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Contradictory developments of the post-fossil transformation: Contested Decarbonisation, Fossil Continuities and Continued Extractivism in the Global Hydrogen Economy

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Abstract:
We are witnessing the rise of a global hydrogen economy characterised by uneven global geographies of energy, industrial production and extractivism. In this new landscape, large-scale hydrogen production is anticipated to develop in Global South countries with the goal of exporting it to the Global North to support their decarbonization and green industrialisation initiatives. Although some exporting countries in the Global South are pursuing plans for self-determined green industrialisation, there is a significant risk that these efforts may fail. Instead, it seems likely that once again extractivist patterns are reproduced and socio-environmental costs externalised to the Global South. Additionally, the debate about the material basis for so-called low-carbon hydrogen is undergoing a shift. While the initial focus had been on hydrogen production from renewable energy, now hydrogen based on fossil fuels with carbon capture and storage as well as from nuclear energy are gaining importance. Furthermore, fossil continuities continue to shape the emerging hydrogen economy even in cases where green hydrogen is prioritised. To analyse these contested and contradictory developments of the global hydrogen economy, we employ the concept of post-fossil extractivism and provide empirical evidence from the EU, Germany, South Africa, Namibia, Argentina and Chile.

Keywords: Decarbonisation, extractivism, fossil fuels, green industrial policy, hydrogen

JEL codes: B52, F18, F52, Q42, Q43, O13

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Introduction

Green hydrogen is viewed as a crucial element in decarbonisation strategies, especially for carbon-intensive sectors that are challenging to decarbonise with electricity alone, such as the steel industry and heavy-duty transportation. Beyond its role in reducing emissions, the development of a transnational hydrogen sector aligns with objectives like diversifying energy sources and securing international leadership in hydrogen technology. Fossil fuel companies are increasingly participating in the hydrogen sector as they seek to preserve their existing business models. In addition, the acceptance of blue hydrogen, which is produced from fossil gas with carbon capture and storage (CCS), is on the rise.

We interpret these developments as part of a post-fossil transformation dynamic. Firstly, there is a noticeable shift in the material foundation of the energy sector and many industrial production processes. Secondly, we are observing conflicts regarding the persistence of fossil structures, particularly concerning the use of fossil fuels as a basis for hydrogen production, as well as the ongoing use of existing infrastructures and resource-intensive, unsustainable production methods. Thirdly, there is contention over the extractivist characteristics of the global hydrogen economy, specifically regarding the extent to which countries in the Global South are being relegated to the role of energy suppliers. This arrangement raises several issues, including land appropriation, energy poverty, and socio-ecological challenges. The pivotal question is whether these countries' aspirations for green industrialisation through hydrogen will be realised, or if they will merely bear the socio-ecological costs of hydrogen production. We explore these contested and contradictory developments in the hydrogen economy through the lens of post-fossil extractivism.

In this study, we examine the political direction established for the development of the global hydrogen economy by focusing on the hydrogen strategies formulated by Germany, the EU, South Africa, Namibia, Argentina, and Chile. Methodologically, our analysis is grounded in a qualitative examination of these strategies, complemented by studies and observations of related political debates sourced from scientific literature, media reports, and webinars. In certain instances, we also incorporate insights from expert interviews (conducted in Germany, South Africa, and Namibia) and participant observations. By adopting a process-analytical approach, we analyse developments in each of these countries to discern overarching trends.

The concept of post-fossil extractivism

Although the concept of post-fossil extractivism (Tittor 2023) has predominantly been explored within the extractivism debate, in the following discussion, we aim to shift the focus towards emphasising the

significance of the post-fossil aspect. 'Post-fossil' does not merely denote a chronological 'after fossilism'; rather, it emphasizes - similar to the concepts of postcolonialism and post-Fordism - the continuities connected to previous social formations.[1] Drawing on Stuart Hall (2021[1996]: 308), the prefix 'post' signifies a 'a notion of a shift or a transition conceptualised as the re-configuration of a field, rather than as a movement of linear transcendence between two mutually exclusive states.' The term 'post' essentially describes an ongoing struggle with the preceding order, where the new is still defined by its differentiation from the old, yet there remains ambiguity about the precise nature of the new.

The concept of post-fossilism describes a transition in the material foundation away from fossil resources, though it remains ambiguous and contested regarding the concrete shape a post-fossil society will assume. The present situation is marked by political and economic conflicts where various strategic options are hotly debated (Kalt 2024a). The extent of transformation processes is still uncertain, as fossil interest groups and fossilist production and consumption patterns persist, largely due to entrenched political and economic power dynamics and established path dependencies. It is becoming evident that fossil structures have, so far, been only partially transformed and, in some instances, are even being maintained, while existing extractivist patterns are intensifying.

A contested formation with fossil continuities

Capitalism has long been underpinned by fossil structures, where the choice of energy sources not only shapes production and consumption norms but also influences broader social structures, as demonstrated by the historical links between fossil fuels and capitalism (Malm 2016) and fossil fuels and democracy (Mitchell 2013). Phasing out fossil fuels could, therefore, lead to profound shifts in societal structures. Unlike the previous decades of a predominantly unchallenged fossil-based capitalist economy, the imperative of reducing carbon emissions is now widely acknowledged in Europe - albeit primarily at an abstract level. Ecological crises, alongside associated social tensions and global political movements, are shaping government transformation strategies. Economic sector representatives are actively debating the pace, depth, and form of ecological transformation across various industries, advocating for the expansion of renewable energies, the creation of new 'green' business fields, and even the emergence of entire sectors, such as the 'low-carbon' hydrogen industry. This has led to a global race for technological leadership in these emerging fields, with new capital groups and competitive dynamics coming to the fore, potentially escalating into geo-economic conflicts. Governments are offering high investment incentives, funding initiatives, and tax breaks to

[1] According to regulation theory, a formation is a spatially and temporally specific manifestation of capitalism. While the theory primarily focuses on formations such as Fordism and post-Fordism, we apply the concept to analyse a fossil and post-fossil formations. In instances where it is still unclear or undecided whether a post-fossil formation is emerging, we refer to 'configuration' instead of 'formation'.

support climate policy measures, which spark discussions about the evolving role of the state in industrial policy (Alami and Dixon 2023). Simultaneously, environmental NGOs and companies or associations within the renewable energy sector are becoming increasingly influential stakeholders in these processes. At the core of these struggles is the transformation of fossil capitalism towards a post-fossil configuration. However, the scope of this transformation remains contested. It involves largely substituting raw materials and fuels to preserve existing production structures, everyday practices, and consumer habits.

Nevertheless, social forces resisting the fossil fuel phase-out are forming alliances and crafting counter-strategies. Fossil capital is focused on sustaining profitable accumulation strategies and avoiding the devaluation of existing infrastructures (Vezzoni 2024: 5). Furthermore, a significant social milieu with fossil mentalities has emerged that strongly opposes socio-ecological transformation (Schmelzer/Büttner 2024). Fossil-based thought patterns, lifestyles, and everyday practices continue to have a strong influence on societies in the Global North and are even spreading geographically (Brand and Wissen 2021). The Russian war on Ukraine and the evolving geopolitical landscape have reinforced a global fossil rollback trend, evident in the rapid construction of new liquefied natural gas (LNG) infrastructures in Europe and the oil boom in the US under the Biden administration and Trumps new turbo-fossilism. This fossil rollback is also reflected in international climate policy. Following intense negotiations at COP28 in Dubai, UN member states committed to pursuing a ‘transition away from fossil fuels’, though a definitive phase-out has only been decided for coal power without emissions capture (referred to as 'unabated coal'; see UNFCCC 2023: 5). A year later, at COP29 in Baku, this commitment was reversed, with no mention of it in the final text. In addition to expanding renewables and green technologies, fossil gas is being promoted as a ‘transition fuel’. Carbon capture and storage (CCS) and utilisation (CCU)[2] technologies are intended to facilitate the continued operation of oil and gas production. Moreover, new fossil fuel extraction projects continue to be initiated on a regular basis. The struggle over either reorienting or maintaining fossil structures is also evident regarding infrastructures. It is not just the flows but also the stocks of the fossil economy that are important. These infrastructures shape energy production and trade, mobility, heating, and energy use. However, maintaining these infrastructures often necessitates further construction. Transnational gas pipelines and overseas ports, for instance, not only create technological path dependencies but their continued use is also deeply intertwined with economic and geopolitical interests.

[2] Carbon emissions are either captured and stored underground (CCS) or utilised further (CCU). Although the technologies involved are featured in various roadmaps to achieve climate neutrality, the extent to which they will be employed in the future remains uncertain (Brad et al. 2024).

We observe that the dominant fossil formation is increasingly being called into question, accompanied by debates and conflicts over shifts in the material base of an emerging post-fossil formation. At the same time, it is also evident that fossil structures are, at best, only partially and gradually being transformed.

Extractivist patterns of fossil and post-fossil formations

For socio-ecological transformation dynamics in (semi-)peripheral countries, a key question is whether, and to what extent, the struggles about a post-fossil society will also change extractivist relations. The fossil economy of capitalist centres is fundamentally reliant on the extraction and importation of fossil fuels, metals, and minerals. As a result, other regions have been relegated to the role of raw material suppliers. This has led to massive transformation of landscapes, the destruction of livelihoods and ecosystems, and escalating pressure on natural resources (Svampa 2019). Historically, such a transnational division of labour has underpinned the formation of capitalist centers and their colonial territories, along with corresponding social and economic structures (Machado Aráoz 2013: 135). Extractivism is therefore a historical pattern intrinsically linked to colonialism and an important driver of ecosystem destruction due to the export of large quantities of raw materials. We classify activities as extractivist when large quantities of raw materials are extracted and primarily exported in minimally processed forms. These materials are then further processed in the industries of capitalist centers, which supports industrial development, or more recently, aids in the decarbonization of these industries, which is a necessary condition for the ongoing existence of these industries. A notable aspect of extractivism is the strongly asymmetrical role of various economies within global production networks (GPNs), where the knowledge-, capital-, and technology-intensive processing activities occur in isolated enclaves or in the capitalist centres that capture most of the added value. Therefore, conflicts over extractivism are not only about resource extraction and its severe socio-ecological impacts but also concern the spatial organization of GPNs and the distribution of value within GPNs (Dorn 2024). In sum, extractivism is not only an economic strategy of (semi-)peripheral societies for exporting raw materials but is also a structural component of North-South relations, heavily shaped by the capitalist centres.

Economic policies in the capitalist centres that respond to climate targets has intensified these dynamics. The academic debate on green extractivism (Dorn et al. 2022; Voskoboynik/Andreucci 2021) highlights that the increase in renewable energy and low-carbon technologies in the capitalist centres necessitates large quantities of lithium, rare earths, copper, and cobalt for electric mobility, storage technologies, solar cells, and wind turbines. Furthermore, solar and wind farms require large areas of land, which often leads to biodiversity loss and the displacement of communities or negative impacts

on their livelihood strategies (Scott/Smith 2017). In addition, the economic risks and social conflicts associated with extractive practices, as well as the destruction of nature, are externalised.

In the following discussion, we examine the development of the global hydrogen economy, considering it part of a struggle over the post-fossil transformation in the EU and Germany, as well as in South Africa, Namibia, Chile, and Argentina. We follow a heuristic approach based on the concept of post-fossil extractivism. First, we investigate the extent to which hydrogen strategies in the various cases exhibit a post-fossil bias. Do these strategies reflect aspects of a crisis of fossilism? Is there evidence of shifts away from the use of fossil resources, and to what extent are these shifts contested? Second, we explore whether and where fossil continuities become visible. Which fossil actors are gaining influence, and what fossil structures are being perpetuated? Third, we assess the extent to which these strategies are extractivist. How export-oriented are the envisioned hydrogen sectors, what transnational division of labour characterises them, and how are socio-ecological costs, risks and benefits distributed?

Same same but different? The development of a hydrogen economy in Germany and Europe

For several years, a hydrogen hype has engulfed Germany and Europe. While recently the hype has weakened substantially, still billions of euros in public funds have been invested in technology development, feasibility studies, and project development undertaken by large corporations, alongside the construction of new infrastructures. The move towards green hydrogen represents, at least in part, a departure from the fossil fuel paradigm.

Contested innovations and fossil continuities

In Germany and throughout the EU, hydrogen-based strategies are being presented as responses to various crisis dynamics. First and foremost, the climate crisis is intensifying the pressure for transformation. With the goal of achieving climate neutrality, sectors that are challenging to electrify, such as the steel industry, construction industry, and heavy-duty transport, are increasingly coming under focus. Additionally, declining economic growth and increasing international competition are enhancing the appeal of developing new ‘green’ fields of accumulation, which also fosters the emergence of new ‘green’ capital groups (Haas et al. 2022: 248ff.). The economic ramifications of the pandemic have further increased the willingness to promote ‘green’ growth strategies. Finally, geopolitical conflicts are contributing to the objective of diversifying sources of affordable energy and have accelerated the race for hydrogen (Thiele 2024). These dynamics not only reflect the growing

contradictions within the fossil formation but also encourage shifts towards post-fossilism and the establishment of a 'green' hydrogen economy.

However, the dynamics of the post-fossil transformation in Europe and the orientation of the hydrogen economy are contested. From the outset, the development of hydrogen strategies has been accompanied by extensive lobbying from the fossil gas industry. Despite its progressive image, the hydrogen sector has thus far remained predominantly fossil-based; approximately 99 per cent of hydrogen is produced from fossil fuels, mainly fossil gas, and is known as 'grey' hydrogen (IEA 2022: 71). The fossil gas industry has advocated for the acceptance of 'blue' hydrogen, i.e. grey hydrogen with carbon capture and storage (CCS) (Corporate Europe Observatory 2020). In Germany, this lobbying strategy was initially not very successful, as evidenced by the German National Hydrogen Strategy (NWS) adopted in 2020 which prioritised the promotion of 'green' hydrogen based on renewable energies, while accepting the use of blue hydrogen only on a transitional basis (BMWi 2020: 3; Deutsche Umwelthilfe 2020). However, lobbying efforts were more successful at the EU level. The European Commission's hydrogen strategy refers to the use of 'clean' or 'low-carbon' hydrogen which can include blue hydrogen and pink hydrogen, i.e. hydrogen made with nuclear energy. This leaves the material basis of hydrogen production more flexible and reflects the diverse interests of EU member states (European Commission 2020). Nevertheless, the decarbonisation of the energy supply and hard-to-abate industries was a primary objective of both the German and EU hydrogen strategies. The development of hydrogen technologies and the emergence of a comprehensive hydrogen production network creates new growth opportunities for German and European companies. The German government is particularly keen for Germany to become a leading provider of hydrogen technologies (BMWK 2023: 4). Another goal is to enhance energy security by reducing dependence on oil and gas imports. Simultaneously, both the EU and Germany promote the use of hydrogen, especially in the industrial sector, such as in steel and ammonia production, as well as in transport areas that are difficult to electrify (BMWi 2020; European Commission 2020).

However, this 'green' orientation has gradually been weakened. The revision of the National Hydrogen Strategy (NWS) in 2023, following prolonged internal government disputes (BMWK 2023; Polansky 2023), along with the EU's REPowerEU programme (European Commission 2022), adopted in response to the war in Ukraine, accelerated market development and sought to increase domestic and European production volumes. Simultaneously, the planned applications for hydrogen were expanded to encompass a broader diffusion path, including private automobiles, power generation, and heating in the building sector (BMWK 2023: 21ff.) - despite this being controversial both economically and ecologically as electrification is a more efficient and cheaper option for decarbonization in these sectors (Liebreich 2023).

Consequently, expanding the areas of application has increased interest in moving away from a sole focus on green hydrogen. Given that green hydrogen is costly and scarce and might not be available in sufficient quantities to support rapid market development, it is argued that a 'technology-open' approach, that accepts blue hydrogen as well, should be adopted (BMWK 2023: 4). While the early version of the German NWS clearly prioritised green hydrogen and 'ambitious standards for certification and sustainability' (BMWi 2020: 12), the updated version is more ambiguous regarding the choice between green or blue hydrogen (BMWK 2023: 9). Although only green hydrogen receives direct funding, greater importance is now placed on blue hydrogen, including explicit references to the German government's carbon management strategy (see Brad et al. 2024) and hydrogen imports from Norway (BMWK 2023: 9, 14). Due to the potential for storing carbon, blue hydrogen is classified as 'low-carbon' (BMWK 2024: 4). However, this classification is misleading, as the carbon footprint of blue hydrogen has been calculated to exceed that of natural gas and coal combustion (Howarth/Jacobson 2021: 9).[3] Moreover, the German government is supporting the expansion of gas infrastructure by constructing a Europe-wide pipeline network, the 'hydrogen backbone', and import terminals for hydrogen. The plan includes continuing to use or repurpose the existing transport infrastructure for fossil gas (BMWi 2020: 7). With current technology, however, transporting hydrogen through these pipelines requires the addition of natural gas, a process known as blending (Eberhardt 2023).

In recent years, there has been a clear shift in hydrogen strategies in favour of fossil fuels. In the struggle over a post-fossil configuration, forces advocating for minimal change in energy sources, infrastructures, and production and consumption norms are increasingly setting the agenda. These policy changes reflect the interests and growing influence of domestic industries in leading the market for 'green' fields of accumulation, as well as the strong political sway of fossil capital. At the same time, even a focus on green hydrogen is accompanied by certain continuities of fossil structures.

Same old story: Extractivist orientation in the hydrogen sector

In contrast to these shifts, the EU's and, more significantly, Germany's orientation towards imports has remained unchanged in the recent updates of hydrogen strategies. Given the limited hydrogen production capacities in Germany, up to 70 per cent of hydrogen is set to be imported (BMWK 2024: 10; Meier 2024), making Germany the largest hydrogen importer in Europe. German companies are supported by the NWS while the import strategy adopted by the federal government in July 2024 aims to promote Germany's international leadership in hydrogen technologies (BMWK 2023: 7f.; BMWK 2024). A variety of policy instruments and initiatives aim at establishing export-oriented production

[3] It is worth noting that a significant proportion of the 'green' hydrogen projects currently planned (ranging from 21 to 85 percent) exceed the EU criteria for the carbon intensity of green hydrogen, particularly when transportation is included (de Kleijne et al. 2024).

sites in the Global South. These include the mapping of the African continent based on the potential profitability of hydrogen production as part of the *H2-Atlas*, the *H2Global* financing mechanism for hydrogen procurement, and the establishment of new hydrogen partnerships. These initiatives are supported by development cooperation actors such as the Gesellschaft für Internationale Zusammenarbeit (GIZ), along with substantial public funding (BMWi 2020: 3). So far, public financing and tax exemption are setting incentives for private capital and derisk private sector investments, as these have been perceived as highly risky and not particularly profitable. But this is putting the risks on the shoulders of the taxpayers and especially in cases, where huge hydrogen projects fail, leaving states with debt problems (Gabor/Sylla 2023). Overall, the import-oriented strategies favour the development of strongly export-oriented hydrogen sectors in the economies of the Global South, driven by financial incentives and asymmetric governance initiatives that take shape in the context of global economic dependencies.

Although bilateral cooperation agreements are referred to as 'partnerships on equal terms' (BMWK 2023: 11), they serve the primary goal of securing the energy supply for the German economy and supporting the overseas operations of German companies. The resources necessary for hydrogen production are provided by the Global South and become part of the accumulation strategies of European companies. This leads to the externalization of environmental risks and socio-ecological conflicts, such as the destruction of natural habitats and the loss of land and livelihoods of communities (Tunn et al. 2024). While these adverse effects are noted in political debates and are acknowledged in Germany's hydrogen strategy (BMWK 2023: 13), discussions about sustainability and certification standards do not fundamentally challenge the extractivist nature of Europe's and Germany's hydrogen strategies.

The development of export-oriented hydrogen sectors in Africa and Latin America

The development of the import-oriented European hydrogen economy impacts the shape of hydrogen sectors in the Global South. These sectors are either directly initiated or heavily supported by the German government and organisations such as the GIZ. Disputes about the orientation of local hydrogen sectors illustate the tension between overcoming or perpetuating fossil dependencies and reflect the extractivist focus of Europe's import-oriented strategies. The specific design and extractivist nature of these hydrogen sectors vary based on national economic conditions and power relations.

Between moments of crisis, post-fossil transformation and fossil continuities

In the future hydrogen export locations in the Global South, a diverse constellation of crises forms the context for the struggles over the orientation of the hydrogen sectors, in which the balance between

ecological transformation and fossil continuities is determined. In Chile, for example, water scarcity, environmental pollution, and climate protection were significant factors in the mass protests of 2019, often referred to as the country's crisis year. Chile is now imposing taxes on large fossil thermal power plants and plans to phase out coal power plants (Lehmann/Irigoyen Rios 2024); by 2030, 80 per cent of power generation aims to come from renewable sources. Concurrently, the government is focusing on the production of green hydrogen, which will be used for producing synthetic fuels (e-fuels), among other applications. Porsche is collaborating with Siemens Energy to test the production of this type of fuel for the European market, which could potentially delay the phase-out of combustion engines in Europe.

While the post-fossil configuration in Chile is characterised by a clear path of ecological modernisation, fossil continuities are more pronounced in Argentina. Since 2018, and especially under President Milei's turn to the extreme right (Boris/Eser 2024), various dynamics of the ecological crisis - such as droughts, floods, and soil erosion - have had little influence on political decisions. The global climate crisis is largely perceived as an opportunity to export biomass, lithium, or hydrogen and to legitimise the intensification of extractivist strategies (Dorn et al. 2022). In the hydrogen sector, there is competition between social forces aiming to produce green hydrogen and those supporting hydrogen production based on fossil gas, biomass, and nuclear energy (Dorn 2024). For blue hydrogen, the large-scale oil and gas extraction in Vaca Muerta[4], which has been criticised for years, will continue to operate. Reservations about grey and blue (and therefore fossil) hydrogen have been dismissed in political debates by price arguments and claims that existing fossil infrastructures can be utilised. Fossil energy companies, such as the Argentine state-owned YPF, and automotive firms like Toyota, have initiated hydrogen projects (Kazimierski 2021: 111). Toyota is relying on Vaca Muerta to produce hydrogen for the export of e-fuels (Sanguinetti 2020).

In contrast, the post-fossil configuration in Namibia is defined by a focus on green hydrogen. The Hyphen megaproject, led by the German energy company Enertrag, aims to produce large quantities of green hydrogen for export to Europe. While there is no discussion of blue hydrogen in Namibia, fossil fuels still likely play a key role in the post-fossil transformation. The Namibian government is considering the exploration of new oil and gas deposits with the intention of using the foreign currency revenues to fund its equity stakes in the Hyphen project (Observations Hydrogen Summit in Cape Town, 17.10.2023).

[4] Vaca Muerta is a natural gas and oil field in southern Argentina where several European companies, such as BP, Total, and Wintershall, are involved in large-scale fracking. The development of Vaca Muerta, which is primarily situated on land claimed by the indigenous Mapuche people, has long been touted as the solution to overcoming Argentina's economic and energy crisis (see Cabrera Christiansen/Cané 2020).

In South Africa, a state-supported form of fossil capitalism built around coal known as the 'minerals-energy complex' has played a dominant role since the apartheid era (Fine/Rustomjee 1996). For a long time, this coal-based energy system, along with the state-owned electricity supplier Eskom and the petrochemical giant Sasol, met the energy needs of the mining sector and industry at low prices. However, this fossil-fuel configuration is now in crisis. Unreliable power supply, rising prices, energy poverty, and South Africa's status as a major carbon emitter are increasing the pressure for transformation. The government plans to reduce the share of coal in the electricity mix from the current 91 per cent to 59 per cent by 2030 and aims to achieve climate neutrality by 2050 (DMRE 2019). Concurrently, the contours of a green capitalist project are emerging, driven by the market expansion of renewable energies and plans to decarbonise export goods, especially in light of climate tariffs in the EU (Müller/Claar 2021). The development of the hydrogen sector is also being discussed in this context. Although the discussions primarily focus on green hydrogen, grey and blue hydrogen will also likely play significant roles. In parts of the South African hydrogen strategy, blue hydrogen is presented as a transitional solution towards establishing green hydrogen (Kalt et al. 2023: 11f.; DSI 2021: 63), while Sasol uses the same argument and highlights the lower costs associated with producing blue hydrogen (Sasol 2021: 12). Some state apparatuses and trade unions support this approach. For instance, in June 2023, the Minister of Mineral Resources and Energy refused to sign international contracts for the production of green hydrogen.

In sum, contrasting with the promise of green development through a hydrogen economy, fossil continuities are also apparent in the orientation of hydrogen sectors in countries of the Global South. This is particularly evident in the shift towards blue hydrogen, the influence of fossil capital groups, the use of fossil infrastructures, and the combination of green hydrogen with applications in fossil-based fields. Two trends can be discerned. Firstly, hydrogen is not always as green as initially envisioned. Fossil capital groups are attempting to portray blue hydrogen as low-carbon – a strategy that has already been wholly successful in Argentina. Secondly, fossil infrastructures and fossil-based production and consumption models will likely continue to persist.

Between hopes for green industrialisation and deepening extractivist structures

The emerging hydrogen sectors in all four of the aforementioned countries exhibit a clear extractivist orientation. They are all strongly export-oriented and significantly influenced by Europe's import-driven hydrogen strategies. In each case, extractivism clearly manifests as a global system of exploitation with a transnational division of labour. Within global production networks (GPNs), countries in the Global South frequently assume the role of exporters of unprocessed or minimally processed goods, such as hydrogen. The Chilean hydrogen strategy aims for an export share of 60 - 70

per cent by 2035 (Ministry of Energy of Chile/McKinsey & Co 2021: 15), while the Argentinian strategy targets an even higher export share of 80 per cent (Secretaría de Asuntos Estratégicos 2023: 24, 28). Their dependent positions in the global economy significantly complicate the pursuit of industrial policies focused on the domestic market for countries in the (semi-)periphery. This dynamic is exacerbated by funding schemes from Global North countries that primarily finance export-oriented hydrogen infrastructures. For instance, in Namibia, the development of Hyphen largely relies on international loans and investments. These not only directly influence the choice between a focus on the domestic market or on export but also reinforce dynamics of financial subordination (Kvangraven et al. 2021). In addition, the German government plays a key role in shaping the Namibian hydrogen economy, influencing its development towards an export-oriented model (Kalvelage/Walker 2024). Critics of the project fear the emergence of an enclave economy with limited long-term employment prospects for the local population, minimal economic spillover effects, and additional debt for the Namibian state (Tunn et al. 2025).

In the countries we focus on, certain state apparatuses, along with specific business groups and trade unions, are striving to counteract the extractivist tendencies within their national hydrogen strategies by fostering domestic industries and green value chains. Whether these efforts will succeed remains uncertain. For instance, Argentina's hydrogen strategy highlights that hydrogen not only serves the purpose of reducing emissions but should also facilitate the "development of industrial and technological capacities" (Secretaría de Asuntos Estratégicos 2023: 33f.) through the creation of domestic production facilities. The strategy emphasises the generation of added value and developmental effects, promising over 80,000 jobs in the hydrogen sector by 2050 (ibid.: 41). Several state bodies have indeed concentrated on an active industrial policy to complement the expansion of renewable energies and the hydrogen sector (Aruguete 2024). However, such proposals, which are aligned with long-term political objectives and planning, have become improbable under President Milei.

In South Africa, too, certain business groups and parts of the state are focused on enhancing domestic value generation in the emerging hydrogen economy, with hopes of initiating a push for green industrialisation. In 2023, South Africa adopted a hydrogen industrial policy strategy aimed at promoting industrial clusters and forging new industrial linkages. This strategy encompasses the establishment of solar and wind plants and electrolysers upstream, as well as the production of fuel cells, green fertilisers, and green steel downstream. Both South Africa and Chile are seeking to deploy hydrogen within their domestic mining sectors. This approach can be viewed either as an attempt to greenwash a fundamentally extractivist economic model or as an industrial policy initiative aimed at achieving domestic decarbonisation and creating added value. However, building domestic value

chains presents challenges, as there are conflicts of interest with hydrogen importers and technology exporters from the Global North. For example, the Just Energy Transition Partnership with South Africa, whereby G7 countries provide funding for the South African energy transition, plans to allocate half of the funds dedicated to green hydrogen to constructing export infrastructure and a third to producing export goods such as green hydrogen and green ammonia. Yet, there are minimal funds allocated for establishing domestic industrial value chains, such as through the production of green steel or fuel cells, or for supporting technical and vocational education and training programmes (Kalt et al. 2023: 309).

The externalisation of socio-ecological costs and conflicts to hydrogen production zones is a significant consequence of extractivism across all four countries, primarily due to the high demand for land, water, and energy by megaprojects. In Namibia, for instance, extensive land use in the biodiversity-rich Tsau-‖Khaeb National Park poses a threat to the local flora and fauna. Additionally, desalination plants could negatively impact marine ecosystems and the local fishing industry (Tunn et al. 2025). Furthermore, there is a notable lack of participation from civil society and affected communities, leading to social discontent and protests (The Namibian 2023).

Similar criticism arises from Chile and Argentina. In Argentina, for instance, the indigenous Mapuche people are protesting against the construction of a hydrogen project on their land in the province of Rio Negro. They assert that, in line with ILO Convention 169, the project requires their prior, free, and informed consent. Despite this requirement not being met, the Australian company Fortescue (Lastra/Ramos 2022) has already initiated the project. In Chile, civil society actors express concerns that large-scale hydrogen projects in the Atacama Desert - one of the driest places on Earth - could worsen the existing water scarcity and severely impact sensitive ecosystems and local communities. Additionally, many hydrogen projects are planned in regions already deemed ‘sacrifice zones’, as they are impaired by mining and thermal power plants (Paz Aedo 2023). In the Magallanes Region, where a climate and environmental emergency was declared in 2020, a citizens’ initiative is advocating a moratorium on hydrogen projects. The principal criticisms highlight the high consumption of water and land, as well as the intended use of scarce renewable energies for producing hydrogen and e-fuels (Open Letter 2023).

Overall, it is evident that the hydrogen hype could result in megaprojects that use large swathes of land, substantial amounts of water, and scarce energy resources, thereby threatening livelihoods and causing displacement. In South Africa and Namibia, the predominantly export-oriented green hydrogen strategies have faced criticism for being neocolonial (Kalt 2024b). In Chile and Argentina, the export focus is perceived as extractivist. As an alternative, activists have advocated for an energy system that is oriented towards local needs (Cabaña Alvear 2023; Open Letter 2023). However, two

important insights emerge from the development dynamics of the hydrogen sectors in the four countries analysed. First, the extent to which fossil continuities will persist in the post-fossil hydrogen economies in the Global South remains contested. Second, there is ongoing debate about how extractivist the overall orientation truly is, or whether value can be generated domestically to a significant degree.

Conclusion

Developing the global hydrogen economy is a complex and contested process. Through the analytical lens of post-fossilism and post-fossil extractivism, three dimensions become apparent. First, there is a struggle, both in Europe and in the Global South, to transition away from the fossil formation. This struggle occurs within the context of a deepening crisis of fossilism, with green hydrogen playing a crucial role. The goal is to use green hydrogen to decarbonise hard-to-abate sectors, such as the steel industry or heavy-duty transport. These strategies go beyond merely expanding renewable energies and take on a more comprehensive industrial policy approach. This should also be viewed in the context of global competition for 'green' fields of accumulation. However, the specific shape of these transformation strategies varies by region. While stronger efforts to transform the material foundation of the economy can be observed in some regions such as the EU, Germany, Chile, and South Africa, these efforts are predominantly rhetorical in Argentina.

Second, even in cases where there is evidence of more extensive transformation efforts, the continuities of fossil actors, exploitation strategies, and infrastructures are still apparent. These dynamics vary from case to case. Nonetheless, we observe two key aspects where elements of fossilism are being reproduced. On the one hand, hydrogen is expected to be produced from fossil gas in the foreseeable future. This was the initial intention in Argentina, while in the EU and Germany a shift has taken place towards accepting blue hydrogen. Similarly, fossil capital in South Africa and Argentina is vigorously lobbying for the acceptance of blue hydrogen. On the other hand, green hydrogen retains significant fossil elements. Fossil capital is actively driving and shaping the development of the global hydrogen economy under the guise of a green image. Drawing on the work of Andreas Malm, Brett Christophers (2022: 153ff.) speak not only about fossil capital but also about 'fossilised' capital. speaks not only of fossil capital, but of 'fossilized' capital. This is because, even if they invest in renewable energy, these corporations will remain fossil actors for the foreseeable future due to their own functional logic and profit orientation. This favours the continuation of fossil infrastructures, such as gas pipelines, which are not only a prerequisite for the global transport of green hydrogen, but also protect existing infrastructure operators from having to write off stranded assets.

Furthermore, the use of green hydrogen in areas such as private transportation or mining projects risks perpetuating energy- and resource-intensive patterns of fossil production and consumption. The hydrogen economy is often presented as a promise to replace fossil inputs with 'green' energy through technical solutions, without necessitating changes to the consumption patterns, infrastructures, and exploitative relations characteristic of the fossil era. In this context, hydrogen strategies primarily focus on substituting fossil fuels rather than achieving a more profound socio-ecological transformation. The ongoing struggle between, on the one hand, the extent of socio-ecological transformation and, on the other, the continuation of existing consumption patterns, infrastructures, and habits, will determine the degree to which fossilism persists in the post-fossil age.

Third, extractivist dynamics within the global hydrogen economy are likely to persist in the post-fossil formation. Once again, the strategy of influential interest groups in the capitalist centres is becoming increasingly evident, as they push economies in the Global South into the role of raw material and energy suppliers, thereby perpetuating postcolonial power dynamics and extractivist exploitation relationships. In response, actors in these export locations are grappling with the challenge of determining how fossil-dependent and export-oriented the emerging domestic hydrogen economy will be.

Within the realm of the hydrogen economy, the post-fossil configuration is contested across three dimensions: the shift away from fossil fuels, fossil continuities, and the reproduction of extractivist dynamics. It is precisely this contentious character that underscores the analytical value of the concept of a post-fossil configuration. Rather than providing a definitive diagnosis that fossilism will persist or adopting the optimistic view that we are already in a transitional phase where fossilism is a relic of the past, the concept of the post-fossil configuration brings to light the conflicts, contradictions, ambivalences, and gradual changes that occur - even beyond specific areas like the hydrogen economy. Other important areas, where the persistence of fossilism is currently contested include global agriculture and the food regime, as well as the transport sector, regarding the role of air travel, private automobility versus public transport and the question which type of fuels these modes of transport use.

This makes it clear that post-fossil transformation processes do not follow a linear path and allows us to concentrate on the social struggles and power dynamics that shape them. Since these dynamics cannot be understood in national containers, it is crucial to examine how north-south relations are (re)configured in the context of post-fossil developments. This raises the important question of whether these developments overcome or renew old patterns of extractivism.

Politically and strategically, the lens of post-fossilism highlights a crucial aspect of the struggles over socio-ecological transformation: current efforts to reduce carbon emissions are embedded within, and structured by, the logics and constraints of capital accumulation and global competition, in a world market characterised by colonial continuities and transnational exploitative relations. These conditions constrain the potential to overcome fossilism and perpetuate the exploitation of people and nature. Extensive decarbonisation is only feasible within the context of a fundamental socio-ecological transformation, which cannot be accomplished without profound systemic changes.

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