Modern Environmental Science and Engineering (ISSN 2333-2581)
February 2024, Volume 10, No. 1–2, pp. 20–27
Doi: 10.15341/mese(2333-2581)/01–02.10.2024/003
Academic Star Publishing Company, 2024
www.academicstar.us

Ecological Transition and Spatial Planning

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Abstract: The energy transition, under the terms of current European and Portuguese public policies, towards a rapid decarbonization of society and the economy, justified by the urgent need to combat climate change and its consequences in terms of extreme events of various kinds.

A total electrification of final energy uses is therefore proposed, to be realized by 2050, through the intense use of renewable energy sources with intermittent characteristics. This option implies very significant and extensive land occupation on the Portuguese mainland with RES production/conversion units, mainly wind and photovoltaic.

Such a transformation of land use, most of which is now rustic/rural and forested, will have consequences for land-use planning, the landscape and the local economy that need to be properly considered *ex ante*.

Key words: transition, energy, spatial planning, land use, territorial economy

"The human species can't stand an excess of reality"
— TS Elliot

1. Introduction

On 1 January 2016, the United Nations (UN) resolution entitled "Transforming our world: 2030 Agenda for Sustainable Development" came into force, defining the 17 Sustainable Development Goals (SDGs).

This Agenda integrates the set of SDGs in a hierarchical way[1] centered on the problems considered most urgent. These include Goal 7 — Ensure access to reliable, sustainable energy; Goal 13 — Combat climate change and its impacts; and Goal 15 — Protect the sustainable use of terrestrial ecosystems, forest sustainability, halt and reverse land degradation and halt biodiversity loss.

In 2015, in Paris, the UN also adopted the first universal and legally binding global climate agreement, to be implemented from 2020, with the aim of limiting global warming to well below 2°C. The European Union's (EU) contribution set a very ambitious target: reducing greenhouse gas (GHG) emissions by at least 40 percent by 2030.

About the effect of GHGs and the concomitant global warming, although these aspects have been known for many dozens of years (Odum 2004, 50), it is only more recently that it has been established socio-politically that they have repercussions on climate (in)stability.

The term transition, applied to transformations related to the provision of primary and final human energy needs, has been known for a long time. The second transition began almost two centuries ago, as illustrated in Fig. 1, and was coeval with the so-called industrial revolution.

The current ecological transition, or, in essence, the energy transition, particularly targeted at the European Union (EU), is very different from those of the past. Invoking the urgent need to combat the consequences of anthropogenic climate change, it is based on the almost total electrification of the world's economy and society through the intense and exclusive use of renewable energy sources, some of which have

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[1] The order in which the topics are mentioned in the Agenda is related to the number of mentions made in the surveys and hearings carried out over nearly two years in various countries. Available online at: https://unric.org/pt/desenvolvimento-sustentavel/.

intermittent characteristics (wind and photovoltaics). The aim is to replace all fossil-based final energy with renewable electricity in just over a quarter of a century. This is represented in Fig. 2 for the Portuguese case.

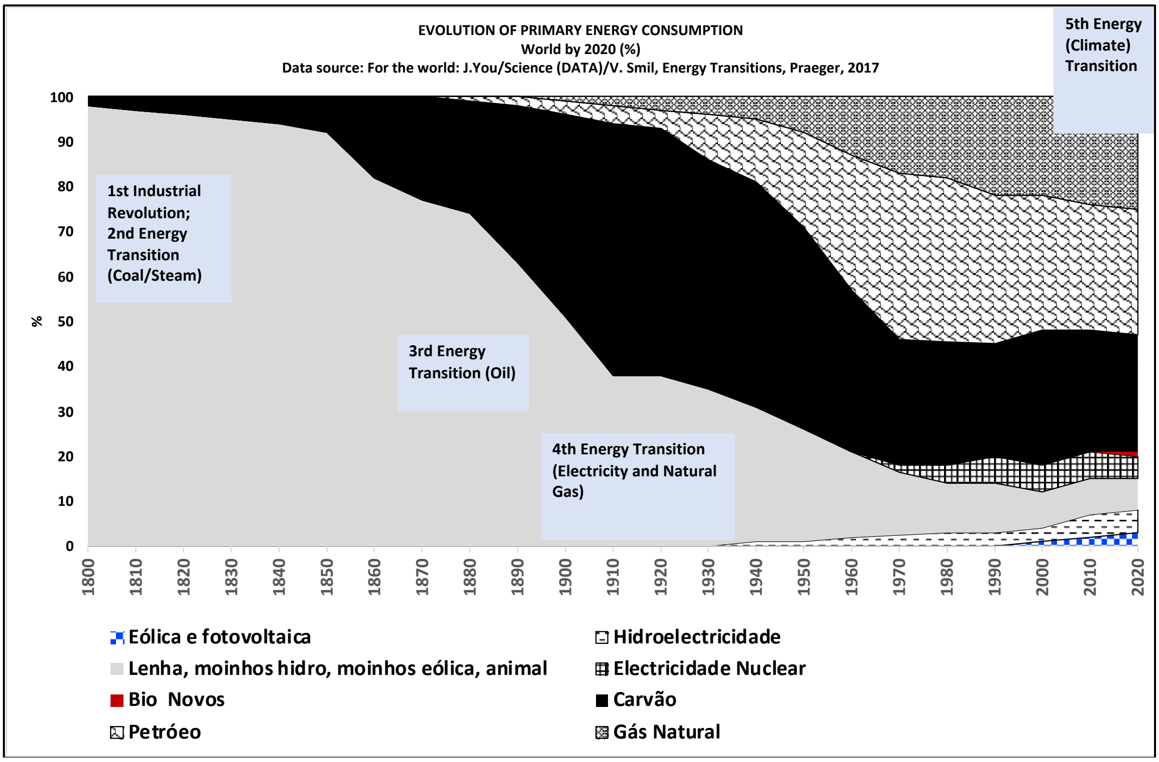

Fig. 1 Evolution of primary energy consumption world by 2020 (%).

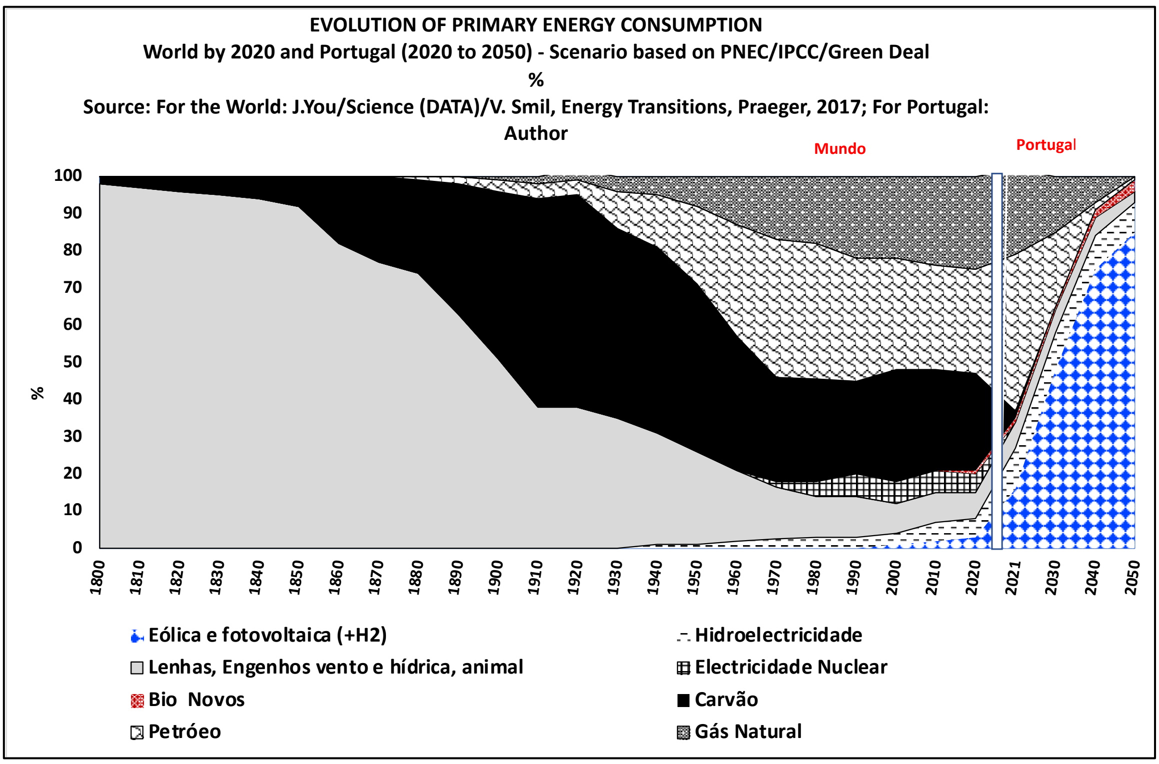

Fig. 2 Evolution of primary energy consumption world by 2020 (%) and Portugal (2020 to 2050) — Scenario based on PNEC/IPCC/Green Deal.

The IPCC Reports, particularly the Summaries for Policymakers, are very vehement about the catastrophic consequences of not acting. However, the energy transition also has a major and immediate negative impact on final energy consumers (increased prices/tariffs and the purchase of new equipment/systems/vehicles), as well as on workers in the banned industries (unemployment), in addition to facilitating vast public financial resources to large economic and financial aggregates.

Another aspect to take into consideration is the huge amount of new mineral resources needed for the energy transition, in particular critical metallic minerals[2] [1] whose future supply is problematic, not only in quantitative terms, but also because their exploitation has very delicate environmental, social and geostrategic aspects.

As for units converting renewable primary energy sources into electricity without emitting GHGs (in the production phase), particularly photovoltaic units, disregarding the fact that they have several advantages as well as several negative implications, whether direct or indirect, is not good for diagnoses or for establishing alternative programs. In addition to the serious limitation related to the intermittency of these sources and the capacity factors very low (Fc)[3] of these units, they represent impacts on land use, as well as drastic modification of the landscape and changes to ecosystems and the territorial economy[4] [2]. They also have an impact on the local climate due to the intense removal of tree cover and/or vegetation in general, promoting changes in evapotranspiration and CO_2 absorption in the photosynthesis process, as well as on water quality and the hydrological cycle, as they contribute to increased soil erosion [3].

Social protest and political disagreements related to the densification of territorial occupation by electricity generation units based on RES — Renewable Energy Sources, particularly wind and photovoltaic, as well as the related infrastructures and given their enormous quantity and dispersion, were disregarded at the start of the energy transition, perhaps due to the political hyper-emphasis given to the need for accelerated decarbonization. Private investment in RES has been intensely leveraged by public instruments of a fiscal and subsidizing nature (*FITs — Feed-in-Tariffs*) and is therefore a lucrative business. But, as might be expected, given the scale that these investments require to be consistent with the real decarbonization needs set out in the National Energy and Climate Plan 2021-2030 — PNEC 2030, "*contestation and opposition is growing, both in Portugal and in other countries*" [4].

Bearing in mind the objectives of the decarbonization transition, it would be desirable to minimize opposition to the installation of RES units, especially photovoltaic and wind power. However, it would then be necessary for EIA — Environmental Impact Assessment — procedures to cease to be "*typically centralized, hierarchical and secretive*" [5].

As part of the effort to make agricultural and livestock production compatible with photovoltaic electricity generation, APV units — agrophotovoltaics [6] — have appeared, which have some interesting aspects. It seems, however, that to increase the socio-economic acceptance of this system, we still have a long way to go to demonstrate its viability, if we want it to become widespread.

There are proposals that point to the advantages of the wide territorial dissemination of small RES units, to "increase the scale of proximity to communities located in rural areas, thus boosting their access to energy (...) and contributing to greater territorial cohesion in terms of access to basic necessities that are indispensable to any development process" [7]. Since it

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[2] See Proposal for a Regulation of the European Parliament and of the Council: Establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020, COM/2023/160 final).

[3] Capacity Factor is the ratio between the actual production of a given power station in a specific period and the maximum total capacity in that same period (usually one year, 8766 hours).

[4] High impact on the price level of rural/rustic land and no significant increase in jobs in the context of very significant investments.

is not possible, for lack of space in this exercise, to record an in-depth analysis, it should be noted, however, that it does not seem appropriate to confuse energy sprawl with the concept of decentralization, nor is it possible to see how there could be greater socio-economic equity with such miniaturization of RES units. Firstly, because no consumer can do without a connection to the national electricity grid, except in isolated cases, i.e., in terms of final price/tariff there will be no significant differences. Energy sprawl has many of the same drawbacks as urban sprawl [8], and they feed back on each other.

RES units, particularly wind turbines and photovoltaics, which will become central to the energy portfolio that is essential for decarbonization, will not be in operation for short periods: their need will continue for decades, and, for this reason, their possible future decommissioning cannot be considered in the short or medium term.

Designing an energy transition with ecological concerns, based almost exclusively on renewable energy sources to generate all the electricity needed by the economy and society, implies considering the three UN SDGs, and not just the one linked to combating climate change.

Spatial planning is closely related to Objective 15 and, according to the European Charter for Spatial Planning (1983), OT is a "*scientific discipline, an administrative technique and a policy*" that should be implemented democratically.

The National Spatial Planning Policy Program (PNPOT)[5] is the top instrument of Portugal's territorial management system, defining objectives and strategic options for territorial development and establishing the model for organizing the national territory.

In the revised version of the PNPOT approved by Law No. 99/2019 of 5 September 2019, you can find 82 references to climate change, 76 times to energy and four times to the energy transition.

2. The Portuguese Energy System and Soil Requirements for the Transition

In addition to the PNEC 2030, the main energy and climate policy instrument[6] , there is also the National Action Plan for Energy Efficiency (PNAEE) and the National Action Plan for Renewable Energies (PNAER), both created by Council of Ministers Resolution 20/2013 of 10 April[7] .

The BE Energy Balance 2022[8] shows that: Energy Oil accounted for 7211.4 ktoe (43.7 percent), Natural Gas for 1646.6 ktoe (25.3 percent), Electricity for 4178.1 ktoe (25.3 percent), Biomass for 1082.9 ktoe (6.6 percent) and oil for non-energy purposes, other renewables (apart from RES integrated into electricity and biomass), heat (industrial steam), miscellaneous waste (including MSW) and coal (which fell sharply after the closure of thermoelectric power stations). Therefore, an essential conclusion is that electricity only accounts for around 25 percent of the final energy consumed in Portugal.

The total decarbonization of the economy and society by 2050[9] implies replacing all primary energy sources that are not already decarbonized with RES (mostly hydroelectricity, biomass, wind and photovoltaics). In other words, if there were no increases in energy consumption — which is unlikely in the Portuguese reality — this would lead to final electricity consumption of around 17,000 to 18,000 ktoe, instead of the current 4,178.1 ktoe, 4.3 times more in just a quarter of a century, with almost exclusive recourse to RES and the intensification of the rational use of energy (RUE) in Fig. 3.

[5] The PNPOT was created by the 1998 Law on the Basis of Spatial Planning and Urbanism Policy, and the first was approved by the Assembly of the Republic through Law 58/2007 of 4 September.

[6] In operational programme terms, this is an energy plan, although it is completely determined by climate objectives.

[7] Available online at: https://files.diariodarepublica.pt/1s/2013/04/07000/0202202091.pdf.

[8] Prepared annually by the DGEG.

[9] The exact terms of the commitments state that the aim is to "*achieve climate neutrality in the EU by 2050, meaning an EU-wide balance of greenhouse gas emissions and removals*".

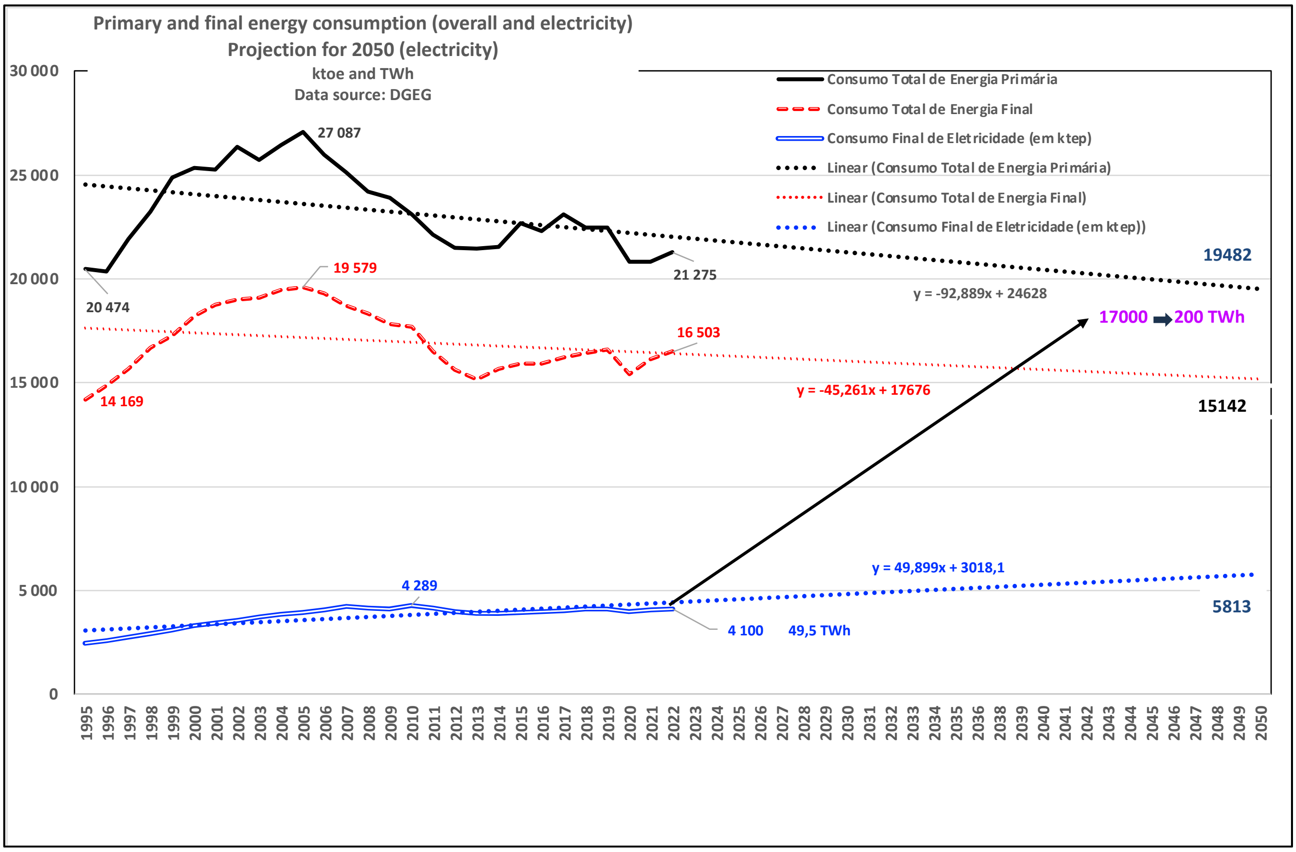

Fig. 3 Primary and energy consumption (overall and electricity) projection for 2050 (electricity).

To meet Portugal's needs in 2050, even in an unlikely (or desirable[10]) scenario in which there would be no significant increase in final energy consumption, there would be around 200,000 GWh (200 TWh[11]) of electricity consumed, i.e., four times more than today. And if final energy consumption were to evolve at the same rate as it did until 2007 (before the subprime crisis, which was then projected in Europe as the sovereign debt crisis), it would reach 580 TWh, a huge amount of electricity in the Portuguese context. In a prudent scenario, this essay points to an expected need for electricity of between 260 and 290 TWh.

The question then arises: how and where would this amount of electricity be produced? It should be noted that today (2022), to meet consumption of 49,465 GWh, 9,254 GWh (19%) are imported. This is a significant external dependency, which has worsened in recent years.

Considering the future need for electricity, between 260 and 290 TWh in 2050, we would have to go from 23.25 GW of installed power integrated into the National Electricity System (SEN) in 2022, to around 250 GW of electrical power[12] , almost eleven times more, in a portfolio fundamentally based on wind,

[10] Energy consumption in general and electricity consumption in particular are demonstrably correlated with economic growth and the level of socio-economic development. Low consumption capacities are linked to energy poverty, which in Portugal affects 700,000 families. As a mere example of topics that have been less addressed, we would like to mention the correlation between low energy availability and mental illness (How to Make Societies Thrive? Coordinating Approaches to Promote Well-being and Mental Health, OECD Publishing, Paris, https://doi.org/10.1787/fc6b9844-en.) and corruption (The impact of corruption on economic growth in developing countries and a comparative analysis of corruption measurement indicators, available online at: https://www.tandfonline.com/doi/full/10.1080/23322039.2022.2129368).

[11] 1 GWh = 86 toe.

[12] The calculation took into account the Fc that the most common RES (photovoltaic and wind) have on average.

hydroelectric and photovoltaic power, and without any natural gas thermal support (Combined Cycle Plants).

At the end of 2022, Portugal generated 3,472 GWh of electricity from solar photovoltaics and had an installed capacity of 2,561 GW according to DGEG data[13] , which shows a very low Fc.

The PNEC 2030 estimates that there will be 12.4 GW of wind power (of which 2 GW offshore and 10.4 GW onshore), 20.4 GW in photovoltaic units, and 1.4 GW of biomass/biogas and waste, with no hydroelectric incorporation expected (only an increase to 3.9 GW in pumping). In other words, a total of 47 GW of installed electrical power, including 5.5 GW of decentralized photovoltaics.

The total number of photovoltaic plants planned in the investment projects already in the licensing process (or already authorized) is 131, to which must be added those relating to the auctions already held, a total of 48.2 GW, which means that 32.8 GW of this total will be operational by 2030.

In the field of wind, both onshore and offshore, the scenario considered involves allocating 10 GW of offshore wind capacity through sequential auctions, plus around 10.4 GW on the mainland.

To supply the 250 GW estimated to be needed in 2050, 170 to 190 GW of photovoltaic power would have to be installed, which means that to place power of this order on the Portuguese mainland, given the ratio of 2 to 3 ha/MW[14] , an additional 340,000 to 570,000 ha would need to be dedicated to this technology. Bearing in mind the units that have already been authorized but have not yet begun to be built, it is estimated that the increase in land consumption for this purpose will be around 600,000 ha.

The LNEG — National Energy and Geology Laboratory, in collaboration with various organizations [15] , carried out an analysis called "Estimation of technical renewable energy potential in Portugal — wind, solar photovoltaic, concentrated solar, biomass and oceans", which resulted in a final report[16] , intended to inform political decision-making. This work included an important autonomous technical assessment called "Identification of areas with lower environmental and heritage sensitivity for the location of renewable electricity production units", issued in January 2023[17] and then revised in July of the same year[18] .

In the first version issued on 26 January 2023, it was considered that 12% of the Portuguese mainland could be mapped as potentially suitable for installing renewable electricity projects while safeguarding the environment. This would mean that 1,069,250 ha could be used to install renewable electricity production units, i.e., more than double all the artificialized areas existing on the continent in 2018.

Subsequently, in July 2023, after analyzing various critical contributions, a second version was conscientiously drawn up with three more scenarios (maps) than the initial one, which differ in the degree of application of exclusion conditions, in which stricter criteria were considered, meaning a significant reduction in the potential areas available.

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13 DGEG (2023). Rapid Renewables Statistics. No. 222 - May 2023, Lisbon, available online at: https://www.dgeg.gov.pt/pt/estatistica/energia/publicacoes/estatisticas-rapidas-das-renovaveis/.

14 Although there are projects with a ratio of 1.5 ha/MW, the occupation of the necessary complementary infrastructure (lines, transformer stations, substations and protection and support areas) is usually neglected. On the other hand, in order to feed photovoltaic and wind power into the SEN electricity grid, a very significant amount of land will be needed to install chemical electricity storage units (accumulator batteries).

15 Portuguese Environment Agency (APA), Directorate-General for Energy and Geology (DGEG), Directorate-General for Territory (DGT), Institute for Nature Conservation and Forests (ICNF) and Directorate-General for Cultural Heritage (DGPC).

16 Available online at: https://repositorio.lneg.pt/bitstream/10400.9/4077/4/Relatorio_LNEGPotenciaisRES_Julho2023.pdf.

17 Available online at: http://repositorio.lneg.pt/bitstream/10400.9/4006/3/RelatorioLNEGAreasMenorSensibilidade_Final.pdf.

18 Available online at: http://repositorio.lneg.pt/bitstream/10400.9/4006/5/2aVersaoMapaAreasMenosSensiveis_Jul2023.pdf.

Taking into account what is registered in COS2018[19] , occupation class 1.3.1.2 — Renewable energy production infrastructures contain 1,749.19 ha (0.02% of the continent's total area), and class 1.3.1.2 — Non-renewable energy production infrastructures contains 1,154.54 ha (0.01% of the total).

In the revised LNEG Report, the total areas that could be artificialized for the purpose of installing renewable electricity production is 372,558.55 ha — 4.00% of the mainland's area (onshore only). However, in the maps of less sensitive areas presented after revision of the initial report, issued in June 2023, the estimates are:

- Scenario 1 (Corresponds to the improved January 2023 version) — areas < sensitivity: 10,350 km^2; ~12% Mainland Portugal area — 1,069,225.68 ha.
- Scenario 2: 2nd version, as 1st version, more mineral resource protection areas, areas < sensitivity, 8977 km^2, ~10% Mainland Portugal area — 897700 ha.
- Scenario 3: As scenario 2 & still: removing SAPC areas[20], removing buffer 500 m in residential buildings, areas < sensitivity 4 162 km^2; ~4.7% Area Mainland Portugal — 416200 ha.
- Scenario 4: Like scenario 3 & still removing available RAN and REN areas; areas < sensitivity 2 652 km^2; ~3% Mainland Portugal area — 265 200 ha.

The LNEG did not indicate, nor would this have been part of the objectives set by the Ministry, Portugal's final energy needs in various socio-economic development scenarios in the medium and long term. It estimated the technical potential of renewables. And the results found only "*report the best knowledge at the time of writing (July 2023) and should be seen as a dynamic estimate to be reviewed and refined in future revisions*". The cautionary notes that the LNEG left in the report, for example on safeguarding underground water resources (SAPC) and on the RAN - National Agricultural Reserve and REN - National Ecological Reserve areas, are very commendable.

3. Discussion and Conclusions

Considering what is mentioned in the 2021-2030 PNEC energy targets[21] and in the 2050 Roadmap for Carbon Neutrality[22] , it is estimated that it would be necessary to occupy around 600,000 ha more of continental land by 2050 to install new RES electricity generation units (wind and photovoltaic).

In the LNEG report entitled "Estimated technical potential for renewable energy in Portugal — wind, solar photovoltaic, concentrated solar, biomass and oceans", from January and July 2023, the technical potential of RES was recorded. In addition, the LNEG studied four progressively more demanding scenarios in terms of the criteria to be applied in excluding land for energy purposes, presented under the designation Sensitive Areas. It is considered that the land available in Scenario 4 is the best match for the levels of territorial sustainability as defined in the PNPOT in force.

The materialization of the energy programming associated with the PNEC and Roadmap would mean, when projected over the long term (2045-2050), notable environmental, territorial and socio-economic effects, which, from what has been analyzed, are fundamentally not positive.

Considering the safeguarding of the relevant values, priorities and principles within the scope of the OT, it is concluded that it will not be possible to sustainably

[19] This information base, COS2018 — Land Use and Occupation Map (COS) for mainland Portugal, is the responsibility of the Directorate-General for Territory (DGT), has 4 levels of hierarchy and can be broken down into 83 land use classes; available online at: https://www.dgterritorio.gov.pt/Carta-de-Uso-e-Ocupacao-do-Solo-para-2018?language=en.

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[22] Council of Ministers Resolution no. 107/2019, of 1st July.

accommodate a large part of the renewable electricity production park, particularly photovoltaic and wind power, estimated as necessary for the ecological energy transition defined politically for the 2050 horizon.

It therefore seems advisable that environmental, energy and territorial licensing methodologies should remain rigorous in the light of key principles, particularly those of sustainable OT, and, on the other hand, that an extraordinary Strategic Environmental Assessment (SEA) of the energy plan/program under development should be carried out before proceeding with the implementation of RES units on the ground on a case-by-case basis.

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