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Geothermal power generation and biodiversity: the business case for managing risk and creating opportunity

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ABSTRACT

There is increasing recognition from global financial institutions and governments of the potential biodiversity risks posed by geothermal energy developments. Inadequate plans to manage biodiversity have a high potential to result in major project delays, lenders withholding funds, stricter regulatory requirements, or community protests. We aim to provide an understanding of the likelihood of biodiversity impacts from geothermal power development, and from these findings, highlight: (i) how poor biodiversity management or lack of consideration of biodiversity issues can lead to obstacles and pitfalls during various phases of geothermal exploration and development, and (ii) the commercial benefits that proactive management of biodiversity can provide for businesses. Through a spatial overlap analysis, we determine the extent of overlap between sensitive biodiversity areas, and active geothermal sites, and potential areas where geothermal power can be harnessed. A high level of overlap was observed between areas of biodiversity importance and current and potential future geothermal power plant locations. This was further exemplified in a focal country case study of Kenya. 71% and 59% of existing geothermal power plants are in or within 10 km of protected areas and Key Biodiversity Areas respectively. Through a literature review and drawing on our experience in geothermal power and other industries (e.g., the Oil and Gas and mining sectors), we discuss the potential impacts to biodiversity that geothermal power developments may pose. We conclude that the biodiversity impacts of geothermal projects can be managed successfully, especially if supported by advance risk screening, application of the mitigation hierarchy and stakeholder engagement.

1. INTRODUCTION

With heightening concerns of the long-term environmental impacts of fossil fuel use, the development of the renewable energy industry has become a global priority (Schlesinger and Mitchell, 1987; UN DESA, 2017). Geothermal power is one such renewable energy resource that has attracted significant and continued investment with a forecasted growth of 28% power generation capacity (approx.. 4GW) between 2018 and 2023 (IEA, 2018). Much of this expansion is expected in the emerging economies of the world (Glenn and Matek, 2014), with the highest increases in Indonesia - due to its available geothermal resources and strong project pipeline in the construction phase, followed by Kenya, the Philippines, and Turkey - responsible for the remaining 30% of additions (IEA, 2018). Unsurprisingly, national geothermal energy targets for installed capacity or generation are high for these countries and are as follows: (i) Indonesia (12.6 GW added by 2025); (ii) Kenya (5 GW by 2030); (iii) the Philippines (1.5 GW added by 2010-2030); and (iv) Turkey (1 GW added by 2023) (REN21, 2019).

However, increases in renewable energy infrastructure can also be associated with negative impacts on habitats and species (e.g. Rehbein et al., 2020). Biodiversity loss and ecosystem collapse is acknowledged as a major global risk to the private sector (WEF, 2020). In recognition of this, both lending institutions and governments have been applying biodiversity standards more regularly and stringently as evidenced by their increasing uptake within financial safeguards and government (ten Kate and Crowe, 2014). Voluntary private sector policies on biodiversity risk are also becoming more common, such as the growth in 'No Net Loss/Net Positive Impact' or 'Zero deforestation' commitments (Addison and Bull, 2018; Donofrio et al., 2018; Rainey et al., 2014).

Various financial lending institutions such as the International Finance Corporation, KfW, and the Asian Development Bank are increasingly financing geothermal energy developments in emerging economies (Chelminski, 2018; Johnson and Ogeya, 2018), and recognising and scrutinizing the biodiversity risks associated with these projects (Watkins et al., 2015). Government environmental policies have also made increasing reference to biodiversity offsets as a desired or required tool (Bull and Strange, 2018). Consequently, failure to develop adequate plans to manage biodiversity has potentially severe consequences for geothermal projects such as major project delays, lenders withholding funds, stricter regulatory requirements, or community protests, all of which present a significant risk to businesses. There is therefore a need to better understand the potential risks and opportunities of geothermal development on biodiversity.

This paper aims to provide an understanding of: (i) the likelihood of biodiversity impacts from geothermal power development, (ii) how poor biodiversity management or lack of consideration of biodiversity issues can lead to obstacles and pitfalls during various phases of geothermal exploration and development, and (iii) the commercial benefits that proactive management of biodiversity can provide for businesses.

2. METHODOLOGY

Global spatial overlap analysis - We overlaid spatial datasets of current geothermal power generation activities, geothermal resource base for power generation and areas of biodiversity importance to illustrate the intersection of geothermal developments and areas identified as important for biodiversity conservation. We conducted two separate analysis using ESRI ArcGIS 10.7.1 (ESRI, 2019) to determine the overlap between: (i) existing geothermal power plants and areas of importance for biodiversity globally, (ii) areas suitable for geothermal power generation and areas of importance for biodiversity globally. For each analysis, we calculated the number, and percentage of plants that fall within these sensitive biodiversity areas.

The spatial datasets of geothermal power used for our analyses are described below:

1. The distribution of existing geothermal power plants worldwide (Uihlein, 2018a). This dataset provides a list of operational geothermal power plants as of 2017 based on a review of multiple global and national data sources (Uihlein, 2018b).

2. The distribution of suitable areas for geothermal power production and plant installation worldwide, i.e., “high probability zones” that have a 60% suitability score (Coro and Trumpy, 2020).

The spatial datasets of areas of importance to biodiversity are described below.

3. The distribution of protected areas (PAs) including national-level Protected Areas; World Heritage sites; Ramsar sites (IUCN & UNEP-WCMC, 2020), sites that have been formally designated for protecting species, ecosystems and associated ecosystem services and cultural values that they provide (Dudley, 2008).

4. The distribution of Key Biodiversity Areas (KBAs) (BirdLife International, 2020), sites contributing significantly to the global persistence of biodiversity, including Important Bird and Biodiversity Areas (IBAs) and Alliance for Zero Extinction sites (AZEs) (The KBA Partnership, 2018).

While these areas do not represent all biodiversity risk (for example, endangered species exist beyond the boundaries of these sites), they are a valid illustration of potential risks as they represent the highest priority biodiversity conservation sites, and provide globally comparable data. KBAs and PAs often overlap resulting in a degree of similarity in the results. The results cannot therefore be combined. Biodiversity risks do not only occur if a development takes place within a sensitive area. Risks can still be present if operating in the vicinity of a sensitive area, either because impacts may be far reaching, or because the biodiversity for which the sensitive area was designated is also present in the wider landscape. To give some indication of this wider risk, a 10-km buffer was created around each KBA and PA, and a similar overlap analysis undertaken on this expanded geothermal layer to account for the presence of existing geothermal plants within sensitive landscapes globally (defined by its proximity to KBAs or PAs). This analysis was not undertaken for areas suitable for geothermal power generation as the 50-km spatial resolution of the data (dataset no. 2) was deemed adequate to account for risks both within and in the vicinity of KBAs and PAs.

Focal country case study - We also conducted a focal country analysis using Kenya as an example to investigate possible future trends and risks. We analyzed the overlap between potential geothermal power generation resources and sensitive biodiversity areas in Kenya (datasets 3 and 4 above). Data on the distribution of areas of geothermal power generation resource potential in Kenya was obtained from ERC (2012).

We determined the number of protected areas and KBAs that intersect with prospective areas of geothermal power generation resource potential. In addition, we conducted a high-level review of publicly available information to illustrate the current and potential biodiversity impacts associated with existing and future geothermal developments in Kenya.

Literature review of biodiversity impacts - Finally, we carried out a literature review to understand what is currently understood about the potential impacts to biodiversity from geothermal power developments, what mitigation measures are considered leading practice, and what, if any, guidance exists to support responsible development of geothermal power.

3. RESULTS

3.1 Global analysis of existing and potential geothermal power generation activities and biodiversity

We mapped the active geothermal projects globally (N = 366) (see Figure 1). These geothermal projects were observed to be clustered in 28 countries, with nine countries having over 10 geothermal plants: (i) the USA (92); (ii) Turkey (49); (iii) Italy (36); (iv) Indonesia (30); (v) the Philippines (24); (vi) Japan (23); (vii) Kenya (22); (viii) New Zealand (14); and (ix) Iceland (10).

Figure 1: Global distribution of active geothermal projects (Source: Uihlein (2018a))

The global analysis of the extent of overlap between sensitive biodiversity areas and active geothermal projects identified 55 geothermal projects (15%) that are located within the boundaries of PAs. The inclusion of the 10-km buffer around the boundaries of protected areas, increased the number of overlapping projects to 260 (71%), i.e., 71% of existing geothermal projects are in, or close to, one or more protected areas. 79 projects (21%) were located within the boundaries of KBA sites, with 215 (59%) geothermal projects located, in or within 10 km of one or more KBAs. These results varied at the continent or country level (see Table 1). For example, there was a very high overlap of existing geothermal sites with PA and KBAs in Africa and Asia, compared to Europe and North America.

Table 1: Level of overlap between existing geothermal plants with Protected Areas (PAs) and Key Biodiversity Areas (KBAs) described at the global, continent and country level.

Region / Country	Number of Plants	% of total geothermal plants			
		within PA	within 10km of PA	within KBA	Within 10km of KBA
Africa	***23***	***70***	***96***	***70***	***96***
Ethiopia	1	0	0	0	100
Kenya	22	73	100	73	95
Asia	***83***	***25***	***78***	***31***	***80***
China	5	0	20	0	20
Indonesia	30	20	73	17	93
Japan	23	61	100	35	65
Philippines	24	0	75	54	88
Thailand	1	100	100	0	100
Europe	***121***	***8***	***55***	***5***	***67***
Austria	3	33	100	0.00	67
France	3	100	100	0	100
Germany	9	11	100	0	44
Hungary	1	0	100	0	0
Iceland	10	0	50	0	50
Italy	36	3	100	8	100
Portugal	4	75	100	0	100
Romania	1	0	100	0	100
Russia	5	20	60	40	40
Turkey	49	0	2	2	49
North America	***120***	***4***	***76***	***26***	***38***
Costa Rica	6	0	100	100	100

Region / Country	Number of Plants	% of total geothermal plants			
		within PA	within 10km of PA	within KBA	Within 10km of KBA
El Salvador	5	0	100	0	40
Guatemala	2	0	100	100	100
Honduras	1	0	0	0	0
Mexico	9	44	67	11	22
Nicaragua	6	0	100	0	50
United States	91	1	73	24	34
Oceania	***17***	***12***	***94***	***0***	***0***
Australia	2	50	50	0	0
New Zealand	14	0	100	0	0
Papua New Guinea	1	100	100	0	0
South America	***1***	***0***	***0***	***0***	***0***
Chile	1	0	0	0	0
Grand Total	***365***	***15***	***71***	***22***	***59***

The global analysis of the extent of overlap between areas suitable for geothermal power generation and sensitive biodiversity areas, identified 8401 PAs and 681 KBAs across 51 countries, that are potentially suitable for geothermal development. Of note, countries which are anticipated to have the biggest geothermal capacity additions over the coming years have the following number of KBAs and/or PAs with geothermal resource potential: (i) Indonesia – 63 KBAs and 65 PAs; (ii) Philippines – 30 KBAs and 70 PAs; and (iii) Turkey – 11 KBAs and 1 PAs.

3.2 Analysis of geothermal activities and biodiversity in Kenya

Installed geothermal capacity in Kenya was 676 MWe in 2018, with a predicted capacity of 1,037 MWe by 2020 (IGA and IRENA, 2018). As illustrated above, much of the installed capacity is within protected areas. The overlay of 23 potential geothermal prospect areas with PAs and KBAs showed that 12 prospect areas overlap one or more protected areas, and nine prospect areas overlap one or more KBAs. The Kenyan Energy Regulatory Commission lists 13 prospects which represent the most promising resources (ERC, 2012). Of these, four intersect one or more protected areas.

Significant levels of international finance have supported geothermal power development in Kenya. Over 1.8 billion dollars of development bank finance has been provided through to 2018 (Johnson and Ogeya 2018). More than 75% of this financing has come from institutions such as the World Bank, DEG/KfW or Overseas Private Investment Corporation (OPIC) with stringent environmental standards (KfW and OPIC both follow IFC Performance Standards).

As of 2020, the Olkaria and Eburru geothermal fields are the only areas utilized for its geothermal resources. Numerous other sites such as the Menengai 1 Project in the Menengai geothermal field, the Arus-Baringo-Silali Project in the Arus-Bogoria, Korosi, Chepchuk, Paka and Silali geothermal prospects, Suswa Geothermal Project in the Suswa geothermal prospect, Longonot project in the Longonot geothermal prospect, Akiira geothermal prospect and Barrier geothermal prospect, are currently in the early planning, exploration, or development phase. Publicly available documents reviewed focused largely on the biodiversity impacts of the Olkaria geothermal developments with limited to no discussion on the biodiversity impacts of other geothermal projects found.

Olkaria geothermal development and activity

The geothermal development and activity in the Olkaria geothermal field is represented by Olkaria I (commissioned between 1981 and 1985), Olkaria II (commissioned in 2003 and 2010) and Olkaria III (commissioned in 2000) plants which are active in Hell's Gate National Park (IGA and IRENA, 2018). The Park was established in 1984, after Olkaria I became operational, with the other developments installed after the park's creation. Olkaria IV (commissioned in 2014) was developed just outside the park (Mangi, 2018). Following a Strategic Environmental Assessment (SEA) for a geothermal expansion programme in Olkaria in 2014, further projects have been proposed within the park. Most recently, Olkaria V, which is situated within the park, was commissioned in mid-2019 (Richter, 2019).

Rapid geothermal development within and adjacent to the park is considered the biggest threat to the park's wildlife. In particular, concerns have been raised on the threat of the geothermal development on one of the only two known nesting sites in Kenya of the Critically Endangered Ruppell's Vulture (*Gyps rueppelli*). Biodiversity impacts are considered to be: (i) habitat loss, (ii) barriers to wildlife migration, (iii) collision with transmission lines, (iv) noise and light pollution, (v) induced wildlife and habitat loss caused by increased human activity, (vi) vehicular collisions, (vii) habitat degradation due to changes in water quality from brine run-off, (viii) hydrogen sulfide pollution and poisoning, and (ix) habitat degradation due to water extraction from Lake Navaisha, which is designated as a Ramsar site (BirdLife International, 2019; Wabua and Birgen, 2017). Only a single study on the biodiversity impacts of geothermal developments in the park was found which identified the reduction in bird species richness in disturbed areas affected by higher levels of hydrogen sulphide, noise pollution, habitat modification and vegetation clearance (Getonto, 2018).

Biodiversity conservation stakeholders have expressed concern through the media and written complaints over the expanding geothermal developments (Barasa, 2016), and inadequate biodiversity mitigation measures implemented within and adjacent the park, some examples being the failure to shut down Well 40 due to the risk of water overspill onto the vulture nesting site and flouting of 'no development' zones within the park (Rotich et al., 2014). This has resulted in project delays with one example being the delay in the ESIA report approval process for the Olkaria V power plant (Barasa, 2016).

3.3 Review of the biodiversity impacts and mitigation guidance for geothermal power developments

Published papers and project-specific documents that do discuss biodiversity impacts from geothermal developments mention land use changes and direct loss of habitat, changes to water quality and temperature impacts mainly to species from vertebrate groups (mammals, birds, reptiles, amphibians, and fish), and vascular plants. Other environmental impacts (e.g., noise, water, soil, and air pollution) occur which could also potentially impact biodiversity (Dhar et al., 2020; Bošnjaković et al., 2019; Meletiou et al., 2019; PT Geodipa Energi, 2019; PT SEML, 2017a; PT SEML, 2017b; PT SERD, 2017; De Jesus, 2016; Griebler et al., 2016; Shortall et al., 2015; IGA and IFC, 2013; Katzner et al., 2013; WWF Indonesia, 2013; Mutia, 2010a; Mutia, 2010b, IFC, 2007; Kagel et al., 2007; Tuyor et al., 2005). The impacts that potentially occur at the different stages of the geothermal development project were consolidated (Table 2). Indirect impacts of development were rarely mentioned in the documents reviewed.

Although many documents outlined mitigation measures of relevance to biodiversity, no specific guidance document was identified outlining how best to manage the biodiversity impacts of geothermal developments.

Table 3. Biodiversity impacts at different stages of geothermal development projects

Impact			Project Stage				
			Exploration & Assessment	Project Design	Execution, Construction & Commissioning	Operation	Reclamation, Closure & Decommissioning
Direct	Habitat loss & fragmentation	Direct habitat removal	√	√	√	√	√
		Direct habitat fragmentation caused by direct footprint and roads	√	√	√	√	√
		Specific impacts on geothermal ecosystems (e.g., specialist plants, thermophilic organisms)	√	√	√	√	√
	Habitat degradation	Changes in water temperature			√	√	
		Changes in water quality (e.g., from sediment run off)	√		√		
		Changes in water flow if water is extracted from natural water courses			√	√	
		Changes in water quality caused by effluent disposal (e.g., CO2, H2S, NH3, CH4, NaCl, B, As and Hg)			√	√	
		Changes in soil quality (e.g., compaction and contamination with emitted elements such as B, NH_3, H_2S, As and Hg)	√		√	√	
		Air pollutants (e.g., H2S, Mercury, trace heavy metals)			√	√	
		Edge effects	√		√	√	
		Invasive species transfer	√	√	√	√	√
	Wildlife mortality and/or population loss	Collisions with project vehicles			√	√	
		Collisions with transmission lines			√	√	
		Disturbance from increased noise and vibration during drilling, stream flashing and venting.	√		√	√	
		Disturbance from increased light levels during construction and operations	√		√	√	
Indirect	Habitat loss & fragmentation	Induced habitat loss caused by project	√	√	√	√	√

Impact			Project Stage				
			Exploration & Assessment	**Project Design**	**Execution, Construction & Commissioning**	**Operation**	**Reclamation, Closure & Decommissioning**
		related in migration and increased access.					
		Increased habitat fragmentation caused by induced habitat loss	√	√	√	√	√
	Wildlife Mortality and/or Population Loss.	Increased harvest/capture of, or collisions with fauna caused by project related in-migration and increased access.	√	√	√	√	√

*Direct impacts = impacts that occur to biodiversity as a direct consequence of the construction or operation of the geothermal plant. Indirect impacts = impacts that are induced by, or by-products of project activities (TBC, 2013).

4.DISCUSSION

Our analysis clearly show that a high percentage of existing geothermal power plants are operating in important areas for biodiversity. There are also overlaps between suitable areas of potential future geothermal power plant development and important areas for biodiversity which we identify at a global scale and exemplify in our case study on Kenya. National-level studies have been conducted which substantiates our findings. Meijaard et al. (2019) revealed that Indonesia's geothermal resource potential do overlap with sensitive areas for biodiversity such as national parks. This may be a result of protected areas in some countries being located in geothermally active areas which have typically not been suitable for other land uses. These areas have remained un-developed and retained biodiversity which is now missing elsewhere. On the densely populated Indonesian island of Java, for example, the few remaining fragments of natural forest are on volcanos which were too steep or volcanically active for farming (Whitten et al., 1996). These remnants are now of high biodiversity importance, being the last refuges of undisturbed and/or protected land for many species and habitats, but they now are also of interest for their geothermal potential.

Geothermal power generation is a low carbon source of power, and thus in some countries has the potential to play an important part in de-carbonizing power generation (IRENA, 2018; IRENA, 2017). Low carbon, however, does not necessarily mean 'environmentally friendly' as our results have shown. Our review identified potentially significant impacts to biodiversity (and ecosystem services, i.e., the benefits society receive from the environment) from geothermal power generation during all phases of the project cycle. Geothermal energy has potential impacts to biodiversity from direct loss, degradation, and fragmentation of habitat; land and water contamination from poor handling of toxic chemicals; withdrawal of water from waterbodies beyond their capacity; and indirect impacts from induced access along roads built during exploration and development (Mariita, 2002; Winden et al., 2014). These impacts may be even more significant considering a number of existing geothermal developments are located in, or adjacent, to areas of high biodiversity value as shown by our analysis. The number of plants in sensitive locationscould potentially increase as countries like Indonesia and Japan have large amounts of geothermal resources in protected forests or national parks (approximately 50 % and 80 % respectively) which can currently be legally accessible for exploration (IGA and IFC, 2013). Thus, inadequate consideration and management of geothermal development activities could lead to major adverse biodiversity impacts.

The intersection of geothermal potential and areas of high biodiversity potential highlights real financial and reputational risks to developers, investors, and regulators. Many sources of international finance, such as from the World Bank Group, regional development backs like the Asian Development Bank and Inter-American Development Bank, national development banks (e.g. KfW) and commercial banks (particularly those who are signatories to the Equator Principals, see https://equator-principles.com/members-reporting/), have strict biodiversity policies. Failure to meet these standards can jeopardize project finance. Additionally, impacts to biodiversity are of increasing concern not only to biodiversity conservation organizations, but also to the wider public. Managing impacts to biodiversity is an important aspect of maintaining a social license to operate. Such stakeholder concern can translate into costly delays. Over half of delays to oil and gas projects are attributed to non-technical issues, with social conflict over environmental resources being the single biggest factor (Franks et al., 2014). Conversely, rerouting a pipeline to minimize biodiversity impacts saved Shell Philippines Exploration an estimated US $50-72 million (Herz et al., 2007). A summary of the risk of poor biodiversity management are presented in Table 2.

Table 2. The business case for managing biodiversity risks, as defined by reputational and regulatory considerations, as well as dependencies to businesses

Risk	Issue	Risks from poor management
Reputation	Lenders, investors, customers, employees, local communities and other stakeholders have increasingly high expectations that business will follow good practice	Reduced access to finance, higher credit costs Damage to brand, divestment, share-price drops Products avoided by consumers and large-scale procurement Reduced ability to recruit & retain staff

Risk	Issue	Risks from poor management
		Stakeholder conflicts, project delays and extra costs Loss of 'social license to operate'
Dependency	Projects themselves may have significant dependence on ecosystem services	Scarcity and increased cost of resources, reduced productivity, disruption of operations and of supply chains Increased vulnerability to natural disasters
Regulation	Biodiversity considerations are increasingly built into both national regulatory frameworks and lender safeguards	Permitting delays, fines, litigation, expensive remedial interventions Restrictions on access to natural resources

Our review revealed that, compared to other sectors, relatively little guidance on managing biodiversity impact exists for the geothermal sector. For example, guidance on the biodiversity risk management in the oil and gas sector has been prepared by IPIECA (IPIECA, 2016) and for mining by the International Council on Mining and Metals (ICMM) (ICMM and IUCN, 2013). Additionally, the Cross-Sector Biodiversity Initiative (CSBI) has produced several guidance documents, much of which are of relevance to the geothermal power sector (CSBI, 2015; Hardner et al., 2015).

The core elements to all guidance stress three key actions:

1) The benefit of up-front screening for the early identification of potential biodiversity risks;

2) Use of the Mitigation Hierarchy (CSBI, 2015) as a framework for biodiversity management; and

3) Proactive stakeholder consultation (Pollard and Bennun, 2016).

Risk screening

Screening for potential biodiversity risks early in the project cycle is a powerful and cost-effective method for reducing potential risk (TBC, 2017b). A biodiversity risk screening assesses potential risks and opportunities from biodiversity in a project's area of interest, based on a rapid desktop evaluation. Expert interpretation of global biodiversity datasets (which are of increasingly high quality) is supplemented – when appropriate – by discreet expert consultation, analysis of site-specific datasets, and occasionally rapid ground truthing. Through appropriate evaluation of global datasets available through the Integrated Biodiversity Assessment Tool (IBAT, see https://www.ibat-alliance.org/), the potential presence of high-risk features (as defined by the developer, regulator or lender policies) can be identified. The most important global data include the IUCN Red List, World Database on Protected Areas (WDPA), and KBA directory, which may need to be supplemented by local data such as regional or national Red Lists, or information on biodiversity conservation priorities from a National Biodiversity Strategy and Action Plan (NBSAP, available from https://www.cbd.int/nbsap/).

The potential outputs of a screening would be identification of possible 'no go' areas, for example some lenders will not finance developments in World Heritage Sites or will give advance indication of areas to avoid - thus influencing project design. Screenings can additionally reduce costs by helping to prioritize and guide baseline survey effort towards understanding highest project risks, avoiding costly and often unnecessary broad-scale surveys usually of all vertebrate groups, and vascular plants, and by focusing impact assessment on mitigation for the key biodiversity risks within the project's area of influence.

The mitigation hierarchy

The mitigation hierarchy is the leading practice framework for managing biodiversity impacts (Phalen et al., 2018; CSBI, 2015; BBOP Principles at criteria; PwC, BBOP, and UNEP FI, 2010). Following the hierarchy is, for example, a requirement of IFC Performance Standard 6. The mitigation hierarchy is that developers must first attempt to avoid impacts to biodiversity, then implement measures to minimize them. After efforts to avoid and minimize have been applied ecological restoration is attempted. Should any residual impacts remain after avoidance, minimization, and restoration then biodiversity offsets may be necessary if No Net Loss of Net Gain of biodiversity be desired (CSBI, 2015).

Paramount in application of the mitigation hierarchy are the first two steps; avoidance and minimization which will strive to reduce the impacts as a far as practicable. The most significant reductions in impact can usually be made by application of these two steps. Additionally, in many locations there are considerable uncertainties over the potential success of restoration or offsets, and they should, and cannot be relied upon alone to deliver positive biodiversity outcomes without appropriate avoidance and minimization (Sonter et al 2020). Compared to other sectors such as mining or agriculture there is considerable opportunity for avoidance and minimization in the geothermal power generation sector. Lessons learned from the oil and gas industry may apply, including for example locating large infrastructure outside sensitive areas, directional drilling allowing for multiple wells on a single wellpad (which reduces footprint and fragmentation), and bundling linear infrastructure such as roads, powerlines, and pipelines. An important prerequisite for successful use of the mitigation hierarchy is a reliable ecological baseline (Hardner et al., 2015; TBC, 2014). Clear information on what biodiversity is present and where, will support the appropriate siting of facilities, and development of other mitigation measures (e.g., looping or burying pipelines at known migration routes). Our analysis has focused on a high-level screening of PAs and KBAs as an illustration of potential overlap between geothermal resources and biodiversity. Such an analysis alone is not enough to inform project design. Mitigation measures should be informed by site-specific studies which may reveal the presence of threatened species (Bennun et al., 2018), or priority ecosystems, even if an area is not in or close to a PA or KBA.

Ultimately after application of the mitigation hierarchy biodiversity offsets may be required to meet lender or regulatory requirements for No Net Loss or Net Gain (IUCN, 2014). Biodiversity offsets are a last resort and should be used with caution. Guiding principles for the appropriate use of offsets have been prepared which are valid for the geothermal sector (Gardner et al., 2013, BBOP, 2012, which acknowledge that there are limits to what can be offset (Pilgrim and Bennun, 2014), and that there may be social impacts of offset initiatives (Griffiths et al. 2019).

Stakeholder consultation

Early and on-going consultation with biodiversity stakeholders helps to manage risk in multiple ways. Biodiversity stakeholders are those with knowledge of, and an interest in biodiversity. They potentially include those with expertise in local biodiversity (e.g. NGOs and academics), local residents, as well as company staff or contractors (Pollard and Bennun, 2016). Appropriate consultation can de-risk by supporting the identification of sensitive biodiversity, or biodiversity of economic or socio-cultural importance to residents, and by managing information and preventing misunderstandings which can lead to the perception of impacts even if they do not actually exist.

Effective management of biodiversity risks can open multiple opportunities ranging from financing, to improved staff morale (TBC, 2017a). The potential opportunities are summarized in Figure 3 below.

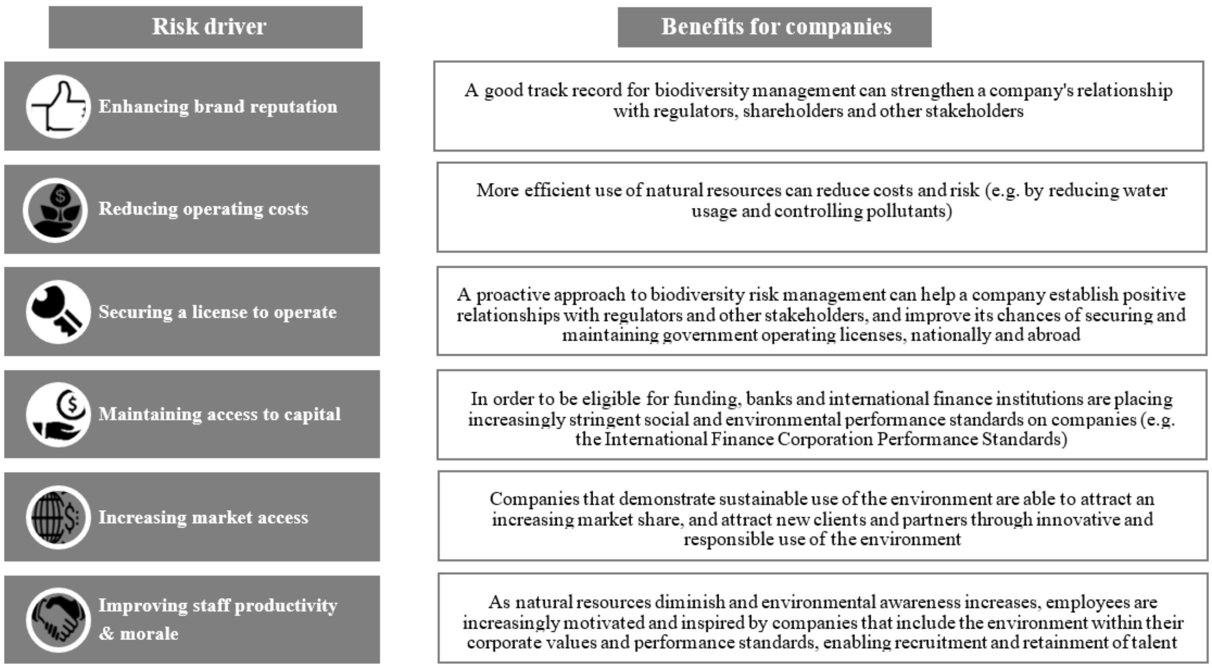

Figure 2: Potential opportunities from improved biodiversity risk management

5. CONCLUSION

The continued growth of the geothermal power sector is likely to see the increased development of facilities in areas of high biodiversity importance. This presents a potential risk to projects where mismanagement of impacts to biodiversity can lead to protests, permitting delays or limited options for finance. Tools and approaches exist, however, which can help manage these risks. As concern grows globally about an on-going biodiversity and climate crisis (IPBES, 2019) the time is right for the geothermal power sector to learn the lessons of other sectors and demonstrate that it can be a biodiversity-friendly as well as climate-friendly source of power.

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