INNOVATION AND TECHNOLOGY TRANSFER IN ENERGY RECOVERY SYSTEMS FROM AGRO-ZOOTECHNICAL WASTE

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Abstract - Romania benefits from adequate geo-climatic conditions that allow for the development of a complex agriculture; the share of Romanian agriculture in the national GDP of 4.8% is the highest in Europe, compared to the average of 1.3% in the EU-28 countries. Agriculture and agro-industries generate huge amounts of solid organic waste, sludge and wastewaters that can be used in the energy sector for biogas production, thus providing energy bioresources without creating political and economic controversies regarding the use of agricultural land for the production of biofuels in the detriment of food. This paper proposes innovative ideas of non-polluting technologies for the recovery of agro-zootechnical waste in decentralized biogas systems. The referred technologies are the result of some experimental research carried out by INCDIE ICPE-CA specialists within national and bilateral research projects; these achievements are intended to be applied for waste water treatment and organic sludge neutralization or transferred to beneficiaries from rural areas. Innovative elements that ensure an advanced recovery of the organic component and the production of biogas with high energy value are presented. Also, the paper makes a brief analysis of the economic, social and environmental benefits that such systems can bring to rural communities and companies generating organic waste. Finally, the results regarding technology transfer to the producer, and the main barriers responsible for the very slow growth of biogas technologies in regions with high agricultural potential are pointed out.

Keywords: energy recovery, biogas, waste, technology transfer.

1. INTRODUCTION

The current development of the energy market, in the context of new energy and environmental policies, redefines the role of agriculture, whose main goal is food security, followed by supplying raw materials for clean energy technologies [1].

Competition for the use of agricultural land becomes an important aspect in making decisions regarding the development of energy technologies by using energy crops in the detriment of food production. This controversy is eliminated in the case of developing energy technologies (biogas, biodiesel, bioethanol) by using agricultural and zootechnical residues.

There are many arguments to support the development and implementation of biogas technologies from different types of biodegradable waste generated by the agro-industrial sector, among which the most important fact is that biogas technologies contribute to the climatic change mitigation and meet energy security objectives [2].

Organic materials of vegetal and animal origin generated from agro-zootechnical activities that can be used for biogas production are very diverse; generally, any low-lignin organic material can be converted anaerobically into biogas and organic fertilizers. By anaerobic digestion of agro-zootechnical waste such as nitrogen-rich manure, methane emissions are managed in a sustainable way and have less carbon footprint compared to emissions from conventional manure storages on landfills. Also, odour from digested manure is lower compared to non-digested manure. Moreover, if the fermented slurry (digestate) is used to replace artificial fertilizers, the generated emissions from the production of the fertilizer would be reduced [3, 4].

In Europe, according to the latest data released by EurObserv'ER in November 2017 for the year 2016, Germany is by far the largest producer of biogas (7.95 Mtoe) which means nearly 50% of the EU28 total biogas production of 16.09 Mtoe, followed by United Kingdom (2.40 Mtoe) and Italy (2.02 Mtoe). Romania had a total biogas production of only 0.018 Mtoe in 2017 despite its wide feedstock potential, coming mainly from agro-zootechnical and organic wastes (72%), followed by landfills (18%) and sewage sludge (9%) [5].

Member States are recommended to develop national strategies on the role of biogas and biomethane to meet future renewable energy and climate goals. This should include an assessment of available suitable feedstock and an outlook for biogas/biomethane production and use, indicating the potential for biogas production and assessing the different options for its use. [1, 5].

The Romanian biogas sector is much underdeveloped, almost inexistent, despite the country has a huge potential for biogas [2]. At the end of January 2019, the total installed capacity for electricity from renewable energy sources was approx. 4,961 MW_{el}, but only 144 MW was the total capacity of biomass-based facilities, out of which only 6.4 MW represents installed power of the biogas plants. [6] The main problem identified with regard to the very low development of biogas sector is the deficient legislative framework, the very long-lasting administrative procedures and the lack of coordination and information between ministries of Energy, Agriculture and Environment. [2].

While biogas plants might provide a very good local power supply solution, especially in rural areas, high costs of biogas plant construction and lack of information on the potentials, financing possibilities or technology itself are other barriers identified to break the progress in the sector.

2. AGRO-ZOOTECHNICAL WASTE AS VALUABLE RESOURCES FOR BIOGAS PRODUCTION

Agricultural policies are very relevant to biogas developments, and Member States could strongly focus on integration of the biogas sector as a part of sustainable agriculture, not limiting policy considerations to energy production. Information on feedstock use for biogas production in the EU is not easy to obtain, but it is estimated that energy crops (maize mainly) provide about half of the biogas production in the EU, followed by landfills, organic waste, sewage sludge and manure [1].

In Romania, agriculture is one of the most important branches of national economy. The contribution of agriculture, forestry and fisheries to the GDP is around 4.8%, that is the highest amongst the EU Member States, the average in the EU-28 countries being of 1.3% [1, 2]. Romania is characterized by the presence of a large number of mixed farms, crop farms and livestock farms. In 2016, over 10.5 million agricultural holdings (farms) in the European Union (EU) were recorded. About one third (32.7 %) of the EU's agricultural farms were located in Romania in 2016, much more than in any other Member State. Moreover, in Romania, nine in every ten farms (91.8 % or 3.1 million farms) were smaller than 5 ha; these is because small farms are perceived as playing an important role in reducing the risk of rural poverty, providing additional income and food [1].

Farms and small food industry generate huge amounts of waste and wastewaters, e.g. whey, that are organic materials suitable to be used as substrate for biogas production, both due to their organic load and the negative environmental impact they create [2, 4]. The different agro-zootechnical residues have specific biogas potential, in terms of biogas volumes produced per tonne of waste. The possibility to treat mixtures of vegetal and animal waste within the same process is an important advantage given that the agricultural sector generates residuals of both types [7, 8].

3. CURRENT STATE OF INNOVATION AND TECHNOLOGY TRANSFER IN ROMANIA

The European Innovation Scoreboard 2018 released on June 2018 highlights that the EU's innovation performance continues to improve, that progress is accelerating, and that the outlook is positive. Since 2010, the EU's average innovation performance has increased by 5.8 percentage points, and it is expected to improve by an additional 6 percentage points over the next 2 years. Within the EU, innovation performance increased in 18 countries and decreased in 10 countries since 2010. Sweden remains the EU innovation leader, while Romania and Bulgaria are ranked as Modest Innovators with performance well below the EU average, as seen in Figure 1[9].

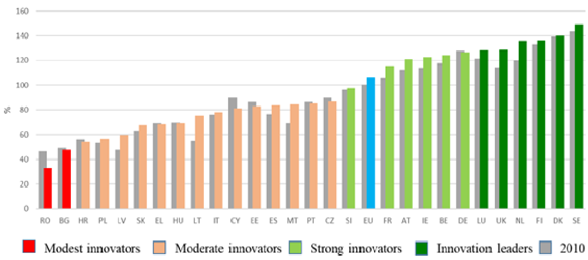

Fig. 1. Performance of EU Member States' innovation systems in 2017 (coloured columns) relative to that of 2010 (grey columns) [9]

A total of 27 different indicators have been used to establish the innovation dimensions, including criteria such as: Human resources, Attractive research systems, Innovation-friendly environment, Finance and support, Firm investments, Innovators, Linkages, Intellectual assets, Employment impacts, Sales impacts etc.

In Romania, since 2010, the innovation performance declined strongly by 14.0 percentage points from 47% to 33% related to that of European Union but, after five years of decline, the performance increased again in 2016 and 2017. Innovation-friendly environment and Intellectual assets (including patent applications, trademark applications and design applications) are the strongest innovation dimensions, while Innovators and Firm investments are the weakest innovation dimensions [9].

The concept of "product for the market" should be the first to consider in deciding funding distribution for innovation activities. Also, the research activity should be financed through "top-down" mechanisms, defined by experts gathered in technology platforms. The investments made through the valorisation of RDI results aim to increase the economic competitiveness of SMEs through technology transfer, achievable by developing public and private support mechanisms for innovation and technology transfer, in all regions of Romania, in line with the principles of smart specialization [10]. The Romanian innovation and technology transfer infrastructure is inadequate, both as number of specialized entities and as diversification of typology. The greatest share belongs to the technological and business incubators, thanks to the financial support granted through programs with external financing [10].

In their study, some authors propose the following three main directions for optimizing and improving innovation and technology transfer at the policy level in Romania [11]:

- Simplifying the legislative framework in order to facilitate technology transfer by a reconfiguration of a public-private partnership law, exemption/reduction of taxes for the technology sellers, incentives offer for technology buyers;
- Supporting the establishment of structures with facilitator potential within the technology transfer process by creating business incubators, clusters and

spin-offs;

o Improving patent activities within public entities by capitalizing property rights (patents, models, designs, trademarks) and copyrights.

It is obvious that any complicated procedures and difficulties in achieving technology transfer generates low competitiveness and lack of added value in the economic sector, while the research results cannot be shared between research institutions and enterprises and cannot bring a positive contribution to the economic growth [10, 11].

4. ACHIEVEMENTS IN TECHNOLOGY TRANSFER TO DEVELOP THE NATIONAL BIOGAS SECTOR

For the recovery of agro-zootechnical waste at a decentralized level there are numerous biogas plant designs that try to reproduce as accurately as possible the natural anaerobic digestion processes to produce biogas [12]. Some innovative solutions have been proposed and developed by researchers under national research programs and bilateral collaborative projects with traditional institutions such as BIOMA China (Romania-China Bilateral Project no. 520/2011 and 611/2013).

Amongst various R&D and innovation activities, INCDIE ICPE-CA Bucharest can offer specialized activities for technology transfer and consultancy on intellectual property rights, as well as assistance in the implementation of the technology transfer of research results in the field of electrical engineering, including in the area of renewable sources and biogas technologies, through its structures CTT ICPE-CA Technology Transfer Centre and ITA ECOMAT ICPE-CA business incubator. [13]

In this section two concepts of biogas units developed in INCDIE ICPE-CA Bucharest and designed for treating biodegradable waste are briefly presented, with focus on the innovative elements for the efficient recovery of the organic fraction. The biogas units are intended for producing biogas and ecological fertilizers from agro-zootechnical waste (animal manure, crop waste, gardening waste, fruit residues, food scraps etc.) while cleaning the land and improving the quality of the environment.

a) Household biogas unit (Patent 125902B1 / 2014)

The prototype of 4 m^3 was built in 2010 in Boteni, Arges County, with public funds provided by the national research program Nucleu 0935/2009. Presently the patent license was transferred to the following 4 small enterprises which will be responsible for manufacturing the product by request, on the basis of the license agreement signed with the institute INCDIE ICPE-CA Bucharest: SC PRODLACTOSERV SRL, SC Wildlife Film Production Romania SRL, SC GXG TRADITII SRL, SC GAMA BIOTECH PRODUCTION SRL.

Due to its innovative internal configuration of the digestion chamber, the biogas unit provides an advanced decomposition of the organic fraction, requiring no any energy-consuming operations such as homogenization and heating of the organic mass [14]. The system consists primarily of a digestion reactor of a semi-spherical shape made of brick and cement mortar with partitioning made by separating chicanes and having a slightly convex concrete bottom. The digestion chamber configuration enables the optimal inner circulation of the organic mass from inlet to outlet and ensures the retention of the organic mass in the reactor for a longer time so that the organic compounds have time to be decomposed to biogas. The biogas unit is fitted with a biogas tank that is a cylindrical floating drum made of stainless steel and guided by a metallic frame above the digestion chamber [14]. The overall image of the household biogas unit concept is shown in the Figure 2, while the prototype of 4 m3 is shown in Figure 3.

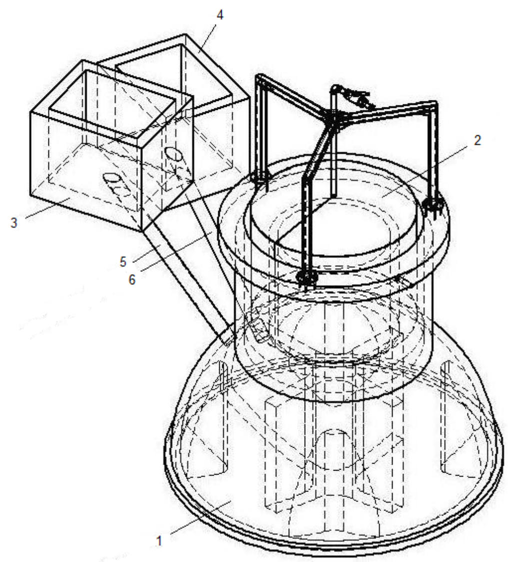

Fig. 2. Household biogas unit (1 - digestion chamber; 2 – floating drum biogas tank; 3 – organic slurry tank; 4 – fermented slurry tank; 5 – inlet pipe; 6 - outlet pipe)

Fig. 3. Biogas unit prototype, digestion chamber of 4m^3, in operation in Boteni, Arges county since 2010

The main advantages that the innovative elements can bring are the followings: Simplicity in building and operation; better yields in degradation of the organic compounds due to the longer mass flow; Profitable materials consumption and easy availability; Ground space saving by buried construction; Possibility to build the unit for larger size up to 16 m^3, function of the substrate availability and the family energy needs; Ensuring sustainable fuel (biogas with 50-70% methane) for domestic applications; Providing a clean and healthy environment for families living in rural areas.

The household biogas plant has a positive impact on the environment by facilitating lands and courtyards sanitation, reducing greenhouse gas emissions, improving the quality of crop lands by using fermented slurry as eco-fertilizers.

b) Tubular bioreactor with the liquid effluent partial recirculation (Patent application A00324 / 2016)

This innovative bioreactor is intended for the anaerobic treatment, in mesophilic temperature regime (20-40^{0}C), of organic waste and wastewaters from agro-food industry, including agricultural residues, animal manure, catering waste, sewage sludge, algal biomass etc., with producing biogas which may be used as fuel gas or to supply heat and electricity.

The bioreactor is of semi-compartmental tubular construction and is designed to allow partial recirculation of the liquid effluent between the two fermentation compartments. The recycled liquid has two major roles: on the one hand it allows the dilution of the organic material introduced into the reactor and on the other hand it ensures the supplementation of the bacterial type of inoculum needed for accelerating and intensifying the fermentative processes [15].

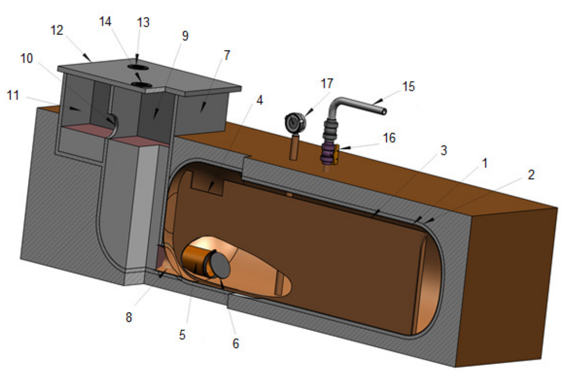

Fig. 4. Tubular bioreactor with the liquid effluent partial recirculation (1 – anaerobic fermenter; 2 – thermal insulating material; 3 – separating wall; 4 – overflow; 5 – inlet pipe; 6 – reversing flap; 7 – organic slurry tank; 8 – outlet pipe; 9 – digested sludge tank; 10 – expansion hole; 11 – expansion chamber; 12 – tanks lid; 13 – inlet valve; 14 – outlet valve; 15 – gas pipe; 16 – flame retaining system; 17 – liquid level measuring system)

The innovative shape has been designed so that the bioreactor can provide a better decomposition of the organic substrate and wastewaters compared to other conventional horizontal tubular bioreactors with no compartmentalization and liquid effluent recirculation. By transferring effluent into the feed chamber, the fermentation mass will be enriched in active fermentation bacteria and the biochemical processes are improved. The mass hydrodynamics is naturally conducted between inlet and outlet by slurry flowing along the longitudinal wall. Feeding the anaerobic digester can be done directly by free flowing from the inlet tank without the need for a pumping system. The underground location of the anaerobic chamber enables the proper fermentation temperatures in mesophilic regime and no any additional heating sources are required. The organic slurry and digested sludge tanks are covered with a lid fitted with flexible flaps at the inlet/outlet holes for a better environmental protection against unpleasant odours [15].

The tubular bioreactor can be manufactured for different sizes/volumes according to available materials to be treated. It is completely energetically autonomous, requiring no energy-consuming operations such as homogenization and heating of the organic mass, neither mechanized extraction of the fermented sludge from the expansion chamber of the digested sludge tank.

5. BARRIERS TO IMPLEMENTING AGRO-WASTE ENERGY RECOVERY SYSTEMS

A wide range of agro-zootechnical feedstock that are abundant in Romania can be used to produce biogas and ensure the energy needs, especially in rural areas. Also, some research and development projects offer innovative solutions for the recovery of organic waste and wastewaters in the production of energy and natural fertilizers to sustain a healthy agriculture.

Heating and electricity grids are deficient in Romania in many rural areas and there is much need to develop biogas facilities for producing fuel gas and electricity, but there are many factors which impede implementation of such green energy systems [16].

The most important barrier is the lack of a stable and reliable legal framework and functional support schemes. In Romania, the renewable energy sources in the electricity sector are supported through a quota system based on quota obligations and tradable green certificates. In case of biomass, biogas and geothermal projects, the state support has not been cut with the latest amendments of the renewable energy law and has been kept for the initial quota of 2 green certificates for each MWh electricity, with 1 additional green certificate /MWh for cogeneration plants and 1 additional green certificate MWh in case of using energy crops. But the system has proved detrimental to the development of the biogas sector in Romania since the market value of a large surplus of 18 million green certificates at the end of 2016 was nullified [2].

Other major barrier to developing biogas systems in Romania is the lack of access to finance since the biogas plant projects require significant capital and operating costs. In the years 80s, Romania had a national biogas programme that included investments both in research, development and building of biogas plants. Under the state financial support, the number of rural plants for households and small farms was estimated at around 5000 at the end of 1989 [2].

The lack of knowledge, expertize and available information for farmers and organic waste generators is another important barrier to be considered. Romania has not enough engineers able to plan a biogas plant. This is the reason why know-how transfer is the essential base for successful implementation of biogas technology in Romania [3].

Romania has a high level of agricultural lands fragmentation. This is a barrier in developing large-scale biogas projects due to the difficulty of supplying raw materials in a constant flow [1]. Land fragmentation is one of the major factors that could influence biogas projects, since access to raw materials requires an efficient management system at local level. For this reason, the present conditions of agricultural lands fragmentation in Romania are favourable for the development of family-scale or small farms biogas projects [16].

6. CONCLUSIONS

A wide range of organic materials such as animal and vegetal by-products, food waste, energy crops etc. are an adequate substrate to produce biogas and organic fertilizers in industrial or small-scale anaerobic digestion systems [17]. The biomass and biogas sector is much underdeveloped in Romania despite plenty of bioresources which are generated by the agro-zootechnical sector [3, 18].

Valorisation of the national RDI results through technology transfer in recovery of agro-zootechnical waste is a strategic goal, not only from energy and environmental considerations but also aims at increasing the economic competitiveness of small and medium enterprises.

Romania is a modest innovator, the national innovation performance declining strongly during the past seven years amid inadequate infrastructure for innovation and technology transfer [9].

There are important market barriers to implementing biogas systems for the agro-zootechnical waste recovery to energy in areas with high feedstock potential despite several research results and systems concepts have been achieved and patented. Currently there is not a stable and reliable legal framework, nor adequate access to know-how or specialized information for farmers or other potential beneficiaries of such systems in order to increase the technology transfer and put into practice the innovative ideas [2, 3].

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