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# Multifunction Land Use to Promote Energy Communities in Mediterranean Region: Cases of Egypt and Italy

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**Abstract:** Mediterranean rural settlements suffer from numerous environmental challenges, specifically the annual decrease of the farmlands, climate change threats, and growing resource consumption and demand, such as energy, the core of development. Rural areas play a significant role in achieving food security and sustainable development. Therefore, this paper promotes the energy community and agrivoltaic key concepts as pillars to show how buildings and farms' land uses positively impact the ecosystem. The study focused on Egypt and Italy as representatives of the entire region. Two rural settlements with the same characteristics representing typical agriculture-based patterns have been selected: Lasaifar Albalad, representing 339 villages in the Delta Region, northern Egypt, and Pontinia, representing rural typologies of the 1930s in the Lazio Region, central Italy. Then, two focus groups with versatile stakeholders were conducted. The results showed the juxtaposition of the key concepts and national rural and agricultural policies and fostered a novel approach between Egypt and Italy. The study presented the first analysis of both contexts. The focus groups promoted the ideas, led to a better understanding of the implementation possibilities, raised awareness, improved social acceptance, and highlighted the significant barriers. It paved the way for a further study (micro-scale on-ground practices) to be planned and implemented soon.

**Keywords:** agricultural-based settlements; rural commons; nexus approach; transdisciplinarity; participatory approach; sustainable development; Delta region; Lazio region

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## 1. Introduction

### 1.1. Mediterranean Rural Settlements: Background

Agriculture lands provide the leading segment of food security and plays a crucial role in boosting local economies, enhancing sustainable development goals, and ecosystems services [1], such as food production, aesthetic value, and recreational services [2]. Rural areas are essential to the function of urban areas [3]. Both correlate complexly [4]. They represent the vast majority of the European territory, where 29.1% of the population live in rural areas [5] and one-half in developing countries.

The Mediterranean rural landscape has been rapidly changing over the past decades [6] because of many aspects, such as: industrialization [7], the modernist movement [8], socio-economic transformations [9–11], urbanization [12], rural population decline, accessibility to productive land resources [13,14], rural abandonment [15], soil degradation, and desertification [16].

Climate change is one of the biggest threats affecting the rural commons in the Mediterranean region that have already faced significant environmental challenges in the past decades [17,18], exceeding the global average trends in many aspects [19]. For instance, the annual mean temperature is 0.4 °C above the global average [20], causing floods and other extreme climatic droughts [21,22], threatening food security, decreasing the croplands' availability [23], agriculture systems' habitat loss, and changing land use patterns [4,24]. Simultaneously, growing human activities add to these pressures [25].

Fortunately, land can be a sink of GHGs and plays a pivotal role in mitigating climate change [26], using many strategies such as the active restoration of habitats on spared land (land separation) [27] and providing policies integrated with agricultural optimization models [28]. Various studies emphasized the essential need for an integrated and holistic approach to managing natural resources, such as water, energy, land, and food (the so-called nexus approach) to achieve sustainable development, particularly in agricultural contexts [29].

In recent decades, the nexus approach has expanded in recognition [29] to support policy planning and development decisions and balance the various objectives, interests, and demands of people and the environment [30]. In parallel with the essential need for a cross-disciplinary trend to solve real-world problems, i.e., the interaction between multi-disciplines (from different perspectives) in professional practices and academia, there needs to be a discussion relating to ecosystems and land science's domain [31,32].

Natural resources are indistinguishably interrelated. In other words, energy is essential for irrigation, food security [33], food transport, and water desalination. Water is essential for irrigating crops and generating electricity, and both are essential for producing crops from the land [34]. Food production supports social welfare [35], energy affects gross domestic production [36], and so on. Therefore, focusing on any element supporting the nexus elements (Figure 1) and enhancing mitigate carbon dioxide is important. (hereafter, $CO_2$) [37].

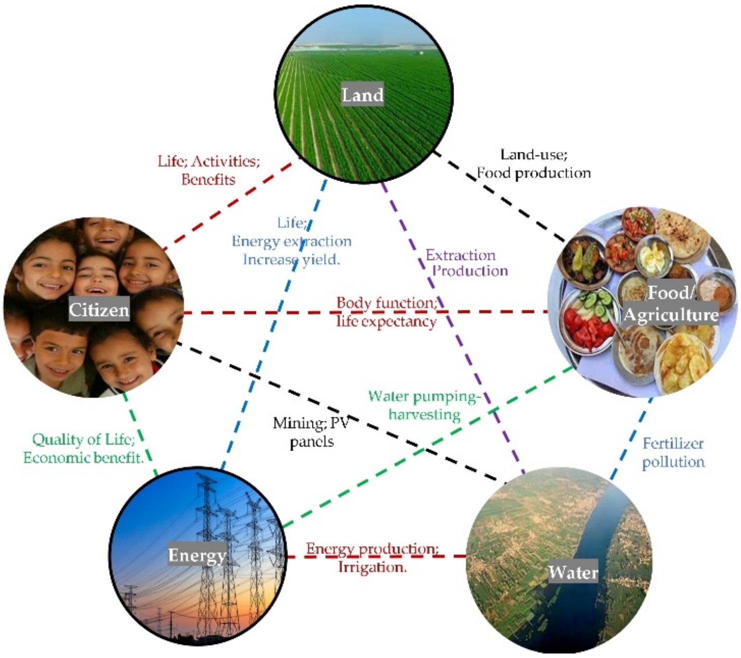



**Figure 1.** Some keys to the high interlocking relations between natural resources nexus and humans. Enhancing one element supports the others. The study focuses on land use and energy.

Regardless of the shared global environmental threats, the Russian–Ukrainian war increases the uncertainties about another anticipated devastating impact that will affect almost everything negatively. The least is wheat export to Egypt and energy supplies to Italy and Europe. It might bring to mind the energy crisis resulting from the Egyptian–Israeli war in 1973. Self-sufficiency must be a dogma. It is inevitable and includes energy production from renewable sources.

### *1.2. Land Use and Energy Relation*

The relationship between land use and energy can be explained bipartitely. Managing land use can reduce energy consumption and necessities and vice versa. Energy manufacturing (generation and production) requires land to be utilized in some such way regarding the technology, such as fossil fuels and renewable resources.

Many studies discussed integrating agricultural production with renewable solar energy, such as the agrivoltaic concept in the 1980s. It is a technology installed at an appropriate height from the ground to enable conventional cultivation regarding the required agriculture technicalities. It can expand agricultural land, improve the microclimate to increase the yield, provide optimum energy conversion, lessen the needed water to irrigate crops, enhance the resilience of farming systems against future drought, and mitigate $CO_2$ emissions [38–40]. Moreover, it can improve the quality of life, stimulate local economies, and provide job opportunities [41,42].

In other words, the high solar energy availability in the Mediterranean [43] can provide prospects to regenerate rurally built environments. In general, the role of renewable energy sources (hereafter RES) is essential to mitigate climate change and contribute to achieving sustainable development goals: (7) affordable and clean energy, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, and (15) life on land.

In this light, this study advocates multifunctional land uses, namely embedding energy production from solar RE, specifically photovoltaics, by providing an exploratory empirical study to promote the energy community and agrivoltaic concepts, from a transdisciplinary perspective, as pillars to make the buildings and farms' land uses positively impact the ecosystems.

## 2. Materials and Methods

This study concentrates on Italy and Egypt as representatives of the region as an inductive approach. Egypt represents developing countries and the southern part of the Mediterranean Sea in location, culture, and religion. Italy represents developed countries and the northern part of the Mediterranean Sea in the same aspects. Many scholars provided common ground between them, for instance, in connection with the Roman–Arabic culture [44], Mediterranean architecture and climate [45,46], and energy-efficiency practices [47]. This study focused on agricultural-based rural settlement patterns to foster a different approach. The study was conducted in three stages using multiple methods (Figure 2):

- The initial step (theoretical approach) has defined the rational background and the key concepts (energy communities and agrivoltaics) to show their juxtaposition with Egypt and Italy's agricultural and rural policies. To better understand the regulations, which play a fundamental function in the clean energy transition [48], it is worth mentioning that, in the Italian case, this study is integrated with the studies of the references [49,50] of those who have investigated recent Italian policies, legislation, and incentive systems dealing with the energy communities.
- The second step (Section 3.1) focused on analyzing the regional levels in two regions in Egypt and Italy, predominated by the same characteristics. The aim is to highlight the main characteristics of the existing built environment pattern, relying on official censuses as an introduction to the next level and a better understanding of the regional contexts.
- The third step (field method) (Section 3.2): two similar case studies have been selected—Lasaifar Albalad, Delta Region in northern Egypt, and Pontinia, Lazio Region in central Italy. In this phase, novel spatial analysis for both contexts has been presented for these settlements. Simultaneously, a transdisciplinary approach was provided, followed by two pilot qualitative focus groups with versatile stakeholders, determined by theoretical analysis and onsite investigation. It is worth mentioning that the first author has implemented these focus groups within his Ph.D. study [51] (supervised by the second author).

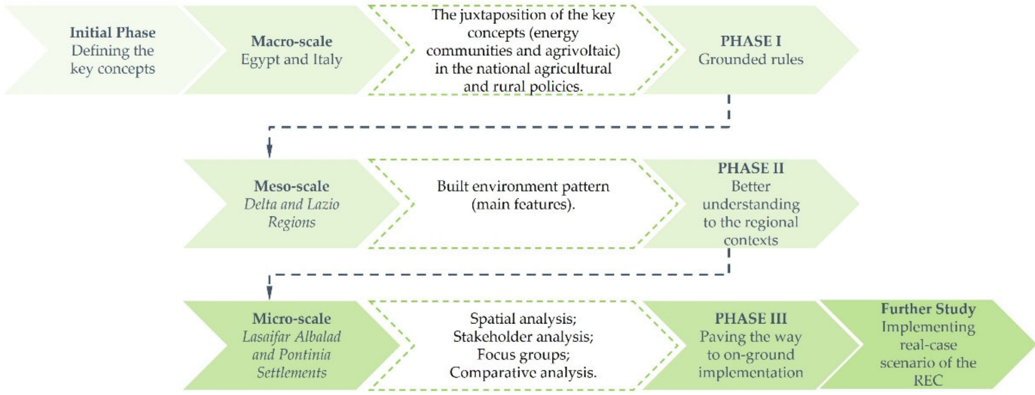



**Figure 2.** A visual summary of the study's methodological concept.

## 2.1. Energy Communities Key Concepts

Europe shows a superior advantage in investments in renewable energy communities [52]. Energy communities' practices have been growing gradually since the 2000s, as significant actors in energy transition have been improving social acceptance and enabling citizen participation [53]. The concept still has vast growth potential, particularly in rural areas in the northwest EU [54]. However, the energy community is an elastic concept granting an assortment of initiatives that have numerous practices [55]. It has many forms, such as the clean energy community [56] and local energy initiatives, and one of its aims is decentralizing energy [57].

In the EU legal context, The European Commission defined the energy communities as "*collective actions of citizens coming together to participate in the energy system, taking ownership of their energy consumption*" [58]. The EU Clean Energy Package (published in 2016) aims to foster energy communities' initiatives, of which member states are committed to creating a mandatory, enabling framework for energy communities [59]. Leonhardt et al. [60] stated that the energy community projects demonstrate high "ownership and control" levels that benefit jointly from governmental tools.

Energy communities have three forms. First, the individual self-consumption has an RE production plant and self-consumes the self-produced energy. The system efficiency, combined with the conscious use of the energy produced and the reduction of waste, contributes to energy savings, bringing environmental and economic benefits. Second, collective self-consumption comprises a plurality of consumers in a building where one or more plants are powered exclusively by renewable sources. Third, the energy community and its members should produce energy to cover their consumption by RES. To share the energy produced, users can use existing distribution networks and use forms of virtual self-consumption, where the inhabitants interact with the energy market as prosumers (who produce and consume their own renewable energy) [61,62].

The self-consumption energy communities have two sorts: Citizen Energy Community (hereafter CEC), which aims to enhance the commitment of energy communities and make it accessible for citizens to combine in the electricity system efficiently, as active participants in line with the directive on shared rules for the internal electricity market (EU) 2019/944 [63]. The Renewable Energy Community (hereafter REC) endeavors to maximize the role of renewables (energy communities and self-consumers) in line with the revised Renewable energy directive (EU) 2018/2001 [64].

Both forms can provide many socio-economic and environmental benefits for their members or the local areas where they operate rather than financial profits. They share the same goal: to self-produce and provide affordable RE to its members in decentralizing and localizing energy production [65,66]. Both have crucial variations related to four rules (Table 1). This study focuses on the REC.

**Table 1.** Key differences between REC and CEC [67].

| Aspect | REC | CEC |
|---|---|---|
| Permissible technologies | Only renewable energy technologies | Technology neutral |
| geographic limitations | The juxtaposition to the project | No limitation |
| Activities domain | RECs can cover any energy sector | limited to the electricity sector |
| Shareholders | Any level (the members do not comprise their leading professional and commercial activities) | Any level |

Mediterranean Practices in Agriculture Settlements

Many micro-scale initiatives have been implemented using many approaches (bottom-up and top-down) in the Mediterranean context. The main aim is to revitalize rural settlements and support clean energy transition in many forms, and which can be applied at many levels, such as residential, public, and farm buildings, and integrated into agricultural activities.

For instance, in France, for two decades, the agriculture cooperative "Fermes de Figeac" consisted of the participation of 110 peasants to develop photovoltaics on the roofs of livestock buildings (farm buildings), with the aim of regenerating the existing rurally built environment by promoting multifunction (agriculture) land use [68]. Whereas in Spain, Som Energia is a citizen–energy cooperative initiative to construct and supply RE projects (biogas, PV, and hydropower). The members are fully responsible for the funding and the decision-making [69].

Poggi et al. [70] suggested new rural land zoning integrated with the RES in Portugal, protecting the landscape and preserving biodiversity. The municipalities can play a notable role in ensuring the effectiveness of sustainable RE planning and management. Another project, Coopernico [71], collaborates with citizens invested in photovoltaics (hereafter, PV) on the top roof of social buildings to produce electricity.

In Italy, in the Energy City Hall (REC) project, Magliano Alpi, the community development and building renovation was blended through innovative energy management models. The objectives were to accelerate the energy transition, decrease bills cost, engage locals, boost local development, and prove that the existing legislation could create a REC [72]. In Sicily, the Ragusa agriculture energy community is a bottom-up practice led by the agricultural condominium that aims to construct a photovoltaic system and an online platform to manage the community through collaboration.

Also, in Italy, in April 2021, the National Agency for New Technologies, Energy and Sustainable Economic Development (hereafter ENEA) has coordinated a national initiative to generate a national network to promote knowledge and methodologies for the development and spreading of agrivoltaic systems "*AgriVoltaico.*" They aim to provide business opportunities to energy communities, boost local economies, and support agricultural policy to enable market growth [73]. An example is shown in (Figure 3).

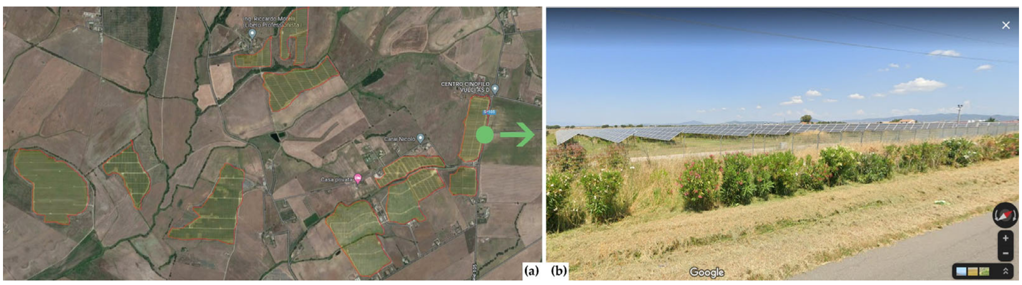



**Figure 3.** Example of the Agrivoltaic practices in Montalto di Castro Municipality, Viterbo Province, Lazio Region, Italy. (**a**) shows the distribution of the PV panels on the agricultural lands as multifunction land uses (Map imagery © 2022/Airbus, European Space Imaging, Landsat/Copernicus, Maxar Technologies, Map data © 2022, Google); (**b**) depicts an example of the installation (SP105 Lazio Google Street View—Jun 2019 © 2022, Google).

On the southern Mediterranean side, Meir et al. [74] have discussed a community energy project in a high poverty rural settlement in Morocco, through agricultural cooperatives participation and given natural resources nexus that combines agriculture practices, water management, irrigation, and community knowledge, and exploits the local solar potential and the competitiveness of solar PV systems, such as using solar pumps that produce electricity from the RE. They stated the national planning processes and policies without considering the cross-sectoral consequences. A high coordination level is mandatory to consider the nexus interrelations.

The national initiative Solar Cell on-grid Systems (Egypt-PV) [75] aims to provide technical and financial support to decentralize electricity generation (the core of energy communities) by installing photovoltaic cells on the rooftops of residential and non-residential buildings. The priority is given to industrial and multi-building sites (i.e., residential complex), due to the high demand by customers and a long waiting list, as the first author has been told in recent contact, and which indicates the essential need to provide economic incentives.

### *2.2. National Policies in Egypt and Italy*

#### 2.2.1. Energy Efficiency in Agricultural and Rural Policies: Egypt

The National Energy Efficiency Action Plan (NEEAP) was released in the past decade. The main vision is to make Egypt a regional energy hub that leads the region towards low $CO_2$ policies, achieving energy supply security, and towards mitigating climate change. In addition, the electricity sector has witnessed noteworthy enhancements since 2014 through numerous directives and legalizations, such as electricity law No. 87 of 2015, which represents the legal framework regulating the energy efficiency industry and encouraging investment in RE in all sectors, which doubled between 2014 and 2020 (Figure 4a).

The Sustainable Agricultural Development Strategy (SADS) 2030 was initiated in 2009 [76] to improve the standard of living of the rural population, reduce rural poverty rates, and achieve a higher degree of food security. In general, Damir et al. [77] have emphasized that policy tool interventions have not achieved sustainable rural development because their impact is still scattered, restricted, and disjointed from rural realities. The SADS has recently been updated [78] and carries a strategic framework for risk and adaptation to climate change in agriculture.

Recently, the mega national initiative Decent Life "*Haya Karima*" was inaugurated by the president in July 2021 (started as an initiative launched in 2019) [79]. The main objectives are to improve the quality of life and regenerate rurally built environments in all of Egypt in 4584 villages (except some urban and the special-nature border and urban governorates) through intensive and instant intervention. The interventions cover many domains at many levels; for example, developing infrastructure, renovating buildings, providing job opportunities, and cultural rehabilitation.

As clearly observed, the development process in Egypt is centralized. The government takes the lead in entire aspects, particularly in the aftermath of the so-called Arab Spring revolutions' well-known political situation (which in some way negatively affected the development scene). This research can contribute by supporting these top-down developments in line with the fourth goal of Egypt Vision 2030: knowledge, innovation, and scientific research, in addition to accelerating achieving the NEEAP.

#### 2.2.2. Energy Efficiency in Agricultural and Rural Policies: Italy

The Italian Energy Efficiency Action Plans (EEAP, first published in 2007) established a strategic plan of energy efficiency measures in all sectors, including buildings [80], and is in line with the in-force Directive 2010/31/EU Energy Performance of Buildings Directive (hereafter EPBD) [81] and the revised EPBD Directive 2018/844 towards decarbonizing building stocks before 2050, in addition to the United Nations Framework Convention on Climate Change (COP 21) [82].

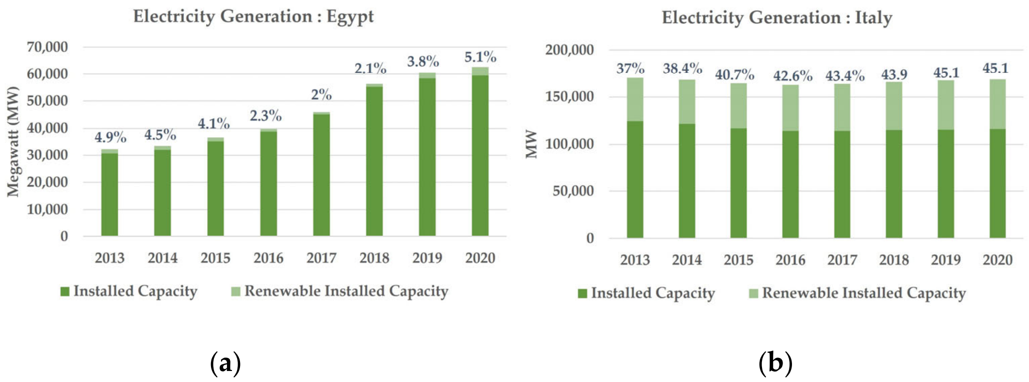



**Figure 4.** Installed capacity, renewable installed capacity of electricity generation, and renewable percentage; (**a**) in Egypt, based on the Egyptian electricity holding company annual reports [83]. The figure shows that the generation was doubled within six years, and the renewable percentage (from wind and solar) reached 5.1%, whereas the aim is 42% in 2035; (**b**) in Italy [84], the growth targets for 2030 for the renewables share in the electricity sector is 55%. The figure shows the generation is steady compared to Egypt.

The critical role of energy efficiency practices was confirmed in the integrated National Energy and Climate Plan (the Italian acronym is PNIEC), "*Energia and Clima 2030*" [85]. The PNIEC promotes self-consumption and REC. In addition to maximizing the RES, which is planned to enable the electricity sector (the highest contribution to the growth of RES) to cover 55.0% of gross final electricity consumption [85], whereas the current share is 45% (Figure 4b).

In an integrated scene, in the wake of the COVID-19 crisis, the Decree-Law n. 59/2021 [86] provides urgent measures related to the fund and complementary to the National Recovery and Resilience Plan (the Italian acronym is PNRR) [87]. It aims to repair the economic and social damage caused by the crisis, address the Italian economy's structural weaknesses, and lead the country along a path of ecological transition, in line with the European recovery plan "Next Generation EU" to rebuild a post-pandemic Europe [88]. It comprises six missions divided into sixteen components, such as the "energy efficiency and building redevelopment" and "sustainable energy transition and mobility" components within the green revolution and ecological transition mission.

In the agriculture and rural development domain, the European Commission (hereafter, EC) presented the reform of the Common Agricultural Policy (hereafter, CAP) 2023-27 Strategic Plan. It aims to simplify and modernize the EU's policy on agriculture, covering many objectives such as promoting sustainable energy, decreasing GHG emissions, and improving carbon sequestration [89]. Moreover, EU Long-Term Vision for Rural Areas 2040 combines a set of measures through leading initiatives to increase energy efficiency in the EU agriculture communities, boost social, climatic, and environmental resilience, and support local authorities [90,91].

In this line, in 2021, the Italian Ministry of Agricultural, Food, and Forestry Policies (the Italian acronym is MiPAAF) delivered the National Strategic Plan (the Italian acronym is PSN) [92]. It provides a set of strategies to regenerate the rurally built environment, including promoting energy communities, particularly in the prioritized geographical altitude territories (plain areas) like in the Lazio region (Italy comprises three altitudes: plains, hills, and mountains).

It is abundantly clear that energy efficiency, harvesting solar RE, and energy communities represent the essential cores of rural development among the presented legalizations, policies, and economic incentives in Europe and Italy. Therefore, it is considered a mandatory step to map the energy communities in the regulatory frame to shortcut the way for researchers and individual implementers. This research will lead to a better understanding that enables further steps in this realm.

## 3. Case Studies

### *3.1. Ultimate Contexts: Delta and Lazio Regions*

#### 3.1.1. Introduction: Egypt and Italy

In Egypt, the total area is 1.01 million km$^2$. According to the Central Agency for Public Mobilization and Statistics (hereafter CAPMAS), the current population of Egypt in January 2022 is 102.9 million inhabitants (Figure 5a) [93], living on 5% of the total area. In total, 44% of the inhabitants live in rural areas. Egypt comprises seven regions, 27 governorates, 185 districts "*Markaz/Kism*", 4741 villages, and 30,888 satellites (Figure 5b).

In Italy, the total area is 301,340 km$^2$. According to the Italian National Institute of Statistics (hereafter ISTAT), the current population is about 59.3 million inhabitants (Figure 5a) [94]. In total, 29% of inhabitants live in rural areas. Italy is subdivided into 20 regions (of which five enjoy a special autonomous status), 110 provinces, and 8101 municipalities (Figure 5b). It is noteworthy that the Nomenclature of Territorial Units for Statistics (hereafter NUTS) [95] is a geographical nomenclature subdividing the economic territory of the EU into zones into three levels (NUTS 1, 2, and 3 [96]. The fourth level is the local administrative units (hereafter LAU), which are classified into three categories (cities, towns, and rural areas) and are based on the geographical contiguity and population size and density [97].

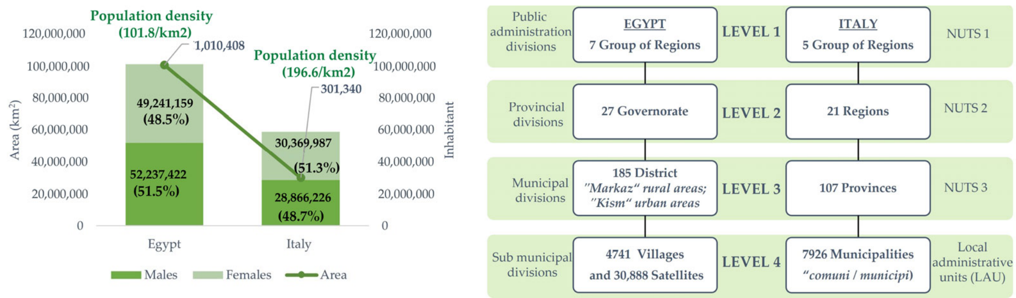



**Figure 5.** (**a**) Area, population by sex, and population density in Egypt and Italy (reference year 2021); (**b**) the administrative system hierarchy in Egypt and Italy, based on CAPMAS and ISTAT.

#### 3.1.2. Location, Population, and Administrative Structure

The Delta Region is in northern Egypt, between latitude 30 22, 31 50 and longitude 30 10, 31 30. The total area is 12,357.4 km$^2$ or 2.94 million "*feddans*" (unit of area used in Egypt equals 4200 m$^2$), representing about 1.22% of the total area. The population is about 21.4 million inhabitants (January 2021), representing 22% of the total. It comprises five governorates, 106 districts and cities, and 1404 villages (Table 2) [98].

**Table 2.** The demographic data (reference year 2021) and the administrative structure of the governorates of the Delta region [98,99].

| Title 1 | Area (km$^2$) | Percentage of Area (%) | Population in 2021 | Population Density/km$^2$ | Centers | Cities/District | Main Villages | Minor Villages |
|---|---|---|---|---|---|---|---|---|
| Dakahlia | 3538.23 | 28.6 | 6,862,389 | 1939.5 | 15 | 18 | 114 | 485 |
| Damietta | 910.26 | 7.4 | 1,578,983 | 1737.7 | 4 | 11 | 43 | 80 |
| *Kafr ElShiekh* * | *3466.70* | *28.1* | *3,600,635* | *1083.6* | *10* | *10* | *44* | *207* |
| Monufia | 2499 | 20.2 | 4,581,813 | 1833.5 | 9 | 10 | 69 | 315 |
| Gharbia | 1943 | 15.7 | 5,288,346 | 2721.7 | 8 | 8 | 53 | 317 |
| Total | 12,357.4 | 100% | 21,912,166 | 1773.2 | 48 | 58 | 339 | 1404 |

* The case study (Lasaifar Albalad settlement) locates in this governorate.

The Lazio Region is located on the Tyrrhenian coast in the central region, between latitude 30 22, 31 50 and longitude 30 10, 31 30 42. The total area is 17,232 km$^2$. The population is about 5.73 million inhabitants (2021), representing 5.6% of the total area [100]. The Lazio

Region (NUTS 2) has five provinces (NUTS 3) and 378 LAU: three cities, 103 towns, and 272 rural areas (Table 3).

**Table 3.** The demographic data (reference year 2021) and the administrative structure of the provinces of the Lazio region (based on ISTAT).

| Provinces | Area ($km^2$) | Percentage of Area (%) | Population in 2021 | Population Density/$km^2$ | Cities | Towns/Suburb | Rural Areas |
|---|---|---|---|---|---|---|---|
| Viterbo | 3615.24 | 21 | 6,862,389 | 85.42 | 0 | 13 | 47 |
| Rieti | 2750.52 | 16 | 1,578,983 | 55.02 | 0 | 1 | 72 |
| Roma | 5363.28 | 31 | 3,600,635 | 788.97 | 2 | 55 | 64 |
| *Latina* * | *2256.16* | *13* | *4,581,813* | 250.97 | *1* | *14* | *18* |
| Frosinone | 3247.08 | 19 | 5,288,346 | 145.53 | 0 | 20 | 71 |
| Total | 17,232.29 | 100% | 21,912,166 | 332.54 | 3 | 103 | 272 |

* The case study (Pontina settlement) is located in the Latina province.

### 3.1.3. Urban Characteristics

The urban fabric of the Egyptian village (Figure 6a), particularly in the Delta region, is characterized by three patterns: organic (Figure 6b), linear (Figure 6c), and scattered (Figure 6d) [101,102].

**Figure 6.** Some urban characteristics of typical Egyptian rural settlements in the Delta region (images taken by Ahmed Abouiana). (**a**) Aerial view of a typical urban fabric of Almahalla Alkobra District, Gharbia Governorate, Delta Region. It depicts the administrative hierarchy from the city towards districts, main villages, and dependents' villages within the ecosystems. (**b**) A typical traditional tissue, Lasaifar Albalad (the preliminary stage of the village's growth). The 2m-width close-end path hosts social events (e.g., funerals); (**c**) Typical linear pattern, Lasifar Albalad settlement (the second growth phase, surrounds the old center); (**d**) Typical scattered pattern, Menouf, Gharbia Governorate. It spreads in marginal parts outside the inhabited centers and encroachment over agrarian land until 2019; the government has prevented this by intensive penalties (Law No. 164 of 2019).

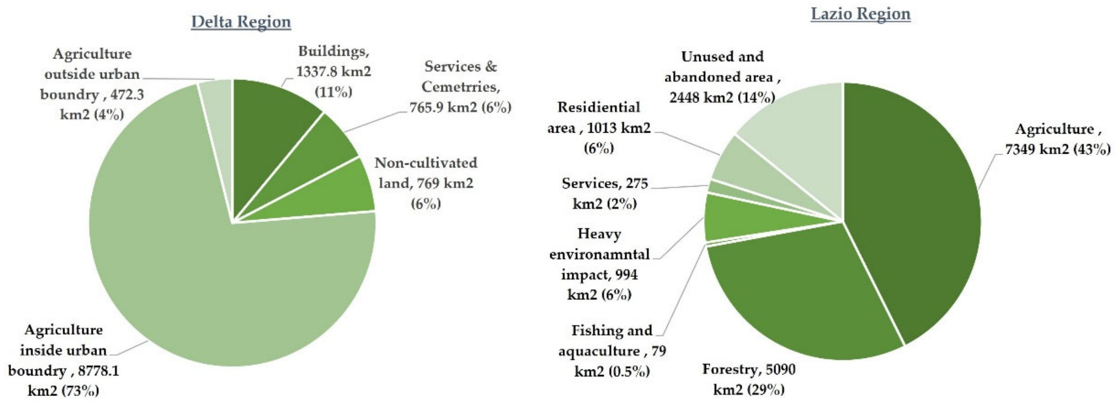
In Italy, rural settlements have several different typologies in terms of population [97], location (coastal and inner areas), geography (hilly, plain, and mountain), accessibility, and services [103] other than economic activities (agriculture, fishing, and forestry). Each pattern has its own urban identity. Despite this, the rural fabric is predominantly characterized by small and medium-sized farms whose rural nature form a scattered settlement system with numerous structures and intensities concerning cultivation order and farm size [104–106].

In the study context, the agriculture-based rural settlement patterns (Figure 7a) witnessed a significant milestone in the era of fascist rule. Benito Mussolini established new settlements and towns in many regions, producing a unique urban fabric inspired by rural architecture [106–108]. The Lazio region has five settlements: Latina, Saupaudia, Pontinia (Section 3.2.2), Aprilia, and Pomezia. Examples of the 1930s rural buildings are shown in (Figure 7b,c).

**Figure 7.** Some characteristics of rural settlements' built environment in the Lazio region (images taken by Ahmed Abouaiana). (**a**) Aerial view of a typical scattered urban fabric of rural and suburban agricultural areas, Rome province; (**b**) an abandoned original dwelling of 1930s architecture, Pontinia settlements. This typology (static mass) is suitable for plain topography and is predominate in the Lazio region; (**c**) Original industrial buildings in Pontinia. As seen, the roof is a light structure (fiber cement) of so-called in Italian "*eternit*", which is predominate in many dwellings (mainly outside the inhabited center, as has been observed in the field survey), farm buildings, and sheds.

### 3.1.4. Land Uses, Buildings and Energy

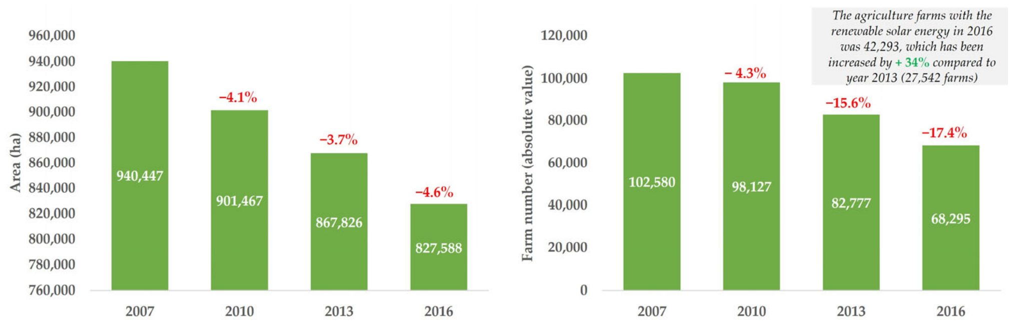
The agricultural lands represented the highest area in the Delta region at 77%, followed by the buildings at 11%, and 6% for each service and non-cultivating land use (Figure 8a). The labor force represented 33% of the region's total population in 2006 [98]. Likewise, in the Lazio region, agricultural land uses predominated at 43%, and in second place, forestry, by 29%. The unused and abandoned areas accounted for 14%, while the buildings and the heavy environmental impact activities represented 6% for each. Finally, the services and fishing activities are represented by less than 3% (Figure 8b).




(**a**) (**b**)

**Figure 8.** Land use distribution by activity. (**a**) In the Delta region [98]; (**b**) in the Lazio region [109]. The buildings and agricultural land use represent 88% in the Delta and 49% in the Lazio, highlighting the potential of the concept we promote (multifunction land use) in contributing to both regions.

The total farm numbers in Italy in 2016 accounted for 1,145,705 farms, distributed over an area of 16,525,472 hectares (hereafter ha) (one hectare equals 1000 m$^2$). In Lazio, the total number of farms is 68,295 (Figure 9b), distributed over 827,588 ha (Figure 9a). They exemplify 5% of the national farm areas. Of note, the number of farms in Lazio is decreasing steadily. For instance, in 2016, farm numbers dropped by 17% compared to 2013 and 30% compared to 2010, whereas in terms of area, the total farm areas in 2016 decreased by 4% compared to 2013, adding a new challenge for Italy to preserve the remaining farmlands.




(**a**) (**b**)

**Figure 9.** Farm areas and numbers in the Lazio region, based on ISTAT and the 2010 Agriculture Census. (**a**) Farm areas by hectare between 2007–2016, where the area lessened by 112,859 ha, and the figure indicates an annual decrease of 1.5%, approximately. (**b**) Farms number in the same period. The figure illustrates that between 2007 and 2010, the amount decreased by 4.3%, 15.6% between 2010 and 2013, and 17.4% between 2013 and 2016. In line with the study context, the number of agricultural farms with solar renewable energy increased by 34% between 2013 and 2016.

For the reference year 2017, Egypt has (16,185,063) buildings. The Delta region has 3,716,088 buildings, representing 23% of the total (Figure 10a). Delta's rural areas have 2,462,216 buildings (78% of the total). By the construction status (Figure 10b), 79% of the buildings do not need renovation, whereas 12% and 5% require minor and medium renovation, respectively. Only 4% need demolition or significant renovation [110].

On the other side, for the reference year 2011, Italy has a total of 14,515,795 buildings. The Lazio region has 954,679 buildings (6.6% of the total). By the construction status, 56% of the buildings are good, 28% are very good, and 16% are poor [111].

The distributed energy in the Delta region in 2018 accounts for 23,043.6 GWh. The residential lighting purpose consumed the highest amount with 55% of the total energy, other activities with 14%, followed by the industry with 9%, then agriculture, public lighting, governmental entities, and commercial with about 6% of each (Figure 10a). On the other hand, in the Lazio region, the total electricity consumption, until 31 December 2020, accounted for 19,927.1 GWh. The services sector has the highest share, 44%, followed by the residential sector at 33%, the industry at 21%, and finally, the agriculture sector at less than 2% (Figure 10b).

It is noteworthy that the electrification systems in both contexts are different. By focusing on the residential sector as an example, in Egypt, electricity is the primary source of residential end-use (including cooling and heating), except for cooking and some water heaters, which rely on natural gas or liquefied petroleum gas. Furthermore, the electricity sector is centralized and government-owned, so all clients have the same electricity selling price tariff in terms of monthly consumption, which is divided into eight segments [112].

Vice versa in Italy where the electricity market is decentralized and subject to free-market mechanisms, which means wide variance because of the competitive market. For instance, on average, the price of electricity is 0.2259 EUR/kWh [113], and the prices vary based on three diverse factors: consumption amount, consumption time during the day, and the selling prices depending on the market (the cost determined by the suppliers). In addition, there are three fixed factors: network service related to infrastructure (bringing the energy from production plants to the end-user), taxes, and electric system rates (i.e., the reserve fund to support RE) [114].

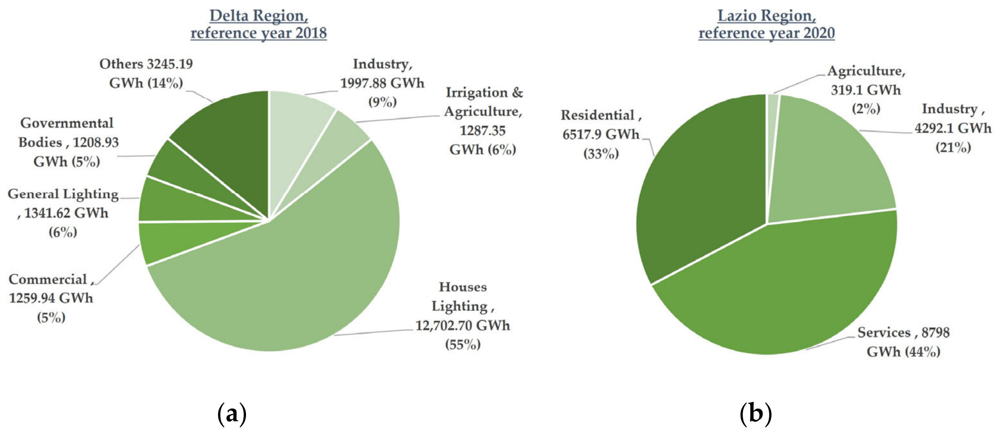



**Figure 10.** (**a**) The distributed energy by GWh by user category, and the percentage of each category in the Delta region for the year 2017/2018 based on reference [115]; (**b**) Electricity consumption by user category, and the percentage of each category until 31 December 2020 based on the reference [116]. The suggested key concepts can reduce domestic and agriculture categories' electricity shares (61% in the Delta and 35% in the Lazio regions).

### *3.2. Case Studies*

#### 3.2.1. Lasaifar Albalad Settlement

Lasaifar Albalad is located between coordinates 31.18° N and 30.72° E. It follows the Konaieset Alsaradoosy local unit, Desouk District, and Kafr el-Sheikh governorate (Figure 11a), representing 339 typical main villages in the Delta region. The population was estimated at 14,000 inhabitants in 2021, and the inhabited area is about 0.4 km$^2$. The elevation map is 6 m. The settlement contains the urban fabric typical of villages in the Delta region. The village's map of the urban fabric and land use is available in AutoCAD (.dwg format) in the reference [117].

The total number of buildings in the settlement is about 700, as counted from the official urban boundary map, which can be classified into two groups. The residential buildings are around 670 buildings (96%) and 30 non-residential buildings (4%). Some residential buildings include different economic activities (e.g., shops) on the ground floor. Few residential buildings are vacant, and contrariwise the bulk has two and three floors and one dwelling unit per floor. Most residents live in extended family buildings (the typical Egyptian typology: the building includes grandfather, father, and son).

3.2.2. Pontinia Settlement

Pontinia is located between coordinates 41.41° N and 13.04° E. It comes under the fourth administrative level. This LAU represents one of 33 LAUs (municipalities) in the Latina province (NUTS 3), Lazio Region (NUTS2) (Figure 11b). The population in 2020 was 14,945 inhabitants [118]. The inhabitant center's area (inside the urban boundary) is 1 $km^2$. The elevation map varied between 0–21 m. The urban fabric is a typical fabric of the fascist era in Lazio. The village's map of the urban fabric and land use is available in AutoCAD (.dwg format) in the reference [119].

The total number of buildings in the inhabited center is approximately 1349, as counted from Google Maps and Open Street Maps (ISTAT census 2011 indicated 2366 buildings in the entire Pontinia). They can be categorized into two groups. The residential buildings account for about 1199 (88%) of the total buildings, including many small, attached structures such as sheds, small stores, and garages, and 150 non-residential buildings (12%), including a few attached buildings. The residential buildings comprise three groups: the detached houses (one or two floors with pitched roofs), the residential buildings (the median varies but are between 3 and 5 floors), and the residential complex in the southern area (four or more floors).

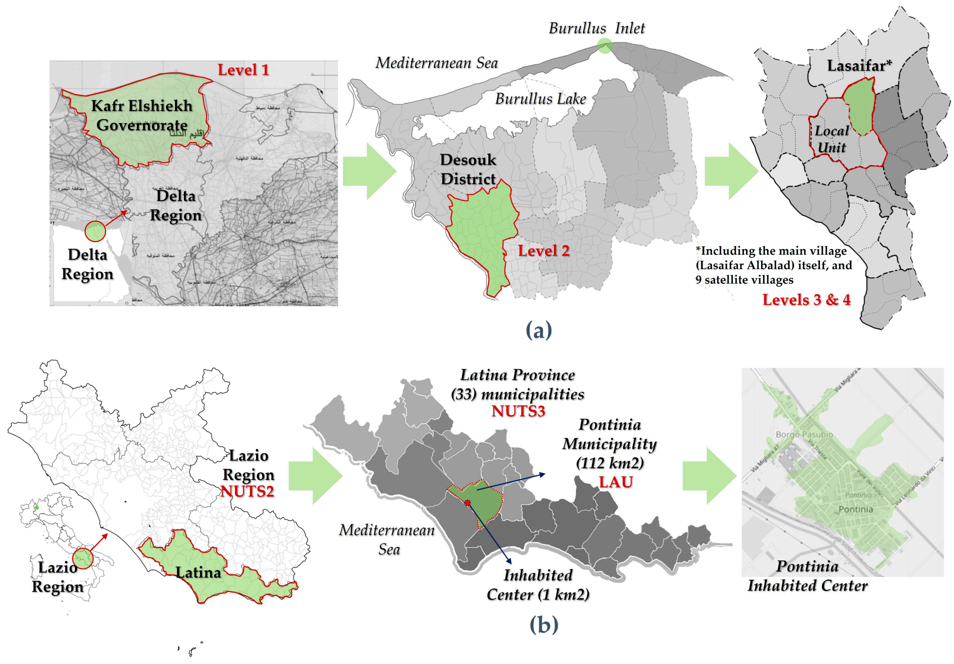



**Figure 11.** (**a**) The Egyptian case study, from the ultimate context to the intimate context; (**b**) The Italian case study, from the ultimate context to the intimate context.

## *3.3. Focus Group*

Participatory approaches are inevitable in development practices and energy transition [120]. In a European context, the Engage2020 Consortium [121] has emphasized the role of two-way dialogue (communication) forms between the participants (local citizens, experts, and policymakers) in planning the energy projects to discuss and evaluate possible solutions to a given issue. They have analyzed 57 participatory approaches, such as focus groups, workshops, and interviews, to discover individual views, normative positions, skills, needs, and motivations.

In line with the study aim, the focus group technique has been utilized to estimate and produce ideas and hypotheses. This study obtained a full-focus group technique, which involves an average of 10 participants within a 90–120 min session. The preparation for the workshops has been revised based on references [122,123].

To identify the stakeholders, at a glance, the Project Management Institute (PMI) [124] has provided several factors to determine the stakeholders in any project, including meetings, data gathering, and the effect on the project's environment. Moreover, many studies (in general) highlighted the importance of engaging academic bodies, local community, consultants, architects, and local authorities, as well as experts in the development process in general [125–128], apart from agricultural extension representatives [129] and farmers [130], particularly in developing rural contexts (similar to the study's contexts).

Two focus groups have been conducted with selected stakeholders by the first author (the moderator) to investigate many aspects, such as informing and analyzing the initial perception of the stakeholders about the energy community concept and harvesting RE. More investigation and analysis might be published in further research by the authors.

Therefore, this study involved versatile stakeholders based on their relevance to the subject from a transdisciplinary perspective—first, an academic body (Sapienza University) and the private sector are those who have high interest, and second, a sample of locals and farmers who would benefit. Finally, the local authorities' representatives have the implementation power and can facilitate the process.

### 3.3.1. Two Pilot Experiments in Egypt and Italy: The Preparation

In Lasaifar Albalad, 14 stakeholders were invited to participate in a focus group (Table 4). They had a range of professional roles, including the lead researcher from the Department of Planning, Design, and Technology of Architecture (hereafter PDTA), external experts, the local community, the private sector, and a facilitator (Figure 12a).

**Table 4.** The characteristics of the engaged stakeholders in the two focus groups.

| Stakeholders and Characteristics | Lasaifar Albalad | Pontinia |
|---|---|---|
| Academic bodies | PDTA (moderator) | PDTA (moderator) |
| Local authorities | Agricultural association manager; Former president of peasants syndicate | Pontinia Municipality |
| Local community | Farmers and employees | Farmers and employees |
| public-private related-agriculture authorities | Public Agricultural association | Italian Farmers Confederation (CIA) and National Confederation of Direct Cultivators (Coldiretti) |
| Experts | Architect, urban planner, project manager, and volunteer researchers | Architect |
| Private sector | Renewable energy and eco-material suppliers | Renewable energy supplier |
| Facilitator | Local NGO | Volunteer translator |
| Total participants | 14 | 13 |
| Female participants * | 3 | 3 |
| Date | 29 December 2021 | 18 January 2022 |
| duration | 120 min | 70 min |
| Location | Local NGO building | Pontinia Municipality |

* It is noteworthy that limited female participation may affect the focus group design related to the gender-specific effects of energy.

In Pontinia, a different approach has been conducted: the first author implemented an onsite study in December 2021. The main aim was to explore Pontinia's context and calibrate the spatial analysis (already being analyzed using GIS). In addition, talking with the locals has led to reaching an influencer, Simone Coco, the Youth Policy Advisor of the Pontinia Municipality.

The first author described to Coco the key concepts and the aims. Coco then took full responsibility for organizing the workshop and inviting the requested stakeholders (Table 4), namely from the Municipality of Pontinia, locals and the private sector, private authorities, experts, and provided a translator (to avoid any miscommunication between the group and the lead researcher (Figure 12b), in addition to informing the locals in Pontinia of the activities on the official Facebook group for Pontinia [131].

(**a**) (**b**)

**Figure 12.** (**a**) Discussion between the first author and the participants in Lasiafar Albalad, hosted by Al-Bakyat Al-Salihat Ngo (image taken by Amira Gaweesh from the NGO); (**b**) Discussion between the first author and the focus group in Pontinia (image taken by Simone Coco from Pontinia Municipality).

3.3.2. Results of the Focus Groups

Firstly, in Lasaifar Albalad, many critical issues and points of view arose and covered vast perspectives: technical, economical, and social; potential and obstacles were also discussed. Technically, the workshop presentation has oriented the discussion toward renovating building envelopes and integrating the photovoltaic into the built environment (buildings and farmlands). A project manager expert has emphasized the essential need to identify a clear scope, timeline, initial cost, and risks plans. Although we agree with his argument, it was too early to discuss these details. Moreover, the stakeholders did not know about the energy community and agrivoltaic concepts.

All the stakeholders have emphasized that funding is the most critical barrier from an economic perspective. Four sources for the funds have been suggested: crowdfunding, banks, the private sector, and the government. The locals claimed the latter is solely responsible for any development. In this line, the moderator asked the locals to assess their willingness to pay to develop their built environment. This suggestion has been refused. However, a local limited the problem to the (estimated) high initial cost, but stated he could pay small monthly installments instead of the high initial cost, supporting Abouaiana's findings [132].

From a social perspective, it was noticed that the interaction between locals and external experts reached a peak while discussing the economic barriers, as well as between the external experts themselves. Finally, the locals suggested a list of target case studies that can be pilot projects. After that, the moderator oriented them to add another case as he previously implemented three relevant studies in rural areas in the Delta region (including Lasaifar Albalad) [132–134]. Overall, the perception and feedback of the participatory approach were positive and encouraging from all the stakeholders. The locals have appreciated the possibility of developing their village.

On the other side, in Pontinia, the workshop discussed technical, economic, and social obstacles from another approach (the moderator mentioned the energy communities' concept). Technically, in line with the energy community concept, self-consumption, the participants encouraged the solution of installing PV on the roof-top of residential and non-residential buildings and farms' structures (i.e., farm buildings and sheds). Meanwhile, they stated that the "*eternit*" (Figure 7c) is a significant barrier to installing the PV, and they argued that 90% of the buildings in Pontinia are made from it. Although the moderator disagreed with them when he showed that most of the buildings (resulting from the spatial analysis) are constructed from reinforced concrete, they emphasized the buildings outside the inhabited center. Therefore, the readiness of buildings' roof-tops should be re-investigated in future studies.

Related to agricultural land uses, the participants had a high level of awareness about the eligibility of the Lazio region (vast plain areas compared to Italy; the Lazio territory comprises three morphologies: hill areas make up 53.9%, mountain ranges 26.1%, and plains 20%) to install PV on the farms. Despite this, all participants have emphasized that the concept can threaten the limited agricultural lands and Italian food security negatively, supporting the arguments of Capellán-Pérez et al. [135]. Instead, the marginal farm areas were suggested for this purpose. Another perspective highlighted by the external expert is that the lack of regulations as one of the barriers to facilitating the energy transition.

The economic aspect is the most critical obstacle regarding the high initial cost and the unknown return of investment, whereas some participants may have different priorities, i.e., one female participant stated that Italian families might have other more critical (socio-economic) priorities. However, the support for the individuals to finance self-consumption photovoltaic cells may reflect the uncertainty about benefiting from the energy efficiency, or it may reflect the lack of information. The aspect is linked somehow with the regulations.

Likewise, in Lasaifar Albalad, the participant's perceptions and feedback were positive and encouraging to all the stakeholders. They appreciated the initiative to develop the potential of developing Pontinia and implementing the second energy community in Lazio (after Ventotene) [136], which motivated the attendees. However, they were reluctant about the intervention and how and where to implement it.

## 4. Discussion and Conclusions

The agricultural areas in the Mediterranean region are facing many challenges because of the steady decrease in farmlands, climate change, and rapid global urbanization [23,137,138] (the global urban population will expand by 2.5 billion persons between 2018–2050 [139]), which threatens biodiversity, food security, local economies, and stresses natural resources. Therefore, managing the natural resources from the nexus perspective is essential to revitalize the limited land resources and support the global sustainable development goals.

Land use and energy go hand in hand. Energy transformation and extraction requires land. Land use plays a vital role in intermediating many environmental impacts of energy extraction land uses that can improve energy efficiency and reduce consumption. Considering that the electrical energy consumption patterns in the Mediterranean region have increased fourfold between the 1970s and 2000s [140], the energy consumption in developing countries has overtaken the developed countries, and fossil fuel resources will be exhausted soon [141].

In this line, the study promoted multifunction land uses by integrating renewable energies in agriculture and buildings land uses that follow two key concepts, characterized by the bottom-up approaches [142]: energy communities and agrivoltaic, to accelerate the energy transition [143] and support national policies, and valorizing the agricultural lands, especially in Italy, with its notable annual decrease.

The study has focused on Egypt and Italy (developing and developed countries) representing the entire region, showing the main features are in line with the study's aim. In each context, two agriculture regions have been selected. Both have similar characteristics at their national levels. Finally, two rural settlements were selected. Both have the same characteristics: area, population, building age, climate, geographical typology, elevation map, and agriculture activities. First, the Lasaifar Albalad settlement is typical of the 339 main villages in the Delta region (vernacular settlement grown by locals). Second, the Pontinia settlement represents a unique pattern of 1930s rural villages in the Lazio region and in Italy. It was planned by Italian architects and inspired by rural Italian architecture (producing so-called fascist architecture).

The aim is limited to theoretical foundation, to break ground for applying actual projects to these specific contexts. This aim has been supported by Heuninckx et al.'s findings [144], who mentioned that "*The successful implementation of an energy community starts with a design that is supported by and meets the needs of all stakeholders concerned*". For this purpose, the study has concluded the integrated steps as:

- Analysis of key concepts (energy communities and agrivoltaic) in the land-use-energy nexus domain, from a rational background, other than discussing relative practices in the Mediterranean agriculture-based rural settlements.
- Investigation of the key concepts' contiguity with Egypt's and Italy's rural and agriculture national policies, as well as in the European context, as Italy is a part of the EU-28.
- Highlighting the feature urban characteristics of the built environment in the Delta and Lazio regions, such as generic buildings characteristics, land uses, farmlands, and electricity and energy profiles.
- Providing the spatial analysis of Lasiafar Albalad and Pontinia settlements, such as urban fabric and building typologies, followed by conducting two focus groups with versatile stakeholders.

The policies in Egypt support the energy transition in line with the NEEAP and Egypt Vision 2030 and the government's focus on increasing the electricity production from RES. However, the energy community and agrivoltaic concepts, as they are, are still far from implementation and still in the legal stage. The prevailed patterns are limited to self-consumption on-grid or off-grid (in remote areas). In line with this, the first author is contacting the decision-makers to present these concepts, whereas on the other side, looking to implement micro-scale projects which support the concept we promote.

In the EU, the REC concept has grown steadily in past years. It is one of the foremost contributors to energy transition and enhances ecosystems. In Italy recently, the energy communities have become regulated. It is now of high interest to many bodies, such as local authorities, the private sector, locals, and research institutes [145]. For instance, the ENEA has developed the RECON online tool [146], which implements a preliminary economic and energetic analysis of the residential sector and is based on easily collected data [147], which can predict the consumption data based on ad-hoc algorithms.

The REC concept in Italy, as proven, increased energy efficiency in the buildings sector (residential and municipalities) and mitigated GHGs [148]. Likewise, as with the agrivoltaic, in greenhouses applications [149], there is an essential need to consider more innovative solutions, such as those discussed in references [150,151], and avoid the possible risks, such as high initial cost, long payback period, and maintenance [152]. The authors intend to discuss the technicalities with mini focus groups in future research.

The onsite investigations have contributed to informing the local community and preparing them psychologically for the next stage. On the other side, the focus group kept the decision-makers informed and raised their awareness, which can help grow the energy communities in Italy, as emphasized in reference [153].

"*Thank you for your effort in developing our village*" and "*I appreciate that Sapienza University is working on developing our municipality*", two participants said in both contexts. From this point and what has been implemented, this study is just a staring point to promote multi-functional land uses and REC that enhances biodiversity and mitigates climate change in distinguished Mediterranean agricultural settlements. However, we declare that the experiment still requires additional details, technical preparation, and finding funding.

Thus, the study intends to deepen this research according to the next milestone and will aim to provide micro-scale experiments in Lasiafar Albalad and Pontinia, following a structured methodology (Figure 13). Namely:

- Refining the work plan and receiving feedback.
- Making other field trips and conducting personal meetings (face-to-face) to improve social acceptance by discussing the result of this study and investigating the possible target case studies (farm, farm building, and building). The participatory approach itself mitigated the uncertainties about social acceptance, which is fundamental to the success of micro-energy projects in agriculture realms in Italy, as emphasized

in reference [154]. It is noteworthy that the first author has already contacted some stakeholders to prepare for the next phase.

- Preparing the technical study and defining the project elements (clear scope, work procedure, time frame, and budget) through these steps: specifying the target case, analyzing the existing situation by the technical team (e.g., architectural analysis and electricity consumption), analyzing the risks, and discussing possible solutions within a mini focus group (the lead researcher, local suppliers, municipality representative, and the client),
- In parallel, we intend to invest the outstanding support from both contexts to apply for the funding, such as but not limited to the PNRR in Italy and Decent Life in Egypt, and to implement two pilot projects.

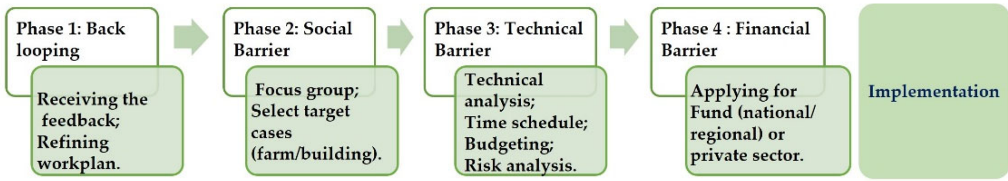



**Figure 13.** The scheme illustrates the following milestones based on the findings of this research and the first author's PhD study [51].

Eventually, although the study focused on specific agriculture contexts and micro-scale practices, it establishes a foundation point to provide a replicable methodology to other settlement patterns, widen the countries' sample, and consider emerging technologies, using advanced participatory approaches.

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