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Green Hydrogen as a Driver of Development? De-Risking and Production Linkages with New Value Chains in South Africa and Chile

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Abstract

Green hydrogen may play a major role in the global energy transition. It moreover offers prospects for industrial development in Southern nations that benefit from natural conditions favourable for the required energy inputs from solar and wind power. Yet, green hydrogen projects need to be de-risked to overcome industry-specific uncertainties and challenges from which the Global South suffers. Focussing on South Africa and Chile, the working paper discusses corresponding policies and assesses the potential for latecomer industrialisation through production linkages. It is shown that costly means of de-risking have, so far, been largely avoided by the two countries, which is particularly sensible because the future development effects of green hydrogen projects remain unclear. Whilst it remains to be seen whether South Africa and Chile will suffer from the pitfalls of de-risking strategies, the authors nevertheless warn against being overly optimistic with regard to the prospects for latecomer industrialisation through participation in global value chains of green hydrogen.

Keywords: Chile, derisking, hydrogen, industrialization, linkage, South Africa

JEL Codes: O54, G18, Q41, O14, O55

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1. Introduction

The prospects of increased production and use of green hydrogen as an energy source are enjoying high levels of global attention. European countries are planning a continent-wide network of 53,000 kilometres of pipelines, the so-called hydrogen backbone, to establish a competitive market for the continent.[1] The first shipments of ammonia, produced with green hydrogen, arrived in Japan in early 2023, with imports projected to reach 3 million tonnes a year by 2030 as part of efforts to decarbonise the energy sector (Reuters, 2023). In the United States, the Inflation Reduction Act has provided for tax incentives for raising domestic production of green hydrogen.

Alongside this, many countries in the Global South have initiated processes to support the production and/or use of green hydrogen (Cordonnier & Saygin, 2022; UNCTAD, 2023). Altogether, the Hydrogen Council, which is an association of large corporations, has listed 1,400 projects worldwide and investments of USD 320 billion through 2030.[2]

The rapid growth of financing and plans for green hydrogen projects, in a context of rising concerns about the inadequacy of climate change mitigation, brings with it considerable pressure for pro-active policies, whether they be in terms of global compacts, regional agreements or national and subnational initiatives. It has been widely argued that action must be taken both in the hotspots of projected consumption in the Global North and also at potentially competitive production sites across the Global South so as to turn green hydrogen into a driver of green industrialisation (Lema & Rabellotti, 2023; World Bank, 2020).

As explained in detail further below, green hydrogen production in Southern nations depends on 'de-risking' – that is, policies to overcome investment uncertainties from which the industry suffers. De-risking implies an expansive role for the state to mobilise private capital for development purposes. In turn, the state can pursue an ambitious agenda of structural transformation within global value chains (GVCs), as Schindler et al. (2023) point out. Unlike Gabor (2021) and Gabor and Sylla (2020, 2023), who maintain that de-risking inevitably leads to poor outcomes for developing countries, we argue that sensible de-risking is promotive of industrialisation. However, not every investment project or business sector must be de-risked. Corresponding decisions need to take the costs of de-risking and potential benefits in terms of industrialisation into consideration.

Because green hydrogen production requires the splitting of water into hydrogen and oxygen through electrolysis, a process that consumes vast amounts of energy, countries with a strong and competitively priced renewable energy potential feature heavily in many proposed and actual schemes. Chile, Colombia, Morocco, Namibia and South Africa are amongst those identified for rapid progress of green hydrogen production (Cordonnier & Saygin, 2022).

This paper deals with two of these countries, South Africa and Chile. In 2021, the Hive Energy Group from the United Kingdom announced plans to develop five large-scale green hydrogen and green ammonia plants in South Africa for export to mainly European markets.[3] South Africa's largest chemicals company, Sasol, is exploring green hydrogen projects at their plants in the country's economic heartland and at the Boegoebaai site in the sparsely populated

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[1] For more information, see: https://ehb.eu.

[2] For more information, see: https://hydrogencouncil.com/en/hydrogen-insights-2023.

[3] For more information, see: https://www.hiveenergy.co.uk/clean-futures/green-ammonia.

Northern Cape province (Engineering News, 2023a; Mining Weekly, 2022a). The same year, Chile's most impressive green hydrogen project was announced. It is being developed in the Magallanes region in the extreme south of the country and aims at becoming the world's largest producer of e-fuels.[4] In the north, the region of Antofagasta plays an important role, first of all because the local mining sector seeks to reduce its carbon footprint by switching to green hydrogen (La Tercera, 2021a, 2021b).

Against the backdrop of de-risking and the concept of linkage-based development, the paper explores the prospects and challenges of South Africa and Chile being able to support their industrialisation through the green hydrogen sector. It addresses the following questions: Firstly, how can South Africa and Chile link with green hydrogen GVCs; and secondly, will the new sector contribute to economic development?

The paper is guided by the conviction that new development paths or, in other words, windows of opportunity not only depend on economic and natural conditions. They are also shaped by policies that aim at providing customised public services and inputs tailored to firms' needs, targeting specific obstacles to investment (on this issue, see: Juhász et al., 2023). Sound policies can, moreover, identify and enable opportunities in GVCs. They can facilitate GVC participation of domestic companies in ways that are realistic and conducive to a structural transformation of local and national economies. Beyond empirical insights on South Africa and Chile, the paper therefore contributes to the policy-oriented GVC literature (esp., Crescenzi & Harman, 2023; Kaplinsky et al., 2011a, 2011b; Morris et al., 2012).

To obtain empirical insights, we screened various policy documents and the websites of associations and companies involved in green hydrogen. We also refer to reports by the German Agency for International Cooperation, contributions from online news portals as well as South African and Chilean media reports. Further information was obtained from a series of interviews with key players (see: annexe). Every interviewee shared his/her personal opinion with us, not the official position of any organisation.

The paper is structured as follows. Section 2 provides background information on green hydrogen: on the case made for it in relation to climate change mitigation, challenges and uncertainties that the industry faces, and locations suitable for production and their potential participation in GVCs. The analytical framework – de-risking and linkage-based development – is explained in section 3. Section 4 provides an overview of the green hydrogen industry in South Africa and Chile. Section 5 sets out the empirical findings, looking first at de-risking and then at linkages conducive to industrialisation. Section 6 concludes.

2. Use and production of green hydrogen

Green hydrogen has been given increasing consideration as a source of energy in recent years for a number of reasons. To begin with, hydrogen is essential to some industrial processes already today. Almost all of it is used in oil refining and for the production of fertilisers with ammonia. Present-day hydrogen production amounts to 94 million tonnes worldwide. This so-called grey hydrogen is based on burning coal and natural gas, and has a significant carbon footprint. Currently, less than 0.1 per cent of hydrogen production is green (IEA, 2019, 2022). Decarbonisation obviously offers benefits in terms of emissions reduction.

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[4] For more information, see: https://hifglobal.com/region/hif-chile and https://hifglobal.com/location/haru-oni.

More importantly, however, green hydrogen has been proposed – and, in some cases, utilised in pilot projects – to lower the carbon dioxide emissions of energy-intensive, hard-to-abate industries such as cement, chemicals and steel production by replacing natural gas. Shipping and long-haul road transport are other potential applications. Meeting peak electricity demand and blending with natural gas for domestic heating have been discussed too (for an overview focussed on developing countries, see: ESMAP, 2020). The attention given to green hydrogen has been boosted by the energy insecurity resulting from Russia's invasion of Ukraine and Europe's subsequent push to diversify energy supplies away from Russian natural gas.

An advantage of green hydrogen is that existing infrastructure can be used to transport it globally and locally, even though there is a need to adapt and expand this infrastructure (IEA, 2022). In principle, hydrogen can be transported as a gas by pipeline or in liquid form by ship, much like natural gas. Conversion into ammonia or methanol for easier maritime transport is another option. This means that green hydrogen is a way of storing solar and wind power, and transporting it from sites highly suitable for energy generation to places where energy consumption is concentrated.

But the use of green hydrogen is marked by obstacles and uncertainties. Michael Liebreich, an influential policy adviser and former CEO of BloombergNEF, warns that only a few applications are actually competitive. They are mostly about substituting fossil fuel-based hydrogen. Other applications in the chemicals and steel industries appear feasible but more difficult from a cost perspective. Various uses in the transport sector – local ferries and long-distance trains, for example – are questionable. Liebreich further argues that domestic heat generation and the use of green hydrogen derivatives to fuel urban transport do not make sense because there are other green, more competitive solutions (Recharge, 2021).

Griffiths et al. (2021) add that the tremendous water consumption by the green hydrogen industry in a global context of water stresses is an issue. Desalination is expensive and has environmental downsides. Further to that, hydrogen molecules are so small that they would escape from conventional pipeline infrastructure. Shipping hydrogen is difficult, given that the gas is very voluminous. Converting it into a compressed liquid or, alternatively, ammonia or methanol requires enormous amounts of energy, making it inefficient to produce hydrogen at one place and ship it for consumption to another. It remains to be seen whether shipping large amounts of green hydrogen and/or its derivatives to Europe and Japan will be cheaper than local production.

Vested interests should not be ignored, as those with an existing position in other energy sources can be expected to slow the demand for and/or supply of alternatives. Power imbalances between the Global North and developing countries are, moreover, likely to favour exports of green hydrogen and its derivatives from Southern nations for subsequent use by energy-intensive industries in the Global North, instead of latecomer industrialisation in the Global South (Corporate Europe Observatory, 2023; Kalt et al., 2023). The limitations of the institutional framework for the green hydrogen sector in the Global South mentioned by Griffiths et al. (2021), meanwhile, can be overcome by the policies discussed in this paper.

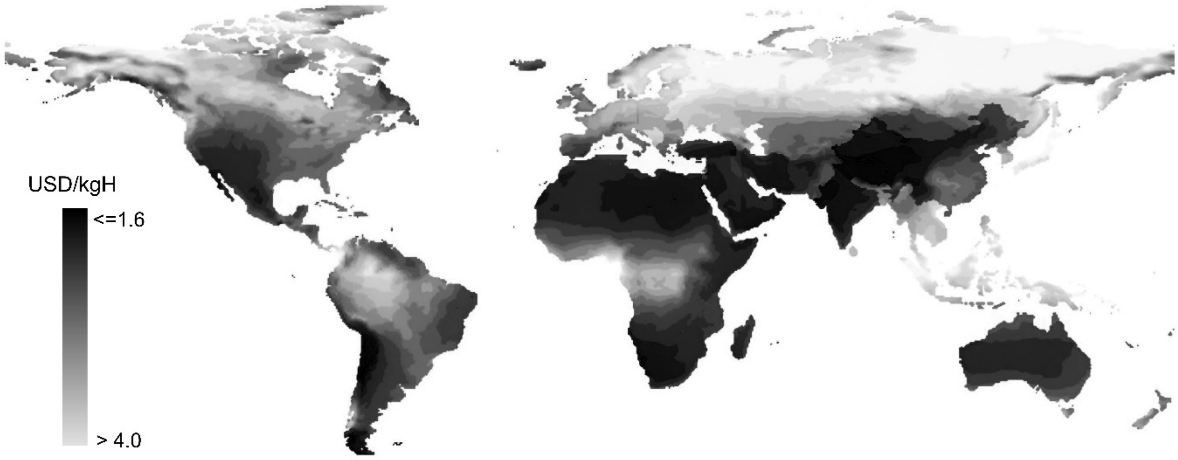
Against the backdrop of all these challenges, it is not surprising that the IEA's (2022, 2023) most recent Green Hydrogen Reviews correct some earlier projections. They point out that lagging policy support and rising cost pressures put investment plans at risk. Whilst more and more projects are announced, installed capacities and volumes remain low. A worryingly high share of 94 per cent of all green hydrogen projects merely exist on paper. The Reviews suggest that worldwide hydrogen demand will reach 115 million tonnes by 2030, with less than

2 million tonnes coming from new uses. This implies that green hydrogen will be produced to substitute grey hydrogen, not for the seemingly countless new applications currently in debate. As an aside, 130 million tonnes and 25 per cent from new uses are needed to meet existing climate change mitigation pledges. Nearly 200 million tonnes are needed to be on track for net zero emissions by 2050.

Nevertheless, many pilot projects around the globe are operational. Corporations and governments are investing considerable amounts in the sector. As noted, green hydrogen is generated by electrolysis, a process that requires a lot of electricity and water. It takes at least 50 kilowatt hours (kWh) of electricity to produce a kilogramme of hydrogen. About 9 litres of water are needed (IEA, 2019). Because direct use of seawater in electrolysis leads to corrosive damage and generates chlorine, desalination – another energy-intensive process – is the only alternative to using freshwater. This implies that green hydrogen ought to be produced where renewables are cheap.

As Map 1 shows, South Africa and Chile are highly attractive locations for producing green hydrogen. The Atacama desert in north Chile exhibits ideal conditions for solar energy, with clear skies and a solar irradiation of more than 7.5 kWh per square metre a day. No other place worldwide benefits from such a high irradiation. In Chile's extreme south, wind speed is more than 14 metres per second at some sites. Onshore wind turbines there are as productive as their offshore peers elsewhere in the world. South Africa, whilst not quite matching this natural endowment, is still one of the countries with amongst the highest combined potential solar and wind power. In 2022, it had the largest renewable energy output in terms of grid connected capacity on the African continent. Chile was the second-most significant renewable energy producer in South America after Brazil (IRENA, 2023).

Map 1: Locations suitable for green hydrogen production



Source: Authors' own draft based on IEA (2019).

Some argue that the availability of solar and wind power at much lower prices than in Europe, in combination with a long coastline that allows for large-scale desalination, makes South Africa a likely frontrunner in the emerging global green hydrogen industry (Bischof-Niemz &

Creamer, 2022). Similar arguments have been advanced with regard to Chile (Acosta et al.,2022; Collis & Schomäcker, 2022).

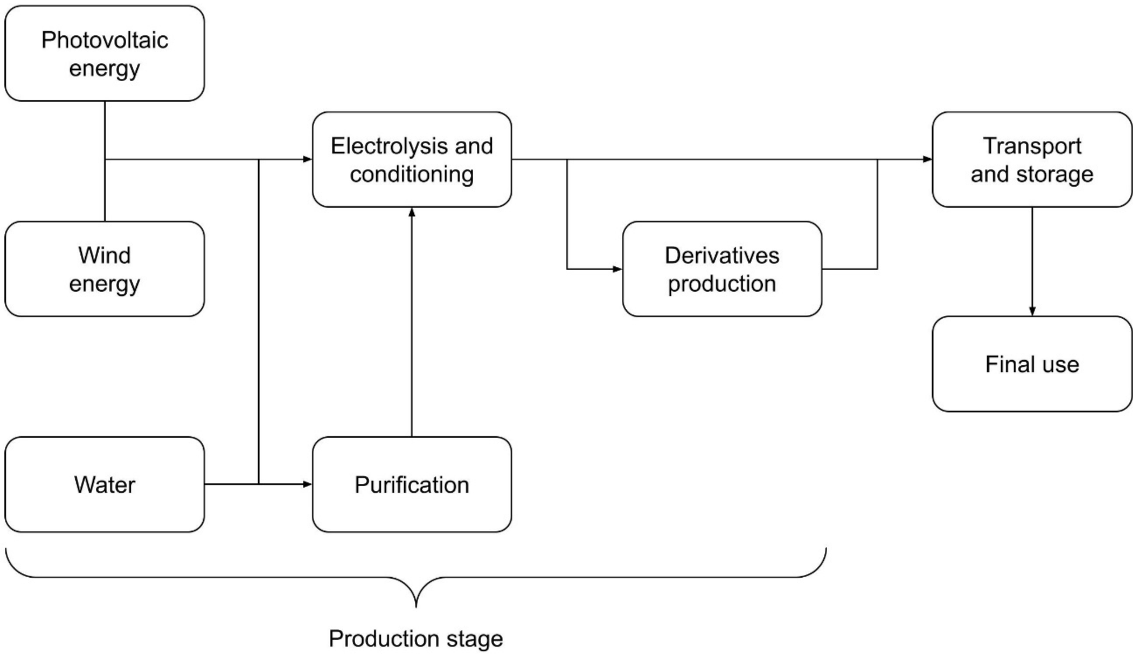
Substantiating these ideas, a recent study based on simulations concluded that Mexico and the south-western United States, the Middle East and North Africa, the south-west of the African continent, north-west Australia and north Chile benefit from the lowest production costs worldwide. They are expected to supply distant industrial hubs. In particular, China and Japan are sound destinations for Chilean exports because Europe and North America may connect to nearer suppliers by pipeline, which would reduce transport costs considerably (Collis & Schomäcker, 2022; for a detailed analysis of hydrocarbon exports from Antofagasta to Japan, see: Gallardo et al., 2021).

South Africa, together with neighbouring Namibia, has seen considerable interest from European players such as the already mentioned Hive Energy Group. The European Union, France, Germany, the United Kingdom and the United States support South Africa's Just Energy Transition Investment Plan (JET-IP). The country's infrastructure for maritime transport, north–south shipping lanes and domestic pipeline networks have been noted as key to the proposed developments (The Presidency, 2022).

Rather than assessing the suitability of specific locations or the contribution of green hydrogen to climate change mitigation, this paper deals with the industry's developmental impact on the countries and, at the subnational scale, sites of production. Hence, GVCs matter as an analytical lens. In the case of green hydrogen, they split into production, handling and final use, as shown by Figure 1:

- Production is electrolysis to obtain hydrogen from water. Inputs such as centrifuges, compressors, electrolysers and pipelines made of different materials are needed at this stage. The associated generation of solar and wind energy is marked by numerous backward linkages too, as is desalination. There are, thus, prospects for boosting and diversifying industrial production where green hydrogen is generated.
- Handling comprises long-term storage in aquifers, depleted gas wells or salt caverns, short-term storage in tanks, gaseous or liquid transmission across long distances by pipeline, rail, road or ship, and short-distance distribution to final users by the same means. Much of this requires innovation and subsequent industrial production for implementation, which could, of course, be done by players located at the sites of green hydrogen generation or, at least, in the same country.
- Final use ranges from heat and power generation to industrial feedstock – for ammonia and methanol production, most importantly – to the transport sector. Some of these forward linkages may be co-located with green hydrogen production. As explained above, not all technically possible applications of green hydrogen make sense in terms of cost rationality.

Figure 1: GVCs of green hydrogen



Source: Authors' own draft.

3. De-risking and linkage-based development

This section explains that green hydrogen production in the Global South suffers from particular risks that hamper investment. De-risking policies appear to be the solution. Afterwards, production linkages that can result from resource exports are presented together with related GVC-oriented policies.

3.1 De-risking in the Global South

Green hydrogen is part of a wider set of industries that hold opportunities for the Global South but are marked by high entry barriers due to particular risks from which Southern nations suffer (for overviews, see: Choi et al., 2022; ESMAP, 2024). Developing countries are often politically unstable. A change of government can lead to a full reversal of economic and investment policies, which implies uncertainty regarding incentives and taxes as well as expropriation scenarios. Regulatory frameworks are not, frequently, overly conducive to private investment. Environmental and land permits are delayed and difficult to obtain. The same applies to so-called social permits. Legal frameworks tend to be weak and not substantially enforced. This matters, for instance, when local partners or suppliers breach contracts. Corruption is widespread.

Currency fluctuation, high inflation and spikes in domestic interest rates are further problems. The convertibility of national currencies is often restricted. If investment depends on returns from domestic markets, the rather low purchasing power and volatile demand will be challenging. The technologies required for new industries may suffer from limited in-country expertise in construction, operation and maintenance, and inadequate supporting infrastructure. Deploying the latter tends to take a long time. Investors therefore demand a risk premium, effectively making many projects non-bankable.

For green hydrogen, there are additional, industry-specific risks. As explained above, several technical challenges have to be solved before large quantities of green hydrogen and its derivatives can be exported from countries such as South Africa and Chile to the Global North. The cost competitiveness of many currently discussed and tested applications remains to be proven. At the moment, there is no clear market for green hydrogen, meaning that the future demand is not known, and production costs are much too high. Supply chains are not functional. Standards for production and products still need to be established (Scita et al., 2020).

Since there is no commercial-scale production of green hydrogen yet, experts are concerned about unforeseen components failure, especially electrolyser degradation, and underperformance in production. Large projects may eventually suffer from underestimated costs and time overruns. There are additional risks with the regard to the supply of electricity, water and qualified labour (ESMAP, 2024). The considerable capital outlays, which result from the huge scale of green hydrogen projects, together with requirements for large-scale renewable energy and connective infrastructure, require intensive coordination of local and non-local companies as well as public institutions on the subnational, national and international level.

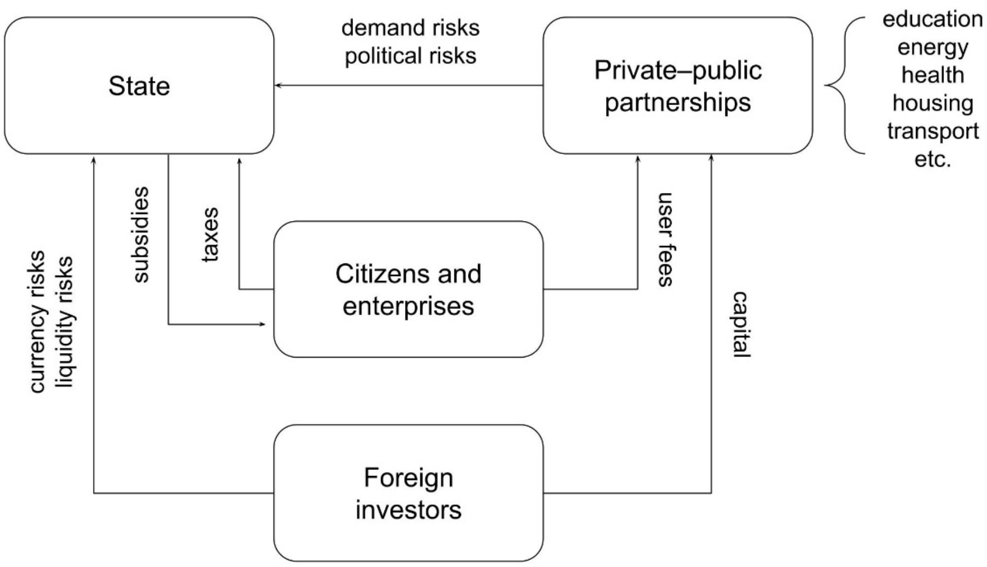
Since so many countries seek to produce green hydrogen, not all of them will be able to do so. Slow movers may eventually be unable to realise any projects at all. These uncertainties make it risky for investors to provide capital for the new industry, which leads to an industry-specific risk premium. It has to be paid on top of the more general risk premium from which Southern nations suffer.

The policy to overcome these barriers is de-risking (IADB, 2022; UNDP, 2013). Being more than a demand increasingly made by the business community, de-risking reflects the return of the state as a prominent player in the economy. Even the International Monetary Fund now discusses industrial policy, presenting it as a way towards latecomer industrialisation (Cherif et al. 2016; Cherif & Hasanov, 2019). De-risking is not identical with industrial policy. It is about guarantees and, perhaps even more importantly, credits provided by the state so that the conditions are right for private investment. In a nutshell, these means decrease the risk that private investors take when making capital available for projects, industries and entire countries across the Global South. This way, the de-risking state enlists private capital, usually blended with public funding, into achieving public policy priorities (Schindler et al., 2023). It corrects uninvestable profiles.

As Gabor (2021) explains, de-risking involves public–private partnerships in education, energy, health, housing and the like. The capital inflow is through shareholding or acquisition of bonds. The state covers demand risks, meaning that it has to make sure that the users – citizens and enterprises – are able to pay for the new assets and services. Subsidies and tax exemptions are typical means. In the case of green hydrogen, public purchase agreements are another option. The state furthermore decreases political and regulatory risks, most importantly by preventing future governments from introducing legislation that disregards the interests of the investors. The state also decreases currency and liquidity risks through the central bank (see also: Musthaq, 2021).

We adapted Figure 2 from Gabor (2021). She is very critical of de-risking, which we are not, and unlike her, we do not think that the state must necessarily transfer cash to the users of the new public–private partnerships.

Figure 2: De-risking



Source: Authors' own draft based on Gabor (2021).

IRENA (2022) has proposed a series of de-risking policies for the green hydrogen industry. Financial and fiscal support for first movers is needed to overcome capital and operational cost barriers and technical barriers, which result from insufficient investment in research and development. There is, at least at present, also a price gap. It could be addressed by quotas for low-emission products, public procurement and carbon pricing instruments that internalise climate change externalities for emission-intensive products. Decarbonisation strategies, perhaps even bans or mandates with regard to emission intensity, would push green hydrogen.

Another means to ease the price gap is bilateral auctions for green hydrogen that bring producers and consumers together, whilst a public body serves as auctioneer and guarantees a minimum price and long-term offtake. This implies, of course, that any cost differential has to be covered with public funding. The IEA (2022) stresses that demand is essential to attract private investment into green hydrogen. Demonstration projects and innovation should be promoted by the state. An appropriate regulatory framework is another further key component of de-risking.

A publication by the World Bank's Energy Sector Management Assistance Program (ESMAP, 2024) indicates that Southern nations are only one player involved in de-risking. They can apply a series of measures that range from public procurement and purchase obligations to one-stop-shops for foreign investors to better performance in terms of legal and regulatory frameworks. Public–private partnerships and dedicated hydrogen hubs are likely to reduce supply risks. Multilateral development banks can play a critical role by making loans available to first movers, which would hardly obtain venture capital from private sources. Northern nations should aggregate the demand for green hydrogen and its derivatives and also sign long-term purchase agreements to minimise price and offtaker uncertainty.

A key argument made in this paper is that not all instruments of de-risking are expensive. Schindler et al. (2023) reason that states that engage in de-risking are developmental states. They seek to guide market forces and create macro-economic environments in which industries of strategic importance thrive. The next subsection presents GVC policies that can contribute to de-risking but cost little money. In the later empirical analysis, we elaborate on how South Africa and Chile de-risk the green hydrogen industry, comparing costly and less costly measures.

Although de-risking and the objectives behind it appear sensible, the reception of de-risking in academia has been quite negative. Schindler et al. (2023) acknowledge its advantages compared to laissez-faire policies, but they are not, certainly, adherents of development practices that are essentially market-driven and further the interests of private capital from the Global North. Gabor (2021), who has published extensively on the topic, suggests that de-risking narrows the scope for a just transition to low-carbon economies. According to her, it entrenches financial and technological dependencies, with developing countries exporting, for example, green hydrogen to fuel Europe's economy (Gabor & Sylla, 2023; see also: Corporate Europe Observatory, 2023; Kalt et al., 2023). Dafermos et al. (2021) see no positive effects of the capital that now flows into the Global South because of de-risking. They warn against new financial vulnerabilities.

We think that the problem is not de-risking per se but, rather, bad governance. For instance, Gabor and Sylla (2020) point out that Ghana and Nigeria took credits in foreign currency to de-risk power generation projects and were later obliged to pay for the output of the new power stations, although the domestic market could not absorb all of it. From our point of view, the question is why Ghanaian and Nigerian politicians agreed to oversized projects in the first place.[5] Southern nations must not de-risk every possible investment. They have to make the right choices, de-risking only those projects and industries that are likely to have a substantial developmental impact and they should, preferably, opt for means of de-risking that are low cost.

3.2 Linkage-based development in GVCs

To assess the development impact of the green hydrogen industry and draw conclusions on the sensibility of related de-risking, we apply an analytical framework drafted by Morris et al. (2012; see also: Morris & Farooki, 2019; *Resources Policy*, vol. 37, no. 4). The framework was designed to better understand the prospects of resource-based development. It reflects Albert Hirschman's (1958) thinking and, thus, calls for development strategies focussed on specific business sectors and the step-by-step broadening of localised, related activities therein. The key message is that the export of resources always creates certain opportunities and some positive effects because of linkages.

[5] To provide another example, about ten years ago, the Kenyan government took a credit from China's EXIM Bank to finance a new railway line from the port of Mombasa to the capital city, Nairobi. The decision was taken, although several consultancy reports by African and Western organisations had demonstrated that the project would operate at a loss. These reports had presented alternatives. Even worse, the Kenyan government disregarded legally binding procurement laws in order to partner with China (Taylor, 2023).

Amongst four types of linkages, production linkages are, perhaps, the most important for industrialisation, and include backward and forward linkages. In the case of green hydrogen, backward linkages comprise electricity generation and the provision of desalinated, purified water. Electrolysers and other industrial inputs are needed; not only for green hydrogen plants but for all upstream and downstream production facilities. Forward linkages are about derivatives production: ammonia and methanol, which can be turned into e-fuels, explosives and fertilisers. Further downstream, almost all energy-intensive industries matter. Countries that achieve abundant production of green hydrogen and its derivatives at low cost will, hence, become attractive for a wide range of industries. These industries, in turn, may provide inputs to many other sectors. Localising at least part of the corresponding production would be a major step towards latecomer industrialisation.

The original linkage concept also takes horizontal dynamics, increasing local consumption – for example, by workers who earn higher salaries – and additional tax income into consideration. Horizontal linkages result from skills gained in sector A that allow companies to expand into sector B – chain upgrading in the terminology introduced by Humphrey and Schmitz (2002). Expansion into related industries means diversification, not necessarily latecomer development towards high value-adding tasks. Consumption and fiscal linkages do not, generally, induce industrialisation. Production linkages, meanwhile, may lead to a structural transformation of the economy. If successful, firms will upgrade from the provision of generic products and services to more complex, high value-adding tasks. In the ideal case, clusters dedicated to specific GVCs emerge.

Research along these lines has uncovered that in addition to in situ processing of raw materials, service provision is a pathway towards increasing value addition and value capture. In South Africa, a mining equipment and services cluster has emerged against the backdrop of resource extraction. Many companies from that cluster have, by now, internationalised their business activities (Kaplan, 2012). Knowledge-based inputs and corporate services are essential for development in Norway's oil and gas industry (Solheim & Tveterås, 2017). Argentina's and Namibia's prospects in that sector apparently depend on turning local providers of generic services into firms that provide specialised services domestically and abroad (Scholvin, 2019, 2021a).

However, industrialisation through linkages is not guaranteed. Southern nations and, in particular, resource peripheries often lack the industrial basis for substantial linkage-based development. In such cases, enclaves form. Transnational corporations export goods with low or no value added. Vulnerability to external shocks and the stagnation of all non-enclave sectors are further problems (Arias et al., 2014). GVC ties with the local economy remain stuck at the level of generic, low value-adding products and services. Linkages rather concentrate at economic hubs, not at the peripheral sites of extraction/production (Breul & Revilla Diez, 2021; Scholvin et al., 2021), whereas companies in the periphery struggle to avoid downgrading and exclusion from GVCs (Scholvin, 2021b).

To avoid such failure, GVC-oriented policies are crucial. Whilst working for the World Bank in Colombia in the 1950s, Hirschman (1958) became convinced that development policies have to facilitate production linkages in the territory under consideration.[6] Hardly used local capabilities and resources need to be joined with projects driven by foreign investors so as to

[6] A biography by Adelman (2013) and a special issue of the journal *Desarrollo y Sociedad* (no. 62) provide more insights on Hirschman's time in Colombia.

benefit from the demand created by the latter and generate externalities. This way, an efficient use of typically scarce investment can be achieved.

Many of the concrete measures discussed in the literature are largely inexpensive for the state, thus fitting what is needed in light of the above-mentioned pitfalls of de-risking. Kaplinsky et al. (2011b) discuss a series of tools to avoid misalignments of key players and policies, ranging from fora that bring public and private decision makers together to supply chain development programmes by corporations. The latter are, of course, also a direct means of making use of local assets. In a more recent contribution, Crescenzi and Harman (2023) emphasise the importance of identifying the competitive advantages of the territory under consideration and suitable niches in GVCs so as to approach transnational corporations in the right way. A targeted industrial policy can be drafted against this backdrop. Investment promotion agencies are decisive for the match-making of global capital and local assets. They support the embedding of corporations and the upgrading of their local suppliers.

From a more general perspective, Morris et al. (2012) stress the need for a well-informed vision of linkage-based development that sets clear benchmarks and a timetable for deepening in-country value addition and developing the necessary capacities, skills and support infrastructure. This way, numerous policies can be harmonised. Typical mistakes, such as local content obligations for items that can hardly be produced domestically, are avoided. Kaplinsky et al. (2011a) add that in addition to a government's vision that is backed by coherent policies and incentives to ensure implementation, the private sector has to follow the same vision. Public and private players need to reflect jointly on the vision and policies to adapt them if necessary. Table 1 summarises these policy tools, including their probable costs.

These are valuable insights, but shared strategic visions, capacity building and upskilling, and subsequent match-making with investors may not always be sufficient to facilitate GVC integration. This is because of the more general risks of investing in the Global South mentioned at the beginning of this section and the industry-specific uncertainties that mark green hydrogen. Before going into details on de-risking, GVC policies and linkage-based development in South Africa and Chile, we now provide an introduction to the case studies.

Table 1: Policy toolkit for GVCs

Means	**Objective**	**Costs**
Well-informed vision for linkage-based development	Clarity on required capacities, skills and support infrastructure	Minimal (consultancy)
… backed by coherent policies and incentives	Effective implementation	None for coherent policies, low to high for incentives
Identification of competitive advantages/GVC niches	Informed interaction with lead firms; foundation for targeted industrial policy	Low (assessment studies, company surveys)

Realistic benchmarks and timetables	Policy harmonisation; avoid overly ambitious localisation strategies	Minimal (consultancy)
Shared vision with private sector (also through public–private fora); reflect and adapt	Avoid misalignments of key players and policies, and allow to correct mistakes	Almost none (hosting of events)
Match-making for lead firms and local suppliers; supply chain development	Embed lead firms and upgrade their suppliers; make use of local assets	Low (assessment studies, company registries/surveys, training of local firms, hosting of events, trips to events abroad)

Source: Authors' own draft.

4. Introduction to the case studies

South Africa has major ambitions to develop a green hydrogen economy and the sector is receiving significant attention from policy makers and private companies. As early as 2007, the National Hydrogen and Fuel Cell Technologies Research, Development and Innovation Strategy, subsequently known as Hydrogen South Africa (HySA) initiative, was launched to undertake research and development.

This was followed by a number of initiatives including the 2021 Hydrogen Society Roadmap (Department of Science and Innovation, 2021a), involving private and public stakeholders and organised civil society. The Roadmap outlines a number of targets such as the creation of an export market for green hydrogen and its derivatives, the implementation of a centre of excellence in manufacturing for green hydrogen products and the development of domestic supply chains. It includes a small-scale electrolysis facility with a capacity of 100 megawatts (MW) by 2025 and electrolyser capacities of 10 gigawatts (GW) in the Northern Cape by 2030, amongst others goals.

The Green Hydrogen Commercialisation Strategy for South Africa (Department of Trade, Industry and Competition, 2022), which is the most important policy document, was released in 2022. It sets the objectives of manufacturing of equipment for green hydrogen GVCs, supplying export markets and using green hydrogen to decarbonise the domestic economy. The Strategy points at an export potential of 2 to 8 million tonnes a year by 2050 and another 3 to 6 million tonnes for domestic consumption. The production targets are lower though, reaching 1 million tonnes a year by 2030 and 7 million by 2050, which we still find ambitious.

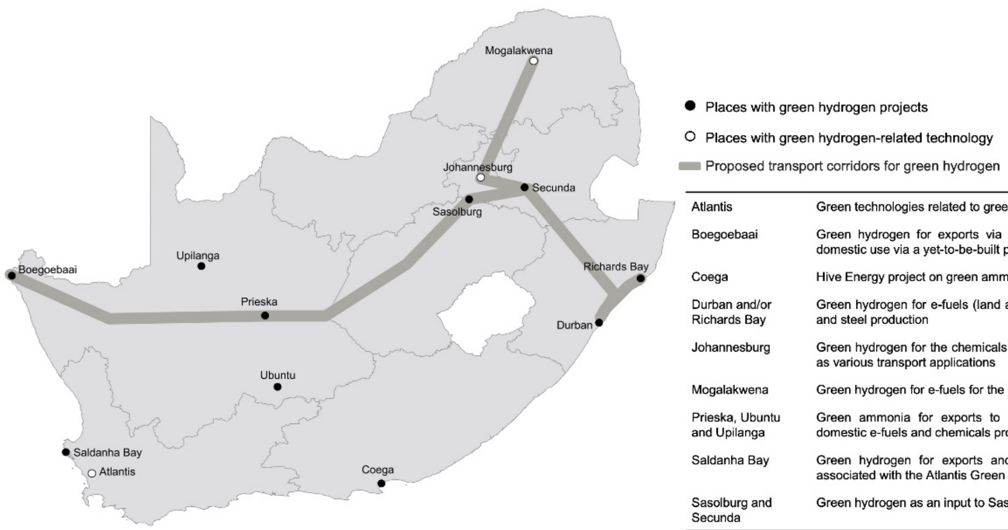
In the short term, meaning within three to five years, the annual production target is 300,000 tonnes, which implies capital investments of USD 13 billion. Projected investments for the next fifteen years amount to USD 164 billion, comprising USD 64 billion for solar energy, USD 40 billion for wind energy, USD 35 billion for electrolysers and USD 22 billion for ammonia production facilities. Desalination will, apparently, only require USD 38 million.

The Commercialisation Strategy suggests that first applications will be heavy-duty vehicles, especially for the mining industry. Before 2030, energy-intensive industries such as cement and steel production are expected to begin to decarbonise by switching to green hydrogen. The same applies to replacing grey hydrogen in ammonia and methanol production. Other applications such as aviation e-fuels and electricity balancing/storage are projected for the 2030s, although it is noted that South Africa’s power shortage may have been solved by other means by then.

In 2023, the Department of Mineral Resources and Energy, the Department of Trade, Industry and Competition and the Department of Science and Innovation (2023) released the draft South African Renewable Energy Masterplan. The document makes a handful of references to green hydrogen. Most importantly, it links green hydrogen production to South Africa’s increasing solar and wind energy generation. Participation in green hydrogen GVCs is associated with economic growth and job creation in the wider manufacturing sector.

A number of projects are at various stages of planning. They are shown by Map 2. Three hubs with significant future demand and production potential – identified by the above-mentioned Roadmap – are located along a yet-to-be-built transport corridor, also referred to as the Hydrogen Valley. These are the ports of Durban and Richards Bay, the wider Johannesburg area and a platinum mine operated by Anglo American in Mogalakwena, Limpopo province. They will host pilot projects on applications such as e-fuels for mining vehicles and heavy-duty trucks as well as feedstock for oil refining, chemicals, iron and steel production, amongst other industrial uses.

Map 2: Green hydrogen projects in South Africa



Atlantis	Green technologies related to green hydrogen
Boegoebaai	Green hydrogen for exports via a new port terminal and for domestic use via a yet-to-be-built pipeline to Gauteng
Coega	Hive Energy project on green ammonia (for exports)
Durban and/or Richards Bay	Green hydrogen for e-fuels (land and sea transport), oil refining and steel production
Johannesburg	Green hydrogen for the chemicals and mining industries as well as various transport applications
Mogalakwena	Green hydrogen for e-fuels for the mining sector
Prieska, Ubuntu and Upilanga	Green ammonia for exports to Europe; green hydrogen for domestic e-fuels and chemicals production
Saldanha Bay	Green hydrogen for exports and domestic steel production; associated with the Atlantis Green Special Economic Zone
Sasolburg and Secunda	Green hydrogen as an input to Sasol’s chemicals production

Source: Authors’ own draft.

At Boegoebaai in the Northern Cape, a special economic zone – with a yet-to-be-built deepwater port, storage facilities and pipelines for green hydrogen as well as transmission grids – will be established. The project is based on an agreement with the port of Rotterdam for exports and close cooperation with Sasol for domestic consumption (Mining Weekly, 2022a). The Saldanha project is driven by Sasol and the steel producer ArcelorMittal. It aims at using green hydrogen for chemicals, e-fuel and steel production for subsequent export (Mining Weekly 2022b), and connects to a nearby special economic zone in Atlantis, which is focussed on green energy technologies. The Coega project – by the Hive Energy Group – is about green ammonia for e-fuels and the maritime industry, aiming at Asian and European markets. Like the Saldanha project, it benefits from an existing deepwater harbour and industrial park (Engineering News, 2021).

Current grey hydrogen production in South Africa is mainly by Sasol, which produces 2.5 million tonnes a year (Daily Maverick, 2022). Unsurprisingly, in all policy documents we screened, Sasol is reported as being central to the country's patterns of future green hydrogen demand. Not only are Sasol's facilities the most significant greenhouse gas emitters, but the ability of the entity to continue to supply products into domestic and global markets is going to depend on its ability to reduce its emissions profile. A first pilot project by Sasol, in collaboration with the chemicals giant Linde, has become operational to test e-fuels for the mining sector (Engineering News, 2023a). Another one involves the mining corporation Anglo American and the carmaker BMW (Engineering News, 2023c).

Chile's National Green Hydrogen Strategy includes clear objectives and a timeframe for the expansion of production (Ministry of Energy, 2020). It derives from a more detailed consultancy paper by McKinsey (2020). Both documents stress that the objective is to produce the cheapest green hydrogen in the world. Investments of USD 5 billion are to guarantee an electrolysis capacity of 5 GW – operating and under construction – by 2025. By then, at least two green hydrogen hubs with an output of 200,000 tonnes a year are to be operational.

It is unlikely that these objectives will be met. The National Strategy and McKinsey report were written at a time of worldwide euphoria on green hydrogen. By now, it has become clear that Chile will not host two hubs with a significant commercial output in about a year's time. Even many pilot projects still only exist on paper. At a recent meeting of the Inter-Ministerial Committee on Green Hydrogen, the new objective of having 10 to 12 projects in development by 2026 was announced (Portal Minero, 2023b). According to the National Strategy, Chile seeks to export 11 to 23 million tonnes of green ammonia and 23 to 34 million tonnes of green hydrogen a year by 2030. Besides the fact that it is highly unlikely that any green hydrogen will be transported by ship prior to conversion into ammonia or methanol, the European Union, which is by far the most important potential importer, plans to import merely 10 million tonnes of green hydrogen or its derivatives a year at that time.

Following the very optimistic National Strategy, investments in green hydrogen are to increase to USD 2.5 billion a year in the early 2030s. Green hydrogen output is to reach an annual growth rate of 15 per cent. Associated renewable electricity will rise from 40 GW in 2030 to 300 GW in 2050 (see: Table 2), which is about ten times Chile's present total power generation capacity.

Markets will primarily be abroad, in Europe and the Far East, accounting for about 60 per cent of the earnings by 2030 and a bit more than 70 per cent by 2050. Green hydrogen will, moreover, enable Chile to export emission-free manufactured goods, gaining a competitive advantage. Domestic usage will be about substituting fossil fuel-based hydrogen in ammonia and methanol production as well as oil refining. The mining sector is expected to use e-fuels and replace heavy oil by green hydrogen in copper processing. Applications in the transport sector might follow later.

Table 2: Projected expansion of Chile's green hydrogen industry

	2025	2030	2035	2040	2045	2050
Domestic market revenues	USD 1 billion	USD 2 billion	USD 5 billion	USD 7 billion	USD 8 billion	USD 9 billion
Export markets revenues	-	USD 3 billion	USD 11 billion	USD 16 billion	USD 19 billion	USD 24 billion
Associated electricity	5 to 8 GW	40 GW	145 GW	200 GW	250 GW	300 GW

Source: Ministry of Energy (2020).

Other government documents also refer to the new source of energy. The Strategy for a Just Transition in the Energy Sector (Ministry of Energy, 2021) links green hydrogen to job creation and local economic development, but it does not go into details. The Energy Agenda 2022–2026 (Ministry of Energy, 2022) sets the target of promoting ten green hydrogen projects across the country – for export and domestic consumption – and establishing corresponding ecosystems in the regions of Antofagasta and Magallanes. It calls for close cooperation amongst key players such as the state-owned copper mining company Codelco, the state-owned oil and gas company ENAP and port authorities to advance pilot projects. Inter-ministerial collaboration is to lead to the introduction of a regulatory framework suitable for green hydrogen.

What is more, Chile's parliament ratified the Framework Law on Climate Change in 2022, according to which the country is to become carbon neutral by 2050 or even earlier. This law mandates that all ministries, regional and municipal governments take effective measures to reach that goal. It is accompanied by the Long-Term Strategy on Climate Change (Government of Chile, 2021), which specifies that by 2040, 20 per cent of the fuels used for transport are to be based on green hydrogen. Already five years earlier, all newly registered buses for intra-urban services, taxis and personal vehicles have to be emission-free (through green hydrogen or lithium-based electric mobility). The same objective applies to long-distance buses and vehicles that transport cargo by 2045.

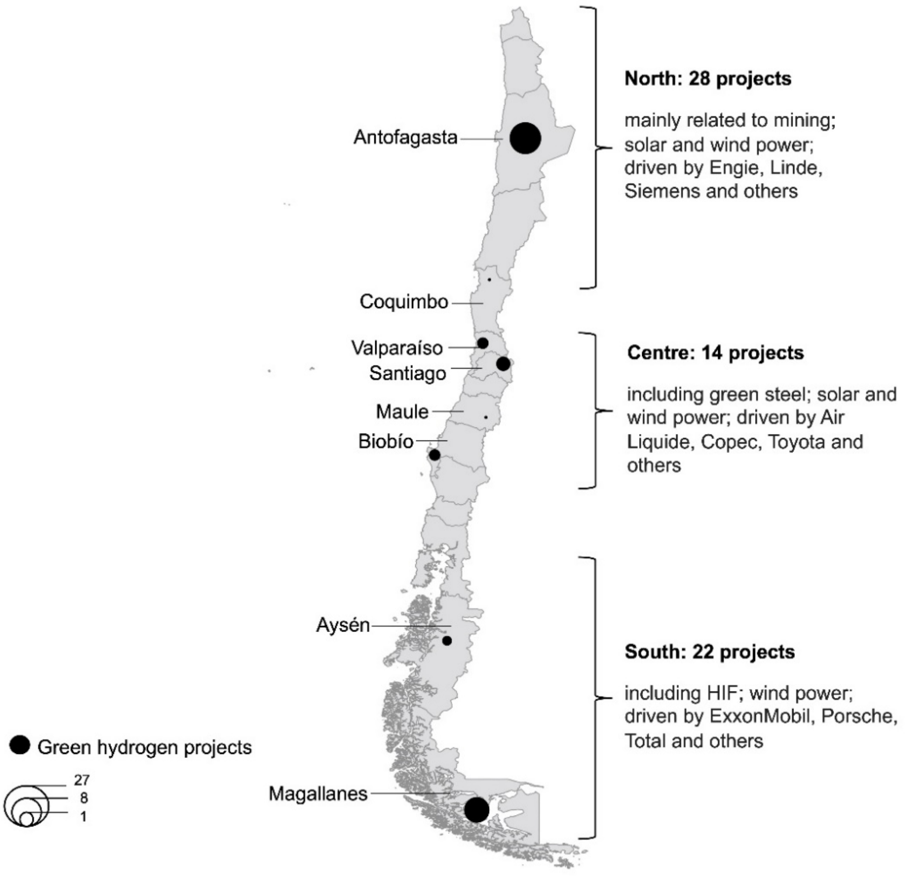
As noted, Chile's most impressive green hydrogen project – the Highly Innovative Fuels (HIF) plant in Cabo Negro, close to Punta Arenas – is in Magallanes, in the very south of the country. It is complemented by other projects, mainly in Antofagasta.[7] HIF will produce methanol and e-fuels. The related Haru Oni pilot plant already produces 130,000 litres of e-fuels a year. In a couple of years, the annual output is to reach 500 million litres, turning HIF into the largest e-fuels producer in the world. The project is driven by the Italian energy company Enel, and Porsche and Siemens from Germany. Enel will provide the necessary electricity through a wind power mega-project known as 'Faro del Sur'.

[7] The following description is based on information obtained from Chilean newspapers, the websites of the corresponding projects and a website of the network H_2Chile, which is available online at: https://h2chile.cl/proyectos.

In the north, an initiative called Antofagasta Mining Energy Renewable (AMER) is being implemented by a consortium of the chemicals producer Air Liquide, EDF Renewables, the methanol producer Proman, the solar and wind power company Sowitec, and the Chilean fuels provider Copec. The objective is to supply the local mining industry with e-fuels. Another project, HyEx, is driven by the energy company Engie and the explosives producer Enaex. Its purpose is to produce ammonium nitrate, which is a key input for explosives for the mining sector. During the pilot phase, AMER and HyEx will operate with an electrolysis capacity of 80 and 26 MW, respectively. Their output will reach 60,000 tonnes of methanol for AMER and 18,000 tonnes of ammonia for HyEx.

A USD 2.5-million project to produce green ammonia by the chemicals company MAE, associated with a 600-MW photovoltaic park, has just entered the environmental impact assessment process. Further to that, the electricity provider AES Andes plans to produce e-fuels for maritime transport, but little is known about the state of this project. The same applies to a project focussed on substituting fossil fuels in industrial processes and heavy-load inland transport. Smaller projects are being implemented in the central regions of Bíobío, Coquimbo, Santiago and Valparaíso to supply the Chilean market for domestic heating, logistics/warehouse operations and industrial production (especially oil refining and steel production). A project in the southern region of Aysén is about electricity generation with green hydrogen. The French company Alstom has proposed a green-hydrogen train from Santiago to the coastal city of Valparaíso, crossing a distance of about 120 kilometres. Map 3 provides an overview of the projects in Chile and names outstandingly important companies:

Map 3: Green hydrogen projects in Chile



Source: Authors' own draft.

Compared to these projects and even more so to the objectives set by the National Green Hydrogen Strategy, Chile's current consumption of grey hydrogen is marginal. Two oil refineries in the regions of Bíobío and Valparaíso account for 90 per cent of it, a total of 46,000 tonnes a year. The remaining 10 per cent are for methanol production (LAC Green Hydrogen Action, 2023).

5. Regional development through green hydrogen?

This section explains how South Africa and Chile de-risk green hydrogen. De-risking is carried out by public authorities on various scales, but national entities and their international partners are the most important ones. Afterwards, light is shed on linkage-based development. That assessment refers to country-wide dynamics and also to what may happen at the peripheral locations where green hydrogen will be produced.

5.1 De-risking strategies

Building institutional capacity for the hydrogen economy in South Africa received its first major boost in 2007 with the launch of the above-mentioned HySA initiative. This led to the creation of three so-called competence centres: HySA Catalysis at the University of Cape Town, HySA Infrastructure at North West University and HySA Systems at the University of the Western Cape. They focussed on applications for small and medium-sized enterprises, hydrogen-related infrastructure and the use of platinum group metals, which are essential for electrocatalysts. Much emphasis was put on using the country's mineral endowment for developments related to green hydrogen and renewable energies.[8] These structures are still seen as critical for ensuring an investment environment responsive to the needs of the new sector (pers. com., 17 October 2023), although it appears that the funding of HySA has now ended and only a number of initial projects are being sustained.

These efforts predated the subsequent global push for green hydrogen, and for this reason the Department of Science and Innovation initiated the above-mentioned Hydrogen Society Roadmap in 2021. This framework has moved South Africa's approach from one primarily about research and development to one that encompasses the wider impact of green hydrogen on the economy and society. The Roadmap recommends learning from the experience of Germany and the United Kingdom in guaranteeing purchases of green hydrogen. It mentions Chile and Morocco in terms of dedicated financial mechanisms to support investment in the new industry, pointing at a potential corresponding role for the Industrial Development Corporation, which is a state-owned entity that finances new industries, being essential for South Africa's industrial policy.

In fact, the Roadmap suggests that clusters dedicated to green hydrogen projects be established. These spatial hubs, including the Boegoebaai project and the Hydrogen Valley, are to concentrate demand and/or production. They 'could help in de-risking investments by identifying a diversified set of off-takers in the hub[s] across many sectors'. De-risking could, furthermore, 'be enabled through shared infrastructure investments between off-takers and producers' (Department of Science and Innovation, 2021a: 69).

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[8] For more information, see: http://www.hysacatalysis.uct.ac.za, https://www.hysainfrastructure.org and http://hysasystems.com.

Amongst the specific interventions proposed in the Roadmap, and subsequently implemented, has been the creation of a dedicated capacity to assess green hydrogen-related projects for inclusion in the country's Strategic Infrastructure Programme, which eases regulatory approval. The above-mentioned Green Hydrogen Commercialisation Strategy additionally stresses the need to develop standards for the new industry in order to support a favourable investment climate (Department of Trade, Industry and Competition, 2022). For example, renewable energy projects associated with green hydrogen production should, ideally, be exempted from electricity policy planning and regulation, especially licensing, regardless of whether they are built as off-grid or on-grid solutions.

The sector has received attention at the highest level of government, with the presidency playing a role in promoting and coordinating activities. This is seen by a wide range of players, inside government and beyond, as a key dimension of de-risking in that issues facing green hydrogen can receive attention from the president (pers. com., 17 October 2023).

Further to that, the Department of Science and Innovation has set up an advisory board with private sector participation. Public–private stakeholder coordination across national, provincial and municipal levels is in place for all main projects, but there is no consistent model that would apply to all of them. These coordination mechanisms are also intended to give investors further confidence as to the support they can expect from the state in resolving investment challenges, be they in national or subnational contexts. The partnerships, working on schemes such as the Hydrogen Valley, have, moreover, been geared to build commitments for future demand – not just for green hydrogen, but for inputs too, chiefly renewable energy and industrial equipment such as electrolysers (pers. com., 13 April 2023).

In South Africa's relatively decentralised system of governance, the provinces, and indeed municipalities, have some considerable powers and functions as well as some level of budgetary responsibility. Several provinces are actively involved in the Hydrogen Valley. In late 2023, the Eastern Cape, Northern Cape and Western Cape signed an agreement to cooperate on the development of South Africa as a global hub to produce green hydrogen and derivative products, as well as to produce the components required in the green hydrogen value chain (Engineering News, 2023d).

The Western Cape is a key player in the special economic zones of Atlantis and Saldanha. Similarly, the Eastern Cape and KwaZulu-Natal, respectively, have been promoting Coega and the Richards Bay as locations for some activities associated with green hydrogen. The Northern Cape has been active in supporting the Boegoebaai project and in lobbying the national government to consider supporting various other development schemes. Typical means employed by the provincial governments include efforts to sign agreements with offtakers from abroad, green bonds and blended finance instruments for infrastructure development, more rapid permit issuing and stakeholder networking, also with local communities (Engineering News, 2023e).

Even though there are effective efforts to align policies and support measures across various scales of governance, a project developer we interviewed did indicate that his consortium remains worried about such a complex governance system. From his viewpoint, multi-level governance in South Africa poses many more risks when compared to a country such as Saudi Arabia, where a decision from the centre ensures the support of all other societal players (pers. com., 19 April 2023).

Further to that, there are many challenges that remain. In particular, the country's infrastructure has been in serious decline. The proposed projects all require considerable investment in infrastructure, especially those driven by Sasol because green hydrogen production at coastal locations needs to be connected to consumption at landlocked sites. Yet, public capacity to provide the corresponding funding is very limited because of a weak fiscal situation. Andreoni et al. (2023) warn that deficiencies in terms of grid connectivity may turn South Africa into a high cost producer of green hydrogen, in spite of favourable natural conditions. The Ramaphosa government has, thus, increasingly emphasised private sector participation.

We find the emerging institutional framework for South Africa's green hydrogen industry promising, but given the country's track record of corruption and state capture, there is a certain risk that the new institutions may not serve their actual purpose. Such a scenario is particularly worrying because of the tremendous amounts of capital involved in green hydrogen production and related infrastructure.

For now, the costs of de-risking are reduced by the support provided by foreign partners. As noted above, the key funding scheme for green hydrogen projects in South Africa is the JET-IP, a USD 8.5 billion package of partly concessional loans from the Global North. The loans are meant as an incentive so that a total of USD 98 billion will be obtained from public and private sources to meet the projected short-term needs of South Africa's energy transition. The first round of the JET-IP covers five years. Subsequent rounds with more funding are likely. The programme has a large green hydrogen component. Funds have already been used in support of policy processes such as those related to the Hydrogen Valley.

It is concerning that grants account for merely 4 per cent of the JET-IP's USD 8.5 billion. Whilst another 15 per cent is guarantees, the remaining 81 per cent is commercial and concessional loans, meaning that South Africa will have to pay them back to the donor countries (The Presidency, 2022). The essential question is whether South Africa's partners from the Global North will shift the financial liability or part of it to the South African state for the yet-to-be-obtained funding. If the JET-IP succeeds in mobilising a total of USD 98 billion, the vast amount of that money should come from sources outside of the country and without an obligation for South Africa to cover defaults. Apparently, this decisive issue remains to be sorted out, as the Presidential Climate Commission (2023) calls for more risk sharing and warns that high liabilities for JET-IP projects may bankrupt the South African state.

The JET-IP is bolstered by parallel financing initiatives, most importantly the SA-H2 Fund, which results from a joint initiative of the Danish and Dutch governments. The fund aims at making USD 1 billion available from South African and foreign sources so as to support large-scale infrastructure projects for the green hydrogen industry. It involves key players: the Development Bank of Southern Africa, the Industrial Development Corporation and the insurance company Sanlam, amongst others (Development Bank of Southern Africa, 2023). Further to that, the Industrial Development Corporation supports shareholding of black economic empowerment partners in prioritised green hydrogen projects.

To overcome a potential shortage of skilled labour, the Department of Science and Innovation, along with the Department of Higher Education and Training, has launched programmes at universities and vocational intuitions to facilitate the participation of South Africans in job opportunities in the green hydrogen industry. A recent report by the Department of Higher Education and Training (2024) identifies the skills needed in the country and explains how to meet them.

For Chile, the above-mentioned McKinsey (2020) report points out that the success of the green hydrogen industry depends on a series of conditions that the government can influence. Much of this falls into the realm of de-risking. Besides having a clear strategy that sets targets and specifies the role of public and private players, there is a need for credits and incentives provided by the state to give an initial push to the sector. The regulatory environment must be streamlined so as to speed up licensing and permit processes. Certification is essential. Partnerships of domestic and foreign players have to be established to promote the industry and develop value chains within the country. It is suggested that the government identify opportunities for local suppliers. Value chain mapping is key in this regard. Backward and forward linkages need to be coordinated. Procurement coordination by corporations would reduce costs too. Free trade zones in Antofagasta and Magallanes are recommended.

Infrastructure such as port facilities and transmission systems must be upgraded, which also requires action by the government, for instance through public–private partnerships. Research and development – on earthquake-resistant ammonia production and wind turbines suitable for the Magallanes region, for example – has to be carried out with national and international partners. Funding and institutions dedicated to this purpose are needed. Skilled labour has to be attracted and local talent developed to meet the demands of the industry.

In other words, Chile's approach to the green hydrogen industry is guided by a clear vision of what needs to be done to facilitate investment. Important steps towards linkage-based development are mentioned, but much of what the McKinsey report suggests remains to be implemented. Chile does not have a clear regulatory framework for green hydrogen yet, although guidelines on project authorisation from production to final consumption and environmental standards are available (LAC Green Hydrogen Action, 2023). The new sector still needs to be incorporated into public land use plans. Investors apparently struggle to find plots where they can build their plants (pers. com., 4 April and 2 June 2023). Obtaining the necessary permits is a time-consuming process that involves various authorities at the national, regional and municipal level (pers. com., 2 June 2023).

Considerable progress has been made with regard to an institutional framework. It is important to note that the National Green Hydrogen Strategy was drafted during the tenure of the centre-right Piñera government, which adhered to liberal economic convictions. The current Boric government, conversely, has its roots in a social protest movement. It initially aimed at fundamentally changing the Chilean economy and state, most importantly through a new constitution, which has, by now, been rejected in a referendum.

Quite surprisingly, the approach to the green hydrogen industry has not been reversed. In early 2023, the Boric government initiated a participatory process to draft the Green Hydrogen Action Plan (Ministry of Energy, 2024), to specify the steps that ought to be taken until 2030 to implement the objectives set by the National Strategy. The Action Plan, which is still undergoing public consultation, proposes an impressive list of 111 measures. It is clear on timeframes and identifies players responsible for each measure. Many measures are, however, simply about diffusion of information. Others refer to clear legislation, efficient regulation as well as GVC integration and subsequent upgrading by Chilean suppliers. Unfortunately, the Action Plan hardly ever goes beyond naming measures. For example, it is good to know that Chile seeks to position itself on international markets as a provider of green hydrogen (measure 106), but it would be even better to learn how this will be done.

The Action Plan is complemented by the Strategic Committee on Green Hydrogen, also established in 2023. It consists of academics and politicians from former centre-left and former centre-right governments, and operates in a top-down manner. One of its key tasks is to make additional sources of funding available, in particular to the regional governments, so that the Action Plan can be implemented. The Committee will also make suggestions on how to provide infrastructure and an institutional framework, addressing matters as fundamental as environmental impact assessments and other regulations, human capital and industrial development (Ministry of Energy, 2023b).

The Ministry of Energy has, furthermore, announced a consulting council that will consist of players from the business sector with an interest in green hydrogen GVCs. To our knowledge, nothing beyond the announcement has been done so far. Further to that, the economic development organisation Corfo and the investment promotion agency Invest Chile have organised various fora for potential investors and support them with information on doing business in Chile, once they decide to invest in the country.

All these measures are certainly relevant. It should have become clear from our explanations on de-risking further above though that finance is the key barrier for the green hydrogen industry in the Global South. Financial support has been provided via numerous schemes by Chilean bodies such as Corfo and the Ministry of Energy, and also individually by international development banks. The corresponding sums are relatively low, amounting to a couple of hundred thousand to a few million dollars for projects with an electrolysis capacity in the lower two digit megawatt range (Portal Minero, 2022a).

Much more importantly, Corfo has signed agreements with the Inter-American Development Bank and World Bank. The former will make USD 400 million available for credits for green hydrogen projects and measures that contribute to the enabling environment, including human capital development, applied research and development, upskilling of suppliers and the like. The World Bank will contribute USD 150 million for the same purpose. The European Investment Bank and Germany’s KfW have announced to grant another USD 110 million and USD 100 million, respectively. With additional funding from European sources and USD 250 million from Corfo, the total amount of money has increased to slightly more than USD 1 billion. It will be used to potentiate private investment. The government quite optimistically expects to reach a total of USD 12.5 billion this way (Ministry of Energy, 2023a; see also: BNamericas, 2023b).

As in the case of South Africa’s JET-IP and the SA-H2 Fund, this credit scheme appears sound to us, unless too much of the liability is shifted to Chile. If this were to happen, the funding mechanism would, indeed, confirm the concerns voiced by the above-mentioned scholars who have argued against de-risking.

So far, financial support has been focussed on the supply side. No concrete steps have been taken with regard to the demand side, except for the above-mentioned general shift to zero emission vehicles. Chile’s energy minister, Diego Pardow, has pointed out that green hydrogen will become competitive if carbon taxes are increased considerably. He has, however, stressed that this is a task for the Global North, not for a Southern nation like Chile (H2 News, 2022). Codelco and ENAP will not buy e-fuels before they become competitive. According to current legislation, state-owned enterprises in Chile are run by their boards like private companies. They cannot be obliged to pursue objectives set by the government (pers. com., 2 June 2023).

5.2 Production linkages[9]

In South Africa, there are significant downstream opportunities for green hydrogen. The first of these is in relation to decarbonising mining, both in relation to processing activities of mined ores and in terms of the scope to use green hydrogen to power mining vehicles. The second sectoral focus area is to decarbonise fuels beyond mining. The Department of Trade, Industry and Competition (2022), apart from highlighting road transport, also notes important demand sources to be developed for processing of non-ferrous metals, oil refining as well as cement and steel production. It stresses the potential to produce green ammonia and green methanol as inputs for fertiliser production and fuels for maritime transport. Green hydrogen as a means of power storage is added to this list of applications.

The most significant linkage opportunity in the short to medium term is that related to the chemicals giant Sasol (see also: Andreoni et al., 2023; Stamm et al., 2023), which is, as noted, South Africa's largest consumer and supplier of hydrogen. Sasol has significant expertise in chemicals processing. It is the single largest carbon-emitting private sector entity in the country due to its large oil-from-coal facilities. Sasol has pledged carbon neutrality by 2050. The company is also the sole ammonia producer in South Africa, with half of this output being a byproduct of its synfuels production. Sasol has indicated plans for greening its existing ammonia production. The company is, furthermore, planning to transition its flagship Sasolburg plant to become a green hydrogen production base (Mining Weekly, 2023). It has already converted an existing electrolyser to produce green hydrogen at its Secunda plant as part of a proof-of-concept exercise (Engineering News, 2023a).

The other major hard-to-abate industries in the country, particularly aluminium, iron and steel production, are also eager to find alternative energy sources in the face of ongoing energy supply issues as well as to decarbonise their production processes. For example, ArcelorMittal is one of the entities exploring the production of so-called green hydrogen-directly reduced iron at its presently mothballed steel plant in Saldanha, which appears to be a rather distant project (Engineering News, 2023b). South32, the owner of an aluminium smelter in Richards Bay, has been less forthcoming, but an interviewee stated that the company faces pressure to decarbonise operations because of possible carbon tax issues for exports (pers. com., 25 October 2023).

As far as backward linkages are concerned, the draft South African Renewable Energy Masterplan 'aims to leverage the rising demand for renewable energy and storage technologies [...] to unlock the industrial and inclusive development of associated value chains in the country' (Department of Mineral Resources and Energy, Department of Trade, Industry and Competition and Department of Science and Innovation, 2023: 7). South Africa does have some local electrolyser producers, including companies that are targeting the green hydrogen sector. However, the country is not, at present, a globally significant producer. Other potential backward linkages are even less clear: Stamm et al. (2023) point out that South Africa has largely failed to localise the manufacturing of inputs for renewable energies. Even though the country is well endowed with platinum group metals, beneficiation takes place abroad.

A number of the projects being mooted in South Africa have been framed as likely to push local and/or regional economic activities. An official working with the Richards Bay Industrial Development Zone noted that by making the zone – and the special economic zones of

[9] With regard to the region of Antofagasta, this section draws on Scholvin (2023).

Atlantis, Coega and Saldanha alike – available for firms related to the green hydrogen sector, linkage-based development could be encouraged, especially through better coordination of key players (pers. com., 25 October 2023). The three special economic zones will set aside areas to accommodate firms associated with the green hydrogen industry.

Going beyond linkages within these zones, the major automotive firms in the Eastern Cape are outside of Coega, but green hydrogen produced in Coega could be key to helping the automotive industry to decarbonise. Fuel cell production for a variety of green hydrogen-powered vehicles could be considered (pers. com., 23 March 2023). Nonetheless, although Coega is the site of the most advanced green hydrogen export project, at least on paper, the proposed production linkages – manufactured inputs during a short construction boom and, on a permanent basis, solar and wind power – remain limited, at best.

As shown by Map 2 further above, the Hydrogen Valley includes hubs across three provinces: Gauteng, KwaZulu-Natal and Limpopo. There is substantial demand for green hydrogen around Johannesburg, for ethylene and steel production as well as for various transport uses. The latter application could, in term, stimulate vehicle production. In Limpopo, green hydrogen could serve as an energy source for mining activities. In KwaZulu-Natal, it could meet demand from oil refineries and supply the global shipping industry with low-carbon fuels (Department of Science and Innovation, 2021b).

An interview added that the provincial authorities in KwaZulu-Natal are hopeful that green ammonia will support a fertiliser plant in Richards Bay and that green hydrogen will assist in ensuring the competitiveness of the local aluminium smelting industry. Fertiliser production appears particularly promising because current prices across the entire Southern African region are above international levels (Andreoni et al., 2023). Another interviewee stressed the existing network of technical suppliers to the chemicals and oil and gas industries . These firms also expect to benefit from future demand generated by the green hydrogen industry (pers. com., 23 March and 13 April 2023). However, all the prospects remain highly speculative because there is no committed green hydrogen producer for KwaZulu-Natal yet.

The Boegoebaai and Saldanha projects in the Northern and Western Cape, respectively, are intended to yield impacts for the aluminium, iron and especially steel industry. Green hydrogen production in Saldanha may connect to the Atlantis Special Economic Zone, which has been designed with a focus on green industries and already hosts some production activities linked to renewable energies. The governments of both provinces have programmes alongside those of the national Department of Trade, Industry and Competition to support manufacturing and service activities associated with green hydrogen. Interviewees pointed at land-based transport and shipping in this regard (pers. com., 17 October 2023).

It was also noted by a respondent that transnational companies active in the production of equipment for the green hydrogen industry may invest in South Africa's special economic zones, provided that a sufficient scale of in-country projects is realised. Examples include metal products for green hydrogen plants such as pipes, tanks and the like. In addition to that, engineering firms could invest in South Africa to convert maritime vessels to run on green hydrogen-based fuels (pers. com., 13 April 2023).

There was a widespread view amongst those interviewed that the first site to build a green hydrogen plant will have an advantage in localising backward production linkages. It was suggested that subsequent projects elsewhere might then struggle to replicate these activities because the corresponding demand is likely to be met at the first-mover location (pers. com., 17 October and 8 November 2023). This concern is reinforced by the fact that the same linkages are mentioned across all regional schemes that we screened. It was also noted in our discussions that there remains a fair degree of uncertainty about forward production linkages in fields such as steel production and the transport sector. Other technologies and energy sources could well trump green hydrogen on either cost or technical terms (pers. com., 8 November 2023).

Another challenge for the mostly peripheral production sites of green hydrogen is that higher-order services, particularly those associated with research and development, are already concentrated in South Africa's major cities. Prospects of such services being co-located with green hydrogen production appear slim. Accordingly, interviewees with a regional perspective focussed on generation and consumption of green hydrogen, instead of sophisticated services, when talking about linkage-based development (pers. com., 30 March and 25 October 2023).

For the most remote projects such as Boegoebaai, co-location is likely to be limited to things such as water treatment and basic services (catering, laundry, transport of personnel etc.) (pers. com., 17 October 2023). This is also implied by the attention that has already been given to transporting green hydrogen and its derivatives from these places to distant sites of domestic consumption.

The largest mining companies in Chile – Anglo American, Antofagasta Minerals, BHP Billiton and Codelco – have signalled considerable interest in green hydrogen (La Tercera, 2021a, 2021b). With the new source of energy, mining can be decarbonised, making sure that it remains globally competitive, especially if the European Union and the United States impose tariffs on copper extracted and processed with fossil energy. Next to processing of copper, the hauling trucks used in mining are crucial for decarbonisation. There are more than 1,500 of these trucks in Chile, causing carbon dioxide emissions of more than 5 million tonnes a year (LAC Green Hydrogen Action, 2023). Antofagasta Minerals announced a pilot project already in 2021 and then expected to have the first trucks running on e-fuels by 2027 (Portal Minero, 2021).

Another potential forward linkage is steel production. Chile's largest steel producer, CAP, plans to build a green hydrogen pilot plant at its Huachipato steel works in the region of Bíobío (BNamericas, 2023a). This steel works meets about 25 per cent of the country's demand, with another 5 per cent coming from other works and the remainder being imported.[10]

Interviewees furthermore suggested that a chemicals hub could emerge in Mejillones or Tocopilla (pers. com., 29 March, 18 April, 29 May 2023), two towns in the region of Antofagasta. Since the 1990s, Mejillones has been a key location for the mining sector. In addition to port facilities, it hosts several thermal power plants and chemicals industries that provide inputs for copper and lithium mining. Tocopilla's thermal power stations are being decommissioned and the town does not host chemicals industries, but there is a considerable effort to facilitate job creation through a transition to renewable energies, including green hydrogen (Portal Minero, 2022b).

Other than that, Chile's pilot projects, as summarised above, raise concerns. Blending green hydrogen with natural gas for domestic heating, as tested in Coquimbo, is one of the least cost

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[10] However, at the time of submission of the manuscript of this working paper, CAP had stopped its steel production at Huachipato because of cheap Chinese steel flooding Chile's market.

competitive applications. Electricity production with green hydrogen is also not sensible from a cost perspective, considering the tremendous energy losses involved. The gigantic HIF project in Magallanes suffers from particular uncertainties. It remains to be seen whether e-fuels will be able to compete with lithium batteries. As noted above, the details of shipping green hydrogen or, rather, its derivatives still need to be figured out – a particular challenge for Magallanes, as there is no local market. Unless transport is free of carbon dioxide emissions, the fuels cannot be considered green, which would make them unsellable. The HIF project is, moreover, prone to become a textbook-like enclave, given that there are no industries in Chile's extreme south that could link up with foreign investors.

Backward linkages are questionable across the entire country. Corfo has launched an initiative to attract foreign manufacturers of electrolysers. It hopes to facilitate partnerships with Chilean enterprises and has, apparently, received investment proposals of USD 850 million (Diario Financiero, 2023). An interviewee from that organisation, who also sits on the Strategic Committee on Green Hydrogen, said that according to the manufacturers, such investments depend on a minimum demand that has to be guaranteed for the Chilean market (pers. com., 5 May 2023). An official from a national association that represents the largest firms involved in green hydrogen was more sceptical. He explained that established producers of electrolysers and other industrial inputs benefit from economies of scale abroad, in particular in China. They will probably ship their products to Chile (pers. com., 29 March 2023).

A report by the German Agency for International Cooperation (2020) identified 817 large and medium-sized companies in Chile that might participate in green hydrogen GVCs. They represent a mere 0.2 per cent of the formally registered companies in the country. About four fifths of them have their head office in the metropolitan region of Santiago. These are joined by an estimated 2,016 small firms with a supposedly realistic potential to become suppliers. It needs to be pointed out that the authors of the report considered the classification of Chilean enterprises for the national taxation system to draw conclusions on whether they can, in principle, make a contribution to green hydrogen GVCs.

In 2021, Chilean and Dutch ministries, as well as the Rotterdam port authority, signed a memorandum of understanding on collaboration on green hydrogen. Mejillones received particular attention as a future logistics and industrial node (H2 News, 2023a). At the World Hydrogen Summit & Exhibition 2023, public and private sector players including the municipality of Mejillones, the Mejillones port authority and the Rotterdam port authority signed another declaration, stressing their intent to jointly develop green hydrogen GVCs (H2 News, 2023b). This has raised hopes that close relations with investors from the Netherlands will enable companies that already operate in Mejillones to access the know-how and technologies needed to play an important role in green hydrogen GVCs (Portal Minero, 2023a).

Earlier this year, the Institute of Clean Technologies was established in Antofagasta to provide and share data as well as infrastructure such as laboratories and scientific equipment. It brings together various Chilean universities and foreign research entities such as Fraunhofer. Large corporations – BHP Billiton and Engie, for instance – are affiliated with it; so are Corfo and the Industrial Association of Antofagasta. The objective of the institute is to generate new knowledge, link corporations and scientists, train the future workforce for clean technologies and facilitate related entrepreneurship. Green hydrogen, along with energy storage and solar power, are key topics.[11]

However, the best that Antofagasta can achieve, at least in an initial phase, is generic, low value-adding tasks. The interviewees from Corfo pointed out that local enterprises lack the technology needed to move beyond that role (pers. com., 4 April 2023). Representatives of larger companies typically mentioned services such as transport and storage, and the provision of standardised goods like cement, common compressors and tanks for local outsourcing. Other locally available services 'are not in the core of the business' – catering and laundry, for example. More sophisticated, high value-adding tasks such as the consulting and engineering behind ammonia, hydrogen and methanol plants will be contracted internationally or in Santiago (pers. com., 29 and 31 March, 4 and 5 April, 30 May 2023). Because of the lack of related industries in Magallanes, even generic service provision appears unlikely there.

Further to that, the green hydrogen industry is capital intensive. Production linkages do not imply significant labour market effects, except for a boom during the construction phase, which will last 12 to 30 months, at best. The German Agency for International Cooperation (2021) predicts that the industry will generate about 36,000 jobs in Chile by 2030 and 325,000 by 2050. These figures appear overly optimistic and, even more importantly, only 10 per cent of the jobs will be in operation and maintenance. Company executives confirmed the low share of permanent jobs. A hydrogen plant with associated solar energy generation in the outskirts of Mejillones, for example, will reach a peak of employment of 1,200 during the 18 to 24 months of construction. Later, this number will drop to 80 or 60 (pers. com., 31 March 2023).

6. Conclusion

Participation in green hydrogen GVCs is of great interest to Southern nations that benefit from a natural endowment for solar and wind power. It appears to offer a potential pathway in support of the energy transition and latecomer industrialisation. Countries like South Africa and Chile will not, however, play a role in the green hydrogen industry, unless they engage in de-risking to overcome investment uncertainties that are characteristic of the Global South and the new industry.

Taking the pitfalls of de-risking into consideration, we argued that developing countries should, preferably, choose corresponding means that are not expensive. They must avoid assuming the liability for credit schemes meant to incentivise investment into the green hydrogen industry. As Table 3 summarises, South Africa has drafted an increasingly complex vision for the industry, starting with the HySA initiative in 2007 and leading to the Hydrogen Society Roadmap and Green Hydrogen Commercialisation Strategy in 2021 and 2022. It is clear that the country concentrates on supplying domestic energy-intensive, hard-to-abate industries, in addition to green hydrogen exports.

The corresponding objectives are ambitious. They are supported directly from the presidency and by stakeholder coordination and partnerships that involve key public and private players. Meaningful, not overly costly policies have been identified and partly implemented, ranging from efforts to sign agreements with foreign offtakers to more rapid permit issuing. These

[11] For more information, see: https://www.asdit.cl.

policies however lack an overall framework for prioritising actions, made more challenging by the array of projects being considered. To date little concrete work has been delivered in terms of match-making and supply chain development, although these issues are clearly on the agenda. It remains to be seen what level of much more costly financial incentives will be required.

Chile has a well-informed vision for developing the green hydrogen industry, although the scale and timing, especially as proposed by the National Green Hydrogen Strategy, is unrealistic. Competitive advantages, meaning forward and backward linkages to concentrate on, as well as means of supporting the sector have been identified. They include regulatory streamlining, rapid permit issuing, match-making for foreign lead firms and local suppliers, and supply chain development. Many of these means still need to be implemented. More importantly, they are not expensive.

Chile has been particularly successful in setting up an institutional framework. It includes bottom-up participation in drafting the Green Hydrogen Action Plan as well as top-down bodies that bring public and private stakeholders together such as the Strategic Committee on Green Hydrogen.

Both South Africa and Chile benefit from cooperation with partners from the Global North to make loans available to first movers and for large-scale infrastructure projects. Chile's largest credit scheme reaches an impressive amount of USD 1 billion. For South Africa, a significant share of the JET-IP's USD 8.5 billion will be used for green hydrogen projects. The key question is whether liability will be passed from Northern nations and organisations such as the World Bank to South Africa and Chile. In that case, the two countries would be likely to suffer from the drawbacks of de-risking summarised above.

Given that these credit schemes are to facilitate much larger loans from public and especially private sources, we are also worried that private companies and investment funds from South Africa and Chile may get heavily involved in de-risking green hydrogen. The above-mentioned SA-H2 Fund explicitly aims at high-risk loans from South African sources. Further to that, we are concerned that the Hydrogen Society Roadmap refers to the country's history of heavy subsidies for domestic companies such as Eskom, Sasol and Transnet, implying that this may be a role model to follow in the green hydrogen sector (Department of Science and Innovation, 2021a). Restrictions of government interference in the economy in Chile prevent such a costly commitment to an emerging sector whose future development impact is unknown.

Against this backdrop, it remains to be seen whether South Africa and Chile can avoid the pitfalls of de-risking. We find it important to stress that the related decisions are taken by their sovereign governments, not by any Western partners. Concentrating on the various inexpensive means of de-risking presented in this paper and shifting financial liabilities to Northern partners is the right way ahead.

Table 3: South Africa's and Chile's policies on green hydrogen

Means	South Africa	Chile
Well-informed vision for linkage-based development	HySA initiative from 2007; Commercialisation Strategy 2022 and Roadmap from 2021	McKinsey report and National Strategy from 2020; Action Plan from 2024
… backed by coherent policies and incentives	Meaningful policies at different levels of governance; overall framework unclear	Many means identified but need for concretisation
Identification of competitive advantages/GVC niches	Opportunities for production linkages identified; focus on energy-intensive, hard-to-abate industries	Opportunities for production linkages identified; strategies reflect on competitive advantages
Realistic benchmarks and timetables	Ambitious in terms of scale	Overly ambitious in terms of scale and timing
Shared vision with private sector; reflect and adapt	Stakeholder coordination and partnership schemes in places across all levels of governance	Intense collaboration of public and private stakeholders at the national and subnational level
Public–private fora	Advisory board with private sector participation at the Department of Science and Innovation	Participatory drafting of the Action Plan; Strategic Committee and consulting bodies
Match-making: lead firms and local suppliers	Opportunities recognised but no clear strategy how to realise them	Identified as important but only rudimentarily implemented
Supply chain development	Unclear	Identified as important but not implemented

Source: Authors' own draft.

With regard to production linkages, numerous opportunities were uncovered. Expanding solar and wind energy in South Africa and Chile is an obvious backward linkage, which may trigger demand for corresponding manufactured inputs and services. Energy-intensive, hard-to-abate industries, such as steel production, offer considerable potential for decarbonisation through green hydrogen in South Africa. Sasol could become a particularly important player. Transport, with likely links to car manufacturing, and the mining sector are other key forward linkages.

In Chile, the mining sector plays the most important role in terms of forward linkages. Oil refineries, steel works and the transport sector may also consume green hydrogen, but in Chile they are much less important to the economy than they are in South Africa.

However, we warn against being overly optimistic. None of these production linkages are certain. Export-oriented projects, as in the Eastern Cape and Magallanes, will not generate forward linkages. Substantial backward linkages are threatened by the import of components and equipment, which can be produced elsewhere in the world with economies of scale. Peripheral production sites – most demonstratively Boegeobaai, but also Antofagasta – can be expected to provide generic inputs only, with high value-adding tasks concentrating in existing hubs or abroad. On top of that, the green hydrogen industry is capital-intensive. A job boom will be limited to the construction phase.

Reinforcing these concerns, it needs to be stressed that green hydrogen GVCs are a scenario for the future, not today's reality. In this paper, we addressed various issues to be resolved before commercial production, and related trade across the globe, can happen. We pointed out that there are alternative, sometimes more competitive pathways towards decarbonisation. Even if South Africa and Chile become commercial-scale producers of green hydrogen, subsidies for green industrial production in Northern nations will work against corresponding linkages in the Global South.

Further to that, South Africa and Chile are not necessarily better positioned than other developing countries. The rapid progress that some Middle Eastern countries have made with setting up pilot projects and related infrastructure suggests that markets in the Global North may already be supplied, once South Africa and Chile are ready to export.

Annexe: Interviews and personal communications

South Africa

Description	**Date**
Official of KwaZulu-Natal's Department of Economic Development, Tourism and Environmental Affairs	9 March 2023
Official of the Economic Development Department of the eThekwini Municipality	15 March 2023
Executive of the Coega Special Development Zone	23 March 2023
Executive of the Freeport Saldanha Industrial Development Zone	30 March 2023
Official of Trade and Investment KwaZulu-Natal	13 April 2023
Official of the Department of Trade, Industry and Competition	17 Oct 2023
Official of multinational energy company	19 Apr 2023
Official of the Richards Bay Special Economic Zone	25 Oct 2023
Researchers based at Trade and Industry Policy Strategies	14 Aug 2023
Official of the Energy Office of the eThekwini Municipality	4 Sept 2023
Researchers of Trade and Industry Policy Strategies	8 Nov 2023

Source: Authors' own draft.

Chile

Description	**Date**
Executives of CICITEM	16 March 2023
Official of Chile's maritime authorities	29 March 2023
Executive of an association of the green hydrogen industry	29 March 2023
Director of a solar energy company	29 March 2023

Director of a start-up that develops technology related to green hydrogen applications	31 March 2023
Executive of a solar energy company	31 March 2023
Director of a solar energy company	3 April 2023
Retired official of the German Agency for International Cooperation	4 April 2023
Executive of an engineering company that specialises in renewables	4 April 2023
Official of a town in Antofagasta	4 April 2023
Officials of Corfo	4 April 2023
Executives of an international consortium	5 April 2023
Executive of a chemicals company	5 April 2023
Official of an industrial association in Mejillones	18 April 2023
Official of Corfo who participates in Chile's National Green Hydrogen Committee	3 May 2023
Official of Invest Chile	25 May 2023
Official of the delegation to Antofagasta of the Ministry of Energy	29 May 2023
Executive of a chemicals company	30 May 2023
Official of the Ministry of Economics	2 June 2023

Source: Authors' own draft.

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