



# Application of Carbon Footprint to an agro-biogas supply chain in Southern Italy



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## HIGHLIGHTS

- We used the methodological approach established by UNI EN ISO 14067 (2013).
- We studied in detail an LCI of an agro-biogas supply chain located in Southern Italy.
- Carbon sequestration was enabled by no-tillage practice in the investigated farm.
- Low impacts were observed for transportation due to the short supply chain.
- Environmental improvement was shown by reduction of the ammonium nitrate use.

## ARTICLE INFO

### Article history:

Received 27 October 2014

Received in revised form 16 January 2015

Accepted 22 March 2015

### Keywords:

Agro-biogas

Carbon Footprint

No-tillage

Carbon sequestration

Mineral fertilisation

Environmental sustainability

## ABSTRACT

Over the last few years, agro-biogas has been receiving great attention since it enables replacement of natural gas, thereby representing a tool which reduces greenhouse gas emissions and other environmental impacts. In this context, this paper is aimed at the application of the Carbon Footprint (CF) to an agro-biogas supply chain (SC) in Southern Italy, according to ISO/TS 14067:2013, so as to calculate the related 100-year Global Warming Potential (GWP<sub>100</sub>).

The topic was addressed because agro-biogas SCs, though being acknowledged worldwide as sustainable ways to produce both electricity and heat, can be source of GHG emissions and therefore environmental assessments and improvements are needed. Additionally, the performed literature review highlighted deficiencies in PCF assessments, so this study could contribute to enriching the international knowledge on the environmental burdens associated with agro-biogas SCs.

The analysis was conducted using a life-cycle approach, thus including in the assessment: functional unit choice, system border definition and inventory analysis development. The primary data needed was provided by a farm located in the province of Foggia (Apulia region in Southern Italy), already equipped with anaerobic digestion and cogeneration plant for biogas production and utilisation. Results from this study are in agreement with those found by some of the most relevant studies in the sector. Indeed, it was possible to observe that GWP<sub>100</sub> was almost entirely due to cropland farming and, in particular, to the production of ammonium nitrate in the amount required for fertilisation. Furthermore, environmental credits were observed thanks to: carbon sequestration enabled by no-tillage practice; and avoided production of chemical fertiliser thanks to 50% organic farming. Based upon the results obtained, a sensitivity analysis was carried out, thus highlighting reduced environmental impacts if ammonium nitrate was replaced with urea.

Finally, thanks to this study, all the target stakeholders will learn more about the input/output flows involved in the system analysed, the related environmental impacts and the improvements needed to reduce them. In this way, it could be possible to compare the analysed agro-biogas SC with others of equal functionality, and so to enable considerations to be made on the resulting similarities and differences in terms of methodological approach, inventory flows and environmental impact.

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## 1. Introduction

Sustainable systems for agro-biogas production and management could provide a significant contribution to the reduction of

## Nomenclature

|                    |                                                |        |                                                            |
|--------------------|------------------------------------------------|--------|------------------------------------------------------------|
| CA                 | conservation agriculture                       | MiPAAF | Ministero delle Politiche Agricole, Alimentari e Forestali |
| CF                 | Carbon Footprint                               | NMVOC  | Non-Methane Volatile Organic Compounds                     |
| EPD                | Environmental Product Declaration              | NT     | No-Tillage                                                 |
| PCF                | Product Carbon Footprint                       | PAS    | Publicly Available Specification                           |
| DLUC               | Direct Land Use Change                         | RED    | Renewable Energy Directive                                 |
| GHG                | Greenhouse Gas                                 | SC     | Supply Chain                                               |
| GWP <sub>100</sub> | 100-year Global Warming Potential              | SF     | (Digestate) Solid Fraction                                 |
| ILUC               | Indirect Land Use Change                       | SOC    | Soil Organic Carbon                                        |
| IPCC               | Intergovernmental Panel on Climate Change      | TS     | Technical Specification                                    |
| ISO                | International Organisation for Standardisation | UM     | Unit of measurement                                        |
| LCA                | Life Cycle Assessment                          | WBCSD  | World Business Council for Sustainable Development         |
| LCI                | Life Cycle Inventory                           | WRI    | World Resources Institute                                  |
| LCIA               | Life Cycle Impact Assessment                   |        |                                                            |
| LF                 | (Digestate) Liquid Fraction                    |        |                                                            |

Greenhouse Gas (GHG) emissions as established by the Renewable Energy Directive (RED) – 2009/28/EC and subsequent amendments and additions [1–3]. In this regard, Life Cycle Assessment (LCA) can be used to address the environmental impacts associated with agro-biogas Supply Chains (SCs), from feedstock production and supply to electricity and heat cogeneration. LCA has evolved significantly during the past three decades so as to become more systematic and robust for both identification and quantification of the environmental impacts associated with products' life-cycles [4,5]. Actually, some studies [6–8] highlighted that two different LCA approaches exist, i.e. attributional and consequential. According to these studies, attributional LCA is based upon the evaluation of systems' environmental performance and the allocation of the environmental burdens among all the outputs. In contrast, consequential LCA evaluates the effect of change in the system and provides application of system expansion or substitution methods. Specifically, RED recommends allocation based upon the product's energy-content, while ISO standards 14040-44:2006 [9,10] suggest application of the attributional approach by both avoiding (when possible) allocation and applying system expansion, thus resulting in an hybrid method. In contrast, according to these standards, where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between the different products and functions so as to reflect the underlying physical relationships between them. The different allocation approaches have led over time to variation of GHG-emission estimates by a factor of almost three, thus affecting the achievement of the RED targets [6]. As a result, according to Capponi et al. [11], the RED default values seem to be too uncertain for specific combinations of agro-biogas plant characteristics, feedstock choice, logistic organisation, digestate management and so. Such an uncertainty increases when GHG-emissions are attributed also to processing residues which are modelled as co-products using an appropriate allocation method. For many years, several studies have been conducted in order to deal with environmental assessment of agro-biogas production system by using LCA and have been published in scientific peer-reviewed journals. Lots of these studies could be considered as milestones in the field of agro-biogas environmental assessment. Some of them focussed on the specific feedstock used, others on biogas production plants by geographical regions and some others on the individual processes in biogas [12–14]. For instance, Dressler et al. [15] and Cherubini [16] highlighted that environmental impact of biogas generally varies according to regional farming operations and, also, to soil and climate conditions, crop production yield and cultivation management. Similarly, the studies of Börjesson and Berglund showed

that different raw-material properties, energy efficiency of biogas production, and end-use technology affect the amount of emission by a factor between three and eleven [17–19]. Poeschl et al. [20], Poeschl et al. [21] investigated a number of biogas SCs in Germany in order to find ways for GHG-emission reduction. In particular, they estimated that the upgrading of biogas to bio-methane, with almost 100% conversion efficiency, causes six-time less Non-Methane Volatile Organic Compound (NMVOC) emissions. Additionally, they highlighted that the harnessing of residual biogas from digestate storage reduces methane releases by a factor of up to fourteen. Furthermore, a number of researchers reviewed the scientific literature dealing with the assessment of GHG-emission and environmental impact related to biofuels and bio-energies detecting papers published over the past two decades. In particular, Quek and Balasubramanian [22] highlighted that generating and using bioenergy from waste, compared to fossil fuel extraction and use, enable reduction of GHG emissions. In contrast, it causes an increase of acidification and eutrophication because of both production and administration of the chemicals commonly used in agriculture. In addition, Cherubini and Strømman [23] pointed out and discussed the key issues and methodological assumptions which are responsible for wide ranges and uncertainties in bioenergy LCAs [24,25].

In this context, Carbon Footprint (CF) can be applied to agro-biogas supply chains, so as to quantify emission of GHGs and to further minimise their potential sources by identifying appropriate improvement solutions. Over the years, a number of studies have been conducted with the aim of calculating CF associated with bioenergy SCs. This was usually done according to PAS 2050:2011 [26] and to the “Greenhouse Gas Protocol” issued by the World Business Council for Sustainable Development (WBCSD, 2013) [27] and entitled as “Product Life Cycle Accounting and Reporting Standard”. These methods consider the Global Warming Potential (GWP) factors published by the IPCC in the Fourth Assessment Report (AR4) [28]. Among the aforementioned studies, Uusitalo et al. [8] integrated the RED approach with the system expansion method based upon both the ISO 14040:2006 standard and the 2011 GHG protocol issued by WBCSD. Additionally, Knudsen et al. (2014) assessed the 100-year Global Warming Potential (GWP<sub>100</sub>) related to crop production from organic and conventional arable rotations using the characterisation factors provided by the [28] standards for greenhouse gases. In contrast to Uusitalo et al. [8], Knudsen et al. [29] used LCA focussing only on GHG emissions. After a long debate, the International Organisation for Standardisation issued the Technical Standard (TS), ISO/TS 14067:2013 [30], in order to

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