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RETHINKING AGRICULTURAL WASTE FOR BIOENERGY IN RURAL AREAS: AN APPLICATION MODEL FOR THE PROVINCE OF FOGGIA (APULIA REGION)*

Introduction. – In recent years, agriculture has been one of the major anthropic activities with impacts on the environment, ecosystems and landscapes. Among the most relevant processes of anthropization there are the reduction of native ecosystems due to urban expansion, processes of deforestation and intensification of agricultural activity (Hernández-Moreno et al., 2021).

Agricultural and forestry policies, such as the Common Agricultural Policy in Europe, have contributed to achieving a quantitative increase in food production, disregarding the quality and sustainability of processes and products but focusing on increasing mechanisation and intensification in order to maximise the unit yields of land. All this has contributed to the progressive impoverishment of land and the release of pollants and waste materials, involving the often significant degradation and homogenization of landscapes, compromising their identity, structural characteristics and the resulting socio-economic potential.

Various attempts have been made to resolve the food-energy problem. In this context, the use of residual biomass from agriculture and livestock waste for energy production currently represents one of the most encouraging alternative sources for energy production. Although it has the potential to achieve sustainable development objectives, including the reduction of waste and polluting emissions, the conservation of valuable assets, landscapes and biodiversity, however it is scarcely encouraged and developed due to various limitations.

But how and when can waste be considered a resource? Moore

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(2012), reiterating the proliferation of geographies of waste, identified the main conceptions of waste in the social sciences through a literature review. Convergences and divergences have emerged on the interpretation of the concepts and subsequent policies. The main categories identified, which however should not be understood in a restrictive sense, concern the positive or negative nature of waste and dualistic-relational aspects which describe the degree of separation with the society and, within them, the political potential and underlying social processes.

A first classification concerns the positive or negative nature of waste. Waste is considered as having a positive nature as a manageable object, commodity, archive and resource; while it is seen as negative in that it is debris that befouls and is alien to the place. The idea of waste as a danger or risk arouses debate among scholars on development, justice, sustainability and progress.

Waste as a resource and its different recovery methods involves aspects like the impacts of formal recycling on efficiency and sustainability in the management of municipal solid waste, on behaviors of participation in recycling, informal recycling, waste collection and recovery as a survival or livelihood strategy, the integration of formal/informal recycling systems, as well as the uses of animal and/or human waste as fertilizer. In this case the focus is on the ways in which waste materials can be recovered by integrating them into economic production cycles or used in informal systems. In this way the value of waste is redeemed, and the question focuses on how to achieve environmental sustainability.

This concept of waste as a resource urges researchers to "demonstrate" the practical and social consequences of waste material being transformed into another form as it passes through the circuits from production to recovery. An interesting aspect is that often when waste is discussed as a resource, geography "plays a determining role" because in transformation processes the attribution of value to waste changes from place to place, so it is important to understand the underlying policies and dynamics (Moore, 2012, p. 6).

In order to understand these policies and dynamics, we need to consider the current orientations in Europe. Since the 2000s inclusive processes have been envisaged within rural development policies to respond to increasingly complex territorial challenges and contexts. They have focused on the importance of involving the various local actors so as to encourage informed choices, especially when it comes to regional planning which can be increasingly attentive to local characteristics, needs and potential.

For this reason, in the scientific debate, collaboratively produced knowledge and a transdisciplinary approach have been encouraged especially in recent years. This generally envisages the active involvement of stakeholders at all stages of a research project or political training, both for ordinary and extraordinary events and planning (Norström et al., 2020; Reed et al., 2023; Beech, 2015).

This allows for a better understanding of the past and present problems that limit the effectiveness of local strategies. They are put together with the knowledge of community, where specific environmental considerations and concerns ensure that future initiatives are not limited by previous barriers and obstacles of different kinds (such as knowledge gaps, conflicting and highly sectoral priorities). All this requires a decision-making procedure that transcends the most common criticisms such as having focused only on certain scientific aspects (Reed et al., 2023), or having assumed that decisions are taken on different territorial scales which are often not representative of the contexts where they should operate (Henderson et al., 2013; Mäkinen, 2021; Labianca, 2021).

These premises provide a better explanation of the proposed application model. In particular, after presenting the context in which Europe is currently operating with regard to sustainable energy issues, a model applied to a case study of national interest will be presented.

Adopting an inclusive and integrated approach, by using a qualitative-quantitative methodology, with correlation and cartographic analysis in the GIS environment, a supply chain model based on the use of agricultural residues as feedstocks, will be explained. In this case, agricultural waste is envisaged and understood as a local resource to be exploited, capable of balancing sustainability objectives and, above all, social acceptability.

The local characteristics and potentialities, considering an area of particular interest in the Apulia region (South of Italy), specifically the province of Foggia, are the fundamental knowledge base to develop a sustainable model for energy production from agricultural waste, poorly supported by regional planning but more compatible with local resources, values and constraints.

European context and energy policies for waste recovery. – In the last few years, on the basis of the recent energy problems and new geopolitical context, there has been a growing attention to the development of alternative renewable energy sources. The legislation and policies are quite

broad and concern various interrelated fields such as climate and rural development, thereby opening new scenarios and perspectives on the socio-economic level especially in favor of marginal rural areas in terms of new opportunities that can derive from innovation and investments.

Considering the relationships between renewable energies and current political agendas, a process of progressive decarbonisation and innovation is advocated in Europe, in which it is also urgent to rethink policies in various fields (biodiversity, circular economy, zero pollution, sustainable and intelligent mobility, agricultural production and sustainable foods etc.). In Europe, for these reasons, financial resources have been progressively increased to support transition towards a green, sustainable, circular and competitive economy by 2050.

In this context, in Italy, as part of the recent National Recovery and Resilience Plan (PNRR), the main Next Generation EU funds identify six Missions. Specifically, mission two is dedicated to a "green revolution and ecological transition" and the National Recovery Plan promotes investments for production of biomethane from waste and organic residues especially in the agricultural sector, supporting sustainable practices in the production of biomethane (low greenhouse gas emissions, land use), promoting consortia for the treatment of digestate and effluents for the production of fertilizers from biological origin (Pelkmans, 2021).

All this has led to a change of perspective towards renewable energy with a central role played by biogas based on agricultural waste, in a new approach compared to the past. In fact, waste can be considered a resource to be exploited and not simply to be managed (Guaran & Venturini, 2022), also in order to achieve various integrated and locally compatible objectives (economic, social, local values etc.), as advocated by the main European agendas, such as the European Green Deal, the Farm to Fork Strategy, the 2030 climate and energy framework.

This brings the energy issue to the centre of the international and national debate and therefore presupposes transformative and innovative changes in various economic, social and innovation fields, in line with an integrated and systemic transformation of the economy, planning and subsequent implementation and monitoring of interventions (EC, 2021). This implies that the green transition paths, operating at various territorial scales and policy areas, should involve different actors, especially at the local level, to favor the concrete implementation of strategies through greater coordination in planning especially in rural areas.

As is known, in Europe, rural areas are often characterized by a strong dependence on the Common Agricultural Policy, by structural and social problems, a progressive growth of renewable sources, above all wind and photovoltaic energy, often without any economic or social benefit for the local community. Another repercussion is the damage to the landscape and the fact that valuable land is often taken away from agriculture.

Furthermore, as is well-known, Italian energy policy is a concurrent responsibility at national and regional level, so that each region defines a legislative and regulatory framework, especially planning, with great autonomy. This situation, in addition to the different incentive systems and policies introduced over the years, has led to the growth of energy sources based on wind and photovoltaics, while little attention has been devoted to bioenergy derived from biomass, more compatible with local resources and values.

A model for agro-biomethane starting from waste. Which innovations? – As confirmed by several case studies (Mangoyana and Smith, 2011; Blair et al., 2021; Scarlat et al., 2018), the production of bioenergy, especially small-scale decentralized, can be a potentially sustainable energy system and represent a valid alternative to local problems because it is no longer based on monocultures and dedicated agricultural crops as in the past. Therefore, it can favor the reconciliation of economic and social objectives, above all the integration of bioenergy activities at local scale and government initiatives (Cavicchi et al., 2014; Pavičić et al., 2022), contribute to the development of rural areas, supporting new supply chains for biomass feedstock, mainly by using waste from agriculture (Scarlat et al., 2018), innovating waste management methods and encouraging the recovery and valorisation of local potential and resources.

The raw materials used for the production of biogas can come from agricultural, urban and industrial waste. The substrates for the production are different and depend on the availability of raw materials at the local level (Pavičić et al., 2022). Therefore, production from predominantly agricultural and organic sources represents the main field of this research and is seen as part of the wider local agro-energy supply chain.

The Apulia region is among the leading regions in Italy for the distribution and power produced by wind and photovoltaic plants (Bencardino et al., 2020; Labianca, 2020). Energy production from biomass is poorly supported despite having extraordinary potential, especially concentrated in specific geographical areas, in particular in the north of the region, in the province of Foggia.

In the perspective inspired by the objectives of sustainability and the circular economy in which waste is considered a resource to be exploited, bioenergy based on local potential can represent a valid alternative, more sustainable and acceptable to the local community, strongly exasperated by past regional choices as highlighted in recent research (see Labianca, 2014; 2020). In fact different opportunities in the field can be mentioned in all regional programming documents (both specific for the energy sector and concerning the rural and urban development) providing particular incentives and funding aimed for this purpose especially in recent years.

However, the redundancy in the number of incentive instruments with obvious overlaps in the territory, the evident conflict between the protection and the development regulation of the sector have produced fragmentation and inhomogeneity of interventions, the realization of investments articulated by mere opportunism and often with short-term limitations with indiscriminate resulted exploitation of the territory. Other aspects, emerging from the analysis of the objectives and priorities of regional programming, highlighted inconsistencies in various policy areas and in particular in the social issues regarding the nature of interventions and final beneficiaries.

On this basis, the agro-biomethane plants, in particular those fed by agro-food residual feedstock, assume particular importance in the Apulia region, being able to foster a sustainable green transition, contribute to the energy security and independence of a territory, promoting the circular economy approach by reducing waste production, as encouraged by Europe (Labianca et al., 2024).

The province of Foggia, in the north of the region, has a marked landscape characterisation and its economy is essentially based on agriculture (in which a significant role at a national level is played by the cultivation of durum wheat, according to Istat data, 2023). Due to its specific characters, wind power and photovoltaics of regional and national importance (83% of Apulian wind energy comes from the province of Foggia, which also represents over 22% of production in Italy) have been strongly developed in recent years, however often resulting in significant alterations and impacts in social, economic, environmental and landscape terms (Labianca et al., 2023).

In particular, the province of Foggia is characterized by an interesting and extraordinary local potential in terms of biomass development but is overlooked in favor of an indiscriminate growth especially of wind power often to the detriment of local environment and landscape.

Based on these considerations, a replicable predictive localization model has been developed capable of providing an initial contribution to the most sustainable choice for the location of agrobiomethane plants in rural areas, considering the specific local characteristics. The model is inspired by sustainable energy planning according to the most recent European policy guidelines, by studies on localization theory (Renner, 1947; Toschi, 1959; Dicken & Lloyd, 1990; Mccann & Sheppard, 2003; Chuch & Murray, 2009; Murray, 2010) and considers the main local characteristics and existing constraints, using spatial analysis methods and techniques developed in a Geographical Information System environment, starting from the regional context, then focusing on the specific case study (see Labianca et al., 2024).

The proposed model, not limited to describing local characteristics and potential, introduces a dynamic, interactive, predictive and prescriptive approch for localization modeling. Notably, in the energy sector various ecological, geopolitical and geoeconomic relationships intervene at different territorial scales (Dicken & Lloyd, 1990; Bencardino et al., 2020), making spatial choices even more complex especially at an operational level.

Considering the various spatial models and the most recent applications in the context of planning choices there is a general tendency to oversimplify reality (Church, 2002; Huang & Leung, 2002; Murray, 2010) ignoring specific characteristics, factors and problems of the territorial context, but as is known, multiple factors are involved in the location choice, often generating conflicts on a local scale and a general rejection by the local community of further interventions (the well-known NIMBY syndrome).

The model, developed on the basis on previous and ongoing research (Labianca, 2020; Labianca et al., 2024), is characterized by a multidisciplinary approach due to the presence of different research areas involved from: Economic Geography, Agricultural Economics, Commodity Science and Applied Economics. It is also participatory, interactive with the involvement of various local actors, such as: CIA – Confederation of Italian Farmers Associations, Confagricoltura (which actively contributed by making updated data available at predefined territorial scales), Legambiente, entrepreneurs' associations, Confindustria, farmers, local community and the Local Action Group. An element of innovation of the model is that it considered knowledge of the local context to be fundamental.

Different relationships and the active involvement of a range of actors

have made it possible to enrich the research activity from the early stages and to integrate and modify the model (subjected to periodic moments of sharing and reflection) according to a flexible and iterative approach.

Another element of innovation consists in the method of acquisition and analysis of data based on direct interaction with qualified local actors. The data came from detailed dossiers that allowed to geolocate all the basic informations enabling spatial and temporal analysis and insights. Compared to other research conducted so far, in fact, the data used usually come from census sources which present various limitations for spatial and temporal analysis. In this case the data were acquired on a voluntary basis and above all, unlike those commonly used in Italian research (e.g. Ispra, 2010; Valenti et al., 2017), this method allows for updated insights at different regional scales. The data collection has been articulated in different phases, starting from the study of the regional and then provincial context, using various sources mainly directed on farms and cultivations, livestock farms, agro-food by-products. As regards farms and crops, the contribution of the Agricultural Associations involved was fundamental. The main data came from the information entered in the individual farmers' requests for access to the CAP (Common Agricultural Policy) contributions collected by the Agricultural Associations. In this data there are detailed information of the farms in the province such as individual crop plans, areas per hectare, specific location for each cadastral unit of production identified for each municipality (Labianca et al., 2024). In most Italian research, in fact, the census data are available only at a municipal scale and not updated for long periods of time, while in our case the data are available at particle scale and can be updated periodically. All this was possible thanks to the active involvement of Agricultural Associations in the project, in accordance with a mutual exchange of specific knowledge.

A further element of innovation concerns the integrative approach adopted in the research, which tries to describe and highlight the complexity of the territory and the issue, as well as the attempt to have a strong applicative and predictive character that can be replicated in other regional contexts. Finally, the knowledge and specific tools of Geography such as regional analysis and cartographic correlation highlighted characteristics, conflicts and problems which would not have emerged in their complexity with other cognitive or planning tools.

A sustainable energy supply chain model in the province of Foggia (Puglia region): overcoming conflicts starting from local potential. – The theoretical framework includes major themes such as land use, industrial production, central locations and spatial competition (Church & Murray 2009; Murray, 2010), highlighting the complexity in the energy sector where various ecological, geopolitical and geoeconomic relationships intervene at different territorial scales (Riggio & Varraso, 2016; Bencardino et al., 2020; Riggio & De Felice, 2016), making spatial choices even more complex, especially at an operational level.

The methodology developed in the case study aims to contribute on an operational, applicative and proactive level by:

- calculating and analyzing the potential of agro-biomethane production in the territory, also according by the current EU policy agenda and regional planning;
- considering the different relationships existing among specific local characteristics (raw potential, anthropic infrastructures, pre-existing constraints and limits);
- identifying the areas involved and chosen for the location of biogas plants;
- fostering dialogue with local communities and encouraging the participation of various stakeholders.

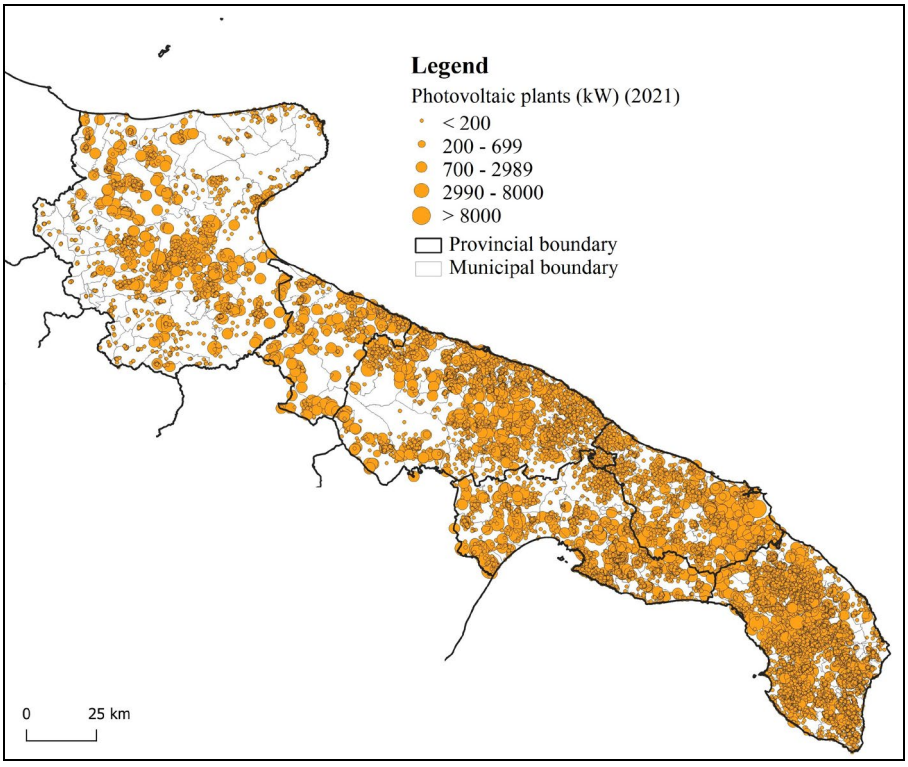
The analysis started from a preliminary evaluation of the regional context, the specific local potential and problems by combining various data. In particular data from ISTAT – Istituto Nazionale di Statistica, CIA – Confederation of Italian Farmers Associations and Confagricoltura, GSE – Gestore dei Servizi Energetici, MASAF – Ministro dell'Agricoltura, della Sovranità Alimentare e delle Foreste), Società Gasdotti Italia Spa, Territorial Information System of the Apulia Region. This data, appropriately geolocalized and transformed into spatial information layers (as ESRI shapefiles) through geoprocessing operations in the GIS environment, highlighed local characters, potential but also conflicts and issues.

The main information layers concerned: local potentialities (calculating the potential given by Agricultural Surface Used for specific crops and livestock and relative waste obtainable, subsequently resulting biogas potential); presence of a system of pre-existing methane pipelines/plants; infrastructure and traffic system; specific characteristics of the territory, areas of vulnerable and valuable rural landscapes and special protection

areas; geographical areas of certified production, in particular DOP – Protected Designation of Origin, PGI – Protected Geographical Indication, TSG – Traditional Specialty Guaranteed certified productions; spatial concentrations of DOP, PGI, TSG certified productions (obtained starting from the mapping of geographical areas and then, calculating areas of overlap and concentration in the GIS environment); territorial distribution and power of photovoltaic, wind and biogas energy plants (by using geolocalized data).

The analysis revealed both the rapid growth in terms of numbers and installed power of energy production plants from renewable sources (mainly wind and photovoltaic) (fig. 1) and socio-economic conflicts for the land-use, environment and landscape at a regional scale, through the cartographic correlation among the vector information layers processed.

Fig. 1 – *Apulia region: photovoltaic plants for distribution and power installed by 2021*

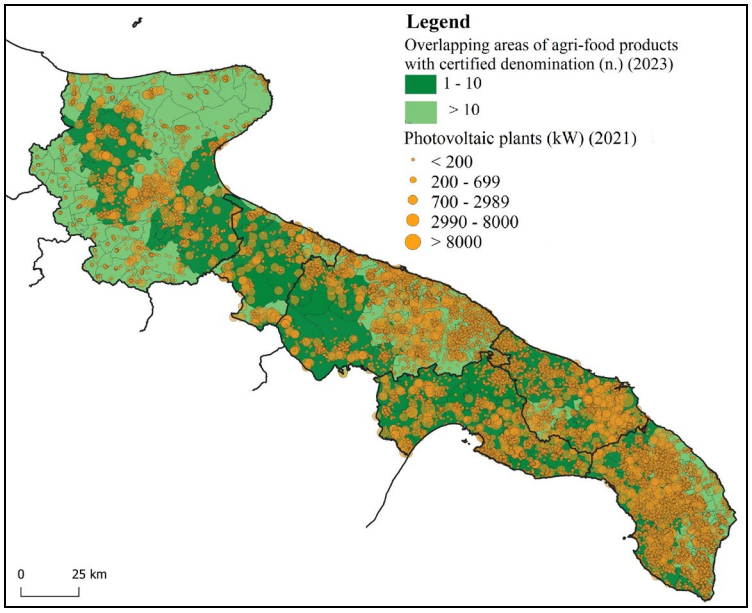


Source: pur elaboration on on GSE data, 2021

Specifically, the cartographic elaborations were obtained through geolocalization operations and spatial analysis by superimposing different information layers for the region in several steps. For instance, fig. 2 was obtained from two information layers: a first spatial information by overlaying the geographical areas of concentration of agro-food products with certified and protected denomination (DOP, PGI, TSG); the distribution of the installed photovoltaic systems classified by power. Fig. 3 was obtained with the same operation, overlaying the distribution by power of the installed photovoltaic plants and the geographical areas of the landscapes designated as valuable according to the Landscape Plan of the Apulia Region.

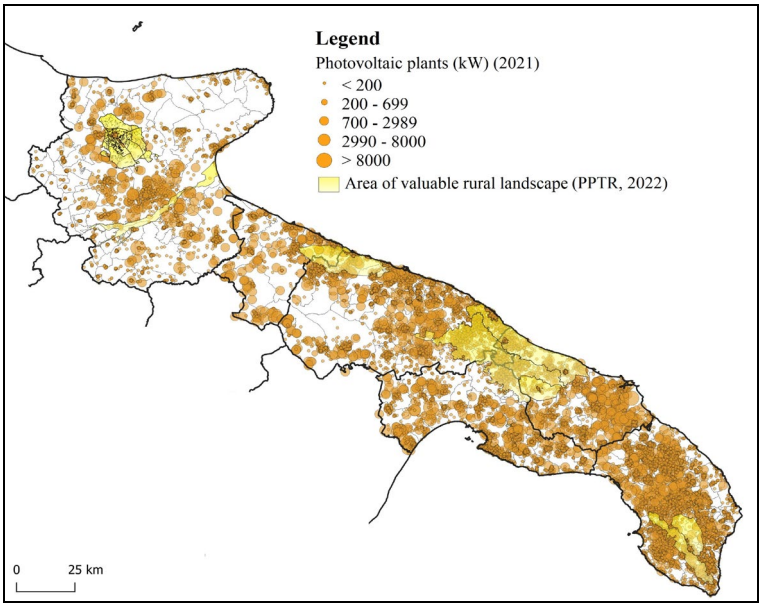
The analysis, which involved cartographic elaborations in different phases, brought out local problems and conflicts of different kinds, but also unexpressed territorial opportunities and potential. Respectively fig. 3 shows conflitcs between objectives of protection and enhancement of biodiversity and valuable rural landscapes, fig. 4 highlights the poor development of biogas even in the presence of a significant potential obtainable from the agricultural sector in the region.

Fig. 2 – *Apulia region: overlapping areas of agri-food products with certified denomination and photovoltaic plants*



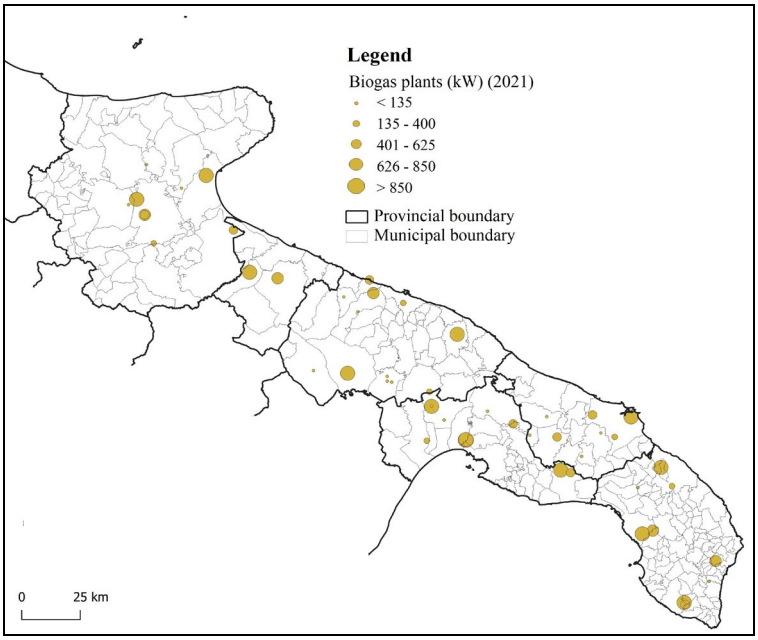
Source: our elaboration based on GSE, 2021, MASAF, 2023

Fig. 3 – *Apulia region: overlapping areas of valuable rural landscape and photovoltaic plants*



Source: our elaboration based on data from: GSE, 2021, Sistema Informativo Territoriale della Regione Puglia, 2022

Fig. 4 – *Apulia region: biogas plants for distribution and power installed by 2021*

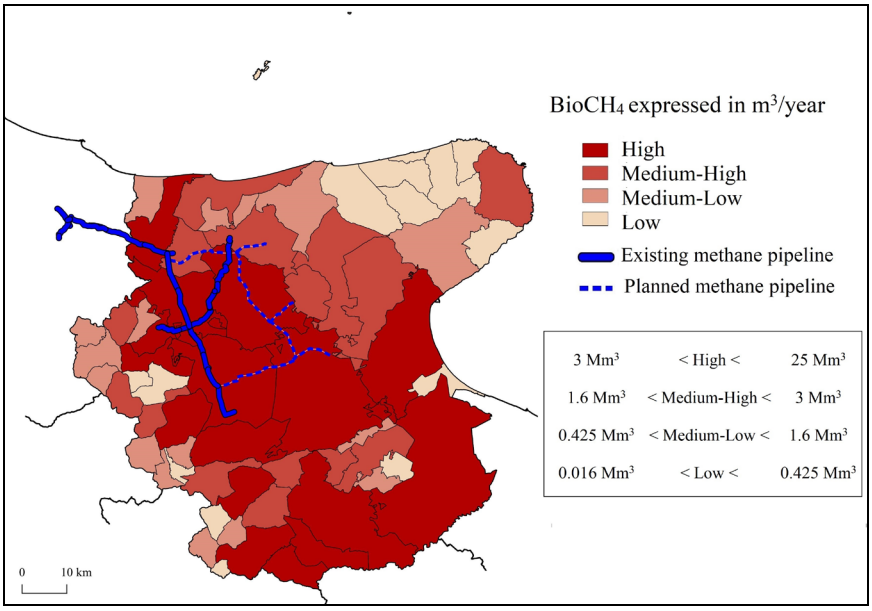


Source: our elaboration based on GSE data, 2021

All these problems and the impacts produced over time on the landscape and crop biodiversity have prompted the need to develop a sustainable agro-energy supply chain model starting from the characteristics of the context and local agricultural potential.

Therefore, on the basis of this regional evidence, the model developed in the province of Foggia (in the north of the Apulia region) (fig. 5) started from the aforementioned analysis of the regional context, and then identified the main localization factors, requiring further data to describe and represent them.

Fig. 5 – *Province of Foggia: biomass potential and the proposed application model for bioenergy from agricultural waste*



Source: Labianca et al., 2024, p. 11

The specific aspects taken into account were the topographic features, the total biomass potential for energy production calculated and obtainable from waste resulting from local agricultural and livestock farming, the accessibility of transport, the technical conditions of plants, the adaptability of the network of pre-existing plants, the political conditions such as specific incentive schemes (fundamental for defining cost ranges) and territorial planning constraints (in particular, areas of protection of the environment and landscape) (tab. 1).

The model took into account the specific geographical characteristics of the area such as the overall potential, constraints and pre-existing limits, with the aim of establishing a predictive localization model in order to minimize costs and environmental and landscape impacts in the identified area.

Then, each factor was processed into a specific information layer within a GIS project, and various cartographic overlay and geoprocessing operations were carried out, to finally identify the areas of optimal location of potential plants considering all the main factors and their interrelations.

The layers of information processed and combined in the GIS environment contributed to modeling and cartographic representation. In the specific sector, in addition to the actual local potential, the cost distance from the production sites to the points of the pre-existing methane pipelines played an important role.

Tab. 1 – Main factors considered in the study with data and sources

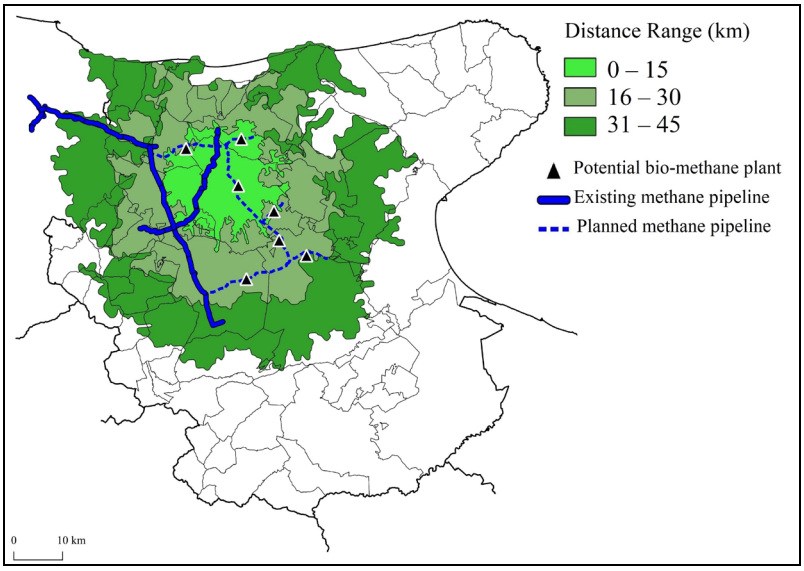
Main factors and description	Data sources
Local potential of bio-methane: cadastrial data for farms and cultivation distinguished in type of category and crops, surface in hectares, organic or not organic, livestock farms, agro-food by-products	Confederazione Italiana Agricoltura Confagricoltura Association Istituto Nazionale di Statistica (farms and agricultural census), http://dati.istat.it
Infrastructure and traffic system: presence and types of transport routes	Open Street Map (basemap) https://www.openstreetmap.org
Existing services, infrastructures for energy production plants: network of services and infrastructures and methane pipeline system	Società Gasdotti Italia Spa
Local characteristics and constraints: hydrogeomorphological, ecosystemic and environmental characteristics, areas of protection and of greater vulnerability	Sistema Informativo Territoriale della Regione Puglia, Piano Paesaggistico Territoriale – PPTR https://pugliacon.regione.puglia.it
Presence of certified productions: geographical areas of certified quality productions	Ministro dell'Agricoltura, della Sovranità Alimentare e delle Foreste https://dopigp.politicheagricole.it
Existing renewable energy systems: locations and power installed of wind, photovoltaic and biogas energy plants	Gestore dei Servizi Energetici S.p.A (GSE)

Source: our elaboration

The factors considered converged in the final result, with the identification of specific isocost areas and an economic sustainability analysis (based on current tariffs). In order to establish the isocost areas, the cost analysis, developed on the basis of the regulatory regimes regarding economic convenience, made it possible to define the different geographical areas within a range of distances (acceptable in terms of overall costs mainly of transport given the type of raw material used). The Euclidean allocation method was used to define the isocost areas, in order to obtain a continuous surface of travel times and to extend the cost distance function within neighboring areas (Zhang et al., 2021).

The geographical areas of interest were calculated using geoprocessing operations, taking into account the Open Street Map cartographic base which shows the actual presence of transport routes in the territory (fig. 6).

Fig. 6 – *Province of Foggia: isocost areas and identification of optimal plant location*



Source: Labianca et al., 2024, p. 13

This analysis, which attempts to simulate reality, considers ordinary conditions so as to obtain different geographical areas with gradually increasing distances and monetary values identified in the map with increasing colors and costs (Labianca et al., 2024). The result of the study was shared with local actors who made specific knowledge available to provide suggestions and improvements to the model.

In addition to the direct involvement of trade associations that provided selected and accurate data for the study, three dissemination thematic workshops were organised with interventions by various stakeholders, representatives of different sectors and interests (representatives of trade associations and environmental and landscape protection associations, entrepreneurs, scholars, experts etc.) as speakers and participants at appropriately selected places (such as the headquarters of Municipality, Local Action Group) capable of facilitating the widest access of potential interested people (stakeholders, entrepreneurs, trade associations, citizens etc.).

The public, thematic discussions were characterized by wide participation, the questions and open reflections were noted from time to time, feedback and corrective proposals were recorded and providing suggestions considered useful for modifying the model developed in progress, introducing further information and bringing out the particular relevance of the social, environmental and not just economic sustainability of the project.

Some important suggestions concerned the need for supporting networking and supply chain agreements among small farmers which can have a significant role in the valorisation of waste, can bring important economic advantages, foster greater social acceptance.

The approach followed in all the phases of the research has tried to consider the difficulties, the needs and the points of view from different actors who in various ways have been involved, as well as the complexity of operational strategies in territories compromised by choices often imposed from above, little aware and respectful of local specificities and potential. It represented a first important attempt at a shared study and analysis in such a sensitive and controversial field, to encourage informed choices, especially for more sustainable planning and management, characterized by social acceptability in full respect of local values, needs and potential.

Conclusions. – In the current context where it is fundamental to reconcile objectives and interests at different territorial scales, excessive exploitation of energy sources that are not always compatible with the local environmental and landscape values require strategies and study models that take into account the complexity of territorial systems.

In the absence of coordination and planning in terms of renewable energies and waste management, the research can promote greater awareness and local acceptance of energy alternatives that are actually

compatible with local characteristics. In fact, the adoption of tools and methods that place the characteristics of the local context at the center of attention and the dialogue with the local communities and all the stakeholders involved can prove strategic and functional in achieving the objectives set by the current international agendas but which encounter difficulties and obstacles in implementation at the local level.

Finally, the development of the proposed model started from an orientation that considers agricultural waste as a resource to be valorised and adopted a multidisciplinary, multidimensional, dynamic and interactive approach with the direct involvement of different actors in the definition of shared objectives starting from knowledge of territorial context up to implementation.

This concept of waste as a resource urges researchers to "demonstrate" exactly what the practical and social consequences are, but above all to understand what dynamics and processes are behind the attribution of value to waste. As emerged in this study, among other aspects, it is fundamental to build and support specific, shared awareness and knowledge, and to try to understand the underlying policies and dynamics at the local level.

The use of data and information from different sources aimed to provide an understanding of the complexity of the issue and in particular of the knowledge and tools that are specific to Geography and which can offer a key strategic contribution, providing the fundamental basis in various policy areas, first of which is integrated territorial planning.

In an international context that considers energy supply chains increasingly subject to changes in geopolitical relations (Zakeri et al., 2022), the agro-biomethane supply chain can be a valid and more sustainable alternative to different energy sources, to the recovery of waste from production activities and can offer development opportunity for various rural areas in Europe, but it is essential that there is awareness of the importance of knowledge of the local context.

In this way, the application model was developed by supporting and promoting the specific knowledge of the regional context, also thanks to the support of qualified and voluntary data and information, thus managing to reconcile different objectives and interests, trying to reduce the impacts in terms of ecological, social and landscape balance, without any alteration of crops or valuable landscapes that representing the local

identity and that can be the subject for territorial enhancement (such as slow tourism).

The analysis also brings out another aspect which concerns the strategic choices of the regional government. Based on the territorial evidence that also emerged from the cartographic analysis, it is more important than ever to rethink energy strategies because the further growth of wind and photovoltaic plants without any social acceptance and poor attention to local resources can exacerbate local conflicts. These are related to the conflicts between the land use for energy facilities and land use for certified quality production, springing from the widespread growth of wind and photovoltaic plants and the loss of biodiversity and valuable agricultural and rural landscapes.

In these terms and as stated during the sharing of results and reflection together with local communities, there would be no reason to continue investing in wind and photovoltaic plants because they no longer have social and economic acceptance in the territories involved. The proposal is to converge towards more sustainable solutions and compatible with local characteristics, such as investing in energy produced from biomass obtainable from waste resulting from agriculture and livestock farming specific of the local context. This would avoid significant alterations and territorial impacts and facilitate the achievement of multiple objectives simultaneously regarding sustainability in an integrated and systemic approach.

Local, institutional and social characteristics and in general context factors as well as economic evaluations are decisive for the development of alternative, more sustainable technologies and energy systems, in particular biogas. To this end, the co-building of knowledge between different local actors such as companies, associations, experts, institutions has proved very promising and therefore to be supported. In this direction, local institutions should play a fundamental role in facilitating these processes, promoting transparency and sharing of strategic choices and increasing awareness of their territorial impacts.

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Ripensare i rifiuti agricoli per la bioenergia nelle aree rurali: un modello di applicazione per la provincia di Foggia (Puglia, Italia). – Studi recenti e agende politiche internazionali si concentrano sempre più sulle geografie dei rifiuti e sull'equilibrio degli obiettivi di sostenibilità nelle politiche energetiche, rivelando problemi soprattutto nell'implementazione su scala locale. Sebbene l'uso della biomassa residua proveniente dai rifiuti agricoli e zootecnici per la produzione di energia rappresenti attualmente una delle fonti alternative più promettenti per la produzione di energia e il raggiungimento degli obiettivi di sviluppo sostenibile, inclusa la riduzione dei rifiuti, delle emissioni inquinanti, la conservazione di beni preziosi, paesaggi e biodiversità, è scarsamente incentivato e sviluppato a causa di varie limitazioni. Questa ricerca mira a sviluppare un modello sostenibile per la produzione di energia dai rifiuti agricoli con la tecnologia appropriata, ancora poco considerata ma compatibile con le risorse, i valori e i vincoli locali. A tal fine, si considerano le specifiche caratteristiche e potenzialità locali, utilizzando una metodologia qualitativa-quantitativa applicata in un'area di particolare interesse nella regione Puglia.

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