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# Legal Perspectives on Fostering Energy Transition through Oil and Gas Venture Capital

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## Abstract

The objective of this study is to discuss the connection between venture capital, energy transition and the oil and gas industry from a legal perspective. This article is grounded mainly in scholarly literature from law and economics and regulatory law and places them in the perspective of ESG and energy transition literature. The main methodology adopted for this study was review and discussion of scholarly work. The results obtained indicate that energy transition is a technical revolution and as such venture capital is a key part of it. At the same time, oil and gas companies have legal and technical expertise, capital and infrastructure that could accelerate the development of clean technologies. Moreover, since emerging technologies need more government support and a big part of the petroleum industry is composed by National Oil Companies, their direct involvement in energy venture capital would set the stage for substantial private sector involvement by demonstrating commitment and confidence, mitigating certain risks of the unproven energy technologies. The implications of this study are significant for scholars, lawyers in the field, policymakers and other private agents. Fostering the energy transition through an oil and gas venture capital legal framework would expedite the development of new technologies that could impact positively society. This study contributes to the literature by discussing important aspects of the connection between the petroleum industry, the venture capital industry and energy transition from a legal perspective.

## Keywords

Energy Transition, Venture Capital, Petroleum Industry

## 1. Introduction

The theory of long-term economic waves—known as Kondratiev waves—explains

how clusters of technological innovations drive structural transformations in the global economy. As the fifth wave, dominated by information and communication technologies, approaches saturation, a sixth wave of innovation is emerging. This new wave centers on sustainability, clean technologies, digital-ecological integration, and mission-driven innovation, reshaping not only industrial sectors but also the financial mechanisms that support them, particularly venture capital (VC).

Whereas earlier waves were propelled by large infrastructure investments or consumer electronics, the sixth wave is characterized by the fusion of digital tools, biological systems, and ecological priorities. It encompasses technological domains such as renewable energy, energy storage, circular economy solutions, green hydrogen, carbon capture and storage (CCS), sustainable agriculture, and synthetic biology.

However, many of these innovations are high-risk, capital-intensive, and face long development timelines, making them poorly suited for traditional financing. Venture capital thus plays a vital role in de-risking and scaling these transformative technologies.

According to the International Energy Agency (2023a), around half of the emissions reductions required for a net zero economy by 2050 must come from technologies that are not yet commercially available. Bridging the so-called 'valley of death' between research and market deployment requires flexible, high-risk capital, typically provided by clean energy and climate-focused VC funds.

The circular economy, another key pillar of the sixth wave, also benefits from VC financing. Startups creating alternative materials, zero-waste packaging, or bio-based inputs often rely on early-stage investment to prove feasibility and scale production. The Ellen MacArthur Foundation emphasizes that financing innovation in materials science, reuse logistics, and digital tracking systems is crucial for enabling circular value chains across sectors such as fashion, construction, and electronics (Ellen MacArthur Foundation, 2021).

Venture capital's role is not only financial but also strategic. VC firms provide governance, mentorship, and access to networks that help clean tech startups navigate regulatory complexity, scale manufacturing, and secure follow-on funding.

In the context of mission-oriented innovation, as advanced by Mazzucato (2021), VC firms are increasingly partnering with public entities and development banks to align investment with societal challenges such as climate resilience and decarbonization. These partnerships are particularly important in Global South countries, where public-private capital blending can support climate adaptation and just transitions.

Moreover, policy frameworks and ESG investing trends are catalyzing a surge in climate-aligned VC activity. Governments and institutional investors are increasingly integrating climate risk disclosures, green taxonomies, and impact metrics into funding criteria, encouraging VC flows into sixth-wave technologies. The OECD (2021) notes that innovation policy and sustainable finance are converg-

ing, with venture capital positioned as a key enabler of clean industrial transformation.

In conclusion, the sixth wave of innovation marks a paradigmatic shift in the global economy toward sustainability and systemic resilience. Its success depends not only on technological ingenuity but also on the financial architecture that supports risk-taking and scale-up. Venture capital, with its appetite for early-stage disruption and potential for high impact, stands at the forefront of this transformation.

As clean tech matures into a central pillar of industrial strategy, VC will be indispensable in aligning innovation with planetary boundaries and societal goals. That's the reason why we decided to study the connection between venture capital, energy transition and the petroleum industry from a legal perspective.

Section 2 of this article talks about the importance of new technologies to energy transition and discusses the relationship between the venture capital industry and clean energy. Section 3 talks about research and development of clean technologies, the petroleum industry and energy transition. Section 4 describes how the integration between VC, energy transition and the petroleum industry can be understood from a legal perspective. Section 5 describes the role of the government and of the NOCs in new technologies and potential new structures or tools to foster the cooperation between the petroleum industry and the VC industry. Finally, in Section 6, this article concludes that the integration of VC strategies into traditional oil and gas players reflects a pragmatic response to decarbonization. However, ensuring these investments are aligned with genuine transition goals rather than greenwashing remains a key governance challenge.

This article adopts a narrative review methodology, focusing on scholarly work in the fields of law, economics, and regulatory studies, complemented by energy transition and ESG literature. Sources were identified through systematic searches in databases such as *Scopus*, *Web of Science*, and *Google Scholar*, covering the period from 2010 to 2024. Selection criteria included peer-reviewed articles, policy reports from international organizations (e.g., IEA, OECD), and regulatory frameworks directly addressing venture capital and clean energy. Only works offering conceptual or empirical insights into the intersection between venture capital, the petroleum industry, and the energy transition were retained. This methodological clarification enhances transparency and replicability, enabling future researchers to assess and expand upon the body of evidence presented here.

## 2. New Technologies and Energy Transition

The clean energy technology (clean tech) sector is experiencing rapid growth and innovation, driven by global efforts to transition to sustainable energy. Clean tech is crucial in addressing the global challenges of climate change, energy security, and environmental degradation. By developing sustainable, low-carbon innovations, clean tech helps transition economies toward net-zero emissions, ensures resource efficiency, and promotes economic growth.

Recent data and developments highlight significant advancements across various regions and technologies. Governments, corporations, and VC investors are fueling this expansion as they push for net-zero emissions, energy security, and sustainability. As explored in Section 4, this change is largely driven by a shifting legal and regulatory landscape which is propelling green finance and the funneling of capital towards energy transition solutions.

In 2025, investments in clean energy technologies are projected to reach 670 billion dollars, surpassing upstream oil and gas investments for the first time. This milestone underscores the growing dominance of renewable energy source, with solar photovoltaic systems expected to account for half of all clean tech investments (S&P Global, 2025).

New technologies play a crucial role in the energy transition by enabling cleaner, more efficient, and more reliable energy systems. Their importance can be seen in several key areas, including:

1) Expanding Renewable Energy Capacity

a) Advanced Solar and Wind Technologies: Higher-efficiency solar panels and larger, more efficient wind turbines are driving down costs and making renewable energy more competitive.

b) Floating Offshore Wind: Expands wind power to deeper waters, increasing global wind potential.

c) Perovskite Solar Cells: Emerging as a cheaper and more efficient alternative to traditional silicon-based panels.

2) Energy Storage and Grid Stability

a) Battery Technology Innovations: New battery chemistries (e.g., solid-state, lithium-sulfur) are improving energy storage capacity and lifespan.

b) Grid-Scale Storage: Technologies like pumped hydro, compressed air, and flow batteries ensure renewable energy can be stored and used when needed.

c) Smart Grids and AI Integration: AI-powered grid management enhances efficiency by predicting demand and optimizing energy distribution.

3) Decarbonizing Heavy Industries

a) Hydrogen Economy: Green hydrogen, produced from renewable energy, can replace fossil fuels in steelmaking, shipping, and aviation.

b) Carbon Capture & Storage (CCS): Captures $CO_2$ emissions from industrial processes and prevents them from entering the atmosphere.

c) Electrification of Industry: High-temperature heat pumps and electric furnaces reduce reliance on fossil fuels in manufacturing.

4) Clean Transportation Revolution

a) Electric Vehicles (EVs): Battery advancements are improving EV range, charging speed, and affordability.

b) Hydrogen Fuel Cells: A viable alternative for long-haul trucking, shipping, and aviation where batteries are less practical.

c) Sustainable Aviation Fuels (SAFs): Biofuels and synthetic fuels help decarbonize air travel.

5) Advancing Nuclear Energy

a) Small Modular Reactors (SMRs): Offer safer, more flexible, and cost-effective nuclear energy solutions.

b) Fusion Energy: Though still in early development, fusion promises a near-limitless clean energy source.

6) Digital and I-Driven Energy Efficiency

a) Smart Meters & IoT Devices: Optimize energy use in homes and businesses.

b) Blockchain for Energy Trading: Enables decentralized energy systems where consumers can trade excess solar or wind power.

7) Sustainable Energy Infrastructure

a) Green Hydrogen Pipelines: Transport clean hydrogen across regions.

b) Superconducting Cables: Reduce energy loss in electricity transmission.

c) Modular Microgrids: Ensure energy security in remote areas and disaster zones.

These technologies matter for energy transition because they i) reduce carbon emissions, which is essential for meeting net-zero goals; ii) lower energy costs, making clean energy more affordable over time; iii) increase energy access: bringing electricity to underserved regions; and iv) enhance energy security: reducing dependence on fossil fuel imports.

Investing in new energy technologies is the foundation of a sustainable, resilient, and economically viable global energy future. However, there are lots of challenges to develop clean tech, including high upfront costs, infrastructure limitations, policy uncertainty and research and development funding particularly for breakthrough innovations.

Still, private VC investment in clean tech is growing due to the strong market demand related to corporate net-zero commitments, policy support and falling costs.

Clean tech startups raised more than 25% of all global VC funding in 2023, surpassing traditional software and fintech sectors, with more than 1,000 clean tech VC deals occurring in 2023. From battery technology and carbon capture to green hydrogen and fusion energy, clean tech startups are securing record-breaking investments.

Breakthrough Energy Ventures (BEV), for example, is a $2 billion plus venture capital fund launched by Bill Gates in 2015 to accelerate innovation in clean energy and climate technology. The fund focuses on investing in companies that can significantly reduce greenhouse gas emissions, aiming for impactful, scalable, and financially viable solutions. Notable investments include companies such as Form Energy, Commonwealth Fusion, Redwood Materials and Carboncure involving new technologies on energy storage, nuclear fusion, battery recycling and Carbon Capture.

Also founded in 2015, Energy Impact Partners (EIP) is a global venture capital and private equity firm focused on investing in clean energy, sustainability, and decarbonization technologies. Unlike traditional VC firms, EIP collaborates closely

with a network of over 50 major utilities and energy companies to fund and scale climate tech innovations. EIP has invested in over 100 climate tech companies, some of its most high-profile investments include Arcadia Energy Data & Management, Highland Electric Fleets, Opower and Sunrun Solar Energy involving new technologies such as AI-powered energy optimization platform, school bus fleet electrification, smart home energy management and residential solar storage solutions.

In addition to traditional VCs, due to regulatory pressure, many Fortune 500 companies are investing in clean tech startups through dedicated corporate VC arms (Corporate Venture Capital—CVC), focused on emerging technologies that align with their environmental goals and business objectives, building strategic growth while accessing innovation.

These CVC funds are uniquely positioned to accelerate cleantech innovation by offering the necessary financial resources for startups to develop and scale their technologies and facilitating collaborations between startups and their established corporations, enabling access to markets, expertise, and infrastructure.

One of the examples is Amazon's Climate Pledge Fund, launched in 2020 with an initial commitment of $2 billion. The Climate Pledge Fund aims to support the development of sustainable technologies and services that help Amazon and other companies achieve net-zero carbon emissions by 2040.

Recent investments include Rivian, an electric vehicle manufacturer producing emission-free transportation solutions, and ZeroAvia, a company that develops hydrogen-electric engines for zero-emission aviation (Stiffler, 2024; Green Reporter, 2025).

## 3. Energy Transition, Research and Development and the Petroleum Industry

Research and development (R&D) has long been a foundational element of the petroleum industry, underpinning its ability to discover, extract, and refine hydrocarbon resources at increasing depths, pressures, and technical complexity. Historically, R&D efforts have focused on enhancing upstream and downstream operations, improving efficiency, and maximizing resource recovery.

For instance, the development of 3D and 4D seismic surveys has dramatically improved subsurface imaging, while advances in horizontal drilling and deepwater engineering have unlocked previously inaccessible reserves. In refining, catalytic cracking, hydroprocessing, and emissions control have all been enhanced through sustained research efforts. These technological developments have been instrumental in increasing reserves, improving cost efficiency, and ensuring operational safety in extreme environments (International Energy Agency, 2021).

In several countries, R&D investment by oil companies is not just encouraged, it is legally mandated as part of concession or production-sharing agreements. These requirements are intended to stimulate local innovation, build technological capacity, and ensure that resource extraction benefits national economies be-

yond royalty payments.

In Norway, the government promotes R&D through initiatives like PETROMAKS and Demo 2000, which co-finance projects in safety, environmental protection, and emissions reduction on the Norwegian continental shelf. While not mandatory in a direct percentage sense, the Norwegian model ties access to licensing rounds with commitments to innovation and local content.

In Nigeria, oil and gas companies are required to contribute to the Nigerian Content Development and Monitoring Board (NCDMB), which supports R&D programs in local universities and technical institutes. The aim is to reduce dependence on imported technologies and develop indigenous capabilities.

Other countries, such as Angola, Kazakhstan, and Indonesia, also include R&D obligations or incentives in production-sharing contracts. These typically target local capacity building, training, and transfer of technology, linking petroleum development to broader national innovation strategies.

However, as the global economy embarks on an energy transition toward net-zero emissions, the petroleum industry is increasingly repurposing its R&D capacities to support low-carbon technologies, renewable energy integration, and system-wide decarbonization, including:

1) Carbon Management Technologies: The most prominent low-carbon R&D area in oil and gas is carbon capture, utilization, and storage (CCUS). Major oil companies such as ExxonMobil, TotalEnergies, and Shell are developing and deploying CCUS technologies to mitigate emissions from both oil operations and hard-to-abate sectors. For example, Shell's Quest facility in Canada and Equinor's Northern Lights project in Norway represent flagship efforts in this space. These projects often rely on the industry's existing subsurface expertise, such as seismic monitoring, reservoir modeling, and injection technologies, making CCUS a natural extension of petroleum R&D capabilities.

2) Hydrogen and Low-Carbon Fuels: Petroleum R&D is also expanding into hydrogen production, particularly blue hydrogen (from natural gas with CCUS) and increasingly green hydrogen (from water electrolysis powered by renewables). Several oil companies are piloting integrated hydrogen value chains for transport, industry, and power generation. Meanwhile, advanced biofuels and synthetic fuels are being developed to decarbonize aviation and shipping, sectors with limited electrification potential.

3) Electrification of Oil and Gas Operations: To reduce operational emissions, companies are researching ways to electrify drilling rigs, compressors, and offshore platforms using renewable power sources. For instance, Equinor's platforms on the Norwegian continental shelf are powered by hydroelectricity from the mainland, and similar approaches are being explored in Brazil and the Gulf of Mexico.

4) Digitalization for Emissions Reduction: Oil companies are leveraging digital R&D—machine learning, AI, and digital twins—to improve energy efficiency, predictive maintenance, and real-time emissions monitoring. These tools not only

lower operational costs but also provide granular data for ESG reporting and regulatory compliance.

In this context, oil and gas companies are also increasingly mobilizing corporate venture capital arms to invest in startups and technologies aligned with the energy transition. By leveraging their VC divisions, oil and gas companies are diversifying their portfolios, accessing disruptive innovation, and signaling long-term commitment to sustainability.

Shell, BP, Chevron, and TotalEnergies, as can be seen on their 2022-2024 corporate disclosures, have established dedicated VC arms to support their transition strategies. These arms operate semi-independently, scouting and funding startups in emerging technology domains that align with low-carbon goals. Rather than replacing core business lines, these investments aim to create new growth pathways and future-proof energy systems.

Shell Ventures, for instance, has invested in electrified mobility and hydrogen technologies. A notable example is its support for Supercritical Solutions, a UK-based startup developing high-efficiency electrolyzers for green hydrogen production. Similarly, Shell has invested in XCharge, a company offering battery-integrated ultra-fast EV chargers, which enhances its capabilities in clean transportation infrastructure.

BP Ventures has oriented up to 90% of its recent investments toward climate tech. In 2023, it backed Advanced Ionics, a U.S. startup creating electrolyzers that use industrial waste heat to reduce the cost of green hydrogen. BP also co-invested in Australia's Hysata, which is developing high-efficiency electrolysis systems. These moves support BP's target of deploying 50 gigawatts of renewables and green hydrogen capacity by 2030.

In the U.S., Chevron Technology Ventures is prioritizing carbon capture, utilization, and storage (CCUS), alongside hydrogen and battery-integrated charging. Chevron co-led a $318 million round in Svante, a Canadian firm making novel filters for industrial $CO_2$ capture. It also backed ION Clean Energy, which designs solvent-based systems for hard-to-abate emissions. In the EV charging space, Chevron invested in Electric Era, a startup deploying battery storage at charging stations to reduce peak grid loads.

Recent empirical studies provide quantitative evidence supporting the claim that corporate venture capital (CVC) can significantly influence clean-technology innovation. For example, Bendig et al. (2022) show that CVC investments in green startups are associated with statistically significant increases in the number of green patent applications by incumbent parent firms. Similarly, Bellucci et al. (2023) find that venture capital financing more broadly is positively correlated with both the propensity and intensity of green patenting among European firms. While these studies do not isolate oil- and gas-specific CVC, they nonetheless provide robust quantitative support for the notion that incumbent-backed venture capital functions not merely as financial support but also as a strategic accelerator of low-carbon technologies.

Oil and gas venture capital offers strategic advantages beyond financial return. It enables companies to monitor and shape emerging technologies, de-risk future energy investments, and meet regulatory or ESG commitments. It also offers startups access to industry-scale pilot opportunities, expertise in engineering and supply chains, and long-term partners for commercialization.

However, challenges remain. Critics argue that these investments still represent a small fraction of overall fossil-focused capital expenditures, and some may be driven more by reputation than transformation. There is also the risk of strategic control limiting scale—VC-backed clean tech startups may be absorbed into legacy systems without fundamentally disrupting carbon-intensive business models.

Moreover, the geographic concentration of these investments, mostly among European majors and select NOCs, highlights the need for broader engagement. For the energy transition to be inclusive, venture-backed innovation must expand into emerging markets, with public-private partnerships to de-risk investment and ensure technology diffusion.

A range of legal and regulatory instruments directly affect the flow of venture capital into clean energy technologies. For example, in the United States, the Inflation Reduction Act of 2022 provides tax credits and incentives for renewable energy projects, which directly increase the attractiveness of clean tech investments, as explored in more detail in Section 4.

In the European Union, the Sustainable Finance Disclosure Regulation (SFDR) and EU Taxonomy Regulation set rigorous requirements for ESG-related investments, influencing both the direction and structure of venture capital funding. Additionally, sector-specific mandates—such as R&D and local content obligations—shape how both domestic and foreign venture capitalists participate in the energy transition.

However, these legal frameworks can also introduce complexity and compliance burdens, requiring investors to carefully navigate cross-jurisdictional challenges.

## 4. The Legal Framework for Supporting Innovation in the Energy Transition

The energy transition is not only a technological and financial challenge, but also a legal one. A robust legal framework is essential to channel VC into clean energy innovation, reduce regulatory uncertainty, and align private incentives with public climate goals. This section explores how international agreements, national legislation, and ESG regulations have shaped the legal environment for energy-focused venture capital, with practical examples and quantitative insights.

On a broader perspective, one of the most influential global instruments in shaping climate-related policies is the Paris Agreement, signed in 2015 by nearly 200 countries. It established a collective goal to limit global warming to well below 2˚C, ideally 1.5˚C, and introduced Nationally Determined Contributions (NDCs) that require countries to submit climate action plans. Legally, the Paris Agreement

has catalyzed domestic legislation that incentivizes clean energy investment. For example, Brazil's updated NDC includes targets for renewable energy expansion and carbon neutrality by 2050. Similarly, in most European countries the adoption of a net zero target in their NDC has led to tax and regulatory incentives for renewable and clean energy.

Two key regulations have transformed the legal landscape for sustainable finance in the European Union. The first notable one is the Sustainable Finance Disclosure Regulation (SFDR), which determines that asset managers and financial advisors disclose how they integrate ESG risks into investment decisions. This has increased transparency and investor confidence in climate-focused VC funds. The SFRD has also helped in differentiating truly innovative and disruptive funding vehicles such as "dark green" funds (those classified under Article 9 of the regulation) from funding vehicles which, despite a general pivot to energy transition, are less centered on sustainability (the "light green" funds classified under Article 8, for example). Dar green funds now account for approximately 4% of the assets managed in the EU (Planet, 2023).

By stablishing standards for classification in the capital markets, the SFRD allows for a common language in the green finance sector and prevents greenwashing. Complementing the SFDR and also strengthening classification systems is the EU Taxonomy Regulation, which defines technical screening criteria for economic activities to be considered environmentally sustainable. This taxonomy may be used, for example, by VC funds to validate the eligibility of clean tech startups—e.g., a startup developing green hydrogen electrolyzers must meet specific lifecycle emissions thresholds to qualify for taxonomy-aligned funding. As of 2024, over €1.3 trillion in EU assets were managed under taxonomy-aligned principles, demonstrating its influence on capital allocation.

Although the European legal landscape is the most robust in terms of energy transition regulation, the United States have recently also implemented relevant legislation in the sector. The Inflation Reduction Act (IRA) of 2022 has been a game-changer in this regard. It provides over $370 billion in climate and energy-related funding, including tax credits for clean energy production, electric vehicles, and carbon capture. Crucially, the IRA expanded the authority of the Department of Energy's Loan Programs Office (LPO), explored in more detail below, which offers loan guarantees to innovative energy projects. The IRA alone appropriated approximately $11.7 billion in total for the LPO to support issuing new loans (US Department of Energy, 2022).

Besides assisting with classification and providing regulatory incentives, legislation may also incentivize innovation in energy transition fields through flexibilization of requirements applicable to other R&D areas. In this respect, countries which have regulatory sandbox regimes can use these frameworks to facilitate innovation in new technologies which have not yet been regulated. In Brazil, for example, the National Agency for Oil and Gas and Biofuels (ANP) has already explicitly stated in rulemaking documents that it may apply sandbox tools to reg-

ulate and incentivize CCUS technologies (ANP, 2025) and low-carbon hydrogen production (ANP, 2024).

As mentioned above, R&D regulations also play a critical role in fostering innovation in the energy sector. In several countries, oil and gas regulation determines that companies engaged in upstream activities must invest a percentage of their revenue in R&D activities, which usually must be vetted and approved by the regulator.

Nigeria, for example, stands out for its robust legislative framework under the Nigerian Oil and Gas Industry Content Development Act (NOGICD Act) of 2010. This Act mandates that operators submit Nigerian Content Plans, which must include provisions for R&D, training, and education initiatives. Specifically, Sections 37 - 39 of the Act require companies to carry out R&D programs and make expenditures to the satisfaction of the Nigerian Content Development and Monitoring Board (NCDMB), with updates to R&D plans required every six months (Nigeria, 2010). The NCDMB has further issued detailed guidelines outlining the structure, implementation, and monitoring of R&D activities, including the establishment of accredited research centers of excellence.

Kazakhstan, in its turn, determines that all subsoil users (including. oil and gas companies operating in the upstream sector) allocate at least 1% of their revenues to R&D and training of local personnel (Kazenergy Association, 2021). Private sector associations such as the Kazenergy Association play a key role in coordinating industry input and promoting innovation, assisting members in the elaboration of joint R&D proposals for state bodies and in the development and implementation of programs.

In the UK, while there is no mandatory R&D investment provision in the regulation, oil and gas companies can significantly reduce tax liabilities or obtain cash refunds through the government's R&D Tax Credit scheme. Additionally, many of the qualifying R&D projects in the industry are increasingly focused on energy transition technologies, including energy sustainability, technologies to monitor and mitigate emissions and techniques for extracting oil and gas resources with minimal environmental impact. Despite this trend, a significant part of the investment is still concentrated in traditional oil and gas fields, including drilling techniques and corrosion prevention and materials (Grantica, 2025).

This regulatory framework, however, is not yet sufficient to propel by itself the investments and changes needed to create new technologies through VC. As argued elsewhere (Ribeiro Loss & Moutinho dos Santos, 2025), part of the lack of investment in and financing of energy solutions is the result of an undue and self-inflicting exclusion of oil and gas companies from the landscapes of green finance. Rather than excluding oil and gas companies from climate finance, targeted financial instruments—such as sustainability-linked loans, transition-linked reserve-based lending, and carbon abatement performance bonds—can align the sector's vast resources with decarbonization goals. Much like in the financial sector, R&D investments by the petroleum industry are not contradictory to climate action but

essential, provided it is conditional, transparent, and strategically designed to support measurable transition outcomes.

Therefore, the legal framework supporting innovation in the energy transition is rapidly evolving to meet the demands of a decarbonizing global economy. On a broader perspective, instruments such as the Paris Agreement, the EU's SFDR and Taxonomy Regulation, and the U.S. Inflation Reduction Act have proven effective in mobilizing capital, enhancing transparency, and incentivizing clean technology development. These frameworks not only reduce regulatory uncertainty but also create standardized criteria for sustainable investment, helping venture capital firms identify and support high-impact startups. Moreover, emerging tools like regulatory sandboxes and sector-specific mandates demonstrate how legal innovation and flexibility can accelerate technological deployment.

More targeted regulations have also contributed to fostering venture capital investments in the petroleum industry, particularly through R&D requirements for upstream oil and gas companies. However, from a legal standpoint, significant challenges remain in integrating the petroleum sector into the green finance and VC landscape. Many investment funds face regulatory restrictions that prevent them from allocating capital to oil-related activities, which in turn hampers innovation within the sector. Paradoxically, innovation in the petroleum industry is both environmentally beneficial and critically necessary to reduce emissions in this carbon-intensive domain, as detailed in Section V.

Lastly, the role of governance must also be emphasized. To strengthen governance and ensure that venture capital investments in clean energy are aligned with genuine decarbonization goals, mandatory science-based targets (SBTs) can serve as a concrete mechanism. These targets require companies to set emissions reduction goals consistent to certain scientific thresholds, such as in accordance with the Paris Agreement, thereby embedding climate accountability into investment strategies. In the European Union, the EU Taxonomy Regulation complements this approach by establishing technical screening criteria for environmentally sustainable activities, which VC funds can use to validate the eligibility of clean tech startups. For example, a startup developing green hydrogen electrolyzers must meet lifecycle emissions thresholds to qualify for taxonomy-aligned funding. Together, SBTs and the EU Taxonomy create a robust framework that mitigates greenwashing risks and enhances transparency in climate finance (European Union, 2020; Science Based Targets initiative, 2023; Planet, 2023).

## 5. New Technologies, Government, NOCs and VC Initiatives

Clean energy technologies often involve high upfront costs, extended development timelines, and uncertain returns, making them less attractive to traditional private investors. Government and NOC-backed VC funds aim to bridge this financing gap by de-risking investments and catalyzing private sector participation.

By providing early-stage funding, these public investments de-risk innovative technologies, making them more attractive to private investors and accelerating

their path to commercialization. This approach not only accelerates technological advancement but also aligns with broader policy objectives, including energy security, economic diversification, and environmental sustainability.

Economist Mariana Mazzucato (2013) emphasizes the critical role of the state in driving innovation. In her book The Entrepreneurial State, she argues that 'the state has been behind the most radical innovations of our time' and advocates for mission-oriented public organizations to tackle grand challenges like climate change. Mazzucato contends that "green is not just about renewable energy. It's also about creating a new direction for the whole economy. This requires government to step up, not step back" (ClimateKIC, 2018).

In her book Mission Economy: A Moonshot Guide to Changing Capitalism, Mazzucato (2021) argues that governments should adopt mission-oriented approaches to tackle grand challenges like climate change. She draws parallels between such missions and the Apollo program, suggesting that ambitious, state-led initiatives can drive significant technological and societal advancements.

Through these works, Mazzucato advocates for a proactive role of the state in shaping markets and directing innovation towards public goals, emphasizing that such involvement is crucial for achieving a green and inclusive economy.

One example of government initiative is the Clean Energy Finance Corporation (CEFC). The CEFC is an Australian government-owned green bank established to invest in clean energy projects, facilitating the country's transition to a low-carbon economy. Operating under the Clean Energy Finance Corporation Act 2012, the CEFC provides financing for renewable energy, energy efficiency, and low-emission technologies.

In mid-2022, the Australian Parliament expanded the CEFC's role, increasing its capital allocation by $20.5 billion to drive investments across priority areas critical to the clean energy transition. This enhancement empowers the CEFC to support a broader range of decarbonization initiatives, including grid transformation and sustainable housing projects.

Launched in October 2024, the UK's National Wealth Fund is another example. The NWF aims to catalyze investments in critical growth sectors, including clean energy technologies such as giga factories, green hydrogen, and carbon capture. With a capital pool of up to £27.8 billion, the NWF seeks to attract private capital by sharing investment risks, operating with a broader mandate than the existing UK Infrastructure Bank (Reuters, 2024).

In February 2025, the UK government pledged £200 million from the NWF to support projects at Grangemouth, Scotland's sole oil refinery, which is slated for closure. This investment aims to transition the facility towards a post-oil industrial future, exploring clean fuel manufacturing options utilizing bio feedstocks and green hydrogen (Financial Times, 2025).

The U.S. Department of Energy (DOE) has implemented several programs to support clean energy innovation. The Loan Programs Office (LPO) provides loans and loan guarantees to projects that employ innovative technologies, including

renewable energy and electric vehicles. Additionally, the Advanced Research Projects Agency-Energy (ARPA-E) funds high-potential, high-impact energy technologies that are too early for private-sector investment.

China has set up a National Venture Capital Guidance Fund to support technology startups in sectors like semiconductors and renewable energy. Structured as a public-private partnership, the fund targets emerging technologies, including hydrogen energy storage, with a focus on long-term investment cycles.

NOCs are also engaging in venture capital as part of broader sustainability efforts. Saudi Aramco, through Aramco Ventures, launched a $1.5 billion Sustainability Fund focused on low-carbon innovations (Aramco Ventures, 2022). One major investment includes Carbon Clean, a modular carbon capture firm targeting industrial emitters in the developing world. Aramco has also invested in hydrogen electrolyzer startups, positioning itself as a leader in future ammonia and hydrogen exports.

Equinor Ventures, backed by Norway's Equinor, has adopted a focused strategy targeting carbon management, hydrogen carriers, and offshore wind innovation. In 2023, it invested in HySiLabs, a company developing a safe liquid hydrogen carrier that releases hydrogen on demand. It also co-led a round for Carbon Recycling International, which converts $CO_2$ into methanol—a synthetic fuel compatible with existing infrastructure.

In Southeast Asia, Petronas Ventures is targeting startups involved in energy storage, waste-to-energy, and smart grid technologies. Notable investments include firms developing thermal energy storage and solid-state switches for efficient power management. Petronas also co-invests in global clean energy startups via international partnerships, aligning with its broader energy transition platform under its clean energy subsidiary Gentari.

Public-private collaboration has become a vital mechanism for driving clean energy research, development, and deployment. These partnerships blend the innovative capacity and market orientation of the private sector with the risk mitigation tools, policy frameworks, and financial muscle of the state.

The rationale for public-private collaboration in clean energy stems from a confluence of market failures, financing gaps, and innovation challenges. Clean energy technologies often face the "valley of death"—a well-documented stage in which promising innovations struggle to secure sufficient capital to transition from laboratory to commercialization (Ghosh & Nanda, 2010).

These technologies may offer long-term environmental benefits, yet private investors are frequently deterred by high capital intensity, long development timelines, and uncertain regulatory environments. Governments, therefore, play a key role in correcting these failures by de-risking investments, setting policy signals, and co-financing innovation.

One major form of collaboration is through co-investment funds and blended finance vehicles, where public institutions invest alongside private capital to support emerging technologies.

An exemplary initiative is the Breakthrough Energy Catalyst fund, launched by Bill Gates and supported by entities such as the U.S. Department of Energy (DOE), the European Commission, and BlackRock. Catalyst pools concessional capital to scale technologies such as green hydrogen, sustainable aviation fuel, and long-duration energy storage, technologies that are critical for decarbonization but remain commercially uncompetitive without public support.

In many countries, public institutions also fund early-stage research and development, with commercialization opportunities later taken up by the private sector. The U.S. ARPA-E program (Advanced Research Projects Agency-Energy), for example, has been instrumental in funding high-risk, high-reward clean energy technologies. One of its beneficiaries, Ambri, developed a novel grid-scale battery and later attracted private investment from Bill Gates and energy companies. Such programs demonstrate how public funding can catalyze private sector engagement when well-targeted and strategically administered.

A third tool of collaboration involves loan guarantees and risk-sharing mechanisms. Public agencies often provide financial backstops to reduce the perceived risk of clean energy investments. A prominent example is the DOE's Loan Programs Office, which provided a $465 million loan guarantee to Tesla in 2010. This funding was critical to the development of Tesla's manufacturing capacity and is often cited, particularly by Mariana Mazzucato, as a case of the state acting as an "entrepreneurial investor". In her book The Entrepreneurial State, Mazzucato argues that the state should not merely 'fix' market failures but actively create and shape markets, a function she deems essential to clean energy innovation.

While government, and NOC-backed venture capital, and PPP initiatives play a crucial role in advancing clean energy, they also face several challenges. Excessive government intervention can lead to market imbalances, where certain technologies are favored over others without clear justification. Changes in government priorities or leadership can disrupt funding and policy continuity, affecting long-term projects. In addition, ensuring that public funds are used effectively requires robust oversight and transparent evaluation mechanisms.

Aligning the incentives, timelines, and risk profiles of public and private actors requires careful design and coordination. There is also the risk of regulatory capture or the subsidization of incumbent firms at the expense of transformative change. Moreover, evaluating the impact of such collaborations can be difficult, as their benefits often materialize over long time horizons and are distributed across multiple sectors and stakeholders.

Still, the clean energy development cannot proceed at the necessary scale and pace without engaging the largest incumbents in the system—oil and gas firms, especially NOCs, and the VC firms. By strategically fostering relationships with venture capital, NOCs can become critical enablers of clean technology innovation, rather than obstacles. Public policy can catalyze this by redesigning incentives, reducing risk, and creating collaborative platforms that align private agility with public purpose.

The rationale for closer collaboration between NOCs and VC firms lies in the complementary strengths of each actor. NOCs bring to the table substantial capital resources, access to infrastructure, and deep sectoral expertise. They are also strategically positioned to test, scale, and deploy new technologies across complex energy systems.

Venture capital, by contrast, excels at identifying early-stage innovation, managing high technological risk, and rapidly scaling entrepreneurial ventures. As the International Energy Agency (2023b) notes, oil and gas companies—especially NOCs—are uniquely positioned to "scale up crucial net-zero technologies" due to their industrial capabilities and technical expertise. However, many of these technologies, including hydrogen, direct air capture, and long-duration energy storage, require financial and developmental support beyond what traditional R&D departments can offer.

Outside corporate venture arms, blended finance and co-investment platforms, a promising avenue for fostering this collaboration is the development of open innovation platforms, incubators, and challenge programs involving NOCs, VC firms, and startups. These programs can promote thematic collaboration around hard-to-abate areas such as methane leakage, industrial heat, and carbon reuse.

The OGCI Climate Investments fund, supported by major oil companies including Petrobras, Shell, and TotalEnergies, provides a case study in which oil firms co-invest in clean tech startups and provide pilot infrastructure for field testing. These platforms enable early-stage ventures to validate and demonstrate technologies in real-world conditions while NOCs gain insight into cutting-edge innovation.

At the institutional level, governments have a pivotal role in shaping the framework for such partnerships. Strategic mandates can be embedded within NOC governance structures to direct a portion of capital expenditures or R&D budgets toward clean technology, including direct investments in startups or co-investment with VC funds. This perspective resonates with the OECD's recommendation that state-owned enterprises should lead by example in the green transition, leveraging their influence to mobilize private capital and accelerate clean energy deployment (OECD, 2021).

Despite its potential, the integration of VC and NOC strategies faces several structural and cultural barriers. NOCs are often embedded in complex political environments and exhibit conservative investment behavior, which can be misaligned with the high-risk, fast-paced nature of VC.

Differences in investment horizons also pose challenges: VCs typically operate on five- to ten-year timelines, whereas NOCs plan on twenty- to thirty-year cycles. Moreover, governance concerns, such as potential conflicts of interest and the risk of greenwashing, must be carefully managed through transparency, accountability, and public oversight.

By aligning the financial capabilities and industrial infrastructure of NOCs with the risk-taking and innovation-driving capacities of venture capital, public and

private stakeholders can create a more effective and inclusive clean energy ecosystem. Achieving this will require targeted policies, institutional innovation, and a shared commitment to the goals of sustainability and transformation.

To address these challenges, policy interventions should focus on five priority areas: 1) setting clear transition mandates within NOCs' investment strategies; 2) establishing dedicated co-investment vehicles combining NOC, public, and VC capital; 3) building institutional capacity within NOCs to engage in venture investing; 4) promoting collaborative R&D and innovation platforms that connect corporates, VCs, and startups; and 5) designing regulatory frameworks and tax incentives that reward clean energy investments. Together, these measures can create a more coherent and dynamic ecosystem for energy transition finance.

It should be recognized, however, that, despite the strategic potential of joint ventures between venture capital firms and National Oil Companies (NOCs), some legal and contractual barriers hinder broader collaboration. NOCs often face public procurement and sovereign investment restrictions that limit their flexibility in partnering with private entities. Governance concerns, such as conflicts of interest and the risk of regulatory capture, further complicate joint ventures. Moreover, many VC funds are subject to ESG mandates or green finance regulations—such as the EU SFDR—that restrict investments in fossil-related activities, even when such investments target decarbonization technologies. These legal constraints must be addressed through tailored co-investment vehicles, regulatory sandboxes, and harmonized ESG standards to unlock the full potential of VC-NOC partnerships (OECD, 2021; Ribeiro Loss & Moutinho dos Santos, 2025; ANP, European Union, 2019).

While this study provides a comprehensive review of the legal and institutional frameworks linking venture capital, the petroleum industry, and clean energy, it relies primarily on secondary sources and qualitative analysis. This reliance limits the ability to establish causal relationships between corporate venture capital (CVC) strategies and actual clean-tech deployment. Future research should incorporate empirical methodologies, such as event studies assessing market reactions to CVC announcements, or econometric analyses of clean-tech adoption rates following targeted investments. Such approaches would strengthen the evidence base and allow for more precise measurement of the transformative role of oil and gas CVC in accelerating the energy transition.

Finally, it is important to note that clean tech is not just an environmental necessity, but also a huge economic opportunity for the public and private sectors. As governments, investors, and companies prioritize sustainability, the clean tech sector will reshape global industries, reduce emissions, and create millions of jobs.

## 6. Conclusion

The energy transition represents not only an environmental imperative but a structural transformation of the global economy. In this context, VC emerges as a key enabler of innovation, capable of mobilizing early-stage financing, de-risking

unproven technologies, and fostering entrepreneurship in clean tech sectors. Simultaneously, oil and gas companies, particularly NOCs, possess capital resources, infrastructure, and technical capabilities that can greatly accelerate the development and deployment of such technologies when strategically aligned with transition goals.

This article has demonstrated that the integration of VC strategies into the petroleum industry, especially through corporate venture capital arms, public-private platforms, and regulatory incentives, reflects a pragmatic and increasingly necessary response to decarbonization challenges. From a legal perspective, these investment dynamics are inserted into increasingly stringent climate-related regulations based on taxonomies, appropriation of funds for investment in new energies, regulatory barriers for the development of polluting energies and flexibilization for clean energy VC. It has also shown that governments play a catalytic role, both as regulators and co-investors, capable of shaping market dynamics and aligning private incentives with public missions, as advocated by Mariana Mazzucato's mission-oriented innovation framework.

However, realizing this vision demands careful governance. The risk of greenwashing, the inertia of bureaucratic institutions, and the mismatch between public and VC investment cycles must be actively managed. Transparency, accountability, and performance-based allocation of funds are critical to ensure that the deployment of capital contributes meaningfully to emission reductions and innovation scaling. Legal professionals, therefore, have a crucial role to play in ensuring the sustainability, transparency and functioning of the green finance landscape.

Additionally, the integration of venture capital into the energy transition has profound implications for legal frameworks and the role of lawyers in the sector. Energy and finance lawyers must be adept at structuring innovative deal models that comply with emerging climate regulations and ESG standards. This includes crafting investment agreements that anticipate regulatory shifts, embedding climate-related performance targets, and addressing potential disputes over intellectual property and technology transfer. Policymakers, in turn, are challenged to harmonize legal frameworks across jurisdictions to foster cross-border VC flows and ensure that regulations promote both innovation and environmental integrity. Effective collaboration between legal practitioners, regulators, and industry stakeholders is thus essential for advancing the energy transition.

In conclusion, fostering a robust partnership between VC and the oil and gas sector, particularly through NOCs, is not a contradiction, but a strategic necessity. It reflects a deeper reconfiguration of industrial policy, innovation finance, and environmental governance in the age of climate urgency. If executed with vision and discipline, this approach can help transform the country's fossil legacy into a platform for sustainable leadership in the clean energy era.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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