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Designing a Biomethane Circular Supply Chain For Agricultural Tractors Engines: the TOBIAS Project

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Abstract

Biomethane is a valuable alternative to fossil fuels, specifically in transport sector, contributing to "energy security" and "carbon neutrality". Though at present, research has mainly invested in the automotive sector, the demand for alternative and low environmental impact fuels is growing. Hence, in the scope of energy transition, also in the agricultural sector machinery manufacturers have started developing the first solutions able to reduce the environmental impact of tractors. In addition, on-farm biomethane production would represents a great opportunity for the development of more "circular" systems producing renewable energy from "residual biomass" (e.g. livestock effluents, agricultural waste). Under this framework, the TOBIAS project, launched in 2020 and funded by the Piedmont Region (North-western Italy), is aimed to investigate the development and application of a biomethane supply chain for agricultural tractors engines. The project involves both industrial and academic partners: FPT Industrial, the project-leader, focusing on development and industrialization of the engines; STC srl, providing support to R&D; DIMSPORT srl, integrating engines and biomethane fuel systems; Torino Crea Engineering srl, specialized in the construction of special vehicles; Hysytech srl, skilled in gas treatment and recovery; CNR-STEMS, focusing on the assessment of the system sustainability and promoting the advancement and dissemination of knowledge and technologies. The project will lead to the development of two biomethane-powered prototypes, one wheeled and one crawler. The development will consist of: i) vehicle and engine components design; ii) engine construction and testing to identify optimal operating conditions; iii) tractors configuration for the use of compressed or liquefied biomethane; iv) field-tests to determine vehicle performance (power, torque, consumption, etc.) in real conditions; v) demonstration of the specialized biomethane-powered tractors while performing agricultural operation in a vineyard and on-farm refueling. In the present contribution, project framework, preliminary results and future implications are discussed.

Introduction

One of the greatest challenges of our time is the search for alternative energy sources with the aim of counteracting climate change. The replacement of fossil fuels is relevant both for the scarcity of non-renewable fuel reserves and for the containment of greenhouse gases emissions. Furthermore, the recent Russia-Ukraine conflict underlines the importance of "energy independence" [1]. Indeed, numerous strategies and policy measures have been implemented to facilitate the transition towards a sustainable and low-carbon energy system [2]. The 2030 Agenda promoted by the United Nations identifies two primary objectives to face climate change and mitigate its impact. The first is to ensure universal access to clean energy, the second is the promotion of sustainable models of energy production and consumption.

The European Union (EU), through the adoption of the so-called "European Green Deal", recently regulated by the European Climate Law (Regulation 2021/1119 of European Parliament and Council) [3], sets the ambitious long-term objective of being climate-neutral by 2050. In order to achieve this goal an intermediate action plan has been adopted, which include for the period between 2020 and 2030: i) reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels; ii) ensuring at least 32% share for renewable energy; iii) improving energy efficiency of at least 32.5% [4]. Moreover, current EU policies for non-CO_2 emissions are projected to reduce methane (CH_4) emissions by at least 29% by 2030 compared to 2005 levels [5]. Furthermore, in the revised Renewable Energy Directive (2018/2001/EU) a specific target for the transport sector is aimed at increasing by 2030 the share of renewable energy in road and rail transport by at least 14%, including a minimum share of 3.5% of "advanced biofuels" [6,7].

At the same time, also the agricultural sector has developed a sensitivity toward the environmental sustainability issues, obtaining competitive advantages from being branded "CO_2 free".

According to Flammini et. al., (2021) [8] more than half (52%) of the global emissions due to energy use in agriculture derives from the combustion of fossil fuels to power tractors and other agricultural machinery. Furthermore, the agricultural sector produces large quantities of organic waste, such as livestock manure, crop residues, straw and agro-industrial waste not fit for food or feed.

In this contest, the Anaerobic Digestion (AD) process represents a solution able to meet agricultural waste management, agricultural and environmental policy goals, producing value-added products including advanced biofuels.

The main product derived from AD process is biogas, mainly composed of CH_4 (50-75%), CO_2 (25-50%) and H_2S (1-2%) [9]. By removing CO_2 and other impurities is possible to produce a high purity methane (CH_4) stream, which is called "biomethane" (bio-CH_4) which can replace traditional natural gas and can also be used as gaseous fuel in transportation applications [10]. Moreover, being fully compatible with natural gas, biomethane can be fed directly into the existing gas grid, transported via tankers to large off-grid users, or dispensed as a vehicle fuel at fueling stations [11,12].

With the aim of a more sustainable agriculture, biomethane represents a valid alternative to fossil fuels to power agricultural tractors. Indeed, it could be potentially produced and consumed within the farm preserving the "land use efficiency".

Some studies have been carried out, mainly related to dual-fuel prototypes which allow using simultaneously biomethane or natural gas and diesel as ignition fuel. Bisaglia et al. [10] focused on the design and performance assessment of a first-generation tractor prototype provided with a commercially available bi-fuel engine adapted for the purpose. The prototype was tested both in laboratory and field conditions and showed similar performances to the comparable baseline with diesel engine. In particular, in field test conditions, the main issue resulted autonomy, equal to 40% of a comparable standard tractor; as underlined by authors, this may not be a problem if the farm produces its own biomethane or if it is close to a fuel station or if the tasks assigned to the methane tractor within the farm fleet are focused on a low intensity use of power. Furthermore, Owczuck et al. [13] focused on the characteristic of the fuel, evaluating the use of biogas without its prior upgrading to biomethane as fuel for tractor with dual-fuel self-ignition engines. The tests performed showed that the engine powered by dual-fuel worked stably when diesel was replaced by 40% biogas (containing a maximum of 50% of CO_2) or 30% methane, without significantly affecting the dynamics of the vehicle and its useful properties. Moreover Thuneke et.al. [14] compared the influence of the operation modes (dual-fuel and pure diesel), focusing on the emissions of nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM). Comparative measurements between dual-fuel and diesel operation showed higher concentrations in dual-fuel mode for all monitored exhaust components (except NOx). However, they reported that the specific emissions in dual-fuel mode could be reduced significantly by change of gas engine control unit settings, emphasizing the importance of further development of dual-fuel tractors. However, pure biomethane based powered tractor concepts have not reached any considerable level of development yet.

Indeed, as pointed out by Ettl et. al., (2014) [15] a number of issues related to the design and development of alternative fueled tractors still need to be solved including: i) high development budget compared to the scale of the production; ii) reduced available space for fuel tank; iii) necessity of refueling station near or within the farm; iv) high energy demand and high range of operation modes for efficient work.; v) environmentally sensitive working condition.

Consequently, steps forward are required for research on biomethane-fueled tractors and their application in real conditions, also with the aim of making such solution technically and economically affordable.

The "TOBIAS" Project

Based on these premises, a research project, named "TOBIAS - *Trazione a biometano per una filiera circolare nell'agricoltura specializzata*" funded by Piedmont Region (North-West Italy) and European Union, through "Programma Operativo Regionale

- *Investimenti a favore della crescita e dell'occupazione*"

F.E.S.R. 2014/2020 was launched in 2020 with the aim of investigating the development and application of a biomethane supply chain for agricultural tractors engines. More in detail, the project intends to develop agricultural vehicles equipped with methane-fueled engines, specifically suited for vineyards and orchards. Hence the TOBIAS project will lead the development of four gas-powered prototypes, two wheeled and two crawlers and to the definition of a local supply chain for biomethane production. The operational autonomy of the prototype tractors, the weak point of all natural gas vehicles, will be increased through the use of a tank for liquefied natural gas specially designed for use on agricultural vehicles, so as to expand the possibilities of adoption and diffusion in new markets. The liquefaction of biomethane will take place in a plant specifically sized for the needs of the agricultural sector characterized by on-farm biomethane production.

The project partnership provides collaboration between companies and research centers and covers all the fundamental aspects of the supply chain. The project leader is FPT Industrial, the global powertrain brand of CNH Industrial N.V., in charge of the main development and industrialization of the engines. The other project partners are: STC srl, a company providing design and engineering services mainly in the automotive and transport sectors; DIMSPORT srl, a company specialized in the development of electronic engine control systems as well as in R&D on alternative fuels in the automotive sector; TORINOCREA ENGINEERING srl., a company specialized in construction of special vehicles, HYSYTECH srl, an engineering company operating mainly in the field of generation, treatment and recovery of industrial gases, organic liquids and energy. Lastly, the Turin branch of CNR-STEMS (National Research Council - Institute of Sciences and Technologies for Sustainable Energy and Mobility), represents the academic partner that will focus on the assessment of the entire supply chain sustainability and on dissemination of knowledge and technologies.

The project implementation will allow FPT Industrial to increase its offer of low environmental impact vehicles and will offer other partners the opportunity to develop technologies and systems suitable for promoting the production of renewable fuels in agriculture, also in line with the Ministerial Decree of 2 March 2018: "Promotion of the use of biomethane and other advanced biofuels in the transport sector", the so-called "Biomethane decree" [16].

The present paper will focus on the description of the fundamental steps of the research project and will present preliminary results obtained during the first two years of activities. In details the activities include on one side the realization of tractor prototypes and, on the other side, the design of a circular and local biomethane supply chain, aimed at substituting diesel engine tractors.

Materials and Methods

The project includes five main steps: i) vehicle and engine components design; ii) engine construction and testing to identify optimal operating conditions; iii) tractors configuration for the use of compressed or liquefied biomethane; iv) field-tests to determine vehicle performance (power, torque, consumption, etc.) in real conditions; v) demonstration of the specialized biomethane-powered tractors while performing agricultural operation in a vineyard and on-farm refueling.

The industrial partners will work on the components of the supply chain, while the academic partner will perform experimental tests and certification of the results.

Prototype Realization and Performance Certification

In detail the following tasks are to be pursued by project partners for the realization and the demonstration of the biomethane supply chain:

1. FPT Industrial will give support in R&D and in particular will design and realize a 55 kW 4-cylinder biomethane engine, aimed at powering two types of specialized tractors: a crawler to be used in hilly vineyards and a wheeled tractor for sectors such as animal husbandry or fruit growing.
2. Hysytech will develop a biogas refining system and a biomethane liquefaction system, both tailored for the agricultural sector. Moreover, a biomethane compression station will be created to supply agricultural vehicles. Hysytech will also design a cryogenic tank for agricultural tractors for the use of liquid biomethane as an alternative to compressed biomethane.
3. STC will design the integration of engines and fuel storage/supply systems on tractors starting from available machines equipped with traditional Diesel engines. STC will perform research on an innovative exhaust system and an innovative concept of tractors to better accommodate gas tanks or other forms of energy storage (batteries).
4. Dimsport will integrate engines and biomethane fuel systems by installing the engine and fuel storage systems on prototype tractors.
5. TORINOCREA ENGINEERING will carry out the modifications on the prototype bodies.
6. CNR-STEMS will experimentally certify the performance of the tractors and the results of the project while on-field testing will be performed with a prototype tractor in "Fontanafredda", a wine-producing farm based at Serralunga d'Alba (Italy. 44°37'N, 8°00'E, 414 m asl).

Definition of Circular and Local Supply Chain for Biomethane Production

In order to validate the circular model pursued by the project, the theoretical biomethane production potential from agricultural waste has been carried out at local level. As a first step, potential availability of agricultural wastes and related biomethane yields have been assessed at the regional level. For a preliminary phase, the analysis has focused on the regional amount of livestock manure and slurry.

Most of the data were obtained from the official Agricultural information system of Piedmont (SIAP) a regional Data Warehouse service that provides statistical information on the entire agricultural sector of Piedmont Region. Within this system, the "Agricultural Register" is the integrated database that manages the information on farms, crops and livestock [17].

Data related to the type and number of housed livestock, and specific production of manure and slurry per live weight, were retrieved from annex 1 of the regional regulation 29 October 2007, n. 10/R [18]. Calculation of the total amount of animal waste was made according to Eq. (1):

$$\begin{aligned} &Tons\ of\ \ manure\left(t\right)=\sum Number\ of\ \ heads_a \\ &\times live\ weight\left(t\right)\times tons\ of\ \ manure \\ &/slurry\ \ produced\ per\ tons\ live\ weight^{-1}\times CF \end{aligned} \quad \text{Eq. (1)}$$

where a is the livestock category and CF is the collection factor, set to 90% in line with regional statistics related to the number of housed animals. Indeed, this quantity cannot be collected and used entirely to produce biomethane, due to agricultural practices that do not involve the housing of animals (e.g., extensive farming, alpine pasture, grazing). The tons of produced slurry were obtained by applying a density

TABLE 1 Quantities of livestock waste calculated and relative theoretical biogas yields.

Biomass type	Amount of collectable livestock waste	DM	VS	Reported biogas yield	CH_4 in biogas	References
	tons	%	% of D.M.	(m^3 t VS^{-1})	%	
Cattle slurry	5853919.4	8	75	375	60	Ravina et al. 2019
Cattle manure	4660934.8	5	68	500	60	Ravina et al 2019
Pig slurry	3110234.9	23	78	290	60	Ravina et al 2019
Pig manure	2835.3	24	83	500	60	Ravina et al 2019
Poultry manure	262896.5	60	65	375	60	Ravina et al 2019

equal to 1 (1 m^3 = 1 t). The potential biomethane yield was calculated using the theoretical biomethane yields reported in literature.

The potential biomethane yield was calculated using the following equation:

$$Nm^3\ of\ BioCH_4 = tons\ of\ collectable\ livestock\ waste \times DM \times VS \times Biogas\ yield \times CH_4\ content \quad \text{Eq. (2)}$$

where DM and VS are the livestock waste dry matter content (%) and the volatile solids content (% of dry matter), respectively. This values, including the potential biogas yields, of each by-product, are derived from Ravina et. al., (2019) [19], while the percentage of methane contained in the biogas derives from Cucui et. al., (2018) [20].

In order to determine the quantity of biomethane necessary for the complete replacement of the diesel (annual energy requirements), the respective net calorific values were used, equal to 33.09 MJ Nm^{-3} for the biomethane [21] and 42.84 MJ kg^{-1} for the diesel [22].

$$MJ\ years^{-1} = L\ years^{-1}\ of\ diesel\ or\ m^3\ of\ biomethane \times Net\ Calorific\ Value \quad \text{Eq. (3)}$$

The annual consumption of diesel fuel for agricultural tractors was obtained from the online database "Agricultural Motors Users" of the Piedmont Region and calculated on the average of the last six years, equal to approximately 215.05 × 10^6 L $year^{-1}$.

In addition, using the equation (Eq. 4) proposed by Shin and Kim, (2018) [23], the carbon dioxide (CO_2) emissions generated by the combustion of both diesel and biomethane were quantified and compared.

$$kg\ of\ CO_2\ emitted = FC \times SG \times EF \quad \text{Eq. (4)}$$

where *FC* is the diesel or biomethane consumption, *SG* is the specific gravity, equal 0.85 kg L^{-1} for the diesel [23] and 0.729 kg m^{-3} for the biomethane [21], finally *EF* is the CO_2 emission factor equal 3.12 kg kg^{-1} [23] and 2.75 kg kg^{-1} [21] for diesel and biomethane, respectively.

Results

Prototype Realization and Performance Certification

During the first two years of the project some preliminary results have been achieved. FPT Industrial carried out the design of the new F28 engine powered by natural gas. Indeed, for first tests on methane-fueled engines it was assumed that natural gas, as fuel, had a similar behavior to biomethane. All necessary components have been realized and the first two prototypes of crawlers have been completed. The engine has been tested at bench dynamometer for an initial set-up phase.

The technical specification of the F28 engine is reported in Table 2. At present, the developed engine is characterized by sustainable solutions ensuring lower CO_2 and pollutant emissions (a virtually "zero carbon" footprint, when powered by biomethane): a stoichiometric combustion technology and multipoint injection have been adopted to guarantee excellent performance and very low emissions. The prototype, designed with a maintenance-free 3-way catalytic converter, does not need Exhaust Gas Recirculation (EGR) valve, Diesel Particulate Filter (DPF) or Selective Catalytic Reduction (SCR).

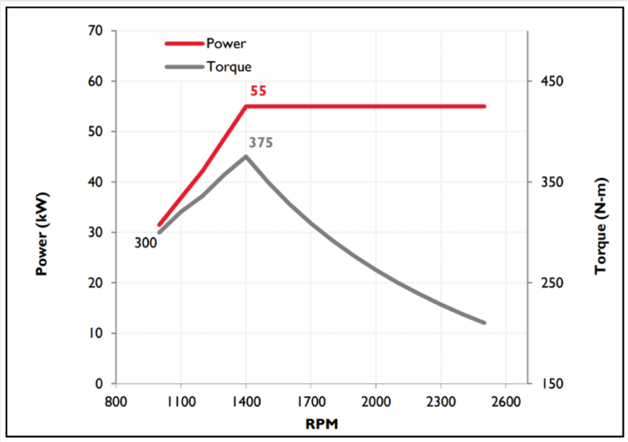
Nevertheless, the development of the F28 gas engine on the test bench will continue with the aim of further improving fuel consumption and further reducing polluting emissions.

On the other hand, the design phase of the crawler's body has been completed. This phase started with the virtual

TABLE 2 Technical specifications of the F28 engine.

Architecture	In-line 4-cylinder engine
Bore x Stroke (mm)	90.8 × 108
Number of Valves per cylinder	2
Injection system	Multi-point injection
Air handling	WG (TCA)
Peak power (kW)	55 (75 hp)
Maximum torque (Nm)	375
Dry weight (kg)	290
Dimension (L x W x H, mm)	623 x 580 x 750
Service interval	600 h
ATS	TWC

FIGURE 2 Engine performance curve.



installation of the gas tanks and the engine, in order to identify the main changes to the frame structure and engine cradle. Then, the body shell of the prototype has been built and installed on the vehicles transformed to run with natural gas (Figure 3 and Figure 4).

S.T.C. and DIMSPORT jointly carried out the transformation of the original machine equipped with a diesel engine, into the prototypes with a gas engine. In particular, STC focused on the design of the tractor body shell necessary to install the new engine and the gas tank, while DIMSPORT removed all the components related to the diesel engine and focused on the new structural components of the vehicle necessary to complete the construction of the first prototypes.

Activities relating to wheeled vehicles began, identifying the production vehicle to be transformed by installing the gas components.

CNR-STEMS defined an adapted test protocol to verify the performance of tractors powered by methane/biomethane, in terms of Power take-off and engine tests, drawbar power

FIGURE 3 Gas-powered crawler. Side view.

FIGURE 4 Gas-powered crawler. Top view.

and fuel consumption. With this regard, the Organization for Economic Co-operation and Development (OECD) standard code for the official testing of agricultural and forestry tractor performance (Code 2) was adopted as the baseline protocol and further implications for tractors powered by methane/biomethane were analyzed. In detail, main amendments have been identified in terms of specific consumption measurements. Indeed, the test protocol and instrumentation must simultaneously detect the torque and the engine speed and the quantity of fuel consumed at the different points of the engine curve (g kWh^{-1}). To perform the fuel consumption measurements, it will be necessary to place the measurement system (a gas flow meter) on the gas supply line, intercepting the flow. The same measurement system will then have to be interfaced with the two different acquisition systems used in stationery and motion conditions since the standard test protocol requires these measurements to be carried out with a dynamometric bench to detect consumption and power delivered at the P.T.O and with a dynamometric vehicle to measure the consumption and the power delivered to the wheels during traction operations on a test track. Once the measurement system has been implemented, it will be possible to carry out the first tests for the system's set-up that would provide further indications for the definition of the test protocol.

At present, the first prototype of crawler with F28 gas engine started the first tests in field conditions at "Fontanafredda" farm situated in the wine production district of Langhe. Such tests were a preliminary setup demonstrating the ability of the vehicle to perform the most common farming operations for working in the vineyard. The tractor was also used to assist traditional vehicles during the autumn 2021 harvest (Figure 5).

Definition of Circular and Local Supply Chain for Biomethane Production

The annual potential biomethane yield from solid and liquid excreta, calculated according to the Eq. 2, is about 246.9 × 10^6 m^3 $year^{-1}$ (Table 3). Using Eq. 3, the thermal energy was calculated, which for the whole annual potential biomethane yield

FIGURE 5 Prototype of crawler endowed with F28 gas engine in practice field test.

TABLE 3 Potential biomethane yield from livestock waste.

Biomass type	Potential biomethane yield	Energetic potential
	m^3 year^{-1}	10^9 MJ year^{-1}
Cattle slurry	79027911.9	2.6
Cattle manure	47541535.0	1.6
Pig slurry	97087848.5	3.2
Pig manure	169437.5	0.0
Poultry manure	23069167.9	0.8
TOTAL	246895900.8	8.2

was found to correspond approximately to 8.2×10^9 MJ year^{-1}.

Based on the average tractor fuel consumption reported by the database of the Piedmont Region "Agricultural Machineries Users data warehouse" equal to approximately 215.05×10^6 L year^{-1} the energy requirements for regional tractor fleet is has been estimated to be equal to 7.8×10^9 MJ year^{-1} (Eq. 3).

By comparing the estimated energetic potential of biomethane from livestock manure with the energy requirements of the tractor fleet in the Piedmont Region, results reveal that 95.7% of the biomethane would be sufficient to replace the diesel fuel.

In order to assess the sustainability of methane/biomethane application in agricultural tractors, the theoretical reduction in GHG emissions was calculated estimating the total amount of CO_2 emissions from the entire fleet of agricultural diesel-fueled tractors at regional scale and comparing the potential amount of total CO_2 emissions from alternative gas fuels. The amount of CO_2 emissions was calculated according to Eq. 4 for both types of fuel, in detail 558.2×10^3 tons of CO_2 per year and 464.4×10^3 tons of CO_2 per year were estimated for diesel and biomethane, respectively. Therefore, approximately 93.9×10^3 tons of CO_2 per year could be potentially saved, which correspond to a 16.8% reduction in CO_2 emissions.

Discussion

The preliminary results of the project are promising, however only after the implementation of laboratory-scale and field tests it will be possible to validate the actual performance of the prototypes realized.

With reference to the design and prototyping phase, the study of the layout of the gas tanks setting and positioning resulted one of the major obstacles to the implementation of the prototype. Indeed, this issues directly affect the amount of gas to be loaded and thus the autonomy of the tractor. In addition, a number of constraints must be respected for the installation of tanks since mass and position of the gas tanks could affect the set-up of the tractor, the position of the center of gravity and the operator's field of vision [10].

At present, the OECD test protocol for determining the engine performance of agricultural tractors (Code 2) only consider the adoption of liquid fuels, typically diesel, the most common fuel used in the endothermic engines. All requirements, measurements and general rules and directions provided to perform tests on agricultural tractor engines just refer to this fuel and in particular to the "specific fuel consumption" which is defined as the mass of fuel consumed per unit of work, expressed in grams per kilowatt hour (g kWh^{-1}). Nevertheless, given the importance that methane/biomethane are acquiring in the transport sector, it is crucial to adapt a test protocol to verify the performance of tractors powered by these types of alternative fuel. Furthermore, to our knowledge, there are no test stations that are currently equipped with instrumentation that allows the measurement of alternative fuels other than diesel for carrying out the tests. Hence, it is necessary to identify a suitable gas measurement system to be used for methane/biomethane.

A part from the prototyping and testing phases, some key economic aspects and considerations from the TOBIAS project may be stressed.

The development of the natural gas engine (suitable for biomethane) for small agricultural vehicles in the "Specialty" and "Utility" categories (2.8 liters of displacement, 55kW power), as well as the construction, demonstration and industrialization of these vehicles is absolutely new for the sector. Previous experiences in the development of natural gas agricultural vehicles have been based on the adaptation of road derivation engines to agricultural vehicles. These first prototypes of APH class gas tractors (with power> 150kW) highlighted the need for the development of dedicated engines for the industrialization of these vehicles and stimulated demand in the agricultural sector.

The type of agricultural vehicles that will be developed as part of the project is usually produced in limited numbers (500-1000 units per year) in traditional configuration with diesel engine. Typically, the launch of a new version, such as the one with biomethane engine developed within the TOBIAS project at prototype stage, includes a phase of project validation and the creation of a remarkable number of pre-series vehicles. This pre-series phase normally involves production volumes that would not justify a complete integration into the production line of agricultural vehicles. In this context, the TOBIAS project, promoting collaboration with external partners, represents a R&D model economically more viable, such model is expected to be applied also for the joint exploitation of the results.

Moreover, a number of expected economic and environmental outcomes can be drawn.

The main economic outcome consists in the practical demonstration of the existence of possible new markets, including not only agricultural machinery powered by biomethane engine but also the demand for plants producing biomethane.

As previously reported, biomethane agricultural machinery could contribute to decarbonization objectives [12], however, without biomethane production plants, the market of biomethane fueled tractors has no chance to further develop. Conversely, the TOBIAS project could demonstrate the feasibility of biomethane fueled tractors and of biofuel production at agricultural scale.

Currently, only some types of livestock manure have been analyzed and considered (pig, cattle and poultry), however according to the fundamental of the circular economy, other types of manure and all agro-industrial by-products (crop residues), including the organic fraction of municipal solid waste (OFMSW), could become part of the energy production chain. The utilization of these by-products improves the land use efficiency, since they do not cause any indirect land use change impacts (ILUC), allowing to improve the agricultural production sustainability and biodiversity by strengthening the economic competitiveness of farms and at the same time reducing greenhouse gas emissions [24,25].

Future Steps of the "Tobias" Project

During 2022, the body of the second crawler tractor will be built and installed. In addition, this second vehicle will be equipped with different tanks, in order to maximize autonomy, while the first crawler will be updated later.

At the same time, the design of wheeled vehicles will be carried out and also in this case the prototyping will start from the virtual installation of the cylinders and the engine, in order to identify the main changes to the frame structure. Then the body shell of the prototypes will be designed and subsequently built and installed on the vehicles which, in the meantime, will have been transformed to run with natural gas.

The development of the vehicles will be carried out through in-field tests demonstrating in real condition the procedure for natural gas refueling and prototype autonomy. In the meantime, the development of the engine on the test bench will continue in order to meet the performance requirements of a wheeled vehicles.

Summary/Conclusions

The new markets connected to the results of the TOBIAS project not only generates new products, jobs and investments, but contributes to the reduction of GHG emissions in the context of the Paris agreements and represents a further step towards decarbonization. Such elements can be particularly exploited in a context of growing demand for sustainability of production in the agricultural sector.

With this regard a theoretical and practical estimation of biomethane producing potential from agricultural waste has been carried out at regional level. Indeed, solutions for biofuels production are country-specific, as they depend on climate, soil conditions, policy and existing agricultural practice, among other factors. Moreover, under a circular economy perspective, agricultural waste should be the preferential development biomass source; thus, as a first step, potential availability of agricultural wastes and related biomethane yield should be assessed at regional level. Agricultural and livestock waste are an important resource already employed for the production of electricity and heat. The project will be the occasion to verify the potential biomethane yield at regional scale in order to offer farms the realistic possibility of starting "CO_2 free" production, being energy self-sufficient for both electricity and fuel, maintaining food safety and land use efficiency and allowing them a significant competitive advantage in a market.

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Definitions/Abbreviations

AD - Anaerobic Digestion

DM - Dry Matter

VS - Volatile Solids

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