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TABLE OF CONTENTS

ABSTRACT…………………………………………………………………P. 6

PART I - SCIENTIFIC PROJECT…...P.9

INTRODUCTION……………………………………………………………..P.10

CHAPTER 1: CIRCULAR ECONOMY AND BIOECONOMY…………………..P.13

1.1 The "Circular Economy" and "Bioeconomy" – concepts, opportunities and limitations ……………………………………………………………………………………….P.13
1.2 Overlaps and differences between "Circular Economy" and "Bioeconomy"……….P.15
1.3 Legislative framework of "Circular Economy" in the European contest…………...P.17
1.4 Priority areas of "Circular Economy" in the European and Italian contest………...P.19

CHAPTER 2: AGRICULTURAL BY-PRODUCTS………………………………...P.22

2.1 Legislative framework for by-products: Ministerial Decree No.264 of October 13, 2016…………………………………………………………………………………...P.22
2.2 Availability of wood by-products from the forestry sector………………………….P.25
    2.2.1 Results………………………………………………………………………..P.28
2.3 Availability of herbaceous and woody by-products from the agricultural sector…...P.29
    2.3.1 Herbaceous crop by-products………………………………………………...P.33
    2.3.2 Tree crop by-products………………………………………………………..P.34
        2.3.2.1 Olive groves……………………..P.35
        2.3.2.2 Vineyards……………………………………………………………...P.36
        2.3.2.3 Orchards………………………………………………………………P.36
2.4. Estimation of livestock and agro-industrial sector by-products…………………….P.39
    2.4.1 Livestock effluents…………………………………………………………...P.39
    2.4.2 Olive processing……………………………………………………………...P.41
    2.4.3 Grape processing……………………………………………………………..P.44

2.5 Circular economy of by-products: nutraceutical, food, cosmetic field and restoration of soil fertility……………………………………………………………………………P.47
2.6 The impact of soil fertility on the characteristics of the rural landscape……………P.49

CHAPTER 3: FOCUS ON WINERY BY – PRODUCTS…………………………...P.57

3.1 The industrial wine-making process and by-products generated……………………P.57
    3.1.1 Wine making by-products…………………………………………………P.60
3.2 Legal framework of wine-making by-products……………………………………...P.61
    3.2.1 The definition of wine making by-products……………………………….P.61
    3.2.2 Distillation alternative re-uses of wine making by-products………………P.62
    3.2.3 Legal framework of winery wastewater re-use……………………………P.63
3.3 State of the art on re-use for wine making by-products……………………………..P.64

PART II - INDUSTRIAL PROJECT..P.72

INTRODUCTION……………………………………………………..P.73

CHAPTER 4: INDUSTRIAL PARTNER "INNOVA"…………………………...P.74

4.1 Innovambiente® software platform…………………………………………………P.74
    4.1.1 Ministerial decrees conformity and certifications…………………………P.74
    4.1.2 References and dissemination in Italy…………………………………...P.75
    4.1.3 System components and informatisation processes……………………..P.76
4.2 Collection center……………………………………………………………………P.78
    4.2.1 Collection center informatisation and conferments registration…………P.78
4.3 Main System…………………………………………………………………………P.81
    4.3.1 Profiling……………………………………………………………………P.82
    4.3.2 Programming and services control…………………………………………P.82
    4.3.3 Door-to-door report and municipal collection center……………………P.85

CHAPTER 5: MUNICIPAL WASTE LEGISLATIVE FRAMEWORK AND ESTIMATION IN BASILICATA REGION………………………………………P.90

5.1 Legislative framework for waste: Legislative Decree 152/06 (Single Environmental Text)……………………………………………………………………………..P.90
5.2 Legislative Decree 205/2010: amendments to the Legislative Decree 152/2006…...P.92
5.3 Legislative Decree 116/2020: amendments to the Legislative Decree 205/2010…...P.92
5.4 Law Decree No. 147 of December 27, 2013: waste tax concept and definition……P.94
5.5 Ministerial Decree of April 20, 2017: the "punctual tax"…………………………...P.94
5.6 Legislative framework of "End of Waste"……………………………………..P.96

CHAPTER 6: ORGANIC WASTE AND WINE BY-PRODUCTS MANAGEMENT STATE OF THE ART IN BASILICATA REGION………………………………...P.98
6.1 Territorial framework……………………………………………………………..P.98
6.2 Estimation of the organic fraction of municipal solid waste………….....................P.99
6.3 Organic waste and wine by-products in Basilicata region: state of the art and related problems……………………………………………………………………………..P.100

MATERIALS AND METHODS………………………………………P.104

CHAPTER 7: PLANNING THE INTEGRATED MANAGEMENT OF ORGANIC WASTE FLOWS AND WINE BY-PRODUCTS FOR A CIRCULAR ECONOMY: PROPOSAL OF ALTERNATIVE MODELS……………………………………...P.104
7.1 Organic waste from non-domestic users and wine by-products: a new valorisation model in the perspective of the circular economy……………………………………..P.104
    7.1.1 Calculation of economic saving…………………………………………P.113
    7.1.2 Calculation of environmental saving…………………………………….P.113
7.2 Organic waste from domestic users: a new valorisation model in the perspective of the circular economy………………………………………………………………………P.116
    7.2.1 Calculation of economic saving…………………………………………P.121
    7.2.2 Calculation of environmental saving……………………………………..P.121
    7.2.3 Calculation of the Waste Tax Reduction for domestic users……………………………………………………………………….P.121

CHAPTER 8: INTERNET OF THINGS (IOT) APPLIED TO PROPOSED MODELS…………………………………………………………………...P.123
8.1 IoT definitions and applications……………………………………………………P.123
8.2 IoT technologies applied to proximity composting……………………………..P.124
8.3 IoT technologies applied to domestic composting: application of a laboratory-scale probe for remote control of key parameters during the process………………………P.131
    8.3.1 "HALO" probe with Bluetooth® technology for direct Temperature and Ph analysis on solid and semi-solid samples………………………………………P.132
        8.3.1.1 Principles of operation……………………………………………P.133
        8.3.1.2 Data reading, saving and transferring……………………………..P.134
    8.3.2 Soil moisture meter Lutron-PMS 714……………………………………P.136
    8.3.3 Probes application: simulation of remote control during home composting……………………………………………………………………..P.137

PART III – INTERNATIONAL PROJECT…….P.145

INTRODUCTION……………………………………………………P.146

MATERIALS AND METHODS……………………………………P.147

CHAPTER 9: ADAPTING HOME COMPOSTING TO THE CITY OF PLOVDIV (BULGARIA)……………………………………………………………………P.147
9.1 Territorial framework of Bulgaria region…………………………………………P.147
9.2 City of Plovdiv: territorial framework and *state of the art* of urban waste management……………………………………………………………………………P.149
9.3 Organic waste from *domestic users* in the city of Plovdiv: a new management model in the perspective of the circular economy………………………………………………..P.150
    9.3.1 Calculation of economic saving……………………………………………P.155
    9.3.2 Calculation of environmental saving……………………………………..P.156

RESULTS AND DISCUSSIONS……………………………………P.157

GENERAL CONCLUSIONS………………………………………..P.161

BIBLIOGRAPHY……………………………………………………..P.164
SITOGRAPHY……………………………………………………..P.175
LEGISLATION……………………………………………………..P.176
SCIENTIFIC PUBLICATIONS PRODUCED BY THE DOCTORAL STUDENT………………………………………………………..P.178

ABSTRACT

Circular economy aims to create a system that allows optimal reuse of products and materials. The term defines an economy designed to regenerate itself. In a circular economy, there are two material flows: the biological ones, able to be reintegrated into the biosphere, and the technical ones, destined to be enhanced without entering the biosphere. The circular economy is therefore a system in which all activities, starting with extraction and production, are organised so that someone's waste becomes a resource for someone else, i.e. an economic system planned to reuse materials in subsequent production cycles, minimising waste. In the linear economy, on the other hand, once consumption is over, the product cycle ends and it becomes waste, forcing the economic chain to continuously repeat the same pattern: extraction, production, consumption, disposal. In this context, the contribution provided by the valorisation of residual biomass and municipal waste is fundamental for the production of renewable biological resources and their conversion into new value-added products. This is the background to the thesis work which has been divided into three main parts.

After an in-depth study on the circular economy concept, the differences and points of contact with the bioeconomy concept and above all the opportunities linked to it, in collaboration with **University of Basilicata** (**Scientific part of the project**) a general review was carried out. This review has considered the residual biomasses coming from the various agricultural activities (mowings and pruning by-products), from zootechnical activities (sludge deriving from animal manure, etc.), from agro-food activities (deriving from olive, wine, dairy, cereal processing, etc.) and from forestry activities (from forest cutting and use, forest cleaning, etc.) that are practised in the Basilicata region. Subsequently, a focus and a cognitive survey on the by-products generated by the wine sector in the Basilicata region, on their reuse state of the art and on their possible valorisation forms with particular attention to restoring soil fertility with a view to the circular economy, was carried out. The **industrial part of the project**, instead, was carried out with the collaboration of **Innova - Consorzio per l'Informatica e la Telematica srl**. After a general review of the waste legislation in the Basilicata region –

especially the differences between waste and by-products - the problems related to the state of the art concerning their production, management and disposal, the phD thesis work has focused on the feasibility study (economic and environmental) of new models for the management, treatment and valorisation of organic waste flows (from separate collection) and agricultural by-products (especially those coming from wine supply chain) from the perspective of the circular economy as an alternative to the current models based on the linear economy. These new governance models called "proximity composting" and “home composting”, alternative and more sustainable than the current one, on the other hand aim at a more sustainable management of these flows based on their “zero-kilometers treatment”. On the other hand, they aim to empower the communities that become an active part of the process: citizens are directly involved and partially autonomous in the management of their municipality waste. Specifically, starting from a basic organisational idea, an in-depth study on its real feasibility was carried out, based on an integrated planning of the different aspects involved in the elaboration of the models themselves. Subsequently, the discussion focused on IoT (Internet of Things) technologies applied to the proposed models with a dual purpose:

- remote control and monitoring in Near Real Time of each phase of the process: the flows collection, the transport, the final destination and the variation of the various parameters during the proposed composting process;
- possibility of implementing the "punctual tax" in accordance with the Ministerial Decree on the Environment of April 20, 2017.

The proposed models, alternatives to the current one - composting in very distant industrial plants - which is unsustainable, very expensive and disadvantageous, aim first of all to improve separate collection in each municipality, and consequently to reduce the amount of organic waste to be treated, but also to give wine by-products a more sustainable second life, in the context of the circular economy. Finally, in cooperation with the **international partner of the project**, the **Energy Agency of Plovdiv (EAP)**, after studying the state of the art regarding the production, management and treatment of municipal waste in the city of Plovdiv, the related problems and possible future challenges, the home composting model, hypothesised for the Basilicata Region, has been adapted to this city. As in the case of the Basilicata region, the model has been planned and studied from an economic and environmental point of view, and its feasibility has confirmed that it could be a good alternative to the current one, which does not provide for separate collection, but directly for the disposal of urban waste in landfills.

PART I

SCIENTIFIC PROJECT

INTRODUCTION

"Extract, produce, consume and reproduce'. This is the new economic model we are aiming for a circular economy that imitates natural cycles by transforming waste. Products are designed to be reused, regenerated and recycled. The transition from a linear economy to a circular economy requires a new model of production and consumption that makes more efficient use of resources. The modern world has exponentially increased its consumption of non-renewable natural resources, covering almost the entire periodic table of elements. Current trends confirm this: according to United Nations Environment Programme (UNEP) data, global material use has almost tripled over the past 40 years, from 26,7 billion tonnes in the year 1970 to 84,4 billion tonnes in the year 2018. As regards supply of these raw materials, the European industrial economy is in a highly vulnerable position, as it was highlighted by the Raw Material Initiative. In the year 2013, the European Commission's Raw Material Initiative identified a list of 20 critical raw materials that are strategic for the European Union (EU), highlighting a situation that is highly at risk from the point of view of supply, with just a few countries holding almost all of the world's production. Italy, the EU's second-largest manufacturing country, is among the countries most at risk because of its heavy dependence on foreign suppliers of raw materials: with rising resource prices and end-of-life treatment costs, this risk is set to grow.

In this context, therefore, where environmental protection in terms of sustainability, reduction of atmospheric emissions and 'substitution' of traditional fossil-based raw materials (oil, gas or coal) for renewable ones (biomass) is increasingly at the centre of political and other discussions, the concept of the 'circular economy' is understood as a radical change of perspective from a linear economic model (based on the exploitation of non-renewable resources) to a circular one, based on really renewable resources, in which every step chain is proposed in terms of social, economic and environmental sustainability and every fraction of the available resources is used in a new model and re-circulation, ideally tending towards a 'zero waste' model. The circular economy can be applied to all production sectors, such as agro-food, agriculture, forestry, livestock production and municipal solid waste, from which processes derive co-products, by-products and wastes, reintroducing into the production cycle the by-products (otherwise disposed as waste), defined by Legislative Decree 152/2006 as *objects or substances that cannot be considered as waste due to a series of characteristics defined in article 183-bis but reused for the energy production or products destined for other sectors such as construction, fertilisers, cosmetics, pharmaceuticals, food supplements, etc.* The term "sustainable bio-refineries" is thus used, by analogy with the concept of refining in the petrochemical industry, adopting chemical, biological and biotechnological processes based on single or multiple second-generation biomasses or by-products used as secondary raw materials, from which products with the highest possible added value can be obtained, taking into account environmental mitigation practices in particular with regard to greenhouse gas emissions, the concept of "zero waste" and the efficient use of resources.

For the agricultural-forestry sector, second-generation biomass chemistry represents a solution for its waste and processing by-products, as well as an opportunity to deal with the progressive land deterioration and marginalisation, to which the desertification risk has been added, and to reverse the trend of abandoning rural areas with new dedicated crops.

The 'zero waste' concept, although difficult to achieve in any production process, is at the basis of the circular economy model and would not only allow atmospheric emissions and disposal costs to be cut but also the valorisation of by-products for our country. This would mean counting on a valuable renewable source, which would allow smart and green growth in Europe and in Italy, with a decisive contribution to the achievement of the objectives that Europe has set for the future. The benefits associated with a transition to a circular economy are greater than the costs involved. According to the European Commission, building a circular economy can save between 10% and 17% of primary resources each year, a percentage that can grow to 24% by the year 2030 with the introduction of new production and recycling technologies. According to the Ellen Mc Arthur Foundation studies, this could result in net annual savings of up to $640 billion for the European manufacturing system in the cost of materials procurement, which is about 20% of the cost currently incurred. From an environmental point of view, reaching the recycling targets set by the European Union would allow a further reduction in greenhouse gas emissions, in addition to the targets already set, of between 424 and 617 million tonnes.

For all these reasons, the circular economy at European level is considered one of the most strategic sectors with the greatest potential for development, so much so that countries such as Sweden, Finland, the Netherlands and Germany have published a national strategy for the circular economy, while others such as Ireland have started the process of developing it and Italy needs to catch up with its main European partners. Under the drive of recent EU policies on the circular economy, and at the same time to sustain competitiveness in international markets, in the coming years Italy too will have to make a profound change in its production and consumption system, in order to convert the current linear model into a circular one. Such a transition will have to aim at improving the efficient use of resources and redefine production processes, the nature of goods and services, waste management, consumption patterns and lifestyles, but also contribute to economic competitiveness and social inclusion, favouring employment, equity and the well-being of individuals.

CHAPTER 1: CIRCULAR ECONOMY AND BIOECONOMY

Since the European Commission presented its Circular Economy Strategy and the related Action Plan, both on the topic of circular economy alone and on the relationship between bioeconomy and circular economy, a lot has been written. Several authors have suggested that both concepts should be fully integrated, or in other words that bioeconomy is simply a part of circular economy and should be treated as such. While some of the publicly discussed concepts seem worthwhile pursuing, some others do not hold up when put against the backdrop of economic, political and physical reality. Others may be based on misunderstandings or oversights.

Therefore, in order to fully understand the different concepts and definitions, the following questions must be answered correctly: what are the overlaps between the concepts? what are the differences? how can one contribute to another and where can we use synergies? But also, what are the limitations to fully integrating the concepts into another and what do we need to pay attention to?

1.1 The “Circular Economy” and “Bioeconomy” – concepts, opportunities and limitations

The ***“bioeconomy”*** encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy. (European Commission, 2012). It promises to:

- introduce healthy, safe and nutritious food, resource efficient and healthy animal feed, new food supplements;
- provide new chemicals, building-blocks and polymers and other materials with new functionalities and properties;
- provide bioenergy and biofuels replacing fossil energy;
- develop new, more efficient and sustainable agricultural and marine practices, improved bio-processing and biorefinery concepts, new process technologies such as industrial biotechnology;

- deliver solutions for Green and Sustainable Chemistry;

  thereby:
- contributing to mitigating climate change through the substitution of petrochemicals by materials with lower Green House Gas emissions from cradle to grave and of fossil fuels by biofuels;
- providing the most important renewable carbon source: biomass is the only source for renewable carbon – as long as the direct utilisation of CO_2 is still in an embryonic state, and
- bringing new business opportunities, investment and employment to rural, coastal and marine areas, fosters regional development and supports Small and medium enterprices (SMEs).

Especially new biorefinery concepts can contribute to an optimised utilisation of biomass to reach these objectives. The European Commission has encouraged that these biorefineries should adopt a cascading approach that favours highest value added and resource efficient products over for example bioenergy (European Commission, 2012): "Biorefineries should adopt a cascading approach to the use of their inputs, favouring highest value added and resource efficient products, such as bio-based products and industrial materials, over bioenergy and the advantages of the products over conventional products range from more sustainable production processes, to improved functionalities (e.g. enzyme-based detergents that work more efficiently at lower temperatures, save energy and replace phosphorus) and characteristics (e.g. biodegradability, lower toxicity)". (European Commission, 2012).

In its Circular Economy Action Plan, instead, the Commission defines the ***"circular economy"*** as "the economic space where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised" (European Commission, 2015). The document sets a special focus on the efficient use of resources (economic and ecological) and not only on waste, which is treated as a resource, consistent with the previous European Commission policy. The Action Plan includes two sectorial priorities directly linked to the circular economy: food waste and efficient conversion of biomass: "food waste is a key area in the circular economy and should be addressed at many levels along the value chain.” The Ellen MacArthur Foundation (2017) as a key player in this debate defines circular economy as a restorative, regenerative model where “nothing is lost and everything feeds a new cycle”.

This concept is still in an early stage, stronger on paper than in practice. Several recent articles indicate that this might still continue, since national policy makers cannot seem to find agreement on ambitious targets as proposed by the Commission. In December 2017, European Union institutions reached a provisional agreement with member states on crucial waste laws to accelerate the transition to a circular economy in Europe, with members required to recycle at least 55% of their municipal waste by the year 2025, 60% by the year 2030 and 65% by the year 2035. So, it seems that circular economy policy is moving in the right direction, but it moves slowly. Nevertheless, it has huge potential and it is crucial for a sustainable world.

The ***“cascading use”*** of biomass is strongly overlapping with the concept of the circular economy and it is mostly a part. The main target of cascading and circular economy is an increased resource efficiency at less demand for fresh materials, with both of these frequently linked to added value and job creation (European Commission, 2012).

1.2 Overlaps and differences between “Circular Economy” and “Bioeconomy”

The bioeconomy and circular economy share some of the targets: a more sustainable and resource-efficient world with a low carbon footprint. Both the concepts avoid using additional fossil carbon to contribute to climate targets. The **circular economy** strengthens the resource efficiency of processes and the use of recycled materials to reduce the use of additional fossil carbon (either embedded in the material or emitted during manufacturing/extraction processes) (Carus and Dammer, 2018). The **bioeconomy** substitutes fossil carbon by renewable carbon from biomass from agriculture, forestry and marine environment (including by-products and wastes) (Carus and Dammer, 2018). These are different but complementary approaches. For this reason, the **“Circular Bioeconomy”** is defined as the intersection of bioeconomy and circular economy (Pursula & Carus, 2017; Newton et al., 2017; Carus and Dammer, 2018) and there are some common topics:

- improved resource and eco-efficiency;
- low GreenHouse Gas (GHG) footprint;

- reducing the demand for fossil carbon;
- valorisation of waste and side streams.

Despite the similarities and overlaps, bioeconomy and circular economy differ in a variety of aspects. The bioeconomy is not fully part of the circular economy, neither are fossil carbon, metals and minerals. The differences between the economic systems derive from various circumstances:

- **at present**, most of the material flows – fossil, biomass, metals and minerals – are NOT part of the circular economy since the economic system does not yet sufficiently accommodate cascading and circulating mechanisms. A large proportion of metals and minerals are not maintained in the economy, but lost in the environment or in landfills. Fossil and renewable carbon is mainly used for energy purposes (fossil: 93%, biomass: two-thirds) and utilised in this way it is lost for cascading use. Fossil or bio-based products often end up in landfills or the environment, so they are also lost to the circular economy;
- **potentially**, a large proportion of all materials can become part of the circular economy, and thus the overlap will increase as we advance in sustainability;
- **some sectors** of the bioeconomy will never be fully part of the circular economy: the impossibility for re-use or recycling is inherent in several applications: energy and fuels are the "dead ends" of carbon utilisation, at least under the current conditions of circular economy (without CO_2 utilisation). But also, most detergents, cosmetics, coating and paints cannot be collected and recycled (Carus and Dammer, 2018).

It is precisely for this reason that the scientific literature refers more to the concept of *circular economy*, which encompasses all spheres for which an effective re-use of resources is possible.

Regarding the inherent impossibility for re-use or recycling, the only way to increase this potential is to utilise an increased amount of fresh biomass as chemicals and materials with the option of cascading after the end of a lifetime, instead of using high amounts of fresh biomass for bioenergy and biofuels. It should be very important thus to encourage the cascading use of biomass, where energy uses come in the last place.

1.3 Legislative framework of "Circular Economy" in the European Contest

On December 2, 2015, the European Commission adopted a "European Action Plan" for the Circular Economy, that analyses the interdependence of all processes in the value chain: from raw material extraction to product design, from production to distribution, from consumption to reuse and recycling. It includes initiatives that regarding the development and/or revision of a number of legislative proposals. Cross-cutting tools such as eco-innovation, green public contracts and European funding instruments play a crucial role. The Action Plan focuses on European-level measures with high added value, but for the circular economy become a reality, long-term engagement is needed at all levels, Member States, regions, cities, businesses and citizens. At the same time as the adoption of the Communication "COM (2015) 614/2" containing the "Plan for the Circular Economy", four proposals to modify six directives falling within the scope of the Circular Economy package of measures have been submitted. The directives subject to modify are:

- Directive 2008/98 EC (Waste Framework Directive);
- Directive 94/62 EC (packaging and packaging waste);
- Directive 1999/31 EC (waste landfills);
- Group of Directives 2000/53 EC on "end-of-life" vehicles, 2006/66 EC on batteries and accumulators and waste batteries and accumulators, 2012/19 EC on waste electrical and electronic devices.

The action plan identifies four key measures below:

1) ***Manufacturing***: the circular economy starts in the very early stages of the product life cycle. Both the design phase and the manufacturing processes affect the reosurces supply, their use and the waste generation throughout the product life cycle. Priority objectives are:

- support repairability, durability, and recyclability through product specifications;
- prepare a program to study potential planned obsolescence;
- take action on green contracts.

2) ***Consumption***: the choices made by millions of consumers can affect the circular economy in positive or negative ways. These choices are determined by the informations consumers have access to, the products range and prices on the market, as well as the legal

framework. This phase is foundamental to avoid and reduce domestic waste generation. Priority objectives are:

- clear labels to be able to assess the products environmental and energy footprint;
- encourage innovative consumption forms, such as sharing products or infrastructure (collaborative economy), consuming services instead of products, or using Information Tecnology or digital platforms.

3) ***Waste Management***: it plays a prominent role in the circular economy because it determines how the European Union's waste hierarchy is applied. The waste hierarchy establishes a priority order and gives first place to prevention, followed by preparation for reuse, recycling, energy recovery and, at the end, disposal. All waste typologies must be considered, from those generated by domestic users, businesses and industry to those from the mining and construction sectors. The Commission has proposed a revision of waste legislation that includes as priority targets: recycling 65% of municipal waste and 75% of packaging waste by the year 2030; reducing landfilling to 10% by the year 2030.

4) ***Promoting markets for secondary raw materials***: by reusing recyclable materials, the raw materials supply chain becomes more safe in a circular economy. These "secondary raw materials" can be exchanged and transported in the same way as primary raw materials from traditional mineral resources. Today, secondary raw materials represent only a small percentage of the materials used in the European Union. The Commission intends to take a number of actions to facilitate water reuse, including a legislative proposal on minimum requirements for its reuse, such as for irrigation. The Commission also intends to submit a review of the “European Union Fertiliser Regulation” to facilitate the recognition of organic fertilisers made from waste in the single market and thus support the role of bionutrients in the circular economy.

Some sectors, such as the plastics, food waste, or construction and demolition sectors, because of their products specificity, their value chains, their environmental footprint, or their materials dependence outside the European Union, have specific problems in the circular economy context. These sectors need a special attention to ensure that the interactions between the various cycle stages are fully taken into account throughout the value chain.

1.4 Priority areas of “Circular Economy” in the European and Italian contest

Not all activities that belong to the primary production sector (agriculture, forestry and fishing) and industrial sectors that use biological resources (food, beverage and tobacco production, wood, textile fiber, tanning and wood paper industry, green chemistry, pharmaceuticals, rubber-plastics and energy) have the same meaning from the sustainability point of view: the circular economy activities are based on biological resources that must be used in a sustainable way ensuring their renewability, the ecosystems resilience and the natural capital stocks conservation that provide them. Using them without these guarantees means weakening the country's wealth and its natural capital. Given that the biological resources renewability and availability are limited, it is necessary to establish ways and priorities in their use (Report on the Circular Economy in Italy, 2020). From the priorities point of view, **food security** should be located in first place: it is important to highlight the necessity to produce food for 7,7 billion people, which will increase in the coming decades. From the methods point of view, for a crucial aspect that is the **generation of biomass** through both crops to produce food and materials and forest management to produce wood in particular, the circular economy must operate in a regenerative way, thus taking into account not only its direct and immediate activities pressure factors that can generate environmental impacts, but also the indirect and medium and long-term ones. The sustainable generation of agricultural biomass must avoid the polluting, toxic and chemicals products use and must ensure the maintenance of soil fertility. The use of forest biomass must be performed according to the sustainable forest management criteria, careful not only to the long-term productive function, but to the maintenance of ecosystem and regulatory functions provided by forests (Report on the Circular Economy in Italy, 2020).

In particular, it is necessary to pay attention to one of the most important natural capital components, **the soil**, whose availability and health depend on the multiple ecosystems balances. The settlements and infrastructure growth is unfortunately continuing to consume large amounts of soil. Very negative is also the soil erosion, with decreasing productivity, depleting habitats and biodiversity: the Joint Research Center (JRC) evaluations on the soil loss level due to water erosion show that Italy has the highest average annual loss index in Europe, equal to 8,46 tons/ha, against an European Union average of 2,46 tons/ha. In fact, organic carbon, an indicator of soil health and quality, has been registered a constant decline due to poor management practices that decrease soil fertility and agricultural yields, now supported almost exclusively by the chemical fertilisers use which in turn deplete it. The soil organic carbon increase, instead, has a key role in mitigating climate change and at the same time contributes to improve and maintain soil fertility and food security: it would to counteract the erosion rates and soil loss reduction. A relevant way to increase soil organic carbon, in addition to the organically farmed land increase, is the use, as a soil conditioner, of compost generated by the treatment of organic waste, either through aerobic digestion processes or through anaerobic processes with production of compost from the digestate after producing renewable energy consisting of biogas and/or biomethane. **Water** is also a natural capital critically important component for the circular economy. Water resources are subject to increasing pressure, coumpounded by ongoing climate change, generated by overconsumption and pollution from various sources. Although the European water bodies ecological status has been improving for the past 15 years, with decreasing pollution levels in both rivers and groundwater bodies (Eurostat, 2019), we are still far from the good ecological water quality objectives: among the main pressure factors for water quality, the European Environment Agency shows the diffuse pollution generated mostly by agriculture. Protecting the marine and coastal systems ecological functions is also very important. A circular and sustainable economy must counter marine and coastal pollution, and paying full attention to limited and sustainable use of marine resources. Then there is the central issue of the **climate crisis**, which interacts in various ways with the circular economy. On the one hand, global warming represents a serious threat to the circular economy, on the other, a regenerative circular economy can offer biomass as an alternative energy source to fossil fuels, contributing to climate change mitigation in terms of avoided greenhouse gas emissions. It must be highlight that the non-regenerative part of the circular

economy generates a **greenhouse gas emissions** important rate. According to the Integrated Pollution Prevention and Control (IPCC), on average in the decade 2007- 2016, activities related to agriculture, forestry and other land uses were responsible for the net emissions of about 12 billion tons of CO_2 equivalent each year, about a quarter of global anthropogenic emissions, which increase if those generated by food industry production and food transportation are added. The circular economy development must therefore aim at decarbonisation both by reducing its direct and indirect emissions and by increasing its capacity to absorb organic carbon present in the soils, forests and long-term organic products (Report on the Circular Economy in Italy, 2020).

CHAPTER 2: AGRICULTURAL BY-PRODUCTS

Considering the validity of by-products definition that we will analyse in the chapter dedicated to regulations, the main by-products categories considered, also decided on the basis of Basilicata region morphological, productive and economic characteristics concern:

- woody by-products resulting from forest management;
- herbaceous and woody by-products from the agricultural sector;
- by-products from the zootechnical and agro-industrial sector.

In this phase, only the by-products quantities available in the regional context and the possible valorisation forms have been determined according to a prioritized hierarchy. In order to allow a more detailed territorial analysis, and to be able to determine the areas in which a greater availability of by-products is concentrated, the data entered in the Geographical Information System through the use of Quantum Gis 3.18 (QGis) software have a level of municipal detail.

The results obtained from the analyses and elaborations have been therefore presented in the form of maps, in order to identify the spatial distribution of biomass in Basilicata region. They represent a powerful tool to help planners in landscape analysis (Statuto et. al., 2013a) and support policy makers in their decisions based on the information derived from these databases (Blanschke et. al., 2013).

2.1 Legislative framework for by-products: Ministerial Decree No. 264 of October 13, 2016

In order to encourage and facilitate the use, as by-products, of substances and objects that derive from a production process and that respect specific criteria, as well as to ensure greater uniformity in the interpretation and application of waste definition, this decree defines some methods by which **the "*holder*" can demonstrate that the general conditions contained in "Article *184-bis* of Legislative Decree April 3, 2006 No. 152" are satisfied**.

The **requirements** and conditions to exclude a by-product from the application of waste legislation are evaluated according to the circumstances and must be satisfied in all by-products management phases, from production to use in the same or a subsequent process.

With reference to the current definitions deriving from national and community legislation, in the present Decree, the following **definitions** are applied:

- product: any material or substance that is deliberately obtained as part of a production process or a technical choice result. In many cases it is possible to identify one or more primary products;
- production residue (below "residue"): any material or substance that is not deliberately produced in a production process and may or may not be a waste;
- by-product: a production residue that is not a waste according to “Article *184-bis* of Legislative Decree April 3, 2006 No. 152”.

The residues as defined by this decree, then, are **by-products** and not waste when the producer demonstrates that, since they were not produced voluntarily and as the production cycle primary objective, they are intended to be used in the same or a subsequent process, by the producer himself or by third parties. For this reason, at each management stage of by-products, it is necessary to provide the demonstration that all the following **conditions** are satisfied:

- the substance or object originates from a production process, whose it is an integral part and whose primary purpose is not the substance or object production;
- the substance or object use during the same or a subsequent production or use process by the producer or a third party is certain;
- the substance or object can be used directly without any further processing other than normal industrial practice;
- the further use is lawful, in example the substance or object satisfies, for the specific use, all requirements concerning products for health and environmental protection and will not lead to overall negative impacts on the environment or human health.

The **requirements of certainty use**, on the other hand, must be demonstrated from the waste production until the moment of its use. For this purpose, the producer and the holder must ensure, each one within its own competence, the organisation and the continuity of a management system, including storage and transport phases, which, in terms of time and method, allows the by-product identification and effective use.

The application of waste regulations remains unaffected, if, in relation to materials and substances storage or management methods, the disposing intention, act or fact is verified.

Therefore, excepted the assessment of specific factual circumstances, to be evaluated on a case-by-case basis, the use certainty is demonstrated by the assessment of production cycle organisational methods, by the characteristics, by the activities documentation from which the materials used originate and by the destination process, assessing in particular the congruity between the used by-products type, quantity and quality and their intended use. In order to ensure the use certainty, the by-product, until it is effectively used, is stored and moved in accordance with specific technical standards, if available, and with the good practice rules, avoiding accidental spillage and environmental matrices contamination in order to prevent and minimise the formation of diffuse emissions and the odors spread. During the by-products storage and transport phases are guaranteed:

- the separation of by-products from waste, products, objects, or substances with different chemical-physical characteristics, or destined for different uses;
- the adoption of necessary precautions to avoid the occurrence of any environmental or health problems, as well as combustion phenomena, or the formation of dangerous or explosive mixtures;
- the necessary precautions adoption to avoid the alteration of by-products chemical-physical properties, or other phenomena that may affect its subsequent use;
- the adequacy of timing and management methods, considering the by-products peculiarities and characteristics.

Following the preparation of the technical data sheet and the signing of conformity declaration, the storage and transport can also be carried out by accumulating by-products coming from different industrial plants or activities, as long as they have the same characteristics and the requirements that guarantee their use according to the above-mentioned decree are not modified.

The producer or the transferee responsibility in relation to the by-product management is limited to its pre-delivery steps to the user, or to an intermediary. In the case of use by the producer himself, he will retain responsibility for the by-product management in the use phase.

2.2 Wood by-products availability from the forestry sector

In the Basilicata region there is a low level of forest utilisation, despite the region is covered by a considerable forest heritage, both private and public property. The forest area according to the "Basilicata Region Forest Map" (2006) is 296.218 hectares. This information agrees with provisional data from the "Forests and Carbon Reservoirs National Inventory" draft - which attributes to the Basilicata Region about 286.000 hectares of wooded area - and with data deriving from the land use map for the year 2015. The review of the most important forest types contained in the "Regional Forest Map" present in the territory, varied in terms of both environmental and vegetation, highlights aspects that constitute "constants" and "peculiarities" of the Lucanian forest and the southern Apennine mountains. For the forest biomass analysis, the wooded area defined by the Forest Map of Basilicata Region (INEA, 2006) was considered as the cartographic base. According to the reported distribution, taking into account the first level physiognomic categories, the following informations have been obtained (Tab.1):

Table 1: Suddivision of the regional forest area, by government form

Level I physiognomic categories	High forest (ha)	Woodland (ha)	Transitory species (ha)
Beech Forests	11.519,7	15.207,4	3.181,2
Oro-Mediterranean pine forests and other montainous and sub-montainous coniferous forests	5.762	0	0
Chestnut wood	24,3	8.461,8	211,6
Mesophilic and meso-termofile oak woods	53.754,7	108.820	21.450,6
Other mesophilic and meso-termofile broadleaf forests	3.231	12.210	4.142,7
Mediterranean pine forests	19.384	0	0

Holm oak forests (or high scrubs)	2.517,1	7.200,8	2.982,1
Hygrophilous formations	13.182,5	406,5	360,5
Wood plantations and reforestation with exotic species	2.079,1	118,8	10,4
TOTAL	**111.454,4**	**152.425,3**	**32.338,8**

In order to estimate the by-product amount (branches and tree tops) resulting from forest management operations, reference to the literature on experiences carried out in similar national contexts (Pettenella, 2000) and to the values of tree branches and wood bundle reported in the stereometric and alsometric tables constructed for Italian forests was made (ISAFA, 1980).

Moreover, the "Basilicata Region Forest Map" does not consider some biomes, such as shrubs and Mediterranean maquis, species which are not subject to cutting because of their particular vegetation. Obviously, all areas without forest cover are also excluded. For each forest type, the average annual growth, expressed in m^3 ha^{-1} $year^{-1}$, was considered, which varies according to species and silvicultural system (Cozzi et al., 2013) (Tab. 2).

Table 2: Biomass average increase by forest type and governance form expressed in m^3 ha^{-1} $year^{-1}$

Level II physiognomic categories	**High forest**	**Woodland**
Beech Forests	3,4	3,5
Oro-Mediterranean pine forests and other montainous and sub-montainous coniferous forests	6,02	-
Chestnut wood	3,5	14,5
Mesophilic and meso-termofile oak woods	2,53	6
Other mesophilic and meso-termofile broadleaf forests	4,44	4,2
Mediterranean pine forests	6,02	-
Holm oak forests (or high scrubs)	5,5	2,2
Hygrophilous formations	5	3,6
Wood plantations and reforestation with exotic species	2	-

In order to guarantee a sustainable harvest and the regional forests safeguard, guidelines by the Basilicata Region indicating the allowed harvesting levels have been elaborated; in particular, harvesting must not exceed 60% of the annual increment for high forests and 90% for coppice woods. Moreover, for the available biomass quantification, some utilisation percentages have been defined; in particular for Mediterranean pine forests, mountain pine forests and hygrophilous formations, all the biomass can be reused while for the other forest types only the cut residual rate has been considered (Tab. 3).

Table 3: Percentage of by-products by forest type

Level I physiognomic categories	High forest %	Woodland %
Beech Forests	8	25
Oro-Mediterranean pine forests and other montainous and sub-montainous coniferous forests	100	-
Chestnut wood	15	16
Mesophilic and meso-termofile oak woods	15	20
Other mesophilic and meso-termofile broadleaf forests	15	20
Mediterranean pine forests	100	-
Holm oak forests (or high scrubs)	25	32
Hygrophilous formations	100	100
Wood plantations and reforestation with exotic species	15	-

Considering then the annual relative increment of the different forest types in relation to the different forms of government and the wooded areas classification, the biomass amount classified as forest utilisations by-product and therefore reusable has been obtained (Tab. 4).

Table 4: Estimation of reusable residual biomass amount

Level I physiognomic categories	High forest (m^3/year)	Woodland (m^3/year)
Beech Forests	3.133,35	13.306,47
Oro-Mediterranean pine forests and other montainous and sub-montainous coniferous forests	34.687,24	-
Chestnut wood	12,75	19.631,38
Mesophilic and meso-termofile oak woods	20.399,9	130.584
Other mesophilic and meso-termofile broadleaf forests	2.151,8	10.256,4
Mediterranean pine forests	116.691,08	-
Holm oak forests (or high scrubs)	3.461,01	5.069,01
Hygrophilous formations	65.912,5	1.463,4
Wood plantations and reforestation with exotic species	623,73	-
TOTAL	**427.384,02**	

2.2.1 Results

The amount of by-products obtainable from forest management takes into account the different forms of governance, the annual increments of biomass and the percentages of by-products; furthermore, considering an average density of 0,7 tons/m^3 and a wood humidity of 45% for the dry matter quantity estimation, according to the following equation, it is equal to 164.542,84 t.d.m./year:

$$T.\mathrm{W.}\ [t.\ \mathrm{d.m./\ year}] = (\mathrm{T.\ W.\ a.i.}) * (\mathrm{D.\ D.\ m.}) * (1 - U100)$$

Where:

- t.d.m. = *Tons dry matter*;
- *U. = Average plants humidity: expressed in %;*
- *T.W. = Total Wood: expressed as tons of available dry matter per year (t.d.m./year);*
- *T. W.a.i. = Total Wood as it is: expressed in* m^3*;*
- *D. D. m. = Density Dry matter: relative to each species and derived from density tables, expressed in tons/*m^3.

With municipal detail (Fig.1), the by-products availability from forest management operations in terms of dry matter (t.d.m./year), has been spatially quantified.

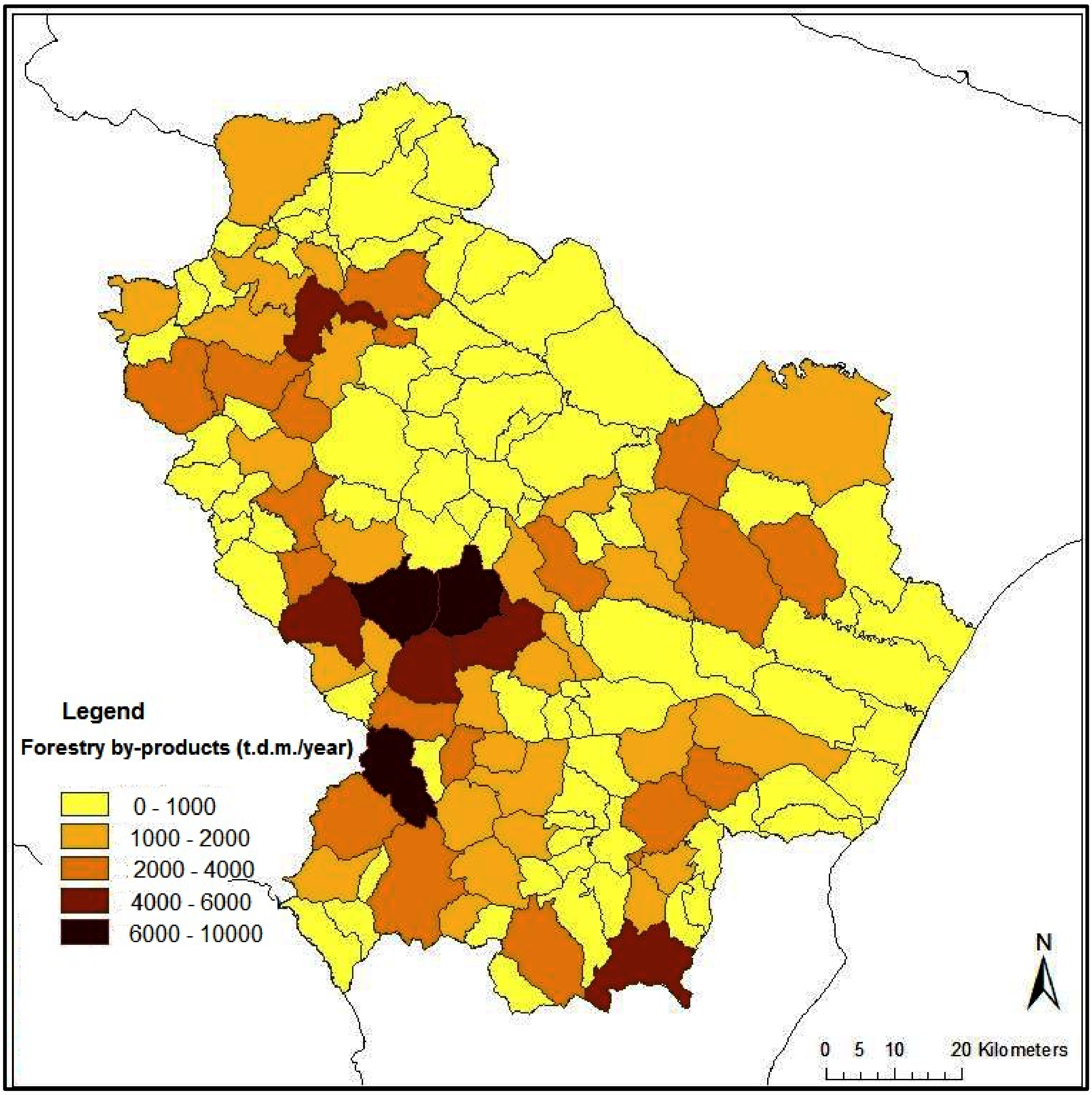


Figure 1: Spatial distribution of biomass coming from forestry sector

2.3 Availability of herbaceous and woody by-products from the agricultural sector

The evaluation of biomass potential produced by the agricultural sector depends on a series of parameters that determine the actual by-products amount produced by an agricultural crop; they are different depending on the crop, on the cultivated variety, on the cultivation and harvesting ways, on the soil and climate conditions and they have a high spatial inhomogeneity. There is also a wide variability, both spatial and temporal, related to the reuse and the actual possibility to collect, transport and utilise these biomasses for other uses, business or agro-industrial uses. This variability explains different hypotheses and calculation assumptions and the lack of shared procedures for the input data and parameters definition, the estimation methods and the returning results. For permanent crops and arable land, by-products left in the field as a result of harvesting or pruning have been considered. In general, for all the analysed categories, the calculation methodology of by-products amount uses parameters identified in the agronomic literature or average values based on statistical informations.

Another important element is to determine the average humidity value of the by-product as it is, in order to calculate the dry matter and make homogeneous the product values with a very variable humidity content and assess which are suitable for combustion and which for other uses. Once the statistical data have been collected and organised, and the calculation parameters have been defined, the processing result aims to quantify the overall by-products amount obtained in relation to that agricultural year results production.

However, by-products are not all really available to be collected and used for off-farm uses. The by-products rate used for other purposes in different Italian agricultural contexts is a variable information in *time* and *space* (Statuto et al., 2015). In *time*, because market conditions can make a by-product marketable one year while the following year, as prices change, the convenience decreases or disappears altogether; *in space*, because in a given territory, straw can be all or almost all reused in the livestock sector, while in other areas, where livestock farming has an irrelevant weight, straw largely exceeds local demand, thus remaining available for alternative uses.

It is important to highlight that, even if the biomass is available on farms, this does not mean for certain that it can be conveniently collected, concentrated or processed for a certain purpose. Various factors come into play, including economic factors to retrieve the net potential from the gross annual potential (machinery, equipment and reference fuels different costs), technical factors (machinery and logistical organisation availability) and territorial factors (distances, gradients, farm areas fragmentation) that can make it variously convenient, in the contingent situation, to collect and use the available potential.

In the year 2019, arable crops covered 58,6% of the Used Agriculture Area (UAA) of Italy (RSDI, 2019) (they were 54,4% in the year 2010) according to ISTAT estimates derived from the 6th Agriculture Census, with a slight decrease in percentage terms; permanent meadows and grasslands account for 29,7% (they were 26,9% in the year 2010) and show an increase of 2,8%; a considerable decrease, equal to 6,7%, occurred with the share of "UAA" destined to agricultural woody crops (11,7% of the total versus 18,4% in the year 2010). Field herbaceous crops occupy the largest national UAA rate, followed by meadows and grasslands and tree crops. Among these, the most widespread crops are cereals, which occupy over 50% of the areas, followed by fodder crops, industrial shrubs, vegetable crops (analysed separately) and grain legumes. In Basilicata region, according to the data derived from the "Regional Spatial Data Infrastructure" (RSDI, 2019) the U.A.A. stands at 472.833 hectares, with the following categories: arable crops (277.080,13 ha equal to 58,6% of the entire U.A.A.), agricultural woody crops 11,7% (55.321,46 ha of which vines amount to 4.475,6 ha), family vegetable gardens (1.038,02 ha) and permanent meadows and grasslands 29,7% (140.431,4 ha). Agricultural by-products, represented in table 5, originate from operations carried out at the end of the cultivation cycle for annual crops (cutting, harvesting, etc.) or from operations carried out with varying frequency on multi-year crops (pruning and explanting). The amount of crop by-products that can be recovered each year depends on many factors, including: cultivated areas, crop productivity, harvesting methods and operating conditions. Moreover, availability is also affected by the harvesting seasonability and the by-product storing possibility. Generally, a good and studied business organisation almost always allows a by-product alternative use.

Crop by-products have intrinsic characteristics that make them different from both the main products from which they derive and from any co-products, and the main differences concern:

- dry matter composition;
- water content during the harvesting;
- apparent volumic mass;
- lower heating value;
- ashes and other minerals content.

Table 5: By-products typology from agricultural crops

Herbaceous		Woody	
Crop	**By-product**	**Crop**	**By-product**
Soft and hard wheat	Straw	Vine	Tailings
Rye	Straw	Olive tree	Wood and branches
Barley	Straw	Apple tree	Wood and branches
Oats	Straw	Pear tree	Wood and branches
Rice	Straw	Peach	Wood and branches
Corn	Stalks and cobs	Citrus	Wood and branches
Sunflower	Stalks	Almond	Wood and branches
		Hazel	Wood and branches
		Apricot	Wood and branches
		Actinidia (Kiwi)	Pruning

Currently, it is important to highlight that the convenience of the agricultural, forestry and agro-industrial by-products valorisation must also be compared with the organic matter depletetion that soils may suffer from excessive removal. This aspect has its greatest value for herbaceous crop by-products, where burial often constitutes a chemical, physical and biological source fertility for agricultural land. The analyses of the by-products economic potential use cannot leave out the collection, loading, transport, unloading and storage operations mechanisation factor, which vary according to the material type, enterprise size and the raw material destination (ENAMA, 2011). Considering the situation of the region cultivation, and given the arable crops clear predominance and the woody crops good presence, the amount of herbaceous crops by-products has been calculated, and therefore the straw from arable crops as regards woody or tree crops, the pruning by-products, in particular of olive trees, vines and orchards in general have been also calculated.

2.3.1 Herbaceous crop by-products

Straw is the by-product of the autumn-winter cereals cultivation (wheat, barley, oats and rye) and it mainly consists of the hollow culm that supports the ear of corn. Autumn-winter cereals harvest is usually between June and July, and this by product becomes available for field collection. Currently the straw is used in the farm itself, if it is zootechnical farm, in the market if there is a zootechny at a compatible distance with transport costs or as reinforcing material during a composting process. The most common uses are:

- bedding for animal shelter;
- animal feed;
- paper industry;
- energy production for large-scale plants.

In order to estimate the amount of the available and reusable straw, we considered some data from a study conducted by ENEA in the year 2009 concerning some indices determination, which emphatised the relationship between agricultural production and residual biomass, conducted in some Italian regions. From the analysis conducted in the southern Italian regions, the estimation of some indexes concerning the straw per hectare has been performed, according to the different crops. Considering an average moisture value of 14% and the extensions of the arable crops different type, the amount of extractable straw deriving from the arable crops of for the Basilicata Region (Fig.2) has been estimated equal to 364.534,73 t.d.m./year (Tab. 6).

Table 6: Dry matter determination from straw

Crop	Surface (ha)	Straw/hectare (tons/ha)	Total straw (tons/year)	Dry matter (t.d.m./year)
Common wheat	7.238,9	2,5	18.097,25	16.563,64
Hard wheat	136.233,8	2,3	313.337,74	269.470,46
Rice	295,2	3	885,6	761,62
Barley	18010,9	3,02	54.392,91	46.777,91
Oats	18.285,38	1	18.285,38	15.725,43
Corn	925,18	14,6	13.507,62	11.616,62
Other cereals	1.743,1	3	5.229,3	4.497,2

TOTAL	**423.735,8**	**365.412,88**

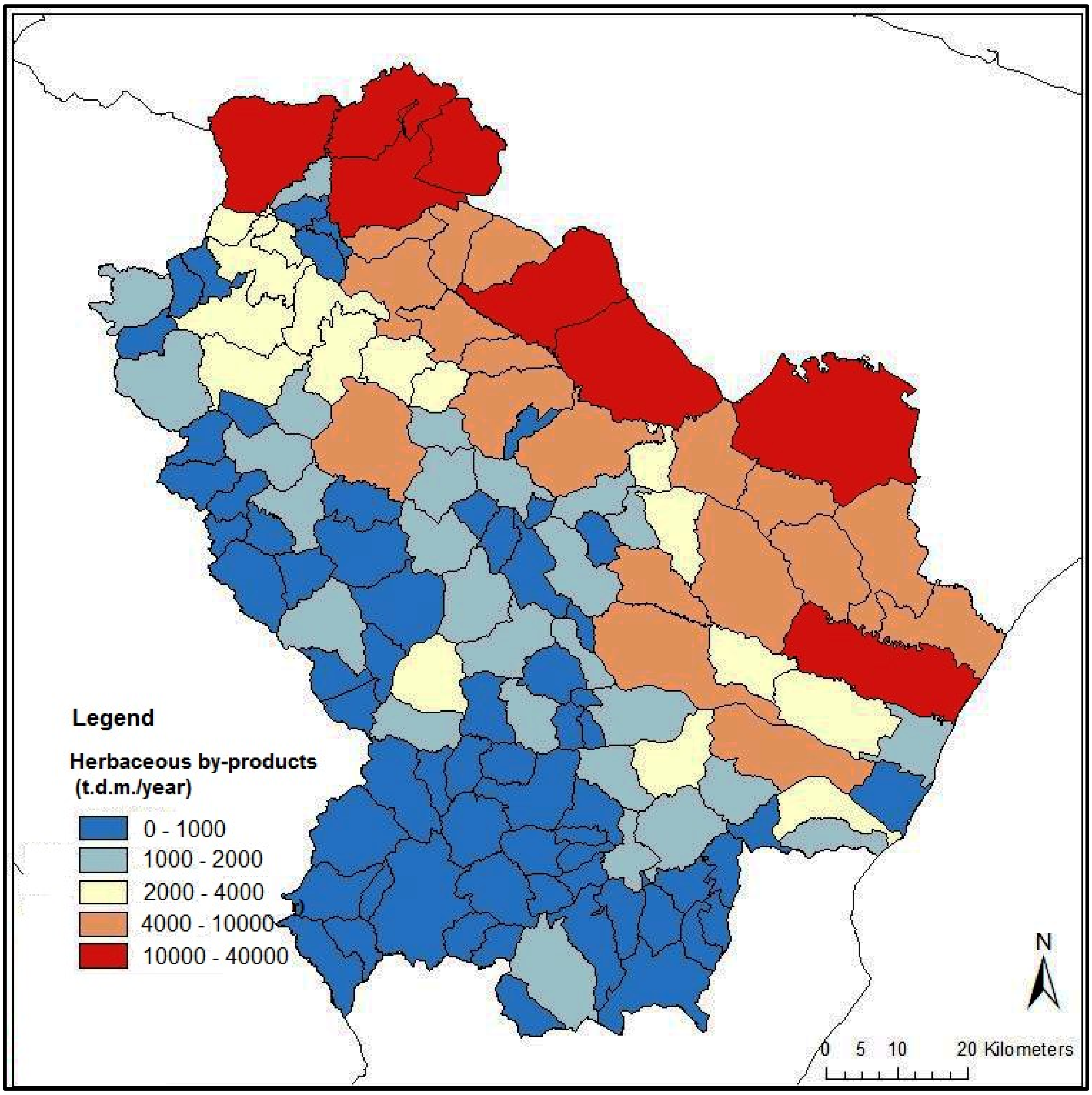


Figure 2: Dry matter availability from herbaceous crops (ENEA)

2.3.2 Tree crop by-products

In Italy, permanent crops such as vines, olive trees and fruit trees extend over a surface of 2.4 million hectares and they are an agricultural landscape distinctive element. In Basilicata region they cover about 9,4% of the agricultural area used (RSDI,2019). During both the primary products cultivation and processing phases, significant amounts of by-products for multiple uses are obtained. At this stage, the analysis considers the wood by-products produced in the agricultural phase, leaving out the processing by-products (pomace, stalks, grape seeds, shells, etc.) that will be considered in the next chapters. The calculation method used considers only the woody pruning annually obtained (olive branches and wood, vine tailings, fruit tree branches) and not the wood produced at the end of the crop life cycle, when it is necessary to explant for renewal or the next crop.

Large amounts of woody biomass can be obtained from pruning operations performed in Mediterranean orchards (McKendry P., 2002). Currently, these by-products are usually burned in the field or destroyed in the soil, thus allowing no direct economic benefit (Askew&Holmes, 2002). As well as for herbaceous crops, the calculation of available biomass in relation to the different tree crops has been performed.

2.3.2.1 Olive groves

The olive tree is a Mediterranean crop type that prefers warm and sunny climates, widespread in Central and Southern Italy. The pruning phase, which generally takes place between January and April, is carried out at variable intervals depending on the cultivation methods and varieties used and according to technical criteria (olive trees can be pruned every year or every two years). Very often prunings are subsequently processed in order to separate trunks and branches from the ashes. The recovery systems are different depending on the by-product: wood is collected by hand, the ashes can be collected with collector machines, which produce ballets of 34-40 kg, or with shredders that convey the shredded product in large bags, boxes integrated to the operating machine or agricultural trailers. The pruning frequency has a strong influence on the quantity of pruning material and therefore on the quantity of biomass produced. The average values obtained for dry matter and substance after pruning in Mediterranean areas, according to several literature studies and for the Mediterranean basin area (Velázquez-Martí B. et al, 2011) are 1,31 tons/ha, for the annual pruning case and 3,02 tons/ha for biennial pruning case. Since it is not possible to know with certainty the frequency of pruning operation, an average value of 2,16 tons/ha has been considered (Tab. 6 and Fig.3).

2.3.2.2 Vineyards

Vine shoots are long and slim branches with a prostrate or climbing development, typical of vine cultivation. Every year, from November to February, vine pruning is carried out in order to control the vegetative-productive cycle of the plant, and in this period there is available biomass. The vine cultivation is spread all over Italy with many varieties, in different stationary conditions and with different management systems.

The vine shoots collection time can vary from 20-30 days up to 80-90 days depending on the pruning beginning, on the production area and in any case, it must conclude before the vegetative resumption (March-April). The classic cultivation techniques provide these by-products combustion at the vineyard edge (40-50% of the total); otherwise, if the cultivation is mechanised, they are shredded and buried (50% of the total).

The available residual biomass obtained from vineyard pruning operations depends on the vineyard type (table or wine grapes) and on the support structure/system. The plant structure form has a strong influence on the amount of biomass produced and therefore on the amount of residual material produced. From estimation procedures of biomass amount conducted in the Mediterranean basin for standard vineyard types result dry biomass amount of about 2,15 tons/ha (Velázquez-Martí B. et al., 2011) (Tab. 6 and Fig. 4).

2.3.2.3 Orchards

The main tree crops pruning by-products consist of branches and the following typology has been considered: apple, pear, plum, peach, apricot, almond, hazelnut, actinidia and citrus. Pruning is made in order to give the plant the desired form and therefore to regulate the vegetative-productive stability. Generally, there are two types of pruning: one of production usually made before the vegetative resumption and one of green type during the spring-summer period in order to eliminate young branches that do not generate fruit. Production pruning is the one which removes the greatest woody mass amount. Considering the average data derived from a study conducted by the CRA-ING Research Laboratory Treviglio, the average amount of reusable by-products at 2,20 tons/ha has been estimated (Bisaglia, 2013) (Tab. 6 and Fig.5).

Table 6: By-products production from tree crops (Estimation methodology according to literature)

Pruning residues	Hectares (ha)	tons/ha	t.d.m./year
Olive groves	27.721,68	2,16	59.878,82
Vineyards	5.567,11	2,15	11.969,28
Orchards	16.651,37	2,20	35.800,44

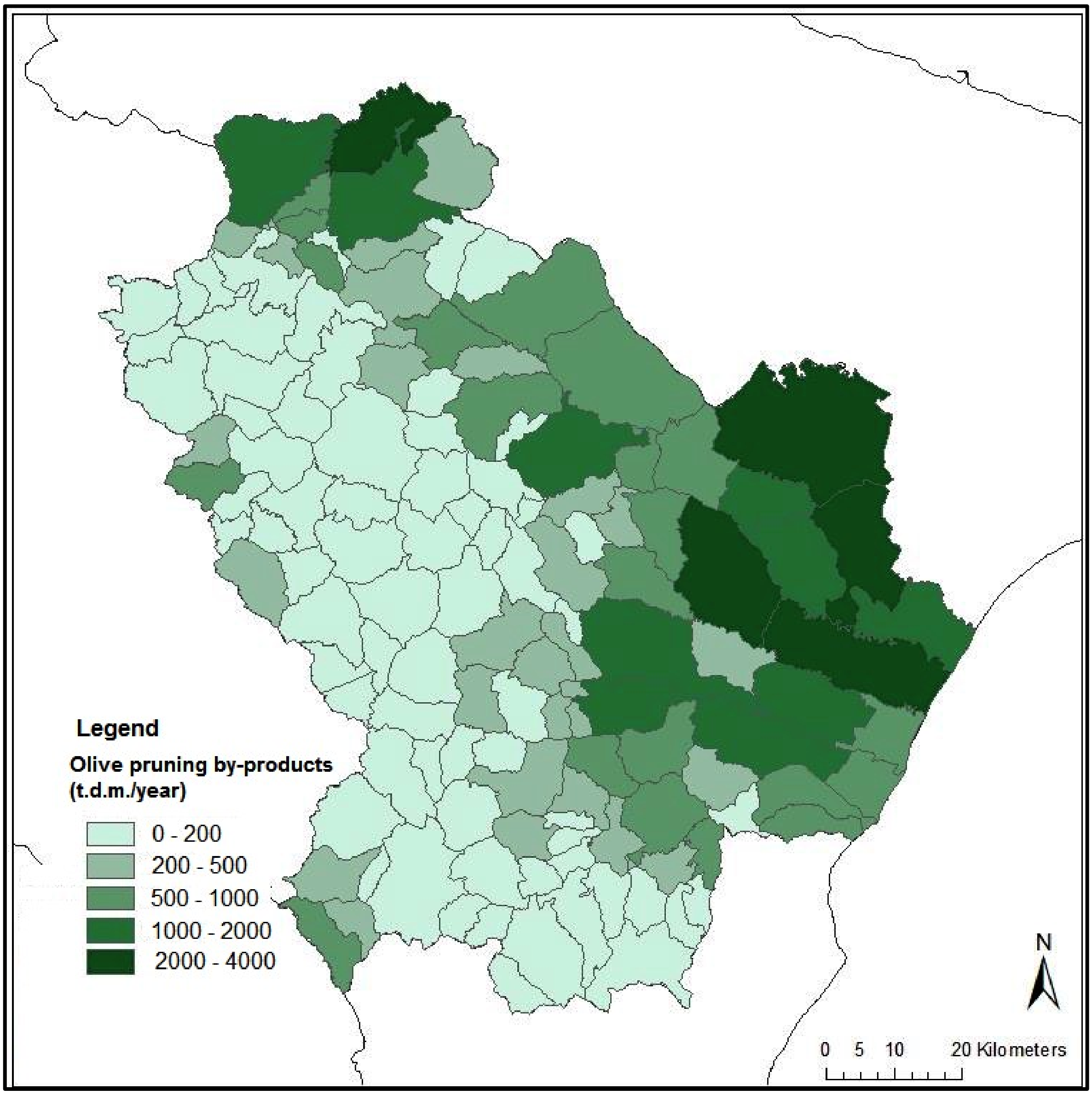


Figure 3: Availability of dry matter from olive groves pruning

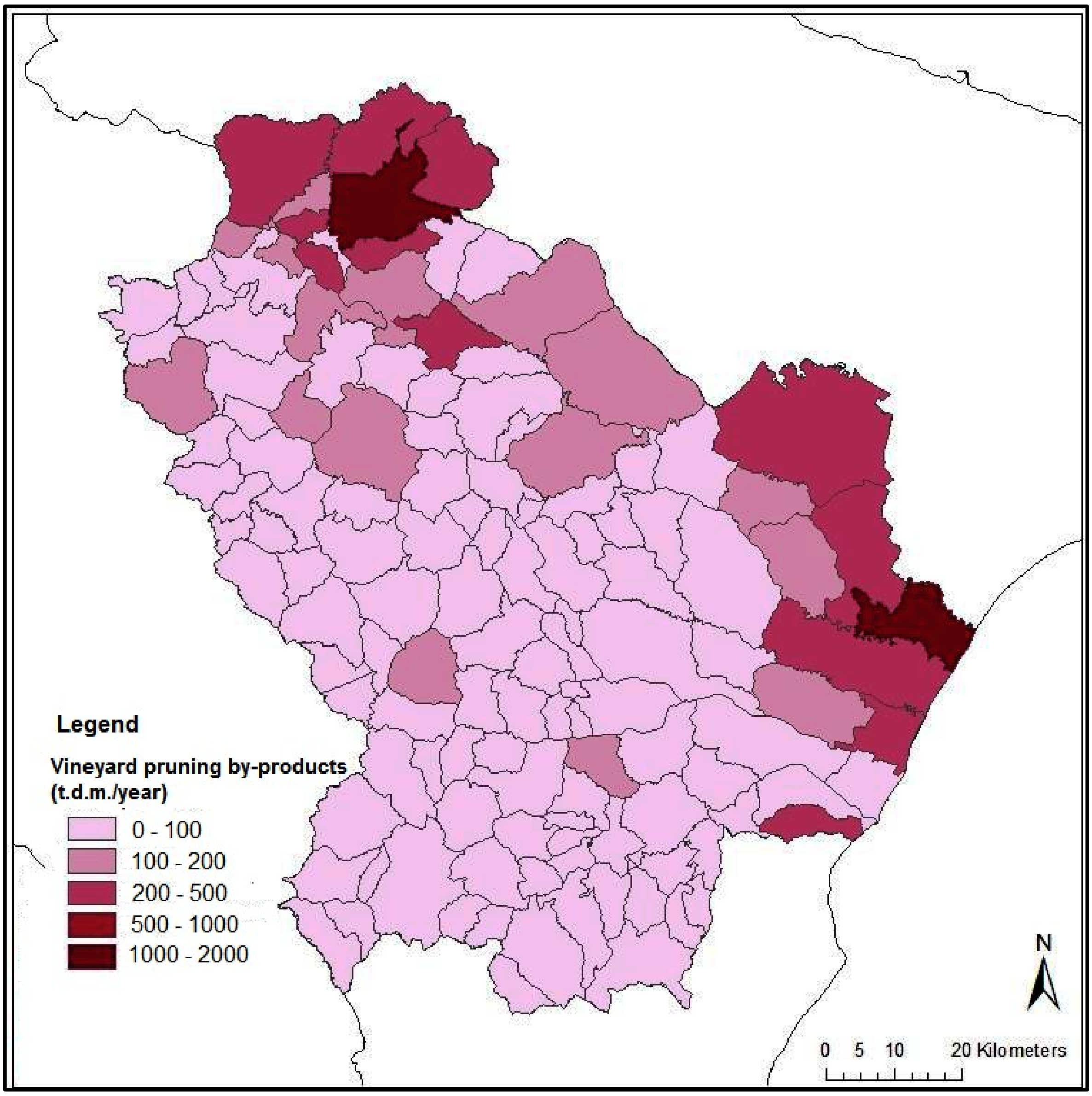


Figure 4: Availability of dry matter from vineyard pruning

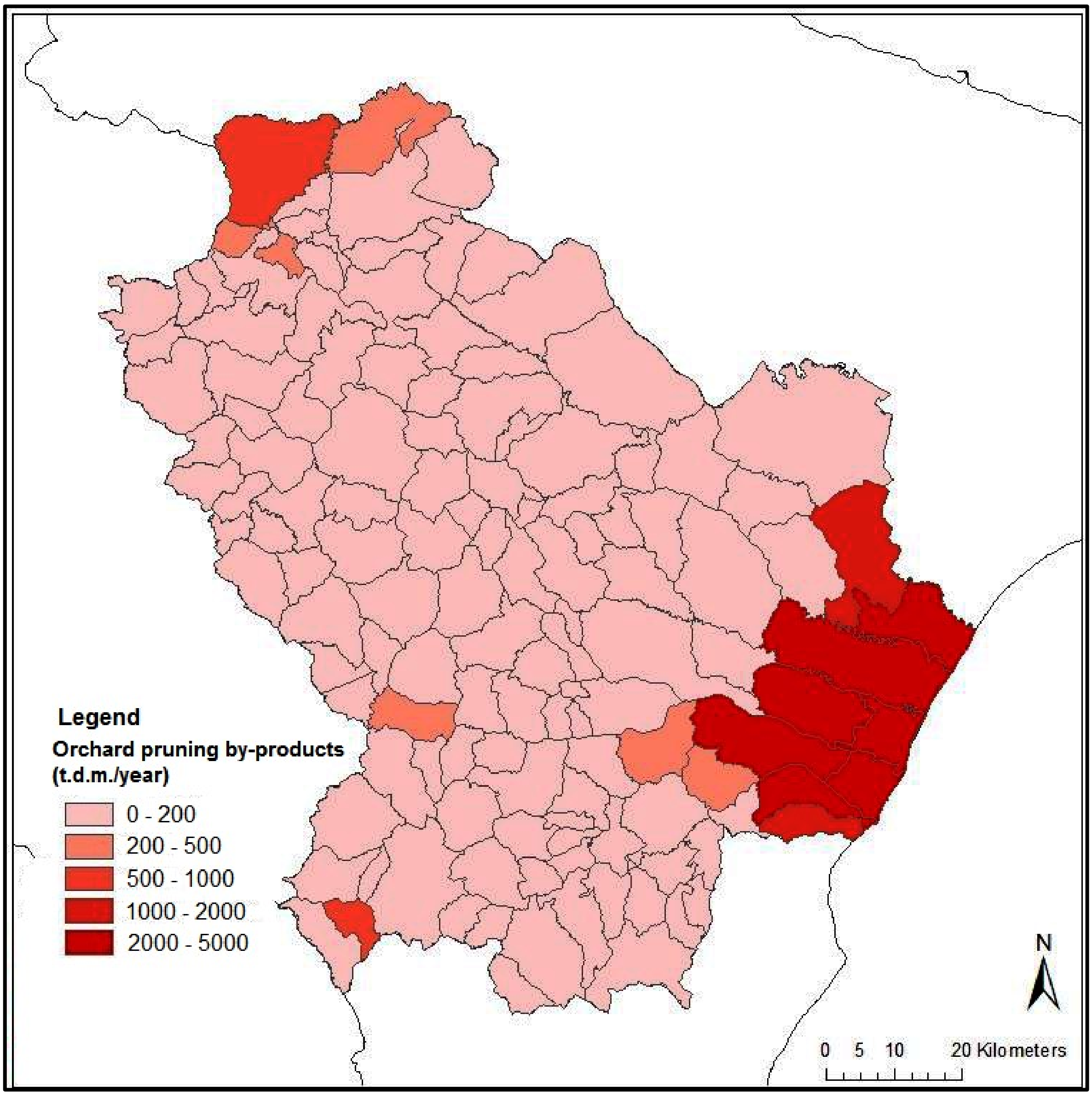


Figure 5: Availability of dry matter from orchard pruning

2.4 Estimation of livestock and agro-industrial sector by-products

2.4.1 Livestock effluents

According to the new "Ministry of Agricultural Food and Forestry Policies Decree" February 25, 2016, which integrates the "Legislative Decree No. 152 of May 11, 1999" for livestock effluent means *"livestock manure or a litter and animal manure mixture, even in the form of transformed product"*. Livestock effluents can be distinguished on the basis of their dry matter content, therefore effluents with a dry matter content less than 12% are defined sewage, effluents with a dry matter content between 12% and 18% are defined semi-solid effluents, finally effluents with a dry matter content upper to 18% are defined solid effluents. It is important to know the livestock effluents chemical and physical characteristics, because each type of them requires appropriate disposal treatments. The chemical composition and the quantities produced per livestock unit vary with the animal species reared, the animal physiological condition, the diet and the rearing type. From the organic material decomposition by specific bacteria type, biogas is produced and it composed of methane, carbon dioxide and molecular hydrogen. Biogas is a very versatile energy vector: it can feed boilers for thermal production and cogeneration plants. It has a high energetic power and it can be distributed through the electricity network or stored and preserved. The amount of biogas that can be produced from animal manure is influenced primarily by the animal species that generated it (pigs, cattle, sheep, poultry, etc..), but also by the animal rearing system (use of bedding, cracked floors, scraping belts, etc..), as it determines the final water content, which is inversely proportional to the dry matter content.

In Basilicata region, according to the estimates of the "Sixth Agriculture Census" (2011), generally comparable with the collected data in a preliminary way for the new agriculture census that is taking place (2021), the livestock population is 809.507 units, consisting of about 40% sheep and goats, 39% poultry, 11% cattle and 10% pigs (ISTAT, 2011). Starting from the livestock units and considering several parameters, such as the average annual production of the effluents for each animal and a manure percentage actually usable, the total amount of the effluents for the different species raised has been calculated (Tab. 7 and Fig. 6).

Table 7: Estimation of manure availability from livestock farms

	Livestock units	Manure production rate	Total manure	Recuperable	Total Usable Manure
	Heads	**t.d.m./head/year**	**t.d.m./year**	**%**	**t.d.m./year**
Cattle	88.354	1,69	149.318,26	25	37.329,57
Pigs	80.522	0,21	16.909,62	85	14.373,18
Sheep and goats	321.809	0,28	90.106,52	10	9.010,65
Poultry	318.822	0,01	3.188,22	85	2.709,99

TOTAL	**63.423,38**

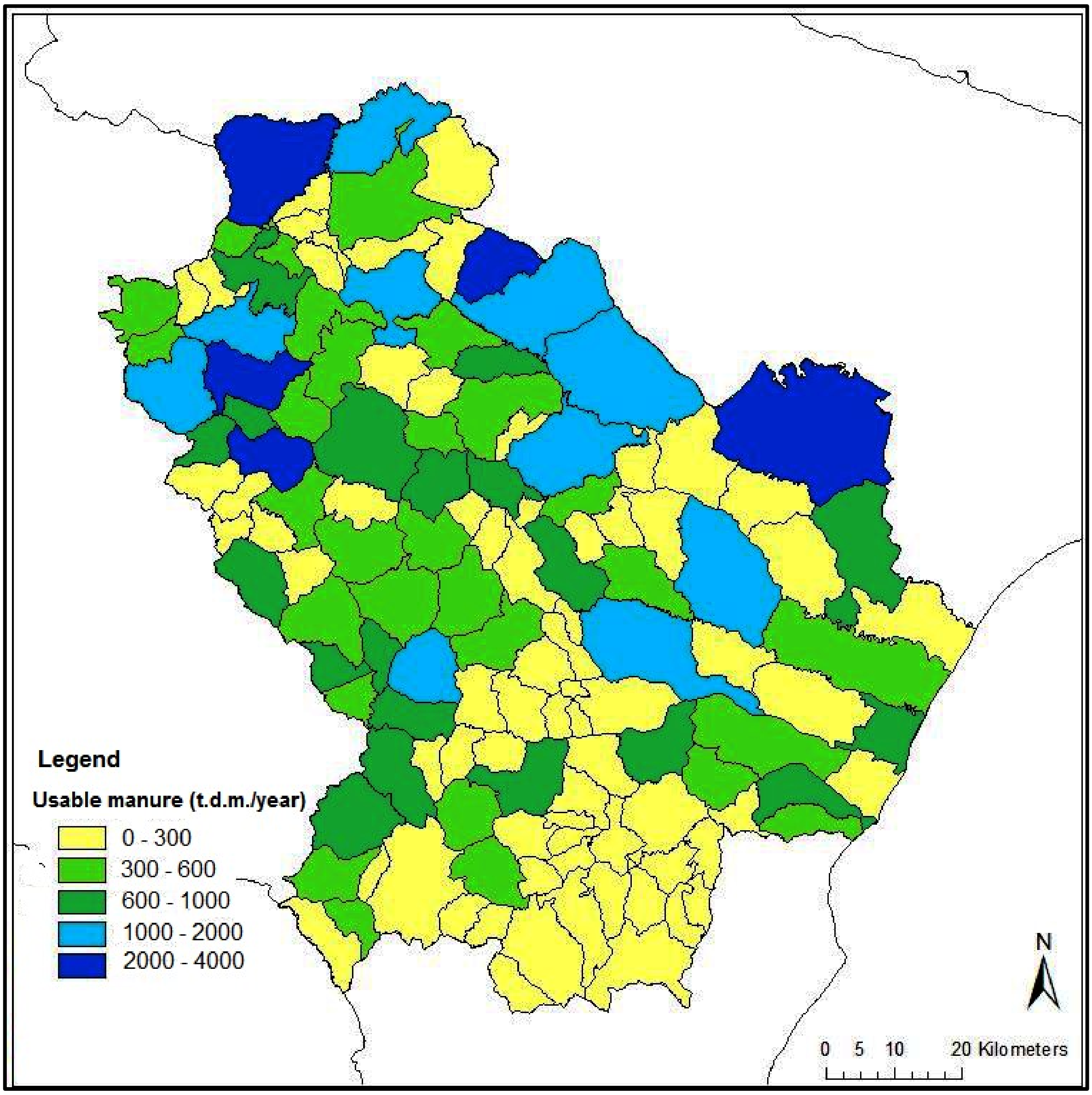


Figure 6: Availability of dry matter from manure

2.4.2 Olive processing

The olive oil industry, like most of the food industry, is characterised by a significant production of by-products, i.e. materials that never enter in the waste chain and, although they are not the main business activity object, they continuously arise from the industrial process and they are used under economically favorable conditions in a subsequent production process, without being subjected to treatments that could modify their chemical composition.

For the sector of oil extraction from olive pomace, instead, in these years there is a similar phenomenon but with reversed factors. In this sector, in fact, the solid biomass (olive pomace) is becoming more important year after year for various uses such as the electrical and thermal energy from renewable sources production (over 95% of pomace is used for energy production) or as a compost production substrate in combination with other by-products, while olive pomace oil, depending on market trends, could find a very interesting valorisation in the food sector. In the olive industry, the olives processing has an average yield of 15-22% of olive oil, about 40% of virgin olive pomace and the rest of vegetation water (Carrassi, 2013).

According to a Coldiretti, Unaprol and Ismea (2020) analysis, the production of extra virgin olive oil in Italy has significantly decreased in recent years; this decline caused mainly by climatic anomalies, which have interested especially the southern regions, without forgetting the effects of Xylella, which has in fact devastated most of the olive groves in the Salento area – Puglia region. According to Coldiretti, in the year 2020 there was a national production of about 287.000 tons compared to 366.000 tons of the previous harvest. The main cause was the harvests collapse in the southern regions, starting from Puglia, where about half of the entire national production is concentrated, while in the Centre-North regions the numbers are increasing everywhere.

Also, according to the Coldiretti Basilicata estimates (2020), on the basis of the forecast update elaborated by Ismea and Unaprol for the 2020/21 harvest, at regional level in the year 2020 there was a production of 5.600 tons of extra-virgin olive oil, with a production decrease of 14% compared to the previous year.

Oil is intended for human nutrition and it represents the oil mills activity product. Virgin olive pomace (humidity lower than 60%) represents the olive mills by-product (on average 1.000.000 tons/year) which is mainly destined to pomace factories for the oil extraction contained in the pomace. Recently, the pitting virgin olive pomace practice to extract the hazel from virgin olive pomace (with a yield of about 10% on the total virgin pomace produced by mills) is spreading in olive mills. This practice is creating several problems to the whole olive oil production chain final phase, which must manage a more humid material and more poor of its wooden component, the hazel, which has a higher "lower heating value" than the pomace pulp. The deoiled olive pomace (humidity lower than 15%) represents the by-product of olive pomace factories activity with considerable annual quantities available mainly destined for animal feed (about 2%), for the wood panels production, for the vegetable amender production, for the energy production as combustible biomass (95%), for the biogas production in anaerobic digesters, for the food field with the olive pomace flour production etc.

In Basilicata region, about 30.000 ha (RSDI, 2019) are cultivated with olive groves with an olive production of 33.400 tons according to the Coldiretti Basilicata estimates (2020).

So, considering the regional area cultivated with olive trees and the olives production, the total olives production per hectare is equal to:

$$\text{Olives production / Olive groves hectares} = 33.400/30.000 = 1{,}11\ tons/ha$$

As in the previous calculations, the ratio between by-product and raw material is 40%, in Basilicata region from the olives milling it is possible to produce 13.360 tons of virgin pomace, of which 55% is classified as exhausted pomace (Fig. 7), which can be used for various purposes.

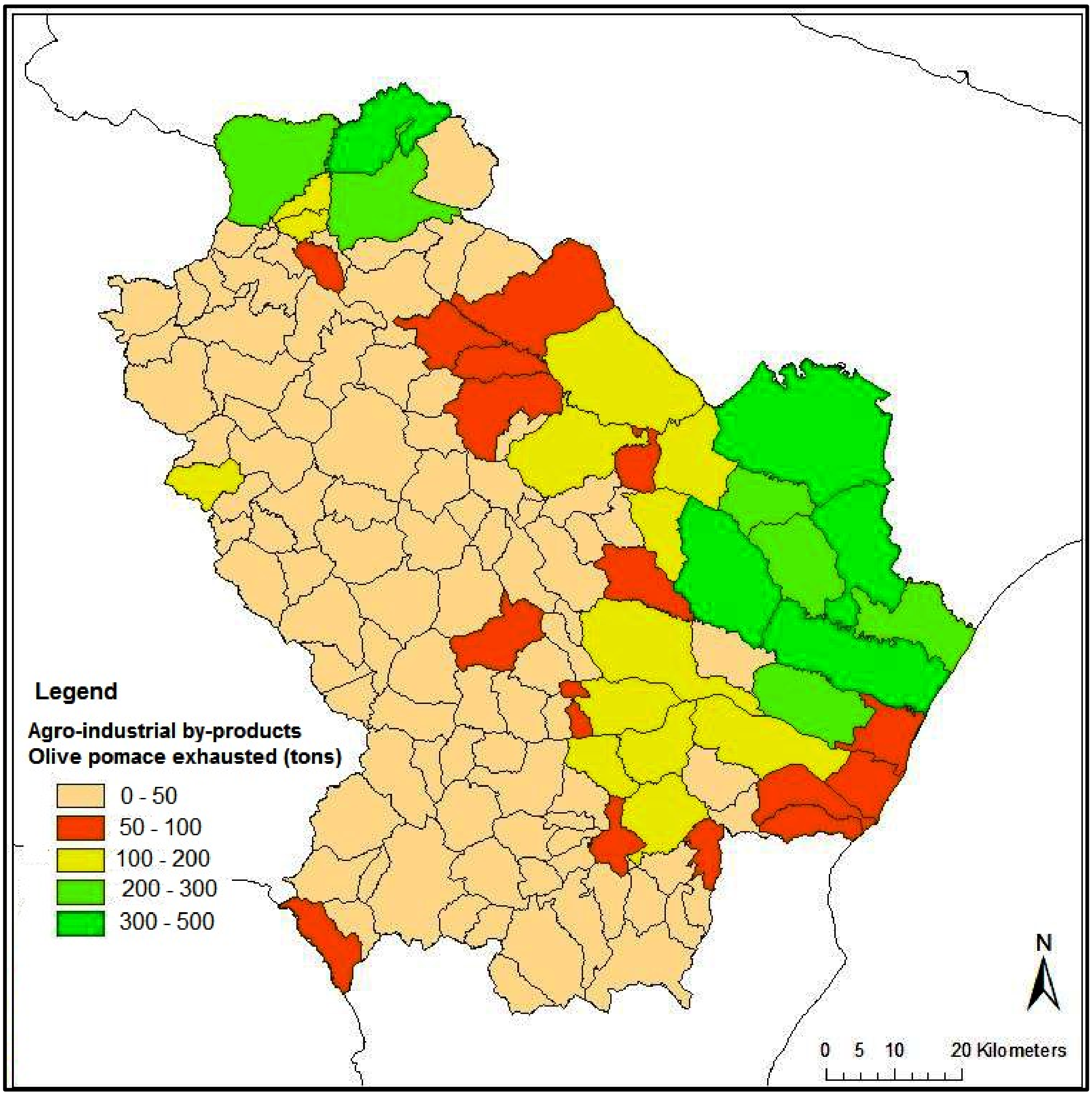


Figure 7: Availability of exhausted olive pomace

2.4.3 Grape processing

In Italy wine is the product of a very vast, heterogeneous and articulated sector; the wine production involves all regions and it is based in vineyards located in extremely diversified environments, from coastal plains to considerable altitudes and slopes. The variety of production conditions in terms of environments and varietal base is confirmed by the 399 origin protected designations (OPD) (of which 70 with controlled and guaranteed designation) and 118 protected geographical indications (PGI). About 240 thousand producers cultivate a declared area of about 540.000 hectares.

In Basilicata region, the wine sector has an increasing importance from a social-economic, environmental and cultural point of view and it represents a driving element for the other agricultural productions due to the increasing quality of wines produced and to the importance on the market. Some elements, such as the technological adaptation of production plants, the renewed awareness of the strong connection between wine and territory, the valorisation of autochthonous vines and the dedication of the local producers, have favored the transition to a quality production in new areas of the region, not exclusively identifiable with the Vulture territories, the elected area of Lucanian viticulture.

The production of wines with “Controlled Origin Denomination” has, in fact, intensified in the last decade and it includes, besides the "Aglianico del Vulture", the Basilicata region symbol wine, other 3 new “COD” (Controlled Origin Denomination) wines: "Terre dell'Alta Val d'Agri" (2003), "Matera" (2005) and "Grottino di Roccanova" (2009). The qualitative progress of Lucanian wines have reached its peak in the year 2010 with the “Controlled and Guaranteed Origin Denomination” recognition for “Aglianico del Vulture Superiore and Riserva” which, in this way, became one of the most prestigious wine in Italy, in addition to the “Typical Geographical Indication” (TGI) designation, approved since 1995, for white, red and rosé wines produced on the whole regional territory (INEA, 2014). In the year 2013, the vineyard areas in Basilicata region amounted to 5.310,43 hectares (RSDI, 2014). The area potentially producing “Controlled Origin Denomination” wines, corresponds to 32% of the total regional vineyard area; therefore only 1.699,33 hectares. Considering the valuable characteristics of local production and the various prescriptions, for each type of wine considered, it is considered that, in these particular conditions, the maximum grapes production is equal to 8 tons/ha (INEA, 2012).

The wine-making by-products destined to a distillation alternative use (Ministerial Decree no 7407/10) are pomace and dregs. At present, most of these by-products are sent to the distillery, thus allowing their complete valorisation until the end of their life cycle. Grape processing by-products (as presented in more detail in the next chapter) are used in different ways: from the energy field to the food and nutraceutical field, or as substrate for the production of biological fertiliser.

The main residual materials that can be qualify as by-products and the grape processing yields are expressed in Table 8 (Nicolini, 2013):

Table 8: Grape processing yields referred to 100 kg of grapes (can also be expressed as percentage values)

Imput products (Kg)		Output products (Kg)		Residues potentially classified as by-products (Kg)	
Grape	100	Wine	77	Virgin and exhausted pomace	10
				Grape seeds	5
				Stalks	3
				Lees	5

In this analysis, only virgin and exhausted pomace have been examined due to their higher percentage, whereas other types of by-products have been excluded.

Considering therefore the wine grapes area cultivated, the grapes production and the reusable residual products yield (virgin and exhausted pomace), the availability of by-product has been estimated (Fig. 8):

$$\text{Vineyards (hectares)} * \text{production} = \text{wine grapes}$$

$$1.699{,}33\ ha * 8\ (tons/ha) = 13.594{,}4\ tons$$

In Basilicata region there is a total wine grapes production equal to 13,594.4 tons, from which it is possible to extract 1.359,4 tons of virgin and exhausted pomace to be reused.

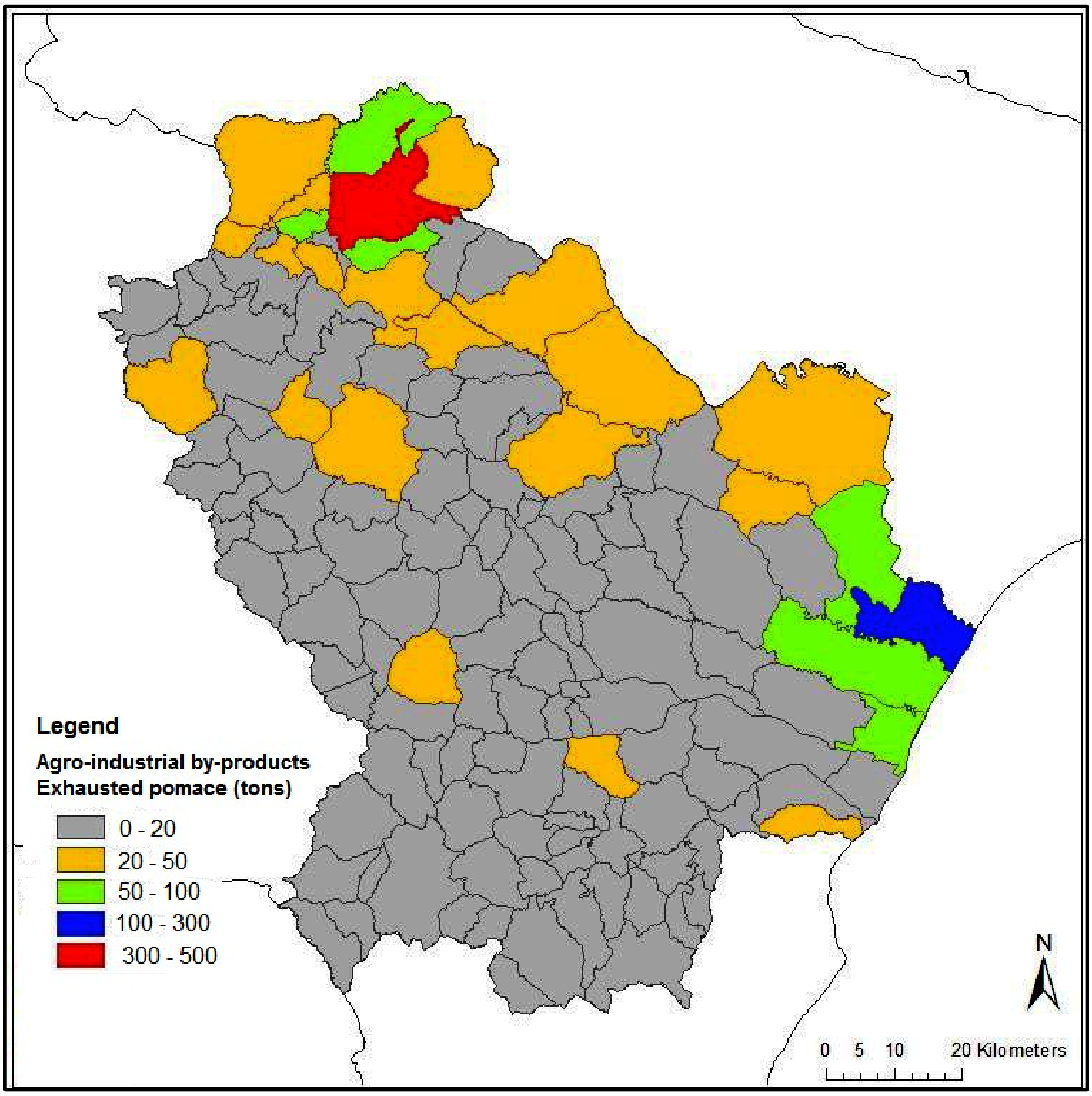


Figure 8: Availability of exhausted pomace reusable

2.5 Circular economy of by-products: nutraceutical, food, cosmetic field and restoration of soil fertility

The reuse of these by-products must be carried out according to the most rational and convenient solution from an economic and environmental point of view by respecting a inverted pyramid of hierarchical priorities (Fig. 9) that allows a high efficiency in the resources use and an increased environmental sustainability (Statuto and Picuno, 2016).

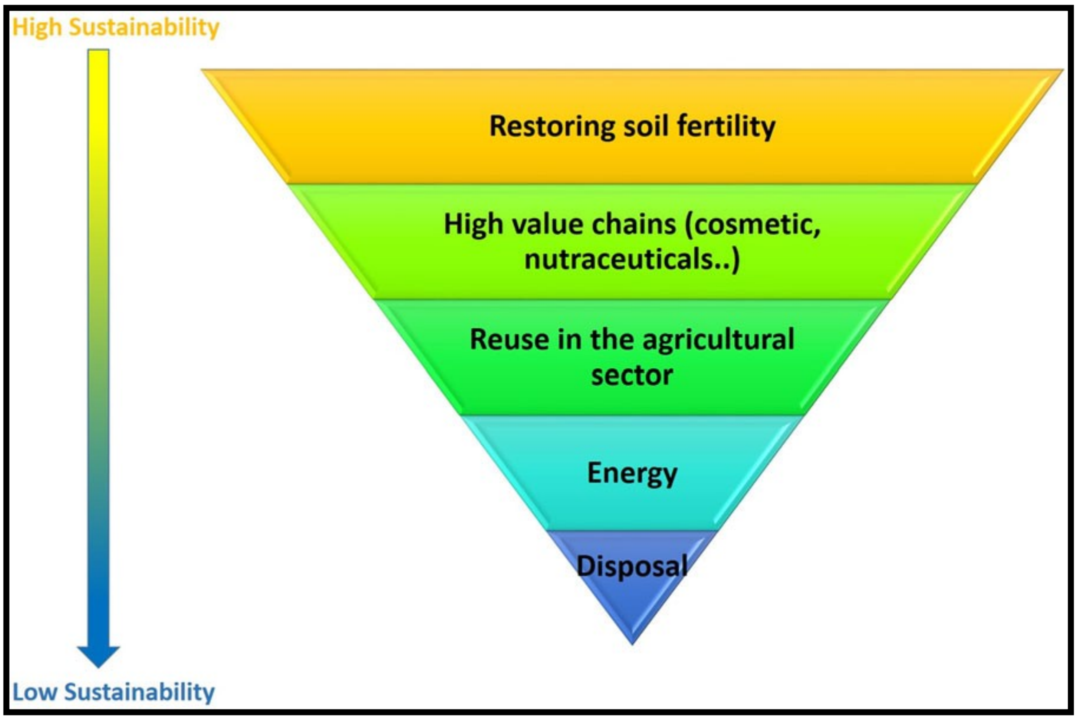


Figure 9: Agricultural by-product management hierarchy

According to this inverted pyramid of hierarchical priorities, which expresses the possible reuse and recycling forms of by-products, priority will be given to the **restoring of soil fertility**, since it is a fundamental component of a sustainable agriculture, as it forms the basis of all chemical and physical processes. In addition, Soil Organic Matter (SOM) improves its structure and increases its ability to retain water (Hossner and Juo, 1999; Woomer et al.,1994). In addition, more **value-added options** could be explored for the reuse of these by-products and their possible exploitation in different production chains **(cosmetics, nutraceuticals, etc.),** as well as in the construction sector, for example, as a natural additive that could be incorporated in clay bricks to increase their technical performance (Statuto et al., 2018).

Subsequently, other secondary possibilities offered in the **agricultural sector** could be exploited, since they can contribute to its sustainable development (Statuto and Picuno, 2016).

Only at the end, non-recoverable fractions could enhanced from an **energetic point of view** (Valenti et al., 2017b; Valenti et al., 2017c) where economically convenient. Renewable energy sources indeed represent a suitable alternative to conventional fossil fuels (Valenti et al., 2016; Valenti et al., 2017) due to possible advantages in terms of reduced environmental impact (Valenti et al., 2017a).

2.6 The impact of soil fertility on the characteristics of the rural landscape

Soil represents a fundamental resource, which plays a key role in ecosystems, since it governs all the mechanisms at the basis of vegetal growth and of all components of the total environment concurring to the formation of a rural landscape (Manniello et. al., 2020). In the study area, indeed, there is a strong correlation between agriculture and human actions, aimed at the sustainability of the rural landscape (Picuno et al., 2019). The environmental changes occurred during the last decades, mainly caused by the concurrent actions of human activities and natural forces, have resulted in continuous interactions with the surrounding context (Statuto et al., 2017). A landscape can be considered as a dynamic open system, in which economic, social and biophysical factors interact among themselves, defining its current structure (Neubert and Walz, 2002; Statuto et al., 2016) and transforming it into a valuable heritage, having a cultural value as well (Statuto and Picuno, 2017; Statuto at al., 2013b).

The long-standing historical relationships that traditional communities have established with their environments, provided a rich diversity of soils. A soil is, then, the result of the complex interaction among specific regional environmental factors and managing strategies. Distinctive landscapes are thereby generally formed by particular soil modeling processes. Land use for agricultural purposes is leading to unprecedented changes in the rural landscape, ecosystems and the environment. Rural landscapes are changing due to the intensification of agriculture, which exploits the soil and changes its state and its natural functions, bringing with it some undesired environmental problems such as climate change, loss of biodiversity and pollution of water, soil and air (European Environment Agency, 1999).

When soils are subjected to human impacts, they influence the value of the cultural landscape (European Policy Brief, 2016). The re-working of soils is the most tangible mean by which human activity has impacted on the landscape, creating field boundaries, spaces, paths and settlements. Behind the complexity of cultural landscapes, there are high levels of soil diversity (i.e., pedo-diversity) within regions, that demonstrate a great spatial variability of soil properties. This variability is not accidental, but rather structured by the activities of past communities. Therefore, pedo-diversity can be intended as the identification of specific cultural signatures present in the soil of local landscapes.

In recent decades, a persisting inadequate substitution of soil nutrients has led to the lack of organic matter and consequent low level of soil fertility (Fig. 10) (Manniello et al., 2020/a), only partly balanced by the reuse of agricultural residues (Manniello et al., 2020/b).

A good soil organic matter content determines in fact a series of positive effects that concern the soil structure, the nutrients supply and solubility, water retention, the cation exchange and adsorptive power capacity, the pH maintained close to neutrality, ferric chlorosis prevention and the soil biodiversity.

The soils with a strong agricultural vocation often present an organic matter average annual deficit with variable data depending on environmental conditions (climate, soil) and cultural techniques (soil management, rotation type). To restore the optimal level, it is necessary to introduce, among the soil management practices, the soil conditioners contribution, with the aim of maintaining at acceptable levels the macronutrients (nitrogen, phosphorus, potassium, calcium and magnesium) and micronutrients (iron, manganese, zinc and boron) quantities.

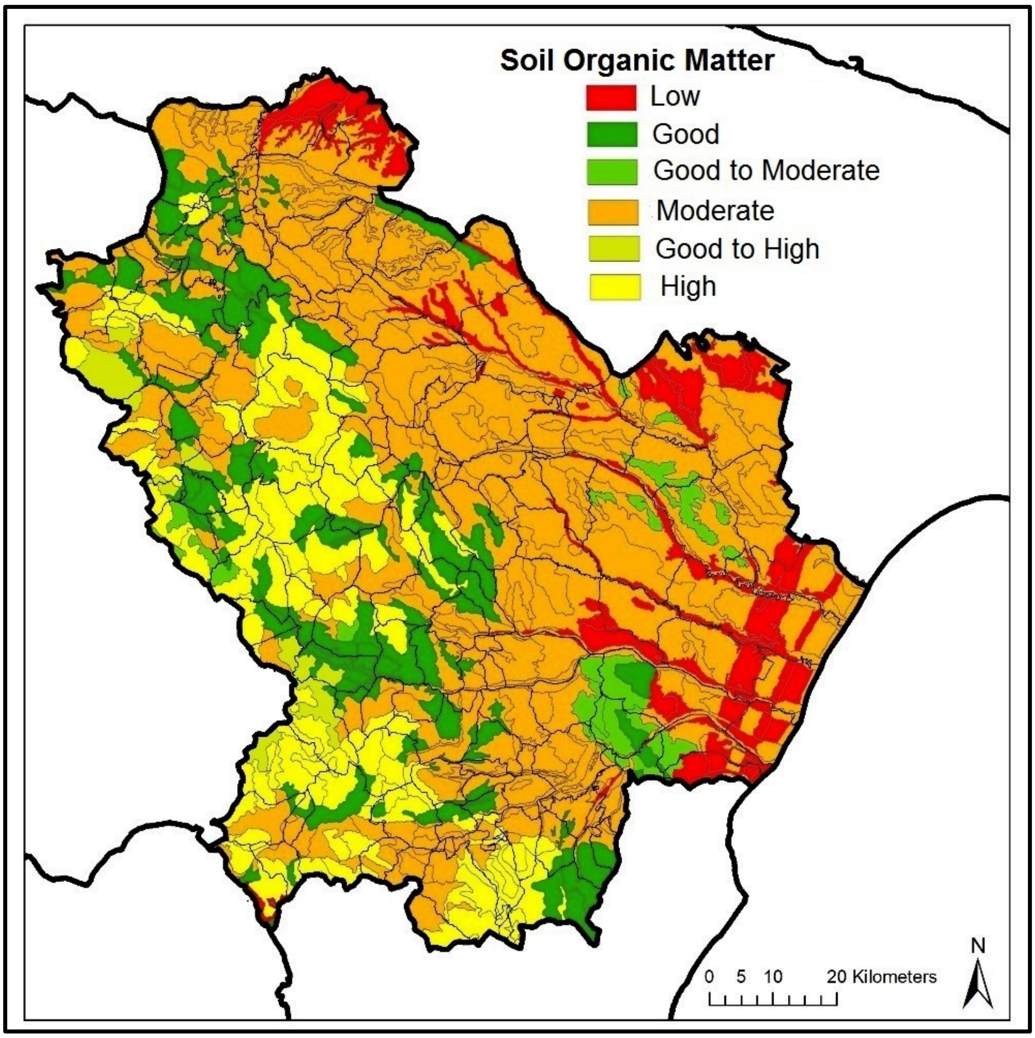


Figure 10: Concentration of soil organic matter in Basilicata region

Starting from an analysis of the content of organic matter present in the soils of the Basilicata region (Fig. 10) it is possible to highlight that in the north-east part of the region there are smaller quantities of organic matter. This area is one of the most important areas of the Basilicata region for the production of wine (“Monte Vulture”). In this area, the warm winds of Adriatic influence contribute to the development of vineyards and the presence of an ancient volcano, but now extinct, gives the wine its rare and much appreciated characteristic taste (Statuto and Picuno, 2016). The DOC wine par excellence is the “Aglianico del Vulture”, to which the lava matrix of the soil gives particular organoleptic characteristics different from other titles of Aglianico. It is cultivated up to 800 m of altitude, although the optimal conditions are between 200 and 600 m. In this area, this type of vine has found its suitable territory, thanks to the composition of the soil and the complex orography that determines a wide variety of climates depending on altitude, slope and exposure. In order to confirm the data shown on the map, some samples were taken from land in vineyards in the area. The survey has been carried out in n.5 specimens soils, using a Global Positioning System (GPS), so as to detect the exact location of soil sampling pits (Fig. 11), with the aim to identify physical and chemical properties of the soil units. The coordinates (latitude and longitude) of these five points have been recorded and imported into the Quantum GIS-v. 3.4.

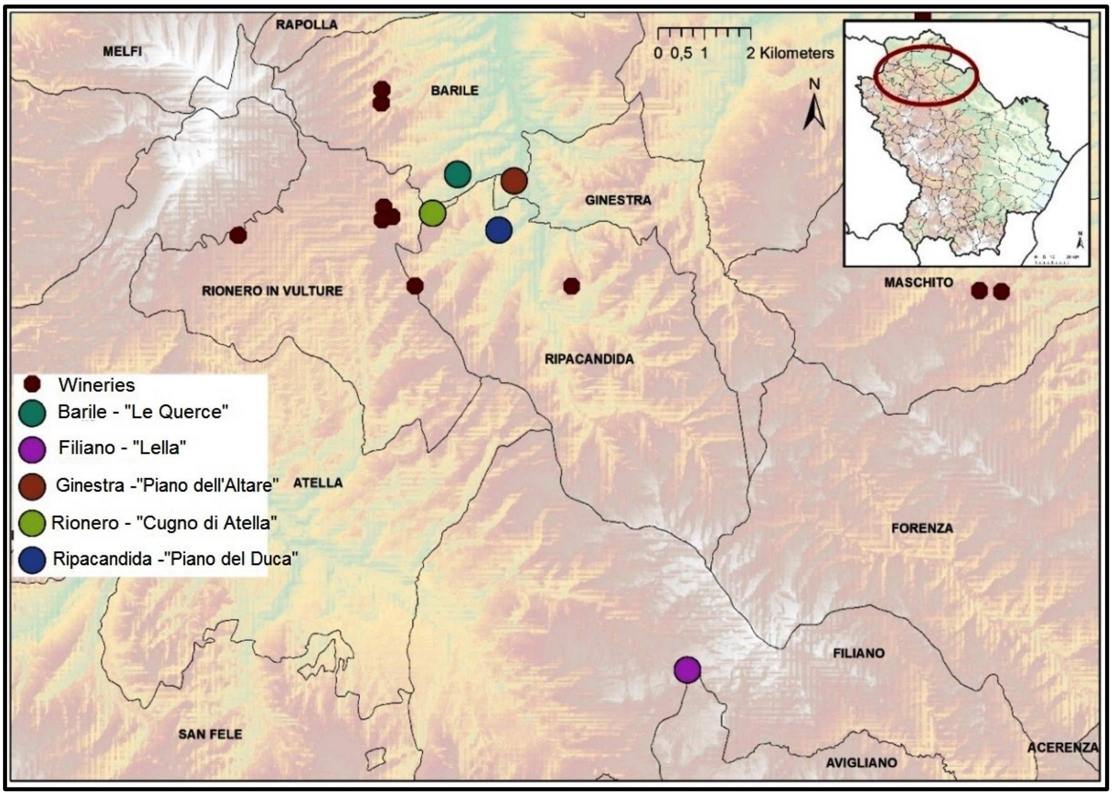


Figure 11. Location of wineries and sampled soils in the study area: EPSG 32633—40°56′01″ N 15°41′39″ E (Barile—"Le Querce"); 40°50′13″ N 15°45′08″ E (Filiano—"Lella"); 40°55′56″ N 15°42′31″ E (Ginestra—"Piano dell'Altare"); 40°55′34″ N 15°41′16″ E (Rionero—"Cugno di Atella"); 40°55′22″ N 15°42′17″ E (Ripacandida—"Piano del Duca").

The collected soil samples were air dried in shade, crushed and sieved for the laboratory analysis. The laboratory analysis on these five have included: total nitrogen, organic matter, total phosphorus and potassium, while the information about particle size distribution and soil pH have been obtained by consulting the soil maps for the Basilicata region (Regione Basilicata, 2019).

According to the results obtained (values elaborated from Regione Basilicata, 2018), in terms of soil structure (Tab. 9), four out of five soils tend to be clayey while only one is completely clayey. The pH is generally comprised between 6,5 and 7,3 (neutral soils) except in a case where the soil is alkaline with a pH value above 8.

The main agronomic characteristic of the soils analyzed is a wide dispersion of their SOM contents, resulting in a general lack of organic matter. The value of the organic matter varies indeed from 8,69 to 24,3 g/kg with an average value of 18,08 g/kg. This contributes to a relatively low total phosphorus content, since many authors (Miele et al., 2004) have underlined the close correlation of this parameter with organic carbon. Indeed, the total phosphorus content in the study area varies from 0,367 to 3,002 g/kg d.m. (dry matter) with an average value of 1,709 g/Kg d.m., so quite close to the lower limit of the acceptability range. This also happens for Potassium, which is also low, since it varies from 3,288 to 8,241 g/Kg d.m. with an average value of 6,293 g/Kg d.m. The total nitrogen content, instead, appears sufficient, since it varies from 1,4 to 2,6 g/Kg, with an average value of 2,08 g/Kg, so even higher than the upper limit of the acceptability range.

The lack of organic matter prevents the soils to perform their functions properly as it significantly reduces their physical, chemical and biological fertility. These types of soil, generally light in color, do not have sufficient nourishment and are characterized by high fragility, and they do not retain the roots of plants and are more vulnerable to erosion. The continuous removal of organic matter from the soil could be balanced by the intake of nutrients present in the agricultural residues, in order to close the cycle of organic matter and facilitate the return to the soil of the substances removed from the agricultural activities.

Table 9. Results obtained on the analyzed soil samples.

Soil Parameter	Barile "Le Querce"	Filiano "Lella"	Ginestra "Piano dell'Altare"	Rionero "Cugno di Atella"	Ripacandida "Piano del Duca"	Acceptability Range *
SOM (g/Kg)	8,69	24,3	22,24	19,31	15,9	15-20 g/Kg
Total N (g/Kg)	1,4	1,9	1,9	2,6	2,6	1-1,8 g/Kg
Total P (g/Kg d.m.)	1,38	0,367	1,612	2,185	3,002	1,5-2,5 g/Kg d.m.

K (g/Kg d.m.)	7,919	3,288	5,871	8,241	6,150	5,5-8,5 g/Kg d.m
pH	6,7	8,1	6,8	6,8	6,9	6,5-7,3 (neutral)
Texture	fine clayey	clayey	fine clayey	fine clayey	fine clayey	100-300 g/Kg

In order to highlight the relationships between land use changes and the surrounding rural landscape fragmentation, an ecological index has been calculated referring to the period 1990-2018 (28 years) (Copernicus, 2020) (Fig. 12).

Through the Sharpe Index (Hulshoff, 1995) it is possible to highlight the significance of certain processes concerning land use transformations that have occurred in an historical period in a study area. The Sharpe Index is applied to individual types of land use classes.

It may assume positive or negative values (Rete Rurale Nazionale, 2016). The Sharpe Index (S.I.) is thus calculated as:

$$S.I. = \frac{\left(\frac{(pk_2 - pk_1)}{(t_2 - t_1)}\right)}{S}$$

Where “pk_1” is the area of the single land use class at year t_1 expressed in hectares; “pk_2” is the surface of the single land use class in year t_2 ($t_2 > t_1$) expressed in hectares; “S” is the total surface of the study area expressed in km^2.

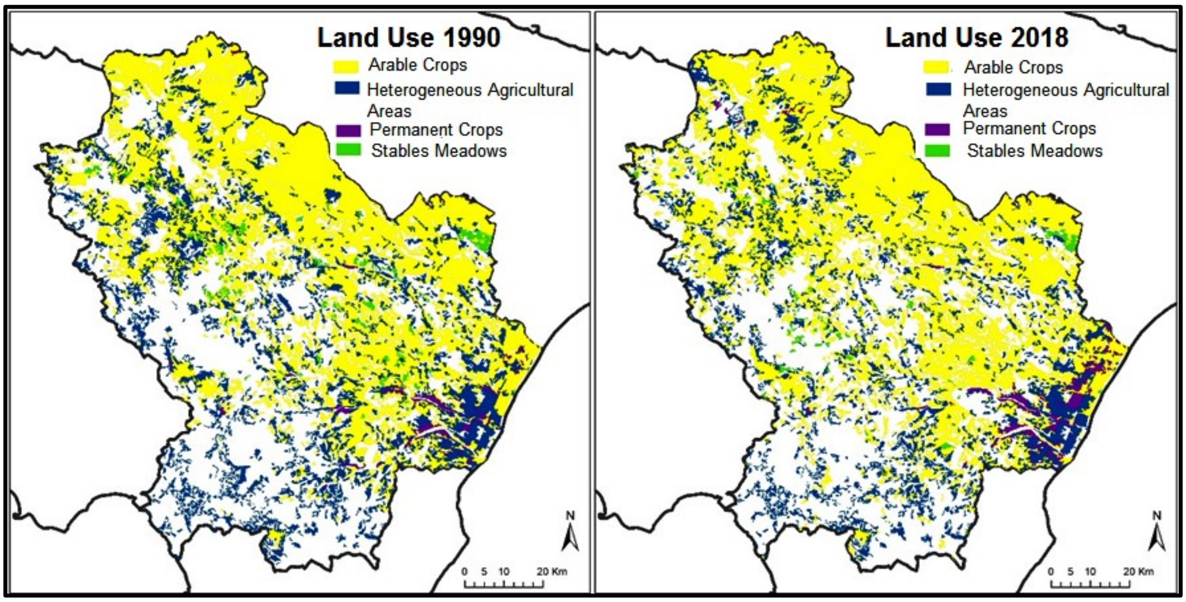


Figure 12: Land use categories in the year 1990 (left) and in 2018 (right).

On the basis of the "Agricultural Area Used" (Corine Land Cover level 2), the Sharpe Index has been calculated for each land use, to provide a comparison between the two different periods. When this Index has assumed a positive value, then the land use has recorded an increase in surface area in the reference period. On the contrary, if the index has assumed a negative value, the land use has recorded a decrease in its surface area. The results of this comparison are showed in Figure 13, in which the land uses responsible for the most significant changes are reported in a bar chart form. As a final result, it is clear that, in the case of Basilicata region, the most meaningful changes are due to the increase in the area used for arable and permanent crops, that has been balanced by a decrease in permanent grassland and heterogeneous agricultural areas.

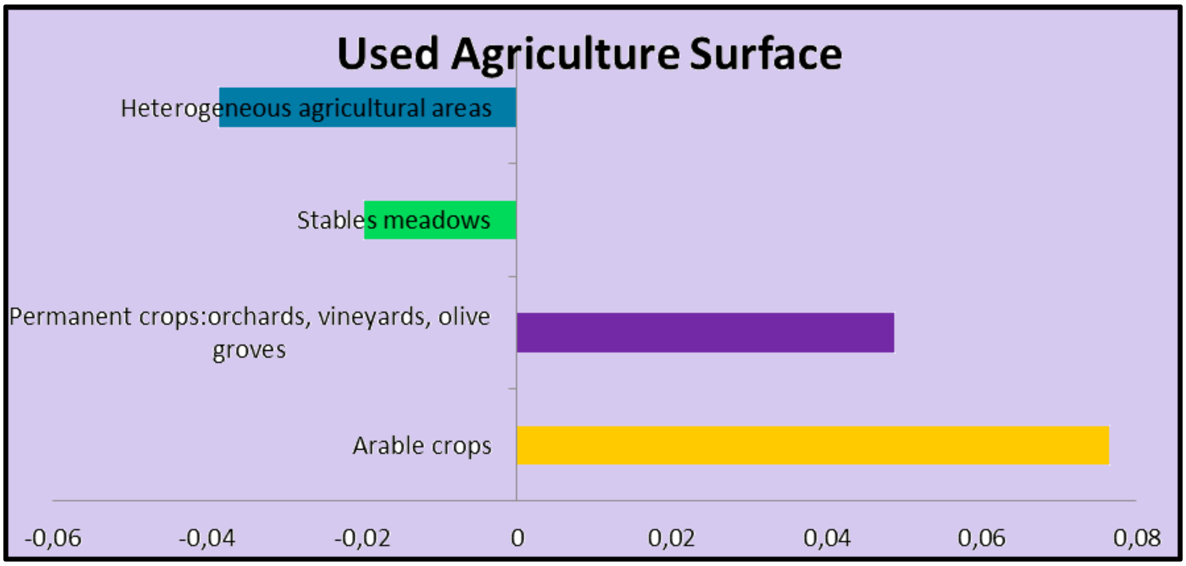


Figure 13: Application of the Sharpe index to the Agricultural Area Used for the Basilicata region.

This increase in the areas intended for arable and permanent crops (orchards, vineyards, olive groves), inevitably presupposes an intensification of agricultural activities in the considered period and a consequent increase in the tillage of the soil. This agricultural practice modified the soil pedological profile, its structure and spatial variability, causing at the same time a reduction of the organic matter content. These activities, like most intensive agricultural practices, require indeed continuous removal of nutrients from the soil, especially in relation to the agronomic techniques used. The arable crops, with their continuous processing, change the soil structure, progressively subtracting nutrients to the plant root systems. In the same way, permanent crops, in order to grow and perform their vital functions, need nutrients constantly, depleting the soil. As a consequence, without the necessary balancing and return to the soil of the substances removed from agricultural activities - which would close the cycle of organic matter - the soil no longer performs its vital functions correctly, as it significantly reduces its physical, chemical and biological fertility, with consequent increase in erosion, causing alterations to the local ecosystems and to the whole rural landscape. Suitable planning interventions are therefore absolutely necessary, in order to restore proper conditions for safeguarding soil health and protecting the relevant landscape.

CHAPTER 3: FOCUS ON WINE BY – PRODUCTS

Human progress depends on the natural environment that surrounds it and it could be limited by its future degradation. The increase of the industrialisation rate, the urbanisation and the population growth that occurred in the twentieth century has forced society to consider the possibility of seeing its essential living conditions profoundly change (Thomson,1997). The environmental degradation, associated with this growth, manifests a multiplicity of negative effects on water, air and soil quality and consequently on human health and ecosystems (El-Swaify and Yakowitz, 1998). The consequence of this scenario is progressively leading to the realisation of new industrial paradigms, not least the wine industry. Thanks to a series of legislative instruments and to technological innovation, the society is aiming towards a more sustainable wine production, thanks to a greater consideration of environmental aspect, above all as regards the wine by-products management and valorisation (Recault, 1998; Marais, 2001; Shepherd, 1998; Shepherd and Grismer, 1999).

3.1 The industrial wine-making process and by-products generated

Wine is defined as "the product exclusively obtained by alcoholic fermentation, total or partial, of fresh grapes whether crushed or not” (Navarre, 1991). From the grapes processing, many types of wine can be obtained, characterised by different processes such as table wines, sparkling wines, sweet wines and grappas. They are distinguished by the vine type from which they are produced, by the processing, by the chemical products used during vinification and by the alcoholic level content to be obtained.

It can be distinguished two types of wine making processes, according to the wine type to be obtained: white wine making and red wine making.

White vinification consists in the pomace separation (draining) from the grape, obtained during the crushing grape phase, proceeding directly with the fermentation process. This operation aims to avoid the transfer of skins color to the grape must, both for white or black grapes. Subsequently, the drained pomace can suffer one or two crushings in order to recover the second wine and other byproducts. Red wine vinification, on the other hand, includes a maceration phase during which the constituents dissolution of the bunch solid fractions (grape seeds, skins and possibly stems) in the grape must takes place. Each process step generates by-products (Pavan et al., 2015) (Fig. 14).

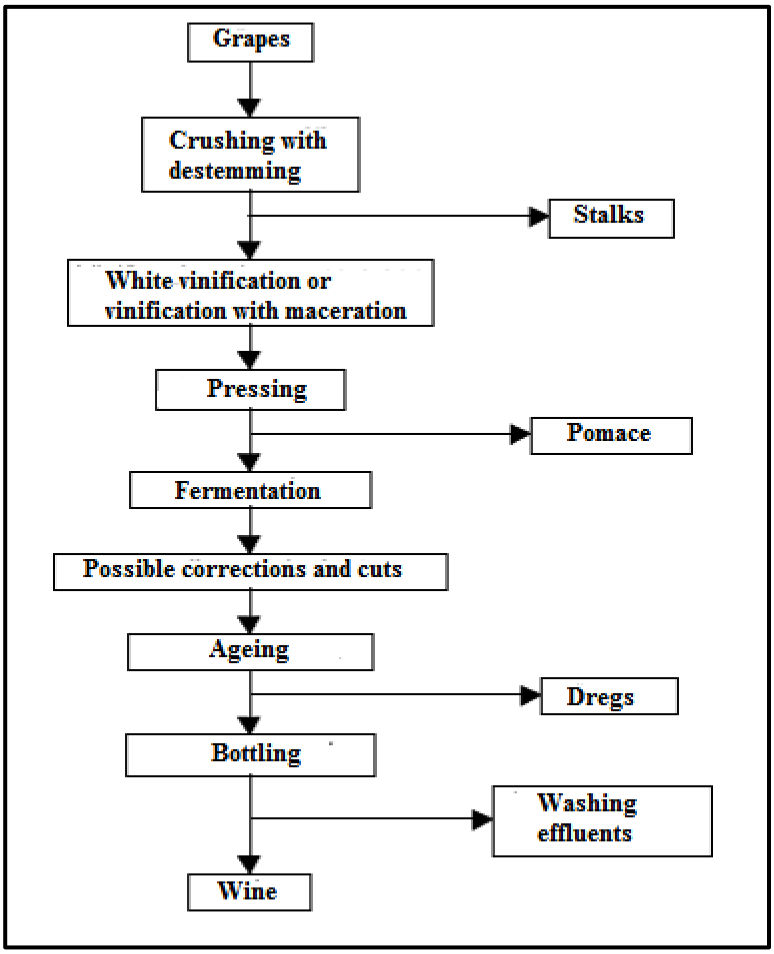


Figure 14: Wine making process phases and related byproducts

The wine making process main phases (Fig.14) are:

- **Grape harvesting**

It is the first phase of wine making process and it often takes place during the less hot periods of the day in order to prevent or delay the heat accumulation in the grapes. During the grape harvesting process, both mechanically and manually, some bunches may have lacerations which cause the release of juice. In order to avoid their oxidative degradation, which favor the yeasts or bacteria growth, sulfur compounds are added.

- **Destemming and crushing**

After grape harvesting phase, grapes are separated from stems, leaves and stalks. This phase is called destemming and it takes place with a destemming machine, composed of a perforated cylinder which rotates in order to prevent the passage of undesiderable fraction such as skins and seeds. Crushing phase, that is the grape crushing in order to allow pulp spillage, can be combined with destemming or can follow it. Usually, grapes are crushed against a wall or a series of rollers. The grape obtained in this phase is transported in a fermentation tank and it is mixed with yeasts and activating substances.

- **Fermentation**

In this phase the yeasts, due to enzymatic activities, convert sugars into ethyl alcohol and carbon dioxide. Among the factors that most influence the fermentation process, there are the grapes composition and its state of health, the thermal factors at the time of inoculation and the oxygen role. The aeration is in fact necessary at the beginning of the fermentation phase in order to allow the yeasts growth and reproduction.

- **Maceration**

In this phase there is a strong enzymes release from grape cells, which promote the organic compounds liberation and solubilisation, in particular the phenolic ones which are present in the grapes skins, seeds and pulp. This phase is responsible for all the visual, olfactory and gustatory characteristics that differentiate red wines from white wines. In order to make a good wine making process, it is necessary to highlight the factors involved in maceration, in particular the duration (it will differentiate young wines and red wines for aging), the temperature, the sulfur dioxide content and the alcohol level.

- **Wine racking**

In this step there is the wine separation by gravity from pomace and dregs, thanks to proper sieves which allow the elimination of eventual grapes and skins fractions from wine.

- **Pomace crushing**

Usually in this phase a press (horizontal, pneumatic or screw press) or a winepress is used in order to extract the wine still contained in pomace. It usually takes place with gradual pressure increases, in order to avoid altering the wine characteristics and quality.

- **Clarification and maturation**

Wine clarification phase is essential in order to remove insoluble fractions present at the end of fermentation. This fraction is mainly composed by dead yeast cells, bacteria, decomposed material, protein precipitates and tartrate crystals. This phase usually takes place by gravity, or by the aggregants addition such as bentonite, gelatin or silica. Afterwards there is the maturation process which involves the precipitation of colloidal material present in the wine, as well as a complex series of physical, chemical and biological changes in order to maintain and improve the characteristics of the wine itself.

3.1.1 Wine making by-products

From each one of the previously described phases, by-products are generated (Fig. 14). **Stalks**, the first by-product to be released (Fig.15), correspond to the grape woody part and they are eliminated during destemming phase. Subsequently, during the white vinification, the crushing releases a **virgin pomace**, not fermented, characterised by a high concentration of sugars used for the transformation into alcohol. In red wine making process, the pomace produced is instead composed of **grape seeds, skins and stalks** by-products (Fig.15) and it is characterised by a good level of sugars fermentation. Grape seeds are mainly composed of vine seeds and they can be extracted by sieving in different grape processing phases. Grape skins represent the grapes epidermis. Similarly to stems, they can be crushed, dried and eventually subjected to milling.

According to EEC Regulation No. 337/79, the **wine dreg** represents the sludge residue which is deposited in grape vats, after fermentation, during storage or after authorised treatments, as well as by-products obtained by filtration or centrifugation of this product. The vinification dreg can be divided into "heavy" or "light", according to the degradation type and it represents on average 2-6% of the total wine produced. It mainly consists of yeast cells produced during alcoholic fermentation, bacteria, tartaric salts, vegetable residues and ethanol (Bai et al., 2008, Naziri et al., 2012).

At the end, there is **waste water,** which mainly derives from the washing operation of the equipments, tanks and production rooms. Their average determination of these volume is not easy because winery operations imply the use of very variable quantities of water, according to the technology adopted and to the plants sizing.

The whole wine production chain does not only include the grape production, transformation and commercialisation, but it also includes a series of processes concerning the by-products transformation, such as those destined to distilleries. This recovery phase therefore represents a fundamental link for the realisation of a virtuous system, capable of enhancing every single phase of the process and therefore reducing the environmental impact as well.

In accordance with OIV (International Organization of Vine and Wine) estimates, in the year 2014, 44,4 million hectoliters of wine have been produced in Italy, with an estimated of 0.8 million tons of pomace including grape seeds (equal to 15% of the vinified grapes) and 2.250.000 hectoliters of lees (equal to 5% of the wine produced) (OIV, 2015), in addition to the estimated production of about 3*106 m^3 of wastewater (Moldes et al, 2008).

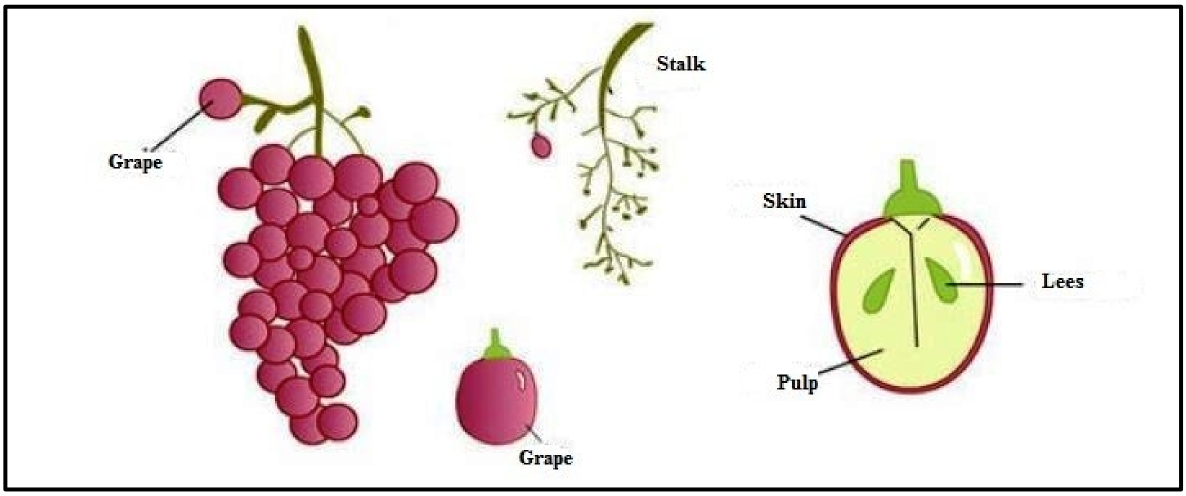


Figure 15: Grape bunch main components (Nicolini, 2013)

3.2 Legal framework of wine-making by-products

3.2.1 The definition of wine-making by-products

The Ministerial Decree of November 27, 2008 defines the wine-making residues as by-products, and not waste, since it is destined to be used in a production cycle.

The article 183 of Legislative Decree 152/2006 (environmental regulations) defines by-products as: *"substances and materials which the producer does not intend to dispose of according to article 183, paragraph 1, letter a), which respect all the following criteria, requirements and conditions: 1) they originate from a process that is not directly intended for their production; 2) their use is certain, from the production phase and it takes place directly during the production or thanks to use process previously identified and defined; 3) they must satisfy requirements of product and environmental quality suitable for* *ensuring that their use does not cause emissions and environmental impacts qualitatively and quantitatively different from those authorised for the industrial plant where they are to be used; 4) they should not be subject to preventive treatments or preliminary transformations in order to satisfy the requirements of product and environmental quality of point 3), but they possess these requirements from the production stage; 5) they have an economic market value".*

The wine making by-products, moreover, according to article 185 point 2 of Legislative Decree 152/2006, are identified as *"vegetable materials coming from agricultural activities used in agricultural activities".*

In this case, the grape processing by-products, dregs, pomace (skins and seeds) and stalks, if the producers do not intend to dispose them, but to reuse them in agricultural activities, satisfy the criteria, requirements and conditions mentioned above; *therefore they are agricultural activities by-products and not waste.*

Wine making by-products destined for an alternative use to distillation (articles 2 and 3 of Ministeria Decree November 27, 2008) are lees and pomace, which represent about 15% by weight of the processed grapes. The minimum alcohol volume and their characteristics (both those intended for distillation and those retrieved under control for alternative uses), in application of article 21, paragraph 1, of Reg. (EC) No. 555/08, are those provided for by article 4 of Ministerial Decree November 27, 2008 and precisely:

a) pomace: 2.8 liters of anhydrous alcohol (actual and potential) per 100 kg;
b) wine dregs: 4 liters of anhydrous alcohol per 100 kg, 45% humidity.

The lack of the requirement relating to the alcohol content in the by-products, is a violation attributable to the provisions of article 1, paragraph 5, of Legislative Decree 260/2000 which, penalises the grapes and the dregs overcrusching also.

3.2.2 Distillation alternative re-uses of wine-making by-products

The Ministerial Decree of December 18, 2008 of the "Ministry of Agricultural, Environmental and Forestry Policies", provides that dregs and pomace not delivered to the distillers can be used for energy purposes, as compacted fertiliser, or for other purposes allowed by article 5 of Ministerial Decree November 27, 2008 and subsequently modified by Legislative Decree No.7407 of August 4, 2010, respecting the related requirements. For production residues different from previous, the alternative uses allowed (Legislative Decree No. 7407 of August 4, 2010), regulated at a regional level, are:

- direct agronomic use: through the by-products distribution on agricultural land within the limit of 3.000 kg per hectare of agricultural surface resulting from the farm documents;
- indirect agronomic use: through the use of by-products for the fertiliser preparation;
- energy use: through the use of by-products as biomass for the biogas production or to feed industrial plants for the energy production also used in combination with other energy sources for the biogas production or combustible biomass;
- pharmaceutical use: through the utilisation of by-products for medicine preparation;
- cosmetic use: through the utilisation of by-products for the cosmetics preparation.

3.2.3 Legal framework of winery wastewater re-use

The Legislative Decree 152/2006 regulates the wastewater reuse in order to limit the withdrawal of surface and underground water, reduce the discharges impacts on rivers and promote water saving. In the regions where this practice is regulated, wastewater from farms that also carry out wine production processing and enhancement, can be reused for agronomic purposes, by spreading on the soil.

Article 74 of this decree specifies that agronomic use means *"the management of livestock waste, residual vegetation water from olive processing, wastewater from farms and small agro-food companies, from their production to their application to the soil or their irrigation use aimed at the use of thei nutrients and soil conditioners".* The term "soil application" is defined as *"the supply of material to the soil by spreading and/or mixing with the surface layers, injection, burial".* In according with these definitions, article 112 establishes that *"the agronomic use of such wastewater is subject to communication to the competent authority",* which issues regular authorisation.

It is therefore clear that it is necessary to verify the position of all wine producers, in order to clarify if they are able to reuse their wastewater for agronomic purposes, above all taking into account the quantities in relation to the soil extension.

3.3 State-of-the-art on reuse for wine making by-products

Worldwide wine production was approximately 279 million hectolitres in the year 2015 (Organisation International of Vine and Wine, 2015); approximately 0,13 tons of pomace, 0,06 tons of dregs, 0,03 tons of stalks and 1,65 m^3 of wastewater are generated from 1 ton of grapes processing (Oliveira and Duarte, 2014). Thus, the main supply chain by-product is the pomace, which represents about 10%-30% of the mass of crushed grapes. It is mainly composed of unfermented sugars, alcohol, polyphenols, tannins, pigments and other valuable products. The winery size and the winemaking methods used directly influence its quantity and quality (Muhlack et al.,2008). Along with residual sugars, it has other physical (e.g., pH, moisture, etc.) and chemical (e.g., lignocellulose, polyphenols, ash, etc.) characteristics that are important to consider when pomace is used as a raw material (Tab. 10).

Table 10: Grape pomace and other by-products chemical and physical characteristics

Parameter	Value	Reference	Parameter	Stalks	Pomace	Dregs	Reference
Ph	3,6 ± 0,2	(Lafka et al,2007)	pH	4,4	3,8	4	(Bustamante et al., 2008)
Moisture	73,6 ± 2,6% w/w		Organic Substance (g/kg)	920	915	759	
Reducing sugars	1,5 ± 0,3% w/w		Oxidizable organic carbon (g/kg)	316	280	300	
Ash	4,6 ± 0,5% w/w		Water soluble carbon (g/kg)	74,5	37,4	87,8	
Cellulose	20,8 % w/w	(Mendes et al.,2013)	Total nitrogen (g/kg)	12,4	20,3	35,2	
Hermicelluloses	12,5 % w/w		P (g/kg)	0,94	1,15	4,94	
Tannins	13,8 % w/w		K (g/kg)	30	24,2	72,8	
Proteins	18,8 % w/w		Ca (g/kg)	9,5	9,4	9,2	
Ash	7,8 % w/w		Mg (g/kg)	2,1	1,2	1,6	
			Fe (mg/kg)	128	136	357	
			Mn (mg/kg)	25	12	12	
			Cu (mg/kg)	22	28	189	
			Zn (mg/kg)	26	24	46	

The disposal of these by-products without a proper treatment can cause a very significant environmental pollution.

As previously discussed, with the new European reform (Regulation EC 479/2008) there is the gradual elimination of subsidies to distilleries, in order to promote the integrated and sustainable valorisation of winery by-products. This approach allows to obtain different products with high added value by applying modular processes, with the possibility to exploit a wide range of compounds and minimising the waste generation. In Table 11, the state-of-the-art related to the different methods of by-products valorisation from the wine industry processing phases has been summarised, together with their relevant references.

Table 11: State-of-the-art of the valorisation of wine industries by-products and relevant references

Wine Industry		
By-products	**Possible Reuse**	**Bibliographic source**
Pomace	Carbon source for lactic acid fermentation (high percentage of sugar) and production of bio-emulsifiers	Portilla-Rivera et al.,2007 Portilla-Rivera et al., 2010
	Nutrition source after fermentation	Sanchez et al.,2002
	Bioethanol production after fermentation	Rodriguez et al.,2010
	Polyphenols extraction	Vatai et al.,2009; Conde et al.,2011
	Wood industry, dyes for the food industry and as antioxidants (high percentage of polyphenols)	Ping et al., 2011; Thorngate and Singleton .,1994; Karleskind,1992
	Precursors for the syntesis of biologically active compounds (palmitic, stearic and linoleic acid)	Gallander and Peng.,1980
	Phytopathogenic control	Santos et al.,2008 ; Bai et al.,2008
	Antioxidant, anti-inflammatory, anti cancer antidepressant and anti aging effects on human health	Rabiei et al., 2017; De Sales et al., 2018; Wittenauer et al., 2015
	Substrate for mushrooms cultivation	Pardo et al.,2007
	Substrate for human and animal food	Marchiani et al.,2016; Guerra-Rivas et al.,2016; Dias et al.,2018; Matassa et al.,2016; Dwyer et al.,2014; Brenes et al.,2016
	Substrate favorable for plant growth	Diaz et al.,2002; Nogales et al.,2005; Bustamante et al.,2009; Paradelo et al.,2010

	Cosmetic and nutraceutical sector	Baydar et al.,2006
Vinification dregs	Additional nutrient for "Lactobacillus"	Bustos et al.,2004
	Polyphenols recovery by microwaves or supercritical compounds	Perez-Serradilla and Luque De Castro.,2011; Wu et al.,2009
	Substrate favorable for plant growth	Diaz et al.,2002; Nogales et al.,2005; Paradelo et al.,2010
	Additional nutrient for "*Debarymyces Hansenii*" after acid tartaric extraction	Salgado et al.,2010
	Raw material for production of ethanol and tartaric acid	Versari et al., 2001; Braga et Al., 2002
	Stabiliser in place of citric acid	Boulton et al., 1995
	Bioactive functional properties (free flavonoids, anthocyanins and aglycones)	Barcia et al.,2014
	Recovery of squalene, lipids and fatty acids useful as food additives	Naziri et al.,2012; Naziri et al.,2014; Gomez et al.,2004
	Biogas production through anaerobic digestion	Rozzi et al.,2004
Stalks	Compost for soil fertility restoration (high content of fiber such as lignin and cellulose and nutrients such as nitrogen and potassium) with consequent spreading in the soil	Diaz et al.,2002; Mustin,1987; Ferrer et al.,2001
	Substrate (in the form of compost) for the cultivation of "*agaricus bisporus*", the species of mushroom most used in traditional cooking	Pardo et al.,2007
	Substrate for feed additives	Sanchez et.,2002
	Fuel in electricity and heat production plants	Università Politecnica delle Marche,2013
	Potent adsorbents for heavy metal removal	Tripathi and Ranjan 2015
Pomace together with vineyard prunings and stalks	Compost or stock feed supplements	Arvanitoyannis et al. 2006

Grape seeds	Fuel (high calorific value)	Università Politecnica delle Marche 2013
	Food and industrial use (grapeseed oil and grapeseed flour)	Università Politecnica delle Marche, 2013; Bail et al., 2008
	Optimal substrate for reuse in agriculture and for human and animal food	Acun and Gul 2014; Taranu et al., 2017; Moate et al., 2014; Sehm et al., 2011; Hao et al.,2015
	Cosmetic and nutraceutical sector with high antibacterial, anti-cancer, neuro protective and anti-aging benefits	Dinicola et al.,2014; Apostolou et al.,2014; Hamza et al.,2018; Ma et al.,2014; Da Porto et al.,2013; Weseler and Bast 2017; Baydar et al.,2006
Winery sludge	Soil nutrient	Bertran et al.,2004
	Biogas production	Da Ros et al., 2014
	Absorbent for metal decontamination	Villaescusa et al.,2004; Yuan-Shen et al.,2004

The key characteristic of **grape seeds** is their high polyphenol and oil content. This makes them a valuable source for the antioxidants and food oils production (grape seeds oil). In fact, they are mainly used in the food and industrial fields for the production of the grape seeds oil and the grape seeds flour (Università Politecnica delle Marche 2013; Bai et al. 2008) but also as fuel due to their high calorific value (Università Politecnica delle Marche 2013). They are also used in the cosmetic and nutraceutical sector, thanks to their high anti bacterial, anti-cancer, neuroprotective and anti-aging properties (Dinicola et al.,2014; Apostolou et al.,2014; Hamza et al.,2018; Ma et al.,2014; Da Porto et al.,2013; Weseler and Bast 2017; Baydar et al.,2006), or as a substrate for reuse in agriculture and for human and animal food (Acun and Gul 2014; Taranu et al., 2017; Moate et al., 2014; Sehm et al., 2011; Hao et al.,2015). They are also used during the wine production process as they are responsible together with the skins for the release of polyphenols such as proanthocyanins/tannins and catechins, with organoleptic and sensory functions.

Therefore, although they are often considered annoying and therefore are discarded by grapes, they are actually precious sources of antioxidant substances.

The treatments involving the **vinification dreg**, mainly concern the enhancement, recovery and transformation of compounds with high added value.

It is traditionally a fundamental raw material for the production of ethanol and tartaric acid (Versari et al., 2001; Braga et al., 2002). The latter has many applications in food field, because it is an excellent stabiliser, replacing citric acid (Boulton et al., 1995). More recently, Rivas et al. (2006) optimised an integrated process for the valorisation of vinification dregs, later improved by Salgado et al. (2010), which increased the extraction efficiency of tartaric acid, obtaining a purer product and reducing the costs associated with evaporation (Rivas et al., 2006). Salgado et al. (2010) also proposed a process for the combined production of citric acid and xylitol (33,4 g/l), using the obtained residue as a supplementary nutrient for different fermentations. This by-product can also be used as an additional nutrient for "Lactobacillus" (Bustos et al.,2004) or as a favorable substrate for plant growth (Diaz et al.,2002; Nogales et al.,2005; Paradelo et al.,2010).

Vinification dregs can be used for the high value-added products recovery such as phenolic compounds, which can be extracted by microwaves (Perez-Serradilla and Luque de Castro, 2011) or supercritical fluids (Wu et al., 2009). In fact, Barcia et al. (2014) determined the presence of low molecular weight phenolic compounds (free flavonols, anthocyanins, aglycones) with bioactive functional properties. There are also numerous publications about the recovery of squalene by ultrasonic extraction (Naziri et al., 2012; Naziri et al., 2014), lipids and fatty acids, useful as food additives (Gomez et al., 2004).

The vinification dregs was also used for nitrogen production by growth of *“Debarymyces hansenii”* with xylose as carbon source (Salgado et al.,2010). This approach is an economically-viable alternative for polymer production, when compared to the synthesis of molecules from hydrocarbons, such as polypropylene.

Further valorisation of this by-product could also be represented by the production of methane-rich biogas through anaerobic digestion. Indeed, there are several studies that use the vinification dregs as a co-substrate for the production of both biogas and biostabilised digestate, through anaerobic co-digestion with civil sewage sludge, both in mesophilic and thermophilic conditions. Both conditions showed similar yields (0,4 m^3/ kg COD added) (Da Ros et al., 2014). On the other hand, direct use in agriculture is not feasible, in fact the high content of phenolic compounds causes negative environmental impacts to the target biota (Bustamante et al., 2008), as also demonstrated by phytotoxicity tests (Morthup et al., 1998).

Grape stalks come from the destemming stage and have a high fiber content, mainly lignin and cellulose, as well as a high percentage of mineral nutrients such as nitrogen and potassium. They are mainly used for composting process (Diaz et al., 2002; Mustin, 1987) with subsequent spreading in the soil (Ferrer et al., 2001). The use of compost in vineyards represents a widespread practice due to the nutrients deplety in the soil, to the low humus concentrations and to the excessive soil erosion (Balanya et al, 1994; De Bertoldi et al, 1986). The compost obtained in this way, can also be used as a substrate for the cultivation of "*Agaricus bisporus*", the mushroom specie most used in traditional cooking (Pardo et al., 2007). On the other hand, Sanchez et al. (2002) used this substrate for solid state fermentation with "*Pleurotus spp"* to obtain feed additives. Max et al. (2009) proposed a sequential treatment process by pre-hydrolysis and alkaline hydrolysis to exploit the presence of antioxidant compounds such as hydroxycinnamic derivatives (mainly ferulic and p-coumaric acid), as well as hydroxybenzoic acids that can be used in food, pharmaceutical and cosmetic fields. They are also used as potent adsorbents for heavy metal removal (Tripathi and Ranjan 2015).

As with stalks, the **pomace** also contains high amounts of hemicellulosic sugars, which are currently used as a carbon source for lactic acid fermentation, with sugar conversion yields of 0,71 g/g, in addition to the bioemulsifiers production (Portilla-Rivera et al., 2007; Portilla-Rivera 2010).

Numerous studies for the polyphenols extraction using organic solvents and supercritical carbon dioxide (Vatai et al., 2009; Conde et al., 2011) have also been performed. The polyphenols can have many applications: tannins are used as adhesives for wood (Ping et al., 2011), while anthocyanins are widely used as colorants for the food industry and as antioxidants (Thorngate and Singleton, 1994; Karleskind, 1992). Following a fermentation process they find further applications as a source of nutrition (Sanchez et al.,2002) or for bioethanol production (Rodriguez et al.,2010).

Gallander and Peng (1980) also determined high concentrations of palmitic, stearic, arachidonic and linolenic acids, which can act as precursors for the synthesis of biosurfactants. Some authors (Santos et al., 2008; Bai et al., 2008) have proposed the use of pomace for phytopathogenic control. An example provided by Santos et al. (2008) explains how dilutions between 5 and 7% in an aqueous solution are able to totally inhibit the fungal growth of "*Fusarium oxysporum*". On the other hand, Bai et al. (2008) used the pomace to obtain control agents after fermentation of this substrate with *"Trichoderma viride"*. Many authors have highlighted the importance of pomace extracts on human health thanks to their anti-inflammatory, antidepressant and anti aging properties (Rabiei et al., 2017; De Sales et al., 2018; Wittenauer et al., 2015).

Other authors have proposed the use of pomace with vinification dregs to obtain substrates favorable for plant growth (Díaz et al., 2002; Nogales et al., 2005; Bustamante et al., 2007,2009, 2010; Paradelo et al., 2010). Paradelo et al. (2010) found that the optimal conditions for a substrate suitable for plant growth was to be composed of a 1:1 ratio of pomace to dregs, with the addition of 5 grams of $CaCO_3$ per 100 grams of substrate. Under these conditions, the pH increases to an optimal value of 8, while the carbon salinity and solubility decrease, making the substrate suitable for growth. Nogales et al. (2005) also studied the composting process of pomace obtained from the earthworm species *"Eisenia Andrei"*, obtaining a final product with a higher agronomic value due to a decrease in the C:N ratio and conductivity, as well as an increase in humic compounds and nutrient content. Liu et al. (2010), on the other hand, used pomace as a carbon source for L-lactic acid production with "*Lactobacillus casei*" by cellulose enzymatic hydrolysis, while Bustos et al. (2004), used "*Lactobacillus rhamnosus*" for lactic acid production (105,5 g/l) on a glucose substrate (110 g/l). This by-product has been further valorized in the nutraceutical cosmetic sector (Baydar et al.,2006) or as a substrate for human and animal feed (Marchiani et al.,2016; Guerra-Rivas et al.,2016; Dias et al.,2018; Matassa et al.,2016; Dwyer et al.,2014; Brenes et al.,2016).

The **sewage sludge from wastewater treatment** contains many nutrients, including nitrogen and phosphorus. For this by-product, however, there are few bibliographic references regarding their possible valorisation. As with civil sewage sludge, the major use is composting, in combination with other wine-derived substrates (Bertran et al., 2004).

Legislation also allows direct use in agriculture if it is in accordance with limits (Saviozzi et al., 1994). On the other hand, Ingelmo et al. (1998) combined winery sludge with municipal solid waste and sewage sludge to produce substrates, promoting the landfills re-vegetation, obtaining extremely satisfactory results. The sewage sludge has also been used as a co-substrate in anaerobic co-digestion with vinification dregs under both mesophilic and thermophilic conditions, for the biogas production and bio-stabilised effluent (Da Ros et., 2014). Other studies have demonstrated a high adsorptive capacity for heavy metals present in aqueous solution. The adsorption takes place by different mechanisms depending on the metal species and sludge type (Villaescusa et al., 2004; Yuan-shen et al., 2004).

PART II
INDUSTRIAL PROJECT

INNOVA

INTRODUCTION

The industrial component of the PhD project was focused on technological solutions (IoT - Internet of Things) applied to new management, treatment and valorisation models both organic waste flows, coming from separate collection, and agricultural by-products, especially those coming from the wine supply chain, in the perspective of circular economy (giving a second life to by-products from the perspective of sustainability). The work has been performed at the headquarter of the Industrial Partner - the Innova Company (Matera - La Martella Industrial Area). This company, as later in this chapter better explained, has invested a lot over the years in the development of intelligent systems for the monitoring and control of the waste collection cycle, which represents a market of extreme interest, that ensures significant potential for the use of research results in the region. This company, will also invest a lot in the coming years, on the information platform development dedicated to the waste sector and called Innovambiente (www.innovambiente.it) also in relation to the limit set by the “Environment Ministry” for the year 2019 (Ministerial Decree April 20, 2017) within italian municipalities should have applied a punctual system for the calculation of the waste tax. In this area, the market appears to be experiencing strong growth for companies able to provide value-added ICT (Information and Communication Technology) solutions, which will be accompanied by a growing demand for specialised figures in a sector which is actually characterised by low levels of informatisation.

CHAPTER 4: THE INDUSTRIAL PARTNER INNOVA

4.1 Innovambiente® software platform

It represents a web-based information system able to integrate, process and present all the data and informations that must be usable for the manager and the contracting entity. The system aims at the contributions accounting for the **Punctual Tax** system implementation through technologically advanced software solutions.

4.1.1 Ministerial decrees conformity and certifications

The INNOVAMBIENTE® software respects the following decrees/deliberations:

- **Ministerial Decree February 13, 2014 "Minimum Environmental Criteria"**
- **Ministerial Decree April 20, 2017 "Punctual Tax"**
- **"ARERA" deliberation 444/2019/R/rif**

In addition, it respects the following laws and standards quality:

- **ISO 9001** "Quality Management System";
- **ISO 27001** "Information Security Management System";
- **ISO 22301** "Business Continuity Management System";
- the requirements of the privacy European regulation.

The ISO 27001 certification is also extended to the controls provided by the ISO 27017 and ISO 27108 standards in accordance with the provisions of the SaaS qualification (https://www.agid.gov.it/it/infrastrutture/cloud-pa/qualificazione-saas) of the Agency for Digital Italy (AgID - https://www.agid.gov.it/) for the provision of services to public administrations.

In this regard it should be noted that INNOVAMBIENTE® software is certified in accordance with the requirements of the "Agency for Digital Italy" and it is inserted in the Marketplace (although it has not yet been published - **https://cloud.italia.it/marketplace/opendata/SA).**

The cloud platform is, moreover, managed on "CSP-qualified server farm" (Cloud Service Provider - https://www.agid.gov.it/index.php/it/infrastrutture/cloud-pa/qualificazione-csp) according to the AgID provisions effective from the year 2019 (https://www.agid.gov.it/index.php/it/infrastrutture/cloud-pa).

The software is based on remote servers located at:

- Microsoft Data Center - Amsterdam, Netherlands;
- Microsoft Data Center - Paris, France (Disaster recovery).

4.1.2 References and dissemination in Italy

INNOVAMBIENTE® software today represents a national software reference in urban waste services and it is adopted, at various levels, by about **180 municipalities in Italy** (Tab. 12) for the management of about **1 million registered users for waste tax payment.**

Table 12: List of municipalities where Innovambiente® software solutions are adopted

Acerra	NA	Campania	Massafra	TA	Puglia
Acquarica del Capo	BA	Puglia	Matera	MT	Basilicata
Acquaviva	BA	Puglia	Melendugno	LE	Puglia
Albano di Lucania	PZ	Basilicata	Mercato San Severino	SA	Campania
Alezio	LE	Puglia	Milis	OR	Sardegna
Altamura	BA	Puglia	Minervino Murge	BA	Puglia
Aradeo	LE	Puglia	Minturno	LT	Lazio
Arbus	SU	Sardegna	Modugno	BA	Puglia
Ardauli	OR	Sardegna	Mola di Bari	BA	Puglia
Arnesano	LE	Puglia	Monopoli	BA	Puglia
Avigliano	PZ	Basilicata	Monte Romano	VT	Lazio
Balvano	PZ	Basilicata	Montemesola	TA	Puglia
Barolo	CN	Piemonte	Montemurro	PZ	Basilicata
Bauladu	OR	Sardegna	Monteroni	LE	Puglia
Bernalda Metaponto	MT	Basilicata	Montescaglioso	MT	Basilicata
Bidonì	OR	Sardegna	Muggiò	MB	Lombardia
Binetto	BA	Puglia	Nardò	LE	Puglia
Bisceglie	BA	Puglia	Neive	CN	Piemonte
Bitetto	BA	Puglia	Nemoli	PZ	Basilicata
Bitritto	BA	Puglia	Neoneli	OR	Sardegna
Bonarcado	OR	Sardegna	Neviano	LE	Puglia
Borgorose	RI	Lazio	Noci	BA	Puglia
Bra	MB	Lombardia	Noicattaro	BA	Puglia
Brindisi	BR	Puglia	Nova milanese	MB	Lombardia
Buccino	PZ	Basilicata	Nughedu Santa Vittoria	OR	Sardegna
Busachi	OR	Sardegna	Nurachi	OR	Sardegna
Calimera	LE	Puglia	Ostuni	BR	Puglia
Camastra	AG	Sicilia	Palo del Colle	BA	Puglia
Campofelice di Roccella	PA	Sicilia	Pantelleria	TP	Sicilia
Camporotondo Etneo	CT	Sicilia	Patù	LE	Puglia
Cancello ed Arnone	CA	Campania	Pertusio	TO	Piemonte
Canicattì	AG	Sicilia	Piobesi d'Alba	CN	Piemonte
Caprarica di Lecce	LE	Puglia	Pocapaglia	CN	Piemonte
Carbonara al Ticino	PV	Lombardia	Poggiorsini	BA	Puglia
Carlentini	SR	Sicilia	Porto Cesareo	LE	Puglia
Carloforte	CI	Sardegna	Porto Torres	SS	Sardegna
Carmiano	LE	Puglia	Presicce	LE	Puglia
Carosino	TA	Puglia	Putignano	BA	Puglia
Casamassima	BA	Puglia	Riccia	CB	Molise
Cassano allo Ionio	CS	Calabria	Rionero in Vulture	PZ	Basilicata
Cassano delle Murge	BA	Puglia	Rivello	PZ	Basilicata
Castelraimondo	MC	Marche	Rocca di Papa	RM	Lazio

Castiglione Falletto	CN	Piemonte	Roma	RM	Lazio
Castrì di Lecce	LE	Puglia	Roma Municipio II	RM	Lazio
Castrignano del Capo	LE	Puglia	Roma Municipio IV	RM	Lazio
Cavallino	LE	Puglia	Roma Municipio V	RM	Lazio
Cellino San Marco	BR	Puglia	Roma Municipio VI	RM	Lazio
Cercola	NA	Campania	Roma Municipio VII	RM	Lazio
Cerveteri	RM	Lazio	Rudiano	BS	Lombardia
Città del Vaticano	SCV	Stato Vaticano	Salandra	MT	Basilicata
Collepasso	LE	Puglia	Salemi	TP	Sicilia
Copertino	LE	Puglia	Sammichele	BA	Puglia
Corbara	SA	Campania	Samugheo	OR	Sardegna
Corleto Perticara	PZ	Basilicata	San Benedetto dei Marsi	AQ	Abruzzo
Corsano	LE	Puglia	San Cesario di Lecce	LE	Puglia
Cuglieri	OR	Sardegna	San Donato di Lecce	LE	Puglia
Faggiano	TA	Puglia	San Felice Circeo	RM	Lazio
Ferrandina	MT	Basilicata	San Pietro Clarenza	CT	Sicilia
Filiano	PZ	Basilicata	San Pietro in Lama	LE	Puglia
Fisciano	SA	Campania	Sannicandro di Bari	BA	Puglia
Foiano di Val Fortore	BN	Campania	Sannicola	LE	Puglia
Fordongianus	OR	Sardegna	Santeramo In Colle	BA	Puglia
Fragagnano	TA	Puglia	Santu Lussurgiu	OR	Sardegna
Francofonte	SR	Sicilia	Scanzano Jonico	MT	Basilicata
Frattamaggiore	NA	Campania	Sciacca	AG	Sicilia
Galatone	LE	Puglia	Seclì	LE	Puglia
Gagliano del Capo	LE	Puglia	Seneghe	OR	Sardegna
Giardini-Naxos	ME	Sicilia	Sorradile	OR	Sardegna
Gioia del Colle	BA	Puglia	Sortino	SR	Sicilia
Giovinazzo	BA	Puglia	Spinazzola	BAT	Puglia
Giuliano di Roma	FR	Lazio	Squillace	CZ	Calabria
Govone	CN	Piemonte	Taurisano	LE	Puglia
Gravina in Puglia	BA	Puglia	Toritto	BA	Puglia
Grinzane Cavour	CN	Piemonte	Torretta	PA	Sicilia
Gropello Cairoli	PV	Lombardia	Tortora	CS	Calabria
Grumo Appula	BA	Puglia	Tramatza	OR	Sardegna
Imperia	IM	Liguria	Trapani	TP	Sicilia
Irsina	MT	Basilicata	Tricarico	MT	Basilicata
Lagonegro	PZ	Basilicata	Turi	BA	Puglia
Lanuvio	RM	Lazio	Tuscania	VT	Lazio
Laurenzana	PZ	Basilicata	Ugento	LE	Puglia
Lauria	PZ	Basilicata	Ula Tirso	OR	Sardegna
Lequile	LE	Puglia	Veglie	LE	Puglia
Lizzanello	LE	Puglia	Vernole	LE	Puglia
Magliano Alfieri	CN	Puglia	Vezza d'Alba	CN	Piemonte
Magliano de' Marsi	AQ	Piemonte	Vibo Valentia	VV	Calabria
Magliano Sabina	RI	Abruzzo	Villanova D'Ardenghi	PV	Lombardia
Maglie	LE	Lazio	Zeddiani	OR	Sardegna
Manduria	TA	Puglia	Zinasco	PV	Lombardia
Marsala	TP	Sicilia			

4.1.3 System components and informatisation processes

The INNOVAMBIENTE® software presents an integrated structure where various software modules tend to manage multiple processes and offer numerous functions in a transversal modality addressed to the **manager**, to the **municipality** or to the contracting entity and the **citizens.** The platform access by the various operators is guaranteed thanks Internet connection (Fig. 16).

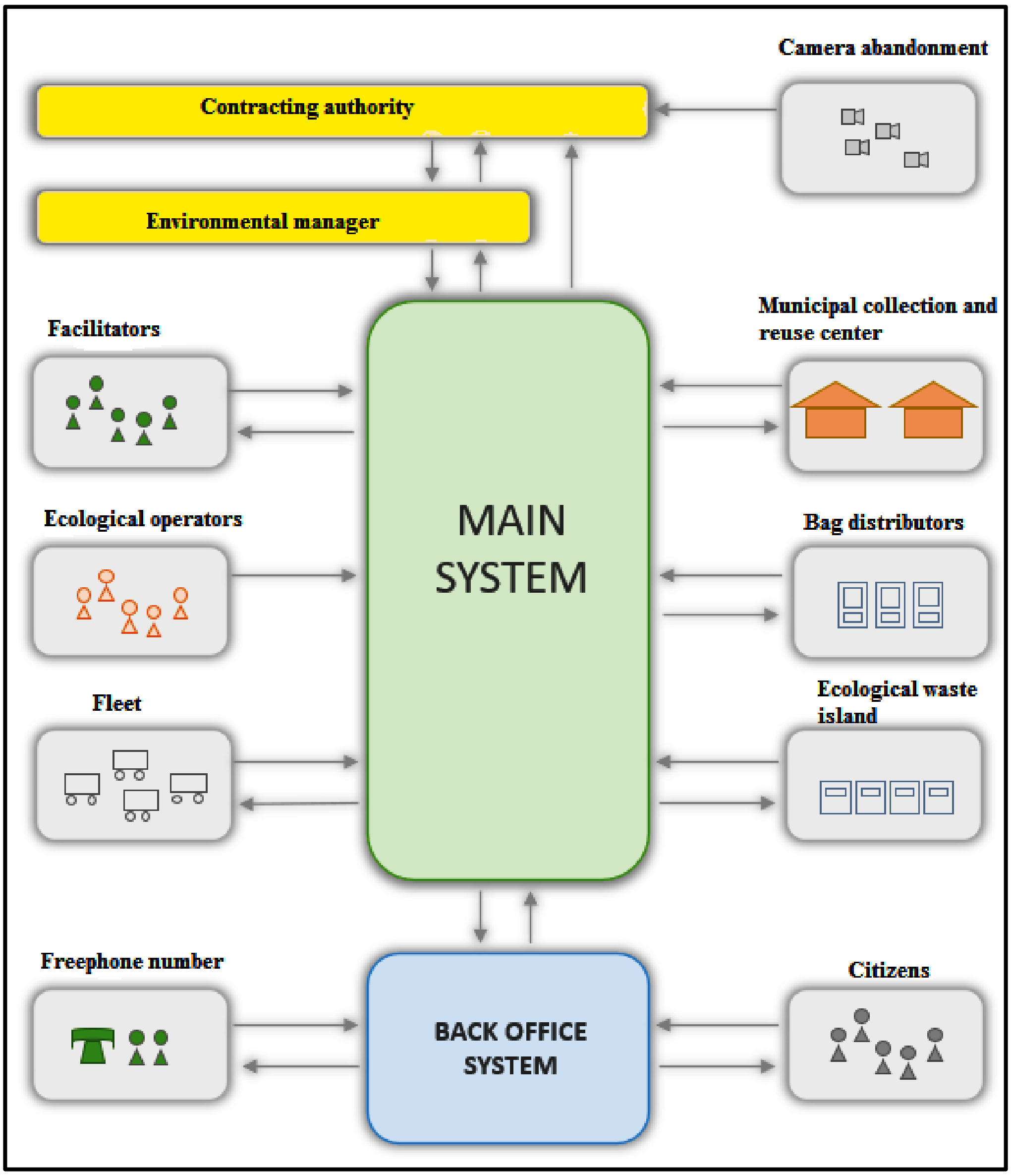


Figure 16: Innovambiente® platform block diagram

The main system components and the processes managed are shown below:

1. **start Up management** through the dedicated App *"Start Up Go"* that allows to perform the users census, the bins distributions and the services planning;
2. **registration of the contributions during door-to-door collection** through RFID readers;
3. **registrations of the contributions at the Collection Center** and production of the documentation required by law through the *"CCR Plus"* software;
4. **management of the Reuse Center** through the "*Reuse Center*" software;
5. **detection of the vehicle routes and activities** through the installation of multi-control locators;
6. **monitoring and operational management of the contract** through the web service "*Main System*";
7. **services for citizens** through the informative and interactive *App*;
8. **management of the helpline** through the "*Back Office*" web service;
9. **management of particular users or areas** through the "*on demand*" collection software;
10. **analysis of user behaviour for the definition of the Punctual Tax** through the "*Business Intelligence*" processor;
11. **abandonments detection** through mobile cameras.

4.2 COLLECTION CENTER

In an informatised context, the management of the Collection Center is very important. It generates an important data flow, that can be aggregated with the door-to-door context for a complete view of the user contributions and therefore of the waste production.

4.2.1 Collection center informatisation and conferments registration

The activity performed at the collection center is carried out by equipping the center with appropriate hardware and software infrastructures. The hardware consists of a POS, i.e. an all-in-one touch screen PC with integrated thermal printer, connected to a weight terminal and a weighting platform.

On the POS, it is installed the *"CCR Plus"* software. This solution is designed to minimise human error in the compilation of documents required by law and to record the user contributions, as it happens during the door-to-door collection, allowing the definitive data collection for pricing and incentive systems implementation purposes. Weighting is carried out in accordance with the reference directives:

- **Weighting platform,** to weight waste in accordance with Directive /2009/23/EEC;
- **Weight terminal,** to visualise the weighting on a digital display; the memorisation data is take place in accordance with Directive /90/384/EEC.

Data copies relating to the conferments are automatically transmitted to the "*Main System*" during the registration process. The *"Main System*" manages:

- information about users who can confer at the Collection Center;
- the "European Code" for each waste that can be conferred.

The citizens who go to the Collection Centre, present their "Healthcare Card" or the "Regional Services Card" of the user inserted in the "Waste Tax Register", on which the tax code is reported: the software recognises the user referring to the information in the database (Fig.17).

Codice Tessera/Kit: 10049
Codice Fiscale: RSSMRO88A12G812R
Nome: MARIO
Cognome: ROSSI
Via/Piazza: MATERA
Civico: 10
Comune: MATERA
CAP: 75100
Tipologia Rifiuto: 200110 Abiti
Peso (Kg): 15.5

Lista Conferimenti

Tipologia Rifiuto	Peso (Kg)
200110 Abiti	15.5

Figure 17: *"CCR Plus*" Registration for domestic user conferment

With the informatisation management of the collection center through "*CCR Plus*" it is possible to:

- search user in the database by reading the card code through a scanner code;
- track the contribution/s through a single procedure;
- define a logic of rewards and automatically associate a score to each contribution (if provided in the regulation);
- release a receipt printout with contribution details and the eventual accumulated score;
- track waste unloading operations from the Collection Center towards the industrial plants;
- print **1A and 1B attachments**, the **waste form** and the **loading and unloading register** (Fig. 18) as required by law; attachment 1A is automatically compiled and generated by the software when any waste is conferred by a non-domestic user; attachment 1B is automatically compiled and generated by the software whenever there is a waste unloading from the center towards the industrial plant.

Scarico: ☑
Carico: ☐
Del: 04-10-2017
Nr. : 1/2017
Formulario
Nr. :
Del:
Rif. oper. di carico n. : 101

(a) C.E.R. : 080318
(b) Descrizione : Cartucce toner esaurite
(c) Stato Fisico:
Solido pulverulento ☑
Solido non pulverulento ☐
Fangoso Palabile ☐
Liquido ☐
(d) Classi di pericolosità:
HP1 ☑ HP4 ☑ HP7 ☐ HP10 ☐ HP13 ☐
HP2 ☐ HP5 ☐ HP8 ☐ HP11 ☐ HP14 ☐
HP3 ☐ HP6 ☐ HP9 ☐ HP12 ☐ HP15 ☐
(e) Rifiuto destinato a:
☑ Smaltimento Cod. D1
☐ Recupero Cod.

Kg: 5.0
Lt:
Mc:

Intermediario / commerciante
Denominazione: Innova
Sede: Matera
C.F. : INNMTR10102017
Iscrizione Albo N. 01012010

Data inizio trasporto
Data fine trasporto

Figure 18: Loading and uploading register

"*CCR Plus*" memorises and correlates all the waste coming in and out of the Collection Center, allowing a stock control: depending on the amount of waste conferred, it is possible to visualise at any time the residual stock of each type of waste, as well as to monitor the stock period, in order to respect the regulations governing the maximum time permanence of the waste in the center.

4.3 MAIN SYSTEM

The "*Main System*" is the secure web platform that allows to organise and monitor the work. It is accessible through different profiles that provide visibility by expertise area. It is the tool to:

- manage users informations that synchronise across all devices;
- configure and manage bins informations;

- configure and manage the operators and work shifts information;
- configure and manage the daily planning of activities;
- configure and activate data exchange from/to external devices;
- configure and activate data exchange from/to Collection/Reuse Centers;
- monitor through reports and statistics the activities and the work evolution.

4.3.1 Profiling

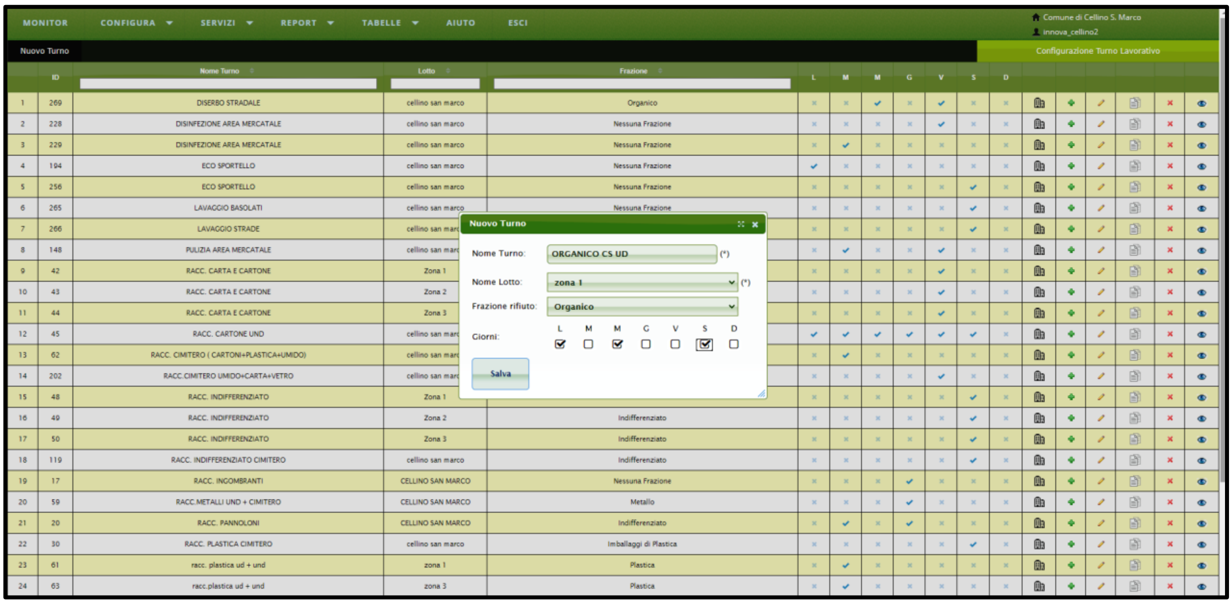
There are several profiles provided by the "*Main System*" and they can be classified in the following macro categories:

- **Administrator**: he accesses the system with administrator functions for the management of the contract to which it belongs;
- **Administrator Dashboard**: he accesses as the administrator to the section for "*business intelligence*";
- **Operator**: he can operate on the door-to-door collection functions;
- **CCR Operator**: he can operate on the management functions of the municipal collection center;
- **Reader**: he can operate on the read-only door-to-door collection and fleet functions.

4.3.2 Programming and services control

The work planning (Fig.19) takes place through the introduction in the system of the operator informations and the services definition. Each service is associated with:

- service name;
- area in which the service is carried out;
- collected fraction;
- days of the week when the service is provided;
- domestic and non-domestic users (starting from the area) involved in the service.



	ID	Nome Turno	Lotto	Frazione	L	M	M	G	V	S	D
1	269	DISERBO STRADALE	cellino san marco	Organico	✗	✗	✓	✗	✓	✗	✗
2	228	DISINFEZIONE AREA MERCATALE	cellino san marco	Nessuna Frazione	✗	✗	✗	✗	✓	✗	✗
3	229	DISINFEZIONE AREA MERCATALE	cellino san marco	Nessuna Frazione	✗	✓	✗	✗	✗	✗	✗
4	194	ECO SPORTELLO	cellino san marco	Nessuna Frazione	✓	✗	✗	✗	✗	✗	✗
5	256	ECO SPORTELLO	cellino san marco	Nessuna Frazione	✗	✗	✗	✗	✗	✓	✗
6	265	LAVAGGIO BASOLATI	cellino san marco	Nessuna Frazione	✗	✗	✗	✗	✗	✓	✗
7	266	LAVAGGIO STRADE	cellino san marc		✗	✗	✗	✗	✗	✓	✗
8	148	PULIZIA AREA MERCATALE	cellino san marc		✗	✓	✗	✗	✓	✗	✗
9	42	RACC. CARTA E CARTONE	Zona 1		✗	✗	✗	✗	✓	✗	✗
10	43	RACC. CARTA E CARTONE	Zona 2		✗	✗	✗	✗	✓	✗	✗
11	44	RACC. CARTA E CARTONE	Zona 3		✗	✗	✗	✗	✓	✗	✗
12	45	RACC. CARTONE UND	cellino san marc		✓	✓	✓	✓	✓	✓	✗
13	62	RACC. CIMITERO (CARTONI+PLASTICA+UMIDO)	cellino san marc		✗	✓	✗	✗	✗	✗	✗
14	202	RACC.CIMITERO UMIDO+CARTA+VETRO	cellino san marc		✗	✗	✗	✗	✓	✗	✗
15	48	RACC. INDIFFERENZIATO	Zona 1		✗	✗	✗	✗	✗	✓	✗
16	49	RACC. INDIFFERENZIATO	Zona 2	Indifferenziato	✗	✗	✗	✗	✗	✓	✗
17	50	RACC. INDIFFERENZIATO	Zona 3	Indifferenziato	✗	✗	✗	✗	✗	✓	✗
18	119	RACC. INDIFFERENZIATO CIMITERO	cellino san marco	Indifferenziato	✗	✗	✗	✗	✗	✓	✗
19	17	RACC. INGOMBRANTI	CELLINO SAN MARCO	Nessuna Frazione	✗	✗	✗	✓	✗	✗	✗
20	59	RACC.METALLI UND + CIMITERO	CELLINO SAN MARCO	Metallo	✗	✗	✗	✓	✗	✗	✗
21	20	RACC. PANNOLONI	CELLINO SAN MARCO	Indifferenziato	✗	✓	✗	✓	✗	✗	✗
22	30	RACC. PLASTICA CIMITERO	cellino san marco	Imballaggi di Plastica	✗	✗	✗	✗	✗	✓	✗
23	61	racc. plastica ud + und	zona 1	Plastica	✗	✓	✗	✗	✗	✗	✗
24	63	racc.plastica ud + und	zona 3	Plastica	✗	✓	✗	✗	✗	✗	✗

Nuovo Turno

Nome Turno: ORGANICO CS UD (*)

Nome Lotto: zona 1 (*)

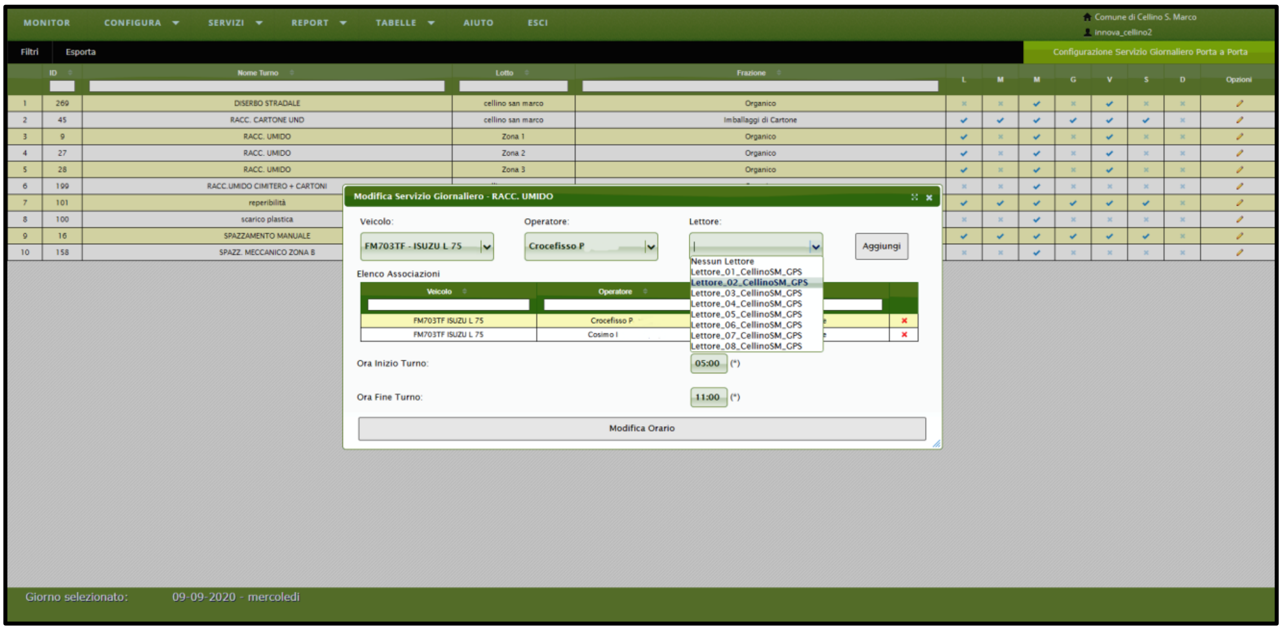
Frazione rifiuto: Organico

Giorni: L ☑ M ☐ M ☑ G ☐ V ☐ S ☑ D ☐

Figure 19: Shift definition

The system automatically daily proposes the table of scheduled services (Fig.20). Each service is compiled by associating to the following informations:

- service responsible vehicle;
- operator carrying out the service;
- RFID reader (if any) in use by the operator or the vehicle;
- start/end time of the service.



	ID	Nome Turno	Lotto	Frazione	L	M	M	G	V	S	D	Opzioni
1	269	DISERBO STRADALE	cellino san marco	Organico	✗	✗	✓	✗	✓	✗	✗	✎
2	45	RACC. CARTONE UND	cellino san marco	Imballaggi di Cartone	✓	✓	✓	✓	✓	✓	✗	✎
3	9	RACC. UMIDO	Zona 1	Organico	✓	✗	✓	✗	✓	✗	✗	✎
4	27	RACC. UMIDO	Zona 2	Organico	✓	✗	✓	✗	✓	✗	✗	✎
5	28	RACC. UMIDO	Zona 3	Organico	✓	✗	✓	✗	✓	✗	✗	✎
6	199	RACC.UMIDO CIMITERO + CARTONI			✗	✗	✓	✗	✗	✗	✗	✎
7	101	reperibilità			✓	✓	✓	✓	✓	✓	✗	✎
8	100	scarico plastica			✗	✗	✓	✗	✗	✗	✗	✎
9	16	SPAZZAMENTO MANUALE			✓	✓	✓	✓	✓	✓	✗	✎
10	158	SPAZZ. MECCANICO ZONA B			✗	✗	✓	✗	✗	✗	✗	✎

Modifica Servizio Giornaliero - RACC. UMIDO

Veicolo: FM703TF - ISUZU L 75

Operatore: Crocefisso P

Lettore:

Nessun Lettore
Lettore_01_CellinoSM_GPS
Lettore_02_CellinoSM_GPS
Lettore_03_CellinoSM_GPS
Lettore_04_CellinoSM_GPS
Lettore_05_CellinoSM_GPS
Lettore_06_CellinoSM_GPS
Lettore_07_CellinoSM_GPS
Lettore_08_CellinoSM_GPS

Elenco Associazioni

Veicolo	Operatore		
FM703TF ISUZU L 75	Crocefisso P	e	✗
FM703TF ISUZU L 75	Cosimo I	e	✗

Ora Inizio Turno: 05:00 (*)

Ora Fine Turno: 11:00 (*)

Giorno selezionato: 09-09-2020 - mercoledì

Figure 20: Filling out the daily service

For each service, reports in tabular (Fig. 21) and cartographic (Fig. 22) format are available; they include vehicles and equipments used informations, as well as the personnel employed, and the following informations:

- waste fraction collected;
- number of users involved;
- percentage of exposure;
- collection area;
- “start” and “end time” of the service;
- weight of the collected waste;
- association of main vehicle – secondary vehicle;
- km covered by the vehicle(s);
- route of the vehicle on the map;
- empty bins geolocalisation;
- geolocalisation of users who have conferred and geolocalisation of users who have not conferred, indicated with different colors.

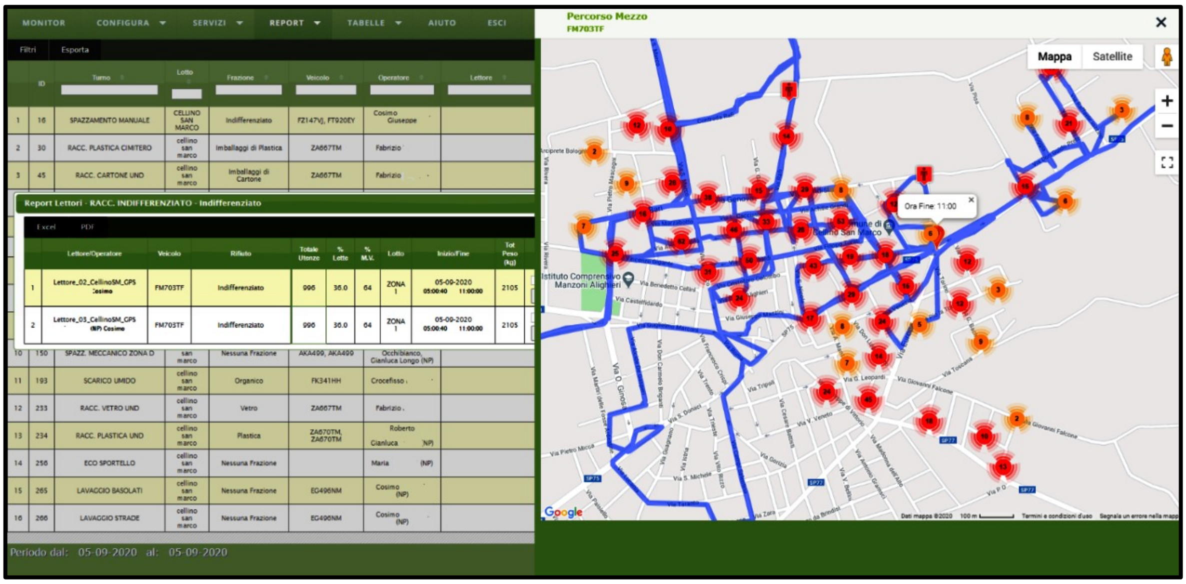
	ID	Turno	Lotto	Frazione	Veicolo	Operatore	Lettore	Utenze	Lette	% Lette	% M.V.	Peso(Kg)	L	M	M	G	V	S	D	Data	Inizio	Fine Tno
1	16	SPAZZAMENTO MANUALE	CELLINO SAN MARCO	Indifferenziato	FZ147VJ, FT920EY	Cosimo Giuseppe		1					✓	✓	✓	✓	✓	✓	×	05-09-2020	05:00	10:00
2	30	RACC. PLASTICA CIMITERO	cellino san marco	Imballaggi di Plastica	ZA667TM	Fabrizio		996					×	×	×	×	×	✓	×	05-09-2020	08:00	09:00
3	45	RACC. CARTONE UND	cellino san marco	Imballaggi di Cartone	ZA667TM	Fabrizio		996					✓	✓	✓	✓	✓	✓	×	05-09-2020	05:00	08:00
4	48	RACC. INDIFFERENZIATO	Zona 1	Indifferenziato	FM703TF, FM703TF	Cosimo Cosimo Jr	Lettore_02_CellinoSM_GPS,	996					×	×	×	×	×	✓	×	05-09-2020	05:00	11:00
5	49	RACC. INDIFFERENZIATO	Zo																	020	05:00	11:00
6	50	RACC. INDIFFERENZIATO	Zo																	020	05:00	11:00
7	86	Racc.Rifiuti Abbandonati	ce m																	020	10:00	11:00
8	101	reperibilità	ce m																	020	12:00	18:00
9	119	RACC. INDIFFERENZIATO CIMITERO	ce m																	020	10:00	11:00
10	150	SPAZZ. MECCANICO ZONA D	ce m																	020	05:00	10:00
11	193	SCARICO UMIDO	cellino san marco	Organico	FK341HH	Crocefisso		1					×	×	×	×	×	✓	×	05-09-2020	05:00	11:00
12	233	RACC. VETRO UND	cellino san marco	Vetro	ZA667TM	Fabrizio		1					×	×	×	×	×	✓	×	05-09-2020	09:00	10:00
13	234	RACC. PLASTICA UND	cellino san marco	Plastica	ZA670TM, ZA670TM	Roberto Gianluca		1					×	×	×	×	×	✓	×	05-09-2020	10:00	11:00
14	256	ECO SPORTELLO	cellino san marco	Nessuna Frazione		Maria		1					×	×	×	×	×	✓	×	05-09-2020	10:00	12:00
15	265	LAVAGGIO BASOLATI	cellino san marco	Nessuna Frazione	EG496NM	Cosimo (NP)		1					×	×	×	×	×	✓	×	05-09-2020	05:00	07:00
16	266	LAVAGGIO STRADE	cellino san marco	Nessuna Frazione	EG496NM	Cosimo (NP)		1					×	×	×	×	×	✓	×	05-09-2020	07:00	10:00

Report Lettori - RACC. INDIFFERENZIATO - Indifferenziato

	Lettore/Operatore	Veicolo	Rifiuto	Totale Utenze	% Lette	% M.V.	Lotto	Inizio/Fine	Tot Peso (kg)	Peso reale(kg)	Mezzo Madre	Ora Scarico	Tot Viaggio	Km percorsi
1	Lettore_02_CellinoSM_GPS M·· Cosimo	FM703TF	Indifferenziato	996	36.0	64	ZONA 1	05-09-2020 05:00:40 11:00:00	2105	0 Modifica			05:59:20	33.768
2	Lettore_03_CellinoSM_GPS (NP) Cosimo	FM703TF	Indifferenziato	996	36.0	64	ZONA 1	05-09-2020 05:00:40 11:00:00	2105	0 Modifica			05:59:20	33.768

Periodo dal: 05-09-2020 al: 05-09-2020

Figure 21: Daily service analytical report



	ID	Turno	Lotto	Frazione	Veicolo	Operatore	Lettore
1	16	SPAZZAMENTO MANUALE	CELLINO SAN MARCO	Indifferenziato	FZ147VJ, FT920EY	Cosimo Giuseppe	
2	30	RACC. PLASTICA CIMITERO	cellino san marco	Imballaggi di Plastica	ZA667TM	Fabrizio	
3	45	RACC. CARTONE UND	cellino san marco	Imballaggi di Cartone	ZA667TM	Fabrizio	
10	150	SPAZZ. MECCANICO ZONA D	san marco	Nessuna Frazione	AKA499, AKA499	Occhibianco, Gianluca Longo (NP)	
11	193	SCARICO UMIDO	cellino san marco	Organico	FK341HH	Crocefisso	
12	233	RACC. VETRO UND	cellino san marco	Vetro	ZA667TM	Fabrizio	
13	234	RACC. PLASTICA UND	cellino san marco	Plastica	ZA670TM, ZA670TM	Roberto Gianluca (NP)	
14	256	ECO SPORTELLO	cellino san marco	Nessuna Frazione		Maria (NP)	
15	265	LAVAGGIO BASOLATI	cellino san marco	Nessuna Frazione	EG496NM	Cosimo (NP)	
16	266	LAVAGGIO STRADE	cellino san marco	Nessuna Frazione	EG496NM	Cosimo (NP)	

Report Lettori - RACC. INDIFFERENZIATO - Indifferenziato

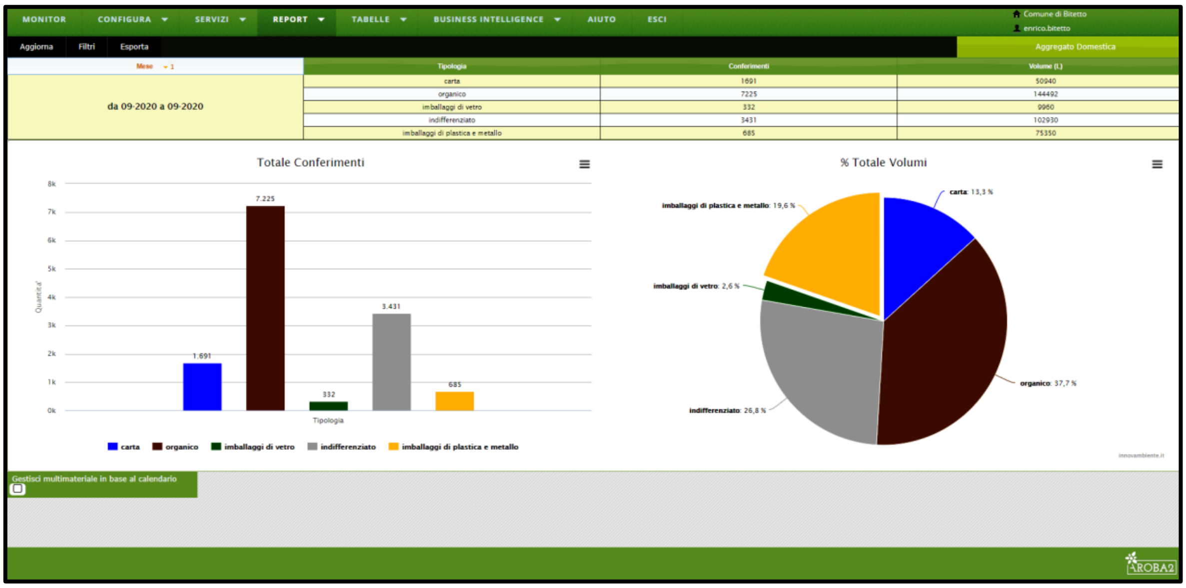
	Lettore/Operatore	Veicolo	Rifiuto	Totale Utenze	% Lette	% M.V.	Lotto	Inizio/Fine	Tot Peso (kg)
1	Lettore_02_CellinoSM_GPS Cosimo	FM703TF	Indifferenziato	996	36.0	64	ZONA 1	05-09-2020 05:00:40 11:00:00	2105
2	Lettore_03_CellinoSM_GPS (NP) Cosimo	FM703TF	Indifferenziato	996	36.0	64	ZONA 1	05-09-2020 05:00:40 11:00:00	2105

Periodo dal: 05-09-2020 al: 05-09-2020

Figure 22: Daily Service Map Report

4.3.3 Door-to-door report and municipal collection center

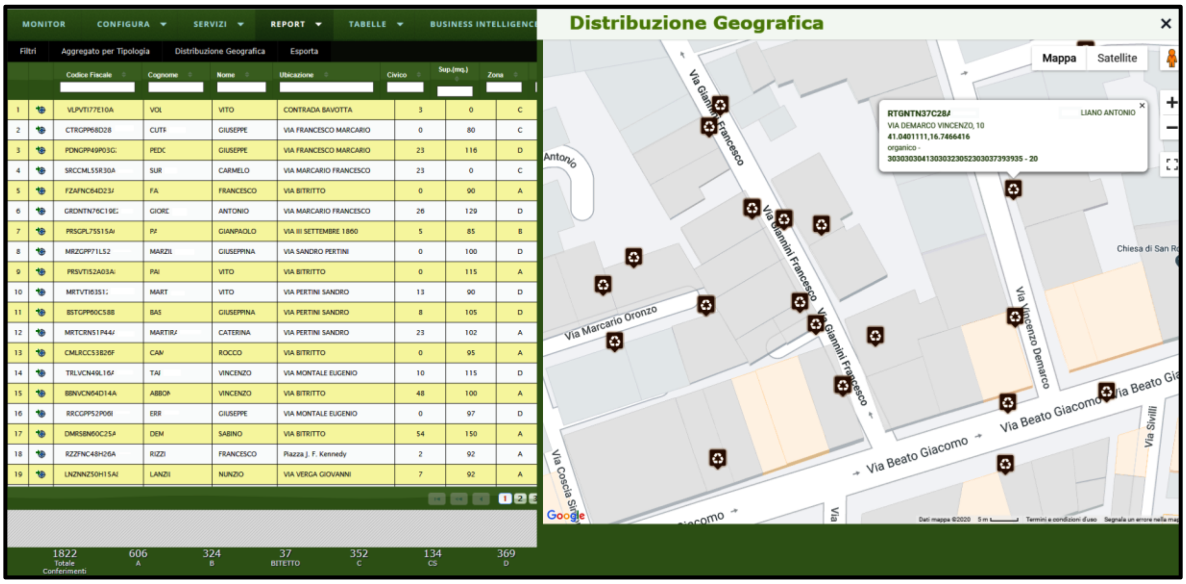
During the bin emptying phase, the reading of “*RFID tags”* installed on the bins, allows the detection of the conferments by the users. The tag code is matched to the type of bins, which is associated itself with the user. The conferments data arrive in “*near real time*” to the mobile device used by the operators and they are represented through different reports, both in analytical/tabular format and in cartographic format through the acquisition of the GPS position at each conferment. The reports are interactive and they are represented in aggregate form, monthly (Fig. 23) or over an arbitrary time period, or in detailed form (Fig. 24) highlighting the individual emptyings.



da 09-2020 a 09-2020

Tipologia	Conferimenti	Volume (L)
carta	1691	50940
organico	7225	144492
imballaggi di vetro	332	9960
indifferenziato	3431	102930
imballaggi di plastica e metallo	685	75350

Figure 23: Monthly aggregate report of conferments



		Codice Fiscale	Cognome	Nome	Ubicazione	Civico	Sup.(mq.)	Zona
1		VLPVTI77E10A	VOL	VITO	CONTRADA BAVOTTA	3	0	C
2		CTRGPP68D28[redacted]	CUTF[redacted]	GIUSEPPE	VIA FRANCESCO MARCARIO	0	80	C
3		PDNGPP49P03G:	PEDC	GIUSEPPE	VIA FRANCESCO MARCARIO	23	116	D
4		SRCCML55R30A[redacted]	SUR[redacted]	CARMELO	VIA MARCARIO FRANCESCO	23	0	C
5		FZAFNC64D23/	FA	FRANCESCO	VIA BITRITTO	0	90	A
6		GRDNTN76C19E[redacted]	GIORE[redacted]	ANTONIO	VIA MARCARIO FRANCESCO	26	129	D
7		PRSGPL75S15A	PA	GIANPAOLO	VIA III SETTEMBRE 1860	5	85	B
8		MRZGPP71L52[redacted]	MARZIL[redacted]	GIUSEPPINA	VIA SANDRO PERTINI	0	100	D
9		PRSVTI52A03A	PAI	VITO	VIA BITRITTO	0	115	A
10		MRTVTI63S1[redacted]	MART[redacted]	VITO	VIA PERTINI SANDRO	13	90	D
11		BSTGPP60C58B	BAS	GIUSEPPINA	VIA PERTINI SANDRO	8	105	D
12		MRTCRN51P44[redacted]	MARTIR[redacted]	CATERINA	VIA PERTINI SANDRO	23	102	A
13		CMLRCC53B26F	CAM	ROCCO	VIA BITRITTO	0	95	A
14		TRLVCN49L16[redacted]	TAI[redacted]	VINCENZO	VIA MONTALE EUGENIO	10	115	D
15		BBNVCN64D14A	ABBON	VINCENZO	VIA BITRITTO	48	100	A
16		RRCGPP52P06I[redacted]	ERR[redacted]	GIUSEPPE	VIA MONTALE EUGENIO	0	97	D
17		DMRSBN60C25A	DEM	SABINO	VIA BITRITTO	54	150	A
18		RZZFNC48H26A	RIZZI	FRANCESCO	Piazza J. F. Kennedy	2	92	A
19		LNZNNZ50H15A	LANZI	NUNZIO	VIA VERGA GIOVANNI	7	92	A

1822	606	324	37	352	134	369
Totale Conferimenti	A	B	BITETTO	C	CS	D

Distribuzione Geografica

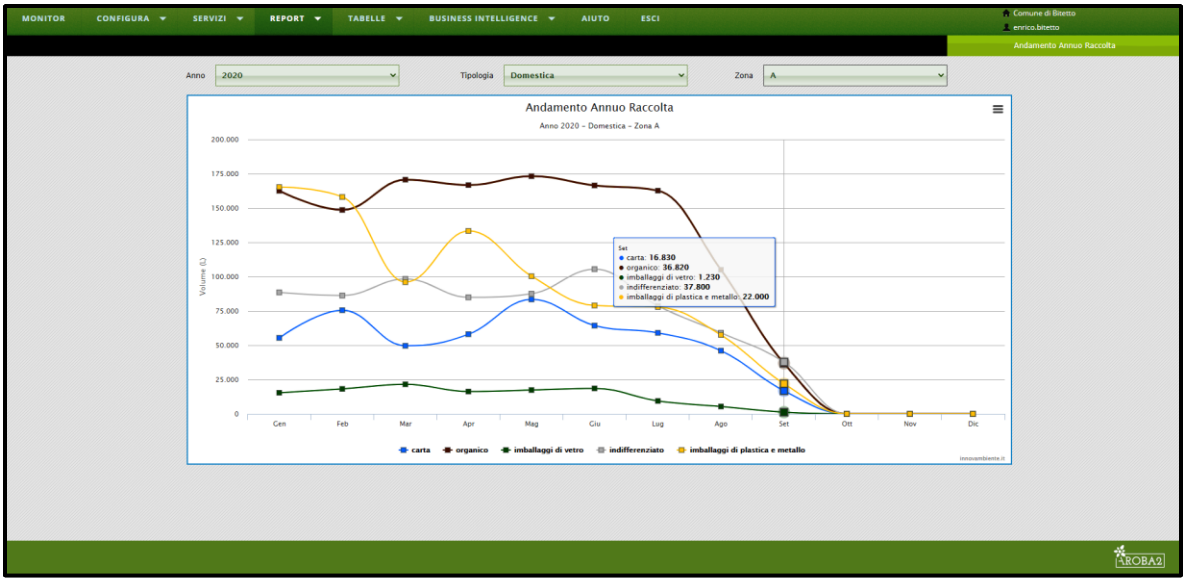
RTGNTN37C28A[redacted] [redacted]LIANO ANTONIO
VIA DEMARCO VINCENZO, 10
41.0401111,16.7466416
organico -
30303030413030323052303037393935 - 20

Figure 24: Detailed report of conferments

In the detail table of conferments it is possible to filter the data (and consequently the graphic representation) in different ways and for different purposes, for example:

- filter on a route to verify the work carried out locally;
- filter on a reader to verify the work carried out by an operator;
- filter to identify and locate the users who have conferred in the wrong way.

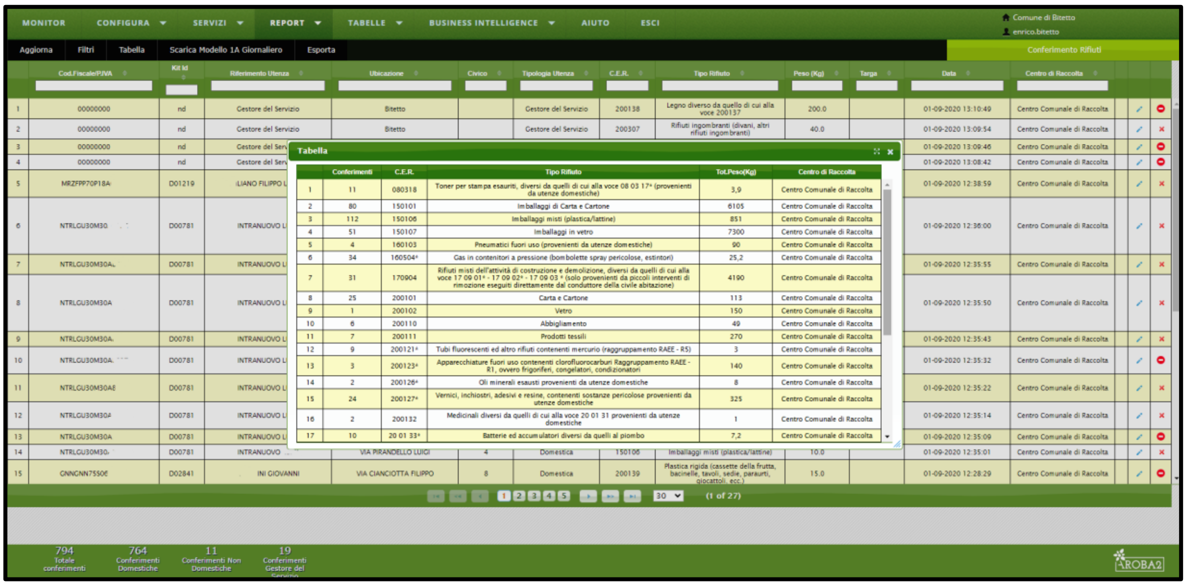
The definition of the zones is very useful for analysis purposes, because we have detailed data at zone level and we can make local analyses on the trend of users conferments (Fig. 25).


Anno: 2020
Tipologia: Domestica
Zona: A

Set
carta: 16.830
organico: 36.820
imballaggi di vetro: 1.230
indifferenziato: 37.800
imballaggi di plastica e metallo: 22.000

Figure 25: Collection annual trend by user type and zone

Thanks to the "*Main System*", it is also possible monitoring and integrating the data of the user conferment to the Collection Centre (Fig. 26). This data is available in detail or aggregated form by "European Code Waste". Both the input data, i.e. the individual user conferments with relative weight, and the waste outputs from the center to the industrial plants, thus the Collection Center **balance,** are registered and represented. For each non-domestic user conferment, the **1A attachment** in PDF format produced on site is available online; for each exit from the Collection Center, the **1B attachment** produced on site in PDF format is available on line.



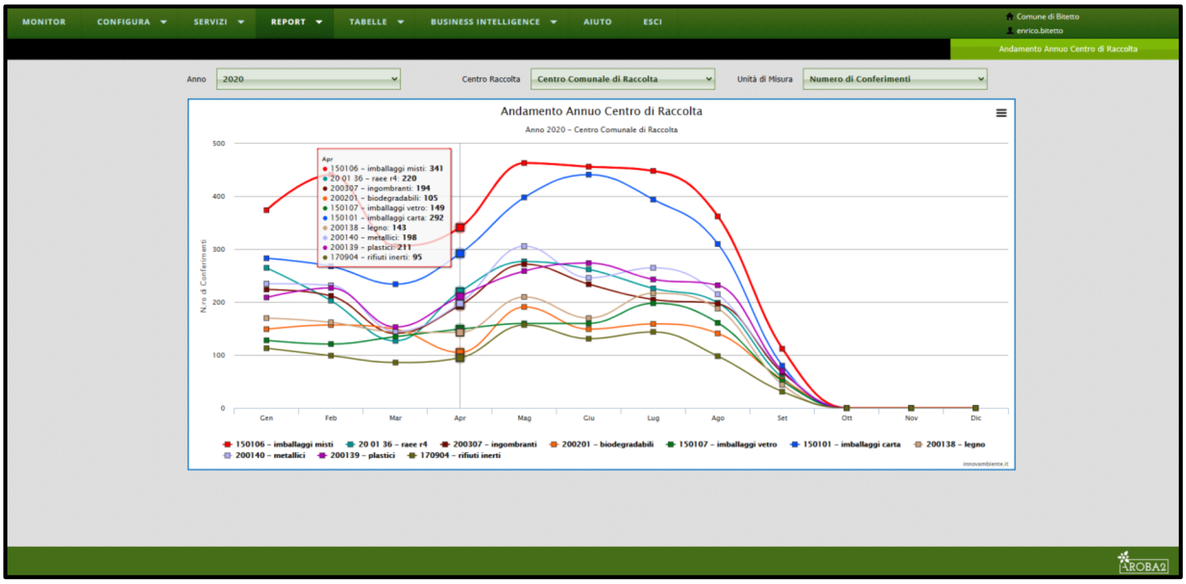
Tabella

	Conferimenti	C.E.R.	Tipo Rifiuto	Tot.Peso(Kg)	Centro di Raccolta
1	11	080318	Toner per stampa esauriti, diversi da quelli di cui alla voce 08 03 17* (provenienti da utenze domestiche)	3,9	Centro Comunale di Raccolta
2	80	150101	Imballaggi di Carta e Cartone	6105	Centro Comunale di Raccolta
3	112	150106	Imballaggi misti (plastica/lattine)	851	Centro Comunale di Raccolta
4	51	150107	Imballaggi in vetro	7300	Centro Comunale di Raccolta
5	4	160103	Pneumatici fuori uso (provenienti da utenze domestiche)	90	Centro Comunale di Raccolta
6	34	160504*	Gas in contenitori a pressione (bombolette spray pericolose, estintori)	25,2	Centro Comunale di Raccolta
7	31	170904	Rifiuti misti dell'attività di costruzione e demolizione, diversi da quelli di cui alla voce 17 09 01* - 17 09 02* - 17 09 03 * (solo provenienti da piccoli interventi di rimozione eseguiti direttamente dal conduttore della civile abitazione)	4190	Centro Comunale di Raccolta
8	25	200101	Carta e Cartone	113	Centro Comunale di Raccolta
9	1	200102	Vetro	150	Centro Comunale di Raccolta
10	6	200110	Abbigliamento	49	Centro Comunale di Raccolta
11	7	200111	Prodotti tessili	270	Centro Comunale di Raccolta
12	9	200121*	Tubi fluorescenti ed altro rifiuti contenenti mercurio (raggruppamento RAEE - R5)	3	Centro Comunale di Raccolta
13	3	200123*	Apparecchiature fuori uso contenenti clorofluorocarburi Raggruppamento RAEE - R1, ovvero frigoriferi, congelatori, condizionatori	140	Centro Comunale di Raccolta
14	2	200126*	Oli minerali esausti provenienti da utenze domestiche	8	Centro Comunale di Raccolta
15	24	200127*	Vernici, inchiostri, adesivi e resine, contenenti sostanze pericolose provenienti da utenze domestiche	325	Centro Comunale di Raccolta
16	2	200132	Medicinali diversi da quelli di cui alla voce 20 01 31 provenienti da utenze domestiche	1	Centro Comunale di Raccolta
17	10	20 01 33*	Batterie ed accumulatori diversi da quelli al piombo	7,2	Centro Comunale di Raccolta

794	764	11	19
Totale conferimenti	Conferimenti Domestiche	Conferimenti Non Domestiche	Conferimenti Gestore del Servizio

Figure 26: Report of the conferments to the Collection Center in detailed and aggregated form.

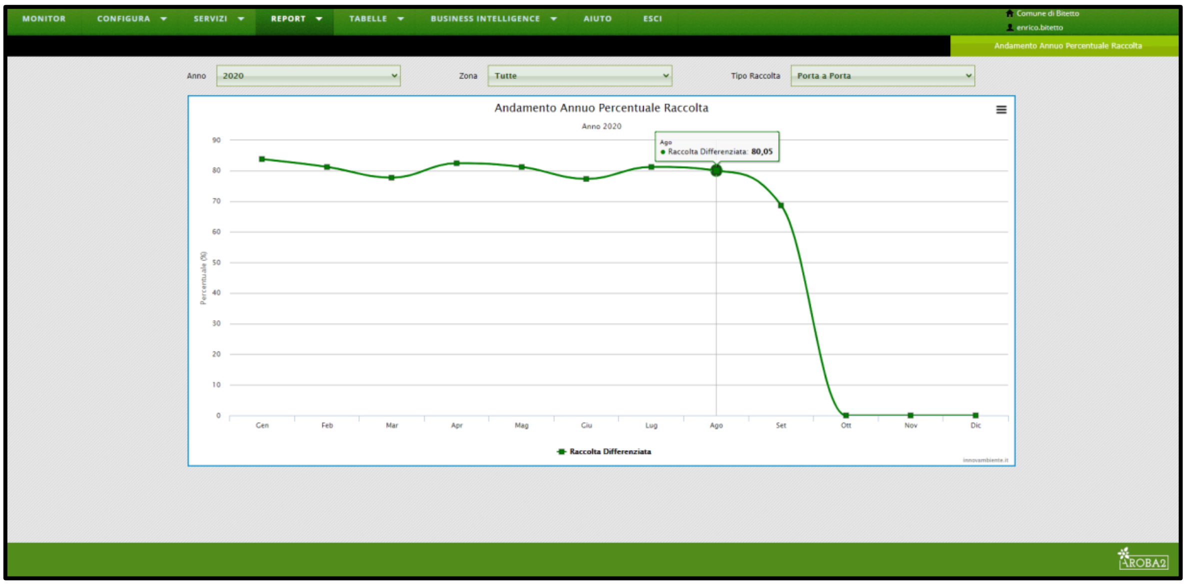
It is possible to represent the data in the annual trend form by "European Code Waste" conferred and by Collection Center (Fig. 27) with the possibility of visualise both the "number of conferments" and the "weight conferred" as measurement units.



Anno: 2020
Centro Raccolta: Centro Comunale di Raccolta
Unità di Misura: Numero di Conferimenti

Figure 27: Annual trend by "European Code Waste" conferred and by Collection Center

The data processing, from collected to uncollected conferments, allows us to monitor the **annual trend of separate collection percentage** (Fig.28).



Anno: 2020

Zona: Tutte

Tipo Raccolta: Porta a Porta

Figure 28: Annual trend of separate collection percentage

CHAPTER 5: MUNICIPAL WASTE LEGISLATIVE FRAMEWORK AND ESTIMATION IN BASILICATA REGION

Over the years, many regulations on waste have been issued. This approach also underlines the importance of this concept. The following summary concerns the regulatory process, from the “Single Environmental Text” dating from the year 2006 until the last legislative decree of the year 2020; for each decree only the most important concepts are reported. Some regulations concerning the concepts closely related to the waste theme such as the relative taxation, the punctual tax (TARIP), the "end of waste" concept and the main differences with the by-products definition are also reported.

5.1 Legislative framework for waste: Legislative Decree 152/06 (Single Environmental Text)

The waste legislation at a national level is the Legislative Decree No. 152 of April 3, 2006, specifically “Part Fourth”, entitled "Regulations on waste management and remediation of polluted sites", supported by specific legal dispositions adopted to implement the European Union directives governing the management of specific waste categories. According to the **article 183**, paragraph 1, letter a) of Legislative Decree No. 152/2006, waste is defined as "*any substance or object that the holder discards or intends or is obliged to discard*". This definition is based on the article 31 of Directive 2008/98/EC, which states that it is necessary to limit the negative consequences and damages connected with waste itself, protecting human health and the environment. From this article, three criteria can be highlighted:

- factual criterion: discarding;
- subjective criterion: having the intention to discard;
- normative criterion: having the obligation to discard.

The term "discard" (always used by the European legislator) is different from "abandonmment", initially used by the Italian legislator in the year 1982 to define waste (article 2 of Decree President of Republic September 10, 1982 No. 915). Despite the first term better highlights the uselessness concept of the thing that no longer satisfies the needs and interests of its holder, the jurisprudence highlighted the substantial equivalence of the two terms: "object abandoned or destined to be abandoned" must be understood as an object now unserviceable, disused or destined to be disused by its holder. Therefore, according to the factual criterion, by "disposing of" is to be understood as a material behaviour objectively appreciable. In order to interpret the disposition contained in article 183 of Legislative Decree 152/2006, it could be concluded that the intention to dispose, instead, is achieved when the waste holder performs an act that is suitable and clearly directed at disposing of a substance or an object.

The article 178 of the decree, on the other hand, states that waste management must be carried out respecting the following principles:

- precaution;
- prevention;
- sustainability;
- proportionality, accountability and cooperation of all parties involved in the production, distribution, use and consumption of products which generate waste;
- "polluter pays".

The same disposition also provides that the waste management is carried out according to *" effectiveness, efficiency, cost-effectiveness, transparency, technical and economic feasibility criteria, as well as respecting the regulations concerning the participation and access to environmental informations"*.

Waste management must be carried out according to a precise hierarchy, indicated in **article 179**, which includes:

- prevention;
- preparation for reuse;
- recycling;
- recovery of other types, for example energy recovery;
- disposal.

The hierarchy establishes a priority order of best environmental options. Within this hierarchy, the options that provide the best overall result, taking into consideration health, social, and economic impacts, including technical and economic feasibility must be preferred.

5.2 Legislative Decree 205/2010: amendments to Legislative Decree 152/2006

Legislative Decree 205/2010, which implements European Directive 2008/98 and modifies the part IV of the so-called “Single Environmental Text” (Legislative Decree 152/06), introduces a number of novelties. The main ones are listed below:

- article 12: the article 184-bis, which defines the “by-product” concept, and the article 184-ter which defines “end of waste” concept have been integrated compared to Legislative Decree 152/06;
- article 16, which modifies the following articles of Legislative Decree No. 152/2006:

- article 188 "Responsibility for waste management";
- article 189 "Waste register";
- article 190 "Loading and unloading registers";
- article 193 "Waste transportation";

- article 36: inserts article 260-bis into Legislative Decree No. 152/2006, regarding the "Informatisation system for waste traceability control", providing for an increase, as of January 1, 2011, in economic administrative sanctions (up to € 93.000) for all subjects that will not register with Sistri; it also introduces the obligation to keep the loading and unloading register for companies and entities that transport and collect their special non-hazardous waste.

5.3 Legislative Decree 116/2020: amendments to the Legislative Decree 105/2010

With Legislative Decree No.116/2020, the legislator reviewed the waste regulations almost exactly ten years after the last systematic legislation revision (by Legislative Decree No. 205/2010, which implemented the Directive 2008/98/EC).

The main changes are summarised below:

- articles 179, 180 and 181 regarding the hierarchy in waste management, prevention of waste production, preparation for reuse, waste recycling and recovery have been amended, and largely rewritten;

- the "urban waste" definition has been included ex-novo in article 183 and the relative classification and regulation have been completely modified. The list of special waste contained in paragraph 3 of the subsequent article 184 has been completely revised. This is, probably, the most relevant novelty introduced by Legislative Decree No. 116/2020 which will have significant repercussions on the activities of numerous economic operators, who will be forced for the first time to classify and manage their waste as urban waste. The novelty consists in the inclusion, in the list of urban waste, next to the "classic" waste (domestic users waste, waste from street sweeping or lying on public or private streets and areas subject to public use or on beaches, waste from the maintenance of public green areas and waste from cemetery areas and activities), of a new category of "undifferentiated waste and waste from separate collection deriving from other sources" (i.e., non domestic users waste) that are similar in nature and composition to the domestic users waste indicated in attachment L-quater, produced by the activities indicated in attachment L-quinquies" (article 183, paragraph 1, letter b-ter, point 2);
- linked to the new waste classification is the new disposition included in the article 238, which states that non-domestic users who produce urban waste and "*who dispose them outside the public service and demonstrate that they have been sent for recovery by a certificate issued by the entity that carries out the waste recovery activity are excluded from the tax component payment in relation to the waste quantity conferred";*
- with reference to the waste classification, a disposition in article 184 whereby *"the correct attribution of waste codes and waste hazard characteristics must be carried out by the producer on the basis of the guidelines drafted within December 31, 2020, by the National System for Environmental Protection and Research and approved by decree of the Ministry of the Environment and Protection of the Territory and the Sea"* has been included*;*
- the "food waste" and "material recovery" definitions have been inserted ex novo into article 183, which have been extracted from the corresponding definitions dictated by Directive (EU) 2018/851;
- the dispositions concerning respectively, the "waste register" (article 189), the "loading and unloading register" (article 190) and the "waste identification form" (article 193)

have been reformulated, making some detailed changes that will, however, have immediate practical consequences for operators.

5.4 Law Decree No. 147 of of Dicembre 27, 2013: "Waste Tax" concept and definition

The "Waste Tax" (in Italian named TARI) is intended to finance the costs related to the waste collection and disposal service. As the "Ministry and Finance" website explains, *"it is destined to all citizens that are ownners or holders, for any reason, of locals or uncovered areas that produce waste".* The tax is a component of the "single municipal tax" together with the "unique municipal tax" and the "tax for indivisible services".

This tax was introduced on December 27, 2013 and it was established by the stability law for the year 2014 (article 1 of Law Decree No. 147 of December 27, 2013). It replaced, starting from January 2014, the previous taxes due to the Municipality by citizens, entities and companies as payment for the waste collection and disposal service, known as "Environmental Hygiene Tax", "Municipal Tax on Waste and Services" and "Solid Urban Waste Disposal Tax".

This tax does not apply to uncovered areas appurtenant or accessory to taxable locals, which are not operational, or to common condominium areas not held or occupied exclusively. They are taxed appurtences such as boxes while accessory areas such as wine cellars, evacuation rooms, access ladders, common parts of the condominium are excluded. The garden is taxable, but not the uncovered parking space. The areas used for economic activities (such as the factory yard) instead, are always taxed.

Each municipality determines the taxes based on surface area and number of inhabitants. It is considered subject to the tax "floor area" of real property units, registered or inscribed in the "urban land register" that can produce waste. The calendar year is the reference period for the tax payment.

5.5 Ministerial Decree April 20, 2017: the "punctual tax"

It establishes the criteria for the implementation by the municipalities of:

- punctual measurement systems of the waste quantity conferred by users to the public service;

- management systems characterised by the use of correctives to the criteria for the service costs distribution with reference to the service rendered.

These criteria are designed to implement an effective model of tax commensurate with the service rendered to cover the management service full costs of municipal and assimilated waste, carried out in the forms permitted by European Union law.

The punctual measurement of the waste quantity conferred is obtained by determining, as a minimum requirement, the weight or volume of the waste quantity conferred by each user to the public waste management service. It is also possible to measure the quantities of other fractions or waste flows subject to separate collection, including the user conferments to municipal collection centers. For the measurement of fractions or waste flows conferred, different from the previous one, simplified systems for determining the quantities conferred are allowed.

The identification of the user associated to the punctual measurement of waste quantity takes place directly and univocally, through suitable electronic control devices integrated in the waste bin or bag, or through suitable equipment installed in special conferment points such as bins with volumetric limiter. Recognition takes place thanks to the user code, or through other methods of univocal identification that make it possible to trace the user code also through the user owner and his cohabiting family members tax code. Punctual measurement systems must be able to:

- identify the user that confers through a code uniquely associated with it or through the identification of the user that confer the waste;
- record the number of conferments thanks to detection the bins or bags expositions or direct conferment identification in controlled-opening bins with limited volume or accesses detection to municipal collection centers by each user. The devices and the organisational methods adopted must guarantee each single conferment registration, associated to the user or the bin identification, with the indication of the withdrawal moment;
- measure the waste conferred quantity, through direct or indirect weighing methods.

The measurement of the waste conferred quantity takes place directly, with weight detection, or indirectly thanks to the volume detection of the conferred waste by each user and it can be:

- carried out on board the vehicle that performs the waste collection, through the bin or bag identification;
- carried out by a device provided to the collection waste operator through the bin or bag identification;
- integrated into the bin used for collection;
- carried out at a collection point.

In cases of direct weighing, the waste quantity, for each waste fraction subject to measurement produced by the individual user (Waste Tax), is calculated as the sum of the records of the weight conferred (WeightConf) for each user expressed in kilograms. Therefore, the quantity waste for each user (RIFut) is determined by the following formula:

$$\text{Waste Tax} = \Sigma \text{WeightConf}.$$

In the cases of indirect weighing, the waste volume conferred is determined by the bin exposed size by the user or by the bag conferred capacity or by the conferment opening size of the bins with a volume limiter.

In the case of both direct and indirect weighing, the electronic equipment, bins and weighing instruments must respect both all applicable technical standards and the personal data protection and their informatised management regulations.

5.6 Legislative framework of ”End of Waste”

The "End of waste" concept indicates a recovery process carried out on a waste, at the end of which it no longer has this status and acquires the statuts of a by-product. It does not mean the final result, but the entire process that allows the waste to become useful as a by-product.

It is an important step away from the concept that "a waste remains a waste forever" and towards a recovery and recycling society, as strongly desired by the "Thematic Strategy on the Prevention and Recycling of Waste", adopted by the European Commission in the year 2005, which defined the necessary conditions for the “end of the waste” status.

The article 184-ter of the “Single Environment Text” (Legislative Decree 152/2006) states that a waste is no longer a waste when it has suffered a recovery operation, including recycling and preparation for re-use, and satisfies the specific criteria, to be adopted in according with the following conditions:

- the substance or object is commonly used for specific purposes;
- there is a market or demand for that substance or object;
- the substance or object satisfies the technical requirements for the specific purposes and respects the existing legislation and standards applicable to products;
- the substance or object use will not lead to negative environmental or human health impacts.

This article has been subject to numerous content changes, above all with reference to the industrial plants authorisation system. Following the amendments made by Legislative Decree 105/2010, the possibility to evaluate case by case, for each type of waste, the conditions under which a waste subjected to recovery or recycling operations, would end his waste status, was introduced thanks to decrees issued by the Ministry of Environment.

Therefore, the regions had to decide case-by-case for the authorisations granting. With circular of the Ministry of the Environment No. 10045 of July 1, 2016 "Discipline of the end of waste classification - Application of article 184-ter of Legislative Decree April 03, 2006, No. 152", with the aim of standardising their administrative action, clarifications were provided to the Administrations responsible for waste management authorisations (i.e. the Regions). This circular was in according with the European framework which stated that, in the absence of European regulations, there could be two possibilities:

- Member States could determine the end-of-waste criteria by defining them by waste class through ministerial decrees;
- or this task could be entrusted to the competent authority for authorisations granting evaluated for each individual case.

Therefore, according to the circular, either the States emanated end-of-waste decrees defining the criteria by waste classes, or, in the absence of such decrees, the Regions setted end-of-waste criteria by authorisations granting on a case-by-case basis.

CHAPTER 6: ORGANIC WASTE AND WINE BY-PRODUCTS MANAGEMENT - STATE OF THE ART IN BASILICATA REGION

In this chapter, with reference to the Basilicata region, firstly the total production of organic waste has been estimated, then the state of the art corcerning many problems connected to the management both the organic waste and wine by-products has been evaluated.

6.1 Territorial framework

The Basilicata region is largely a mountainous and hilly region: 45% of the population (especially in the Province of Potenza) lives in mountainous areas, 42% (mostly in the Province of Matera) in hilly areas while only 13% in flat areas. Almost all of the region's municipalities have a low level of urbanization, with a poor concentration of the population in the largest cities and a marked spread of inhabitants throughout the rest of the territory. Potenza and Matera municipality, indeed, together represent 22% of the total region population while the vast majority is located in small or very small municipalities (Urbistat, 2019). As for the economic situation, the data (ISTAT, 2019) show a significant delay respect to national values, but a better placement than the average of the other southern regions.

The Gross Domestic Product (GDP) per capita (20,6 thousand euros), indeed, is higher than other southern regions (18,4 thousand euros) but below the Italian average (27,7 thousand euros). Similarly, the performance of the region in terms of invoiced and added value per employee and the average employees income indicate a better position of Basilicata region compared to the south, but clear delay in relation to the national data. This is also true for the employment rate which is equal to 51,6% compared to 44% in the South Italy and the Italian average of 58% (Studi e Ricerche per il Mezzogiorno, 2020). These data affect the *per capita* production of waste, which is correlated to the level of income and consumption (which is, in turn, directly influenced by the disposable income of households). In Basilicata region, indeed, there is a per capita annual waste production of 354 kg/inhabitant, below not only the national data (497 kg/inhabitant), due to the economic delay of Basilicata region compared to the Central-Northern regions, but also compared to the Southern regions (450 kg/inhabitant) (Studi e Ricerche per il

Mezzogiorno, 2020) which presents lower development indicators than Basilicata region. This result is due to a greater "virtuosity" of the Basilicata region, which respects the European and national strategies in the field of waste, inspired by the circular economy, which provide for the reduction of waste production in the first place of the hierarchy. This conclusion, moreover, is confirmed, at least in part, by the percentage of collected waste (39,2%), below the national level (52,5%) but better than the average for Southern Italy (37,6%) (Studi e Ricerche per il Mezzogiorno, 2020).

6.2 Estimation of the organic fraction of municipal solid waste

The recovery and management of municipal solid waste, through separate collection, produces interesting by-products to be reused in the circular economy. From the process of aerobic or anaerobic transformation of the organic fraction of municipal solid waste, two by-products of particular interest can be obtained: biogas, further transformed into biomethane, and quality compost, defined by Legislative Decree 75/2010, reusable in agriculture.

The organic fraction of municipal solid waste, or bio-waste, is composed mainly of food waste of vegetable or animal origin and green waste, whose amount depends on the area considered (Eurostat, 2013). According to European recommendations and environmental considerations, this waste must be collected separately at home to be biologically treated by composting or anaerobic digestion to ensure the production of high-quality compost, in accordance with new European regulations (European Union, 2008). Anaerobic processes represent one of the most interesting treatment methods for the organic fraction of municipal solid waste (Cesaro et al., 2014). In the last decades, anaerobic digestion treatment for this type of waste has been heavily used in waste treatment industrial plants in Europe.

In Basilicata region the organic waste represents the 40% of the total municipal waste (Isprambiente, 2019). Obviously moving the analysis to the municipal level, this information must be understood as an average value, because there will be some municipalities that will produce greater quantities of organic waste as they are provided with restaurants, canteens, beach resorts etc.. while other municipalities will produce smaller quantities.

Starting from the population data at the municipal level, the total amount of waste produced by each inhabitant and considering the average fraction of organic waste equal to 40%, the total amount of organic fraction of municipal solid waste produced at the municipal level (Fig. 29) has been estimated (Isprambiente – Catasto rifiuti, 2019).

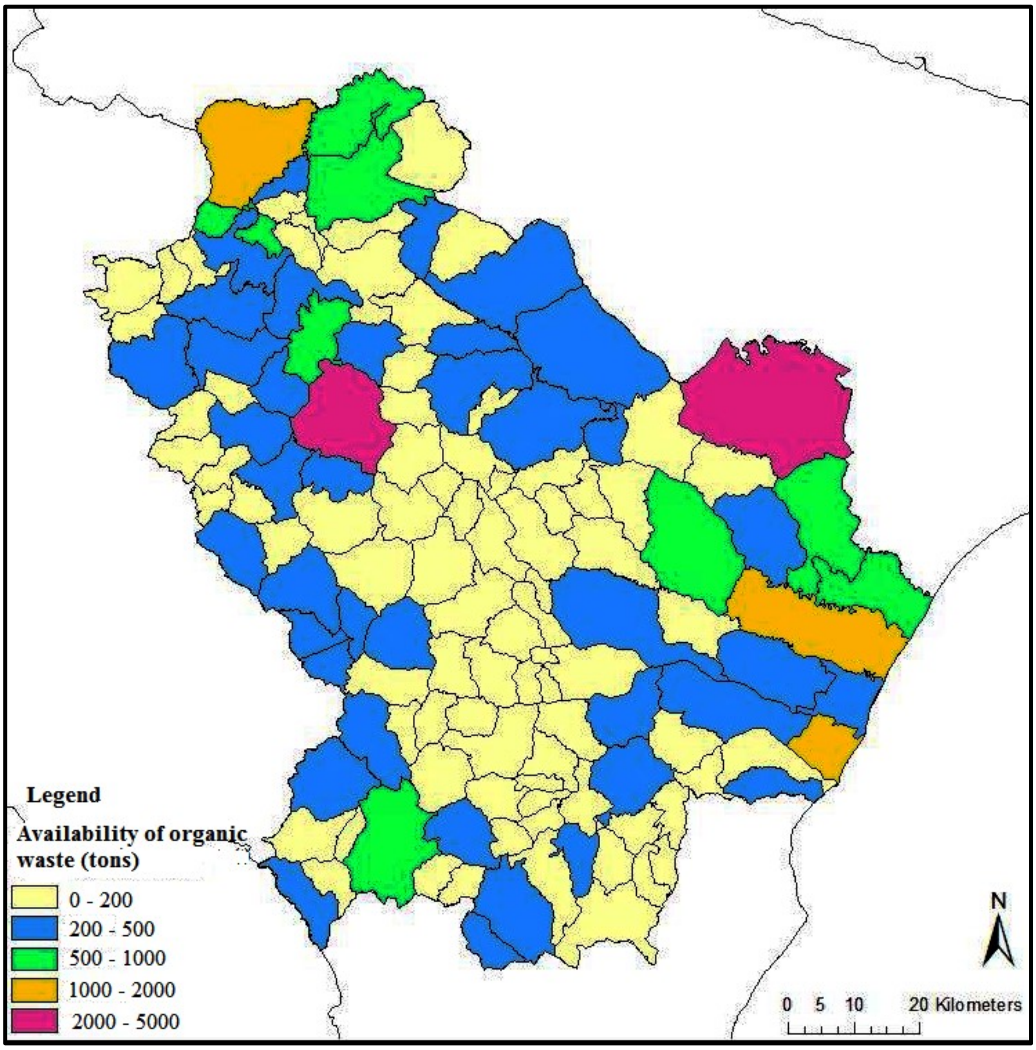


Figure 29: Availability of solid waste organic fraction at municipal level

6.3 Organic waste and wine by-products in Basilicata region: state of the art and related problems

There are many significant and concrete problems that negatively affect the current management organisation of both organic waste and wine by-products.

Some problems concern organic waste. The imbalance between the various areas of the country, indeed, forces the center and south of Italy to transfer their organic waste (from separate collection) in other regions, with great expenditure of money and air pollution for emissions due to the constant and prolonged movement of vehicles. The Basilicata region, indeed, disposes its organic waste to the “Laterza” composting plant (located in the municipality of Laterza - province of Taranto - Puglia region) but there are many municipalities that disposes their organic waste even in the much far away Veneto or Emilia-Romagna regions, with negative consequences both economic and environmental point of view. The Basilicata region, indeed, is the only region in Italy (Fig. 30) that is not equipped with an industrial composting plant.

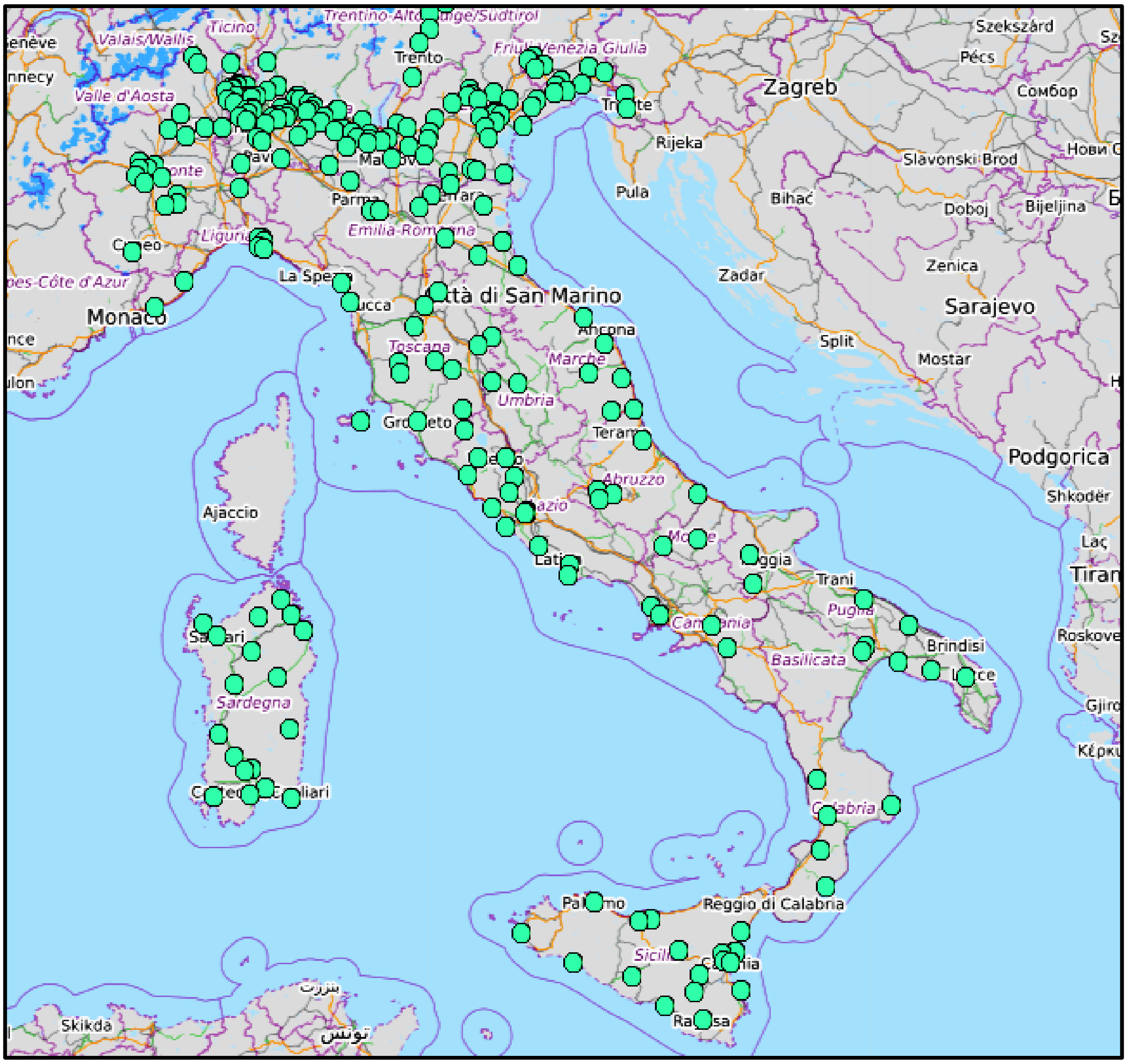


Figure 30: Geographical distribution of industrial composting plants in Italy

The organic waste that instead is not treated but is transferred to landfills, has a high cost of disposal, due to the difficulty of finding suitable landfills, with an increase in expenditure on citizens. Also the separate collection itself and in particular the "door to door" model (more widely used) presents significant criticalities such as

- the traffic caused by vehicles (especially in narrow streets or, on the contrary, in very crowded and busy streets) with consequent excessive road surface wear as well as the emission of CO_2 into the atmosphere;
- the exposure of the bins on the street subject to the bad weather, or to the presence of dogs and cats;
- the concentrated collection in restricted time slots, as well as errors in the waste exposure calendar with consequent inconveniences for the operators and for the citizens themselves, etc.

Other problems concerns wine by-products. Their management is currently complicated because they are produced in considerable quantities but concentrated in short periods of the year (September-October generally). Their disposal has, on the other hand, many problems (as emerged from numerous interviews carried out directly with producers) due to strictly regulations concerning, for example:

- the maximum disposable quantity per hectare;
- the preliminary treatments (required) to which they must be subjected;
- the continuous controls by the authorities;
- etc.

Precisely for this reason, they represent a real problem for producers. Very often, indeed, they are:

- disposed directly on the ground, very often manually, not respecting the limits imposed by the regulations, creating a harmful effect on the soil;
- used as animal feed, without taking into account the effective well-being of the animals;
- in the best case, sent to a distillery, following a very expensive process as these centers are very distant from our region, with evident and significant disadvantages in terms of CO_2 emissions related to road transport.

In both cases, therefore, at present, both for organic waste and wine by-products, there are many problems that weigh in various ways on the strategies of the various municipalities and that are complicated to manage.

MATERIALS AND METHODS

CHAPTER 7: PLANNING THE INTEGRATED MANAGEMENT OF ORGANIC WASTE FLOWS AND WINE BY-PRODUCTS FOR A CIRCULAR ECONOMY: PROPOSAL OF ALTERNATIVE MODELS

After the analysis, in the previous chapter, of the main problems related to the current model of management and especially disposal of organic waste and wine by-products, two new models, alternative to the current one, to improve the management of these flows in the perspective of circular economy, have been proposed. They have been studied in an integral way, therefore from the environmental, territorial and economic point of view.

7.1 Organic waste from *non-domestic users* and *wine by-products*: a new valorisation model in the perspective of circular economy

To overcome some of the main problems existing in the current organizational model of collection, management and disposal of organic waste (from separate collection) and wine by-products, a new integrated model of collection and management of *organic waste of non-domestic users* (from separate collection), in union with other *by-products coming from different agricultural activities, primarily wine by-products (especially pomace which represents the largest percentage), but also small quantities of mowing and pruning waste* that are practiced in the Basilicata region have been hypothesised, studied and proposed. This new model, different from the current one (composting in very distant industrial plants), which is unsustainable, very expensive and disadvantageous, on the one hand aims to improve the separate collection in individual municipalities, and consequently reduce the amount of organic waste to be treated, on the other hand to give a second life, more sustainable, to wine by-products in the perspective of a circular economy. The hypothesized model, called "***proximity composting***" is a middle ground between *industrial composting* (large plants for high flows) and *community composting* (carried out by associations of citizens within a radius of 1 km and for a maximum amount of 130 tons/year).

Subsequently we show the steps concerning the municipality of Matera, considered as a case study, but the same procedure has been repeated for other municipalities in Basilicata region.

The organizational idea at the base of the hypothesized model provides for:

- deposit of *urban green waste*, *organic waste* produced by non-domestic users and *pomace* produced by farmers at a ***temporary collection center*** located *within the municipality* itself;
- subsequent transfer of these flows in areas, near or not the collection center, but still within the municipality, designed to accommodate ***mini-composting plants (composter)*** for the production of biological fertiliser, that each user or farmer can reuse in their land, to close the circle of circular economy and restore the soil fertility level.

The main objective was essentially to answer the following question: **with the new hypothesized model, i.e. the valorization of zero-kilometer flows, what are the economic, environmental and territorial advantages compared to the current scenario, i.e. the composting of organic waste outside the region and the disposal of wine by-products in distilleries also outside the region?**

The feasibility study (economic and environmental) of the hypothesised model has been carried out through several steps summarised below:

1. **Calculation of the amount of organic waste produced by non-domestic users** (tons/year): non-domestic users such as schools with refectory service, hotels with restaurant, nursing and retirement homes, hospitals, offices, restaurants, trattorias, inns, taverns, pubs, bed and breakfasts, agritourisms ecc. have been considered, i.e., the users that mostly contribute to waste production (Tab. 13), their municipal solid waste production (tons/year) which depends on the surface area and the relative production coefficient (Department of Finance, 2018), and taking into account the composition of waste in the Basilicata region according to which the organic fraction corresponds to 40% of total waste production, the total amount of organic waste has been also determined (Tab.13).

Table 13: Organic waste production for non domestic users considered

Category	Urban Waste Production (tons/year)	Organic Fraction (%)
Museums, libraries, schools, associations, worship places	313,06	40
Hotels with restaurant	8,64	
Nursing and retirement home	186,4	
Hospital	525,91	
Offices, agencies and professional offices	2.108,6	
Restaurants, inns, taverns, pubs	444,49	
Refectories, breweries	13,21	
Bar, coffee bar, bakeries	120,26	
Fruit and vegetables, fishmongers, flowers and plants	80,93	
Bed and Breakfast	22,27	
Agritourisms	14,21	
Total Organic Waste Production **1.525,19 tons/year**		

The amount of ***mowing and pruning***, that is plant by-products coming from the cleaning of parks and public gardens as well as from the cleaning of cemeteries have been obtained (Tab.14) (Isprambiente, 2019).

The amount of ***pomace*** coming from wine chain (tons/year) (Tab.14) have been calculated, taking into account the total regional area (hectares) occupied by vineyards (RSDI, 2015), the area (hectares) currently used to produce wine grapes, the resulting annual production of wine grapes (tons per hectare) (Università Politecnica delle Marche, 2013).

Table 14: Imput flows for the hypothesised model

IMPUT FLOWS			
Non domestic organic waste (tons/year)	**Urban green waste (tons/year)**	**Pomace (tons/year)**	**Total quantity (tons/year)**
1.415,21	93,95	20,84	1.530

2. **Analysis of the costs referred to the current scenario**: currently the organic waste in Basilicata region are disposed at the industrial composting plant of Laterza (which is 22 km far from Matera municipality) even if, as already mentioned, there are many municipalities that confer their organic waste at much more distant industrial plants located in Lombardy, Veneto and Emilia-Romagna region. In the following table the

most important data used to calculate the costs related to the current scenario concerning the management of organic waste and pomace have been represented.

Table 15: State of the art data for the collection and disposal of organic waste and pomace

Current scenario		Reference
Organic waste collection cost (€/ton)	200	Direct inteviews with operators
Organic waste disposal cost (€/ton)	150	Direct inteviews with operators
Distance from the nearest composting plant (Km)	22	
Fuel yield (Km/l)	2,8	Ministero dello Sviluppo Economico, 2018 (vehicles with a mass greater than 26 tons)
Fuel cost (€/l)	1,5	Ministero della Transizione Ecologica, 2020
Average transportable quantity (tons)	30	Direct inteviews with operators
Pomace disposal cost (€/ton)	0,22	Novello, 2015
Distance from the nearest distillery (Km)	500	Direct interviews with operators

3. **Proposed alternative scenario: land use planning for the location of the temporary collection center and the composter**. Given the small size of both the area to host the collection center and the composter, it was not necessary to carry out an environmental impact assessment. The choice of location (Fig.31) has been performed taking into account some parameters, avoiding that the area fell within particular constraints such as **areas at risk of landslides, or near polluted sites (and therefore sites reported and to be reclaimed) or industrial areas, nature reserves or areas with landscape and archaeological constraints, "SCI", i.e.: Sites of Community Interest and "SPA", i.e.: Special Protection Areas.** Obviously, preferential factors such as the multiplicity of access roads, accessibility not conditioned by atmospheric events (snow, ice), barycentricity with respect to flows production, the financial cost of acquiring the areas and the absence of industrial plants with a strong environmental impact in the vicinity, have been also considered.

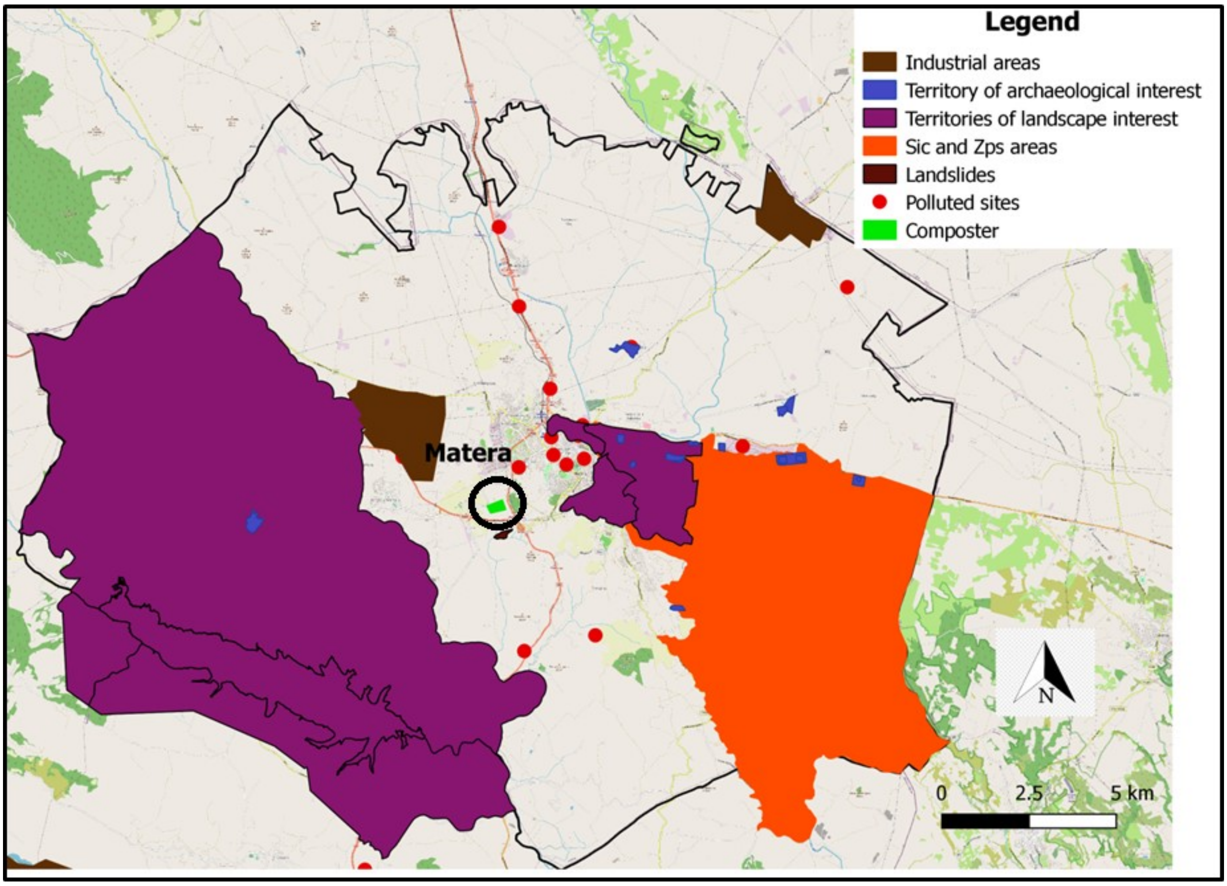


Figure 31: Geographical localisation of the area for "proximity composting"

4. **Composter sizing based on flows quantification (tons).** Two types of composter have been analysed:

- **Electro-mechanical composter**: it is widely used in northern European countries. From the technological point of view, figure 32 shows an example of an "Ecorotor" composter designed, patented and made entirely in Italy by the company Comar S.r.l. The electromechanical composters are quite simple: they usually consist of a rotating cylinder which, thanks to the action of electric motors, turns the organic material for about 1-2 minutes every 1-2 hours. Aeration and turning are guaranteed automatically. The final compost is gradually ejected into a ready-made bag or container. These equipments can be positioned under roofs or inside closed spaces equipped with an electrical system (three-phase or single-phase power supply). Table 16 summarises the dimensional characteristics of the composter chosen for the municipality of Matera.

Figure 32: Example of electro-mechanical composter "ECOROTOR" designed, patented and realised totally in Italy by Comar S.r.l.

Table 16: Dimensioning of an ECOROTOR electro-mechanical composter

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	1.600
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/days)	4.380
Obtainable compost (tons/year)	480
Expected consumption (€/year)	500

- **Mechanical-biological composter:** the biocell configuration consists of containers (an example of a biocell composter by Duma Recycling Equipment is displayed in figure 33) with a standard size of 25 m^3 (Tab. 17) inside which, through real-time control and monitoring of temperature, humidity and oxygen concentration, the process of degradation of organic matter or biodrying is accelerated. The intensive fermentation in the biocell is carried out through the insufflation of air from the bottom of the container that allows to homogeneously oxygenate the mass and maintain an optimal temperature for the microbial fauna in a range where the activity of these organisms is maximum. There are many advantages of this type of configuration: process acceleration of degradation of organic matter or waste biodrying, easy and intuitive management of the process, odors reduction, space and footprint, compliance with legal parameters (respirometric index, odorigenic substances, etc.). The progress of the process is monitored and recorded in real time, ensuring the optimal treatment for each biocell in operation, according to the needs of the material to be treated. Table 17 summarises the dimensional characteristics. The sizing has been carried out taking into account the standards of the company "Duma Recycling Equipment" in relation to the flows (tons) in input in our case.

Figure 33: Example of bio-container belonging to Duma Recycling Equipment

Table 17: Dimensioning of the Duma Recycling Equipment mechanical-biological composter

BIOCELL PLANT DIMENSIONING	
M - Total mixture to biocells (tons/year)	1.600
D - Average mixture density (tons/m$^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	146,12
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	5,8

- **Analysis and quantification of all costs (fixed and variable) of the process incurred by the municipality.** For the electromechanical configuration (Tab. 18) the *investment cost* is approximately 600 euros per tons of organic waste treated (estimated from direct interviews with operators). Various costs (assumed on the basis of direct experience in the field) due to *video surveillance of the area* used as a collection center and to host the composter, *bureaucracy and the purchase of the area* itself have been considered. Obviously, they have been proportioned to the size of the area in question. For the *staff training,* the costs related to the training and updating courses for the conduction of the composter have been considered . The cost for the *informatisation of the collection center and of the whole process*, as we will see in the next chapter, that is information technology solutions to follow and to trace in near real time every phase of the process cycle, from the flows production to their transport up to the final destination have been foreseen. These costs, classified as **initial costs of the municipality**, have been spread over 5 years in the economic calculation. Then**, annual fixed costs** including *personnel costs* (starting from the gross annual cost of an ecological operator according to the "Contratto Collettivo Nazionale di Lavoro per i Servizi Ambientali" updated to 2016 and considering the number of operators employed based on the size of the composter and the amount of incoming flows), the *electricity consumption* of the machinery (obtained directly from the data sheet) and the *related maintenance* costs obtained from direct interviews with operators have been also considered.

Table 18: Initial and annual fixed costs for the electro-mechanical composter

Composter Investment Cost (€)	**900.000**
Various costs (Videos, Bureaucracy, Area) (€)	10.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	25.000
Municipal Initial Costs (€)	**936.500**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	500
Composter maintenance (€/year)	3.500
Municipality Fixed Costs (€/year)	**54.000**

For the biocell configuration (Tab. 19) the costs are comparable to the electro-mechanical composter. The only relevant difference is the much lower investment cost as each standard size biocell of 25 m^3 (as previously calculated) costs € 65.000, as evidenced following direct interviews with operators.

Table 19: Initial and annual fixed costs for the mechanical-biological composter

Biocell Investment Cost (€)	**379.909**
Various costs (Videos, Bureaucracy, Area) (€)	12.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	25.000
Municipal Initial Costs (€)	**418.409**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	400
Composter maintenance (€/year)	3.000
Municipality Fixed Costs (€/year)	**53.400**

5. Avoided costs

At this point, the avoided transport (equation 1) and disposal (equation 2) costs of the organic waste to the composting plant as well as the avoided disposal costs (equation 3) for the pomace to distillery have been calculated:

$$\textbf{Organic Waste} - \textbf{Avoided Transport Cost}\left(\frac{\text{€}}{\textbf{year}}\right) = \frac{\mathrm{D}}{\mathrm{R}} * 2 * \mathrm{C} * \left(\frac{\mathrm{Qt}}{\mathrm{Qm}}\right) \quad (1)$$

where “D” is the distance from the nearest composting plant considered (Laterza-Taranto) (Tab.15); “R” is the average fuel yield for vehicles transporting waste (Tab. 15); “C” is the fuel cost calculated in table 15; “Factor 2” because the round trip has been considered; “Q_m” is the average transportable quantity (Tab. 15); “Q_t” is the total organic waste production (Tab. 14).

$$\begin{aligned}&\textbf{Organic Waste} - \textbf{Avoided Disposal Cost}\ (\text{€}/\textbf{year})\\ &\qquad = \text{Disposal cost}\ (\text{€}/(\text{tons} * \text{year})) * \text{Qt}\ (\text{tons}) \qquad (2)\end{aligned}$$

where “Disposal cost” represents the disposal cost per ton of waste (Tab. 15); “Q_t” is the total organic waste production (Tab. 14).

$$\begin{aligned}&\textbf{Pomace} - \textbf{Avoided Disposal Cost}\ (\text{€}/\textbf{year})\\ &\qquad = \text{Disposal cost}\ (\text{€}/(\text{tons} * \text{year})) * \text{Qt}\ (\text{tons}) \quad (3)\end{aligned}$$

where “Disposal cost” represents the disposal cost for pomace in distillery (Tab. 15); “Q_t” is the total pomace production, previously calculated (Tab. 14).

7.1.1 Calculation of economic saving

Following the adoption of the hypothesized model, the economic (equation 4) and environmental saving (equation 5), compared to the current scenario, both for organic waste and for pomace have been calculated as follows:

$$\textbf{Organic Waste Economic saving}(€/\textbf{year}) = [(Ci/5) + Cf](€/year) - [Avoided\ \ Transport\ Cost + Avoided\ Disposal\ Cost]\ \ (€/year) \quad (4)$$

where "C$_i$" are initial costs of the municipality (spread over 5 years); "C$_f$" are the fixed costs of the municipality; "Avoided Transport Cost + Avoided Disposal Cost" are the economic savings due to the lack of movement of flows to the composting plant, because in the hypothesised model they remain within the municipality of production (composting of proximity).

$$\boldsymbol{Pomace -\ \ Economic\ saving}\left(\frac{€}{year}\right) = Avoided\ disposal\ cost\ in\ distillery\left(\frac{€}{year}\right) \quad (5)$$

For pomace, the economic saving is essentially due to the avoided disposal to distillery because in the hypothesized model it is valorised within the municipality itself.

The transport cost due to the distiller who, during the harvest season, withdraws the wine by-products from the various farmers when the amount is considerable has been deliberately omitted. This choice is due to a very specific reason: as emerged in many interviews with some wine producers in the region, indeed, this cost is canceled out by the market value obtained from the sale of the distillate which, in exchange, remains in the possession of the distiller.

7.1.2 Calculation of the environmental saving

The related environmental saving is essentially due to CO$_2$ avoided due to non-movement vehicles to the composting plant (equation 6) or to the distillery (equation 7), since in the proposed model the flows are valorised within the municipality itself:

$$\boldsymbol{Avoided\ CO2\ emissions\ composting\ plant}(Kg/year) = CO2\ consumption(g/Km) * No\ of\ trips\ (Km/year) \quad (6)$$

$$\boldsymbol{Avoided\ CO2\ emissions\ distillery}(Kg/year) = CO2\ consumption\ (g/Km) * No\ of\ trips\ (Km/year) \quad (7)$$

The calculation, in addition to considering the number of trips per year, which is a function of the distance (roundtrip) to the composting plant or to the distillery, the average quantity transportable by each vehicle and the amount of the flows handled by the single municipality, takes also into consideration the parameter of CO_2 consumption which deserves a little reflection. To obtain this data, we referred to the Arpa Lombardia study based on the "Copert IV methodology: traffic emissions factors in Europe". This methodology called COmputer Program for the calculation of road transport emissions (Copert) proposes calculation algorithms to estimate the emission factors (g / Km) obtained from experimental measurements on vehicle classes representative of the different engine methods. The emission factors, within the study, have been divided by pollutant, type of vehicle (160 types divided into classes of displacement and age of vehicles) and by classes of average speed. This methodology provides interpolating functions between their various parameters: vehicle speed with emission factors (defined by European Union directives), fuel consumption and vehicle speed, hydrocarbon emission factors totals and speed. Following many tests and considerations, Arpa Lombardia estimated a CO_2 consumption of 667 g/km for vehicles over 3,5 tons.

Obviously, it is an average value that also depends on the speed, the displacement of the vehicle, the slope and the state of the roads, the type of power supply of the vehicle. For the Basilicata region there are no tables, study or literature references with CO_2 consumption indices. Therefore, the value used (800 g/Km) has been obtained from personal calculations by studying the circulation books of the waste vehicles, the relative CO_2 consumption and considering an average value that is representative of the regional parameters.

The feasibility study and all the steps described for the municipality of Matera, has also been extended to the other capital municipality, namely Potenza, therefore the two most populous municipalities in Basilicata region for which the saving (resulting from the greater number of inhabitants, the greater flow managed and consequently the greater economic saving due to the lack of disposal and transport outside the region) justified the costs. The smaller municipalities, on the other hand, have been organised at the district level since, if considered individually, the limited flows did not justify the costs incurred and therefore there was no saving. With this distinction, the feasibility of the proposed model in relation to the number of inhabitants and the extent of the municipality has been highlighted (**Attachment 1**).

In addition to **Potenza** and **Matera** municipality, the following disctict have been considered:

- **Vulture district**: Venosa, Barile, Rapolla, Lavello, Ginestra, Ripacandida, Rionero, Melfi, Atella;
- **Materano district**: Montescaglioso, Pomarico, Ferrandina, Craco, Tursi, Rotondella, Nova Siri, Bernalda, Pisticci, Montalbano Jonico, Policoro, Scanzano Jonico;
- **Alto Bradano district**: Genzano di Lucania, Palazzo San Gervasio, Oppido Lucano, Tolve, Forenza, Maschito[1], Montemilone, Banzi, Acerenza, San Chirico Nuovo, Banzi, Pietragalla, Avigliano;
- **Val d'Agri district**: Moliterno, San Martino D'Agri, Grumento Nova, Tramutola, Paterno, Marsicovetere, Calvello, Marsiconuovo, Viggiano, Sarconi, Spinoso, San Chirico Raparo, Montemurro, Sasso di Castalda, Roccanova.

For these districts, compared to the steps shown for the individual municipalities there are only some differences:

- collection cost of organic waste: it varies according to the number of the municipalities, as this item cost includes other sub-items that are not considered anywhere else such as costs due to personnel management, handling, wear or possible failures to vehicles, costs associated with the information and awareness campaign, the costs associated with the purchase of bags, bins, etc. It is therefore clear that different values must be used based on the size of the municipality in question.
- disposal cost of organic waste: a single cost for all municipalities regardless of their number has been considered, as this item depends on the waste acceptance industrial plant and not on the municipality that confers.

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[1] Although geographically it belongs to the Vulture-Melfese territory, it has been included in the Alto Bradano district as it already shares many waste management practices with these municipalities..

- unlike the single municipality, the district provides a temporary collection center for each municipality and an area hosting the composter in the barycentric municipality of the district itself. As a result of this organization, the initial and fixed costs have been divided among the municipalities, based on the incidence of waste that they will treat to the composter.

7.2 Organic waste from *domestic users*: new valorisation model in the perspective of the circular economy

For ***organic waste from domestic users***, on the other hand, a model to improve an already partially existing process, namely *domestic composting* has been proposed, thanks to the use of domestic mini-composters, which very often each municipality offers to the citizen on loan for use. Therefore, for this second model, the objective was to answer the following question: **if 10% of the population adopted domestic composting, then if 10% of organic waste were subtracted from the separate collection, how would the costs change? What would be the economic/environmental benefits?** A band study has been carried out. In addition to 10%, we have also hypothesized 20%, 30% and 40% of domestic composting. Also for this second proposed model, Matera municipality as a case study has been considered, but the procedure has also been repeated for numerous municipalities considered in the previous model. The development of the model has been divided into the following steps:

1. **Amount of organic waste collected separately:** after calculating the total production of municipal solid waste (tons/year) (equation 8) which depends on per capita production (Isprambiente, 2019) and on the number of inhabitants (Istat, 2019), the production of organic waste for domestic users (equation 9) which also depends on the percentage of separate waste collection (Isprambiente, 2019) and on the waste composition for Basilicata region has been calculated:

$$\textbf{Total Production Urban Waste}\ (\textbf{tons/year}) = Urban\ Waste\ production\ per - capita.\ (tons/(inhabit.* year)) * No\ inhabitants \quad (8)$$

$$\mathbf{Organic\ Waste\ Production\ (tons/year)} = Urban\ Waste\ Total\ production(tons/year) * Separate\ Collection\ (\%) * 0{,}4 \qquad (9)$$

Table 20 shows the imput flows which represents the starting point for the elaboration of our model:

Table 20: Imput flows for the model elaboration

IMPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
479,39	28960,43	24,28	2812,64

2. **Organic waste produced by 10%, 20%, 30%, 40% of domestic users and destined for home composting.**

After calculating the number of families, knowing the number of inhabitants and assuming that each family unit is made up of 4 people, the following data have been calculated:

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ Production * 0{,}10$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ Production * 0{,}20$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ Production * 0{,}30$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ Production * 0{,}40$$

3. **Analysis of costs referred to the current scenario.** Compared to the proximity composting model described in the previous paragraph, the collection and disposal costs, the distance from the nearest composting plant, the yield and fuel cost and the average quantity transported are the same (Tab. 21).

Table 21: State of the art data for the collection and disposal of organic waste

Current scenario		Reference
Organic waste collection cost (€/ton)	200	Direct inteviews with operators
Organic waste disposal cost (€/ton)	150	Direct inteviews with operators
Distance from the nearest composting plant (Km)	22	

Fuel yield (Km/l)	2,8	Ministero dello Sviluppo Economico, 2018 (vehicles with a mass greater than 26 tons)
Fuel cost (€/l)	1,5	Ministero della Transizione Ecologica, 2020
Average transportable quantity (tons)	30	Direct inteviews with operators

4. **Sizing of the domestic composter.** It has been hypothised that each domestic user is equipped with a domestic composter for 3-6 people.
5. **Analysis and quantification of all costs (fixed and variable) of the process incurred by the municipality.** Also in this case, various cost items have been considered. The initial costs of the municipality (Tab. 21) which in the economic calculation have been spread over an initial period of 5 years, include:

- Investment cost of the domestic composter:

$$\mathbf{Total\ Cost}\ (\text{€}/\mathbf{year}) = Single\ Domestic\ Composter\ Cost\ (\text{€}/year) * 2 * No\ Domestic\ Users$$

where a market value of € 35 for the single domestic composter has been considered. Moreover, it has been considered that in a period of 6 years, 2 of them are needed, since their useful life is 3 years.

- Sensors applied to the model. This item is extremely important. It has been included, since periodically domestic users will be subjected to checks to verify the correct progress of the domestic composting process. As it will be discussed in the next chapter, these sensors allow remote control of the various steps of the domestic composting process. In this way it will be possible to intervene in near real time to avoid obtaining a non-compliant product for reuse and therefore obtaining a waste that in any case must be disposed of. The check will be carried out by technicians hereinafter referred to as "operator".

$$Sensors\ Total\ Cost\ (\text{€}) = 500\ \text{€} * No\ Operator$$

where the sensors market value equal to 500 euros has been considered, while the number of operators has been calculated taking into account that the checks take place every three months and therefore in a month it is possible to carry out a total of 276 checks (equal to 2 checks / hour equal to 12 checks/day):

$$\text{No Operators} = \frac{\frac{\text{Total Number of Domestic Users}}{3}}{\text{No Monthly Checks}}$$

- staff training costs. No cost has been foreseen, as no training or updating is required by the legislation for the composter, also considering the extremely limited volumes.

As regards the fixed costs (Tab. 22) incurred each year by the municipality, the following costs have been calculated:

- operator check calculated from the gross cost of an ecological operator (based on the *"Contratto Collettivo Nazionale di Lavoro per i servizi ambientali* "updated to 2016) and considering the number of operators, which varies according to the size of the municipality:

$$Cost\ \ of\ the\ check\ Operator\ \left(\frac{€}{year}\right) = Gross\ Cost\ Operator\ (€/year) * \text{No Operators}$$

The costs related to the consumption of electricity have been neglected, while the costs related to the maintenance of the machinery provided directly by sector operators have been added.

It must be highlighted that in various cases, as the % of composting domestic increases (it goes from 10% to 40%), the number of domestic composters and therefore the investment and sensors costs and the consequent operator check cost increases at the same place.

Table 22: Initial and annual fixed costs for home composting

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	105.719,3	211.438,5	317.157,8	422.877
User training (€)	0	0	0	0
Sensors (€)	912	1.824	2.736	3.648
Municipality initial costs (€)	106.631,3	213.262,5	319.893,8	426.525
Operator control (€/year)	63.840	127.680,3	191.520,4	255.361
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	639.90,13	127.830,3	191.670,4	255.510,5

6. Avoided Costs

In this phase, the avoided costs due to the lower collection (equation 10), lower transport (equation 11) and lower disposal (equation 12) of the organic waste to the composting plant have been calculated as a percentage in the proposed model, then valorised through the home composting.

$$\textbf{Organic Waste} - \textbf{Avoided Collection cost}(€/\textbf{year}) = \mathit{Collection\ cost}\left(\frac{€}{\mathit{tons}*\mathit{year}}\right) * (Qt - Q10\%)(\mathit{tons}) \quad (10)$$

where “Q_t” is the total organic waste production (Tab. 20); “Q10%” represents the amount of organic waste produced by 10% of domestic users that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%); “Collection cost” represents the cost for each ton of organic waste collected (Tab. 21).

$$\textbf{Organic Waste} - \textbf{Avoided Transport Cost}\left(\frac{€}{\textbf{year}}\right) = \frac{\mathrm{D}}{\mathrm{R}} * 2 * \mathrm{C} * \left(\frac{\mathrm{Qt} - \mathrm{Q}10\%}{\mathrm{Qm}}\right) \quad (11)$$

where “D” is the distance from the nearest composting plant considered (Laterza-Taranto) (Tab. 21); “R” is the average fuel yield for vehicles transporting waste (Tab. 21); “C” is the fuel cost calculated in table 21; “Factor 2” because the round trip has been considered; “Q_m” is the average transportable quantity (Tab.21); “Q_t” is the total organic waste production (Tab. 20); “Q10%” represents the amount of organic waste produced by 10% of domestic users, that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%).

$$\begin{aligned}&\textbf{Organic Waste} - \textbf{Avoided Disposal Cost}\ (€/\textbf{year})\\&\quad = \text{Disposal cost}\ (€/(\text{tons} * \text{year})) * (\text{Qt} - Q10\%)\ (\mathit{tons}) \quad (12)\end{aligned}$$

where “Disposal cost” represents the disposal cost per ton of waste (Tab. 21); “Q_t” is the total organic waste production (Tab. 20); “Q10%” represents the amount of organic waste produced by 10% of domestic users, that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%).

7.2.1 Calculation of economic saving

The related economic savings (equation 13) are essentially due to the collection, management and handling of a smaller quantity, respectively 10%, 20%, 30% and 40% of organic waste, as it is subject to domestic composting.

$$\begin{aligned}\textbf{Organic Waste Economic saving}(\text{€}/\textbf{year}) &\\ &= [(Ci/5) + Cf](\text{€}/year) - [Avoided\ Collection\ Cost \\ &+\ Avoided\ \ Transport\ Cost + Avoided\ Disposal\ Cost]\ \ (\text{€}/year) \quad (13)\end{aligned}$$

where “C_i” are initial costs of the municipality (spread over 5 years); “C_f” are the fixed costs of the municipality; “Avoided Collection Cost + Avoided Transport Cost + Avoided Disposal Cost” are the economic savings due to the lack of movement of flows to the composting plant because in the hypothesised model they are subject to home composting, therefore outside the separate collection service.

7.2.2 Calculation of environmental saving

The related environmental saving (equation 14) is essentially due to the CO_2 saving following the management of a smaller quantity, respectively 10%, 20%, 30% and 40% of organic waste moved to the composting plant as they are subject to home composting.

$$\begin{aligned}\boldsymbol{Avoided\ CO2\ emissions\ composting\ plant(Kg/year)} &\\ &= CO2\ consumption(g/Km) * No\ of\ trips\ (Km/year) \quad (14)\end{aligned}$$

The calculation, in addition to considering the number of trips per year which depends on the distance (roundtrip) from the nearest composting plant, the average quantity transportable by each vehicle and the amount of flows handled by the single municipality, also takes into consideration the parameter of CO_2 consumption for which the same considerations made in the previous paragraph apply. The calculation has been repeated for the other bands (20%, 30%, 40%).

7.2.3 Calculation of the waste tax reduction for domestic users

According to the regulations of each municipality, each domestic user that adopts the domestic composting of its organic waste has a 30% discount on the waste tax. Then the calculation for the single domestic user has been performed:

- Fixed and variable part of the waste tax for each domestic user. Assuming an average surface area of each domestic user of 80 m² and an average composition of 4 members per family, by adding the provincial tax of 5%, the value of the Waste Tax (equation 15) and the related economic saving (equation 16) (Dipartimento delle Finanze, 2018) have been calculated:

$$\text{Waste Tax}\left(\frac{€}{\text{year}}\right) = \left[\left(\text{Fixed part}\left(\frac{€}{\text{m}^2 * \text{year}}\right) * \text{Average Surface Area}(\text{m}^2)\right) + \left(\text{Variable Part}\left(\frac{€}{\text{year}}\right)\right)\right] + \text{Provincial Tax }(\%) \qquad (15)$$

$$Economic\ Saving\left(\frac{€}{year}\right) = 30\% * Waste\ Tax\left(\frac{€}{year}\right) \qquad (16)$$

All these steps, reported with reference to the municipality of Matera, have been carried out for many of the municipalities considered in the first proposed model (described in the previous paragraph) in order to highlight the feasibility of the model (**Attachment 2**) in relation to the number of inhabitants. To optimize the costs, the municipalities belonging to the same district have only shared the costs related to the sensors and the operator control, and each of them will pay the share based on the incidence, *i.e.*, the number of domestic users on the total of the district. In conclusion, we must make an important consideration regarding CO_2. In both the hypothesized models, the production at the composting plant has been neglected in our calculations: in fact, it is negligible for our quantities, as well as for the production at the electro-mechanical composter or biocell. The production of CO_2 emitted by organic waste or wine by-products has not considered too, as their production is not eliminated, what changes is their final destination.

CHAPTER 8: INTERNET OF THINGS (IOT) APPLIED TO THE PROPOSED MODELS

Once the feasibility of the proposed models has been defined (**Attachment 1 and Attachment 2**) the IoT (Internet of Things) technologies have been focalised in order to understand what they are, what they are used for, but above all **how they can be applied to our models**.

8.1 IoT definitions and applications

The term *"Internet of Things" (IoT*) indicates that path in technological development whereby, through the Internet, potentially every object of daily experience acquires its own identity in the digital world. It is based on the idea of "intelligent" objects interconnected in order to exchange informations owned, collected and/or processed. The term IoT is first used by Kevin Ashton, a researcher at MIT, Massachussets Institute of Technology, where the standard for RFID and other sensors was found (Bellini, 2020).

The examples of the Internet of Things are innumerable. The cars, for example, initially connected "only" via GPS-GPRS boxes for insurance purposes, and which now come out of dealerships already equipped with on-board connectivity. To give even simpler examples of IoT, let's think of the very common street lamps in our cities, able to adjust their brightness based on visibility conditions, or the traffic lights that synchronize to create a green wave for the passage of an emergency vehicle. There are also other applications:

- cars that communicate with the road infrastructure to prevent accidents;
- household appliances that coordinate to optimise the power commitment;
- skis that send informations on the state of the snow, or on the severity of a fall;
- irrigation systems that regulate water demand based on needs;
- monitoring of micro-climatic parameters to support agriculture to improve the quality of products, reduce the resources used and the environmental impact (Smart Agriculture).

If it is true that all objects can become "intelligent" by connecting to the network and exchanging informations about themselves and the surrounding environment, it is equally true that this process does not occur in all areas with the same speed: this depends on the existence of consolidated technological solutions, from the competitive equilibrium in a given market and, ultimately, from the balance between the value of information and the cost of creating the network of intelligent objects.

8.2 IoT technologies applied to *proximity composting*

For the *remote control* of each phase of the proposed proximity composting model and consequent *Near Real Time monitoring* of the various phases, from the collection of flows, to their transport and their final destination (informatisation of the model), the platform web implemented by the industry "Innova" has been used. This platform, called INNOVAMBIENTE®, is a cloud software that makes each phase of the model controllable and efficient, it is constantly updated and implemented and allows the acquisition of data relating to the activity of the vehicles and to the contributions by users at the hypothesised collection center, which can be consulted by the operational center web service, represented in this case by the service manager, i.e. the company that carries out the collection in that municipality or district.

Thanks to its features and applications, it guarantees the manager himself a control, 24 hours a day and 365 days a year, of each phase of the waste and by-products management cycle. At all times, the manager knows what is happening within the collection cycle. It identifies in near real time strengths or criticalities of the cycle, user satisfaction and trend in service costs. Thanks to this approach, it is also possible to control any "points of interest" within the process: for example, a high production of waste in a non domestic user could hide an abusive "*Bed and Breakfast*" facility, or on the contrary a too low production could hide one illegal disposal. Using INNOVAMBIENTE®, again with reference to the municipality of Matera as a case study - even if, as already mentioned above, the same procedure has also been extended to other municipalities - we see below how the remote control of each phase of the process takes place.

Specifically, the following Information Technology solutions for Near Real Time control of the process have been applied to the proposed model:

- ***Municipal Personal Data Management:*** collection of all informations relating to non-domestic users (NDU), domestic users (DU) and producers of pomace (PP) (Fig. 34). The informations displayed, some of which omitted for privacy reasons, that change according to the type of user are the VAT number, the company name, the location (street or, alternatively, the latitude and longitude coordinates automatically obtained by Google Enterprise integrated into the INNOVAMBIENTE® software), the surface area of each user (m^2), the municipality and the category to which the user belongs, the data processing date.

Anagrafica Non Domestica

Ragione Sociale	Ubicazione	Civico	Esp.	Sup.(mq)	Zona	Cat_Utz	Categoria	Data	Stato			
[redacted]	[redacted]	[redacted]			MATERA	0	07 - Alberghi con ristorante	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	01 - Musei, biblioteche, scuole, associazioni, luoghi di culto	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	11 - Uffici, agenzie, studi professionali	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]				MATERA	0	01 - Musei, biblioteche, scuole, associazioni, luoghi di culto	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	24 - Bar, caffè, pasticcerie	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	22 - Ristoranti, trattorie, osterie, pizzerie, pub	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	27 - Ortofrutta, pescherie, fiori e piante, pizza al taglio	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	22 - Ristoranti, trattorie, osterie, pizzerie, pub	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]	[redacted]			MATERA	0	07 - Alberghi con ristorante	24-07-2020 11:02	📖	ⓘ	✎	✖
[redacted]	[redacted]				MATERA	0	01 - Musei, biblioteche, scuole, associazioni, luoghi di culto	24-07-2020 11:02	📖	ⓘ	✎	✖

Figure 34: Some non-domestic users informations for Matera municipality ***(personal information erased for privacy reasons)***

- ***Zoning of the territory***: geolocation of domestic users (DU), non-domestic users (NDU), producers of pomace (PP). These personal data can therefore be consulted and modified at any time through the INNOVAMBIENTE® software. They are automatically processed by the system which associates the GPS position based on the address and house number, or alternatively based on latitude and longitude, making it possible and available for the distribution of users on a Google map. In this way it is possible to obtain the spatial distribution of all the users in the considered municipality on a georeferenced map. Figure 35 shows the example for an area of the municipality considered.

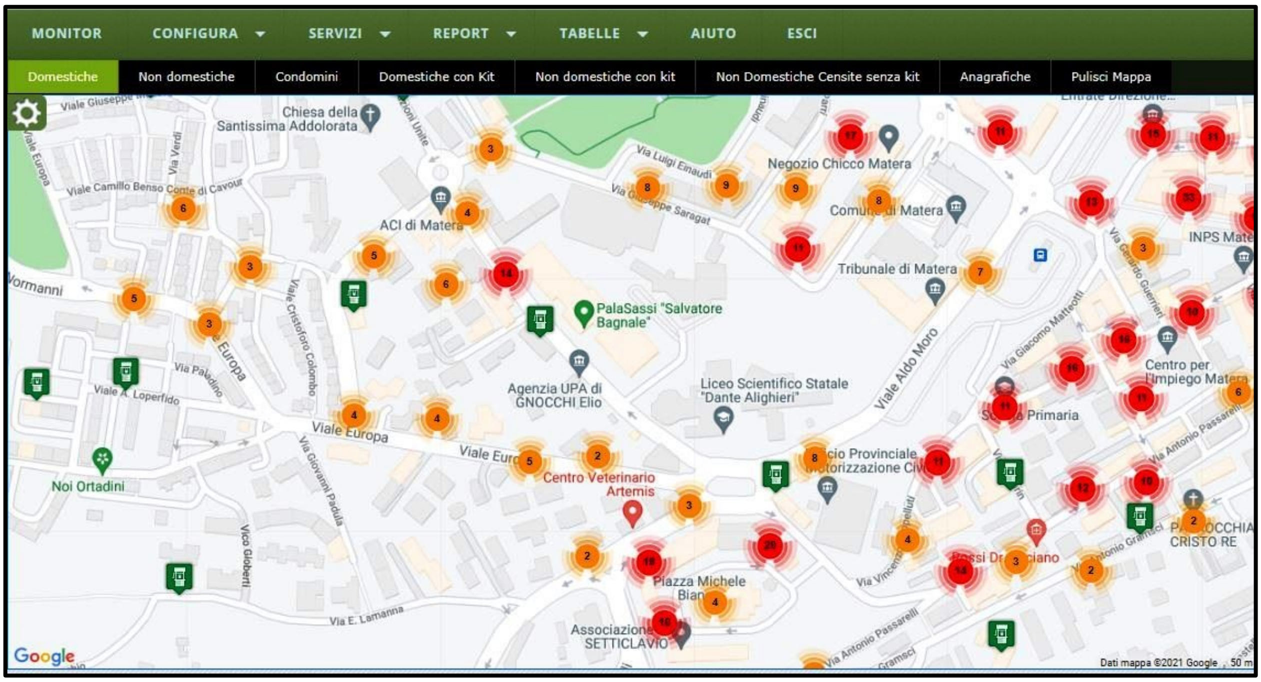


Figure 35: Non-domestic users (yellow icon), domestic users (red icon), producers of pomace (green icon) geo-coding, in an area of Matera municipality

- ***Census of users***: this is an important step, because it allows the database to be consolidated and updated. The INNOVAMBIENTE® "Start Up Go" App (Fig. 36) is the ideal tool to perform a user census as, installed on a mobile device and through a simple and intuitive interface, it allows us to check and correct the data of the users managed, acquire the GPS position of the users, enter the data of a new user:

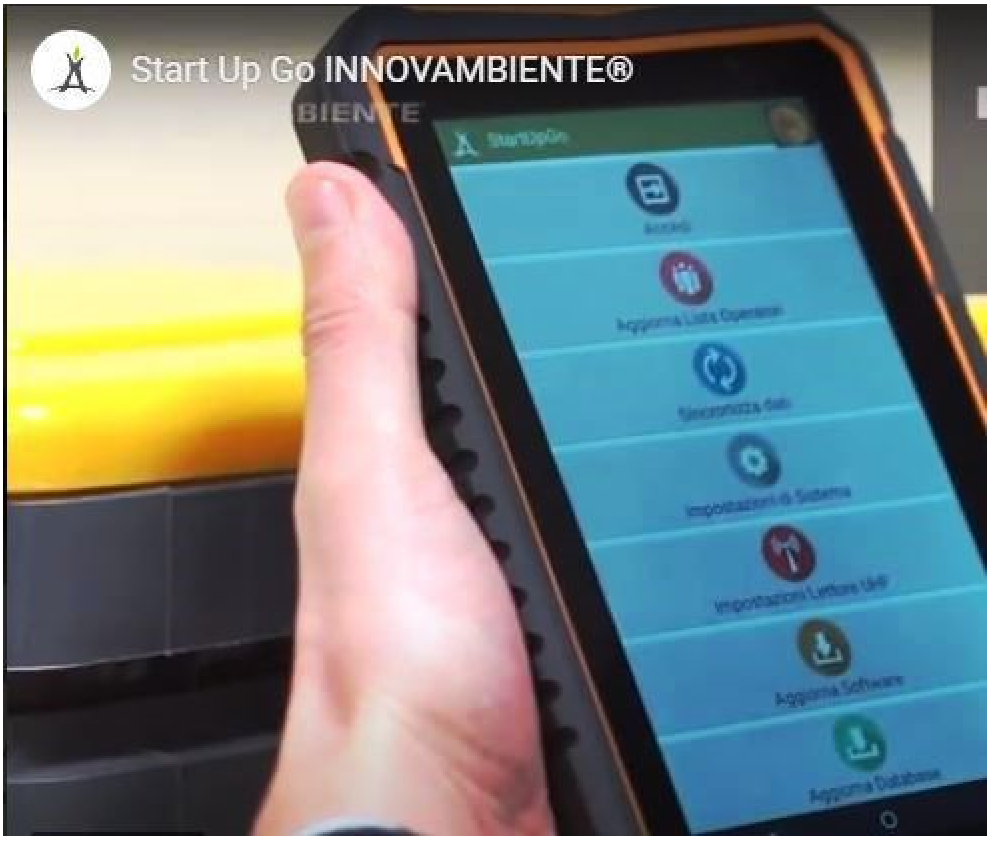


Figure 36: INNOVAMBIENTE® app "Start Up Go" graphic interface

- ***Informatisation of the collection centers***: remote control, thanks to INNOVAMBIENTE® software, of the conferments by the various users (non-domestic users and pomace producers) to the collection center. These conferments are recorded and contribute to the definition of a user score referable to punctual pricing. "CCR Plus" is the INNOVAMBIENTE® solution for the complete informatisation of Municipal Collection Centers. It consists of a hardware component consisting of a POS (Fig. 37) interfaced to a scale (Fig. 38) and a software component that manages the registration phase of the conferments and production of the documentation required by law.

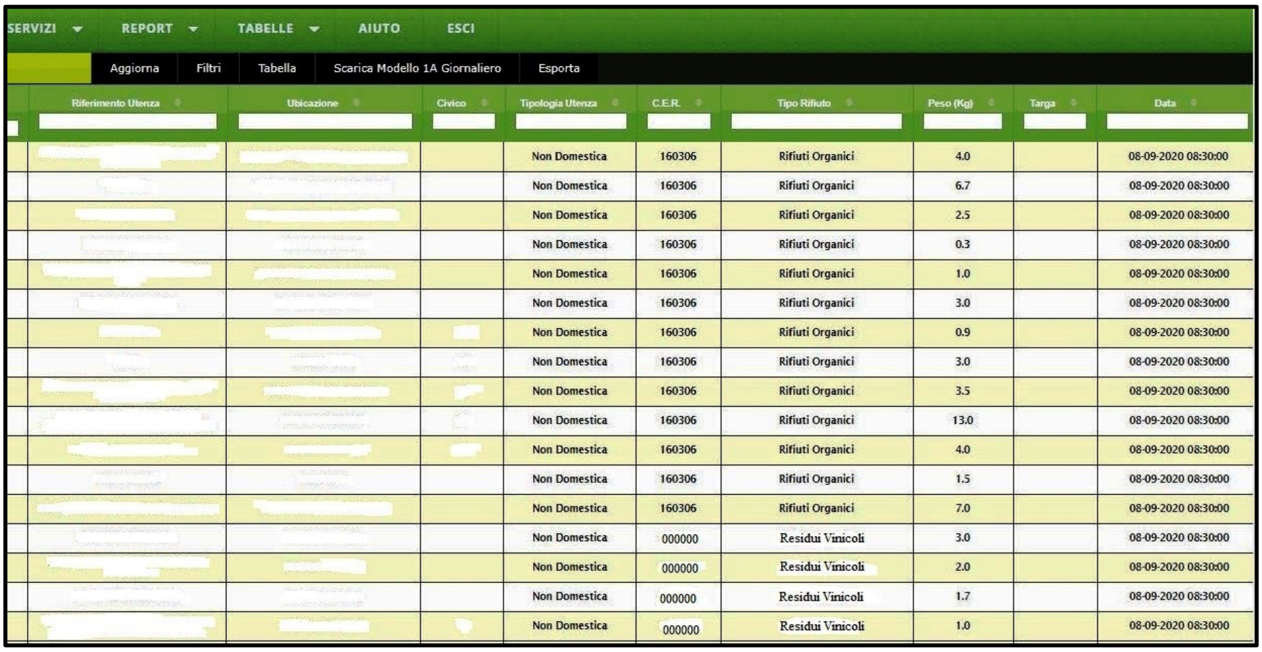
Figure 37: "Pos" for data recording

Figure 38: Scales for conferments recording

"CCR Plus" allows us to:

- search for the user in the database by reading an identification card or registry, then informations on the type and location of the user;
- trace the conferments made by users, therefore the date of conferment, type of waste, CER and weight in line with the provisions of the Environment Ministerial Decree April 20, 2017;
- issue the printout of a receipt with the details of the conferment;
- print attachments 1A and 1B, the waste form and the loading and unloading register;
- check the stock in the Collection Center.

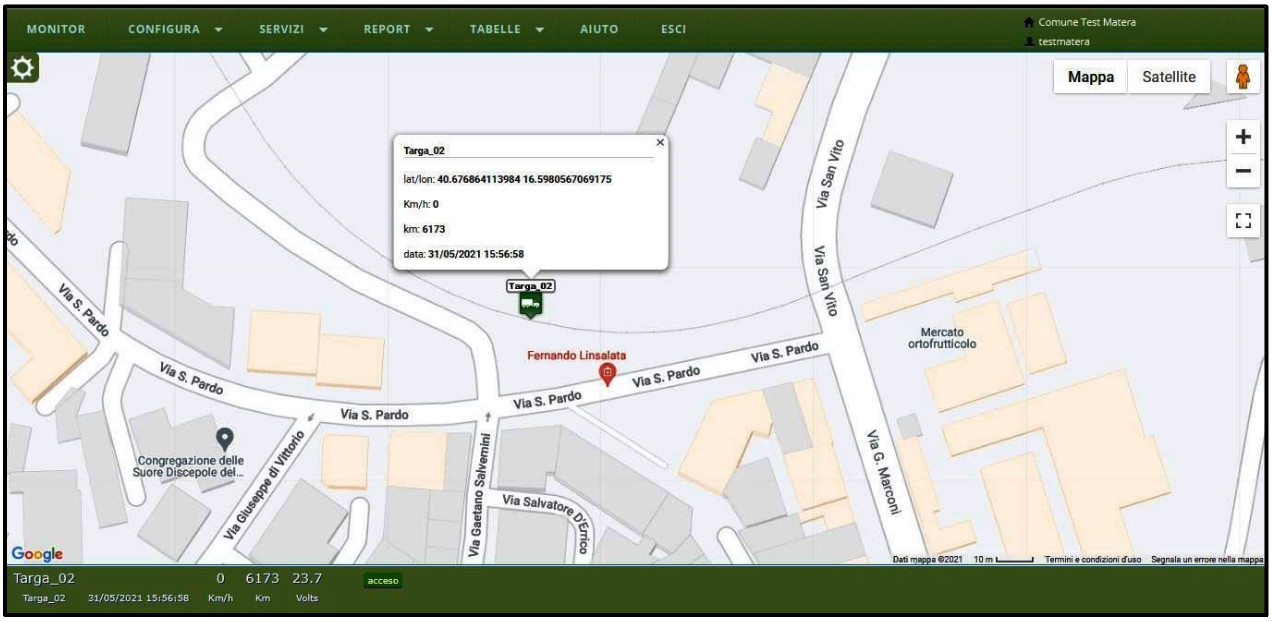
Figure 39 reproduces the example of informatisation of the collection center hypothesized for the municipality in question. Again, some informations has been omitted for privacy reasons.



Riferimento Utenza	Ubicazione	Civico	Tipologia Utenza	C.E.R.	Tipo Rifiuto	Peso (Kg)	Targa	Data
			Non Domestica	160306	Rifiuti Organici	4.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	6.7		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	2.5		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	0.3		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	1.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	3.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	0.9		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	3.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	3.5		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	13.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	4.0		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	1.5		08-09-2020 08:30:00
			Non Domestica	160306	Rifiuti Organici	7.0		08-09-2020 08:30:00
			Non Domestica	000000	Residui Vinicoli	3.0		08-09-2020 08:30:00
			Non Domestica	000000	Residui Vinicoli	2.0		08-09-2020 08:30:00
			Non Domestica	000000	Residui Vinicoli	1.7		08-09-2020 08:30:00
			Non Domestica	000000	Residui Vinicoli	1.0		08-09-2020 08:30:00

Figure 39: Example of informatisation of the collection center for Matera municipality *(personal information erased for privacy reasons)*

- ***Vehicle activity detection:*** geolocation of the route vehicle to the flows processing point (composter). The INNOVAMBIENTE® solution for fleet control consists of the latest generation of multi-control GPS detectors. The GPS position is acquired at high frequency, in the order of a few seconds, dynamically based on the occurrence of conditions imposed on time, distance and curvature angle. This characteristic is very important because it allows us to trace the route vehicle carefully. All data is transmitted in real time and can be consulted through the Operations Center web service thanks to tables and graphs, as well as through the representation on the map. Figure 40 shows the departing vehicle for the transfer of flows to the processing point with the remote control of the route followed (Fig. 41) and the consequent detail of the activities (Fig. 42). By clicking on the icon, informations relating to the license plate, the date, the current position (latitude and longitude), the kilometers traveled and the speed (Km/h) of the vehicle are displayed.



Targa_02

lat/lon: 40.676864113984 16.5980567069175

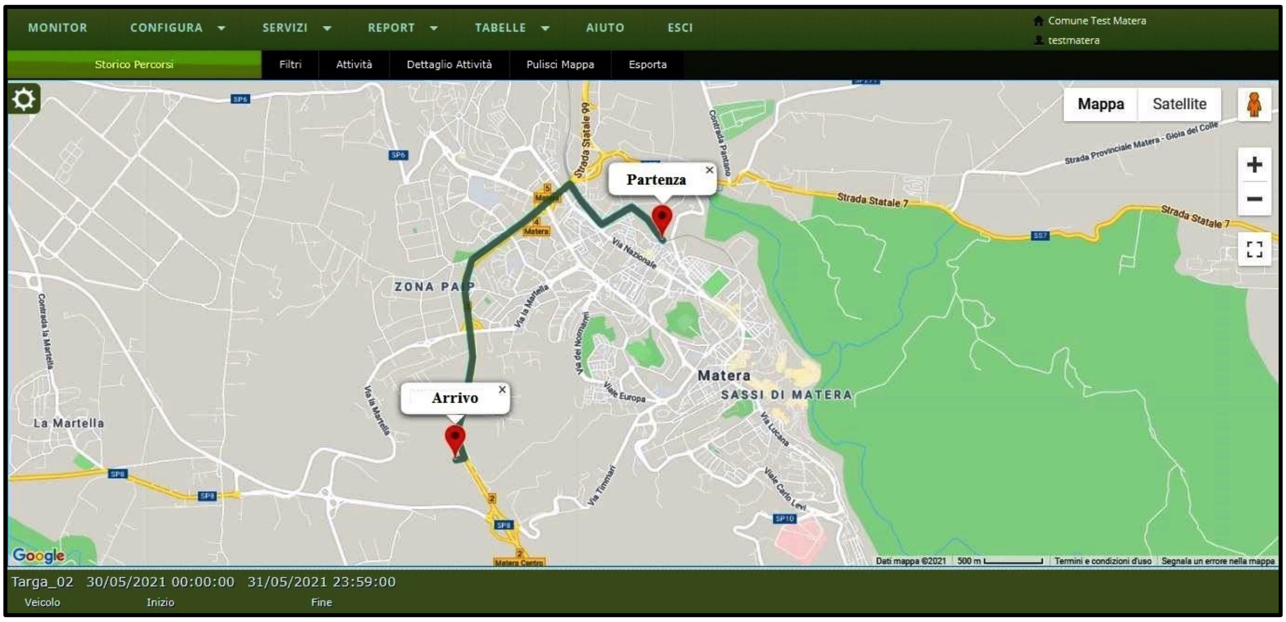
Km/h: 0

km: 6173

data: 31/05/2021 15:56:58

Targa_02		0	6173	23.7
Targa_02	31/05/2021 15:56:58	Km/h	Km	Volts

Figure 40: Information about the departing vehicle for transferring flows



Targa_02 30/05/2021 00:00:00 31/05/2021 23:59:00
Veicolo Inizio Fine

Figure 41: Route followed by the vehicle for the flows transfer

Dettaglio Attività

	Stato	Data	Indirizzo	Km/h	Km	Volts	Pesatura(Kg)	Extra Info	Latitudine	Longitudine
0	acceso	31-05-2021 15:40:58	SS7	0	6173	23.71	0.0		40.6597768921323	16.5768414064594
1	acceso	31-05-2021 15:41:58	SS7	0	6173	23.71	0.0		40.6599375590601	16.5777112965484
2	acceso	31-05-2021 15:42:58	SS7	0	6173	23.71	0.0		40.6617543744984	16.5769412224467
3	acceso	31-05-2021 15:43:58	SS7	0	6173	23.71	0.0		40.6645990471931	16.5778901195824
4	acceso	31-05-2021 15:44:58	SS7	0	6173	23.71	0.0		40.6678026555502	16.5785287848763
5	acceso	31-05-2021 15:45:58	SS7	0	6173	23.71	0.0		40.6707606308652	16.5781526983211
6	acceso	31-05-2021 15:46:58	SS7	0	6173	23.71	0.0		40.6732652771919	16.5777028473052
7	acceso	31-05-2021 15:47:58	SS7	0	6173	23.71	0.0		40.6753383722933	16.5784849278202
8	acceso	31-05-2021 15:48:58	SS7	0	6173	23.71	0.0		40.6782663508643	16.5837398697522
9	acceso	31-05-2021 15:50:58	SS7	0	6173	23.71	0.0		40.6813130781964	16.5885088704943
10	acceso	31-05-2021 15:52:58	Via dei Bizantini	0	6173	23.71	0.0		40.6800174390174	16.5896199290851
11	acceso	31-05-2021 15:53:58	Contrada Gravinella	0	6173	23.71	0.0		40.678067359944	16.5917665234471
12	acceso	31-05-2021 15:54:58	Via Gravinella	0	6173	23.71	0.0		40.67945406734	16.5948762896676
13	acceso	31-05-2021 15:55:58	Via Gravinella	0	6173	23.71	0.0		40.6784816830142	16.5964420533366
14	acceso	31-05-2021 15:56:58	Via San Pardo	0	6173	23.71	0.0		40.676864113984	16.5980567069175

Figure 42: Vehicle activities detail during the route

8.3 IoT technologies applied to home composting: application of a laboratory-scale probe for remote control of key parameters during the process

As for the domestic composting model, however, a small laboratory-scale test in order to investigate the usefulness of some sensors applied to a mixture of organic waste and agricultural by-products has been carried out. Thanks to the sensors operation, based on bluetooth technology, the aim was to "simulate" what happens inside a domestic composter and then evaluate the trend of the key parameters (Temperature, Ph, Humidity, etc.) and control them remotely, basically the task of the operator in our proposed model.

8.3.1 “HALO” probe with Bluetooth® technology for direct temperature and PH analysis on solid and semisolid samples

For our experimentation the "HALO®" probe produced by the American company "Hanna Instruments" has been used: it is equipped with three porous ceramic septa in the external reference cell, built-in temperature sensor and conical glass tip ideal for direct measurements of pH and temperature in solid samples - such as soil - and semi-solid samples such as a mixture of organic waste during a domestic composting process (Fig. 43).

Figure 43: Halo probe used during the experimentation

Many users rely on pH measurement to make very important decisions. The values, therefore, must be reliable, then it is necessary to periodically calibrate the measurement system (instrument and electrode), using quality buffer solutions. The buffer used for calibration is the reference point for all subsequent measurements of the electrode: an analysis is reliable, indeed, if the buffer used for calibration is reliable itself. Buffers are produced in accordance with ISO 3696/BS3978 standards, using high purity salts, deionized water, certified check weighing scales in a temperature-controlled environment monitored with certified thermometers. The solutions can be purchased with or without a certificate of analysis and in various formats, volumes and packages. Disposable sachets are ideal for the user who works in the field or for those who use the tool infrequently.

The considerable advantage of this probe is represented by the possibility of measure two parameters at the same time, namely pH and Temperature, which usually represent the "sensitive" values that are mostly taken into consideration during composting processes.

8.3.1.1 Principle of operation

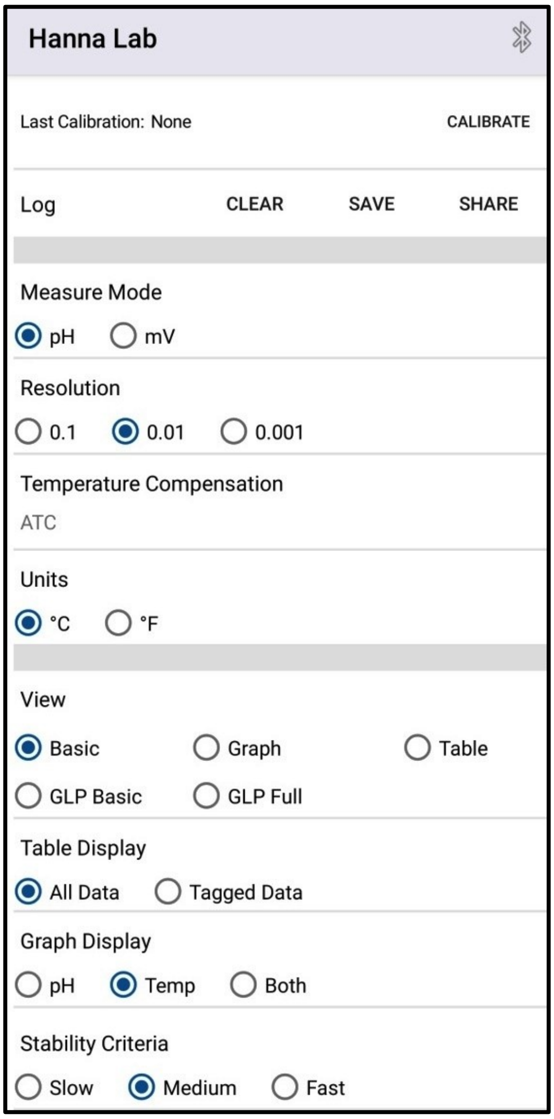
The probe is easily connected to the Hanna Lab App, which can be downloaded for free on our smartphone, via bluetooth technology by pressing a button. A blue LED flashes to indicate the status of the probe and then the recognition between the probe itself and the application takes place. From this moment on, the operation of the probe can be followed through the application itself. All the readings, indeed, are transmitted directly to the Apple or Android device or to the edge®blu instrument. The probe uses a simple, easy-to-replace lithium battery, which guarantees a duration of approximately 500 hours. There are many characteristics that make it ideal for measuring various parameters in the soil or similar mixtures: the glass of the tip for low temperatures, for example, allows rapid stabilisation and more precise results at lower temperatures; the three porous ceramic septa allow a greater flow of electrolyte from the reference cell to the solution and this determines a greater continuity between the reference electrode and the measuring element. The conical tip allows penetration into solid, semisolid and emulsion samples. The probe is compatible with the following devices:

- Android: most devices equipped with Bluetooth (4.0) and Android 4.3 or following operating system;

- iOs and iPad (3rd generation or newer);
- iPhone (4S or newer);
- iPod Touch (5th generation or newer);
- HI2202 edgeblu instrument.

8.3.1.2 Data reading, saving and transferring

The pH and temperature values are updated every second. The readings are automatically saved every hour based on memory availability in the device. The reference screen on the "Hanna Lab" app for viewing the measurements is shown in Figure 44.



Hanna Lab

Last Calibration: None

Measure Mode

● pH ○ mV

Resolution

○ 0.1 ● 0.01 ○ 0.001

Temperature Compensation

ATC

Units

● °C ○ °F

View

● Basic ○ Graph ○ Table

○ GLP Basic ○ GLP Full

Table Display

● All Data ○ Tagged Data

Graph Display

○ pH ● Temp ○ Both

Stability Criteria

○ Slow ● Medium ○ Fast

Figure 44: "Hanna Lab" App screen

In the application (Fig.44) it is possible to enter different display settings:

- **set the measurement mode, pH or mV (electrode potential)** which represents the reference value for a correct calibration and therefore a correct reading of the data;
- the **resolution** of the measurements;
- **the measurement unit** of the Temperature in degrees centigrade (^{0}C) or degrees Farenheit (^{0}F);
- **graphical representation of the data**: the measurements can be displayed as tabulated data (table) or graphically (graphs) that can be resized using the functions of the device used. GLP (Good Laboratory Practice) mode, on the other hand, is the most complete display mode as it displays the date and time of the current calibration, offset and slope values (parameters concerning the goodness of the calibration), buffer solutions used for calibration, reference values mV, pH and temperature values. It is also possible to display only the temperature data or only the pH data or both. Finally, it is possible to set the measurement speed, i.e. the measurements can be set with a frequency of 1 second, 10 seconds or lower frequencies;
- **calibration reminders and measurement alarms**: the application alerts the user when the probe needs to be calibrated or if the measurement limit is exceeded. The probe used calculates and stores the state of the electrode at each calibration. Results from consecutive single calibrations are compared to each other and help maintain precise and accurate readings. In this way, even a minimal decrease in electrode performance is detected and can be immediately managed (for example, the need to clean as the electrode is dirty);
- **data recording and transfer:** as mentioned, the measurements are automatically saved every hour. The saved data can be simply viewed at any time during measurement or annotated with specific measurement information. **The data can be saved (Save) and easily transferred (Share) at any time via email in CSV or PDF format and therefore can also be controlled remotely.** There are 4 different ways to save and transfer data:

- all data present at the last save;
- only the annotations;

- all data within a predetermined interval;
- only the annotations within a predetermined interval;

- **help function and demo mode**: the Demo mode helps the user to explore the functions of the App. This section contains general app informations, probe informations, pH tutorials, maintenance tutorials and contact informations.

8.3.2 Soil moisture meter Lutron PMS-714

The other measurer used instead is of a punctual type (Fig. 45). The "Lutron PMS-714" moisture meter has been used: it is designed to accurately measure the moisture content of soil or semi-solid mixtures. It has a measurement range of 0-50% with a resolution of 0.1%. The microprocessor guarantees high accuracy (± 5% at 23^{0}C). It is powered by 4 1.5-volt batteries (AAA). The integrated LCD screen simplifies the reading of the measures and the “reading lock” function allows us to block the value read on the display. The measure has max/min functions and a low battery indicator.

Figure 45: Punctual measuring device

8.3.3 Probe application: simulation of remote control during home composting

In order to obtaine, as the final result of the domestic composting process, a compost to be reused and not waste to be disposed of, the process must be controlled in real time by the operator with the ability to send data anywhere and therefore allow simultaneous remote control. For this purpose, a probe that allows remote control of the most important parameters and to be kept more under control during the process - i.e., temperature and ph - and a punctual meter for the less important and more easily controllable parameter - i.e., humidity - have been used. We focused on the concept of "remote control", and therefore did not follow the entire composting process which, in most cases, lasts 3 months. The following steps for the experimentation have been performed:

- **Preparation of the mixture** consisting of organic waste and pomace (Fig.46), reinforcing material such as straw and dry branches (Fig. 47), dry leaves and ground (Fig. 48).

Figure 46: Organic domestic waste (left) and pomace (right)

Figure 47: Straw (left) and dry branches (right)

Figure 48: Dried leaves (left) and ground (right)

- **Mixing the flows to be subjected to home composting**. We have positioned the mixture in layers, alternating more humid material, organic waste and pomace, with lignocellulosic and more reinforcing materials such as straw and ground, branches and dry leaves (Fig.49).

Figure 49: Mix of organic waste and pomace (left), ground and straw (center), branches and dried leaves (right)

- **Application of a fine mesh net** (Fig.50) on the mixture in order to avoid the infiltration of molluscs and unwanted material into the mixture itself.

Figure 50: Application of a fine mesh net

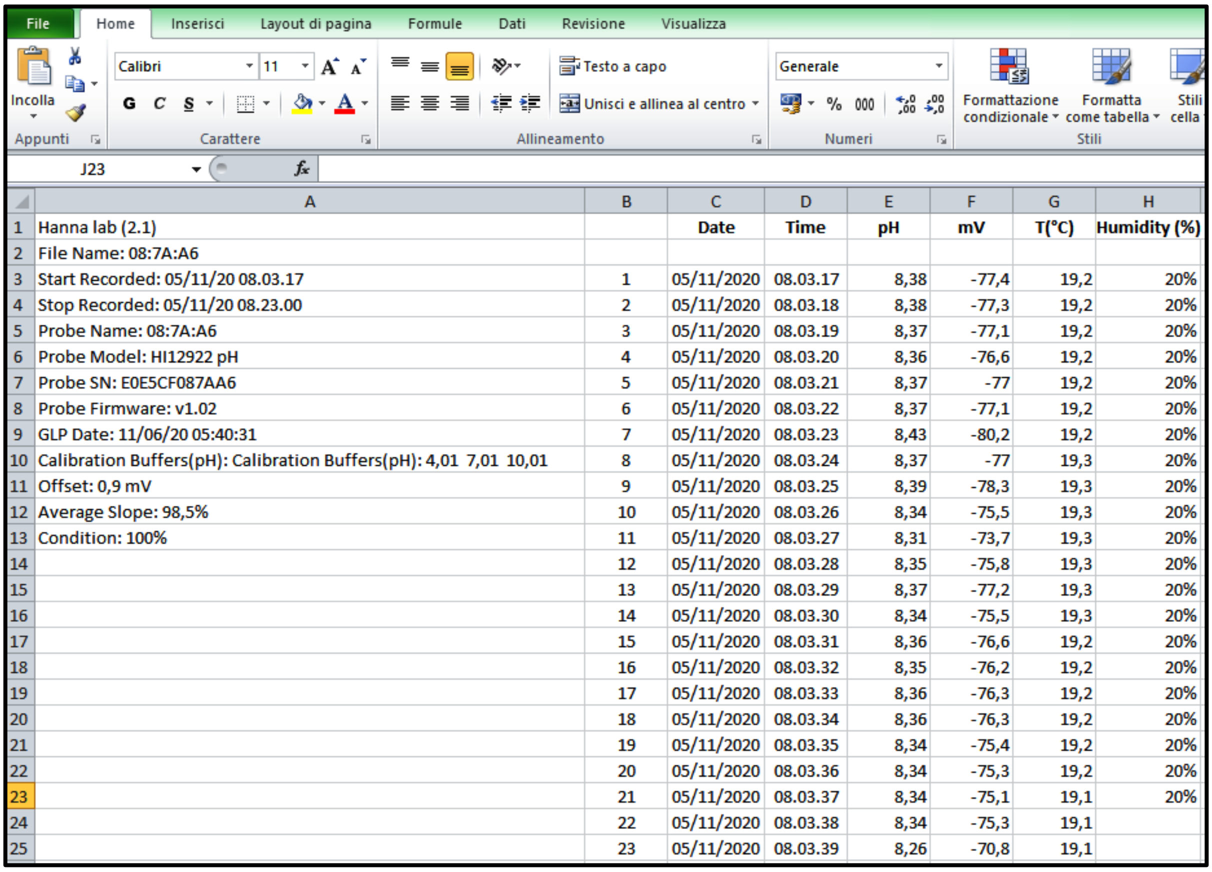
- **Probe application**: the pH and temperature probe has been applied continuously (Fig.51) at different times of the day and at different points in the mixture, in order to highlight changes also based on external temperature. The humidity sensor (Fig.51) has been applied 2-3 times a day following significant variations in the humidity values.

Figure 51: Application of pH and Temperature (left) and humidity (right) probe

- **Data collection**: temperature, pH and humidity data of the mixture have been collected day by day and they have been sent by email (in csv format) to the operations center that could control them remotely. In figure 52 the classic screen of the data acquisition has been showed. The measurements have been taken on the following days:

- November 5, 2020 from 8.03 to 8.23 and from 11.41 to 12.01
- November 6, 2020 from 9.03 to 9.17 and from 13.21 to 13.40
- November 7, 2020 from 15.08 to 15.19 and from 18.00 to 18.20
- November 8, 2020 from 10.08 to 10.31 and from 19.25 to 19.37
- November 9, 2020 from 08.48 to 08.58 and from 12.46 to 12.56
- November 10, 2020 from 09.20 to 09.39 and from 20.15 to 20.30
- November 11, 2020 from 15.55 to 16.08 and from 17.01 to 17.30
- November 12, 2020 from 11.06 to 11.25 and from 14.35 to 14.37

- November 13, 2020 from 16.15 to 16.34 and from 20.00 to 20.14
- November 14, 2020 from 16.51 to 17.00
- November 15, 2020 from 08.23 to 08.48, from 14.10 to 14.34 and from 16.35 to 16.46
- November 16, 2020 from 09.40 to 09.57 and from 18.20 to 18.27
- November 17, 2020 from 15.35 to 15.54 and from 17.30 to 17.49
- November 18, 2020 from 10.35 to 10.48 and from 19.05 to 19.24
- November 19, 2020 from 2.00 to 2.10 and from 18.48 to 19.04
- November 20, 2020 from 12.21 to 12.45
- November 21, 2020 from 13.06 to 13.20 and from 15.20 to 15.34
- November 22, 2020 from 11.26 to 11.40 and from 12.06 to 12.



	A	B	C	D	E	F	G	H
1	Hanna lab (2.1)		Date	Time	pH	mV	T(°C)	Humidity (%)
2	File Name: 08:7A:A6							
3	Start Recorded: 05/11/20 08.03.17	1	05/11/2020	08.03.17	8,38	-77,4	19,2	20%
4	Stop Recorded: 05/11/20 08.23.00	2	05/11/2020	08.03.18	8,38	-77,3	19,2	20%
5	Probe Name: 08:7A:A6	3	05/11/2020	08.03.19	8,37	-77,1	19,2	20%
6	Probe Model: HI12922 pH	4	05/11/2020	08.03.20	8,36	-76,6	19,2	20%
7	Probe SN: E0E5CF087AA6	5	05/11/2020	08.03.21	8,37	-77	19,2	20%
8	Probe Firmware: v1.02	6	05/11/2020	08.03.22	8,37	-77,1	19,2	20%
9	GLP Date: 11/06/20 05:40:31	7	05/11/2020	08.03.23	8,43	-80,2	19,2	20%
10	Calibration Buffers(pH): Calibration Buffers(pH): 4,01 7,01 10,01	8	05/11/2020	08.03.24	8,37	-77	19,3	20%
11	Offset: 0,9 mV	9	05/11/2020	08.03.25	8,39	-78,3	19,3	20%
12	Average Slope: 98,5%	10	05/11/2020	08.03.26	8,34	-75,5	19,3	20%
13	Condition: 100%	11	05/11/2020	08.03.27	8,31	-73,7	19,3	20%
14		12	05/11/2020	08.03.28	8,35	-75,8	19,3	20%
15		13	05/11/2020	08.03.29	8,37	-77,2	19,3	20%
16		14	05/11/2020	08.03.30	8,34	-75,5	19,3	20%
17		15	05/11/2020	08.03.31	8,36	-76,6	19,2	20%
18		16	05/11/2020	08.03.32	8,35	-76,2	19,2	20%
19		17	05/11/2020	08.03.33	8,36	-76,3	19,2	20%
20		18	05/11/2020	08.03.34	8,36	-76,3	19,2	20%
21		19	05/11/2020	08.03.35	8,34	-75,4	19,2	20%
22		20	05/11/2020	08.03.36	8,34	-75,3	19,2	20%
23		21	05/11/2020	08.03.37	8,34	-75,1	19,1	20%
24		22	05/11/2020	08.03.38	8,34	-75,3	19,1	
25		23	05/11/2020	08.03.39	8,26	-70,8	19,1	

Figure 52: Csv file screenshot following data acquisition

In the classic data return format following informations have been displayed:

- **On the left** side of the screen it is possible to visualise the name of the application (Hanna Lab), the file name (08:/A:A6), the start and end of data logging, the probe name (Hanna Lab) and model (HI12922 PH), the probe number (E0E5CF087AA6) and associated code (v.1.02), the date of the last calibration performed, the type of calibration, the offset and the slope associated with the calibration.

- **On the right** side of the screen, the date of measurement, the progress of the measurement (a measurement frequency of 1 second has been setted), the pH, mV and temperature values measured with the probe are displayed. The humidity values instead, since the probe is punctual, are added manually when we go to measure.

When the operator that control the home composting process sends the data via email in csv format to the operation center, it can analyse the data, highlight any abnormal temperature, pH and humidity values and also display the related graphs. Figures 53 and 54 show the graphs of pH and temperature during the first measurement.

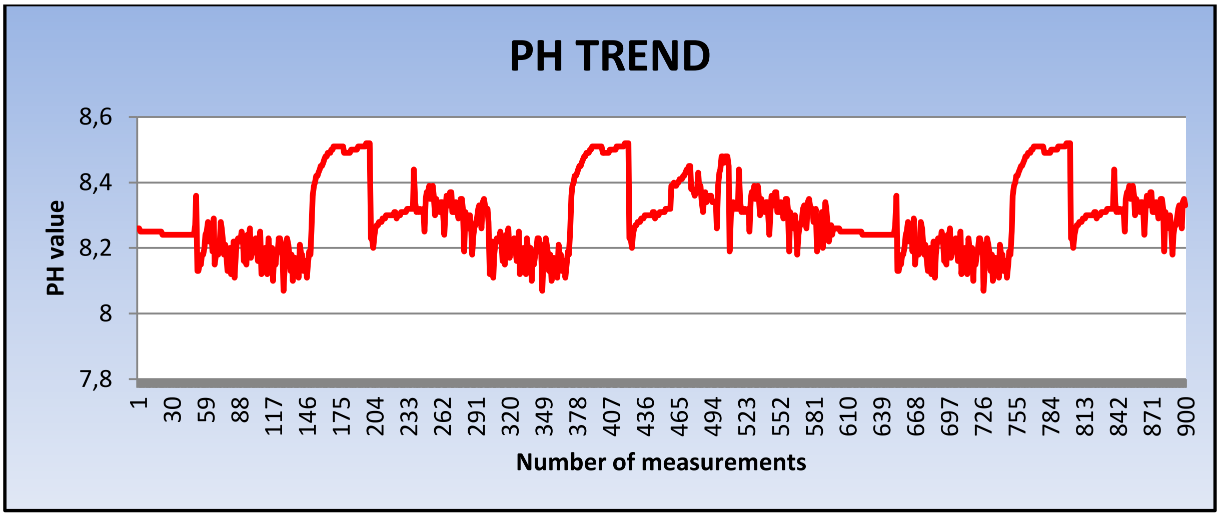


Figure 53: PH trend during the first measurement

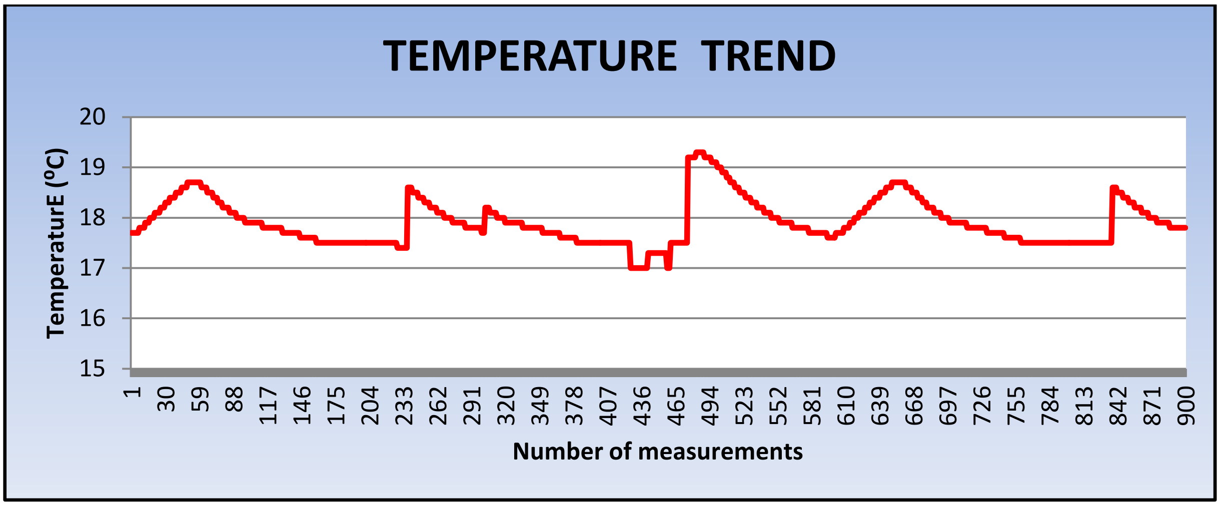


Figure 54: Temperature trend during the first measurement

In this way it has been possible to intervene in real time in the process, but above all to correct any anomalies during the process:

- if, for example, the humidity was too high, lignocellulosic materials (straw, ground, leaves and dry branches) have been added to balance the most humid materials;
- if, on the contrary, the humidity was too low, more humid materials (organic waste and pomace) have been added.
- if the temperature was too high or if the pH was too acid or too basic, or if the process generated unpleasant odors, the frequency of turning the mixture has been increased to allow air exchange and ensure the right porosity to the mixture.

These advantages for this type of probe are very important, since they allow to:

- control in near-real time the process, thanks to the presence of the operator, who can correct and improve any anomalies;

- enable the simultaneous possibility of remote control, by sending data.

PART III

INTERNATIONAL PROJECT

INTRODUCTION

In this phase, in cooperation with the foreign industrial partner of the project, the **Energy Agency of Plovdiv** (Plovdiv - Bulgaria), the **home composting model** (hypothesised for the Basilicata region) has been adapted to the city of Plovdiv (Bulgaria). It has been considered the territorial reality in which we have inserted the model, because in Bulgaria no system for waste separated collection is yet existing, or however it is still in its infancy, with all the difficulties arising from this type of organisation.

The Energy Agency of Plovdiv (EAP) was established on April 22, 2000 to promote energy efficiency and renewable energy sources at regional and local level. It initiates and coordinates projects to reduce energy consumption and use efficient and renewable energy technologies. It also develops action plans, conducts investment research, to promote sustainable energy development, and coordinates projects by municipalities, small and medium-sized enterprises, attracts investment, and provides assistance and advice. Other sectors of action are transportation and sustainable mobility, environmental management and modeling. It is also equipped with a very efficient laboratory for the analysis of solid biofuels and compost, with modern and specialised equipment and it is accredited according to the requirements of "BDS EN ISO/IEC 17025" and it has an accreditation certificate with registration number 192 LI/07.01.2020 valid until 07.01.2024. It is the first accredited laboratory specialised in Bulgaria Region to test solid biofuels, organic waste and compost, approved by the "European Biomass Association" as a testing agency in the **ENplus**® certification process of wood pellet producers and traders worldwide and in the **GoodChips**® international certification for wood chips.

MATERIALS AND METHODS

CHAPTER 9: ADAPTING HOME COMPOSTING TO THE CITY OF PLOVDIV (BULGARIA)

After a small territorial framework of the Bulgarian region and the city of Plovdiv, and after the state of art analysis on waste management and the correlated issues, the *"home composting" model* (already hypothesised for the Basilicata region in the previous chapters) has been adapted to the city of Plovdiv (falling in the homonymous district). The model has been contextualised to the Bulgarian reality, with the purpose to make a first step towards a better management of waste, since unfortunately there is no good management organisation.

9.1 Territorial framework of Bulgaria region

The Bulgaria region is a member state of the European Union since 2007 and it is located in the eastern half of the Balkan Peninsula (Fig.55).

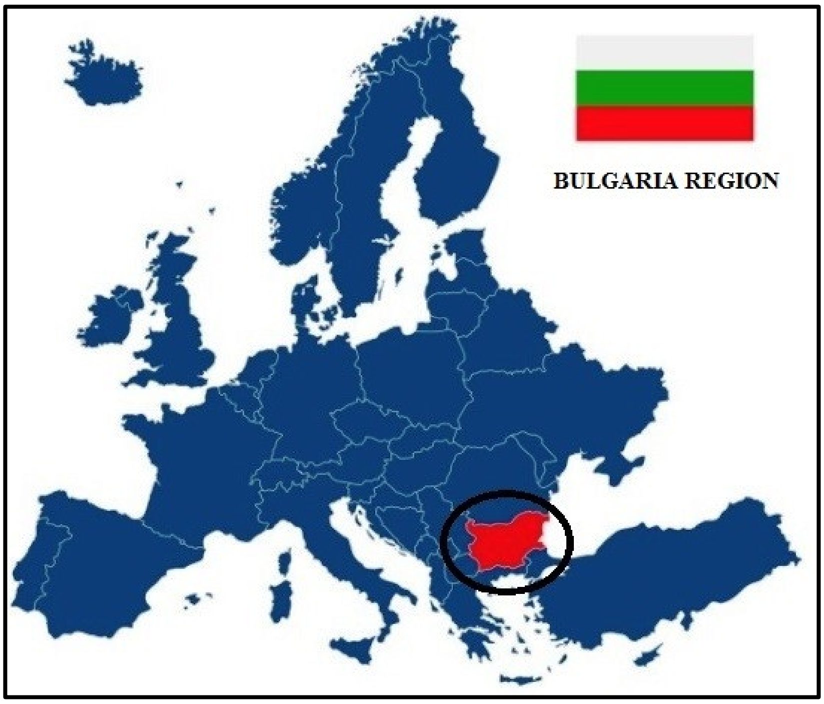


Figure 55: Geographical localisation of Bulgaria region

With a surface of 110.994 km² it is the 14th largest country in Europe. The total length of the Bulgarian borders is 2.245 km, of which 1.181 are land borders, 686 are river borders and 378 are coastal borders. It has a population of 6.925.454 inhabitants and a population density of 66,4%. (Bulgarian National Institute of Statistics, 2014). The population is primarily urban and it lives mainly in the capitals of the twenty-eight districts. Most commercial and cultural activities are concentrated in the capital Sofia. The predominant employment sectors are agriculture, services, tourism, power engineering and light industry, all supported by local natural resources. The most important sectors of the Bulgarian economy in the year 2018 was industry (23,1%), wholesale and retail trade, transport, hotels and restaurants (22,6%), and public administration, defense, education, health and social assistance (14,1%).

From an administrative point of view, Bulgaria region is divided into 28 districts (Fig.56) and 287 municipalities in total. The actual division into districts dates to the year 1999, whereas previously since 1987 the division was into nine provinces. All districts are governed by a district governor appointed by the government and they are named after their capital city.

Figure 56: Geographical suddivision of Bulgaria region

9.2 City of Plovdiv: territorial framework and state of the art in urban waste management

Plovdiv is the second largest city in Bulgaria region and it is located in the district of the same name (Fig.57), with a population of about 346.843 inhabitants, a surface of 53 km^2 and a population density of 6.328,25 inhabitants/km^2 (Urbistat, 2019).

It represents the second most important industrial and commercial center, after the capital Sofia and one of the most popular tourist destinations in the country. The famous International Exhibition, which every year hosts the presentation of goods and the exchange of contacts and experiences between operators from all over the world, takes place right here.

Figure 57: Geographical localisation of Plovdiv city

In the city of Plovdiv, as well as in the entire region of Bulgaria, the waste management system suffers from a chronic lack of organisation and planning. During the years, there was many citizen protests that have affected almost every district in the region due to disorganization in waste collection. In fact, until the year 2019 there was no separate collection with considerable and imaginable inconvenience for citizens due to the abandonment of waste in the middle of the street, resulting in bad odors and the presence of animals in the vicinity. Since the second half of the year 2019, not only a small composting plant has been opened ***(only for the tratment of the green fraction of biodegradable waste from the cleaning of parks and gardens***) but also the separate collection has started, but only for some districts and only for some fractions such as paper and plastic of domestic users. All other fractions instead, including organic waste produced, are currently sent directly to the landfill and precisely to the landfill located in Shishmantzi (Fig. 58).

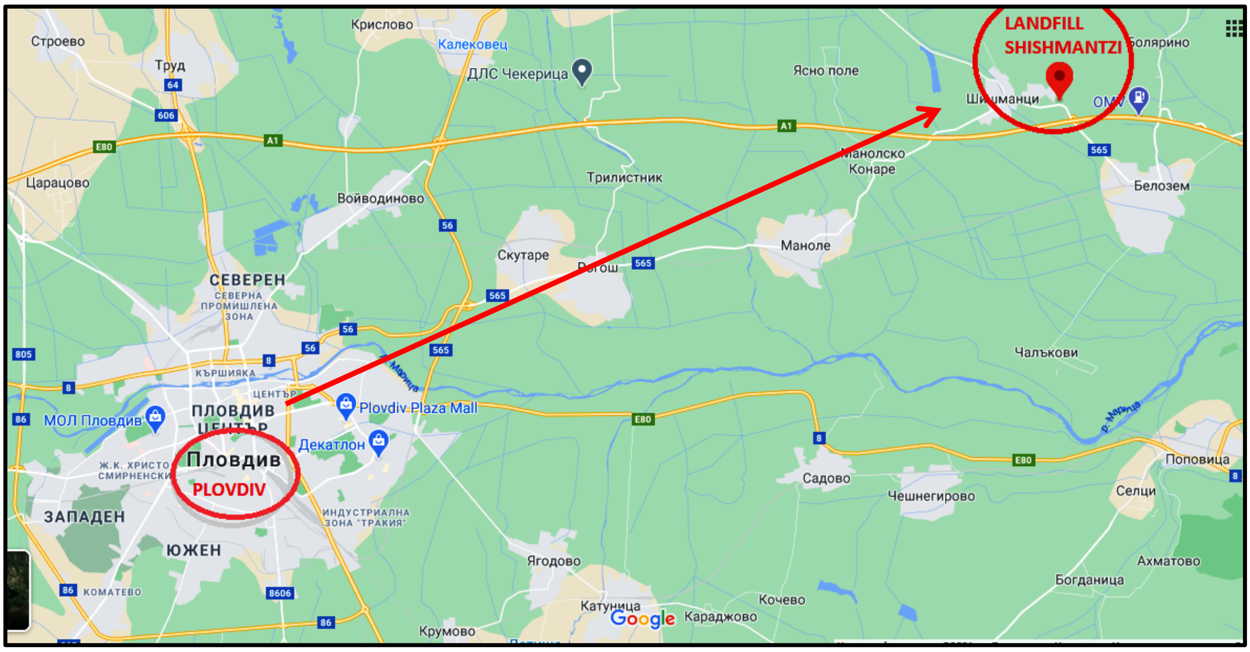


Figure 58: Geographical localisation of Plovdiv city's reference landfill for municipal waste disposal

9.3 Organic waste from domestic users in the city of Plovdiv: a new waste management model in the perspective of circular economy

In order to overcome the main problem of the lack of waste collection in the city of Plovdiv, a feasibility study of home composting has been proposed. The objective, as for the municipalities considered for the Basilicata region, was to answer the following question: **if the domestic users of the city of Plovdiv performed home composting, and therefore the valorisation of the organic waste produced aimed at the production of compost, instead dispose them in landfill, how would the scenario change, compared to the state of the art?** In this way, the organic waste from domestic users would be removed from the landfill disposal. And given that, as mentioned above, the city of Plovdiv - like the entire Bulgaria Country - suffers from lack of organisation and planning in waste collection with all the related problems, this would be an excellent starting point for decreasing the flow of waste produced and above all the amount of waste to be disposed of.

We would like to highlight, that for many cost items, the same parameters used for the feasibility study carried out for the municipalities of the Basilicata region have been considered, as they are values that are independent of the context in which the project operates; for other items cost, such as the cost of waste collection and disposal, references to the Bulgarian reality have been considered as values that are closely related to the reference context.

The following steps, that allowed to demonstrate the feasibility of the proposed model **(Attachment 3),** have been performed:

1. **Amount of organic waste collected separately:**

After calculating the total production of municipal solid waste (tons/year) (equation 17) which depends on the per capita production (Plan-account of the municipality of Plovdiv, 2020) and on the number of inhabitants (Istat, 2019), the production of organic waste for domestic users (equation 18) which also depends on the waste composition for the city of Plovdiv, according to which 57% of the total municipal waste is organic waste (Plan-account of the municipality of Plovdiv, 2020) has been calculated.

$$\textbf{Total Production Urban Waste }(\textbf{tons/year}) = Urban\ Waste\ production\ per - capita\ (tons/inhabitants * year) * No\ inhabitants (17)$$

$$\textbf{Organic Waste Production }(\textbf{tons/year}) = Urban\ Waste\ Total\ Production\ (tons/year) * 0{,}57 \quad (18)$$

Table 23 represents the imput flows which represents the starting point for the elaboration of our model.

Table 23: Input flows for the model elaboration

IMPUT FLOWS		
Per-capita municipal waste production (Kg/year)	Total municipal waste production (tons/year)	Total organic waste production (tons/year)
472	160.069	91.239,27

2. **Organic waste produced by 10%, 20%, 30%, 40% of domestic users and destined for home composting.**

After calculating the number of families, knowing the number of inhabitants and assuming that each family unit is made up of 4 people, the following data have been calculated:

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ production * 0{,}10$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ production * 0{,}20$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ production * 0{,}30$$

$$Amount\ of\ Organic\ Waste\ (tons) = Organic\ Waste\ Total\ production * 0{,}40$$

3. **Analysis of costs referred to the current scenario.** Currently, organic waste, as mentioned above, is disposed of directly in landfills. Table 24 shows the most important data used to calculate costs for the current organic waste management scenario.

Table 24: State of the art data for the collection and disposal of organic waste

Current scenario		Reference
Organic waste collection cost (€/tons)	18	**Plan-account of the municipality of Plovdiv, 2020**
Organic waste disposal cost (€/tons)	12	**Plan-account of the municipality of Plovdiv, 2020**
Distance from landfill (Km)	34,5	**Plan-account of the municipality of Plovdiv, 2020**
[2]Fuel yield (Km/l)	2,8	Ministero dello Sviluppo Economico, 2018 (vehicles with a mass greater than 26 t)
[3]Fuel cost (€/l)	1,5	Ministero della Transizione Ecologica, 2020
[4]Average transportable quantity (tons)	30	Direct inteviews with operators

4. **Sizing of the domestic composter**. It has been hypothised that each domestic user is equipped with a domestic composter for 3-6 people.

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[234] The same sources of the Italian model have been used here because they are characteristics independent of geographic context but depending on the type of vehicle used.

5. **Analysis and quantification of all costs (fixed and variable) of the process incurred by the municipality.** Various cost items have been considered. The initial costs of the municipality (Tab. 25) which in the economic calculation have been spread over an initial period of 5 years, include:

- Investment cost of the domestic composter:

$$\textbf{Total Cost}\ (€) = Single\ Domestic\ Composter\ Cost\ (€) * 2 * No\ Domestic\ Users$$

where a market value of € 35 for the single domestic composter has been considered. Moreover, it has been considered that in a period of 6 years, 2 of them are needed since their useful life is 3 years.

- Sensors applied to the model. This item is extremely important. It has been included since periodically domestic users will be subjected to checks to verify the correct progress of the domestic composting process. In this way it will be possible to intervene in real time to avoid obtaining a non-compliant product for reuse and therefore obtaining a waste that in any case must be disposed of. The check will be carried out by technicians hereinafter referred to as "operator".

$$Sensors\ Total\ Cost\ (€) = 500\ € * No\ Operator$$

where the sensors market value equal to 500 euros has been considered while the number of operators has been calculated taking into account that the checks take place every three months and therefore in a month it is possible to carry out a total of 276 checks (equal to 2 checks / hour equal to 12 checks/day):

$$\text{No Operators} = \frac{\frac{\text{Total Number of Domestic Users}}{3}}{\text{No Monthly Checks}}$$

- staff training costs. No cost has been foreseen as no training or updating is required by the legislation for the composter, also considering the extremely limited volumes.

As regards the fixed costs (Tab. 25) incurred each year by the municipality, the following costs have been calculated:

- operator check calculated from the gross cost of an ecological operator (Plan-account of the municipality of Plovdiv, 2020) and considering the number of operators, which varies according to the size of the municipality:

$$Cost\ \ of\ the\ check\ Operator\ \left(\frac{€}{year}\right) = Gross\ Cost\ Operator(€) * \text{No Operators}$$

The costs related to the consumption of electricity have been neglected while the costs related to the maintenance of the machinery provided directly by sector operators have been added.

It must be highlighted that in various cases, as the% of composting domestic increases (it goes from 10% to 40%) the number of domestic composters and therefore the investment and sensors costs, and the consequent operator check costs increase at the same place.

Tabella 25: Initial and annual fixed costs for home composting

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Composter bin investment cost (€)	593.475,8	1.186.952	1.780.427	2.373.903
Staff training (€)	0	0	0	0
Sensors (€)	5.119,7	10.239,4	15.359,1	20.478,8
Municipality initial costs (€)	598.595,5	1.197.191	1.795.786	2.394.381,8
Operator control (€/year)	153.591	307.182,1	460.773,1	614.364
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	153.741	307.332,1	460.923,1	614.514,1

6. Avoided Costs

In this phase, the avoided costs due to the lower collection (equation 19), lower transport (equation 20) and lower disposal (equation 21) of the organic waste to the landfill have been calculated as a percentage in the proposed model is valorised through the home composting.

$$\textbf{Organic Waste Avoided Collection cost}(€) = Collection\ cost\ (€/tons) * (Qt - Q10\%)(tons) \quad (19)$$

where "Q_t" is the total organic waste production (Tab. 23); "Q10%" represents the amount of organic waste produced by 10% of domestic users that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%); "Collection cost" represents the cost for each ton of organic waste collected (Tab. 24).

$$\textbf{Organic Waste} - \textbf{Avoided Transport Cost}\left(\frac{\text{€}}{\textbf{year}}\right) = \frac{\mathrm{D}}{\mathrm{R}} * 2 * \mathrm{C} * \left[\left(\frac{\mathrm{Qt} - \mathrm{Q10\%}}{\mathrm{Qm}}\right)(tons)\right] \quad (20)$$

where “D” is the distance from the nearest landfill considered (Shishmantzi) (Tab. 24); “R” is the average fuel yield for vehicles transporting waste (Tab. 24); “C” is the fuel cost calculated in table 24; “Factor 2” because the round trip has been considered; “Q_m” is the average transportable quantity (Tab.24); “Q_t” is the total organic waste production (Tab. 23); “Q10%” represents the amount of organic waste produced by 10% of domestic users that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%).

$$\textbf{Organic Waste} - \textbf{Avoided Disposal Cost}\left(\frac{\text{€}}{\textbf{year}}\right) = \text{Disposal cost}\left(\frac{\text{€}}{\text{tons}}\right) * (\mathrm{Qt}\ (\mathrm{t}) - Q10\%)\ (tons) \quad (21)$$

where “Disposal cost” represents the disposal cost per ton of waste (Tab. 24); “Q_t” is the total organic waste production (Tab. 23); “Q10%” represents the amount of organic waste produced by 10% of domestic users that is subtracted from separate waste collection as it remains in domestic composting. The calculation has been also repetead for the other bands (20%, 30%, 40%).

9.3.1 Calculation of economic saving

The related economic saving (equation 22) is essentially due to the collection, management and handling of a smaller quantity, respectively 10%, 20%, 30% and 40% of organic waste as it is subject to domestic composting.

$$\begin{aligned}&\textbf{Organic Waste Economic saving}(\text{€}/\textbf{year})\\&\quad = [(Ci/5) + Cf](\text{€}/year) - [Avoided\ Collection\ Cost\\&\quad + Avoided\ Transport\ Cost + Avoided\ Disposal\ Cost]\ (\text{€}/year) \quad (22)\end{aligned}$$

where “C_i” are initial costs of the municipality (spread over 5 years); “C_f” are the fixed costs of the municipality; “Avoided Collection Cost + Avoided Transport Cost + Avoided Disposal Cost” are the economic savings due to the lack of movement of flows to the landfill because in the hypothesised model are subject to home composting.

9.3.2 Calculation of environmental saving

The related environmental advantages (equation 23) are essentially due to the CO_2 savings following the management of a smaller quantity, respectively 10%, 20%, 30% and 40% of organic waste moved to the landfill as they are subject to home composting.

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$$\boldsymbol{Avoided\ CO2\ emissions\ landfill}\left(\frac{Kg}{year}\right) = CO2\ consumption\left(\frac{g}{Km}\right) * No\ of\ trips\ \left(\frac{Km}{year}\right) \quad (23)$$

The calculation, in addition to considering the number of trips per year which depends on the distance (roundtrip) from the landfill, the average quantity transportable by each vehicle and the amount of flows handled by the municipality, also takes into consideration the parameter of CO_2 consumption, for which the same considerations made for Basilicata region apply. The calculation has been repeated for the other bands (20%, 30%, 40%).

Results and Discussions

Thanks to the obtained results, expressed in tabular form, it is possible to highlighth some very important concepts. With regard to the first model hypothesised, i.e. **proximity composting (Attachement 1)**, we must firstly highlight the different values of the "payback period" depending on the two plant configurations used, electro-mechanical composter or biocell configuration. For the latter, indeed, there is an investment return already in the first year for all municipalities and districts considered, while for the electro-mechanical composter there are different payback periods: from 6 years for Potenza and Matera, 7 years for municipalities belonging to the district of Matera, 8 years for municipalities in the districts of Vulture and Val D'Agri to end up at 9 years for the municipalities of Alto-Bradano.

This is mainly due to the difference in investment cost of the two plants configuration (spread over 5 years for convenience), much more expensive for the electro-mechanical composter than for the biocell. Despite this, there are no doubts about the convenience of both solutions considering a useful life of the equipment of about 15-20 years.

Another important consideration concerns the numerousness of municipalities: the greatest economic savings regards the bigger municipalities, i.e. Potenza and Matera among the municipalities considered individually, Lavello, Rionero and Melfi (Vulture district), Nova Siri, Pisticci and Policoro for the Materano district and Avigliano for the Altobradano district. This is essentially due to the greater amount of organic waste generated, and therefore their lack of disposal outside the region generates greater economic saving than smaller municipalities where the organic waste flow is obviously smaller.

The concept is slightly different with regard to wine by-products and distillery: ***the greatest economic saving is for municipalities that treat greater quantities of these flows whose lack of disposal outside the region obviously generates greater benefits regardless of the size of the municipality.*** These municipality, specifically, are Venosa, Lavello and Barile for the district of Vulture, Montescaglioso, Bernalda, Pisticci and Scanzano Jonico for the district of Matera and finally Maschito belonging to the district of Alto-Bradano from the organizational and bureaucratic point of view but geographically a municipality of the area of Vulture. As highlighted in the previous chapters, indeed, these areas are the most responsible for the production of winery by-products.

A complementary discussion is valid for avoided CO_2 emissions. The greater is the amount produced (of organic waste or pomace) indeed, and the greater is the amount of CO_2 avoided annually, due to avoided disposal outside the region. In general, these amounts might seem low if considered at the municipal level, but they obviously assume great importance if considered at the regional level, i.e. if we consider the sum of the emissions avoided by all municipalities together.

Very important aspects must also be taken in consideration for the second model hypothesized, namely **home composting (Attachement 2)**. In this case, indeed, the most important factor is not so much represented by the size of the municipality, but by the percentage of separate collection in the waste management of the individual municipality. This limit value has been considered at around 40%-45%, i.e. in order to have significant advantages in the first band (10% of domestic users adopting home composting), it is necessary to have this percentage of separate waste collection in the municipality considered. There are, however, in Basilicata region many other municipalities that for reasons of time and space have not been included in our analysis, that do not exceed this limit value. In this case, therefore, it is necessary to go further and calculate other ranges that can reach even 80-90%, that is, almost replacing separate collection with home composting. For these municipalities, therefore, the advantages that would be gained by removing organic waste from the separate collection would not compensate for the investment in compost bins and sensors. This further underlines the importance of separate collection as the basis for proper waste management. In these municipalities, therefore, it would be necessary to make a preliminary step, that is to encourage and increase the percentage of separate collection.

As previously mentioned, the saving of CO_2 is directly linked to the size of the municipality. In fact, it is clear that values are higher already in the first band considered (home composting for 10% of domestic users) for larger municipalities as a greater amount is subtracted from separate collection than in a smaller municipality. In general, the first band considered for Potenza and Matera (66.459 and 60.411 inhabitants, respectively) is much higher than the advantages of the fourth band considered (home composting for 40% of domestic users) for all other municipalities, which do not exceed 18.000 inhabitants.

Finally, we make an assessment of the discount on waste tax that individual domestic users can take advantage of according to the municipality they belong to and according to the percentage provided by municipal regulations (the value of 30% dictated by national legislation has been considered). Also in this case, from the results obtained, it can be deduced that the practice of home composting must be encouraged, in order to obtain economic saving at the level of the individual domestic user. This saving may seem low in some municipalities, but when compared to the size of the municipality itself, it appears very considerable, especially if we consider that it will be constantly repeated over the years.

Also for the city of Plovdiv, thanks to the obtained results **(Attachement 3),** expressed in tabular form, it is possible to highlight some very important concepts.

First of all, as well as for the municipalities considered for the Basilicata region, the feasibility of the model hypothesized and proposed has been highlighted, since considerable economic and environmental saving have been obtained, also and above all in relation to the geographical context in which our idea has been contextualised.

The economic saving is considerable especially if compared to the Bulgarian reality because, despite the collection and disposal costs are relatively low compared to Italy, we have an extremely high flow of waste (due to the numerosity of the city considered) directly sent to the landfill as totally uncollected. Obviously, high flows correspond to high collection and disposal costs. So, many advantages thanks to domestic composting model have been obtained, because both the collection and the disposal of organic waste have been avoided.

Directly linked to this concept, is the environmental saving obtained, which is very considerable already in the first band considered (home composting for 10% of domestic users) as subtracting 10% of organic waste from the collection and disposal service already represents a good starting point in the organization of waste management as it contributes significantly to reduce the amount in landfills.

This result, already important at single reality level, would become even more considerable if we consider the municipalities as a whole and then at a more general level the entire Bulgaria region.

The results obtained further highlight about the importance of a good organization in waste management, since a good planning action would allow to obtain numerous economic and environmental advantages.

GENERAL CONCLUSIONS

The current model of waste production (half of which is disposed of in landfills) and wine by-products (in most cases disposed of, without any regard to regulations) represents a model that we can no longer sustain, both from an environmental and economic point of view. This type of organization is part of the so-called *linear economy,* based on the production of a good, its consumption and subsequent disposal. It is essential to contrast this with a model of *circular economy* that goes beyond the concept of "*end of life*" of the material.

This is not an utopian objective, but it is undoubtedly complex to achieve, because it is necessary the joint intervention of various parties: from legislators to producers, from environmental protection entities to the infrastructures for the materials management, the personnel in charge of collection and disposal and finally the citizen, who must commit to following a model of eco-sustainable living and consumption that minimises his ecological footprint.

This transition to a circular economy therefore presupposes a real paradigm shift, a clear deviation from the path taken so far. This new approach offers solutions to deal with **decreasing resources, global warming and growing waste and it is based on some fundamental concepts such as resource sustainability, product as a service, sharing platforms, life cycle extension and recovery and recycling.**

In addition, thanks to measures such as waste reduction and material reuse, European companies could achieve considerable savings, while consumers would get more long-lasting and innovative products that can save money and improve their quality of life. A fundamental step in the process of valorization of materials (waste or agricultural by-products) and reuse is represented by a good separate collection.

For a correct waste management and therefore a high attention to the environment, a crucial role is played by the differentiation of waste itself. This procedure ensures greater sustainability to the production cycle of materials, reducing the consumption of raw materials, the use of energy and the emission of greenhouse gases. It is the best alternative to disposing of waste in landfills, ensuring not only a more efficient use of resources, but also benefits the environment and the economy.

In addition, this process defends collective health: if waste is not collected and open-air landfills are created, the problem will affect everyone. In fact, land and water are also affected, with inevitable repercussions on the food we put on our tables every day, much of which is at risk of contamination. Without forgetting the damage caused by environmental degradation: non-recycled synthetic waste, indeed, damages the climate and the ecosystem. To suffer the consequences is also the fauna - birds and mammals in primis.

The entire world is moving towards this new approach, facing numerous challenges and critical issues. One of these, perhaps the most serious, with regard to the management and disposal of organic waste and agricultural by-products (which are very often disposed of incorrectly) is represented by the chronic lack of facilities: there are many municipalities that do not make (or make little) collection of organic waste and agricultural by-products because there are no industrial plants "on site" for their treatment and therefore have to support high transport costs.

Currently, the most modern approaches suggest actions aimed at the treatment and recovery of waste and agricultural by-products, to be carried out as close as possible to the places of production, through small plants of negligible impact. In this context, the two models proposed for the Basilicata region, namely ***proximity composting*** for organic waste of non-domestic users and wine by-products (essentially pomace which represents the largest percentage), and ***home composting*** for organic waste of domestic users, which is also contextualized in the foreign reality of the city of Plovdiv (Bulgaria) have been inserted.

These ***new organizational models in the management of organic waste integrated with agricultural by-products***, allow to introduce an additional "eco-innovative" path in the system, as through this technique we respond to the targeted needs of many local realities contributing, in addition to the reduction of waste production and environmental impacts, to enhance the reuse of compost on site and to increase the possibility of a behavioral change of citizens, as it can further stimulate more conscious lifestyles.

In this perspective, the feasibility of the proposed models for the Basilicata region and for the city of Plovdiv appears to be a good starting point. They present two very important characteristics, namely adaptability and flexibility as:

- they are adaptable to any context-region-municipality with a similar number of inhabitants;
- they are flexible, i.e., other agricultural by-products (for example, olive by-products) can be also considered.

They also present a series of advantages:

- **Economic-cultural point of view**: valorise a resource instead considering it as a waste; reducing the costs associated with the transport, management and disposal of waste and by-products; reducing the volume of waste in landfills; investing the Municipality's energy and economic resources, which should no longer be spent on waste management but on other purposes;
- **Social point of view**: to become a model for other regions/municipalities in sustainable waste management; citizens well-being in its municipality; to make citizens involved and partially autonomous in the waste management of their municipality; get satisfaction in producing their own fertilizer, decreasing the need to buy chemical fertilizers;
- **Environmental point of view**: improve air quality; reduce pollution related to transport and demand for fuel, bags, etc.; return to the land all those elements that make it fertile.

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8. Manniello C., Cillis G., Statuto D., Di Pasquale A., Picuno P. **2021**. *GIScience and Historical Cartograpghy for evaluating Land Use changes and resulting effects on Carbon Balance.* Submitted to the International Journal of Geo-Information ISPRS (under review).
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ATTACHMENT 1

PROXIMITY COMPOSTING– MODEL 1

In this section all the economic (divided by type of configuration used) and environmental saving associated with the "*proximity composting*" model in relation to each municipality and district considered, in tabular format have been presented.

MUNICIPALITY OF POTENZA

IMPUT FLOWS			
Non domestic organic waste (tons/year)	**Urban green waste (tons/year)**	**Pomace (tons/year)**	**Total quantity (tons/year)**
1.425,41	35,8	20,48	1.481,69

CURRENT SCENARIO	
Organic waste collection cost (€/tons)*	200
Organic waste disposal cost (€/tons)**	150
Distance from the composting plant (Km)	125
Fuel yield (Km/l)***	2,8
Fuel cost (€/l)***	1,5
Average transportable quantity (tons)	30
Winery by-products disposal cost (€/tons)	0,22
Distance from the nearest distillery (Km)	500

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	1.600
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/day)	4.380
Obtainable compost (tons/year)	480
Expected consumption (€/year)	500

BIOCELL PLANT DIMENSIONING	
M - Total mixture to biocells (tons/year)	1.600
D - Average mixture density (tons/m$^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	136,99
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	5,5

ANNUAL COSTS FOR THE ELECTRO-MECHANICALCOMPOSTER	
Composter Investment Cost (€)	900.000
Various costs (Videos, Bureaucracy, Area) (€)	10.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	25.000
Municipal Initial Costs (€)	**936.500**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	500
Composter maintenance (€/year)	3.500
Municipality Fixed Costs (€/year)	**54.000**

ANNUAL COSTS FOR THE BIOCELL PLANT	
Biocell plant Investment Cost (€)	356.164
Various costs (Videos, Bureaucracy, Area) (€)	12.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	25.000
Municipal Initial Costs (€)	**394.664**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	400
Composter maintenance (€/year)	3.000
Municipality Fixed Costs (€/year)	**53.400**

Electro-mechanical composter	Costs (€)	Saving (€)	Final saving (€)
First Year	241.300	225.704,76	-15.595,24
Second Year	241.300	225.704,76	-31.190,48
Third Year	241.300	225.704,76	-46.785,72
Fourth Year	241.300	225.704,76	-62.380,96
Fifth Year	241.300	225.704,76	-77.976,21
Sisth Year	54.000	225.704,76	93.728,55
Investment return 6^{0} YEAR			

Biocell	**Costs (€)**	**Saving (€)**	**Final saving (€)**
First Year	132.333	225.704,76	93.371,88
Second Year	132.333	225.704,76	186.743,76
Third Year	132.333	225.704,76	280.115,65
Fourth Year	132.333	225.704,76	373.487,53
Fifth Year	132.333	225.704,76	466.859,41
Sisth Year	53.400	225.704,76	639.164,17
Investment return 1^0 YEAR			

Pomace - Economic saving (€/year)
450,56

Avoided CO_2 emissions (Kg/year) – composting plant	**Avoided CO_2 emissions (Kg/year) - distillery**
9.741,40	546,13

MUNICIPALITY OF MATERA

Electro-mechanical composter	**Costs (€)**	**Saving (€)**	**Final saving (€)**
First Year	241.300	227559,62	-13.740,38
Second Year	241.300	227.559,62	-27.480,76
Third Year	241.300	227.559,62	-41.221,15
Fourth Year	241.300	227.559,62	-54.961,53
Fifth Year	241.300	227.559,62	-68.701,91
Sisth Year	54.000	227.559,62	104.857,71
Investment return 6^0 YEAR			

Biocell	**Costs (€)**	**Saving (€)**	**Final saving (€)**
First Year	137.082	227.559,62	90.477,88
Second Year	137.082	227.559,62	180.955,77
Third Year	137.082	227.559,62	271.433,65
Fourth Year	137.082	227.559,62	361.911,53
Fifth Year	137.082	227.559,62	452.389,41
Sisth Year	53.400	227.559,62	626.549,03
Investment return 1^0 YEAR			

Pomace - Economic saving (€/year)
458,48

Avoided CO_2 emissions (Kg/year) – composting plant	Avoided CO_2 emissions (Kg/year) - distillery
1.770,75	555,73

VULTURE DISTRICT

IMPUT FLOWS				
Municipality	**Non domestic organic waste (tons/year)**	**Urban green waste (tons/year)**	**Pomace (tons/year)**	**Total quantity (tons/year)**
Venosa	110,5	18,58	209,049	338,129
Barile	36,51	4,57	55,25	96,33
Rapolla	46,17	6,38	20,485	73,035
Lavello	203,65	73,1	50,688	327,438
Ginestra	6,71	4,89	6,19	17,79
Rionero	303	8,02	18,826	329,846
Ripacandida	18,36	7,89	27,53	53,78
Melfi	245,37	0,11	31,72	277,2
Atella	55,29	9,37	7,3	71,96

CURRENT SCENARIO						
Municipality	**Organic waste collection cost (€/ton)**	**Organic waste disposal cost (€/ton)**	**Distance from the composting plant (Km)**	**Fuel yeld (Km/l)**	**Fuel cost (€/l)**	**Average transportable quantity (tons)**
Venosa	180	150	109	2,8	1,5	30
Barile	165	150	128	2,8	1,5	30
Rapolla	165	150	125	2,8	1,5	30
Lavello	180	150	113	2,8	1,5	30
Ginestra	155	150	118	2,8	1,5	30
Rionero	180	150	131	2,8	1,5	30
Ripacandida	155	150	121	2,8	1,5	30
Melfi	180	150	134	2,8	1,5	30
Atella	165	150	134	2,8	1,5	30

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	1.600
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/day)	4.380
Obtainable compost (tons/year)	480
Expected consumption (€/year)	500

BIOCELL PLANT DIMENSIONING	
M - Total mixture to biocells (tons/year)	1.600
D - Average mixture density (tons/$m^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	146,12
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	5,8

ANNUAL COSTS FOR THE ELECTRO- MECHANICAL COMPOSTER	
Composter Investment Cost (€)	900.000
Various costs (Videos, Bureaucracy, Area) (€)	10.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	80.000
Municipal Initial Costs (€)	**991.500**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	500
Composter maintenance (€/year)	3.500
Municipality Fixed Costs (€/year)	**54.000**

ANNUAL COSTS FOR THE BIOCELL PLANT	
Biocell plant Investment Cost (€)	379.909
Various costs (Videos, Bureaucracy, Area) (€)	12.000
Staff Training (€)	1.500
Collection Center and Processing Informatisation (€)	80.000
Municipal Initial Costs (€)	**473.409**
Personnel costs (€/year)	50.000
Electricity consumption (€/year)	400
Composter maintenance (€/year)	3.000
Municipality Fixed Costs (€/year)	**53.400**

Electro-mechanical composter

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period 8^0year
28.111,98	-8.247,49	13.847,66	Venosa	305,53
8.946,70	-2.624,78	4.407,05	Barile	97,24
11.444,72	-3.357,65	5.637,55	Rapolla	124,38
60.272,62	-17.682,77	29.689,64	Lavello	655,06
2.526,33	-741,18	1.244,44	Ginestra	27,46
67.736,19	-19.872,44	33.366,12	Rionero	736,18
5.716,92	-1.677,23	2.816,09	Ripacandida	62,13
53.462,42	-15.684,80	26.335,01	Melfi	581,04
14.082,12	-4.131,41	6.936,70	Atella	153,05

Biocell

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period
16.499,68	3.364,80	13.914,51	Venosa	For all municipalities the investment return takes place in the first year
5.251,06	1.070,86	4.428,32	Barile	
6.717,21	1.369,85	5.664,76	Rapolla	
35.375,64	7.214,21	29.832,98	Lavello	
1.482,77	302,38	1.250,45	Ginestra	
39.756,21	8.107,54	33.527,20	Rionero	
3.355,41	684,27	2.829,69	Ripacandida	
31.378,54	6.399,07	26.462,15	Melfi	
8.265,18	1.685,53	6.970,19	Atella	

Municipalities	Pomace Economic saving (€/year)
Venosa	4.599,078
Barile	1.215,5
Rapolla	450,67
Lavello	1.115,13
Ginestra	136,18
Rionero	414,17
Ripacandida	605,66
Melfi	697,84
Atella	160,6

Municipalities	Avoided CO_2 emissions (Kg/year) – composting plant	Avoided CO_2 emissions (Kg/year) - distillery
Venosa	750,39	5.574,64
Barile	245,38	1.426,19
Rapolla	301,85	527,37
Lavello	1.399,25	1.302,48
Ginestra	66,94	161,83
Rionero	1.851,19	482,55
Ripacandida	1.51,76	715,63
Melfi	1.455,86	807,30
Atella	374,51	184,78

MATERANO DISTRICT

IMPUT FLOWS

Municipality	Non domestic organic waste (tons/year)	Urban green waste (tons/year)	Pomace (tons/year)	Total quantity (tons/year)
Montescaglioso	72,44	39,95	53,2	165,59
Pomarico	27,96	9,95	12,81	50,72
Ferrandina	131,52	33,58	2,46	167,56
Craco	1,28	3,56	0,23	5,07
Tursi	142,38	8,93	10,85	162,16
Rotondella	39,65	9,98	6,35	55,98
Nova Siri	302,98	17,34	36,53	356,85
Bernalda	180,95	23,32	119,88	324,15
Pisticci	330,11	10,02	50,688	390,818
Montalbano Jonico	54,69	7,1	13,57	75,36
Policoro	280,45	20,66	4,65	305,76
Scanzano Jonico	230,43	13,45	50,43	294,31

CURRENT SCENARIO

Municipality	Organic waste collection cost (€/ton)	Organic waste disposal cost (€/ton)	Distance from the composting plant (Km)	Fuel yeld (Km/l)	Fuel cost (€/l)	Average transportable quantity (tons)
Montescaglioso	165	150	36	2,8	1,5	30
Pomarico	155	150	47	2,8	1,5	30
Ferrandina	165	150	63	2,8	1,5	30
Craco	155	150	76	2,8	1,5	30
Tursi	165	150	79	2,8	1,5	30
Rotondella	155	150	80	2,8	1,5	30

Nova Siri	180	150	77	2,8	1,5	30
Bernalda	180	150	36	2,8	1,5	30
Pisticci	180	150	65	2,8	1,5	30
Montalbano Jonico	165	150	64	2,8	1,5	30
Policoro	180	150	57	2,8	1,5	30
Scanzano Jonico	180	150	53	2,8	1,5	30

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	2.400
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/day)	6.570
Obtainable compost (tons/year)	720
Expected consumption (€/year)	900

BIOCELL PLANT DIMENSIONING	
M - Total mixture to biocells (tons/year)	2.400
D - Average mixture density (tons/m$^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	219,18
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	8,8

ANNUAL COSTS FOR THE ELECTRO- MECHANICAL COMPOSTER	
Composter Investment Cost (€)	1.300.000
Various costs (Videos, Bureaucracy, Area) (€)	15.000
Staff Training (€)	2.500
Collection Center and Processing Informatisation (€)	100.000
Municipal Initial Costs (€)	**1.417.500**
Personnel costs (€/year)	75.000
Electricity consumption (€/year)	900
Composter maintenance (€/year)	5.500
Municipality Fixed Costs (€/year)	**81.400**

ANNUAL COSTS FOR THE BIOCELL PLANT	
Biocell plant Investment Cost (€)	569.863
Various costs (Videos, Bureaucracy, Area) (€)	15.000
Staff Training (€)	2.500
Collection Center and Processing Informatisation (€)	100.000
Municipal Initial Costs (€)	**687.363**
Personnel costs (€/year)	75.000
Electricity consumption (€/year)	1.000
Composter maintenance (€/year)	5.000
Municipality Fixed Costs (€/year)	**81.000**

Electro-mechanical composter

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period 7^0year
21.144,90	-4.023,88	12.529,93	Montescaglioso	4.940,44
7.132,33	-1.357,29	4.226,44	Pomarico	1.666,45
31.061,68	-5.911,05	18.406,37	Ferrandina	7.257,47
910,59	-173,29	539,59	Craco	212,76
28.467,25	-5.417,33	16.868,98	Tursi	6.651,29
9.337,32	-1.776,90	5.533,06	Rotondella	2.181,64
60.264,55	-11.468,38	35.711,26	Nova Siri	14.080,64
38.431,07	-7.313,45	22.773,29	Bernalda	8.979,31
63.991,58	-12.177,63	37.919,80	Pisticci	14.951,45
11.625,08	-2.212,26	6.888,73	Montalbano Jonico	2.716,17
56.650,41	-10.780,60	33.569,61	Policoro	13.236,21
45.883,24	-8.731,60	27.189,26	Scanzano Jonico	10.720,49

Biocell

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period
12.322,17	4.798,84	12.552,50	Montescaglioso	For all municipalities the investment return takes place in the first year
4.156,36	1.618,69	4.234,05	Pomarico	
18.101,16	7.049,46	18.439,51	Ferrandina	
5.30,65	206,66	540,56	Craco	
16.589,26	6.460,66	16.899,35	Tursi	
5.441,31	2.119,11	5.543,02	Rotondella	
35.119,11	13.677,07	35.775,56	Nova Siri	
22.395,67	8.721,95	22.814,29	Bernalda	
37.291,03	14.522,92	37.988,08	Pisticci	
6.774,51	2.638,32	6.901,14	Montalbano J.	
33.012,97	12.856,84	33.630,05	Policoro	
26.738,41	10.413,22	27.238,21	Scanzano Jonico	

Municipalities	Pomace Economic saving (€/year)
Montescaglioso	3.642,98
Pomarico	281,82
Ferrandina	54,12
Ceaco	506
Tursi	238,7
Rotondella	139,7
Nova Siri	803,66
Bernalda	2.637,36
Pisticci	1.115,13
Montalbano Jonico	298,54
Policoro	102,3
Scanzano Jonico	1.109,46

Municipalities	Avoided CO_2 emissions (Kg/year) – composting plant	Avoided CO_2 emissions (Kg/year) - distillery
Montescaglioso	19,78	1.317,09
Pomarico	31,74	319,94
Ferrandina	342,53	62,49
Craco	14,61	5,89
Tursi	386,55	270,93
Rotondella	62,20	150,23
Nova Siri	408,30	870,68
Bernalda	154,70	3.052,94
Pisticci	1.186,37	1351,68
Montalbano Jonico	122,59	337,19
Policoro	377,39	116,66
Scanzano Jonico	305,66	1.344,80

ALTO-BRADANO DISTRICT

IMPUT FLOWS

Municipality	Non domestic organic waste (tons/year)	Urban green waste (tons/year)	Pomace (tons/year)	Total quantity (tons/year)
Genzano di Lucania	60,21	12,36	21,76	94,33
Palazzo San Gervasio	48,6	12,55	4,29	65,44
Oppido Lucano	35,66	6,78	9,6	52,04
Tolve	12,8	3,55	11,76	28,11
Forenza	25,87	5,53	21,02	52,42
Maschito	5,83	4,67	57,56	68,06
Montemilone	6,7	5,67	20,65	33,02
Banzi	10,91	6,78	7,76	25,45
Acerenza	51,23	9,86	28,05	89,14
San Chirico Nuovo	34,1	12,35	2,3	48,75
Cancellara	10,16	8,99	5,95	25,1
Pietragalla	42,67	9,52	11,21	63,4
Avigliano	120,99	12,54	10,42	143,95

CURRENT SCENARIO

Municipality	Organic waste collection cost (€/ton)	Organic waste disposal cost (€/ton)	Distance from the composting plant (Km)	Fuel yeld (Km/l)	Fuel cost (€/l)	Average transportable quantity (tons)
Genzano di Lucania	165	150	83	2,8	1,5	30
Palazzo San Gervasio	165	150	91	2,8	1,5	30
Oppido Lucano	150	150	88	2,8	1,5	30
Tolve	150	150	91	2,8	1,5	30
Forenza	150	150	108	2,8	1,5	30
Maschito	150	150	108	2,8	1,5	30
Montemilone	150	150	108	2,8	1,5	30
Banzi	150	150	96	2,8	1,5	30
Acerenza	165	150	96	2,8	1,5	30
San Chirico Nuovo	150	150	89	2,8	1,5	30
Cancellara	150	150	98	2,8	1,5	30
Pietragalla	165	150	101	2,8	1,5	30
Avigliano	165	150	137	2,8	1,5	30

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	800
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/day)	2.190
Obtainable compost (tons/year)	240
Expected consumption (€/year)	350

BIOCELL PLANT DIMENSIONING	
M - Total mixture to biocells (tons/year)	800
D - Average mixture density (tons/m$^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	73,06
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	2,9

ANNUAL COSTS FOR THE ELECTRO- MECHANICAL COMPOSTER	
Composter Investment Cost (€)	450.000
Various costs (Videos, Bureaucracy, Area) (€)	7.000
Staff Training (€)	1.000
Collection Center and Processing Informatisation (€)	60.000
Municipal Initial Costs (€)	**518.000**
Personnel costs (€/year)	25.000
Electricity consumption (€/year)	400
Composter maintenance (€/year)	2.000
Municipality Fixed Costs (€/year)	**27.400**

ANNUAL COSTS FOR THE BIOCELL PLANT	
Biocell plant Investment Cost (€)	189.954
Various costs (Videos, Bureaucracy, Area) (€)	8.000
Staff Training (€)	1.000
Collection Center and Processing Informatisation (€)	60.000
Municipal Initial Costs (€)	**258.954**
Personnel costs (€/year)	25.000
Electricity consumption (€/year)	300
Composter maintenance (€/year)	1.500
Municipality Fixed Costs (€/year)	**26.800**

Electro-mechanical composter

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period 9^0year
16.479,46	-5.344,37	7.688,24	Genzano di Lucania	4.031,11
13.886,16	-4.503,35	6.478,38	Palazzo San Gervasio	3.396,76
9.637,43	-3.125,47	4.496,20	Oppido Lucano	2.357,45
3.712,82	-1.204,08	1.732,16	Tolve	908,21
7.130,43	-2.312,43	3.326,59	Forenza	1.744,21
2.384,38	-773,27	1.112,40	Maschito	583,25
2.809,02	-910,98	1.310,51	Montemilone	687,13
4.017,11	-1.302,77	1.874,12	Banzi	982,64
13.872,54	-4.498,93	6.472,02	Acerenza	3.393,42
10.548,03	-3.420,78	4.921,02	San Chirico Nuovo	2.580,20
4.348,65	-1.410,29	2.028,80	Cancellara	1.063,74
11.851,49	-3.843,50	5.529,13	Pietragalla	2.899,05
30.322,48	-9.833,73	14.146,49	Avigliano	7.417,32

Biocell

Costs (€/a)	Saving 1^0-5^0 year (€/year)	Saving from 6^0 year (€/year)	Municipalities	PB Period
9.886,53	1.248,56	7.763,72	Genzano di Lucania	For all municipalities the investment return takes place in the first year
8.330,73	1.052,08	6.541,98	Palazzo San Gervasio	
5.781,79	730,18	4.540,34	Oppido Lucano	
2.227,43	281,30	1.749,16	Tolve	
4.277,76	540,24	3.359,25	Forenza	
1.430,46	180,65	1.123,32	Maschito	
1.685,22	212,83	1.323,37	Montemilone	
2.409,99	304,36	1.892,52	Banzi	
8.322,56	1.051,05	6.535,56	Acerenza	
6.328,09	799,17	4.969,34	San Chirico Nuovo	
2.608,89	329,47	2.048,71	Cancellara	
7.110,07	897,93	5.583,42	Pietragalla	
18.191,37	2.297,38	14.285,37	Avigliano	

Municipalities	Pomace Economic saving (€/year)
Genzano di Lucania	498,72
Palazzo San Gervasio	94,38
Oppido Lucano	211,2
Tolve	258,72
Forenza	462,44

Maschito	1.266,36
Montemilone	454,3
Banzi	170,72
Acerenza	617,1
San Chirico Nuovo	50,6
Cancellara	130,9
Pietragalla	246,62
Avigliano	229,24

Municipalities	**Avoided CO_2 emissions (Kg/year) – composting plant**	**Avoided CO_2 emissions (Kg/year) - distillery**
Genzano di Lucania	243,06	556,82
Palazzo San Gervasio	190,14	106,80
Oppido Lucano	168,18	248,88
Tolve	56,24	296,60
Forenza	143,02	535,20
Maschito	43,85	1.443,76
Montemilone	40,57	499,45
Banzi	71,23	198,24
Acerenza	313,76	748,00
San Chirico Nuovo	190,51	59,78
Cancellara	81,20	152,64
Pietragalla	177,86	276,75
Avigliano	975,66	277,87

VAL-D'AGRI DISTRICT

IMPUT FLOWS

Municipality	**Non domestic organic waste (tons/year)**	**Urban green waste (tons/year)**	**Pomace (tons/year)**	**Total quantity (tons/year)**
Moliterno	50,06	2,34	3,11	55,51
San Martino D'Agri	1,75	0,56	4,1	6,41
Grumento Nova	37,29	12,35	3,99	53,63
Tramutola	52,5	1,35	0,63	54,48
Paterno	49,35	3,45	4,73	57,53
Marsicovetere	50,23	2,35	2,74	55,32
Calvello	53,1	2,3	1,47	56,87
Marsiconuovo	37,24	8,45	4,36	50,05
Viggiano	110,58	4,56	20,48	135,62
Sarconi	42,35	8,95	0,8	52,1
Spinoso	14,21	3,42	0,8	18,43

San Chirico Raparo	14,38	3,65	3,44	21,47
Montemurro	15,51	12,34	4,07	31,92
Sasso di Castalda	12,08	4,2	3,34	19,62
Roccanova	18,41	3,35	21,76	43,52

CURRENT SCENARIO						
Municipality	**Organic waste collection cost (€/ton)**	**Organic waste disposal cost (€/ton)**	**Distance from the composting plant (Km)**	**Fuel yeld (Km/l)**	**Fuel cost (€/l)**	**Average transportable quantity (tons)**
Moliterno	155	150	143	2,8	1,5	30
San Martino D'Agri	155	150	121	2,8	1,5	30
Grumento Nova	155	150	137	2,8	1,5	30
Tramutola	155	150	147	2,8	1,5	30
Paterno	155	150	149	2,8	1,5	30
Marsicovetere	155	150	151	2,8	1,5	30
Calvello	155	150	119	2,8	1,5	30
Marsiconuovo	155	150	154	2,8	1,5	30
Viggiano	165	150	138	2,8	1,5	30
Sarconi	155	150	139	2,8	1,5	30
Spinoso	155	150	127	2,8	1,5	30
San Chirico Raparo	155	150	130	2,8	1,5	30
Montemurro	155	150	151	2,8	1,5	30
Sasso di Castalda	155	150	108	2,8	1,5	30
Roccanova	155	150	124	2,8	1,5	30

ECOROTOR COMPOSTER DIMENSIONING	
Capacity (tons/year)	800
Continuous Automatic Cycle	
Dwell time (days)	14
Dimensions (m): 13*2,4 - h=3 2 PIPES	
Capacity (Kg/day)	2.190
Obtainable compost (tons/year)	240
Expected consumption (€/year)	350

BIOCELL PLANT DIMENSIONING

M - Total mixture to biocells (tons/year)	800
D - Average mixture density (tons/$m^{3)}$	0,6
G – days/year	365
T - Average dwell time (days)	20
Volume required (M/D/G)*T (m^3)	73,06
Standard biocell size (m^3)	25
n – biocells (Volume/Dimension)	2,9

ANNUAL FIXED COSTS FOR THE ELECTRO- MECHANICAL COMPOSTER

Composter Investment Cost (€)	450.000
Various costs (Videos, Bureaucracy, Area) (€)	7.000
Staff Training (€)	1.000
Collection Center and Processing Informatisation (€)	60.000
Municipal Initial Costs (€)	**518.000**
Personnel costs (€/year)	25.000
Electricity consumption (€/year)	400
Composter maintenance (€/year)	2.000
Municipality Fixed Costs (€/year)	**27.400**

ANNUAL COSTS FOR THE BIOCELL PLANT

Biocell plant Investment Cost (€)	189.954
Various costs (Videos, Bureaucracy, Area) (€)	8.000
Staff Training (€)	1.000
Collection Center and Processing Informatisation (€)	60.000
Municipal Initial Costs (€)	**258.954**
Personnel costs (€/year)	25.000
Electricity consumption (€/year)	300
Composter maintenance (€/year)	1.500
Municipality Fixed Costs (€/year)	**26.800**

Electro-mechanical composter

Costs (€/year)	Final saving 1^0-5^0 year (€/year)	Final saving from 6^0 year (€/year)	Municipalities	PB Period 8^0year
10.850,06	-2.731,80	5.848,85	Moliterno	3.887,54
478,31	-120,43	257,84	San Martino D'Agri	171,37
10.278,57	-2.587,92	5.540,79	Grumento Nova	3.682,77
11.150,30	-2.807,40	6.010,70	Tramutola	3.995,11
10.932,89	-2.752,66	5.893,50	Paterno	3.917,21
10.887,33	-2.741,19	5.868,95	Marsicovetere	3.900,89

11.471,25	-2.888,21	6.183,71	Calvello	4.110,11
9.460,67	-2.381,99	5.099,89	Marsiconuovo	3.389,72
23.841,15	-6.002,67	12.851,85	Viggiano	8.542,20
10.622,29	-2.674,46	5.726,07	Sarconi	3.805,93
3.650,51	-919,12	1.967,85	Spinoso	1.307,96
3..733,33	-939,97	2.012,50	San Chirico Raparo	1.337,64
5766,68	-1.451,92	3.108,60	Montemurro	2.066,18
3.370,97	-848,74	1.817,16	Sasso di Castalda	1.207,80
4.505,67	-1.134,43	2.428,84	Roccanova	1.614,36

Biocell

Costs (€/a)	**Saving 1^0-5^0 year (€/year)**	**Saving from 6^0 year (€/year)**	**Municipalities**	
6.509,28	1.608,98	5.898,55	Moliterno	
286,95	70,93	260,03	San Martino D'Agri	For all municipalities the investment return takes place in the first year
6.166,43	1.524,23	5.587,86	Grumento Nova	
6.689,40	1.653,50	6.061,77	Tramutola	
6.558,97	1.621,26	5.943,58	Paterno	
6.531,64	1.614,50	5918,81	Marsicovetere	
6.881,95	1.701,09	6.236,25	Calvello	
5.675,74	1.402,94	5.143,22	Marsiconuovo	
14.303,03	3.535,45	12.961,05	Viggiano	
6.372,64	1.575,20	5.774,73	Sarconi	
2.190,05	541,34	1.984,57	Spinoso	
2.239,74	553,62	2.029,60	San Chirico Raparo	
3.459,61	855,15	3.135,01	Montemurro	
2.022,35	499,89	1.832,60	Sasso di Castalda	
2.703,09	668,16	2.449,47	Roccanova	

Municipalities	**Pomace Economic saving (€/year)**
Moliterno	68,42
San Martino D’Agri	90,2
Grumento Nova	87,78
Tramutola	13,86
Paterno	104,06
Marsicovetere	60,28
Calvello	32,34
Marsiconuovo	95,92
Viggiano	450,56
Sarconi	17,6
Spinoso	17,6

San Chirico Raparo	75,68
Montemurro	89,54
Sasso di Castalda	73,48
Roccanova	478,72

Municipalities	**Avoided CO_2 emissions (Kg/year) – composting plant**	**Avoided CO_2 emissions (Kg/year) - distillery**
Moliterno	349,3	79,95
San Martino D'Agri	11,42	103,15
Grumento Nova	330,4	103,80
Tramutola	380,3	16,31
Paterno	371,4	121,82
Marsicovetere	387	71,17
Calvello	277,1	37,22
Marsiconuovo	321,4	111,13
Viggiano	847,4	546,13
Sarconi	322	20,42
Spinoso	84,44	19,75
San Chirico Raparo	109,4	88,76
Montemurro	173,9	101,17
Sasso di Castalda	51,14	80,32
Roccanova	143,9	580,27

ATTACHMENT 2

DOMESTIC COMPOSTING – MODEL 2

In this section, the economic and environmental saving associated with the **"domestic composting"** for each municipality considered in tabular form have been presented.

MUNICIPALITY OF POTENZA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
386,62	25.694,3	64,33	6.611,68

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	116.303,2	232.606,5	348.909,7	465.213
User training (€)	0	0	0	0
Sensors (€)	1.003,3	2.006,6	3.009,9	4.013,2
Municipality initial costs (€)	117.306,5	234.613,1	351.919,6	469.226,2
Operator control (€/year)	70.231	140.462,8	210.694,2	280.926
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	70.381,4	140.612,8	210.844,2	281.075,7

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	93.843	234.360,35	140.517,61
Second Year	93.843	234.360,35	281.035,22
Third Year	93.843	234.360,35	421.552,84
Fourth Year	93.843	234.360,35	562.070,45
Fifth Year	93.843	234.360,35	702.588,06
Sixth Year	70.381	234.360,35	866.566,98

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	187.535	468.720,71	281.185,22
Second Year	187.535	468.720,71	562.370,45

Third Year	187.535	468.720,71	843.555,67
Fourth Year	187.535	468.720,71	1.124.740,89
Fifth Year	187.535	468.720,71	1.405.926,12
Sixth Year	140.613	468.720,71	1.734.033,96

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	281.228	703.081,06	421.852,84
Second Year	281.228	703.081,06	843.705,67
Third Year	281.228	703.081,06	1.265.558,51
Fourth Year	281.228	703.081,06	1.687.411,34
Fifth Year	281.228	703.081,06	2.109.264,18
Sixth Year	210.844	703.081,06	2.601.500,94

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	374.921	937.441,42	562.520,45
Second Year	374.921	937.441,42	1.125.040,89
Third Year	374.921	937.441,42	1.687.561,34
Fourth Year	374.921	937.441,42	2.250.081,79
Fifth Year	374.921	937.441,42	2.812.602,23
Sixth Year	281.076	937.441,42	3.468.967,93

Avoided CO_2 emissions (Kg/year)	
4.407,78	case 1
8.815,57	case 2
13.223,35	case 3
17.631,14	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	242,84	73

MUNICIPALITY OF MATERA

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	85.316	98.663,28	13.346,91
Second Year	85.316	98.663,28	26.693,81
Third Year	85.316	98.663,28	40.040,72
Fourth Year	85.316	98.663,28	53.387,63
Fifth Year	85.316	98.663,28	66.734,53
Sixth Year	63.990	98.663,28	101.407,69

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	170.483	197.326,57	26.843,81
Second Year	170.483	197.326,57	53.687,63
Third Year	170.483	197.326,57	80.531,44
Fourth Year	170.483	197.326,57	107.375,26
Fifth Year	170.483	197.326,57	134.219,07
Sixth Year	127.830	197.326,57	203.715,38

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	255.649	295.989,85	40.340,72
Second Year	255.649	295.989,85	80.681,44
Third Year	255.649	295.989,85	121.022,16
Fourth Year	255.649	295.989,85	161.362,88
Fifth Year	255.649	295.989,85	201.703,60
Sixth Year	191.670	295.989,85	306.023,08

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	340.816	394.653,14	53.837,63
Second Year	340.816	394.653,14	107.675,26
Third Year	340.816	394.653,14	161.512,88
Fourth Year	340.816	394.653,14	215.350,51
Fifth Year	340.816	394.653,14	269.188,14
Sixth Year	255.511	394.653,14	408.330,77

Avoided CO_2 emissions(Kg/year)	
330,02	case 1
660,03	case 2
990,05	case 3
1320,06	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	518,11	155,43

MUNICIPALITY OF BARILE

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
397,64	1.091,92	57,16	249,66

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	4.805,5	9.611	14.416,5	19.222
User training (€)	0	0	0	0
Sensors (€)	39,6	99,1	119,0	158,7
Municipality initial costs (€)	4.845,1	9.710,1	14.535,4	19.380,6
Operator control (€/year)	2902	5803,744	8705,616	11607
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	3.051,872	5.953,744	8.855,616	11.757,49

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	4.021	7.979,20	3.958,30
Second Year	4.021	7.979,20	7.916,60
Third Year	4.021	7.979,20	11.874,90
Fourth Year	4.021	7.979,20	15.833,20
Fifth Year	4.021	7.979,20	19.791,50
Sixth Year	3.052	7.979,20	24.718,82

CASE 2: 80% Separate collection + 20% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	7.896	15.958,40	8.062,62
Second Year	7.896	15.958,40	16.125,25
Third Year	7.896	15.958,40	24.187,87
Fourth Year	7.896	15.958,40	32.250,50
Fifth Year	7.896	15.958,40	40.313,12
Sixth Year	5.954	15.958,40	50.317,77

CASE 3: 70% Separate collection + 30% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	1.1763	23.937,60	12.174,89
Second Year	1.1763	23.937,60	24.349,78
Third Year	1.1763	23.937,60	36.524,67
Fourth Year	1.1763	23.937,60	48.699,56
Fifth Year	1.1763	23.937,60	60.874,45
Sixth Year	8.856	23.937,60	75.956,43

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	15.634	31.916,80	16.283,18
Second Year	15.634	31.916,80	32.566,35
Third Year	15.634	31.916,80	48.849,53
Fourth Year	15.634	31.916,80	65.132,70
Fifth Year	15.634	31.916,80	81.415,88
Sixth Year	11.757	31.916,80	101.575,18

Avoided CO_2 emissions (Kg/year)	
171,76	case 1
343,53	case 2
515,29	case 3
687,05	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	181,44	54,43

MUNICIPALITY OF RAPOLLA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
309,54	1.327,62	62,92	334,13

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	7.505,75	15.011,5	22.517,25	30.023
User training (€)	0	0	0	0
Sensors (€)	61,9	154,9	185,8	247,8
Municipality initial costs (€)	7.567,658	15166,36	22.703,05	30.270,8
Operator control (€/year)	4.532,4	9.064,9	13.597,3	18.130
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.682,4	9.214,9	13.747,3	18.279,8

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	6.196	10.674,41	4.478,42
Second Year	6.196	10.674,41	8.956,84
Third Year	6.196	10.674,41	13.435,26
Fourth Year	6.196	10.674,41	17.913,68
Fifth Year	6.196	10.674,41	22.392,10
Sixth Year	4.682	10.674,41	28.384,05

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	12.248	21.348,82	9.100,63
Second Year	12.248	21.348,82	18.201,26
Third Year	12.248	21.348,82	27.301,89
Fourth Year	12.248	21.348,82	36.402,52
Fifth Year	12.248	21.348,82	45.503,15
Sixth Year	9.215	21.348,82	57.637,06

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	18.288	32.023,23	13.735,24

Second Year	18.288	32.023,23	27.470,49
Third Year	18.288	32.023,23	41.205,73
Fourth Year	18.288	32.023,23	54.940,98
Fifth Year	18.288	32.023,23	68.676,22
Sixth Year	13.747	32.023,23	86.952,08

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	24.334	42.697,64	18.363,64
Second Year	24.334	42.697,64	36.727,29
Third Year	24.334	42.697,64	55.090,93
Fourth Year	24.334	42.697,64	73.454,57
Fifth Year	24.334	42.697,64	91.818,22
Sixth Year	18.280	42.697,64	116.236,02

Avoided CO_2 emissions (Kg/year)	
222,76	case 1
445,51	case 2
668,27	case 3
891,03	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	319	95,7

MUNICIPALITY OF LAVELLO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
339,09	4.533,97	61,39	1.113,36

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	23.399,2	46.798,5	70.197,75	93.597
User training (€)	0	0	0	0
Sensors (€)	193	482,8	579,2	772,6
Municipality initial costs (€)	23.592,2	47.281,2	70.776,9	94.369,5

Operator control (€/year)	14.129,9	28.259,9	42.389,9	56.520
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	14.279,9	28.409,9	42.539,9	56.669,9

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	18.998	37.190,28	18.191,84
Second Year	18.998	37.190,28	36.383,69
Third Year	18.998	37.190,28	54.575,53
Fourth Year	18.998	37.190,28	72.767,38
Fifth Year	18.998	37.190,28	90.959,22
Sixth Year	14.280	37.190,28	113.869,51

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	37.866	74.380,55	36.514,33
Second Year	37.866	74.380,55	73.028,66
Third Year	37.866	74.380,55	109.543,00
Fourth Year	37.866	74.380,55	146.057,33
Fifth Year	37.866	74.380,55	182.571,66
Sixth Year	28.410	74.380,55	228.542,25

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.6695	111.570,83	54.875,49
Second Year	5.6695	111.570,83	109.750,97
Third Year	5.6695	111.570,83	164.626,46
Fourth Year	5.6695	111.570,83	219.501,95
Fifth Year	5.6695	111.570,83	274.377,44
Sixth Year	4.2540	111.570,83	343.408,32

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	75.544	148.761,10	73.217,26
Second Year	75.544	148.761,10	146.434,53
Third Year	75.544	148.761,10	219.651,79
Fourth Year	75.544	148.761,10	292.869,06
Fifth Year	75.544	148.761,10	366.086,32
Sixth Year	56.670	148.761,10	458.177,50

Avoided CO$_2$ emissions (Kg/year)

670,99	case 1
1341,97	case 2
2012,96	case 3
2683,95	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	249,93	74,98

MUNICIPALITY OF RIONERO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
386,48	5.001,05	50,59	1.012,01

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.2645	45.290	67.935	90.580
User training (€)	0	0	0	0
Sensors (€)	186,8	467,2	560,6	747,7
Municipality initial costs (€)	22.831,7	45.757,2	68.495,5	91.327,6
Operator control (€/year)	13.674,5	27.349,0	41.023,5	54.698
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	13.824,5	27.499,0	41.173,5	54.848,0

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	18.391	33.869,90	15.479,02
Second Year	18.391	33.869,90	30.958,05
Third Year	18.391	33.869,90	46.437,07
Fourth Year	18.391	33.869,90	61.916,10
Fifth Year	18.391	33.869,90	77.395,12
Sixth Year	13.825	33.869,90	97.440,50

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	36.650	67.739,79	31.089,32
Second Year	36.650	67.739,79	62.178,63
Third Year	36.650	67.739,79	93.267,95
Fourth Year	36.650	67.739,79	124.357,27
Fifth Year	36.650	67.739,79	155.446,59
Sixth Year	27.499	67.739,79	195.687,35

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	54.873	101.609,69	46.737,03
Second Year	54.873	101.609,69	93.474,06
Third Year	54.873	101.609,69	140.211,09
Fourth Year	54.873	101.609,69	186.948,12
Fifth Year	54.873	101.609,69	233.685,15
Sixth Year	41.174	101.609,69	294.121,29

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	73.114	135.479,59	62.365,99
Second Year	73.114	135.479,59	124.731,98
Third Year	73.114	135.479,59	187.097,97
Fourth Year	73.114	135.479,59	249.463,96
Fifth Year	73.114	135.479,59	311.829,95
Sixth Year	54.848	135.479,59	392.461,47

Avoided CO_2 emissions (Kg/year)	
707,06	case 1
1.414,12	case 2
2.121,18	case 3
2.828,24	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	277,68	83,3

MUNICIPALITY OF MELFI

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
453,78	7.892,9	64,94	2.073,64

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	30.786	61.572	92.358	123.144
User training (€)	0	0	0	0
Sensors (€)	253,9	635,2	762,1	1.016,4
Municipality initial costs (€)	31.039,9	62.207,1	93.120,07	124.160,4
Operator control (€/year)	18.590,5	37.181,1	55.771,7	74.362
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	18.740,5	37.331,1	55.921,73	74.512,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	24.949	69.429,83	44.481,26
Second Year	24.949	69.429,83	88.962,53
Third Year	24.949	69.429,83	133.443,79
Fourth Year	24.949	69.429,83	177.925,05
Fifth Year	24.949	69.429,83	222.406,31
Sixth Year	18.741	69.429,83	273.095,56

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	49.773	138.859,66	89.087,06
Second Year	49.773	138.859,66	178.174,12
Third Year	49.773	138.859,66	267.261,18
Fourth Year	49.773	138.859,66	356.348,24
Fifth Year	49.773	138.859,66	445.435,30
Sixth Year	37.331	138.859,66	546.963,79

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**

First Year	74.546	208.289,48	133.743,73
Second Year	74.546	208.289,48	267.487,46
Third Year	74.546	208.289,48	401.231,19
Fourth Year	74.546	208.289,48	534.974,92
Fifth Year	74.546	208.289,48	668.718,65
Sixth Year	55.922	208.289,48	821.086,39

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	99.344	277.719,31	178.374,90
Second Year	99.344	277.719,31	356.749,81
Third Year	99.344	277.719,31	535.124,71
Fourth Year	99.344	277.719,31	713.499,62
Fifth Year	99.344	277.719,31	891.874,52
Sixth Year	74.512	277.719,31	1.095.081,51

Avoided CO_2 emissions (Kg/year)	
1.493,02	case 1
2.986,04	case 2
4.479,06	case 3
5.972,08	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	88,26	26,48

MUNICIPALITY OF ATELLA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
470,46	1.739,39	32,45	232,78

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	6.671	13.342	20.013	26.684
User training (€)	0	0	0	0

Sensors (€)	55	137,6	165,1	220,3
Municipality initial costs (€)	6.726,02	13.479,6	20.178,1	26.904,2
Operator control (€/year)	4.028,3	8.056,7	12.085,1	16.114
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.178,3	8.206,7	12.235,1	16.263,5

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	5.524	7.444,05	1.920,46
Second Year	5.524	7.444,05	3.840,93
Third Year	5.524	7.444,05	5.761,39
Fourth Year	5.524	7.444,05	7.681,86
Fifth Year	5.524	7.444,05	9.602,32
Sixth Year	4.178	7.444,05	12.867,99

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	10.903	14.888,10	3.985,41
Second Year	10.903	14.888,10	7.970,82
Third Year	10.903	14.888,10	11.956,23
Fourth Year	10.903	14.888,10	15.941,65
Fifth Year	10.903	14.888,10	19.927,06
Sixth Year	8.207	14.888,10	26.608,40

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	16.271	22.332,15	6.061,38
Second Year	16.271	22.332,15	12.122,76
Third Year	16.271	22.332,15	18.184,15
Fourth Year	16.271	22.332,15	24.245,53
Fifth Year	16.271	22.332,15	30.306,91
Sixth Year	12.235	22.332,15	40.403,92

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	21.644	29.776,20	8.131,83
Second Year	21.644	29.776,20	16.263,66
Third Year	21.644	29.776,20	24.395,48
Fourth Year	21.644	29.776,20	32.527,31
Fifth Year	21.644	29.776,20	40.659,14

Sixth Year	16.264	29.776,20	54.171,82

Avoided CO_2 emissions (Kg/year)	
166,36	case 1
332,72	case 2
499,09	case 3
665,45	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	196,13	58,84

MUNICIPALITY OF MONTESCAGLIOSO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
297,86	2.864,22	68,69	786,97

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	16.828	33.656	50.484	67.312
User training (€)	0	0	0	0
Sensors (€)	144,30	288,60	432,89	577,19
Municipality initial costs (€)	16.972,3	33.944,6	50.916,8	67.889,1
Operator control (€/year)	10161,84	20323,67	30485,51	40647
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	10.311,8	20.473,6	30.635,5	40.797,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	13.706	24.848,13	11.141,83
Second Year	13.706	24.848,13	22.283,67
Third Year	13.706	24.848,13	33.425,50
Fourth Year	13.706	24.848,13	44.567,33

Fifth Year	13.706	24.848,13	55.709,17
Sixth Year	10.312	24.848,13	70.245,46

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	27.263	49.696,26	22.433,67
Second Year	27.263	49.696,26	44.867,33
Third Year	27.263	49.696,26	67.301,00
Fourth Year	27.263	49.696,26	89.734,66
Fifth Year	27.263	49.696,26	112.168,33
Sixth Year	20.474	49.696,26	141.390,92

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	40.819	74.544,39	33.725,50
Second Year	40.819	74.544,39	67.451,00
Third Year	40.819	74.544,39	101.176,50
Fourth Year	40.819	74.544,39	134.902,00
Fifth Year	40.819	74.544,39	168.627,50
Sixth Year	30.636	74.544,39	212.536,37

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	54.375	99.392,51	45.017,33
Second Year	54.375	99.392,51	90.034,66
Third Year	54.375	99.392,51	135.052,00
Fourth Year	54.375	99.392,51	180.069,33
Fifth Year	54.375	99.392,51	225.086,66
Sixth Year	40.797	99.392,51	283.681,83

Avoided CO_2 emissions (Kg/year)	
87,30	case 1
174,60	case 2
261,90	case 3
349,21	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	212,29	63,69

MUNICIPALITY OF TURSI

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
324,01	1.587,97	76,35	484,97

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	8.576,7	17.153,5	25.730,2	34.307
User training (€)	0	0	0	0
Sensors (€)	73,54	147,09	220,63	294,18
Municipality initial costs (€)	8.650,2	17.300,5	25.950,8	34.601,1
Operator control (€/year)	5179,197	10358,39	15537,59	20717
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	5.329,1	10.508,3	15.687,5	20.866,7

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.059	15.414,50	8.355,25
Second Year	7.059	15.414,50	16.710,49
Third Year	7.059	15.414,50	25.065,74
Fourth Year	7.059	15.414,50	33.420,98
Fifth Year	7.059	15.414,50	41.776,23
Sixth Year	5.329	15.414,50	51.861,53

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	13.969	30.829,00	16.860,49
Second Year	13.969	30.829,00	33.720,98
Third Year	13.969	30829,00	50.581,47
Fourth Year	13.969	30.829,00	67.441,97
Fifth Year	13.969	30.829,00	84.302,46
Sixth Year	10.508	30.829,00	104.623,07

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	20.878	46.243,50	25..365,74
Second Year	20.878	46.243,50	50.731,47

Third Year	20.878	46.243,50	76.97,21
Fourth Year	20.878	46.243,50	101.462,95
Fifth Year	20.878	46.243,50	126.828,69
Sixth Year	15.688	46.243,50	157.384,60

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	27.787	61.658,01	33.870,98
Second Year	27.787	61.658,01	67.741,97
Third Year	27.787	61.658,01	101.612,95
Fourth Year	27.787	61.658,01	135.483,93
Fifth Year	27.787	61.658,01	169.354,92
Sixth Year	20.867	61.658,01	210.146,13

Avoided CO_2 emissions (Kg/year)	
206,14	case 1
412,29	case 2
618,43	case 3
824,57	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	304,94	91,48

MUNICIPALITY OF ROTONDELLA

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
292,77	743,93	53,14	158,13

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	4.446,7	8.893,5	13.340,2	17,7
User training (€)	0	0	0	0
Sensors (€)	38,13	76,26	114,39	152,52
Municipality initial costs (€)	4.484,8	8.969,7	13.454,64	17.939,5

Operator control (€/year)	2685,236	5370,471	8055,707	10741
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	2.835,2	5.520,4	8.205,7	10.890,9

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	3.732	4.868,07	1.135,86
Second Year	3.732	4.868,07	2.271,72
Third Year	3.732	4.868,07	3.407,58
Fourth Year	3.732	4.868,07	4.543,44
Fifth Year	3.732	4.868,07	5.679,30
Sixth Year	2.835	4.868,07	7.712,14

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.314	9.736,14	2.421,72
Second Year	7.314	9.736,14	4.843,44
Third Year	7.314	9.736,14	7.265,16
Fourth Year	7.314	9.736,14	9.686,88
Fifth Year	7.314	9.736,14	12.108,60
Sixth Year	5.520	9.736,14	16.324,28

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	10.897	14.604,22	3.707,58
Second Year	10.897	14.604,22	7.415,16
Third Year	10.897	14.604,22	11.122,74
Fourth Year	10.897	14.604,22	14.830,32
Fifth Year	10.897	14.604,22	18.537,90
Sixth Year	8.206	14.604,22	24.936,41

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	14.479	19.472,29	4.993,44
Second Year	14.479	19.472,29	9.986,88
Third Year	14.479	19.472,29	14.980,32
Fourth Year	14.479	19.472,29	19.973,76
Fifth Year	14.479	19.472,29	24.967,20
Sixth Year	10.891	19.472,29	33.548,55

Avoided CO_2 emissions (Kg/year)	
67,38	case 1
134,77	case 2
202,15	case 3
269,54	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	192,78	57,83

MUNICIPALITY OF NOVA SIRI

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
443,61	2.982,39	50,31	600,18

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	11.765,2	23.530,5	35.295,75	47.061
User training (€)	0	0	0	0
Sensors (€)	100,89	201,77	302,66	403,54
Municipality initial costs (€)	11.866,1	23.732,2	35.598,4	47.464,5
Operator control (€/year)	7104,62	14209,24	21313,86	28418
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	7.254,6	14.359,2	21.463,8	28.568,47

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	9.628	19.970,00	10.342,16
Second Year	9.628	19.970,00	20.684,32
Third Year	9.628	19.970,00	31.026,47
Fourth Year	9.628	19.970,00	41.368,63
Fifth Year	9.628	19.970,00	51.710,79
Sixth Year	7.255	19.970,00	64.426,18

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	19.106	39.940,01	20.834,32
Second Year	19.106	39.940,01	41.668,63
Third Year	19.106	39.940,01	62.502,95
Fourth Year	19.106	39.940,01	83.337,26
Fifth Year	19.106	39.940,01	104.171,58
Sixth Year	14.359	39.940,01	129.752,35

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	28.584	59.910,01	31.326,47
Second Year	28.584	59.910,01	62.652,95
Third Year	28.584	59.910,01	93.979,42
Fourth Year	28.584	59.910,01	125.305,90
Fifth Year	28.584	59.910,01	156.632,37
Sixth Year	21.464	59.910,01	195.078,53

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	38.061	79.880,02	41.818,63
Second Year	38.061	79.880,02	83.637,26
Third Year	38.061	79.880,02	125.455,90
Fourth Year	38.061	79.880,02	167.274,53
Fifth Year	38.061	79.880,02	209.093,16
Sixth Year	28.568	79.880,02	260.404,70

Avoided CO_2 emissions (Kg/year)	
245,19	case 1
490,38	case 2
735,58	case 3
980,77	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	196,04	58,81

MUNICIPALITY OF BERNALDA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
458,29	5.552,18	65,16	1.447,12

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	21.201,2	42.402,5	63.603,7	84.805
User training (€)	0	0	0	0
Sensors (€)	181,80	363,60	545,39	727,19
Municipality initial costs (€)	21.383,05	42.766,1	64.149,1	85.532,1
Operator control (€/year)	12.802,6	25.605,3	38.408,06	51.211
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	12.952,69	25.755,37	38.558,06	51.360,7

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	17.229	47.944,67	30.715,37
Second Year	17.229	47.944,67	61.430,75
Third Year	17.229	47.944,67	92.146,12
Fourth Year	17.229	47.944,67	122.861,50
Fifth Year	17.229	47.944,67	153.576,87
Sixth Year	12.953	47.944,67	188.568,86

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	34.309	95.889,34	61.580,75
Second Year	34.309	95.889,34	123.161,50
Third Year	34.309	95.889,34	184.742,25
Fourth Year	34.309	95.889,34	246.323,00
Fifth Year	34.309	95.889,34	307.903,75
Sixth Year	25.755	95.889,34	378.037,72

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	51.388	143.834,01	92.446,12

Second Year	51.388	143.834,01	184.892,25
Third Year	51.388	143.834,01	277.338,37
Fourth Year	51.388	143.834,01	369.784,50
Fifth Year	51.388	143.834,01	462.230,62
Sixth Year	38.558	143.834,01	567.506,57

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	68.467	191.778,69	123.311,50
Second Year	68.467	191.778,69	246.623,00
Third Year	68.467	191.778,69	369.934,50
Fourth Year	68.467	191.778,69	493.246,00
Fifth Year	68.467	191.778,69	616.557,49
Sixth Year	51.361	191.778,69	756.975,43

Avoided CO$_2$ emissions (Kg/year)	
283,25	case 1
566,50	case 2
849,75	case 3
11.33,00	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	301,44	90,43

MUNICIPALITY OF PISTICCI

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
375,29	6.542,06	63,88	1.671,63

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	30.506	61.012	91.518	122.024
User training (€)	0	0	0	0
Sensors (€)	261,58	523,17	784,75	1.046,34
Municipality initial costs (€)	30.767,5	61.535,1	92.302,7	123.070,3

Operator control (€/year)	18421,5	36843	55264,49	73686
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	18.571,5	36.993	55.414,4	73.835,9

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	24.725	55.554,10	30.829,09
Second Year	24.725	55.554,10	61.658,17
Third Year	24.725	55.554,10	92.487,26
Fourth Year	24.725	55.554,10	123.316,35
Fifth Year	24.725	55.554,10	154.145,43
Sixth Year	18.571	55.554,10	191.128,04

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	49.300	111.108,20	61.808,17
Second Year	49.300	111.108,20	123.616,35
Third Year	49.300	111.108,20	185.424,52
Fourth Year	49.300	111.108,20	247.232,69
Fifth Year	49.300	111.108,20	309.040,86
Sixth Year	36.993	111.108,20	383.156,07

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	73.875	166.662,30	92.787,26
Second Year	73.875	166.662,30	185.574,52
Third Year	73.875	166.662,30	278.361,78
Fourth Year	73.875	166.662,30	371.149,04
Fifth Year	73.875	166.662,30	463.936,30
Sixth Year	55.414	166.662,30	575.184,11

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	98.450	222.216,40	123.766,35
Second Year	98.450	222.216,40	247.532,69
Third Year	98.450	222.216,40	371.299,04
Fourth Year	98.450	222.216,40	495.065,38
Fifth Year	98.450	222.216,40	618.831,73
Sixth Year	73.836	222.216,40	767.212,14

Avoided CO_2 emissions (Kg/year)	
583,06	case 1
1.166,13	case 2
1.749,19	case 3
2.332,25	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	214,03	64,21

MUNICIPALITY OF MONTALBANO JONICO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
312,76	2.185,57	65,94	576,47

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	12.229	24.458	36.687	48.916
User training (€)	0	0	0	0
Sensors (€)	104,86	209,72	314,59	419,45
Municipality initial costs (€)	12.333,8	24.667,7	37.001,5	49.335,4
Operator control (€/year)	7.384,6	14.769,3	22.153,9	29.539
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	7.534,6	14.919,3	22.303,9	29.688,6

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	10.001	18.290,62	8.289,19
Second Year	10.001	18.290,62	16.578,37
Third Year	10.001	18.290,62	24.867,56
Fourth Year	10.001	18.290,62	33.156,75
Fifth Year	10.001	18.290,62	41.445,93
Sixth Year	7.535	18.290,62	52.201,89

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	19.853	36.581,24	16.728,37
Second Year	19.853	36.581,24	33.456,75
Third Year	19.853	36.581,24	50.185,12
Fourth Year	19.853	36.581,24	66.913,49
Fifth Year	19.853	36.581,24	83.641,86
Sixth Year	14.919	36.581,24	105.303,78

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	29.704	54.871,86	25.167,56
Second Year	29.704	54.871,86	50.335,12
Third Year	29.704	54.871,86	75.502,68
Fourth Year	29.704	54.871,86	100.670,24
Fifth Year	297.04	54.871,86	125.837,80
Sixth Year	22.304	54.871,86	158.405,67

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	39.556	73.162,48	33.606,75
Second Year	39.556	73.162,48	67.213,49
Third Year	39.556	73.162,48	100.820,24
Fourth Year	39.556	73.162,48	134.426,98
Fifth Year	39.556	73.162,48	168.033,73
Sixth Year	29.689	73.162,48	211.507,56

Avoided CO_2 emissions (Kg/year)	
197,07	case 1
394,15	case 2
591,22	case 3
788,30	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	250,98	75,29

MUNICIPALITY OF POLICORO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
484,96	8.674,96	63,06	2.188,17

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	31.304	62.608	93.912	125.216
User training (€)	0	0	0	0
Sensors (€)	268,43	536,85	805,28	1.073,71
Municipality initial costs (€)	31.572,4	63.144,8	94.717,2	126.289,7
Operator control (€/year)	18.903,3	37.806,7	56.710,1	75.614
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	19.053,3	37.956,7	56.860,1	75.763,5

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	25.368	72.659,85	47.291,98
Second Year	25.368	72.659,85	94.583,96
Third Year	25.368	72.659,85	141.875,95
Fourth Year	25.368	72.659,85	189.167,93
Fifth Year	25.368	72.659,85	236.459,91
Sixth Year	19.053	72.659,85	290.066,38

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	50.586	145.319,70	94.733,96
Second Year	50.586	145.319,70	189.467,93
Third Year	50.586	145.319,70	284.201,89
Fourth Year	50.586	145.319,70	378.935,85
Fifth Year	50.586	145.319,70	473.669,82
Sixth Year	37.957	145.319,70	581.032,75

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	75.804	217.979,55	142.175,95
Second Year	75.804	217.979,55	284.351,89

Third Year	75.804	217.979,55	426.527,84
Fourth Year	75.804	217.979,55	568.703,78
Fifth Year	75.804	217.979,55	710.879,73
Sixth Year	56.860	217.979,55	871.999,13

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	101.021	290.639,40	189.617,93
Second Year	101.021	290.639,40	379.235,85
Third Year	101.021	290.639,40	568.853,78
Fourth Year	101.021	290.639,40	758.471,71
Fifth Year	101.021	290.639,40	948.089,63
Sixth Year	75.764	290.639,40	1.162.965,50

Avoided CO_2 emissions (Kg/year)	
6.72,21	case 1
1.344,41	case 2
2.016,62	case 3
2.688,83	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	348,78	104,63

MUNICIPALITY OF GENZANO DI LUCANIA

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
289,82	1655,16	67,54	447,16

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	9.994,25	19.988,5	29.982,7	39.977
User training (€)	0	0	0	0
Sensors (€)	28,5	85,7	114,2	142,8
Municipality initial costs (€)	10.022,8	20.074,2	30.097,02	40.119,8

Operator control (€/year)	6.035,1	12.070,3	18.105,5	24.141
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	6.185,1	12.220,3	18.255,5	24.290,7

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	8.190	14.218,05	6.028,31
Second Year	8.190	14.218,05	12.056,61
Third Year	8.190	14.218,05	18.084,92
Fourth Year	8.190	14.218,05	24.113,23
Fifth Year	8.190	14.218,05	30.141,54
Sixth Year	6.185	14.218,05	38.174,41

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	16.235	28.436,09	12.200,90
Second Year	16.235	28.436,09	24.401,80
Third Year	16.235	28.436,09	36.602,70
Fourth Year	16.235	28.436,09	48.803,60
Fifth Year	16.235	28.436,09	61.004,51
Sixth Year	12.220	28.436,09	77.220,25

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	24.275	42.654,14	18.379,21
Second Year	24.275	42.654,14	36.758,42
Third Year	24.275	42.654,14	55.137,62
Fourth Year	24.275	42.654,14	73.516,83
Fifth Year	24.275	42.654,14	91.896,04
Sixth Year	18.256	42.654,14	116.294,65

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	32.315	56.872,18	24.557,52
Second Year	32.315	56.872,18	49.115,03
Third Year	32.315	56.872,18	73.672,55
Fourth Year	32.315	56.872,18	98.230,06
Fifth Year	32.315	56.872,18	122.787,58
Sixth Year	24.291	56.872,18	155.369,06

Avoided CO_2 emissions (Kg/year)	
197,94	case 1
395,88	case 2
593,83	case 3
791,77	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	242,15	72,65

MUNICIPALITY OF PALAZZO SAN GERVASIO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
320,66	1.657,39	67,54	423,45

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	8.554	17.108	25.662	34.216
User training (€)	0	0	0	0
Sensors (€)	24,45	73,35	97,80	122,25
Municipality initial costs (€)	8.578,4	17.181,3	25.759,8	34.338,2
Operator control (€/year)	5.165,4	10.330,9	15.496,3	20.662
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	5.315,4	10.480,9	15.646,3	20.811,8

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.031	13.476,89	6.445,75
Second Year	7.031	13.476,89	12.891,49
Third Year	7.031	13.476,89	19.337,24
Fourth Year	7.031	13.476,89	25.782,98
Fifth Year	7.031	13.476,89	32.228,73
Sixth Year	5.315	13.476,89	40.390,16

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	13.917	26.953,79	13.036,60
Second Year	13.917	26.953,79	26.073,20
Third Year	13.917	26.953,79	39.109,80
Fourth Year	13.917	26.953,79	52.146,40
Fifth Year	13.917	26.953,79	65.183,00
Sixth Year	10.481	26.953,79	81.655,87

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	20.798	40.430,68	19.632,35
Second Year	20.798	40.430,68	39.264,69
Third Year	20.798	40.430,68	58.897,04
Fourth Year	20.798	40.430,68	78.529,38
Fifth Year	20.798	40.430,68	98.161,73
Sixth Year	15.646	40.430,68	122.946,03

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	27.679	53.907,58	26.228,09
Second Year	27.679	53.907,58	52.456,18
Third Year	27.679	53.907,58	78.684,27
Fourth Year	27.679	53.907,58	104.912,36
Fifth Year	27.679	53.907,58	131.140,45
Sixth Year	20.812	53.907,58	164.236,19

Avoided CO_2 emissions (Kg/year)	
206,64	case 1
413,28	case 2
619,92	case 3
826,56	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	230,44	69,13

MUNICIPALITY OF OPPIDO LUCANO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
262,25	989,99	67,54	267,46

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	6.606,2	1.3212,5	19.818,7	26.425
User training (€)	0	0	0	0
Sensors (€)	18,88	56,65	75,53	94,41
Municipality initial costs (€)	6.625,1	13.269,1	19.894,2	26.519,41
Operator control (€/year)	3.989,2	7.978,5	11.967,8	15.957
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.139,2	8.128,5	12.117,8	16.107,12

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.464	8.241,68	2.777,37
Second Year	5.464	8.241,68	5.554,74
Third Year	5.464	8.241,68	8.332,11
Fourth Year	5.464	8.241,68	11.109,48
Fifth Year	5.464	8.241,68	13.886,85
Sixth Year	4.139	8.241,68	17.989,25

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	10.782	16.483,36	57.00,96
Second Year	10.782	16.483,36	11.401,93
Third Year	10.782	16.483,36	17.102,89
Fourth Year	10.782	16.483,36	22.803,86
Fifth Year	10.782	16.483,36	28.504,82
Sixth Year	8.129	16.483,36	36.859,62

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	16.097	24.725,04	8.628,34
Second Year	16.097	24.725,04	17.256,67

Third Year	16.097	24.725,04	25.885,01
Fourth Year	16.097	24.725,04	34.513,34
Fifth Year	16.097	24.725,04	43.141,68
Sixth Year	12.118	24.725,04	55.748,87

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	21.411	32.966,71	11.555,71
Second Year	21.411	32.966,71	23.111,41
Third Year	21.411	32.966,71	34.667,12
Fourth Year	21.411	32.966,71	46.222,82
Fifth Year	21.411	32.966,71	57.778,53
Sixth Year	16.107	32.966,71	74.638,12

Avoided CO_2 emissions (Kg/year)	
125,81	case 1
251,62	case 2
377,43	case 3
503,25	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	189	56,7

MUNICIPALITY OF TOLVE

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
247,01	800,31	67,54	216,21

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	5.670	11.340	17.010	22.680
User training (€)	0	0	0	0
Sensors (€)	16,21	48,62	64,83	81,03
Municipality initial costs (€)	5.686,2	11.388,6	17.074,8	22.761,03

Operator control (€/year)	3.423,9	6.847,8	10.271,7	13.696
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	3.573,9	6.997,8	10.421,7	13.845,6

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	4.711	6.665,21	1.954,06
Second Year	4.711	6.665,21	3.908,11
Third Year	4.711	6.665,21	5.862,17
Fourth Year	4.711	6.665,21	7.816,22
Fifth Year	4.711	6.665,21	9.770,28
Sixth Year	3.574	6.665,21	12.861,58

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	9.276	13.330,42	4.054,87
Second Year	9.276	13.330,42	8.109,74
Third Year	9.276	13.330,42	12.164,61
Fourth Year	9.276	13.330,42	16.219,48
Fifth Year	9.276	13.330,42	20.274,35
Sixth Year	6.998	13.330,42	26.606,95

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	13.837	19.995,63	6.158,93
Second Year	13.837	19.995,63	12.317,85
Third Year	13.837	19.995,63	18.476,78
Fourth Year	13.837	19.995,63	24.635,71
Fifth Year	13.837	19.995,63	30.794,64
Sixth Year	10.422	19.995,63	40.368,53

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	18.398	26.660,84	8.262,98
Second Year	18.398	26.660,84	16.525,97
Third Year	18.398	26.660,84	24.788,95
Fourth Year	18.398	26.660,84	33.051,93
Fifth Year	18.398	26.660,84	41.314,92
Sixth Year	13.846	26.660,84	54.130,11

Avoided CO_2 emissions (Kg/year)	
105,63	case 1
211,25	case 2
316,88	case 3
422,51	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	203,83	61,15

MUNICIPALITY OF FORENZA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
248,57	511,56	67,54	138,2

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	3.601,5	7.203	10.804,5	14.406
User training (€)	0	0	0	0
Sensors (€)	10,29	30,88	41,18	51,47
Municipality initial costs (€)	3.611,7	7.233,8	10.845,6	14.457,4
Operator control (€/year)	2.174,8	4.349,6	6.524,4	8.699
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	2.324,8	4.499,6	6.674,4	8.849,2

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	3.047	4.268,48	1.221,30
Second Year	3.047	4.268,48	2.442,60
Third Year	3.047	4.268,48	3.663,89
Fourth Year	3.047	4.268,48	4.885,19
Fifth Year	3.047	4.268,48	6.106,49
Sixth Year	2.325	4.268,48	8.050,15

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**

First Year	5.946	8.536,95	2.590,54
Second Year	5.946	8.536,95	5.181,07
Third Year	5.946	8.536,95	7.771,61
Fourth Year	5.946	8.536,95	10.362,15
Fifth Year	5.946	8.536,95	12.952,68
Sixth Year	4.500	8.536,95	16.990,00

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	8.844	12.805,43	3.961,83
Second Year	8.844	12.805,43	7.923,67
Third Year	8.844	12.805,43	11.885,50
Fourth Year	8.844	12.805,43	15.847,34
Fifth Year	8.844	12.805,43	19.809,17
Sixth Year	6.674	12.805,43	25.940,14

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	11.741	17.073,90	5.333,13
Second Year	11.741	17.073,90	10.666,26
Third Year	11.741	17.073,90	15.999,40
Fourth Year	11.741	17.073,90	21.332,53
Fifth Year	11.741	17.073,90	26.665,66
Sixth Year	8.849	17.073,90	34.890,29

Avoided CO_2 emissions (Kg/year)	
79,60	case 1
159,21	case 2
238,81	case 3
318,42	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	271,05	81,31

MUNICIPALITY OF MASCHITO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
272,04	445,33	67,54	120,31

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.864,7	5.729,5	8.594,2	11.459
User training (€)	0	0	0	0
Sensors (€)	8,19	24,56	32,75	40,94
Municipality initial costs (€)	2.872,9	5.754,06	8.627	11.499,9
Operator control (€/year)	1.729,9	3.459,8	5.189,7	6.920
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.879,9	3.609,8	5.339,7	7.069,6

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	2.455	3.715,87	1.261,36
Second Year	2.455	3.715,87	2.522,72
Third Year	2.455	3.715,87	3.784,07
Fourth Year	2.455	3.715,87	5.045,43
Fifth Year	2.455	3.715,87	6.306,79
Sixth Year	1.880	3.715,87	8.142,73

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	4.761	7.431,73	2.671,08
Second Year	4.761	7.431,73	5.342,16
Third Year	4.761	7.431,73	8.013,23
Fourth Year	4.761	7.431,73	10.684,31
Fifth Year	4.761	7.431,73	13.355,39
Sixth Year	3.610	7.431,73	17.177,28

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	7.065	11.147,60	4.082,44
Second Year	7.065	11.147,60	8.164,87

Third Year	7.065	11.147,60	12.247,31
Fourth Year	7.065	11.147,60	16.329,74
Fifth Year	7.065	11.147,60	20.412,18
Sixth Year	5.340	11.147,60	26.220,01

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	9.370	14.863,47	5.493,79
Second Year	9.370	14.863,47	10.987,59
Third Year	9.370	14.863,47	16.481,38
Fourth Year	9.370	14.863,47	21.975,17
Fifth Year	9.370	14.863,47	27.468,97
Sixth Year	7.070	14.863,47	35.262,75

Avoided CO_2 emissions (Kg/year)	
69,30	case 1
138,60	case 2
207,90	case 3
277,19	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	285,17	85,55

MUNICIPALITY OF MONTEMILONE

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
300,6	479,16	67,54	129,45

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.789,5	5.579	8.368,5	11.158
User training (€)	0	0	0	0
Sensors (€)	7,97	23,92	31,89	39,87
Municipality initial costs (€)	2.797,4	5.602,9	8.400,3	11.197,8

Operator control (€/year)	16.84,4	33.68,9	5.053,4	6.738
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.834,4	3.518,9	5.203,4	6.887,9

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	2.394	3.998,12	1.604,15
Second Year	2.394	3.998,12	3.208,29
Third Year	2.394	3.998,12	4.812,44
Fourth Year	2.394	3.998,12	6.416,58
Fifth Year	2.394	3.998,12	8.020,73
Sixth Year	1.834	3.998,12	10.184,37

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	4.640	7.996,24	3.356,70
Second Year	4.640	7.996,24	6.713,40
Third Year	4.640	7.996,24	10.070,09
Fourth Year	4.640	7.996,24	13.426,79
Fifth Year	4.640	7.996,24	16.783,49
Sixth Year	3.519	7.996,24	21.260,77

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	6.884	11.994,36	5.110,84
Second Year	6.884	11.994,36	10.221,69
Third Year	6.884	11.994,36	15.332,53
Fourth Year	6.884	11.994,36	20.443,38
Fifth Year	6.884	11.994,36	25.554,22
Sixth Year	5.203	11.994,36	32.345,14

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	9.127	15.992,49	6.864,99
Second Year	9.127	15.992,49	13.729,98
Third Year	9.127	15.992,49	20.594,97
Fourth Year	9.127	15.992,49	27.459,96
Fifth Year	9.127	15.992,49	34.324,95
Sixth Year	6.888	15.992,49	43.429,51

Avoided CO_2 emissions (Kg/year)	
74,56	case 1
149,13	case 2
223,69	case 3
298,25	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	196,15	58,85

MUNICIPALITY OF BANZI

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
302,69	401,37	67,54	108,43

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.320,5	4.641	6.961,5	9.282
User training (€)	0	0	0	0
Sensors (€)	6,63	19,90	26,53	33,16
Municipality initial costs (€)	2.327,1	4.660,9	6.988,03	9.315,1
Operator control (€/year)	1.401,27	2.802,54	4.203,8	5.605
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.551,2	2.952,5	4.353,8	5.755,07

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	2.017	3.344,59	1.327,89
Second Year	2.017	3.344,59	2.655,78
Third Year	2.017	3.344,59	3.983,67
Fourth Year	2.017	3.344,59	5.311,57
Fifth Year	2.017	3.344,59	6.639,46
Sixth Year	1.551	3.344,59	8.432,78

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	3.885	6.689,17	2.804,46
Second Year	3.885	6.689,17	5.608,91
Third Year	3.885	6.689,17	8.413,37
Fourth Year	3.885	6.689,17	11.217,83
Fifth Year	3.885	6.689,17	14.022,28
Sixth Year	2.953	6.689,17	17.758,92

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.751	10.033,76	4.282,35
Second Year	5.751	10.033,76	8.564,70
Third Year	5.751	10.033,76	12.847,04
Fourth Year	5.751	10.033,76	17.129,39
Fifth Year	5.751	10.033,76	21.411,74
Sixth Year	4.354	10.033,76	27.091,69

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.618	13.378,34	5.760,24
Second Year	7.618	13.378,34	11.520,48
Third Year	7.618	13.378,34	17.280,72
Fourth Year	7.618	13.378,34	23.040,96
Fifth Year	7.618	13.378,34	28.801,20
Sixth Year	5.755	13.378,34	36.424,47

Avoided CO_2 emissions (Kg/year)	
55,81	case 1
111,61	case 2
167,42	case 3
223,23	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	219,85	69,95

MUNICIPALITY OF ACERENZA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
269,72	641,93	67,54	173,42

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	4.165	8.330	12.495	16.660
User training (€)	0	0	0	0
Sensors (€)	11,90	35,71	47,62	59,52
Municipality initial costs (€)	4.176,9	8.365,7	12.542,6	16.719,5
Operator control (€/year)	2.515,1	5.030,1	7.545,2	10.060
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	2.665,1	5.180,1	7.695,2	10.210,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	3.500	5.522,53	2.022,05
Second Year	3.500	5.522,53	4.044,10
Third Year	3.500	5.522,53	6.066,15
Fourth Year	3.500	5.522,53	8.088,20
Fifth Year	3.500	5.522,53	10.110,24
Sixth Year	2.665	5.522,53	12.967,67

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	6.853	11.045,05	4.191,72
Second Year	6.853	11.045,05	8.383,43
Third Year	6.853	11.045,05	12.575,15
Fourth Year	6.853	11.045,05	16.766,87
Fifth Year	6.853	11.045,05	20.958,58
Sixth Year	5.180	11.045,05	26.823,44

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	10.204	16.567,58	6.363,77
Second Year	10.204	16.567,58	12.727,53

Third Year	10.204	16.567,58	19.091,30
Fourth Year	10.204	16.567,58	25.455,06
Fifth Year	10.204	16.567,58	31.818,83
Sixth Year	7.695	16.567,58	40.691,12

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	13.554	22.090,11	8.535,81
Second Year	13.554	22.090,11	17.071,63
Third Year	13.554	22.090,11	25.607,44
Fourth Year	13.554	22.090,11	34.143,26
Fifth Year	13.554	22.090,11	42.679,07
Sixth Year	10.210	22.090,11	54.558,79

Avoided CO_2 emissions (Kg/year)	
89,07	case 1
178,14	case 2
267,21	case 3
356,28	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	286,13	85,84

MUNICIPALITY OF SAN CHIRICO NUOVO

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
269,5	362,48	67,54	97,93

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.353,75	4.707,5	7.061,2	9.415
User training (€)	0	0	0	0
Sensors (€)	6,73	20,18	26,91	33,64
Municipality initial costs (€)	2.360,4	4.727,6	7.088,1	9.448,6
Operator control (€/year)	1.421,3	2.842,6	4.264,04	5.685,3

Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.571,3	2.992,6	4.414,04	5.835,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	2.043	3.018,11	9.74,67
Second Year	2.043	3.018,11	1.949,33
Third Year	2.043	3.018,11	2.924,00
Fourth Year	2.043	3.018,11	3.898,66
Fifth Year	2.043	3.018,11	4.873,33
Sixth Year	1.571	3.018,11	6.320,09

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	3.938	6.036,22	2.097,99
Second Year	3.938	6.036,22	4.195,97
Third Year	3.938	6.036,22	6.293,96
Fourth Year	3.938	6.036,22	8.391,94
Fifth Year	3.938	6.036,22	10.489,93
Sixth Year	2.993	6.036,22	13.533,45

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.832	9.054,32	3.222,65
Second Year	5.832	9.054,32	6.445,30
Third Year	5.832	9.054,32	9.667,95
Fourth Year	5.832	9.054,32	12.890,60
Fifth Year	5.832	9.054,32	16.113,26
Sixth Year	4.414	9.054,32	20..753,54

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.725	12.072,43	4.347,32
Second Year	7.725	12.072,43	8.694,63
Third Year	7.725	12.072,43	13.041,95
Fourth Year	7.725	12.072,43	17.389,27
Fifth Year	7.725	12.072,43	21.736,58
Sixth Year	5.835	12.072,43	27.973,63

Avoided CO_2 emissions (Kg/year)	
46,80	case 1
93,59	case 2
140,39	case 3
187,18	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	262,93	78,88

MUNICIPALITY OF CANCELLARA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
232,1	282,93	67,54	76,44

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.133,2	4.266,5	6.399,7	8.533
User training (€)	0	0	0	0
Sensors (€)	6,10	18,29	24,39	30,49
Municipality initial costs (€)	2.139,3	4.284,7	6.424,1	8.563,4
Operator control (€/year)	1.288,1	2.576,3	3.864,5	5.152,7
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.438,1	2.726,3	4.014,5	5.302,7

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	1.866	2.358,20	492,13
Second Year	1.866	2.358,20	984,27
Third Year	1.866	2.358,20	1.476,40
Fourth Year	1.866	2.358,20	1.968,53
Fifth Year	1.866	2.358,20	2.460,67
Sixth Year	1.438	2.358,20	3.380,67

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	3.583	4.716,40	1.133,05
Second Year	3.583	4.716,40	2.266,10
Third Year	3.583	4.716,40	3.399,14
Fourth Year	3.583	4.716,40	4.532,19
Fifth Year	3.583	4.716,40	5.665,24
Sixth Year	2.726	4.716,40	7.655,25

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.299	7.074,59	1.775,18
Second Year	5.299	7.074,59	3.550,36
Third Year	5.299	7.074,59	5.325,54
Fourth Year	5.299	7.074,59	7.100,73
Fifth Year	5.299	7.074,59	8.875,91
Sixth Year	4.015	7.074,59	11.935,92

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	7.015	9.432,79	2.417,32
Second Year	7.015	9.432,79	4.834,63
Third Year	7.015	9.432,79	7.251,95
Fourth Year	7.015	9.432,79	9.669,26
Fifth Year	7.015	9.432,79	12.086,58
Sixth Year	5.303	9.432,79	16.216,59

Avoided CO_2 emissions (Kg/year)	
40,15	case 1
80,31	case 2
120,46	case 3
160,62	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	256,64	76,99

MUNICIPALITY OF PIETRAGALLA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
279,56	1.116	49,9	222,75

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	6.986	13.972	20.958	27.944
User training (€)	0	0	0	0
Sensors (€)	19,97	59,90	79,87	99,84
Municipality initial costs (€)	7.005,9	14.031,9	21.037,8	28.043,8
Operator control (€/year)	4.218,6	8.437,2	12.655,8	16.874,4
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.368,6	8.587,2	12.805,8	17.024,4

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.770	7.097,11	1.327,32
Second Year	5.770	7.097,11	2.654,64
Third Year	5.770	7.097,11	3.981,96
Fourth Year	5.770	7.097,11	5.309,27
Fifth Year	5.770	7.097,11	6.636,59
Sixth Year	4.369	7.097,11	9.365,10

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	11.394	14.194,22	2.800,64
Second Year	11.394	14.194,22	5.601,29
Third Year	11.394	14.194,22	8.401,93
Fourth Year	11.394	14.194,22	11.202,57
Fifth Year	11.394	14.194,22	14.003,22
Sixth Year	8.587	14.194,22	19.610,24

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	17.013	21.291,33	4.277,96

Second Year	17.013	21.291,33	8.555,92
Third Year	17.013	21.291,33	12.833,89
Fourth Year	17.013	21.291,33	17.111,85
Fifth Year	17.013	21.291,33	21.389,81
Sixth Year	12.806	21.291,33	29.875,35

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	22.633	28.388,44	5.755,28
Second Year	22.633	28.388,44	11.510,56
Third Year	22.633	28.388,44	17.265,84
Fourth Year	22.633	28.388,44	23.021,12
Fifth Year	22.633	28.388,44	28.776,40
Sixth Year	17.024	28.388,44	40.140,45

Avoided CO_2 emissions (Kg/year)	
119,99	case 1
239,98	case 2
359,97	case 3
479,96	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	208,59	62,58

MUNICIPALITY OF AVIGLIANO

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
308,97	3.538,63	55,7	788,41

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	20.042,7	40.085,	60.128,2	80.171
User training (€)	0	0	0	0
Sensors (€)	57,29	171,86	229,15	286,44
Municipality initial costs (€)	20.100	40.257,4	60.357,4	80.457,4

Operator control (€/year)	12.103,1	24.206,2	36.309,3	48.412,4
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	12.253,1	24.356,2	36.459,3	48.562,4

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	16.273	25.217,78	8.944,66
Second Year	16.273	25.217,78	17.889,32
Third Year	16.273	25.217,78	26.833,98
Fourth Year	16.273	25.217,78	35.778,64
Fifth Year	16.273	25.217,78	44.723,30
Sixth Year	12.253	25.217,78	57.687,97

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	32.408	50.435,56	18.027,86
Second Year	32.408	50.435,56	36.055,73
Third Year	32.408	50.435,56	54.083,59
Fourth Year	32.408	50.435,56	72.111,45
Fifth Year	32.408	50.435,56	90.139,32
Sixth Year	24.356	50.435,56	116.218,65

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	48.531	75.653,33	27.122,52
Second Year	48.531	75.653,33	54.245,05
Third Year	48.531	75.653,33	81.367,57
Fourth Year	48.531	75.653,33	108.490,09
Fifth Year	48.531	75.653,33	135.612,62
Sixth Year	36.459	75.653,33	174.806,62

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	64.654	10.0871,11	36.217,18
Second Year	64.654	10.0871,11	72.434,37
Third Year	64.654	10.0871,11	108.651,55
Fourth Year	64.654	10.0871,11	144.868,73
Fifth Year	64.654	10.0871,11	181.085,92
Sixth Year	48.562	10.0871,11	233.394,59

Avoided CO_2 emissions (Kg/year)	
571,86	case 1
1143,72	case 2
1715,57	case 3
2287,43	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	178,44	53,53

MUNICIPALITY OF MOLITERNO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
250,81	945,8	82,53	312,53

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	6.599,25	13.198,5	19.797,7	26.397
User training (€)	0	0	0	0
Sensors (€)	18,86	37,73	56,59	75,45
Municipality initial costs (€)	6.618,1	13.236,2	19.854,3	26.472,4
Operator control (€/year)	3.985,05	7.970,1	11.955,1	15.940,2
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.135,05	8.120,1	12.105,1	16.090,2

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	5.459	9.682,44	4.223,77
Second Year	5.459	9.682,44	8.447,53
Third Year	5.459	9.682,44	12.671,30
Fourth Year	5.459	9.682,44	16.895,07
Fifth Year	5.459	9.682,44	21.118,83
Sixth Year	4.135	9.682,44	26.666,22

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**

First Year	10.767	19.364,89	8.597,53
Second Year	10.767	19.364,89	17.195,07
Third Year	10.767	19.364,89	25.792,60
Fourth Year	10.767	19.364,89	34.390,14
Fifth Year	10.767	19.364,89	42.987,67
Sixth Year	8.120	19.364,89	54.232,45

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	16.076	29.047,33	12.971,30
Second Year	16.076	29.047,33	25.942,60
Third Year	16.076	29.047,33	38.913,90
Fourth Year	16.076	29.047,33	51.885,20
Fifth Year	16.076	29.047,33	64.856,50
Sixth Year	12.105	29.047,33	81.798,67

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	21.385	38.729,78	17.345,07
Second Year	21.385	38.729,78	34.690,14
Third Year	21.385	38.729,78	52.035,20
Fourth Year	21.385	38.729,78	69.380,27
Fifth Year	21.385	38.729,78	86.725,34
Sixth Year	16..090	38.729,78	109.364,90

Avoided CO_2 emissions (Kg/year)	
238,13	case 1
476,25	case 2
714,38	case 3
952,51	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	235,66	70,7

MUNICIPALITY OF GRUMENTO NOVA

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
261,72	432,88	71,63	124,03

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.894,5	5.789	8.683,5	11.578
User training (€)	0	0	0	0
Sensors (€)	8,27	16,55	24,82	33,09
Municipality initial costs (€)	2.902,7	5.805,5	8.708,3	11.611,09
Operator control (€/year)	1.747,8	3.495,7	5.243,6	6.991,5
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.897,8	3.645,7	5.393,6	7.141,5

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	2.478	3.843,61	1.365,17
Second Year	2.478	3.843,61	2.730,33
Third Year	2.478	3.843,61	4.095,50
Fourth Year	2.478	3.843,61	5.460,66
Fifth Year	2.478	3.843,61	6.825,83
Sixth Year	1.898	3.843,61	8.771,55

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	4.807	7.687,21	2.880,33
Second Year	4.807	7.687,21	5.760,66
Third Year	4.807	7.687,21	8.640,99
Fourth Year	4.807	7.687,21	11.521,32
Fifth Year	4.807	7.687,21	14.401,65
Sixth Year	3.646	7.687,21	18.443,09

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	7.135	11.530,82	4.395,50
Second Year	7.135	11.530,82	8.790,99

Third Year	7.135	11.530,82	13.186,49
Fourth Year	7.135	11.530,82	17.581,99
Fifth Year	7.135	11.530,82	21.977,48
Sixth Year	5.394	11.530,82	28.114,64

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	9.464	15.374,43	5.910,66
Second Year	9.464	15.374,43	11.821,32
Third Year	9.464	15.374,43	17.731,99
Fourth Year	9.464	15.374,43	23.642,65
Fifth Year	9.464	15.374,43	29.553,31
Sixth Year	7.142	15.374,43	37.786,19

Avoided CO_2 emissions (Kg/year)	
90,62	case 1
181,25	case 2
271,87	case 3
362,50	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	288,77	86,63

MUNICIPALITY OF TRAMUTOLA

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
252,75	756,23	94,56	286,04

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	5.236	10.472	15.708	20.944
User training (€)	0	0	0	0
Sensors (€)	14,97	29,93	44,90	59,86
Municipality initial costs (€)	5.250,9	10.501,9	15.752,9	21.003,8

Operator control (€/year)	3.161,8	6.323,6	9.485,5	12.647,3
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	3.311,8	6.473,6	9.635,5	12.797,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	4.362	8.874,26	4.512,23
Second Year	4.362	8.874,26	9.024,46
Third Year	4.362	8.874,26	13.536,68
Fourth Year	4.362	8.874,26	18.048,91
Fifth Year	4.362	8.874,26	22.561,14
Sixth Year	3.312	8.874,26	28.123,56

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	8.574	17.748,51	9.174,46
Second Year	8.574	17.748,51	18.348,91
Third Year	8.574	17.748,51	27.523,37
Fourth Year	8.574	17.748,51	36.697,82
Fifth Year	8.574	17.748,51	45.872,28
Sixth Year	6.474	17.748,51	57.147,12

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	12.786	26.622,77	13.836,68
Second Year	12.786	26.622,77	27.673,37
Third Year	12.786	26.622,77	41.510,05
Fourth Year	12.786	26.622,77	55.346,74
Fifth Year	12.786	26.622,77	69.183,42
Sixth Year	9.636	26.622,77	86.170,68

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	16.998	35.497,03	18.498,91
Second Year	16.998	35.497,03	36.997,82
Third Year	16.998	35.497,03	55.496,74
Fourth Year	16.998	35.497,03	73.995,65
Fifth Year	16.998	35.497,03	92.494,56
Sixth Year	12.797	35.497,03	115.194,24

Avoided CO_2 emissions (Kg/year)	
224,25	case 1
448,50	case 2
672,76	case 3
897,01	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	175,05	52,51

MUNICIPALITY OF MARSICOVETERE

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
314,7	1.756,97	64,82	455,55

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	9.770,2	19.540,5	29.310,7	39.081
User training (€)	0	0	0	0
Sensors (€)	27,9	55,8	83,7	111,7
Municipality initial costs (€)	9.798,1	19.596,3	29.394,5	39.192,7
Operator control (€/year)	5.899,9	11.799,8	17.699,7	23.599,6
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	6.049,9	11.949,8	17.849,7	23.749,6

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	8.010	14.139,86	6.130,32
Second Year	8.010	14.139,86	12.260,63
Third Year	8.010	14.139,86	18.390,95
Fourth Year	8.010	14.139,86	24.521,26
Fifth Year	8.010	14.139,86	30.651,58
Sixth Year	6.050	14.139,86	38.741,53

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**

First Year	15.869	28.279,72	12.410,63
Second Year	15.869	28.279,72	24.821,26
Third Year	15.869	28.279,72	37.231,89
Fourth Year	15.869	28.279,72	49.642,52
Fifth Year	15.869	28.279,72	62.053,15
Sixth Year	11.950	28.279,72	78.383,05

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	23.729	42.419,58	18.690,95
Second Year	23.729	42.419,58	37.381,89
Third Year	23.729	42.419,58	56.072,84
Fourth Year	23.729	42.419,58	74.763,78
Fifth Year	23.729	42.419,58	93.454,73
Sixth Year	17.850	42.419,58	118.024,58

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	31.588	56.559,44	24.971,26
Second Year	31.588	56.559,44	49.942,52
Third Year	31.588	56.559,44	74.913,78
Fourth Year	31.588	56.559,44	99.885,04
Fifth Year	31.588	56.559,44	124.856,31
Sixth Year	23.750	56.559,44	157.666,11

Avoided CO_2 emissions (Kg/year)	
366,87	case 1
733,73	case 2
1100,60	case 3
1467,47	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	138,71	41,61

MUNICIPALITY OF CALVELLO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
296,41	548,65	67,3	147,7

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	3.239,2	6.478,5	9.717,7	12.957
User training (€)	0	0	0	0
Sensors (€)	9,26	18,52	27,78	37,03
Municipality initial costs (€)	3.248,5	6.497,02	9.745,5	12.994,03
Operator control (€/year)	1.956,07	3.912,1	5.868,2	7.824,2
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	2.106,07	4.062,1	6.018,2	7.974,2

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	2.756	4.567,56	1.811,79
Second Year	2.756	4.567,56	3.623,57
Third Year	2.756	4.567,56	5.435,36
Fourth Year	2.756	4.567,56	7.247,15
Fifth Year	2.756	4.567,56	9.058,94
Sixth Year	2.106	4.567,56	11.520,42

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	5.362	9.135,12	3.773,57
Second Year	5.362	9.135,12	7.547,15
Third Year	5.362	9.135,12	11.320,72
Fourth Year	5.362	9.135,12	15.094,30
Fifth Year	5.362	9.135,12	18.867,87
Sixth Year	4.062	9.135,12	23.940,85

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	7.967	13.702,67	5.735,36
Second Year	7.967	13.702,67	11.470,72

Third Year	7.967	13.702,67	17.206,08
Fourth Year	7.967	13.702,67	22.941,44
Fifth Year	7.967	13.702,67	28.676,81
Sixth Year	6.018	13.702,67	36.361,27

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	10.573	18.270,23	7.697,15
Second Year	10.573	18.270,23	15.394,30
Third Year	10.573	18.270,23	23.091,44
Fourth Year	10.573	18.270,23	30.788,59
Fifth Year	10.573	18.270,23	38.485,74
Sixth Year	7.974	18.270,23	48.781,70

Avoided CO_2 emissions (Kg/year)	
93,74	case 1
187,48	case 2
281,22	case 3
374,96	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	124,56	37,36

MUNICIPALITY OF MARSICONUOVO

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
263,35	1.066,04	51,91	221,35

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	7.084	14.168	21.252	28.336
User training (€)	0	0	0	0
Sensors (€)	20,25	40,50	60,74	80,99
Municipality initial costs (€)	7.104,2	14.208,5	21.312,7	28.416,9
Operator control (€/year)	4.277,7	8.555,5	12.833,3	17.111,1

Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	4.427,7	8.705,5	12.983,3	17.261,1

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.849	6.873,00	1.024,37
Second Year	5.849	6.873,00	2.048,75
Third Year	5.849	6.873,00	3.073,12
Fourth Year	5.849	6.873,00	4.097,50
Fifth Year	5.849	6.873,00	5.121,87
Sixth Year	4.428	6.873,00	7.567,10

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	11.547	13.746	2.198,75
Second Year	11.547	13.746	4.397,50
Third Year	11.547	13.746	6.596,25
Fourth Year	11.547	13.746	8.794,99
Fifth Year	11.547	13.746	10.993,74
Sixth Year	8.706	13.746	16.034,19

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	17.246	20.619,01	33.73,12
Second Year	17.246	20.619,01	6.746,25
Third Year	17.246	20.619,01	10.119,37
Fourth Year	17.246	20.619,01	13.492,49
Fifth Year	17.246	20.619,01	16.865,61
Sixth Year	12.983	20.619,01	24.501,29

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	22945	27.492,01	4.547,50
Second Year	22.945	27.492,01	9.094,99
Third Year	22.945	27.492,01	13.642,49
Fourth Year	22.945	27.492,01	18.189,99
Fifth Year	22.945	27.492,01	22.737,49
Sixth Year	17261	27.492,01	32.968,38

Avoided CO$_2$ emissions (Kg/year)	
181,80	case 1
363,61	case 2
545,41	case 3
727,22	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	149,55	44,87

MUNICIPALITY OF SARCONI

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
259,59	369,4	90,45	133,65

ANNUAL FIXED COSTS

Sustained costs	Case 1 (10%)	Case 2 (20%)	Case 3 (30%)	Case 4 (40%)
Compost bin investment cost (€)	2.490,2	4.980,5	7.470,7	9.961
User training (€)	0	0	0	0
Sensors (€)	7,12	14,24	21,35	28,47
Municipality initial costs (€)	2.497,3	4.994,7	7.492,1	9.989,4
Operator control (€/year)	1.503,7	3.007,5	4.511,3	6.015,1
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.653,7	3.157,5	4.661,3	6.165,1

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	2.153	4.142,60	1.989,35
Second Year	2.153	4.142,60	3.978,71
Third Year	2.153	4.142,60	5.968,06
Fourth Year	2.153	4.142,60	7.957,41
Fifth Year	2.153	4.142,60	9.946,77
Sixth Year	1.654	4.142,60	12.435,59

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)

First Year	4.156	8.285,20	4.128,71
Second Year	4.156	8.285,20	8.257,41
Third Year	4.156	8.285,20	12.386,12
Fourth Year	4.156	8.285,20	16.514,82
Fifth Year	4.156	8.285,20	20.643,53
Sixth Year	3.158	8.285,20	25.771,18

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	6.160	12.427,80	6.268,06
Second Year	6.160	12.427,80	12.536,12
Third Year	6.160	12.427,80	18.804,18
Fourth Year	6.160	12.427,80	2.5072,24
Fifth Year	6.160	12.427,80	3.1340,30
Sixth Year	4.661	12.427,80	3.9106,77

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	8.163	16.570,40	8.407,41
Second Year	8.163	16.570,40	16.814,82
Third Year	8.163	16.570,40	25.222,24
Fourth Year	8.163	16.570,40	33.629,65
Fifth Year	8.163	16.570,40	42.037,06
Sixth Year	6.165	16.570,40	52.442,37

Avoided CO_2 emissions (Kg/year)	
99,08	case 1
198,15	case 2
297,23	case 3
396,31	case 4

Waste tax reduction

Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	271,73	81,52

MUNICIPALITY OF SAN CHIRICO RAPARO

INPUT FLOWS

Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
315,93	305,19	67,54	82,45

ANNUAL FIXED COSTS

Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	1.690,5	3.381	5.071,5	6.762
User training (€)	0	0	0	0
Sensors (€)	4,83	9,66	14,50	19,33
Municipality initial costs (€)	1.695,3	3.390,6	5.086	6.781,3
Operator control (€/year)	1.020,8	2.041,6	3.062,5	4.083,3
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.170,8	2.191,6	3.212,5	4.233,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	1.510	2.551,23	1.041,33
Second Year	1.510	2.551,23	2.082,66
Third Year	1.510	2.551,23	3.123,99
Fourth Year	1.510	2.551,23	4.165,32
Fifth Year	1.510	2.551,23	5.206,65
Sixth Year	1.171	2.551,23	6.587,04

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	2.870	5.102,46	2.232,66
Second Year	2.870	5.102,46	4.465,32
Third Year	2.870	5.102,46	6.697,98
Fourth Year	2.870	5.102,46	8.930,63
Fifth Year	2.870	5.102,46	11.163,29
Sixth Year	2.192	5.102,46	14.074,08

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	4.230	7.653,69	3.423,99
Second Year	4.230	7.653,69	6.847,98

Third Year	4.230	7.653,69	10.271,96
Fourth Year	4.230	7.653,69	13.695,95
Fifth Year	4.230	7.653,69	17.119,94
Sixth Year	3.213	7.653,69	21.561,13

CASE 4: 60% Separate collection + 40% Domestic composting			
	Costs (€)	**Saving (€)**	**Final saving (€)**
First Year	5.590	10.204,92	4.615,32
Second Year	5.590	10.204,92	9.230,63
Third Year	5.590	10.204,92	13.845,95
Fourth Year	5.590	10.204,92	18.461,27
Fifth Year	5.590	10.204,92	23.076,59
Sixth Year	4.233	10.204,92	29.048,17

Avoided CO_2 emissions (Kg/year)	
54,53	case 1
109,05	case 2
163,58	case 3
218,11	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	142,01	42,6

MUNICIPALITY OF MONTEMURRO

INPUT FLOWS			
Per capita municipal waste production (Kg/inhabit.*year)	Total municipal waste production (tons/year)	% Separate collection	Organic waste total production (tons/year)
222,92	258,59	73,49	76,01

ANNUAL FIXED COSTS				
Sustained costs	**Case 1 (10%)**	**Case 2 (20%)**	**Case 3 (30%)**	**Case 4 (40%)**
Compost bin investment cost (€)	2.030	4.060	6.090	8.120
User training (€)	0	0	0	0
Sensors (€)	5,80	11,60	17,41	23,21

Municipality initial costs (€)	2.035,8	4.071,6	6.107,4	8.143,2
Operator control (€/year)	1.225,8	2.451,6	3.677,5	4.903,3
Electricity consumption (€/year)	0	0	0	0
Compost bin maintenance (€/year)	150	150	150	150
Municipality fixed costs (€/year)	1.375,8	2.601,6	3.827,5	5.053,3

CASE 1: 90% Separate collection + 10% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	1.783	2.359,43	576,42
Second Year	1.783	2.359,43	1.152,85
Third Year	1.783	2.359,43	1.729,27
Fourth Year	1.783	2.359,43	2.305,69
Fifth Year	1.783	2.359,43	2.882,12
Sixth Year	1.376	2.359,43	3.865,70

CASE 2: 80% Separate collection + 20% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	3.416	4.718,86	1.302,85
Second Year	3.416	4.718,86	2.605,69
Third Year	3.416	4.718,86	3.908,54
Fourth Year	3.416	4.718,86	5.211,39
Fifth Year	3.416	4.718,86	6.514,23
Sixth Year	2.602	4.718,86	8.631,40

CASE 3: 70% Separate collection + 30% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	5.049	7.078,29	2.029,27
Second Year	5.049	7.078,29	4.058,54
Third Year	5.049	7.078,29	6.087,81
Fourth Year	5.049	7.078,29	8.117,08
Fifth Year	5.049	7.078,29	10.146,35
Sixth Year	3.828	7.078,29	13.397,10

CASE 4: 60% Separate collection + 40% Domestic composting

	Costs (€)	Saving (€)	Final saving (€)
First Year	6.682	9.437,72	2.755,69
Second Year	6.682	9.437,72	5.511,39
Third Year	6.682	9.437,72	8.267,08
Fourth Year	6.682	9.437,72	11.022,78
Fifth Year	6.682	9.437,72	13.778,47
Sixth Year	5.053	9.437,72	18.162,81

Avoided CO_2 emissions (Kg/year)	
61,22	case 1
122,43	case 2
183,65	case 3
244,87	case 4

Waste tax reduction		
Discount (%)	Waste tax (€/year)	Final saving (€/family/year)
30	246,52	73,96

ATTACHMENT 3

DOMESTIC COMPOSTING – MODEL 3

This section presents in tabular format the economic and environmental saving associated with the "home composting" model relative to the city of Plovdiv.

CASE 1: 90% Landfill + 10% Domestic composting

	Costs(€)	Saving (€)	Final Saving (€)
First Year	273.460	284.959,78	11.499,66
Second Year	273.460	284.959,78	22.999,31
Third Year	273.460	284.959,78	34.498,97
Fourth Year	273.460	284.959,78	45.998,63
Fifth Year	273.460	284.959,78	57.498,28
Sixth Year	153.741	284.959,78	188.717,03

CASE 2: 80% Landfill + 20% Domestic composting

	Costs(€)	Saving (€)	Final Saving (€)
First Year	546.770	569.919,56	23.149,31
Second Year	546.770	569.919,56	46.298,63
Third Year	546.770	569.919,56	69.447,94
Fourth Year	546.770	569.919,56	92.597,25
Fifth Year	546.770	569.919,56	115.746,57
Sixth Year	307.332	569.919,56	378.334,06

CASE 3: 70% Landfill + 30% Domestic composting

	Costs(€)	Saving (€)	Final Saving (€)
First Year	820.080	854.879,34	34.798,97
Second Year	820.080	854.879,34	69.597,94
Third Year	820.080	854.879,34	104.396,91
Fourth Year	820.080	854.879,34	139.195,88
Fifth Year	820.080	854.879,34	173.994,85
Sixth Year	460.923	854.879,34	567.951,09

CASE 4: 60% Landfill + 40% Domestic composting

	Costs(€)	Saving (€)	Final Saving (€)
First Year	1.093.390	1.139.839,12	46.448,63
Second Year	1.093.390	1.139.839,12	92.897,25
Third Year	1.093.390	1.139.839,12	139.345,88
Fourth Year	1.093.390	1.139.839,12	185.794,51
Fifth Year	1.093.390	1.139.839,12	232.243,13
Sixth Year	614.514	1.139.839,12	757.568,12

Avoided CO_2 emissions (Kg/year)	
20.985,03	case 1
41.970,06	case 2
62.955,09	case 3
83.940,12	case 4