

Development of innovative integrated waste recycling schemes for remote areas

V. Panaretou¹, E. Ploumistou¹, E. Katsou¹, D. Tsoukleris², D. Hidalgo³, K. Moustakas¹,
D. Malamis¹, M. Loizidou¹

¹ Unit of Environmental Science & Technology, School of Chemical Engineering, National Technical University of Athens, 9 Iroon Polytechniou Str., Zographou Campus, GR-15773 Athens, Greece

² Municipality of Naxos & Small Cyclades Islands, City Hall, Chora of Naxos, 84300 South Aegean, Greece

³ Agrofood and Sustainable Processes Department, CARTIF Technology Centre, Parque tecnológico de Boecillo, 205. Boecillo, Valladolid, 47151, Spain

Author's email: vpanaretou@gmail.com

Abstract

The **LIFE PAVetheWAYSTE** project, entitled: "Development of innovative integrated waste recycling schemes for remote areas" (LIFE Ref. No: LIFE 14 ENV/GR/000722) is a project co-funded by LIFE, the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. The project implementation areas are the Municipality of Naxos and Small Cyclades Islands (Prefecture of South Aegean) and the Municipality of Ancient Olympia (Prefecture of Western Greece). The main goal of the LIFE PAVetheWAYSTE project is to encourage the local and regional authorities, being the key players in waste management, to implement the provisions of the Waste Framework Directive 2008/98/EC in isolated regions. This will be achieved through the development and implementation of sustainable solid waste management schemes, including the demonstration of innovative systems used for the fine separation and treatment of municipal solid waste at source. The pilot project envisages to facilitate the selected remote municipalities to significantly improve their municipal waste recycling performance and, thus, pave the way to high resource efficiency. The main focus of the present work is the presentation of the main project objectives, as well as of the results achieved so far during the preparatory activities, implemented in the context of Actions A.

Keywords

Remote areas; Integrated Solid Waste Management; Waste Framework Directive; Recyclables; Source separation

1. Introduction

LIFE PAVetheWAYSTE is a pilot project that aims to put into practice, test, evaluate and disseminate a recycling method that is new Union wide. It will facilitate the implementation of waste and resource efficiency-related policy and legislation, including the Roadmap to Resource Efficient Europe, the 7th Environment Action Programme and the Waste Framework Directive (WFD), with particular emphasis on the first steps of the Union waste hierarchy (notably recycling).

Even though recycling rates have been significantly improved throughout the Members States of European Union, there are parts of Europe that still lag behind to implement waste legislation. More particularly, remote areas face difficulties in complying with current waste policies due to lack of infrastructure or lack of accessibility to urban centers. Many parts of Europe (35%) are classified as remote areas - particularly isolated areas, islands and rural areas – which are poorly connected to each other and to central administrative and economic centres. Due to inherent conditions of remote areas (i.e. distance), high transportation and management costs are entailed, making difficult for these territories to adopt options at the upper part and, thus, turning to the lower parts of the waste hierarchy, namely landfilling or even illegal waste management practices, such as uncontrolled dumping of waste. Landfilling of waste causes environmental damage in two ways: (a) *Direct Greenhouse Gas (GHG) emissions* from the decomposition of biowaste (organics and paper); and (b) *Indirect GHG emissions* through increased energy requirements to extract raw materials instead of recycling/recovering the materials from waste. Notably, recycling of aluminium requires 95% less energy than extracting bauxite ore from the physical environment. Unsustainable waste management practices causes, therefore, valuable materials leaking from our economies, when enduring on linear metabolism lifestyles (extract-produce-consume-dispose) rather than following the circular economy model suggested by the Resource Efficient Europe Roadmap. What is more, the WFD also sets specific targets for recycling of MSW (50% of MSW must be recycled by 2020), while source separation of at least metal, plastic, paper and glass should be established since 2015.

In light of the above mentioned, getting the most out of new technologies can improve the waste performance of remote areas, by integrating source separation and volume minimization methods prior to waste transportation to final markets for further exploitation. This project aims to provide a technically feasible and environmental sound technology that is innovative at EU level, suitable for being replicated and transferred in other remote areas in the EU.

More specifically, the main objectives of the project are:

- To establish an integrated, replicable system of innovative character for source separation and treatment of MSW for remote areas in Greece and EU;
- To treat MSW at source avoiding waste collection, transportation and treatment of MSW in central recovery facilities;
- To recover the maximum possible resources generating more than five streams of clean materials, while contributing to diversion of waste from landfill;
- To assess the quality and the marketability of the end products in correlation with the local/regional market specifications and industry specific standards;
- To make recycling of waste an economically attractive option for remote areas, where transportations costs predominate (reduction of waste management cost by 50%);
- To eradicate landfilling and more importantly illegal waste management practices such as uncontrolled waste dumping, currently applied in remote areas;
- To inform and train more than 2,000 citizens on how to sort different types of recyclable material through the set up of innovative prototype systems, operated from specially trained personnel;
- To provide an integrated approach for implementing the targets of Union policy and legislation in the area of resource efficiency through sustainable management of waste in remote areas.

The Municipality of Naxos and Small Cyclades Islands (GR) is the coordinating beneficiary and the Associated Beneficiaries are:

- The National Technical University of Athens (GR),
- The Municipality of Ancient Olympia (GR),
- CARTIF Technology Centre (ES)

More information on the LIFE PAVetheWAYSTE project can be found on the project's website: www.pavethewayste.eu/

2. Methodology

The methodology for the project implementation foresees a series of interrelated actions and activities as shown in Figure 1.

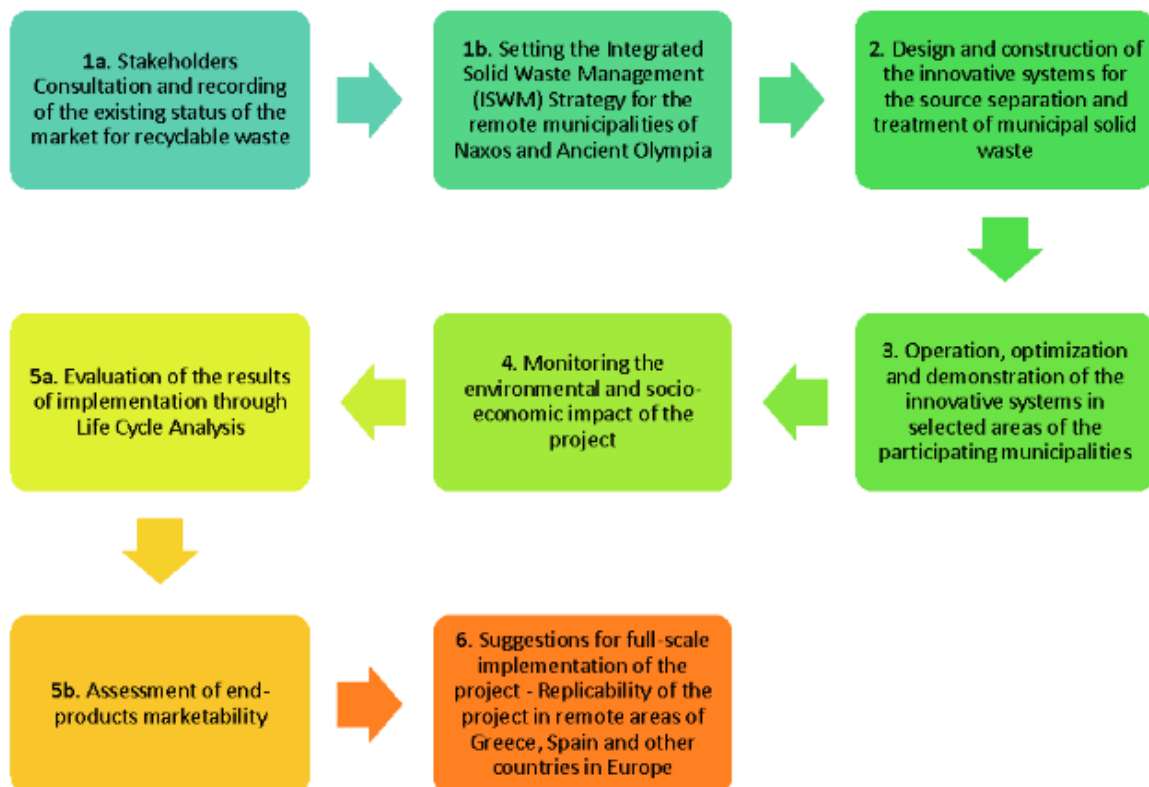


Figure 1 Work methodology steps of LIFE PAVetheWAYSTE project

More specifically, **Steps 1a and 1b** include the preparatory actions of the project that will produce practical recommendations and information to be used during the implementation phase of the project. Such information is related to:

- stakeholder consultation activities in order to identify the most important groups of stakeholders (waste management actors/companies, recycling industries etc.) and establish a dialogue towards determining the existing situation of the market for recyclable waste and engaging potential stakeholders for the demonstration phase of the project; and,
- setting the Integrated Solid Waste Management schemes, tailored to meet the needs of the remote Municipalities of Naxos & Small Cyclades islands and Ancient Olympia.

Furthermore, **Step 2** includes the design and construction of a prototype, innovative system that will recover materials of high quality and purity that can be easily directed to recycling markets for local/regional exploitation. Following, **Step 3** envisages the installation, operation and optimization of the innovatively

designed systems in selected areas of the participating municipalities. The innovative recycling systems will be demonstrated for a certain period of time in the remote communities of the target areas so as to collect sufficient data for the evaluation of the results of the implementation phase through Life Cycle Analysis (**Step 5a**), as well as to conduct an assessment of the end-products marketability in the local and regional markets (**Step 5b**). The demonstration outcomes and impact will be continuously monitored using key performance indicators for assessing the current state and the progress made in the target areas of the project in environmental and socio-economic terms (**Step 4**). Therefore, the overall results from **Steps 5a and 5b** will be used for the investigation of the possibility of full-scale implementation in the target areas and the development of replication studies of the project outcomes in other remote areas (follower municipalities) or Greece, Spain and elsewhere in Europe (**Step 6**).

3. Results

Regarding the progress made so far, the following aspects have been examined and analysed.

Stakeholders' consultation and recording of the existing status of the market for recyclable waste in local and regional level

In the context of this preparatory action (Step 1a), all interested and potential stakeholders activated in the waste management chain and recycling sectors in the proximity to the project target areas, were identified and contacted in order to:

- make stakeholders (companies, industries etc.) understand the aim of the project and appreciate its significance for their own organization and clients;
- organize two stakeholder consultation events in the target areas;
- establish and maintain dialogue with and between relevant stakeholders;
- discuss and debate on the Integrated Solid Waste Management Strategy that will be developed for the targeted remote areas;
- engage stakeholders, including recycling industries & SMEs, during the demonstration action
- determine the specific technical and quality specifications of the waste materials accepted by each company and, thus give critical input for the design of the prototype systems

The findings of this work are summarized below:

The clarification and determination of the requirements set by recycling companies and waste management bodies on the types of materials and the quality specifications required for the further processing of recyclable waste and/or the production of secondary products took place. Firstly, the waste materials targeted in the framework of the project were determined according to the categorization of the European Waste Catalogue (EWC) including the basic waste materials of paper, plastic, metal, glass and organics, as envisaged in the original project proposal (Table 1).

Table 1 Categorization of basic target-materials according to EWC grouping

Code (EWC)	Material
BASIC WASTE STREAMS	
15 01 01	Paper packaging
15 01 02	Plastic packaging
15 01 04	Metal packaging
15 01 05	Mixed packaging

Code (EWC)	Material
BASIC WASTE STREAMS	
15 01 07	Glass packaging
20 01 01	Paper/paperboard
20 01 02	Glass
BIODEGRADABLE WASTE STREAMS	
20 02 01	Biodegradable waste
20 01 08	Biodegradable kitchen and canteen waste

In the course of the preparatory activities, apart from the basic waste streams, specific special waste streams were also considered for being included in the integrated solid waste management schemes for the remote areas since the existing alternative waste collection systems are not sufficiently extended in remote areas. Therefore, the inclusion of the special waste streams will have a positive contribution to the overall recycling rates of the participating municipalities. The special waste streams are included in Table 2, below.

Table 2 Categorization of targeted special waste streams according to EWC grouping

Code (EWC)	Material
SPECIAL WASTE STREAMS	
20 01 33, 20 01 34	Batteries and accumulators included in 16 06 01, 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries
20 01 25, 20 01 26	Edible oil and fat
20 01 36, 20 01 21*, 20 01 35	Discarded electrical and electronic equipment other than those mentioned in 20 01 23 and 20 01 35
20 01 40	Metal scrap
20 01 39	Plastic scrap

Secondly, the identification of the potential interested stakeholders took place, according to the relevant Registry of companies, published at the Greek Ministry of Environment and Climate Change website. This database was updated and the potential interested stakeholders were determined based on their geographical distribution (Peloponnese, Aegean Islands & Attika region). Finally, they were contacted for data collection using telephone, emails and a dedicated questionnaire which was developed for the specific purpose. The action of the “Stakeholders’ Consultation” will be concluded with the organization of two (2) events, one for each remote area in order to inform and establish cooperation with at least 2 stakeholders per targeted waste material.

Regarding the communication results, in total, 473 stakeholders were contacted, being waste management companies, recycling bodies and intermediate actors. From the total number, 64 companies expressed their interest for information and potential active involvement in the project (Response: “Yes”), 143 companies were not interested (Response: “No”), while 229 companies were categorized under responding “Other” which implies that: (i) the company does not exist anymore, (ii) no reply to the phone survey & questionnaire, (iii) their response is still pending from the relevant communication department.

From the 64 companies with the positive response, their interest (i.e. number of companies per waste material) was further classified as follows:

- Paper: 37
- Glass: 28
- Plastic: 36
- Metal: 49

➤ Special waste streams: 8

It is observed that metal, paper and plastic waste streams reflect the highest interest among the other waste streams, and this could be attributed to the higher market value of the specific waste streams.

Furthermore, concerning the geographical distribution vs. interest of companies, 39 companies were interested for collecting materials from the Municipality of Ancient Olympia, whereas for Naxos & Small Cyclades Islands the interest recorded was quite lower, i.e. 25 companies. Additionally, there were also interviewed 12 companies which were interested for participation in the project as long as the source-sorted materials were delivered to their facilities. Here, it was concluded that the majority of stakeholders showed their interest towards the Municipality of Ancient Olympia due to the easier access compared to island regions. The stakeholders interested in waste collection from insular areas posed additional requirements, such as minimum quantity of source-sorted materials and limitations on collection frequency.

In addition, certain quality standards for targeted waste materials were examined, with respect to: (a) separation of materials, (b) reduction of transportation costs (volume reduction and baling). The recording and prioritization of data gave the following results. In total, 59 companies (94%) required the separation of waste materials, while only 4 companies (6%) showed no interest about collecting source-separated waste materials (Figure 2). Going one step further, 8 companies (14% of 59 companies) required the materials to be separated in the basic waste group (i.e. paper, plastic, glass, metal) and 2 companies were only interested for a specific sub-category of waste e.g. PET plastic (Figure 3).

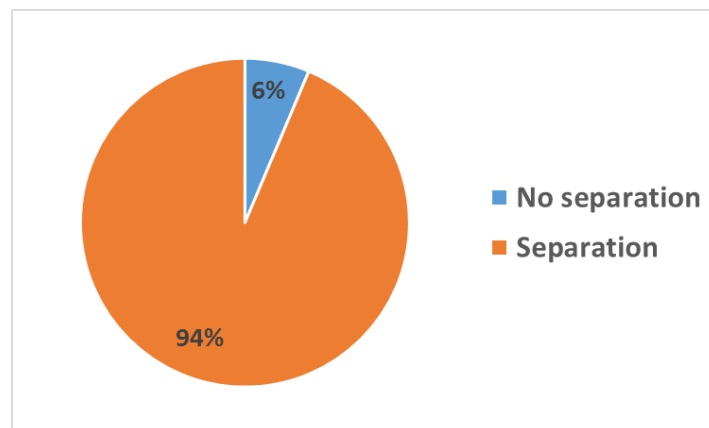


Figure 2 Market requirement for separation or no separation of waste

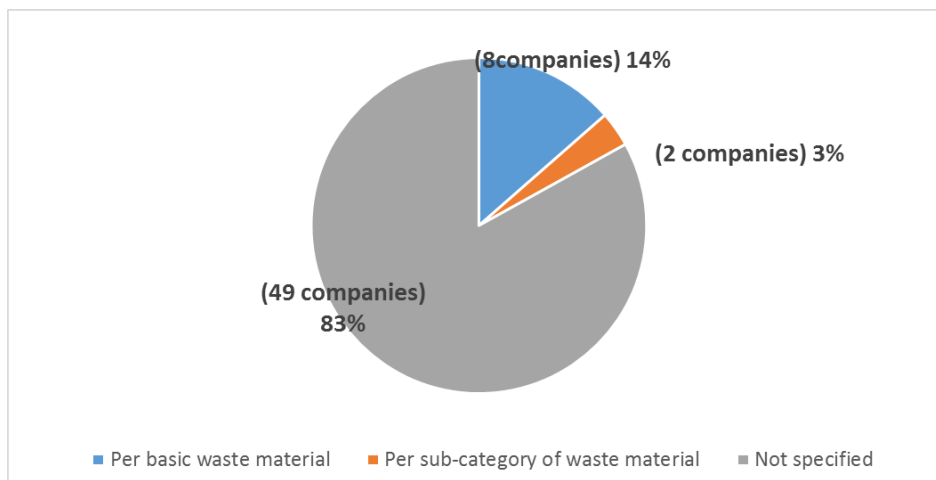


Figure 3 Market requirement for separation of distinctive target waste materials

The high percentage of "no" on the separation of materials can be based on the fact that the majority of the stakeholders contacted were intermediates, and not material processing industries. However, as a general remark it can be said that in the case of source-separated materials, much higher prices can be achieved.

To acquire a more comprehensive "picture" of the market, 37 recyclable materials' processing industries were conducted throughout Greece. The analysis of information collected showed that the top prerequisite of quality specifications was the purity level of waste materials, followed by compression and baling.

Finally, regarding the price of the various targeted materials, it was found that it ranges depending on:

- the type of recyclable material (paper, glass, plastic, metal, WEEE etc.)
- the separation grade of each material (basic material and sub-categories)
- the purity level
- the way of transportation (baled, compressed or loose)
- the transport distance and type of vehicle (by truck, by boat etc.)
- the selling price of recyclables currently in the market, and the price of raw material to determine whether recycling or not economically viable.

Indicatively, the price ranges for various waste materials is shown in Table 3. For the materials reaching the highest market values, their separate collection at source is considered important.

Table 3 Price ranges per basic waste materials and sub-categories

Waste group		Price range (€/tonne)
Paper	News & PAMs	101 - 113
	Mixed papers: domestic	63 - 67
	Mixed papers: export	69 - 75
Plastic	Clear PET	238 - 288
	Coloured PET	38 - 50
	Mixed Bottles	63 - 151
	Natural HDPE	428 - 440
	Mixed HDPE	126 - 145
Other Plastic	LDPE 98/2	377 - 403
Ferrous metals	Grade 10	91 - 189
Non-ferrous metals	Copper dry bright wire	4349 - 4591
	Aluminium pure cuttings	818 - 931
	Lead batteries	503 - 579
Glass	Clear	31 - 44
	Amber	33 - 44
	Green	19 - 31
	Mixed	25 - 31

Setting of the Integrated Solid Waste Management strategies for the remote Municipalities of Naxos & Small Cyclades islands and Ancient Olympia

A. Selection of installation sites for the innovative recycling systems in the target remote areas

The project foresees the demonstration of nine (9) innovative systems for the recycling of MSW produced in the target implementation areas. Each system shall be able to sort and treat different types of recyclables and organic waste in a way to directly recover end-products of high quality and purity in order to be further exploited in the local/regional markets.

The selection of indicative installation points within the project implementation areas was accomplished considering the following:

- ✓ Target for Municipality of Naxos and Small Cyclades Islands: 4 systems to be installed in Donoussa, Schinoussa, Iraklia and Koufonisia
- ✓ Target for Municipality of Ancient Olympia: 5 systems to be installed in the Municipal Department of Ancient Olympia

Assumptions for the siting of systems:

- ✓ Determination of the maximum range to be covered by the population: 200 m.
- ✓ Identification and mapping of large waste producers eg hotels, health stores, etc.
- ✓ Findings of public consultation with local communities and authorities for the finalization of the installation points
- ✓

To this end, the following indicative installation sites were determined for each of the targeted remote area:

Table 4 Donoussa installation sites and data


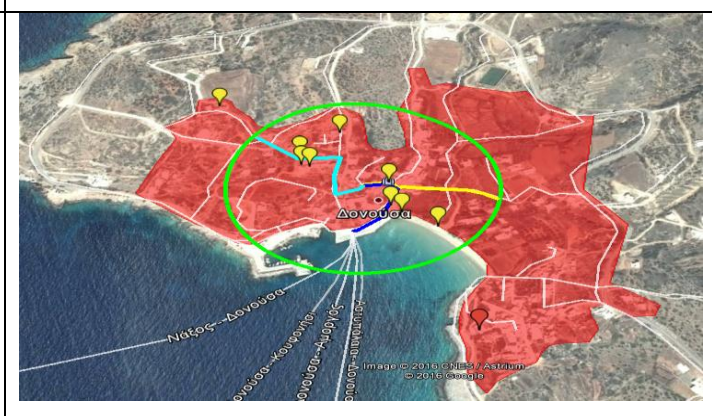
Population (inhabitants): 150	MSW production (tn/year) in 2020: 213
	

Table 5 Koufonisia installation sites and data

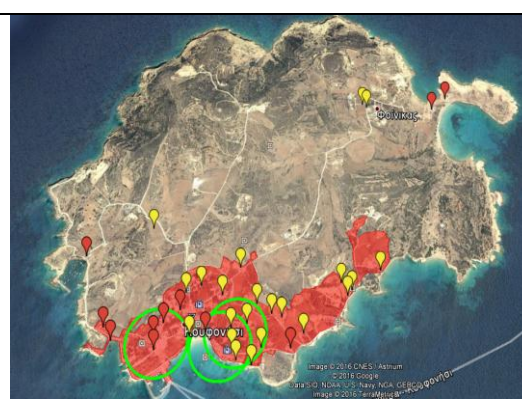
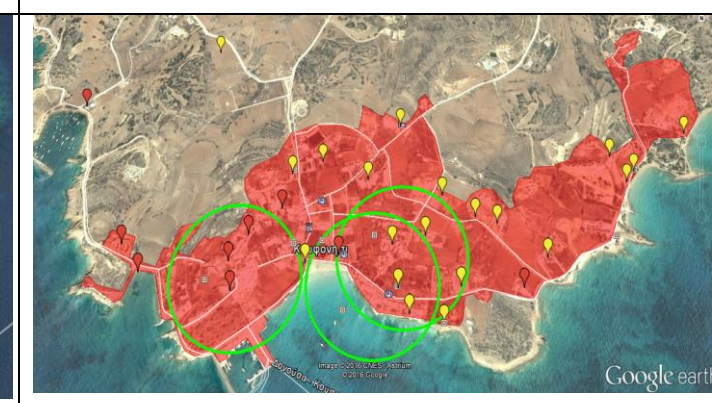
Population (inhabitants): 398	MSW production (tn/year) in 2020: 725
	

Table 6 Schinoussa installation sites and data

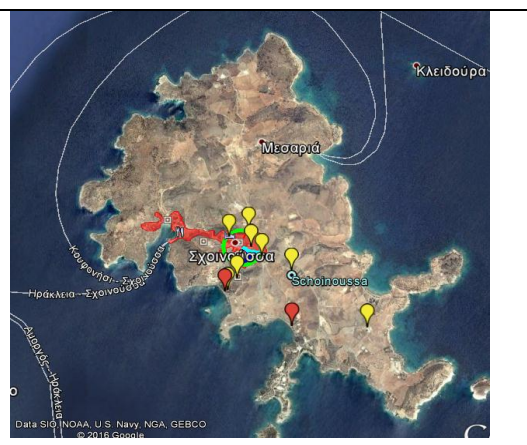
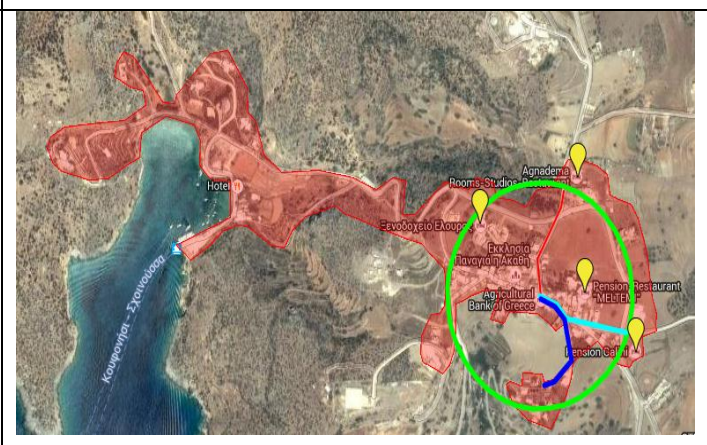
Population (inhabitants): 210	MSW production (tn/year) in 2020: 233
	

Table 7 Irakleia installation sites and data


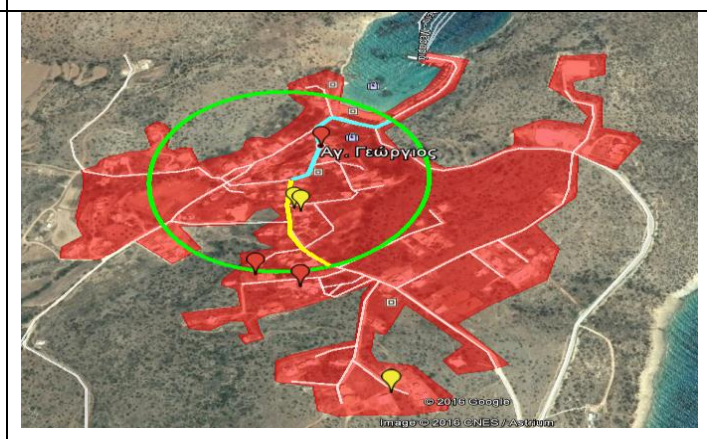
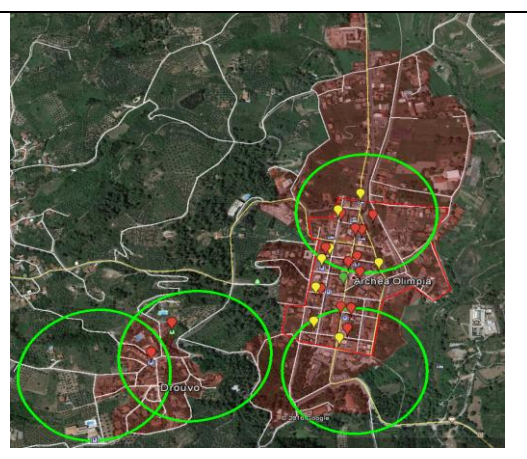
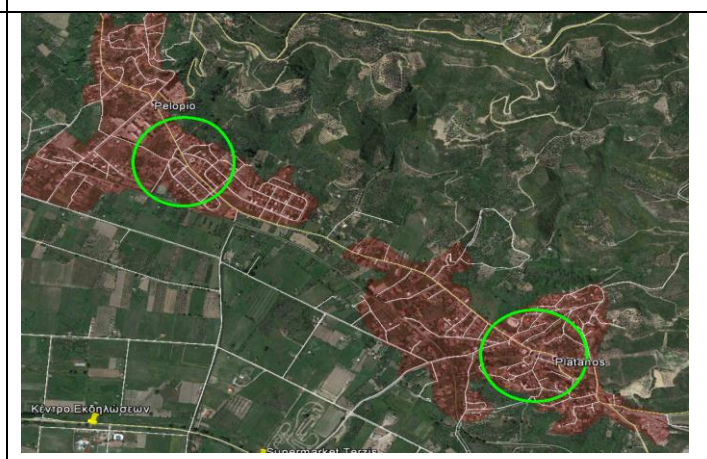
Population (inhabitants): 117	MSW production (tn/year) in 2020: 156
	

Table 8 Municipal Department of Ancient Olympia installation sites and data

Population (inhabitants): 3108	MSW production (tn/year) in 2020: 1697
	

The aforementioned installation sites are expected to be finalized after the public consultation events which will give the appropriate feedback on the consent of the local population and responsible authorities for each remote region.

B. Organization of the Integrated Solid Waste Management schemes for the target remote areas

In the framework of the preparatory activities, prerequisite actions for the development of the Integrated Solid Waste Management schemes to the selected target areas were implemented. To this end, the conduction of an ISWM Plan for the separation and treatment at source of MSW is envisaged for each targeted area. For the conduction of the ISWM plan the following steps were followed.

- Identification of the need for ISWM in the selected communities of the participating municipalities

The identification of the need for implementation of integrated solid waste management is based on the findings of the existing environmental policy in Greece and EU in regard to MSW management objectives and on the existing situation on waste management status in the examined areas.

To this end, the selected communities for the development of the ISWM schemes in Small Cyclades Island comprise of small-sized populations ranging from 117-398 inhabitants. The population of the islands, however, is multiplied during the summer period. Waste management in these South Aegean islands relies on uncontrolled landfilling of MSW. Efforts have been made to gradually close and restore the operating dumpsites, while the first engineered landfill on the main island of Naxos is under construction. There is no organized recycling system in Small Cyclades Islands, as the transportation costs to the main island, at first, and then to Attica region by ship entail prohibitive costs.

Regarding the Municipality of Ancient Olympia, the picture is quite the same. The density of the population is low and the included communities/villages are distributed in very long distances from each other within the boundaries of the Municipal Department of Ancient Olympia. Almost 1,000,000 tourists visit the remote area per year, making waste management a challenging task. Currently, waste management is heavily relied not only on unsustainable, but also on illegal practices, since MSW are disposed in uncontrolled landfills. Recycling rates are very low and mixed MSW are transported to central material recovery facilities in more than 100 km away. Thus, the current waste management status results in environmental problems and high transportation costs.

Consequently, the need for sustainable and integrated waste management schemes is imperative for both the examined remote areas.

- Establishing quantitative objectives for the selected MSW streams in the area under examination

The next planning step of the ISWM scheme is the establishment of quantitative targets for recyclables and biowaste according to the existing EU and Greek legislation. Therefore, the % targets set and the relevant MSW quantities for each target area are given in Table 9.

Table 9 Quantitative targets established for the ISWM schemes for the remote target areas

Municipality of Naxos and Small Cyclades Islands	Biowaste 40%	Recyclables 65%	MSW 43.6%
	tn/year	tn/year	tn/year
	212.3	366.6	578.9
RECYCLABLES & BIOWASTE	Biowaste 40%	Recyclables 80%	MSW 50.0%
	tn/year	tn/year	tn/year
	212.3	451.2	663.5

Municipality of Ancient Olympia	Biowaste 40%	Recyclables 65%	MSW 41.5%
	tn/year	tn/year	tn/year
	368.5	335.7	704.3
RECYCLABLES & BIOWASTE	Biowaste 60%	Recyclables 80%	MSW 60.0%
	tn/year	tn/year	tn/year
	552.8	465	1018

- Planning of the MSW source separation and treatment scheme

Finally, for the planning of the source separation and treatment scheme for the selected communities, the following were determined:

i. The equipment required for the effective and efficient source separation of MSW

ii. The conditions of the collection, transportation and temporal storage of source separated MSW considering the existing infrastructure, equipment (vehicles, routing, collection frequency etc) and public perception.

iii. The transportation and trading options of the separately collected recyclables namely paper, glass, plastic, metal and organics and their most important sub-categories with high demand on the market.

The aforementioned aspects are summarized in the following figure.

- Planning of the communication strategy

Throughout the project implementation various communication tools and events will be developed in order to raise the environmental awareness of the target groups (local population, stakeholders, local/regional/national waste management authorities, recycling industries, potential users of the proposed innovative recycling systems, scientists etc.)

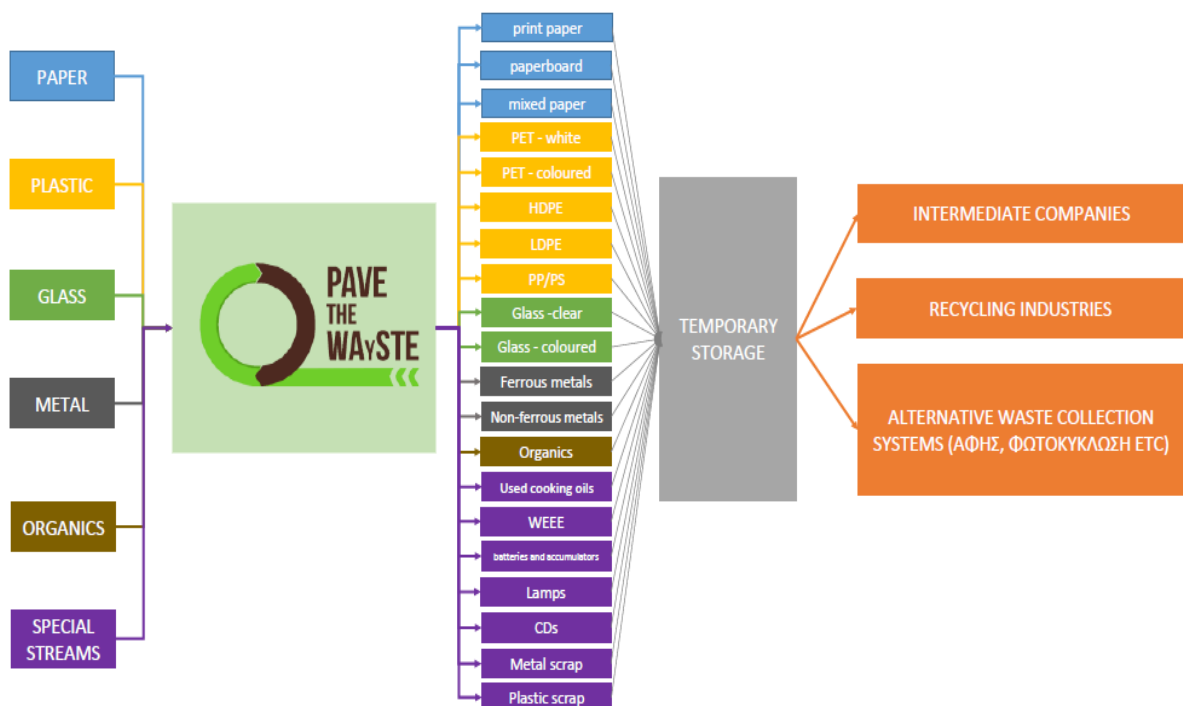


Figure 4 Integrated Solid Waste Management Scheme for the selected Municipalities in the remote areas

4. Conclusions

LIFE PAVEtheWAYSTE project aims at the development of an innovative method for recycling MSW in remote areas. Based on the findings from the completion of the preparatory actions of the project, even though the appropriate legislative framework for the implementation of integrated waste management options is in place at national level, the remote areas of Greece, such as the Municipality of Naxos & Small Cyclades Islands and the Municipality of Ancient Olympia face the challenges of lack of infrastructure and limited accessibility to central administrative and economic facilities. This makes the establishment of recycling schemes difficult due to high transportation costs. As a result remote and insular areas are currently relying on disposing their MSW in uncontrolled landfills, causing environmental problems and hampering the development of the local economies. The capturing of the existing solid waste management situation in the target areas highlighted that there is imperative need to develop and implement rational integrated systems. Moreover, the recording of the existing status of the market for recyclable waste showed the great potentials and the benefits resulting from the application of source separation schemes with respect to the market values and technical specifications of various waste materials. This information will give valuable input for the innovative design, construction and operation of the prototype systems for MSW recycling. The project's results are expected to have an added value, both locally and at European level, contributing to more efficient use of local resources, economic and energy savings. This way, isolated areas such as remote and island regions shall apply sustainable waste management schemes and shift from the linear to circular economy.

Acknowledgements

The partners of the PAVEtheWAYSTE project would like to acknowledge the financial support of LIFE, the financial instrument of the EU for the environment and climate action.

References

1. PAVEtheWAYSTE, Deliverable A1-3: Report on the market specifications set by local/regional recycling companies
2. PAVEtheWAYSTE, Deliverable A2-1: Integrated Solid Waste Management strategy for the remote area of NAXOS
3. PAVEtheWAYSTE, Deliverable A2-2: Integrated Solid Waste Management strategy for the remote area of OLYMPIA