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Biomethane Community: A Research Agenda towards Sustainability

Idiano D'Adamo [1,*] and Claudio Sassanelli [2]

1 Department of Computer, Control and Management Engineering, Sapienza University of Rome, Via Ariosto 25, 00185 Rome, Italy
2 Department of Mechanics, Mathematics and Management, Politecnico di Bari, Via Orabona 4, 70125 Bari, Italy; claudio.sassanelli@poliba.it
* Correspondence: idiano.dadamo@uniroma1.it

Abstract: The bioeconomy is an effective solution to align with the sustainability agenda and to meet the pressing calls for action from Cop26 on a global scale. The topic of the circular bioeconomy has gained a key role in the literature, while the theme of energy community is a basic form of social aggregation among stakeholders. This work focuses on biomethane and proposes a framework based on several criteria that are evaluated using a hybrid Analytic Hierarchy Process (AHP) and 10-point scale methodology. The results show that regulation and energy community are considered the two most relevant categories. The overall ranking of criteria sees the stakeholders' engagement as the most important, followed by more significant subsidies for small- and medium-sized plants and the principle of self-sufficiency applied at the inter-regional level. Subsequently, the Italian Adriatic corridor composed of four MMAP (Marche, Molise, Abruzzo, and Puglia) regions is considered as a case study in order to evaluate the possible environmental (854 thousand $\frac{\text{tons } CO_2\text{eq}}{\text{year}}$) and economic (from 49 million EUR to 405 million EUR in function of plant size) benefits associated with potential biomethane production of 681.6 million m^3. It is found that the biomethane community is an enabler of sustainability and this strategy can be used for sharing different natural resources.

Keywords: AHP; bioeconomy; biomethane; energy community; Italy; point scale; stakeholders' engagement; sustainability

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1. Introduction

In a world constantly affected by wars, geopolitical risks, and a constantly surging need to modify production models to cope with resource depletion and scarcity, sustainability [1] is becoming the main challenge worldwide, involving different types of stakeholders in society. Sustainability is "development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs" [2]. Sustainability is the balance point between economic prosperity, environmental improvement, and social equity, famously known as the three dimensions. The Triple Bottom Line captures the spectrum of values that organizations must embrace to be competitive given the increasing weight they are gaining [3].

Sustainable development [4] and the Circular Economy (CE) [5] are the dominant concepts suggesting new business models [6] that are able to reach the Sustainable Development Goals (SDGs) [7]. The CE proposes the criteria of narrowing, slowing, and closing resource loops [8] to promote sustainable development [9]. For this aim, the concept of waste is proposed as an added value [10,11].

Europe, with its strategy of the European Green Deal, aims to be the first climate-neutral continent by 2050 [12]. Consequently, the European Commission explicitly seeks to achieve a just transition to a low-carbon energy system. The topic is very much felt in the literature and is becoming increasingly relevant. Some authors highlight three different perspectives: "energy justice occurring within community energy initiatives, between initiatives and related actors, and beyond initiatives" [13]. Energy communities need government tools to develop, and a review of the topic highlighted four categories: (i) community planning and capacity; (ii) environmental protection; (iii) grid access; and (iv) payment-based [14]. For this scope, it is crucial to enhance the integration of the prosumer [15] but also to clarify the role of the stakeholders [16]. These concepts can be studied on individual projects [17] or can identify suitable indicators to measure performance [18].

In addition, the recent war in Ukraine has highlighted energy problems of national self-sufficiency for some countries, and society is no always able to reduce and limit the impact of the main industries on energy consumption (manufacturing [19], transportation [20], and both civil and industrial buildings [21]) through digital technologies adoption. In the current situation, to avoid a placebo effect, this is no longer sufficient, and a breakthrough is needed. The greater energy dependence on foreign countries and the greater dependence on speculative aspects related to the different actors involved in the chain of sale of the energy sources ask for urgent actions in the safe restoration and valorization of waste and biomass to produce valuable and competitive materials and energy [22]. The bioeconomy plays a key role in trying to answer this call, enabling the conversion of natural renewable resources, originating from the biological world, into energy sources [23,24]. The bioeconomy provides suitable answers to the requirements of sustainability in several areas [25,26].

Biomethane can be considered a reference model for the circular bioeconomy [27] through which sustainable best practices could be followed. Indeed, composed of different substrates (e.g., crop leftovers, organic components of municipal solid waste, etc.), it allows the displacement of non-renewable resources with biological ones, triggering the use of biomass and shrinking biowaste presence in landfills [28]. In addition, biomethane can be allocated for different uses (e.g., natural gas grids, energy source for vehicles) and/or converted into feed cogeneration units [29].

Even if different benefits deriving from biomethane adoption can be envisaged for different stakeholders of society levels [30–32], a quite heterogeneous and relevant set of issues can be registered that hinder its full diffusion (e.g., improvement in cleaning and upgrading technologies and processes [33], distrust towards related production plants, and regulation inefficiency [34]). To bridge all the issues related to the full adoption of biomethane towards a widespread solution in current society, pushing the criticalities analysis and leading policymakers to identify guidelines to be implemented to foster biomethane development, innovative frameworks are needed.

Indeed, there is a clear need for understanding how to distribute and deliver the latent value coming from biomethane among all the stakeholders in society through a sustainable hand [22]. The main issue is that to manage to achieve sustainability effectively, the huge quantity of different flows involved (of resources, energy, and wastes) needs a systematization of the related data and information [35]. The main means of bolstering this mechanism are not only digital technologies, which need to be implemented and exploited along the entire product lifecycle [36], but also innovation ecosystems, which are necessary to trigger cooperation and foster the birth of communities able to propose sustainable solutions addressing present and future necessities.

The sustainability bioeconomy aims to provide concrete answers to current problems but also to meet the needs of the literature [22]. For this reason, biomethane is proposed as a virtuous example of a circular bioeconomy, and its potential within an energy community is identified. A topic that needs attention and that finds little space is the use of biomass. Grounded on the concept of energy communities, the goal of this work is to build, propose, and assess a meso-level framework that is needed in CE models to analyze the large number of variables affecting rising biomethane communities. The framework is also engaged to explore the advantages deriving from cooperation dynamics characterizing the MMAP regions model.

The paper is structured as follows. Section 2 presents the research process, detailing the criteria chosen in the hybrid AHP and 10-point scale methodology conducted that are useful for building the biomethane framework development and for its application to the Italian context of the central and southern Adriatic regions. Section 3 shows the results of the survey related to the framework proposed, detailed with the category, local, and global priority (in Sections 3.1–3.3, respectively). It is also proposed in Section 3.4 a discussion to drive a future direction towards the sustainability of the biomethane community composed by the MMAP regions in Italy. Finally, Section 4 concludes the paper, raising the gaps of the research and unveiling that there is room for further studies to address the challenges to be addressed in the near future to bolster local communities in approaching sustainability.

2. Materials and Methods

A framework gains greater visibility when composed of a substantial number of criteria. The number of criteria can better explain the differences among conflicting criteria or to better delineate a topic. In this paper, we follow the Triple Bottom Line but choose not to propose the three dimensions as reference categories. We aim to identify how other categories influence these dimensions. The need to individuate categories arises from the substantial number of criteria chosen. The AHP is characterized by a small number of criteria and the aggregation of criteria within categories allows for comparison. The local priority and global priority method has precisely this objective.

This section is divided into six parts. In Section 2.1, the hybrid AHP and 10-point scale methodology are proposed with an identification of the experts in Section 2.2. A framework for assessing the impact of biomethane development is proposed in Section 2.3. Furthermore, the environmental and economic values associated with biomethane plants are shown in Sections 2.4 and 2.5. Finally, the case study is proposed in Section 2.6.

2.1. Hybrid AHP and 10-Point Scale Methodology

Decision models allow for the comparison of alternative solutions and decision making through quantitative data. These methods include AHP, which is used to evaluate energy projects [37,38]. The method proposed by Saaty [39] allows obtaining a priority list to be identified through pairwise comparisons based on expert judgments. The AHP, also known as the analytical hierarchy process, is a structured technique for organizing and analyzing complex decisions and is based on mathematics and psychology [40].

The dimension of the AHP comparison matrix ranges from one to ten factors but is typically set to seven $\pm$ two. When the number of criteria is very large, some authors have suggested the use of an integrative method applied to the biogas based on local–global priority [41]. The local priority measures the relevance of a criterion within the same category. The category priority evaluates the relevance of each category and, finally, the global priority is obtained as a product of the local priority and the category priority.

For each matrix, a nine-level scale can be used [42]: 1 $\rightarrow$ equally preferred; 2 $\rightarrow$ equally to moderately; 3 $\rightarrow$ moderately preferred; 4 $\rightarrow$ moderately to strongly; 5 $\rightarrow$ strongly preferred; 6 $\rightarrow$ strongly to very strongly; 7 $\rightarrow$ very strongly preferred; 8 $\rightarrow$ very strongly to extremely; and 9 $\rightarrow$ extremely preferred.

All values are normalized to 1, and to verify the goodness of the results, the consistency ratio (CR) is calculated. The CR is calculated as the ratio between the consistency index and the random inconsistency. This value must be less than 0.10 [42]. This verification occurs automatically during the survey such that experts are not disturbed by an inconsistent assessment.

As a result, this work proposes a hybrid method in which AHP is used to assess local priority. Instead, the 10-point scale—which ranges from not at all (1) to extremely (10)—is chosen to evaluate category priority. This new approach emerged from the need to propose new methodological approaches that maintain a high quality of the result obtained but also from the time requirements related to experts (as highlighted in the pre-check phase of the survey).

2.2. Identification of Experts

The experts for this work were chosen, leading to 10 academic profiles. The invitation was made through an e-mail to those who have developed a Special Issue on scientific journals in the domains of biomethane, biogas, and, more generally, of bioenergy. The invitation was addressed to European colleagues and contained within it the objective of this work. Participation required a minimum number of years of experience equal to 10 and it was reported that the accessions would be chosen in chronological order. Once the adherence was received, the authors proceeded to organize an interview through Skype or Google Meet, lasting up to 1 h, in which they specifically reported what the study was aimed at, and feedback was also collected. It was important that the excel sheet includes only the necessary values and the self-check associated with the consistency ratio. Table A1 proposes the list of the experts with relative data on the role, country of work, and years of experience.

It should be noted that two of these ten experts were chosen in a phase called the pre-check phase of the survey in which the questionnaire was presented to receive feedback and the methodology was proposed in detail. In this phase, the necessity to replace the AHP methodology with the 10-point value emerged because it was considered more accessible. The motivation was not only due to the potential 9×9 matrix but also to the fact that, with a 10-point scale, the criteria were seen as non-conflicting. This information was re-proposed to the other experts as a modification of the first e-mail.

2.3. Biomethane Framework Development

The goal of this work was to assess a meso-level that is needed in CE models in order to provide a comprehensive framework for analysis [43]. To this end, the framework was built through an analysis of the literature [34,44–47] and the expertise acquired by the experts involved in this research, which led to considering a large number of variables and to ground the framework on the global/local priority approach [48].

Once the criteria were identified, it was decided to divide them into categories to allow for their comparison. To allow for a uniform comparison when evaluating global priority, an identical number of criteria per each category (in this case, chosen equal to three) was considered. As the criteria were chosen, the categories that could contain them were also identified. For the category priority, the number of nine was chosen.

Consequently, this survey consisted of nine 3×3 matrices related to the assessment of local priority conducted through the AHP method, while a 10-point scale was more preferred than an AHP-based 9×9 matrix to evaluate category priority.

It should be noted that the two pre-survey experts (see Section 2.2) validated the initial list of criteria but indicated changes to make the questions clearer. In addition, the two methodologies were compared (AHP and 10-point scale) to evaluate the category priority, from which emerged a preference for the second one. Furthermore, the values were then normalized to 1 to maintain consistency with what was obtained in the local priority evaluation phase and to make the calculation of global priority consistent.

The chosen categories addressed:

(i) Two phenomena that typically hinder plant deployment, e.g., Not in my back yard (Nimby) and Not in my term of office (Nimto);
(ii) Four variables that are characteristic of biomethane plants, e.g., size, substrate, final use, and technology;
(iii) Three variables that can help explain aggregation phenomena, e.g., energy community, regulation, and communication.

Among the categories, the three dimensions of sustainability were not considered to avoid triggering discussions about how the other categories might be viewed in contrast. However, all 27 criteria have an influence on the three dimensions of sustainability. In some categories, emphasis was placed on subsidies that are currently in place even in developed markets such as Italy. Table 1 proposes the list of all twenty-seven criteria, which is the first result of this work that was to be used as input for the survey.

Table 1. Biomethane framework.

Category	Acronym	Criteria
Regulation	R1	Self-sufficiency principle (regional level)
	R2	Self-sufficiency principle (inter-regional level, but not national)
	R3	Self-sufficiency principle (national level)
Substrates	S1	All substrates available
	S2	Only sustainable substrates (regional or inter-regional)
	S3	Only sustainable substrates (national)
Plant size	P1	More significant subsidies for small–medium size
	P2	More significant subsidies for large size
	P3	Subsidies not differentiated by plant size
Final use	F1	Electricity
	F2	Transport
	F3	Mix
Technology	T1	Enterprise–university relationships
	T2	Mature technology
	T3	Internally produced plant components
Nimby	N1	Stakeholders' engagement
	N2	Nimby with residues produced in your area
	N3	Nimby with residues not produced in your area
Energy community	E1	Bonus for installations in an energy community (tax deduction)
	E2	Bonus for installations in an energy community (subsidies)
	E3	No bonus for installations in an energy community
Nimto	I1	Nimto determined by local politicians
	I2	Nimto determined by national politicians
	I3	Nimto has not relevance
Communication	C1	Organization of webinars/public meetings
	C2	Transparent site in which to report the results
	C3	No additional actions required

2.4. Environmental Analysis

The environmental benefits associated with biomethane over the use of fossil sources are verified in several works: 23 $\frac{g\ CO_2eq}{MJ}$ [49], 40 $\frac{g\ CO_2eq}{MJ}$ [50], 53 $\frac{g\ CO_2eq}{MJ}$ [51], and 62 $\frac{g\ CO_2eq}{MJ}$ [52]. However, it is necessary to specify that several values are proposed for these analyses. The International Renewable Energy Agency (IRENA) estimates the greenhouse gas (GHG) emissions of biomethane according to the feedstock type: liquid manure 33 $\frac{g\ CO_2eq}{km}$, organic waste 48 $\frac{g\ CO_2eq}{km}$, and maize 66 $\frac{g\ CO_2eq}{km}$. These values are significantly lower than those produced by fossil sources: methane 124 $\frac{g\ CO_2eq}{km}$, diesel 156 $\frac{g\ CO_2eq}{km}$, and petrol 164 $\frac{g\ CO_2eq}{km}$ [53]. These data show that methane has a less negative impact on the environment than other sources and that biomethane has significant reductions. The highest value recorded for maize is caused by cultivation and harvesting processes.

In this research, three scenarios are considered, defined according to the literature [44]:

- The baseline green scenario, in which the unitary value of reduction in GHG emissions is assumed equal to 83.5 $\frac{g\ CO_2eq}{km}$.
- The alternative green scenario, in which the unitary value of reduction in GHG emissions is assumed equal to 76 $\frac{g\ CO_2eq}{km}$.
- The alternative strongly green scenario, in which the unitary value of reduction in GHG emissions is assumed equal to 91 $\frac{g\ CO_2eq}{km}$.

According to D'Adamo et al. [44], we defined a model to assess the potential reduction in terms of GHG emissions. It is necessary to make some assumptions to define the environmental savings associated with the use of a certain amount of biomethane. Considering that a natural gas vehicle (NGV) has an annual mileage of 20,000 km and multiplying this value with that of the three scenarios examined, it is possible to calculate how much less impact an NGV has on the environment if it is fueled by biomethane compared to natural gas. The next step is to estimate how many NGVs can be used by dividing the potential biomethane calculated in the previous subsection and the consumption of one NGV (1333 m^3). Finally, it is possible to estimate the overall emissions reduction by calculating the savings associated with a single NGV by their total number.

2.5. Economic Analysis

Economic analysis related to biomethane plants can be conducted on estimated production costs equal to 0.54–0.73 $\frac{EUR}{m^3}$ [29], 0.5–1.5 $\frac{\$US}{m^3}$ [53], and 90 $\frac{EUR}{MWh}$ [54], as well as on profitability values with a Net Present Value (NPV) that ranges from −585 thousand USD if subsidies were not provided to 5667 thousand USD [55], or from 0.49 million EUR to 132.7 million EUR based upon the mix of recovered waste [56]. However, in the analysis of the costs, the value associated with the externalities is not considered, and for this reason, it is suggested a minimal subsidy equal to 0.13 $\frac{EUR}{m^3}$ for biomethane production systems [57].

In March 2018, the Italian government adopted a policy decree (GU (Official Journal) no. 65 of 19 March 2018) to stimulate the development of biomethane [58]. This provides a value of incentive equal to 0.305 $\frac{EUR}{m^3}$ (single-counting) for the first ten years. Furthermore, this value is assumed equal to 0.61 $\frac{EUR}{m^3}$ (double-counting) if using some sustainable substrates (i.e., the Organic Fraction of Municipal Solid Waste (ofmsw) and by-products). The decree does not differentiate incentives by plant size.

In this research, two scenarios are considered, defined according to the literature [44]:

- The minimum scenario where the minimum size for which biomethane plants are profitable (200 $\frac{m^3}{h}$ and 350 $\frac{m^3}{h}$ for the ofmsw and by-products, respectively).
- The maximum scenario in which the size chosen for large plants is considered acceptable by citizens (500 $\frac{m^3}{h}$ for both substrates).

In the recent period, the conflict in Ukraine has led to a rise in costs, to which speculation has also been added, leading to the biomethane selling price (virtual trading point) being estimated at different values. The base value of 0.25 $\frac{EUR}{m^3}$ [44] is modified to 0.375 $\frac{EUR}{m^3}$ and 0.50 $\frac{EUR}{m^3}$ [22]. Table 2 proposes the economic profitability associated with the minimum and maximum scenarios for two distinct substrates as a function of biomethane selling price.

Table 2. NPV of biomethane plants [22,44]. Data are expressed in thousand EUR.

Biomethane Selling Price	**0.25 $\frac{EUR}{m^3}$**	**0.375 $\frac{EUR}{m^3}$**	**0.50 $\frac{EUR}{m^3}$**
ofmsw 200 $\frac{m^3}{h}$	421	2199	3779
ofmsw 500 $\frac{m^3}{h}$	8016	11,733	15,450
By-products 350 $\frac{m^3}{h}$	131	3028	5581
By-products 500 $\frac{m^3}{h}$	1656	5623	9131

Another useful indicator to monitor the delay in the realization of the projects is the Discounted Do Nothing Cost (DDNC), which, when considered for 1 year, presents the following values [44]:

- Six kEUR and 20 kEUR for the 350 $\frac{m^3}{h}$ by-products plant, and 200 $\frac{m^3}{h}$ for the ofmsw in the minimum scenario, respectively.
- Seventy-nine kEUR and 382 kEUR for the 500 $\frac{m^3}{h}$ by-products plant and 500 $\frac{m^3}{h}$ for the ofmsw in the maximum scenario, respectively.

It should be noted that the decree provides a bonus for an alternative "biomethane producer and distributor" business model. This is an important aspect as the number of points of sale is currently not suitable to meet the needs of consumers, especially in some areas of the country.

2.6. The Italian Context: Central and Southern Adriatic Regions

The 2019 Integrated National Plan for Energy and Climate assigns a priority role to renewable gas in order to achieve the biofuel release targets set by the directive on the promotion of the use of energy from renewable sources—RED II—in the European Union. The total theoretical potential, which is calculated with data updated to 2016, is estimated to be approximately 6.2 billion m^3 per year of advanced biomethane [59]. In particular, these authors have considered the following substrates: (i) straw; (ii) residues from the grape-wine chain; (iii) tomato peel residues; (iv) citrus juice residues; (v) residues from the olive oil industry; (vi) solid urban waste; (vii) zootechnical waste; (viii) sludge from wastewater purification; and (ix) milk whey. The aim of the Italian government is to inject 2.3 billion m^3 of biomethane into the gas network by 2026, plus 1.1 billion m^3 in transport within the Next Generation EU. The National Federation of Methane Distributors and Transporters (*Federmetano*) proposes the potential production of 8 billion m^3 by 2030.

In this context, the regions of central–southern Italy on the Adriatic side (MMAP) have started forms of collaboration to strengthen the Adriatic ridge and constitute a point of overall connection with all of Italy and Europe [60]. This is a political gesture among regions of different political orientation but that are united in building the future of their communities. Italy's population exceeds 60 million, and MMAP regions account for about 12% (Figure 1).

Figure 1. MMAP regions.

Table 3 proposes data on the potential of biomethane from substrates relative to the regions examined [59]. However, for the ofmsw, the values proposed by *Istituto superiore per la protezione e la ricerca ambientale* (ISPRA) were considered [61]—Table 4. The conversion factor ($\frac{tons\ of msw}{m^3}$ biomethane) proposed in Table 3 was considered, 75% of separate collection was assumed for all regions (a value currently achieved by the Veneto region), and the weight of organic waste on the total calculated in Table 3 was considered.

Table 3. Potential biomethane in MMAP regions (data in thousand m^3) [59].

	Marche	Abruzzo	Molise	Puglia	MMAP
Straw	119,106	51,554	31,044	328,206	529,910
Residues from the grape-wine chain	1071	3303	1766	14,512	20,652
Tomato peel residues	2	102	69	3660	3833
Citrus juice residues	0	4	0	12,559	12,563
Residues from the olive oil industry	358	1881	1993	14,252	18,484
Solid urban waste	21,573	14,098	1284	23,395	60,530
Zootechnical waste	30	21	18	197	266
Sludge from wastewater purification	141	22	104	109	376
Milk whey	3786	708	3904	9569	17,967
Total	146,247	71,693	40,182	406,459	664,581

Table 4. Data on waste in MMAP regions [61].

	Marche	Abruzzo	Molise	Puglia	Total
Total (kt)	797	600	111	1872	
Separate collection (%)	70.3	62.7	50.4	50.6	
Total separate collection (kt)	560	376	56	947	
Total organic fraction (kt)	248	162	23	383	
%organic/total	44.3	43.1	41.1	40.4	
Potential biomethane (thousand m^3)—estimated	23,558	15,432	2109	36,424	77,523

Thus, our estimates of an increase in separate collection to 75% for all regions predict an increase in the value of 60,530 thousand m^3 of biomethane. The final value is 77,523 thousand m^3 of biomethane (an increase of about 17 million m^3). Consequently, the potential biomethane in MMAP regions is assumed equal to 681,574 million m^3.

3. Results

This section presents results regarding the relevance of the framework criteria associated with biomethane. Sections 3.1 and 3.2 show the results for category and local priority, respectively, while Section 3.3 shows the results for global priority. Section 3.4 shows the sustainable benefits associated with MMAP regions.

3.1. The Assessment of Category Priority

The aggregation phase of the judgments provided by the experts consists of receiving the weighted data for each category (Table A2) and each criterion (Table A3). Their product determines the global priority, the result of which obviously depends on the incidence of the two specific components. In particular, the weight of each expert is the same during the aggregation phase. The experts evaluated the incidence of the categories and, in six cases, the maximum value of 10 was assigned to both regulation and the energy community. It should be pointed out that, in four cases, this value was also assigned to substrates and plant size. For the other five categories, the maximum value has never been assigned. It should be pointed out that normalization for this weight does not take place in such a way that the sum of all is equal to 1 but is conducted by comparing the absolute value obtained by the experts divided by the maximum value (equal to 10).

The results show that the four categories proposed above have the highest value that is also close to 10 (Figure 2): regulation (0.96), energy community (0.95), and substrates and plant size (both 0.93). However, all nine categories were considered to be of some relevance as the lowest value is given to communication with a weight of 0.74. Other categories have the following weight: technology (0.88), final use (0.84), Nimby (0.83), and Nimto (0.82).

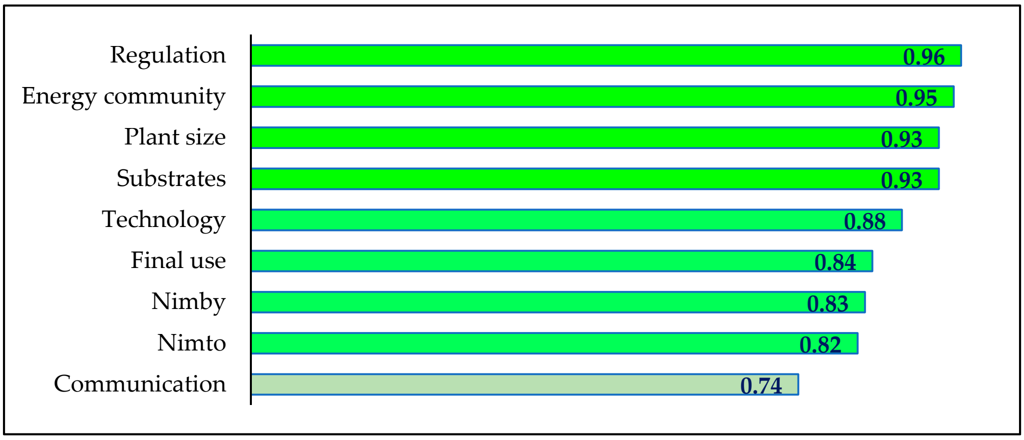

Figure 2. Category priority.

Regulation is seen as a key element as it dominates the sector, defining the guidelines to be followed. Similarly, the theme of the energy community has recently been introduced by the European Union in the Clean Energy for all Europeans package of 2019. It is worth highlighting how the energy community theme has been characterized by the presence of subsidies that play a key role in the development of the sector [48,62]. The same subsidies are used to assess the theme of plant size and for substrates (although not implicitly for the latter category).

3.2. The Assessment of Local Priority

The analysis conducted within each category made it possible to highlight the role of the specific criteria. In this subsection, the specific result is assessed accordingly, while in the next subsection, the interconnections are identified.

As far as regulation is concerned, all the experts assigned the greatest importance to R2—self-sufficiency principle (inter-regional level and not national)—which assumed a weight of 0.54, followed by R1—self-sufficiency principle (regional level)—with 0.30 (Figure 3). Therefore, the meso-approach is preferred to a macro or micro model as it is considered that the theme of sustainability cannot be circumscribed to a restricted geographical area, which is, in any case, called upon to meet objectives with respect to national performance. In particular, the relationship between local and regional authorities is seen as a strategic lever for moving towards ambitious goals. Some authors have highlighted the relevance of quantifying the potential of biomethane for strategic choices by defining the relevance of the territorial context of reference [63].

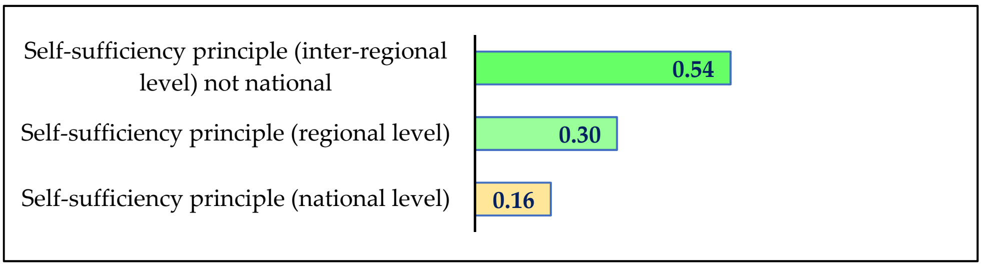

Figure 3. Local priority (regulation).

The analysis of substrates shows that unsustainable choices cannot be made and, therefore, each area must deal with residues, waste, and raw materials that do not, however, lead to a worsening of eco-systems. This weight of 0.93 is divided between S2—only sustainable substrates (regional or inter-regional)—with 0.51, and S3—only sustainable substrates (national)—with 0.42 (Figure 4). In particular, the sustainability of the resources used also suggests the use of resources coming from outside the area in question as the environmental balance is, in any case, compensated. In fact, the recovery of resources is linked to a longer transport than expected. The idea prevails that the inability of some areas to grasp sustainable opportunities can be a source of competitive advantage for others. Criterion S2 was considered most important to eight experts, while criterion S3 was considered most important to the other two. The relevance of substrates for energy and sustainable purposes is also evident in the different contributions that can be provided by resources that are classified as first, second, and third generation substrates [64].

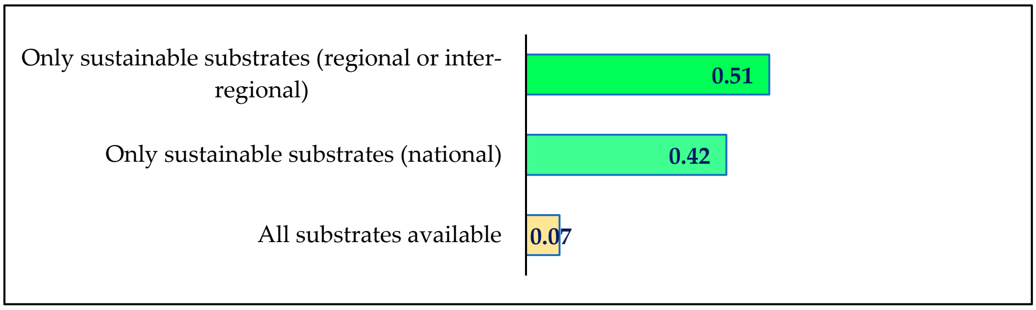

Figure 4. Local priority (substrates).

Regarding the size of the plants, it is clear that larger plants present significant economic results due to the economies of scale. In addition, this can also depend on incentive policies that do not distinguish between subsidies according to size. Experts did not consider this a particularly critical aspect (P3—subsidies not differentiated by plant size—with 0.30). However, they assigned greater importance to P1—more significant subsidies for small–medium size—with 0.62 (Figure 5). In particular, it emerges that small-scale plants can support sustainable development in areas that do not have a large quantity of raw materials. The risk run is that the non-profitable nature of such plants would rightly not allow their realization. All experts agreed on the greater relevance of criterion P1. The role of size should be properly identified in order to capture both the exploitation of available resources and public acceptance. This is an essential aspect that could be reflected in causing significant delays to the implementation of the work. However, such delays can also be determined by aspects related to bureaucracy [44].

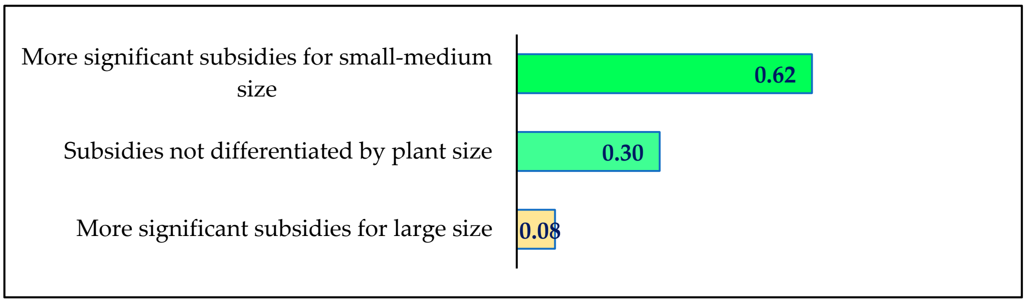

Figure 5. Local priority (plant size).

The issue of final use is one of the great advantages of biomethane that takes advantage of its flexibility. However, the perception is that electrical use can be reduced given the presence of other renewable sources and it is hoped that greater use will be made of transport—F2 with 0.60 (Figure 6). The contribution of renewables in the transport sector is still marginal in most European countries. However, the experts did not underestimate the flexible role of biomethane and, therefore, the mix is still given relevance, albeit less significant—F3 with 0.33. All experts agreed on the greater relevance of criterion F2. The purposes of biomethane use are all relevant as they contribute to the reduction in fossil fuels in different applications. However, a comparison of them should be verified in the function of the energy portfolio of the country under analysis [65].

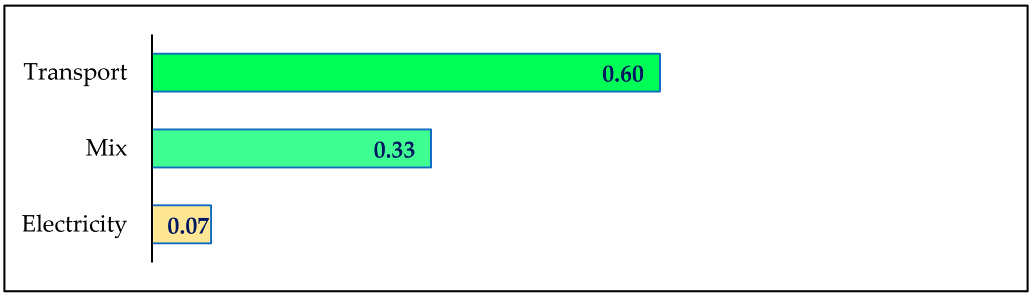

Figure 6. Local priority (final use).

The technology category shows that the biogas–biomethane chain is considered mature, but there is space for improvement. In particular, during the interviews with experts, it emerged that particular studies should be placed on how to increase the yield of raw materials. Therefore, the maturity of the technology takes a low weight not because it is considered a weak factor, but because other aspects must be valued. The academic world clearly highlights the importance of collaboration and, therefore, factor T1—enterprise–university relationships—takes on a weight of 0.42. However, the factor considered most important was T3—internally produced plant components—with 0.50 (Figure 7). This figure should also be understood in the period in which the survey was conducted, in which the importance for companies of internally producing the components they use most emerged. Experts were split almost down the middle on the most relevant criterion (six of them identified T3 while the others identified T1). Studies of biomethane in Europe provide experiences that can be examined in other countries as well. The relevance of the connection between technology, subsidies, and domestic production of components plays a favorable role in supporting the development of the sector [66].

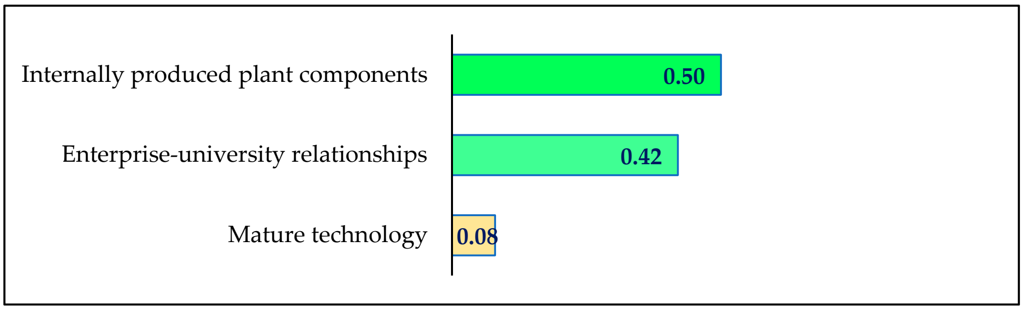

Figure 7. Local priority (technology).

As far as Nimby is concerned, the experts unanimously penalized this phenomenon if it develops for residues produced in their own area of competence, while they assigned a slight relevance to criterion N3—Nimby with residues not produced in your area—with 0.25. On the other hand, all agreed to consider criterion N1—stakeholders' engagement—the most relevant in this category and the weight assigned was decidedly very significant compared to the others, with an average weight of 0.70 (Figure 8). In particular, sustainable development is also associated with inclusive development and provides for decision-making models that involve all stakeholders. It was highlighted by experts as often being underestimated, but the achievement of which allows implementing good actions and to be a model of best practice. The correct balance between personal interest and the interest of an organization theorized by the school of human relations is the basis of this concept. The topic of stakeholder engagement is not well discussed in the literature and is one of the topics that will need to be explored [67]. In fact, this aspect turns out to be a decisive factor towards the implementation of energy community models [22].

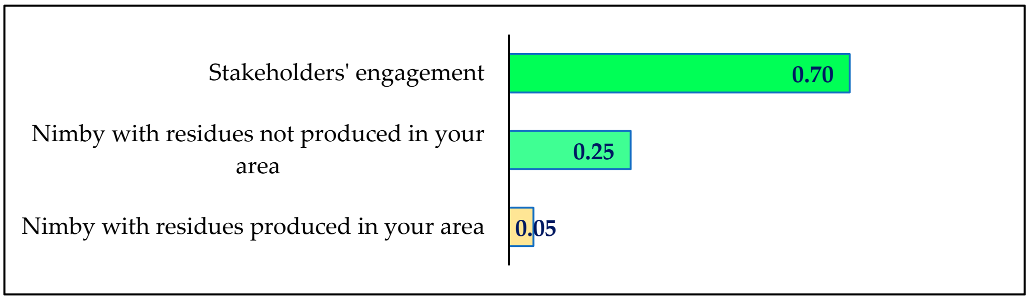

Figure 8. Local priority (Nimby).

The topic of the energy community is analyzed by considering whether its aggregation should be encouraged. The answer provided by the experts was clear. However, the way in which this happened sees seven of them favoring the subsidy while three favored the tax deduction. These aspects are reflected in the final weight, where, however, the difference is not so great: criterion E2—bonus for installations in an energy community (subsidies)—has a weight of 0.51, which is greater than the 0.44 associated with criterion E1—bonus for installations in an energy community (tax deduction)—Figure 9. The subsidy is seen with interest because it stimulates greater production of output. Instead, tax deduction typically affects investment costs. However, the need emerges to introduce a form of incentive to stimulate this ecological transition and to encourage such models of aggregation. A crucial aspect is therefore the contribution of local community energy initiatives to support a decentralized sustainable energy system. The key elements highlighted are the type of organization, the level of activities, and the development of a shared vision. All this translates into a very communicative slogan "power to the people" [68].

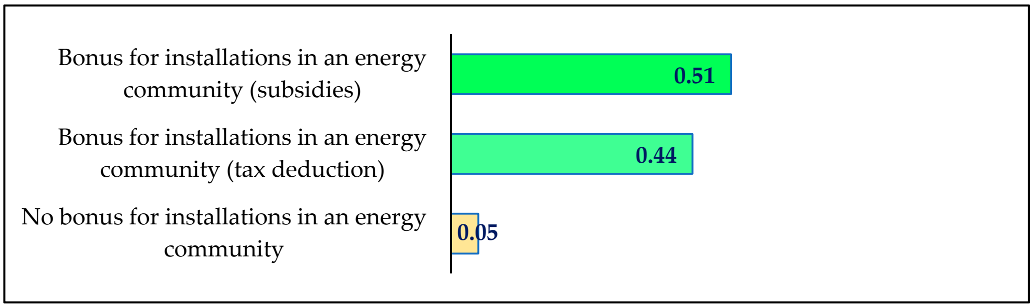

Figure 9. Local priority (energy community).

With regard to Nimto, it is highlighted how this aspect also influences the results. The judgment of the experts on this aspect was unanimous. However, the judgment changed as to who should be attributed greater responsibility in the non-realization of strategic work. In fact, criterion I1—Nimto determined by local politicians—has a weight of 0.51 and was considered the most relevant by seven experts. The others assigned it to criterion I2—Nimto determined by national politicians—with a weight of 0.44 (Figure 10). The rationale that emerges is that we do not always see a sharp distinction between these two categories based on the actual responsibilities that are laid out in the laws. What does emerge, however, is how political non-decision making can delay change towards ecosystem defenses. Support schemes and innovation are among the main forces that drive investment in renewable energy technologies, and both involve considerable uncertainty. These aspects identify the ability to pursue the fight against climate change. However, one element that can destabilize these choices is uncertainty [69].

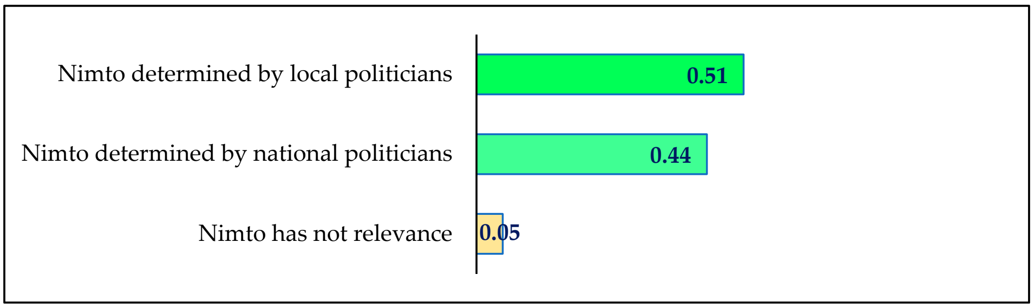

Figure 10. Local priority (Nimto).

Finally, the communication aspects show that, additionally in this case, the experts agreed on the need to implement changes compared to the current situation. Criterion C2—transparent site in which to report the results—achieved by the sorting and recovery of waste has a weight of 0.42, while criterion C1—organization of webinars/public meetings—is considered more relevant with 0.54 (Figure 11). These data highlight, on the one hand, that autonomy is given to people, to their digital skills. Similarly, interaction, both in human and digital form, is important as it is considered fundamental for dispelling doubts and perplexities. Almost all the experts (nine) identified C1 as the most relevant. However, key aspects of the development of biomethane plants are represented by appropriate communication models [22,70]. It should be emphasized that the literature shows that the topic of the circular economy needs to be more appropriately addressed [71].

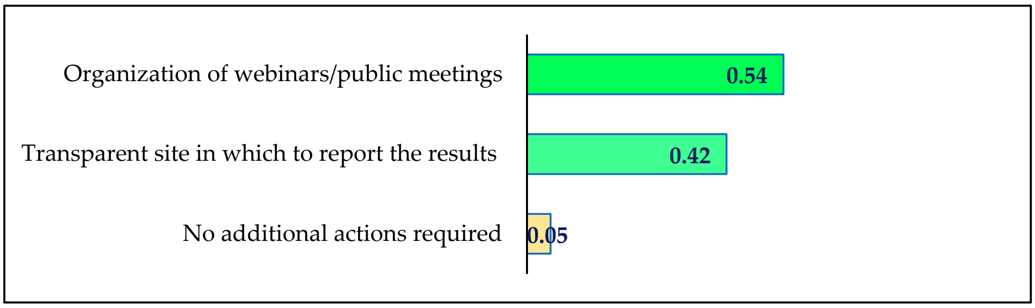

Figure 11. Local priority (communication).

3.3. The Assessment of Local Priority

The results show that global priority does not follow the order defined by category priority. In fact, in first place in the ranking, we find criterion N1 (with a value of 0.581), despite the fact that the Nimby category occupies only the seventh position in the relative ranking associated with the categories. This figure can be explained by what was determined within the local priority for this category: N1 has a weight of 70%, which is the most significant among all the cases analyzed.

In numerical terms, in second place in the global ranking is placed criterion P1 (with a value of 0.577). Additionally in this case, with 62%, this occupies the second most significant weight in terms of local priority when considering all the numerical values, even if the plant size category is the third most significant. In third place in terms of local priority, criterion F2 with 60% occupies the fourth place in the global ranking with 0.504, with the category to which it belongs positioned in sixth place. The most relevant category, regulation, sees its most significant criterion (R2) in third place in the global ranking with 0.518.

Among the top ten criteria in the global ranking (which have a value of at least 0.400), we find all the criteria positioned in first place in all categories. The only category that has two criteria is the energy community with criterion E2 positioned in fifth place in the global ranking with 0.485. This result can be explained by the minimal difference between the first two criteria that have a distance of seven percentage points (the same happens for the Nimto category).

In addition, the nine least relevant criteria for each category occupy the last positions in the overall ranking. It is worth noting that eight of the nine criteria have a weight as local priority less than 0.10, and all these criteria have a global priority value of less than 0.100. The exception is criterion R3 (regulation—self-sufficiency principle (national level)), which has a local weight of 0.16 and a global weight of 0.154—Table 5.

Table 5. Global priority.

Acronym	Criteria	Global Weight
N1	Stakeholders' engagement	0.581
P1	More significant subsidies for small–medium size	0.577
R2	Self-sufficiency principle (inter-regional level, but not national	0.518
F2	Transport	0.504
E2	Bonus for installations in an energy community (subsidies)	0.485
S2	Only sustainable substrates (regional or inter-regional)	0.474
T3	Internally produced plant components	0.440
I1	Nimto determined by local politicians	0.418
E1	Bonus for installations in an energy community (tax deduction)	0.418
C1	Organization of webinars/public meetings	0.400
S3	Only sustainable substrates (national)	0.391
T1	Enterprise–university relationships	0.370
I2	Nimto determined by national politicians	0.361
C2	Transparent site in which to report the results	0.311
R1	Self-sufficiency principle (regional level)	0.288
P3	Subsidies not differentiated by plant size	0.279
F3	Mix	0.277
N3	Nimby with residues not produced in your area	0.208
R3	Self-sufficiency principle (national level)	0.154
P2	More significant subsidies for large size	0.074
T2	Mature technology	0.070
S1	All substrates available	0.065
F1	Electricity	0.059
E3	No bonus for installations in an energy community	0.048
N2	Nimby with residues produced in your area	0.042
I3	Nimto has not relevance	0.041
C3	No additional actions required	0.037

These results highlight that the theme of the biomethane community can be defined as an enabling factor towards sustainability. The integration between the different criteria allows for highlighting how the aggregation between regions is a winning element because it allows for pursuing the spirit of a European community and can be suitable for intercepting public funds available. In addition, collaboration would allow the aggregation of skills and resources and could have greater weight as a leading player in a market.

The essential elements for an energy community foresee the collaboration among all the actors involved in which one could think of a bottom-up decision-making model that is not, however, confirmed by the relevance given to Nimto (the joint weight given both to the political and national class should be underlined), which could push to a top-down model. Clearly, the solution lies in stakeholder engagement where choices are made with everyone's input, but if a final choice is not reached (and it is necessary to make such a choice in order to not reduce future opportunities), a leader who can synthesize is needed. Incentives should privilege small plants to allow a greater spectrum of choices by providing some territories lacking raw materials with this option as well. The choice of biomethane towards transport appears to be the desired end use, and substrates from one's own geographical area can be preferred but others can be accepted if they follow sustainability criteria. The formation of an energy community should be subsidized and, in particular, there is a push for a choice that would increase the production of this energy carrier. Another aspect considered critical is to strengthen the industrial fabric to increase the competitive advantage of a territory.

3.4. Biomethane Community Composed of MMAP Regions: A Future Direction towards Sustainability

The results obtained from Section 3.3 have highlighted how the theme of the energy community, and specifically that represented by biomethane, is capable of providing various points for reflection. Sustainability requires the contribution of everyone, and during the green transition, it is clear that global scenarios based on competitiveness will change. The recent war in Ukraine, which has led to the death of many children, has highlighted the need for a change in mentality. A sustainable approach as reported in the editorial in which this new section within the *Sustainability* journal was introduced [22] has the ambition of being a meeting point among different stakeholders. A metaphor could indicate a port where ships from different parts of the world can dock, where ideas, projects, and ambitions of everyone can be gathered, but with a special eye on new generations. The Adriatic corridor and its four regions, MMAP, are fortunate to have uncontaminated territories where the relationship between man and nature is not disfigured. There are ideas for improvement that can be pursued and circular bioeconomy models can support the achievement of the Sustainable Development Goals [3].

The strategy can proceed in this direction by expanding the fields of collaboration and creating what could be called the sustainable innovation hub, the idea of an innovation ecosystem based on the involvement of different stakeholders, a result that emerges unequivocally from this research. Sustainable innovation hubs are grounded on the concept of Digital Innovation Hubs (DIHs), i.e., ecosystems that assist companies to improve their competitiveness through innovations and fostering the implementation of up-to-date digital technologies [72,73]. Involving different stakeholders belonging to a heterogeneous ecosystem, DIHs provide a set of supportive services that help companies to become more competitive by improving their business by means of digital technology [74].

The four regions have already signed important agreements in terms of infrastructure, transport, and communications, leaving aside political affiliation, which is certainly an element to be stressed. The need for teamwork is emphasized. This work, in a simple way, aims to unite this great strategic project with the results obtained previously, highlighting how the theme of biomethane development can be an element of sustainable success. This is confirmed not only by the environmental and economic results associated with them but also by a substantial number of social opportunities and related economic opportunities induced that could be connected. In addition, it would allow resources to be acquired at lower values and would allow all interested parties to present valid projects by choosing appropriate technologies, adopting models of public participation and reasoning on how this meso-approach reaches the macro-level of sustainability and is then architected at the micro-level on where to install these plants.

Economic estimates are that ofmsw is treated separately while the other substrates are all incorporated at the by-products level. Environmental estimates consider one cubic meter of biomethane regardless of its source of origin. Figures 12 and 13 provide environmental and economic results.

The obtained results are based on an estimate of potential biomethane production of 681.6 million m^3 for the four regions examined (an increase of 17 million compared to values proposed by Pierro et al. [59]). It is evident that this value also includes raw materials currently used for other purposes (e.g., for electricity production through biogas) and that all raw materials are recovered at the technical factors assumed in the reference study. It is also true that an increase in the percentage of separate waste collection has been considered. These data clearly call for the virtuous contribution of all stakeholders. It is clear that ofmsw plants are more profitable than by-products, but a reduction in the profitability of these plants should be envisaged with a simultaneous reduction in the bill paid by citizens, rewarded for good separate collection. In fact, nowadays, it is not only necessary to differentiate but also to do it correctly. This obviously translates into lower costs for the companies that treat such waste in a better energy yield from a technical point of view. As for by-products, it is necessary to inform all stakeholders of the advantages they could have from the recovery of these residues and their sending first to an anaerobic digestion plant and then to an upgrading plant.

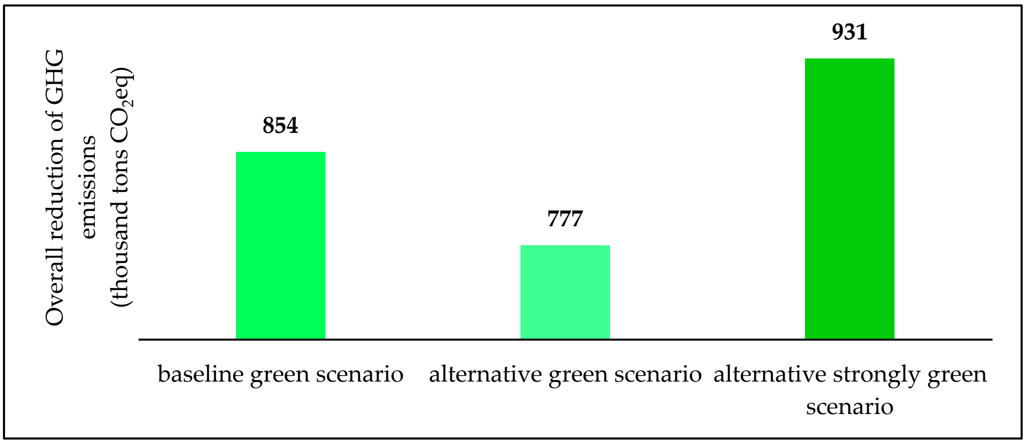

Figure 12. Potential environmental results (thousand tons CO_2eq).

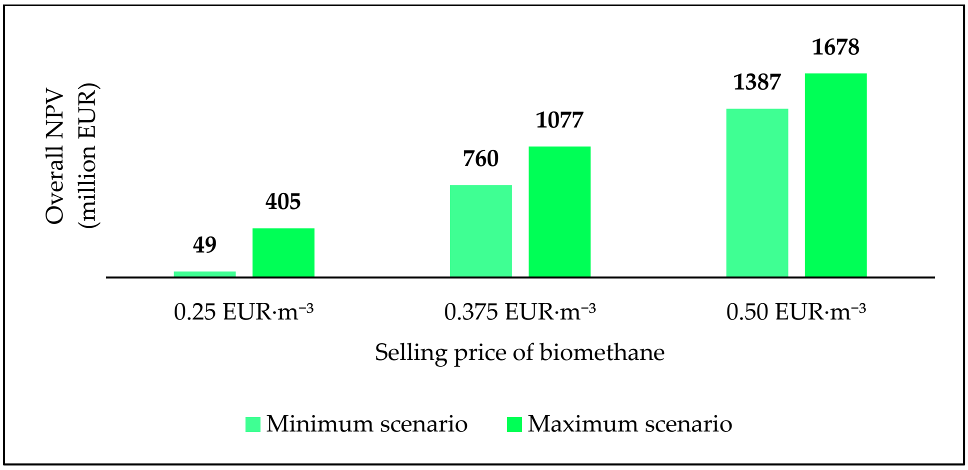

Figure 13. Potential economic results (million EUR).

The economic results also show that as the sale price of biomethane increases, the plants would become more profitable for investors. However, a higher sales price would have a negative impact on consumers. Thus, it is necessary to be vigilant of these aspects. Sustainability is the meeting point of all stakeholders, thus it cannot only support renewable plant owners but also consumers. Taxes that are paid on resources that are more environmentally damaging are considered appropriate. In addition, attention should be paid to the less affluent income groups who do not have the opportunity to take advantage of these sources. It could happen that these groups would have to pay higher prices (taxes on fossil fuels), which would worsen their difficult economic situation.

In this period, great attention has been given to the development of electric vehicles, which, if powered by green sources and with proper battery disposal, are able to provide important environmental results. However, no less important is the role that can be played by NGVs, which are known to pollute less than diesel and gasoline, are a widely known technology, and are typically chosen by consumers for their savings. Evidently, these aspects can be confirmed if natural gas is gradually replaced by green gas. However, we would like to point out that, currently, the energy policy of countries should be projected towards a strong expansion of renewables but the transition should not disregard the use of some fossil sources. Among these, gas has the lowest impact, and the European Commission has indicated this source as necessary for this transition.

The reduction in geopolitical risk and the production of domestically produced energy are necessary steps for the energy development of a country and for energy communities to move towards these directions. The previous analysis has underlined the role of subsidies, which are justified if it is considered at present that several fossil sources are agreed. However, their value cannot be fixed forever in the long term but should be reduced gradually while assuming, however, a stable regulatory framework.

The results of this work assume that at the usual selling price of biomethane and not subject to increases, there would be 49 million EUR in the minimum scenario and 405 million EUR in the maximum scenario (see Figure 13). The choice of plant size must be referred to individual territories. However, some considerations emerge:

- Where it is possible to build a larger plant, it is desirable for the territory to provide significant raw materials;
- Incentives for small plants should be provided to allow the recovery of these residues that in the absence of economic unprofitability could lead to the non-realization of the plants;
- Technical analysis should be conducted on how the different substrates can be mixed as clearly a shared plant allows for taking advantage of different opportunities.

The associated DDNC 1-year amounts to 2263 million EUR in the minimum scenario and 19,333 million EUR in the maximum scenario. The delay in the non-construction of the plants has led to greater energy dependence on foreign countries, greater dependence on speculative aspects related to the different actors involved in the chain of sale of the final product, and, above all, a non-contradiction of environmental aspects. The results of this work show a reduction of 854 thousand $\frac{\text{tons } CO_2\text{eq}}{\text{year}}$ in the baseline green scenario and 777 $\frac{\text{tons } CO_2\text{eq}}{\text{year}}$ and 931 thousand $\frac{\text{tons } CO_2\text{eq}}{\text{year}}$ in the alternative ones (see Figure 12).

4. Conclusions

This work contributes to clarifying how the theme of biomethane, a virtuous model of the circular bioeconomy, is relevant to the reduction in geopolitical risks. The transport sector is called to reduce its environmental impact. The biogas–biomethane supply chain moves towards this direction as it can be used as a vehicle fuel, but it can also be used for other purposes (e.g., it can be distributed into the natural gas grid or converted into cogeneration units).

At present, those who have economic interests in fossil fuels are speculating because they are aware that, today, many countries depend on this raw material. The future foresees the presence on the market of an alternative resource, and this will inevitably lead to a reduction in economic opportunities associated with those who use fossil fuels. It is necessary to identify the transition to advance renewable sources and, in the same way, allow businesses and citizens to have controlled prices.

From a methodological point of view, this work proposes a hybrid approach based on AHP and 10-point value to determine the incidence of the criteria, and this model is suitable when it comes to consider weights based on the local–global priority in which the category priority is calculated considering a consistent number of criteria.

From a conceptual point of view, the model of a united Europe is based on the breaking down of barriers among several countries. The idea of a collaboration of the four regions of the Adriatic corridor (Marche, Molise, Abruzzo, and Puglia) has proved to be a winning strategic idea. The strategy can proceed in this direction by expanding the fields of collaboration and creating what could be called the sustainable innovation hub.

From an operational point of view, the energy communities are able to create new forms of market and alternatives to centralized structures to combine the interests of multiple subjects. However, their realization is by no means simple as it requires an approach based on the concept of shared value. Biomethane is an example of a shared resource that can affect these territories.

The work has some limitations:

- Need to conduct an up-to-date analysis on the energy yields of substrates;
- Environmental performance as a function of specific substrates;
- Economic evaluations applied to specific substrates;
- Development of a network of plants distributed throughout the territory in order to maximize available resources;
- Communication and dissemination models to inform stakeholders and citizens about these changes;
- Research method hybridization has a major impact and changing the combined method may result in different results.

However, this work reports economic and environmental results that are verified with an implementation plan for the development of biomethane, whose values may vary as a result of changes in critical variables. Nevertheless, findings underline that the biomethane community is seen as an enabling factor towards sustainable development.

The ecological transition is a great challenge and the increase in energy costs cannot be described as being caused by the development of sustainable sources. Obviously, this change will affect the interests of some companies and investors whose portfolios were based on fossil sources. However, the transition cannot be to the disadvantage of companies and citizens. For this reason, it should be monitored, and cooperation between the private and public sectors is required. Renewables can take advantage of the funds that are made available, but these projects should be implemented quickly in order to avoid generating costs of doing nothing. In addition, the intervention of a third party is required where abnormal market phenomena are created. This outcome would allow for proper movement towards the goals of the Next Generation EU.

The MMAP project may be able to combine tourism and industry to attract young people from all over the world and it may represent a strategic crossroads within the corridors of integrated logistics. The element that can make the difference is the ability to be a team creating a strong, cohesive, resilient, inclusive, and sustainable community.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Survey participants.

No.	Role	Country	No. Years
1	Full Professor	Sweden	18
2	Full Professor	Spain	19
3	Full Professor	Italy	20
4	Full Professor	Denmark	16
5	Associate Professor	Finland	12

Table A1. *Cont.*

No.	Role	Country	No. Years
6	Associate Professor	Germany	15
7	Associate Professor	Switzerland	16
8	Associate Professor	Greece	11
9	Associate Professor	Italy	12
10	Associate Professor	France	14

Table A2. Category weights provided by ten experts.

Category	1	2	3	4	5	6	7	8	9	10
Regulation	10	9	10	9	9	10	10	10	10	9
Substrates	8	10	9	9	10	9	9	10	9	10
Plant size	8	10	10	9	9	9	10	9	10	9
Final use	9	8	8	8	9	9	9	8	8	8
Technology	9	9	9	9	9	8	8	9	9	9
Nimby	8	8	8	9	9	9	8	8	8	8
Energy community	9	8	9	10	9	10	10	10	10	10
Nimto	8	9	9	8	8	8	8	9	7	8
Communication	8	7	8	8	7	7	7	7	8	7

Table A3. Local weights provided by ten experts.

Criteria	1	2	3	4	5	6	7	8	9	10
R1	30	25	30	20	35	35	30	30	30	35
R2	60	60	60	60	45	50	55	50	60	40
R3	10	15	10	20	20	15	15	20	10	25
S1	5	10	5	5	5	5	10	5	10	10
S2	55	50	55	55	60	40	50	55	40	50
S3	40	40	40	40	35	55	40	40	50	40
P1	62	70	60	55	60	55	70	50	65	60
P2	8	5	10	5	10	5	10	10	10	5
P3	30	25	30	40	30	40	20	40	25	35
F1	5	5	10	5	5	5	10	15	5	5
F2	75	50	55	65	65	65	50	60	50	65
F3	20	45	35	30	30	30	40	25	45	30
T1	55	35	40	30	50	40	40	50	30	50
T2	5	10	5	10	5	10	5	10	10	10
T3	40	55	55	60	45	50	55	40	60	40
N1	60	75	70	70	65	75	70	70	75	70
N2	5	5	5	5	5	5	5	5	5	5
N3	35	20	25	25	30	20	25	25	20	25
E1	50	45	60	40	55	40	40	40	35	35
E2	45	50	35	55	40	55	55	55	60	60
E3	5	5	5	5	5	5	5	5	5	5
I1	45	50	55	40	55	60	45	50	55	55
I2	50	45	40	55	40	35	50	45	40	40
I3	5	5	5	5	5	5	5	5	5	5
C1	55	50	45	55	55	60	55	50	60	55
C2	40	45	50	40	50	35	40	45	35	40
C3	5	5	5	5	5	5	5	5	5	5

References

1. Tang, M.; Liao, H.; Wan, Z.; Herrera-Viedma, E.; Rosen, M.A. Ten Years of Sustainability (2009 to 2018): A Bibliometric Overview. *Sustainability* **2018**, *10*, 1655. [CrossRef]
2. World Commission on Environment and Development. *Our Common Future*; Oxford University Press: Oxford, UK, 1987; ISBN 019282080X.
3. D'Adamo, I.; Gastaldi, M.; Imbriani, C.; Morone, P. Assessing regional performance for the Sustainable Development Goals in Italy. *Sci. Rep.* **2021**, *11*, 24117. [CrossRef] [PubMed]
4. United Nations. THE 17 GOALS | Sustainable Development. Available online: https://sdgs.un.org/goals (accessed on 18 February 2022).
5. The Ellen MacArthur Foundation. *Towards the Circular Economy Economic and Business Rationale for an Accelerated Transition*; Ellen MacArthur Foundation: Cowes, UK, 2013; pp. 21–34.
6. Bocken, N.M.P.; Short, S.W.; Rana, P.; Evans, S. A literature and practice review to develop sustainable business model archetypes. *J. Clean. Prod.* **2014**, *65*, 42–56. [CrossRef]
7. Velenturf, A.P.M.; Purnell, P. Principles for a sustainable circular economy. *Sustain. Prod. Consum.* **2021**, *27*, 1437–1457. [CrossRef]
8. Bocken, N.M.P.; de Pauw, I.; Bakker, C.A.; van der Grinten, B. Product design and business model strategies for a circular economy. *J. Ind. Prod. Eng.* **2016**, *33*, 308–320. [CrossRef]
9. Kirchherr, J.; Reike, D.; Hekkert, M. Conceptualizing the circular economy: An analysis of 114 definitions. *Resour. Conserv. Recycl.* **2017**, *127*, 221–232. [CrossRef]
10. Aldieri, L.; Ioppolo, G.; Vinci, C.P.; Yigitcanlar, T. Waste recycling patents and environmental innovations: An economic analysis of policy instruments in the USA, Japan and Europe. *Waste Manag.* **2019**, *95*, 612–619. [CrossRef]
11. Caruso, G.; Fortuna, F. Mediterranean diet Patterns in the Italian Population: A functional data analysis of Google Trends. In *Decisions and Trends in Social Systems, Innovative and Integrated Approaches of Care Services*; Springer: Cham, Switzerland, 2020; pp. 1–10.
12. Cambini, C.; Congiu, R.; Jamasb, T.; Llorca, M.; Soroush, G. Energy Systems Integration: Implications for public policy. *Energy Policy* **2020**, *143*, 111609. [CrossRef]
13. Van Bommel, N.; Höffken, J.I. Energy justice within, between and beyond European community energy initiatives: A review. *Energy Res. Soc. Sci.* **2021**, *79*, 102157. [CrossRef]
14. Leonhardt, R.; Noble, B.; Poelzer, G.; Fitzpatrick, P.; Belcher, K.; Holdmann, G. Advancing local energy transitions: A global review of government instruments supporting community energy. *Energy Res. Soc. Sci.* **2022**, *83*, 102350. [CrossRef]
15. Pena-Bello, A.; Parra, D.; Herberz, M.; Tiefenbeck, V.; Patel, M.K.; Hahnel, U.J.J. Integration of prosumer peer-to-peer trading decisions into energy community modelling. *Nat. Energy* **2022**, *7*, 74–82. [CrossRef]
16. Heuninckx, S.; te Boveldt, G.; Macharis, C.; Coosemans, T. Stakeholder objectives for joining an energy community: Flemish case studies. *Energy Policy* **2022**, *162*, 112808. [CrossRef]
17. Ceglia, F.; Marrasso, E.; Roselli, C.; Sasso, M. Small Renewable Energy Community: The Role of Energy and Environmental Indicators for Power Grid. *Sustainability* **2021**, *13*, 42137. [CrossRef]
18. Bianco, G.; Bonvini, B.; Bracco, S.; Delfino, F.; Laiolo, P.; Piazza, G. Key Performance Indicators for an Energy Community Based on Sustainable Technologies. *Sustainability* **2021**, *13*, 68789. [CrossRef]
19. Böttcher, C.; Müller, M. Insights on the impact of energy management systems on carbon and corporate performance. An empirical analysis with data from German automotive suppliers. *J. Clean. Prod.* **2016**, *137*, 1449–1457. [CrossRef]
20. Rauf, A.; Ozturk, I.; Ahmad, F.; Shehzad, K.; Chandiao, A.A.; Irfan, M.; Abid, S.; Jinkai, L. Do Tourism Development, Energy Consumption and Transportation Demolish Sustainable Environments? Evidence from Chinese Provinces. *Sustainability* **2021**, *13*, 12361. [CrossRef]
21. Villa, S.; Sassanelli, C. The Data-Driven Multi-Step Approach for Dynamic Estimation of Buildings' Interior Temperature. *Energies* **2020**, *13*, 6654. [CrossRef]
22. D'Adamo, I.; Gastaldi, M.; Morone, P.; Rosa, P.; Sassanelli, C.; Settembre-blundo, D.; Shen, Y. Bioeconomy of Sustainability: Drivers, Opportunities and Policy Implications. *Sustainability* **2022**, *14*, 200. [CrossRef]
23. Castaldi, M.; van Deventer, J.; Lavoie, J.M.; Legrand, J.; Nzihou, A.; Pontikes, Y.; Py, X.; Vandecasteele, C.; Vasudevan, P.T.; Verstraete, W.; et al. Progress and Prospects in the Field of Biomass and Waste to Energy and Added-Value Materials. *Waste Biomass Valorization* **2017**, *8*, 1875–1884. [CrossRef]
24. Atabani, A.E.; Pugazhendhi, A.; Al-Muhtaseb, A.H.; Kobayashi, T.; Lee, C. Editorial Preface to the Special Issue on "The 2nd International Conference on Alternative Fuels and Energy: Futures and Challenges (ICAFE 2017)" 23rd–25th October 2017, Daegu, Republic of Korea. *Waste Biomass Valorization* **2020**, *11*, 1017. [CrossRef]
25. Tsalidis, G.A. Human Health and Ecosystem Quality Benefits with Life Cycle Assessment Due to Fungicides Elimination in Agriculture. *Sustainability* **2022**, *14*, 846. [CrossRef]
26. Sili, M.; Dürr, J. Bioeconomic Entrepreneurship and Key Factors of Development: Lessons from Argentina. *Sustainability* **2022**, *14*, 2447. [CrossRef]
27. Kardung, M.; Cingiz, K.; Costenoble, O.; Delahaye, R.; Heijman, W.; Lovrić, M.; van Leeuwen, M.; M'Barek, R.; van Meijl, H.; Piotrowski, S.; et al. Development of the Circular Bioeconomy: Drivers and Indicators. *Sustainability* **2021**, *13*, 10413. [CrossRef]

28. Barragán-Escandón, A.; Olmedo Ruiz, J.M.; Curillo Tigre, J.D.; Zalamea-León, E.F. Assessment of Power Generation Using Biogas from Landfills in an Equatorial Tropical Context. *Sustainability* **2020**, *12*, 2669. [CrossRef]
29. Rotunno, P.; Lanzini, A.; Leone, P. Energy and economic analysis of a water scrubbing based biogas upgrading process for biomethane injection into the gas grid or use as transportation fuel. *Renew. Energy* **2017**, *102*, 417–432. [CrossRef]
30. Haider, J.; Qyyum, M.A.; Kazmi, B.; Ali, I.; Nizami, A.-S.; Lee, M. Simulation study of deep eutectic solvent-based biogas upgrading process integrated with single mixed refrigerant biomethane liquefaction. *Biofuel Res. J.* **2020**, *7*, 1245. [CrossRef]
31. Zhu, T.; Curtis, J.; Clancy, M. Promoting agricultural biogas and biomethane production: Lessons from cross-country studies. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109332. [CrossRef]
32. Mohammed, M.N.; Atabani, A.E.; Uguz, G.; Lay, C.H.; Kumar, G.; Al-Samaraae, R.R. Characterization of Hemp (*Cannabis sativa* L.) Biodiesel Blends with Euro Diesel, Butanol and Diethyl Ether Using FT-IR, UV–Vis, TGA and DSC Techniques. *Waste Biomass Valorization* **2020**, *11*, 1097–1113. [CrossRef]
33. Awe, O.W.; Zhao, Y.; Nzihou, A.; Minh, D.P.; Lyczko, N. A Review of Biogas Utilisation, Purification and Upgrading Technologies. *Waste Biomass Valorization* **2017**, *8*, 267–283. [CrossRef]
34. Budzianowski, W.M.; Brodacka, M. Biomethane storage: Evaluation of technologies, end uses, business models, and sustainability. *Energy Convers. Manag.* **2017**, *141*, 254–273. [CrossRef]
35. Acerbi, F.; Sassanelli, C.; Terzi, S.; Taisch, M. A Systematic Literature Review on Data and Information Required for Circular Manufacturing Strategies Adoption. *Sustainability* **2021**, *13*, 42047. [CrossRef]
36. Sassanelli, C.; Rossi, M.; Terzi, S. Evaluating the smart maturity of manufacturing companies along the product development process to set a PLM project roadmap. *Int. J. Prod. Lifecycle Manag.* **2020**, *12*, 185–209. [CrossRef]
37. Ikram, M.; Sroufe, R.; Awan, U.; Abid, N. Enabling Progress in Developing Economies: A Novel Hybrid Decision-Making Model for Green Technology Planning. *Sustainability* **2022**, *14*, 258. [CrossRef]
38. Kyriakopoulos, G.L.; Kapsalis, V.C.; Aravossis, K.G.; Zamparas, M.; Mitsikas, A. Evaluating Circular Economy under a Multi-Parametric Approach: A Technological Review. *Sustainability* **2019**, *11*, 6139. [CrossRef]
39. Saaty, T.L. *The Analytic Process: Planning, Priority Setting, Resources Allocation*; McGraw: New York, NY, USA, 1980.
40. De Felice, F.; Petrillo, A.; Saaty, T. *Applications and Theory of Analytic Hierarchy Process: Decision Making for Strategic Decisions*; BoD–Books on Demand: Norderstedt, Germany, 2016; ISBN 9535125605.
41. Brudermann, T.; Mitterhuber, C.; Posch, A. Agricultural biogas plants—A systematic analysis of strengths, weaknesses, opportunities and threats. *Energy Policy* **2015**, *76*, 107–111. [CrossRef]
42. Saaty, T.L. Decision making with the analytic hierarchy process. *Int. J. Serv. Sci.* **2008**, *1*, 83–98. [CrossRef]
43. Nikolaou, I.E.; Tsagarakis, K.P. An introduction to circular economy and sustainability: Some existing lessons and future directions. *Sustain. Prod. Consum.* **2021**, *28*, 600–609. [CrossRef]
44. D'Adamo, I.; Falcone, P.M.; Huisingh, D.; Morone, P. A circular economy model based on biomethane: What are the opportunities for the municipality of Rome and beyond? *Renew. Energy* **2021**, *163*, 1660–1672. [CrossRef]
45. Baena-Moreno, F.M.; Malico, I.; Marques, I.P. Promoting Sustainability: Wastewater Treatment Plants as a Source of Biomethane in Regions Far from a High-Pressure Grid. A Real Portuguese Case Study. *Sustainability* **2021**, *13*, 68933. [CrossRef]
46. Wall, D.M.; McDonagh, S.; Murphy, J.D. Cascading biomethane energy systems for sustainable green gas production in a circular economy. *Bioresour. Technol.* **2017**, *243*, 1207–1215. [CrossRef]
47. Rasi, S.; Timonen, K.; Joensuu, K.; Regina, K.; Virkajärvi, P.; Heusala, H.; Tampio, E.; Luostarinen, S. Sustainability of Vehicle Fuel Biomethane Produced from Grass Silage in Finland. *Sustainability* **2020**, *12*, 3994. [CrossRef]
48. D'Adamo, I.; Falcone, P.M.; Gastaldi, M.; Morone, P. RES-T trajectories and an integrated SWOT-AHP analysis for biomethane. Policy implications to support a green revolution in European transport. *Energy Policy* **2020**, *138*, 111220. [CrossRef]
49. Ammenberg, J.; Feiz, R. Assessment of feedstocks for biogas production, part II—Results for strategic decision making. *Resour. Conserv. Recycl.* **2017**, *122*, 388–404. [CrossRef]
50. Collet, P.; Flottes, E.; Favre, A.; Raynal, L.; Pierre, H.; Capela, S.; Peregrina, C. Techno-economic and Life Cycle Assessment of methane production via biogas upgrading and power to gas technology. *Appl. Energy* **2017**, *192*, 282–295. [CrossRef]
51. Vo, T.T.Q.; Wall, D.M.; Ring, D.; Rajendran, K.; Murphy, J.D. Techno-economic analysis of biogas upgrading via amine scrubber, carbon capture and ex-situ methanation. *Appl. Energy* **2018**, *212*, 1191–1202. [CrossRef]
52. Valli, L.; Rossi, L.; Fabbri, C.; Sibilla, F.; Gattoni, P.; Dale, B.E.; Kim, S.; Ong, R.G.; Bozzetto, S. Greenhouse gas emissions of electricity and biomethane produced using the Biogasdoneright™ system: Four case studies from Italy. *Biofuels Bioprod. Biorefining* **2017**, *11*, 847–860. [CrossRef]
53. IRENA. *Renewable Capacity Statistics*; IRENA: Abu Dhabi, United Arab Emirates, 2021.
54. IEA World Energy Outlook. 2019. Available online: https://www.iea.org/ (accessed on 12 February 2019).
55. Gutiérrez, E.C.; Wall, D.M.; O'Shea, R.; Novelo, R.M.; Gómez, M.M.; Murphy, J.D. An economic and carbon analysis of biomethane production from food waste to be used as a transport fuel in Mexico. *J. Clean. Prod.* **2018**, *196*, 852–862. [CrossRef]
56. O'Shea, R.; Wall, D.; Kilgallon, I.; Murphy, J.D. Assessment of the impact of incentives and of scale on the build order and location of biomethane facilities and the feedstock they utilise. *Appl. Energy* **2016**, *182*, 394–408. [CrossRef]
57. Rajendran, K.; Browne, J.D.; Murphy, J.D. What is the level of incentivisation required for biomethane upgrading technologies with carbon capture and reuse? *Renew. Energy* **2019**, *133*, 951–963. [CrossRef]

58. MISE Interministerial Decree of 2 March 2018. Promotion of the Use of Biomethane and Other Advanced Biofuels in the Transportation Sector. Available online: https://www.mise.gov.it/index.php/it/ (accessed on 5 June 2019).
59. Pierro, N.; Giocoli, A.; De Bari, I.; Agostini, A.; Motola, V.; Dipinto, S. *Potenziale Teorico di Biometano Avanzato in Italia*; ENEA: Rome, Italy, 2021.
60. Cianciotta, S.; D'Adamo, I. The Evolution of Sustainability: The Automotive Supply Chain Opportunity in Southern Italy. *Sustainability* **2021**, *13*, 10930. [CrossRef]
61. ISPRA Urban Waste Report. Available online: https://www.isprambiente.gov.it/files2020/pubblicazioni/rapporti/rapportorifiutiurbani_ed-2020_n-331-1.pdf (accessed on 12 March 2022).
62. Baena-Moreno, F.M.; Malico, I.; Rodríguez-Galán, M.; Serrano, A.; Fermoso, F.G.; Navarrete, B. The importance of governmental incentives for small biomethane plants in South Spain. *Energy* **2020**, *206*, 118158. [CrossRef]
63. Smyth, B.M.; Smyth, H.; Murphy, J.D. Determining the regional potential for a grass biomethane industry. *Appl. Energy* **2011**, *88*, 2037–2049. [CrossRef]
64. Allen, E.; Wall, D.M.; Herrmann, C.; Murphy, J.D. A detailed assessment of resource of biomethane from first, second and third generation substrates. *Renew. Energy* **2016**, *87*, 656–665. [CrossRef]
65. Khan, M.U.; Lee, J.T.E.; Bashir, M.A.; Dissanayake, P.D.; Ok, Y.S.; Tong, Y.W.; Shariati, M.A.; Wu, S.; Ahring, B.K. Current status of biogas upgrading for direct biomethane use: A review. *Renew. Sustain. Energy Rev.* **2021**, *149*, 111343. [CrossRef]
66. Xue, S.; Zhang, S.; Wang, Y.; Wang, Y.; Song, J.; Lyu, X.; Wang, X.; Yang, G. What can we learn from the experience of European countries in biomethane industry: Taking China as an example? *Renew. Sustain. Energy Rev.* **2022**, *157*, 112049. [CrossRef]
67. Guerin, T.F. Business model scaling can be used to activate and grow the biogas-to-grid market in Australia to decarbonise hard-to-abate industries: An application of entrepreneurial management. *Renew. Sustain. Energy Rev.* **2022**, *158*, 112090. [CrossRef]
68. Van der Schoor, T.; Scholtens, B. Power to the people: Local community initiatives and the transition to sustainable energy. *Renew. Sustain. Energy Rev.* **2015**, *43*, 666–675. [CrossRef]
69. Sendstad, L.H.; Chronopoulos, M. Sequential investment in renewable energy technologies under policy uncertainty. *Energy Policy* **2020**, *137*, 111152. [CrossRef]
70. Shanmugam, K.; Baroth, A.; Nande, S.; Yacout, D.M.M.; Tysklind, M.; Upadhyayula, V.K.K. Social Cost Benefit Analysis of Operating Compressed Biomethane (CBM) Transit Buses in Cities of Developing Nations: A Case Study. *Sustainability* **2019**, *11*, 4190. [CrossRef]
71. Mies, A.; Gold, S. Mapping the social dimension of the circular economy. *J. Clean. Prod.* **2021**, *321*, 128960. [CrossRef]
72. Crupi, A.; Del Sarto, N.; Di Minin, A.; Gregori, G.L.; Lepore, D.; Marinelli, L.; Spigarelli, F. The digital transformation of SMEs—A new knowledge broker called the digital innovation hub. *J. Knowl. Manag.* **2020**, *24*, 1263–1288. [CrossRef]
73. Sassanelli, C.; Terzi, S.; Panetto, H.; Doumeingts, G. Digital Innovation Hubs supporting SMEs digital transformation. In Proceedings of the 27th ICE/IEEE International Technology Management Conference, Cardiff, UK, 21–23 June 2021; IEEE: Piscataway, NJ, USA, 2021; pp. 1–8.
74. Hervas-Oliver, J.L.; Gonzalez-Alcaide, G.; Rojas-Alvarado, R.; Monto-Mompo, S. Emerging regional innovation policies for industry 4.0: Analyzing the digital innovation hub program in European regions. *Compet. Rev.* **2021**, *31*, 106–129. [CrossRef]