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Landscape as a Palimpsest for Energy Transition: Correlations between the Spatial Development of Energy-Production Infrastructure and Climate-Mitigation Goals

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Abstract: The spatial footprint of energy infrastructures requires a re-evaluation of design and planning processes, especially in relation to the sustainable development goals enshrined in the United Nations 2030 Agenda. This study investigates the Ravenna area (Italy)'s transition potential towards renewable energy sources, considering their spatial interaction with the landscape and the environment. The primary objective is to identify the opportunities and limitations associated with each type of renewable energy production and provide indications for the strategic actions needed to achieve total emissions reduction by 2050. The methodology applied involves several steps to compare both the efficiency and the spatial arrangements of alternative mono-energy scenarios over time. In order to manage the uncertainty inherent in technological development and the variability of territorial policies, the study puts forward the hypothesis of a mixed strategy capable of structuring the energy transition on the specificities of the local landscape palimpsest by identifying location criteria and related impacts. The research demonstrates how site-specific assessments are important to inform resilient strategic choices, and provide decision-makers and stakeholders with data and spatialized representations of future scenarios to discuss and share.

Keywords: landscape design; landscape planning; energy infrastructure; energy-production footprint; scenario planning

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1. Introduction

1.1. Landscapes from Energy Production

The territorial transformations resulting from human activity cause permanent modifications to the spatial arrangements of the landscape and interfere with the natural functioning of ecosystems [1,2]. Infrastructures, which span across various fields and sectors today [3,4], are complex systems that leave a significant spatial footprint amplified by ever-increasing needs, making the earth a continuously reshaped space [5]. Human activity is the main cause of the transformations and processes that deeply and permanently modify the landscape [6,7]: terracing, deforestation and reforestation, excavations for canals, tunnels, road construction, and, with specific reference to the topic discussed here, power-generation plants, such as thermoelectric, hydroelectric, geothermal, photovoltaic installations, wind farms, distribution lines, and storage plants. The high energy demand of industrial economies that emerged after the Second World War has created invisible extractive landscapes, increasingly distant from the energy-consumption centres, with production facilities, storage plants, and distribution/transmission networks that have changed the perception of the landscapes into which these elements are inserted [8]. As a result of these short-sighted functional grafts, the energy demand has become a direct and indirect cause of voluntary and thoughtless landscape mutations [9]. While there are numerous examples of spatial situations influenced by energy-production apparatuses, it is essential to emphasize the significance of energy-production and -distribution infrastructure systems as tangible landscape features. Consequently, accurate planning and design methodologies are required. The spatial footprint of energy-production and -distribution infrastructures should be regarded as a consolidated phenomenon, necessitating re-evaluating the planning and design processes to integrate them into the territory effectively. This research proposes an innovative approach to the siting of energy-production infrastructure by projecting spatial and landscape-scale scenarios. The objective is to develop effective communication tools that foster dialogue among administrative bodies, stakeholders engaged in landscape management, and citizens affected by these transformations.

1.2. Energy Policies

The policies resulting from the increasingly urgent altered climate conditions have pushed technical and political bodies towards a change in the type of energy production, with direct implications in terms of territorial arrangement and spatial modification. In December 2019, within the European Council Conclusions, the Italian government supported the European Commission's Green Deal, which outlined a growth strategy to transform the EU into a resource-efficient society, setting the objective that by 2050 it will no longer generate net greenhouse gas emissions [10]. In this context, the proposal for a national long-term strategy identifies possible pathways to achieve climate neutrality in Italy by 2050. The National Integrated Plan for Energy and Climate 2030 (Piano Nazionale Integrato per l'Energia ed il Clima—PNIEC) [11] is the tool identified to direct our country's energy and environmental policy towards decarbonization. The plan is structured into five integrated lines of intervention, ranging from decarbonization to energy efficiency and security, through the development of the domestic energy market, research, innovation, and competitiveness. Italy aims to accelerate its transition from fossil fuels to renewable sources, promoting the creation of a mix of electricity production from clean and inexhaustible sources. However, the actual realization of this goal can only occur with infrastructure and tools that are tailored to the actual size of the plants and the types of interventions required. Moreover, this approach should aim to contain land consumption and mitigate the related impact on the landscape, as underlined by the long-term Italian strategy on the reduction of greenhouse gas emissions 2021 [12]. Regardless of the type of energy produced, it is clear that energy-production systems consume land [13]. Every form of energy production has a more or less invasive impact on the landscape. The spatial development of energy infrastructure should be intrinsically linked to the study of the components of the landscape and the opportunities it offers, both in environmental and cultural terms [14]. In light of EU strategic guidelines related to energy production, it is necessary to delve into the issue of territorial planning, as it will need to accommodate new or modified productive plants, and energy transport infrastructure [15–17].

1.3. Spatiality and Procedural Implications

It is possible to characterize energy landscapes based on energy density. This distinction can be directly and immediately observed and consists of the relationship between the amount of energy produced in relation to the occupied surface and land use. Considering different types of energy production, the land use efficiency varies greatly, from 0.13 km^2/TWh for nuclear to 809 km^2/TWh for biomass production, it follows that renewable energy generally has a greater direct footprint than extractive energy. Different amounts of land surfaces are necessary to cover the needs of an entire region such as Emilia-Romagna, which in 2020 had a consumption of 26.18 TWh [18,19]. Renewable sources have a low energy density, which refers to the amount of energy produced per unit of surface area, and they require extensive territories. Each form of energy production has a different spatial relationship, which must find specific places and contexts. Furthermore, renewable energy sources are highly dependent on the landscape characteristics in which they are installed, as they rely on elements such as water, sun, wind, soil heat, and biomass. Wind turbines can only be installed in areas with strong and consistent winds, while photovoltaic panels require suitable sunlight exposure to be effective. This close relationship between environmental components and energy production emphasizes the need to properly locate energy-production systems in sensitive areas that require greater attention in the project and planning choices [20,21].

An energy-transition strategy, such as the one adopted at the European community level, implicitly involves the fields of landscape planning and spatial design [22]. Authorities should involve these areas and stakeholders from the early stages of work related to the development of energy infrastructure projects, as only through an immediate integrated and transdisciplinary approach will it be possible to achieve satisfactory design results.

1.4. Literature Overview

The relationship between energy production and landscape has become a crucial factor in territorial planning, enabling a comprehensive energy transition where each component can serve both productive and integrative purposes within its contextual surroundings. Numerous global examples illustrate the exploration of energy transition in connection with landscape and related aspects, encompassing case studies and applications that utilize diverse approaches and methodologies to address energy considerations. However, these examples often neglect to prioritize the issue of space and landscape management, instead focusing predominantly on quantitative and/or logistic-economic factors.

It is well known that the widespread impact of energy production and consumption on landscapes worldwide necessitates a shift towards cleaner and more sustainable energy alternatives [23]. Spatial planning and territorial design focus on maximizing the benefits of renewable energy while minimizing potential conflicts with other land uses. The prevailing approach for renewable energy facility development revolves around mono-energy scenarios concentrating on a single energy source such as wind, solar, hydro, or biomass, aiming to determine suitable locations within a given territory based on their potential [24–27]. By utilizing GIS-based methodologies to map the territory's potential, it becomes possible to identify areas capable of accommodating specific energy sources in the analyzed mono-energy scenario [28,29]. Renewable energy sources also exert perceptual impacts on the surrounding space, transforming and leaving traces on the landscape. Understanding the perception of these new landscapes and exploring alternative configurations are fundamental aspects for their integration within diverse landscapes, communities, and places [30]. Various elements of spatial planning, including the identification of appropriate locations for renewable energy infrastructure, consideration of environmental and technical factors, and the role of spatial planning, play pivotal roles in supporting the transition towards renewable energy. Emphasizing holistic and context-specific approaches is a key objective in strategic and territorial planning to achieve sustainable energy systems. The findings of the above-mentioned studies contribute to a theoretical understanding of how spatial planning can shape the renewable energy landscape, optimize resource utilization, and facilitate sustainable energy transitions at regional, urban, and local scales. They investigate how spatial planning principles and practices can foster the development and efficient utilization of renewable energy resources within specific territories [31–36]. Integrating new energy landscapes involves comparing and aligning with regional or national planning policies. Governments and policymakers bear the responsibility of formulating strategies that address the challenges and opportunities presented by energy production, distribution, and consumption, while considering the needs of communities and stakeholders involved in the process [37,38]. At the regional scale, implementing new energy systems can be achieved through the construction of new infrastructure, aligning with the planning of multi-regional energy pathways [39] which, however, often have time horizons that are too long compared to the speed at which different energy supply systems are updating.

This research addresses the energy-transition challenge by considering long-term scenarios to generate location hypotheses for different energy sources to achieve national and European decarbonization goals. In addition, this contribution emphasizes the primacy of spatial considerations over economic and social factors, asserting that spatial aspects should be given precedence as a preliminary step in political decision-making processes. It does not argue for the exclusive prioritization of spatial concerns, but, rather, advocates for their integration as an initial consideration in formulating management decisions.

Planning in the case of complex systems requires accounting for several interrelated factors that may be affected in the future. Conventionally, decision-makers rely on forecast-based assumptions; however, this approach could lead to more harm than good when we are not just facing short-term objectives but also feasible long-term options in a highly uncertain environment. Scenario planning [40] is a valuable aid for decision-makers to face the indetermination of the future. Strelkovski [41] provided a straightforward, yet exhaustive, overview of the possible approaches falling under this planning paradigm.

Broadly speaking, it is possible to summarize three different kinds of scenarios: predictive, normative, and explorative. The first is often based on historical series aiming to provide a reliable source to describe the future. The use of scenarios as a predictive tool is strongly questioned in the literature, as data stationarity is no longer a certainty due to climate change [42]. However, there are different levels of uncertainty [43]. Therefore, the approach should be tailored to the specific case and prediction used "*cum grano salis*", relying on the decision-makers' know-how and the general aim of the scenario. The normative scenario is often used to describe a desirable future and the policies and strategies to follow in order to reach the stated objective given the current situation (e.g., strategies to reach a specific target of CO_2 reduction based on an intergovernmental agreement). This approach can also be combined with other kinds of scenarios [44]. The latter kind of scenario is used to explore plausible futures, which is a valuable aid in case of complex systems under deep uncertainty, as it helps decision-makers to evaluate their options over a wide range of futures that cannot be conceived just relying on human reasoning [45]. Several model-based approaches have been developed to characterize "*what if*" scenarios in many fields that require planning [46,47], and they fall under the umbrella of decision-making under deep uncertainty (DMDU) [48]. Kwakkel and Haasnoot provided a comprehensive taxonomy of the approaches and tools that can be applied, given the nature of the problem [49]. In the present study, we followed the normative scenario based on the goal set by the UN for sustainable development and adopted by the European Union [50].

This paper aims to demonstrate how a careful analysis of landscape components can optimize the placement of energy-production facilities and related distribution and transmission networks, thereby improving the environmental and ecosystemic conditions of the areas involved. The following chapters present a case study on energy transition within the mitigation and adaptation actions to climate change of the Sustainable Energy and Climate Action Plan (Piano d'Azione per l'Energia Sostenibile e il Clima—PAESC) of the Municipality of Ravenna [51]. The study analyzes the spatial relationship and relative location of different renewable energy sources within the municipal territory through various temporal scenarios (Figure 1).

Specifically, in Section 2, we present the material, methods applied, and the quantitative data gathered for the scenario development. In Section 3, we summarize the obtained results, and in Section 4 we discuss the outcomes and the possible outlooks for the future steps of the presented research. Lastly, in Section 5, we provide the final remarks regarding the research, the limitations to date, and how the scenario approach could help overcome some of the current issues in the interaction between administrations and stakeholders.

Figure 1. Location of the Municipality of Ravenna.

2. Materials and Methods

We developed our scenario according to the European Sustainable Development Goals, goal n.7 "Affordable and clean energy" and goal n.11 "Sustainable cities and communities", providing different pathways structured on different technologies and techniques. The following paragraphs describe the research carried out for scenarios on territorial/landscape positioning of energy-production assets through renewable sources. The work is part of the broader adaptation and mitigation strategy to climate change. The analysis of the energy-transition potential of the Municipality of Ravenna aims to highlight how much and how different renewable sources, examined individually and then integrated into an energy-mix scenario, can affect landscape transformations. This way, it is possible to expose the limits and opportunities associated with each type of energy production (photovoltaic, wind-turbine, and biomass production) in order to guide the strategic choices and necessary actions to meet the commitment of total emission reduction by 2050 (Figure 2). The approach to the energy–landscape theme involved several methodological steps, which were preparatory to each other, specifically:

- Identification of sources and quantitative calculation: in this stage, renewable energy sources are identified for the definition of the energy-transition potential in the municipal territory of Ravenna, specifically photovoltaic, wind-turbine, and biomass production, and the calculation of tonnes of CO_2 to be counterbalanced by energy production from identified renewable sources;
- Spatial conversion: a transformation from quantitative to qualitative–spatial data is carried out, corresponding to the theoretical extension of the different energy sources and their respective technological systems considered;
- Identification of location criteria and estimation of effect: the choice of places and their propensity to accommodate energy-production facilities is made, and the potential effect associated with each source is estimated;
- Energy-mix hypothesis: taking into account the data and potential locations extrapolated from the previous steps, a mixed-energy-production strategy is projected that

includes all studied energy sources and projects a hybrid scenario capable of satisfying the predetermined CO_2 reduction targets.

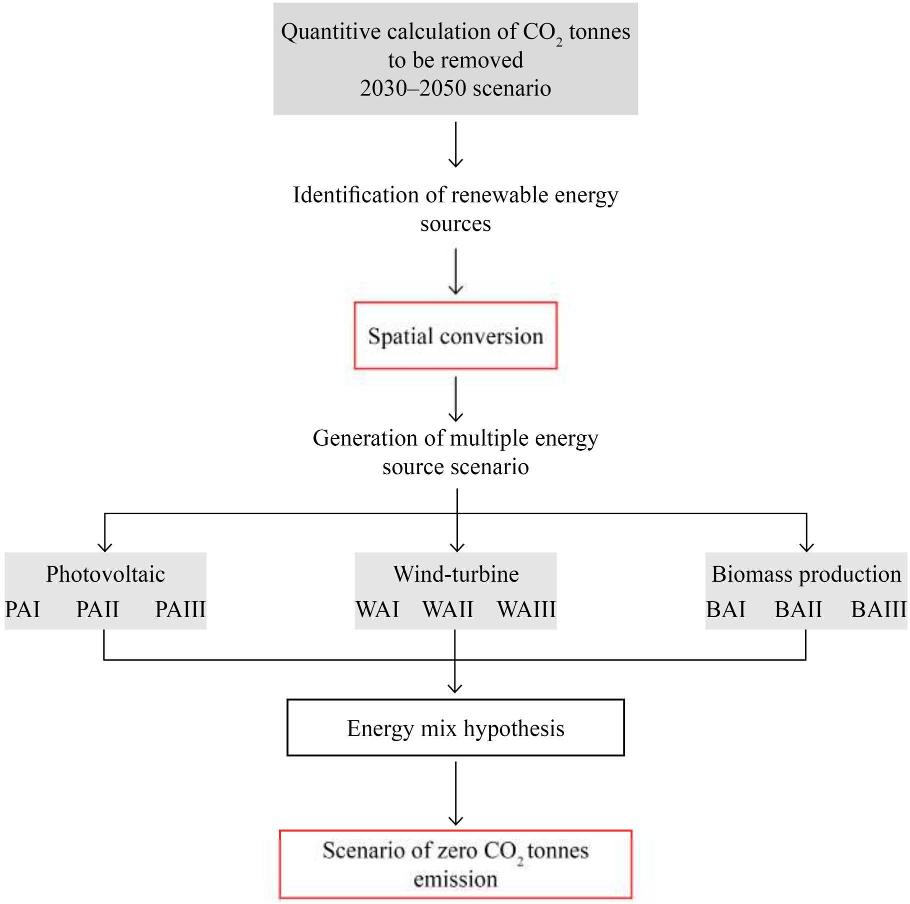

Figure 2. Flowchart of work steps.

2.1. Identification of Sources and Quantitative Calculation

The calculation of the CO_2 emissions to be reduced by 2050 was based on the inventory of emissions in 2007, which amounted to a total of 1,683,317.65 tonnes. This figure constitutes the baseline reference for the PAESC. The present research contribution on energy transition focuses on the period from 2030 to 2050, during which the amount of CO_2 to be mitigated corresponds to 1,009,990.59 tonnes, or 60% of the total, considering that the decarbonization actions adopted by the municipality until 2030 can fill up to 40% of the total, equivalent to 673,327.06 tonnes. For research purposes, this figure has been fully considered, assuming that the reduction in emissions related to the use of renewable energy sources contributes entirely to achieving it, defining a mono-energetic scenario. The renewable energy technologies considered compatible with the territory and resources of the Municipality of Ravenna are photovoltaic, wind-turbine, and biomass production. For the subsequent conversion operation, that is, the transformation from CO_2 to spatial data, a cautionary factor was applied to the production efficiency of the plants, which was inferred from current parameters without considering potential future technological improvements. For the three identified energy sources, the following data related to energy production were assumed: (a) photovoltaic 1 ha has a power of 0.94 MW; (b) biomass 1 ha has a power of 0.01 MW; and (c) wind power 1 turbine has a power of 11.8 MW.

2.2. Spatial Conversion

In this section, we aim to assess to what extent and with what effect on the territory the development of energy infrastructures can contribute to the reduction of CO_2 emissions for illustrative and strategic purposes. With this premise, we sought a correlation between quantitative data and spatial extension values associated with the development of infrastructures that enable adequate energy production. By using the conversion parameters provided by the "Emilia-Romagna Climate Plans "(Piani Clima in Emilia-Romagna), it was possible to convert tonnes of CO_2 into corresponding hectares of land required for the development of dedicated systems [52]. For this purpose, the research analyses the potential for energy transition associated with each type of energy infrastructure (photovoltaic, wind-turbine, and biomass production) based on its actual footprint on the territory. For each energy source, a conversion factor has been assigned that translates the power produced (MW) per unit of surface area (1 ha) to a consequent value of tonnes of CO_2 removed. The conversion factors for the energy sources are as follows: (a) photovoltaic 380 t/ha; (b) biomass production 0.38 t/ha; and (c) wind-turbine 24.45 t/ha with 0.008 turbines/ha. As a result, the hectares to be converted into productive energy landscapes necessary for the 100% reduction of CO_2 amount to: (a) photovoltaic scenario 2658 ha; (b) biomass production scenario 2,569,199 ha; and (c) wind-turbine scenario 41,300 ha (330 turbines). Considering biomass production, for example, an area approximately 41 times the municipal area would be required. These data were verified based on the actual availability of areas where the installation of plants would be plausible, efficient, and less impactful (Figure 3).

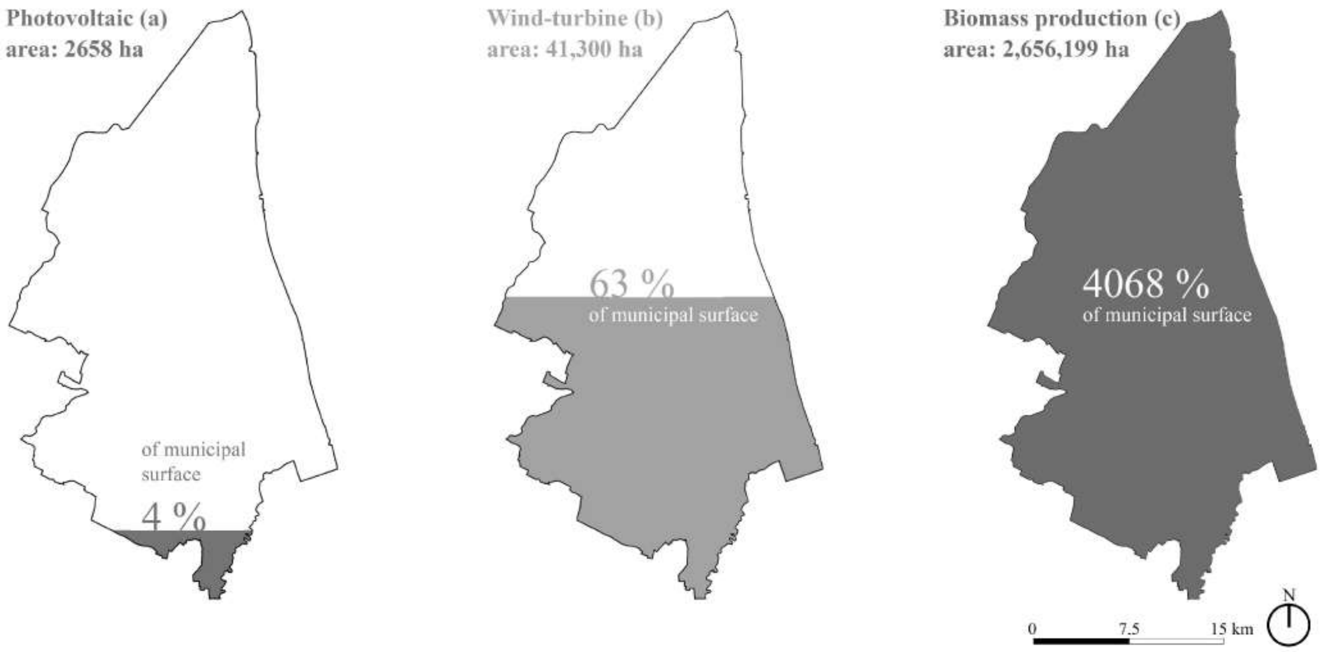

Figure 3. Comparative diagram of the theoretical spatial footprint of mono-energy scenario to achieve the 100% emission reduction target in the period 2030–2050. Percentages relate to the total municipal area of 65,290 ha. (**a**) Photovoltaic mono-energy spatial scenario; (**b**) wind-turbine mono-energy spatial scenario; and (**c**) biomass production mono-energy scenario.

2.3. Identification of Location Criteria and Estimation of Effect

Following the amount of CO_2 to be reduced and quantitative data translation into spatial footprint related to energy sources within the municipal territory, a total of nine colonisation actions were created, namely, three for each of the energy sources: (a) photovoltaic actions I, II, and III; (b) biomass production actions I, II, and III; and (c) wind-turbine actions I, II, and III. The scenarios are articulated in actions of alternative positioning that show how the plants can be distributed within the territory of the Municipality of Ravenna according to different criteria of strategic insertion to achieve a coherent relationship with the landscape.

3. Results

The results demonstrate a considerable difference in the theoretical footprint of each energy landscape scenario. Each scenario corresponds to the amount of territory required to transition from a 40% reduction (2020–2030) to a 100% reduction (2030–2050) in CO_2 emissions within the period of 2030–2050. Actually, achieving the goal of a 100% reduction by 2050 is only feasible through a balanced mix of various renewable sources. Therefore, by creating new energy landscapes developed through the identification of specific criteria for the placement of infrastructure consistent with territorial vocations and natural environmental processes, it is possible to attain emission neutrality and implement an efficient and high-performing energy-transition strategy.

3.1. Photovoltaic 2030–2050

3.1.1. Photovoltaic Action I (PA I)—Buildings Coverage

The first action concerning the installation of photovoltaic panels was obtained by considering all buildings, except the historical centre of Ravenna and restricted areas in general, whose plan area is greater than 100 m^2. This choice allows only medium–large installations to be included in the calculation, statistically considering the negative incidence of the geometric factor linked to the position of the roof pitches. The unit conversion value between photovoltaic extension and emission reduction is 1 ha = −376.59 t CO_2. The total area of buildings with the above selection criteria is 1144.5 ha. The tons of CO_2 removed with Action I are 419,709.59 (Table 1, Figures 4 and 5a).

Table 1. Table summarising the area and amount of CO_2 removed for each photovoltaic energy source action in the time scenario 2030–2050. * −40% corresponding to mitigation actions in the period 2020–2030 is added to the total calculation of the percentage of emission reductions.

Photovoltaic Actions	Surface (ha)	CO_2 Removed (1 ha = −376.59 t CO_2) (Tons)	Emission Reduction per Relative Action (%)
Action I	1114.5	419,709.59	−25%
Action II	775	291,857.25	−17.3%
Action III	793	298,635.87	−17.7%
Total Actions I + II + III	2663.2	1,010,202.68	−60% + (−40%) * = −100%

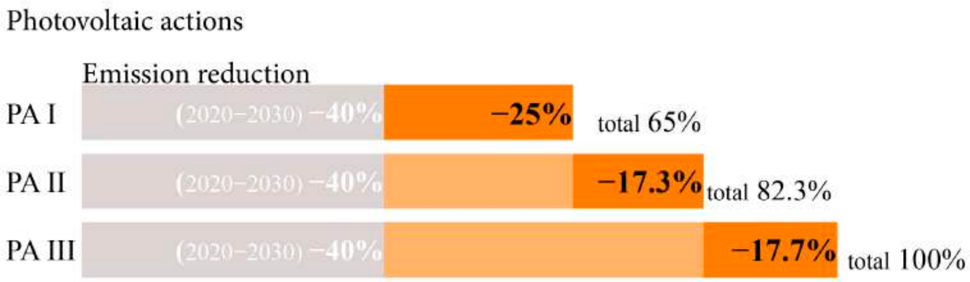

Figure 4. Graphical chart of the percentage of emission reduction related to photovoltaic actions.

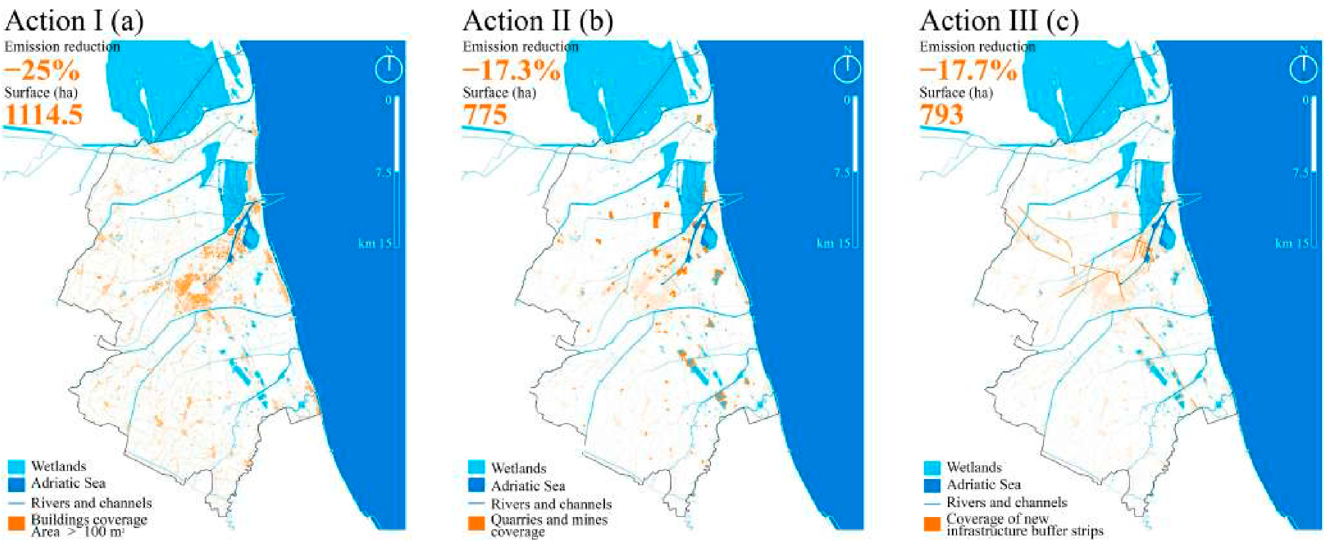

Figure 5. Maps of the spatial distribution of photovoltaic source energy infrastructure in the individual strategic actions following the specific selection criteria: (**a**) building coverage; (**b**) quarries and mines coverage; and (**c**) coverage of new infrastructures buffer strips.

3.1.2. Photovoltaic Action II (PA II)—Quarries and Mines Coverage

The second criterion adopted to locate areas of possible development for new photovoltaic parks was the selection, within the municipal territory, of areas affected by quarry, mine, and landfill activities that are no longer active and, therefore, available to be converted into a new energy landscape. From these, areas in environmentally and ecologically protected areas were excluded. The municipal area with the above selection criteria is 775 ha. The unit conversion value used to determine the emission reduction factor is the same as in the first step, i.e., 1 hectare = −376.59 t CO_2. The tonnes of CO_2 removed by Action II are 291,857.25 (Table 1, Figures 4 and 5b).

3.1.3. Photovoltaic Action III (PA III)—Coverage of New Infrastructure Buffer Strips

The selection criterion applied for the third phase of hypothetical photovoltaic development considers buffer strips (60 metres) relating to road infrastructures to be built in the future and the upgrading of existing ones [53]. Within these areas, unproductive land was taken into account, identified on the basis of soil organic carbon mapping, and considering a threshold value of 50 CO $Mg \times ha^{-1}$ [54]. The total area identified according to the above criteria is 793 ha. The unit conversion value is 1 ha = −376.59 t CO_2. The tonnes of CO_2 removed with Action III are 298,635.87. The summation of these areas with those described in the previous steps, combined with the 40% reduction target to 2030, results in an overall 100% reduction of CO_2 emissions (Table 1, Figures 4 and 5c).

3.2. Biomass Production 2030–2050

3.2.1. Biomass Action I (BA I)—Agricultural Areas with Low Organic Carbon Content

The area that can be used for biomass production is commensurate in the first strategic action with agricultural areas whose organic carbon content is less than 40 $Mg \times ha^{-1}$ [54]. Such soils, which are inherently unproductive, require a very abundant use of fertilisers. Should they be used for biomass production (wood chips), they would be subject to new forestation processes that would improve their chemical composition and overall permeability. These positive factors compensate for the low contribution in terms of CO_2 emission reduction, estimated at −0.37 tonnes per hectare. The total area with these requirements is 8306 ha. The tonnes of CO_2 removed through Action I are 3073.22 (Table 2, Figures 6 and 7a).

Table 2. Table summarising the area and amount of CO_2 removed for each biomass production energy source action in the time scenario 2030–2050. * −40% corresponding to mitigation actions in the period 2020–2030 is added to the total calculation of the percentage of emission reductions.

Biomass Production Actions (BA)	Surface (ha)	CO_2 Removed (1 ha = −0.37 t CO_2) (Tons)	Emission Reduction per Relative Action (%)
Action I	8306	3073.22	−0.2%
Action II	14,206	5256.22	−0.3%
Action III	12,794	4733.78	−0.3%
Total Actions I + II + III	35,306	13,063.22	−0.8% + (−40%) * = −40.8%

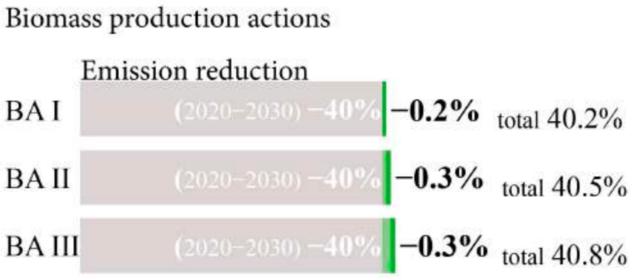

Figure 6. Graphical chart of the percentage of emission reduction related to biomass production actions.

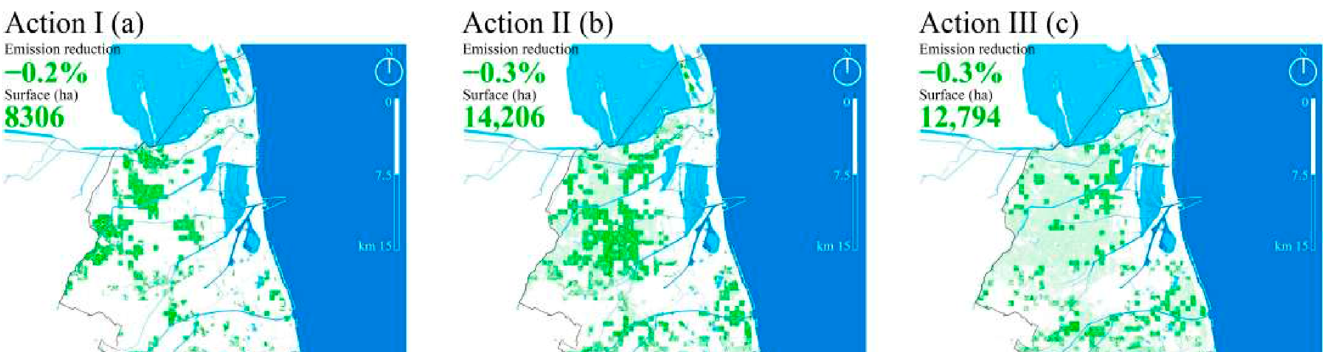

Figure 7. Maps of the spatial distribution of the biomass production source energy infrastructure in the individual strategic actions following the specific selection criteria: (**a**) agricultural areas with medium-low organic carbon content; (**b**) agricultural areas with medium-low organic carbon content; and (**c**) agricultural areas with medium organic carbon content.

3.2.2. Biomass Action II (BA II)—Agricultural Areas with Low–Medium Organic Carbon Content

The second selection criterion applied to the development of areas for biomass production includes agricultural land whose organic carbon value is estimated between 40 and 50 $Mg \times ha^{-1}$ [54], thus with a medium–low content. This condition suggests their conversion into mixed areas alternating new woodland, for the production of wood chips, with crops from which maize silage can be obtained, which is also destined for the energy chain. Again, the low direct impact on CO_2 abatement is offset by the beneficial effect on soil quality. The unit conversion value used to determine the emission reduction factor is 1 hectare = −0.37 t CO_2. The total area of the areas corresponding to these requirements is 14,206 ha. The tonnes of CO_2 removed through Action II are 5256.22 (Table 2, Figures 6 and 7b).

3.2.3. Biomass Action III (BA III)—Agricultural Areas with Medium Organic Carbon Content

In this third step, the area to be used for biomass production refers to agricultural soils whose organic carbon content is between 50 and 60 Mg×ha^{-1} [54]. These soils are considered to be averagely productive and, therefore, require small amounts of chemical fertilisers. In these areas, it is assumed that extensive cultivation of maize and other cereals will be developed, from which the raw material for biomass energy production can be obtained. In this case, actions would be limited to optimising the supply chain and reducing agricultural waste. The unit conversion value used is 1 hectare = −0.37 t CO_2. The total area of the areas corresponding to these requirements is 12,794 ha. The tonnes of CO_2 removed through Action III are 4733 (Table 2, Figures 6 and 7c).

3.3. Wind-Turbine 2030–2050

3.3.1. Wind-Turbine Action I (WA I)—Offshore Platform Reuse

The location of wind energy systems only considers offshore development as wind conditions are more favourable and constant at sea. In addition, the existing gas network provides an already infrastructured space where a new submarine energy transport system can be grafted. In the first step, it is assumed that individual turbines with a capacity of 700 GWh/year, each corresponding to −3118 tonnes of CO_2, will be associated with the platforms (decommissioned, in the process of being decommissioned, or still active) located beyond 15 km from the coast. According to the above-mentioned requirements, the total number of turbines to be included is 54. The tons of CO_2 removed through Action I are 168,372 (Table 3, Figures 8 and 9a).

Table 3. Summary table of the number of turbines and amount of CO_2 removed for each action of the wind-turbine energy source in the time scenario 2030–2050. * −40% corresponding to mitigation actions in the period 2020–2030 is added to the total calculation of the percentage of emission reductions.

Wind-Turbine Actions	Turbine (Number)	CO_2 Removed (1 wt = −3118 t CO_2) (Tons)	Emission Reduction per Relative Action (%)
Action I	54	168,372	−10%
Action II	85	255,676	−15.7%
Action III	185	576,830	−34.3%
Total Actions I + II + III	321	1,000,878	−60% + (−40%) * = −100%

Figure 8. Graphical chart of the percentage of emission reduction related to wind-turbine actions.

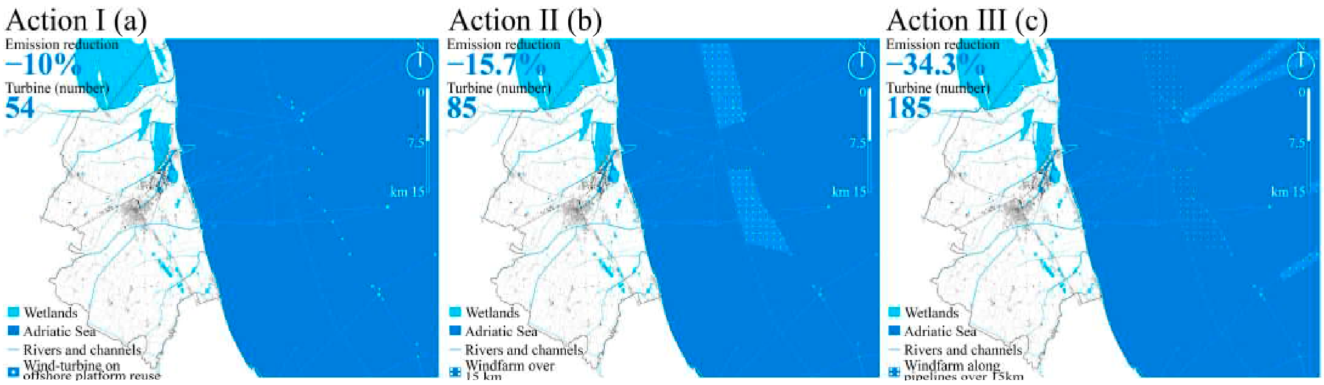

Figure 9. Maps of the spatial distribution of wind-turbine energy infrastructure in the individual strategic actions following the specific selection criteria: (**a**) off-shore platforms reuse; (**b**) wind farm over 15 km; and (**c**) wind farm along pipelines over 15 km.

3.3.2. Wind-Turbine Action II (WA II)—Wind Farm over 15 km

The second location criterion refers to the development of a wind farm consisting of 82 turbines located close to the 15 km line from the coast and positioned at a distance of 1 km from each other. The shallow depth of the seabed facilitates the installation of the plants in this area, which can easily utilise existing submarine cable routes to transport the energy ashore. The layout of the park takes into account ship transit zones and maritime buffer zones comprising a total of 82 turbines. The unit conversion value used to determine the emission reduction factor is 1 turbine = −3118 t CO_2 for a total of 168,372 tonnes of CO_2 removed through Action II (Table 3, Figures 8 and 9b).

3.3.3. Wind-Turbine Action III (WA III)—Wind Farm along Pipelines over 15 km

The third location criterion considered for further wind power development allows the complete fulfilment of the emission reduction target. An extension of the park is assumed along the defined routes of the existing submarine cables with a maximum deviation of 2 km of the turbines from the tracks. The gradual increase in the seabed depth requires special floating machines whose efficiency is assumed to be equal to that of the rooted turbines, thus equal to 3118 t of CO_2 per turbine. The total tonnes of CO_2 removed through Action III are 576,830. The combination of the turbines mentioned in the previous steps, along with the 40% reduction target by 2030, leads to a comprehensive achievement of 100% reduction in CO_2 emissions (Table 3, Figures 8 and 9c).

3.4. Energy-Mix Hypothesis

The energy-transition hypotheses, developed for each renewable source and presented in the previous paragraphs, are useful examples to measure different systems' potential and spatial footprint in a mono-energy scenario. In reality, the goal of a 100% emission reduction by 2050 is only credibly attainable through a weighted mix of the different renewable sources. This section presents a possible mixed-energy-transition scenario in which all sources participate in reducing emissions. Such a strategy ensures, in perspective, to optimise production by diversifying renewable resources across the territory and increasing their degree of resilience with respect to socio-environmental variables that may interfere with their development. The location criterion is inspired by maximum spatial diffusion and variety. Assuming, again, the attainment of the 40% CO_2 reduction target by 2030, the proposed energy landscape aims to close the remaining gap in the period 2030–2050. Assuming that a share of the emissions (around 20%) can be reduced through efficiency-enhancing infrastructure systems and practices already in place, the differential that the proposed new systems have to affect is reduced to just over 40% of the total. The breakdown of this value into the different energy sources examined was carried out in such a way as to address infrastructure development in areas of the territory that can be considered residual and, thus, be potentially upgraded by the creation of new energy landscapes.

In the mixed-energy-transition scenario, the implementation of photovoltaic is divided between building coverage, occupying 50% of the available territorial area of 572.3 ha, and part of the exhausted quarry, mine, and landfill areas totalling 453.4 ha equal to 60% of the available area. Through the use of the conversion factor of the previous actions equal to 1 ha = −376.59 t of CO_2, the new photovoltaic landscape will reduce the amount of CO_2 by 386,268.36 tonnes, or 22.9% of the total. The same aim is pursued with converting agricultural land with low organic carbon content into reforestation areas for biomass production, with 80% of the low organic carbon content areas equal to 6644.8 ha, and 20% of the medium–low content areas at 2841.2 ha. Using the unit conversion value of 1 hectare = −0.37 t CO_2, the land converted to biomass production can subtract 3509.82 t CO_2, or 0.2% of the total. The offshore insertion of wind power plants is concentrated on disused platforms and areas furthest from the coast, considering a total of 110 turbines. The advantage of offshore plant insertion is that it does not occupy municipal land and, simultaneously, meets the required energy production. Considering the conversion factor of 1 turbine = −3118 t CO_2, the new wind-turbine landscape subtracts 342,980 t CO_2, contributing to a 20.4% reduction of the total (Table 4 and Figure 10).

Figure 10. Mixed-energy-transition landscape. All sources are integrated and contribute to the achievement of objectives.

Table 4. Summary table of the areas and quantities of CO_2 removed for each energy source (photovoltaic, wind-turbine, and biomass production) in the time scenario 2030–2050. * −40% corresponding to mitigation actions in the period 2020–2030 and −20% for the efficiency of existing municipal energy plants are added to the total calculation of the percentage of emission reductions.

Energy Sources Mix Actions	Surface or Turbines (ha; Number)	CO_2 Removed (Tons)	Emission Reduction per Relative Action (%)
Photovoltaic	1025.7 ha	386,268.36	−22.9%
Biomass production	9486 ha	3509.82	−0.2%
Wind-turbine	110 turbines	342,980	−20.4%
Total energy sources mix	10,511.7 ha + 110 turbines	732,758.18	−43.5% + (−40% − 20%) * = −103.5%

The new energy-transition landscape consisting of photovoltaic parks, agricultural biomass production fields, and offshore wind farms contributes, together with the reductions for the 2020–2030 actions (40%) and the efficiency of municipal plants (20%), to the set target of 100% CO_2 abatement.

4. Discussion

The presented research, in line with the studies reviewed in the Section 1.4, addresses a sensitive field that is highly influenced by external factors. While other studies also identify areas for proper placement of energy infrastructure [55,56], the approach taken in this study differs in its theoretical foundation, considering infrastructure as a possible formal and spatial improvement to the landscape rather than a detriment. The results demonstrate that the required quantity can be achieved by selecting landscape areas, but this strategy should be implemented to assess the consequential effects of such infrastructural interventions. This study has identified strategic measures for locating new energy-production resources by analyzing the distinct characteristics and components that define the current landscape configuration. The employed tools aim to effectively implement infrastructure systems in alignment with energy-transition objectives while ensuring spatial coherence with the landscape. However, projecting the attributes of the proposed energy landscape in the long-term horizon (2030–2050) poses a significant challenge. The variability of available global and local climate forecasts and the influence of political, economic, and social factors introduce uncertainties into the developmental trajectory. Future climate models typically encompass a range of possibilities for temperature increase. Similarly, when formulating an energy-transition strategy, it is crucial to acknowledge that the responses to be implemented may vary depending on contingencies and orientations that cannot be precisely determined at present. Overcoming these uncertainties necessitates engaging in dialogue with stakeholders and the governing bodies responsible for the territory. Normative scenarios are valuable tools for assessing potential pathways involving different strategies or combinations to achieve short-term goals.

Nevertheless, it is important to acknowledge the limitation stemming from the exclusion of a long-term timeframe. Thus, to evaluate the performance of proposed strategies in an uncertain future, a paradigm shift is required, transitioning from a "predict-then-act" approach to a "monitor-and-adapt" approach [48]. In light of this perspective, the next steps of this study aim to integrate alternative normative conditions with explorative scenarios to incorporate uncertainties and develop dynamic pathways that can adapt the plans as the future unfolds [57,58].

Numerous factors, such as energy demand, climate, societal and economic changes, political shifts, and emerging technologies, contribute to future uncertainties. The study has certain limitations that also pertain to the aspects taken into consideration. Specifically, it focused mostly on technical aspects related to energy-production sources and their spatial impacts. Further research and implementation should aim to expand the scope of the study, considering additional factors and dimensions to provide a more comprehensive understanding of the subject matter. Additionally, it is worth noting that considerations of social and economic aspects could complement the technical analysis conducted in this study. Incorporating these dimensions would enhance our understanding of the energy-transition process more holistically. For instance, similar to various studies conducted on hydrodynamic environments and their management in recent decades have interpreted these landscapes as the outcome of diverse cultural aspirations. The balance of these aspirations, to varying degrees, directly or indirectly influences the ecosystem's response to human modifications [59–61]. In this direction, a promising tool to assess the equilibrium of future landscape configurations related to energy production is the calculation of ecosystem services provided by each alternative scenario [62,63]. Future research should explore these avenues to enhance the comprehensive analysis of energy infrastructure integration within the landscape.

Despite its limitations, the present research has shown that is imperative to explore plausible scenarios that incorporate sources of indeterminacy that may undermine the original goal or present potential opportunities precisely because it enables the proactive integration of uncertainty into the decision-making process. The comparison of scenarios facilitates the development of a vision that is receptive to alternative trajectories and, consequently, more resilient in the face of possible future outcomes [64].

5. Conclusions

The convergence of landscape and infrastructure management competences necessitates a more intense dialogue between administrative institutions and the stakeholders involved in the practical transformation and maintenance of territorial arrangements. The European Adaptation Policy "Covenant of Mayors" and the development of the PAESC (Piano di Azione per l'Energia Sostenibile e il Clima) can serve as foundations for strengthening this collaboration and fostering a shared vision for the future of landscape management [65]. This contribution has presented an approach that advances the mechanism of the energy transition by outlining a strategy that consciously addresses the associated challenges while considering the effects and initial conditions related to landscape and territorial arrangements. The primary objective has been to provide competent authorities with a supportive decision-making tool that can be further developed through additional investigations and the exploration of specific case studies. Possible top–down approach would allow for greater detail of project actions with additional design insights. However, additional challenges persist, such as citizen involvement and simplifying complex issues for effective communication with non-expert parties. Likewise, the outcomes of these studies can serve as a basis for fostering discussions among the municipality, territorial stakeholders, and citizens. On the other hand, the study proposes a technical design feasibility related to a new territorial asset that can become a speculative image on which to base projects and strategies to be consolidated over time by integrating expertise derived from technical offices operating at the territorial administrative level.

The presented research serves as a means to communicate the magnitude of the challenges that Ravenna faces, along with many other cities, and to encourage their active participation in addressing the landscape transformation issues associated with changes in energy infrastructure in order to put these themes at the forefront of the political and cultural agenda.

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References

1. Gellert, P.K.; Lynch, B.D. Mega-projects as displacements. *Int. Soc. Sci. J.* **2003**, *55*, 15–25. [CrossRef]
2. Lin, Y.; Zhaoyuan, Y.; Jing, Q.; Muhammadjon, K.; Chaoliang, C.; Xiuwei, X. Evaluation of the heterogeneity in the intensity of human interference on urbanized coastal ecosystems: Shenzhen (China) as a case study. *Ecol. Indic.* **2021**, *122*, 107243. [CrossRef]
3. Bélanger, P. *Landscape as Infrastructure: A Base Primer*, 1st ed.; Routledge: New York, NY, USA, 2017; pp. 116–155. ISBN 978-1-138-64391-8.
4. Fulmer, J.E. What in the world is infrastructure? *Infrastruct. Invest.* **2009**, *1*, 30–32.
5. Corboz, A. The land as palimpsest. *SAGE J.* **1983**, *31*, 12–34. [CrossRef]
6. Pasini, R. Nature, dwelling—A needed new balance. *Rev. Nodo* **2020**, *15*, 8–19. [CrossRef]
7. Lewis, S.L.; Maslin, M.A. Defining the Anthropocene. *Nature* **2005**, *519*, 171–180. [CrossRef]
8. Wuebben, D.L. *Power-Lined: Electricity, Landscape, and the American Mind*, 1st ed.; University of Nebraska Press: Lincoln, NE, USA, 2019; pp. 131–168. ISBN 978-1-4962-0366-3.
9. De Waal, R.M.; Stremke, S. Energy Transition: Missed Opportunities and Emerging Challenges for Landscape Planning and Designing. *Sustainability* **2014**, *6*, 4386–4415. [CrossRef]
10. European Commission. The European Green Deal. 2019. Available online: https://eur-lex.europa.eu/legal-content/IT/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN (accessed on 15 January 2020).
11. Ministry of Economic Development; Ministry of the Environment and Protection of Land and Sea; Ministry of Infrastructure and Transport. Piano Nazionale Integrato per l'Energia e il Clima. 2019. Available online: https://www.mase.gov.it/sites/default/files/archivio/pniec_finale_17012020.pdf (accessed on 10 March 2023).
12. Ministry of the Environment and Protection of Land and Sea; Ministry of Economic Develompment; Ministry of Infrastructure and Transport; Ministry of Agriculture, Food Sovereignty and Forestry. Strategia Italiana di Lungo Termine sulla Riduzione delle Emissioni dei Gas a Effetto Serra. 2021. Available online: https://www.mase.gov.it/sites/default/files/lts_gennaio_2021.pdf (accessed on 10 March 2023).
13. Marquard, E.; Bartke, S.; Gifreu i Font, J.; Humer, A.; Jonkman, A.; Jürgenson, E.; Marot, N.; Poelmans, L.; Repe, B.; Rybski, R.; et al. Land Consumption and Land Take: Enhancing Conceptual Clarity for Evaluating Spatial Governance in the EU Context. *Sustainability* **2020**, *12*, 8269. [CrossRef]
14. Ahern, J. Spatial concepts, planning strategies and future scenarios—A framework method for integrating landscape ecology and landscape planning. In *Landscape Ecological Analysis—Issues and Applications*; Klopatek, J., Gardner, R., Eds.; Springer: New York, NY, USA, 1999; pp. 175–201. [CrossRef]
15. Calvert, K.; Smit, E.; Wassmansdorf, D.; Smithers, J. Energy transition, rural transformation and local land-use planning: Insights from Ontario, Canada. *SAGE J.* **2022**, *5*, 1035–1055. [CrossRef]
16. Hastik, R.; Basso, S.; Geitner, C.; Haida, C.; Poljanec, A.; Portaccio, A.; Vrščaj, B.; Walzer, C. Renewable energies and ecosystem service impacts. *Renew. Sustain. Energy Rev.* **2015**, *48*, 608–623. [CrossRef]
17. Howarda, D.C.; Wadswortha, R.A.; Whitaker, J.A.; Hughes, N.; Buncec, R.G.H. The impact of sustainable energy production on land use in Britain through to 2050. *Land Use Policy* **2009**, *26*, S284–S292. [CrossRef]

18. Trainor, A.M.; McDonald, R.I.; Fargione, J. Energy Sprawl Is the Largest Driver of Land Use Change in United States. *PLoS ONE* **2016**, *11*, e0162269. [CrossRef] [PubMed]
19. Terna Driving Energy. Italy Consumption Energy. Available online: https://www.terna.it/it/sistema-elettrico/statistiche/pubblicazioni-statistiche (accessed on 15 March 2023).
20. Ginelli, E.; Daglio, L. Infrastructures for renewable energies in landscape. Design tools and innovation trends. *TECHNE J. Technol. Archit. Environ.* **2016**, *11*, 119–126. [CrossRef]
21. Treu, M.C. Energy: Territory and new landscapes scenarios. *City Territ. Archit.* **2018**, *5*, 14. [CrossRef]
22. European Commission. *Clean Energy for All Europeans*; Publications Office of the European Union: Luxemburg, 2019. Available online: https://data.europa.eu/doi/10.2833/9937 (accessed on 10 March 2023).
23. Sijmons, D.; Hugtenburg, J.; Feddes, F.; van Hoorn, A. *Landscape and Energy: Designing Transition*; Nai Uitgevers Pub: Rotterdam, The Netherlands, 2004.
24. Li, T.; Liu, P.; Li, Z. Impacts of Low-Carbon Targets and Hydrogen Production Alternatives on Energy Supply System Transition: An Infrastructure-Based Optimization Approach and a Case Study of China. *Processes* **2021**, *9*, 160. [CrossRef]
25. Frombo, F.; Minciardi, R.; Robba, M.; Scaile, R. A decision support system for planning biomass-based energy production. *Energy* **2009**, *34*, 362–369. [CrossRef]
26. Jay, S. Planners to the rescue: Spatial planning facilitating the development of offshore wind energy. *Mar. Pollut. Bull.* **2010**, *60*, 493–499. [CrossRef]
27. Schallenberg-Rodríguez, J.; Montesdeoca, N.G. Spatial planning to estimate the offshore wind energy potential in coastal regions and islands. Practical case: The Canary Islands. *Energy* **2018**, *143*, 91–103. [CrossRef]
28. Dìaz-Cuevas, P. GIS-based methodology for evaluating the wind-energy potential of territories: A case study from Andalusia (Spain). *Energies* **2018**, *11*, 2789. [CrossRef]
29. Marques-Perez, I.; Guaita-Pradas, I.; Gallego, A.; Segura, B. Territorial planning for photovoltaic power plants using an outranking approach and GIS. *J. Clean. Prod.* **2020**, *257*, 120602. [CrossRef]
30. Colafranceschi, D.; Sala, P.; Manfredi, F. Nature of the Wind, the Culture of the Landscape: Toward an Energy Sustainability Project in Catalonia. *Sustainability* **2021**, *13*, 7110. [CrossRef]
31. Burinskiene, M.; Rudzkiene, V. Future insights, scenarios and expert method application in sustainable territorial planning. *Technol. Econ. Dev. Econ.* **2009**, *15*, 10–25. [CrossRef]
32. Belmonte, S.; Núñez, V.; Viramonte, J.G.; Franco, J. Potential renewable energy resources of the Lerma Valley, Salta, Argentina for its strategic territorial planning. *Renew. Sustain. Energy Rev.* **2009**, *13*, 1475–1484. [CrossRef]
33. De Pascali, P.; Bagaini, A. Energy transition and urban planning for local development. A critical review of the evolution of integrated spatial and energy planning. *Energies* **2018**, *12*, 35. [CrossRef]
34. Bagliani, M.; Dansero, E.; Puttilli, M. Territory and energy sustainability: The challenge of renewable energy sources. *J. Environ. Plan. Manag.* **2010**, *53*, 457–472. [CrossRef]
35. Santana-Sarmiento, F.; Velázquez-Medina, S. Development of a territorial planning model of wind and photovoltaic energy plants for self-consumption as a low carbon strategy. *Complexity* **2021**, *2021*, 1–22. [CrossRef]
36. Cherix, G.; Capezzali, M.; Rager, J. Territorial energy systems: A methodological approach and case study. In Proceedings of the 10th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2015), Dubrovnik, Croatia, 27 September–2 October 2015; pp. 1–20.
37. Zanon, B.; Verones, S. Climate change, urban energy and planning practices: Italian experiences of innovation in land management tools. *Land Use Policy* **2013**, *32*, 343–355. [CrossRef]
38. Novarina, G.; Seigneuret, N. Territorial energy transition strategies: New models for cooperation between actors and resource management? In *Local Resources, Territorial Development and Well-Being*; Edward Elgar Publishing: Cheltenham, UK, 2020; pp. 121–142. [CrossRef]
39. Song, S.; Li, T.; Liu, P.; Li, Z. The transition pathway of energy supply systems towards carbon neutrality based on a multi-regional energy infrastructure planning approach: A case study of China. *Energy* **2022**, *238*, 122037. [CrossRef]
40. Peterson, G.D.; Cumming, G.S.; Carpenter, S.R. Scenario Planning: A Tool for Conservation in an Uncertain World. *Conserv. Biol.* **2020**, *17*, 358–366. [CrossRef]
41. Strelkovskii, N.; Komendantova, N.; Sizov, S.; Rovenskaya, E. Building plausible futures: Scenario-based strategic planning of industrial development of Kyrgyzstan. *Futures* **2020**, *124*, 102646. [CrossRef]
42. Milly, P.C.D.; Betancourt, J.; Falkenmark, M.; Hirsch, R.M.; Kundzewicz, Z.W.; Lettenmaier, D.P.; Stouffer, R.J. Stationarity Is Dead: Whither Water Management? *Science* **2008**, *319*, 573–574. [CrossRef] [PubMed]
43. Kwakkel, J.H.; Walker, W.E.; Marchau, V.A.W.J. Classifying and communicating uncertainties in model-based policy analysis. *InderScience* **2010**, *10*, 299–315. [CrossRef]
44. Skea, J.; Van Diemen, R.; Portugal-Pereira, J.; Al Khourdajie, A. Outlooks, explorations and normative scenarios: Approaches to global energy futures compared. *Technol. Forecast. Soc. Chang.* **2021**, *168*, 120736. [CrossRef]
45. Barredo, J.I.; Engelen, G. Land Use Scenario Modeling for Flood Risk Mitigation. *Sustainability* **2010**, *2*, 1327–1344. [CrossRef]
46. Kwakkel, J.H.; Auping, W.L.; Pruyt, E. Dynamic scenario discovery under deep uncertainty: The future of copper. *Technol. Forecast. Soc. Chang.* **2013**, *8*, 789–800. [CrossRef]

47. Mannucci, S.; Morganti, M. How to tackle climate fragilities by DMDU. Making possible with regenerative design. *TECHNE J. Technol. Archit. Environ.* **2022**, *23*, 45–53. [CrossRef]
48. Marchau, V.A.W.J.; Walker, W.E.; Bloemen, P.J.T.M.; Popper, S.W. *Decision Making under Deep Uncertainty: From Theory to Practice*, 1st ed.; Springer International Publishing: Cham, Switzerland, 2019; ISBN 978-3-030-05251-5.
49. Kwakkel, J.H.; Haasnoot, M. Supporting DMDU: A Taxonomy of Approaches and Tools. In *Decision Making under Deep Uncertainty: From Theory to Practice*, 1st ed.; Springer International Publishing: Cham, Switzerland, 2019; Part III; pp. 355–364. ISBN 978-3-030-05251-5.
50. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. Available online: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981 (accessed on 10 March 2023).
51. Comune di Ravenna. PAESC Piano di Azione per l'Energia Sostenibile e il Clima 2020. Available online: https://www.comune.ra.it/aree-tematiche/ambiente-e-animali/ambiente-e-territorio/strumenti-di-gestione-ambientale/paes-piano-dazione-per-lenergia-sostenibile/ (accessed on 20 November 2022).
52. ERVERT (Emilia-Romagna Valorizzazione Economica Territorio) Spa. Schede Metodologiche per il Calcolo delle Riduzioni di CO2eq. Piani Clima 2007–2020 2013, Regione Emilia-Romagna. Available online: https://ambiente.regione.emilia-romagna.it/it/cambiamenti-climatici/materiali-vari/documenti_vecchia_versione/piani-clima/materiale-di-approfondimento/piani-clima-2007-2020-schede-metodologiche-per-la-riduzione-della-co2eq (accessed on 30 January 2020).
53. Decreto del Presidente della Repubblica del 11 Luglio 1980, n. 753. Nuove Norme in Materia di Polizia, Sicurezza e Regolarità dell'Esercizio delle Ferrovie e di Altri Servizi di Trasporto. Available online: https://territorio.regione.emilia-romagna.it/codice-territorio/semplificazione-edilizia/non-rue/2.2 (accessed on 10 January 2020).
54. Staffilani, F.; Guermandi, M.; Tarocco, P.; Ungaro, F.; Calzolari, C. Carta del Carbonio Organico Immagazzinato nei Suoli della Pianura Emiliano-Romagnola da 0 a 30 cm. Available online: http://mappegis.regione.emilia-romagna.it/gstatico/documenti/dati_pedol/NOTE_ILLUSTRATIVE_stockCO30_pianura.pdf (accessed on 15 February 2020).
55. Barrington-Leigh, C.; Ouliaris, M. The renewable energy landscape in Canada: A spatial analysis. *Renew. Sustain. Energy Rev.* **2017**, *75*, 809–819. [CrossRef]
56. Poggi, F.; Firmino, A.; Amado, M. Planning renewable energy in rural areas: Impacts on occupation and land use. *Energy* **2018**, *155*, 630–640. [CrossRef]
57. Haasnoot, M.; Warren, A.; Kwakkel, J.H. Dynamic Adaptive Policy Pathways (DAPP). In *Decision Making under Deep Uncertainty: From Theory to Practice*; Marchau, V.A.W.J., Walker, W.E., Bloemen, P.J.T.M., Popper, S.W., Eds.; Springer International Publishing: Cham, Switzerland, 2019; pp. 71–92. ISBN 978-3-030-05252-2.
58. Lobosco, G. Il paradosso dei paesaggi disturbati dalla transizione energetica. L'isola di Pantelleria verso nuovi ecosistemi. *Ri-Vista. Res. Landsc. Archit.* **2019**, *17*, 176–191. [CrossRef]
59. Mathur, A.; Da Cunha, D. *Mississippi Floods: Designing a Shifting Landscape*, 1st ed.; Yale University Press: London, UK, 2001.
60. Mathur, A.; Da Cunha, D. *Design in the Terrain of Water*, 1st ed.; Applied Research + Design Publishing: Novato, CA, USA, 2014.
61. Sijmons, D.; Feddes, Y.; Luiten, E.; Feddes, F.; Nolden, M. *Room for the River: Safe and Attractive Landscapes*, 1st ed.; Uitgeverij Blauwdruk: Wageningen, The Netherlands, 2017; ISBN 978-94-9247-496-4.
62. Redford, K.H.; Adams, W.M. Payment for ecosystem services and the challenge of saving nature. *Conserv. Biol.* **2009**, *23*, 785–787. [CrossRef]
63. Rodríguez-Robayo, K.J.; Merino-Perez, L. Contextualizing context in the analysis of payment for ecosystem services. *Ecosyst. Serv.* **2017**, *23*, 259–267. [CrossRef]
64. Brown, K. *Resilience, Development and Global Change*, 1st ed.; Routledge: London, UK, 2016; pp. 138–139. ISBN 978-0-415-66346-5.
65. Covenant of Mayors. Available online: https://climate-adapt.eea.europa.eu/en/eu-adaptation-policy/covenant-of-mayors (accessed on 10 March 2022).