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Energy transition and regional adaptation potential in hydrocarbon-rich countries

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Abstract

Hydrocarbon-rich countries face complex challenges in transitioning to renewable energy (RES), particularly in sub-national regions economically dependent on oil, gas, and coal (OGC) extraction and export. This study investigates the regional capacity for the energy transition and the ability to adapt in four OGC-rich countries—Kazakhstan, Azerbaijan, South Africa, and Australia—each with distinct governance structures, economic profiles, and RES potentials. Drawing on evolutionary economic geography and elements from Sustainability Transitions theory, we develop a conceptual framework to assess four key factors: OGC dependence, RES expansion, governance mechanisms, and regional planning capabilities. Using expert surveys and probabilistic analysis, we evaluate the current significance and projected future impact of these factors over a 10 year horizon. Results indicate persistent path dependencies and governance constraints in Kazakhstan and Azerbaijan, whereas Australia demonstrates greater adaptability owing to its federal structure and diversified economy. South Africa, despite decentralised governance, faces infrastructural and financial limitations that hinder transition planning. Across all cases, RES expansion is progressing, but community-level benefits and regional planning remain underdeveloped. Governance emerges as a critical enabler, yet its effectiveness varies widely. The findings highlight the need for enhanced capabilities in polycentric governance, inclusive stakeholder engagement, and integrated regional planning to support just and effective transitions. This comparative analysis emphasises the necessity of aligning national energy strategies, policies, and funding with regional realities and priorities, particularly within carbon-intensive economies. The findings also provide policy-relevant insights to enhance regional adaptability and facilitate energy transitions that adhere to global climate commitments.

1. Introduction

Transitioning to greater reliance on renewable energy (RES) is essential to avoid exceeding the 2 °C threshold for global warming and the subsequent climate changes that could have catastrophic consequences for ecosystems, economies, and people worldwide. Many nations have developed energy transition plans to reform policies and shift towards cleaner energy sources. However, the transition requires significant reforms across the primary, industrial, and services sectors, which will have substantial effects on economic activities reliant on existing energy systems. These impacts will be more

profound in hydrocarbon-rich countries, particularly regions that are almost entirely dependent on oil, gas, and coal (OGC) extraction, processing, and export (Tsani 2022, World Economic Forum 2025). In this paper, we use the term 'region' to refer to sub-national territories—such as provinces, states or mono-industrial basins—whose economies are strongly shaped by OGC extraction, processing and related industries. These regions are situated within diverse national and federal settings; rather than presuming internal uniformity, our analysis emphasises their common trait of high OGC dependence while recognising significant socio-economic and institutional differences within and among them.

Transitions to lower-carbon futures are expected to have significant economic effects on the fiscal and macroeconomic balances of oil-producing countries such as Azerbaijan and Kazakhstan, and on the oil-exporting regions within them in particular (International Monetary Fund (IMF) 2022, Blankenship *et al* 2024). In other cases, there are significant economic uncertainties regarding the retrofitting of infrastructure related to hydrocarbon production for domestic and export markets (e.g. Kazakhstan, South Africa), which host regionally important industrial complexes that extract or depend on fossil fuels (International Energy Agency (IEA) 2024). Significant uncertainties also exist in the differing priorities at the national and regional levels regarding the pace of energy transitions, which increases the risk of carbon lock-ins in economies that remain reliant on carbon-intensive exports. Notable examples include regions in Australia that are heavily reliant on coal exports, although the country aims to achieve net-zero greenhouse gas emissions within about two decades (Arranz *et al* 2024).

Hydrocarbon-rich countries face a dual challenge: on one side, there is ongoing strong demand for energy resources like coal, gas, and oil, fuelled by global supply chains, end-users, and investments, which significantly boost their economies; on the other side, there are commitments to global decarbonisation and financial incentives for climate mitigation strategies, creating a complex balancing act. This duality creates difficult political and economic tensions and trade-offs for hydrocarbon-rich governments. The dichotomy is quite evident at the regional (sub-national) level, where, despite their transition efforts, hydrocarbon-producing regions continue to depend on mono-economic activities and energy exports (Mey *et al* 2024). This dependence creates local reluctance towards change, compounded by limited alternative economic opportunities. At the community level, resistance often emerges from existing infrastructure, social norms, governance arrangements and skills-oriented professionals supporting current pathways (Skoczkowski *et al* 2020).

The topic of regional energy transitions has received considerable academic attention in recent years, given the close alignment between factors such as resource dependence, the regional nature of energy geographies and associated value-chain dependencies (Coenen *et al* 2021, Loewen 2022). Given global and national commitments to embark on energy transitions, the ability of energy-dependent regions to develop new economic foci has gained increasing attention. Of equal concern is the need to account for the impacts on resource-dependent communities and to assess whether transitions can be socially just (Nel *et al* 2023). When trying to understand the potential and constraints to transitioning, nationally and regionally, a range of theories can be drawn on.

Evolutionary economic geography (EEG) examines how regions evolve from dependence on one economic activity to another, with adaptation being contingent on governance, politics, resources, established value chains, dominant skills and infrastructure (Boschma and Martin 2007). These factors either facilitate change to new socio-economic regimes—known as path creation—or stifle change if local realities resist change, leading to what is referred to as 'path dependency', 'lock-in' and the failure to diversify or transition (Martin 2012, MacKinnon *et al* 2019). As a result, EEG argues that historically embedded processes shape regional outcomes as they evolve over time (Kogler *et al* 2023). According to Hassink (2010), EEG shows how 'the economic landscape—the spatial organisation of economic production, distribution and consumption' resists change or can adapt to new circumstances. The need for carbon-dependent energy regions to transition is a case in point. Boschma and Frenken (2018) have more recently drawn attention to the role of clusters and networks of economic activities, institutions, and agency in potentially driving regional change. Extending the argument into the realm of metacognition, it is apparent, as Fischer and Fleming (2024) note, that it is necessary to factor in and anticipate the complex nature of human decision-making, choice, and reflective thinking when navigating complex transitions for individuals and institutions in regions with strong levels of path dependence.

Related to EEG, Sustainability Transitions and determining contextual variables have been analysed in work by Geels (2010, 2011) and Coenen *et al* (2021). Geels (2010, 2011) developed the multi-level perspective on the socio-technical aspects of transitions to explain the degree to which any change in energy and other systems is embedded in complex, long-term processes. Change depends on the interaction and engagement between exogenous variables such as international commitments and market forces, dominant national and regional systems of production, marketing and economic activity and localised realities and networks. Similar to EEG, the Sustainability Transitions and related perspectives recognise that change is a long-term process influenced by various factors, including infrastructural,

resource, economic, social, and governance legacies. These factors can shape future outcomes, leading to either path dependence or the creation of new paths. Additionally, they determine the ability to adapt and innovate in response to change. Aspects such as established value chains and contextual variables—national, regional and local—as well as the capacity to innovate are key determinants in energy and related transitions, the speed at which they can occur, and whether change is resisted or supported (Baker *et al* 2014, Coenen *et al* 2021).

This paper analyses the factors influencing the regional ability in four hydrocarbon-rich nations and their energy-dependent sub-national regions with high carbon footprints and export levels to cope with the transition to RES systems. By explicitly linking energy transition dynamics to regional political economy, the study extends insights from EEG and Sustainability Transitions theory into energy policy debates, highlighting conditions under which decarbonisation pathways may become economically fragile and politically destabilising.

We compare Kazakhstan, Azerbaijan, South Africa and Australia, acknowledging their different stages of economic development and sociodemographic structures. All four countries rely heavily on the direct or indirect (embedded in commodities) export of OGC resources, with some regions within these countries being much more exposed to extraction, processing, and/or export. We focus on the dependence on OGC resources, the availability and opportunities for RES, the governance context (i.e. the institutional and organisational arrangements) and the capabilities for developing proactive regional planning as the overarching factors affecting the energy transition and regional adaptation potential in each country, currently and into the near future (10 year time horizon). In hydrocarbon-rich countries, adaptation is not often formalised as a set of discrete policies. Thus, observable governance, planning, and infrastructure stocks that shape regional adjustment to the energy transition can be used as proxies.

The primary factors are structured within a proposed conceptual framework and are linked to indicators employed to evaluate individual performance. The evaluation is conducted through an expert survey that maintains a consistent structure and set of questions across all four countries, as detailed in Supplementary Material 1. The suggested approach, employed herein, recognises that adaptation in carbon-dependent regions often occurs indirectly, through the misalignment of energy policy and investment frameworks, rather than through explicitly labelled adaptation policies.

The study contributes to the energy policy and economic literature by reframing energy transition as a politically and economically contingent process rather than a primarily technical challenge. Drawing on a comparative analysis, it shows that nationally articulated transition strategies, while sound in theory, are often constrained in practice by entrenched regional path dependencies in governance, infrastructure, and economic structures. The paper suggests a reusable analytical framework that operationalizes regional adaptive capacity through governance, infrastructure, finance, and economic structure, enabling systematic cross-country comparison. Empirically, the findings reveal a structural misalignment between national transition objectives and regionally concentrated adjustment costs. Analysis shows commonalities in the importance of governance and regional planning for the transition, despite variability in the relative importance of these factors across countries.

2. Methods

We developed a conceptual framework of the factors and associated indicators affecting the ability of hydrocarbon-rich countries and regions within these countries to adapt and transition to RES. Adaptation is examined herein as the capacity of carbon-dependent regions to adjust their economic structures, governance, and infrastructure in response to pressures associated with the energy transition. In our study, governance is defined as the set of institutional arrangements, policy processes, and actor interactions through which energy transitions and regional adaptation are steered across scales. Governance structures shape the pace, direction, and distribution of the costs and benefits of decarbonisation, while differentials affect countries' planning and action capacity. Drawing on EEG and Sustainability Transitions theory, governance is treated herein as both an enabling and constraining factor that mediates path dependency, lock-in, and the potential for regional path creation. Infrastructure also refers to physical assets and networks (e.g. grids, pipelines, transport systems) developed under hydrocarbon-based development. These assets can be both enabling (e.g. through repurposing) and constraining (e.g. due to technological standards and dependence on historical investments) factors for low-carbon development paths.

Adaptation policies consider the set of implicit and explicit national, regional, and local policies aimed at managing the socio-economic impacts of decarbonisation (e.g. employment reskilling and upskilling, industrial diversification, infrastructure repurposing). In many hydrocarbon-rich countries, such policies are not articulated as standalone adaptation strategies but are embedded within energy, industrial, and regional development frameworks.

The proposed conceptual framework aims to better comprehend how governance systems and planning capacities shape regional responses to the low-carbon transition, particularly in regions facing strong path dependencies and risks of carbon lock-in. We further explore how formal policies and institutional practices influence regional adaptation capacity over time.

The framework is presented in figure 1, where the factors are shown in bold, and the indicators are listed below each factor. Each of these factors and their indicators were identified by drawing upon EEG theory and frameworks, the IPCC assessment reports under the auspices of the conferences of the parties (COPs) of the UNFCCC, and a range of case studies (Hassink 2010, Christopherson *et al* 2010, Skoczkowski *et al* 2020, Grabner 2021, Hu *et al* 2022, Kogler *et al* 2023, Sutton *et al* 2023). The factors identified were:

- OGC Economic dependence—reflecting the heavy economic dependence of the selected countries on OGC, both nationally and regionally, which aligns with EEG notions of sunk costs, path dependency and lock-in.
- Potential for RES expansion (i.e. RES systems) due to the greenhouse gas mitigation commitments of signatories to the UNFCCC Conference of the Parties (COP) and the global recognition of the need for countries to embark on net-zero energy transitions.
- Governance—drawing on EEG and socio-economic transition literature, the focus is on the national, regional, and local capacity to innovate and to coordinate collective efforts.
- Regional planning—similar to the preceding point, but referring more specifically to the capabilities and capacity for integrated strategic assessment and planning required to underpin and sustain actions and investments in regional transitions.

We initially identified hydrocarbon-rich countries that directly export OGC resources to third countries, and then considered indirect hydrocarbon exports via the fossil-fuel energy embedded in commodities (e.g. mining products). The focus on countries with both direct and indirect fossil-fuel export profiles aimed to highlight the challenges faced by local communities, regions, and nations that rely on OGC production and exports for their livelihoods and tax revenues. These regions are often trapped by 'locked-in' extraction technologies, which require dependence on specific qualifications and expertise and frequently entail more localised externalities of fossil fuel production, such as air pollution and health problems (Skoczkowski *et al* 2020). Various layers of governance are involved in the energy transition and in the engagement of local communities in maintaining or reshaping local/regional economies. These governance arrangements often have unclear roles and restrictive or weak mandates (Drobniak 2020, Nel *et al* 2023).

We focused on Australia, Azerbaijan, Kazakhstan, and South Africa. Within each of these countries, we explored the energy transition in the oil-, gas- and coal-producing sub-national regions rather than at the national level. In practice, this meant western oil and gas regions and central coal basins in Kazakhstan, the coal-dependent province of Mpumalanga and associated power-industry clusters in South Africa, major coal and gas basins in Australia, and offshore and onshore producing areas around Baku–Absheron and the Caspian, alongside newly designated 'green energy zones' in Azerbaijan. Although unequal in socio-economic and technological development and with different development priorities, all regions in these countries exhibit high levels of direct and indirect hydrocarbon exports, regional economic dependence on these activities, and multi-scale governance mechanisms that have a distinct impact on energy transition pathways. The profiles of the four countries are presented in appendix.

An initial review of the literature was conducted to identify indicators and assess their relative importance across the four thematic areas of the framework. We explored the policy framework, the status of the energy transition, national practices, and each country's regional (sub-national) dependence, with extensive information and relevant citations provided in supplementary material 2.

The authors selected four indicators for each thematic factor, based on their experience with energy transition and adaptation in both national and regional contexts. A consultation was also held with three experts from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, specialising in global energy transitions and regional adaptation, to assess the rationale and suitability of these indicators. Additionally, the likelihood of each indicator increasing or decreasing in significance over the next 10 years was examined to assess potential effects on regional adaptation and the energy transition. The thematic factors and indicators are presented in table 1.

A survey was designed in Microsoft Forms for each country in a uniform format to enquire about the significance (currently) and likelihood (10 year horizon) of the relevant aspects affecting energy transitions and regional adaptation in the four countries. The survey was pilot tested with two experts from CSIRO and then distributed to 25–30 individuals with expertise in each country. The survey sample was relatively small because it aimed to reach selected well-educated professionals in the energy and

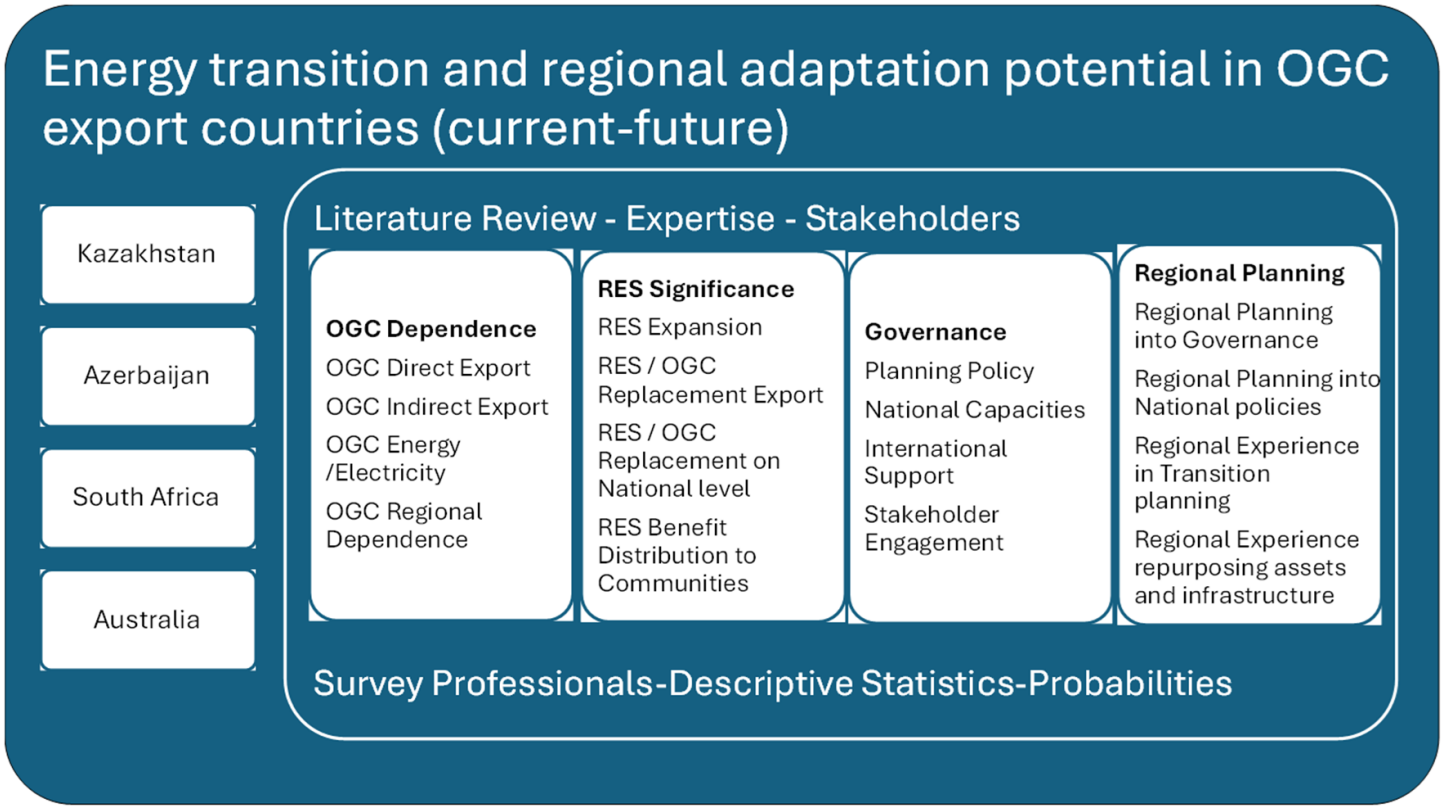

Figure 1. Conceptual framework for reviewing energy transitions and their effects on adaptive capacity in hydrocarbon-rich countries with an export-oriented profile. Descriptions of each factor are provided in table 1.

Table 1. Description of the thematic factors and indicators for characterising hydrocarbon-rich countries in terms of their capabilities for regional energy transition and climate adaptation.

Factors	Indicators	Description
OGC Dependence	OGC Direct Export	Dependence on revenues from nationally produced/refined oil, gas, and coal used for exporting purposes
	OGC Indirect Export	Dependence on revenues from exported commodities relying on nationally produced/refined hydrocarbon resources (e.g. exported minerals relying on coal energy)
	OGC Energy/Electricity	Dependence on nationally produced/refined hydrocarbon resources for domestic energy and electricity
	OGC Regional Dependence	Dependence on regional economies within the country on nationally produced/refined hydrocarbon resources
RES Significance	RES Expansion	Expansion of renewables for domestic/export purposes
	RES/OGC Replacement Export	Replacement of fossil fuel production, purposed directly/ indirectly for exporting due to RES expansion
	RES/OGC Replacement on National level	Replacement of fossil fuels production purposed for national consumption due to RES expansion
	RES Benefit Distribution to Communities	Distribution of economic benefits from RES projects to local communities
Governance	Planning Policy	Planning policy to steer the energy transition on national and regional levels in ways that are climate-adapted
	National Capacities	Institutional and technological support from national capacities to steer the energy transition and climate adaptation on national and regional levels
	International Support	Economic, institutional and technological support from international development organisations to steer the energy transition and climate adaptation at national and regional levels
	Stakeholder Engagement	Stakeholder engagement to steer the energy transition on national and regional levels and support just adaptations to climate change
Regional Planning	Regional Planning into Governance	Governance system enabling regional energy and climate adaptation planning and initiatives
	Regional Planning into National Policies	Incorporation of regional energy and climate adaptation planning provisions into national planning and policies
	Regional Experience in Transition Planning	Regional experience of socio-economic transitions derived from endogenous/exogenous factors
	Regional Experience repurposing assets and infrastructure	Regional experience to repurpose assets and infrastructure to revitalise economic activities in ways compatible with a changing climate

adaptation fields, employed across different sectors at mid- to senior career levels. The experts chosen were drawn from academic institutions, the public sector, the private sector, international organisations, and government bodies. It is noted that, although the survey was distributed to experts residing in the four designated countries, it was also sent to individuals knowledgeable about the energy aspects of the study

areas who reside in other countries. Our objective was to gather expert opinions on the energy transition and regional (sub-national) adaptation, regardless of whether they were located within or outside the four countries. The answers were anonymised to adhere to the requirements of the human ethics approval. The survey was conducted online from May to July 2025, and ethics approval (No. 058/25) was granted by the CSIRO Social Science Research Ethics Committee.

The significance of each factor was assessed on a qualitative ordinal scale from 1 to 5 (minor significance—little significance—somewhat significant—quite significant—very significant), while the option of not responding or indicating unawareness was also available. Similarly, the likelihood was formatted on a qualitative ordinal scale from −2 to 2 (Very likely to deteriorate—likely to deteriorate—Will possibly remain the same—somewhat likely to improve—very likely to improve), with slight variations in the case of OGC dependence to better reflect the context of this factor. The ordinal data on the significance of each factor and indicator were analysed using descriptive statistics (mean, standard deviation). The likelihood of each factor in the 10 year horizon was estimated as a probabilistic outcome. We converted the vote counts for each option (e.g. likely to deteriorate) into percentages and multiplied them by the ordinal scale outcomes (e.g. 1). The total expected value (TEV) was calculated as the sum product of the probabilities and the ordinal scale as follows:

$$\mathrm{TEV} = (\mathrm{Probability1} \times \mathrm{Value1}) + \ldots (\mathrm{Probability5} \times \mathrm{Value5}). \quad (1)$$

It is noted that future dependence scores may exceed the upper limit of the ordinal scale (0–5) because calculations are based on the TEV, which can yield higher overall scores. However, the comparison between current and TEV values is intended to indicate the potential difference between present and future conditions rather than the absolute difference between the two. Also, the unanswered and unaware ('do not know') responses were excluded from the analysis. We further estimated the aggregate mean values of the indicators associated with each factor's significance and future probability by identifying potential correlations among the four countries.

The comparative, theory-driven approach adopted aims at analytical and qualitative contributions rather than at a statistical generalisation. The use of expert elicitation (purpose-selected samples of experts per country) aims to capture informed assessments of governance, infrastructure, and regional planning capacities in contexts where these attributes are not directly observable through standard quantitative indicators. Experts were selected based on their institutional roles and direct engagement with energy transition processes, allowing the analysis to focus on structural and institutional dynamics rather than individual preferences. The ordinal scales employed do not aim to produce precise measurements but rather to enable systematic cross-country comparisons and to structure interpretation across heterogeneous political and economic contexts. Scores are discussed in light of the scholarly literature on the subject, with the aim of providing country-based, theory-informed interpretations of regional path dependency, adaptive capacity, and transition-related political and economic constraints.

3. Results

A total of 63 respondents participated in the country surveys, with nearly equal representation across the countries (Kazakhstan-16, Azerbaijan-16, South Africa-15, Australia-16). The socio-demographic profiles across the four surveys are shown in table 2. Most respondents reside in the targeted countries (∼80%), though some experts from Europe and the Middle East/Gulf region responded for the Kazakhstan and Azerbaijan cases. Participants from focus countries represent varied professional backgrounds, with most holding postgraduate degrees. The respondents' experience levels are relatively balanced, with most aged 26–55 years.

The current and future significance of the four factors affecting energy transitions and regional adaptation is depicted in figure 2 for all four countries. As shown in figure 2(A), all four measures of economic dependence on OGC were scored by respondents as almost equally important across the four countries, with Australia's values being slightly lower than the others. Regarding the contribution to regional economies (OGC Reg), however, only South Africa and, to a lesser extent, Kazakhstan demonstrate high OGC dependence, while Australia and Azerbaijan show moderate dependence. All countries, except Kazakhstan, exhibit a trend toward reduced future dependence, underscoring the OGC's diminished role in the energy grid and regional economies. The standard deviation of the significance attributed to the indicators varies across countries, with Kazakhstan showing the lowest and Australia the highest, particularly for export-related indicators.

The findings for the RES shown in figure 2(B) indicate a moderate dependence in Kazakhstan and Azerbaijan, which is expected to increase over the next 10 years. South Africa and, more notably, Australia exhibit higher scores. The distribution of RES benefits to communities (RES Comm) is consistently lower across all four countries than for other indicators, with a higher standard deviation indicating greater heterogeneity.

Governance factors receive similar attention across all countries (figure 2(C)), with the

Table 2. Profile of the experts participating in the four surveys on energy transition and regional (sub-national) adaptation. Source: Authors.

Experts' Profile	Regions				
Age	*Australia/ New Zealand*	*Central Asia/ Caucasus*	*Europe*	*Middle East/ Gulf region*	*South Africa*
18–25	0%	0%	33%	0%	0%
18–25	0%	4%	0%	0%	0%
26–35	0%	32%	0%	0%	0%
36–45	17%	32%	33%	100%	14%
46–55	56%	16%	33%	0%	43%
55+	28%	16%	0%	0%	43%
Experience					
1–3 years of experience	6%	4%	0%	0%	21%
3–5 years of experience	17%	24%	0%	100%	21%
5–10 years of experience	22%	36%	50%	0%	29%
10–15 years of experience	33%	24%	25%	0%	0%
More than 15 years of experience	22%	12%	25%	0%	29%
Education					
Graduate Degree	11%	8%	0%	0%	7%
Postgraduate (Master's)	11%	40%	25%	0%	21%
Postgraduate (PhD)	78%	52%	75%	100%	71%
Professional Sector					
Government	17%	12%	0%	0%	0%
International Organisation	0%	8%	0%	0%	0%
NGOs	0%	12%	0%	0%	7%
Private Sector	17%	24%	0%	0%	21%
Public service	11%	0%	0%	0%	0%
Research Institute	50%	8%	0%	0%	29%
University	6%	36%	100%	100%	43%

Note: OGC DRC Exp = OGC Direct Export; OGC IND Exp = OGC Indirect Export; OGC En/El = OGC Energy/Electricity; OGC Reg = OGC Regional Dependence; RES/OGC DR = RES Expansion; RES/OGC Repl = RES/OGC Replacement Export; RES/OGC Nat = RES/OGC Replacement on National level; RES Comm = RES Benefit Distribution to Communities; Pol Planning = Policy Planning; Nat Capac = National Capacities; Intern Supp = International Support; Stakeh Eng = Stakeholders Engagement; RegGov = Regional Planning into Governance; RegNat = Regional Planning into National Policies; Reg Exp Trans = Regional Experience in Transition Planning; Reg Exp Infra = Regional Experience repurposing assets and infrastructure.

expected future significance increasing. A notable exception is international support (Intern Supp) in Australia, which assigns much lower importance than in other nations. A relatively lower score is also observed for Australia and Azerbaijan regarding stakeholder engagement (Stakeh Eng) in the transition process and community resilience. Australia exhibits a high standard deviation in stakeholder engagement, as does Kazakhstan.

Regional planning significance receives low scores for Kazakhstan and Azerbaijan, as shown in figure 2(d), whereas Australia shows low scores for regional experience with transition processes (Reg Exp Trans) and for repurposing assets and infrastructure at the local level (Reg Exp Infra). However, all four indicators indicate higher future dependence. Kazakhstan and Australia exhibit higher standard deviations, particularly in regional experience with transition processes.

The overall trends and relationships among the contributing factors across the four countries are shown in a dumbbell plot in figure 3, with mean and standard deviation indicated by shaded lines in each country. For OGC dependence, current significance shows mixed trends across countries ($r = -0.19$), whereas future trends are polarised between Kazakhstan and Australia, with a negative correlation ($r = -0.86$). The trends align positively for current RES significance ($r = 0.62$), becoming more pronounced over 10 years ($r = 0.94$). The variation in the current significance of governance ($r = -0.11$) is partly indicated by South Africa's high attention versus Australia's lower score, becoming more divergent in future significance ($r = -0.56$). For regional planning, a positive and more cohesive pattern is observed ($r = 0.45$), though this association is attenuated in future trends ($r = 0.12$). A further presentation of the statistical indicators is provided in supplementary material 3.

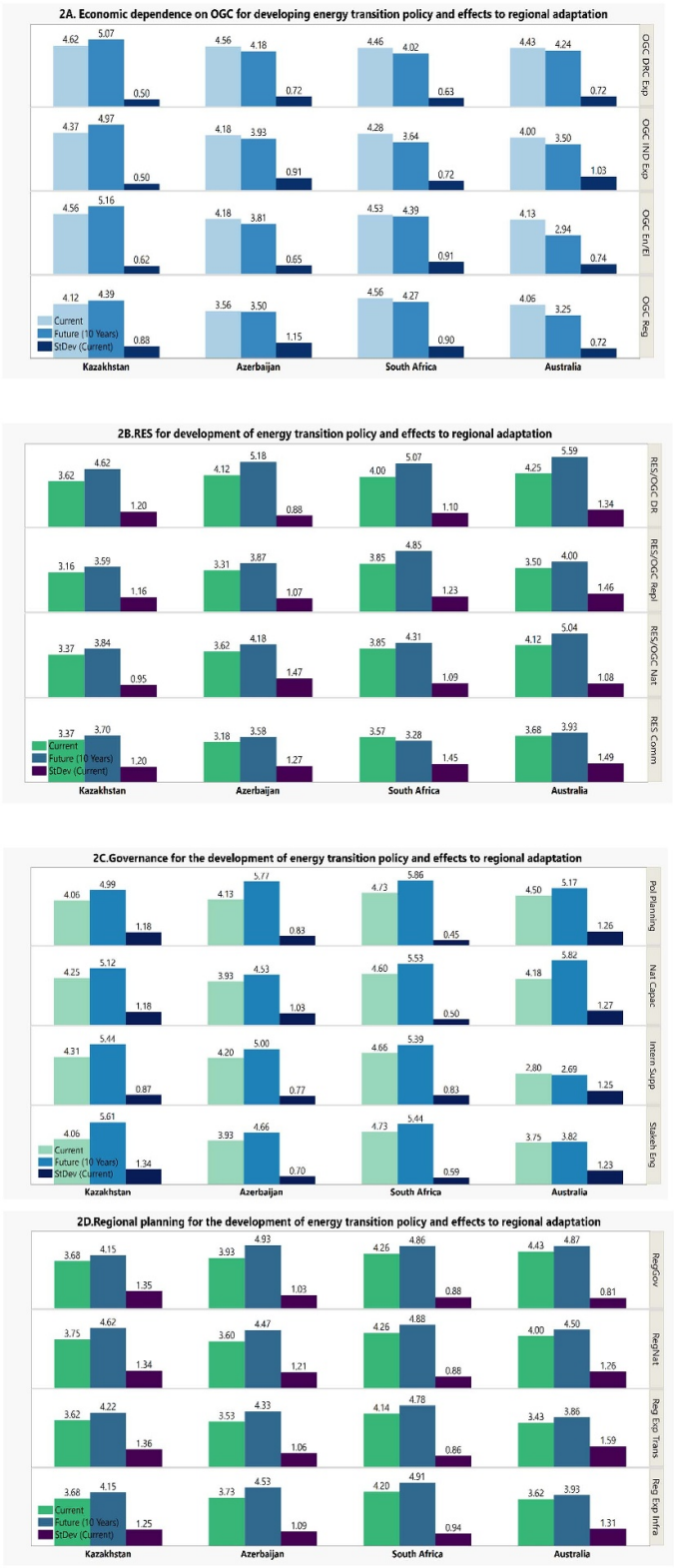

Figure 2. Significance and TEV scoring on energy transition and regional adaptation of each indicator in the four countries for the assessed factors
Source: Authors.

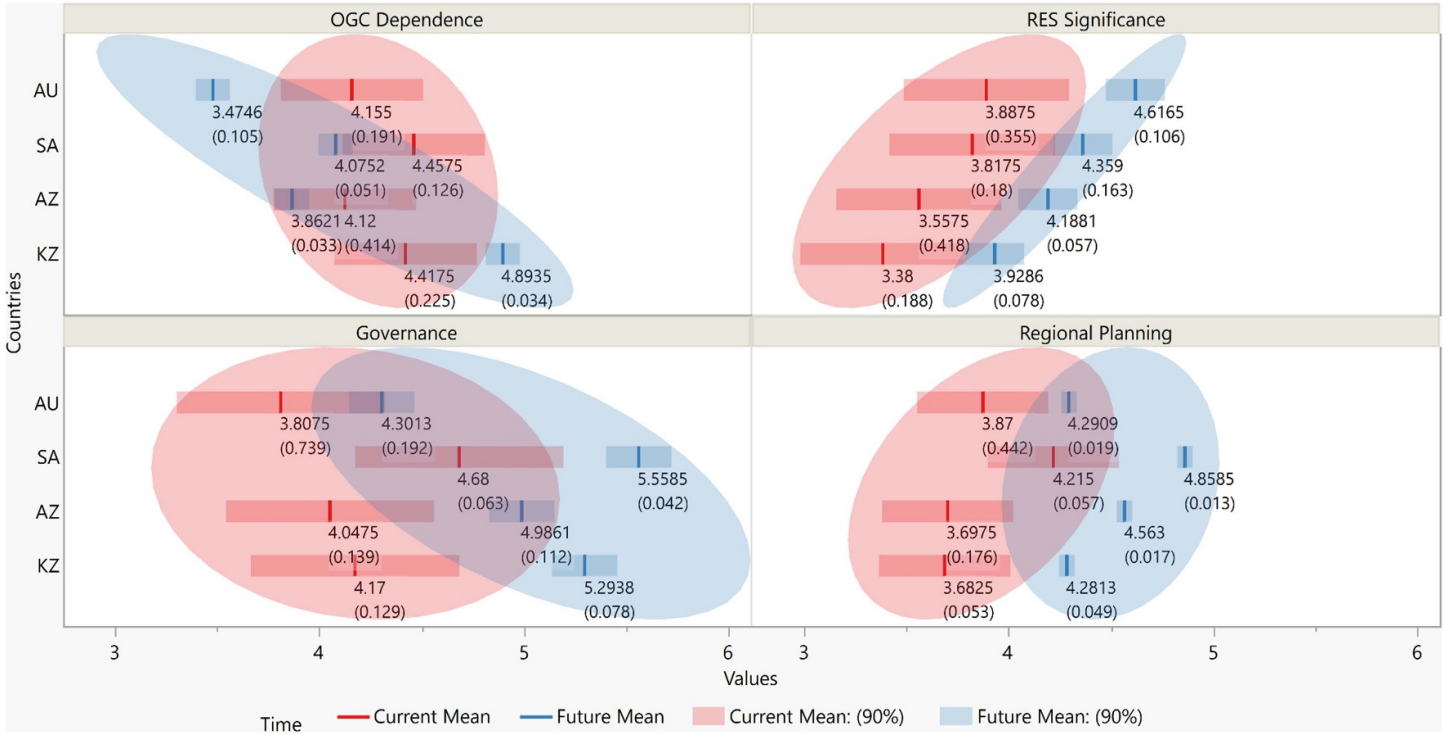

Figure 3. Current and future trends of significance and TEV scoring in the four countries for the assessed factors and indicators.

4. Discussion

In this section, the survey results are discussed within the broader context of the existing literature and empirical research evidence.

4.1. OGC dependence

The high levels of economic dependence on OGCs observed in all four countries are deeply embedded in their structural reliance (i.e. institutional, cultural, economic, and infrastructural) on fossil-fuel-based energy networks and industries.

However, this dependence is not evenly distributed within countries but is concentrated in oil-, gas- and coal-producing regions whose exposure and adaptive capacity differ from more diversified areas. Our analysis, therefore, focuses on these energy-producing regions as indicative of higher transition risks, while recognising substantial variation within and between them. The variability between Kazakhstan and South Africa, compared with Azerbaijan and Australia, and the expected future increase for Kazakhstan alone, requires further elaboration.

Kazakhstan demonstrates the most entrenched and spatially extensive dependence. Hydrocarbons account for 70% of total exports and contribute 21% of GDP, with the broader extractive sector's share being even higher (Xenarios *et al* 2024). Hydrocarbons also account for nearly the entire electricity generation in the country and employ approximately 220 000 people. This dependence has clear regional dimensions, shaped by the Soviet industrial legacy. The western regions of Atyrau and Mangystau are dominated by oil and gas extraction, centred on the Tengiz, Kashagan, and Karachaganak fields. In contrast, the central and northeastern regions of Karaganda and Pavlodar remain heavily reliant on coal, hosting numerous large coal mines, power stations, and carbon-intensive industries. Despite stated intentions to close some fossil-fuel based energy plants, this has not materialised. These regions exhibit deep technological, infrastructural, and institutional lock-in, exemplified by limited labour-market diversification, OGC-company towns, and rail and pipeline systems designed for fossil-fuel flows. Kazakhstan has experienced downsizing in coal mining since the 1990s (notably in Karaganda), which has led to unemployment and out-migration, thereby increasing political caution toward transitions. Regional elites and populations continue to view fossil-fuel extraction as the foundation of future development, while RES investment is primarily occurring in central and southern regions, which are geographically distant from the core hydrocarbon regions. Current national policies, including subsidised pricing, limited regional autonomy, and continued prioritisation of fossil-fuel expansion, reinforce path dependency and explain why Kazakhstan is the only country projected to increase OGC reliance (International Energy Agency (IEA) 2022, Kazenergy 2023, Jianzhong *et al* 2018).

South Africa's high dependence score stems from its coal-centric energy system. While coal accounts for approximately 2%–3% of GDP, it supplies 85% of electricity and supports more than 150 000 direct and indirect jobs. Considering the total value of exports, coal exports account for approximately 7% of this value. The Mpumalanga coal belt, developed under apartheid-era industrial planning, hosts most of the coal mines, coal-fired power stations (Kendal, Duvha, Matla), and related logistics. The province of Mpumalanga exhibits a strong lock-in to coal-based industries as its transmission infrastructure is designed around coal, municipalities' revenues rely on coal mining, and employment and services are tied to the coal value chain. South Africa also has a history of coal mine closures (linked to local resource availability and international demand and price), which have led to unemployment, fiscal decline in municipalities, and rising poverty (e.g. the Optimum and Highveld Steel closures). Although the national government has articulated ambitions for a just transition away from coal, local communities and unions remain uncertain about their future, often perceiving coal as irreplaceable. Large-scale RES investments are, however, growing rapidly but have been concentrated mainly in the Northern Cape region rather than in the Mpumalanga coal region, thereby limiting opportunities for regional transition planning in this region (Makamela and Ramfol 2024).

Australia's lower dependence reflects a more diversified national economy, in which fossil fuels contribute approximately 50% of local electricity generation (a percentage that is declining), a smaller share of GDP (around 1.5%), and a reduced impact on employment and fiscal revenue. At the same time, coal accounts for approximately 14% of Australia's export value and employs about 65 000 people. Coal mine closures are a direct result of the higher costs of coal-based electricity generation compared to that of renewables. Nevertheless, dependence is spatially concentrated in regions such as Queensland (metallurgical and thermal coal), New South Wales (the Hunter Valley coal), and Western Australia (LNG and gas) (Tunny 2025). While parts of Queensland and the Hunter Valley experience regional lock-in, Australia's federal structure and robust service and manufacturing sectors mitigate national vulnerability. Several mine and power plant closures (e.g. Hazelwood in Victoria) have occurred, causing

localised disruption, but this was mitigated by labour-market flexibility, retraining schemes, and diversification strategies. Many regions are now increasingly viewing their future in hydrogen, critical minerals, and advanced manufacturing, with RES development increasingly occurring with the intent to replace coal and gas, leveraging existing grid access and workforce skills. Australia's transition trajectory is therefore demonstrating itself to be more decentralised and regionally adaptive than most of the regions considered across the four countries in this study.

In the case of Azerbaijan, national-level dependence on hydrocarbons remains exceptionally high, with oil and gas accounting for over 90% of exports and between 30% and 50% of the country's GDP. The subsector employs about 30 000 people. However, regional dependence is moderated by the country's highly centralised governance model (Tuğrul and Karimli 2020). Hydrocarbon activities are concentrated around the Absheron Peninsula in Baku, while revenues are redistributed nationally, limiting localised economic integration and reducing regional lock-in relative to Kazakhstan or South Africa (Felver 2020). Historical field decline in the 1990s led to worker displacement, but this was mitigated by the rise of offshore megaprojects, such as Azeri–Chirag–Gunashli. Local economies outside Baku are less reliant on extraction and more diversified, with a focus on agriculture, services, and transportation. Regions and their populations generally view their future as being aligned with continued national oil and gas production, complemented by logistics and petrochemical development. There is no evidence of downsizing. RES, particularly offshore wind near Absheron and solar energy in central regions, is expanding, but its geographical footprint seldom overlaps with Azerbaijan's core hydrocarbon areas, limiting its immediate influence on entrenched fossil fuel dependencies.

4.2. RES trends and projections

RES development presents a mixed but promising trajectory across the four countries. Australia leads in current and future RES significance as shown in figure 3 Its federal structure has enabled state-level innovation and investment, with ambitious targets, including 83% renewable electricity by 2050 (Nong *et al* 2025). Widespread rooftop solar adoption, robust policy incentives, and grid-scale battery investments have positioned Australia at the forefront of renewables deployment. These are also supported by national subsidies and by a highly educated, relatively wealthy community that is willing and able to invest in RES sources.

Figure 3 reinforces Ausrtalia's leading position but also a large dispersion in responses—indicating that while national momentum is high, regional benefits remain uneven. This variability is consistent with dispersion patterns seen in stakeholder engagement and community benefit indicators, suggesting that some states and communities are better positioned than others to capture value from RES expansion.

South Africa also shows relatively high current RES significance, though its future trajectory is more moderate. The target is 70% renewable electricity by 2035, and policies like the RES Independent Power Producer Procurement Programme (REIPPPP) have attracted investment (Nel *et al* 2023). Still, implementation is constrained by grid limitations, ageing infrastructure, and limited provincial funding. The findings reflect these challenges, with lower scores for community-level benefits and regional planning experience. Nonetheless, the cost competitiveness of renewables and the urgency of addressing energy insecurity continue to drive interest, primarily from the private sector, in RES expansion.

Figure 3's patterns support this interpretation: South Africa shows relatively high mean RES significance but with noticeable future divergence, reflecting the disconnect between strong national ambition and weak provincial capacity. The country's moderate spread of scores suggests uncertainty about whether governance and grid reform will progress fast enough to support large-scale RES uptake, particularly in Mpumalanga, where entrenched coal infrastructure increases the risk of transition delays.

Kazakhstan and Azerbaijan exhibit moderate current significance of RES, with Azerbaijan scoring higher in policy momentum and near-term deployment. Azerbaijan's RES strategy aims to diversify its energy mix and free up natural gas for export, leading to large-scale solar and wind projects (Nuriyev *et al* 2023). This export-oriented motivation, combined with international partnerships and investment guarantees, contributes to its relatively higher current scores (UNCTAD 2023). Figure 3 shows a relatively tight clustering for Azerbaijan, indicating coordinated expansion where RES complements, rather than displaces, hydrocarbons.

Kazakhstan, on the other hand, with a target of 50% renewable electricity by 2050, faces structural barriers including low electricity tariffs, centralised governance, and a geographical mismatch between renewable potential and existing fossil fuel infrastructure (Agora Energiewende 2024). However, higher future scores indicate projected RES growth, reflecting optimism about future expansion despite current limitations. In line with that optimism, figure 3 displays one of the largest gaps between Kazakhstan's current and future RES significance—but with sizable dispersion, reflecting tension between strong RES resource potential and entrenched fossil-fuel regions.

Across all four countries, community-level benefits from RES remain limited, with high variability

in responses. This suggests that while national targets and investments are advancing, the distributional aspects of the energy transition—particularly on local adaptation and equity—require greater attention (Rountree *et al* 2022). Australia is the only country with structured regional adaptation strategies, while South Africa's provincial responses remain underfunded and fragmented (Chandrashekeran *et al* 2025). Kazakhstan and Azerbaijan, meanwhile, continue to develop and enhance subregional planning mechanisms. As also presented in figure 3, convergence in RES significance across countries does not translate into convergence in governance or regional planning, and persistent dispersion implies that equitable, locally anchored benefits will lag without targeted reforms.

4.3. Governance structures and their role in energy transition

Governance plays a crucial role in shaping energy transition pathways, with findings showing its consistent importance across the four countries. South Africa scores the highest in terms of current significance attributed to governance. Its unitary system incorporates a relatively decentralised structure, allowing provincial and municipal governments to participate in energy planning, reflected in the higher stakeholder engagement scores. However, the country faces persistent challenges in ensuring coherence between national policy and local implementation, compounded by limited subnational funding and administrative capacity. Despite these constraints, the governance framework is increasingly important for future transition efforts, particularly for managing the social dimensions of coal phase-down.

Australia, by contrast, operates under a federal system enabling region-specific governance, scoring moderately on governance significance—the lowest among the four countries. The scoring is distinctively low for international support and stakeholder engagement, which may be explained by Australia's self-reliant approach, where states lead on RES and climate adaptation, often independently of federal coordination (Chandrashekeran *et al* 2025). It is also less reliant on external economic support compared with the other countries. Lower future governance expectations indicate that while Australia's system allows for innovation, it may lack cohesion and inclusivity in stakeholder engagement processes.

Kazakhstan and Azerbaijan exhibit centralised governance systems with limited regional autonomy. Kazakhstan's governance is top–down, with regional authorities implementing national directives. This structure restricts localised responses and contributes to policy-practice gaps, particularly in stakeholder engagement, which shows high variability. Azerbaijan's governance is similarly centralised, with energy policy dominated by state-owned enterprises and limited municipal powers. Although the governance significance is expected to rise for both countries, limited decentralisation and participatory mechanisms hinder current adaptive transition planning.

4.4. Regional planning and impediments to transition

Regional planning findings suggest an expected increase in its future importance, although current scores remain low, particularly in Kazakhstan and Azerbaijan, where centralised governance constrains region-specific transition plans. In Kazakhstan, the low significance attributed to regional planning reflects a top–down governance model where subnational authorities have limited autonomy to initiate or adapt transition strategies. This is compounded by the geographical mismatch between fossil fuel-dependent regions (e.g. Karaganda, Pavlodar) and areas with high RES potential, which are often located elsewhere. As a result, regions most in need of transition support lack targeted planning or investment (Sumer *et al* 2019, Sembayeva *et al* 2024). The high standard deviation in Kazakhstan's responses indicates uncertainty or inconsistency in how planning is perceived or implemented across regions. Azerbaijan shows a similar pattern where, despite national-level ambitions for RES expansion, regional planning mechanisms are largely absent, and energy policy remains highly centralised. The country's energy strategy focuses on maximising gas exports, with minimal attention paid to subnational adaptation. This is reflected in low scores for both current and future regional planning indicators. These aggregate scores, however, conceal considerable differences both between and within regions in institutional capacity, fiscal autonomy, and planning instruments; therefore, they should be interpreted as highlighting broad patterns rather than uniform regional conditions.

South Africa scores higher but faces significant challenges. Despite decentralised governance, provincial and local governments often lack the financial and institutional capacity to lead transition planning. The Mpumalanga province, for example, is highly dependent on coal but has not received adequate support or funding to develop a comprehensive transition strategy. Australia presents a more nuanced case. While its federal system enables state-led innovation, the findings show that regional planning experience—particularly in infrastructure repurposing—is still underdeveloped. This is surprising given the existence of structured regional adaptation strategies in states like Victoria. The relatively low scores may reflect uneven implementation across states or limited integration of regional planning

into national energy policy frameworks. Nonetheless, Australia shows a consistent upward trend in future planning significance, indicating growing recognition of regional approaches.

4.5. International commitments and energy policy implications

The findings highlight a gap between national decarbonisation commitments and coherent regional adaptation policies in hydrocarbon-dependent regions. With the partial exception of Australia and South Africa, adaptation is not governed through dedicated policy frameworks but remains embedded within broader energy and industrial strategies. In Kazakhstan and Azerbaijan, centralised governance systems and export-oriented energy policies constrain the emergence of region-specific adaptation measures, limiting the ability of subnational actors to plan, coordinate, and invest in transition-related adjustments (Pentayev *et al* 2025). In South Africa and Australia, which have decentralised governance structures, adaptation outcomes are uneven due to disparities in infrastructure readiness and institutional coordination across regions. The results suggest that effective regional adaptation in hydrocarbon-rich economies requires a shift from top–down transition planning to polycentric governance arrangements that explicitly integrate regional planning, infrastructure repurposing, and community participation.

All four nations have ratified the Paris Agreement, each establishing specific targets for greenhouse gas emissions reduction, with substantial policy implications for the energy transition and regional adaptation in each country. Azerbaijan has committed to a 40% reduction in emissions by 2050 relative to 1990 levels, while Kazakhstan aims for a 15% unconditional reduction by 2030 relative to 1991 levels, with a further 25% reduction contingent on international assistance, with the goal of carbon neutrality by 2060 (Temireyeva *et al* 2022). South Africa's goal for 2030 is to reduce emissions by 19% relative to 1990 levels (Chapungu *et al* 2022), whereas Australia has a 43% reduction target by 2030 relative to 2005 levels (Scott *et al* 2020).

Several issues arise regarding the current emissions-reduction commitments. First, except for Australia, progress in reducing emissions has been slow, difficult to quantify, and has even increased in Azerbaijan and Kazakhstan (Wang *et al* 2019, Gurbanov 2021). It is important to note that in the case of Australia, the exports of gas and coal remain exceedingly high and continue to increase, while the fossil fuel industry receives approximately $10 billion in annual subsidies (van Asselt 2023). In this context, Australia demonstrates ambivalence towards the Paris Agreement, enacting relatively straightforward domestic measures while simultaneously engaging in export practices that contradict these commitments. In the case of South Africa, emissions have stabilised but show no significant reduction over the past decade (Salahuddin *et al* 2019). A critical factor is South Africa's dependence on coal-fired power generation, as nearly all stations, with two exceptions, are expected to remain operational until 2050. A decision was made to amend plans for closing ten power stations due to energy security concerns.

All countries have committed to sourcing cleaner energy domestically in the future; however, no policies prohibit the export of carbon resources, effectively exporting emissions. Moreover, these commitments rely heavily on international funding in Azerbaijan, Kazakhstan, and South Africa. This remains a significant barrier to implementing timely change. Although there is a global ethical obligation, this raises concerns about the extent of national commitment. The increase in emissions in Azerbaijan and Kazakhstan exemplifies this issue, likely fostering a perception that the transition is externally driven.

4.6. Methodological challenges on energy transition

Applying the suggested framework across diverse national contexts revealed several methodological challenges. A primary challenge was the interdependency and overlap among indicators. For example, governance-related indicators, such as stakeholder engagement and policy coherence, are closely linked to regional planning outcomes. Similarly, the expansion of RES cannot be fully disentangled from governance capacity and infrastructure readiness. These overlaps are not merely technical; they reflect the complex, multi-scalar nature of the energy transition, in which institutional, economic, and spatial dynamics interact nonlinearly. This complexity aligns with the principles of EEG, which emphasise that regional development trajectories are shaped by historically embedded structures, institutional arrangements, and adaptive capacities. EEG suggests that transitions are not uniform or linear but are contingent on local contexts, path dependencies, and the ability to reconfigure existing systems. In this study, the overlapping indicators reflect the reality that regions do not evolve in isolation; rather, adaptation emerges from the interplay of governance, infrastructure, economic specialisation, and innovation systems.

Another challenge was comparability across countries. While indicators were standardised, their interpretation varied across national contexts and regional experiences. For instance, stakeholder engagement in Australia operates within a federal system with strong state autonomy, whereas in

Kazakhstan and Azerbaijan, it is constrained by centralised governance. This requires careful calibration of the scoring and weighting mechanisms to ensure indicators capture meaningful differences without oversimplifying context-specific realities, which were not provided for in the analysis. A related challenge has been our use of the term 'region' to describe spatial areas of varying extent, scope and scale. In this study it denotes internally diverse sub-national energy-producing territories—such as western oil and gas regions and central coal basins in Kazakhstan, coal-dependent Mpumalanga versus more diversified Eastern and Northern Cape in South Africa, major coal and gas basins in Australia, and offshore/onshore hydrocarbon areas alongside newly designated 'green energy zones' in Azerbaijan—which are aggregated in the scoring. Consequently, the regional scores should be read as indicative averages across heterogeneous localities rather than as implying homogeneous regional conditions. Moreover, characterising the speed, scope, and scale of each transition introduced an additional layer of complexity. The survey responses and TEV calculations revealed that while the future significance of most factors is expected to increase, the pace of change is uneven and often constrained by institutional inertia. This reinforces the EEG insight that transitions are shaped by both enabling and constraining forces—what Boschma and Martin (2007) describe as the tension between path creation and path dependency.

We also acknowledge the limited sample size in each country, which may not provide sufficient statistical power to further consolidate our findings. We, however, emphasise that the analysis was not based on a large number of loosely associated stakeholders, but rather on selected experts with a specific profile who expressed their perspectives on the energy transition and adaptation in sub-national regions of the four countries. Thus, we used statistical indicators indicating potential association, deviation, and probabilistic outcomes in the future.

Despite these methodological considerations, the suggested approach offers a comparative framework for assessing adaptability across countries with an OGC-exporting profile and a means to estimate its future trajectory. While many studies on energy transition focus on single-country cases, this approach highlights the global interdependencies, similarities and structural constraints that shape transition pathways. Our findings suggest that energy transitions remain a considerably top–down process, driven by national and international commitments. Despite a growing discourse around a 'just transition,' there is often a lack of concrete frameworks to support carbon-dependent regions in identifying viable alternatives. The assumption that national or federal governments can centrally plan and deliver transition outcomes overlooks the institutional fragmentation, regional disparities, and temporal pressures that characterise real-world transitions. In many cases, the speed of transition collides with the inertia of carbon lock-in, limiting the ability of regions to adapt to new economic and technological realities (Xenarios *et al* 2024, Box *et al* 2025). In addition, commitments to international binding agreements and the need to catch up with developed nations that rely on technological innovations may clash with the existing realities of each country's energy security and regional dependence.

5. Conclusion

The global pressure to reduce carbon emissions is intensifying, particularly for hydrocarbon-rich economies where reliance on OGC exports, both directly and indirectly, is significant. The four case study countries have ratified the Paris Agreement and formulated ambitious plans for energy transition towards renewables, while also aiming to strengthen the economic resilience of regions dependent on OGC extraction and processing.

The contribution of the paper is a cross-national comparison of four carbon-dependent economies, using a novel conceptual framework that focuses on the economic dependence of sub-national regions within each country on OGC resources and the challenges of the energy transition. The study has shed light on similarities and differences in experiences and on the ongoing issues that require attention. In doing so, we aim to encourage further debate and research into the diverse experiences and associated challenges and opportunities that countries face in energy transitions. While there is consensus that RES should supplant carbon-based economies, implementing this transition is fraught with challenges. These nations exhibit, on average, a significant dependency on OGC sources, with the forms and intensity of this dependence varying across and within regions, making it difficult to diverge from established practices due to direct and indirect path dependencies, as well as ongoing export activities. Continued exports effectively transfer the responsibility for carbon emissions to the recipient countries. Demand in export markets undermines efforts toward adopting RES solutions. In the study countries, except for Australia, the transition away from carbon-intensive economies toward cleaner production is primarily orchestrated through national planning and international funding. This scenario poses challenges to the development of regional responses and resilience to climate change.

All four countries exhibit elements of path dependency in their carbon regions, with only Australia demonstrating more comprehensive decarbonisation strategies. This dependence is evident at three levels: reliance on carbon-based products for economic growth; indirect effects of carbon energy on dependencies throughout the broader economy; and the significance of dependence on carbon exports. These conditions, together with the fact that three countries are currently unable to independently fund transition infrastructure, will probably sustain the existing carbon-based economic paths. This does present the reality of 'path dependency' and the challenges to effectively embark on a new' path creation' for regional energy transition in the three countries (Martin 2012, MacKinnon *et al* 2019). Further research should also consider the importance of metacognition in understanding the complex engagements between people, institutions and transition realities (Fischer and Fleming 2024).

As global efforts to address the energy transition and sustainability concerns respond to the outcomes of COP 30, the financial constraints, resource-based lock-ins, and governance challenges identified in this paper require greater attention if energy transitions are to be successfully realised.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Supplementary data 1 available at https://doi.org/10.1088/1748-9326/ae63e4/data1.

Supplementary data 2 available at https://doi.org/10.1088/1748-9326/ae63e4/data2.

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Appendix. Socio-economic profile of the four countries (reference year 2023)

	Kazakhstan	Azerbaijan	South Africa	Australia
Size (million km^2)	2.7	0.83	1.2	7.68
Population (million)	20.2	10.3	63	27
GDP (billion $US)	$288.4	$74.3	$400.3	$1780
GDP per capita (thousand $US)	$14 149	$7,251	$6,517	$67 979
Direct economic value of OGC to economy (%)	21%	35.3%	3.2%	3.1%
Annual production of OGG (Mt bcm^{-1})	Oil: ∼88 Mt Gas: ∼40 bcm Coal: ∼116 Mt[3]	Oil: ∼29.1 Mt Gas: ∼45.4 bcm	Oil: ∼5 Mt Coal: ∼224 Mt	Oil: ∼21.8 Mt Gas: ∼147 bcm Coal: ∼487 Mt
Share of OGC in total merchandise exports (%)	Coal: 4% Oil: 73% Gas: 15%	Oil: 78% Gas: 42%	Oil&Coal: 44% Direct and embedded	90%
Global export ranking (no.)	Oil: 10 Gas: 12 Coal:7	Oil: 19 Gas: 13	Oil: 35 Coal:5	Oil: 30 Gas:1 Coal:2
Global ranking in production (no.)	Oil: 12 Gas: 20 Coal:10	Oil: 27 Gas: 30	Oil: 50 Coal:7	Oil: ∼30 Gas: 8 Coal:6
World rankings on CO_2 emissions per capita (no.)	26	66	15	16
Employment in OGC sectors (including mining)	Oil&Gas: 170 000 Coal: 45 000	Oil&Gas: 31 600	Coal: 91 000	Coal: ∼51 000 Oil&Gas: ∼20 000
Governance system	Unitary state with decentralised government, but mainly for the implementation of national policies	Unitary state with high levels of centralised government and an omnipotent role of state-owned enterprises	Unitary state with high levels of decentralised government to provincial and local governments	Federal state with high levels of decentralisation for state and local governments
Level of state control over OGC production	State actively intervenes in strategic projects and pricing	Oil & gas deeply tied to political power and state revenue	State has strong regulatory and ownership powers	Strong private sector role; state earns revenue via royalties and taxes
Nature of dependence in terms of electricity	Coal contribution: ∼70%	Gas contribution: 90%	Coal contribution: >80%	Coal contribution: 46%

(Continued.)

(Continued.)

Main OGC-dependent regions	Oil: Tengiz, Karachaganak, Mangistau, Aktobe, Uzen (West Kazakhstan) Gas: Karachaganak, Kashagan, Imashevskoye (West Kazakhstan) Coal: Ekibastuz, Karaganda, and Pavlodar regions (North and Central Kazakhstan)	Oil: Absheron Peninsula Azeri–Chirag–Gunashli (ACG) field, an offshore complex in the Caspian Sea approximately 100 km east of Baku.) Gas: Shah Deniz (offshore Caspian Sea), Absheron Peninsula	Oil: Bredasdorp Basin (offshore Western Cape), Mossel Bay (synthetic fuels) Gas: Karoo Basin (unconventional shale gas, coal bed methane) Coal: Mpumalanga (81% of coal), Limpopo, Free State, KwaZulu-Natal	Oil: North West Shelf (WA), Cooper Basin (SA/QLD) Gas: Bowen Basin (QLD), Surat Basin (QLD), Gippsland Basin (VIC) Coal: Bowen Basin, Surat Basin (QLD); Sydney Basin, Gunnedah Basin (NSW); Collie (WA)
RES in the same regions with OGC	No	No	No	Partially yes
Total renewable electricity (2023) (MW)	5.6	1.6	10.6	54.6
Percentage of electricity in terms of renewables	6%	7%	20%	35%

Note: Oil Mt = Oil Million Tonnes; Gas bcm = Gas billion cubic meters; Coal Mt = Coal Million Tonnes; WA = Western Australia; SA/QLD = South Australia/Queensland; VIC = Victoria; NSW = New South Wales.

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