

# Resource transparency and energy transition: The role of SEC oil and gas reserve reporting in future energy systems

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## CITATION

Fan G, Guo M, Wang Y. Resource transparency and energy transition: The role of SEC oil and gas reserve reporting in future energy systems. *Energy Storage and Conversion*. 2026; 4(2): 4190. <https://doi.org/10.59400/esc4190>

## ARTICLE INFO

Received: 24 March 2026

Revised: 21 April 2026

Accepted: 27 April 2026

Available online: 12 May 2026

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**Abstract:** The world energy paradigm shift is changing the manner in which oil and gas resources are rated, regulated, and reported. The review studies the purpose of the U.S. Securities and Exchange Commission (SEC) oil and gas reserve reporting as one of the main transparency tools of resources and evaluates its applicability in future energy systems. Conventionally, the SEC reserve reporting has minimized information asymmetry in the capital markets through standardization of disclosure of economically viable production of hydrocarbon reserves and therefore, facilitated the protection of investors, asset-pricing, and corporate responsibility. Nonetheless, the article states that the traditional reasoning behind reserve reporting is being more and more questioned by decarbonization, financial risk associated with climate, carbon limits, and shifting capital allocation trends. Even with reported reserves, technical, and commercial producibility may remain, but innovation does not entirely account for transition-related risk conditions like stranded asset risk, fossil entrapment, emissions exposure, and demand decline in low-carbon systems. With a combination of the views of reserve classification, securities regulation, energy governance, and transition finance, this review indicates that SEC reserve reporting is still needed but not sufficient as a standalone transparency measure. The article identifies the necessity to revise the reserve disclosure by incorporating more deeply into climate-related reporting, scenario-based analysis, and better addressing uncertainty. It comes to a conclusion that reserve reporting needs to be redesigned as a fossil asset-centric accounting system into one that is more dispositionally inclusive of transition to control resource value in the decarbonization of energy systems.

**Keywords:** SEC reserve reporting; resource transparency; energy transition; stranded assets; climate-related financial disclosure

## 1. Introduction

The global energy system is undergoing a radical structural change driven by the imperatives of decarbonization, climate policy, and technological change. The shift to low-carbon energy systems, characterized by the growth of renewable energy, electrification, and new uses for natural gas, has fundamentally changed the approach to energy asset valuation, management, and reporting [1, 2]. In this regard, oil and gas reserves that have consistently been seen as indicators of future production and firm value are increasingly exposed to new sources of uncertainty related to carbon constraints, policy risk, and changing demand patterns. With the development of energy systems, transparency and perception of hydrocarbon reserves will be crucial not only in financial markets but also in overall energy governance.

The U.S. Securities and Exchange Commission (SEC) reserve reporting system has been a pillar of transparency in capital market resources. The SEC has made disclosure of proved reserves comparable across firms and has minimized information asymmetry for investors. Reserves are not observable quantities but are estimates (probable) based on geological, engineering, and economic assumptions. Their reporting, hence, converts the uncertainty that exists below the earth into information that is financially viable. The current literature highlights the significance of reserve disclosure for valuation, investment decisions, and regulatory compliance, particularly in scenarios such as privatization and access to capital markets. Nevertheless, most of these studies remain within the traditional paradigm, which presupposes the continued topicality of hydrocarbon mining [3–6].

Although there is a large body of literature on the estimation of reserves, accounting, and disclosure, significant gaps remain. Firstly, the bulk of previous studies approach reserve reporting as a technical or financial reporting concern, and little has been done to recognize its contribution to the overall energy transition process. Second, the current research tends to focus on the accuracy of estimation or regulatory compliance, but does not consider the interplay between reserve disclosure and transition risks such as stranded assets, fossil-fuel lock-in, and capital reallocation. Third, research on low-carbon energy systems, such as renewable energy applications and the interim status of natural gas, has developed in parallel, and there is a lack of integration with resource reporting systems. Recent studies point to the increasing complexity of energy systems in decarbonization, such as the shifting role of natural gas as a transition fuel and the need to balance energy security, affordability, and sustainability, but these dynamics are not often included in reserve-disclosure analyses [7–9].

This article fills these gaps by redefining SEC oil and gas reporting on reserves as an essential point of interface between resource transparency and energy transition governance. This review takes an interdisciplinary approach to reporting standards and estimation methods, unlike some earlier work, which focuses on narrower aspects of the topic, such as reporting standards or estimation methods. The main thesis is that reserve reporting is not a passive process of reflecting subsurface resources, but a dynamic process that can influence how fossil resources are valued, financed, and maintained in changing energy regimes [10,11].

This work was novel and made three contributions. First, it logically connects SEC reserve reporting to energy transition dynamics, emphasizing the interplay among disclosure frameworks, decarbonization pressures, climate policy, and energy development. Second, it precedes a conceptual shift in the transparency of resources from their stillness to the transparency of the transition, highlighting that the value of resources depends on future policy, market, and technological decisions. Third, it is a critical assessment of what current reporting frameworks are constrained by and recommends reform directions, such as incorporation with climate-related disclosure, scenario assessment, and better consideration of uncertainty [12].

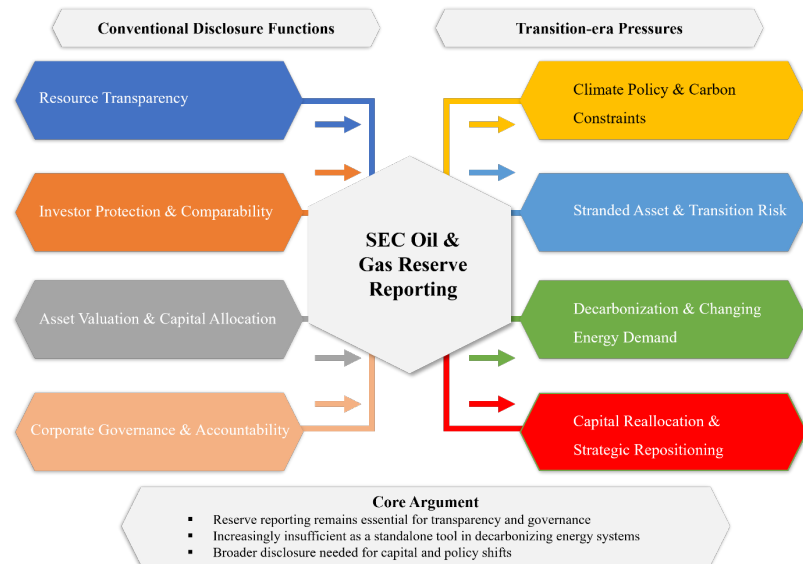
This research methodologically uses a conceptual synthesis with a structured literature review. It is based on regulatory documents, financial reporting literature,

new studies of the energy transition, natural gas systems, and the integration of renewable energy. The article contrasts the traditional reserve reporting rationale with new transition-focused analytic models, reveals the dimensions of the misalignment, and suggests a future-oriented redefinition of resource transparency [13].

This research has triple value. To academia, it diffuses two rather different disciplines: reserve reporting and energy transition studies; it provides a common analytical framework. For policymakers and regulators, it underscores the need to update disclosure systems to accommodate the risks and uncertainties of the transition era. It is an additional insight for investors and industry practitioners into the quality of reserves and long-term asset sustainability in a decarbonizing world [14].

The rest of this paper is organized as follows. Section 2 discusses the foundations of SEC reserve reporting and classification systems. Section 3 investigates the disclosure of reserves to create transparency in resource use and presents its constraints in the case of transition. Section 4 examines the relationship between reserve reporting and energy transition dynamics, including stranded asset risk and capital allocation. Section 5 suggests reform directions for transition-conscious disclosure systems. Section 6 ends by offering implications for future governance of the energy system [15,16].

The analytical framework of this review, as shown in **Figure 1**, correlates SEC reserve reporting with resource transparency, financial governance, and energy transition pressures [17–19].



**Figure 1.** Analytical framework linking SEC oil and gas reserve reporting, resource transparency, and energy transition dynamics.

Second, the article combines the studies that are frequently written separately: petroleum reserve classification, securities disclosure, climate-related financial risk, and transition governance. By combining these strands, it is possible to gain a better insight into how the changing role of reserves in corporate and financial decision-making is to be understood. Instead of concentrating on reserves as physical stocks or as financial assets, the article defines reserves as socio-technical and regulatory constructions whose meaning relies on shifting assumptions about energy

demand, popular policy, and environmental justice. This is an interdisciplinary synthesis that is especially valuable when the literature being reviewed is to be consumed by a broad audience in the SCI community: it bridges the gap between the technical reporting practices on the one hand and macro-level questions of sustainability and institutional adaptation on the other [3,20].

Third, the article presents a future-oriented critique of existing reporting of reserves in terms of exposing the necessity of climate-conscious and transition-sensitive reporting. Current SEC regulations have been necessary for standardization and disclosure, yet they were not made to deal with net-zero solutions, carbon budget limitations, or the selective susceptibility of reserves to other energy solutions. This review thus goes beyond the limitation identification and therefore offers a conceptual foundation for updating disclosure frameworks. It reflects on the way in which reserve reporting could be supplemented with scenario analysis, carbon intensity metrics, lifecycle emissions factors, and others that are more reflective of the future of energy systems. In this respect, the article is not solely an interpretative, but also an agenda-setting one: it reveals the points of regulatory reform and future studies of the connection between resource disclosure and sustainability governance [21,22].

The relevance of this subject goes beyond the technicalities of regulations. The main requirement of effective markets, credible governance, and socially legitimate transition planning is transparency. In the hydrocarbon industry, the tradition of transparency has been based on volumes, potential output, and short-term market value [4]. The change of energy requires a wider definition of transparency, one that incorporates policy sensitivity and climate exposure, the implications of the emissions, and the dissonance in time between long-lived fossil assets and the changing decarbonization objectives. The focus of this tension is SEC reserve reporting. It is still essential to see the material foundation of oil and gas companies, but it may not be enough on its own as a reporting standard in assessing companies in the transitional markets [4,23–25].

In that order, this review poses three fundamental questions. What role does SEC oil and gas reserve reporting play in the transparency of resources in financial and governance aspects? How does traditional reserve disclosure work with risks and uncertainties of the energy transition, stranded assets, and fossil fuel lock-in? And in what ways would reporting structures evolve so that the disclosure of reserves would be decision-useful in the future energy systems in a decarbonized and volatile format, altered by the evolving demands of corporate responsibility? The article seeks to answer these questions in order to explain how reserve reporting remained relevant even today, besides critically reviewing its boundaries.

The rest of the review goes as follows. In Section 2, the conceptual and regulatory basis of SEC reserve reporting, such as definition, historical development, and connection with other reserve classification systems, is discussed. In Section 3, SEC reserve reporting is evaluated as a resource transparency mechanism; its financial, technical, and governance functions are considered. Section 4 investigates the interplay between reserve disclosure and energy transition, with the areas of lock-in to fossil fuels, risk of stranded assets, and the changing capital market interpretation. Section

5 addresses the redesign of reporting of reserves in future energy systems, both in combination with climate disclosure and transition-sensitive metrics. Section 6 also ends by summarizing the key lessons and providing regulators, firms, investors, and researchers with implications [18,26–29].

## **2. Conceptual and regulatory foundations of SEC reserve reporting**

### **2.1. Reserve reporting as a transparency institution**

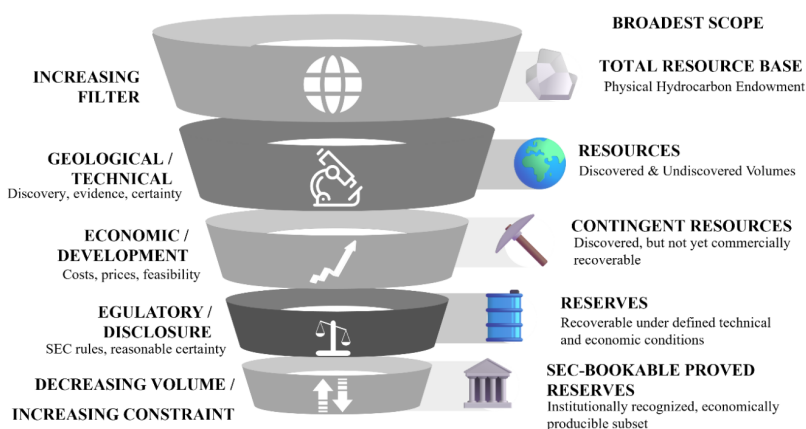
The SEC oil and gas reserve reporting is at the crossroads of geology, engineering, accounting, and securities regulation. The significance of it is that it transforms uncertain subsurface hydrocarbons into standardized disclosures that can be interpreted by investors as a predictor of future production and value of the asset. The reserve reporting is thus not just a technical process but is an institutional process in which underground resources are brought to light so that they become financially visible [3,30–32].

Its key role is to deal with uncertainty. The volumes of hydrocarbons are never certain concerning size, recovery, time, and profitability, but the capital market needs categories that seem to be constant and similar. This is tackled by the SEC structure through codifying the amount of economically producible reserves, particularly proved reserves. This enhances comparability and investor protection, whereas it also reduces the number of uncertainties under disclosure. Traditional reporting is more effective in capturing geological and commercial risks as compared to extended transition risks like climate policy, declining demand, or technological replacement [33].

This difference is becoming a significant feature of the energy transition. A model that reveals the feasibility or otherwise of hydrocarbon production is now also employed to determine whether such assets can be used in a decarbonizing system. Conceptual foundations of SEC reporting are thus seen to bring forth its maintained value as well as its increased limitations.

### **2.2. Reserves, resources, and classification logic**

The simplest difference in petroleum reporting concerns resources and reserves. The term resources is used to describe the hydrocarbons within the subsurface broadly and the resources that are recovered because they can be economically produced given the current technical and regulatory circumstances. Such a difference exists between the geologic possibility and the commercial supply. This classification is illustrated in **Figure 2** as a sequential filtering process that explains how geological, economic, and regulatory constraints gradually reduce the entire base of hydrocarbon resources into reserves and finally SEC-bookable proved reserves. **Table 1** summarizes the chief conceptual differences between resources, contingent resources, reserves, and proved reserves [34–36].



**Figure 2.** Hydrocarbon resource classification as a sequential filtering process.

**Table 1.** Conceptual distinctions among hydrocarbon resources, contingent resources, reserves, and proved reserves.

Category	Definition	Degree of certainty	Economic condition	Relevance to this review	References
Resources	Total concentration of hydrocarbons potentially present in the subsurface	Low to high	Not necessarily economic	Represents the broad physical base from which reserves are derived	Etherington and Ritter [37]
Contingent resources	Discovered hydrocarbons not yet commercially recoverable due to technical, regulatory, or economic constraints	Moderate	Conditional	Highlights how viability depends on changing external conditions	Senturk [38]
Reserves	Discovered hydrocarbons expected to be recoverable under defined conditions	Higher	Must be economic	Core category for SEC disclosure and financial interpretation	Senturk [38]
Proved reserves	Quantities estimated with reasonable certainty to be economically producible from known reservoirs	Highest among reserve classes	Economic under prescribed assumptions	Primary focus of SEC reporting and capital market valuation	U.S. Securities and Exchange Commission [39]
Probable/Possible reserves	Additional recoverable quantities with lower confidence than proved reserves	Lower than proved	May be economic	Useful for broader industry comparison, but less central in SEC filings	European Union [40]

The overall hydrocarbon resource base is a wide physical endowment encompassing both the discovered and undiscovered volumes. The division into reserves and disclosed is done based on a series of filters. Geological and technical constraints limit resources to the volumes discovered, whereas economic and development conditions define the volumes as commercial and thereby as reserves. This is further limited to SEC-bookable proved reserves, which are determined by standards of reasonable certainty and economic producibility. The figure underscores that reserves are not a predetermined physical amount but the product of a series of technical, economic, and institutional filters that increasingly convert subsurface resources into decision-relevant and reportable forms.

Proved reserves have traditionally been the primary disclosure category to the SEC. These are those quantities that may be estimated with reasonable confidence that they are economically feasible to be produced from known reserves. However, the seemingly factual quality of this definition should not be exaggerated. Reasonable certainty: It is a regulated opinion that is founded on accessible information, engineering opinion, development assumptions, and anticipated market circumstances.

The reserves are not thus fixed natural facts, and they are contingent representations of resource viability.

This contingency is even more important in conditions of energy transition. The border between resources and reserves is being defined more and more not by price and technology, but by carbon regulation, investor pressure, and anticipations of future demand. These influences are reflected in the traditional definitions of reserves in a partial way. Consequently, reserve figures can continue to be indicative of financial reporting strength further, while long-term strategic value is increasingly frail [41].

### **2.3. Historical development of the SEC framework**

The SEC reserve reporting system should be seen as the way to minimize information asymmetry within the industry, where companies are much more aware of their assets than investors themselves. The regulated disclosure regulations were to ensure overblown statements were avoided, enhance comparability, and build trust in securities markets. Reserve reporting thus evolved as a market discipline tool.

Historically, the SEC used a conservative strategy that was based on proven reserves and demonstrations of economic producibility in the current circumstances. This was logical, given the time that the primary issue was hyperbolism of the resource potential, as opposed to the risk of the asset in relation to climate. Subsequent changes were made to suit technological change and more complex development of the resource, such as unconventional plays, but the underlying logic was the same: reserve reporting was made to reveal commercially recoverable hydrocarbons rather than to determine whether the hydrocarbons were viable in a low-carbon future or not [42,43].

It is also included in this history that reserve reporting contributed to forming, rather than describing, the financial rationale of hydrocarbon expansion. Reserved bookings turned into a symbol of corporate power, future revenues, and strategic depth. This heritage is one reason why the system is still powerful, but also why it is institutionally hard to fix and make it responsive to issues of transition.

### **2.4. SEC reporting and other classification systems**

SEC reserve reporting is used alongside other systems, and in particular, the Petroleum Resources Management System (PRMS). Both are based on similar technical principles, although they are different in their purpose. PRMS is more comprehensive and flexible, and includes prospective resources, contingent resources, and different classes of reserves. The SEC system is more limited and is focused more on standardized public disclosure and investor protection.

This variation gives rise to a significant trade-off. PRMS is able to better represent the uncertainty and development pathway around the hydrocarbon assets, and SEC reporting is more consistent and comparative to capital markets. What is obtained in standardization, however, is perhaps lost in descriptive richness. To multinational companies and international investors, the presence of various systems may involve comparability across companies and leave room for strategic interpretation.

The two systems have a similar limitation in the energy transition. They were created, narrow or broad, to categorize extractive opportunity and not transition

exposure. Carbon limitations, intensity of emission, and conformity to decarbonization tracks tend to be beyond the main rationale of a classification of reserves [44,45].

## **2.5. Economic assumptions and the limits of disclosure objectivity**

Reserves do not just exist as physical recovery, but also as economically producible. This implies that even with a constant geology, the reserve volumes can vary with the prices, costs, fiscal terms, and development plans. Reserves are, therefore, a hybrid creation, which is created in the interaction between subsurface knowledge and market assumptions.

These assumptions are standardized in SEC reporting to enhance comparability, but standardization can also give a false impression of objectivity that is more powerful than reality. The reserve estimates are still model-driven and judgmental. They are disciplined representations and not direct observations.

This constraint is more acute in a transitional situation. A reserve can meet the immediate needs of economic requirements and be vulnerable to significant risks due to climate policy, carbon pricing, reputational pressure, or declining demand, all in the long term. It is not that the rules may be inaccurate, but simply that they may no longer be reflective of the most decision-relevant aspects of asset viability. Having previously been viewed as a simple indication of financial strength, reserve expansion can now also be viewed as an increased exposure to transition risk [46].

## **2.6. Implications for this review**

The theoretical and regulatory principles of SEC reserve reporting show a paradigm that has and continues to be vital to investor protection and transparency of resources, but is becoming more and more incomplete in a decarbonizing energy system. It has the strength of rigorous revelation of technical and economic recoverability. Its weakness is that it pays little attention to more general uncertainties, which are now defining hydrocarbon value.

This review thus does not just view SEC reserve reporting as a technical disclosure system, but also a governance system that would determine how fossil resource value is captured and communicated. The following part goes on this basis by analyzing the practicality of reserve reporting as a tool of resource transparency, and where the primary loopholes are manifested in environments of transition [44].

# **3. SEC reserve reporting as a mechanism of resource transparency**

## **3.1. Reserve disclosure and financial interpretability**

SEC reserve reporting can be viewed as one of the most significant processes by which oil and gas companies can turn subsurface uncertainties into financial significance. The reserves are not interpreted as geological approximations of reserves; they are read in the capital markets as a message of fun and productive existence, cash flow, and placement. This discloses reserves central to the financial legibility of upstream firms. Reserve data helps investors, lenders, analysts, and rating agencies evaluate the quality of assets, the sustainability of production, and vulnerability to

fluctuations in commodity prices. In this regard, the transparency which is offered by SEC reporting is not merely informational but constitutive: it assists in defining how hydrocarbon value is being identified and priced [31,47].

The position is also important because the upstream assets are otherwise hard for outside parties to assess. Unlike manufactured inventories or traditional fixed assets, reserves are buried underground and cannot be directly confirmed by market actors. Disclosure regulations, thus, minimize information asymmetry by creating a standardized language in which companies purport to exercise control and output. The consistency in reserve classification requirements increases comparability among firms and across periods, and reserve measures can be part of valuation models, debt ratings, and strategy.

But this type of transparency is discriminatory. Reserve figures reveal some dimensions of value and obscure others. They shed light on technical and business manufacturability under specified conditions, but do not tell the whole story of how the broader political, climate, or demand-side uncertainties will determine whether production will be appealing over time. Subsequently, the transparency of the reserve tends to underpin financial interpretation, although not necessarily complete strategic transparency. A company can be seen to be in a good position based on the reported reserves, but be highly vulnerable to long-term transition risks [48].

### **3.2. Technical credibility and the production of trust**

Reserve disclosure should be useful, which requires trust in the procedures used to estimate the reserves. The presence of technical rigor is a major source of the authority of SEC reporting. Geologic information, reservoir development, production history, development schemes, and financial assumptions are united to establish one reason why there are claims on recoverable volumes. This procedure makes reserve reporting scientific and professional in nature, which enhances its credibility in the capital markets.

But complete certainty should not be compared with technical credibility. Reserve estimation is still a modelling exercise that is influenced by interpretation, assumptions, and professional judgment. Although this is done to rigorous standards, it remains a forecast of what will be mined in the future, as it is not a fact that can be observed. The power of the reserve reporting is thus not in the removal of uncertainty, but in its management in an established disclosure system. In this instance, transparency implies controlled approximation and not perfect representation.

This trust is further strengthened by the third-party reserve audits and internal governance controls. They limit the area of arbitrary claims and contribute to aligning disclosure with professional norms. Meanwhile, the dependency on expert systems may produce a deceptive effect of finalizing things. Since the reserve figures are in standardized number form, they might feel more secure and objective than the assumptions they are based on deserve. This is especially worrisome where external audiences do not take sufficient steps to surf the disclosed reserves as rather hard signals of future value without doubting the underlying price, policy, and development assumptions behind them.

This is an even more acute issue in the environment of energy transition. Even technically plausible reserve estimates can be strategically weak when they rely on long-term fossil demand, which could prove unrealized under decarbonization pathways. In this way, the technical strength of reserve disclosure does not necessarily imply the use of such in transition markets. Not frail engineering but a lack of full disclosure on the external circumstances that decide whether technically recoverable hydrocarbon can support long-term economic and political legitimacy is a problem [6,49,50].

### **3.3. Governance, accountability, and strategic disclosure**

SEC reserve reporting also has a governance role in that it punishes the manner in which firms present extractive assets to the market. Reserve figures, being determinants of valuation and investor confidence, are closely related to corporate accountability. The boards, executives, auditors, and technical managers have interests in ensuring that the disclosures of reserves are defensible, consistent, and consistent with the rules and regulations. Reserve reporting in this regard assists the governance in exerting formal limits on managerial claims on future production potential.

Meanwhile, disclosure is never completely independent of strategy. There is a reason why firms would like to report reserves in forms that reinvent a perception of operational resilience, future growth prospects, and portfolio quality. Reserve reporting may be influenced by the decision regarding the timing of development, the type of project, assumptions regarding prices, and prioritization of the asset, even within regulatory limits. This does not mean that they systematically misreport, but only that disclosure is, to some extent, strategic. SEC reporting generates transparency that is thus institutional and not neutral: it is institutionally structured, but influenced by corporate interests and interpretation.

This duality plays a significant part, especially during a transitional period. Reserve reports have become intertwined with wider corporate discourses of resilience, diversification, and decarbonization preparedness in many oil and gas companies. A big reserve base can continue to be shown as an indicator of strength, but investors are increasingly beginning to judge the same indicator in a different light, posing whether the reserves are cheap, clean, or susceptible to write-downs at some point in the future. By doing so, the meaning of governance of disclosure of reserves is evolving. It is no longer a measure of the size of a hydrocarbon opportunity for a firm; it also casts doubts on the quality and compatibility of the transition to the opportunity [51].

Reserve reporting, therefore, emerges as a point of conflict between the old logic of valuation and new accountability demands. The conventional governance systems are concerned with proper reporting of extractive potential, and transition-based governance is increasingly overseeing the perception of carbon exposure, scenario resilience, and compatibility with the energy course of action in the future. SEC reserve reporting does not change its focus on accountability, but these larger requirements are challenging its governance range.

### 3.4. Transparency gaps in the transition era

The fact that SEC reserve reporting is not a perfect transparency mechanism is not that it does not provide important information, but rather it provides only a section of the information that has become significant. Its categories are very useful in classifying technical and commercial information related to hydrocarbons, but not as much as in capturing the ambiguities related to the energy transition. The actual feasibility of reserves can be influenced by carbon pricing, climate litigation, methane regulation, demand substitution, electrification, and the promise of net-zero policies, yet none of them are directly reported.

This leads to a structural transparency gap. Reserve disclosure may be formally true, but substantively false. It is possible to have a reserve that fulfills all the booking criteria and still has a high probability of ending up being stuck, crippled, or politically disputed during its development period. It is facing a paradox, then, in that the disclosure regime itself can be operating well within its own boundaries, and yet still not give a complete picture of the risks that are becoming central to asset valuation [52–55]. The comparison between the conventional SEC reserve reporting and the one that cannot be covered under the transition conditions is summarized in **Table 2**.

**Table 2.** Comparison between conventional SEC reserve reporting content and transition-era transparency requirements.

Dimension	What conventional SEC reserve reporting captures	What remains insufficiently captured	Transition implications	References
Geological certainty	Reservoir-based estimate of recoverable hydrocarbons	Long-term uncertainty under system transformation	Reported reserves may appear more stable than they are	U.S. Securities and Exchange Commission [39]
Economic producibility	Viability under prescribed price and cost assumptions	Carbon pricing, policy tightening, future demand decline	Economic reserves may still face future impairment	Vicknair et al. [56]
Financial relevance	Asset value, production potential, reserve life	Climate resilience and pathway compatibility	Investors need broader interpretive context	Beredugo [57]
Governance value	Standardization, comparability, investor protection	Accountability for transition exposure	Disclosure can be formally sound but strategically incomplete	U.S. Securities and Exchange Commission [39]
Risk disclosure	Near- to medium-term technical and commercial risk	Stranded asset risk, lock-in risk, emissions exposure	Reserve transparency alone is no longer sufficient	United Nations Environment Programme [58]

The gap is also temporal. SEC reserve reporting is meant to reflect economic productivity under existing or stipulated circumstances, but transition risk is frequently experienced over more extended and more unpredictable periods. This implies that reserve reporting is biased towards short- to medium-term technical-economic transparency as opposed to transformation of the system in the long term. Because of this, they can systematically under-affirm the susceptibility of long-lived hydrocarbon assets to high-speed policy and technology shifts.

In this sense, reserve reporting can be seen as a type of transparency that is quite necessary but not enough. Although it is still vital in assessing the physical and economic basis of upstream companies, it cannot give a full image of the risk in the transition era alone. This is the reason why reserve disclosure is progressively required to be read together with climate-associated financial reporting, scenario studies, and

other futuristic indicators. It is not whether reserve reporting continues to be an important instrument of transparency in a decarbonized future energy system, but the ability of such reporting to remain as a standalone transparency instrument in a decarbonized future energy system [59].

### **3.5. Reinterpreting transparency beyond reserve volumes**

One of the most significant implications of the discussion above is that transparency in future energy systems cannot be narrowed down to reserve quantities disclosure. Historically, in the extractive model, larger reserves usually equated to a higher level of security, high valuation, and the ability to stay competitive in the long term. That relationship is weaker in the context of transition. Huge reserve quantities can give the impression of strategic richness in one case and massive exposure to transition in another. Transparency must then go beyond the unquestioning and unskeptical number of barrels of hydrocarbon a company can generate to whether, under what circumstances, and with what hazards, such production can continue to exist.

This change necessitates a change in the understanding of the purpose of reserve transparency. Instead of acting as a tool for standardization of the disclosure of fossil assets, it might have to be incorporated into a more comprehensive system of the evaluation of the quality of resources in the context of carbon-constrained futures. This would involve matching reserve data with such questions as emissions vigor, breakeven expenses, vulnerability to regulations, as well as their adaptability with the numerous transition pathways. Cadres without such contextualization dangerously cling to an outdated discourse of extractive value despite radically different changes in the energy system.

It is on this basis that SEC reserve reporting is still a very relevant reporting, but one that is getting more contentious. Its advantage is that it adds structure and standardization to a technically complicated industry. Its weakness is that it is unable to embrace the evolving content of hydrocarbon assets in a decarbonizing world. The following discussion expands on this point by taking a more direct look at the relationship between reserve reporting and the energy transition, and how this relationship relates to fossil fuel lock-in, stranded asset risk, and capital allocation pattern changes [60–62].

## **4. Interactions between reserve reporting and the energy transition**

### **4.1. Reserve disclosure and the persistence of fossil fuel development**

Such reporting of SEC reserves is not just a description of the availability of hydrocarbons but also assists in maintaining expectations regarding future production. After being booked and disclosed, reserves gain financial and strategic transparency in a manner that influences corporate planning, investor confidence, and decisions on infrastructure. The reported reserves are often viewed as a hint at the continuity of production and portfolio power, which can support the belief that the current fossil fuel systems will be at the core of the future energy provision. In this regard, reserve

reporting may be an indirect contributor to the persistence of fossil fuels through stabilizing the economic imagination of onward extraction [63].

This is a critical effect, especially in the case of energy transition, where it is not only necessary to create alternative sources of energy but also to minimize the reliance on carbon-intensive assets. Such a high revealed reserve base can prompt firms to preserve long-term growth tracks, justify further capital expenditures, and highlight the strategic worth of upstream portfolios. A logic of delayed adjustment can be promoted even in circumstances where market entities recognize the existence of transition risks, given that reserves are formally recognized as being economically producible assets. Reserve disclosure thus possesses a performative aspect: it is not just an expression of the presence of hydrocarbons, but it can serve to legitimize their expected future application as well.

The value of this dynamic cannot be emphasized deterministically overestimated. Reporting of reserves in itself is not a source of lock-in in fossil fuels, nor does this report ignore policy, technology, or market signals. It does, though, connect up with these forces in that it offers a standardized platform on which the hydrocarbon assets can continue to be legible, financeable, and defensible. With the disclosure of a factor in valuation and expectations, the persistence of the metrics of reserves in a system might slow the conceptual shift from expansion and growth of fossil assets into a planned decline. It means that reserve reporting is not only a tool of transparency, but also belongs to the institutional environment in which the carbon-intensive pathways are recreated [3,46].

#### **4.2. Transition risk and the problem of stranded reserves**

Among the most significant questions of energy transition, one can name the possibility of economical production of all the now-reported reserves of oil and gas over the course of their projected existence. In traditional disclosure logic, the proved reserves are commercial recoverable hydrocarbons given specified technical and economic conditions. However, in a future where there is a constraint on carbon, commercial recoverability can be compromised by forces that are partially external to conventional reserve accounting. The long-term feasibility of assets that continue to be bookable according to existing rules can be decreased by carbon pricing, emissions control, methane control, demand destruction, electrification, and the substitution of low-carbon technology. This brings the issue of stranded reserves.

Stranded reserves are not merely those assets that are turned into unprofitable by the short-term volatility of the market. They are reserving whose expected extraction is curtailed, postponed, debased, or abandoned due to wider structural circumstances that do not support development. Analytically, the issue is significant as it demonstrates a conflict between accounting validity and strategic viability. A reserve can be reported correctly based on SEC definitions, and it still can have a high likelihood of impairment in a net-zero or low-demand situation in the future. Here, the disclosure is formally correct, although not full, in terms of information on long-horizon risk [64,65].

This strain makes the use of reserve metrics in valuation and governance difficult. In the past, the increase in reserves was traditionally viewed as a measure of power,

indicating revitalized production capacity and future earnings. In energy transition conditions, though now, growth in reserves can also be associated with increased exposure to tightening of policy or market re-evaluation. The definition of reserves is thus taking on a more conditional meaning. Lower-emissions, low-cost, short-cycle assets could be comparatively resistant, and carbon-intensive initiatives are less resistant or less costly. Not only is the amount of reserve volume that a company has a critical issue, but also what kind of reserves it has and on what assumptions of transition they are developable [66,67].

In this sense, stranded reserve risk brings out the boundaries of traditional disclosure. SEC reporting provides a picture of the economic productivity in a concrete framework; however, it does not differentiate in a systematic way between those reserves that are robust in a variety of transition pathways and those that are only viable under assumptions that are favorable to fossil fuels. The very notion of stranded reserves thereby represents a more extensive change in terms of analytical priorities: a transition to reporting the quantity of hydrocarbons to evaluating which of them is conditionally viable in the face of decarbonization [68].

### **4.3. Capital allocation and changing investor interpretation**

Reserve reporting has been a factor in long-term capital allocation by assisting the investor, the lenders or analysts in assessing the magnitude and sustainability of the hydrocarbon asset bases. According to conventional financial reasoning, a good reserve base helps to promote belief in future production, borrowing ability, and business worth. Consequently, the reserves that are disclosed have been put into the centre of the capital outlay in the oil and gas industry, therefore influencing the availability of finance as well as the strengthening of growth-oriented investment [17]. The conservatism of reserves has thus served not only as a disclosure advantage, but also as a means by which capital is channeled toward this or that type of energy development.

This relationship is changing due to the energy transition. The investors are becoming more differentiated in the reserve quantity and quality as to whether the disclosed assets are competitive in low-carbon situations, subject to future write-downs, or are not aligned with new climate requirements. This revolution does not eradicate the usefulness of the reserve data but modifies how the reserve data is deciphered. The presence of a huge reserve base is no longer necessarily taken as a positive signal. Rather, when evaluating long-term corporate resilience, markets are placing an ever-increasing amount of scrutiny on the cost structure, emissions profile, geographic risk, and projected development horizon of reserves [69].

This change provides a more complicated role of SEC reporting in transition finance. On the one hand, reserve disclosure will always be essential in comprehending the material bases of the oil and gas companies. Conversely, the reserve measures have become contextualized and are not limited to the reporting framework only. Reserve numbers and climate disclosures, scenario analysis, decarbonization promises, and asset-by-asset emissions estimations can help investors assess whether the portfolio of a company is prepared to adapt over the long term or is at risk of structural deterioration. Reserve transparency, in such a setting, is more valuable to the extent that it is combined

with more information that might be related to the transition [19].

The most important implication of all this is that reserve reporting could no longer have a consistent meaning among all players in the market. Others can still take reserve expansion as an indication of a shift in strategic possibility, especially where issues of energy security or temporary limitation of supply prevail. The same expansion can be interpreted by other people as a sign of transition misalignment. The identical revealed base of reserve can thus corroborate divergent financial accounts [70,71]. This implies that reserve reporting is quite central to capital allocation, but the interpretive regime of reserve reporting is disaggregating, due to the pressure to transition. The main routes of interactions between the reserve reporting and the energy transition are listed in **Table 3**.

**Table 3.** Main pathways through which SEC reserve reporting interacts with energy transition processes and outcomes.

Interaction pathway	Mechanism	Positive function	Potential concern	References
Capital allocation	Reserve disclosures influence investor and lender decisions	Improves visibility of upstream asset quality	May continue directing capital toward long-lived fossil assets	Alshahmy and Abdo [72]
Corporate strategy	Reserve base informs development planning and portfolio management	Supports operational planning and valuation discipline	Can reinforce fossil expansion narratives	Cherepovitsyn and Rutenko [73]
Market signaling	Reserve growth or replacement signals future production strength	Enhances comparability across firms	May be reinterpreted as transition vulnerability	Ewing and Thompson [74]
Transition risk exposure	Reserves are increasingly assessed against climate and policy scenarios	Encourages scrutiny of asset resilience	Conventional reporting does not fully distinguish resilient from vulnerable reserves	United Nations Environment Programme [58]
Energy governance	Reserve disclosure informs debates on resource availability and future supply	Provides a transparent baseline for policy and market analysis	Can preserve an extractive legacy if not paired with transition metrics	Florini and Saleem [75]

#### 4.4. Corporate strategy, portfolio restructuring, and disclosure tension

Oil and gas businesses are being pressured to balance traditional hydrocarbon-based operations with new demands for decarbonization, diversification, and transition preparedness. Reserve reporting in this environment is directly related to corporate strategy. In a firm that has maintained a high level of upstream operations, reserve replacement and development are still the main indicators of operational continuity. Meanwhile, numerous companies are also trying to rebrand themselves as more expanded energy companies, diversifying into carbon capture, hydrogen, renewable energy, bioenergy, or other less-carbon operations. This presents a strategic dilemma: maintaining the financial relevance of reserves while showcasing a viable transition.

The focal point of the tension is reserved disclosure that reminds us of the persistence of fossil assets despite the changes in the stories about corporations. A firm may encourage transition-related investments, but a reported reserve base may indicate that the cash flow is still heavily petroleum-based in the future. Reserve reporting in these situations is a form of honesty in strategy. It unveils how far diversification is really changing the structure of corporate values or is just adding to an already domineering fossil portfolio. This renders the disclosure of reserves as a significant

device in assessing the material support of transition claims by the configuration of underlying assets [76].

Simultaneously, the companies are likely to be interested in redefining the meaning of reserves in terms of wider strategic discourses. Gas reserves, such as those, can be positioned as transition-friendly compared to coal, whereas those that are cheaper can be positioned as more resilient in a carbon-scared world. These arguments are not always baseless, but they are presented to demonstrate that the policy of disclosing reserves is becoming more and more integrated with the strategic positioning than it is depicted as technical information of neutral character. It is no longer just a question of how many reserves are reported but how companies explain these reserves and how these companies make sense of the reserves in transforming policy and market environments.

This portfolio strategy disclosure interaction also demonstrates an institutional asymmetry. The reserve terms do not reflect transition-oriented use, e.g., renewables or low-carbon technologies, but the assets of hydrocarbons remain very conspicuous by the laboratory standards of the reserve. Consequently, the old fossil assets tend to have a higher disclosure clarity and financial legibility as compared to the new transition investments. This risks a distortion of strategic perception in that hydrocarbons are perceived as more tangible and quantifiable than other energy resources, even in those situations in which the latter may be more conducive to system change over time. Reserve reporting as such is thus not only a mirror of corporate portfolios; it may also influence the way the portfolios are interpreted and appreciated [20,77–79].

#### **4.5. Reserve reporting in future energy system governance**

It is these two effects of reserve reporting that the energy transition creates, alongside the decision to disclose fossil assets, that pose the larger question of governance in the future energy system: what are the disclosure roles of the fossil assets? Reserve reporting in the traditional regime was useful in protecting investors and maintaining market discipline by publicizing the extractive potential. In a transitional regime, however, transparency should have a broader agenda. It should assist markets and policymakers in differentiating between reserves that can be kept and retained as strategically compatible with decarbonization, and those that are vulnerable to losing value amid worsening climate constraints.

This does not imply that reserve reporting is outmoded. To the contrary, it is still essential in view of the scale, the composition, and the horizon of development of the oil and gas assets. But its role in governance is evolving. Reserve disclosure is increasingly anticipated to make the carbon lock-in, stranded assets, and the timing of the energy system's sequencing debated. That expectation places strain on a framework intended to serve a more limited purpose. The main issue is that, even in reserve reporting, hydrocarbon assets may be shown as they are without fully stating their compatibility with transition.

It is on this basis that reserve reporting should be considered as a requisite, albeit imperfect, element of energy regulation in the future. It provides a fundamental basis for asset transparency, yet it alone is incapable of determining the strategic viability

of further fossil development. To play a more useful role in energy systems in the future, reserve disclosure must be viewed in a broader context, including climate policy exposure, emission intensity, demand conditions, and pathway-based evaluations of asset resilience. In the absence of this growth, reserve reporting could be stuck in an outmoded logic of extractive value when energy governance is a more and more demanding transition-conscious analysis [80].

## **5. Reforming reserve reporting for future energy systems**

### **5.1. The need for an expanded disclosure logic**

The increasing inappropriateness of traditional reserve reporting and the shift in decision-making during transition eras point to the need to start the process of change not merely with technical changes but also with a reevaluation of the purpose of disclosure. The purpose of SEC reserve reporting was to find out whether hydrocarbons can be produced under specified conditions at an economically viable price and report the same to the capital markets in a standard manner. That role has not become less significant. Nevertheless, in our future energy systems, there is no longer an exclusive focus on the central issue of producibility. It is more often incorporating how reported reserves can be resilient to carbon-constrained pathways, how they are open to regulatory tightening and demand erosion, and how their construction is in line with new demands on corporate responsibility [81].

This change suggests that the rationale for reserve transparency should be broadened. A disclosure system that exclusively focuses on recoverable volumes and near-term economic circumstances is not enough any longer when long-lived hydrocarbon assets are under consideration in the context of decarbonization. The need to reform should therefore not be based on the failure of conventional reserve reporting itself, but rather on the changed terms of relevance. What once seemed to be sufficient data to protect investors might no longer be sufficient to determine the feasibility of long-horizon assets.

A logic of fuller disclosure would not substitute reserve reporting, but rather would be reassigned in a broader context of transition-sensitive disclosure. Reported reserves would continue to be a fundamental measure of extractive potential, but their interpretation would be implicit to have a better understanding of the assumptions that determine their future value. This would help prevent the further use of the reserve figures as independent measures of corporate strength. Reserve data are not to be read out of context in a transition context in terms of questions of policy sensitivity, emissions exposure, and strategic durability [82,83].

The association between disclosure and governance would also be changed by such a reform. Rather than serving to reaffirm the financial soundness of fossil resources, reserve reporting would come to serve in a more assistive role, assisting in differentiating between those assets which will be strong, in a variety of future regimes, and those whose value will be sensitive to the persistence of fossil-friendly environments. This would render transparency more receptive to the facts of energy system change as opposed to maintaining a tight-fisted extractive frame.

## **5.2. Integrating reserve disclosure with climate-related reporting**

A major direction for reform lies in stronger integration between reserve reporting and climate-related financial disclosure. At present, these reporting domains often operate in parallel. Reserve reporting communicates quantities, categories, and economic producibility of hydrocarbons, while climate disclosure addresses emissions, governance, strategy, and transition risks. Both are relevant to the valuation of oil and gas firms, yet they are rarely structured in ways that fully inform one another. This separation can produce an incomplete picture of asset quality, since a company may disclose a substantial reserve base without clearly connecting that base to its carbon profile or transition vulnerability.

A more coherent reporting architecture would link reserves to the climate-related factors that increasingly shape their value. This would involve greater visibility into the emissions implications of reserve development, the sensitivity of those reserves to policy tightening, and the extent to which corporate strategies assume continued fossil demand under contested future scenarios. Such integration would not require reserve reporting to become climate reporting in itself. Rather, it would require a clearer interface between the two so that investors and regulators can interpret reserve figures in light of transition risk rather than as standalone technical assets [84].

This integration is especially important because climate-related reporting is often strategic and narrative, whereas reserve reporting is numerical and standardized. The former may communicate ambition and governance structure, while the latter anchors disclosure in material asset configurations. Bringing the two together would reduce the risk that transition narratives remain detached from the firm's underlying hydrocarbon base. It would also improve accountability by enabling closer scrutiny of whether stated decarbonization commitments are consistent with the scale, type, and expected development horizon of reported reserves [85,86].

Critically, integration should not be understood as merely adding more disclosure categories. The main value lies in interpretive alignment. Reserve figures become more meaningful when read alongside pathway assumptions, emissions exposure, and asset-level resilience. Climate disclosures become more credible when they are tested against the company's disclosed reserve structure. Reform should therefore focus not only on expanding the volume of information, but on making disclosures mutually intelligible across reporting domains.

## **5.3. Scenario-based reporting and conditional asset viability**

Among the most obvious constraints of the existing reserve disclosure is that it is more likely to reveal asset viability within a comparatively narrow range of established conditions. However, the uncertainty that future conditions may differ radically from current assumptions is exactly what the energy transition is about. For this reason, reform should focus more on scenario-based reporting. Instead of managing reserves as though they were of constant value in plausible futures, disclosure might give more information about how the quality of reserves varies in response to varying demand, policy, and carbon-price paths [87].

Scenario-based approaches would not eliminate uncertainty, but they would be

more visible and useful in analysis. They would enable stakeholders to differentiate between reserves that can survive under more decarbonized pathways and those that can survive only under conditions of high future fossil demand. It would be a great enhancement to the existing practice that tends to make such distinctions implicit. The disclosure of reserves would then approach a conditional depiction of value instead of an unidentified declaration of technical-economic producibility.

This reform has a significant analytical advantage. It would assist in focusing on changing the focus from reserve quantity alone to reserve robustness. A company with a smaller reserve base, low-cost, low-cycle, and low-emissions production may seem more robust than a company with large reserves that relies on long development horizons or high-carbon production. Disclosure would be situation-dependent in this way, ensuring that financial interpretation can be more discriminating as well as more consistent with the uncertainties of transition [88,89].

However, there exist practical and conceptual challenges. The scenario design can be biased, assumptions can be disputed, and there is too much flexibility that can destroy comparability. Besides, scenarios are not dispassionate projections; they reflect opinions regarding policy aspirations, the use of technology, and the transformation of society. These are genuine issues, although they are not sufficient reasons to ignore the issue of scenario sensitivity at a time when future conditions are of primary concern in asset valuation. The question is not whether to implement conditionality, but how to do so in a disciplined, standardized manner without compromising usability, while recognizing that reserve value is becoming pathway-dependent.

#### **5.4. Methodological innovation and the treatment of uncertainty**

The methodological innovation needed to change how uncertainty is reported to enable reforms to reserve reporting for future energy systems is also required. The conventional disclosure systems have been tailored to facilitate comparability by reducing uncertainty to a set of standardized categories, especially proved reserves. This has obvious regulation advantages, but it can also squeeze variation and obscure the strength of results based on assumptions of prices, development timing, regulation, or technology. During the transition period, when uncertainty has become multidimensional, such compression becomes even more problematic.

A more adaptive system would maintain the discipline of standardized classes of reserves, but provide more information regarding the extent and form of uncertainty about the classes. This may include being more open regarding the disclosure of sensitivity, being more open regarding the disclosure of breakeven conditions, or better expressing the relationship between the reserve estimates and external policy assumptions. This would not be done to confuse the users of disclosure with technicality, but to prevent earlier portrayals of reserves as being more solid and objective than they are in reality [90,91].

The asymmetry between hydrocarbon and transition-oriented investments should also be tackled through methodological innovation. Reserve reporting offers fossil portfolios with a very formalized visibility, whereas a less standardized strategic description is frequently a disclosure of low-carbon activities. This leaves an imbalance

in financial legibility. Reform might thus be seen as not just an enhancement of disclosure of fossil assets, but a re-orientation of the informational structure of the energy company. The more the reserve reporting is made transparent and measurable in terms of transition, the easier it is to appraise hydrocarbons and other alternative investments as opposed to an extractive prism only.

On a more profound level, better handling of uncertainty would assist in rectifying the long-standing flaw of reserve reporting, which is that it takes professional judgment and converts it into numbers that seem conclusive. This quantitative power has aided market discipline, yet it may also hide the contingency of the asset value of a transitioning energy system. A transformed methodology would be rigorous, but would also expose uncertainty as a structural attribute of decision-making as opposed to a remnant technical issue [92].

### **5.5. Policy implications and an agenda for future research**

Reserve reporting reform does not just have disclosure implications. It gives a direct response to the way regulators, firms, and investors determine materiality in future energy systems. To the regulators, the key dilemma is to maintain the merits of the current reserve's disclosure, especially the comparability and investor protection, and revise the structure to capture the risks of the transition era that are increasingly influencing the value of assets. This implies a policy strategy that does not exclude reserve reporting, but adds to it further and more forward-looking, climate-relevant, and conditional types of transparency.

As a matter of strategy, reserve disclosure would probably have a different meaning to firms as a result of reform. Businesses would have more pressure trying to explain the extent of their reserve base and its resilience during low-carbon trajectories. That would enhance strategic discipline by discouraging further reporting reserves as homogeneously positive corporate assets. It can also promote more differentiated portfolio management, where less risky and more transition-friendly assets can be distinguished as those that can be subject to long-term decline in value.

To investors, a reformed structure would enhance the capacity to decode hydrocarbon exposure in a manner that is in line with the changing market realities. It would provide more sophisticated analyses of the quality of reserves, minimize reliance on the simplistic volumetric metrics, and enhance the incorporation of reserve information with more general transition-finance analysis. To this effect, improved disclosure is not just a reporting advantage; it is a pre-requisite to more sensible capital investment in an energy system that is being transformed by decarbonization.

An agenda for research is a direct result of these needs. Further research is also needed on the implications of market pricing of transition sensitive reserve reports, the impact of various design choices in reporting on corporate incentives, and how reserve measures interrelate with climate change scenarios, emissions indicators, and cost structures in influencing investor decisions. A cross-jurisdictional approach would also be useful, as disclosure reform cannot succeed when key reporting systems are developed separately. The future of reserve reporting will not be judged on how technical this can be refined, but on whether or not it can be re-conceptualised

in terms of becoming a part of a broader system of governance to the decline, adaptation, or selective persistence of fossil assets in the context of low-carbon energy systems [92,93]. **Table 4** summarizes the key reform directions, benefits to be expected, and challenges in the implementation.

**Table 4.** Proposed directions for reforming reserve reporting for future energy systems.

Reform direction	Main purpose	Expected benefit	Implementation challenge
Integration with climate disclosure	Connect reserves with emissions and transition risk	Improves consistency between asset reporting and climate strategy	Harmonizing different reporting systems
Scenario-based reserve assessment	Show reserve resilience under alternative policy and demand futures	Better reflects conditional asset viability	Ensuring comparability across firms and scenarios
Expanded uncertainty disclosure	Clarify sensitivity to assumptions on price, regulation, and demand	Reduces false impression of certainty	Avoiding excessive reporting complexity
Asset-quality differentiation	Distinguish reserves by cost, emissions intensity, and development horizon	Helps investors assess transition resilience	Data availability and standardization
Transition-aware transparency framework	Reposition reserve reporting within broader future energy governance	Makes disclosure more decision-useful in decarbonizing systems	Regulatory reform may lag behind market change

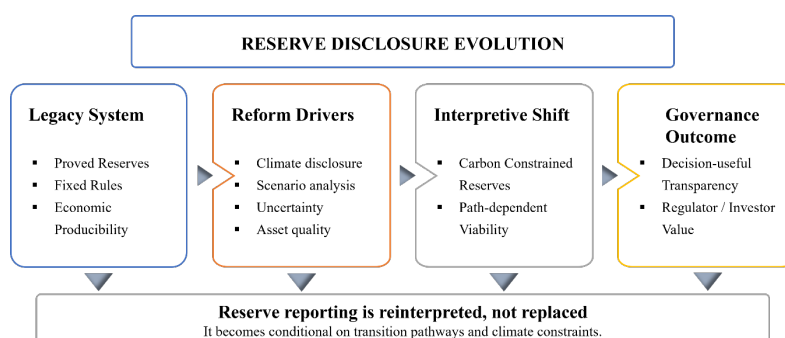
## 5.6. Toward transition-aware resource transparency

The more general objective of reform ought to be the formulation of transition-conscious resource transparency. This implies leaving a model in which reserves are revealed only as volumes of economically recoverable hydrocarbons and moving to a model in which they are treated as an asset, the value of which is contingent on rapidly varying, constrained external conditions. Transparency would no longer lie in disclosing what can be created within such a framework. It would also involve explaining under which conditions future production can remain defensible, profitable, and aligned with larger-scale energy system transformation.

The traditional reserve disclosure models assume standardized reporting of proved reserves and economic producibility, with standard regulatory assumptions. New reforms extend this framework to include climate-related disclosure and scenario-based evaluations of reserve viability, and explicitly treat uncertainty, sensitivity, and asset-level heterogeneity. These transformations make possible a conceptual shift to transition-conscious interpretation of the reserves where reserves are considered in terms of carbon constraints, policy sensitivity, and pathway-dependent economic viability. This redefinition eventually reinvents the role of governance of reserve disclosure that makes it more usable in decision-making by regulators, firms, and investors in the scenario of energy system transition. Reserve reporting is not eliminated, but recontextualized in terms of transition risk and changing restrictions on the use of hydrocarbons in the future. **Figure 3** illustrates this conceptual development, as the move towards transition-conscious disclosure frameworks and the implications of such a move on governance are described.

The fact that reserves are not as important as viewed from this perspective does not diminish their significance. Quite on the contrary, it acknowledges the fact that reserve reporting is necessary exactly because fossil resources cannot be forgotten. However, the meaning of risk requires disclosure to be transformed and changed to govern assets in the transition in a responsible way. The economic, regulatory, and social conditions of fossil fuel development are now being redefined fundamentally,

and reserve transparency can no longer rely on a legacy extractive language [94–96].



**Figure 3.** Evolution of hydrocarbon reserve disclosure under transition-aware reporting frameworks.

## 6. Conclusion

This review has discussed SEC oil and gas reserve reporting as an old tool for resource transparency and as an increasingly contentious institution in the energy transition. In the past, SEC reserve disclosure has been the key to making subsurface hydrocarbons readable in the financial markets. It has also minimized information asymmetry by harmonizing the reporting of economically producible reserves and improved investor protection, as well as, offering a standard platform on which upstream assets are valued. Reserve reporting, in this respect, has played a pivotal role in the securities regulation, as well as the overall governance of hydrocarbon development.

Simultaneously, the article has revealed that the rationale behind this disclosure system is facing criticism as structural shifts develop in the future energy systems. Conventional reserve reporting is still useful in reporting technical and economic recoverability under specific conditions, but it only reflects part of what is now used to determine the value of assets. The strategic sense of reserves is no longer fixed in an era of decarbonization targets, financial risk in relation to climate, policy uncertainty, demand changes, and changes in standards relating to corporate accountability. It is in no way insignificant that the reported reserves can portend the future production potential, yet they can also be an indicator of increased exposure to the stranded asset risk, carbon lock-in, and fragility in the long-term portfolios. The point of debate is therefore not whether SEC reserve reporting is useful or not, but whether it can be considered as a sufficient standalone transparency tool or not.

One of the critical points of the given review is that we should interpret reserve disclosure not only as a technical accounting procedure. It is a governance system that assists in the formation of the meaning of the value of fossil resources in the capital markets. Reserve reporting is an active mediator as it affects valuation, financing, corporate strategy, and investor expectations because it affects the relationship between hydrocarbon assets and energy transition pathways. This renders the issue of reform of the reserve disclosure to be of greater institutional concern. The framework is not just a mirror of the fossil energy system, but is also useful in replicating its financial rationale. It is due to this reason that any serious attempt to reconcile energy governance with transition objectives should be more sensitive to the manner in which reserves are

categorized, reported, and understood.

The review has also pointed out that what is weak about present-day SEC reserve reporting is not technical inadequacy in the narrow sense but conceptual incompleteness. The framework was meant to regulate extractive uncertainty but not transition uncertainty. It is still very efficient in punishing disclosure of geological and commercial producibility, but less efficient in exposing climate policy and emissions exposure, substitution of technologies, and variant future and energy. This generates continuing disparity of transparency. Reserve disclosures can be formally correct and at the same time not give enough information on strategic risk over a long horizon. Consequently, financial consumers are becoming more obliged to understand reserve information and climate reports, scenario analysis, emissions indicators, and even more comprehensive evaluation of transition resilience.

In this view, reserve reporting can remain relevant in the future because it can be modified. The article has proposed that reform must not aim to forsake the disclosure of reserves, but should rather broaden and re-frame it in a broader context of transition-conscious disclosure. It means that there will be a closer alignment of reserve reporting and climate-related financial disclosure, more emphasis on the viability of conditional assets in a variety of pathways, and better conveyed uncertainty, not on the standard volumetric terms. This type of reform would assist in changing disclosure towards a point where it includes more of the aspects of whether, under what circumstances, and how long these hydrocarbons can be used to decarbonize energy systems.

The bigger picture of this is that the transparency of resources should be redefined as well. Under the traditional fossil-fuel system, transparency was strictly linked to the amount of reserves, production capacity, and commercial worth. Transparency in the future energy systems has to also include carbon exposure, policy sensitivity, and technological displacement, and must also be aligned to long-sustained transition trajectories. The role of SEC reserve reporting as a basis for this task is still required, but it can no longer do it single-handedly. Whether it will remain legitimate will be determined by its ability to connect to a more elaborate disclosure framework that will be able to render the shifting sense of fossil assets.

To sum up, the SEC oil and gas reserve reporting is one of the most powerful tools through which hydrocarbon resources are transformed into financial literacy. However, as the nature of the energy transition alters the foundation of the valuation of resources, their management, and even contestation, the presumptions inherent in the historical disclosure of reserves are being challenged. It is not merely the task of enhancing the accuracy of reporting, but to redefine what decision-useful transparency is in a carbon-constrained future. The way reserve reporting will cope with this challenge will also be of interest in deciding whether it will continue as a fossil asset accounting tool or an increasingly useful part of future energy systems governance.

**Funding:** This work received no external funding.

**Institutional review board statement:** Not applicable.

**Informed consent statement:** Not applicable.

**Data availability statement:** Not applicable.

**Conflict of interest:** The authors declare no conflict of interest.

**AI use statement:** The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

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