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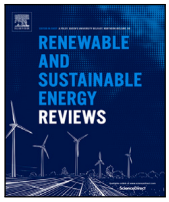

Renewable energy in Morocco: Assessing resource curse risks

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ABSTRACT

Renewable energy development and export creates an opportunity for low- and middle-income countries to foster green economic growth while supporting global decarbonisation. However, without careful assessment of risks, a renewable energy boom could create a resource curse which paradoxically slows growth and development. Here, the likelihood of a resource curse driven by renewable energy development in Morocco is evaluated. Specifically, 14 potential negative impacts of the resource curse (i.e. "symptoms") relevant to renewable energy are studied. Through surveys with 21 Moroccan energy experts, the highest-risk (i.e. most likely and highest-impact) symptoms are found to be: (1) increased economic dependence on other countries and international organisations, (2) increased dependence on other countries for technology and expertise, and (3) damage to local flora, fauna, and landscape. The risks associated with these symptoms, while serious, are preventable via policy strengthening or intervention. Through 10 follow-up semi-structured interviews and subsequent complex systems analysis, the following policy interventions are identified to mitigate resource curse risks: careful negotiation of robust co-funding arrangements to safeguard Moroccan autonomy; the development of local renewable energy innovation capability, including technology manufacturing and test-bedding; and continuation and enhancement of environmental protection mandates.

1. Introduction

This study investigates whether a resource curse is likely to occur as a result of renewable energy (RE) developments in Morocco, and how related risks can be prevented or mitigated through policy.

The resource curse is a paradoxical situation where a resource-abundant country grows more slowly than resource-poor counterparts [1]. It is traditionally prompted by non-renewable subsoil resources (e.g. oil, minerals), as observed in Nigeria [2,3], the broader Gulf of Guinea [4], or Angola [5], where oil abundance has negatively impacted growth and increased corruption. The famous "Dutch disease" [6] saw a resource curse prompted by a natural gas boom ravage the Dutch manufacturing sector. The resource curse can cause diverse negative social and economic impacts including rent-seeking, overconfidence, neglect of education [7], and poor investment [8], amongst others.

Transitioning to RE is seen as a way to reduce existing resource curse symptoms in countries that are already large oil and gas producers [9,10]. However, it could engender its own resource curse risk in RE-dominant countries [11]. Though oil and RE are certainly different [12], their similarities – as energy commodities with complex, multi-stage developments and expensive assets – bring some shared risks. RE avoids the shocks after resource depletion, macroeconomic fluctuations, and competition for a fixed amount of resources inherent to oil, but bears the same risks of crowding-out of the manufacturing sector, incentives for corruption, and reduced government accountability [13]. Previous work advocates for an early assessment of these risks to prevent or mitigate potential negative effects [11].

The risk of a RE-based resource curse is particularly high in low- and middle-income countries (LMICs). RE resources such as solar energy tend to be more abundant in LMICs [14], creating significant opportunity to develop RE for export in the now-commonplace regional electricity trade [15]. As the global community seeks to minimise climate damage [16], crowded and energy-hungry high-income countries (HICs) are increasingly likely to import RE from LMICs in order to reduce their CO_2 emissions at low cost. This transnational RE trade can create economic development; for instance, RE generated an estimated 28,000 jobs in North Africa in 2019 [17]. However, this opportunity is also accompanied by risks, which are amplified by the tendency of LMICs to have weak states (e.g. [18]): weak institutions can cause or exacerbate a resource curse [19].

Previous research on RE-based resource curse effects has focused on individual sectors or symptoms – in the context of hydropower [20],

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Nomenclature

Abbreviations

CSP	Concentrated solar power
HIC	High-income country
IFI	International finance institution
LMICs	Low- and middle-income countries
MASEN	Moroccan Agency for Sustainable Energy
PV	Photovoltaics
RE	Renewable energy
SSIs	Semi-structured interviews

Notations/Symbols

i	Risk
j	Respondent
l	Likelihood
n	Total quantity of respondents
r	Ranking

Units

m^3	Meters cubed
GW	Gigawatt
kWh	Kilowatt-hour
m/s	Meters per second
MW	Megawatt
MWh	Megawatt-hour

metal and metalloid mining key to RE production [21], wind developments (particularly with relation to crime) [22], and RE-driven land-use conflict [23]. More recent work expands beyond these segmented approaches, to provide a framework to holistically assess resource curse symptoms across diverse RE developments in LMICs [11]. This work builds on this approach, offering a novel applied example of the proposed theoretical framework.

Additionally, work in this field tends to view the resource curse as a unidirectional cause–effect relationship, often modelled through regression (e.g. [24–26]). However, this approach has some limitations [27], particularly that the resource curse may in reality have complex interdependent causes (e.g. weak institutions [19]). This work therefore accounts for these potentially intertwined causes by considering institutions, resource abundance, and policy holistically through a complex systems lens. It is the first work which takes this approach to our knowledge.

This study therefore assesses the likelihood of an RE-based resource curse in Morocco using a holistic framework informed by complex system analysis. Based on this assessment, policy objectives which convert high-risk resource curse symptoms into development opportunities are identified. This work focuses on Morocco as an LMIC signatory to the 2015 Paris Agreement with high solar and wind potentials [28] and existing interconnections throughout North Africa and Europe [15,29] which position it well for RE development and export. Building on the risk assessment framework from [11] through surveying, interviews, and complex system analysis, policy intervention points are identified to prevent and mitigate potential negative impacts. This refreshingly balances the opportunity of RE development with a realistic appreciation of risks.

The remainder of this work is organised as follows. Section 2 reviews the Moroccan context as it relates to RE development and resource curse risk. Section 3 presents the methodology used to identify high-impact resource curse symptoms in Morocco. This is followed by a detailed discussion of the resource curse symptoms identified as high-risk in Section 4. Section 5 discusses intervention points to mitigate these high-risk symptoms, illustrated through complex system representations. Finally, the work is concluded in Section 6, presenting the main findings and policy recommendations for resource curse prevention and mitigation.

2. Case study context: Morocco

While nearly all (99.6%) of Morocco's citizens have electricity access [30], with an average annual electricity consumption of 1053 kWh per capita [31], Morocco is currently a net energy importer. 91% of total used energy in 2014 was imported [32], and only 20.7% of Morocco's current electricity mix comes from RE [31].

Despite this, Morocco seems well-positioned to benefit from RE development. It has abundant wind and solar energy, with a minimal mean wind availability rate of 50%–60%, regular average wind intensity over 12 m/s, and 2500–3000 h of sun per year [28,33]. It has plenty of available land for RE development and existing interconnections throughout North Africa and Europe [15,29]. While diverse options to benefit from their RE potential are available, including the manufacture of value-added energy intensive products for export, these existing interconnections make it likely that energy itself will be the key export in the near-term.

Moreover, Moroccan governance for RE has been developed through the creation of institutions such as the Moroccan Agency for Sustainable Energy (MASEN) and the Research Institute for Solar Energy and New Energies. Legal frameworks for energy development, such as law 13-09 [34], also suppport RE development. The 2009 Moroccan national energy strategy aimed to overcome supply problems, in a context of strong dependency on other countries, oil prevalence, and national technical limitations [33], problems which could be solved by increased RE development.

There is enthusiasm for RE research and development in Morocco [35]. Given the various large RE developments ongoing (e.g. Ouarzazate's Noor Complex solar power station, which will be the largest concentrated solar power (CSP) plant in the world with 510 MW nameplate capacity [36,37]) and on the horizon (e.g. a 10.5 GW solar-wind-storage project, of which 3.6 GW is slated for export to the United Kingdom [38]), Morocco is set to increase the scale of its RE production and trade in the coming decades. This has the potential to bring job creation and increased development.

However, Morocco is also susceptible to many resource curse symptoms. For instance, to construct RE infrastructure, Morocco may take loans from international organisations like the Arab Fund for Economic and Social Development and the European Investment Bank, as it has done previously (e.g. [39,40]), risking economic dependence. Similarly, Morocco currently relies on external technology for solar panels and wind turbines, as well as on external engineers to install and maintain these assets. This reliance is already evident in the contracting of a company from the United Arab Emirates to maintain its Noor I CSP plant and various Spanish companies for the project's engineering, procurement, and construction [41]. While land availability is not a strong constraint in Morocco, RE developments could exacerbate existing pressure on water resources. Water scarcity has long created developmental and environmental challenges [42], and RE projects require large amounts of water for cooling (e.g. 1,663,796 m^3 per year for Noor I CSP station or 3.5 m^3 per MWh [43]). Tensions could arise over diversion of water from agriculture, especially since agriculture employs about 33% of Morocco's workforce [44] and makes up a substantial share of local food supply and exports. Furthermore, Morocco claims ownership of a territory known either as Southern Morocco or Western Sahara; the construction of RE infrastructure there could heighten tensions in this already disputed region. The extraction of RE could lead to legal and political conflicts similar to those over the exploitation of fish or phosphate resources in the area. There

Table 1
Resource curse symptoms studied in the Moroccan context and their relevance to renewable energy.
Source: Adapted from [11].

Resource curse symptom	Relevance to RE development in Morocco
Damage to local flora, fauna, and landscape	Possible habitat damage from transmission lines, RE farms; strain on scarce resources (e.g. water to wash photovoltaics (PV)); reduced natural capital can harm other industries (e.g. ecotourism, agriculture).
Diversion of investments away from human capital	Investment in social programmes could be neglected if RE revenues from exports skyrocket despite limited human development.
Diversion of land	RE could become more profitable than farming, becoming a new "cash-crop" and reducing food yields and food security.
Diversion of talent from other sectors	RE jobs already pay above average, and this could increase to a point where other sectors become drained of talent – internal "brain drain" within Morocco.
Economic dependence	Loans from other countries or international organisations to facilitate RE infrastructure development could create dependence or outsized influence.
Expatriates dominating high-income/skilled jobs	If relevant training for all aspects of RE production are not available in country, expatriates may dominate the best jobs (e.g. management, technical roles).
Heightening of tensions and conflicts	Violent crime could increase in RE boom-towns. Theft of RE equipment possible. Conflict could arise over land with high RE potential. RE revenues and developments could exacerbate existing civil/political conflicts in Western Sahara/South of Morocco. Moroccan aggression may be difficult to discourage if other countries are energy-dependent on them.
Income inequality	Those who own RE resources/assets may reap high benefits without corresponding changes to worker wages, exacerbating income inequality in Morocco.
Income volatility and trade imbalance	Electricity prices fluctuate; countries like Morocco with high RE resources could have volatile income and unstable social programmes.
Land grabs	RE developments are often built in poorer rural areas where land is plentiful/cheap. Rural Moroccan residents residents may be susceptible to unfair agreements.
Loss of competitiveness of other export sectors	The export of RE could lead to trade imbalance and currency appreciation, making other local industries suffer.
Reduced economic diversity	A focus on RE could be made at the expense of other sectors. However, RE can also be used to power other sectors.
Technological or expertise dependence	Importing specialised RE technology (e.g. as with CSP in the past) or expertise can render Morocco dependent on the provider.
Weakening of institutions	High RE revenues could render the government less accountable to the will of its people and encourage corruption.

are debates over whether European Union investments with Morocco should include this region [45,46].

While similar risks can apply to many LMICs with high RE potentials, Morocco is selected as a case study where substantial RE development for export is planned in the near term. A risk assessment is therefore timely and useful. Its geographic, political, and economic specificities place it at risk of various resource curse symptoms while also offering substantial potential benefits.

3. Methodology

Using the RE-based resource curse risk assessment framework proposed in [11], 14 negative potential social or economic impacts of the resource curse are identified, termed "symptoms" relevant to RE in Morocco. These are listed in Table 1.

The following alterations are made from the original framework in [11] to suit this case study context. External conflict, internal conflict, and crime are studied as one symptom ("Heightening of tensions or conflicts") based on similar traits and ambiguity over the definitions of external and internal conflict in Morocco (i.e. based on the definition of the South of Morocco/Western Sahara). Gender inequality is omitted in this study as Morocco is 121st of 189 countries in the United Nations' gender inequality index [47]; gender inequality is pervasive in Morocco, and it is hard to disentangle the influence of RE on this. Additionally, material dependence is omitted. Material dependence, as defined in the original framework, refers to the dependence on other countries for raw inputs and mining of critical minerals for RE technology manufacturing [11]. Using this definition, it is therefore important for countries that produce RE technologies, and not those that purchase and import them, such as Morocco. So, it is excluded here. However, if Morocco escalates its manufacturing capabilities in RE technologies, it would need to be added to this risk assessment.

To explore which of these resource curse symptoms are likely to be particularly high-risk, surveys and semi-structured interviews (SSIs) were undertaken with key informants with work experience in RE in Morocco. A total of 21 key informants took part in the survey, while 10 participated in the SSIs. Note that not all survey respondents answered all questions. Participant sampling was initially driven by a group of known RE experts in Morocco, representing research institutions, government, and industry. This was followed by snowball sampling (i.e. participants were asked to introduce other practitioners with expertise relevant to RE in Morocco). Potential interviewees were then approached both from organisations that had been highlighted as relevant by previously interviewed experts, and from organisation types that were thus far underrepresented in our interviewee sample,

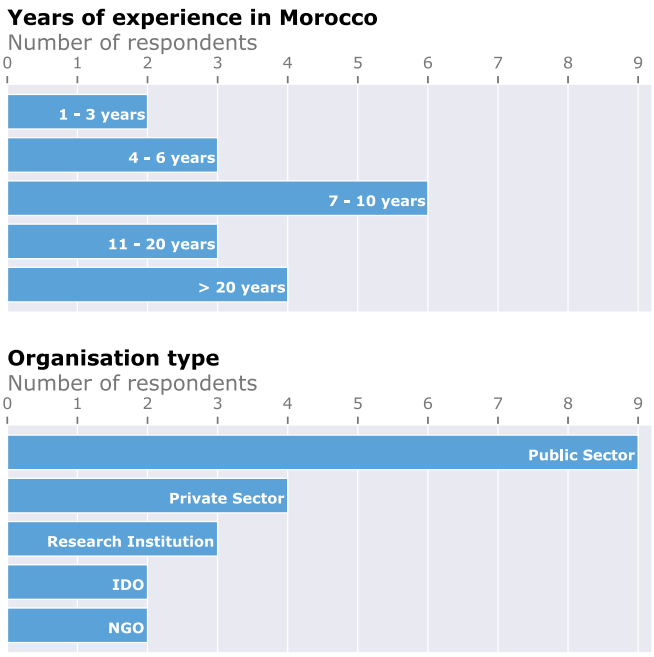

Fig. 1. Work experience levels and occupations of 21 key informants who participated in the survey. Note that not all replied to all questions so the number of responses to these two questions does not add up to 21.

so that the total sample would represent a wide array of perspectives relevant to our study. Survey participants consisted primarily of middle or senior managers with strong work experience in RE in Morocco — details on work experience and organisation type are given in Fig. 1. Following surveys and SSIs, complex system representations were used to summarise findings and identify key policy intervention points to prevent negative resource curse impacts.

To ensure the study's integrity, a risk and ethics assessment following the Medical Sciences Interdivisional Research Ethics Committee at the University of Oxford in accordance with the procedures laid down by the university for ethical approval for all research involving human participants was completed and approved with reference: R78832/RE001. To protect the participants' identity, all data were anonymised.

3.1. Survey

The survey assessed the risk of resource curse symptoms in terms of likelihood of occurrence and potential level of impact. It required participants to first rate the likelihood of each symptom on a 5-point Likert scale, and then to rank the potential impact of all symptoms from highest to lowest. Respondents could also comment qualitatively on their numerical answers to provide more nuance. Background information was also collected on the respondent's sector and their years of energy-related work experience in Morocco to facilitate the sampling which ensured diversity. The survey was available in both French and English.

3.2. Semi-structured interviews

The purpose of the SSIs was to analyse the aspects of each potential symptom which influenced their likelihood and impact. They also aimed to identify features specific to the Moroccan context which made symptoms more or less salient. Existing policies which could help to mitigate negative impacts associated with these symptoms were also discussed. The following general guiding questions were used:

1. Which three resource curse symptoms do you feel are the most important for Morocco, should Morocco greatly increase RE production and international RE trade, and why? Note that by important, we mean high probability of occurring and high impact if it occurs.
2. What policies or practices are already in place in Morocco that try to tackle the three selected resource curse symptoms, or others?
3. What features of the Moroccan context, if any, could affect the applicability of policies to mitigate the resource curse symptoms in Morocco?

Interviews were conducted in French or English according to the preference of each interviewee. Those conducted in French were translated into English for analysis.

3.3. Data analysis

To assess the relative risk of each resource curse symptom, a risk matrix was drawn using survey results. Risk was assessed in terms of estimated likelihood of occurrence and level of impact. The mean likelihood score and impact ranking for each risk were re-scaled to a relative value between 0 and 1 corresponding to minimum and maximum likelihood and impact respectively. Coordinates for each risk were obtained as follows.

- **Impact x-coordinate**. Respondents were asked to rank the 14 resource curse symptoms in order of increasing impact in case of occurrence. Using individual rankings $r_{i,j}$ corresponding to risk $i \in \{1..14\}$ and respondent $j \in \{1..n\}$, a mean ranking score was obtained for each risk as:

$$\bar{r}_i = \frac{\sum_j r_{i,j}}{n} \tag{1}$$

The minimum and maximum individual ranking scores are $r_{\min} = \min_i \bar{r}_i$ and $r_{\max} = \max_i \bar{r}_i$. A relative ranking score x_i was then obtained for each risk, such that risks ranked highest in terms of impact (i.e. with lowest numerical average risk ranking), have values closest to 1:

$$x_i = \frac{r_{\max} - \bar{r}_i}{r_{\max} - r_{\min}} \tag{2}$$

- **Likelihood y-coordinate**. For each risk i, respondent j was asked to provide a likelihood score $l_{i,j}$ on a 5-point Likert scale, from very unlikely (1) to very likely (5). A mean likelihood score was obtained for each risk as $\bar{l}_i = \frac{\sum_j l_{i,j}}{n}$. The minimum and maximum individual likelihood scores are $l_{\min} = \min_i \bar{l}_i$ and $l_{\max} = \max_i \bar{l}_i$. A relative likelihood score y_i was then obtained for each risk, such that risks with highest average likelihood scores have values closest to 1:

$$y_i = \frac{\bar{l}_i - l_{\min}}{l_{\max} - l_{\min}} \tag{3}$$

SSI results were then analysed to contextualise survey results, better understand existing policies, and assess potential policy options. Anonymous excerpts from these are inserted to support assertions in the text, labelled with I1, I2, I3 ... I10.

3.4. Complex system representation

Survey and SSI results were interpreted through complex system representations to identify policy intervention points. Complex systems involve multiple components that can interact with each other in bi-directional and non-linear ways, possibly leading to non-trivial

feedback loops and emergent effects [48]. This is in contrast to a regression model that assumes a single-directional cause–effect relationship between two variables, and which is traditionally used to model the resource curse [49]. The complex system approach views the resource curse as the emergent property of a complex system of symptoms, stakeholders, institutions, and policy mechanisms. System diagrams are constructed for the highest-risk resource curse symptoms, as identified through surveys, and influence points and feedback loops are mapped based on insights gained from SSIs.

3.5. Research limitations

This work has a number of limitations:

- **Sample size**: The sample size (i.e. 21 survey respondents and 10 SSI participants) is insufficient for statistical analysis. The findings are therefore non-conclusive, and this research has sought to identify trends qualitatively to analyse sector dynamics. Nevertheless, there was strong consensus around the most relevant symptoms in quantitative responses.
- **Translation**: Some quotes were translated from French. While some language subtleties might have been lost in translation, the authors are confident that the key messages could be communicated with the help of native speakers from both languages in the research team.
- **Transferability and geographic specificity**: The resource curse symptoms studied here and subsequent policy results may have limited transfer beyond the Moroccan context. The symptoms may need to be refined or expanded for individual contexts based on region-specific factors such as resource potentials, economic factors, and politics. For instance, Morocco's geographic proximity to Europe, relatively strong existing electricity system, and enthusiasm for RE (as discussed in Section 2) are likely to enhance the viability of RE export relative to other resource-rich LMICs (e.g. in sub-Saharan Africa). Even within Morocco, the prevalence of different risks may vary from project to project and location to location. As such, this work could be complemented by similar analysis in other countries, and more geographically disaggregated analysis within each country.
- **Stakeholder representation**: Interviewees for this study may not represent all stakeholders relevant to decision-making in RE projects. For example, in the SSIs the highest share of participants was part of the academic sector. This was partially due to the lack of response of stakeholders from the first list of actors contacted, which was then exacerbated by the use of snowball sampling. Future work may revisit the established roster of interviewed professionals to diversify the data collected.
- **Scope of effects studied**: By definition, studying the resource curse requires studying negative effects. However, there are certainly also positive effects of RE developments. While these are out of scope in this study, future work could re-analyse the collected data or collect new data to contrast the risks discussed here with the potential benefits.

4. Results

From the analysis of the survey data presented in Fig. 2, three high-risk resource curse symptoms clearly emerge with the highest likelihood and impact consensus:

1. Economic dependence.
2. Technological or expertise dependence.
3. Damage to flora, fauna, and landscape.

While the risk of other symptoms cannot be outright discarded, respondents did not evaluate them to be as important in Morocco. The development of RE was even deemed to reduce the likelihood and impact of some of those symptoms, as others have anticipated [50]. For instance, I4 discussed various symptoms which could be minimised through RE development, including "Dutch disease", the risk of reduced economic diversity, and the potential for diversion of talents from other sectors to RE:

> "We are hungry for growth and development. [...] [The Dutch Disease] would be a nice problem to have. Morocco has development priorities for its citizens, food security, health, education, which necessitate reinforcing high-potential sectors for production and exports in our economy. This will keep us busy at least in the two coming decades. We can then look into the "Dutch disease". [...] Those large projects in RE will allow Morocco, quite on the contrary, to keep diversifying the country's economy. [...] The rate of unemployment is still high in Morocco, so we could still train human capital towards the industrial needs of the country."

Similarly, I10 discussed the symptom of job market domination by expatriates in terms of its potential benefits:

> "It's a possibility to have more expats but I don't take it as a risk. It is a transfer of competence."

Given this, this work focuses on the top three symptoms identified to analyse how to prevent and mitigate their anticipated negative effects.

4.1. Economic dependence

The highest risk resource curse symptom identified by survey respondents was economic dependence on other countries or international organisations. Most Moroccan RE projects are co-funded by the government and international organisations or banks in arrangements facilitated by MASEN [51], such as two recent loans worth $237 million from the Arab Fund for Economic and Social Development [39]. As RE is likely to be a large source of income and job creation, the welfare of Morocco's people may also rely on these investments. Furthermore, some see these economic arrangements as putting Morocco at risk of the misappropriation of state finances, as this quote from I3 indicates:

> "Renewable energy projects in Morocco are partially financed by international banks, partially financed by the Moroccan state. There is a risk of misappropriation of Moroccan state finances. Funding for infrastructure, social projects, and health could be diverted. But these risks have been evaluated by the government. However, it is not certain and things might change in the future."

Some informants framed this economic dependence as a matter of fairness. They saw external economic support as necessary, particularly to support large-scale projects which will largely benefit HICs aiming to lower emissions targets. As I4 states:

> "The urgency or the need for green hydrogen or green molecules is expressed by advanced countries which have already polluted the environment, and because of their progress we have reached those levels of greenhouse gas. [...] We don't need to pay for that as a poor country. Morocco shouldn't pay for this."

However, given the stiff competition for RE investments, with so many countries and projects vying for funding, there is a heightened power imbalance between investors and countries like Morocco. This creates the risk of being subject to influence as a result of economic dependence, as alluded to by I5:

> "When you are not a superpower, you cannot claim that national policy is not influenced by foreign policy."

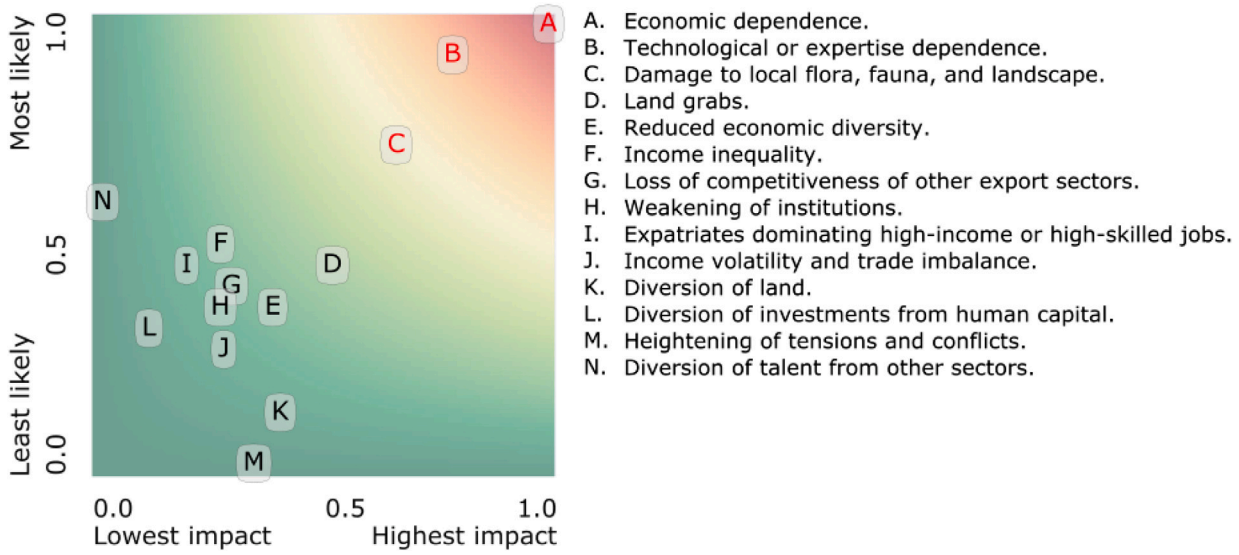

Fig. 2. Risk analysis for RE-related resource curse symptoms in Morocco. Symptoms in the top right corner have the highest likelihood and potential impact. The *x*- and *y*-axes denote a score relative to other risks, as evaluated by the Moroccan energy sector practitioners presented in Fig. 1. Zero represents the least likely or least impactful and one represents the most likely or most impactful symptom. In red are the three symptoms with the highest likelihood and impact consensus.

I7 communicated similar concerns regarding cooperative projects with European companies in RE:

> "We have a lot of European countries interested in developing renewable energy . . . we're getting countries like Norway, Switzerland who don't want to sacrifice the competitiveness of their industrials; they're coming to Morocco to purchase cheap carbon credits . . . They're win-wins, but they're still influential at an international level. They're trying to push us in certain directions."

One particular circumstance where economic dependence may hold greater influence on Morocco is with regards to the South of Morocco/Western Sahara. Some funders are unwilling to finance RE projects in this region, as indicated by I4 in the following quote.

> "We believe that the South of Morocco belongs to Morocco. Some of the IFIs are not okay with funding projects that are in that part of Morocco."

Reluctance of international financial institutions (IFIs) to fund projects in this region may influence Moroccan decision-making around development there. This shows an interconnection between the symptoms of economic dependence and heightening of tensions and conflicts.

This interplay between economic dependence and conflict was discussed with varying degrees of concern by stakeholders. Although IFIs may be reluctant to fund projects in the South, many interviewees did not see this as a significant problem, as shown in the following quote from I5:

> "Most of the Moroccans, they don't go a lot to the South. It is very far. [...] They don't have a lot of information about what's going on there. [...] Most of the projects that are there are governmental projects, or projects that are part of collaborations or partnerships with other countries. [...] This is part of the Moroccan diplomacy. [...] We already know that we control these regions for over 40 years, especially economically and in terms of media. I think it's very unlikely to have problems there."

While foreign capital has the potential to interfere with Moroccan autonomy, there is a deeper appreciation of neocolonialist risks. Combined with increased transparency and accountability, Moroccan NGOs [52], for instance, have been able to maintain their autonomy by choosing their funders. Informants share similar sentiments about Moroccan RE development, as expressed by I2:

> "There is no longer capital rule as in oil countries (in the 20th century), when if you brought significant foreign investment you could do what you want. There is a spirit of the 21st century. In Morocco, it is no longer possible for capital to arrive and dominate; we no longer accept this."

Thus, while there is certainly risk of economic dependence in Morocco based on RE development, there is an optimism and will for it to not materialise. Policy can be crafted to support this. Indeed, informants also communicated that RE developments can help to reduce existing economic dependence, as I10 indicates:

> "Morocco, it knows that it is 90% dependent on energy imports, so it is a risk. But on the contrary, the development of renewable energy can reduce this dependence."

4.2. Technological or expertise dependence

The resource curse symptom identified as having the second-to-highest risk level is technological or expertise dependence. RE development can provoke increased technical dependence on other countries. While Morocco has significant capacity for RE research and community enthusiasm for RE developments [35], it has less capacity for technology manufacturing [53]. This has led to some dependence on external companies which manufacture RE technologies for the country, as highlighted by I1:

> "The government had policies for industrial integration, but they have failed to live up to expectations. There was supposed to be a transfer of technology between external companies and Moroccan companies. However, large international companies were brought in to build solar power plants almost as if it was a transaction. Moroccan companies did not really learn deep technological skills. Local companies were able to learn and perform less specialised and technical jobs, or 'supporting' jobs. However, there is no single Moroccan company that is doing specialised solar stuff such as research and development or manufacture."

This issue relates to the symptom of expatriate job domination. While some see expatriates as transferring skills, others do not see any meaningful capacity transfer, entrenching technological and expertise dependence. A desire for more capability transfer was, for instance, expressed by I9:

> "Instead of having expats to work, they should come and train our local employees. Maybe if there is a policy in this direction, then it will be more effective."

Some stakeholders also highlighted the interplay between technological and economic dependence, in that funders dictate which type of technology must be used, and from where, as mentioned by I5:

> "We are dependent right now for some technologies – CSPs produced in Europe. For the World Bank, one of the conditions to give you the loan is to avoid PV as this is produced in China."

Informant I8 highlighted a similar concern regarding the choice of CSP technology being influenced by external countries, leading to dependence on a technology which may not best fit the Moroccan context and possibly causing environmental concerns:

> "Morocco has ties to Germany [...] back when Morocco started to gear into renewable energies, the decision to go with CSP was influenced by Germany. The choice was not rationalised in the sense that Morocco already had wind power that was producing energy at a reasonable cost [...] What turned out was that CSP was more costly and took up more space and used up water in a country with water scarcity."

Technological dependence has historically been an issue for LMICs [54] and continues to present a risk for many, including Morocco. Similar dependency risks can be seen, for instance, in Chinese nuclear technology in Pakistan [55] and infrastructural developments throughout the African continent [56]. For Morocco, the development of in-country RE technology manufacturing capacity can turn this risk into a sustainable economic development opportunity. This may also require improvements to other sectors, such as education, as highlighted by I8:

> "We don't have the expertise and the technology. Technology and industrial integration remains limited, even though it is increasing. We have real problems in research and the education system in Morocco, and in the integration between research and the business world. We are trying to change this situation, but it will not be done in one year."

4.3. Damage to local flora, fauna, and landscape

While the deserts often used for wind and solar development in Morocco are commonly seen as unproductive land ideal to exploit for RE production [57], they are a valuable part of the natural world. Scarce water resources can also be contaminated or depleted through RE infrastructure developments which require cooling or washing. Furthermore, Morocco is home to nomadic pastoralist cultures, whose traditional land-based knowledge [58] could be threatened by RE development.

Exploitation of the environment has already been observed in Moroccan mining [59]. Similar exploitation could replicate in RE generation or transmission. However, Morocco does have strong environmental protection practices for RE development, as I2 described:

> "Zero risk doesn't exist, there will be an impact [on the ecosystem]. However, we do not work blindly. [...] The desert is not entirely deserted."

Environmental impact assessments are usually required for Moroccan RE projects (e.g. [60]). However, these are mandated through investors (e.g. Centres Regionaux d'Investissement or IFIs) rather than on a governmental level. This means that private projects without external investments may not undertake environmental impact assessments. Informants expressed frustration over a lack of centralised follow-up on these assessments at a governmental level, as discussed by I9:

> "If we talk to the company, their efforts will always be aimed at maintaining the project. [...] But there is no follow-up from the government. There is no parallelism between the two. [...] What I really wanted was for the state to introduce regulations. The banks demand actions for the environment but at the same time there is no such support from the government. [...] A follow-up report on these requirements is only sent for 5 years. After that, there is no follow-up."

Morocco has strong policies on water use, from law 10-95 [61] to the National Water Plan [62]. Nevertheless, these policies could still be strengthened, and additional focus could be placed on enforcement. Informant I4 highlighted that there can be win-win situations by designing RE developments that account for water scarcity and using these to ensure water supply to local populations:

> "Water makes living creatures live, but also makes industry live. In Morocco, we have water scarcity in some regions. [...] Those are also the best locations for these [green hydrogen] plants. In this case, the mitigation is desalination. [...] The ocean is really very convenient for this. [...] We can oversize the desalination capacity to provide water for local communities."

While large swathes of non-agricultural land are available for RE development, increased hostility from local populations towards large-scale projects may limit land availability and lead to increased environmental pressures. Informants shared instances of land exploitation with limited economic development for local populations, poor communication, and temporary local hiring that resulted in degradation of farmland, which had been abandoned in favour of short-term high-paying work. Such instances increase resistance to RE projects and make it more difficult to acquire land for development in areas which can cause the least impact to flora and fauna. This highlights an interconnection between the resource curse issues of conflict, environmental damage, land grabbing, and low economic development. It was mentioned by I6, I7, and I9 respectively:

> "It becomes difficult to mobilise land. When they mobilise land, the population has to sell it cheaply. They are made promises of job creation, which did not materialise."

> "What mainly affects the rural areas, especially for Ouarzazate, it's built in quite a poor region and suddenly you get this huge investment and need for labour. Suddenly people left their farming and artisan activities to work for this project. It paid well, but it was temporary [...] Only a skeleton crew was left after launch. [...] People had to go back and re-till their land."

> "There are lands that have been exploited [...] but there are no parallel projects that maintain the economy of the population. That you will find not only in the South but also in the North. In the West, there was an obstacle of the citizens who lived there [...] [there is] exploitation of our land, but no projects to develop the economy. [...] [In the South,] there are existing political tensions, but above all there are political tensions that are created by the lack of economic development for communities associated with the projects. Why does it create these tensions in the South? Because there is no job creation."

There seems to be a genuine desire to maintain the environment for the benefit of people, flora, and fauna while also acknowledging that these developments cannot happen without some environmental impact, as again indicated by I4:

> "We do care about our environment. It is the only asset we have for this kind of business model."

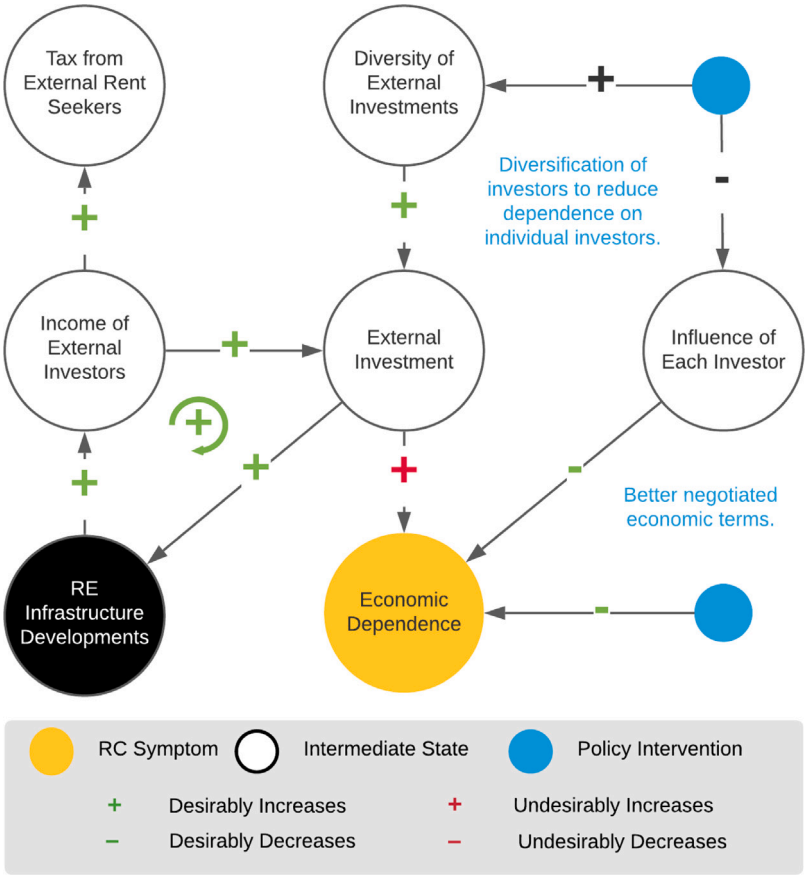

Fig. 3. Complex system representation of the economic dependence resource curse risk based on RE development in Morocco. The black circle represents the underlying premise of RE infrastructure development.

5. Discussion and complex system representations

The highest-risk resource curse symptoms are discussed and contextualised as complex systems to identify possible intervention points. These are often hard to spot, as I5 highlighted:

> "At each level, you have a way of doing things. And sometimes, this way of doing things can create tensions with different levels of the supply chain. [...] Sure you could make changes, but at which level?"

A system diagram is presented for each symptom illustrating the variables and relationships that describe it. This enables the identification of policy intervention points and objectives to minimise risks. It can also help to visualise their potential effectiveness in a broader context. Where possible, policy objectives are selected such that they turn risks into sustainable development opportunities. Finally, the nature of risk in RE development and the purpose of RE development within LMICs is discussed.

5.1. System of economic dependence

Fig. 3 shows the system of economic dependence. External investments in RE increase infrastructure developments, which produce income for external investors. This income attracts more external investments and the cycle repeats, forming a desirable positive feedback loop that increases RE development. The income from external rent-seekers also generates taxes which can be used for social development projects. However, external investments (i.e. loans, projects owned by foreign companies) make the host country economically dependent to sustain the desirable RE development feedback loop. This gives foreign entities influence over the host country.

One policy strategy to address economic dependence could be to negotiate better economic terms in co-funding agreements that better reflect Moroccan needs and preserve autonomy. Another strategy could be to diversify investors, increasing both the number of investors and possibly the total investment. By having multiple sources of foreign investment, the influence of each investor is reduced, minimising dependence and threats to autonomy. This may also attract external investments that would otherwise not be available (i.e. by attracting multiple smaller investments instead of fewer larger ones), increasing financial flows and boosting the desirable positive feedback loop that develops RE infrastructure.

5.2. System of technological dependence

Fig. 4 shows the system of technological and expertise dependence. The development of RE infrastructure generates income for asset owners; this promotes investment in more RE development. These two flows create a desirable positive feedback loop. The income of asset owners also generates taxes that can be used for social development. However, the development of RE infrastructure increases the requirements for RE expert labour and technologies. These are met by the import of foreign experts and RE technologies, making this revenue stream dependent on the countries from which they are imported.

The intuitive policy to minimise this dependence would be to force the use of local content (e.g. local labour and goods), or equivalently to restrict the import of foreign content (i.e. protectionism) for RE

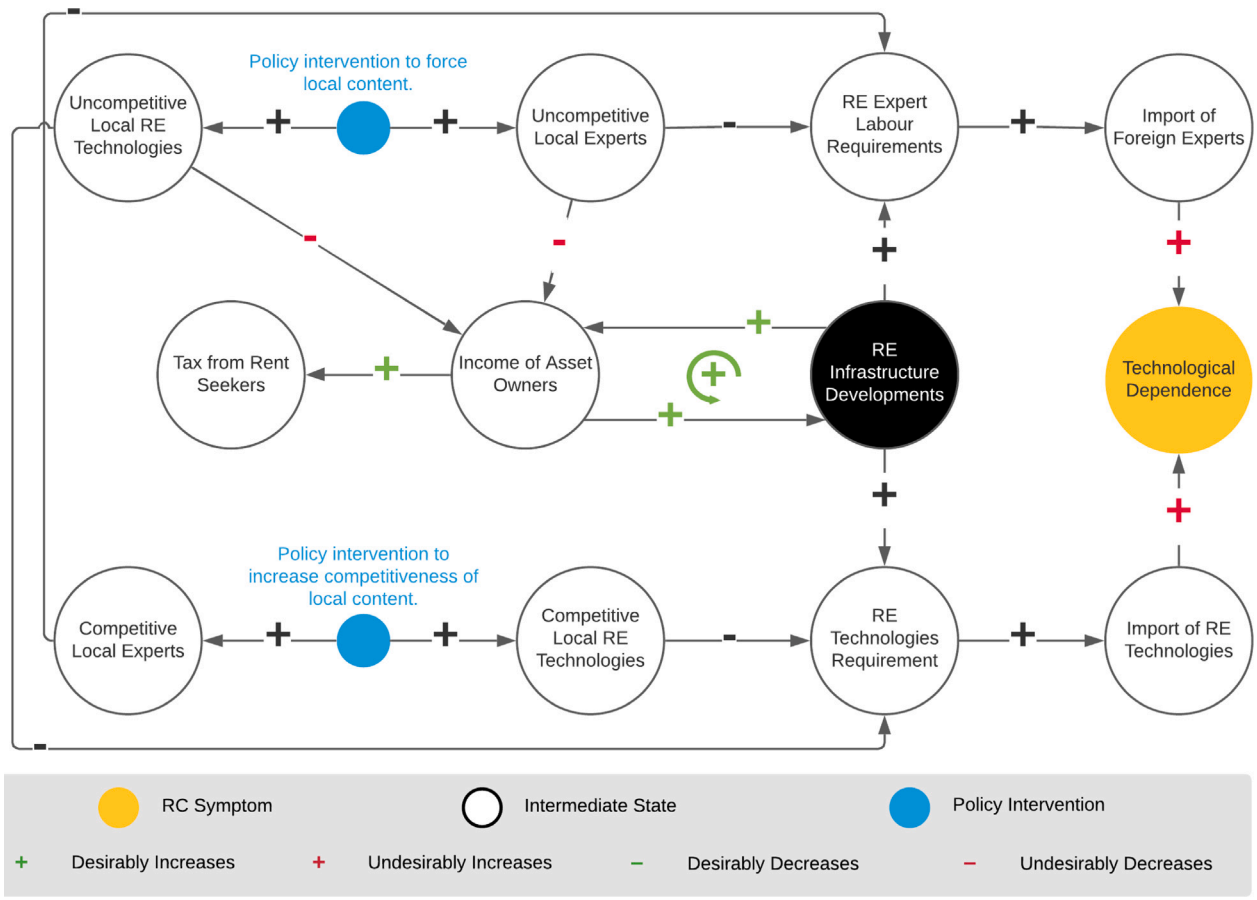

Fig. 4. Complex system representation of the technological dependence resource curse risk based on RE development in Morocco. The black circle represents the underlying premise of RE infrastructure development. Blue circles represent two similar local content policies and their impact on the whole system. Policy interventions to force the use of local content (protectionism) leads to a loss of income from RE projects and thus hamper the development of RE infrastructure. Policy intervention to increase the competitiveness of local content (investments) mitigates the technological dependence without negatively impacting the competitiveness of RE projects.

development. This would require hiring local RE experts and producing RE technologies locally, even if they are not competitive with external alternatives. While this would, in the short term, reduce imports and resulting dependence, the use of non-competitive local labour and goods could increase the cost of RE projects in the long term, reducing the income of asset owners and eventually hindering the development of RE by decreasing the desirable positive feedback loop. It could also reduce the tax from rent-seekers (RE asset owners) and the potential social benefits from these taxes. This protectionism may convert the technological dependence to an economic dependence, as the country may need to take up foreign loans to make up for the loss of investments into RE development via taxes and the positive feedback loop.

Local content policies have had mixed results in other resource sectors [63]. While it has been argued that such policies could benefit LMICs (e.g. through "petro-development" in sub-Saharan Africa [64, 65]), others argue that such requirements compound local problems and actually hurt the global economy through their protectionism [66]. In the Moroccan context, uncertainty about local content policies was discussed by several interviewees, including I8:

> "If you don't have the profiles and skills, you can't say 'buy from this Moroccan company or industry' when there is no company."

An alternative approach is to use public resources to train local RE experts and build infrastructure to produce RE technologies locally. This solves the symptom of technological dependence more sustainably in the long term. Investing in the competitiveness of local RE experts and technologies can make them more desirable than foreign imports, such that companies preferentially pick local content without compromising profits (or even while increasing profits, given the relatively lower labour costs of LMICs compared to imported labour from HICs). There are however risks to these investments; certain technologies may become obsolete by the time manufacturing infrastructure and talent pool are built. An example is Morocco's investment in CSP. Though Morocco has invested heavily in CSP, PV has become the dominant solar technology, leaving Morocco with expertise in a technology that is no longer competitive. The risks of various RE technologies must be considered when investing in them.

The difference between encouraging the use of local labour and content and investing in its competitiveness is subtle but important. Viewing the symptom of technological dependence as a complex system elucidates this difference and shows why the less direct or intuitive strategy in this case could be more effective in the long term with fewer negative side effects.

5.3. System of damage to flora, fauna and landscape

Fig. 5 shows the system of damage to flora, fauna and landscape. The symptom of land-use conflict is also included to illustrate how, in this case, multiple symptoms can be tackled using as a single policy. If left unchecked, rapid development of RE infrastructure could damage flora and fauna by disturbing habitats, degrading land, or wasting

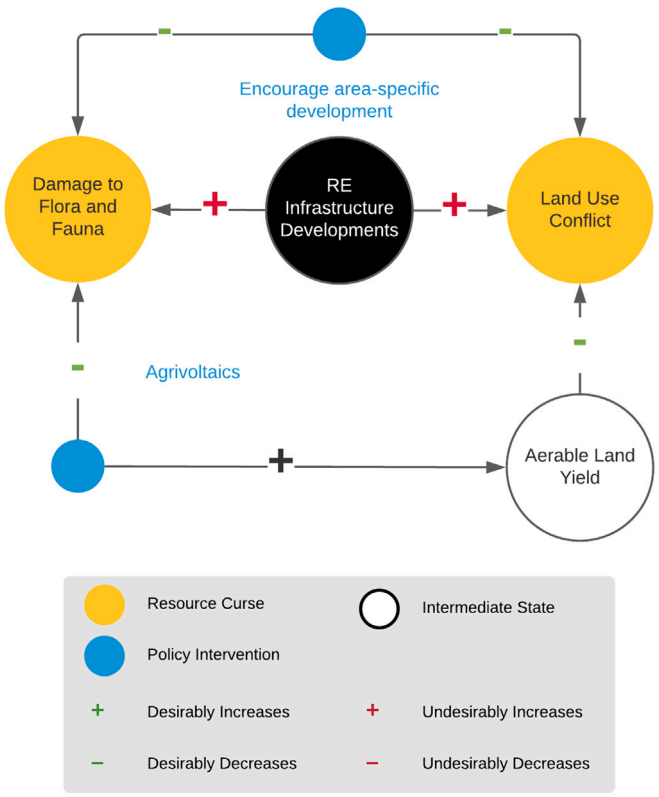

Fig. 5. Complex system representation of the risk of damage to flora and fauna based on RE development in Morocco. The black circle represents the underlying premise of RE infrastructure development.

scarce natural resources (e.g. water). Additionally, the income from RE production could encourage farmers to switch from production of food and other crops to the production of RE, creating a land-use conflict similar to that observed in "cash crops" [67]. This could affect food security and could cause unemployment if labour is not retrained or moved to other sectors. There is a unidirectional causal flow between RE infrastructure development and these two symptoms.

An intuitive policy, and the policy adopted by Morocco, is to limit the land that can be used for RE development. This is accomplished through environmental impact analysis and identifying/avoiding land used for crops. Morocco maps the regions which are allowed for RE development: these regions will have minimal damage to flora and fauna and are not arable (thus eliminating land-use conflicts with farming).

Another more innovative strategy currently under development would be to encourage the use of agrivoltaics. Agrivoltaics use solar panels placed on top of crops to create a symbiotic relationship, which increases the yield of both farms (i.e. solar and food) by shading the crops from direct sunlight and using this sunlight to generate energy. Furthermore, the crops underneath the panels transpire and cool the panels, improving their efficiency. This approach can provide benefits across all three elements of the food-water-energy nexus [68]. It can reduce damage to flora and fauna, increase arable land yield, and reduce land-use conflict. While early experimental results are promising [69,70], this technology is still in its infancy and is not applicable to all crops. However, it is an interesting example of a win-win intervention with multiple benefits that would help prevent this negative impact.

5.4. Risk in RE development and win-win policies

Some risk is necessary and unavoidable in any large infrastructure development. It is possible to simultaneously acknowledge that there is significant risk involved and that it is a significant opportunity. This was highlighted by I4:

> "You are right to point out, to be waving vigilance or red flags whenever we talk about using lots of land and natural resources for industrial purposes. [...] However, we see it as a way to make growth, sustainably, and make job creation. [...] Entropy is always positive. [...] We don't do anything without bothering the other."

Additionally, resource curse symptoms present both positive and negative risks. For instance, the risk of degradation to flora and fauna can result in negative impacts (e.g. habitat degradation) or positive impacts that address pre-existing issues (e.g. improved water access by oversizing desalination for PV farms). By identifying these risks and bringing them to light, policy steps can be taken which not only mitigate the problem but strengthen surrounding systems, creating positive ripple effects.

The question is therefore not how to avoid risk altogether, but how to prevent and mitigate negative impacts while capitalising on opportunities to strengthen adjacent systems. In RE development, risks can have big pay-offs in emission reductions, economic growth, and job creation which are often large enough to make these risks reasonable. However, this should not be assumed always to be true as the potential pay-of is context-dependent.

Equipped with an understanding of resource curse symptoms and risks, there is a huge opportunity to create win-win dynamics for Morocco and the international community. Morocco's RE track record and environmental safeguards create a context conducive to positive outcomes for RE development. This is highlighted regarding the economics of hydrogen by I4:

> "We believe that we have the time or the opportunity as a developing country to get into a deep win-win situation with technology developers in the whole world to engage in a partnership with Morocco, not with a charity perspective but a pragmatic perspective to reduce costs."

These positive outcomes are amplified when RE development is understood as a means, not an end, towards social development and economic growth. RE development, if seen itself as a goal to be maximised, can be accomplished in socially detrimental ways, prompting a resource curse. However, when understood as a means towards goals such as energy security and carbon reduction, policy safeguards can be implemented to encourage positive outcomes.

6. Conclusions and policy recommendations

This study has evaluated the likelihood of a resource curse occurring based on large-scale renewable energy (RE) development in Morocco, particularly as it increasingly exports energy to high-income countries. Fourteen resource curse symptoms (i.e. negative social or economic impacts) were identified as potentially relevant to both RE and the Moroccan context. A survey was conducted with energy system stakeholders (21 respondents) in Morocco to determine which of these symptoms held the highest risk, defined as likelihood and potential impact. The three highest risk resource curse symptoms for RE development in Morocco are found to be (1) economic dependence, (2) technological or expertise dependence, and (3) damage to flora, fauna, and landscape. Ten follow-up semi-structured interviews were used to understand resource curse symptoms and risks in more depth and to gain a greater understanding of the policy options to mitigate these. The results were contextualised as complex system diagrams to identify policy intervention points.

Based on our results and analysis, current and future policy objectives of Morocco are examined. While the Moroccan national energy strategy has increased the reliability of energy and electricity supply and initiated the liberalisation of electricity markets [33], it has some

inadequacies and limits that now need to be addressed. For instance, initiatives such as the 13-09 law on the integration of privately generated RE in 2010 and the launch of the National Authority for Electricity Regulation in 2016 have had slow implementation — the National Authority for Electricity Regulation was still waiting for the nomination of a council to launch its work in 2020 [33]. Moreover, there have been limited benefits to Moroccan citizens as electricity prices have increased rather than decreased as set out. Furthermore, while the near-full rural electrification in Morocco is commendable [30], it did not achieve its targets for raising living standards and the creation of income-generating activities [33].

New policies and strategies can allow Morocco to reinforce its international climate leadership by building economically viable large-scale RE generation which benefits its population, strengthens its industry, and protects its environment. The risk of resource curse symptoms based on RE exploitation can be managed to minimise harm and maximise community benefit. To prevent and mitigate high-risk resource curse symptoms in Morocco, the following policy objective recommendations are made:

1. **Carefully negotiate robust co-funding agreements to safeguard Morocco's long-term growth and political autonomy.**
   Under Morocco's current strategy, expensive technological choices were made, such as investing in concentrated solar power (CSP), which is no longer competitive compared to PV and wind. Additionally, limited integration with and benefit to local industry was achieved in CSP development. Public companies such as the national office for electricity and water and MASEN run at a deficit, as their business model does not yield fair returns on their projects [33].
   Morocco can use its resources and geographical position to strengthen its negotiating position as a competitive provider of RE for European and West African countries. While funding contracts are often negotiated to ensure benefits to the local population in terms of education and employment on an individual project level, this should be made systematic. Morocco should employ strategies such as having multiple co-funders, ensuring those co-funders are politically neutral, and negotiating mutually beneficial terms to minimise the influence of any particular foreign entity in Morocco. Furthermore, robust funding agreements can help to ensure that only Moroccan state funds allocated to renewable energy are used, preventing any fund diversion from other portfolios and associated negative social impacts.
2. **Develop innovation capabilities for RE.**
   This will not only reduce Morocco's reliance on foreign entities for state-of-the-art RE technologies, but also generate high-value jobs in Morocco. For instance, improving capabilities in manufacturing and test-bedding could provide significant benefits. More broadly, building innovative capabilities in firms, universities, and other institutions can also allow Moroccan companies to grow independently.
   So far, Morocco's energy transition has been primarily managed by the state within large-scale projects such as the Noor Ouarzazate complex. While the liberalisation of electricity markets was initiated from 1994, and the 13-09 law could in theory open the market to private RE electricity generators, in practice many private investors still do not get authorisation to develop RE generation: governance, market, and conflicting interest hurdles adversely affect implementation [33]. Demand remains limited to high voltage networks, as national planning did not integrate the share of private generation capacity.
   A successful energy transition will require strong industrial integration throughout Morocco. Technological capacity-building should be a key component of each industrial project to build up local expertise. This could be formalised through contractual clauses for industrial integration. Partnerships with universities and research institutes as well as public and private companies, both national and international, may help to promote the manufacture of components (e.g. electrical wind turbine parts for which Morocco so far does not have capacity).
3. **Continue, strengthen, incentivise, and enforce environmental impact assessment for RE developments.**
   Solar and wind currently accounts for about 13% of Morocco's domestic electricity supply [71]. The Moroccan Agency for Sustainable Energy (MASEN) has implemented mandates have been successful in minimising environmental impact and land-use conflict due to RE in Morocco; other countries can learn from Morocco's success. However, RE production in Morocco could increase by orders of magnitude when it starts exporting RE more broadly. This will increase land scarcity and will create economic incentives to overlook current protections. Existing policies need be updated and strengthened as the pressures to exploit the environment increase. Particularly, environmental impact is currently only monitored by funding bodies over a limited period; this should be enforced in the long run by the government.

This work is limited by its sample size and ability to transfer beyond Morocco. However, it presents an interesting case study and qualitative results which can spark further work into the possibility of resource curse symptoms arising from RE development. As RE continues to grow, and LMICs develop larger scale RE for electricity export, resource curse risks require attention in order to be converted to development opportunities through robust policy interventions.

CRediT authorship contribution statement

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

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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