scale project
	Especially with respect to large-scale greenfield projects: Development of required infrastructures, environmental issues and (local) acceptance	

while competition in the Global South to supply the Global North hydrogen demand is already rampant (Collins, 2022).

> "I think Namibia has got a[n] … advantage around getting things off the ground quicker. So … we've got fewer people in the room to make decisions, versus South Africa with its complexities and as well as their energy crisis… Their … priority around … green hydrogen is probably different from Namibia. But again, it's a race currently. Everyone is in a race to be the pioneer." (I_bus-ass)

South Africa features very different context conditions with its diversified industrial base and existing hydrogen expertise, the dominant role of coal in its energy system and economy, as well as its much larger size and more complex political structure. In contrast to Namibia, there are many more projects in development, and overall actor constellations are much more diversified. The governance of green-hydrogen future-making can be characterized as distributed and involving both industrial players and state actors at different levels, reflecting the greater governance capacities to imagine and make green-hydrogen futures. However, competing interests and conflicts around the future role of the coal industry result in an unresolved governance of expectations at the national level, so that regional governments and the private sector have become important drivers of South Africa's green-hydrogen future-making.

6.2. Towards green-hydrogen path creation: From roadmaps and strategies to increasingly binding governance instruments

Hydrogen roadmaps and strategies constitute central governance instruments for green-hydrogen future-making. Both the Namibian and the South African government have developed several such documents (Table 2). They derive their argumentative authority about the feasibility of green-hydrogen futures from numerous techno-economic studies about the competitiveness of green-hydrogen production in the two countries (Roos & Wright, 2021; Sasscal, 2023).

Expectations about developing green-hydrogen value chains in South Africa are reflected in increasingly binding governance instruments. Whereas the initial Hydrogen Society Roadmap (2021) was still characterized by an innovation perspective, the following Hydrogen Commercialisation Strategy (2022) offers much more concrete commitments by the national government to support the industry. In addition, the South African governance of expectations is increasingly associated with an emerging governance by expectations, as the government and leading private actors agree on focusing efforts on certain strategic projects, which then receive prioritization in the planning process (see 5.2).

In Namibia, the government's focus on one project closely links governance of and by expectations. The request for project proposals (NIPDB, 2021) strengthened the national government's bargaining position and allowed to compare the expectations of different developers. The selection of the Hyphen consortium demonstrates the commitment of the national government to this project and has effectively bound the government to support its realization. The binding relationship between the government and the project developer is reflected in a Feasibility and Implementation Agreement, a contract that assigns mutual responsibilities including ambitious local-content targets (Hyphen & Government of Namibia, 2023).

However, in both countries, the current governance of future-making still focuses on the planning of green-hydrogen projects. While there are binding governance instruments for spatial planning, such as the concession area in Namibia or the SIPs in South Africa, subsidy and especially final investment decisions are still pending. Only when project developers are further advanced in project development, data about the costs of green-hydrogen production will become more reliable. Expected costs and the economic viability of green-hydrogen projects will then govern the willingness of investors, potential offtakers and subsidy providers to make binding decisions, which arguably constitute the main challenge regarding the materialization of the projects. Given that export-oriented green-hydrogen projects will serve foreign markets and the fiscal constraints of the South African and Namibian government, it is unlikely that the two states will be willing and able to subsidize export-oriented green-hydrogen projects (Scholvin et al., 2025). At the same time, the hydrogen ambitions of countries such as Germany increasingly face financing challenges as well (EWI, 2024). Nonetheless, there are various actors involved in pushing positive expectations and thus the governance of expectations, in order to facilitate project development and investment, thereby fostering a governance by expectations. Whether these future-making activities will lead to the realization of projects, is still an open question.

6.3. The roles of international actors and cooperation within Southern Africa

International actors exhibit considerable agency in both Namibia's and South Africa's green-hydrogen future-making. South Africa benefits from a clear commitment to support its energy transition by various international partners. Furthermore, its diversified industry and export structure cushion it against becoming too dependent on single projects and the export of green hydrogen. As a longstanding and important industrial partner of especially European countries and the EU, power relations are less asymmetric than in Namibia. As could be expected, international industry actors, technology and capital providers play a

larger role in the more peripheral context of Namibia, have become important actors in the governance of and by expectations, and will ultimately take the decisive binding investment decisions – or not:

> "You can just see the German industry moving hand in hand to derisk the [Hyphen] project and then the Namibians need to realize that that's a huge opportunity for us and figuring out how do we fit in." (I_gov-nat)

While Namibia's focus on the Hyphen project and German partners might seem to lead to dependencies, this government strategy also helps to avoid a situation in which several projects compete, and investors or off-takers can play them off against each other. There are already ambitions and activities to diversify green-hydrogen export well beyond Germany by working with the Netherlands, Spain, at EU Commission level and also by pursuing partnerships with Japan, South Korea and the US (I_gov-nat). Last but not least, South Africa is also regarded as a potential partner and a bilaterial governance of expectations is emerging between the two countries:

> "What I like right now is that there are discussions between the two countries around complementing one another." (I_bus-ass)

In the long run, Namibia "aspires to establish an integrated, thriving green ecosystem across Southern Africa by creating synergies in shared infrastructure, manufacturing collaboration and power exports, e.g., with South Africa, Botswana, Zambia and Angola" (Ministry of Mines and Energy of Namibia, 2022, p. 7). With a similar goal, the South African government and Sasol plan the development of hydrogen pipelines to create new infrastructural links throughout South Africa as well as with neighboring countries, particularly Namibia, to enable closer economic integration among countries and regions. This integration provides a common vision for the Namibian and South African governments, as well as private companies with a huge energy demand, like Sasol, to develop a common market and, thus, jointly advance path creation towards a new green-hydrogen economy. The idea is to use South Africa's hydrogen demand in its industrial heartland as an offtake opportunity for hydrogen produced in the Northern Cape Province and Southern Namibia, thereby also making Namibia more independent from European export markets (I_gov-nat).

7. Conclusion and Outlook

While the green-hydrogen sector has received increasing attention in social science research (Kalt et al., 2023; Scholvin, 2023; Scholvin & Kalvelage, 2025; Tunn et al., 2024), most articles focus on the sector's potential development impacts instead of scrutinizing whether and how the governance of future-making is progressing towards path creation eventually. Addressing this question is particularly important against the background of the growing implementation gap between announcements of green-hydrogen projects and investment decisions (Odenweller & Ueckerdt, 2025). Therefore, we suggest the "governance of future-making" approach, which relates future-making actors and governance instruments with the dynamics between governance of and by expectations. Building on Konrad and colleagues, we posit that the governance of expectations and the governance by expectations shape actors' strategies and institutions, "a dynamic which leads to governance patterns evolving over time" (Konrad et al., 2016; Konrad and Palavicino, 2017, p. 189).

Based on this conceptual approach, we argue, first, that understanding the development from future-making towards path creation requires attention to different governance instruments and their bindingness, which increases from, e.g., roadmaps and spatial imaginaries to subsidy schemes and, finally, contracts and investment decisions. Second, following the literature on path creation (Hassink et al., 2019; Steen, 2016), we argue that the governance of future-making as well as associated expectations are contingent upon industrial and political context conditions. Dependent on these contexts, various actors, unevenly equipped with agency, govern expectations across scales.

To illustrate our arguments, we analyze and compare the governance of green-hydrogen future-making in Namibia and South Africa. We found a top-down governance of green-hydrogen future-making dominated by dedicated national-state actors in Namibia, with the potential to achieve first-mover advantages in cooperation with international partners. By contrast, South Africa has a much more distributed governance structure involving industrial players and state actors at different levels, in which national state support is hampered by competing interests and different visions of desirable futures within the government. Moreover, our analysis shows that green-hydrogen future-making and the associated governance structures in South Africa and Namibia are contingent upon pre-existing economic and political contexts, especially the (non–)existing industrial base and the different political structures. Furthermore, international support for the making of green-hydrogen futures exists in both countries for different reasons, namely the Namibian government's strong support for the green-hydrogen industry, particularly the Hyphen project, and South Africa's large carbon footprint and diversified industrial base.

Focusing on the bindingness of governance instruments and the distinction between governance of and by expectations was helpful to understand how governance of green-hydrogen future-making in Namibia and South Africa has been developing over time and is moving towards path creation. The governance of expectations in the two countries increasingly coalesces around a number of strategic projects in South Africa and one project in Namibia, respectively. Thereby, the governance of expectations has been complemented by a more binding governance by expectations, as different actors, particularly national governments, project developers and, in South Africa, industrial firms, have started to enter into contractual relationships. While, with respect to large-scale green-hydrogen production, the Hyphen project in Namibia is most advanced, neither the private sector nor international actors have made major binding decisions yet. This reflects not only the prolonged timelines of the very capital-intensive and new-to-the-world green-hydrogen industry, but also the complex dynamics between governance of and by expectations in a new industry, where reliable conventions are still missing, and various interests and expectations are to be coordinated.

Our research reports from an ongoing process, as the governance of green-hydrogen future-making is just unfolding and path creation still only an expectation. More research is required, especially on the international implications as well as on the integration of local and civil-society actors. Regarding international relations, the negative expectation of green extractivism and the reproduction of neocolonial patters (Kalt et al., 2023) is part of the governance of expectations already. In our interviews South African and especially Namibian actors were aware of the associated risks of becoming dependent on (demand from) the Global North, but, so far, actively manage their international relationships in self-confident ways (also see Kalvelage and Walker, 2024; Scholvin and Kalvelage, 2025). For example, there are discussions about future cooperation, e.g., through pipelines between the two countries, but also with other African countries in the Africa Green Hydrogen Alliance (UNFCC, 2022). In this regard it is an open question whether such cooperation could help to reduce competition and forestall being played out against each other by international investors and off-takers in the Global North (Claar, 2022; Kalt et al., 2023). On the other side of the coin, expectations about green industrialization in the Global South need to be linked with discussions and expectations about deindustrialization in Germany and other countries with insufficient renewable-energy sources (Samadi et al. 2023; Verpoort et al. 2024). Future research should further engage with the governance of such contradictory and conflictive green-hydrogen futures in different contexts and how they relate to each other.

Lastly and importantly, the novelty of green hydrogen, lack of (e.g. technical) knowledge and power dynamics across scales seem to put local and civil-society actors at the receiving end of green-hydrogen

future-making, although criticism and even protest, especially against large-scale greenfield projects, already exist in both countries (Kalt et al., 2023; Tunn et al., 2024). They therefore tend to be less influential in the envisioning and planning of green-hydrogen projects and thus in the (early) governance of expectations. However, the capacities of civil-society actors and local governments to engage with green-hydrogen futures and to develop their own visions of desirable futures are likely to increase over time, as knowledge about the industry diffuses and first projects are realized. Moreover, as project developers advance their plans, they will be required to undergo environmental and social impact assessments, in which local actors and civil-society actors will have the opportunity to voice their expectations and take a more active role in the governance by expectations. As a result, power asymmetries in future-making between project developers and national governments, on the one hand, and civil-society organizations and local governments, on the other hand, are likely to change over time and might decrease as green-hydrogen futures materialize.

Against this background, long-term research is needed on how power imbalances in the governance of future-making evolve, as stakeholders beyond national governments and industry actors gather knowledge, develop future-making capacities and demand participation, potentially even interrupting project implementation and operation. Therefore, instead of rushing from governance of expectations to governance by expectations, national governments and international investors should be encouraged to support local as well as civil-society stakeholders in developing capacities to engage with green-hydrogen futures and thus become part of the governance of expectations from early-on. From an academic perspective, we should also critically reflect on our own role in the governance of expectations and thus future-making. With its current focus on the assessment of the potential developmental impacts of green-hydrogen projects, the social science literature assumes that these projects will be built and thus tends to reproduce the green-hydrogen hype. We recommend that future studies further conceptualize the transition from the governance of future-making to path creation, for example, by focusing on the transformation of built environments in anticipation of project realization, e.g. through establishing supporting infrastructures that change environments and livelihoods even without projects being realized (cf. Greiner & Klagge, 2024; Njøs et al., 2024).

CRediT authorship contribution statement

Britta Klagge: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Funding acquisition, Conceptualization. **Benedikt Walker:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Linus Kalvelage:** Writing – review & editing, Methodology, Investigation. **Clemens Greiner:** Writing – review & editing, Investigation, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank our interviewees for sharing their knowledge and experiences with us. Furthermore, we are grateful to two reviewers for their detailed and constructive comments and suggestions, which helped to improve the paper. We also thank Martin Gref and Irene Johannsen for production of the map. This research as well as funding for Open Access was supported by the German Research Foundation (DFG) through funding for the projects "Energy futures" and "Futures in Chains" as part of the Collaborative Research Center "Future Rural Africa" (Project-ID 328966760—TRR 228/2).

Data availability

The data that has been used is confidential.

References

Alesbury, J., 2024. Hive Hydrogen South Africa confirms 1230MW Crossroads Green Energy Solar Project Development to Power Coega Green Ammonia. Hive Energy. https://www.hiveenergy.co.uk/2024/05/22/hive-hydrogen-south-africa-confirms-1230mw-crossroads-green-energy-solar-project-development-to-power-coega-green-ammonia/.

Angula, V., 2024. Namibia's Nama community rejects green-hydrogen port expansion. Voice of America. https://www.voanews.com/a/namibia-s-nama-community-rejects-green-hydrogen-port-expansion-/7574111.html.

Bakker, S., Budde, B., 2012. Technological hype and disappointment: Lessons from the hydrogen and fuel cell case. *Tech. Anal. Strat. Manag.* 24 (6), 549–563. https://doi.org/10.1080/09537325.2012.693662.

Bal, A., Afacan, K., Clardy, T., Cakir, H.I., 2021. Inclusive future making: building a culturally responsive behavioral support system at an urban middle school with local stakeholders. *Cogn. Instr.* 39 (3), 275–305. https://doi.org/10.1080/07370008.2021.1891070.

Bampaou, M., Panopoulos, K.D., 2025. An overview of hydrogen valleys: current status, challenges and their role in increased renewable energy penetration. *Renew. Sustain. Energy Rev.* 207, 114923. https://doi.org/10.1016/j.rser.2024.114923.

Benner, M., 2024. An ideational turn in economic geography? *Progress in Economic Geography* 2 (1), 100014. https://doi.org/10.1016/j.peg.2024.100014.

Bessarabov, D., Human, G., Kruger, A.J., Chiuta, S., Modisha, P.M., du Preez, S.P., Oelofse, S.P., Vincent, I., Van Der Merwe, J., Langmi, H.W., Ren, J., Musyoka, N.M., 2017. South African hydrogen infrastructure (HySA infrastructure) for fuel cells and energy storage: Overview of a projects portfolio. *Int. J. Hydrogen Energy* 42 (19), 13568–13588. https://doi.org/10.1016/j.ijhydene.2016.12.140.

Beswick, R.R., Oliveira, A.M., Yan, Y., 2021. Does the green hydrogen economy have a water problem? *ACS Energy Lett.* 6 (9), 3167–3169. https://doi.org/10.1021/acsenergylett.1c01375.

Bunnell, T., Gillen, J., Ho, E.-L.-E., 2018. The prospect of elsewhere: engaging the future through aspirations in Asia. *Ann. Am. Assoc. Geogr.* 108 (1), 35–51. https://doi.org/10.1080/24694452.2017.1336424.

Chateau, Z., Devine-Wright, P., Wills, J., 2021. Integrating sociotechnical and spatial imaginaries in researching energy futures. *Energy Res. Soc. Sci.* 80, 102207. https://doi.org/10.1016/j.erss.2021.102207.

Cidell, J., 2011. Distribution centers among the rooftops: the global logistics network meets the suburban spatial imaginary. *Int. J. Urban Reg. Res.* 35 (4), 832–851. https://doi.org/10.1111/j.1468-2427.2010.00973.x.

Claar, S., 2022. Green colonialism in the European Green Deal: Continuities of dependency and the relationship of forces between Europe and Africa. Culture, Practice & Europeanization 7 (2), 262–274. https://doi.org/10.5771/2566-7742-2022-2-262.

Cleanergy Solutions, 2023. *Cleanergy Solutions Namibia*. https://www.cleanergynamibia.com/.

Climate Fund Managers, 2022. Launch Of The New 'SDG Namibia One Fund' At Cop27 Targets The Development Of A Green Hydrogen Economy In Namibia – Climate Fund Managers. https://climatefundmanagers.com/2022/11/09/launch-of-the-new-sdg-namibia-one-fund-at-cop27-targets-the-development-of-a-green-hydrogen-economy-in-namibia/.

CMB, 2023. CMB.TECH Hydrogen Demonstration Hub Namibia. CMB.TECH. https://cmb.tech/business-units/h2-infra/hydrogen-demonstration-hub-namibia.

Collins, L., 2022, December 6. *"Tough competition ahead" | Global demand for hydrogen imports set to be three times lower than export supply by 2030: BNEF | Hydrogen news and intelligence*. Hydrogen News and Intelligence | Hydrogen Insight. https://www.hydrogeninsight.com/production/tough-competition-ahead-global-demand-for-hydrogen-imports-set-to-be-three-times-lower-than-export-supply-by-2030-bnef/2-1-1367057.

Crootof, A., Shrestha, R., Albrecht, T., Ptak, T., Scott, C.A., 2021. Sacrificing the local to support the national: Politics, sustainability, and governance in Nepal's hydropower paradox. *Energy Res. Soc. Sci.* 80, 102206. https://doi.org/10.1016/j.erss.2021.102206.

CSIR, 2024. CSIR conducts environmental assessment for proposed green hydrogen hub | CSIR. https://www.csir.co.za/csir-conducts-environmental-assessment-proposed-green-hydrogen-hub.

Daures Green Hydrogen, 2023. Home. Daures Green Hydrogen. https://daures.green/.

DBSA, 2023. Unveiling the 'SA-H2 Fund': South Africa's Dedicated Green Hydrogen Fund | Development Bank of Southern Africa. https://www.dbsa.org/press-releases/unveiling-sa-h2-fund-south-africas-dedicated-green-hydrogen-fund.

Department of Public Works and Infrastructure, 2022. Strategic Integrated Projects (Government Notices 47658). https://www.gov.za/sites/default/files/gcis_document/202212/47658gon2835.pdf.

Department of Science and Innovation, 2021a. Hydrogen Society Roadmap for South Africa 2021. https://www.dst.gov.za/images/South_African_Hydrogen_Society_RoadmapV1.pdf.

Department of Science and Innovation, 2021b. South Africa Hydrogen Valley Final Report. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf.

Department of Trade, Industry and Competition, 2022. Green Hydrogen Commercialisation Strategy for South Africa [Final report released for public

comment]. http://www.thedtic.gov.za/wp-content/uploads/Full-Report-Green-Hydrogen-Commercialisation-Strategy.pdf.
Donald, M., 2024. Hyphen boss warns against corruption in green hydrogen projects. The Namibian. https://www.namibian.com.na/hyphen-boss-warns-against-corruption-in-green-hydrogen-projects/.
Dorn, F.M., 2024. Towards a multi-color hydrogen production network? Competing imaginaries of development in northern Patagonia, Argentina. Energy Res. Soc. Sci. 110, 103457. https://doi.org/10.1016/j.erss.2024.103457.
Eaton, W.M., Gasteyer, S.P., Busch, L., 2014. Bioenergy futures: framing sociotechnical imaginaries in local places. *Rural. Sociol.* 79 (2), 227–256. https://doi.org/10.1111/ruso.12027.
Eicke, L., De Blasio, N., 2022. Green hydrogen value chains in the industrial sector—geopolitical and market implications. *Energy Res. Soc. Sci.* 93, 102847. https://doi.org/10.1016/j.erss.2022.102847.
EIF, 2023. SDG Namibia One Press Release 20 June 2023. https://www.eif.org.na/post/sdg-namibia-one-press-release-20-june-2023.
Eltham, D.C., Harrison, G.P., Allen, S.J., 2008. Change in public attitudes towards a Cornish wind farm: Implications for planning. *Energy Policy* 36 (1), 23–33. https://doi.org/10.1016/j.enpol.2007.09.010.
Energy&Capital, 2023. South Africa Signs Pact for $1 B Green Hydrogen Fund with Denmark and the Netherlands [2023]. https://energycapitalpower.com/south-africa-signs-pact-for-1-b-green-hydrogen-fund-with-denmark-and-the-netherlands/.
Enertrag, 2024. Resources. https://enertrag.com/global/enertrag-south-africa/resources.
Engelmann, T., Rohrmeier, R., 2022. Green hydrogen opportunities for (impact) investors. In Green H2 investments from buzz to Boom (pp. 42–48). KGAL. https://www.kgal.de/fileadmin/9.5_Downloads/KGAL_Whitepaper_Green_Hydrogen_EN_18-09-2022.pdf.
EWI, 2024. The financing gap in the hydrogen market ramp-up: Analysis of demand and price scenarios. https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2024/10/241004_Financing_Gap_Endbericht.pdf.
Flick, U., 2017. Triangulation in der qualitativen Forschung. In: Flick, U., von Kardorff, E., Steinke, I. (Eds.), Qualitative Forschung: Ein Handbuch (12. Auflage, Originalausgabe, pp. 309–318). Rowohlt Taschenbuch Verlag.
Forensic Architecture, 2024. Shark Island. An Architectural Reconstruction of a Death Camp. https://content.forensic-architecture.org/wp-content/uploads/2024/04/Shark-Island-Report.pdf.
FuelCellsWorks, 2022. South Africa: HDF Energy Awarded Coal Region Leases To Deploy Its Renewstable(R) Hydrogen-Based Long-Term Storage Power Plants. https://fuelcellsworks.com/news/south-africa-hdf-energy-awarded-coal-region-leases-to-deploy-its-renewstabler-hydrogen-based-long-term-storage-power-plants/.
Gabor, D., Sylla, N.S., 2023. Derisking developmentalism: a tale of green hydrogen. Dev. Chang. 54 (5), 1169–1196. https://doi.org/10.1111/dech.12779.
Gasparatos, A., von Maltitz, G.P., Johnson, F.X., Lee, L., Mathai, M., Puppim de Oliveira, J.A., Willis, K.J., 2015. Biofuels in sub-Sahara Africa: drivers, impacts and priority policy areas. *Renew. Sustain. Energy Rev.* 45, 879–901. https://doi.org/10.1016/j.rser.2015.02.006.
German Embassy Windhoek, 2023. Germany supports Namibia in urban planning in the area of green hydrogen production. https://windhuk.diplo.de/na-en/-/2602390.
GH2 Organisation, 2023. Namibia. http://gh2.org/countries/namibia.
Gong, H., 2024. Futures should matter (more): toward a forward-looking perspective in economic geography. *Prog. Hum. Geogr.* 03091325231224434. https://doi.org/10.1177/03091325231224434.
Greiner, C., Klagge, B., 2024. The temporalities and externalities of ancillary infrastructure in large-scale renewable energy projects: insights from the rural periphery. *Energy Policy* 193, 114303. https://doi.org/10.1016/j.enpol.2024.114303.
Grillitsch, M., Sotarauta, M., 2020. Trinity of change agency, regional development paths and opportunity spaces. *Prog. Hum. Geogr.* 44 (4), 704–723. https://doi.org/10.1177/0309132519853870.
Hassink, R., Isaksen, A., Trippl, M., 2019. Towards a comprehensive understanding of new regional industrial path development. *Reg. Stud.* 53 (11), 1636–1645. https://doi.org/10.1080/00343404.2019.1566704.
HDF Energy, 2023. RSWK | RENEWSTABLE SWAKOPMUND. Namibia. https://www.renewstable-swakopmund.com.
Hielscher, S., Kivimaa, P., 2019. Governance through expectations: examining the long-term policy relevance of smart meters in the United Kingdom. *Futures* 109, 153–169. https://doi.org/10.1016/j.futures.2018.06.016.
HyIron, 2023, April 11. Home DE - Green iron—Zero emissions | HyIron. https://hyiron.com/de/startseite/.
Hyphen, 2023. Projects—Hyphen Hydrogen Energy. https://hyphenafrica.com/projects/.
Hyphen, & Government of Namibia, 2023. Feasibility and Implementation Agreement. https://hyphenafrica.com/wp-content/uploads/2023/05/Hyphen-Hydrogen-Energy-FIA-Infographic-03.pdf.
IEA, 2019. The Future of Hydrogen. https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf.
IEA, 2023a. Electricity Grids and Secure Energy Transitions – Analysis. IEA. https://www.iea.org/reports/electricity-grids-and-secure-energy-transitions.
IEA, 2023b. Executive summary – Global Hydrogen Review 2023 – Analysis. IEA. https://www.iea.org/reports/global-hydrogen-review-2023/executive-summary.
IPPR, 2022. Procurement Tracker Namibia. https://ippr.org.na/wp-content/uploads/2022/04/PTN16-web-2.pdf.
IRENA, 2020. Green Hydrogen Cost Reduction. https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Green_hydrogen_cost_2020.pdf.
Kalt, T., Simon, J., Tunn, J., Hennig, J., 2023. Between green extractivism and energy justice: competing strategies in South Africa's hydrogen transition in the context of climate crisis. *Rev. Afr. Polit. Econ.* 1–20. https://doi.org/10.1080/03056244.2023.2260206.
Kalvelage, L., Walker, B., 2024. Strategic coupling beyond borders: Germany's extraterritorial agency in Namibia's green hydrogen industry. *J. Econ. Geogr.* lbae036. https://doi.org/10.1093/jeg/lbae036.
Kangootui, M.-R., 2021. UNAM leads the establishment of Namibia's Green Hydrogen Research Institute – UNAM Forum Online. https://forumonline.unam.edu.na/unam-leads-the-establishment-of-namibias-green-hydrogen-research-institute/.
Knappe, H., Holfelder, A.-K., Löw Beer, D., Nanz, P., 2019. The politics of making and unmaking (sustainable) futures: introduction to the special feature. *Sustain. Sci.* 14 (4), 891–898. https://doi.org/10.1007/s11625-019-00704-w.
Konrad, K., Lente, H. van, Groves, C., Selin, C., 2016. Performing and Governing the Future in Science and Technology. In: Felt, U., Fouche, R., Miller, C.A., Smith-Doerr, L. (Eds.), The Handbook of Science and Technology Studies, Fourth Edition (pp. 465–493). MIT Press.
Konrad, K., Palavicino, C.A., 2017. Evolving Patterns of Governance of and by, Expectations: The Graphene Hype Wave. In: Bowman, D.M., Stokes, E., Rip, A. (Eds.), *Embedding New Technologies into Society*. Jenny Stanford Publishing, pp. 187–218.
Longhurst, N., Chilvers, J., 2019. Mapping diverse visions of energy transitions: co-producing sociotechnical imaginaries. *Sustain. Sci.* 14 (4), 973–990. https://doi.org/10.1007/s11625-019-00702-y.
MacKinnon, D., Dawley, S., Pike, A., Cumbers, A., 2019. Rethinking path creation: a geographical political economy approach. *Econ. Geogr* 95 (2), 113–135. https://doi.org/10.1080/00130095.2018.1498294.
Martin, H., Martin, R., Zukauskaite, E., 2019. The multiple roles of demand in new regional industrial path development: a conceptual analysis. *Environ. Plann. A: Econ. Space* 51 (8), 1741–1757. https://doi.org/10.1177/0308518X19863438.
Martin, R., 2010. Roepke lecture in economic geography—rethinking regional path dependence: beyond lock-in to evolution. *Econ. Geogr* 86 (1), 1–27. https://doi.org/10.1111/j.1944-8287.2009.01056.x.
Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. *J. Econ. Geogr.* 6 (4), 395–437. https://doi.org/10.1093/jeg/lbl012.
McDowall, W., 2012. Technology roadmaps for transition management: the case of hydrogen energy. *Technol. Forecast. Soc. Chang.* 79 (3), 530–542. https://doi.org/10.1016/j.techfore.2011.10.002.
McDowall, W., Eames, M., 2006. Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: a review of the hydrogen futures literature. *Energy Policy* 34 (11), 1236–1250. https://doi.org/10.1016/j.enpol.2005.12.006.
McEwan, C., 2017. Spatial processes and politics of renewable energy transition: Land, zones and frictions in South Africa. *Polit. Geogr.* 56, 1–12. https://doi.org/10.1016/j.polgeo.2016.10.001.
Ministry of Mines and Energy of Namibia, 2022. Green Hydrogen and Derivatives Strategy. https://gh2namibia.com/wp-content/uploads/2022/11/Namibia-GH2-Strategy-Rev2.pdf.
Mlilo, M., Bollig, M., Revilla Diez, J., 2024. Nation-state influence on tourism path creation in Southern Africa. *Reg. Stud., Online First* 1–16. https://doi.org/10.1080/00343404.2024.2393685.
Monaisa, L., Maimele, S., 2023. The European Union's Carbon Border Adjustment Mechanism and implications for South African exports [Policy Brief]. TIPS. https://www.tips.org.za/policy-briefs/item/download/2346_8d222d7082d759e04a49a49ea3ff171c.
Müller-Mahn, D., 2020. Envisioning African Futures: Development corridors as dreamscapes of modernity. *Geoforum* 115, 156–159. https://doi.org/10.1016/j.geoforum.2019.05.027.
Namibia Green Hydrogen Programme Office, 2024. Traction II. Namibia's Green Hydrogen Overview and Report 2024. https://gh2namibia.com/wp-content/uploads/2024/12/Traction-2.pdf.
NCE, 2024. When green hydrogen turns red—Threatening a global biodiversity hotspot. Namibian Chamber of Environment. https://n-c-e.org/wp-content/uploads/Green-hydrogen-Tsau-Khaeb-National-Park-NCE-Position-Paper.pdf.
NCEDA, 2021. Northern Cape Green Hydrogen Strategy. https://onedrive.live.com/?authkey=%21ADemf9Sm3qWNYms&id=90FC3A032E485CC8%2130674&cid=90FC3A032E485CC8&parId=root&parQt=sharedby&o=OneUp.
NCEDA, 2023. NCGH2. NCEDA - Empowering The Green Transformation. https://www.ncgh2.co.za/.
NIPDB, 2021. Southern Corridor Development Initiative (SCDI). Market Sounding for Request for Proposals. https://gh2namibia.com/gh2_file_uploads/2022/09/GHN-RFP-rev-2.pdf.
Njøs, R., Sjøtun, S.G., Jakobsen, S.-E., Fløysand, A., 2024. (Re)Incorporating "the Tangible" in Industrial Path Development Analyses: The Role of Sociomaterial Contingencies in Explaining Potential Emergence of Hydrogen Production in Western Norway. *Econ. Geogr* 1–22. https://doi.org/10.1080/00130095.2024.2389858.
Nzo, T., Mahabir, J., 2023. Inclusive and decentralized renewable energy development. PARI. https://pari.org.za/wp-content/uploads/2024/01/Green_Hydrogen-v3.pdf.
Odenweller, A., Ueckerdt, F., 2025. The green hydrogen ambition and implementation gap. *Nat. Energy* 1–14. https://doi.org/10.1038/s41560-024-01684-7.
Ponte, S., 2014. The evolutionary dynamics of biofuel value chains: from unipolar and government-driven to multipolar governance. *Environ. Plann. A: Econ. Space* 46 (2), 353–372. https://doi.org/10.1068/a46112.
Ponte, S., Birch, K., 2014. Guest editorial. *Environ. Plann. A: Econ. Space* 46 (2), 271–279. https://doi.org/10.1068/a46296.

PRDW, 2022. Boegoebaai Port Project: Business Case Preliminary Results. https://www.etenders.gov.za/home/Download/?blobName=5f516016-1a04-44c4-a16d-a82db7147200.pdf&downloadedFileName=Annexure%20S-%20Boegoebaai%20Business%20Case%20Validation.pdf.

Purwins, S., 2022. "Come what may, we bring those resources to play": Narratives, future-making, and the case of bauxite extraction at Atewa Forest. Ghana. *Area* 54 (2), 233–241. https://doi.org/10.1111/area.12765.

Ritchie, H., Roser, M., Rosado, P., 2023. CO_2 and Greenhouse Gas Emissions. Our World in Data. https://ourworldindata.org/co2/country/south-africa.

Roos, T., Wright, J., 2021. Powerfuels and Green Hydrogen (public version). https://www.euchamber.co.za/wp-content/uploads/2021/02/Powerfuels-Final-Report-South-Africa-EU-SA_Partners-for-Growth-Final-28-Jan-2021..pdf.

Samadi, S., Fischer, A., Lechtenböhmer, S., 2023. The renewables pull effect: how regional differences in renewable energy costs could influence where industrial production is located in the future. *Energy Res. Soc. Sci.* 104, 103257. https://doi.org/10.1016/j.erss.2023.103257.

Sasscal, 2023. H2 Atlas Africa. https://africa.h2atlas.de/sadc.

Schneider, C., Lösch, A., 2019. Visions in assemblages: Future-making and governance in FabLabs. *Futures* 109, 203–212. https://doi.org/10.1016/j.futures.2018.08.003.

Scholvin, S., 2023. Green hydrogen and linkage-based development in Antofagasta, Chile. *Local Economy* 38 (5), 506–517. https://doi.org/10.1177/02690942241230450.

Scholvin, S., Black, A., Robbins, G., 2025. De-risking green hydrogen? Insights from Chile and South Africa. *Energy Policy* 198, 114485. https://doi.org/10.1016/j.enpol.2024.114485.

Scholvin, S., Kalvelage, L., 2025. New development paths through green hydrogen? An ex-ante assessment of structure and agency in Chile and Namibia. *Energy Res. Soc. Sci.* 120, 103904. https://doi.org/10.1016/j.erss.2024.103904.

Schwabe, J., 2024. Regime-driven niches and institutional entrepreneurs: adding hydrogen to regional energy systems in Germany. *Energy Res. Soc. Sci.* 108, 103357. https://doi.org/10.1016/j.erss.2023.103357.

Seawright, J., Gerring, J., 2008. Case Selection techniques in case study research: a menu of qualitative and quantitative options. *Polit. Res. Q.* 61 (2), 294–308. https://doi.org/10.1177/1065912907313077.

SLR Consulting, 2022. *Environmental and Social Screening Study*. https://cdn.slrconsulting.com/uploads/2022-05/Hyphen_E%26S%20Screening_BID_10052022.pdf.

SLR Consulting, 2024. *Local and International NGO Meeting: BIODIVERSITY*. https://cdn.sanity.io/files/b0ecix6u/production/a3077d98339006956c6e1b0b85b772706962a4d6.pdf.

Smith, T., 2022, November 29. Creating a green hydrogen corridor in Northern and Western Cape. ESI-Africa.Com. https://www.esi-africa.com/business-and-markets/green-hydrogen-corridor-for-economic-growth-in-northern-and-western-cape/.

Steen, M., 2016. Reconsidering path creation in economic geography: Aspects of agency, temporality and methods. *Eur. Plan. Stud.* 24 (9), 1605–1622. https://doi.org/10.1080/09654313.2016.1204427.

Steen, M., Hansen, G.H., 2018. Barriers to Path Creation: The Case of Offshore Wind Power in Norway. *Econ. Geogr* 94 (2), 188–210. https://doi.org/10.1080/00130095.2017.1416953.

Stemerding, D., Betten, W., Rerimassie, V., Robaey, Z., Kupper, F., 2019. Future making and responsible governance of innovation in synthetic biology. *Futures* 109, 213–226. https://doi.org/10.1016/j.futures.2018.11.005.

Strömmer, K., Ormiston, J., 2022. Forward-looking impact assessment – an interdisciplinary systematic review and research agenda. *J. Clean. Prod.* 377, 134322. https://doi.org/10.1016/j.jclepro.2022.134322.

The Brief, 2023a. *EU's carbon tax threatens Namibia's N$19bn exports—Business Financial Website*. https://archive.thebrief.com.na/index.php/news/item/3502-eu-s-carbon-tax-threatens-namibia-s-n-19bn-exports.

The Brief, 2023b. *GIPF targets oil and green hydrogen industries—Business Financial Website*. https://thebrief.com.na/2023/05/gipf-targets-oil-and-green-hydrogen-industries/.

The Presidency of Namibia, 2022. Traction. Namibia's Green Hydrogen Overview. https://gh2namibia.com/wp-content/uploads/2022/09/Traction-Namibias-Green-Hydrogen-Overview.pdf.

Thompson, N.A., Byrne, O., 2022. Imagining futures: theorizing the practical knowledge of future-making. *Organ. Stud.* 43 (2), 247–268. https://doi.org/10.1177/01708406211053222.

Tunn, J., Kalt, T., Müller, F., Simon, J., Hennig, J., Ituen, I., Glatzer, N., 2024. Green hydrogen transitions deepen socioecological risks and extractivist patterns: Evidence from 28 prospective exporting countries in the Global South. *Energy Res. Soc. Sci.* 117, 103731. https://doi.org/10.1016/j.erss.2024.103731.

UNFCC, 2022. Africa Green Hydrogen Alliance. Climate Champions. https://climatechampions.unfccc.int/africa-green-hydrogen-alliance/.

van de Graaf, T., Overland, I., Scholten, D., Westphal, K., 2020. The new oil? The geopolitics and international governance of hydrogen. *Energy Res. Soc. Sci.* 70, 101667. https://doi.org/10.1016/j.erss.2020.101667.

van Merkerk, R.O., van Lente, H., 2008. Asymmetric positioning and emerging paths. *Futures* 40 (7), 643–652. https://doi.org/10.1016/j.futures.2007.12.007.

Vanheukelom, J., 2023. Two years into South Africa's Just Energy Transition Partnership: How real is the deal? ECDPM. https://ecdpm.org/work/two-years-south-africas-just-energy-transition-partnership-how-real-deal.

Verpoort, P.C., Gast, L., Hofmann, A., Ueckerdt, F., 2024. Impact of global heterogeneity of renewable energy supply on heavy industrial production and green value chains. *Nat. Energy* 1–13. https://doi.org/10.1038/s41560-024-01492-z.

Walker, B., Klagge, B., 2024. Infrastructure bottlenecks as opportunity for local development: the case of decentralized green-hydrogen projects. *Tijdschrift Voor Economische En Sociale Geografie* 115 (5), 643–659. https://doi.org/10.1111/tesg.12633.

Worldbank, 2024. World Bank Open Data. World Bank Open Data. https://data.worldbank.org.