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More Hype than Hope. Hydrogen Policy, Projects and Environmental Conflicts

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More Hype than Hope. Hydrogen Policy, Projects and Environmental Conflicts*

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Abstract

Hydrogen plays a central role in policies aimed at decarbonisation, energy autonomy, industrial competitiveness, and development. This study analyses hydrogen policies, revealing how their design may undermine just transition goals and instead reinforce existing spatial inequalities. Drawing on International Energy Agency (IEA) data on clean hydrogen projects, investment trends are examined. A spatial analysis combining project data with environmental conflicts, sourced from the Atlas of Environmental Justice, reveals a concentration of hydrogen projects in areas affected by ecological degradation and socio-environmental disparities, raising concerns about the socio-ecological distributive effects. Hydrogen development appears largely driven by market logics and seems unlikely to meet climate targets.

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1 Introduction

In the aftermath of the COVID-19 crisis and amid growing geopolitical tensions and concerns about energy security, hydrogen has re-emerged in policy discourses as a multipurpose energy vector, capable of enhancing energy autonomy, supporting decarbonization, and maintaining industrial competitiveness. The convergence of climate and geopolitical objectives has renewed attention toward industrial policy in managing the challenges of decarbonization and energy security. Green New Deal proposals and broader national green industrial strategies have gained increasing relevance, both in institutional agendas and activist discourses (Klein, 2020; Pianta & Lucchese, 2020; Rodrik, 2014). Hydrogen is central to many national Net-Zero strategies, particularly for the European Union. As a clean energy vector, it supports decarbonization not producing emissions when converted into electricity or burned, and being a feedstock for hard-to-abate industries (IEA, 2023). Although it is currently produced from fossil sources, it can also be generated from water and electricity, offering potential for energy independence and, when the latter is renewable, decarbonisation. The push for hydrogen is increasingly driven by geopolitical goals of energy independence and green tech competition, particularly for the EU, which is attempting to regain leadership in clean technologies, after China's rise as dominant player and the fragmentation of U.S. policy efforts (Van Renssen, 2020). Hydrogen, unlike electricity, can be traded globally, in its pure form or as a derivative compound, such as ammonia (Fakhreddine et al., 2025) and its diffusion could contribute to rebalance the energy geopolitical arena (Falcone et al., 2021; IRENA, 2022; Van de Graaf et al., 2020). The current hydrogen consumption is not related to clean energy. In 2023, it reached 97 million tonnes, almost entirely produced by fossil sources. Production happens on-site mainly for chemical industries and oil refining and, in 2023, less than 1% was used for new applications in the energy and mobility sectors (IEA, 2024). Despite ambitious policy declarations, the shift toward clean hydrogen remains marginal: only 3.4 Mtpa of low-carbon hydrogen capacity reached final investment decision in 2023, equivalent to 3.5% of total global hydrogen demand. Given the low-state of development of green hydrogen production, a reality check is required to ensure that policy designs and investments in hydrogen are effectively targeted and grounded in feasibility (Johnson et al., 2025). Moreover, the fossil-based production of hydrogen remains the dominant, cheaper alternative (IEA, 2024). The actual scale of hydrogen trade is negligible: in Europe, only 29,767 tonnes were traded in 2023 (European Hydrogen Observatory), accounting for 0.03% of global production. Still, hydrogen strategies are very ambitious. The EU's Net-Zero Industry Act aims to import up to 10 Mt of low-carbon hydrogen by 2030, outsourcing production to countries where renewable energy is cheaper, while reinforcing old North–South hierarchies and dynamics of exploitation (Fladvad, 2023; Müller et al., 2022). From the production perspective, green hydrogen is highly resource-intensive. Water electrolysis requires vast amounts of water, energy and land when powered by renewable energy (Johnson et al., 2025). These conditions entail significant trade-offs, especially in regions with limited renewable capacity or water stress (Kakoulaki et al., 2021).

In this contribution, we shed light on the contradictions arising from hydrogen policies, whose design and implementation may not reflect the stated goal of a just transition and may instead amplify existing spatial inequalities. The political economy of hydrogen is marked by an inherent ambiguity toward the continuation of the fossil economy. On the one hand, policies promote "low-carbon" hydrogen produced from fossil fuels with carbon capture and storage (CCS), fostering investments in gas infrastructures. On the other hand, public support is also directed toward green hydrogen for refineries, meant to reduce emissions in fossil fuel production itself. In contrast, scientific evidence underlines that a complete phase-out of fossil fuels is essential for mitigating climate change (IPCC, 2022; Trout et al., 2022), despite the the economic losses it generates (Semieniuk et al., 2022). Therefore, policy intervention is essential to govern and socially redistribute the losses and gains of this transition (Healy & Barry, 2017).

Ambiguous policies in hydrogen plans sustain, rather than dismantle, the fossil fuel regime, increasing the level of carbon lock-in (Sovacool et al., 2019; Szabo, 2021). The promotion of hydrogen is part of a broader techno-enthusiasm. The "hydrogen myth", or the idea of a future where water powers the economy through hydrogen, has recurred throughout the last century. It emerged clearly in the early 2000s alongside peak oil narratives, but was largely dismissed with the shale gas revolution. Today, it is resurfacing, driven by growing concerns over energy autonomy. This reinforces the appeal to forms of technological fixes, often used to delay concrete climate action (Lamb et al., 2020; Sovacool & Brossmann, 2010; Szabo, 2022). Most policies show a bias toward minimising risk for private capital. Particularly EU green industrial strategies rely on de-risking mechanisms, as tax credits and equity loans, favouring public-private partnerships without strong milestones or conditionalities (Gabor, 2023). Although well-designed industrial policies would jointly pursue social and environmental goals, this institutional framework, appears to be more aligned with the priorities of financial investors and incumbent industries than with the principles of a just transition (Dosi et al., 2025). The symbolic and strategic value of hydrogen is growing. Therefore, a critical analysis of policy designs, implementations and implications is required. Despite the necessity of models of hope for societal transformation (Freeman, 1992), the optimistic narratives surrounding hydrogen may easily devolve into forms of technological solutionism. The current race for energy technologies appears increasingly shaped by existing power structures. Hydrogen is being absorbed into an eco-modernist agenda that promises climate mitigation without altering the foundational structures of production, consumption, and resource extraction (Haas et al., 2022). In this sense, hydrogen appears to reinforce the status quo, rather than to drive systemic change. This position is supported by the advocacy of technological neutrality. By contrasting the symbolic narratives of hydrogen as a solution with the material constraints and political interests that shape its deployment, this contribution highlights the gap between the "hydrogen hope" as a model of transformative change and the "hydrogen hype" that surrounds hydrogen as a technocratic solution.

The paper is structured as follows. First, an overview of green industrial policies is provided, followed by an examination of hydrogen strategies across European, national, and international contexts 2. Second, the role of incumbent industries, in Section 3, and the environmental justice considerations, in Section 4, are discussed. This translates empirically on the analysis of hydrogen investment projects looking at the IEA data. To explore the contradicting implications of hydrogen polices, we spatially match projects' location with areas crossed by environmental conflict, using EJAtlas data. Data and methodology are described in Section 5 and empirical evidences in Section 6. Results reveal a pattern of co-location between hydrogen projects and environmentally degraded areas, as indicated by the presence of an environmental conflict. Hydrogen projects, when located in already abandoned places, may legitimize the left-behind nature of such places (C. Bez & Virgillito, 2024) rather than representing opportunities for restorative justice. The study concludes by advocating for a place-based, inclusive regional governance framework in Section 7.

2 Green industrial policy and the hydrogen race

Green New Deal initiatives, especially in the United States and Europe seek environmental sustainability and inclusive growth, promoting a comprehensive socio-technical transition by integrating environmental policy with industrial strategies and financial instruments. These frameworks are designed to support the decarbonization of the economy while fostering growth, employment opportunities, and social inclusion. A central feature of these initiatives is the emphasis on the role of technological innovation as the predominant element of the low-carbon transition. Although low-carbon technologies are an essential component, the scientific community is debating whether the current policy frameworks over-rely on technological solutions to address systemic challenges (Verbruggen et al., 2025). Critics argue that this reliance may risk minimising other critical dimensions of the transition, such as increasing raw material dependence, skill development, and equity considerations. A more balanced approach would integrate technological advancement with structural reforms in governance, labour markets, and consumption patterns to ensure a just and effective transition (Bloomfield & Steward, 2020; Mastini et al., 2021; Vezzoni, 2023). Green industrial policy is mainly directed to attract investment from the private sector by risk minimisation tools such as loans, equity shares, tax credits, and public-private partnerships. Conversely, industrial policy in the field of national security follows a distinct approach. As noted by Gabor (2023), a clear distinction exists between the CHIPS Act, focused on direct control of semiconductor supply chains the Inflation Reduction Act (IRA) derisking green investments. The first represents a state-led model of industrial upgrading, where traditional risk-mitigation instruments such as grants and tax credits are supplemented by mechanisms that enforce investments' effectiveness, such as operational milestones, periodic due diligence, and restrictions on practices like share buybacks. These enforcement mechanisms are absent in green industrial policy. The EU embraces an even more radical de-risking approach, consistently with its macro-financial governance framework. Public funds are directed towards private actors or channelled through public-private partnerships, without oversight or performance enforcement instruments in place. The EU's Net-Zero Industry Act calculates the volume of public investment required to attract sufficient private capital for clean energy projects, using what is named *de-risking multiplier*. This metric assumes a direct and immediate link between capital mobilization and environmental targets, calculating the amount of public funds to attract capital and translating it directly into emission reduction gains (Gabor, 2023). The implications of this policy design both for decarbonization and inequality do not seem positive but remains uncertain. However, some models suggest that the distributional effects are more pronounced for market-based instruments such as carbon taxes than for financial instruments like green bonds (Monasterolo et al., 2022).

Furthermore, as (Nelson, 1986, p. 187) argues, the challenge of industrial policy is to balance private and public aspects:

> From one point of view, the job of institutional design is to get an appropriate balance of the private and public aspects of technology, enough private incentive to spur innovation, and enough publicness to facilitate wide use. But from another point of view, the job is somehow to get the best of both worlds, by establishing and preserving property rights where profit incentives are most effective in stimulating action and where the costs of keeping things proprietary are not high, making public those aspects of technology where the advantages of open access are greatest.

In the realm of technological innovation in the energy sector, particularly in renewable energy, the initial top-down, regulation-driven approach has increasingly given way to a strategy that focuses on investment incentives and risk mitigation for the private sector (Herman & Sovacool, 2024). The same applies to hydrogen. Given the failure of previous policy (see Box 2.2), the 'stick' has been replaced with the 'carrot' market-oriented instruments. In contrast, several scholars have proposed different modes of public involvement to foster renewable energy. One perspective argues that the state should directly invest in, develop, and manage renewable infrastructure, to prevent the privatization of profits and the socialization of risks (Gabor, 2023; Mazzucato et al., 2024). A complementary view suggests that public intervention is necessary not because renewables are too profitable, but because their expected returns are too low to attract adequate private capital (Christophers, 2024). The structure of ownership also appears to influence the pace and direction of renewable technology adoption: evidence shows that state-owned utilities are more likely to invest in renewables than privately held ones (Steffen et al., 2022).

Blue and Green Hydrogen

Green hydrogen refers to hydrogen produced through water electrolysis. While the term is sometimes used interchangeably with renewable hydrogen, the latter more precisely highlights the origin of the electricity used. Due to the energy intensity of the electrolysis process, the overall climate benefits of green hydrogen can only be realized if the electricity is sourced from renewables. When the process is powered by grid electricity, which it is still largely dependent on coal and natural gas, the net reduction in emissions would be so low that directly using natural gas would be preferable (Bhandari et al., 2014). Green hydrogen production is highly capital-intensive and currently remains significantly more expensive than fossil-based alternatives. The dominant method for conventional hydrogen production is Steam Methane Reforming (SMR), which yields what is commonly referred to as grey hydrogen. This pathway is the most cost-competitive, with the majority of its production cost being variable and primarily influenced by natural gas prices. Blue hydrogen refers to hydrogen produced from fossil fuels in combination with end-of-pipe carbon capture and storage (CCS) technologies (IEA, 2023). It is classified as a form of clean or low-emission hydrogen within policy frameworks and is generally regarded as a transitional option toward the full-scale deployment of green hydrogen. The environmental benefits of blue hydrogen are limited: CO_2 emissions are only 9–12% lower than those of grey hydrogen, while methane emissions can be higher when natural gas is used to power the energy-intensive CCS process. Moreover, the approach relies on the unproven assumption of permanent CO_2 storage (Howarth & Jacobson, 2021). However other studies find environmental positive effect of blue hydrogen under certain conditions (Bauer et al., 2022).

2.1 EU Hydrogen Policy

The EU Hydrogen Strategy, first published in 2020 and updated in 2022, finances €18.8 billion for 2021–2027, primarily through the Recovery and Resilience Facility and the Innovation Fund. REPowerEU, introduced in response to the energy crisis following the Russian-Ukraine war, significantly raised the EU's ambition, targeting 10 Mt of domestic renewable hydrogen production and 10 Mt of imports by 2030, doubling the previous targets. This is expected to drive the deployment of 65–100 GW of electrolysis capacity and to raise EU electrolyser manufacturing capacity to 17.5 GW per year by 2030. The program identifies supply corridors for hydrogen in Europe, as promoted by the European Clean Hydrogen Alliance (European Commission, 2014). The European Court of Auditors has criticised the Commission for setting overly ambitious targets without conducting adequate analysis or securing binding national commitments. This has resulted in fragmented implementation and reduced feasibility of achieving the 2030 goals. (ECA, 2024). The EU strategy focus on the development of Hydrogen Valleys (see Box 2.1.1) which would be connected by a network infrastructure in accordance with the Backbone Initiative, as outlined in Section 3. EU's objective also include the creation of a market for hydrogen through the Hydrogen Bank (see Box 2.1). An important financing tool within the European policy framework is the Important Projects of Common European Interest (IPCEI). IPCEIs support the development of strategic sectors, requiring the participation of at least four Member States. These countries launch national calls for proposals, inviting companies to submit their projects. While IPCEIs are intended to coordinate and funding complex industrial initiatives across multiple countries, they often favour national champions by operating under a broader reinterpretation of EU state-aid rules and environmental policy. Moreover, they provide subsidies without clearly defined criteria and lack robust governance mechanisms, reflecting a strong deference to private capital (McNamara, 2023; Poitiers & Weil, 2022; Vezzoni, 2024a). Four IPCEI initiatives on hydrogen has been announced from 2022. *Hy2Tech*, for technological development, supports 41 projects across 15 EU countries is was financed by €5.4 billion and expected to attract €8.8 billion in private investment. The second, *Hy2Use* focuses on applications in the industrial sector. It funded 35 projects in 13 countries with €5.2 billion, projected to leverage €7 billion from the private. The *Hy2Infra* targets infrastructure development and involves France, Germany, Italy, the Netherlands, Poland, Portugal, and Slovakia. Backed by €6.9 billion in public funding, it is expected to mobilize €5.4 billion in private investment. The project, involving 32 companies, covers key segments of the hydrogen value chain, including the installation of 3.2 GW of electrolysers for renewable hydrogen production, the development of approximately 2,700 km of hydrogen pipelines (both new and repurposed), large-scale storage infrastructure and port facilities. A fourth initiative for transport *Hy2Mobility* should be completed by the end of 2025.

The Hydrogen Bank

"Hydrogen can be a game changer for Europe. We need to move our hydrogen economy from niche to scale", stated Commission President von der Leyen when announcing the creation of the European Hydrogen Bank (EHB) (von der Leyen, 2022). Launched in 2022 with €3 billion from the Innovation Fund, the European Hydrogen Bank is a de-risking instrument designed to establish a market for renewable hydrogen by supporting both domestic production and imports. One of the main pillar is the creation of a domestic market, with procurement allocated through competitive auctions that award fixed premiums (in €/kg) for certified renewable hydrogen. The first auction, held in late 2023, offered €800 million and attracted 132 bids from 17 countries. By April 2024, €720 million had been awarded to seven projects expected to produce 1.58 million tonnes of hydrogen over ten years. The second auction, held in December 2024, mobilized up to €2 billion, and a third round is scheduled for late 2025. As of May 2025, 15 projects have been selected to receive nearly €1 billion in EU funds, with an additional €836 million in national co-funding pending allocation. Selected projects are required to reach financial close within 2.5 years and to begin production within five years. The international pillar is being developed through the establishment of joint European auctions, where the EU acts as a single buyer on the international platform H2Global (European Commission, 2023). While the EHB sustains hydrogen production in Europe through reverse auctions, its international strategy aim to import hydrogen through long-term contracts and reselling it in the short term to domestic buyers (Vezzoni, 2024a). The Bank coordinates the emerging market via the Hydrogen Mechanism, a platform designed to match buyers and producers of renewable and low-carbon hydrogen (or its derivatives), to aggregate demand and supply, and to collect market information. Finally, the Bank managed the existing EU and Member State support instruments, including technical assistance and investments both within and outside the EU (European Commission, 2023).

2.1.1 Public-Private Partnership: the Clean Hydrogen Joint Undertaking

Public-private partnerships (PPPs) are increasingly used as instruments to mobilise the private sector in hydrogen development. PPPs tend to incentivise investment in low-risk, incremental innovations. More generally, innovation occurs when performance-based contracts are in place (Carbonara & Pellegrino, 2018; Roumboutsos & Saussier, 2014). In the case of low-carbon infrastructure, the creation of PPPs would undermine both the amount of investments and the sustainability benefits, in absence of a stringent regulatory framework, mutual commitment, reciprocity, and effective knowledge management and stakeholder inclusion (Koppenjan, 2015; Pinilla-De La Cruz et al., 2022). Since 2010, the Clean Hydrogen Joint Undertaking (CHJU) or Partnership, previously named Hydrogen and Fuel Cell Joint Undertaking, has played a central role in shaping European hydrogen policy by directing EU funds for research and innovation projects. The CHJU operates as a PPP composed of three main constituents: the European Commission, Hydrogen Europe, and Hydrogen Europe Research. Hydrogen Europe represents the industrial alliance of the hydrogen sector, comprising over 600 members, including major oil and gas players, integrated energy companies, automotive manufacturers, and chemical producers. Hydrogen Europe Research, on the other hand, brings together around 150 research organizations, including universities and research foundations. Governance within the CHJU reflects a dominance of stakeholders from industry as the governing board consists of ten members, of which six represent Hydrogen Europe, one represents Hydrogen Europe Research, and three are appointed by the European Commission. As of 2025, the board includes representatives from companies such as Snam, Bosch, Air Liquide, as well as the Bruno Kessler foundation. This structure positions the private sector in a leading role in steering EU hydrogen strategy, influencing funding allocation and the broader direction of technological development within the EU hydrogen agenda. Currently this PPP manages the funds from the Horizon Europe programme (2021–2027) for hydrogen development and deployment, with an annual budget of €1.2 billion. According to their most recent report, CHJU has supported 85 projects through Grant Agreements, providing approximately €544 million in funding (Clean Hydrogen Joint Undertaking, 2024).

Hydrogen Valleys

A Hydrogen Valley refers to an integrated initiative or cluster of projects that combines hydrogen production, storage, distribution, and utilization within a defined geographic area. Emerging in recent years as a mission-oriented approach, the concept seeks to de-risk hydrogen technologies and catalyse the broader diffusion of the hydrogen economy. Conceived also as an investment model for large-scale hydrogen deployment, Hydrogen Valleys have become a cornerstone of the European Commission's strategy. The EU supports both small- and large-scale projects through dedicated funding mechanisms. The Clean Hydrogen Partnership although managing only a minor share of the funds, promotes coordination across initiatives and maintains a database of ongoing projects under the H2V platform. Currently, 90 Hydrogen Valleys are registered globally, varying in technological scope, maturity, and geographic context (Bampaou & Panopoulos, 2025). The most recent H2V report (2023) suggest that Hydrogen Valley programs are increasingly facing implementation barriers.

2.2 National and International Strategies

Worldwide, sixty countries have adopted national hydrogen strategies. In developed economies, public subsidies have been the most common policy instrument, while tax incentives are widely used across emerging and developing economies. Competitive bidding has been implemented in a range of countries, with auctions held in Egypt, Europe, India, and Oman to support market formation, price discovery, and competition. Nine countries have introduced incentives for electrolyser and fuel cell manufacturing, although only six have policies currently in force (IEA, 2024). National hydrogen strategies are prioritizing the scale first and clean later approach, and several countries advocate technology neutrality for supporting fossil-fuel based hydrogen (Cheng & Lee, 2022).

In the United States, the Biden administration allocated $9.5 billion to support the development of regional clean hydrogen hubs through the Infrastructure Investment and Jobs Act. The Hydrogen Hubs program, administered by the Department of Energy, is a central component of this strategy. It aims to create regional networks for the production, distribution, and utilization of clean hydrogen. Additionally, the Inflation Reduction Act (IRA) strengthens hydrogen deployment by providing a range of risk-reducing incentives, including tax credits, to encourage investment and accelerate market growth. However, these funds were suspended under the Trump administration. The EU has prioritized renewable hydrogen, primarily produced from wind and solar sources, while recognizing the short-term role of low-carbon hydrogen derived from fossil fuels with CCS. In contrast, the UK adopted a low-carbon hydrogen strategy from the outset, leveraging domestic fossil resources, significant CO_2 storage capacity, and medium-term decarbonization targets. The United States targeted clean hydrogen production based on nuclear and fossil sources combined with CCS. The US green hydrogen strategy prioritise cost reduction through R&D in electrolysis technologies. Large-scale deployment of renewable hydrogen for US is therefore conditional on future technological advances. This contrasts with the approach of EU and the UK, who have set production targets and initiated electrolysis projects (Moura & Soares, 2023).

The hydrogen strategies of emerging economies vary according to the different national priorities and structural contexts. Countries such as Chile and South Africa hold significant potential for low-cost renewable energy and are therefore projected to be cost-competitive in green hydrogen production in the near future (IRENA, 2022). Both Chile and South

Africa prioritise green hydrogen. However, coal abundance in South Africa may led to a different pathway (Giwa & Taziwa, 2024). Chile is pursuing an export-oriented strategy aimed at exploiting its renewable energy potential for the global market. In contrast, Brazil and China focus primarily on domestic market development and do not prioritise renewable production, adopting a technology-neutral logic. These divergent pathways are shaped by differences in natural resource endowments, energy infrastructure, and market dynamics. Across all four countries, industrial policies are predominantly supply-driven, focusing on supporting production capacity and infrastructure development. Meanwhile demand-side incentives remain underdeveloped. In Chile and South Africa value chain-oriented policies and access to credit are the preferred instruments for de-risking investments. However, such mechanisms may increase exposure to financial vulnerabilities and raise concerns over potential debt dependency (Bacil et al., 2025; Scholvin et al., 2025). Other Latin America countries are targeting hydrogen for domestic fertiliser production. Currently, 80% of the Region's demand for nitrogen-based fertiliser is met by imports, resulting in a trade deficit equivalent to up to 0.4% of GDP. Producing domestically low-emission ammonia (the basis of fertilisers) could reduce this deficit and improve price stability (IEA, 2024). In the emerging international hydrogen market, countries such as Germany, Japan, and South Korea anticipate a significant demand for hydrogen that exceeds their domestic production capabilities. Conversely, countries with abundant renewable energy resources and comparatively lower electricity prices—such as Australia and Morocco- are positioning themselves as future exporters of clean hydrogen (IRENA, 2022). However Australia's abundance of coal may foster the development of a fossil-based production system (Boretti, 2020). Several international cooperation initiatives are already underway. One notable example is the partnership between Japan and Australia, focusing on the production and export of hydrogen (IRENA, 2022).

The EU internationalization strategy is also based on de-risking, and it is led by

Germany (Nunez & Quitzow, 2024). Germany has set specific hydrogen import targets and it is initiating projects abroad with different targets and severe implications for the environmental and distributive justice (Kalt & Tunn, 2022). The country leads the H2Global initiative which, supported by the European Hydrogen Bank, provides financial instruments that promotes import partnerships with countries with high renewable potential and lower cost of production, such as Namibia. An intermediary company (HINTCO) would purchase hydrogen under long-term contracts and resell it under short-term contracts to the German industry via annual auctions. HINTCO will use public funds to cover the difference between higher purchase prices and resale prices, altering risk/return profiles on both green hydrogen production and green hydrogen adoption in European industries (Gabor & Sylla, 2023). In derisking settings, foreign capital plays a dominant role in the state-capital relationship, often shaping national priorities. This dynamic deepens structural dependencies, exposes countries to debt vulnerabilities, and exacerbates macroeconomic instability, prioritizing investors' interests over social equity, democratic control, and structural transformation (Gabor, 2023; Gabor & Sylla, 2023).

National hydrogen in time

National hydrogen policies first emerged during the oil shocks of the 1970s, framed within energy autarky narratives and primarily targeting mobility applications. From the early 2000s, hydrogen's prospects became closely linked to automakers' commitments to fuel cell vehicles (J. D. Hunt et al., 2022; Sperling & Ogden, 2004). In the United States, interest dates back to the 1970s, when the Energy Research and Development Administration (ERDA) allocated $24 billion annually to hydrogen development as part of an energy independence agenda (Herman & Sovacool, 2024). Hydrogen regained momentum under the Bush administration with a $1.2 billion initiative launched in 2003 and the establishment of a federal dedicated office. Several states also initiated investment programs between 1999 and 2002. Canada pursued similar R&D efforts for mass hydrogen vehicle adoption by 2020. Outside North America, Iceland announced in 1999 its ambition to become a hydrogen economy, while Norway funded a National Hydrogen Commission in 2003 and an "hydrogen highway" project. The European Union set ambitious targets in 2003, aiming for 5% of new cars to be hydrogen-powered by 2020 and over 30% by 2040. Nonetheless, by 2023, the total number of fuel-cell vehicles in Europe, including the UK, remained below 6,000 (European Hydrogen Observatory). Japan is the first country to pursue hydrogen industrial planning for mobility and energy as well in the nineties. South Korea pursued similar investments to reduce fossil fuel dependence. In 2003 the International Partnership for the Hydrogen Economy was established. It brought together Australia, Brazil, Canada, China, the European Commission, France, Germany, Iceland, India, Italy, Japan, South Korea, Norway, Russia, the UK, and the US and it was directed to developing competitive and safe hydrogen-powered vehicles by 2020 (Solomon & Banerjee, 2006).

3 The Role of the Incumbents

When considering the role of hydrogen as an energy carrier alongside the involvement of oil and gas companies in the transition towards decarbonization, some controversial interests may emerge. These companies would not allow their business to be cannibalised by energy and environmental policies. Transnational energy corporations are ramping up efforts to control the emerging energy regime (Haas, 2019). Major oil and gas companies see hydrogen as a way to diversify and remain competitive, responding to the threat of electric vehicles (J. D. Hunt et al., 2022). Automotive plays also an important role. Since the early 2000s, hydrogen's prospects have been closely tied to the automotive's commitments to fuel cell vehicles (J. D. Hunt et al., 2022; Sperling & Ogden, 2004). In this sector, DaimlerChrysler and GM have actively pursued hydrogen-related initiatives (Solomon & Banerjee, 2006). On the energy side, BP and Royal Dutch Shell established hydrogen-focused business units in 1998 and 1999. As already noticed in early 2000s, "Oil companies will not allow the hydrogen economy to develop without them" however, they "would not bear the risk of this transition by being early investors, leaving this to the states and entering strategically when hydrogen takes off investments" (Sperling & Ogden, 2004). Vezzoni (2024b), examining also patent ownership, describes hydrogen economy as associated, in a path-dependent dynamics, with the Oil&Gas industry. Besides their lobbing efforts (Errichiello et al., 2025), these companies are effectively shaping the agenda for hydrogen development, especially in Europe, advocating for hydrogen development replicating LNG market (J. D. Hunt et al., 2022), while ensuring the persistence of their core business via blue hydrogen and green refinery (more on blue hydrogen in Box 2) .

From an historical materialist perspective, policy-making is conceived as a site of contestation where power relations and social conflicts are expressed and negotiated (Brand et al., 2022). Within this framework, in line with the regulation theory, policy functions as a regulatory mechanism that anticipates, articulates, and mediates contradictions and crisis tendencies through specific institutional forms (Brand et al., 2022). It translates the underlying interests of social forces into concrete policy outcomes, which, in turn, may contribute to stabilising or reinforcing particular social formations by regulating their internal contradictions (Schneider et al., 2023). European policy, especially, exhibits traits of *transformismo*, in the Gramscian sense, increasingly aligning with the dominant narrative of incumbent energy actors. This shift first emerged through the endorsement of natural gas as a transitional fuel and, more recently, focusing on hydrogen as a win-win solution to the climate crisis (Szabo, 2022). Moreover, the involvement of the incumbent industry in green policy has shown to result in a reinforcement of their fossil-based activity (Hellsmark & Hansen, 2020).

The actors shaping hydrogen policy are deeply embedded in the incumbent energy industry. In addition to individual corporations, powerful stakeholder associations such as the European Hydrogen Alliance and Gas for Climate play a significant role in guiding policy decisions. Public funds are being directed to oil and gas companies through investments in green hydrogen. A striking example of this is the support for so-called "green refineries", where public money finances green hydrogen production facilities designed to decarbonize existing fossil fuel operations. This dynamic can be observed in different EU-funded initiatives. For instance, the Refhyne project, financed by the European Commission's Clean Hydrogen Partnership, operates Europe's largest PEM electrolyser for Shell's refinery in Wesseling, Germany. Likewise, the second wave of the Important Project of Common European Interest (IPCEI) on Hydrogen, which focuses on industrial deployment and infrastructure, has largely favoured incumbent fossil fuel firms (Vezzoni, 2024a). The geographic location of many Hydrogen Valleys reinforces this pattern, as they are often located alongside refineries and promoted as emblematic examples of hydrogen integration. Prominent examples include the Repsol Cartagena Refinery in Spain, Masshylia joint venture between ENGIE and TotalEnergies to supply the La Mède biorefinery, and Italian projects involving ENEL and ENI for Gela and Taranto refineries, as well as ENEL's partnership with Saras for the Sarroch site in Sardinia.

In designing all the segments of future hydrogen value chains, sectoral alliances are explicitly promoting hydrogen infrastructure investments that primarily benefit their industry. For example, the H2eart initiative advocates for underground hydrogen storage and it is mainly composed by midstream oil and gas companies. The same players are joined in a consortium that leads the European Hydrogen Backbone initiative (Wang, 2020), which is adopted as the EU policy planning for hydrogen infrastructure and transport. The initiative aims to replicate the LNG market model for hydrogen. The Backbone Initiative presents the development of a hydrogen pipeline network in Europe, with production in peripheral areas and Africa, as the only viable and economically appealing solution. Alternative approaches are dismissed without considering the potential cost savings and benefits of a more distributed hydrogen production system (Wang et al., 2021). This initiative poses Europe as hydrogen importer, while studies suggest that domestic hydrogen production would be sufficient to meet the EU's 2030 targets (Kountouris et al., 2024). Framing hydrogen development as a replica of the LNG market is, however, misleading. Oil and gas companies possess the knowledge-base, technical expertise, capital, and infrastructure for gaseous fuels which can be use for hydrogen (Cardinale, 2023; J. D. Hunt et al., 2022). However, hydrogen poses distinct technical challenges: it is highly reactive, has low volumetric energy density, and requires strict pressure and temperature control for safe handling (Kovač et al., 2021). These characteristics impose cautious energy planning in imagining hydrogen value chains. Moreover, fossil fuel production typically operates as a natural monopoly, justified by the geographic concentration of resources and the high fixed costs of extraction and infrastructure. In particular, the midstream segment, which cover transportation and storage, is structurally monopolistic due to the capital-intensive nature and network characteristics of pipeline infrastructure (Inkpen & Moffett, 2011). These global value chains often consolidate wealth and power, leading to adverse societal impacts, especially in developing economies (Selwyn & Leyden, 2022). For Oil and Gas companies such dynamics are coupled with energy injustice implications and ecological degradation (Healy & Barry, 2017). Hydrogen projects require substantial capital investment but not necessary the monopoly structures. Hydrogen, unlike fossil fuels, can be produced locally using renewable energy, challenging the logic of natural monopolies and large-scale production and enabling a more democratic, regionally distributed ownership models. A decentralized approach can help distribute costs and risks more equitably (Herman & Sovacool, 2024; Sovacool et al., 2024). Yet, such models remain marginal in current policy frameworks, which tend to prioritize incumbent interests.

4 Justice Considerations and Environmental Conflicts

The climate crisis exemplifies the inherent contradictions within capitalist social relations and the ensuing consequence in terms of exploitation of nature (Schneider et al., 2023). Although green hydrogen may present opportunities, its production entails substantial environmental costs, particularly in terms of land use, water consumption, and energy requirements (Johnson et al., 2025). As an energy carrier, hydrogen enables the storage and transport of renewable energy. Therefore, the siting of hydrogen production facilities must prioritize regions with abundant resource endowments, while simultaneously addressing potential negative impacts on local communities and ecosystems (Kakoulaki et al., 2021). Such projects hold potential benefits when owned and governed locally and aligned with just transition principles (Dillman & Heinonen, 2022).

However, when production is controlled by foreign actors to satisfy external energy demand, these projects predominantly benefit wealthier nations, and as such exacerbate environmental and socio-economic inequalities. The expansion of hydrogen infrastructure risks shifting the socio-environmental costs of clean energy production from industrialized, resource-intensive central region to peripheral, resource-abundant regions (Kalt & Tunn, 2022). This dynamic is evident in Western-led initiatives, particularly German projects in the Global South, such as those implemented in Namibia (Monteith & Escobar, 2025). Although green hydrogen can support equitable energy transitions, evidence from several countries illustrates how market mechanisms and import-dependent hydrogen policies in consuming countries, as well as export-oriented hydrogen development in producing countries, can exacerbate the risk of social and environmental injustice. These risks are further intensified by factors including high vulnerability to drought, widespread energy poverty, limited integration of renewable energy in local grids, insufficient community participation and weak governance (Müller et al., 2022). The global green hydrogen rush is prone to perpetuate extractivist patterns at the expense of economies, ecologies, and communities in the production zones in the Global South (Tunn et al., 2024).

4.1 Environmental Conflicts

Environmental conflicts are social struggles focused on the control, access, and allocation of environmental goods and burdens (Martinez-Alier, 2021). While often linked to issues of class, territory, identity, or gender, they stem from historically embedded power imbalances and social inequalities rather than just material scarcity. The concept of ecological distribution conflicts highlights these struggles over the unequal sharing of environmental benefits, like clean air or land access, and harms, such as pollution or displacement (Martinez-Alier, 2021; Temper et al., 2018). The role of multinational energy companies in exacerbating environmental conflicts has also been analysed in recent studies, particularly in relation to TotalEnergies and the French governments (Llavero-Pasquina et al., 2024).

5 Data and Methodology

The analysis focuses primarily on investment projects in the production phase of clean hydrogen, as this is the stage where material extraction, land use, and infrastructure development have the most direct environmental and socio-spatial consequences. Moreover, the spatial planning of these activities directly shapes the development of infrastructure for storage and transportation. The empirical analysis has two objectives: first, to examine how hydrogen policy translates into investment capacity and, second, how environmentally controversial these projects tend to be. The aim is to characterise the actual diffusion of hydrogen production. We construct a dataset that integrates two different sources of information. First, the Clean Hydrogen Projects database compiled by the International Energy Agency (International Energy Agency (IEA), 2024), which provides a broad overview of investments in hydrogen technologies across different sectors and regions. This dataset offers one of the most comprehensive global overviews of hydrogen investments, although it does not capture the financial governance or institutional support behind individual projects. An important limitation of the dataset is the it lacks information regarding funding sources and amounts. Currently, there is no unified database detailing public funding for hydrogen, and many projects appear to be financed through a mix of local, national, and supranational scheme. A comparable study, using the same dataset, looks at the electrolysis production capacity of EU planning, showing that is much more inferior with respect to the renewable energy potential of the regions (Wolf, 2023). Afterward, using data from the Environmental Justice Atlas (Temper et al., 2018), we focus on the spatial distribution of clean hydrogen projects in relation to sites already disproportionally affected by environmental damages. Environmental conflict is not considered in this study as a site of contestation but as a broader indicator of territorial exploitation and unequal distribution of environmental harms and goods (Martinez-Alier, 2021). In this framework, the presence of a conflict signals previous or ongoing impacts associated with large-scale energy infrastructures and resource extraction. For this reason, only conflicts that are either ongoing or concluded after the year 2000 are included. After applying these filters, the final dataset includes 490 environmental conflicts at the global level. The IEA hydrogen projects list has also been subjected to a data-cleaning process where projects registered under different IDs but representing various development phases at the same geographic location were consolidated and treated as a single project to avoid overestimation in the spatial analysis. The resulting global dataset comprises 1,273 distinct hydrogen projects. The spatial analysis is conducted by mapping the proximity of new hydrogen projects to areas historically affected by environmental conflicts. Each conflict is represented by a geolocated point, used as a proxy for a broader affected area, and a buffer zone of 50 km is applied to capture the territorial scale of potential exploitation. We explore the frequency of spatial co-occurrence between hydrogen production projects and areas with a documented history of environmental conflicts. Spatial point pattern analysis is used, looking at the Cross-K function and the Pair Correlation Function (PCF) between environmental conflicts and hydrogen projects. These statistical tools enable the evaluation of spatial dependence between two distinct points across multiple spatial scales (Baddeley et al., 2016). The Cross-K function provides a cumulative measure of spatial interaction, capturing the extent to which events of one type (e.g. hydrogen projects) are spatially correlated with events of another type (e.g. environmental conflicts) within increasing distance thresholds. In contrast, the PCF offers a non-cumulative, distance-specific indicator of spatial correlation, which is normalised by the spatial density, allowing to find local clustering or dispersion. Both functions are estimated under a null hypothesis of spatial independence.

6 Empirical evidence

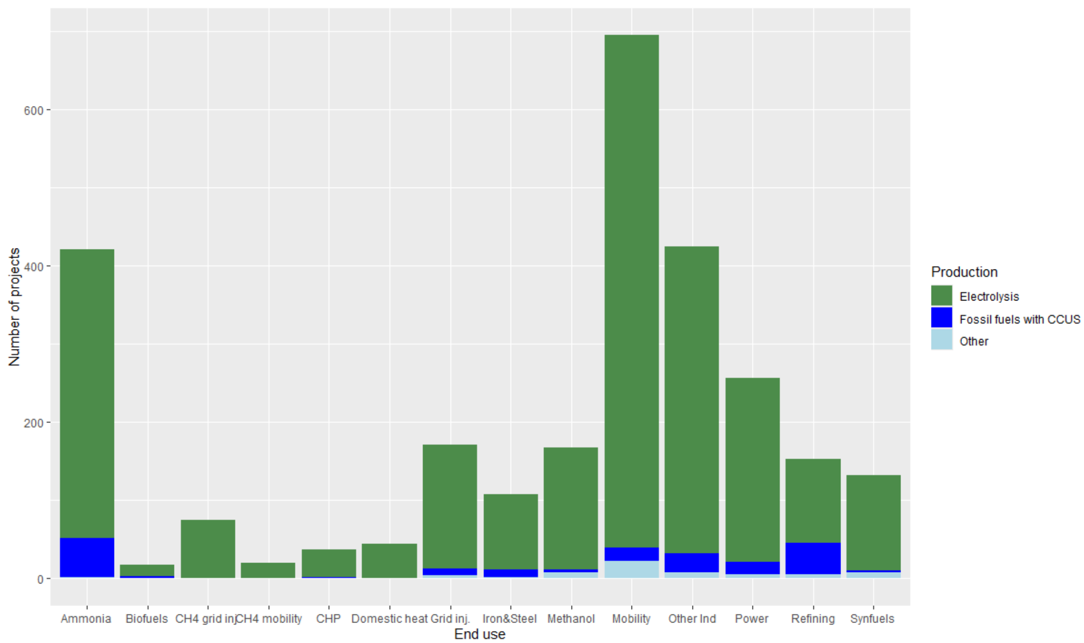
6.1 Clean Hydrogen Projects

The projects vary by production source and technology. Clean hydrogen here includes both hydrogen produced through electrolysis, green hydrogen, and hydrogen derived from fossil fuels using Carbon Capture, Utilisation and Storage (CCUS), blue hydrogen. The majority of the projects listed plans to use electrolysis, while a smaller share is dedicated to blue hydrogen. As shown in Figure 1, most projects target applications in the mobility sector and ammonia production, followed by other industrial applications and power production. It is important to note, that many of these projects are still in the planning or announcement phase. When considering only those projects that have reached a Final Investment Decision (FID)—and are thus under construction or in the operational phase—the overall number decreases significantly. Even looking at after-FID projects (Figure 1b), projects destined to mobility continues to lead in terms of project count, although this likely reflects the pilot nature of these initiatives rather than their scale in terms of actual hydrogen production capacity. Notably, fossil-based hydrogen finalised investment projects (blue bars in the figure) remain concentrated in traditional sectors such as ammonia and refining. Figure 2 shows the distribution of hydrogen projects and their associated production capacity by country. Germany, Spain, and the United Kingdom are among the top countries for green hydrogen projects. However, this does not necessarily correspond to higher production capacity. In particular, Germany leads in project count but lags behind in associated capacity. This discrepancy is consistent with its international strategy, which emphasizes securing hydrogen imports rather than investing in large-scale domestic production. With regard to post-FID projects, the United States and Canada emerge as the countries with the highest blue hydrogen capacity, in line with their fossil fuel production, especially from unconventional sources. This is coupled with their higher end-use destination for refinery, the orange bar in Figure 2b, as higher hydrogen demand comes from unconventional oil production. Operational projects for those under construction following a final investment decision (FID),are distributed across a variety of applications. Mobility (in yellow) accounts for the largest number, although this largely reflects the pilot nature of these projects, which generally do not translate into significant production capacity. For most countries, the production capacity associated with post-FID projects remains negligible. In contrast, the United States and Australia lead in terms of planned production capacity. This aligns with their strategies to develop fossil-based hydrogen, which is typically associated with larger-scale output. The United States and China currently hold the largest shares of actual production capacity. However, their end-use strategies are different. The U.S. exhibits a more heterogeneous approach, with applications spanning ammonia, refining, and iron and steel. China, on the other hand, is particularly focused on ammonia and increasingly on methanol production. The latter fits China's coal-based energy system, as coal gasification is well suited for methanol production. Methanol and ammonia, moreover, can serve as a transportable carrier for hydrogen (Sánchez et al., 2024). This would give China an advantage in terms of its position in future international hydrogen value chains and allow the transport of cleaner energy within the country.

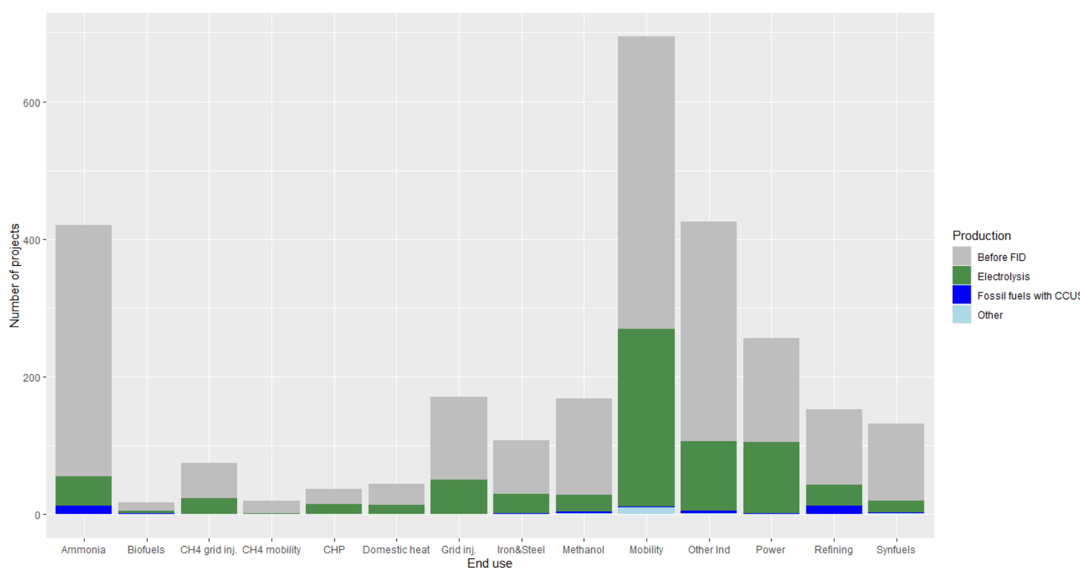
Surprisingly, Japan does not appear among the major investors in hydrogen production, despite its early commitment to a hydrogen economy dating back to the 1990s and its continued specialization in green hydrogen technologies (Lundin & Eriksson, 2016; Negro et al., 2024). While Japan has initiated collaborations with Australia and tested the first hydrogen shipments (IRENA, 2022), neither country currently shows signs of developing substantial production capacity. This could reflect a strategic long-term posture, waiting to avoid to bare the technological uncertainty, or a tacit acknowledgment of the limited short-term feasibility of their hydrogen ambitions.

Overall, as shown in Figure 3, the number of hydrogen projects is significantly higher in

Europe compared to the rest of the world: 530 out of 1,273 projects are located in European countries. However, the planned production capacity associated with these projects remains relatively limited regardless of whether a Final Investment Decision (FID) has been made. This discrepancy reflects both the current policy-driven momentum surrounding hydrogen in Europe and a strategic positioning that emphasizes the continent's role as an import hub, while externalizing large-scale production to other regions.



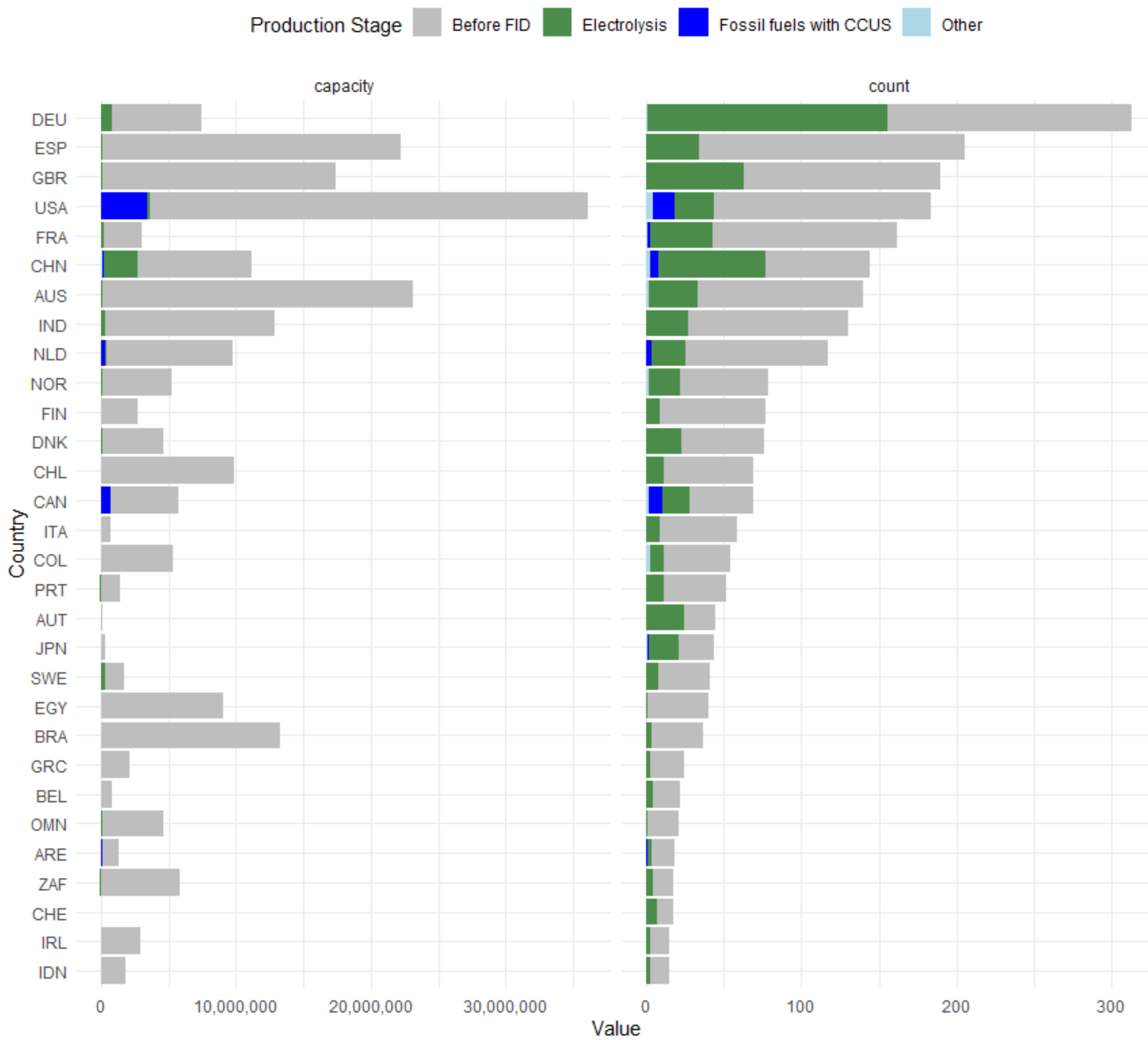
(a) Count of H_2 projects by end use



(b) Count of projects accounting for FID

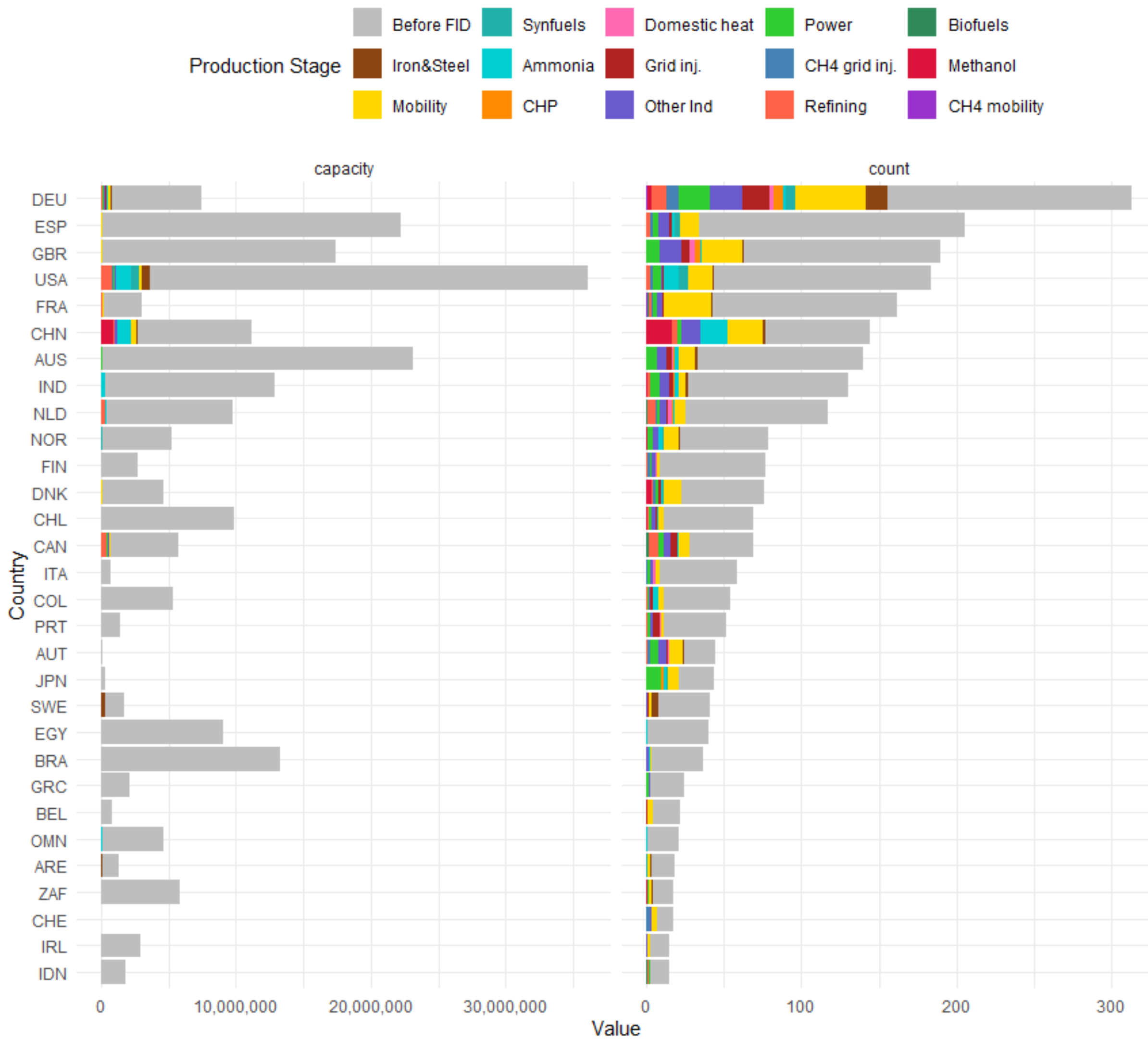
Figure 1: Overview of hydrogen projects by end use and FID status

The figures show the distribution of projects by planned end use of hydrogen. Figure (a) distinguishes by type of production; Figure (b) also accounts for investment status, with grey indicating projects pending Final Investment Decision (FID).



(a) Projects and capacity by country, by type of production

Figure 2: Overview of hydrogen projects by country (part 1)



(b) Projects and capacity by country, by end use

Figure 2: Overview of hydrogen projects by country (continued)

Distribution of hydrogen projects across countries, by planned capacity (left) and number of projects (right). Fig.(a) colours indicate the project status: grey for those before the Final Investment Decision (FID); coloured by type of hydrogen production for projects under construction or operational. Fig. (b) presents the same in terms of the planned end use of hydrogen.

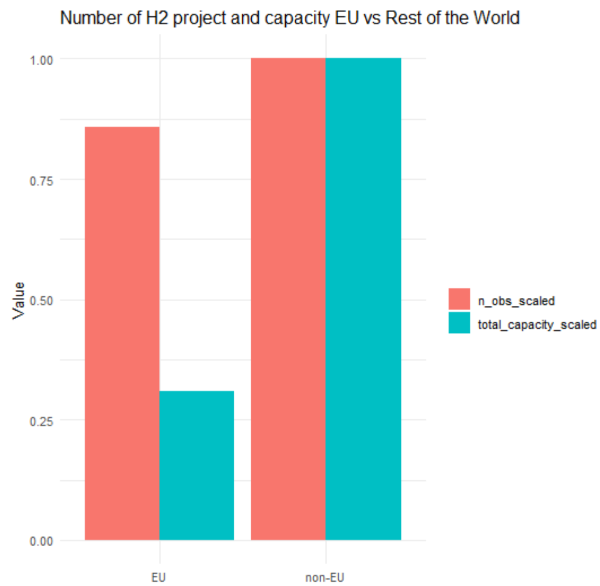


Figure 3: Number of projects and capacity of EU and Rest of the World

The figure shows the normalized count of hydrogen projects and their capacity for EU and non-EU countries.

6.2 Environmental Conflicts and the Geography of Clean H2 Projects

Looking at the spatial geography of clean hydrogen projects in Figure 10, red points represent environmental conflicts around the world, of which 112 have at least one hydrogen project located within a 50 km radius. In Europe specifically, 53 conflicts meet this criterion. Over the 112 areas of co-occurrence of hydrogen planning and environmental conflict, almost half presents more than one hydrogen project, as displayed in Figure 6. For the count of projects in a conflict area, we remove the projects accounting for different phases of the development of the project. The spatial analysis reveals statistically significant patterns of geographical clustering between hydrogen projects and environmental conflicts. Figure 5 shows the results of both the Cross-K function and the Pair Correlation Function (PCF) which consistently indicate that hydrogen infrastructure tends to be located closer to conflict sites than would be expected under a model of spatial randomness. The Cross-K function shows elevated values at short to medium distance ranges, suggesting a concentration of hydrogen projects in areas of environmental conflict. These findings are corroborated by the PCF, Figure 5b, which exhibits spatial clustering. These results suggest a non-random spatial relationship between hydrogen deployment and socio-environmental tensions, indicating a spatial convergence between sites of investment and areas of ecological distress or social inequalities. This clustering raises important questions regarding territorial justice, risk distribution, and the governance of energy transitions.

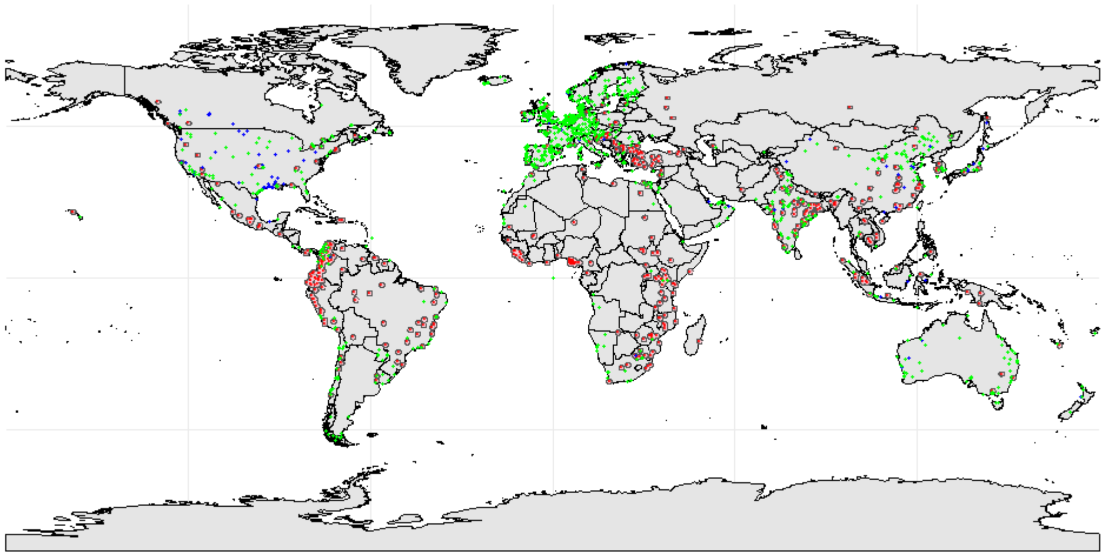
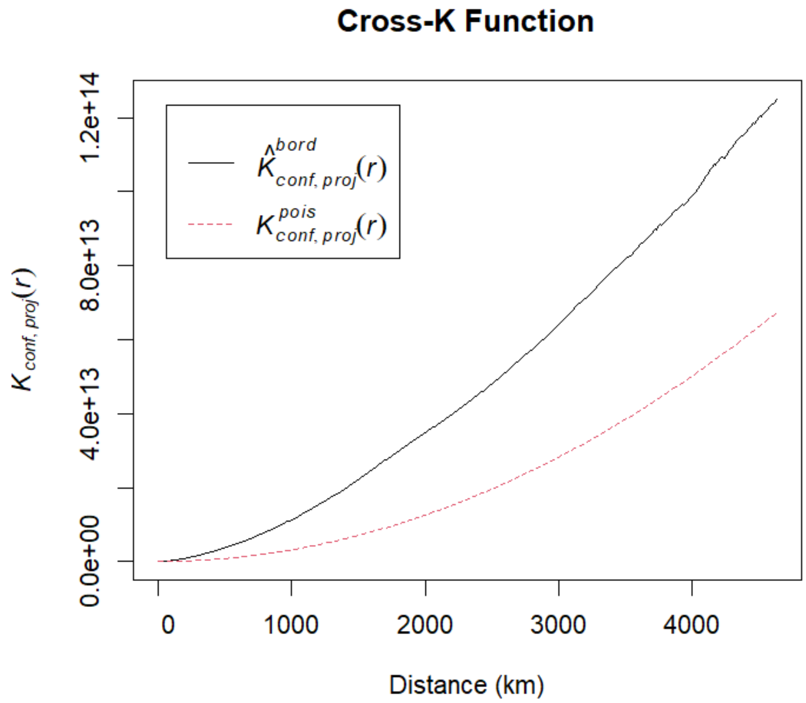
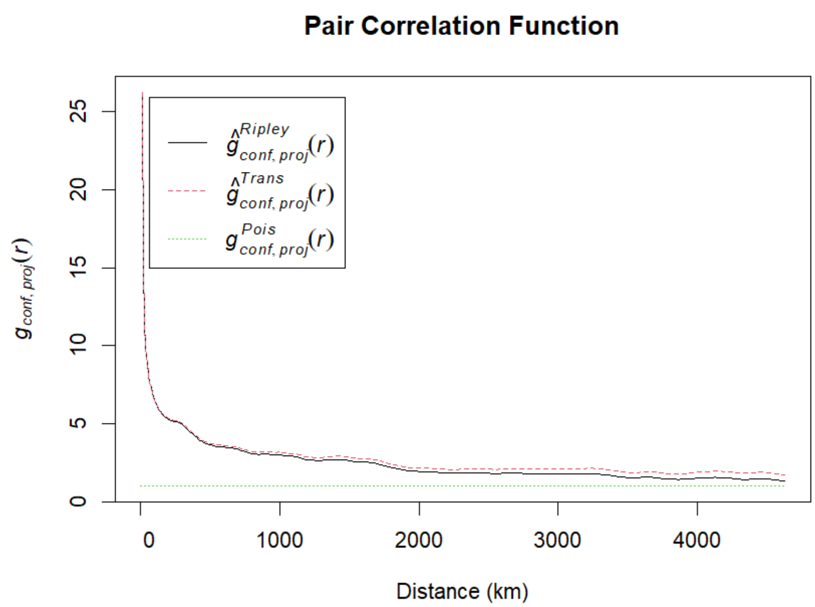


Figure 4: Hydrogen projects and Environmental conflicts

Authors' elaboration on IEA and EJAtlas data. Green points represent hydrogen investments in water electrolysis (green hydrogen), the blue ones represent fossil-based production with CCUS (blue hydrogen), and the red points indicate the selected environmental conflicts and their surrounding 50 km radius.



(a) Cross-K correlation between environmental conflicts and H_2 projects



(b) Pair correlation function (PCF)

Figure 5: Spatial correlation between hydrogen projects and environmental conflicts.

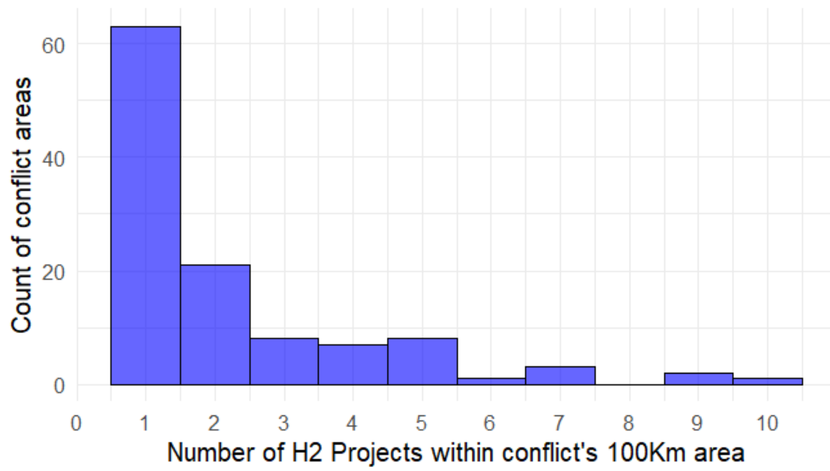


Figure 6: Count of Conflict Areas by Number of H_2 Projects

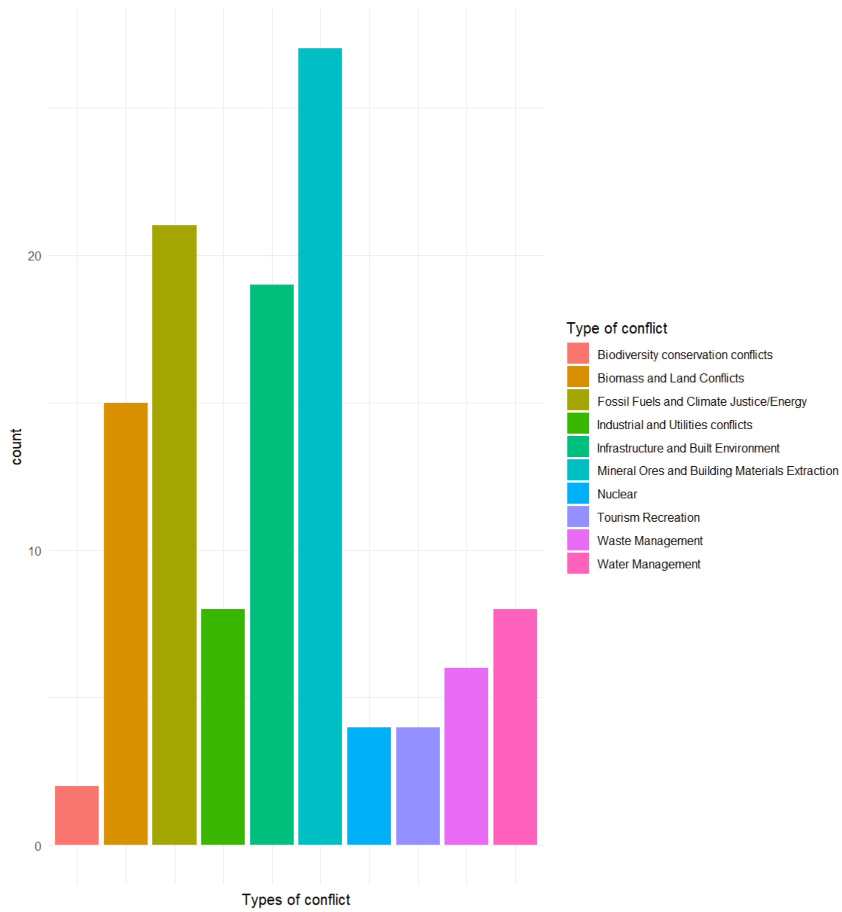


Figure 7: Features of Environmental Conflict Areas near H2 project by type of conflict

The figure shows the distribution of environmental conflict areas associated with hydrogen projects distinguishing the type of environmental issue that generates the struggle.

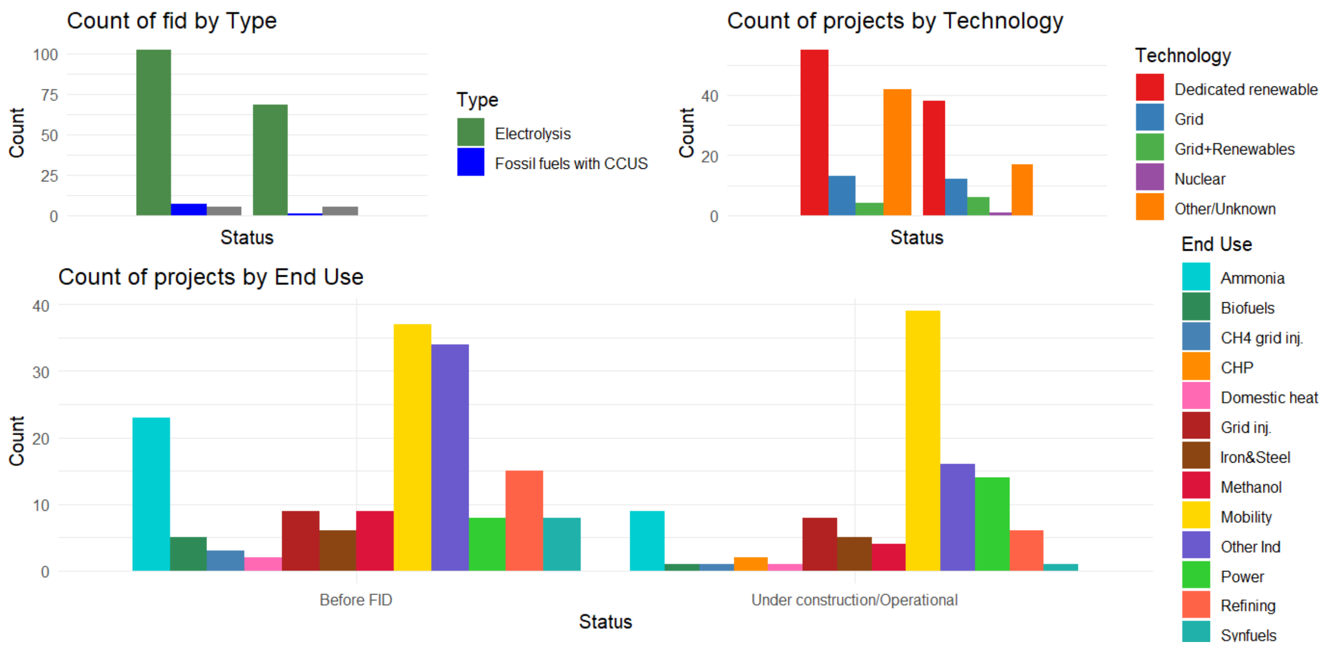


Figure 8: Features of H_2 projects within environmental conflict areas

The figure shows the hydrogen projects' features in environmentally vulnerable areas. On the right it is reported the distribution of projects that are operational or under construction, on the left the projects at earlier stages before the Final Investment Decision (FID). The upper-left quadrant shows the type of hydrogen production. The upper-right plots the energy planning of the hydrogen projects and the Bottom plot shows the the EndUse targeted for the hydrogen production.

6.3 Justice Implications and Discussion

The spatial dimension is critical in analysing hydrogen production projects due to the high requirement and uneven distribution of natural resources such as land, water, and renewable energy. Resource availability varies significantly across regions, directly affecting the feasibility and the environmental and social impacts of these projects. Furthermore, the different levels of vulnerability of local ecosystems and communities make it clear that adverse effect must be identified and mitigate on a spatial base. Additionally, the proximity of projects to infrastructure and markets influences their costs and efficiency, while local governance and regulatory frameworks shape their outcomes (Wolf, 2023). Understanding these spatial dynamics is vital for allocating resources use and ensuring sustainable and equitable development of hydrogen infrastructure. Areas identified for hydrogen development are disproportionately affected by environmental degradation, particularly related to extraction activities and fossil fuel or energy production, as illustrated in Figure 7. Several regions exhibit a concentration of multiple hydrogen projects in proximity to existing or historical environmental conflict sites. The distribution of hydrogen project density within conflict-affected areas (Figure 6) reveals 112 areas of spatial co-occurrence. Remarkably, almost half of these areas host more than one planned hydrogen project, suggesting a recurring pattern of development in environmentally sensitive or contested territories. The 51 environmental conflict cases associated are listed in the Appendix.

Selected cases involving multiple hydrogen projects within conflict sites are described in below, using the information of the EJAtlas (Temper et al., 2018), to further illustrate the spatial convergence of energy transition infrastructure and socio-environmental contention. In Brazil, for instance, five hydrogen projects are planned in the region of Caucaia, within the lands of the Indigenous Tapeba people. This area has been under threat since 1985 due to the pressure of industrial and infrastructural expansion. The cumulative effect of these new hydrogen projects risks exacerbating existing socio-environmental tensions, further marginalizing local communities whose territorial rights have long been disregarded. In India, four hydrogen projects are planned in Paderu, Visakhapatnam, a place already severely impacted by bauxite mining in tribal landownership. The mining activities have caused significant environmental and social harm, including displacement of local communities, depletion of water resources, and degradation of ecosystems. In Germany, several hydrogen projects are intended in the proximity of Garzweiler, a massive lignite surface mine in North Rhine-Westphalia operated by RWE. Originally restricted to the 66 km^2 Garzweiler I area, mining operations were expanded to the 48 km^2 Garzweiler II zone in 2006, sparking renewed protests. The mining creation and activity imply several environmental and social impacts, including forced displacement, air and water pollution, biodiversity loss, landscape degradation, and significant contributions to greenhouse gas emissions. These impacts have fuelled widespread mobilizations, supported by Germany's largest climate movements and transnational networks such as Ende Gelände and Fridays for Future. Germany's case exemplifies a broader policy contradiction: while the country has one of the largest shares of renewable energy in Europe, it also remains heavily dependent on lignite, the most carbon-intensive fossil fuel (Weber & Cabras, 2017). The siting of hydrogen projects in such contested and environmentally degraded areas calls into question the coherence of policy energy transition strategies and highlights the importance of incorporating justice into clean energy planning.

7 Conclusions

This contribution has highlighted a series of contradiction in hydrogen development and its public support. First, it has clearly pointed out the contradiction in the policy domain. Hydrogen policy seems to be shaped by technical optimism and an ex-ante belief in market neutrality. This has led to a preference for market-based approaches without taking into account the distortion or the concentration of power this may led to. It appears that these strategies are unlikely to achieve their ambitious goals and aligned to the incumbents' interests. The fragmented landscape of the institutional response risks reinforcing the existing fossil fuel regime and delaying systemic change. An analysis of hydrogen strategies in various countries further underscores this concern (Cheng & Lee, 2022). Second, the study has indicated a pattern of geographical co-location between hydrogen projects and existing environmental conflicts. The absence of clear governance and directionality further raises concerns about the actual benefits of ongoing projects, particularly with respect to industrial strategy, regional planning, environmental impacts, and distributive outcomes. It remains unclear whether hydrogen policies have effectively supported environmental and social sustainability. However, under certain conditions, green hydrogen infrastructure may also offer opportunities for environmental restoration. This is the case in deindustrialised, brownfield areas, where hydrogen production can contribute to the re-development sites (Sessa & Malandrino, 2022). Regional path-dependencies and industrial lock-ins already act as structural drivers of environmental inequality (C. S. Bez, 2025), therefore place-based policies are needed to address hydrogen's territorial deployment (Hanson, 2023)

For a just transition to occur, a strong steering of the economy toward collective social interests is essential, accompanied by a targeted focus on regions and workers most affected by structural change. Although risk mitigation is necessary, profit maximization should not be the primary rationale guiding the energy transition. A sustainable transformation would require a reconfiguration of socio-economic structures to operate within planetary boundaries and uphold principles of social justice (Vezzoni, 2023). Therefore, policy must address the underlying power asymmetries that shape current economic systems, rather than merely serving as an incentive to expand corporate investment portfolios. Furthermore, the escalating geopolitical tensions and the change in the U.S. administration are prompting many countries to shift their focus from the energy transition to national security and rearmament. Consequently, the outlook for hydrogen deployment appears increasingly uncertain.

This study provides a general framework for analysing hydrogen policies, with a particular focus on those in the European Union. However, a comprehensive assessment of individual hydrogen projects would benefit from case studies focusing on specific regions that take into account key economic and structural characteristics, such as employment levels and composition, industrial capacity, diversification, innovation systems, social structures, natural resource endowments, and geographical characteristics. These factors are critical for evaluating both the production potential and the distributional impacts of hydrogen initiatives. The spatial correlation patterns identified in this analysis could be further developed through the application of spatial regression models, which would allow for a more comprehensive assessment of regional determinants and policy outcomes. Moreover, greater efforts are required to enhance the availability of hydrogen project data. The dataset published by IEA does not provide enough information to assess the extend of public participation in hydrogen investments. Many hydrogen projects are structured as public-private joint ventures, often co-financed by multiple sources across EU, national, and local levels. The fragmentation of the funding sources poses significant challenges in tracing the total amount and origin of public investment, as well as assessing the extent of private sector participation, ownership structures, and governance arrangements. For many projects, publicly available information remains limited and scattered, hindering transparency and accountability.

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A Appendix

H_2 Projects	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	NA's
All	0	192	4444	89428	50151	9238727	11
After FID	0	108.7	480.8	11645.4	4372.0	626882.2	4
Green (water electrolysis)	0	217	4444	89178	45383	9238727	11
Green after FID	0	108.7	468.2	7239.2	3192.0	282608.7	4
Blue (fossil-based production)	0	0	18380	92005	84316	1880647	0
Blue after FID	0	2289	27830	60880	80571	626882	0

Table 1: Capacity distribution for different project types and aggregation

Source: Authors' elaboration of IEA data
This are summary statistics of the capacity of the investment projects aggregated for different types. FID is the Final Investment Decision, the project that rich the Final Investment Decision are Under construction or Operational. Before FID a project's realisation is not certain. Blue is shortened for Blue Hydrogen project, using fossil-based production techniques. Green hydrogen investments are considered as those investing in Electrolysis process (technique that produces H_2 from water) irrespectively from the power source.

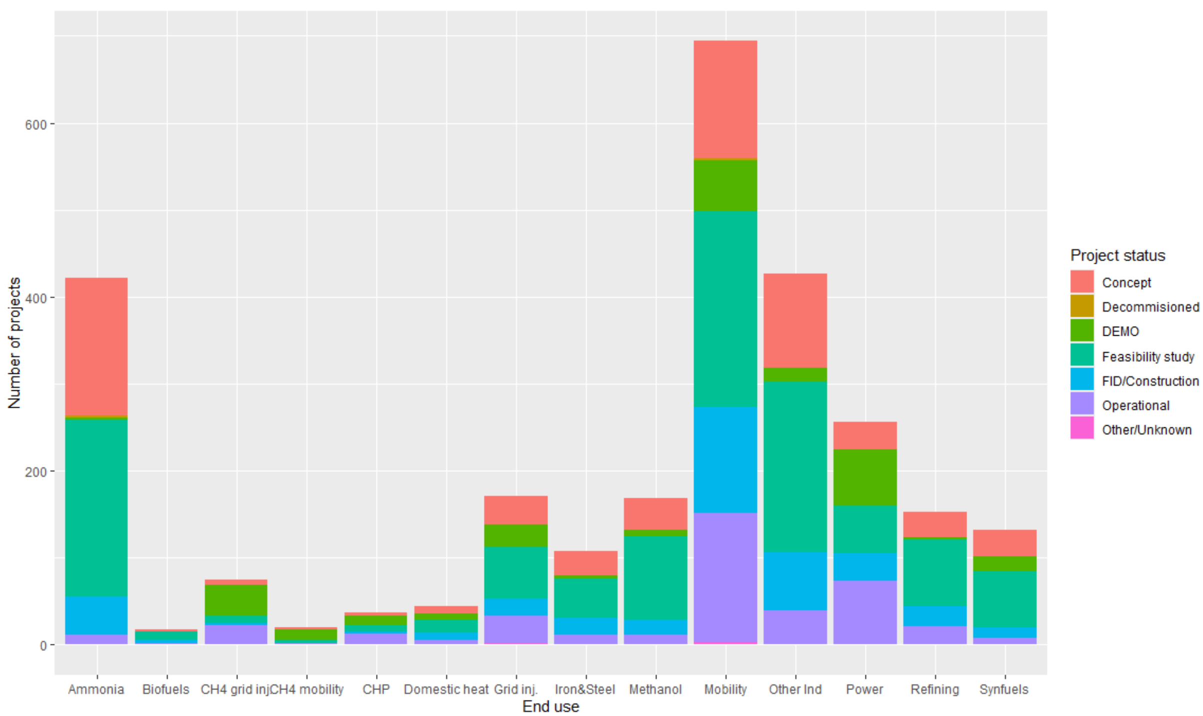

Figure 9: Count of projects by End Use with Status

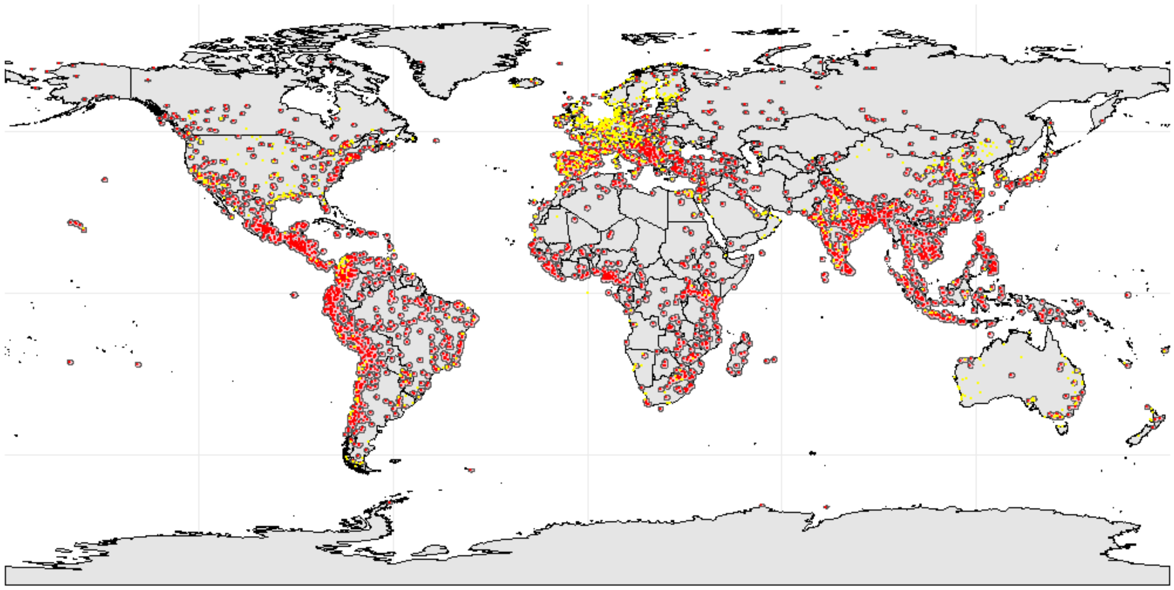

Figure 10: Clean H2 projects and Environmental conflicts

Source: authors' elaboration of IEA and EJAtlas data

The Figure shows the geographical distribution of the Environmental Conflicts, considering the whole dataset with correct geographic coordinates, and the hydrogen projects in the IEA database. The number of climate conflict areas (present or past) with a planned hydrogen project within 50km radius are 960 over 1890, more than 50% worldwide. In Europe are 451 over 1259, the 36%.

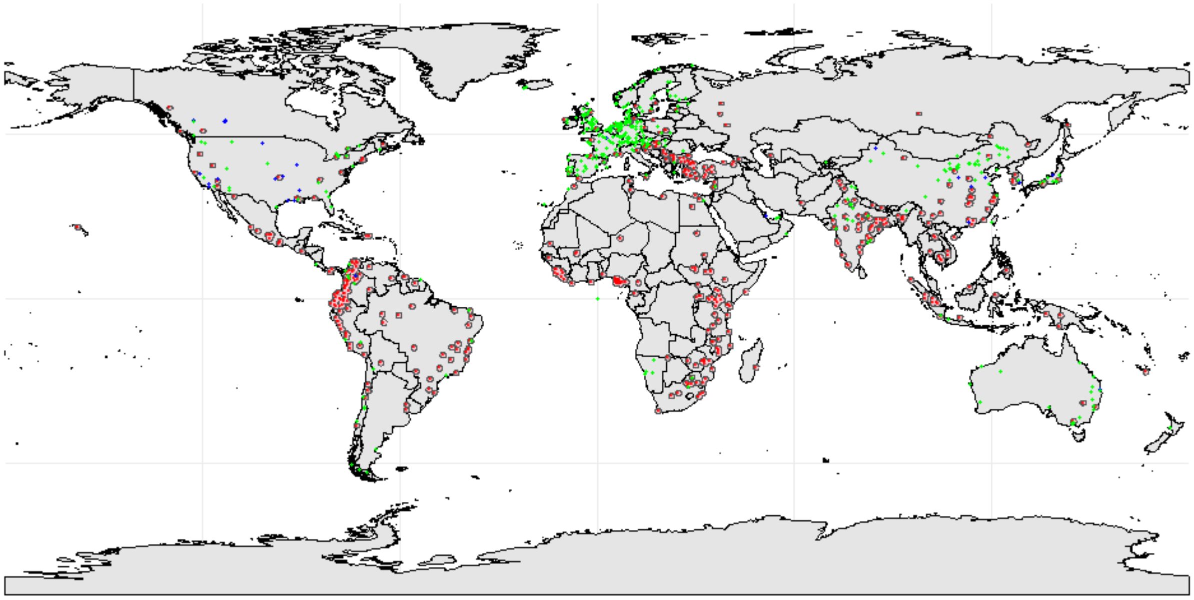

Figure 11: Clean H2 projects (blue and green) after FID, and Environmental conflicts

Source: authors' elaboration of IEA and EJAtlas data

Table 2: Environmental conflicts sites with count of surrounding hydrogen projects. Source: authors' elaboration of EJAtlas and IEA data

	Country	**Case of conflict**	**Size**	**Start**	**End**	**Type**	**n H2 proj**
1	Australia	Yes 2 Renewables campaign #VRET, Victoria	Local	2013	2016	Fossil Fuels/ Climate Justice/ Energy	5
2	Australia	Class Action against SP AusNet (power distribution company) in Kilmore East–Kinglake	Regional	2009	2014	Industrial and Utilities conflicts	3

	Country	Case of conflict	Size	Start	End	Type	N H proj
3	Brazil	Tapeba Indians threatened by companies and public policies in Caucaia	Local	1985	NULL	Biomass and Land	5
4	Brazil	Chongquing Soybean Growing and Manufacturing in Bahia	Local	2011	NULL	Biomass and Land	2
5	Brazil	Petrochemical Complex in Itaborai e Rio de Janeiro	Regional	2008	NULL	Industrial and Utilities conflicts	2
6	China	Waste-to-Energy Incinerator in Haiyan County	Regional	2016	2019	Waste Management	2
7	China	Dead pigs dumping in Jiaxing of Zhejiang causing water pollution in Huangpu River, Shanghai	Local	2013	2013	Biomass and Land	2
8	Colombia	Cerro Matoso, Montelíbano and others	Regional	2001	NULL	Mineral Ores Extraction	5
9	Colombia	Cienaga Grande de Santa Marta	Regional	1956	NULL	Infrastructure	4
10	Colombia	Cienaga de Ayapel	Regional	2008	NULL	Mineral Ores Extraction	3
11	Colombia	Cerro El Alguacil (INARWA)	Regional	2006	NULL	Infrastructure	2

	Country	Case of conflict	Size	Start	End	Type	N H proj
12	Colombia	Landázuri, Santander, Colombia	Regional	2008	NULL	Mineral Ores Extraction	2
13	Colombia	Proyecto Mandé Norte, Murindó	Local	2009	NULL	Mineral Ores Extraction	2
14	Colombia	Quebrada la Lata, Magdalena	Regional	2009	NULL	Mineral Ores Extraction	2
15	Croatia	National Park Sjeverni Velebit	Regional	2012	2015	Tourism Recreation	2
16	France	ITER Reactor	Regional	NULL	NULL	Nuclear	5
17	France	Nice - OIN plaine du Var	Local	2008	NULL	Infrastructure and Built Environment	2
18	France	LGV Bretagne train line	Local	2012	2017	Infrastructure and Built Environment	2
19	Germany	Lignite mining Garzweiler II (Immerath)	Regional	NULL	NULL	Fossil Fuels/ Climate Justice/Energy	9
20	Germany	Lignite mining Garzweiler I	Regional	1987	NULL	Fossil Fuels/ Climate Justice/Energy	9
21	Germany	Remunicipalisation Energy Hamburg	Country	2007	NULL	Industrial and Utilities	6

	Country	Case of conflict	Size	Start	End	Type	N H proj
22	Germany	Fracking Voelkersen	Local	NULL	NULL	Fossil Fuels/ Climate Justice/Energy	5
23	India	Bauxite Mining in Paderu, Visakhapatnam	Regional	2012	NULL	Mineral Ores Extraction	4
24	India	Save Yamuna Protest March, Delhi	Regional	1994	NULL	Water Management	4
25	India	Yamuna Expressway, Uttar Pradesh	Regional	2001	NULL	Infrastructure and Building	4
26	India	Visakhapatnam Port	Regional	2000	NULL	Infrastructure and Building	3
27	India	Bhogapuram Airport and Aerotropolis	Regional	2015	2018	Infrastructure and Building	3
28	India	Protest against plywood units	Regional	2012	NULL	Waste Management	2
29	India	Mithivirdi nuclear power station, Bhavnagar	Regional	2013	NULL	Nuclear	2
30	India	Nitta Gelatin India Ltd (NGIL)	Regional	1996	NULL	Waste Management	2
31	India	Bara thermal power plant, Allahabad	Local	NULL	NULL	Fossil Fuels/ Climate Justice/Energy	2
32	India	Dugarajapatnam Port, Andhra Pradesh	Regional	2013	NULL	Infrastructure and Building	2

	Country	Case of conflict	Size	Start	End	Type	N H proj
33	Ireland	Corib Gas in Rossport	Local	1998	NULL	Fossil Fuels/ Climate Justice/Energy	2
34	Italy	Installation of a photovoltaic park by Limes Renewable Energy in Val di Noto, Sicily	Regional	2021	2021	Fossil Fuels/ Climate Justice/Energy	4
35	Italy	Villaggio Turistico Di Forti - Porto Tolle	Regional	2000	2003	Tourism Recreation	3
36	Japan	Women "Soap Movement" against Freshwater Red Tide by Uroglena Americana in Lake Biwa, Shiga	Local	1977	2008	Industrial and Utilities	4
37	Japan	Water Supply Project in Lake Kasumigaura, Ibaraki	Local	2009	2017	Water Management	2
38	Latvia	Skulte LNG Terminal and Pipeline	Regional	7-02	3-03	Fossil Fuels/ Climate Justice/Energy	2
39	Netherlands	Noordoostpolder Wind Farm	Regional	2008	2017	Fossil Fuels/ Climate Justice/Energy	7
40	Portugal	A2 Motorway	Regional	1997	2002	Infrastructure and Building	10

	Country	Case of conflict	Size	Start	End	Type	N H proj
41	Slovenia	Mezica Valley	Country	NULL	NULL	Mineral Ores Extraction	4
42	Slovenia	Cinkarna Celje	Regional	2007	NULL	Industrial and Utilities	3
43	Spain	Privatisation of the Almoraima, Cádiz	Regional	NULL	NULL	Tourism Recreation	3
44	Spain	High Speed Train Basque Country	Country	2001	NULL	Infrastructure and Building	2
45	Sweden	Highway, Part of Scan Link, Ljungskile	Regional	1984	NULL	Infrastructure and Building	5
46	United Kingdom	Cauldhall Open Cast Coal Mine in Midlothian, Scotland	Local	2008	NULL	Fossil Fuels/ Climate Justice/Energy	7
47	United Kingdom	High Speed Two railway	Country	NULL	NULL	Infrastructure and Building	5
48	United Kingdom	London Array offshore wind farm	Regional	2006	2013	Fossil Fuels/ Climate Justice/Energy	3
49	USA	Dow Plaquemines LA	Regional	1997	2001	Industrial and Utilities	7
50	USA	Shell petrochemical plant and Pollution in Norco	Regional	1916	2002	Industrial and Utilities	5
51	USA	Dewayne Johnson against Monsanto, glyphosate exposure, California	Regional	2016	2018	Biomass and Land	2