Energy Strategy Reviews 41 (2022) 100841

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.elsevier.com/locate/esr

Case study

The resource curse in renewable energy: A framework for risk assessment

Alycia Leonard *, Aniq Ahsan, Flora Charbonnier, Stephanie Hirmer

University of Oxford, Oxford, UK

ARTICLE INFO

Keywords:
Resource curse framework
LMICs
Renewable energy export
Decarbonisation
Green energy transition

ABSTRACT

Renewable energy development can enable climate-compatible growth in low- and middle-income countries, particularly given the substantial opportunities for energy export to high-income countries seeking to decarbonise their energy systems. However, this also comes with significant risks, including the potential to trigger a resource curse of adverse social, environmental, and economic effects resulting in paradoxically slowed growth. Here, we propose a novel framework to assess potential risks associated with renewable energy development in low- and middle-income countries rooted in the resource curse literature. Eighteen symptoms of the resource curse are evaluated in terms of relevance to renewable energy, and their potential risks and benefits during renewable energy development are established. We find that context-specific factors are key in determining whether resource developments will provoke adverse impacts or positive opportunities; so, preemptive context-specific risk assessment is needed to implement prevention and mitigation strategies. For example, while fossil fuel development has been seen in some circumstances to increase dependence on external capital and technology, where adequate education and financing strategies are implemented, it can instead enhance autonomy and development. Similar risks can apply to renewable energy development, and must be evaluated. The proposed resource curse risk assessment framework can be applied to individual contexts to help countries, companies, sectors, or projects maximise the positive outcomes of renewable energy development and avoid a renewable energy resource curse.

1. Introduction

This paper presents a novel framework to assess the risk of a renewable energy (RE)-based resource curse in low- and middle-income countries (LMICs).

As global warming is driven ever higher by CO_2 emissions [1], RE development is increasingly critical to decarbonising the global energy supply. This transition towards RE-based generation, though often treated as a technological problem, is rife with social and geopolitical complexities [2]. Many cramped high-income countries (HICs) with high energy consumption may not be able to generate enough RE internally to meet their needs, given the scale of generation needed to produce reliable electricity from variable solar and wind resources [3]. Regional electricity trade is a common way to address internal shortages [4], with transnational RE initiatives such as the Gulf Cooperation Council India interconnector [5], the Australia–Asia Powerlink [6], the Asian RE Hub [7], Gobitec [8], Desertec [9], and the RUSTEC Russia–Europe interconnection concept [10] gaining growing attention. HICs are increasingly likely to import RE from LMICs, where RE resources (e.g. solar) tend to be more abundant [11] and infrastructure construction costs are lower. This can create opportunities for growth and job creation [12] in LMICs, while helping them avoid the CO_2 emissions which typically accompany economic growth and industrialisation [13] and reducing energy poverty [14]. However, it could also provoke a resource curse: the phenomenon of seemingly paradoxical slowed growth [15] and negative social, environmental or economic consequences in resource-abundant countries. While the resource curse is traditionally prompted by non-renewable subsoil resources (e.g. oil, minerals), and the RE transition could reduce existing resource curse symptoms in countries that are already large oil and gas producers [16], it could engender resource curse risk in RE-dominant countries. This should be assessed early in the RE transition to prevent or mitigate potential negative effects.

Understanding RE-relevant resource curse risks is particularly important in LMICs, which are hampered by low institutional quality [17] and are under-regulated, increasing their risk of exploitation and social, economic and environmental harms. We therefore focus on LMICs in this paper, given their combination of institutional and regulatory weakness combined with financial, technological and resource dependence on HICs which makes them more vulnerable to many risks as RE is developed for export.

Framing RE transition risks in terms of a resource curse is rather academically novel, with research only beginning to flourish in this

* Corresponding author.
E-mail address: alycia.leonard@eng.ox.ac.uk (A. Leonard).

https://doi.org/10.1016/j.esr.2022.100841
Received 6 December 2021; Received in revised form 28 February 2022; Accepted 18 March 2022
Available online 13 April 2022

field. Evidence or arguments for the likelihood of an RE-based resource curse have been proposed for hydropower [18], metal and metalloid mining used in RE production [19], wind developments (particularly with relation to crime) [20], and RE-driven land-use conflict [21]. While these early studies are interesting, a holistic assessment framework of the potential risks and impacts of an RE-based resource curse in the context of LMICs does not exist. Here, we seek to bridge this gap and propose a framework to assess the risks of negative resource curse impacts (or "symptoms") for RE development in LMICs, which can be used to develop context-specific risk mitigation policies. We explore the literature on the resource curse and analyse its relevance to RE (Section 2), develop a resource curse symptom framework (Section 3), and discuss how this can be applied in risk assessment, illustrated through a hypothetical case study (Section 4) before offering concluding thoughts (Section 5).

2. The resource curse and renewable energy

The resource curse, coined by Auty [22] and developed by Sachs and Warner [23], occurs when "countries with great natural resource wealth tend nevertheless to grow more slowly than resource-poor countries" [15]. It presents as an "inverse association between natural resource dependence and economic growth" [24]. This concept has been observed in the literature since the 1980s, with interest increasing over time [*ibid*]. A multitude of variations on this definition exist in the literature; some pinpoint resource abundance as the curse trigger, while others claim it is caused by high resource usage, economic dependence, or extraction for export. Additionally, the definitions may include or be limited to a number of negative symptoms, including rent-seeking, overconfidence, and neglect of education [25]; poor investment and savings [26]; slow economic growth, political instability, autocracy, corruption, crime, conflict, and gender inequality [27], among others. Here we adopt a broad definition of the resource curse following Sachs [23]: the observation that countries with greater resources develop more slowly than their resource poor counterparts.

A number of economic and political similarities between RE and subsoil resources point to the potential for a RE-based resource curse. Resource curses arising from subsoil resources are well-evidenced, with examples including the Gulf of Guinea [28], Angola and Venezuela [29], and Nigeria [30,31]. Perhaps the most well-known historic example is the "Dutch disease", the natural gas boom and subsequent appreciation of exchange rate in the 1960s which had a negative effect on the Dutch manufacturing sector [32]. As we transition from subsoil to RE dominance, there is a potential for RE-based resource curses to develop. This is not to say that subsoil resources and RE are the same; subsoil resources are undoubtedly in many ways different from RE. Vakulchuk et al. [33] highlight similarities and differences between RE and hydrocarbons, and their implications on geopolitics, which include differences in resource scarcity, importance of location, control of resources, geopolitical power, international competition, international interdependence, security of supply, geopolitical tensions, conflict type, critical materials, cybersecurity, and key market aspects. That said, both RE and subsoil resource involve complex developments and rely on the state to manage financial flows around assets to produce an energy commodity which can be sold domestically or exported. Eisgruber [34] highlights that while RE export avoids certain oil-related symptoms (i.e. shocks after resource depletion, macroeconomic fluctuations, competition for a fixed amount of resources) it bears the same risks of crowding-out the manufacturing sector, incentives for corruption, and reduced government accountability.

As already evident, the literature is divided on the likelihood of the RE-based resource curse. There is scepticism [16] amongst researchers who laud RE as an antidote to existing resource curses [35] or who see the risks as uncertain and overstated [36]. The environmental benefits and spatially distributed nature of RE compared to subsoil resources support this argument. However, other researchers see the RE-based resource curse as a credible threat. A recent study which investigated a resource curse related to hydroelectric projects argued "that many of the same causal mechanisms used for fossil fuels apply equally well to hydropower" [18, p. 627]. It has also been argued that a resource curse is likely to occur based on metal and metalloid mining for RE production in countries with weak governance [19], though this is also subject to scepticism, given the relatively high prevalence (if in dilute concentrations) and the recyclable nature of many rare earth elements and critical materials [36]. Previous work has highlighted that while RE may have low potential to provoke international conflict, it may provoke local resource curse symptoms in conflict over land use [21] and increased crime (e.g. related to wind RE development in [20]).

Despite the uncertainty around whether and how RE development could prompt a resource curse, it is crucial to assess these risks at the beginning of the RE transition in LMICs before any negative curse impacts take stubborn hold. Therefore, we next study the components that may constitute a RE-based resource curse in detail.

3. RE relevance of resource curse symptoms

While there are numerous similarities between RE and subsoil resources in the context of the resource curse, there are simultaneously critical differences, especially in the broader context of geopolitics. Thus, we cannot simply view RE through the same lens as subsoil resources such as hydrocarbons and apply the existing resource curse literature directly. We instead dissect the resource curse into its constituent parts or "symptoms" and assess whether these could apply to RE, as indeed some symptoms may be applicable to subsoil resources but not RE, and vice versa. Below, we therefore summarise eighteen resource curse symptoms identified through a rigorous review of the existing literature, analyse their potential to intersect with RE development, and justify these potential interactions. These symptoms are listed alphabetically, and their risks are summarised in Table 1. An extended literature review synthesis table is presented in the Appendix.

Crime: Resource-abundant areas tend to experience increased crime, particularly in boom-towns (e.g. rural towns with many unattached young men working in resources who have new money). In the US, natural gas boom-towns have suffered increased violent crime, primarily aggravated and sexual assaults [37]. Similar crime increases were seen in "The Patch" in North Dakota [38] and the Canadian boom-town of Fort McMurray [39]. While much of the literature on this symptom refers to petroleum in North America, the same principles could apply to RE boom-towns in LMICs. Theft of expensive RE equipment (e.g. PV, inverters, batteries) already occurs [40,41], and could increase. Many RE farms will be built in remote areas with lower income levels, heightening this risk.

Damage to local flora, fauna, and landscape: Resource extraction can harm the environment while adding pressure on scarce natural resources (e.g. water [42]). Examples include deforestation [43], fracking [44], oil spills [45], and mining-related environmental degradation [46]. The development of RE infrastructure can cause environmental degradation [47], habitat loss [48], and animal fatalities (e.g. bats and wind farms [49]). Additionally, metal production in the RE supply chain creates "new mining threats for biodiversity" [50, p. 6]. RE projects also add strain to water resources (e.g. hydropower, PV washing, green hydrogen production). That said, RE can also be used for environmental benefit (e.g. wastewater treatment [51]) and RE consumption is generally positively linked to forest area [52]. While RE development carries a small localised environmental risk, which can be minimised through policies and other mitigation strategies if identified, the threats from fossil fuels and climate change generally outweigh said localised risks.

Diversion of investments away from human capital: Resource abundant countries may see little need to invest in human capital given the

Table 1
Summary resource curse symptoms and their possible RE-relevant negative risks.

Resource curse symptom	RE-related negative risks
Crime	Boom-town crime, equipment theft.
Damage to local flora, fauna, and landscape	Habitat damage, strain on scarce resources (e.g. water).
Diversion of investments away from human capital	Under-skilled workforce, poor economic diversity, low education.
Diversion of land	Food insecurity
Diversion of talent from other sectors	Internal brain-drain.
Economic dependence	Dependence, influence, investment does not benefit population.
Expatriates dominating high-income/skilled jobs	Income inequality.
External conflict	Withholding RE as geopolitical weapon, hard to sanction RE exporters.
Gender inequality	Women discouraged from entering industrial RE work.
Income inequality	Disparity between RE owners and waged workers.
Income volatility and trade imbalance	Abrupt cuts to social programmes, exploitation.
Internal conflict	Land conflicts, political and civil unrest.
Land grabs	Rural land grabs for RE farms, displacement of poor inhabitants.
Loss of competitiveness of other export sectors	Exports more expensive, imports cheaper, local industry displaced.
Material dependence	Extortion, difficult to sanction provider country.
Reduced economic diversity	Low-diversity economy post-boom.
Technological or expertise dependence	Extortion, reduced autonomy, local content policies exacerbate other symptoms.
Weakening of institutions	Reduced investment, lowered democracy.

high benefit of their resources. This can manifest in the under-funding of public services and education. An inverse relationship between resource dependence and education spending [53] can lead to reduced educational attainment, especially where the resource is booming [54]. This creates an under-skilled workforce, a low-diversity economy, and lower GDP post-resource boom. A similar boom in RE could provoke under-investment in social programmes and education. While increased human capital development is actually a trigger for increased internal RE consumption [55], this link cannot be assumed for RE developed in LMICs for export.

Diversion of land: The diversion of agricultural land away from growing crops to extracting more profitable resources can induce food insecurity [56] as less food is produced. This has recently been observed with regards to bio-energy production [57] and may also hold true for RE. If RE is more profitable than agriculture to landowners, large-scale wind or PV could be built on agricultural land, making it unusable for crop production.

Diversion of talent from other sectors: Resource jobs in boom industries are frequently better paid than jobs in other sectors. For instance, oil and gas construction and extraction workers in the US receive double the national median hourly wage [58,59]. While RE cannot match this yet, the gap is widening, with hourly wages about 25% higher than the national median [60] and more equitable pay [61]. This could incentivise workers to join the RE sector, draining other industries of skilled staff, creating internal "brain-drain" within other sectors in LMICs.

Economic dependence: Substantial capital is required to construct infrastructure and purchase equipment for large-scale resource extraction. This may need to be borrowed from other countries or international organisations, creating economic dependence [62,63]. Many LMICs are already dependent on multi- or bi-lateral loans, and RE development may increase this dependence, as large-scale projects (e.g. concentrated solar power, hydrogen electrolysers) can require up to billions of euros in investment. Additionally, capital borrowed to purchase RE technologies may not benefit the local population (e.g. through job creation) if they cannot be manufactured in-country. Promoting local content could mitigate these symptoms, but such policies have had mixed results in oil and gas [64].

Expatriates dominating high-income/skilled jobs: Resource development requires specialised skills. If training is unavailable in-country, expatriates may dominate the job market for technical and specialised roles. This exacerbates income inequality as locals do not benefit from resource jobs. For instance, research in Ghana found that: "large-scale extractive industries [...] create few jobs for youth, and, as a result, drive individuals to pursue employment in informal sector activities" [65]. RE developments require long-term infrastructure maintenance and generate more local jobs requiring specialised skills than oil or gas have done [36], and relevant training may not be available in many LMICs. This could lead to expatriates dominating these high-paying jobs.

External conflict: External conflict can arise over control of resources or land and the distribution of their benefits. Existing conflict can be fuelled or exacerbated by resource revenues, or used to increase these revenues (e.g. mining to produce weapons). Common examples are the petro-competition and -aggression [66] prevalent in revolutionary petro-states [67]. Similar conditions have occurred in areas with high-value wildlife [68]. Conflict could arise over the control of valuable land with high RE potential. RE could also be sanctioned or withheld as a geopolitical weapon; though, this is debatable, as RE trade is likely to be bi-directional, based more on balancing than dependence [16], and such "prosumer" activity is suggested to minimise tensions [69]. Furthermore, energy trade has also been shown to have a pacifying effect, rendering the importer more docile [70]. Flipping this around, however, it could be difficult for countries dependent on RE imports to discourage aggression from RE exporters.

Gender inequality: Resource-abundant countries experience higher levels of gender inequality. Decreased participation of women in the non-agricultural workforce (e.g. few women tend to work in the oil sector) results in higher fertility, lower education rates, and less influence for women and girls in both family and political or legislative spheres. While various programmes exist in LMICs to bring women into RE sales (e.g. Solar Sister), policy and the design and implementation of energy projects (e.g. ECOWAS Programme on Gender Mainstreaming in Energy Access in West Africa region) [71], for large-scale RE developments requiring more heavy physical labour and high engineering expertise and less sales and installation, women may be less welcomed into the workforce.

Income inequality: Resource abundance can increase the wealth of resource owners (i.e. rent seekers) with minimal consideration for the productivity and wages of workers, increasing income inequality. Such inequality is prominent in ethnically divided societies and possibly inverted in ethnically homogeneous societies [72]. In Iran, the trend between oil revenues and income inequality follows a U-shape, where both low and high oil revenues beyond a threshold lead to increased income inequality [73]. In RE, those with the land or capital needed to own generation could profit while waged workers are left behind. Governments might divert funds towards subsidies for RE owners, while

those who work for wages may not directly benefit. This is particularly concerning in LMICs with high existing poverty levels.

Income volatility and trade imbalance: Natural resource prices can fluctuate, creating volatility in government revenues, which can in turn create abrupt cuts to social programmes or breaking of promises. RE revenue depends on the price of electricity. The energy sector is highly volatile – indeed, it was the most volatile sector in the 2010s [74] – so national economies relying on energy-based income are more susceptible to fluctuations. As RE has zero marginal costs, there is a risk of exploitation and revenue volatility depending on the market structure/power purchase agreements.

Internal conflict: This is similar to external conflict, but within one country (e.g. civil war, political conflict). Examples include the complex relationship between mining and internal conflict in the Philippines [75], the increase of civil conflict in rural Colombian coca-harvesting areas following an upswing in coca prices [76], and local political conflicts in Peru exacerbated by a commodity price boom affecting the mining industry [77]. Conflicts could arise over land valuable for RE development and RE revenues could exacerbate existing civil or political conflicts in LMICs.

Land grabs: Land can be "grabbed", particularly from poor and rural citizens, to enable resource development. This is one of many drivers of land grabs, which also include tourist developments, urban extensions, and land purchases by migrants [78]. Poor and rural citizens can be dispossessed or unfairly compensated due to information asymmetry, monopolistic power, or threat of violence. This is especially prevalent in LMICs with poor governance and enforcement of human rights. This was observed in oil extraction in Uganda, where the poor were initially presented with a "bad deal", and those unwilling to accept were later forced to accept a "no deal" option [79]. RE developments require land and are often developed in rural low-income areas where land is plentiful and cheap, making residents susceptible to unfair land agreements.

Loss of competitiveness of other export sectors: As one resource sharply increases in export price, other sectors may suffer unintended negative side effects [80]. This effect, known as the "Dutch disease", arises when sharp increase in exports of one sector leads to exchange rate appreciation [81]. This causes the export of products from other sectors (i.e. local products sold overseas) become more expensive, and imports to become cheaper. So, local industry becomes replaced by imports as it is neither competitive locally nor overseas. There is the possibility for a sharp increase in RE exports to provoke the Dutch disease in LMICs, decimating local industries.

Material dependence: Extracting any resource require material inputs (i.e. extraction equipment). In RE, this is particularly relevant to the mining of metals, minerals, and other critical materials for solar photovoltaics and batteries (e.g. for electric vehicles) [82]. If the production of these materials is dominated by particular countries, dependence can result. For instance, China currently produces 44% of primary metals globally, and is the dominant supplier of 34 metals [83]; this market dominance could engender out-sized dependence and influence. Competition between the United States and China over certain minerals is likely [84], which could exacerbate geopolitical tensions. There is also the consideration of scarcity: while some metal deposits are not yet nearing exhaustion, others are demonstrating their finite nature. About half of all copper deposits, for instance, are already in use or in landfill [85]. As materials are increasingly mined for RE production, they will become both more in demand and more scarce. While studies suggest that current metal reserves are adequate to accommodate future renewable generation needs, certain technology types may be limited, and increased demand for lithium is highlighted as a key challenge [86].

Reduced economic diversity: The limited economic links between sectors traditionally susceptible to the resource curse (e.g. oil) and other industries make national economies disproportionately dependent on revenues from these sectors, limiting economic diversification [87,88]. In LMICs, a focus on the RE sector could be at the expense of other sectors, especially if there are limited connections between RE and other industries. However, other industries also rely on RE for the electricity they need to grow. So, depending on the situation, RE development could empower the development of other industries and diversify the economy, or detract from them.

Technology or expertise dependence: Importing resource extraction technology and staff can create dependence on foreign equipment suppliers and labour. This can jeopardise political autonomy or risk extortion, as observed for fossil fuels and minerals [89]. As RE technologies advance, up-to-date expertise is required for research, manufacturing, installation, and maintenance. Meanwhile, governments are incentivised to import equipment and labour to maximise RE rents. While "local content" policies (i.e. promoting the use of local labour and locally-produced equipment) can help to mitigate this, they may exacerbate other resource curse symptoms, (e.g. they may weaken institutions through patronage or increase income inequality through rent-seeking) [90].

Weakening of institutions: Resource-abundant countries tend to experience lower levels of democracy and higher likelihood of authoritarian government. High wealth from subsoil resources can allow for, and encourage, low taxes, which weakens the people's relationship with governments. This creates a "self-sustaining dynamic" of low accountability, elite appropriation of resources, and continued repression [91]. Oil prices, and particularly price shocks, have been found to be tied to democracy levels [92]. This has been observed in the context of low democracy in oil-fuelled states, particularly in the Middle East [93]. The relationship may however flow in both directions; it has been found that in developing and middle-high income economies, if there are weak institutions, then oil is not growth enhancing [94]. However, "geology need not be destiny" [93] for institutions or democracy, nor institutional quality a death sentence if rigorous structures can be put in place to manage RE resources. Given that political and institutional instability decreases rates of private RE investment [95], such a focus on regulatory stability can also mitigate the concerns of RE investors and encourage investments [96]. It is uncertain whether RE revenue could potentially render a government sufficiently wealthy to disregard the will of its people or reject democracy.

4. Context-informed risk assessment

While each of these symptoms could be relevant to large-scale RE development, their likelihood and impact is context-dependent (e.g. to a country, sector, or specific project). This generic framework of symptoms and potential associated risks is therefore intended to be applied to individual context-informed risk assessments. These can help countries, companies, sectors, or projects maximise the positive outcomes of RE development and avoid negative impacts. Such a risk assessment requires context-specific data collection as there is limited historical data available concerning RE-based resource curse symptoms, due to the fact that RE is only recently becoming a significant part of many countries' energy economies.

4.1. Contextual case studies

The use of this framework can be illustrated through a hypothetical case. Let us consider a project-specific risk assessment for the construction of a large-scale solar photovoltaic farm for both consumption and export on the outskirts of Laayoune: depending on one's viewpoint, Laayoune is either in Western Sahara or Southern Morocco. This is a plausible example, given the area's high solar and wind potential,

existing RE developments, and electrical interconnections within North Africa and Europe.

To assess the potential of negative resource curse risks in this project, literature and policy could first be reviewed to determine the contextual relevance of each symptom. For instance, the reviewer may note that, given the large swathes of deserted land in this region, land diversion away from farm use may be minimally impactful. Meanwhile, after investigating the literature on internal conflict in the region, they may highlight internal conflict as a symptom worthy of particular investigation.

Subsequently, data must be collected to assess these symptoms in the context. Given the lack of empirical data often available, a useful source can be expert surveys or interviews with relevant energy system stakeholders across public, private, academic, civil society, political, and financial sectors. These stakeholders can be asked to quantitatively rank the likelihood and magnitude of potential negative impacts related to these symptoms from the solar project and to qualitatively justify their rankings. Such information can be used to generate a quantitative context-specific resource curse risk matrix for the project. Results can be applied in tandem with geopolitical risk indices such as the GeGaLo index [97] to craft policies which prevent negative risks, and can be used in project design to avoid choices which exacerbate risks.

For a more detailed example application of this framework, an assessment of the risk of a resource curse driven by RE in Morocco informed by expert surveys and interviews is provided in [98].

4.2. Policy implications

With an understanding of resource curse symptoms and risks related to RE in a specific context, policies can be designed to prevent or mitigate negative consequences. As shown in the proposed framework, incautious RE developments could replicate the failures of fossil fuels by reducing economic diversity, degrading the local environment and fostering an over-reliance on other countries for capital and technology. Meanwhile, strategic RE development that adequately develops legislative, industrial, educational and financing policies on the other hand can turn these risks into co-benefits such as job creation, environmental protection and energy independence.

Risk assessment using this framework can help to identify RE-supportive policies and regulations which symbiotically strengthen institutions and prevent resource curse harms. As LMICs tend to have weak states (e.g. see [99]), and resource development requires "well-intentioned, far-sighted, and highly capable" governments to appropriately invest and use resource revenue to ensure sustainable economic growth [100], combating institutional weakness is a key element to both encouraging RE development and preventing a resource curse in LMICs. Indeed, in the context of a weak institutional environment, states are less likely to attract investment in RE [101, 102] and a resource curse is more likely to occur [103]. By assessing the risks of RE development and proactively implementing rigorous preventative policies, resource curse risk can be reduced while institutions are strengthened and investment is attracted, a proactive two-birds-one-stone outcome.

4.3. Framework limitations

This work drew on the literature available on non-renewable resources, such as oil and minerals, in framework development. Substantial research has been done to quantify the effect of a subsoil-based resource curse, fitting historical data to empirical models using tools such as regression analysis. While this helps us to derive a theoretical framework and baseline, subsoil resource development data in specific contexts cannot translate directly to RE development in those contexts. So, future work could strengthen this framework using RE-specific empirical data, stemming from countries with a high RE penetration, so that explanatory models evidencing this RE-based resource curse phenomenon can be developed.

5. Conclusions

In this paper, a framework has been proposed to assess the potential symptoms of a resource curse prompted by RE development in low- and middle-income countries (LMICs). While the emerging literature on the subject largely focuses on individual examples of negative impacts of RE development (which we refer to as symptoms), we provide a novel holistic risk assessment framework identifying RE-relevance and risks across resource curse symptoms. Eighteen possible symptoms have been analysed in terms of pertinence to RE development. It is suggested to use these symptoms as a framework for risk assessment in LMICs, to help practitioners identify potential risks relevant to RE in their own countries, sectors, or projects. Subsequently, risks can be mitigated through appropriate policy interventions which maximise the positive social, environmental, and economic outcomes of RE development.

Assessing RE-based resource curse risks before they materialise provides the exciting opportunity to "nip them in the bud". Policy makers can identify the most important resource curse risks in their country's context, and implement strategies to mitigate them before they ever occur. Little data currently exists to understand a RE-based resource curse; future research needs to gather more data to apply standard regression analysis approaches to this. Furthermore, to best design risk mitigation strategies, predictive models would be required rather than retroactive explanatory models traditionally used. This is an exciting area for future work. Additionally, the resource curse has many interdependent and often bi-directional cause–effect relationships. Thus, future research should use the knowledge acquired from regression analysis of past resource curses to model potential interactions in future RE contexts as components of a complex system which accounts for these interactions. With this work, we propose a first iteration of a framework identifying which resource curse symptoms may be provoked by RE, opening an interesting discussion and inviting future work and developments.

CRediT authorship contribution statement

Alycia Leonard: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Aniq Ahsan:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Flora Charbonnier:** Investigation, Writing – original draft, Writing – review & editing. **Stephanie Hirmer:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.esr.2022.100841. Stephanie Hirmer reports financial support was provided by Loughborough University Climate Compatible Growth Programme. However, the outcomes of this research are unaffected by the aims of Stephanie's funding programme.

Appendix. Extended literature review synthesis table

See Table A.2.

Table A.2
Synthesis of the resource curse symptoms, their possible RE-relevant negative risks, and the factors impacting their likelihood and severity.

Resource curse symptom	RE-related negative risks	Factors impacting likelihood and severity
Crime	Boom-town crime, equipment theft	Increase in crime is common in resource-abundant areas, particularly in boom-towns [37–39]. Likelihood and severity will increase in regions with high levels of poverty and inequality, particularly if there are preexisting networks of unattached young men already involved in a cycle of conflict and illicit economies [104].
Damage to local flora, fauna, and landscape	Habitat damage, strain on scarce resources (e.g. water)	The likelihood of environmental impacts due to energy is high, as all infrastructure projects extract resources and have an environmental footprint. The development of RE infrastructure and its associated supply chains can thus cause environmental degradation [47], habitat loss [48], animal fatalities [49]) and threats for biodiversity [50, p. 6]. But the threats from the fossil fuels otherwise used and subsequent climate change generally outweigh said localised risks, and RE can also be used for environmental benefits [51,52]. The severity of the impacts is highly dependent on the regulations and policies implemented to limit negative impacts and promote environmental benefits.
Diversion of investments away from human capital	Under-skilled workforce, poor economic diversity, low education	While this symptom has been documented in the context of fossil fuels [53,54] where wealth from underground resources can be obtained without needing to invest in social capital, we expect that investment in skill-building will be seen as a prerequisite for large-scale RE development, and as such that ambitious RE goals will promote investment in education. This is to be verified through experimental data in LMICs.
Diversion of land	Food insecurity	The likelihood of this resource curse is highly context-dependent, conditioned on land availability, the amount of overlap between lands useable for RE production and for food production, and the comparative income obtainable from each activity. The severity could be severe if food prices are impacted, however most RE is not produced on arable land.
Diversion of talent from other sectors	Internal brain-drain	For LMICs with high unemployment levels, hires in the RE sector are not expected to come at the expense of other industries. However, depending on the education levels of each country, RE industries may need to provide skill training in case there is a shortage of skilled workers at the national level and that hiring such workers directly would cause internal brain-drain.
Economic dependence	Dependence, influence, investment does not benefit the population	The economic dependence of LMICs seeking to scale up RE production on external investors will depend on the barrier to entry for local investors, both economic and regulatory. Thankfully, many forms of RE are modular and initial investments can be low relative to fossil fuel-based energy infrastructure. For large-scale resource extraction infrastructure with substantial capital investment required, loans may need to be taken up from other countries or international organisations, creating or exacerbating economic dependence [62,63]. Depending on how these loans are negotiated in terms of ensuring positive impacts for local populations and growth, this could have a large resource curse impact. Policy design to mitigate this issue should be a focus, as previous policies have had mixed results in oil and gas [64].
Expatriates dominating high-income/skilled jobs	Income inequality	The two main factors conditioning the materialisation of this symptoms are the level of skills required for high-income jobs, and the availability of these skills in the country. If training is unavailable in-country, expatriates may dominate the job market for technical and specialised roles. This exacerbates income inequality as locals do not benefit from resource jobs. RE development could provide significant economic opportunities for local populations as they require long-term infrastructure maintenance and generate more local jobs requiring specialised skills than oil or gas have done [36]. However the relevant training may not be available in many LMICs.
External conflict	Withholding RE as geopolitical weapon, hard to sanction RE exporters	External conflict can arise over control of resources or land and the distribution of their benefits. As presented in [105], "[t]he rapacity (sometimes called "state prize") effect refers to the idea that valuable economic resources can provide an incentive to fight over their control." The higher the value of resources that can be easily appropriated through fighting, such as minerals and oil, the greater is the incentive to fight over them. Though the fuelling of conflict in the context of oil extraction has thus been well documented [66,67], access to RE resources is more evenly distributed, and the related infrastructure assets and high-potential land are less easily appropriated. RE could also be sanctioned or withheld as a geopolitical weapon; though, this is debatable, as RE trade is likely to be bi-directional, based more on balancing than dependence [16], and such prosumer activity is suggested to minimise tensions [69]. Furthermore, energy trade has also been shown to have a pacifying effect, rendering the importer more docile [70]. Trade with neighbours was shown to reduce the duration and the intensity of conflict, to encourage the reallocation of resources to more efficient activities, and thus to open up opportunities and creates jobs. Factors that can impact the likelihood and severity of conflict are the changes in relative prices as a result of trade, the volatility of trade flows, existing historic grievances, the state's institutional capacity and the form of political arrangements, conditions in neighbouring countries, for example the level of violence, that might encourage or discourage conflict in the country of interest, and policies that affect the transmission of changes in international commodity prices to the domestic market [105].
Gender inequality	Women discouraged from entering industrial RE work	The factors impacting the share of women entering the RE industry include cultural norms, economic context, the amount of unpaid care work performed by women, and its compatibility with market work. The gap between the likelihood of studying STEM subjects like engineering, manufacturing, and construction between women and men is lower in LMICs than in HICs, which can reduce the risk of women being shut out of the industry in LMICs [106]. However, the female-to-male ratio of time devoted to unpaid care activities is higher in LMICs then in HICs [107]. While it is hoped that the professional and economic opportunities provided by large-scale RE development could benefit women, this risk remains to be assessed with experimental data.

(*continued on next page*)

Table A.2 (*continued*).

Resource curse symptom	RE-related negative risks	Factors impacting likelihood and severity
Income inequality	Disparity between RE owners and waged workers	Income inequality is prominent in ethnically divided societies and possibly inverted in ethnically homogeneous societies [72]. Resource abundance can increase the wealth of resource owners (i.e. rent seekers) with minimal consideration for the productivity and wages of workers, increasing income inequality. This is particularly concerning in LMICs with high existing poverty levels. While those with the land or capital needed to extract fossil fuel and own generation infrastructure could profit while waged workers were left behind, the distributed nature of the wind and sun resources means that fairer competition can exist, where workers dissatisfied with their income can find other opportunities to gain wealth from the RE resources. Maintaining low barrier to entry to the RE sector and ensuring that government RE subsidies benefit both the owners and the wage-earners will be key factors in determining the likelihood and severity of this symptom.
Income volatility and trade imbalance	Abrupt cuts to social programmes, exploitation	Natural resource prices can fluctuate, especially given the natural variability of solar and wind resources. The energy sector was the most volatile sector in the 2010s [74], so national economies relying on energy-based income are more susceptible to fluctuations. However, for LMICs, deriving revenues from RE resources may be part of an economical diversification strategy and help promote a more balanced overall national portfolio, for economies that are currently highly dependent on one or few concentrated resources or industries. As RE has zero marginal costs, there is a risk of exploitation and revenue volatility depending on the market structure/power purchase agreements, but no LMIC has yet reached such levels of RE exports that there would be a risk of the national revenues being disproportionately dependent on these incomes. This is however a risk that can be relevant in the future, as demonstrated in the UK where wind availability is a key factor in alleviating or aggravating the current energy crisis [108].
Internal conflict	Land conflicts, political and civil unrest	Factors that will determine the likelihood and severity of this symptom include existing civil or political conflicts in LMICs, inequalities, location of the RE resources to be extracted (e.g. if causing disturbances to independent cultural communities, particularly if they may not benefit economically from the extraction of the RE resources). Conflicts could arise over land valuable for RE development and RE revenues could exacerbate perceived inequalities. Both the approach taken by private companies with regards to their impacts on local communities and public policies towards promoting fairness will be key.
Land grabs	Rural land grabs for RE farms, displacement of poor inhabitants	Poor and rural citizens can be dispossessed or unfairly compensated due to information asymmetry, monopolistic power, or threat of violence. This is especially prevalent in LMICs with poor governance and enforcement of human rights [79]. RE developments require land and are often developed in rural low-income areas where land is plentiful and cheap, making residents susceptible to unfair land agreements. Key factors determining the severity and likelihood of this symptom are therefore both the amount overlap between RE resource-rich areas and community-inhabited lands, and governmental citizen protection laws.
Loss of competitiveness of other export sectors	Exports more expensive, imports cheaper, local industry displaced	While this symptom can be severe, as exemplified by the Dutch disease [81], the current scale of RE industries in LMICs does not pose immediate risks of exchange rate appreciation. At this stage of development, increase in exports would be desirable, though this risk of threat to local industries in LMICs could become relevant in the future.
Material dependence	Extortion, difficult to sanction providing country	RE development depends on the mining of metals, minerals, and other critical materials for solar photovoltaics and batteries (e.g. for electric vehicles) [82]. There is therefore a high likelihood that countries will be dependent on a few concentrated mining areas for material imports. For instance, China currently produces 44% of primary metals globally, and is the dominant supplier of 34 metals [83]; this market dominance could engender out-sized dependence and influence. Competition between the United States and China over certain minerals is likely [84], which could exacerbate geopolitical tensions. There is also the consideration of scarcity: while some metal deposits are not yet nearing exhaustion, others are demonstrating their finite nature. About half of all copper deposits, for instance, are already in use or in landfill [85]. As materials are increasingly mined for RE production, they will become both more in demand and more scarce. While studies suggest that current metal reserves are adequate to accommodate future renewable generation needs, certain technology types may be limited, and increased demand for lithium is highlighted as a key challenge [86]. Technological advances reducing the dependence on few rare metals (e.g. cobalt [109] could reduce the likelihood and severity of this risk.
Reduced economic diversity	Low-diversity economy post-boom	In LMICs, a focus on the RE sector could be at the expense of other sectors, especially if there are limited connections between RE and other industries. However, other industries also rely on RE for the electricity they need to grow. So, depending on the situation, RE development could empower the development of other industries and diversify the economy, or detract from them. While in a hypothetical future, an economy over-reliant on RE with low diversity would weaken other industries, LMICs are still far from that stage, and the development of RE could promote economic diversity.
Technological or expertise dependence	Extortion, reduced autonomy, local content policies exacerbate other symptoms	Importing resource extraction technology and staff can create dependence on foreign equipment suppliers and labour, as observed for fossil fuels and minerals [89]. As RE technologies advance, up-to-date expertise is required for research, manufacturing, installation, and maintenance. Meanwhile, governments are incentivised to import equipment and labour to maximise RE rents. While local content policies (i.e. promoting the use of local labour and locally-produced equipment) can help to mitigate this, they may exacerbate other resource curse symptoms, (e.g. they may weaken institutions through patronage or increase income inequality through rent-seeking) [90].

(*continued on next page*)

Table A.2 (*continued*).

Resource curse symptom	RE-related negative risks	Factors impacting likelihood and severity
Weakening of institutions	Reduced investment, lowered democracy	Resource-abundant countries tend to experience lower levels of democracy and higher likelihood of authoritarian government. However, "geology need not be destiny" [93] for institutions or democracy, nor institutional quality a death sentence if rigorous structures can be put in place to manage RE resources. Given that political and institutional instability decreases rates of private RE investment [95], such a focus on regulatory stability can also mitigate the concerns of RE investors and encourage investments [96]. It is uncertain whether RE revenue could potentially render a government sufficiently wealthy to disregard the will of its people or reject democracy.

References

[1] M.R. Allen, O.P. Dube, W. Solecki, F. Aragón-Durand, W. Cramer, S. Humphreys, M. Kainuma, J. Kala, N. Mahowald, Y. Mulugetta, R. Perez, M. Wairiu, K. Zickfeld, IPCC Special Report on the Impacts of Global Warming of 1.5% C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response To the Threat of Climate Change: Framing and Context, Tech. rep., 2018.

[2] F.N. Laird, Against transitions? Uncovering conflicts in changing energy systems, Sci. Cult. 22 (2) (2013) 149–156, http://dx.doi.org/10.1080/09505431.2013.786992.

[3] I. Capellán-Pérez, C. de Castro, I. Arto, Assessing vulnerabilities and limits in the transition to renewable energies: Land requirements under 100% solar energy scenarios, Renew. Sustain. Energy Rev. 77 (2017) 760–782, http://dx.doi.org/10.1016/j.rser.2017.03.137.

[4] L. Ji, X. Jia, A.S. Chiu, M. Xu, Global electricity trade network: Structures and implications, PLoS ONE 11 (8) (2016) 1–15, http://dx.doi.org/10.1371/journal.pone.0160869.

[5] A. Shivakumar, L. Kruitwagen, M. Weinstein, S. Spiteri, A techno-economic and financial analysis of a gulf-India undersea electricity interconnector, in: CCG COP26 policy briefings, 2021, pp. 2–5, URL https://www.researchsquare.com/article/rs-690329/latest.pdf.

[6] Sun Cable, Sun cable Australia-Asia PowerLink, AAPowerLink (2022) URL https://aapowerlink.sg/.

[7] Asian Renewable Energy Hub, Asian Renew. Energy Hub (2017) URL https://asianrehub.com/.

[8] M. Shuta, O. Bavuudorj, S. Zafar, P. Martin, J. Verena, S. Dmitry, Gobitec and Asian Super Grid for Renewable Energies in Northeast Asia, Tech. rep., Frauenhofer Institute, 2013.

[9] C. Cooper, B.K. Sovacool, Miracle or mirage? The promise and peril of desert energy part 1, Renew. Energy 50 (2013) 628–636, http://dx.doi.org/10.1016/j.renene.2012.07.027.

[10] A. Boute, P. Willems, RUSTEC: Greening Europe's energy supply by developing Russia's renewable energy potential, Energy Policy 51 (2012) 618–629, http://dx.doi.org/10.1016/j.enpol.2012.09.001.

[11] M. Suri, J. Betak, K. Rosina, D. Chrkavy, N. Suriova, T. Cebecauer, M. Caltik, B. Erdelyi, Global Photovoltaic Power Potential by Country (English), Tech. rep., Energy Sector Management Assistance Program (ESMAP), 2020, URL http://documents.worldbank.org/curated/en/466331592817725242/Global-Photovoltaic-Power-Potential-by-Country.

[12] IRENA, Renewable Energy and Jobs – Annual Review 2020, Tech. rep., International Renewable Energy Agency, 2020, URL www.irena.org.

[13] S.A.R. Khan, P. Ponce, Z. Yu, Technological innovation and environmental taxes toward a carbon-free economy: An empirical study in the context of COP-21, J. Environ. Manag. 298 (2021) 113418, http://dx.doi.org/10.1016/j.jenvman.2021.113418.

[14] Z. Yu, S.A.R. Khan, P. Ponce, A.B. Lopes de Sousa Jabbour, C.J. Chiappetta Jabbour, Factors affecting carbon emissions in emerging economies in the context of a green recovery: Implications for sustainable development goals, Technol. Forecast. Soc. Change 176 (2022) 121417, http://dx.doi.org/10.1016/j.techfore.2021.121417.

[15] J.D. Sachs, A.M. Warner, The curse of natural resources, Eur. Econ. Rev. 45 (4–6) (2001) 827–838, http://dx.doi.org/10.1016/S0014-2921(01)00125-8.

[16] M. O'Sullivan, I. Overland, D. Sandalow, The geopolitics of renewable energy, 2017, Harvard Kennedy School Working Paper No. RWP17-027.

[17] B. Aydin, Ghana: Will it be gifted or will it be cursed? IMF Work. Pap. 2011 (104) (2011) A001, http://dx.doi.org/10.5089/9781455260393.001.A001, URL https://www.elibrary.imf.org/view/journals/001/2011/104/article-A001-en.xml.

[18] K.J. Hancock, B.K. Sovacool, International political economy and renewable energy: Hydroelectric power and the resource curse, Int. Stud. Rev. (2018) 615–632, http://dx.doi.org/10.1093/isr/vix058.

[19] A. Månberger, B. Johansson, The geopolitics of metals and metalloids used for the renewable energy transition, Energy Strategy Rev. 26 (2019) 100394, http://dx.doi.org/10.1016/j.esr.2019.100394.

[20] C. Gennaioli, M. Tavoni, Clean or 'Dirty' Energy: Evidence on a Renewable Energy Resource Curse, Tech. rep., Fondazione Eni Enrico Mattei (FEEM), 2011.

[21] A. Månsson, A resource curse for renewables? Conflict and cooperation in the renewable energy sector, Energy Res. Soc. Sci. 10 (2015) 1–9, http://dx.doi.org/10.1016/j.erss.2015.06.008.

[22] R. Auty, Sustaining Development in Mineral Economies: The Resource Curse Thesis, Routledge, 1993, http://dx.doi.org/10.4324/9780203422595.

[23] J.D. Sachs, A. Warner, Natural resource abundance and economic growth, National bureau of economic research Cambridge, Mass., USA, 1995, http://dx.doi.org/10.3386/w5398.

[24] R.A. Badeeb, H.H. Lean, J. Clark, The evolution of the natural resource curse thesis: A critical literature survey, Resour. Policy 51 (2017) 123–134, http://dx.doi.org/10.1016/j.resourpol.2016.10.015.

[25] T. Gylfason, Natural resources, education, and economic development, Eur. Econ. Rev. 45 (4–6) (2001) 847–859, http://dx.doi.org/10.1016/S0014-2921(01)00127-1.

[26] T. Gylfason, G. Zoega, Natural resources and economic growth: The role of investment, World Economy 29 (8) (2006) 1091–1115, http://dx.doi.org/10.1111/j.1467-9701.2006.00807.x.

[27] B. Smith, D. Waldner, Rethinking the Resource Curse, Cambridge University Press, 2021, http://dx.doi.org/10.1017/9781108776837.

[28] N. Shaxson, Oil, corruption and the resource curse, Int. Aff. 83 (6) (2007) 1123–1140, http://dx.doi.org/10.1111/j.1468-2346.2007.00677.x.

[29] J.L. Hammond, The resource curse and oil revenues in Angola and Venezuela, Sci. Soc. 75 (3) (2011) 348–378, http://dx.doi.org/10.1521/siso.2011.75.3.348.

[30] X. Sala-i Martin, A. Subramanian, Addressing the natural resource curse: An illustration from Nigeria, J. Afr. Econ. 22 (4) (2013) 570–615, http://dx.doi.org/10.1093/jae/ejs033.

[31] M. Watts, Resource curse? Governmentality, oil and power in the Niger Delta, Nigeria, Geopolitics 9 (1) (2004) 50–80, http://dx.doi.org/10.1080/14650040412331307832.

[32] W.M. Corden, Booming sector and dutch disease economics: survey and consolidation, Oxf. Econ. Pap. 36 (3) (1984) 359–380.

[33] R. Vakulchuk, I. Overland, D. Scholten, Renewable energy and geopolitics: A review, Renew. Sustain. Energy Rev. 122 (2020) 109547, http://dx.doi.org/10.1016/j.rser.2019.109547.

[34] L. Eisgruber, The resource curse: analysis of the applicability to the large-scale export of electricity from renewable resources, Energy Policy 57 (2013) 429–440, http://dx.doi.org/10.1016/j.enpol.2013.02.013.

[35] A.N. Menegaki, An antidote to the resource curse: The blessing of renewable energy, Int. J. Energy Econ. Policy 3 (4) (2013) 321.

[36] I. Overland, The geopolitics of renewable energy: Debunking four emerging myths, Energy Res. Soc. Sci. 49 (2019) 36–40, http://dx.doi.org/10.1016/j.erss.2018.10.018.

[37] T.M. Komarek, Crime and natural resource booms: evidence from unconventional natural gas production, Ann. Reg. Sci. 61 (1) (2018) 113–137, http://dx.doi.org/10.1007/s00168-018-0861-x.

[38] C.A. Archbold, T. Dahle, R. Jordan, Policing "the patch": Police response to rapid population growth in oil boomtowns in Western North Dakota, Police Q. 17 (4) (2014) 386–413, http://dx.doi.org/10.1177/1098611114549629.

[39] R. Ruddell, Boomtown policing: Responding to the dark side of resource development, Policing: J. Policy Pract. 5 (4) (2011) 328–342, http://dx.doi.org/10.1093/police/par034.

[40] E.C. Ikejemba, P.C. Schuur, Analyzing the impact of theft and vandalism in relation to the sustainability of renewable energy development projects in sub-saharan africa, Sustainability 10 (3) (2018) http://dx.doi.org/10.3390/su10030814.

[41] E.C. Ikejemba, P.C. Schuur, J. Van Hillegersberg, P.B. Mpuan, Failures & generic recommendations towards the sustainable management of renewable energy projects in Sub-Saharan Africa (Part 2 of 2), Renew. Energy 113 (2017) 639–647, http://dx.doi.org/10.1016/j.renene.2017.06.002.

[42] K. Vairavamoorthy, S.D. Gorantiwar, A. Pathirana, Managing urban water supplies in developing countries – Climate change and water scarcity scenarios, Phys. Chem. Earth Parts A/B/C 33 (5) (2008) 330–339, http://dx.doi.org/10.1016/j.pce.2008.02.008.

[43] I. Coxhead, A new resource curse? Impacts of China's boom on comparative advantage and resource dependence in southeast Asia, World Development, World Dev. 35 (7) (2007) 1099–1119, http://dx.doi.org/10.1016/j.worlddev.2006.10.012.

[44] B.K. Sovacool, Cornucopia or curse? Reviewing the costs and benefits of shale gas hydraulic fracturing (fracking), Renew. Sustain. Energy Rev. 37 (2014) 249–264, http://dx.doi.org/10.1016/j.rser.2014.04.068.

[45] E.S. Osuagwu, E. Olaifa, Effects of oil spills on fish production in the Niger Delta, PLoS One 13 (10) (2018) e0205114, http://dx.doi.org/10.1371/journal.pone.0205114.

[46] Y. Ouoba, Economic sustainability of the gold mining industry in burkina faso, Resour. Policy 51 (2017) pp194–203, http://dx.doi.org/10.1016/j.resourpol.2017.01.001.

[47] L. Bennun, J. van Bochove, C. Ng, C. Samper, H. Rainey, H.C. Rosenbaum, et al., Mitigating biodiversity impacts associated with solar and wind energy development: Guidelines for project developers, Tech. rep., IUCN and The Biodiversity Consultancy, 2021.

[48] T.J. Conkling, S.R. Loss, J.E. Diffendorfer, A.E. Duerr, T.E. Katzner, Limitations, lack of standardization, and recommended best practices in studies of renewable energy effects on birds and bats, Conserv. Biol. 35 (1) (2021) 64–76, http://dx.doi.org/10.1111/cobi.13457.

[49] E.B. Arnett, W.K. Brown, W.P. Erickson, J.K. Fiedler, B.L. Hamilton, T.H. Henry, A. Jain, G.D. Johnson, J. Kerns, R.R. Koford, C.P. Nicholson, T.J. O'Connell, M.D. Piorkowski, R.D. Tankersley, Patterns of bat fatalities at wind energy facilities in north america, J. Wildl. Manage. 72 (1) (2008) 61–78, http://dx.doi.org/10.2193/2007-221.

[50] L.J. Sonter, M.C. Dade, J.E. Watson, R.K. Valenta, Renewable energy production will exacerbate mining threats to biodiversity, Nature Commun. 11 (1) (2020) 1–6, http://dx.doi.org/10.1038/s41467-020-17928-5.

[51] S.A.R. Khan, P. Ponce, Z. Yu, H. Golpîra, M. Mathew, Environmental technology and wastewater treatment: Strategies to achieve environmental sustainability, Chemosphere 286 (2022) 131532, http://dx.doi.org/10.1016/j.chemosphere.2021.131532.

[52] P. Ponce, M.d.l.C. Del Río-Rama, J. Álvarez-García, C. Oliveira, Forest conservation and renewable energy consumption: An ARDL approach, Forests 12 (2) (2021) http://dx.doi.org/10.3390/f12020255.

[53] L. Cockx, N. Francken, Natural resources: a curse on education spending? Energy Policy 92 (2016) 394–408, http://dx.doi.org/10.1016/j.enpol.2016.02.027.

[54] D.S. Rickman, H. Wang, J.V. Winters, Is shale development drilling holes in the human capital pipeline? Energy Econ. 62 (2017) 283–290, http://dx.doi.org/10.1016/j.eneco.2016.12.013.

[55] P. Ponce, M. López-Sánchez, P. Guerrero-Riofrío, J. Flores-Chamba, Determinants of renewable and non-renewable energy consumption in hydroelectric countries, Environ. Sci. Pollut. Res. 27 (2020) 29554–29566, http://dx.doi.org/10.1007/s11356-020-09238-6.

[56] D. Headey, S. Fan, Anatomy of a crisis: The causes and consequences of surging food prices, Agric. Econ. 39 (SUPPL. 1) (2008) 375–391, http://dx.doi.org/10.1111/j.1574-0862.2008.00345.x.

[57] P.A. Owusu, S. Asumadu-Sarkodie, A review of renewable energy sources, sustainability issues and climate change mitigation, Cogent Eng. 3 (1) (2016) http://dx.doi.org/10.1080/23311916.2016.1167990.

[58] US Bureau of Labor Statistics, Occupational Employment and Wage Statistics, United States Department of Labor, 2021, Retrieved 2021-10-19 from: https://www.bls.gov/oes/current/naics3_211000.htm/#47-0000.

[59] Statista, Median Hourly Earnings of Wage and Salary Workers in the United States from 1979 to 2019, Statista Research Department, 2021, Retrieved 2021-10-19 from: https://www.statista.com/statistics/185335/median-hourly-earnings-of-wage-and-salary-workers/.

[60] B.W. Research, Clean jobs, better jobs: An examination of clean energy job wages and benefits, Tech. rep., E2 (Environmental Entrepreneurs), the American Council on Renewable Energy (ACORE), and the Clean Energy Leadership Institute (CELI).

[61] M. Muro, A. Tomer, R. Shivaram, J. Kane, Advancing Inclusion through Clean Energy Jobs, Tech. rep., Metropolitan Policy Program, 2019.

[62] C. Chase-Dunn, The effects of international economic dependence on development and inequality: A cross-national study, Am. Sociol. Rev. (1975) 720–738.

[63] A. Armstrong, The political consequences of economic dependence, J. Confl. Resolut. 25 (3) (1981) 401–428, http://dx.doi.org/10.1177/002200278102500302.

[64] S. Tordo, M. Warner, O. Manzano, Y. Anouti, Local Content Policies in the Oil and Gas Sector, World Bank Publications, 2013.

[65] P. Ackah-Baidoo, Youth unemployment in resource-rich Sub-Saharan Africa: A critical review, Extractive Ind. Soc. 3 (1) (2016) 249–261, http://dx.doi.org/10.1016/j.exis.2015.11.010.

[66] J.D. Colgan, Petro-Aggression: When Oil Causes War, Cambridge University Press, 2013.

[67] J.D. Colgan, Oil and revolutionary governments: Fuel for international conflict, Int. Organ. 64 (4) (2010) 661–694, http://dx.doi.org/10.1017/S002081831000024X.

[68] L.R. Douglas, K. Alie, High-value natural resources: Linking wildlife conservation to international conflict, insecurity, and development concerns, Biol. Cons. 171 (2014) 270–277, http://dx.doi.org/10.1016/j.biocon.2014.01.031.

[69] D. Scholten, R. Bosman, The geopolitics of renewables; exploring the political implications of renewable energy systems, Technol. Forecast. Soc. Change 103 (2016) 273–283, http://dx.doi.org/10.1016/j.techfore.2015.10.014.

[70] O.Z. Gökçe, E. Hatipoglu, M.A. Soytas, The pacifying effect of energy dependence on interstate conflict: A large-n analysis, Energy Res. Soc. Sci. 78 (2021) 102133, http://dx.doi.org/10.1016/j.erss.2021.102133.

[71] IRENA, Renewable Energy: A Gender Perspective, Tech. rep., 2019, pp. 1–92.

[72] R.M. Fum, R. Hodler, Natural resources and income inequality: The role of ethnic divisions, Econom. Lett. 107 (3) (2010) 360–363, http://dx.doi.org/10.1016/j.econlet.2010.03.008.

[73] Y. Nademi, The resource curse and income inequality in Iran, Qual. Quant. 52 (3) (2018) 1159–1172, http://dx.doi.org/10.1007/s11135-017-0510-y.

[74] M. Moran, Performance and Volatility for Sectors in the 2010s, S&P Global, 2020, Retrieved 2021-10-19 from: https://www.spglobal.com/en/research-insights/articles/performance-and-volatility-for-sectors-in-the-2010s.

[75] W.N. Holden, R.D. Jacobson, Mining amid armed conflict: nonferrous metals mining in the Philippines, Can. Geographer/Le Géographe Can. 51 (4) (2007) 475–500, http://dx.doi.org/10.1111/j.1541-0064.2007.00193.x.

[76] J.D. Angrist, A.D. Kugler, Rural windfall or a new resource curse? Coca, income, and civil conflict in Colombia, Rev. Econ. Stat. 90 (2) (2008) 191–215, http://dx.doi.org/10.1162/rest.90.2.191.

[77] J. Arellano-Yanguas, Aggravating the resource curse: decentralisation, mining and conflict in peru, J. Dev. Stud. 47 (4) (2011) 617–638, http://dx.doi.org/10.1080/00220381003706478.

[78] A. Zoomers, Globalisation and the foreignisation of space: seven processes driving the current global land grab, J. Peasant Stud. 37 (2) (2010) 429–447, http://dx.doi.org/10.1080/03066151003595325.

[79] T. Ogwang, F. Vanclay, A. van den Assem, Rent-seeking practices, local resource curse, and social conflict in Uganda's emerging oil economy, Land 8 (4) (2019) 53, http://dx.doi.org/10.3390/land8040053.

[80] J.A. Frankel, The natural resource curse: A survey of diagnoses and some prescriptions, Commod. Price Volatility Inclusive Growth Low-Income Countries (2012) 7–34.

[81] N. Usui, Dutch disease and policy adjustments to the oil boom: A comparative study of Indonesia and Mexico, Resour. Policy 23 (4) (1997) 151–162, http://dx.doi.org/10.1016/S0301-4207(97)00023-8.

[82] M.D. Bazilian, The mineral foundation of the energy transition, Extractive Ind. Soc. 5 (1) (2018) 93–97, http://dx.doi.org/10.1016/j.exis.2017.12.002.

[83] K. Habib, L. Hamelin, H. Wenzel, A dynamic perspective of the geopolitical supply risk of metals, J. Cleaner Prod. 133 (2016) 850–858, http://dx.doi.org/10.1016/j.jclepro.2016.05.118.

[84] A.L. Gulley, N.T. Nassar, S. Xun, China, the United States, and competition for resources that enable emerging technologies, Proc. Natl. Acad. Sci. 115 (16) (2018) 4111–4115, http://dx.doi.org/10.1073/pnas.1717152115.

[85] A. Exner, C. Lauk, W. Zittel, Sold futures? The global availability of metals and economic growth at the peripheries: distribution and regulation in a degrowth perspective, Antipode 47 (2) (2015) 342–359, http://dx.doi.org/10.1111/anti.12107.

[86] A. Månberger, B. Stenqvist, Global metal flows in the renewable energy transition: Exploring the effects of substitutes, technological mix and development, Energy Policy 119 (2018) 226–241, http://dx.doi.org/10.1016/j.enpol.2018.04.056.

[87] N.A. Phelps, M. Atienza, M. Arias, Encore for the enclave: the changing nature of the industry enclave with illustrations from the mining industry in Chile, Econ. Geogr. 91 (2) (2015) 119–146, http://dx.doi.org/10.1111/ecge.12086.

[88] J. Ayelazuno, Oil wealth and the well-being of the subaltern classes in sub-saharan africa: A critical analysis of the resource curse in ghana, Resour. Policy 40 (2014) 66–73, http://dx.doi.org/10.1016/j.resourpol.2013.06.009.

[89] I. Kolstad, A. Kinyondo, Alternatives to local content requirements in resource-rich countries, Oxf. Dev. Stud. 45 (4) (2017) 409–423, http://dx.doi.org/10.1080/13600818.2016.1262836.

[90] S.J. Patel, The technological dependence of developing countries, J. Modern Afr. Stud. 12 (1) (1974) 1–18, http://dx.doi.org/10.1017/S0022278X00008946.

[91] H.M. McFerson, Extractive industries and African democracy: can the "resource curse" be exorcised? Int. Stud. Perspect. 11 (4) (2010) 335–353, http://dx.doi.org/10.1111/j.1528-3585.2010.00410.x.

[92] K.W. Ramsay, Revisiting the resource curse: natural disasters, the price of oil, and democracy, Int. Organ. 65 (3) (2011) 507–529, http://dx.doi.org/10.1017/S002081831100018X.

[93] M.L. Ross, Will oil drown the Arab Spring? Democracy and the resource curse, Foreign Aff. (2011) 2–7.

[94] N. Antonakakis, J. Cunado, G. Filis, F.P. de Gracia, Oil dependence, quality of political institutions and economic growth: A panel VAR approach, Resour. Policy 53 (2017) 147–163, http://dx.doi.org/10.1016/j.resourpol.2017.06.005.

[95] L.H. Sendstad, V. Hagspiel, W.J. Mikkelsen, R. Ravndal, M. Tveitstl, The impact of subsidy retraction on European renewable energy investments, Energy Policy 160 (2022) 112675, http://dx.doi.org/10.1016/j.enpol.2021.112675.

[96] A. Boute, Regulatory stability and renewable energy investment: The case of Kazakhstan, Renew. Sustain. Energy Rev. 121 (2020) 109673, http://dx.doi.org/10.1016/j.rser.2019.109673.

[97] I. Overland, M. Bazilian, T. Ilimbek Uulu, R. Vakulchuk, K. Westphal, The GeGaLo index: Geopolitical gains and losses after energy transition, Energy Strategy Rev. 26 (2019) 100406, http://dx.doi.org/10.1016/j.esr.2019.100406.

[98] A. Leonard, A. Ahsan, F. Charbonnier, S. Hirmer, Renewable energy in Morocco: Assessing risks to avoid a resource curse, 2022, http://dx.doi.org/10.2139/ssrn.4025835, URL https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4025835.

[99] N. Birdsall, Do no harm: Aid, weak institutions and the missing middle in Africa, Dev. Policy Rev. 25 (5) (2007) 575–598, http://dx.doi.org/10.1111/j.1467-7679.2007.00386.x.

[100] A.J. Venables, Using natural resources for development: why has it proven so difficult? J. Econ. Perspect. 30 (1) (2016) 161–184, http://dx.doi.org/10.1257/jep.30.1.161.

[101] A. Boute, Regulatory stability and renewable energy investment: The case of Kazakhstan, Renew. Sustain. Energy Rev. 121 (November 2019) (2020) 109673, http://dx.doi.org/10.1016/j.rser.2019.109673.

[102] L.H. Sendstad, V. Hagspiel, W.J. Mikkelsen, R. Ravndal, M. Tveitstøl, The impact of subsidy retraction on European renewable energy investments, Energy Policy 160 (October 2020) (2022) http://dx.doi.org/10.1016/j.enpol.2021.112675.

[103] H. Mehlum, K. Moene, R. Torvik, Institutions and the resource curse, Econ. J. 116 (508) (2006) 1–20, http://dx.doi.org/10.1111/j.1468-0297.2006.01045.x.

[104] A. Bish, Soldiers of Fortune. The Future of Chadian Fighters After the Libyan Ceasefire, Tech. Rep. December, Global Initiative against transnational organized crime, 2021, URL https://globalinitiative.net/analysis/chadian-fighters-libyan-ceasefire/.

[105] M. Calì, Trading Away from Conflict. Using Trade to Increase Resilience in Fragile States, Tech. rep., International Bank for Reconstruction and Development / The World Bank, Washington, 2015, http://dx.doi.org/10.1596/978-1-4648-0308-6.

[106] A. Hammond, E. Rubiano Matulevich, K. Beegle, S.K. Kumaraswamy, The equality equation - advancing the participation of women and girls in STEM, Tech. rep., The International Bank for Reconstruction and Development / The World Bank, Washington, 2020, URL https://openknowledge.worldbank.org/bitstream/handle/10986/34317/Main-Report.pdf.

[107] G. Ferrant, L.M. Pesando, K. Nowacka, Unpaid Care Work: The Missing Link in the Analysis of Gender Gaps in Labour Outcomes, Tech. rep. December, OECD Development Centre, 2014, URL https://www.oecd.org/dev/development-gender/Unpaid_care_work.pdf.

[108] H.M. Government, Energy White Paper: Powering Our Net Zero Future, HM Government London, UK, 2020, URL https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf.

[109] H.-H. Ryu, H.H. Sun, S.-T. Myung, C.S. Yoon, Y.-K. Sun, Reducing cobalt from lithium-ion batteries for the electric vehicle era, Energy Environ. Sci. 14 (2) (2021) 844–852, http://dx.doi.org/10.1039/D0EE03581E.