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The Role of Bioenergy in Italy in the Transition towards a Bio-based Economy

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Abstract: The opportunities and challenges for the development of a sustainable Italian bioeconomy vary according to the bioenergy used in the various sectors, in line with the principle of "making better use of what we already use" and "effectively using what we do not yet use". The aim of the present paper is to analyse the main driving factors "for and against" innovative energy policies, focused on bioenegy related to natural cycles and systems, including turning the "energy" present in agricultural and industrial waste and byproducts into usable forms. The role of biogas and biomethane, particularly, in the Italian scenario, will be analysed in the light of current environmental policy trends.

Key words: Bioenegy, bio-economy, circular economy.

1. Background

The recent orientation of energy policy, especially at European level, towards sustainability, understood in terms of economic competitiveness, environmental protection and security of supply, has led to profound changes in energy scenarios, which are still dominated by fossil sources.

In this context, renewable energy sources (RES) have acquired an increasingly significant role, as a fundamental instrument of European energy governance, in line with the "2030 climate & energy framework" which sets new objectives for the diffusion of renewable sources, energy and reduction of CO_2 emissions, overall much more ambitious than those foreseen for 2020 in the "Climate-Energy Package".

An important outcome of the work on the "2030 Framework" was the approval of Regulation 2018/1999 on the governance of the Energy Union (EU) and climate action.

The regulation inaugurates a transparent and dynamic governance system for the management of energy-climate objectives by 2030 and provides, among other things, for all Member States to draw up and send to the European Commission an Integrated National Plan for Energy and Climate to be updated every two years.

Based on the initiatives undertaken at European level, Italy has recently drawn up the "Piano Nazionale Integrato per l'Energia e ilClima" (PNIEC) sent to the European Commission on 31 December 2019.

The main objectives stated in the PNIEC foresee to increasingly direct research and innovation in the energy sector towards the development of product and process technologies, organizational and management systems and models functional to the energy transition and safety, in order to favor the modernization of the production system in line with the long-term energy and environmental scenario. In terms of financial resources, Italy has committed itself to doubling the resources for research in these areas in the short term.

In this context, RES are confirmed as a strategic resource for the sustainable development of the country. This is due to the potential benefits related to the reduction of polluting and climate-altering emissions,

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the improvement of energy security and the economic and employment opportunities for families and the production system.

The development of RES in Italy has been widely supported over the years both through diversified incentive systems and by adopting planning and direction tools. In 2010, the Ministry of Economic Development issued, in implementation of Directive 2009/28/EC, the "National Action Plan for Renewable Energy Sources" (NAP RES), which identified, among other things, specific actions for each technology and application, together with the quantitative objectives in the various areas of intervention (electricity, air conditioning and transport).

In order to ensure the achievement of the objectives defined in the NAP RES, Legislative Decree No. 28 of 3 March 2011 which, in addition to organically redefining the institutional, financial and legal framework, provided for the adoption of a series of tools to support renewable sources, aimed at pursuing greater effectiveness, efficiency and stability over time, as well as a reduction in the specific charges borne by users/consumers [1].

More recently (March 2013, revised in November 2017), the Ministry of Economic Development has published the National Energy Strategy (SEN), a medium-long term policy and planning tool aimed at defining a stable regulatory framework and consistent over time for the development of the Italian energy sector [2, 3].

The SEN formed the programmatic and political basis for the subsequent adoption of the PNIEC.

A central element of the SEN was represented by the support for the sustainability of renewable energies, with a view to decarbonising the energy sector and reducing the vulnerability of fossil fuel supplies, which currently represent over 70% of our Energy Balance and almost 80% from abroad.

In recent years, the RES have shown, through these support actions, growth trends in all sectors of use (electricity, heat, transport); the estimated share of total national energy consumption covered by renewables has exceeded the threshold of 18% (of which 11% associated with the latest generation renewables—wind, solar, biomass, geothermal, hydroelectric, biofuels, etc., and the remaining 7% to traditional biomass), a value higher, for the sixth consecutive year, than the target of 17%, assigned to Italy by directive 2009/28/EC for 2020. The absolute difference to be bridged to reach the target to 2030 set by the Integrated National Plan for Energy and Climate (RES share equal to 30%) would therefore be just less than 12 percentage points.

In the electricity sector, in particular, Italy is one of the most dynamic markets at EU level, ranking sixth for new installed power in 2019 (2.1 GW of new RES-powered plants, compared to 2018) after Spain (6.3 GW), Germany (6.1 GW), Great Britain (2.7 GW), France (2.4 GW) and the Netherlands (2.3 GW).

The RES that, over the last few years, have recorded a significant increase in production are above all wind and photovoltaic ones. Instead, the increase in bioenergy was more contained. This national trend follows the one that characterizes the situation at the international level.

Suffice it to say that globally, in the electricity sector, the new installed power of bioenergy plants in 2019 was equal to 6.1 GW compared to 97 GW of new photovoltaic power, 59 GW of new wind power and 12.5 GW of hydroelectricity. In the transport sector, the global production of biofuels represents—according to IEA data—93% of the use of renewable sources in the sector, while the remainder is attributable to electric vehicles. For the thermal sector, which concentrates more than 50% of total final consumption, excluding the traditional use of solid biomass, the other thermal renewables, with 21.2 EJ of total energy supplied, satisfied about 10% of the global heat demand mainly through the use of modern bioenergy (cogeneration systems combined with district heating, biomass boilers and biomethane injection) for about 72% of the total (15.3 EJ), followed by renewable electricity to

produce heat (18% equivalent to 3.8 EJ), from solar thermal (7% of the total equal to 1.5 EJ) and from geothermal (3% of the total equal to 0.6 EJ).

From the picture outlined, the importance of further enhancing bioenergy which has the advantage of being continuous and programmable emerges. In fact, despite the great technological development of wind and photovoltaic sources and the greater economic convenience of the same, the energy produced is not programmable and is, by itself, insufficient to power, for example, a transition to a 100% renewable electricity system.

Bioenergy can make a substantial contribution to meeting future energy demand in a sustainable way and has a significant potential for expansion both in the production of electricity and heat and—in the form of biofuels—in the transport sector.

The production of bioenergy in Italy is a widespread and consolidated reality, which makes use of a plurality of raw materials—both residual and from dedicated crops—and the availability of mature and reliable technologies.

The importance of supporting the growth of bioenergy with the development and industrialization of innovative technologies, processes and components and the development of reliable methodologies for assessing the potential of biomass and the creation of agro-energy chains is widely recognized, truly sustainable in both economic and environmental terms.

Based on Terna-Gse data, in 2018 bioenergy covered 18% of electricity production from renewable sources, equal to 5.6% of our country's electricity demand. At a European level, Italy, together with France, Germany, Spain and Romania, is among the countries with the highest potential (the European Environment Agency).

Among bioenergy, the production of biogas for the generation of heat and/or electricity or for conversion into biomethane plays an extremely important role.

To date, biogas is the only renewable, versatile and technologically established energy source capable of producing heat, steam, electricity and vehicle fuel.

Furthermore, biomethane can count on a potential, estimated on the basis of electricity production from biogas, of approximately 2.5 billion cubic meters, with an estimated growth of approximately 8 billion cubic meters by 2030, equal to approximately 12-13% of the current annual natural gas requirement and two thirds of the storage potential of the national network. In this perspective, biomethane also makes it possible to allocate at least part of the biogas used for electricity production to transport.

The introduction of regulatory constraints in the treatment of organic waste and recent commitments in the field of renewable energy has fueled the interest of market operators in these technologies.

This work aims to highlight how, driven by the initiatives implemented at European level, Italy has promoted the development and dissemination of bioenergy through diversified incentive systems and through various planning and direction tools.

This is in order to evaluate the contribution that can be offered by bioenergy and, in particular, biogas to the affirmation of a bioeconomy, or rather an economy capable of reorienting current models of economic development towards sustainable production and consumption systems.

2. The Role of Bioenergy in Italy

The bioenergy sector in Italy, in recent years, has experienced a period of great development both in terms of installed capacity and energy produced (Tables 1 and 2).

Between 2004 and 2018, electricity generated with bioenergy grew by an average of 11% per year, from 4,499 GWh to 19,153 GWh.

Production in 2018 comes to 43.3% from biogas, 34.3% from solid biomass (in particular, 12.6% from biodegradable waste and 21.7% from other solid biomass) and 22.4%% from bioliquids.

Particularly significant in recent years is the growth of biogas production, which rose from 1,665 GWh in 2009 to 8,300 GWh in 2018 [4].

As regards the thermal energy obtained in Italy from bioenergy, in 2018 they amounted to 292,409 TJ.

Direct consumption, in particular, amounted to 270,383 TJ; industry absorbs about 45% of it, while the remaining 55% refers to trade and services. There is no direct consumption of biogas in the residential sector.

The region characterized by the highest levels of direct thermal consumption of bioenergy is Lombardy, which alone reaches just under 42% of total national consumption; followed by Lazio (8.5%), Veneto (7.9%), Emilia Romagna (7.5%) and Piedmont (6.3%). The southern regions concentrate 14.1% of total consumption.

In 2018, 586 TJ of biomethane was introduced into the network, of which 529 TJ of direct consumption and 57 TJ in the form of derived heat.

The use of biomethane, on the other hand, in the transport sector still plays a marginal role compared to the other biofuels used (biodiesel, bio-ETBE, bioethanol) (Table 3).

However, it is necessary to highlight that bioenergy represents a singularity in the panorama of renewable sources. Unlike other RES, bioenergy is characterized by high generation costs, mainly attributable to the costs of the raw material. The sector, therefore, requires practically constant public incentives even in cases where the raw material should come from agricultural self-production.

The recent SEN, however, provides for a downsizing of the forms of incentives for existing bioenergy, since the variable cost of the raw material does not show any signs of reduction over time, and indeed, probably, remains high precisely because of the incentives. This is in order to reduce system charges on the bill and

Table 1 Evolution of the number and power of plants powered by bioenergy (2010-2018).

	2010		2015		2018		Δ% 2010-2018	
	No.	MW	No.	MW	No.	MW	No.	MW
Bioenergy	686	2,352	2,818	4,056	3,096	4,180	335%	76%
Solid biomass from	138	1,243	369	1,612	475	1,725	244%	39%
-urban waste	71	798	69	953	65	939	-8%	18%
-other biomasses	67	445	300	659	410	787	512%	77%
Biogas from	451	508	1,924	1,406	2,136	1,448	374%	185%
-waste	228	341	380	399	403	406	77%	19%
-sludge	47	15	78	44	79	44	68%	193%
-animal waste	95	41	493	217	615	239	547%	483%
-agricultural and forestry activities	81	110	973	746	1,039	760	1,183%	591%
Bioliquids from	97	601	525	1,038	485	1,007	400%	68%
-crude vegetable oils	86	510	436	892	391	857	355%	68%
-other bioliquids	11	91	89	146	94	150	755%	65%

Source: Ref. [4].

Table 2 Bioenergy in the thermal sector (2018).

	Direct consumption (TJ)	Gross production of derived heat		Total (TJ)
		Thermal production only plants (TJ)	Cogeneration plants (TJ)	
Solid biomass	270,383	3,359	18,667	292,409
Bioliquids	-	28	2,134	2,162
Biogas	1,749	6	8,946	10,701
Biomethan	529	4	53	586
Total	272,661	3,397	29,800	305,858

Source: Ref. [4].

Table 3 Biofuels released for consumption in Italy—2018.

Biofuels	Quantity (tons)	Energy (TJ)
Biodiesel	1,377,205	50,957
Bio-ETBE	36,995	1,332
Bioethanol	1,243	34
Biomethane	363	18
Total	1,415,806	52,341

Source: Ref. [4].

avoid treatments that do not stimulate efficiency. The introduction of more efficient tools than those recently introduced by legislation is planned to promote fair competition on the raw materials market [3].

New forms of tariff incentives are envisaged only for very small plants, which have higher costs than large ones, and for lower impact supply chains such as bioenergy from agricultural waste and residues.

For various forms of bioenergy, the SEN provides for an enhancement of the tools to support the production of biomethane to be used for transport.

In fact, biomethane can be used, without technical limitations and no technological changes, in vehicles already running on natural gas for light and heavy transport, in the urban distribution of goods, in public transport and soon also in agricultural mechanization. The fleet of cars and methane gas stations is already highly developed in Italy. In the form of bio-LNG, liquefied biomethane, it would partially replace the use of biodiesel which, in Italy, constitutes 92% of the biofuels used, but is almost entirely produced from imported raw materials [5].

Furthermore, in terms of emissions, in a well-to-wheel perspective, biomethane vehicles produce CO_2 emissions comparable to those of an electric vehicle powered by energy from renewable sources, with a reduction in emissions of 80-90% compared to traditional fuels. PM10 emissions are practically absent and NO_X emissions are reduced by 70% [6].

Italy therefore has a green resource of inestimable value that must be adequately supported by a clear and stable regulatory framework.

The model of agricultural biogas/biomethane made in Italy is a best practice at a global level as biogasdoneright is promoted nationally [7-9].

The biogas supply chain consists of various biological processes and various energy conversion steps [10]. In particular, the spinneret can be divided into four phases: procurement, biogas production, use of digestate and biogas.

In the procurement phase it is possible to use a large variety of raw materials such as municipal and industrial organic waste, animal waste, agricultural by-products or dedicated energy crops [11].

In particular, biogas is usually distinguished as follows:

- landfill biogas, produced by the digestion of waste in landfills;
- biogas from sewage sludge, produced by the anaerobic fermentation of sewage sludge;
- biogas, produced for example by the anaerobic fermentation of livestock sewage, agricultural products or agro-industrial by-products.

In Italy, according to a survey conducted by the Energy Services Manager (GSE) in 2017, dedicated energy crops, crop residues, organic waste, slurry and manure from farms accounted for 49%, 1% respectively, 19% and 31% of the total raw materials used in biogas plants [4]. Preferably, the input materials are produced close to the biogas plant to avoid leaks and reduce transport costs [12].

In the context of Life Cycle Assessment (LCA) studies conducted on biogas, manure and, in general, organic waste appear to be the most sustainable way of producing biogas, unlike dedicated energy crops which require higher costs [10]. Some studies show that the environmental performance of biogas, used as fuel and deriving from organic waste and sewage sludge, is comparable to those attributable to the use of diesel or natural gas.

As regards the construction and demolition phases of a biogas plant, some studies in the literature highlight the small environmental impacts that can be further

reduced through greater use of the plant [13].

In general, electricity produced from biogas has a lower environmental impact than electricity generated from fossil fuels [14].

Furthermore, numerous studies have shown the main environmental benefits, in terms of global warming potential (GWP) and resource consumption (RC), of energy systems using biogas compared to those powered by fossil fuels [15].

3. Conclusions

Bioenergy is transforming the Italian energy landscape. In the next decades, these sources will play an increasingly central role in the energy field, also in view of the ambitious goals to be achieved by 2050. In the electricity sector, for example, it is necessary to increase the current production share generated by bioenergy, especially in the long term period.

In recent years, our country has accelerated the spread of installations of RES-fueled systems, even if government policies have been anything but linear; in fact, continuous and profound changes in the regulatory framework and too high incentives have represented major obstacles.

The support policies have led to concentrating resources only on some technologies of the electricity sector, in particular wind and photovoltaic [16]. Therefore, the new incentive system will have to be projected solely towards the enhancement of some RES, for example a greater diffusion of biogas and biomethane is hoped for.

A strong stimulus could also come, at a national level, from the research sector to improve the characteristics and performance of current technologies and favor particular innovative applications, such as two-stage plants for the production of biomethane and hydrogen.

A large-scale diffusion of bioenergy can take place above all through a strong reduction in costs that makes them economically competitive. In order to achieve the priority objective aimed at a greater penetration of bioenergy, it will be necessary to identify a clear and timely regulatory framework for incentives.

The recent guidelines, however, are aimed at progressively reducing financial incentives for the development of RES in order to guide the energy production system towards the diffusion of more complex energy management interventions characterized by greater competitiveness and their correct integration at territorial.

Bioenergies represent an essential tool for the decarbonisation of the Italian energy system. In particular, biogas/biomethane can play a strategic role in this regard [17].

A biogas plant, in fact, if connected to both the gas and electricity networks, becomes a small, flexible and decentralized biorefinery capable of producing biomethane, electricity, heat and organic fertilizers. The greening of the gas network makes the network itself an infrastructure that collects renewable energy from the territory, concentrates it, accumulates it and transports it at competitive costs.

Energy can be used where and when it is most convenient and in the most appropriate form, such as electricity, fuel, to cover different energy needs.

The biogas supply chain also generates value for society through the creation of new jobs, the spread of RES and the enhancement of a wide range of substrates (industrial and urban wastewater and sludge, organic fraction of solid urban waste, animal waste, crop residues) [18].

In fact, anaerobic digestion technologies allow not only a reduction in emissions that varies according to the type of substrate, the technology used and the operating practices of the supply chain, but also the elimination of bad odors and the replacement of chemical fertilizers with the digestate.

Energy systems that use biogas, therefore, contribute to the affirmation of production paradigms designed to promote an economy based on sustainability and circularity in the use of resources.

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