Energy Landscapes

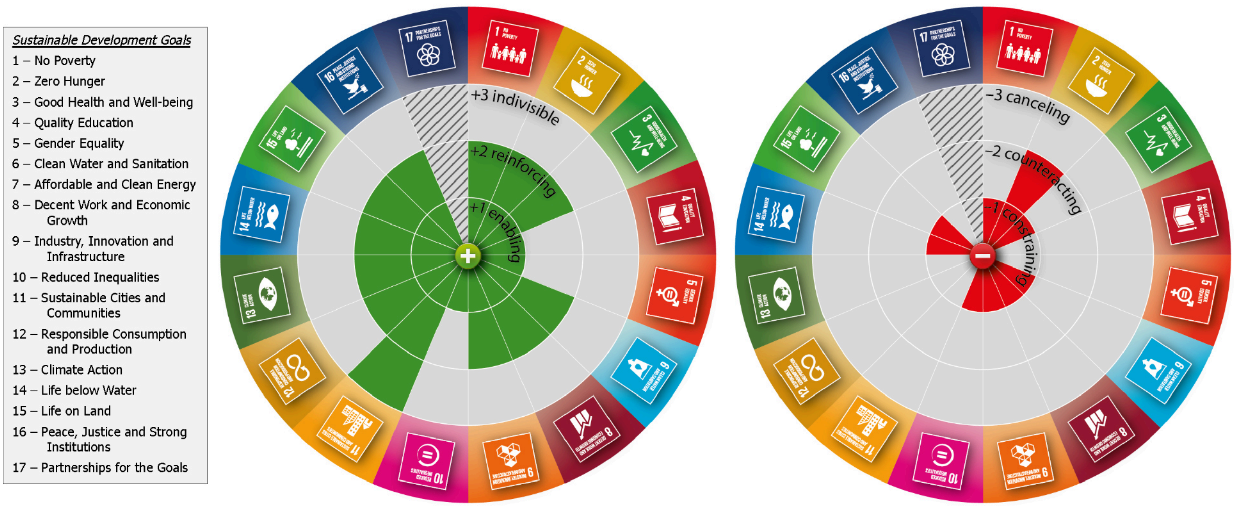
Chapter author

Dr. Dorothee **Apfel,** Nürtingen-Geislingen University, Germany

Introduction

Europe is currently facing major challenges with regard to its energy supply. On the one hand, the challenge of climate change must be met more quickly and effectively, while on the other, Russia's war against Ukraine has painfully highlighted geopolitical dependencies. Both challenges require sustainable energy solutions. These solutions require more energy efficiency and a shift from fossil fuels to renewable energies (RE).

As part of the sustainability challenges humanity is facing, the importance of RE is reflected in the UN's Sustainable Development Goals (SDG). The cross-cutting nature of *SDG 7 Affordable and Clean Energy* becomes apparent, when investigating its linkages with the other SDGs. While most of them are positively facilitated by SDG 7, there are also conflicting objectives, particularly with *SDG 2 Zero Hunger* (see figure), which is directly related to the availability of agricultural land (McCollum et al., 2018).



Positive and negative relations between SDG 7 and other SDGs*, Source: McCollum et al., 2018, p. 13.*

In Europe, countries have set targets to reduce emissions and progressively implemented measures to move towards more sustainable energy systems. The European Green Deal and the 'Fit for 55' package, which adapts existing climate and energy legislation to meet the EU's new target of reducing greenhouse gas (GHG) emissions by at least 55% by 2030, have boosted the European Union's energy agenda.

This decarbonisation changes the energy system as we have known it since industrialisation. Energy systems based on renewables are decentralized and vary in scale. They can be used to generate energy in places where there was previously no potential for energy generation, either because there were no fossil fuels or because local density was considered to be too low. These changes in generation systems and infrastructures come along with transformation of land use, reshaping European landscapes (Frolova et al., 2019, p. 318). But this is not unique to the current energy transition, energy and space have been constantly changing each other over history. Each era and dominating energy source has had its own spatial characteristics. (Sijmons, 2014, p. 10). Thus, each RE technological system – solar, wind, bioenergy, geothermal, hydro – brings specific impacts, depending on the context of the landscape they unfold in (Frolova et al., 2019, p. 318) (Enserink et al., 2022, p. 1).

The pace of the transition to renewable energy has accelerated in recent years and has gained further momentum in Europe in particular since Russia's war on Ukraine. This is linked to a growing interest in understanding the landscape-energy nexus. REs are the visual proof that our energy is generated somewhere, which reminds us of the effects and consequences of our energy-intensive lifestyles. Beyond this visual reminder, energy is immanent for socio-economic practices, attracting investments, creating jobs, shaping new stakeholder networks, demanding new integrative spatial policies and forms of governance (Nadaï & Van Der Horst, 2010, p. 144). This composition of energy systems and spatial changes is recognized in the concept of energy landscapes, which is defined as *"multilayer landscape characterized by one or more elements of the energy chain comprising combinations of technical and natural sources of energy within landscape. Energy landscapes are best understood in terms of their multiple spatiality, including material and immaterial dimensions."* (Frolova et al., 2019, p. 318).

Making the case for a positive transition pathway: Energy landscapes are shaped by the perceptions and goals of a wide range of stakeholders. They involve different ideas about how landscapes are used, shared and valued. Both in rural areas and in urban-rural dynamics, energy transition processes offer the opportunity to reshape energy-related socio-economic conditions. In such productive landscapes, agriculture and the renewable energy sector do not simply coexist. Rather, a co-evolution of diverse landscapes takes place based on the prevailing local characteristics. An interplay of agriculture, forestry, energy, water and socio-economic parameters empowers local communities to shape their future without neglecting their heritage. Rural areas can be the beneficiaries of new value creation and employment effects. In densely populated areas where energy consumption is concentrated, urban energy landscapes can be designed to create sustainable energy systems for self-sufficiency.

This chapter explores renewable energy landscapes at different scales: First of all, it is analysed how they affect traditional rural landscapes by looking at four aspects influencing landscape characters: *direct impacts* with expected impacts and internalized costs, *indirect impacts* with variable effects and externalised costs, mitigation measures helping to overcome the negative direct and indirect impacts (as suggested by Pasqualetti, 2012, p. 13; Roth et al., 2018) as well as potential positive impacts (Roth et al., 2018). Second, the case of a specific project shows how the transformation has already been successfully achieved at local level.

The renewable energy landscape as a technological landscape
In the design of sustainable energy landscapes, ethical considerations, aesthetic challenges and planning and design issues are of particular importance, as they are linked to changes in land use (Frolova et al., 2019). Thus, the focus of this part is on the technological and the spatial characteristics of RE landscapes. In order to understand the changes in landscape character resulting from the transition to renewable energy, it is important to consider which negative effects can be avoided and how positive effects can be enhanced (Frolova et al., 2019, p. 319). The specific effects of each RE technology on the landscape, which then characterize these technological RE landscapes, are summarized below as described by (Roth et al., 2018).

Energy landscape examles pictures 1 + 2

Geothermal energy landscape examles pictures 3 + 4

As for the **direct landscape impacts** of bioenergy, there is a trend to large industrial scale facilities, which evokes a change in agricultural cultivation. Pre-existing agricultural activity is converted into new, often more intensive forms. So-called energy crops, such as maize, are often grown in monocultures. Also scale-dependent impacts of processing facilities and technical infrastructure also change the landscape character. **Indirect landscape impacts** become evident in changes in the ecosystem, altering flora and fauna, which might lead to a loss of biodiversity. The operation of biogas plants might cause water contamination, gaseous emissions, unfamiliar smells and increased traffic due to biomass transport. The shift from low-height crops to above-eye-height crops might influence intervisibility. To **mitigate** these impacts, the cultivation of energy crops is best on marginal or abandoned land. Additionally, the usage of a wider range of substrates, e.g. domestic, economic and forest waste, manure and residues is favorable. Closing the biomass loop, in the sense of a circular economy does not only help to mitigate the impacts, but also holds potentials for **positive** impacts, such as the recovery of fertilizer from the fermentation residues.

For geothermal energy, the **direct impacts** are closely related to technical infrastructure. The drilling of wells, the installation of pipelines and the construction of access roads are spread over kilometers. Visual quality is affected by the industrial appearance of power plants (steam generators, cooling towers, piping, generator buildings). The process of exploiting geothermal energy itself has an **indirect impact** on the environment: thermal changes in the ground might influence slope stability and trigger landslides, fluid extraction affects land subsidence and the reinjection of heat might alter hot springs and fumaroles or even cause earthquakes. To **mitigate** the effects of landscape quality, measures are smart drilling, underground pipelines, the application of colors that harmonize well with the landscape and the design of inconspicuous buildings. Also, the reclamation of destroyed vegetation with local species, helps to mitigate impacts. Although infrastructure is a major feature of geothermal landscapes, there are examples of regions that have managed to make positive use of it e.g. using the spill water of geothermal power stations in a SPA which has become a major tourist attraction in Iceland.

In the case of hydropower, serious impacts can be identified, particularly in the case of large projects. **Direct impacts** are similar to those of geothermal energy, mainly related to the technical infrastructure of plants. The presence of large structures, such as power stations, dams, artificial reservoirs, pipes and transmission lines significantly alters landscape features. Villages can even be flooded to create water reservoirs (see Picture 5). Pipes, turbines and pumps also have a direct impact on the subsurface. Smaller installations, such as run-of-the-river systems with a canal or pipe that turns turbines, have less impact but also require infrastructure systems. The **indirect effects** should not be underestimated and can go far beyond local power generation. Building reservoirs can dry up large watercourses. The damming of lakes and rivers can lead to bank erosion, which can also occur downstream of power plants. Drastic changes in water-related ecosystems (physical and chemical) can be triggered by changes in flow velocities. Cases of large hydropower dams with extreme challenges and impacts can be found around the world. The most famous are the Balbina Dam in Brazil, the Three Gorges Dam in China or the Grand Ethiopian Renaissance Dam, all of which have serious environmental and societal impacts and even cause political tensions with neighboring countries. These serious impacts can be **mitigated** by using existing infrastructure and reservoirs, and by seeking underground solutions for power plants and transmission lines. Simple solutions such as fish ladders are also available on a small scale. While the impact may seem enormous, depending on the original state of the landscape and its cultural value, artificial lakes are often perceived as a **positive** attraction. They often become major regional attractions, boosting tourism and local incomes.

Hydro energy landscape examles pictures 5 + 6

Wind energy landscape examles pictures 7

Wind energy is the technology with which the general public has the most emotional attachment. Wind turbines have a striking **direct** visual impact due to their height. They range from single turbines to wind farms of 20-30 turbines. They can be off-shore or on-shore, in open fields or in forests. Wind turbines are accompanied by infrastructure development such as access roads, power lines, buildings, night lighting for aircraft, shadow flicker, etc. The actual visual appearance depends on the orientation of the wind turbines, the type of landscape, the size of the wind turbines and the proximity of settlements and cultural heritage sites to the wind turbines.

The change in landscape character appears most striking in coastal areas and mountain ridges. **Indirect impacts** are mainly related to risks to birds and bats, noise pollution and habitat destruction and degradation. Impacts on water bodies such as groundwater, surface water and also coastal erosion. As a **mitigation strategy** and to increase acceptance, it is sensible to avoid the visibility of sensitive viewpoints. In addition, sites and their design can be adapted to the surroundings to better align with the landscape, for example by using different shades of color. Landscapes where technical installations are already present can be adapted more easily, as people already associate them with industrial structures or infrastructure. In contrast to emotional conflicts over wind farms, they can promote local identities by creating a **positive** identification with progress, technological efficiency and climate friendliness. In coastal areas, they can also help to create new sources of income and new habitats by reducing pressure from shipping.

Solar energy is a widespread form of RE across the globe as not the highest amounts of solar radiation are needed for economic operation. They can be integrated in different scales, from the residential balcony power plants to solar roofs, and industrial parks to concentrated solar power systems. Because

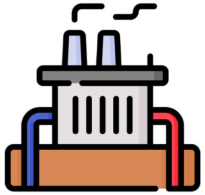
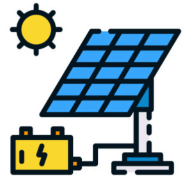
Solar energy landscape examles pictures 8 + 9

of the different scales, the **direct effects** vary greatly. Impacts are evident for larger scale stations. For example, large-scale ground-mounted PV has implications for land use, biodiversity, water-related aspects and visual-aesthetic challenges. Glare may also be an issue. In the case of concentrated solar thermal power plants, the main direct impacts are glare from mirrors, the visual impact of tall cooling towers and the challenges of water management in arid regions.

Mitigation can include siting larger solar fields in former mines, industrial areas and low visibility locations, design to fit the landscape in which it is embedded and integration into buildings. There are **positive** options for dual use of land, such as coexistence with agriculture and grazing, which could lead to an increase in crop production, and the structures of PV can be used for land stabilization. In urban areas, PV panels can be used to provide shade or to define certain areas such as public spaces, cycle paths, etc.

In summary, all energy production, including renewable energy, is closely linked to the landscape. For each RE we can identify significant direct and indirect impacts, but we can also identify ways not only to mitigate them, but also to take advantage of the positive development opportunities they offer (see figure on the following page). Landscapes are thus areas of both impact and action.

Landscape planning at all levels can help to minimize these impacts, promote transparency and accountability, and increase social acceptance. Landscape architects and planners are therefore required to contribute to and develop integrated planning and design practices in order to facilitate the rapid transition to renewable landscapes. However, achieving the goal of a comprehensive assessment of the social and environmental impacts requires interdisciplinary understanding and cooperation. It is therefore important to think in terms of multifunctional synergies when developing renewable energy projects. Knowing about the influencing aspects of landscapes with renewable energies, we look at a success story in the next section.

					
Landscape impacts of RE	**Bio Energy**	**Geothermal Energy**	**Hydro Energy**	**Wind Energy**	**Solar Energy**
Direct landscape impacts What are the expected impacts?	• Visual impacts and land use change due to monocultures • Agricultural intensification • Trend to large industrial scale	• Infrastructure development • Industrial looking generation stations	• Large facilities significantly alter landscape features • Underground impacts • Flooding of villages and structures in place	• Visual impact due to great height • Requires the development of a diverse infrastructure • Change in landscape character, esp. in coastal zones and mountain ridges	• Alteration in land use, biodiversity and water-related aspects • Glare from panels and mirrors • Concentrated solar thermal with visual impact of tall towers
Indirect landscape impacts What other variable imapcts might occur?	• Effects on soil and water, gaseous emissions, unfamiliar smells • Changes in the ecosystem, altering flora and fauna, loss of biodiversity • Intervisibility due to high crops	• Hillside stability and landslides • Earthquakes • Alteration of hot springs and fumaroles	• Drying up of large watercourses • Erosion of the shoreline due to the dams and the river banks downstream • Changes in water-related ecosystems due to rapid flow	• Hazards to birds and bats, destruction and degradation of habitats • Impacts on ground and surface water • Coastal erosion	• Shadow casting • Change in micro-climate
Mitigation strategies How can the negative impacts be overcome?	• Biorefineries with closed local loop can limit impacts • Usage of diverse substrates, e.g. domestic, economic and forest waste • Production of energy crops on marginal or abandoned land	• Restoration of vegetation • Intelligent drilling, underground pipelines, buildings and colors	• Use of existing infrastructure and lake reservoirs • Give preference to underground solutions • Simple solutions like fish-ladders	• Landscapes with existing technical installations can assimilate easier • Avoid visibility from sensitive viewpoints • Location and design aligned to surrounding landscape	• Appropriate sitting in sites with low visibility • Integration into buildings • Dual use of land
Positive impacts What positive synergies can be expected?	• Use of waste in a circular economy sense • Production of local fertilizer from digestat	... hard to envisage...	• Water reservoirs turn into a regional tourist attraction	• Windfarms can facilitate local identities • Coastal areas benefit from new source of income and development of new habitats	• Co-existence with agriculture and grazing • Usage of construction for land stabilization • PV as spatial definition of certain areas

Summary of the four aspects influencing landscape characters.
Source: Author, adapted from Roth et al., 2018. Icons designed by bsd or freepik from www.flaticon.com.

Bundorf Solar Park, picture 10

Example of a successful transition case: Bundorf Citizen Solar Park

Having looked at the different energy landscapes and their special features, the question arises as to how the energy transition is already being implemented, especially as the energy transition rests on the shoulders of different actors. As an example of successful decentralized and locally anchored renewable energy generation, the approach of energy cooperatives is presented. In such energy coops, private individuals come together to jointly generate renewable energy. With their democratic participation model, they ensure that the energy transition is implemented in a sustainable way.

This is illustrated by using the example of solar energy cooperatives in Germany. They have become a symbol for a citizen-oriented energy transition in Germany. The large number of participants shows that citizens can and want to play an active role. In 2022, 220,000 people in Germany were engaged in 877 energy cooperatives. In total, 8 TWh of renewable electricity was generated, which corresponds to a 3% share of electricity generation in Germany in 2022. Participation as members was already possible starting from €732, while the actual participation per member was €5,239 (DGRV 2023). The implemen-tation of the projects involves new forms of local governance, based on the strengthening of existing and the initiation of new local networks. By working closely with these networks, energy cooperatives contribute to regional value creation. This means that local contractors install the systems, existing land is used optimally, and local banks finance and advise the projects. In addition, profits from production stay in the region and are invested in new projects (DGRV, 2023).

Projects are implemented in close cooperation with local communities. As Schmid et al.(2020) found in an empirical study, municipalities are members of 60% of German energy cooperatives. This constellation can benefit from a good exchange of information, the consolidation of networks and thus the building of trust.

A Bavarian citizens' cooperative – EGIS eg – took the energy transition into its own hands in 2013, growing to a cooperative of 2,400 members within 10 years and now implementing projects beyond the district. They are committed to ensuring that the large-scale facilities blend in harmoniously with the mostly rural surroundings. The concerns of community represen-tatives and local residents regarding the landscape and agricultural land on which the solar farms are to be built are therefore taken into account at the project planning stage. This also applies to the greening concepts to be implemented (EGIS a, 2023).

One of the flagship projects is the Bundorf Citizen Solar Park, which was commissioned in 2023. The

Excerpt from the development plan for the Bundorf citizen solar park. *Source: VG Hofheim (2022)*

project covers an area of 125 hectares. With an installed capacity of 125 MWp, it will generate enough electricity to supply around 37,500 four-person households. In addition to the solar park, a district heating network was built to supply residents and municipal buildings. An e-charging infrastructure has also been created.

The PV park consists of six sub-fields (see Fig. 2), which are planted and managed differently. Long-term monitoring is used to investigate which areas are best suited for nature and thus biodiversity to recover and spread. Special emphasis was placed on lean meadows, which are particularly threatened with extinction, but which also have a high level of biological diversity. In addition, due to the size of the project, a wildlife corridor is in place (EGIS b, 2023).

Under the bottom line

In order to develop measurable KPIs for the uptake of the energy transition and its impact on the landscape, it is worth taking a look at the existing literature. On the one hand, renewable energy systems must make an equivalent contribution to achieving the energy supply targets as fossil systems: security, affordability and environmental compatibility. On the other hand, the decarbonization of the energy system brings in new players, new business models, decentralization, and also new customer behavior - imagine operating your own PV panel and adjusting your energy consumption patterns. We also need to think beyond these aspects when we want to look at the energy landscape economy. We have to think about the SDGs that may benefit from renewable energy systems, and those that may come into conflict (see first figure on SDG goal conflicts).

There is no single list that researchers and policymakers agree on when it comes to key figures for renewable energy landscapes. This is certainly partly due to the enormous scope of energy – reducing CO2 emissions in all sectors – but also due to its high interdisciplinarity. We have to admit that it was not possible to identify such a set in the context of the TELOS ERASMUS project, but we still have very good opportunities to cover them.

The reports published by the International Renewable Energy Agency (IRENA, 2022) [1], as well as scientific articles for smart cities (Angelakoglou et al., 2020) [2], allow us to explore appropriate KPIs for our context.

The table below provides an overview of the KPIs based on the two sources [1]/[2] mentioned above. The list is not exhaustive. It intend to illustrate appropriate KPIs. As it is primarily the system characteristics that can be influenced, it is necessary to consider which aspects of the indicators can be used to measure them. KPIs should be able to indicate the extent to which change has occured..

In the case of defined targets, as in the case of the energy transition at EU, national, regional and city levels, they can provide information on the degree of target achievement. It is particularly important to select factors for which data can be generated and which are comparable. It is not trivial to find the appropriate KPIs for the chosen research area and the corresponding scale of the perspective taken on that area. This depends very much on the research question being asked. The following list of KPIs has been identified as important in the context of landscape economy.

1	Share of renewables in electricity generation (%)	***(1)***
2	Share of renewables-based electricity generation in electricity consumption (%)	***(1)***
3	Addition of renewable energy capacities (GWh/year) by technology	***(1)***
4	Investments in renewable energy generation (EUR/year) by technology	***(1)***
5	Share of renewables in final energy consumption (%)	***(1)***
6	Development of heat pump stock (number and installed capacity/year)	***(1)***
7	Development of PV collectors (m^2 and installed kWp/year)	***(2)***
8	Percentage of positive energy buildings (%)	***(2)***
9	Greenhouse gas emissions (kg CO_2/year)	***(2)***
10	People benefiting from the project (#)	***(2)***
11	Connection to the existing cultural habitat (Likert scale)	***(2)***
12	Local community involvement in the implementation and planning phase (Likert scale)	***(2)***
13	Degree of satisfaction (Likert scale)	***(2)***
14	Social compatibility (Likert scale)	***(2)***
15	Technical compatibility (Likert scale)	***(2)***
16	Market demand (Likert scale)	***(2)***
17	Diffusion to other locations (Likert scale)	***(2)***
18	Environmental impact assessment according to applicable law, in accordance with Directive 2011/92/EU	own

KPIs for renewable energy landscapes. Source: author based on IRENA (2022), Angelakoglou et al. (2020).

Suggest research and analysis tasks for learners

"With the energy transition in mind, we can look at the same space through new eyes, and discover something there that had not been seen before: different spatial qualities, different forms of using space and different perception of space" (Sijmons, 2014, p. 11).

Two basic questions can serve as a good starting point, especially when working with students who are just beginning to engage with the complex issue of an ever-changing energy landscape:

- What kind of **energy future** do we envision as individuals and communities, and at different regional scales? Past developments shape our future options, which need to be embedded in existing landscapes.
- What kind of **governance,** regulatory or planning systems are needed to steer the processes to make the energy transition fast and yet sustainable for the European landscapes? (Nadaï & Van Der Horst, 2010, p. 153).

Deeper insights can be gained by looking at other pressing areas of social action: Questions of energy justice are also becoming increasingly important. Let's take the example of energy cooperatives. These are growing in rural areas.

- Who can actually participate in the energy transition? Who can actively participate in them? What about tenants in blocks of flats in cities?

Another important question is how we can make intelligent use of the space available. Given that renewable energy takes up more space (m2/kWh) than fossil fuels (Sijmons, 2014), we need to think more in terms of multifunctional systems so that space can be used twice in the future.

- Which conflicts can arise from multifunctional systems and what are the planning challenges?

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Pictures

1. Picture 1: Biogas Plant, author: Martina Nolte, Licence: Creative Commons by-sa-3.0 de (Last accessed 15.10.2024).
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