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Perspective

Social, Ecological and Economic Synergies of Forests for Sustainability Contradict Projects Involving Large-Scale Deforestation for Energy Production

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ABSTRACT: Good projects and solutions aiming at sustainable development must repair the damage done in past decades by being explicitly designed and monitored to achieve synergetic benefits for the environment and society. We identify environmental, social and economic aspects of sustainability in which enlightened forest management can increase the fulfillment of human and ecological needs and hence the quality of life of present and future generations. Projects aiming at energy production and profits at the cost of biodiversity, nature protection, and human health and well-being are therefore questionable and increasingly socially and politically unacceptable—especially where the viability of alternative options with better social and ecological footprints can be easily demonstrated. This is also true for renewable energy projects. The perspective presented here demonstrates how ostensibly renewable energy projects in natural areas, such as large-scale wind and solar power plants in traditional forests, which are planned, for example, in Germany, may be detrimental to ecological and social sustainability. Forests cut down for such projects are "non-renewable" within reasonable time-scales left to stabilize our climate and ecosystems. Such projects also impair the credibility of the proclaimed role model character and sustainability leadership of Global North countries, which can lead to negative implications for the protection of forests in tropical countries.

Keywords: Renewable energy; Deforestation; Sustainability; Synergies; Biodiversity; Quality of life; Conservation; Forest protection

1. Introduction

It is broadly acknowledged that forest areas play a crucial role in the social, economic and environmental dimensions of sustainability [1–3]. Consequently, counteracting deforestation has been an important global sustainability goal for many years [4,5]. The creation and maintenance of forests can foster valuable synergies for a possible future in which humans live harmonically in symbiosis with nature. Still, too often, economic decisions and actions impair this potential [6]. In spite of the broad international acceptance of the sustainable development goals [7] and international efforts aiming at the protection of existing forests, reforestation of destroyed areas, and planting and creating new additional forest areas, the global forest cover has nevertheless been declining continuously and still is [8–10].

Forests are crucial for sustainability as they represent important habitats of animals and plants and hence safeguard biodiversity [9]. The social benefits of forests include their cultural values and their significance in the preservation of traditions and identity of people [1,11]. Forest furthermore provides benefits for human health and well-being and, hence, quality of life, through offering natural spaces for mental restoration, stress reduction and physical activities in the context of nature experiences and tourism [12–14]. Economic benefits of forests include the generation of employment and income opportunities and the production of timber as an important basic economic resource.

There are also synergetic benefits that transcend the borders between single sustainability dimensions. For example, social and economic outcomes result from the health benefits for people achieved by the clean air provided through forests by airborne resorption of pollutants in the tree canopy [15–17]. Forests also have the potential to clean soils from

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pollutants via uptake through the root systems of trees and to improve soil quality and fertility [18–20] with ecological, social and economic implications. The effects of forests on global and local micro-climate climate are a further example of how forests can provide synergistic sustainability benefits in terms of the social, economic and ecological dimensions [21]. The environmental cooling effect of forests and trees by providing shade during heatwaves is valuable for human health. The absorption of CO_2 by trees can reduce atmospheric CO_2 concentration which has corresponding social, economic and ecological implications ([3,22,23]). So, in summary, it is obvious that forests synergistically reinforce the three main pillars of the ecological, social and economic dimensions of sustainability [24]. Table 1 accordingly summarizes some of the important sustainability benefits of forests.

Table 1. Benefits of forests for different dimensions and aspects of sustainability.

	Dimensions, Beneficial Aspects and Synergies	References
Social and cultural aspects		
*	**Forests as cultural heritage:** Forests are a crucial part of the natural and social-cultural heritage and hence play an important role in traditions, culture, identity and myths.	[25–27]
*	**Forests enhance the quality of life, support the reduction of stressand ameliorate mental problems:** Leisure activities in natural environments often avoid or reduce stress.	[3,13,28,29]
*	**Forests facilitate health through enabling physical activity:** Forest visits are usually connected to (more or less intense) physical outdoor activity. On the contrary, indoor leisure activities are frequently sedentary and thus obesity promoting (e.g., watching TV, use of computers/internet).	[12,30]
Economic aspects		
*	**Employment and income generation:** Forests offer possibilities for subsistence economies and employment opportunities.	[2,11]
	Resources: Forests generate economic resources such as timber and non-wood forest products	[2,31]
Ecological aspects		
	Biodiversity: Forests are natural habitats for plants and animals and hence safeguard biodiversity	[1,9]
	Water and humidity reserves: Forests bind humidity, have cleaning effects on water and store it, hence counteracting water pollution and overuse	[2]
Synergetic social, economic and ecological effects		
	Promoting health outcomes and economic benefits through clean air: Air pollution in cities is caused by traffic and industrial production. Forests offer clean air because of their distance to emissions and through direct removal of pollutants (→ Leaves directly resorb CO, SO_2, NO_2, ozone, and particulates.)	[17–20]
	Shading and cooling: Forests have a cooling effect and provide shade, which is particularly important during heat waves, where high temperatures promote suffering and increase mortality in cities.	[3,13]
	Removal of CO_2: Forests and trees absorb CO_2 from the air and hence lower atmospheric CO_2 concentration with social, economic and ecological implications	[3,22,23]
	Sustainable Forest-based tourism in natural landscapes offers possibilities for recreation and generates income in rural areas.	[32–34]

Note: ***** Generic terms are printed in bold and are then explained in more detail.

2. Synergetic Sustainability Benefits of Forests Require Their Protection

In consideration of the large synergistic sustainability benefits of forest, deforestation and projects involving deforestation constitute a serious threat to sustainable development. In ecological regard, deforestation is connected to the loss of bio-diversity, has negative climatic implications and deteriorates habitats and living conditions for plants and animals. In social terms, it has tremendous negative implications for human societies [4]. On the background of the large and synergetic climate and sustainability benefits of forests, a global forest transition that stops deforestation andsupports reforestation and forest creation is highly desirable [6,35,36]. Emerging energy projects involving substantial deforestation, for example, for the construction of large-scale wind energy or solar energy power plants in forests, are at odds with such a transition. They should accordingly be considered with great scepticism. Instead of achieving positive synergetic effects for sustainability, deforestation projects with an isolated focus on CO_2 reduction can involve negative effects on environmental, economic and social aspects of sustainability, including negative climatic effects as outlined previously.

In the current context of a project planning comprising the clearing of 370 hectares of mixed forest to build a photovoltaic plant near Bad Freienwalde in Brandenburg, Germany, therefore, even a representative of the Solar Energy Promotion Association Germany (SFV, Solarenergie-Förderverein Deutschland spoke out publicly ([37], p.1) against the project stating that: “We at the SFV have been fighting for the rapid expansion of photovoltaics in Germany for 36

years and also support the inclusion of conversion areas in the EEG's {German Renewable Energies Act} land use plan. But we firmly reject these plans!".

He provided two main reasons for this rejection. Firstly, the planning needs to be rejected for reasons of nature conservation, even more so as the mixed forest in question seemed particularly valuable in regards to biodiversity, and secondly because "the destruction of such a forest for a ground-mounted photovoltaic plant is likely to jeopardize the high level of acceptance that exists among the population for solar energy. This is a disservice {orig. Proverbial German term: Bärendienst, meaning "serving like a bear"} to the energy transition." [37] (p. 1). He thus called upon federal legislators "to clarify the provisions on conversion areas in the EEG, in such a way that the clearing of entire forests for large ground-mounted systems is excluded from the privileged status" not only to protect the forest-environments but also to ensure public acceptance of solar energy plants.

If the construction of large-scale wind turbines and solar power plants is connected to deforestation and destruction of natural, ecologically valuable paces of high biodiversity, such projects run diametrically against important ecological aims of sustainability [38–40]. Furthermore, large-scale wind turbines can reduce tourism demand and residential satisfaction [41–43] with negative implications for the economy and quality of life in affected regions. Accordingly, tourists' and locals' acceptance of renewable energy projects should always be carefully considered before the planning of such projects [44]. In most cases, better, superior alternative options are viable that can synergistically promote all three dimensions of sustainability as has been recommended for preferable sustainability-oriented measures [24]. Both solar and wind energy are generally accepted in Switzerland and Germany. Still, instead of acceptance, highly visible large-scale projects in natural areas such as the Alps or forests tend to be rejected by the resident population [37,43]. As power can also be harvested from rooftops and wind turbines may also be located offshore or on farm land previously used for monocultures with low biodiversity. Small-scale plants show lower impacts on the landscape and biodiversity and seem to offer more social benefits as ownership may be distributed over more people and social networks may emerge. The possibilities for achieving large-scale economic gains with small-scale energy production projects are limited, and such profits are presumably the main driving force for investors of large-scale projects requiring deforestation. Still, large-scale renewable energy projects that do not involve deforestation may well be equilibrated over the three main sustainability dimensions and may indeed achieve economic gains as well as social and biodiversity benefits. For example, photovoltaic power plants may even be combined with forestation in arboricultural agrivoltaic systems, which integrate PV power generation and, for example, apple-tree [45] or olive groves [46] in hot and dry regions where PV-based shading systems could be beneficial. Agrivoltaic systems may offer possibilities for combining food and energy production with positive synergistic effects for economic, social and ecological aspects of sustainability [47–49]. Forest gardens combining arboriculture and horticulture with agrivoltaic components may also be possible in this regard [50]. Achieving positive synergies for sustainability in social, ecological and economic regards through renewable energy projects seems possible.

3. Credible Sustainability Role Models and Public Protests

Further aspect requiring the stop of deforestation in favor of PV-plants and wind parks in progressive Western countries such as Germany is that they could, in this way, act as sustainability role models for other countries. Tropical countries are, to a considerable extent, failing in their efforts to achieve an end to deforestation [6,51] even though Northern countries and international NGOs aim to support the protection of forests. However, if Western countries urging tropical countries to protect their forest better, do not protect their forests, this may deteriorate their credibility and may eventually even elicit the impression that these Western countries aim to prevent the Southern countries from achieving the same progress, which they themselves have achieved. In this context, some people may even regard deforestation as progress or at least as an indicator. This raises the question of how a self-proclaimed sustainability-oriented country such as Germany can persuasively showcase the importance of forest protection to a highly forested country such as Brazil if its government and administrations grant permissions to manifold projects involving deforestation. There are many such projects in Germany with diverse aims ranging from highway construction, airport enlargements, flood protection, mining, industrial development, new settlements and city enlargement to solar and wind energy parks. Public protests of people aiming to protectforests have emerged in Germany over a diverse topical range of such projects, as shown in Table 2, as some citizens recognize the great ecological, social and cultural value of forests.

Table 2. Some examples of public protests against recent deforestation projects in Germany.

Topical Areas and Projects Involving Deforestation
Highway construction
Protest and forest occupation against the expansion of a motorway at Dannenröder Forst (Hessen, Germany)
"… Environmentalists have been protesting [against the felling] for over a year in Dannenröder Forst. The situation seems to be escalating from day to day. Fireworks are shot at officers, demonstrators speak of police violence." [52]
"… environmental and climate protection activists have been occupying the forest for more than a year and have set up tree house camps and numerous barricades there, which have been gradually cleared by the police since 10 November. This has repeatedly led to dangerous incidents. Two activists were injured in two crashes." [53]
Airport enlargement
Protest and forest occupation against the expansion of Frankfurt airport at Treburer Wald (Hessen, Germany)
"Trees are to be felled in the Trebur Oberwald forest to make way for Terminal 3 at Frankfurt Airport—but there has been renewed protest this week. Forest conservationists keep watch in the treetops near Zeppelinheim—and the activists have decided to stay." [54]
"Environmental activists are currently protesting against constructing the third terminal at Frankfurt Airport by occupying trees." [55]
"The police cleared a protest camp in a wooded area at Frankfurt Airport on Tuesday. The site, which the airport operator Fraport wants to clear in connection with the construction of the third terminal, was secured with a fence." [56]
Mining project
Protests and forest occupation against the clearing of Hambach forest for the mining of brown coal at Hambacher Forst (North Rhine-Westphalia, Germany)
"Thousands of environmentalists from numerous regions have protested against the planned clearing of the Hambach Forest. But even if the demonstrators can no longer stop the planned clearing of the ancient forest west of Cologne, they want to return. […] It was a broad, colourful and largely peaceful protest organised by around 5,000 people around Hambach Forest on Sunday." [57]
"… The German government has decided that Hambach Forest will not be cleared. A victory for the activists? They say no. And the protest continues. […] The excavators are about 50 metres away from the forest […] RWE [*Rheinisch-Westfälisches Elektrizitätswerk AG*] has moved closer and closer to the forest. "They have created facts," [...] The future of the forest is still unclear, even if it is not allowed to be cleared." [58]
Solar power plant
Protest against planning of the clearing of a mixed forest In Bad Freienwalde in Brandenburg to build a photovoltaic plant
"… As residents, we have made it clear at several meetings that we do not agree with the project […] According to reports, existing expert opinions also speak against a solar system. Quite apart from common sense! […] On June 3, we met with the citizens' initiative (BI) Pro Wald Hohensaaten, NABU, the Lower Oder Valley Nature Park, […] and other opponents of the project in the square in front of the church " [59]
Wind energy plants
Protest against a wind power plant with 18 wind turbines up to 240 metres high in Reinhardswald (Hessen, Germany)
"After more than 740 citizens had already campaigned against wind power in Hesse's fairytale forest at the beginning of February, the follow-up event yesterday attracted 720 critics to the Gottsbüren field area. The event was organised by the Free Voters Association (FWG) from Trendelburg and the 'Save the Reinhardswald' Organisation" [60]
Seven nature guides, some of whom have been offering guided tours and environmental education courses in the nature park for years, have now cancelled their cooperation with the park because the park administration is not opposed to constructing wind turbines. [...] Opponents [...] are criticising that trees are being felled for the large wind turbines and wide routes are being built in the forest area. Soil, groundwater and biodiversity would be affected and the concept against forest fires would be poor." [61]
Flood protection—dyke consruction
Protest against a dyke project at river Rhine for which a 60 metre wide and 3.9 kilometre long aisle woukd be cut through a forest park near Mannheim (Baden, Germany)
"In April last year, Mannheim citizens demonstrated against the dyke construction plans with a human chain. [...] The city of Mannheim is objecting to the Rhine dam redevelopment plans of the regional council on the southern bank of the Rhine, which would involve the felling of thousands of trees, some of which are very old and unspoilt. [...] The city is thus officially backing the objections and protests of citizens ..." [62]
City expansion—settlement building project
Protest against the felling of a forest area for expansion of the city of Freiburg, Baden, Germany
"Climate activists have been occupying trees in a forest near the new Dietenbach neighbourhood in Freiburg since Friday. They want to prevent trees from being felled over an area of around 3,000 square metres." [63]
Development/enlargement of industrial area
Protest against the clearing 5.6 hectares of the Lohwald forest (Bavaria, Germany) to expand a steel plant.
"...When activists from the Augsburg climate camp responded to a call for help from a citizen of Meitingen last Saturday (22 October 2022) and took the next train to Lohwald near Meitingen, a large contingent of police was already waiting for them. The citizen had called the activists to the scene because he discovered clearing work in the Lohwald forest early on Saturday morning—even though three lawsuits are pending at the Bavarian Administrative Court in Munich against the Lech steelworks' development plan, […] The steelworks want to increase the area's economic value by clearing the forest. Another plant is to be built on a small part of the cleared area; plans for the remaining area are in the works but have not yet been presented to the public. For residents, the Lohwald forest protects from the noise and emissions of the steelworks and makes an important contribution to the microclimate" [64]

Note: The quotations stem from online newspapers or other websites in German translated to English by the Author (classical page numbering does not apply).

4. Economic and Policy Considerations

It seems clear—based on the previous sections—that the social and ecologic benefits of forests are crucial and therefore, renewable energy production plants should be located outside forests, on land with less biodiversity, where they

have similar potential and emission reduction benefits. However, if renewable energy policies and laws do not require encompassing sustainability evaluations of corresponding projects, mechanisms addressing this aspect are missing.

Germany introduced intensive economic subsidies for renewable energy production. Already in 1991, an Act on Supplying Electricity from Renewables [Stromeinspeisegesetz, StrEG] was introduced, which ensured that electricity from renewable energy could be fed-in the electric supply network with fixed remuneration and also granted tax exemptions and direct subsidies to renewable energy projects [65]. In 2000, this law was replaced by the Renewable Energy Act (REA [German: Erneuerbare-Energien-Gesetz, EEG]), which has been revised and adapted several times to enhance the funding of renewable energy projects further. Again, a main instrument was to guarantee fixed feed-in tariffs for renewable energy producers. The corresponding incentives proved very effective in promoting the production of wind and solar power. For example, Germany now has the second highest capacity of photovoltaic power production per inhabitant (714 kw/1000 inhabitants in 2021) among all 27 EU countries, surpassed solely by the Netherlands (Figure 1). This makes Germany the largest solar power producer in the EU by far. Germany's overall share of electricity produced through renewable energy sources increased more than threefold in 14 years, from 15.2% in 2008 to 46.2% in 2022 (Figure 2). However, during this period, electricity prices in Germany increased strongly (Figure 2), and four private households are now the third highest in the EU (Figure 3).

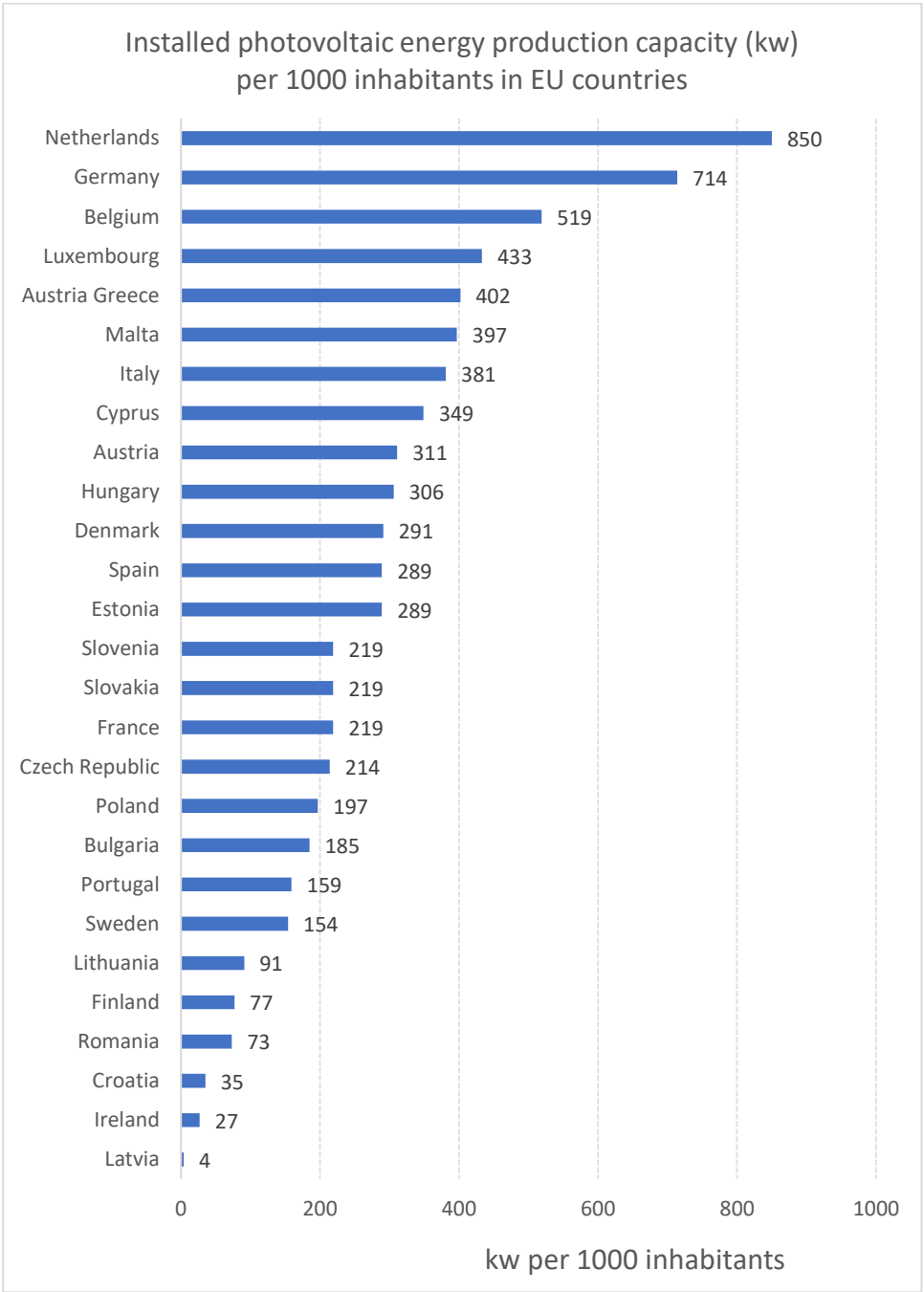

Figure 1. Installed photovoltaic energy production capacity (kw) per 1000 inhabitants in the 27 countries of the EU in 2021 (Source: [66]).

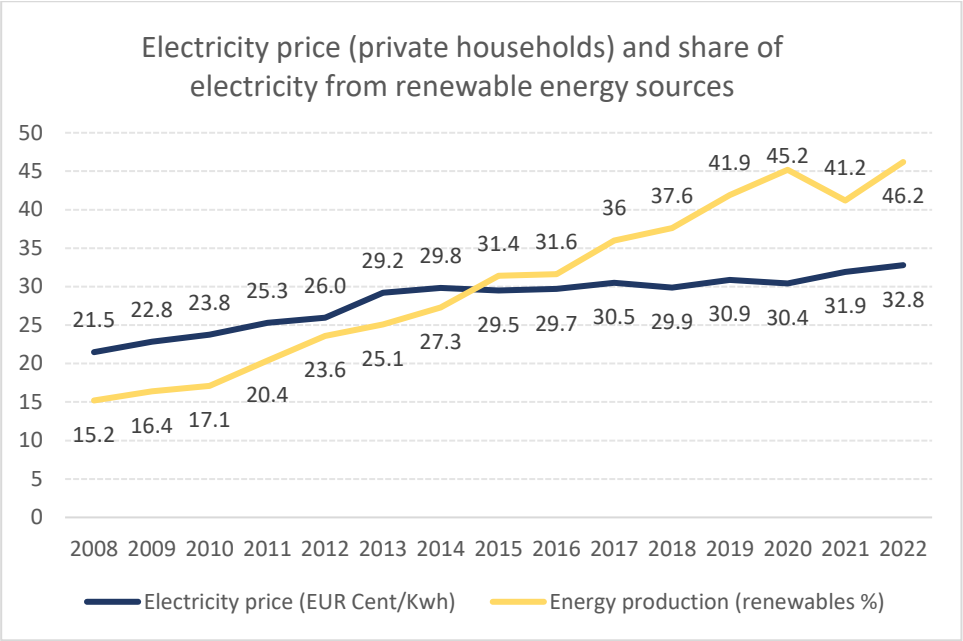

Figure 2. Contribution of renewable energies to covering the gross electricity consumption in Germany (Source: [67,68]) and development of electricity prices for private households in Germany (Source: [69]).

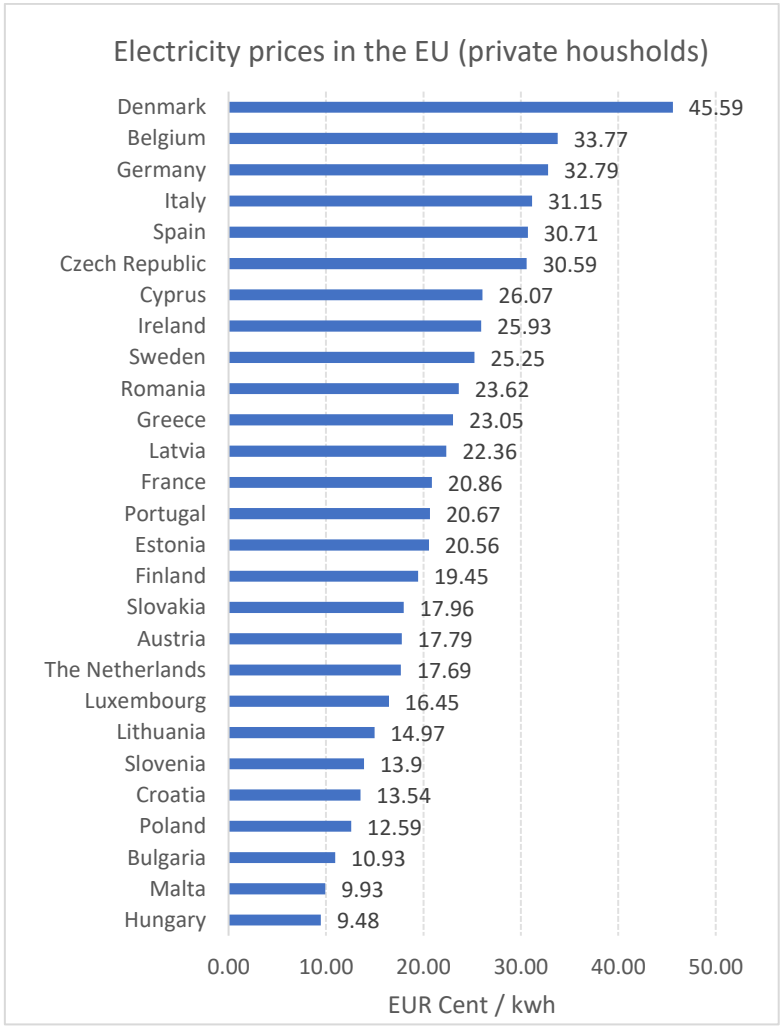

Figure 3. Average electricity prices for private households in the 27 countries of the EU in the first half year of 2022 (Source: [69]).

Despite the increase in the share of renewable energies coinciding with price increases for electricity, studies using resource economic models suggest that the promotion of renewable energy has reduced electricity costs for private households in relative terms, as even higher cost increases would have resulted in Germany without the expansion of

renewable energies [70,71]. However, this positive economic outcome of the German energy policy for consumers remains, unclear. Some authors nevertheless see the fixed feed-in tariffs of the REA, as well as the termination (respectively fading out) of the German engagement in nuclear energy during the Merkel era (in connection with the Fukushima catastrophe), as the main causes of the observed electricity price increases [72,73].

However, without any doubt, the German policy achieved its aim of promoting the production of solar, wind and other types of renewable energy. As a consequence, there resulted in a considerable reduction in the emissions of non-renewable energy production.

Still, the REA policy was not sensitive to the overall sustainability outcomes of single projects. Generally, conducting some form of overall sustainability evaluation for all projects applying for and receiving public funding oriented towards sustainability would be a good idea. This refers not only to the renewable energy sector. In the current context, for example, conducting a sustainability-oriented SWOT analysis for German renewable energy projects connected to deforestation (which are mainly solar and wind-power projects)—as presented in the following—could be a basis for rejecting public funding for such projects, if such an analysis indicates that they tend to impair sustainable development.

5. SWOT Analysis of Renewable Energy Projects Connected to Deforestation

A SWOT analysis investigates the *S*trengths, *W*eaknesses, *O*ptions and *T*hreads (respective risks) of certain projects, policies or strategies.

The strength of renewable energy projects lies in producing electric power, which partially substitutes conventional energy production with coal, oil and gas and, therefore reduces CO_2 and other emissions. A major weakness is the volatility of the power production from renewable sources, particularly when considering wind and solar power with phases of very high and low production.

These basic strengths and weaknesses also apply to wind and solar energy projects realized inside forest areas, which constitute the specific focus of the SWOT analysis presented in Table 3. However, as shown here, the substitution of forest areas by wind power or photovoltaic plants lead to the loss of manifold sustainability benefits of the cut-down forest areas. This represents a major weakness of such projects. The corresponding risks of such projects for sustainable development are particularly high because various current external trends such as increased land use demands, increased demands for wood, and direct and indirect climate change impacts (storms, drought, treepests) concomitantly put pressure on forests. Forests, therefore, need intense protection from deforestation and overuse.

The development of options to store energy from wind and solar power in times of overproduction and the further development of the electricity grid for the better distribution of renewable energy are currently the most crucial options for making the corresponding electricity production from renewables economically more effective in Germany. The main problem does not primarily lie in a scarcity of available space for production sites. Therefore the substitution of renewable energy projects requiring deforestation by similar projects outside forests represents the recommendable option. The situation is presumably similar in many other European and Non-European countries.

Table 3. SWOT analysis of renewable energy projects inside forest areas in Germany.

Internal Factors		**Internal Factors**	
Strengths (+)	**Sustainability Dimension(s)**	**Weaknesses (−)**	**Sustainability Dimension(s)**
1 Renewable energy production (photovoltaic, wind-energy) in Germany contributes to the domestic and European energy supply	Economic/social	1 Volatility: Low electricity production in times of scarce wind/sun and potential overproduction with strong wind/sun	Economic
2 Emission reduction (through substitution of non-renewables)	Ecological/social	2 Loss of renewable energy resources (energy wood production)	Ecological/economic
3 Economic gains for investors/owners	Economic	3 Loss of forestry income (wood production)	Economic
4 (Potential) Economic savings for consumers	Economic/social	4 Potential loss of other forest-related gains (e.g., tourism, non-wood forest products)	Economic
		5 Loss of removal of emissions (absorption of pollutants and CO_2 by tree canopy)	Ecological
		6 Loss of soil and water cleansing and water storage through forests (roots & canopy)	Ecological
		7 Loss of cooling effects during heatwaves (shading, micro-climate)	Ecological/ social

	8	Loss of natural spaces with considerable biodiversity, deterioration of landscape	Ecological/ social
	9	Loss of natural space for leisure activities connected to physical activity and stress reduction	Social
	10	See Table 1 for further beneficial aspects of forests lost through deforestation	Ecological/ economic/ social

External Factors		**External Factors**
Options (+)		**Risks (−)**
1 Development and expansion of energy storage facilities (e.g., hydrogene production) buffering periods of over-/underproduction of wind and solar power could increase economic effectivity	1	Manifold contemporary interests and developments lead to land use demands exerting pressure on forests (see Table 2), which increases the significance of the weaknesses listed above.
2 Further development of the power grid for the better distribution of (renewable) energy could increase the economic effectivity of renewable energy power plants	2	Increased demands for wood (e.g., increased use of wood for energy production) put pressure on forests, thus increasing the significance of the above weaknesses.
3 Use of non-forested areas for production of renewable energy (e.g., on roofs without photovoltaic installations) could harness the strengths of renewable energy production while circumventing the weaknesses listed above-right.	3	Climate change-related factors put direct (weather events e.g., droughts, storms) and indirect (forest pests e.g., bark beetle, ash dieback) pressure on forests increasing the significance of the above weaknesses.
	4	Climate changes involving more heatwaves and droughts directly increase the significance of the weaknesses 4 to 6 above.

Note: Numbers do not necessarily reflect priorities.

6. Conclusions

The main conclusion of the presented analytical argumentation is that forests are far too valuable for sustainable development to sacrifice for wind or solar energy production. To ignore this may lead to sustainability losses and endangers the currently high acceptance of renewable energy production among a population that highly esteems forests. Forests provide benefits for social, economic, and ecological aspects of sustainability as well as individual benefits for the health and well-being of humans [3,74] that need to be safeguarded to make sustainable development a truly life-enhancing and nature-protecting endeavor.

The presented SWOT analysis suggests that the required expansion of renewable energy production, which is important to reduce emissions, should primarily use spaces with less biodiversity and sustainability benefits than forests. The analysis also acknowledged that forests produce an important renewable energy resource, namely wood, which gets lost when substituting forested areas with wind or solar power plants.

Promoting renewable energy production while protecting our forests seems possible, as alternative space exists, for example, when considering a significant further increase of small-scale photovoltaic or wind energy production on existing buildings. In addition, the further development of options for the storage of renewable energy in times of overproduction and of the networks for electricity distribution could allow more flexibility in selecting suitable locations for larger-scale energy production outside forests.

These conclusions were drawn mainly at the hand of the example of Germany, but seem to more or less extent transferable to many other European and Non-European countries.

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