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Energy Production from Renewable Sources: Evolution and Development Prospects for the North West of Sardinia

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ABSTRACT

The issues related to energy production and the development of renewable sources (RES), connected to the contextual policy of "phase out" from coal by 2025, in line with EU directives, are considered a strategic objective of the Italian energy system and a priority of new infrastructure investments for the electricity grid system. The geo-economic and infrastructural characteristics of Sardinia constitute the ideal environment for the development of RES. This work highlights some basic issues due to the importance that Sardinia has assumed for the production of energy from renewable sources in the national grid system. The study investigates and traces the stages of the evolution of this system, through the historical and technological path that has accompanied the development of electricity production in Sardinia, the impacts on the territories and the influence on the changes and transformation of Sardinian society. We analyse the dynamics of how Sardinia has passed from self-sufficiency in energy production to an intermediate phase, with traditional energy production and RES, in which it exported energy, to become an energy hub destined to produce 5 gigawatts from RES to the national grid. The case study concerns the North West of Sardinia which, due to the particular weather and climatic conditions, is considered one of the most important potential "fields" of energy production from waves and wave motion. The work highlights an important issue concerning 'the consumption of the territory' with no return for the community. The production of energy from wind and sun, with the proliferation of plants and requests for new concessions and authorisations both on land at sea by private individuals, risks feeding a speculative, economic and production phenomenon which is already visible. At the same time, an account must be taken of the complex geopolitical situation caused by the conflict between Russia and Ukraine, which has changed the international scenario. The serious crisis has evolved into what is now called a 'war economy' with complications and consequences whose effects have taken on worrying contours.

1. Introduction

The peculiarity of Sardinia as an island and it's isolation is also visible in the characterization of the electricity production and distribution system that has accompanied the development of its

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economic system and the historical phases of its evolution. The change in Sardinian society and above all in infrastructures is closely linked to energy production issues to the point of providing, in the new phase, an energy hub for RES. At present, the North West of the island and in particular the macro-area of Sassarese, requires an important response to the crisis of the socio-economic system, originating from the processes of delocalization and deindustrialization.

Enhancing the experimentation and innovative projects can contribute, with the new technologies from RES, to favour a strategic repositioning of the territory in response to the current crisis.

A strategic repositioning of the territory to respond to the current crisis is favoured by the enhancement of the experimentation and innovation resulting from the new technologies associated with RES.

In this presentation, two relevant issues that affect the development of RES in Sardinia were addressed. The first concerns the transition from a phase of energy production linked above all else to the needs of the island and the industrial centres that have developed since the 1960s, which was then followed by the phase of post-industrialization and delocalization. The second issue concerns the choices and strategic directions by the central government within the PNIEC, to which are added the consequences due to the war between Russia and Ukraine, relating to the supply of hydrocarbons, currently indispensable to guarantee energy production.

The study highlights an historical and technological path that has accompanied the evolution and development of the Sardinian electricity grid and its energy production; also underlining the influence in the transformation of Sardinian society and its production system which started with the nationalisation of energy production, with the establishment of ENEL.

Until then Sardinia experienced a phase of self-production; the industrialization process, altered the social and entrepreneurial fabric of Sardinia, and created a significant increase in the demand for electricity.

During this period of development to meet the increased demand for energy production, the construction of various thermoelectric plants started, meanwhile the large companies in the industrial centres created their own plants to produce their (own) energy.

These transformations have had consequences, in the medium term, a crisis due to deindustrialization, the repercussions of which are still evident today. The analysis highlights how Sardinia passed from the self-consumption of its energy production to a phase with both traditional energy production and RES, in which it also exported energy, to become an energy hub destined to produce and supply 5 gigawatts from RES to the national network. The strategic guidelines, adopted by the State with the DPCM Sardinia on energy (March 2022) and to be implemented by its investee and / or subsidiary companies (ENEL TERNA, GSE, ENI, SNAM) have a before and after the DPCM. It should be borne in mind that to this is added the strong speculative drive by private individuals for the production of energy from wind and photovoltaic. The production potential from RES is an important response addressing the effects of the international crisis caused by the ongoing conflict: the supply of raw materials and the costs associated with energy production.

2. The Territorial Context

According to ENEA, "a clean energy field is hidden in the north-western part of Sardinia; wave motion, currents and tides have extraordinary potential", Sannino [1]. In this context, the focus of our work on the energy production of renewable sources concerns the North West of Sardinia, which is characterised by ideal conditions from a climactic point of view in which it is possible to find

homogeneous sub-regions characterised by varied socio-economic realities, where the complexity of this vast territory is connected to the geographical dimension and its functionality.

Specifically, the case study focuses on the Sassarese macro-area considering a strategic repositioning of its current condition,that best expresses its development potential

Linked to the Porto Torres industrial crisis originating from the processes of delocalization and deindustrialisation which was declared a complex crisis area for the municipalities of Porto Torres and Sassari, Ministerial Decree 8 February 2017, [2].

3. The Geographical and Environmental Area of the North West

The Province of Sassari represents about 32% of the entire regional territory and has an extension of about 7690 km ^ 2 and also includes the main islands of Asinara and La Maddalena. The current configuration is 96 municipalities with a resident population of 489.634 inhabitants and according to the Provincial Strategic Plan,divided across Anglona Bassa Valle, Meilogu Villanova, Monte Acuto-Goceano, Sassarese, Province of Sassari [3]. the names of the historical and geographical regions.

The North West of Sardinia is characterised by the important gateway infrastructures: Alghero airport and the port of Porto di Porto Torres. These infrastructures are considered the driving forces for tourism, commercial and industrial development of the entire provincial territory but also relevant for the entire regional territory, by the programming and strategic planning documents of the Province of Sassari, the Municipalities of Sassari, Alghero and Porto Torres and more recently the programming documents of the Rete Metropolitana of Northern Sardinia.

The macro-area is characterised by the environmental, naturalistic and cultural complexity which constitutes a significant territorial capital considered decisive in the structuring of the residential and economic settlement and its subsequent evolution. "The Sassarese area has the highest concentration of population and built-up area in the North West of the Province, due to the attractiveness of the activities and functions. From the urban facilities and services present to which the rest of the provincial territory also refers […]", Balestrieri *et al.*, [4]. In fact the territory historically represents one of the most important territorial realities of the regional tourism system.

The wealth of natural resources in the coastal municipalities has meant that their economy has always been characterised by the"tourism industry'' that has always resulted in important national and international attractions.

The industrial areas of Truncu Reale di Sassari, the area of San Marco di Alghero and the area of P. Torres are located on the perimeter of the coastal territories, and complete the picture of this geographical and territorial system/area.

In the initial phase of the industrialization process, especially in the Porto Torres area, a radical transformation changed the socio-economic fabric of the territory which, in the phase of decline, was characterised by a poor capacity to react. This is evidenced particularly in the industrial area of Porto Torres based on the petrochemical pole, considered at the time, among the most important in Italy, the industrial and commercial port, as well as the passenger port, the thermoelectric plant of Fiume Santo. The infrastructural and productive reconversion interventions are the attempt for a strategic repositioning of the territory in response to a consistent and continuous decrease in production of value to the entire regional territory.

In this context, energy production from renewable sources, albeit with a highly critical problem linked to governance, could represent an important intervention for a new development model.

4. The Consequences of the Russia-Ukraine Conflict on the Economic System

The progressive improvement globally registered by the economic systems of the EU, two years after the start of the pandemic had led the European Commission to forecast a growth of 4% over 2022, to then drop to 2.7% in 2023, European Commission, [5].

The geopolitical and consequently geoeconomic situation, due to the conflict between Russia and Ukraine, has radically changed that, leading to a serious economic and social crisis in the international scenario.

"In the first weeks of the conflict between Russia and Ukraine, the EU economy has already lost 0.5% of growth. In worst-case scenarios, the slowdown could be even greater (up to 2% of GDP). Still much less than what could happen in Russia (-10%), but still a significant slowdown", ISPI, [6].

In this context, given its fragility, the economic system of Sardinia presents a high and further degree of risk compared to the crisis already underway. In times of crisis the factors that affect and condition the economy of Sardinia are the transport system and the supply of raw materials.

The immediate effects of the conflict, for Sardinia, considered the only Region in these particular conditions, concern the cost of transport, connections with the peninsula, the cost of raw materials and the forwarding of finished products. The tensions are strongly reflected on the rise in the prices of electricity production, fossil fuels and in particular gas, oil, aluminium and on the entire production chain of these goods as well as on the relevant agricultural production sector. The numerous manufacturing and industrial businesses and chains on the island, from agri-food to mechanics, from stone to chemical, from construction to cork, risk seeing their production capacity jeopardised. It should be noted that Sardinia exported goods worth € 5.5 billion in 2021. A highly critical risk factor is the indirect consequences of the sanctions against Russia. For example, the disruptive effects on tourism, the leading sector of Sardinia. According to Federalberghi Sardinia: "The absence of tourism arriving from areas such as Russia, Ukraine and Belarus will have a regional impact that is around 100 million euros, one half concerns the hotel sector and the other related activities between villas, yachts, airports, helicopters and other services ", Manca, [7].

The analysis The analysis by the Confartigianato Study office, [8]: "focuses on" companies on the front line due to the impact of the war in central Europe ", highlights that:" the effects of the Russia-Ukraine conflict, due to increases in raw materials, energy and fuels, such as gas, oil, wheat and aluminium, but also due to the slowdown in tourist flows, are putting more than 30,000 Sardinian companies and about 95,000 employees under pressure, thus risking to compromise the recovery of island companies ".

The studies and analyses refer to the period prior to the conflict. It should be considered that we are currently talking about a "war economy" with all the implications and impacts that follow. In particular, the evolution of the conflict puts at risk "among others, the supplies of gas and oil necessary to guarantee energy production with any disruptive effects on the entire economic system.

5. The International and National Context

The regional energy policy, like the national one, refers to the international agreements to which Italy has adhered by assuming the relative commitments implemented in the National Energy Strategy, MISE, [2], and in the Integrated National Plan for Energy and the Climate [9], published on 21 January 2020. Italy must also confront: "with the scenarios of evolution of energy demand and consider that the development of infrastructures and the solutions adopted must be compatible with international, community and national energy and environmental policies, both by 2030 and 2050 ", RSE, [10].

The European Union has over the various programming periods approved several initiatives, which have merged into the European Green Deal strategy, to achieve its climate target by 2050, with a budget of 10 billion euros and is a package of strategic initiatives that aims to start the EU on the road to a green transition. This substantial intervention was intended to address the major challenges in the energy sector, which relate to dependence on imports, limited diversification, high and volatile energy prices, the increase in global energy demand, security risks in production and transit countries, the growing threats posed by climate change, and decarbonisation. Moreover, it is planned to take action on the slow pace of progress in the field of energy efficiency, on the challenges posed by increasing the share of renewable energy sources, and on the need for greater transparency and further integration and interconnection of energy markets, European Council, [11].

"The transition phase does not only represent the change from the use of one type of energy to another, but deeply involves the transformations of the global space, with social, economic and political implications that proceed far beyond the energy sector, redrawing the geopolitical map of the planet in the coming years", Perrone, [12].

According to the European Energy Agency, [13]: "European countries consume less energy than 10 years ago, mostly thanks to greater energy efficiency. Europe also relies less on fossil fuels thanks to energy savings and faster-than-expected adoption of renewable energy. In the decade 2005-2015, the percentage of renewables compared to EU energy consumption almost doubled, from 9% to almost 17%. Some sectors and countries are at the forefront in the use of clean energy. However, despite the decline in their market share, fossil fuels are still the prevailing energy source in Europe".

For Sardinia, in line with the National Energy Strategy, the closure of electricity production plants powered by fossil fuels is expected by 2025. The island was considered the only region in these particular conditions, due to its geographical, environmental and economic characteristics. Condition enhanced by the study of RSE, [10], (a company wholly owned by the MEF), on behalf of the Regulatory Authority for Energy, Networks and the Environment (ARERA), [called "Energy supply of the Sardinia region (years 2020-2040)". In addition to the geographical and economic ones, the study also considers the demographic and social conditions which, taken together, differentiate it from other Italian regions. Again according to the study: "The region's insularity has limited the development of infrastructures, especially in the energy sector. At present Sardinia is the only Italian region excluded from methanisation: the island does not have a natural gas transport system, while there are distribution networks, in some cases still under construction, which currently use other fuels ", [10].

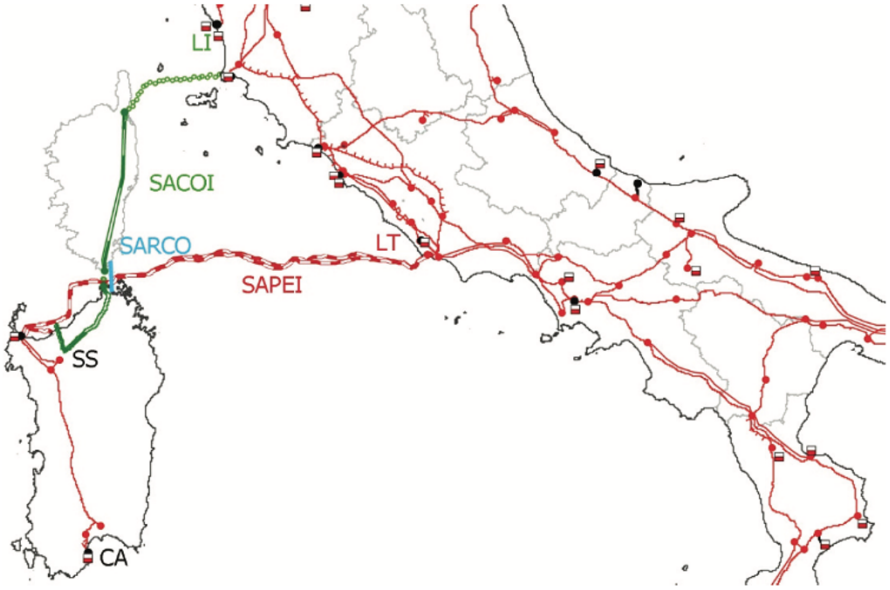
Insularity is the element that has always characterised the socio-economic development of the island, as it has determined, in this specific case, evident critical factors: "Sardinia is" isolated "from the rest of Italy and therefore the systems of production and distribution of electricity, having no mix with other systems, at least until 1962, the year of nationalisation, are clearly identifiable in geographical and electrical terms; something that does not happen in other regions […] ", Benincasa, [14].

The purpose of the study referred to is to evaluate the possible hypotheses of adaptation of the infrastructures of the Sardinian network and energy system and of the related interdependencies starting from an analysis of costs and benefits (ACB). In addition, the study provides an assessment that provides for the sole use of renewable sources to replace the phase-out of coal by 2025, which is in line with the climate neutrality goal by 2050.The national strategy for the Sardinian decarbonization project includes major infrastructural interventions with the construction of a new generation capacity from renewable sources and an important energy storage system. The construction of a new cable for the transmission of high voltage direct current electricity (HVDC) Sardinia-Sicily-Continent (Tyrrhenian Link) is planned.

For methane gas, in Sardinia, the insertion into the national network is envisaged with an infrastructure project consisting of new storage and regasification terminals, to be placed on the island consisting of floating storage and regasification units (FSRU, Floating storage and regasification unit), which is also believed to have a lower impact on the territory. The current infrastructure of Sardinia consists of the two coal-fired thermoelectric power plants and other minor fossil fuel power plants; it also has energy production from plants powered by RES. It is also interconnected with the continent through three power lines:

i. Continuous connection SA.PE.I. (500 kV - 1000 MVA) (Sardinia - Peninsula, Lazio) 2011.
ii. SACOI continuous connection (200 kV - 300 MVA) (Sardinia-Tuscany, with Corsica as a bridge), 1966.
iii. SARCO alternating connection (150 kV100 500MW) (Sardinia- Corsica)

Figure 1 shows Sardinia-Italy connection power lines.



Name	Total km	Submarines Km	Power (1) kV	Electrical voltage (1) kV	Current	Year of Realisation
SACOI (2)	385	121	300	200	DC	1968
SARCO (3)	38	15	100	150	AC	2006
SAPEI (4)	435	420	1000	500	DC	2011

(1) Power and voltage data refer to the current structure
(2) Sardinia Corsica Italy: Codrongianus-Ploaghe (SS), Santa Teresa di Gallura, Bonifacio, Lucciana, Suvereto (LI)
(3) Sardegna Corsica: Santa Teresa di Gallura, Bonifacio
(4) Sardinia Italian Peninsula: Fiume Santo (Porto Torres- SS9, Borgo Sabotino (LT)

Fig. 1. Sardinia-Italy connection power lines: The SACOI (green line) and the SAPEI (red-white), through conversion / transformation substations, are inserted into the electricity network of the Peninsula (red lines). The SARCO (blue) connects the Sardinian electricity grid to the Corsican one, Source: Carboni, de Vincenzi, Fasano, [15]

6. The Regional Scenario of Energy Production and Its Evolution Over Time

Sardinia, as has been said, until 1962 expressed its peculiarity as an island and its isolation also in the characterisation of the production and distribution system of electricity and the two energy sources, water and heat, for the production of electricity, were easy to locate, [14].

The history of traditional electricity production accompanies and distinguishes the evolution of society and the economy of Sardinia. The socio-economic system of Sardinia, starting from the 1960s, underwent important changes, first of all with the establishment of ENEL (1962) and the nationalisation of electricity production, with the aim of unifying the national electricity system and nationalising electricity producing companies. Thirty-three electricity companies were nationalised in Sardinia [15]. In the same period there were important investments, within the framework of national policy, in the chemical industry, with industrial and petrochemical settlements (Porto Torres-Fiume Santo, Ottana, Assemini, Portovesme, Sarroch). In addition to transforming the social and entrepreneurial fabric of Sardinia, the establishment of industries, determined a consistent demand for electricity. To meet this need, ENEL planned and made important investments. The construction of various thermoelectric plants began in that period while the large companies of the industrial poles created smaller plants to self-produce electricity. Production from thermal sources concentrated on industrial areas and became prevalent over hydroelectricity, which had previously been developed in inland areas and as a function of the need to exploit basins and river systems.

At the same time, the first connection with the Italian peninsula was made: "The first" import "of electricity took place in Sardinia between the end of 1967 and the beginning of 1968 with the completion of the power line connecting the island with Corsica and the Italian Peninsula: SACOI (Sardinia-Corsica-Italy), connecting the Sardinian electricity grid to the national grid […]. This allowed both to export the surplus of Sardinian production to other Italian regions and Corsica, and to import electricity in the event of increased demand on the island ", De Vincenzi, [16].

Towards the end of the 90s, the production of energy from renewable sources, especially from solar energy with photovoltaic panels and from wind energy, developed, benefiting from incentives and subsidies.

Based on these assumptions, in 2006, the Region of Sardinia redefined its strategic lines of the regional energy and environmental policy and adopted the Regional Environmental Energy Plan, Regione Sardegna, [16], in which a "strategic framework was outlined, aimed at achieving the priority objectives of the diversification of sources, energy autonomy, and compliance with international constraints on environmental protection, through the following lines of action:

i. Methanisation of the Island;
ii. Activation of the mine-central supply chain of the Sulcis centre;
iii. Development of renewable sources and promotion of energy saving and efficiency, [17]

From the analysis of electricity production in Sardinia in this period, a figure clearly emerges that differs from the national one, the absence of gas-fired power plants (0.00%). Another important starting point is the use of coal (50.9%) and petroleum products (44.2%) which contributed to transforming primary energy into electricity for 2,882 ktep

Renewables contributed to electricity generation with a 4.9% share deriving mainly from water and wind sources [17].

Also according to the Plan, the lower efficiency of the Sardinian system compared to the national average is attributable, among other things, to an industrial system characterised by the presence of energy-intensive industries and the absence of gas-fired power plants with greater efficiency than

coal and fuel oil plants. ; the PEAR envisaged, in this sense, an important development of RES, as a function of a new way of thinking about saving and energy efficiency, but also for the protection of the environment with the aim of reducing polluting sources and emissions . The PEAR also outlined the strategy to get the region out of energy isolation and which provided for the diversification of primary sources of energy with a consequent reduction in dependence on petroleum products.

7. The Methanisation of Sardinia

One of the priority objectives of the PEAR concerned the methanisation of the island. To address this the construction of a gas pipeline was planned which, starting from Algeria, crossed Sardinia and connected to the peninsula, the Algeria Sardinia Italy (GALSI) gas pipeline, which provided for a 284 km submarine pipeline. The agreement for its construction, between Algeria and Italy, was concluded in 2009 and the conclusion of the project, worth 3 billion dollars, was scheduled for 2012. From the port of Koudiet Draouche, in the north-east of Algeria the conduit was supposed to reach Sardinia, in the municipality of Giba, and then cross the whole island to Olbia. another submarine pipeline would leave Olbia for Tuscany (Piombino), from where the connection with the Italian national network would branch off. Once completed and fully operational, the pipeline would guarantee Italy about 8 billion cubic metres of gas per year. Between 2014 and 2017 the entire project with a series of various and complex situations, was abandoned.

More recently the project to include Sardinia in the national gas network has been resumed taking into account that in the short and medium-term RES energy production alone cannot guarantee the necessary energy and the stability of the system. The extension of the national gas network to Sardinia will be through a virtual connection that includes a set of infrastructures mainly with FSRU.

8. The Sardinia Region Environmental Energy Plan (P.E.A.R.S.)

With the adoption of the PEAR, the Sardinia Region approved various guidelines for the development of RES, such as the study for the identification of the areas in which to locate the wind farms (2007), the guidelines for the identification of potential impacts of photovoltaic systems and their correct insertion in the territory (2008), a resolution of the G.R. which approves a guideline document for renewable energy sources [18]. In 2010, it initiated the procedure to draw up a new proposal for an Energy Plan incorporating the guidelines on RES, the new guidelines that had been outlined at EU and national level. In fact, in the 2014-2020 programming period, the European Union decided to promote energy efficiency, committing member states to pursue the objectives to reduce consumption and climate-changing emissions in the various production sectors.

Italy has planned a reduction in primary energy consumption, compared to 1990 data, equal to 20 million "tons of oil equivalent" (TOE). It also set the share of final energy consumption produced by RES at 17%. For 2030, the target envisaged a 40% reduction in greenhouse gas emissions with reference to 1990 data, and a share of the use of renewable sources of at least 27% compared to final energy consumption (PEARS 2016) (RAS, PEARS, 2016). According to this approach, Italy has established a breakdown by regions of specific shares of competence (so-called burden sharing, Ministerial Decree, March 15, 2012 [9].

Table 1
Trajectory of the binding regional objectives, from the initial situation to 2020 - BURDEN SHARING: final consumption from RES on the total final consumption (ratio between the sum of the shares of energy consumed from renewable energy sources in the electricity sector and in the thermal sector (RES- E + RES-C) and gross final consumption (CFL) equal to 17.8% in 2020) (D.M. MISE, 15 marzo 2012)

SARDEGNA	Reference year 2005	2012	2014	2016	2018	2020
	3,8%	8,4%	10,4%	12,5%	14,9%	17,8%

With resolution of the Regional Council n. 45/40 of 2 August 2016, the new environmental energy plan of the Sardinia Region was approved, [18]. With this programmatic tool, the Region has set itself the goal of achieving the objectives established by the Community and national commitments. The Plan also provided for a threshold of 50% reduction in climate-altering emissions by 2030, which is also higher than the 40% set by the E.U.

The strategy tends to enhance policies and energy efficiency from renewable sources on the basis of approved regional guidelines, with programming and planning in all areas of intervention, depending on the type, from solar to wind, from thermal production to biomass. At the same time it planned to downsize energy sources from fossil fuels.

The Plan to achieve the objectives of burden sharing, provided for the elaboration of a new regional energy balance but also an optimization of the production from RES that would allow to detect final consumption and such as to be able to verify and adopt the necessary measures on production imbalances from renewable between the electricity and heat sectors, [18]. With the Plan, a governance and monitoring system was envisaged and approved at the same time to verify the implementation of the PEARS, the evaluation of the effects of the actions carried out.

The first Monitoring Report was published in April 2019; the second Report was published in April 2020.

9. The Production of Electricity in Sardinia

Sardinia developed an articulated and complex electricity production system with its own production capacity. TERNA, as every year, has published the report on "Statistical data on electricity in Italy, year 2020" which provides, on the one hand, the picture of the consistency of electrical systems and their production of electricity, broken down by source and type electricity operator - producer or self-producer; on the other, a breakdown of electricity consumption according to the different territorial typologies. The 2020 statistical report "Energy from Renewable Sources in Italy" of the GSE, [20], and the aforementioned study of the RSE, [10].

Here it is also considered interesting to report a study carried out on behalf of the WWF by the University of Padua and the Polytechnic of Milan, [20].which has as its object "A socio-economic evaluation of the renewable scenario for Sardinia".

The study analyses the relevant issues concerning the decarbonisation, in particular, of Sardinia by 2050. It also proposes a simulation of a possible regional energy system considering a hypothesis of complete climate neutrality.

In 2020, the gross electricity production was 13,144.6 GWh of which 8,846.4 was requested in Sardinia, with an excess of 3,301.6 GWh (37.3%) that was exported. As regards the energy production plants from RES, it is interesting to note, from a comparison of RES between 2008 and 2020, the number of hydro-electric plants that go from 487 with a MW production of 3,500.4 to 18 with a 466.4 MW production; photovoltaic plants that go from 2655 with a MW production of 32.7 to 39,690 with a production of 973.8 MW. At 31 December 2020, against a gross efficient electrical power of 4

thousand and 913 megawatts, the thermoelectric component was equal to 2 thousand and 386 megawatts produced from coal, diesel and their derivatives and from biomass.

Renewable sources generated power equal to 2,000 and 957 megawatts referring to 49,000 343 plants including hydroelectric, solar, wind and bioenergy.

10. The Energy Network of Sardinia

The Sardinia Region with the PEARS, [18], tool, as we have seen, has set itself some strategic objectives to ensure:

i. “the stability and safety of the electricity grid through a considerable strengthening of the energy infrastructure;
ii. the adaptation of the energy system to make it functional within the regional production system;
iii. diversification of energy sources to ensure efficient supply;
iv. the decrease in dependence on petroleum products, the guarantee of the compatibility of the interventions and actions of the energy system with environmental protection and the harmonisation of the structures of the energy networks.

In considering these strategic objectives, it is necessary to consider and keep in mind that the national energy grid and therefore also the regional one are managed by Terna Spa which has the task of guaranteeing both the transmission of energy flows and the internal needs, in connection with the national electricity grid,[19]. In addition, the development of a gas infrastructure for the Region, initially envisaged in the PEARS, has merged into the "Methanisation of Sardinia" project starting with the 2017-2018 development plans of Snam Rete Gas S.p.A and Società Gasdotti Italia S.p.A. Below is an important passage contained in the aforementioned study "The Sardinian electricity generation sector, especially when compared with the rest of the national electricity system, represents a particular context, characterised by a few large units, often subservient to industrial plants with poor profiles. flexible, and with circumstances that are often critical to the security of the system. " [19]. Figure 2 shows electricity system of Sardinia

With regard to the energy network of Sardinia, TERNA with the "Italy 2021 Adequacy Report", TERNA Driving Energy, [21], poses the problem that the progressive replacement of conventional programmable sources with non-programmable sources implies "the need to face and overcome important challenges in management of the electricity system, such as, among others:

i. a reduction in the reserve margin at the peak due to the strong disposal of thermoelectric capacity with possible difficulties in covering the maximum demand values and consequent risk of activation of the Emergency Plan for the Safety of the Electricity System - PESSE - which involves the rotation of utilities to avoid general blackouts;
ii. a progressive reduction of the regulating power and of inertia, due to the modification of the operating structures of the generation park, with ever decreasing presence in service of programmable rotating capacity;
iii. an increase in grid congestion linked to the non-homogeneous development of RES; "

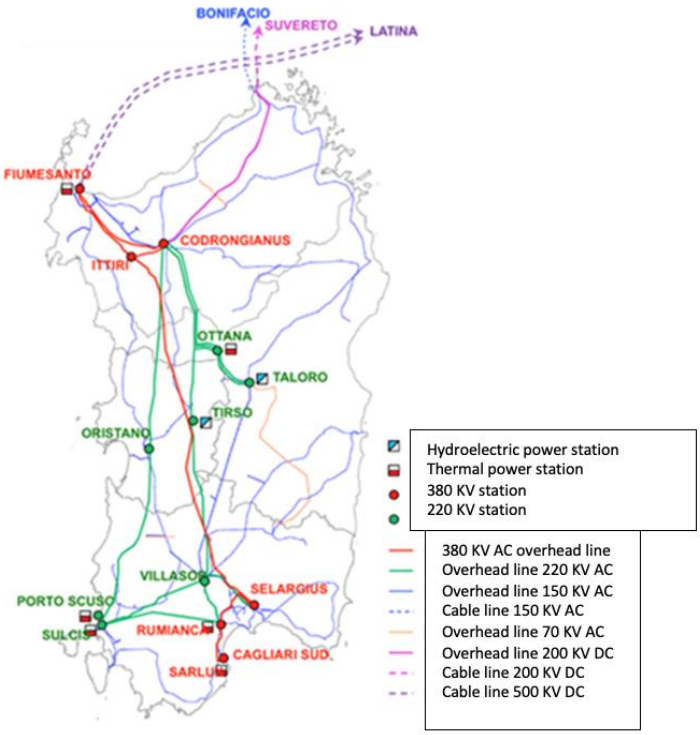


Fig. 2. Electricity system of Sardinia, Source: TERNA [20]

The Report highlights the need to verify that the conditions of the Sardinian system are adequate to ensure that the available production capacity, including imports and accumulations, is sufficient to meet the demand for energy required at any time and in each area of the country.

The main critical areas are due to the decommissioning of the coal plants (for a total installed power of approximately 1000 MW); the loss of the current transmission capacity with the Continent, which does not allow the limit value of 3 h / year of LOLE to be respected.

These conditions, again according to the TERNA Report [20], make the Sardinian system considered inadequate and unsafe: "as it would be very likely the occurrence of one or more events of detachment of a part of Sardinian consumers, especially in the event of outage (due to breakdown or maintenance) connection of the HVDC SA.PE.I. (in this configuration, the expected demand could exceed the resources available to satisfy it in the absence of coal plants) […].

To solve the critical issues in Sardinia and allow the decommissioning of coal plants it will be necessary (1) to create new capacity for approximately 500 MW of CDP appropriately distributed on the island and (2) to create the new Central South - Sicily - Sardinia link (Tyrrhenian Link), [21].

Furthermore, another critical element emerges from the Report which, according to Terna, concerns the transmission system in Sardinia:

i. a poorly meshed net;
ii. captive productions;
iii. a substantial number of non-programmable RES generation plants.

TERNA's projects and investments arise from this situation, considering that: “these risks can largely be mitigated through the creation of the Tyrrhenian Link. However, the analysis carried out by Terna indicates that it will also be necessary to supply at least 200 MW of new CDP in the north of Sardinia and at least 300 MW of new CDP in the south. ", [10].

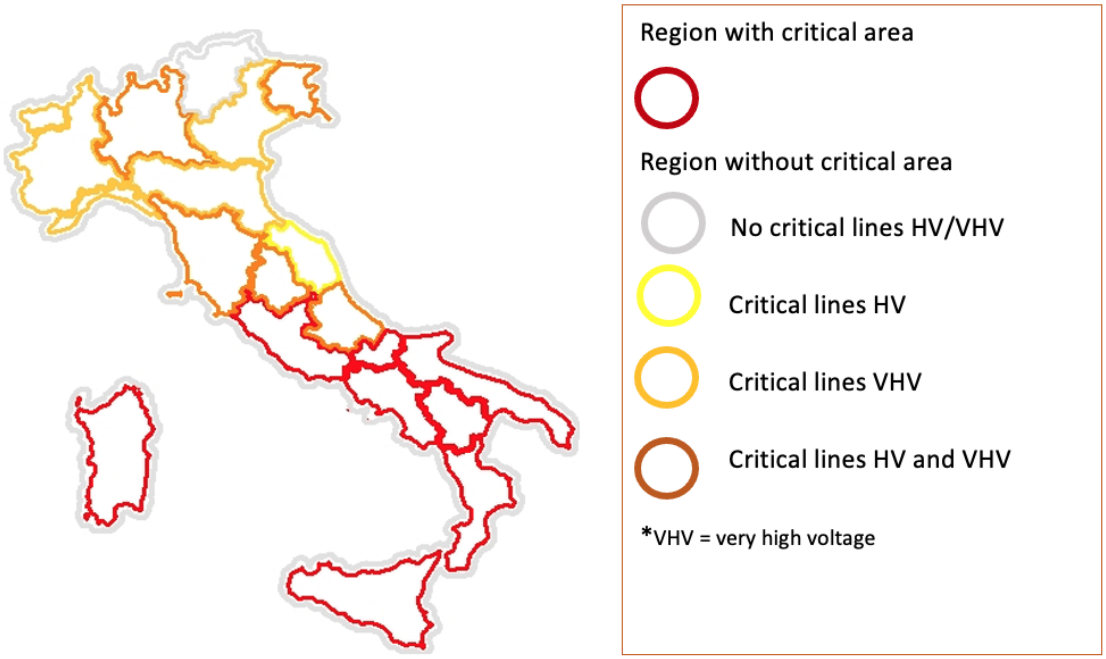


Fig. 3. Critical areas present in the Sardinian electricity system, source: TERNA, [20]

The project considers a constantly increasing strong production from non-programmable renewable sources, solar and wind,that exists in Sicily, Sardinia and especially in Campania. On this basis, the disposal of over 1000 MW of coal capacity is planned by 2025. Consequently, the Tyrrhenian Link will improve the electricity exchange capacity and the best use of energy flows from renewable sources, guaranteeing, among other things, stability and grid security in addition to the development of RES and the increase in interconnections.

These are the prerequisites which form part of the new scenario of the regional electricity system and which include the guidelines and intervention strategies, including regulatory ones which come from the state. A new and more cohesive system of the Sardinian energy network hinged on the national one.

11. DPCM (The Prime Ministerial Decree) of 29 March 2022

On 29 March 2022, the Prime Minister's Decree, the “Sardinia energy decree”, [2], was a planning intervention that defined a new scenario for the transition of the regional territory, the President of the Sardinia Region and the territory were not in agreement with the decision.

In the introduction the Decree amongst various references refers to the relaunch of production activities in Sardinia including some relevant objectives envisaged by the PNIEC 2019, such as the decarbonisation of industrial sectors, the creation of the virtual connection between the national transport network gas and Sardinia, and the need expressed by TERNA to maintain the safety of the electricity system, and therefore the need to have 550 MW of new programmable power to ensure its adequacy, regulation and reserve, with 300 MW in the south and 250 MW in the north of Sardinia; in this way the complete phase out of coal would be guaranteed. In support of these indications, the Decree takes into account both the study conducted by RSE concerning "Energy supply of the Sardinia region" which was discussed in the course of this work and the communication from TERNA [21].

The Decree in art. 1 establishes and identifies the infrastructures necessary for the phase out of the use of coal and in art. 2 establishes that the activities referred to in art. 1 are connected and contribute to the creation of a new energy generation capacity from RES with the necessary energy

storage structures. The Terna S.p.a, [20], proposal for the construction of the infrastructures and work of the electricity system are envisaged more detailed are the extension of the national electricity transmission network with the construction of the Sardinia - Sicily HVDC cable, part of the Tyrrhenian Link, in the 500 + 500 MW configuration referring only to the bipolar HVDC Sardinia-Sicily connection mentioned in the previous paragraph.

The decree met with opposition from regional and local administrators. The President of the Region expressed "concern and disappointment" and considered the measure "an act imposed from above". Three points considered indispensable for Sardinia are highlighted, such as tariff equalisation, robust and stable energy system to give certainty to businesses and save what little is left of the industrial sector. Finally, "for an island like ours it is unthinkable or acceptable to actually lose energy autonomy". In the interview there is a fear of the risk of "an invasion" in the island of photovoltaic panels, wind turbines and storage batteries whose future criticalities will also be linked to disposal, without Sardinia having any return, Solinas, [22].

The Region on 28 July 2022 filed an appeal against the energy decree with the Lazio Regional Administrative Court. The Regional Administrative Court, with its sentence of September 14, 2022, rejected the appeal and for which the Region subsequently appealed to the Council of State.

12. The Industrial Centre of Porto Torres: The Birth and Development of The Energy Centre

The evolution of the electricity grid and energy production of Sardinia, as we have seen, is characterised by the industrialization of the island starting from the coastal areas and then in the seventies, in the inland areas, with the presence of industrial centres and energy-intensive factories and a high density of capital.

The Sassarese area with the petrochemical pole and the industrial area of Porto Torres had both a on a regional and national level importance: "In terms of the strategies of large companies, the new fact of the 1970s was Enel's decision to build its own thermoelectric power station (two groups with a total power of 320 megawatts) in the Fiume Santo area, on the edge of the industrial area: a production facility destined to become the largest energy hub in Sardinia over the years. To determine the choice of the site which was originally outside the boundaries of the industrial area and belonging to the municipal territory of Sassari, State Energy Authority encountered difficulties dealing with a reality that, as we have seen, was characterised by a overwhelming presence (and power) of SIR", Ruju, [23].

From the beginning, the Enel coal-fired power plant project raised strong concerns in public opinion, due to the fear of atmospheric pollution and impacts on the environment. However, many years passed between the definition of the project and its concrete realisation […] (Ruju, [23]. In this period, in fact, a particular sensitivity on the protection of the territory and the environment was established, triggered by the first situations of degradation and environmental damage. In anticipation of an expansion of the industrial site, ENEL acquired an area much larger than that originally planned, 242 hectares (10.47% of the entire surface), equal to that occupied by the petrochemicals plants. In fact: "[...] While the construction sites for the new Enel plant began to be installed in Fiume Santo, Sir was proceeding, not far away, with the construction of another large plant with a power of 300 megawatts, which should have guaranteed electricity and steam for a new refinery (capable of processing 10 million tons per year), for a new steam-cracking (from 400 thousand tons of ethylene per year) and to the other plants connected to it [...], Ruju, [23].

13. From the Porto Torres Industrial Centre to the Complex Crisis Area

The impact of industrialisation in the north-west of Sardinia and in the Sassarese has led to a radical transformation of the territory as well as the economic system and a new energy production system. The industrial centre of Porto Torres was considered one of the most important industrial complexes of the petrochemical sector in Italy. The reference basin for labour concerned about sixty municipalities in the then Province of Sassari. "In the seventies, the industrial zone occupied about eight thousand working units, 70% employed at SIR and 30% in external companies, increasing in the same decade to nine thousand people, half direct employees of SIR and for the other half employees of procurement companies engaged in the maintenance and construction of new plants, Brigaglia, [24] .

The crisis in the sector dates back to 2007 when the closure of most of the plants and a reduction in activities began, due to the processes of relocation and deindustrialisation, which immediately resulted in a huge loss of employment. Between 2007 and 2009 there was a sharp contraction in the growth rates of registered companies in the province of Sassari (-0.13% in 2009), as a result of the petrochemical crisis. The trend of the following years shows that growth rates have no longer returned to pre-crisis levels, INVITALIA, [24].

In order to intervene and try to respond to the serious situation and the job losses among the various interventions, it was declared 'the area of complex industrial crisis' for the municipalities of Porto Torres and Sassari, DM 8 February 2017. On August 10, 2020, a Program Agreement was signed between the Ministry of Economic Development, the National Agency for Active Labour Policies, the Ministry of the Environment, the Ministry of Infrastructure and Transport, the Autonomous Region of Sardinia, the Province of Sassari, the Municipality of Porto Torres, the Municipality of Sassari, the Port System Authority of the Sea of Sardinia and Invitalia with the bodies committed to implementing the reconversion and redevelopment of the industrial areas of Porto Torres Project [25].

14. The Scenario of Renewables in the Industrial Conversion and Retraining (PRRI) And Land Development Project

The need to recreate the conditions for a new model of local development has led the Region of Sardinia to propose some strategic guidelines for the elaboration of the Industrial Reconversion and Redevelopment Project (PRRI) of the industrial centre of Porto Torres:

i. Resolve the main infrastructure deficiencies to cushion the non-competitive factors of the territory, including in particular port logistics and energy supply;
ii. Contribute to the development of an energy hub, promoting integrated source management and the use of natural gas, in line with the methanisation plan provided by PEARS

To this must be added the decarbonisation project of the Fiume Santo power plant and its possible conversion.

The industrial area is currently the subject of important private interventions both in the areas of competence of the Industrial Consortium and in those owned by ENI, [26]. In fact, in 2020 a photovoltaic park with an installed capacity of 31 MW considered the largest in Sardinia was inaugurated in some areas of the Eni site in Porto Torres. The Park can produce up to 51 GWh per year; the energy produced is partly destined for industrial activity in the area, avoiding emissions of about 26 thousand tonnes of carbon dioxide per year. In addition, an additional area has been

identified for the construction of a 34 MW photovoltaic park, which is being designed. “Such a project will allow, in line with the principles of the circular economy, to enhance brownfield land for new industrial life, through the reclamation and generation of energy from renewable sources”, [26].

The Mayor of Porto Torres interviewed on the subject, Mulas [27], states that: “The territory presents for the FER a rather advanced state of the art site of national interest (SIN) but poorly distributed in the sense that Porto Torres is an industrial zone largely decommissioned [...] at the national level identified to be able to best dispose of renewable energies ... and what is currently available in the current technology. Out of 2400 hectares of industrial area, to date, among authorised authorisations, we have 480 hectares for renewable energy. In addition to the amount of territory that is very large and strongly impacting, the problem lies in the type of investment that has been made; companies will have utilities from these investments, but they are not contemplated in a single, coordinated reasoning.

We find ourselves being invaded by a whole series of production that do not give us a necessary value to have energy production for the territory; it must be considered that to date it is not programmable except in the form of large accumulations that we would like to see exclusively with accumulators consisting of large batteries while instead the production with the water element that has an immediate transformation is not doing this ..., if you consume the whole area, you produce energy but an end in itself and there are no more storage space and there is no more accessible programmable energy to make a company decide to come and invest in this territory ...So if we occupy all the available land area maybe we exceed 19% of the national average of production, with a percentage of twice as much, but there will be no possibility of being able to have an economic advantage that can be immediately spent on the community".

The territory of Sassarese is also interested in another important intervention concerning the security of the electricity grid, with the closure of the thermal power plants and the simultaneous entry into operation of the Tyrrhenian Link. ENEL together with IREN Energia will also install the storage batteries in the Sassarese, in Ploaghe, in land owned by it, for an allocated power of 94 MW. The area needed is estimated at 35MW per hectare thus with a maximum area area of 10 hectares, La Nuova Sardegna, [28].

Table 2
The new accumulations of ENEL

Macroarea	Comune	Accumulo in MW
Sassarese	Ploaghe	94
Nuorese	Ottana	135
Sulcis	Portoscuso aree vecchia centrale	115
Sulcis	Centrale Grazia Deledda	82
Cagliaritano	Quartucciu	197
Assemini	Aree piccola Centrale a turbogas	52
IREN Energia		
Nuorese	Ottana	18
Sulcis	Guspini	4

In this context, the production of renewables, as the interviews show, is not programmable except with immense extensions of wind and photovoltaics and storage batteries. For programmable means the possibility, on the part of TERNA, of having a storage and despatch site that allows it to cope with the average and peak consumption and to guarantee, stability and safety for new connections.

15. The Methanisation in the Context of the Island's Energy Transition to 'A War Economy'

The DPCM (Prime Minister's Decree) "Energia Sardegna" intends to guarantee, within three years, the energy transition of Sardinia starting from the cessation of coal fired production of thermal power plants, production from renewables and storage batteries; resume the project to include Sardinia in the national methane gas network with a system defined as "virtual pipe-line" with methane. This programming stems from the details and strategies contained in the SEN 2017 and the National Energy Plan, but it is thought that the closure of the thermal power plants should wait for the completion of the T-Link and the new electricity production system.

In the meantime, consequences of the Russia and Ukraine conflict have made the situation very problematic. An immediate problem that has arisen is the problem of coal supply whilst the Fiume Santo power plant is maintained.

As far as methane gas is concerned, there are the problems of finding suitable gas vessels to be placed in the identified ports, as well as supply and storage. Strong doubts have also been raised about the storage values, due to the absence of data and special studies on the needs of both the production system and the uses intended for the needs of civil society.

16. The Energy System of the Northwest of Sardinia After the 'DPCM Energie Sardinia'

There is a situation of uncertainty specifically for the North West of Sardinia and the micro area of Sassarese and more broadly the entire region. The uncertainty stems from plans for the regional programming and the plans for the conversion and redevelopment of the industrial area and the crisis area. These criticalities have been identified and attributed by many regional actors and local institutions to programming that does not take into account the needs manifested by the territory and for which they do not detect a vision and coordinated plan of the energy transition:

"We have reached the point that state subsidiaries, have completely impromptu designed projects that concern the energy structure of the island and that would recommend a transition from fossil to electric short cut, without any transition and without any credible guarantee for the system [...]" (Interview with Solinas, the President of the Region, La Nuova Sardegna, [22].

According to the Mayor of Porto Torres: "The added value for the peninsula is easily identifiable in the sense that it guarantees stability and distribution throughout the territory, it stabilises the national power line, guarantees the possibility and the right for Sicily to convert everything to gas, but it does not guarantee anything else to us [...] We will produce three times our needs based on Enel's decision on hypothetical production stemming from the national strategy of the central government. The production does not come from the needs of the territory that has another strategy, another philosophy and another idea. It is not only me but the unions too that say it [...]", Mulas, [27].

In summary, in the overall framework of the interventions provided for by the DPCM, for the territory of Sassarese there are still uncertainties about the possibility of converting the Fiume Santo power plant, there will be a substantial increase in the Ploaghe wind farm and hectares destined for photovoltaics and storage batteries with considerable 'territorial consumption'.

Also with regard to methane gas, P. Torres will be affected by a gas ship anchored on a dock in the Industrial Port with an availability of 25,000 cubic metres of Gnl with no data on the potential need. Above all uncertainties remain in order to ensure the implementation of an operational plan addressing the problem of the socio-economic development of the territory, the development of the business system and specific case of energy production, employment.

All these critical issues between the State and the Region for the adoption of the DPCM were already present before the war between Russia and Ukraine, the war will accentuate the difficulties and complexity of ensuring the systeming of these projects and of giving organic responses to the territory for the so-called transition.

17. The Development Prospects of the Erfs: Ideas and Projects

The studies and analyses mentioned in this presentation provide important food for thought but also hypotheses for solutions: starting from the proposals for the decarbonisation of Sardinia; the introduction of the 'virtual methane gas pipeline' but it predominantly enhances the production by FER. It should be noted that all the studies, analyses and solutions proposed relate to the period leading up to the outbreak of the Russia-Ukraine conflict and the international implications. This situation further emphasises the need to refer to clean and renewable energy sources, but recognising that the transition phase will have to be accompanied by measures affecting methane in particular. The study was carried out by the University of Padua and the Politecnico di Milano on behalf of the aforementioned WWF., [20], is interesting and current, with analyses of the possible scenarios, in line with the mid-term Phase Out 2025 from coal and proposes an analysis of the costs / benefits of infrastructure investments, considering hypotheses that avoid an increase in costs. Actually in relation to methane gas estimates that the RSE study, [10]: "has analysed a period of only 20 years (2020-2040) that did not allow to take into account the climate neutrality goals by 2050 and adequately capture the processes of technological innovation, particularly relevant for those green technologies on which, according to the European Commission, it is essential to orient future investments (e.g., In the long run, methane gas is not compatible with a decarbonised energy system, unless it is in the form of biomethane, synthetic methane or hydrogen." In the conclusions, it simulates two scenarios for the transition to 2025 and 2030 respectively, which are also consistent with the PNIEC 2030, RSE, [10]. It also does not take into account methane gas and consider the stability of the system by means of hydroelectric pumping and hydrogen.

Also according to this analysis, the use of hydroelectric pumping and an immediate development of FER are considered compatible options for the transition to 2030 as well as the climate neutrality targets to 2050, for the disposal and replacement of traditional plants with new pumping plants or new 'Power-To-Hydrogen' plants.

The production and accumulation of green hydrogen linked to the relative electricity production from FER, with the need for accumulation, are among the investments still necessary in the region, with significant economic and employment repercussions. Here the Sassarese area and the industrial area due to the infrastructure and environmental conditions described could be of relevance to the new network configuration, regional energy production and its connections with the national grid and production

18. The Repositioning of the Territory

In 2021 in response to the economic and productive crisis in which the territory has been located for some time, the Metropolitan Network of Northern Sardinia proposed, to the political and institutional representations, the trade union and employer representatives a strategic document, Rete Metropolitana of Northern Sardinia, [29], on the theme of the planning of development and growth of the North-West of Sardinia, within the framework of the opportunities offered by the new cycle of community programming 2021-2027 and of those within PNRR.

The initiative is based on two strong ideas to open up new prospects for the revival and sustainable development of the territory and with it, all of Sardinia. The first of which concerns the transformation of the territorial energy system, following progressive decarbonisation, with generation plants based on renewable sources taking into account the peculiar characteristics of the coasts of the territory, the energy produced by the waves and wave motion. The second involves the predominant use of clean energy thus produced for the production of green hydrogen as a fuel for the production, civil and future sustainable mobility needs. With a unified position of the institutions of the territory, the social partners, trade unions and employers, a 'Table of Institutions, Social Partners (TIPS)' has been established, with the participation of all the institutional, trade union and employer entities of the territory.

The work of the TIPS resulted in a document that contains the strategic priorities and presents "first insight into the level of consistency with the missions, components, overall objectives of the components and the investments envisaged by the PNRR and the complementary fund.", Rete Metropolitana, [29]. Among the macro-themes that summarise the priorities contained in the two documents, [28]; the first concerns the ecological transition, within which the objective of the "energy revolution" is inserted, which is based on two relevant evaluations:

"Energy supply, however, cannot take place, even with renewable sources (wind, photovoltaic, biomass, sea), at the expense of assets and non-renewable resources of the local territory, such as irrigated and arable land removed from agricultural use, or in the case of the proposal to build off-shore platforms to produce energy from wave motion of the Sardinian coast.

The solution identified by TIPS and the Rete Metropolitana the industrial area of Porto Torres which presents the ideal conditions:

i. Availability of areas for the construction of photovoltaic and wind fields for the production of electricity
ii. The industrial port forage dam, for the transformation of wavecraft energy into electricity, as a first trial for a possible transformation of the port into 'green ports'

In this 'energy revolution' reference is made to green hydrogen, 'energy captured from the sea' and bio-industry (green chemical industry).

19. The Production of Green Hydrogen

The territory of the North West, macro-area of Sassarese has used an innovative key: "to build a robust industrial ecosystem based on clean hydrogen solutions. The industrial agglomeration of Porto Torres for its geographical location and its existing infrastructure services is the ideal site for the development of new technologies aimed at the production and distribution of green hydrogen. The creation of the green hydrogen district would also constitute a genuine driving force for the process of re-industrialisation and economic development of Northern Sardinia."

The design idea of green hydrogen production together with that considered indispensable of FER production (solar and wind) should be supplemented with another important piece that is represented by the hypothesis of transforming one of the groups of the Fiume Santo power plant to biomass both to guarantee the security of the entire network and to guarantee industrial and employment security.

The project is both consistent with the programming of the Sardinia Region in the P.E.A.R.S. 2015-2030 hydrogen was identified "as a strategic vector", and with the National Recovery and Resilience Plan (PNRR), which provides for the conversion of the energy supply system from fossil sources to

green hydrogen, to be realised in disused industrial areas. In this regard, the Sardinia Region has adopted a special act of address with Del. G.R. no. 6/19 of 25.02.2022, to respond to a call from the Ministry of Ecological Transition (MITE) on the PNRR, to intervene on industrial sites and disused areas to be converted and among them that of Porto Torres, which make them suitable for the development of projects for the production, distribution and use on a local scale of hydrogen.

However, there are different projects that the Region is pursuing for the production of Hydrogen, also with its own research and development companies such as CRS4, which has signed with Italgas a memorandum of understanding for the study and construction on the island "of a plant ‘’(Centre for Research, Development and Higher Studies in Sardinia-CRS4, [30].

In this context, an important project for the North West of Sardinia concerns the financing of 140 million euros for the Regional Transport Company (ARST) for the railway connection between Alghero and the ‘Riviera del Corallo’ airport with a hydrogen and rolling stock production plant for the railway line of the Sassari Alghero-airport.

20. The Production of Energy from the Sea

Among renewable energy sources, 'sea energy (universally identified as ocean energy) is the least known due to the still residual production quantities'[...] Today, considering the world's scarce energy reserves from traditional sources and the growing inclination towards renewable energy conversion, sea energy is the subject of several experiments and research projects, Bencardino, [30].

Another innovative project proposed by the TIPS-Rete Metropolitana, [28], is connected to the peculiar characteristics of the territory and the coasts of the North West, the energy produced by the waves and waves of the sea.

“[...] For the particular weather-climatic conditions, the North-West of Sardinia is the most important ‘day’ potential for energy production from waves and waves. This particular condition, therefore, would allow the North-West of Sardinia to add an additional and important renewable source, beyond wind, sun and biomass, which becomes an important competitive advantage over other territories, but until now totally neglected".

This figure is confirmed by an ENEA study according to which: “Sardinia is the area of the entire Mediterranean that could produce the most energy from the sea, with a potential of 13 kW per metre of coast, a value very similar to EU states more at the forefront in the development of this renewable source such as Denmark. The main areas on the island belong to the north-western area near Alghero and to the one to the south-west", Sannino, [1].

ENEA's elaborations assess that: “a 3 MW mini marine park, built with the current offshore devices off Alghero, could produce over 9.3 GWh / year, would be able to meet the electricity needs of over 2 thousand households” [...]. the greater energy potential of the sea of western Sardinia is double that of that of the Channel of Sicily (7 kW / m), over three times kW/m on average)” Sannino, [1].

The Sassarese area is also proposed with two experimental and highly innovative projects. The first called ‘Waves4water’ was prepared and implemented by the Regional Park of Porto Conte in collaboration with the Marine Protected Area of Capo Caccia, Natural Park of Porto Conte, [31]. The Project involves the realisation of a process of producing electricity from sea waves and desalination, made self-sufficient at the energy level, through the use of the energy produced by the sea waves themselves. Through a research activity it was proposed to develop and experiment with a prototype, “for energy production and desalination that will integrate an energy converter from sea waves and a desalinator with which fresh water will be produced for self-consumption and agricultural uses within the Park”, Porto Conte Natural Park, [30]. The research produced a hydraulic machine, starting

from an EPO patent no. 3376023, with the advice of the DICM of the University of Cagliari, which has the ability to suck up from the middle sea level and transfer to relevant geodetic quotas and / or even in some cases in an autoclave the energy inherent in sea waves causing OWC accidents in adequate expansion chambers producing electricity,

On the basis of this experiment, the Port System Authority of the Sea of Sardinia as part of the call of the Ministry of Ecological Transition Green Ports has obtained three million, eight hundred thousand euros of financing to carry out the experimental project called "Hydraulic Plant for the capture of energy from the sea "Millepiedi", to be carried out in Porto Torres in the forage dam.

The project involves the restoration of a section of a port infrastructure damaged in 2019 by a violent storm from the North-East that caused the breakthrough of a stretch of the forage pier of the Industrial Port of Porto Torres. 'The project consists of the installation of the hydraulic machine to exploit the energy captured by the wave motion by installing an innovative hydraulic machine', Parco di Porto Conte, [31], Port System Authority of the Sea of Sardinia, in the damaged part of the dam.

21. Conclusions

The theme of this work requires an approach to reflect on the underlying issues, starting with the importance that Sardinia has in the national energy production from renewable sources, but also from the resulting impacts. In this context, our in depth study emphasises the inconsistencies and contradictions by highlighting what has been called 'the consumption of the territory', an end in itself and without any return for the community, as well as the contradictions of governance relating to strategic choices at national level.

The production of energy from the wind and the sun in addition to the consumption of the territory, with the proliferation of plants and requests for new concessions and authorisations by private individuals, both on land and at sea, is fuelling a speculative phenomenon to the detriment of the economic and productive and environmental system of Sardinia aggravated by the fact that there is no adequate institutional governance especially between the State, Region and local Compared to territorial policies.

According to some authors, the location choices of installations require careful consideration of the relationship and impacts of the installation of wind farms on the landscape, Moderini, Selano, [32]. Indeed, there are numerous aesthetic and economic impacts of wind landscapes with, in some cases, benefits and advantages for local communities, Mauro, [33]. As pointed out by Ferrario [34]: "Energy can be considered one of the major driving forces in the transformations of the landscape, which is shaped by the ways in which humans produce, transform or employ it. Every time a new energy production system emerges, socio-spatial configurations profoundly change, Smil, [35]: the interdependence between energy and territorial systems is so profound that it is not possible to imagine a transformation of the former without repercussions on the latter and vice versa, Puttilli […], [36].

Sardinia sees its energy autonomy cancelled, with the loss of its production capacity and with the closure of thermal power plants. All motivated by the need both to intervene to adapt and secure the electricity grid, to guarantee the increase in production from FER and the accumulation of energy, and in line with the 'phase out' policy from coal by 2025, with the progressive reduction, until zeroing, of all emissions from the combustion of all types of fossil sources. In this context, there is a forecast to include Sardinia in the national methane gas network. In this sense, it was found that the State and its investees do not have adequate governance, given the different approach of the Companies to implement energy policies (ENEL and SNAM) and on the other hand the difficulties of coordinating to implement the integration of Sardinia into the national gas network as provided for in the DPCM

'Sardinia Energy'. To this is the forecasted closure of the Fiume Santo and Portovesme power plants for which there is at the moment uncertainty about their conversion.

It is evident, from the historical and technological path analysed, how Sardinia has gone from a system of self-consumption of its energy production, to an intermediate phase with traditional energy production and from FER and in which it has exported energy, to become an energy hub intended to produce 5 gigawatts from FER to the national network. This means, as highlighted, that you 'have a before and after the Sardinian DPCM on energy', in terms of strategic guidelines and decisions adopted by the State and implemented by the companies investee or controlled by it. The adoption of the DPCM, which has had a long gestation period, has also overlapped with the outbreak of the war between Russia and Ukraine. Due to the conflict the geopolitical and consequently geoeconomic situation, has changed the international scenario resulting in a serious crisis that has evolved into what is considered a 'war economy', with complications both for the supply of raw materials and for the resulting costs related to energy production and the disruptive effects on production processes. The consequences of this emergency are reflected, in economic and social terms, both in the misalignment of the planned investments and in the need to ensure the necessary energy production.

Finally, the case study analyses the North West of Sardinia and in particular the macro-area of Sassarese. The strategic repositioning of the territory proposes to enhance its peculiarities in relation to the potential of the ERFs with reference to innovative and/or experimental productions such as green hydrogen and the energy produced by the waves and the opportunities offered by the sea. The relevant fact is that, for the particular weather-climatic conditions, the North-West of Sardinia is considered one of the most important potential 'hubs'' of power generation from the wave motion. Once the testing has been validated, this may constitute an important competitive advantage which could allow western Sardinia to add an additional and important renewable source, in addition to wind, sun and biomass. All this could also lead to consideration of a reconversion of the Fiume Santo thermal power plant which once 'decarbonised' could have its own use and operation with biomass and/or with the production of green hydrogen by electro.

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