# Limiting Land-Use Conflicts Associated with the Renewable Energy Transition Using Integrated Landscape Management

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# ABSTRACT

Economies around the world are in various stages of an energy transition from fossil fuels to renewable, low-carbon energy sources. This is largely a result of concerns over climate change, as well as a response to dramatic cost decreases for electricity from renewable sources that have occurred over the past decade. While there are many reasons to be hopeful about this transition, it does present significant challenges. Given the low power densities of currently-available renewable technologies, compared to conventional fossil fuel sources, a far greater allocation of land will be needed to make this transition. This increase in land requirements will put a great deal of pressure on other land use objectives, most notably food production, conservation and the ability of communities that rely on the use of natural resources to support their livelihoods. Integrated landscape management provides a framework for responsible siting of renewable energy projects, which can limit the pressure from increased land requirements for renewable energy installations. Additionally, landscape scale energy production can support a myriad of objectives typical within an integrated landscape. This project paper examines these topics and provides a rationale for incorporating renewable energy considerations within a larger, integrated planning framework.

# BIOGRAPHICAL SKETCH

Jamie holds a bachelor’s degree in economics from Union College in Schenectady, New York. Before beginning his graduate studies at Cornell, he spent six years working as the Director of Sustainability for an NGO in western Nepal, where he was fortunate to be involved in a variety of projects in the areas of green construction, regional food systems and sustainability education. His professional and academic interests lie within and at the intersections of agriculture, renewable energy and sustainable development.

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GDP - Gross domestic product
GHG - Greenhouse gas emissions
GoN - Government of Nepal
HDI - Human development index
IEA - International Energy Agency
ILI - Integrated landscape initiative
ILM - Integrated landscape management
IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC - Intergovernmental Panel on Climate Change
IRENA - International Renewable Energy Agency
IUCN - International Union for the Conservation of Nature
PV - Photovoltaic
RE - Renewable energy
USAID - United States Agency for International Development
WWF - World Wildlife Fund (Worldwide Fund for Nature)

# CHAPTER I: INTRODUCTION

There is a global transition underway in how electricity is generated. Dependence on the combustion of fossil fuels, derived from finite reserves of ancient biomass, is slowly, but increasingly, being replaced by renewable sources of energy, derived almost entirely from incoming solar radiation. There are a number of reasons why this transition should be welcomed and expedited. It will play a crucial role in abating the climate crisis (Arvizu et al. 2011), provide greater electricity access to communities around the world (Gollwitzer et al. 2017) and is becoming a financially prudent investment (IRENA 2020). This transition does not come without challenges, however. Due to the unprecedented amount of land that will need to be allocated, renewable energy installations are expected to become the largest threat to conservation and agricultural production over the coming century (Kiesecker & Naugle 2017).

In response to these concerns, planning for the renewable energy transition must be done in a way that safeguards other essential land uses. Landscape-scale integrated-planning approaches have shown promise in being able to achieve a diverse set of conservation, agricultural production and livelihood goals given limited, shared resources within a geographical area. Integrated landscape management (ILM) is one such landscape-level planning framework.

This project paper provides rationale for incorporating renewable energy considerations within a larger, integrated planning framework. The paper begins with a literature review, which delves into the origins of the renewable energy transition and describes some of the anticipated negative impacts of a renewables-dominated world. Integrated landscape management is then discussed as a potential planning framework to reduce these negative impacts and create synergies between energy development and other landscape objectives. A case study on renewable energy development in Nepal is used to show how an integrated approach to renewable energy planning can be done in a real-world scenario. A set of criteria is then proposed to evaluate the impacts energy development within an integrated landscape. Finally, a policy brief, included as an appendix, summarizes these findings for a broader readership.

## CHAPTER II: LITERATURE REVIEW

### Background

The transition from fossil fuel to renewable energy, currently underway, can be attributed to several factors. The most obvious of these is to address the climate crisis. The use of fossil fuels for electricity and other energy needs has contributed significantly to the accumulation of excess greenhouse gas emissions in the atmosphere, subsequently trapping a greater amount of solar radiation and causing a warming trend around the world (IPCC 2018). The impacts of this warming are expected to be widespread, disruptive, and deadly. Oceans are anticipated to rise as terrestrial ice melts, inundating coastal cities and forcing migration, and extreme weather events are expected to become more common, creating lethal conditions for millions around the world and threatening food supply (IPCC 2019). The Intergovernmental Panel on Climate Change (IPCC), the United Nations expert body and leading voice on climate science, has stated with high confidence:

> “Staying within a remaining carbon budget of 580 $GtCO_2$ implies that $CO_2$ emissions reach carbon neutrality in about 30 years, reduced to 20 years for a 420 $GtCO_2$ remaining carbon budget… This assessment suggests a remaining budget of about 420

GtCO$_2$ for a two-thirds chance of limiting warming to 1.5$^0$C, and of about 580 GtCO$_2$ for an even chance (medium confidence)" (IPCC 2018).

Figure 1 illustrates a potential pathway to limit warming to two degrees Celsius. As it shows, the majority of solutions will need to come from abatement technologies, such as electric vehicles, energy efficient construction, low-carbon industrial processes and renewable energy generation (National Academy of Sciences 2019). Currently, global energy production is responsible for the largest emissions by sector, contributing over 30 GtCO$_2$ in 2020 alone (IEA 2021). It is clear, therefore, that a transition to low carbon renewable energy sources must happen rapidly in order to stay within the carbon budget and avoid the catastrophic impacts of a two-degree change scenario.

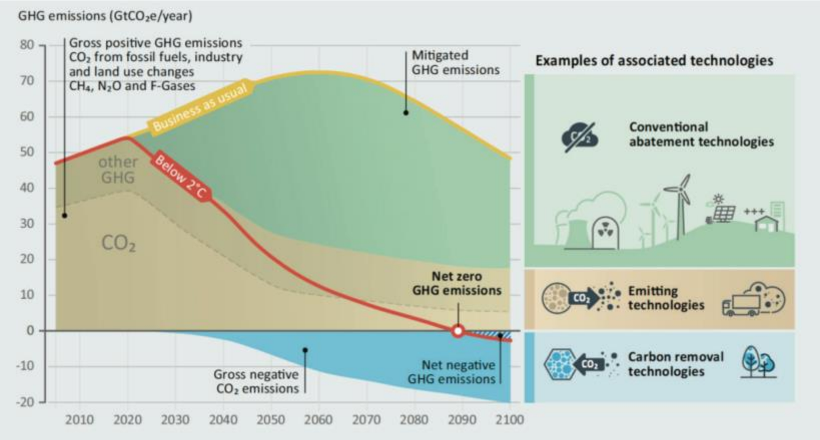

Figure 1: Pathway to Stay Below 2$^o$C: illustrates the dramatic reduction in greenhouse gas emissions, shown by the red line, that will be needed to keep warming to 2$^o$C (Source: National Academy of Sciences, Engineering and Medicine 2019)

In addition to the climate change mitigation benefits, there are also financial factors expediting this transition. Renewable energy technologies, most notably solar photovoltaics (PV), have seen remarkable cost decreases in the past decade (Figure 2). In some markets around the world, electricity from these sources is now regularly cheaper than the equivalent from a fossil fuel source (IRENA 2020).

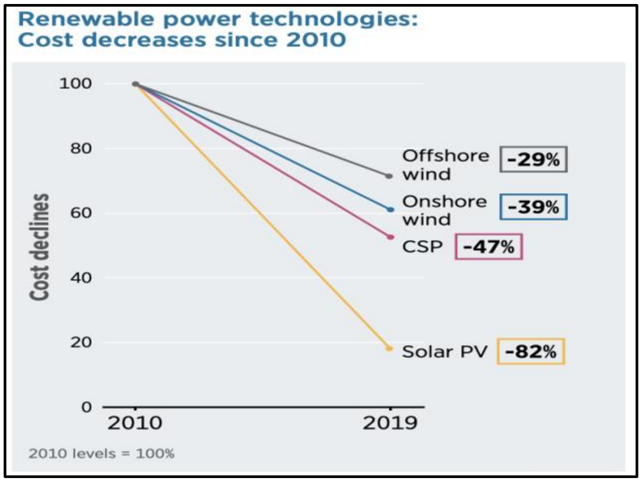

Figure 2: Cost decreases for four common renewable energy sources between 2010 and 2019 (Source: IRENA 2020)

Fossil fuel-based sources of electricity are expected to experience a different trend in the future. While reserves of oil, coal and gas are still considerable, much of the easily accessible supply has already been consumed. As a result, future extraction will require moving to areas of higher risk, such as deep seas and the Arctic, and will require greater processing, as in the case of bitumen from tar sands in Alberta, Canada (Prince 2012). This will ultimately raise costs for these conventional energy sources.

## The Downside of the Transition

While there are a number of reasons to welcome this energy transition, it also presents significant challenges. Current renewable energy technologies are far less power dense than fossil fuel sources, meaning that they produce less power per area, indicated as watts per square meter ($W/m^2$) (Smil 2010). Conventional fossil fuel sources have power densities in the range of 1,000-2,000 $W/m^2$, whereas one of the most power-dense renewable sources, PV, is between 4-9 $W/m^2$ (ibid). As a result, the ability to produce equivalent levels of energy will require vastly more land area dedicated to electricity generation. Figure 3 illustrates the power density disparity between common renewable and fossil sources of energy. Note the scale on the X-axis is logarithmic, not linear.

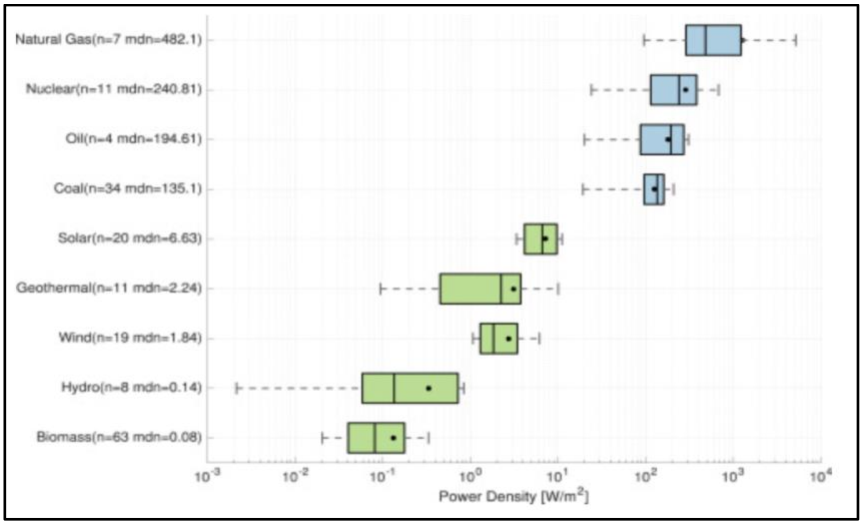

Figure 3: Power densities of conventional and renewable energy sources (Source: Zalk & Behrens 2018)

Figure 4 shows land-use intensity and $CO_2$ emissions from common electricity sources. There is something of an inverse relationship between the amount of GHG emissions produced by a source and the amount of land required for it.

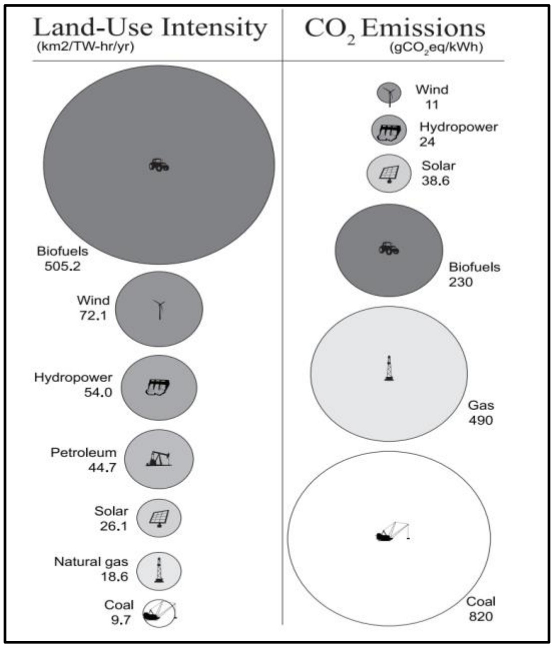

Figure 4: Land-use intensity and $CO_2$ emissions of common energy sources. There is something of an inverse relationship between the amount of GHG emissions produced by a source and the amount of land required for it (Source: Kiesecker & Naugle 2017)

This issue is further exacerbated by the fact that renewable energy sources are intermittent or variable, and thus have low capacity factors (Zalk & Behrens 2018). For example, a solar panel may have the theoretical ability to produce a certain amount of electricity, but the fact that the sun sets and clouds occasionally obscure panels, among other reasons, means that only a fraction of that potential can ever be met. To make up for this, additional capacity must be installed in order to generate excess electricity for storage, thus increasing the total land area needed.

This large increase in land-use intensity, also referred to as energy sprawl (Kiesecker & Naugle 2017), is anticipated to have far reaching impacts. It is expected to become the greatest threat to biodiversity conservation over the coming century (Rehbein et al. 2020), causing habitat loss, fragmentation and other disturbances. It is also expected to put significant pressure on agricultural lands and food systems (Hernandez et al. 2015). With demand for food anticipated to rise significantly in the coming decades and climate change threatening to reduce yields (Tigchelaar et al. 2018), it is imperative that solutions are developed that limit conflict between renewable energy production and food production to ensure greater food security over the coming century.

A third impact of this extensive land cover change will fall on local and indigenous communities (WWF 2021). These groups historically have had limited bargaining power when it comes to issues of land rights and risk losing significant areas and livelihood opportunities to energy development. However, given how successful these communities have proven to be at protecting biodiversity and producing much of the world’s food supply (Garnett et al. 2018), it is essential that their rights to ancestral lands be maintained, and that these groups have an active and leading role in the renewable energy transition.

## Mitigating Risks and Developing Complementary Solutions

A report recently published by IPCC and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Pörtner et al. 2021) emphasizes the need for the dual crises of climate change and biodiversity loss to be addressed in tandem, and to develop solutions for one that does not negatively impact the other. Given the scale of the renewable energy transition needed to reduce emissions and stave off climate change, as well as the catastrophic impacts on biodiversity that could result if it is poorly planned, there is potentially no development sector in greater need of a coordinated, synergistic approach.

Fortunately, solar radiation reaches Earth's surface in abundance throughout much of the world. This solar radiation contributes to the production of wind, precipitation and biomass, all phenomena that can be harnessed for energy generation (Figure 5). With such an abundant supply of resources, it should be feasible to select sites that have limited value for other uses.

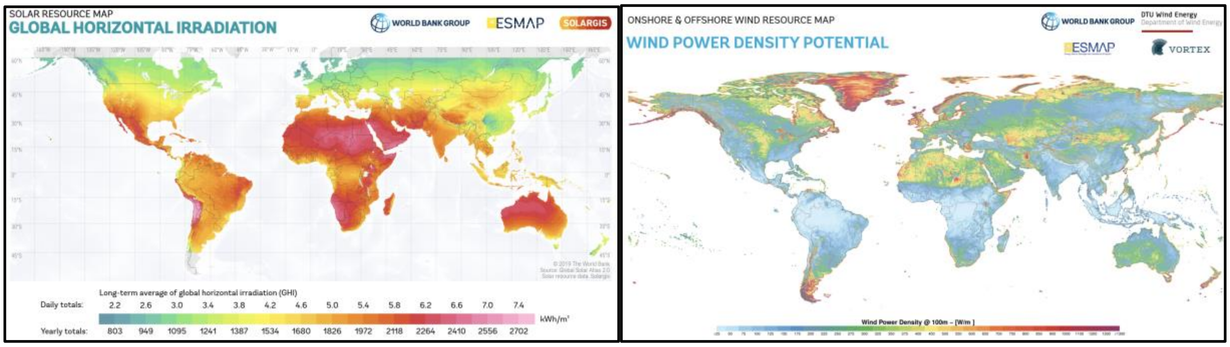

Figure 5: illustrates the generation potential from both solar (left) and wind energy (right) around the world (Sources: Global Solar Atlas 2021, Global Wind Atlas 2021)

A recent study suggests that renewable energy targets outlined in Nationally Determined Contributions (NDCs), in response to the Paris Agreement, could be met nineteen times over on converted lands alone, leaving wildlands untouched (Baruch-Mordo et al. 2019). Figure 6 illustrates where areas of high energy potential and converted lands overlap.

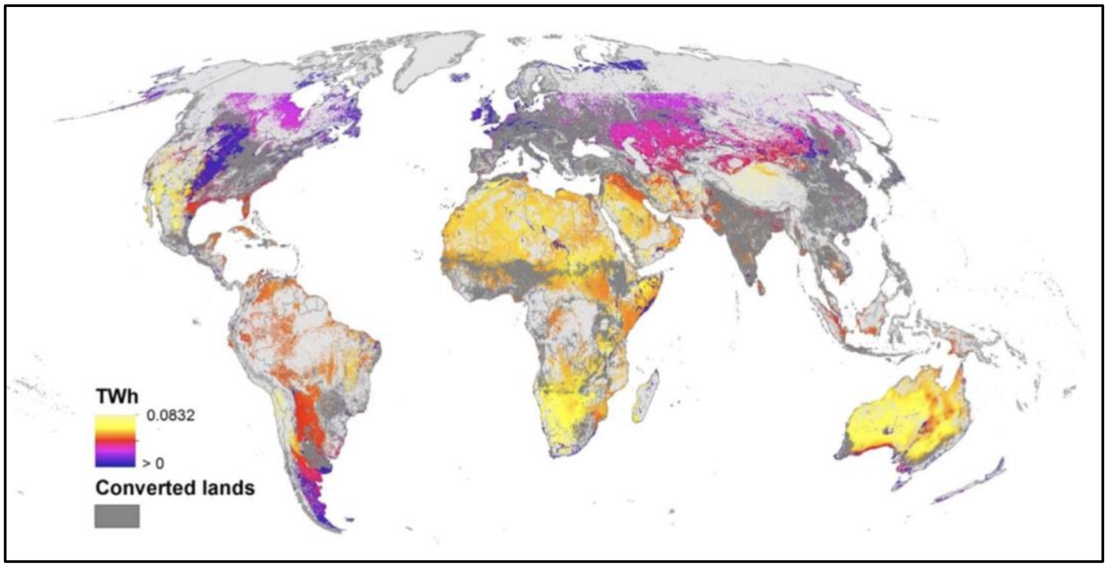

Figure 6: World map showing the overlap of converted lands and RE generation potential (Source: Baruch-Mordo et al. 2019)

Converted lands, in this case, are defined as "terrestrial landscapes or freshwater systems already impacted by human activities (e.g., human settlements, agriculture lands, roads, and dams)" (ibid). While certain countries, including Japan, China and India, are not expected to be able to meet anticipated energy demand in 2050 with domestic renewable energy supplied from converted lands alone, this study found that the vast majority could, including five of the top ten highest emitters. With such an excess of supply available on non-wild lands, it is then possible to look to reduce conflicts with other important land uses, most notably agriculture.

Historically, energy planning is done almost exclusively on a project-by-project basis. However, the anticipated impacts, outlined above, indicate that a more organized and strategic approach is desperately needed. The challenge becomes developing planning frameworks and policies that can lead to these synergistic outcomes.

## Integrated Landscape-Scale Planning to Mitigate Impacts

Conventional land-use planning often leads to the segregation of land areas for management by different sectors. While this model may work in situations where land and resources are abundant, it does not often lead to the most ideal outcomes in situations where resources are scarce and/or competition is high (Sayer et al. 2013). Integrated landscape management (ILM) offers an alternative framework that could greatly reduce the negative impacts of the renewable energy rollout. ILM is defined by long-term collaborations between a diverse set of stakeholders for the coordinated management of natural resources within a specific area, known as a landscape (Scherr et al. 2013). A landscape, in this case, is characterized first by geographical boundaries, such as a watershed, but crucially considers socioeconomic factors as well, such as the extent of a regional food system or value chain. The three overarching goals of integrated landscapes are conservation of biodiversity and ecosystem services, sustainable agricultural production and viable livelihoods for local people (McNeely & Scherr, 2003; Scherr & McNeely, 2008). Figure 7 illustrates the generally integrated nature and the wide variety of objectives that can be achieved through the ILM approach.

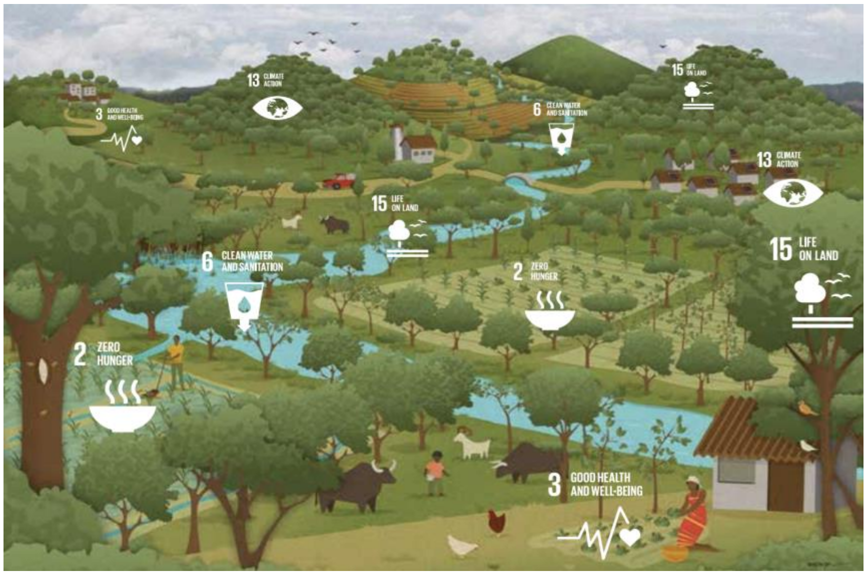

Figure 7: An integrated landscape approach (Source: Thaxton et al. 2015)

Integrated landscape management has been shown to produce more ideal conservation outcomes, mainly as a result of collaborative long-term planning and coordination of resource-use at scale (Denier et al. 2015; Kennedy et al. 2016). There is no specific standard for which sectors need to be involved in an ILM project but Figure 8 illustrates those that are often included.

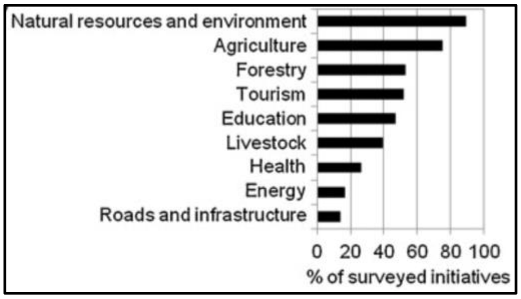

Figure 8: Common sectors involved in integrated landscape management projects. This graphic illustrates sectors involved in 104 integrated landscape initiatives within Latin America and Caribbean surveyed in 2014 (Source: Estrada-Carmona 2014)

As shown in Figure 8, energy is not often a common consideration in ILM projects. Surveys from other regions around the world show a similar trend. Under 20% of 87 ILM projects in Africa and 166 in Asia, surveyed in 2014, include energy-related activities or stakeholders within their design (Estrada-Carmona et al. 2014, Milder et al. 2014). It should be noted that, historically, energy refers almost exclusively to biomass production, further reducing the inclusion of modern renewable energy considerations (Milder et al. 2008). However, given the anticipated growth of renewable energy and the potential impacts on the core objectives of ILM, it is logical that energy should take a more central role in the design of ILM projects.

## Benefits of Energy Planning at a Landscape Scale

Little consideration is often given to the role of an energy project within the larger system in which it is located, aside from environmental impact assessments that are performed within the immediate vicinity of a project. This strategy often leads to negative externalities and unintended social costs. Instead, the ILM framework seeks to internalize these costs, considering multiple objectives within a given space and arranging for an optimal outcome for all (Denier et al. 2015).

## Benefits to Energy Development

The landscape provides a unique opportunity to design energy systems that limit negative impacts and compliment other objectives. These systems can range significantly in capacity and can either operate independently or be connected to a regional grid (Figure 12). The modular nature of many renewable energy technologies, like PV and wind, also allows for a far greater level of flexibility in project sizing and location (IRENA 2014).

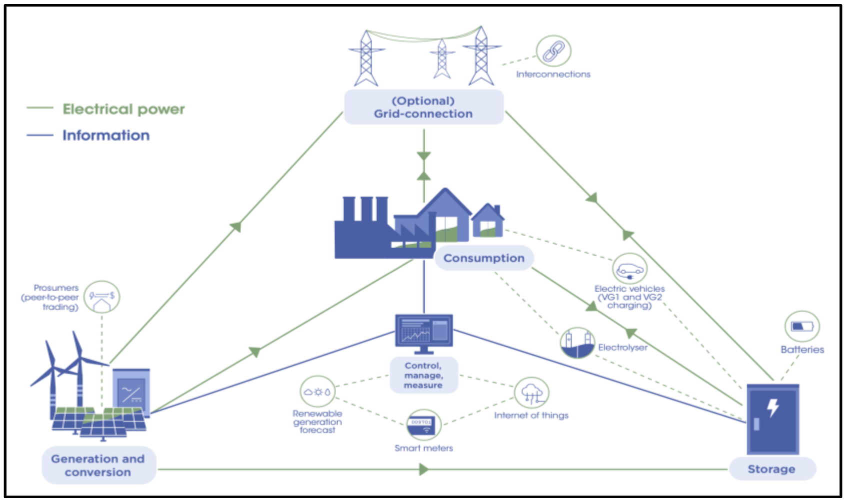

Figure 9: Minigrids for local, distributed energy generation (Source: IRENA 2020)

This allows for a greater potential for energy systems to fit into niche areas in a landscape where they can cause minimal disturbance. They can also be installed in areas yet unreached by regional or national grids, helping to increase access to energy resources and the economic opportunities that can come from them (Gollwitzer et al., 2017)

Taking a landscape approach to energy planning can also encourage a greater mix of sources. Any given landscape can have a variety of energy resources, such as solar, wind, hydro and biomass. The development and integration of multiple sources can drastically increase the reliability of electricity supply and resilience to disturbances. (IRENA 2020)

One final benefit of planning at the landscape scale is it can offer significant cost savings, as opposed to individual stakeholders acting alone and installing their own systems. This is a result of economies of scale, which can lower the levelized cost of electricity as the size of the system increases. It can also result from the coordination, or scheduling, of demand between users to reduce overall capacity needs (Figure 13).

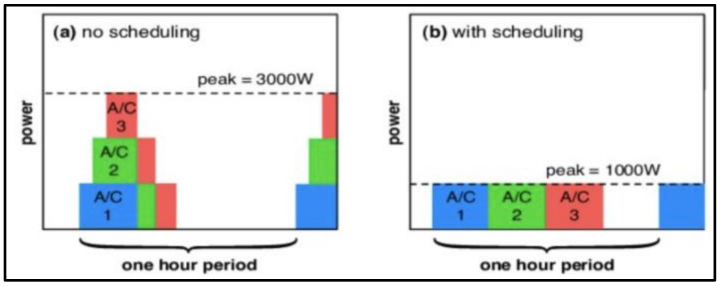

Figure 10: By scheduling energy demand among landscape objectives so that there is minimal overlap, total capacity needs can be decreased. Scenario (b) requires ⅓ of the installed capacity of scenario (a) even though the total energy consumption remains equal. This can lead to lower costs and smaller land footprint (Source: Barker 2012)

## Elements of ILM

In addition to the direct benefits to energy development, the inclusion of energy within an integrated planning process can have positive impacts on other common objectives. Practitioners of the ILM framework have developed five core elements they believe are essential to any ILM project (Denier et al. 2015). Table 1 lists these elements and suggests how energy considerations may impact each. Detailed descriptions of the benefits to common landscape objectives then follow.

| ILM Element | Energy Impact |
|---|---|
| 1. Shared or agreed management objectives that encompass multiple benefits from the landscape | Increasing access, quality and quantity of electricity can positively impact many objectives within a landscape. As a result, sufficient and reliable energy access should be a core management objective within the landscape |
| 2. Land use practices contribute to multiple landscape objectives | Devoting area to energy generation can contribute in the following ways:<br>Agriculture<br>- Field work, Irrigation, Processing, Storage, Distribution<br>Conservation<br>- Reduced pressure on natural areas for resources<br>- Conservation operations support<br>Livelihood<br>- Reduced manual labor and time commitments<br>- Trained local RE technicians<br>Sustainable development objectives<br>- Success of the three previous objectives creates a strong base for sustainable development and green growth |
| 3. Synergies are captured and trade-offs reduced among objectives across the landscape | Landscape-scale planning can reduce trade-offs by prioritizing installations<br>- Away from wild lands and agricultural lands<br>- On previously-disturbed lands, brownfields, and existing buildings |
| 4. Markets, policies and programs are shaped to achieve a diverse set of landscape objectives | Access to electricity can create opportunities for a far greater set of objectives, and can help landscapes meet standards that can open up new markets |
| 5. Collaborative processes guide multistakeholder governance | Energy development is not and end but a means to elevate a diverse set of landscape objectives. Renewable energy, in particular, is a common pool resource, the management of which should be collaborative and governed by a diverse group of stakeholders within the landscape |

Table 1: ILM Elements (Source: Denier et al. 2015) and Energy Impacts (Source: author)

## Benefits for Conservation

**Reducing Conflict**: Biodiversity conservation is a core objective of landscape-scale planning (Kiesecker et al. 2010). Naturally, then, one would assume that incorporating energy considerations into a larger, integrated plan would yield some conservation benefits. By taking a landscape approach, energy planners are able to identify and avoid areas of high conservation value, such as key biodiversity hotspots, protected areas, and wildlife corridors. Ideally, there is a sufficient availability of alternate locations within the landscape to site renewable energy systems so that only the least invasive can be chosen. This type of macro analysis helps to internalize what are traditionally seen as externalities, the burden of which tends to fall on society and not on those who have installed and operate the systems.

The introduction of renewable energy systems can also contribute to reductions in deforestation, such as through the adoption of technologies like electric cookers and heaters. Woody biomass, often used by rural communities in much of the world for cooking and heating needs, is a cause of localized deforestation and forest degradation (Specht 2015).

**Supporting Conservation Objectives**: The ‘off-grid’ capabilities of renewable energy systems can provide benefits to conservation operations, which tend to be in remote areas and may not have the ability to connect to a regional grid. Access to electricity can improve communications and coordination among and within conservation groups, ensuring greater potential for successful conservation outcomes.

**The mitigation hierarchy**, a common tool used in conservation planning, helps to further illustrate why the landscape is such an ideal scale for energy development. It defines four major outcomes of conservation planning, in descending order from most ideal to least. On a site-by-site basis, it would be challenging to reach the more ideal outcomes, leading to less than desirable results. Expanding planning to a landscape scale changes this. Descriptions of the mitigation hierarchy outcomes specific to energy planning at the landscape scale follow.

- **Avoid**

The primary benefit of landscape-scale planning is to avoid conflicts with other land-use objectives. This can be done by identifying areas where installations should be avoided, such as protected areas, key biodiversity hotspots and wildlife corridors. The multi-stakeholder platform is key for identifying these zones, as a diversity of stakeholders are able to voice their concerns and come to consensus on areas suitable for these installations. Modern mapping and geographic information systems (GIS) technologies have also assisted greatly in the ability to plan at the landscape level.

Instead, siting should be encouraged on lands that have limited value to conservation and agriculture. Figure 11 illustrates examples of previously disturbed locations that can be appropriate for solar power development (Hernandez et al. 2015). One such strategy is to install these systems on brownfield sites. In the United States, alone, there are currently over 450,000 such sites, which are too contaminated for agricultural production and are often too expensive to restore (US EPA). Other strategies include siting installations on rooftops and artificial water bodies, which can serve additional purposes of reducing heat gain in buildings and evaporation from reservoirs, respectively (Hernandez et al. 2019).

Figure 11: Left - Kopila Valley School in Surkhet, Nepal sites solar panels on rooftops to minimize land disturbance. Center - Solar installation on a brownfield site in Colorado. Right - Panels installed on ponds or reservoirs (Sources: author, National Renewable Energy Lab, Hernandez et al 2019, respectively)

- **Mitigate**

At sites chosen for installations, there are novel strategies in various stages of development that allow for dual uses from a single plot of land. This stacking of functions allows for greater land-use efficiency and has minimal impact on the primary function of the land (Hernandez et al. 2019). Figure 12 illustrates several of these techniques.

Figure 12: Left - A single plot of land operates simultaneously as a solar facility and grazing land for sheep. Center -Solar panels installed in the unused area of a center-pivot crop field. Right - Wind turbines placed to minimize footprint on agricultural land (Sources: Cornell Small Farms Program, Hernandez et al 2019, Inman 2011, respectively)

- **Restore**

Temporary impacts from access, construction, operations and decommissioning should always be minimized, but can rarely ever be fully avoided. There is limited potential for landscape-scale renewable energy to aid in this level of the hierarchy. However, restoration needs should be minimized by attempts to accomplish the two higher orders of the hierarchy. This being said, solar panels have been shown to aid in the restoration of pollinator habitat (Hernandez et al. 2019), and off-shore wind installations can limit the use of trawling practices, eliminating a damaging fishing practice and allowing these areas to be restored (Gill et al. 2020).

- **Offset**

Offsets are used to balance the negative impacts of a project by creating positive outcomes of a similar type elsewhere (Kiesecker et al. 2010). They are employed as a last resort when the three higher targets of the mitigation hierarchy are unattainable. By pursuing the landscape approach, the proportion of impacts needing to be offset is minimized. It is likely that offsetting will never fully be eliminated, but planning at the landscape level should help to eliminate the vast majority of cases where offsets would be needed. Figure 13 illustrates that offsets are used to counteract the residual impacts of a project, once avoidance and mitigation measures have been exhausted.

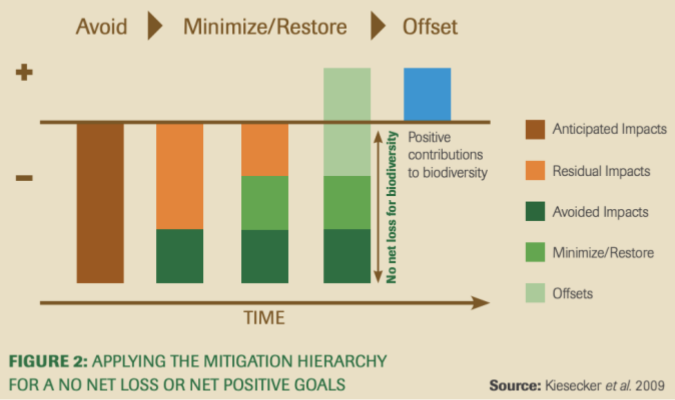

Figure 13: Use of the mitigation hierarchy. (Source: McKenney & Wilkinson 2015)

### Benefits for Agriculture

**Reducing Conflict**: Similar to conservation, the exclusion of energy considerations can be detrimental to agriculture, as these energy systems can then encroach on agricultural space and harm production objectives. Therefore, including energy within the integrated planning process will help to identify zones for energy development that limit the use of land with sufficient agricultural production potential. In addition, there are certain instances where renewable energy technologies can be installed on agricultural land with little to no disturbance, as mentioned previously.

**Supporting Agricultural Objectives**: Greater access to electricity can have significant impacts on agricultural systems. Electricity can increase access to irrigation, allowing for higher yield potential (Hartung, H., & Pluschke, L. 2018). It can reduce the drudgery and time commitment of some field- and post-harvest work, such as threshing and milling. Electricity also allows for greater food storage capabilities. Access to modern refrigeration and drying systems can reduce spoilage, which would have significant impacts on food security within a landscape (UN FCCC 2019).

## Benefits to Livelihoods

**Reducing Conflict**: Livelihoods in many areas around the world are closely tied to agricultural and ecological health. Efforts that can reduce risks to those other objectives, as discussed above, will also help to secure the livelihoods of those living within the landscape.

**Supporting Livelihood Objectives**: Livelihoods are highly impacted by energy availability, and renewable energy systems provide greater potential for equitable access. Figure 14 illustrates the relationship between electricity access and Human Development Index (HDI), an indicator of income level and quality of life.

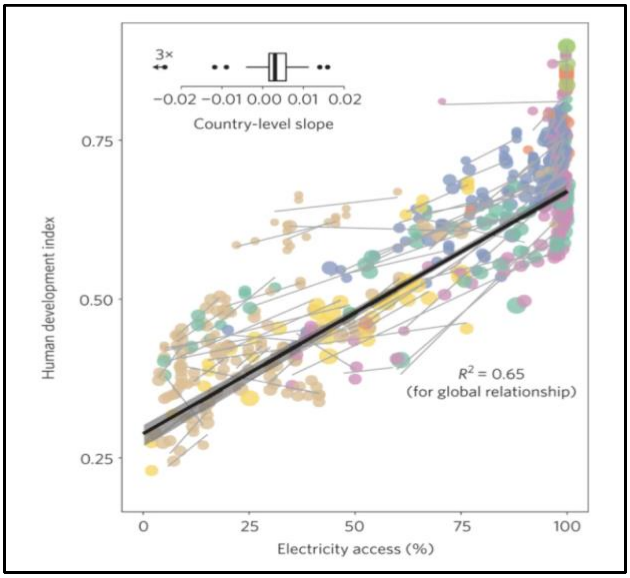

Figure 14: Electricity access and Human Development Index (Source: Alstone et al. 2015)

As mentioned above, electricity access can reduce labor associated with agriculture and household work, like collecting firewood or processing crops. This creates opportunities for people to invest their time in endeavors that can produce greater economic value. Access to electricity can also improve the quality of public infrastructure, such as water, sanitation, health and education services. These can subsequently benefit livelihoods within the landscape.

# CHAPTER III: INCORPORATING ENERGY CONSIDERATIONS INTO AN INTEGRATED LANDSCAPE

Now that the case has been made for the inclusion of renewable energy as a beneficial objective in the management of integrated landscapes, it is vital to understand how it can be accomplished. This chapter discusses the process for energy planning at the landscape scale, including demand forecasting, energy supply accounting and overlay mapping to determine areas of competition.

**Demand forecasting** refers to the ability to anticipate cumulative demand for electricity within the landscape. As is common with the ILM framework, it is the discretion of the stakeholders of a given initiative to define the landscape and the specific objectives and individual sectors that are included. This will have an obvious impact on the energy needs. However, for the sake of this example, the common objectives used so far in this review, including conservation, agriculture and livelihoods, will be used again. Some of the common energy needs for these landscape objectives are outlined in Table 2.

| **Sector** | **Energy Need** |
|---|---|
| Household/Domestic | Cooking, lighting, heating/cooling |
| Agriculture | Irrigation, field work, processing, storage, distribution |
| Public Infrastructure/Livelihoods | Schools, transportation, clinics/hospitals |

Table 2: Common energy needs for various landscape objectives

Once needs and population size of the landscape have been determined, a general sense of the capacity can be calculated. It is essential to plan well off into the future, as these systems can last for several decades. Systems should be designed to support what is anticipated toward the end of their lifetime, not only what is needed at the time of planning. Figure 15 illustrates how energy consumption changes as a country's HDI rises. As energy consumption increases, the benefits to HDI become less apparent.

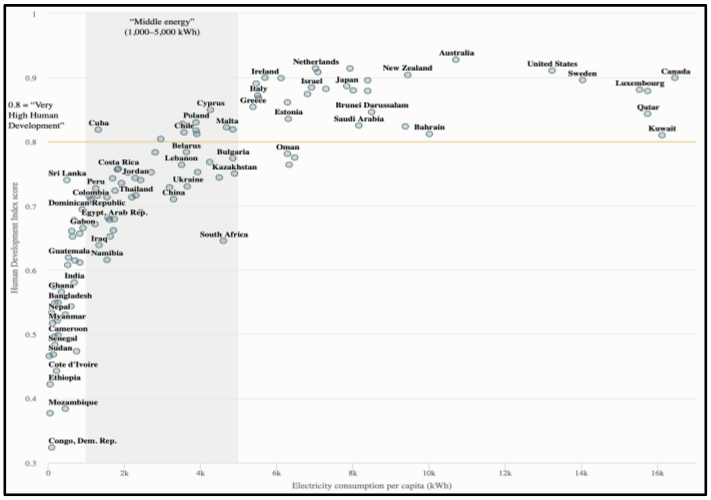

Figure 15: Relationship between Human Development Index and electricity consumption (Source: CGD 2016)

**Supply accounting** refers to the ability to quantify and map the various renewable energy sources available within the landscape. Figure 16 illustrates some of the variables used for supply accounting by Hernandez et al. (2015). These variables include generation potential, site characteristics like slope and direction, and proximity to roads, transmission lines and the eventual end-use locations. Geographic information systems (GIS) technology used in Figure 16 has been instrumental in the growth of supply accounting, as it provides precise details over vast areas of land.

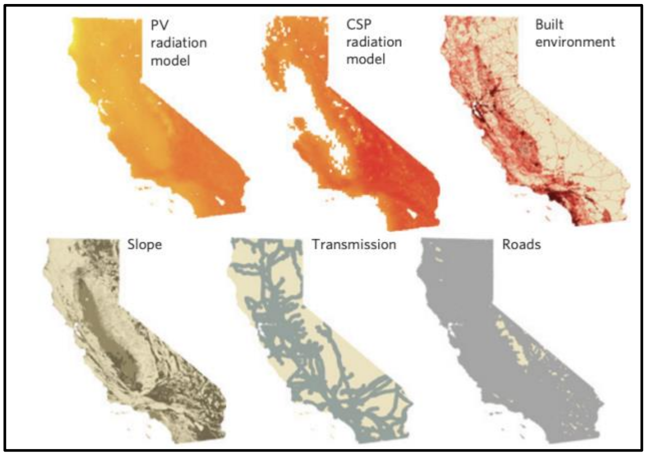

Figure 16: Various GIS layers showing important data for supply accounting (Source: Hernandez et al. 2015)

An important point to note about supply accounting, which can be discussed within the multi-stakeholder platform, is whether or not energy production should be achieved solely for use within the landscape, or if it should be exported for profit. While this could present a new revenue stream for energy-rich landscapes, there is a likelihood that it could lead to exploitation.

Figure 17 depicts the tradeoffs between food production/conservation and biofuel production at three different scales. In system 1, fuels are produced solely for use within the farm. System 2 moves to a more regional scale, and system 3 is commercial production for external markets.

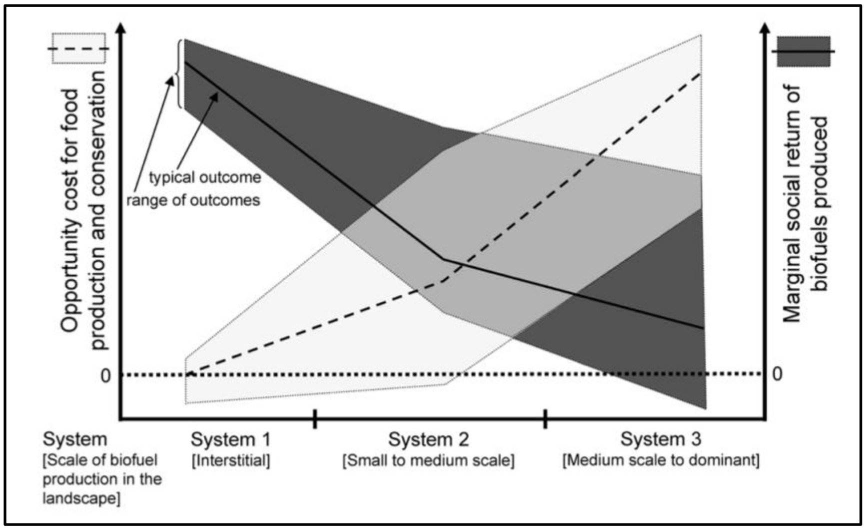

Figure 17: Opportunity costs of energy (Source: Milder et al. 2008)

While it should be noted that modern renewables have a much better power density than biofuels (Smil 2010, Kiesecker et al. 2015), the relationship between the various systems still holds true. As the goal transitions from power production for local use to production for export, the opportunity costs rise for conservation and food production. While the farm or landscape may receive compensation for energy sales, these groups become exposed to risks of energy market fluctuation and volatility, while reducing the resilience and self-sufficiency of their agricultural and natural support systems (Milder et al. 2008). It is essential, then, to understand what the carrying capacity of the landscape is, and how all of the stakeholders within the landscape will benefit.

The information collected through these needs and supply assessments, overlayed with similar data on other land uses, as illustrated in Figure 18, can then be used to inform the multi-stakeholder group of optimal siting locations.

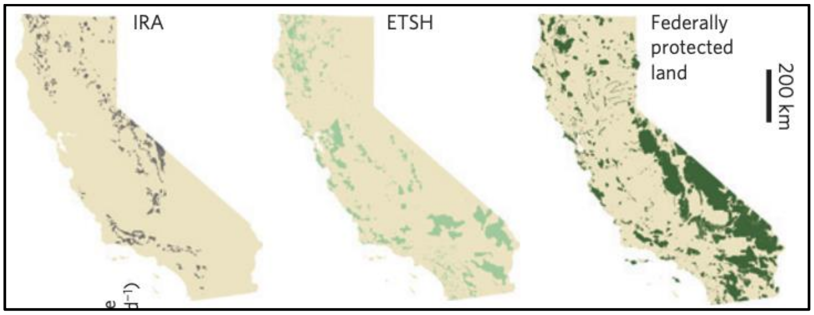

Figure 18: Key environmental data needed for this assessment. IRA = Inventoried Roadless Area, ETSH = Endangered/Threatened Species Habitat (Source: Hernandez et al. 2015)

## Measuring Landscape Performance

Monitoring and evaluation are essential components of any successful ILM project. In 2006, EcoAgriculture Partners and the International Union for the Conservation of Nature (IUCN) developed a framework for assessing the performance of integrated landscape-scale initiatives (Buck et al. 2006). This consists of four overarching goals and twenty criteria, or sub-goals, that can move a landscape toward a more integrated, sustainable outcome. Table 3, taken from Buck et al. (2006), lists the original goals and criteria that were proposed to evaluate the impacts of integrated landscape planning on conservation, agriculture and livelihood objectives. The right-hand column suggests how energy considerations, planned using an integrated landscape framework, could aid in achieving many of these criteria. The table illustrates the direct impact that energy considerations can have toward advancing criteria for all the major objectives of an integrated landscape.

| **Original Criteria** | **Energy Impact** |
|---|---|
| **Conservation Goal: Conserve, maintain, and restore wild biodiversity and ecosystem services.** | |
| C1: Do land use patterns across the landscape optimize habitat value and landscape connectivity for native species? | Landscape-scale energy planning identifies locations of least-impact for energy installations in order to preserve high-conservation-value and production areas |
| C2: Are natural and semi-natural areas within the landscape highly intact? | See above |
| C3: Are all critical populations, species, and ecosystems that occur within the landscape conserved? | See above |
| C4: Does the landscape provide a high level of locally, regionally, and globally beneficial ecosystem services? | Not applicable |
| C5: Do productive areas of the landscape limit the degradation of near-by natural areas, upstream and downstream | Systems are sited to limit disturbance. Productivity gains in agriculture, brought about by greater energy supply, can reduce land needed for production. Electricity access can also reduce pressure for resources from natural areas |
| **Agriculture Goal: Provide for sustainable, productive, and ecologically compatible agricultural production systems.** | |
| A1: Do ag production systems satisfy food security and nutrition requirements | Access to electricity can lead to higher yields from irrigation, more efficient post-harvest processing, and enhanced food storage capabilities |
| A2: Are ag production systems financially viable and can they respond to changes | Mechanization in production and processing and longer-term storage capabilities can increase financial viability |
| A3: Are ag production systems resilient to natural and anthropogenic disturbances? | Greater access to electricity can enhance resilience, mainly through greater control of water resources and food |

| | |
|---|---|
| | preservation. Greater mix of energy sources can improve resilience further. |
| A4: Do ag production systems improve or have a neutral impact on wild biodiversity and ecosystem services in the landscape | Greater production per area, better processing and more reliable storage, made possible by electrification, can reduce land needed for agriculture, thus increasing land for wild biodiversity |
| A5: Is agrobiodiversity optimally managed for current and future use? | Not Applicable |
| **Livelihoods Goal: Sustain or enhance the livelihoods and well-being of all social groups in the landscape.** | |
| L1: Are households and communities able to meet their basic needs while sustaining natural resources? | Electricity access can enhance the ability to meet basic needs (health services, food safety, water availability, etc.), while reducing pressure for local resources like fuelwood |
| L2: Is the value of household and community assets increasing? | Electricity access can increase productivity of labor, thus increasing assets. It can also allow more time for higher-value endeavors. |
| L3: Do households and communities have sustainable and equitable access to critical natural resource stocks and flows? | Distributed energy production allows for more equitable access to energy resources, which can then lead to greater access to other resources, such as water |
| L4: Are local economies and livelihoods resilient to changes in human and non-human population dynamics? | Energy planning anticipates demand well into the future and plans for changes in population and demand over time |

Table 3: Evaluating impacts of renewable energy inclusion (Source: author) on other landscape objectives (Source: Buck et al.,2006)

Using the same template, suggestions are made in Table 4 for what the goal, criteria and indicators of renewable energy planning might be within the context of a whole, integrated landscape.

| | |
|---|---|
| **Goal - Define the ecoagriculture concept** | |
| Energy Goal | Produce a sufficient and reliable supply of electricity from resources available in the landscape for benefit within the landscape |
| **Criteria - Characteristics of a highly successful landscape** | |
| E1 | Do the energy systems provide sufficient and reliable electricity to support a variety of landscape activities? |
| E2 | Does the siting of energy systems limit negative impacts on agriculture, conservation, and other livelihood activities within the landscape? |
| E3 | Do energy systems reduce workload and manual labor associated with landscape activities? |

| | |
|---|---|
| E4 | Is the energy produced within the landscape distributed equitably to stakeholders throughout the landscape? |
| E5 | Do the energy systems increase productivity, or provide any other financial benefits to stakeholders within the landscape? |
| **Indicators - Factors that are measured to reveal how well each criterion is being fulfilled** | |
| 1 | Increase in electricity consumption per capita |
| | Rationale: Figure 15 illustrates correlation between electricity consumption and HDI at lower levels of consumption. After a certain consumption level, the correlation becomes less apparent (Center for Global Development) |
| 2 | Percentage of landscape stakeholders with access to electricity or services powered by electricity |
| | Rationale: Figure 14 illustrates the correlation between electricity access and HDI (Alstone et al., 2015) |
| 3 | Increase in GDP per unit of labor. |
| | Rationale: This indicates an increase in profitability from labor and a reduction in manual labor needs. Results from mechanization and greater efficiency, especially in agricultural production (OECD 2021) |
| 4 | Reduction in purchased electricity from outside the landscape or, in cases of excess production and grid connectivity, increases in payments for electricity delivered to parties outside the landscape |
| | Rationale: Indication of energy self-sufficiency. Energy provided from outside the landscape may not have been designed with an integrated landscape approach, meaning that these imports could be producing negative impacts on landscape objectives elsewhere |
| 5 | Net area in need of restoration/offsetting as a result of the energy installation. 'Net' is emphasized because RE installations have the potential to decrease land requirements for agricultural production (e.g., RE-powered irrigation can lead to greater yields and small land footprint needed for food production), and can reduce pressure on natural areas (e.g. Electric cookers can replace biomass fuel) |
| | Rationale: The main purpose of energy planning through an integrated landscape approach is to minimize disturbances to other landscape objectives |

Table 4: Energy goals, criteria and indicators for evaluating landscape performance (Source: author)

# CHAPTER IV: CASE STUDY OF LANDSCAPE-SCALE RENEWABLE ENERGY DEVELOPMENT IN KARNALI BASIN, NEPAL

The Karnali River Basin in western Nepal is a case in which an integrated landscape approach to energy development presents significant advantages over the over-reliance of a single energy source that is expected to negatively impact other landscape objectives.

The country of Nepal is blessed with an abundance of natural resources, including those that can be harnessed to fulfill its energy needs. To date, however, only a small fraction of these energy resources has been developed (ADB 2017). Figure 19 indicates that the vast majority of Nepal's energy supply still comes from traditional biomass, with electricity only accounting for 1% of total supply. Furthermore, only 1% of energy resources go toward agriculture and 6% toward industry. This lack of industrial and modern agricultural development is indicative of why Nepal is still considered to be a Least Developed Country (UN CDP 2020).

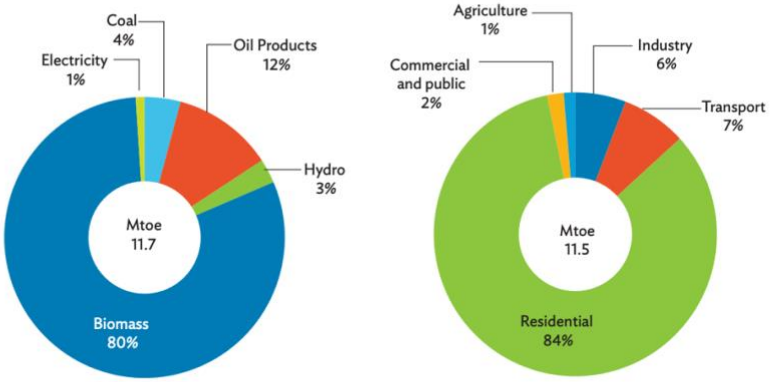

Figure 19: Energy types (left) and consumption by sector (right) in 2014 (Source: ADB 2017)

The Government of Nepal has identified domestic hydropower as a pathway to economic progress and is subsequently considering the development of a number of hydropower projects on many of its river systems, including the Karnali River and its tributaries (Figure 20).

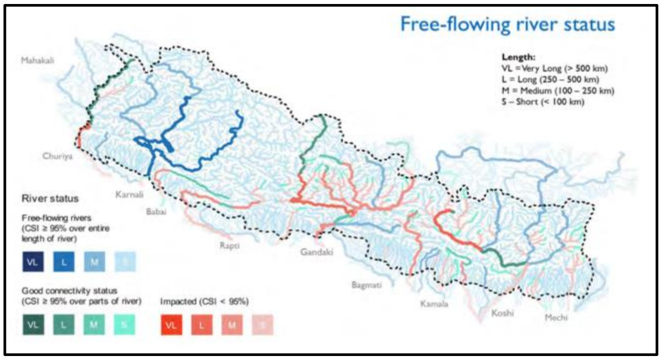

Figure 20: Flow status of Nepal's major rivers. The Karnali and Bheri rivers, shown in dark blue, are the last long free-flowing rivers remaining in Nepal (Source: USAID 2020)

The Karnali River is one of the last free-flowing rivers in the Himalayan region, stretching over 500 kilometers from its headwaters in the mountains until it converges with the Ganges River in the plains of northern India (Figure 21). The river is home to a variety of threatened aquatic species, such as the Golden Mahseer, Gharial Crocodile and Gangetic River Dolphin, and its watershed supports a wide range of habitats from its alpine origins to the subtropical south. The river basin also supports the largely agrarian livelihoods of many thousands of people.

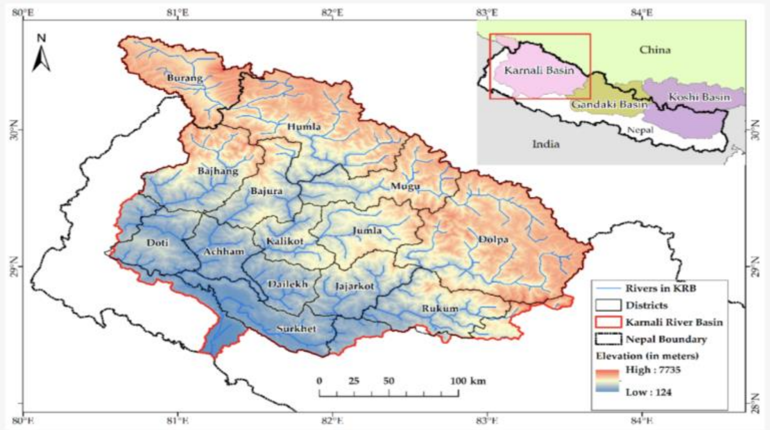

Figure 21: The Karnali Basin ranges in elevation from 7700 meters in the mountains to 124 meters in the southern Terai plains, and contains a catchment area of 44,000 square kilometers (Source: Shrestha et al. 2019)

## Energy Development without Landscape-Scale Planning

The impacts of large-scale hydroelectric power development on local ecosystems and communities in the Karnali Basin would be significant and far reaching. The creation of reservoirs for water storage would inundate vegetated areas, cropland and villages. Downstream, reduced movement of sediment from the mountains would lead to erosion and nutrient loss in the Terai, threatening rich biodiversity and some of the country's most productive agricultural land (Collier et al. 1996). Hydropower plants would also block migratory fish routes, effectively fragmenting their habitat and threatening the livelihoods of those that depend on these fisheries (Barbarossa et al. 2020).

In addition to the direct impacts of hydropower development on biodiversity conservation, agriculture and livelihoods within the basin, there are other reasons to reconsider putting such an emphasis on hydropower. First, large-scale hydropower can perpetuate existing inequities with regard to access. These systems would connect to a regional or national grid, providing additional electricity to only those with grid access. Electricity access is strongly correlated with economic development potential, so this may serve to exacerbate inequalities within the country. Low-impact renewable energy technologies, like PV and wind, are deployable in a far greater diversity of locations and can increase access to a much larger subset of the population (IRENA 2019).

Second, investing heavily in a single source of power from a single river system presents a high level of risk. Climate change is expected to increase the unpredictability of precipitation within the Himalayan region, and droughts are likely to occur that could negatively impact electricity output (Moran 2018). A more resilient strategy should be taken.

### Developing More Optimal Scenarios with an Integrated Landscape Approach

Conservation experts argue that such a focus on hydropower development will cause significant disturbances to the region's ecosystems and to the livelihoods of its people (Opperman et al. 2019). They also stress that this need not be the case. By taking a broader, landscape-scale view of energy resources within the river basin, a comparable amount of energy can feasibly be generated by a mix of renewable energy sources that are strategically selected to limit land-use conflicts. Figure 22 illustrates that there is widespread availability of solar and wind power throughout the region.

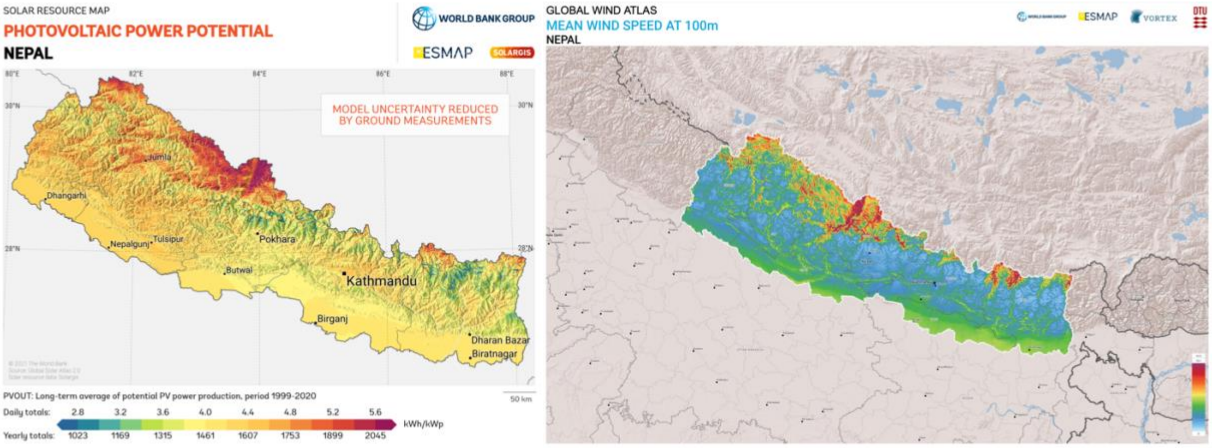

Figure 22: Solar power potential in Nepal (left). Wind power potential in Nepal (right) (Sources: Global Solar Atlas 2021, Global Wind Atlas 2021, respectively)

Figure 23 shows land cover types within the basin, including areas where energy development should be avoided, such as forests, shrub/grassland and agricultural areas, as well as developed areas, where there will be greater demand for energy.

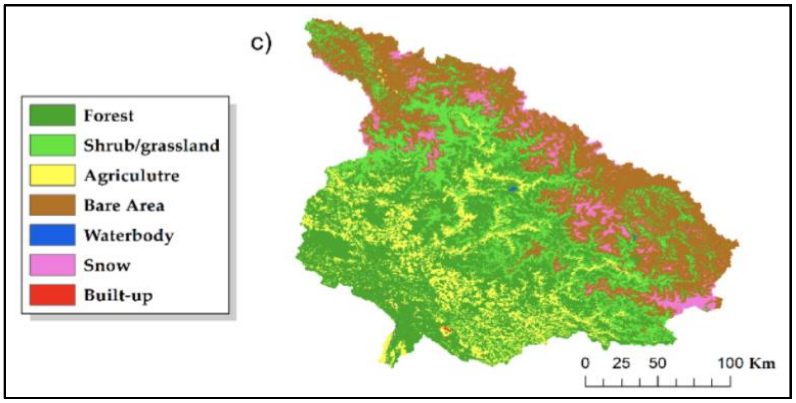

Figure 23: Land cover in the Karnali River Basin in 2017 (Source: Shrestha et al. 2019)

A study recently conducted by USAID, DAI and WWF (Martin & Grill 2020) indicates that, by pursuing a mix of renewable energy technologies throughout the Karnali Basin, electricity generation comparable to a 100% hydropower scenario could be achieved, while leaving the main stem of the Karnali River free-flowing. Figure 24 shows the wide variety of variables that were used for the analysis, ranging from energy-specific metrics, such as generating potential and cost, to impacts on biodiversity, livelihoods, human displacement, roads and even recreation. The study refers to this approach as Systems Scale Planning, but it is clear that this is an integrated, landscape-scale analysis of energy development.

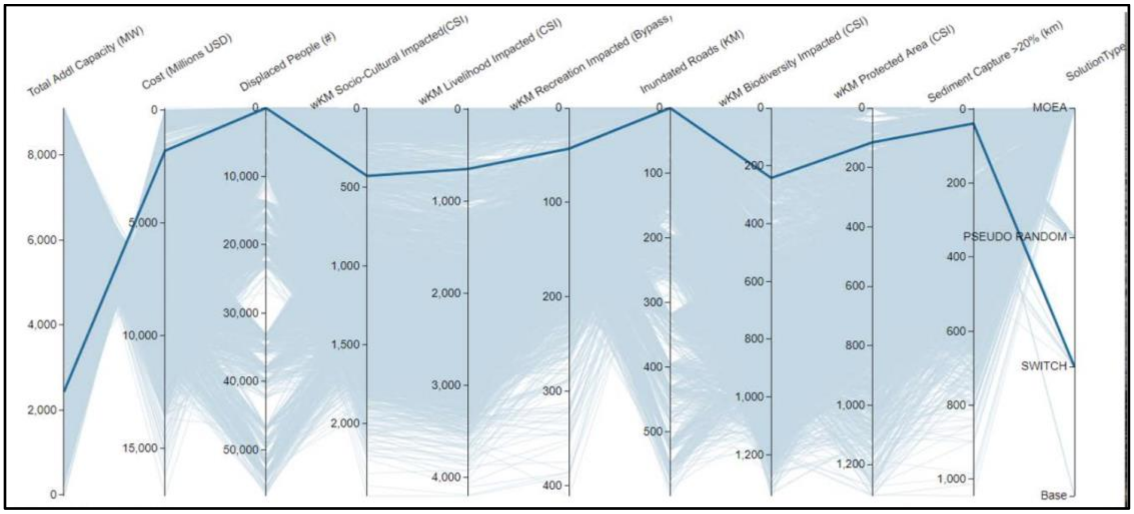

Figure 24: USAID's SWITCH Model uses a variety of variables, shown across the top of the graph, to determine the best set of hydroelectric projects to pursue (Source: Martin & Grill 2020)

## Case Study Conclusion

Nepal has great potential to rise from the status of a Least Developed Country but the lack of sufficient and reliable electricity is a major hindrance to meeting this goal. While the country is rich in hydropower resources, it also has a wealth of other renewable energy sources that should also be utilized. It is essential that the Government of Nepal take a wider view of domestic energy development by incorporating a diverse mix of sources and building an electrical grid that is not based on generation potential and cost, alone, but also considers impacts on other land-use objectives. The USAID analysis has illustrated that an integrated landscape approach can lead to low-impact renewable energy development that does not have to compromise other essential landscape objectives.

# CHAPTER V: CLOSING

The transition to renewable energy presents a generational opportunity to redesign major infrastructures in order to address the threats of climate change and increase access for a far greater number of the world's population. However, the comparatively poor power densities of current renewable energy technologies will require the use of much more land than is currently allocated, and this is anticipated to cause conflicts with other land-use objectives. This project paper has presented information to show that conflict is not inevitable. However, planning frameworks will be required that emphasize coordination and collaboration, and aim to develop optimally for the whole system, not individual parts. Integrated landscape management presents great promise in supporting the renewable energy transition in a way that will limit conflicts, while expanding opportunities for other important objectives that would not have been possible through segregated or sectoral approaches. It is hoped that this project paper will contribute to eventually meeting this critical challenge. To that end, Appendix I provides a summary policy brief covering this complex topic for a wider readership, including regional planners, renewable energy developers, landscape practitioners and conservationists.

# APPENDIX I: A POLICY BRIEF ON RENEWABLE ENERGY PLANNING AND INTEGRATED LANDSCAPE MANAGEMENT

## At a Glance

There is currently a transition underway in how electricity is generated around the world. Conventional fossil fuel sources are slowly, but increasingly, being replaced by renewable energy sources. This is expected to play a crucial role in mitigating the climate crisis, while providing unprecedented energy access to populations around the world. This transition also holds the potential to replace agriculture as the greatest threat to conservation and biodiversity protection, as current technologies produce significantly less power per area than conventional fossil fuel sources and, thus, will require a large increase in land allocation. Incorporating renewable energy considerations within integrated landscape planning can help to limit these conflicts, while simultaneously supporting other common landscape objectives.

## Background

Transitioning to renewable energy sources is the single most important strategy currently available to address the climate crisis (Fawzy et al. 2020). The transition is being advanced by the fact that the levelized cost of energy from renewables has plummeted in recent years (IRENA 2020). Costs associated with conventional sources, on the other hand, are expected to increase in the years ahead, as the readily accessible sources become more scarce and greater effort and expense are needed for extraction and processing (Prince 2012). Placing a price on carbon pollution, which is becoming a likely scenario, will hasten this transition further (IEA 2020).

This transition is, in many ways, a positive development. However, the low power density of currently available renewable energy technologies, as well as their high variability and low capacity factors, will mean that vastly more land will need to be dedicated to energy production in order to meet future demand projections (Smil 2010). This will lead to significant conflicts for land area, and there is high potential for it to negatively impact global food production and conservation objectives (Kiesecker & Naugle 2017).

### Dealing with Multiple Crises Simultaneously

A joint report recently published by the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) highlights the need for integrated solutions that address the climate and biodiversity crises simultaneously (Pörtner et al. 2021). Given the scale of renewable energy infrastructure needed for this transition and its potential impacts, there may be no greater example of a development sector in need of an integrated solution.

While the potential for conflict between these two objectives is high, it is not inevitable. Studies indicate that projected renewable energy targets outlined in Nationally Determined Contributions (NDCs) to the Paris Agreement can be met nineteen times over solely on converted lands, and that five of the top ten global emitters are able to meet their 2050 NDC goals without damaging wild lands (Boruch-Mordo et al. 2019).

The key challenge will be to develop planning frameworks that lead to this desired outcome. Energy installations are often managed on a project-by-project basis and include a limited analysis of impacts on the surrounding environment. A planning framework is needed that considers multiple land-use objectives at a scale that can allow for flexibility and optimization. Integrated landscape management (ILM) has been identified as a potential such framework.

### Renewable Energy Planning with Integrated Landscape Management

Integrated landscape management is defined by five core elements (Denier et al. 2015). Below, these elements are listed, along with the potential impacts of energy inclusion.

| ILM Element | Energy Impact |
|---|---|
| Shared or agreed management objectives that encompass multiple benefits from the landscape | Increasing access, quality and quantity of electricity can positively impact many objectives within a landscape. As a result, sufficient and reliable energy access should be a core management objective within the landscape. |
| Land use practices contribute to multiple landscape objectives | Agriculture<br>- Field work, irrigation, processing, storage, distribution<br>Conservation<br>- Reduced pressure on natural areas for resources<br>- Conservation operations support<br>Livelihood<br>- Reduced manual labor and time commitments<br>- Trained local renewable energy technicians<br>Sustainable Development Objectives<br>- Success of the three previous objectives creates a strong base for sustainable development and green growth<br>- UN Sustainable Development Goals, Nationally Determined Contributions (Paris Agreement), Green Growth Targets |
| Synergies are captured and trade-offs reduced among objectives across the landscape | Landscape-scale energy planning can reduce trade-offs by prioritize installations:<br>- Away from wild and agricultural lands<br>- On previously-disturbed lands, brownfields, existing buildings |
| Markets, policies and programs are shaped to achieve a diverse set of landscape objectives | Access to electricity can create opportunities for a far greater set of objectives, and can help landscapes meet standards that can open up new markets. |
| Collaborative processes guide multistakeholder governance | Energy development is not and end but a means to elevate a diverse set of landscape objectives. Renewable energy, in particular, is a common pool resource, the management of which should be collaborative and governed by a diverse group of stakeholders within the landscape. |

Table A1: ILM elements (Source: Denier et al. 2015) and energy impact (Source: author)

## Benefits of Renewable Energy Planning at the Landscape Scale

The landscape presents an opportune level at which to plan for renewable energy installations. This scale is large enough to produce utility-scale generation, taking advantage of economies of scale, while still allowing for distributed installations that provide greater siting flexibility and access than conventional, centralized power plants (Alanne & Saari 2006).

## Benefits to Other Landscape Objectives

**Conservation** is at the heart of landscape-scale planning (Kiesecker et al. 2010). The ability to plan at an ecologically-significant scale can lead to far more successful conservation outcomes, as it can limit fragmentation and maintain whole, fully-functioning ecosystems. This emphasis on avoidance is paramount, as it is the first order of the mitigation hierarchy, a common tool used in conservation. Planning on a site-by-site level would require greater compromise, leading to lower-level outcomes that do not offer the same conservation value. Below are detailed descriptions of the various levels of the mitigation hierarchy and the benefits of planning at the landscape scale.

### Avoid

The primary benefit of landscape-scale planning is to avoid conflicts with other land-use objectives. This can be done by identifying areas where installations should be avoided, such as protected areas, key biodiversity hotspots and wildlife corridors. The multi-stakeholder platform is key for identifying these zones, as a diversity of stakeholders are able to voice their concerns and come to consensus on areas suitable for these installations. Modern mapping and geographic information systems (GIS) technologies have also assisted greatly in the ability to plan at the landscape level. Figure A1 illustrates the various variables that can be mapped to evaluate appropriate sites for solar power development, using California as an example (Hernandez et al. 2015).

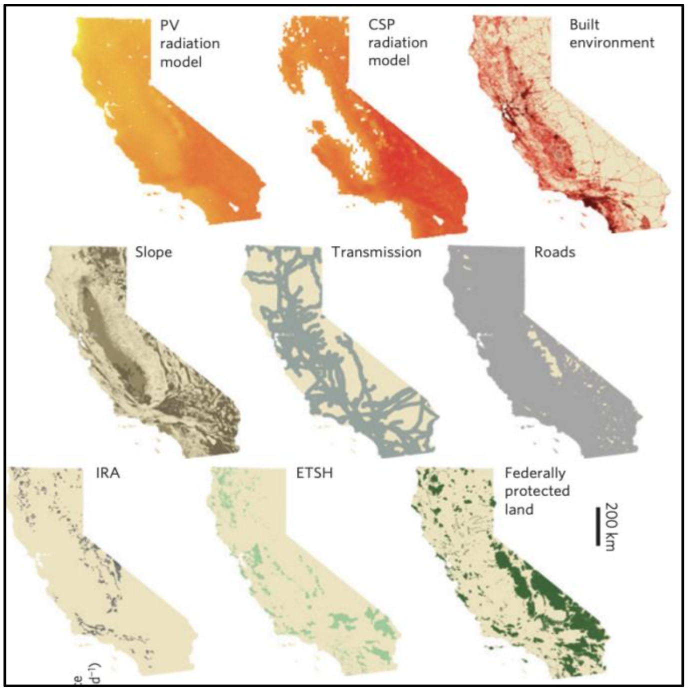

Figure A1: Common variables used for integrated energy planning analysis (Source: Hernandez et al. 2015)

Instead, siting should be encouraged on lands that have limited value for conservation or other productive uses. One such strategy is to install renewable energy systems on brownfield sites. In the United States, alone, there are currently over 450,000 such sites, which are too contaminated for agricultural production and are often too expensive to restore (Lisell 2017). Other strategies include siting installations on rooftops or artificial water bodies, which can serve to reduce heat gain in buildings and evaporation from reservoirs, respectively (Hernandez et al. 2019).

Figure A2: Left - Kopila Valley School in Surkhet, Nepal sites their solar on rooftops to minimize land disturbance. Center - Solar installation on a brownfield site in Colorado. Right - Panels installed on ponds or reservoirs (Sources: author, Kiatreungwattana et al. 2013, and Hernandez et al. 2019, respectively)

### Mitigation

Where renewable energy systems are installed, there are novel strategies in various stages of development and implementation that allow for dual uses from a single plot of land. This stacking of functions allows for greater land-use efficiency, and has minimal impact on the primary function of the land (Hernandez et al. 2019). Figure A3 illustrates several of these techniques.

Figure A3: Left - A single plot of land operates simultaneously as a solar facility and grazing land for sheep. Center - Solar panels installed in the unused area of a center-pivot crop field. Right - Wind turbines placed to minimize footprint on agricultural land (Sources: left - Cornell Small Farms Program; center - Hernandez et al 2019; right – Inman 2011)

### Restore

Restoration needs should be minimized by attempts to accomplish the two higher orders of the hierarchy. This being said, solar panels have been shown to aid in the restoration of pollinator habitat (Hernandez et al. 2019), and off-shore wind installations can limit the use of trawling practices, eliminating a damaging fishing practice and allowing these areas to be restored (Gill et al. 2020).

### Offset

By employing the mitigation hierarchy at the landscape scale, offsets have been reduced to the lowest possible level. Undoubtedly, some will be needed. However, this will be a fraction of what would be needed if these projects were planned on a site-by-site basis.

**Agriculture** is another major land-use objective common to integrated landscape-scale planning, and there are a number of ways in which the increased availability of electricity can benefit agricultural objectives. Electrification at various stages of agricultural supply chains can save time, reduce waste and add value. For instance, electric water pumps can increase irrigation capabilities and allow for greater yields (IRENA 2016). Electrification can also increase efficiency in processing, reducing labor and allowing for greater time to be spent adding additional value to an agricultural initiative (UN FCCC 2019). Electricity can also improve refrigeration and prevent spoilage, which can have profound impacts on production, profitability and food security (ibid).

**Economic development and livelihoods** are closely linked with agricultural production and ecosystem health. Actions that protect the proper functioning of natural systems and food production will ultimately lead to greater resilience and growth opportunities. The strong relationship between the Human Development Index and energy access suggests further that energy should be a major consideration in integrated landscapes.

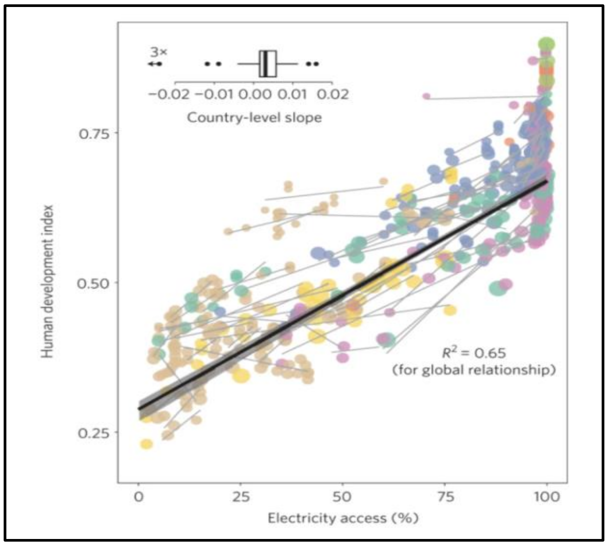

Figure A4: Relationship between human development index and electricity access by country (Source: Alstone et al. 2015)

## Status of Energy Considerations in Integrated Landscape Initiatives

Despite the importance of considering energy needs and generation potential within an integrated landscape, surveys of Integrated Landscape Initiatives (ILIs) performed over the last decade indicate that energy is not often a central consideration. In South Asia and Southeast Asia, only 24% and 3%, respectively, of 166 ILIs surveyed included stakeholders from the energy sector (Zanzanaini 2017). In Latin America and Africa, less than 20% of the 191 ILIs incorporated energy into the planning process (Estrada-Carmona 2014, Milder et al. 2014).

## Case Study - Karnali River Basin as an Integrated Landscape

The Karnali River in western Nepal is one of the last free flowing rivers in the region. It stretches over five hundred kilometers from its headwaters in the Himalayan mountains until it converges with the Ganges River in the plains of northern India. It is home to a variety of threatened species, such as the Golden Mahseer, Gharial crocodile, and Gangetic River Dolphin, and supports the largely agrarian livelihoods of thousands of people along its banks. At the same time, the Government of Nepal has identified domestic hydropower as a major pathway to economic development, and has subsequently approved the development of a number of hydropower projects along the Karnali River and its major tributaries. Conservation experts argue, however, that such developments will cause significant disruptions to the region's ecosystems and to the livelihoods of its people. They also argue that this need not be the case. By taking a broader, landscape-scale view of energy potential within the river basin, it is believed that a comparable amount of energy can be generated by pursuing a more diverse mix of renewable energy sources that are strategically placed to limit land-use conflicts. Studies performed by USAID, DAI and WWF in 2020 (Martin & Grill 2020) indicate that, by taking into consideration the broader impacts of large-scale hydropower development and, instead, employing a mix of renewable energy technologies within the Karnali Basin, the main stem of the Karnali River could remain free flowing.

## Call to Action

The energy transition currently underway is essential to limit the impacts of anthropogenic climate change and provide more equitable access to electricity for communities around the world. However, it is vital that this transition be done in such a way that it limits harm to other important land-use objectives, most notably biodiversity conservation and agricultural production. Including energy planning within an integrated landscape management framework can help achieve this goal, while simultaneously enhancing other objectives within the landscape.

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