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Strategic Local Content Frameworks for Energy Transition Projects: Enhancing Supply Chain Competitiveness in Hydrogen, LNG, and Carbon Capture Developments.

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Abstract

Energy transition projects in hydrogen, liquefied natural gas (LNG), and carbon capture and storage (CCS) represent critical pathways toward global decarbonization, yet their deployment raises fundamental questions about supply chain competitiveness and local economic value capture. This paper examines strategic local content frameworks across these three sectors, analyzing how policy mechanisms, industrial strategies, and supply chain configurations interact to enhance competitiveness while promoting localization objectives. Drawing on comparative policy analysis and empirical evidence from multiple jurisdictions, the study identifies sector-specific competitiveness drivers, evaluates local content policy instruments, and proposes an integrated conceptual framework linking localization strategies to supply chain performance. Findings reveal that hydrogen supply chains prioritize resource endowments, electrolyzer technology access, and certification systems; LNG developments emphasize infrastructure investment and carbon mitigation integration; and CCS projects depend on proximity to geological storage sites, transport logistics, and regulatory de-risking. Cross-sectoral analysis demonstrates that effective local content frameworks require tailored policy approaches combining conditional subsidies, procurement mechanisms, capacity-building initiatives, and contractual instruments, while navigating World Trade Organization (WTO) constraints. The paper contributes a comparative assessment of local content leverage points and competitiveness indicators across the three sectors, offering policy implications for governments and industry stakeholders seeking to balance localization ambitions with global competitiveness imperatives in energy transition investments.

Keywords: Local Content Requirements, Supply Chain Competitiveness, Hydrogen Economy, Liquefied Natural Gas, Carbon Capture and Storage

1. Introduction

The global energy transition toward low-carbon systems has accelerated investment in hydrogen production, liquefied natural gas (LNG) infrastructure, and carbon capture and storage (CCS) technologies as essential components of decarbonization strategies. These capital-intensive projects involve complex, geographically dispersed supply chains spanning equipment manufacturing, engineering services, construction, operations, and maintenance activities. Governments and project developers face competing pressures to maximize local economic benefits through content requirements while maintaining international competitiveness in rapidly evolving global markets (Yin et al., 2024; Noussan et al., 2020). Local content requirements (LCRs), policies mandating minimum shares of domestic inputs in project procurement, have emerged as prominent but contested instruments for capturing value from energy investments, raising questions about their design, implementation effectiveness, and compatibility with international trade obligations (Nelson & Puccio, 2021).

The strategic importance of local content frameworks extends beyond immediate employment and procurement effects to encompass long-term industrial capability development, technology transfer, and supply chain resilience. However, empirical evidence reveals significant variation in local content policy effectiveness across sectors and jurisdictions, with implementation challenges including institutional capacity constraints, trade law conflicts, and misalignment between policy ambitions and domestic industrial capabilities (Chuwa, 2023; Suleman & Zaato, 2021). The hydrogen, LNG, and CCS sectors present distinct supply chain characteristics, technological maturity levels, and competitiveness determinants that necessitate differentiated localization approaches rather than uniform policy prescriptions. This paper addresses three central research questions. First, what are the principal supply chain competitiveness drivers in hydrogen, LNG, and CCS sectors, and how do these vary across jurisdictions? Second, which local content policy instruments are most effective in enhancing supply chain competitiveness in each sector, given legal, institutional, and market constraints? Third, what integrated policy framework can reconcile localization objectives with global competitiveness imperatives across energy transition sectors? To answer these questions, the paper draws on a systematic review of the scholarly and policy

literature, comparative case analysis across multiple jurisdictions, and a conceptual framework synthesizing localization theory with supply chain competitiveness models.

The paper is organized as follows. Section 2 reviews the literature on local content frameworks and supply chain competitiveness. Section 3 develops the conceptual framework. Sections 4, 5, and 6 analyze local content dynamics in hydrogen, LNG, and CCS sectors respectively. Section 7 presents a cross-sectoral comparative analysis. Section 8 discusses policy implications, and Section 9 concludes.

2. Literature Review

2.1 Local Content Requirements: Origins and Evolution

Local content requirements have historically been associated with extractive industries in resource-rich developing economies, where governments sought to translate natural resource revenues into broader industrial development (Suleman & Zaato, 2021). The theoretical rationale for LCRs draws on infant industry arguments, linkage theory, and resource curse literature, positing that without deliberate policy intervention, enclave dynamics prevent resource extraction from generating economy-wide benefits (Mbuyi Olua, 2021). Over time, LCR frameworks have evolved from simple workforce nationality requirements to sophisticated multi-dimensional systems encompassing procurement, technology transfer, training, and financial participation (Chuwa, 2023). The transition of LCR discourse from extractive industries to clean energy sectors reflects the growing recognition that energy transition investments represent comparable opportunities for industrial policy intervention (Meckling & Nahm, 2019). The scale of investment required for hydrogen, LNG, and CCS infrastructure creates potential for domestic value capture through targeted localization policies, particularly in countries with existing industrial bases, engineering capabilities, or strategic resource endowments (Yin et al., 2024). However, the clean energy context introduces additional complexity, including technology novelty, international competitiveness pressures, and the imperative to accelerate deployment to meet climate targets. Hepburn et al. (2019) emphasize that the economic recovery potential of clean energy investments is contingent on the quality of accompanying industrial policy, a finding that directly informs the design of local content frameworks for energy transition projects.

2.2 WTO Constraints and Policy Design

A critical dimension of local content policy design is compatibility with international trade law, particularly WTO disciplines on subsidies and trade-related investment measures (TRIMs). Nelson and Puccio (2021) demonstrate that explicit LCRs in renewable energy subsidy schemes have been consistently found discriminatory under WTO law, as illustrated by the *United States – Renewable Energy* dispute. This legal constraint does not eliminate the possibility of localization-oriented policies but requires reframing support through instruments such as conditional subsidies, performance-based contracts, and technology partnership requirements that may pass WTO scrutiny (Nelson & Puccio, 2021). The tension between industrial policy ambitions and trade law obligations is particularly acute for emerging economies seeking to leverage energy transition investments for domestic industrial development. O'Brien and Banet (2021) extend this analysis to the hydrogen-CCS nexus, arguing that legislative and contractual instruments can de-risk integrated supply chains while maintaining compatibility with trade rules. Their analysis emphasizes that clarity in liability allocation, standardized contract terms, and transparent regulatory frameworks reduce investor uncertainty and can substitute for explicit content mandates as mechanisms to attract and retain local investment. This approach aligns with broader literature on regulatory de-risking as an alternative or complement to direct LCRs (Hilali, 2025).

2.3 Supply Chain Competitiveness in Energy Transition

Supply chain competitiveness in energy transition sectors is shaped by multiple interacting factors including resource endowments, technological capabilities, infrastructure quality, institutional frameworks, and market size. Yin et al. (2024) develop an international hydrogen competitiveness index across seven case studies, finding that resource availability, institutional support, and infrastructure readiness are the dominant determinants of competitive positioning. Their analysis identifies the United States and Australia as leading competitors owing to abundant renewable energy resources, established industrial infrastructure, and supportive policy environments. For LNG, competitiveness is primarily determined by feedstock gas availability, liquefaction infrastructure, shipping logistics, and increasingly by the carbon intensity of production and transport (Sergeeva & Ward, 2024). The integration of CCS into LNG value chains has emerged as a critical competitive differentiator, as importing countries impose progressively stringent

carbon content requirements on energy supplies (Sergeeva & Ward, 2024). The economic feasibility of CCS deployment in LNG supply chains varies significantly by region, with producer-side CCS generally more cost-effective than import-side mitigation (Sergeeva & Ward, 2024).

CCS supply chain competitiveness is shaped by distinct factors including geological storage proximity, CO_2 transport infrastructure, capture technology costs, and regulatory frameworks governing liability and long-term storage obligations (Buirma et al., 2022). Gough and Mander (2022) demonstrate that social license considerations are central to CCS cluster development, with community acceptance and stakeholder engagement determining the feasibility of industrial-scale deployment. The cluster model for CCS development creates specific local content opportunities through shared infrastructure, coordinated procurement, and collective governance arrangements.

2.4 Industrial Policy for Clean Energy Localization

Industrial policy literature provides theoretical grounding for understanding how governments can strategically promote local content in clean energy sectors. Meckling and Nahm (2019) identify a transition from traditional industrial policy approaches focused on import substitution toward more sophisticated strategies combining market creation, technology push, and supply chain development. This evolution is particularly relevant for hydrogen, where policy must simultaneously stimulate demand, develop supply infrastructure, and build domestic manufacturing capabilities across a complex value chain (Shin, 2022). Ding et al. (2022) analyze hydrogen policy instruments across multiple jurisdictions, classifying them into environmental, demand-side, and supply-side categories and finding that local policies most often target infrastructure and end-use applications while underinvesting in supply-side capabilities. Zhang et al. (2022) examine Chinese hydrogen industrial policy, recommending diversified subsidy forms and stronger complementarity between policy instruments to optimize sector outcomes. Reigstad et al. (2022) synthesize lessons from national hydrogen strategies in Germany, the United Kingdom, the Netherlands, Switzerland, and Norway, emphasizing the need for coordinated planning, public support mechanisms, and infrastructure development to make hydrogen business cases viable. These studies collectively suggest that effective industrial policy for energy transition localization requires policy mixes rather than single instruments, with careful sequencing and coordination across value chain segments.

3. Conceptual Framework

3.1 The Local Content Competitiveness Nexus

The conceptual framework developed in this paper integrates three analytical dimensions: local content policy design, supply chain competitiveness determinants, and sectoral context. The framework posits that local content policies can enhance supply chain competitiveness when they are aligned with existing or developable domestic capabilities, designed to address specific market failures, and implemented through instruments compatible with international trade obligations. Conversely, poorly designed LCRs can distort supply chains, increase project costs, and undermine competitiveness by forcing procurement from sub-optimal domestic suppliers (Chuwa, 2023; Mbuyi Olua, 2021). The framework distinguishes between three categories of local content leverage points: *resource-based leverage* (exploiting domestic resource endowments such as renewable energy or geological storage capacity), *capability-based leverage* (building on existing industrial and engineering capabilities), and *infrastructure-based leverage* (developing shared infrastructure that reduces costs and enables scale). Each leverage point corresponds to different policy instruments and creates different competitiveness outcomes. Resource-based leverage is most relevant for hydrogen and CCS, where geological endowments determine fundamental competitiveness; capability-based leverage applies across all three sectors; and infrastructure-based leverage is particularly important for LNG and CCS cluster development.

3.2 Policy Instrument Taxonomy

Building on the literature review, a taxonomy of local content policy instruments is developed along two dimensions: directness (explicit content mandates versus implicit localization incentives) and mechanism (regulatory, financial, contractual, or institutional). Explicit regulatory instruments such as minimum domestic content percentages carry the highest legal risk under WTO rules but may be appropriate in contexts with limited trade exposure or where treaty exemptions apply (Nelson & Puccio, 2021). Financial instruments including conditional subsidies, tax incentives, and public co-investment can achieve localization objectives while remaining within WTO-permissible subsidy categories (Zhang et al., 2022). Contractual instruments embedded in project agreements, concession terms, and public procurement requirements offer flexibility to tailor localization obligations to specific project contexts without triggering trade

disputes (O'Brien & Banet, 2021; Mbuyi Olua, 2021). Institutional instruments encompassing training programs, technology transfer requirements, and capacity-building initiatives address supply-side constraints that limit the effectiveness of demand-side local content mandates (Suleman & Zaato, 2021).

4. Local Content in Hydrogen Supply Chains

4.1 Hydrogen Supply Chain Structure and Competitiveness Drivers

The hydrogen supply chain encompasses production (electrolysis or steam methane reforming with CCS), purification, compression, storage, transport, and end-use applications across industrial, transport, and power sectors. Each segment presents distinct local content opportunities and competitiveness challenges. Production competitiveness is primarily determined by renewable energy costs, electrolyzer capital costs, and operational efficiency, with resource-rich countries holding structural advantages in green hydrogen production (Noussan et al., 2020; Yin et al., 2024). However, the concentration of electrolyzer manufacturing capacity in a small number of countries creates supply chain vulnerability and limits local content potential in markets without domestic manufacturing capabilities (Hilali, 2025). The geopolitical dimension of hydrogen supply chains is increasingly significant, particularly regarding rare earth elements (REEs) essential for electrolyzer and fuel cell manufacturing. Hilali (2025) identifies critical vulnerabilities in REE supply chains that could constrain green hydrogen deployment, with concentration of REE production in China creating strategic dependencies for countries pursuing hydrogen industrial strategies. This geopolitical risk dimension strengthens the case for local content frameworks that prioritize technology and manufacturing capability development rather than simply procurement localization.

4.2 Policy Mechanisms for Hydrogen Localization

Shin (2022) documents South Korea's value chain approach to hydrogen industrial development, emphasizing roadmap creation, infrastructure sequencing, and policy pacing to connect production, storage, transport, and application segments. Korea's strategy demonstrates the importance of coordinated industrial policy that addresses the full value chain rather than focusing on individual segments in isolation. Reigstad et al. (2022) identify similar lessons from European

national hydrogen strategies, highlighting that public support for anchor infrastructure, including storage facilities, pipeline networks, and refueling stations, is essential to create the conditions for private investment and local supply chain development. Ding et al. (2022) find that local hydrogen policies most frequently target end-use applications and infrastructure, with relatively less attention to upstream production and manufacturing. This imbalance suggests a gap in local content strategy that could be addressed through more deliberate supply-side industrial policy, including support for domestic electrolyzer manufacturing, component production, and engineering services. Zhang et al. (2022) recommend diversified policy instruments combining subsidies, procurement mandates, and technology partnership requirements to build domestic hydrogen industrial capabilities, with particular attention to complementarity between instruments targeting different value chain segments.

5. Local Content in LNG Developments

5.1 LNG Supply Chain Structure and Competitiveness Dynamics

LNG supply chains involve upstream gas production, liquefaction, shipping, regasification, and distribution, with capital-intensive infrastructure at each stage creating significant local content opportunities. The competitiveness of LNG projects is fundamentally shaped by feedstock gas costs, liquefaction efficiency, shipping distances, and increasingly by the carbon intensity of the entire value chain (Sergeeva & Ward, 2024). The emerging hydrogen economy creates both competitive pressures and opportunities for LNG, as natural gas infrastructure can serve as a platform for blue hydrogen production and distribution, while LNG shipping capabilities can potentially be adapted for hydrogen or ammonia transport (Hydrogen Economy and LNG, 2022). Local content in LNG developments has traditionally focused on construction and operational workforce localization, with engineering, procurement, and construction (EPC) contracts as the primary vehicle for domestic content requirements. However, the integration of CCS into LNG value chains creates new local content dimensions related to capture technology deployment, CO_2 transport infrastructure, and geological storage development. Sergeeva and Ward (2024) demonstrate that CCS deployment on the producer side of LNG supply chains is generally more economically feasible than import-side mitigation, suggesting that LNG-producing countries have strategic opportunities to develop integrated CCS capabilities as competitive differentiators.

5.2 Carbon Integration and Supply Chain Repositioning

The imperative to decarbonize LNG value chains is reshaping competitive dynamics and creating new local content opportunities in CCS-related activities. Countries with geological storage capacity adjacent to LNG production facilities are particularly well-positioned to develop integrated CCS capabilities that enhance both the carbon competitiveness of their LNG exports and the local content of CCS activities (Sergeeva & Ward, 2024; Buirma et al., 2022). This convergence of LNG and CCS supply chains creates policy opportunities for governments to design integrated local content frameworks that capture value across both sectors simultaneously. The institutional framework for LNG local content has evolved significantly in major producing regions, with contractual instruments increasingly supplementing or replacing regulatory mandates. Mbuyi Olua (2021) proposes a contractual fiscal framework that integrates local content variables into petroleum contracts, offering a model that could be adapted for LNG developments. This approach embeds localization objectives into the fundamental economics of project development rather than imposing external compliance requirements, potentially improving both effectiveness and investor acceptance.

6. Local Content in Carbon Capture Projects

6.1 CCS Supply Chain Structure and Feasibility

CCS supply chains encompass capture technology installation, CO_2 compression and dehydration, transport (pipeline or ship), injection, and long-term geological storage monitoring. The geographic specificity of geological storage sites creates fundamentally different local content dynamics compared to hydrogen or LNG, as the location of storage determines much of the supply chain geography. Buirma et al. (2022) analyze ship-based CCS supply chains, demonstrating technical feasibility but sensitivity to transport distances and storage capacity that create site-specific viability assessments. Pipeline-based CCS transport, while more capital-intensive, offers different local content opportunities through infrastructure construction and operation. The cluster model for CCS development, in which multiple industrial emitters share common transport and storage infrastructure, creates specific local content opportunities through coordinated procurement and shared infrastructure investment. Gough and Mander (2022) identify social

license as a critical success factor for CCS cluster development, with community acceptance and stakeholder engagement determining the feasibility of industrial-scale deployment. Building social license requires meaningful local engagement, transparent communication about risks and benefits, and demonstrable local economic benefits, all of which align with local content objectives. This convergence of social license and local content imperatives suggests that CCS projects may achieve better outcomes by integrating community benefit commitments into local content frameworks.

6.2 Legal and Regulatory De-Risking for CCS Investment

O'Brien and Banet (2021) analyze how legislative and contractual instruments can de-risk hydrogen-CCS value chains and mobilize private capital by clarifying liability allocation and market rules. Their analysis highlights that legal uncertainty around long-term storage liability is a major barrier to CCS investment, and that clear regulatory frameworks governing monitoring, verification, and liability transfer are prerequisites for commercial-scale deployment. Local content frameworks for CCS must therefore be developed within the context of broader regulatory de-risking initiatives, ensuring that localization requirements do not add complexity or uncertainty that deters investment. The institutional capacity requirements for CCS local content are substantial, encompassing geological assessment expertise, CO_2 monitoring and verification capabilities, regulatory oversight, and specialized engineering and construction skills. Chuwa (2023) documents comparable institutional capacity challenges in Tanzania's natural gas sector, where weak regulatory frameworks, limited technical expertise, and poor stakeholder participation constrain local content implementation. These lessons are transferable to CCS contexts, where institutional capacity building must accompany local content policy development to ensure that domestic suppliers can meet project requirements. Ringrose et al. (2021) further demonstrate that geological characterization and storage site selection require sustained technical investment, underscoring that CCS local content strategies must include provisions for developing domestic geoscience and subsurface engineering capabilities.

7. Cross-Sectoral Analysis

7.1 Comparative Local Content Policy Mechanisms

A cross-sectoral comparison of local content policy mechanisms reveals both common elements and sector-specific variations across hydrogen, LNG, and CCS developments. **Table 1** presents a comparative assessment of policy mechanisms, implementation challenges, and effectiveness indicators across the three sectors.

Table 1. Comparative Local Content Policy Mechanisms Across Hydrogen, LNG, and CCS Sectors

Dimension	**Hydrogen**	**LNG**	**Carbon Capture & Storage (CCS)**
Primary Policy Instruments	Conditional subsidies; certification standards; procurement mandates for domestic electrolyzer content	EPC contract localization clauses; workforce nationality requirements; in-country value (ICV) scoring	Cluster governance agreements; contractual liability frameworks; public co-investment in shared infrastructure
Key Competitiveness Drivers	Renewable resource endowment; electrolyzer manufacturing capability; certification and standards systems	Feedstock gas cost; liquefaction efficiency; CCS integration for carbon competitiveness	Geological storage proximity; CO_2 transport logistics; regulatory clarity on long-term liability

WTO Compatibility Risk	Medium – subsidy conditionality may attract scrutiny	Low–Medium – contractual instruments reduce exposure	Low – primarily contractual and regulatory instruments
Institutional Capacity Requirements	High – technology assessment, standards development, manufacturing oversight	Medium–High – EPC oversight, workforce training, content verification	Very High – geological expertise, monitoring/verification, regulatory oversight
Implementation Challenges	REE supply chain dependencies; technology concentration; demand uncertainty	Carbon intensity pressure; infrastructure scale requirements; capital intensity	Social license; long-term liability uncertainty; site-specific feasibility variation
Local Content Leverage Points	Manufacturing (electrolyzers, components); engineering services; infrastructure construction	Construction; operations workforce; CCS integration services	Capture technology installation; transport infrastructure; monitoring services

Key References	Yin et al. (2024); Shin (2022); Hilali (2025)	Sergeeva & Ward (2024); Hydrogen Economy and LNG (2022)	Buirma et al. (2022); Gough & Mander (2022); O'Brien & Banet (2021)

Note. EPC = Engineering, Procurement, and Construction; ICV = In-Country Value; REE = Rare Earth Elements.

7.2 Supply Chain Competitiveness Indicators and Local Content Leverage

The cross-sectoral analysis identifies a set of supply chain competitiveness indicators that are applicable across hydrogen, LNG, and CCS sectors, albeit with varying weights and measurement approaches. **Table 2** presents these indicators alongside the corresponding local content leverage points and policy implications for each sector.

Table 2: Supply Chain Competitiveness Indicators and Local Content Leverage Points

Competitiveness Indicator	**Hydrogen Sector**	**LNG Sector**	**CCS Sector**	**Policy Implication**
Resource Endowment Score	High importance – renewable energy availability determines LCOH	High importance – feedstock gas reserves and quality	High importance – geological storage capacity and quality	Prioritize resource mapping and access frameworks
Technology Capability Index	Critical – electrolyzer and fuel cell manufacturing	Moderate – established technology,	High – capture technology deployment and optimization	Support R&D, technology transfer, and

		CCS integration emerging		domestic manufacturing
Infrastructure Readiness	Medium – pipeline, storage, refueling networks needed	High – liquefaction, shipping, regasification	High – CO_2 transport and injection infrastructure	Public investment in anchor infrastructure
Institutional Quality	High – certification, standards, market design	Medium–High – regulatory oversight, content verification	Very High – liability frameworks, monitoring, oversight	Build regulatory capacity alongside project development
Cost Competitiveness	LCOH relative to international benchmarks	Levelized cost of LNG including carbon costs	Cost per tonne CO_2 captured and stored	Use subsidies and carbon pricing to close cost gaps
Supply Chain Resilience	REE dependencies; electrolyzer concentration	Shipping route diversification; feedstock security	Storage site diversification; transport redundancy	Diversify supply chains; build domestic manufacturing
Local Economic Multiplier	Employment in manufacturing and construction	Construction and operations employment	Specialized engineering and monitoring employment	Design content requirements to maximize multiplier effects

Carbon Intensity Performance	Near-zero for green hydrogen; blue hydrogen with CCS	Declining with CCS integration; methane management	Measured by capture efficiency and storage permanence	Integrate carbon performance into competitiveness metrics

Note. LCOH = Levelized Cost of Hydrogen; CCS = Carbon Capture and Storage.

7.3 Convergence and Divergence in Local Content Strategies

The cross-sectoral analysis reveals important convergences in local content strategy across hydrogen, LNG, and CCS. All three sectors benefit from contractual instruments that embed localization objectives into project economics, institutional capacity building that enables domestic suppliers to meet project requirements, and public investment in shared infrastructure that reduces barriers to local participation. The common thread is a move away from blunt regulatory mandates toward sophisticated policy mixes that align incentives across government, industry, and communities.

Significant divergences also emerge, however. Hydrogen local content strategy must grapple with the technology concentration and REE supply chain vulnerabilities that limit localization potential in markets without domestic manufacturing capabilities (Hilali, 2025; Noussan et al., 2020). LNG local content is increasingly shaped by carbon competitiveness imperatives that create new opportunities for CCS-related local content while potentially displacing traditional content in fossil fuel operations. CCS local content is uniquely shaped by geological specificity and long-term liability considerations that have no direct analogs in hydrogen or LNG.

8. Policy Implications

8.1 Framework Design Principles

The analysis generates several design principles for effective local content frameworks in energy transition projects. First, local content policies should be grounded in honest assessments of domestic industrial capabilities, distinguishing between areas where local suppliers can realistically compete and areas where capability development requires sustained investment and

time (Suleman & Zaato, 2021; Chuwa, 2023). Unrealistic local content mandates that exceed domestic supply capacity generate compliance costs without local economic benefits, undermining both project economics and policy credibility. Second, policy instruments should be selected based on their compatibility with international trade obligations, with explicit regulatory mandates reserved for contexts where legal exposure is limited or treaty exemptions apply (Nelson & Puccio, 2021). Financial and contractual instruments offer greater flexibility and lower legal risk while potentially achieving comparable localization outcomes. Third, local content frameworks should be integrated into broader industrial policy strategies that address supply-side capacity constraints through training, technology transfer, and infrastructure investment (Reigstad et al., 2022; Ding et al., 2022). Demand-side content requirements without corresponding supply-side support are likely to generate compliance gaming rather than genuine capability development.

8.2 Institutional Capacity and Governance

Effective implementation of local content frameworks requires institutional capacity across multiple dimensions: regulatory expertise to design and enforce compliance mechanisms, technical capability to verify local content claims, and governance structures to manage stakeholder engagement and dispute resolution (Chuwa, 2023; Suleman & Zaato, 2021). The institutional demands of CCS local content are particularly high, given the technical complexity of geological storage oversight and the long-term nature of monitoring obligations (O'Brien & Banet, 2021). Building this institutional capacity requires deliberate investment and cannot be assumed to develop organically alongside project development. Governance structures for local content implementation benefit from multi-stakeholder platforms that bring together government, industry, communities, and civil society in the design, monitoring, and evaluation of local content frameworks (Suleman & Zaato, 2021; Gough & Mander, 2022). Such platforms can build trust, identify implementation barriers, and enable adaptive management of local content requirements as projects evolve and domestic capabilities develop. The social license dimension of CCS cluster development, analyzed by Gough and Mander (2022), illustrates how community engagement can simultaneously build social acceptance and identify local economic benefit opportunities that strengthen local content outcomes.

8.3 Sector-Specific Policy Recommendations

For hydrogen, the priority is developing certification and standards systems that enable domestic production to access premium markets while embedding local content requirements in public support programs for electrolyzer manufacturing and infrastructure development. Addressing REE supply chain vulnerabilities through strategic stockpiling, recycling programs, and technology development for REE-lean designs should be integrated into hydrogen industrial strategy (Hilali, 2025). For LNG, the integration of CCS capabilities into local content frameworks creates an opportunity to develop domestic expertise in carbon capture technology, CO_2 transport infrastructure, and geological storage that will have value across multiple energy transition applications. For CCS, the priority is establishing clear legal and regulatory frameworks that de-risk investment while creating contractual vehicles for local content commitments, supported by public co-investment in shared transport and storage infrastructure (O'Brien & Banet, 2021; Buirma et al., 2022).

9. Conclusion

This paper has examined strategic local content frameworks for energy transition projects in hydrogen, LNG, and carbon capture sectors, analyzing how policy mechanisms, supply chain competitiveness drivers, and institutional contexts interact to determine localization outcomes. The analysis demonstrates that effective local content frameworks in these sectors require sophisticated approaches that go well beyond simple procurement mandates, integrating financial instruments, contractual mechanisms, capacity-building initiatives, and governance structures tailored to the specific competitiveness dynamics of each sector. The cross-sectoral comparison reveals both convergences and important divergences in local content strategy across hydrogen, LNG, and CCS. Common design principles include grounding policies in realistic capability assessments, selecting instruments compatible with trade law obligations, and integrating demand-side requirements with supply-side capacity building. Sector-specific considerations include the REE supply chain vulnerabilities affecting hydrogen localization, the carbon competitiveness imperatives reshaping LNG local content, and the geological specificity and long-term liability considerations that shape CCS frameworks. The conceptual framework developed in this paper, distinguishing resource-based, capability-based, and infrastructure-based leverage points, and

classifying policy instruments by directness and mechanism, provides a structured approach for policymakers designing local content frameworks for energy transition projects. The two comparative tables synthesize competitiveness indicators and policy mechanisms across sectors, offering practical reference tools for policy design and evaluation.

Several limitations warrant acknowledgment. The analysis draws primarily on published academic and policy literature, which may not fully capture recent developments in rapidly evolving sectors. Country-level case evidence is necessarily selective, and generalization across diverse institutional contexts requires caution. Future research should examine the empirical effectiveness of specific local content instruments through longitudinal case studies, analyze the interaction between local content policies and carbon pricing mechanisms, and investigate the distributional effects of localization strategies across different stakeholder groups. Bos and Gupta (2019) note that distributional justice considerations are increasingly central to energy transition governance, and future local content research should engage more explicitly with equity dimensions of localization policy. Despite these limitations, the paper contributes to a growing literature on the political economy of energy transition by demonstrating that local content frameworks, when carefully designed and implemented, can enhance supply chain competitiveness while promoting domestic industrial development. The energy transition represents an unprecedented opportunity for industrial policy intervention, and strategic local content frameworks are essential tools for ensuring that the benefits of this transformation are broadly shared.

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