Output 6.3
Replicability & Transferability Plan
Quantitative & Qualitative Analyses

Contributions by

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Abstract

Decentralized Composting in Small Towns (DECOST) is a project that aims to develop a new framework for waste management, building a closed-loop system of organic waste valorization, integrating decentralized home and community composting systems with urban agriculture.

The Replicability & Transferability (R&T) Plan for the DECOST project provides guidelines and a methodological framework to quantify economic, operational, environmental, social, and legal aspects in order to examine the feasibility of Decentralized Composting (DC) projects at any given location. The R&T plan provides a powerful tool for decision making based on the quantification of the DC project characteristics and the Benefit/Cost (B/C) index calculations, which take into account the various influencing variables.

This report describes the R&T model for DC projects, along with guidelines, numerical examples and simulations, to demonstrate case applications. The simulations illustrate the implementation of the R&T model and guidelines for the cities of Shefa-Amr and Patras, in Israel and Greece, respectively, which were chosen to demonstrate domestic and commercial DC.

Abbreviations

APC	After Placing Composter
BPC	Before Placing Composter
B/C	Benefit/Cost
CCT	Core Competence Tree
DC	Decentralized Composting
DECOST	Decentralized Composting in Small Towns
ECN	European Compost Network
EEA	European Environment Agency
EPR	Extended Producer Responsibility
EU	European Union
fCRT	Focused Current Reality Tree
ILS	Israeli New Shekel
IMoEP	Israeli Ministry of Environmental Protection
IMoI	Israeli Ministry of Interior
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
N/A	Not Applicable
O&M	Operation and Maintenance
OECD	Organization for Economic Co-operation and Development
PAYT	Pay As You Throw
SWOT	Strengths, Weaknesses, Opportunities, and Threats
R&T	Replicability and Transferability
VAT	Value-Added Tax
WCB	Waste Collection Bins

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1 Introduction

Over the past decades, municipal solid waste management (MSWM) has been considered one of the major environmental challenges. Biodegradable material, especially food waste, usually accounts for over 50 wt% of municipal solid waste (Awasthi, 2020; Wei et al., 2017), and its reduction was ranked 3rd of 100 solutions to reducing climate change (Hawken, 2017). Yet, in most countries, it is the least recovered material (Pai et al., 2019; World Bank, 2018; World Bank, 2020). According to Eurostat (2020), in 2018, only about 17% of the municipal waste in the EU-27 countries was composted (data is presented in Figure 1). In OECD countries too, composting is relatively low compared to other treatment and disposal methods. The municipal waste by treatment operations in the OECD countries is presented in Figure 2. That said, there has been increasing attention to improving the management of the organic fraction of municipal solid waste (Awasthi, 2020; Bruni et al., 2020; EEA, 2020; OECD, 2020; Pai et al., 2019; Siebert et al., 2020; Wei, 2017).

Figure 1: EU-27 Municipal Waste Treatment 1995-2018

Municipal waste landfilled, incinerated, recycled and composted, EU-27, 1995-2018

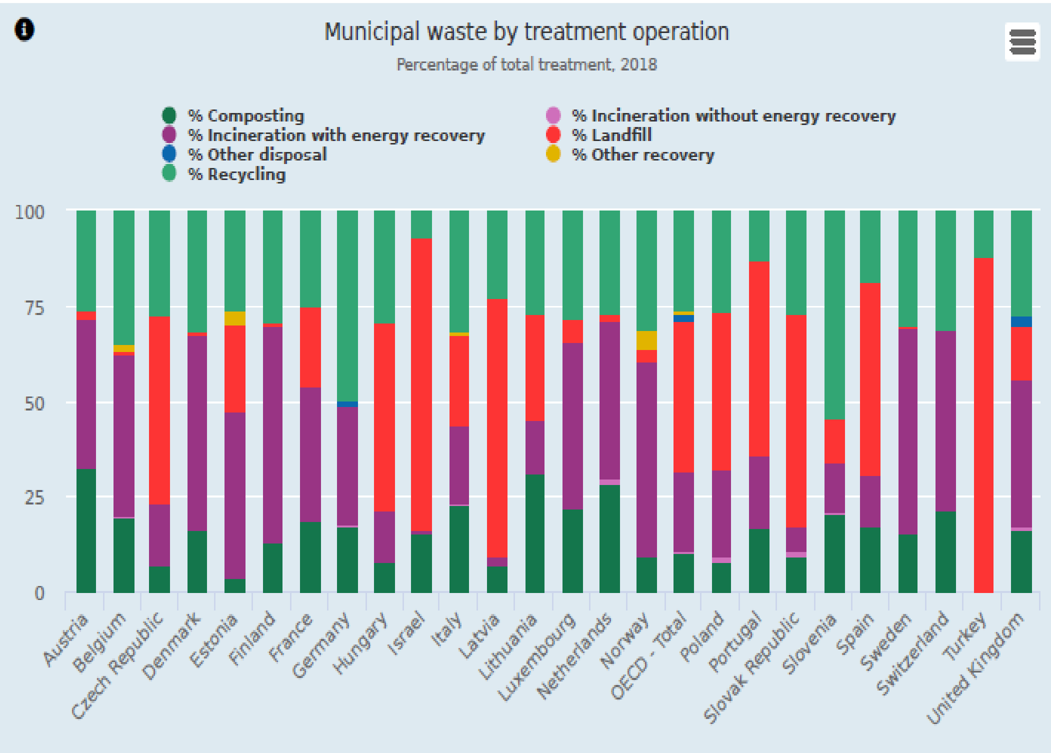
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Change 2018/1995 (%)
million tonnes																									
Landfill	121	117	117	114	113	112	107	104	99	93	88	88	87	83	82	79	74	67	63	59	57	54	53	52	-57
Incineration	29	30	33	33	34	36	37	39	39	41	45	48	49	51	52	53	55	54	55	56	56	58	59	58	101
Material Recycling	23	26	30	32	37	38	40	43	43	43	46	47	52	53	54	55	56	58	56	59	63	65	66	67	190
Composting	14	16	17	18	19	23	23	24	24	26	26	27	28	30	30	29	29	30	31	33	33	36	37	37	163
Other	10	13	12	11	12	11	12	12	12	13	16	13	11	10	7	6	6	6	5	5	5	5	5	5	-51
kg per capita																									
Landfill	286	276	276	266	263	262	250	241	229	215	202	202	199	190	186	178	167	153	142	134	127	121	118	117	-59
Incineration	34	36	39	39	79	84	87	90	90	95	103	111	112	116	117	121	125	122	125	126	127	130	132	131	285
Material Recycling	54	62	69	75	85	87	92	100	100	100	105	109	119	120	123	125	128	130	128	134	141	145	147	150	178
Composting	33	38	41	42	45	53	54	57	57	59	59	61	64	69	67	66	66	69	71	73	75	81	83	83	152
Other	60	66	66	65	28	27	26	27	26	31	37	30	23	23	17	13	13	14	12	11	10	11	11	11	-82

Note: estimated by Eurostat.

Source: Eurostat (online data code: env_wasmun)

Source: Eurostat Online Data (2020)

Figure 2: OECD Municipal Waste Treatment in 2018



Source: OECD (2020)

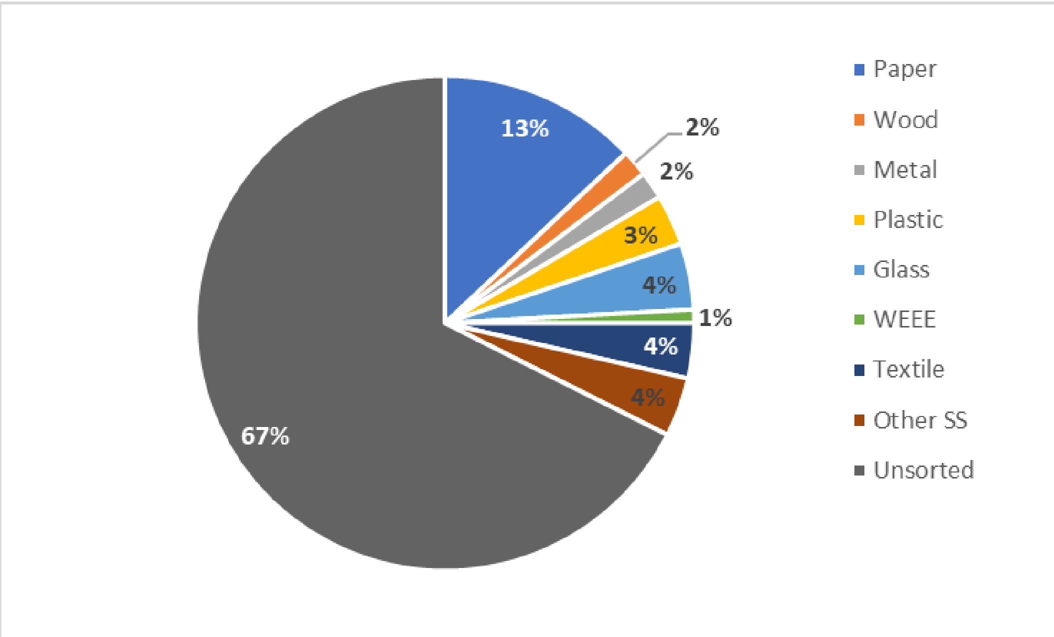
Decentralized Composting in Small Towns (DECOST) is a project that aims to develop a new framework of waste management, building a closed-loop system of organic waste valorization, which integrates decentralized home and community composting systems with urban agriculture (DECOST, 2020). This goal can only be achieved by using a people-centered approach, empowering civil society, and increasing institutional capacity building. DECOST integrates MSWM plans and pilot initiatives in five different municipalities to reduce food waste, treat 1,500-2,000 tons of organic waste/year and use the produced compost in urban agriculture projects (DECOST, 2020). The countries participating in the project are Spain, Italy, Palestine, Jordan, Israel, and Greece.

In Europe and the Mediterranean countries, organic waste typically accounts for about 35 wt% - 57 wt% of municipal solid waste. The composition of MSW by weight in Italy, Israel, Greece, Jordan, Palestine, and Spain is presented in Figure 3.

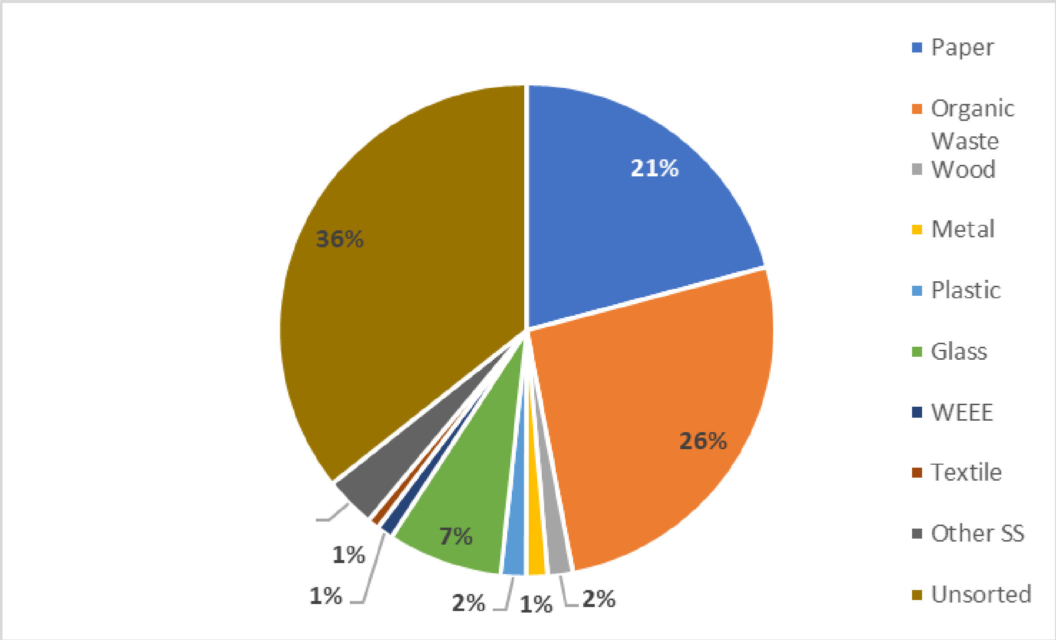
Figure 3: MSW Composition by Weight

ITALY

a. Distribution of Municipal Solid Waste in Atella



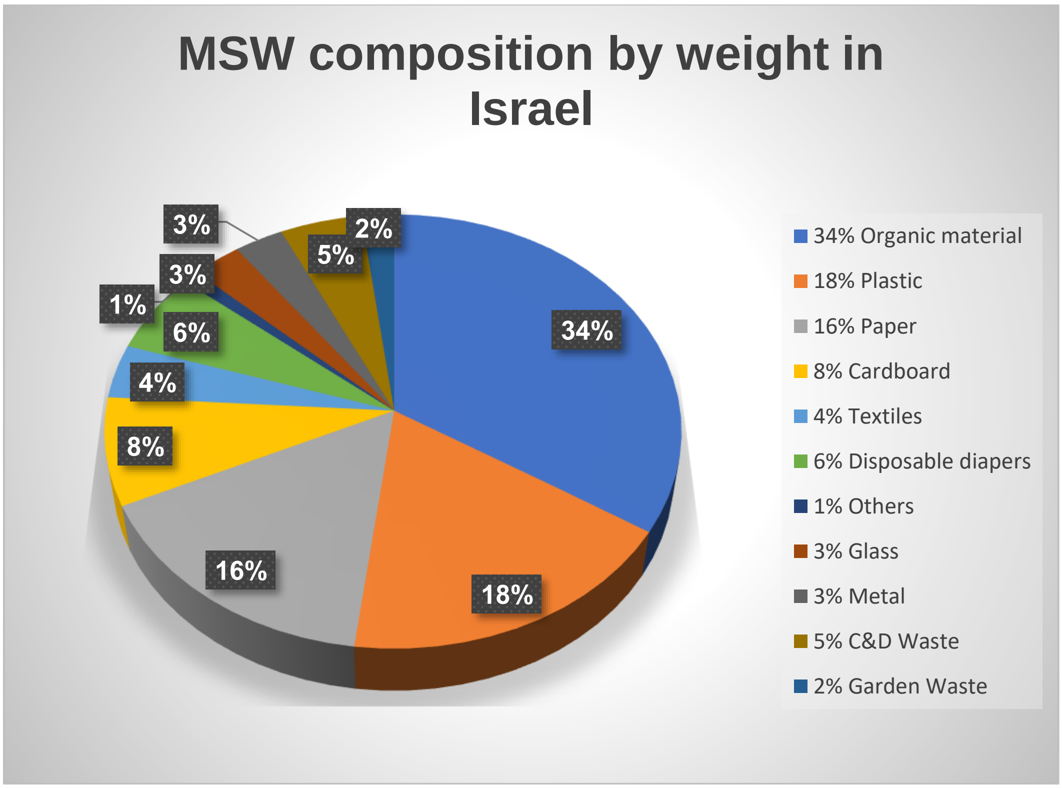
b. Distribution of Municipal Solid Waste in Potenza



* Other SS: Other source separated.

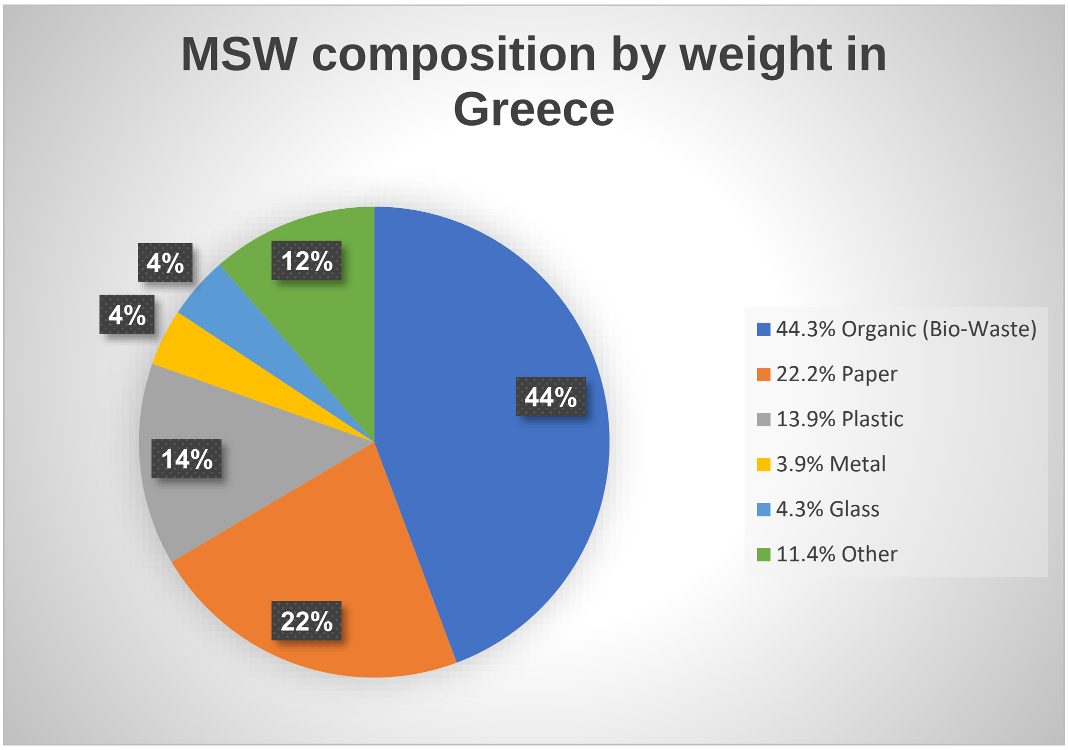
Source: Sorted and unsorted urban waste collected in the municipalities of Atella and Potenza (DECOST, 2019).

ISRAEL



Source: Shahaf Environmental Planning (2014)

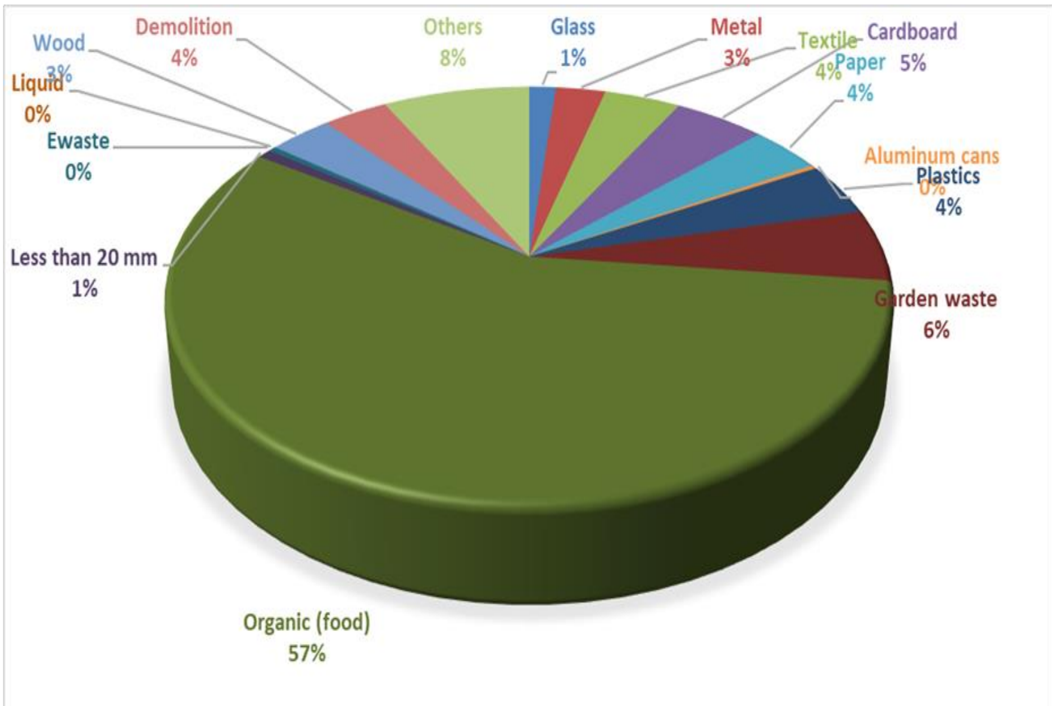
GREECE



Source: National Waste Management Plan (2015)

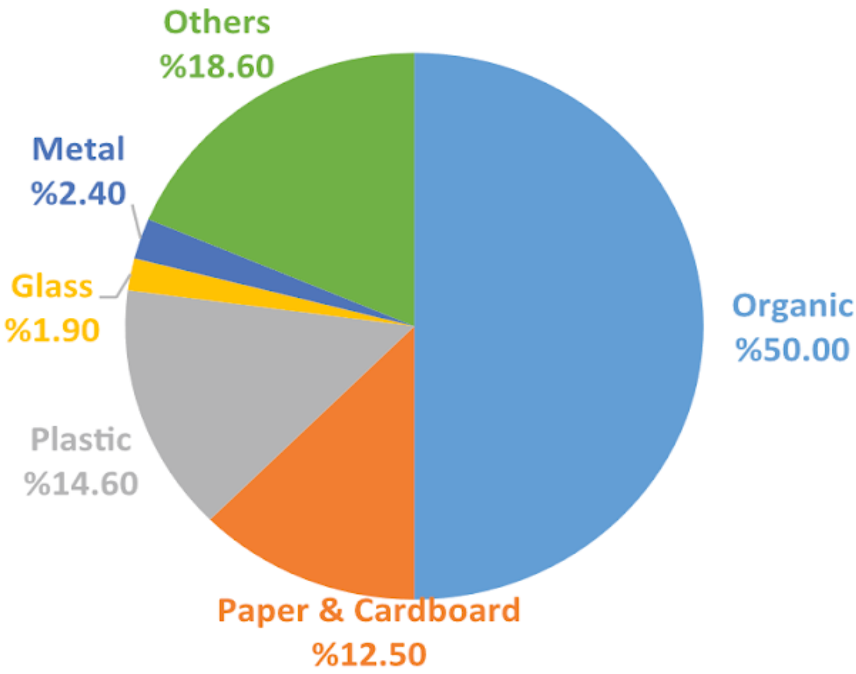
<u>JORDAN</u>

Composition of solid waste from rural areas in Bani Kenanah district.



Source: Abu Qdais et al. (2017)

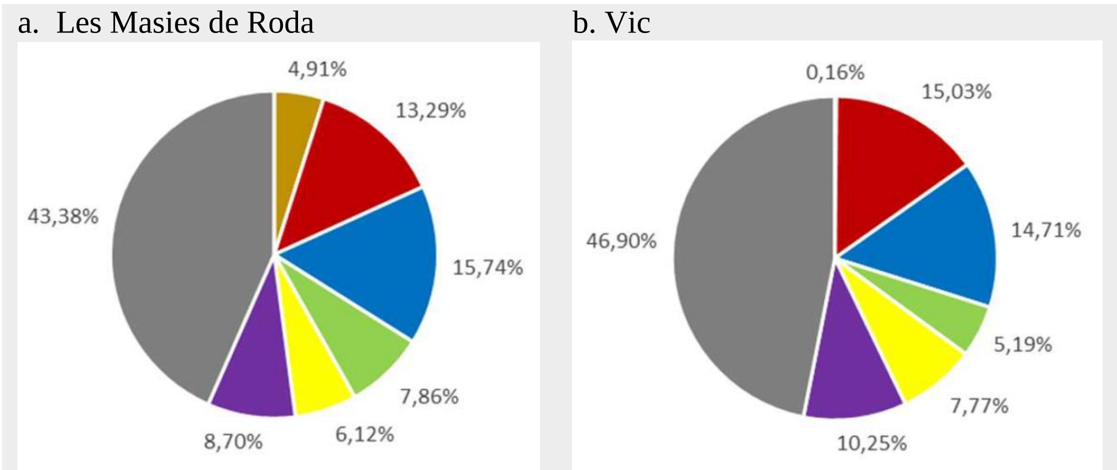
<u>PALESTINE</u>



Source: SW composition in 2016 (MoLG-JICA, 2017a)

SPAIN

Municipal Solid Waste composition in Les Masies de Roda and Vic.



Organic matter composted at home (brown), Organic matter (red), Paper (blue), Glass (green), Plastic (yellow), other segregated fractions (purple) and mixed MSW (grey). Source: Catalan Waste Agency (2018).

The Replicability and Transferability (R&T) Plan for the DECOST project aims to provide a methodological framework and guidelines to quantify economic, technical, environmental, social, and legal aspects to examine the feasibility of Decentralized

Composting (DC) projects. The R&T plan is designed to provide supporting tools to enable the replication and transfer of the DECOST project concept to additional municipalities in various countries and regions.

The R&T plan has been developed with an innovative approach to planning and designing DC projects, an approach that is both holistic and very practical.

The R&T plan is based on the quantification of the cost and benefit components for examining incremental expenditure and savings related to decentralized composting compared to the existing situation, and for examining various alternatives and scenarios for the implementation of the DC project, at a particular point in time or over time. The plan provides powerful tools for decision making based on a Benefit/Cost (B/C) index. The B/C index is a pseudo cost-benefit ratio defined for assessing the project's economic, social, and environmental viability, taking into account the various impact variables.

This report presents the R&T plan model and guidelines, along with numerical examples and simulations to demonstrate case applications in the cities of Shefa-Amr, Israel, and Patras, Greece, which were chosen to demonstrate domestic and commercial DC.

A key challenge in implementing the R&T plan involves the collection and consolidation of the data required to calculate the B/C indices, therefore, detailed tables have been constructed as a supporting tool for collecting the relevant data into a built-in template (see Appendices A-D).

2 Decentralized Composting Overview

Decentralized composting has the potential to reduce landfill volumes, save on transportation costs and reduce emissions (Awasthi et al., 2020; Bruni et al., 2020; Pai et al. 2019). In addition, waste management in the community is important in terms of education for sustainability and environmental protection, especially if the products of the process are used to grow local edible plants.

3 Decentralized Composting Characteristics

The aim of DC is to enhance MSWM. The benefits of decentralized composting, as defined by Pai et al. (2019), involve logistical, environmental and ecological, economic, and social aspects, and are listed below:

1. **Logistical characteristics** – DC should drastically reduce the transportation of waste for processing and treatment. Additionally, the finished product is often used on-site or by members of the community.
2. **Environmental & Ecological characteristics** – DC enables the reuse of organic matter, offers compost as a substitute for energy-intensive fertilizers, and engages the local community in source separation of food waste, which has been shown to reduce the generation of food waste.
3. **Economic characteristics** – With the reduction in the transportation of waste, there will be a consequent reduction in transportation costs, and in collection and treatment costs as well.
4. **Social characteristics** – DC stimulates local economies by creating local small-scale enterprises.

These characteristics drive the DECOST General Characteristics Questionnaire, presented in Appendix A.

4 Decentralized Composting Regulation Guidelines

MSWM regulations have a profound impact on the implementation of MSWM solutions (Daskal et al., 2019). Extended Producer Responsibility (EPR), landfill levy, waste collection fees, and other regulatory tools in this field have a significant impact on the economic viability of different MSWM solutions (Daskal, 2018; Daskal et al., 2018; Daskal et al., 2019; Daskal et al., 2020). Thus, to examine the feasibility of DC projects, the analysis should include the relevant regulations, and the quantification of their impact on costs and benefits. Regulations that may be relevant to DC projects are presented in Table 1, along with examples, and the regulations' possible relevance to locations interested in implementing DC projects, to be answered (Yes/No) by those locations.

The regulations can motivate or limit the implementation of various waste treatment solutions. For example, businesses that are required to pay a waste collection fee will strive to promote local solutions that reduce the amount of waste generated. Therefore, it is likely that businesses that produce large amounts of organic waste, such as restaurants, catering kitchens, hotels, hospitals, etc. will collaborate with DC projects. Local authorities that pay the landfill levy will also strive to increase the amount of waste treated, and decrease the amount of waste sent to the landfill, and consequently the landfill levy. Similarly, residents who pay according to the amount of waste they produce (PAYT) are more likely to collaborate, over time if not immediately, with DC projects relative to those residents who do not pay according to the waste they produce. Thus, the quantification of the regulatory impact must be taken into account in examining the costs and benefits of the DC project. It worth noting that a generic “cookbook” approach is used in this R&T document, therefore, each city/community wishing to adopt and implement DC projects, will be able to follow the guidelines using its own data.

Table 1: Regulations that may be relevant to DC projects

Regulatory tool	Examples	Relevance Yes/No
PAYT	USA: • In communities with pay-as-you-throw programs (also known as unit pricing or variable-rate	

Regulatory tool	Examples	Relevance Yes/No
	pricing), residents are charged for the collection of municipal solid waste - ordinary household trash - based on the amount they throw away. This creates a direct economic incentive to recycle more and to generate less waste. (Source: here)	
Separate collection at source	Greece: • Mandatory universal separate collection of Biological Waste as of December 31, 2022. • *National Goal:* Law 4042/2012, Article 41 sets the following national goal for separate collection: By 2015, the percentage of separate collection of biological waste should be at least 5% of their total weight, and by 2020, at least 10% of their total weight.	
Clear targets regarding food waste (organic waste) and/or prohibition of landfilling of organic waste	EU/UN : The current indicative EU wide food waste reduction target is 30% by 2025 and 50% by 2030, which is aligned with SDG target 12.3 .	
Landfill Levy	Israel: • Requires landfill operators to pay a levy for every ton of MSW landfilled.	
Composting registeration / permits	USA : • Any small compost site that has more than 4 cubic yards of material on site at any time during the year is required to register with the local authority.	
Composting limitation/ Organic waste treatment capacity limitation	Italy: • Local composting: Not exceeding 80 t/y • Community composting: Not exceeding 130 t/y USA : • Backyard compost sites shall not exceed a total of four cubic yards in volume. The maximum height of the composting container shall be five (5) feet. • Small compost sites cannot exceed 120 cubic yards of material on site at any time. • See: Model Backyard and Small Composting Site Ordinance	
Home composting limitations	Germany : • Space requirement for the utilizing of compost produced in home composting (gardening space) should be at least 25 m^2, preferable about 50 m^2. • (Source: here)	
Backyard compost site limitations	USA : • Composting containers shall be located and designed so that seepage from the compost will not run off into public or private streets, storm sewers,	

Regulatory tool	Examples	Relevance Yes/No
	drainage ditches, water retention basins, streams or lakes . • No compost container may be located closer than five (5) feet to any rear or side property line, or closer than twenty (20) feet to any residential dwellings, except the dwelling on the property at which the compost container is located . • No compost container may be placed within twenty (20) feet of any body of water or area designated as 100-year flood plain or state protected wetland. • (Source: here)	
Incentives, grants, and financial support (From the government, from local authorities, or from non-governmental organizations)	Spain: • Municipalities in Spain get 60€ per composter per year from the Government in the case of community composting. Italy: • Italian regulations provide tariff discounts for those who participate in community composting projects.	
Commercial waste collection fee	Israel: • There is a criteria for collecting basic waste and excess waste from businesses. USA: • Commercial waste generators with a projected generated annual volume of 52 tons or more of source-separated organic material AND are located within 20 miles of a permitted recycling facility must comply with this law. • Source: https://is.gd/Jsf3cG	
Targets to reduce MSW landfill	Israel: • Regulations require local authorities to reduce their waste for disposal through recycling, under graduated recycling targets.	
Targets to reduce organic waste landfill	EU: • The Landfill Directive (1999/31/EC) obliges Member States to reduce the amount of biodegradable municipal waste that they landfill. • (Source: here)	
Location requirements for small compost sites	USA : • Composting containers shall be located and designed so that seepage from the compost will not run off into public or private streets, storm sewers, drainage ditches, water retention basins, streams or lakes . • Small Compost Sites are allowed in (insert local zoning region codes [ex: C3, R2] areas or in R1 areas as an accessory to a community garden or urban farm). Compost sites may not be located	

Regulatory tool	Examples	Relevance Yes/No
	closer than ten (10) feet to any rear or side property line, or closer than twenty (20) feet to any residential dwellings, except the dwelling on the property at which the compost pile is located . • No compost activities may be conducted within twenty (20) feet of any body of water or area designated as flood plain, shoreland or state protected wetland according to MN Rule 7035.2555.	
Green Jobs allocation	Spain: • Master composter: qualified technicians who understand the composting process and can analyze and handle any problems that may arise in the process.	

Relevant data definitions were included in the R&T model, as presented in Appendices A, B, and D. An example for waste and recycling legislation in Israel, 1984-2017, is presented in Appendix E.

5 The Decentralized Composting R&T Model

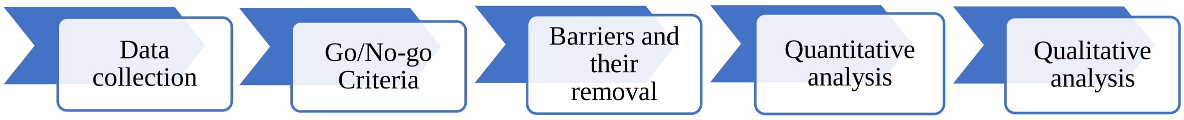
The DC R&T model is based on quantifying the characteristics of DC projects, and performing a cost-benefit analysis to quantitatively assess the impact of these projects. The suggested methodological framework can be implemented to address the long-term viability of DC projects, by calculating B/C indices for different scenarios and over time. Such a feasibility timeline can be assessed according to different criteria, alternatives, and scenarios, and serve as a decision-making support tool for planning the initial set-up of the project and its viability over time.

The DC R&T model consists of several stages, each of which uses a specific

methodology to examine the feasibility of the project and its effectiveness.

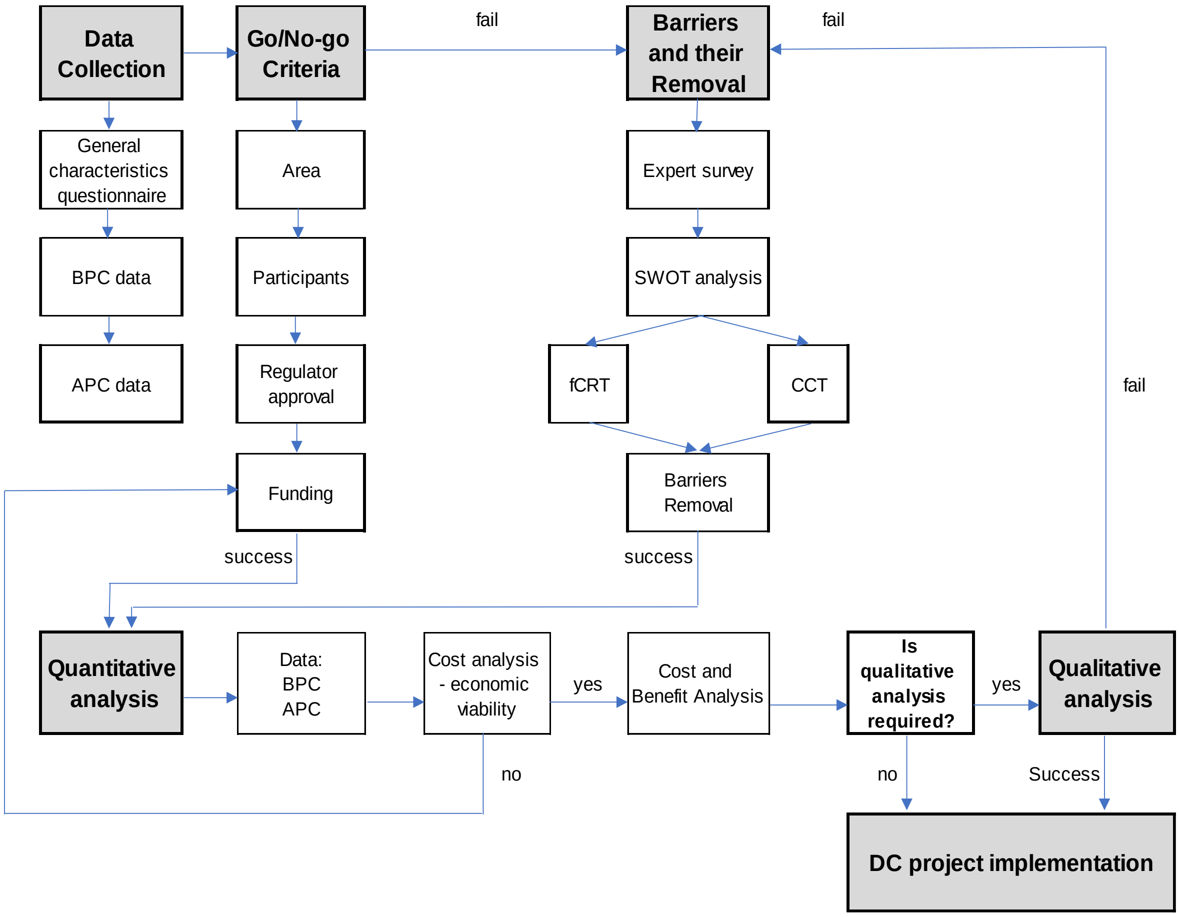
Figure 4: shows a schematic description of the stages of the DC R&T model.

Figure 4: The stages of the DC R&T model



The model provides quantitative and qualitative methodological tools to support decision making. The model includes tools and guidelines for collecting relevant data to examine the economic viability and the cost effectiveness of the project. Figure 5 shows the schematic framework of the DC R&T model.

Figure 5: Framework of the DC R&T model

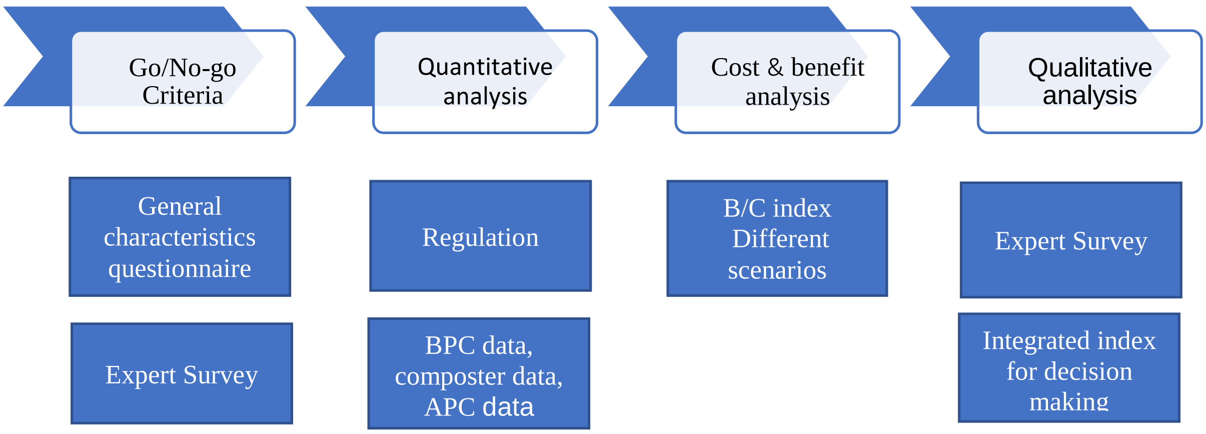


5.1 Data Collection

A major challenge in DC project planning and design is accessing and collecting the relevant data to evaluate the impact of the project. If available, MSW generation and management data are usually aggregated to the city, region, or state, while estimating the impact of DC projects requires data to be disaggregated to a community or household level (Pai et al., 2019).

The DC R&T plan requires a variety of data, including specific data regarding the participants in the DC project, in order to enable quantifying the costs and benefits of the project. This includes the quantification of waste generated by the participants, and the percentage of organic waste in this stream. Later in this chapter, there is a description of the required data, the components of the R&T model, and the calculation of the B/C index. The model takes into account various aspects, including economic, environmental, technical, and regulatory, as illustrated in Figure 6, which summarizes the main categories of the required input for the DC R&T model.

Figure 6: Input data for the DC R&T plan



The following data are required for the benefit/cost analysis and the calculation of the B/C indices:

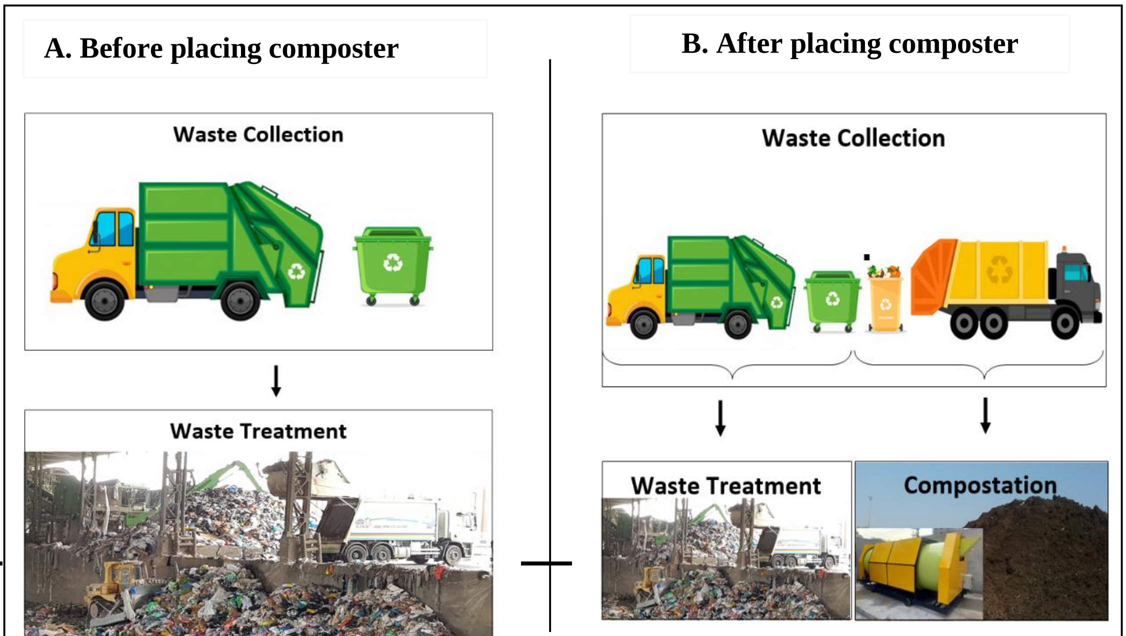
1. Total monthly costs of waste collection and treatment, before placing the composter (BPC), and after placing the composter (APC).
2. Monthly amount of organic waste that is directed to composting.
3. Monthly amount of compost produced.

Detailed tables are provided for gathering the relevant data for calculating the costs and benefits of a DC project (Appendices A-D).

The data should relate to the participants in the project only, and reflect the change as a result of composting alone (before and after placing the composter). Thus, the relevant data is the data that indicates the change as a result of the DC project. That includes the organic fraction or mixed waste, in case there is no waste separation at source BPC. Other source-separated fractions (plastic, glass …), which are not expected to change due to the DC project, are irrelevant.

The data are used to calculate: (1) the total monthly costs before and after placing the composter, and (2) the benefit, in order to calculate the B/C indices, and evaluate the economic feasibility of the project. A schematic illustration of the waste collection and treatment before and after placing the composter is presented in Figure 7.

Figure 7: Schematic illustration of MSW collection and treatment BPC and APC

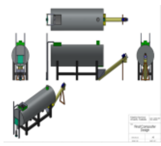


The participation rate is reflected in the amount of organic waste that is directed to composting, and thus can be quantified accordingly. A schematic illustration of the organic waste compostation is presented in Figure 8.

Figure 8: Schematic illustration of organic waste compostation

The organic waste to compost ratio usually varies between 3:1 to 5:1, depending on the raw materials, technology, level of maintenance, etc. (see Appendix F). The actual composters used in the DECOST project's DC pilot sites and their characteristics are shown in Table 2.

Table 2: Current composters in DECOST DC projects

DECOST Pilot Site	Kufur Rumman Palestine	Sama Rusan Jordan	Vic Spain	Potenza Italy	Atella Italy	Anabta Palestine
Type of composting	Home Composting	Home Composting	Community Composting	Community Composting	Community Composting	Community Composting
Composter type						
Model	Customized local design	Aerobin	VERMICAN	CtTec -Bio - Bi I.3.X	CtTec - Bio - Bi I.9.X	
Volume	320 L	400 L	3 m^3			5 m^3
Potential Users	5-6	5-32	75	117	626	

Capacity	0.5-0.7 tons/year	0.5-2.0 tons/year	3 tons/site/year	20 tons/year	80 tons/year	66 tons/year
Price	375€	150€	670€	25,000€	65,000€	20,000€
Required area	2 m^2	1 m^2	5 m^2	10 m^2	14 m^2	15 m^2

Please note that the prices are relevant for the time period when they were obtained, and they may have changed since then.

5.2 Go / No-go Criteria

The Go / No-go criteria are very necessary for the DC project to exist (pass/fail criteria), with all the criteria being met cummulatively. Therefore, examining the Go / No-go criteria is the very first step in any DC R&T plan. Four such Go / No-go criteria were identified, as detailed in the following paragraphs.

The first Go / No-go criteria is the existence of suitable areas to place the composters, for the implementation of the composting project, without which the project obviously cannot be carried out. Locating a suitable area depends on the project characteristics, the definitions of land designations, and various regulatory restrictions. To locate a suitable area, it is strongly advisable to work in cooperation with the local authority and the relevant regulatory bodies.

The second Go / No-go criteria is the willingness of organic waste producers to participate in the project[1]. For this purpose, suitable participants must be identified, and their consent to participate in the project needs to be obtained. These participants can be domestic or commercial waste producers. To identify suitable participants, an examination of the existing regulations is recommended, along with the impact of these regulations on

[1] Unless composting is mandatory, and there are supervision, control and sanctions.

potential participants, as well as the possible incentives, challenges, and limitations. Needless to say that without project participants, there is no project.

A DC project is required to meet various regulatory requirements, and obtain the approval of the regulator. As such, the third Go / No-go criteria is the regulator's approval.

The fourth and final Go / No-go criteria is securing funding for the project. This is necessary for the purchase of the composter(s), and to finance the ongoing costs for operation and maintenance, without which funding, the project is a no-go.

The aforementioned four Go / No-go criteria are summarized in Table 3.

Table 3: Go / No-go Criteria

Go / No-go Criteria	Yes/No
1. Existence of a suitable area for placing a composter	
2. Participants and consent to participate in the project	
3. Regulator approval	
4. Funding for the project	

5.3 Barriers and their Removal

The perception of waste varies from person to person, and among different groups in the population. It depends, among other things, on the socio-economic status of the people or groups that produce the waste (Daskal, 2018). Despite local and global efforts to produce a public perception of turning waste "from a nuisance to a resource", most of the public still treats waste as something that needs to be disposed of as quickly and remotely as possible without having to deal with it in person. The literature describes different approaches and methods on how to create public involvement in waste treatment, as well as assess the public's willingness to cooperate. For a community composting project to be successful, it is strongly advisable to map out the barriers and explore ways to remove them, in order to incentivize waste producers and act to reduce objections.

Different countries and regions face common barriers, and also barriers specific to their areas, so may have different ways to overcome them, along with the related costs to these actions. For example, some challenges can be overcome through proper maintenance (to keep the composter area clean, to prevent odour hazards, etc.), which has associated costs. Public information costs, workforce costs, costs of adequate facilities, etc., must also be taken into account in the pricing of the project. Some of these barriers can be addressed qualitatively.

A common practical way to map barriers and ways to overcome them is to conduct an expert survey, and analyze the survey results. One strategic methodology that allows the mapping of major barriers and ways to remove them, is the Strengths, Weaknesses, Opportunities and Threats (SWOT) methodology.

The main barriers can be deduced from the Weaknesses and Threats, using the Focused Current Reality Tree (fCRT) tool. The Weaknesses and Threats are taken from the SWOT analysis, which are undesirable (unwanted) effects. The fCRT tree is then constructed by making logical connections between those unwanted phenomena, and identifying 1 to 3 strategic root problems, which are essentially the main barriers.

Ways to overcome those barriers can be deduced from the Strengths and Opportunities, using the Core Competence Tree (CCT) tool. The Strengths and Opportunities are taken from the SWOT analysis, which are the desirable effects. The CCT is then constructed by making logical connections between those desirable phenomena, and identifying 1 to 3 strategic ways to overcome the barriers.

Daskal et al. (2019) used this methodology to analyze barriers and the ways to overcome them in the MSW market in Israel. A schematic description of the process is shown in Figure 9.

Figure 9: Identifying barriers and ways to overcome them

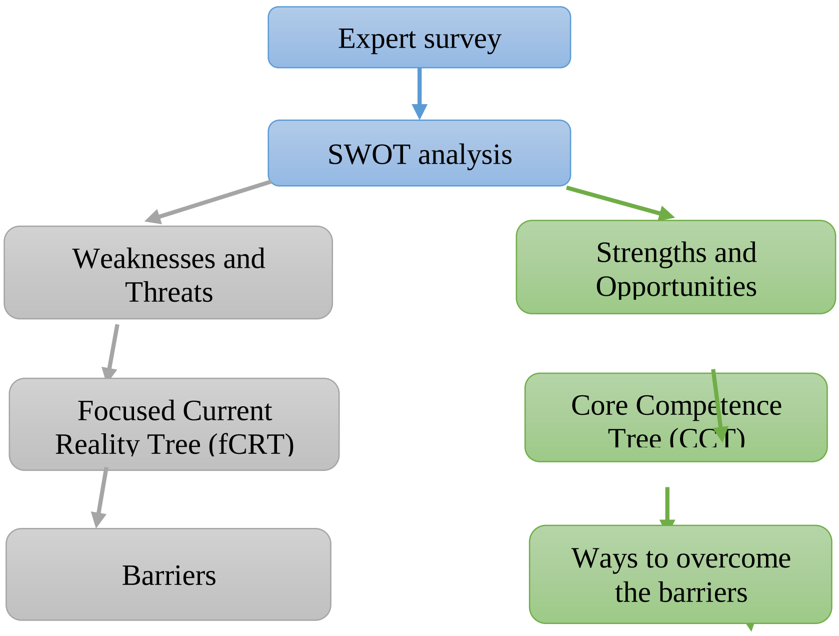


Table 4 below presents possible barriers/challenges and suggested ways to overcome them, as provided by the DECOST project partners.

Table 4: Barriers/challenges and suggested ways to overcome them

The barrier/challenge	Suggested ways to overcome barrier/challenge
NIMBY (Not In My Backyard)	▪ Initiating and managing public participation processes ▪ Education and information programs
Quality of input material	▪ Awareness campaigns ▪ Participant training ▪ Continuous quality control ▪ Enforcement of and charges under a Municipal By-Law
Odor management	▪ Assurance of proper compost mix ▪ Adequate facilities, i.e. moisture content control, fans
Animal/rodent hazards	▪ Completely closed composting system ▪ External coating against rodents
Seasonal fluctuations	▪ Insulation for temperature maintenance
Availability of bulking/pruning material	▪ Acquiring from the municipality (for example tree waste) ▪ Collaboration with relevant industries
Storage area for feedstock and compost	▪ Preparation in advance of suitable infrastructure

The barrier/challenge	Suggested ways to overcome barrier/challenge
Demand for compost (creating / increasing demand)	▪ Production of high-quality compost ▪ Marketing and advertising ▪ Making compost accessible to potential consumers
Availability of energy/water for the process	▪ Securing from the municipality
Maintaining / increasing the participation rate	▪ Reasonable and convenient distances from participants (households / businesses) ▪ Enforcement of and charges under a Municipal By-Law

5.4 Quantitative Analysis

5.4.1 The Costs

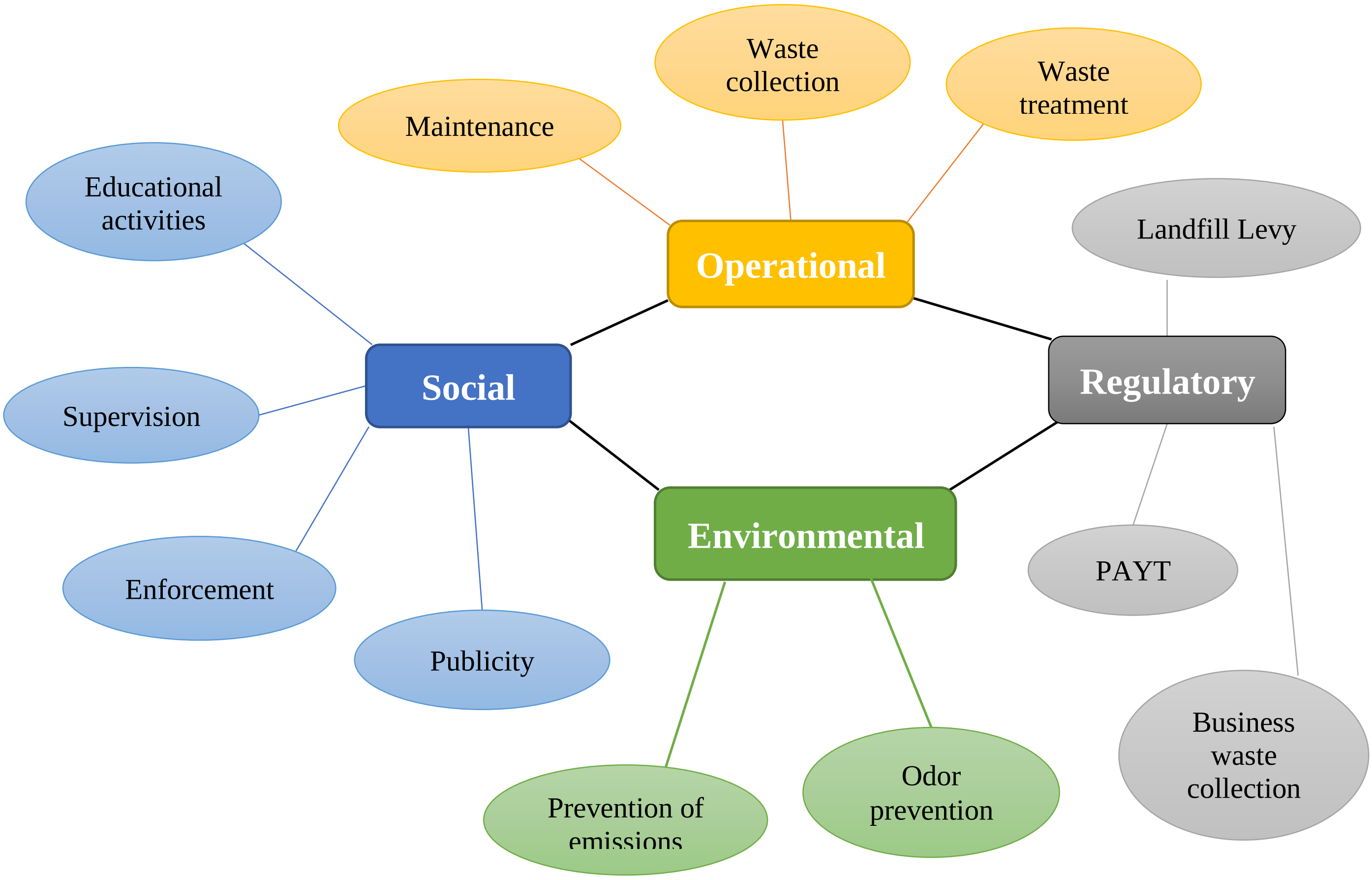
It is customary to refer to the cost components on a monthly basis, as in most cases this is how the various provided services are accounted and paid for. The total monthly cost should be evaluated before and after placing the composter as follow:

I. The total <u>actual</u> monthly costs of the waste collection, transfer and treatment, before placing the composter (BPC), i.e. existing situation.

II. The total <u>estimated</u> monthly costs of the waste collection and treatment, after placing the composter (APC). This can be assessed according to various implementation options, including a long-term forecast for assessing feasibility according to the expected participation rate, and/or other criteria. Different alternatives and scenarios are presented in section 5.4.3.

Typical cost components that may be relevant to the cost analysis of the DC project are shown in Figure 10, sorted into Operational, Social, Environmental, and Regulatory categories.

Figure 10: Typical cost components



5.4.2 The Benefits

The main benefit of the project is in the treatment of organic waste through composting. This is quantified based on the amount of organic waste that is diverted from the landfill to composting. Another indication is the monthly amount of compost produced. However, in the proposed model, reference is made to the amount of organic waste directed to composting, as that indicates both the reduction of collection and treatment costs, and the environmental benefits from directing organic waste to composting.

The total monthly benefit should be evaluated before and after placing the composter as follow:

I. The monthly amount of organic waste composted **before** placing the composter (BPC), if any, i.e. the existing situation.

II. The estimated monthly amount of organic waste directed to composting **after** placing the composter (APC).

The amount of organic waste that is directed to composting is an indicator of the reduction in the waste disposal. It is an indicator of the participation rate, when the number of participants is fixed, and it can also indicate the growth in that rate when the number of participants increases. Thus, the amount of organic waste that is directed to composting can be used to examine the feasibility of the DC project for different participation rate scenarios, at a certain point in time and over time periods.

5.4.3 The Benefit/Cost (B/C) Index

MSWM solutions should be analyzed taking into account economic, operational, and environmental aspects (Daskal, 2018; Daskal et al., 2018; Daskal et al., 2019; Daskal et al., 2020). Asi (2020) concluded that various factors affected the economic viability of DC, including the utilization of the maximum capacity of both the compressed garbage truck and the composting facility, and the volume of production as it is reflected in the absorption capacity of the organic waste. Therefore, it is estimated that DC projects are more likely to be sustainable and worthwhile for commercial waste – of restaurants, greengrocers, catering, hotels, etc. – than for household waste.

The B/C index is a pseudo-cost-benefit ratio defined for assessing the economic, social, and environmental viability of a project, taking into account the various impact variables. The calculated B/C indices allow the comparison of various alternatives and scenarios by measuring the change in cost and benefit, in particular before and after placing the composter. The cost refers to the total expenditure for the waste collection and treatment, while the benefit refers to the amount of organic waste directed to composting (which indicates the reduction in the organic waste being disposed ofl). Table 5 presents the generic data and calculations of the B/C index.

Table 5: The Benefit/Cost index

	BPC	APC
Cost (C)	X1	X2
Benefit (B)	Y1	Y2
B/C calculation	Y1/X1	Y2/X2
B/C index	In.1 = Y1/X1	In.2 = Y2/X2

If In.1 > In.2 ➔ choose option 1 (BPC)

If In.1 < In.2 ➔ choose option 2 (APC)

Table 6 presents a simple numerical example of the B/C index calculations. The calculations in Table 6 show that In.2 > In.1, therefore, option 2 is more beneficial than option 1.

Table 6: A numerical example for comparing different options

	Option 1	Option 2
Cost (C)	100	120
Benefit (B)	4	8
B/C calculation	4/100	8/120
B/C index	In.1 = 0.0400	In.2 = 0.0667

The model can be used for comparing different options that reflect various alternatives and scenarios. This may include considerations such as budget constraints, different technological solutions, different collection methods, transportation alternatives, implementing different regulatory tools, examining different scenarios of participation rates, and more.

5.4.4 Comparison between different alternatives and scenarios

The Benefit/Cost index is a very practical and effective tool for comparing different alternatives and scenarios. The comparison is made according to the index values obtained for each one of the options, as demonstrated in section 5.4.3.

The efficiency of the DC project can be evaluated according to different characteristics, alternatives, and scenarios, examples of which are shown in the following list.

1. Composter types
2. Technological solutions
3. Amounts of organic waste
4. O&M costs
5. Domestic vs. Commercial (or mixed options)
6. Participation rates (at a specific time and/or over time)
7. Waste collection methods
8. Waste collection frequency
9. Comparison between regions
10. Comparison between countries (set the cost according to the same rate)
11. Transportation alternatives
12. Implementation of regulatory tools

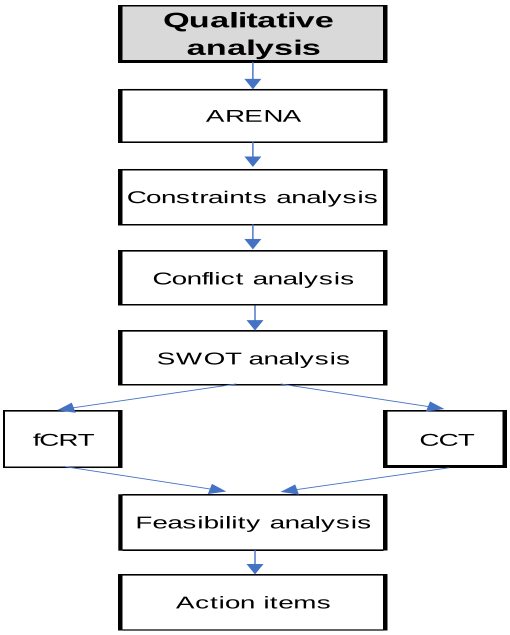
5.5 Qualitative analysis

Qualitative analysis is a complementary tool to support decision-making in cases where the quantitative analysis is equivocal.

The qualitative analysis in the DC R&T plan is based on obtaining information from experts that is relevant to the field, and analyzing the information to identify root problems and ways and means to resolve these problems.

The starting step is to locate the main "players" relevant to the project, which involves the identification and mapping of stakeholders, and the construction of the market Arena. Information obtained about those stakeholders is used to perform a SWOT analysis. To collect and process the information, a methodology has been defined that allows the classification of desirable and undesirable phenomena. The methodology entails performing a constraints analysis, a conflict analysis, SWOT, fCRT, CCT, and a feasibility analysis using the "traffic light" method, and the determination of the actions to be performed using the easy/important method. Figure 11 shows the framework of the DC R&T qualitative analysis.

Figure 11: Framework of the DC R&T Qualitative Analysis



5.5.1 The Arena Model

The Arena model is a strategic tool for the analysis of a market or an industry. It includes locating the various different organizations in the environment in which they operate, and mapping their interrelationships (Coman, 2008; Coman & Ronen, 2002;

Ronen & Pass, 2008). The methodology presented in this work focuses on two main stages of the analysis and construction of the market Arena:

(1) Mapping the main actors (stakeholders) in the MSW market by sector, as detailed in section 5.5.1.1.

(2) Analyzing the interrelationships and conflicts between the different stakeholders in the market, as detailed in section 5.5.3.

5.5.1.1. Mapping the main actors in the MSW market by sector

The starting point of building the MSW market Arena deals with mapping the main actors in the market according to sector.

In order to identify the main actors, including key persons in the organic waste management in Shefa-Amr, Israel, an extensive survey was conducted. The survey involved collecting data and documents including by-laws, minutes of government meetings, local government tenders, contracts of local authorities with various contractors, local authorities' financial reports and more.

In addition to mapping the main actors, we have classified the different actors / stakeholders in a composting system process according to the relevancy level of each "actor", the significance and effectiveness grade, and the field or major role that the actor has in the process.

For the relevancy level, we have classified the actors as national, regional, or local actors. For DC, we tried to focus on the regional and local actors.

The significance and effectiveness grade were based mainly on the fact that different actors had different influences and impact on composting projects generally, and decentralized composting projects specifically. Also, some actors may be very important, but their involvement and engagement are not guaranteed, so their ability to influence is very limited.

The actors play major roles in specific fields, so it is very important to classify them according to their roles, and also to classify those roles according to their importance in the whole organic waste management plan.

See Arena EN sheet: https://docs.google.com/spreadsheets/d/1_R61sNlyurg6JZA8OMZ4agSgC5xi-OH5Py0f8DLREp8/edit?usp=sharing

5.5.2 Constraints

According to Goldratt (1999), a constraint is defined as a limiting factor preventing a system from moving closer to achieving its goal.

In DC systems, there are various constraints. Some of them are physical, and are caused by environmental or technical limitations, while others are caused by regulations and social factors.

Various studies have reviewed the most important constraints in DC systems, with each study showing the contraints in its particular case. In other words, studies that were done on home composting analyzed the constraints on home composting, while those on community composting analyzed constraints for that case.

In our case, the model for the Constraints analysis in DC included three alternatives which were based on the three composting solutions. In the table below, we summarize four main constraints for each type of DC solution.

Table 7: DC Solutions and Related Constraints

Constraint		Type of Composting		
Type	**Description**	**Home**	**Residential Community**	**Commerical Community ***

Resources	Identify the busiest resource in the system that will limit the performance of the entire system	No time for composting activities	Existence of facilities for the treatment of waste at suitable distances Complex factors in identifying suitable locations[1] Allocating budget for the implementation, operation and maintenance of the plant, including access to initial capital cost for setup and equipment	Existence of facilities for the treatment of waste at suitable distances Complex factors in identifying suitable locations[1] Allocating Budget for the implementation, operation and maintenance of the plant, including access to initial capital cost for setup and equipment
Market	When demand is lower than the capacity of each resource, market demand becomes the factor limiting the system's ability to achieve its goals	No gardening activities	No community gardens	Demand for end facility products Low compost Quality
Policy failure	Adoption of inappropriate policies that limit the system's performance and goal achievement, which often operate contrary to the set goals	Public participation & cooperation Low participation rates[1]	Low participation rate[1] Lack of separation at source The use of the final compost product[2]	No Cooperation between the central and local government levels Lack of a regulatory framework[1] Access to land and limited space[3] Lack of public cooperation Emphasis on centralized solid waste planning[1]
Bottleneck	A situation where the bottleneck of the system is an extremely cheap resource relative to the other resources in the system	Human resources, equipment and support systems	Data constraints about food waste flow[1] Lack of technical support in operating and building community composting facilities[4]	Marginal resources Little data about food waste flow[1] Lack of technical support in operating and building community composting facilities[4]

* Commercial composting relates to organic waste generated in commercial activities.

1. Pai et al. 2019
2. Adhikari, Trémier, Martinez, & Barrington, 2010
3. Platt, 2015
4. Drescher et al., 2006

5.5.3 Conflicts

The main actor in DC is the local authority that is responsible for operating the composting systems, or at least managing them. Varying interests and points of view between this actor and other actirs could cause conflicts.

Conflicts vary depending on the type of the composting system in place. Conflicts related to home composting differ from conflicts related to community composters, or even conflicts in commercial organic waste composting. Still, all conflicts can be categorized and analyzed according to the following issues:

- The readiness and participation rate
- The ability to operate and maintain the system without problems
- The quality of the input material (organic fraction)
- The quality of the output material (compost)

In addition to these issues, setting up the composting system in an appropriate location is important, so that it is accessible, all the needed infrastructure can be easily supplied, and there is a "sufficient buffer" as a safeguard, should the composting system malfunction, which will help minimize potential conflicts.

A significant conflict is a phenomenon known as “Not in My Back Yard” (NIMBY). This phenomenon is characterized by local objections to the location of "undesirable" facilities such as renewable energy facilities (Horst, 2007), or the establishment of sites and facilities for the treatment of MSW (Garrar, 1993). A significant aspect of land use that is considered to be hazardous is Distributive Justice (Rosen-Zvi, 2007; Nakazawa, 2015), whereby residents not only object to their exposure to various environmental hazards, but also to inconveniences and decline in the value of their real estate property (Eshet et al., 2007).

The conflict with residents exits despite the fact that the residents are themselves also interested in an alternative solution to landfilling, which will reduce the negative externalities and enable the conservation of land, factors that, on the bottom line, result in a higher standard of living.

The literature shows that it is possible to reduce the residents' objections by various means such as persuasion, compensation (money), public campaigns, education and information, legislation and political proceedings, as well as by mobilizing people with public status to support an idea or a plan (Halstead et al, 1993; Lee & Jones, 1991; Nissim et al, 2005).

Additionally, some case studies from around the world present concrete solutions (Halstead et al, 1993; Lee & Jones, 1991; Rahardyana et al, 2004), indicating that this conflict may also be solvable in other places in the world, as well as in Israel.

Table 8: Conflict Analysis for a DC Project

SIDE 1	SIDE 2	CONFLICT DESCRIPTION
HOME COMPOSTING		
Households with HC	Neighbors	Poor operation of the composter can cause odour problems and attract mice and insects. The continued operation of a poorly operated composter will depend on the degree of patience of the neighbours towards such "faults".
Local Authority	Residental Waste Generators	The local authority must ensure the existence of certain conditions, such as sufficient space to carry out the composting and decentralization of the compost (for instance, over 25 square meters of garden).
Local Authority	Residental Waste Generators	The percentage of participation in composting projects is typically not high, generally below 20% and low participation rates will reduce the economic viability of the project.

RESIDENTIAL COMMUNITY COMPOSTING		
Waste Generators	Local Authority	Residents expect the authority to manage the composting process in the best way possible, so that the composting systems do not become environmental / visual nuisances. If this expectation is not met, it will lead to friction, conflict and possibly the failure of the entire process. This conflict can play major role in local authorities where the waste management services are already poor.
Local Authority	Contractor / Operating Body	Contractors tend to perform the work in the most economical and efficient way for them. This may cause the compost operator at times to try operating / handling the maximum number of composters possible in each visit, resulting in a higher possibility of malfunctions. Even when the composters are operated by volunteers and/or environmental activists, there may also be operational malfunctions, especially when volunteers are unable to invest the time required to perform the work, or when the responsibility of operating and maintaining the composter changes rapidly between volunteers.
Contractor / Operating Body	Residents	If residents participating in “waste separation” do not adhere to the organic waste separation guidelines (what belongs and what does not), many challenges can result in producing quality compost. In addition, compost operators / contractors may refuse the input material, if not properly separated.
COMMERCIAL COMMUNITY COMPOSTING		
Waste Generators / Business Owners	Local Authority	The frequency of removal of organic waste is a very critical issue, especially after "weekends", during “shopping seasons”, and on holidays, and also every time the organic waste amounts reach maximum capacity. Also, in the hot summer months, the frequent removal of organic waste is essential in order to prevent “bad odours”. According to the initial review conducted in Shefa-Amr, sometimes organic waste generated by Green grocers must be removed twice or more per day, which means higher transportation costs, that the local authority cannot afford. It should be noted that knowledge about this constraint came from the experience of local authorities with plastic and carton recycling, where the high transportation costs often led to the

		failure of the system. As such, "correcting experiences" will also be a necessary condition for promoting such a project.
Local Authority	Waste Generators / Business Owners	The rate of business owners' participation in such a process is "not understood in advance". When the participation is not “mandatory” and not based on well-planned regulations and by-laws, the participation rate is not guaranteed. It is very important to conduct an "in-depth" survey before the project begins. Not many studies exist in the field, and in Israel, such a process was carried out in Ramat Gan, in addition to a "preliminary" survey conducted in Shefa-Amr. Along with the willingness to participate in the separation of organic waste, it is very important for business owners to comply with the waste separation procedures. The presence of large amounts of "polluting" streams in the separated stream will not allow the production of quality compost or enable its economic viability.
Contractor / Operating Body	Waste Generators / Business Owners	Non-compliance of "waste producers" with organic waste separation practices (what belongs and what does not) can create many challenges in producing quality compost.

5.5.4 Strengths, Weaknesses, Opportunities, Threats

The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis originates in the business administration discipline, but is widely used in other disciplines. It is a cornerstone of the strategic analysis to identify and analyze the strengths, weaknesses, opportunities and threats in an organization’s internal and external environments (Coman &Ronen, 2009; Daskal et al., 2019; Rachid & Fadel, 2013, Ronen & Pass, 2008 ; Yuan, 2013). This methodology is also used to analyze and evaluate projects, and as a basis for strategic decision making (Coman & Ronen, 2009; Daskal et al., 2019; Rachid & Fadel, 2013 ; Ronen and Pass, 2008; Yuan, 2013).

The methodology for performing the SWOT analysis in the current research consisted of interviews with shareholders and stakeholders, both at the local and national levels, but also at the international level based on the DECOST pilot sites.

Table 9: SWOT Results for a DC Project

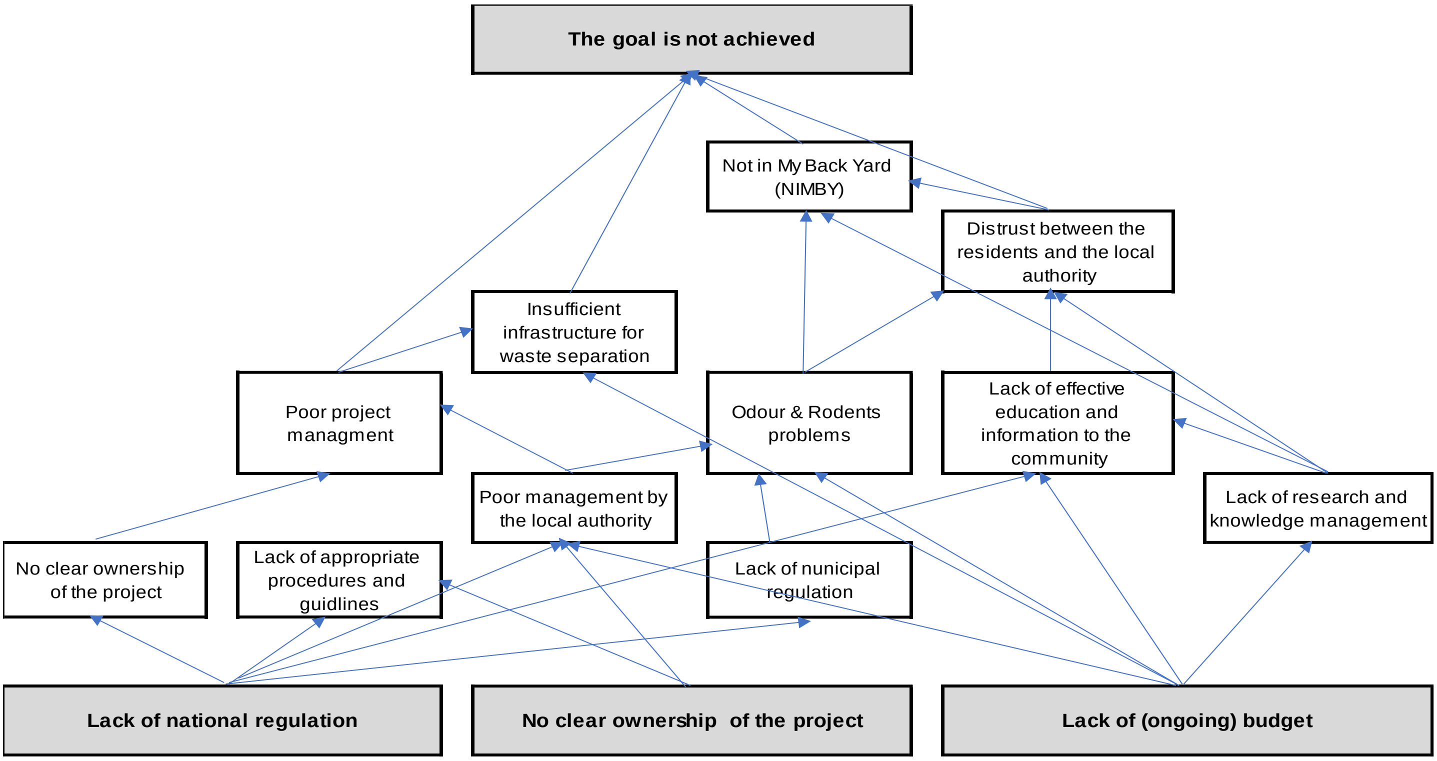
Strengths	Social	Projects for Environmental Education / Awareness
	Operational	Willingness to separate waste
		Readiness for self-clearing
		Availability of a transfer station in the city
	Environmental	Reduction of landfill waste
		Low (current) recycling percentage (also an Opportunity)
	Regulation	Landfill levy cost
Weaknesses	Social	Participation percentage
		Not in My BackYard
	Operational	Treatment capacity limitation
		The need for removal of organic waste with high frequency
		Infrastructure for waste separation in the local authority district is not sufficient
		There is not adequate infrastructure for treating separated waste, especially dry waste
	Environmental	The authority is not prepared for management of complex waste systems that include separation of waste at source
	Regulation	There are no bylaws for excess waste
		Distributive injustice in waste treatment (lack of differential regulation)
		There is no target for recycling / reducing food waste
		There are no regulations / procedures for compost planning
		Waste management by a contractor (monopoly)
		There is no mechanism to encourage composting
Opportunities	Social	Website for environmental education / awareness, i.e. support and growth in the environmental education system
		Potential for new jobs (should be examined in depth)
	Operational	Reducing operating costs in the main waste stream owing to the reduction in organic waste
	Environmental	Encouraging local agriculture / farming
		Encouraging urban agriculture
		Local compost production
		Improving health and soil quality as a function of compost quality
	Regulation	Standards for "green" jobs such as Master Composters
		Low (current) recycling percentage (also a Strength)

Threats	Social	A hotline for recycling and composting advice does not exist
		Lack of effective education and information in the field of composting
		Weak enforcement
		Extremely low participation rate
		Low readiness for the operation and maintenance of the composter over time
	Operational	Odour and rodent hazards
		Clearing costs (following increased clearing rounds)
		Need for routine maintenance and the related high costs
	Environmental	Poor compost quality
	Regulation	Non-application of bylaws

5.5.5 Focused Current Reality Tree

The focused Current Reality Tree (fCRT) is a methodology that enables the identification of root problems which prevent achieving the desired goals and objectives. The method involves taking the undesirable phenomena from the SWOT analysis, i.e. weaknesses and threats, and forming the fCRT by making logical connections between the undesirable phenomena leading to the "goal is not achieved”, and revealing 1 to 4 strategic root problems that would prevent the achievement of the goal (Coman & Ronen, 2002; Coman & Ronen, 2009; Ronen & Pas, 2008). The fCRT for identifying root problems in the implementation of a DC project is shown in Figure 12.

Figure 12: Focused Current Reality Tree for the Implementation of a DC Project



Three root problems were identified as follows:

1. Lack of national regulations

   Until today, there have been no specific regulations regarding composting in most municipalites, therefore it is problematic to plan for community composting or even home composting. For example, the setting up of the composters should be done according to clear guidlines, and the responsibility for taking part in waste composting or recycling activities should also be clear (see Table 1 for regulatory tools).

2. No clear ownership of the project

   To have clear guidelines and professional management for a project, the project should be under the ownership of a professional entity. The situation today in a city like Shefa-Amr is that the team responsible for the waste management is overloaded with lots of problems on a daily basis, and the team of the entire "unit" comprises no more than 10 people for a city of 45,000 residents. Comparing this data and numbers with those for other cities in the region, we found that the number should be bigger. For example, Nesher, a Jewish city with 24,000 residents has 30 workers just for street cleaning.

3. Lack of (ongoing) budget

According to our analysis, the allocated budget for waste management is very limited, and this budget is not sufficient for handling all the waste. In this many conflict occurs between the municipality, contractors and citizens. Conflict are almost solved by by the method of "putting out fires" and no orderly planning is done. In addition, contractors are paid lump sum prices, with extra pay for extra waste. The result of this payment method is almost an inefficient waste management system. There are no clear guidelines for the needed optimal budget of waste management and also for the required human power in the waste and cleaning unit in the Municipality.

Figure 13: Number of cleaning and gardens workers vs. population for Shefa-Amr and neighbouring cities. Source: Shafaram Municipality 2022

	Shefa-Amr		**Afula**		**Nesher**		**Kiryat Ata**	
Authority's area (dunum)	24,000		29,310		13,000		20,000	
# of residents	43,000		60,000		24,000		70,000	
# of street cleaners	5	1 per 8,600 residents	30	1 per 2,000 residents	30	1 per 800 residents	60	1 per 1,166 residents
Intensive gardening areas	To be completed		800	1 per 26 dunums	306	1 per 19 dunums	930	1 per 30 dunums
# of gardening workers	5	1 per 4,800 dunums	30	1 per 977 dunums	16	1 per 812 dunums	31	1 per 645 dunums

* Dunum = 1,000 m^2

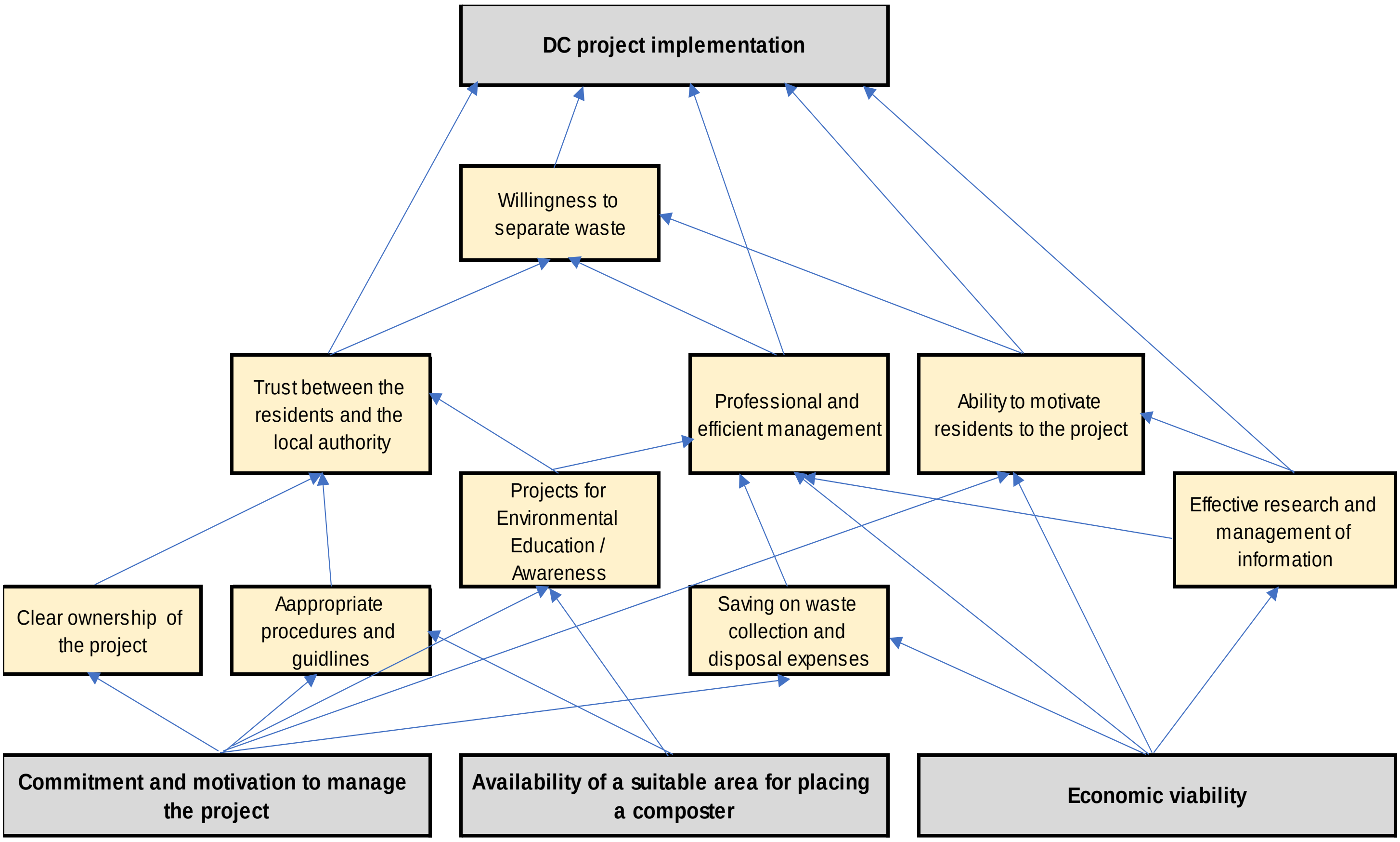
As we can see in the figure, Shefa-Amr has just one cleaning worker for every 8,600 residents, while the budgets in the neighbouring cities of Afula, Nesher and Kiryat Ata allow for one cleaning worker for every 2,000, 800 and 1,166 residents, respectively.

This shows a serious lack of budget in Shefa-Amr for cleaning, waste collection and recycling projects.

5.5.6 Core Competence Tree

The Core Competence Tree (CCT) is a methodology that enables the identification of core competencies for achieving desired goals and objectives. The method takes the desirable phenomena from SWOT, i.e. strength and opportunities, and forms the CCT by making logical connections between the desirable phenomena that always lead to achieving the defined goal. The result is revealing 1 to 4 strategic root core competences which are the core strategic capabilities to be strengthened, and to which the activity must be strategically subordinated (Coman & Ronen, 2002; Coman & Ronen, 2009; Daskal et al., 2019; Ronen & Pass, 2008). The CCT for identifying root competences in the implementation of a DC project is shown in Figure 16.

Figure 14: Core Competence Tree for the implementation of a DC project



Three core competencies were identified as follows:

1. Availabilty of a suitable area for placing the composter

   This core competency is a priority, and plays a major role in achieving the goal of the project, therefore, it also appears as a "Go / No-go" criterion, meaning that if such an area is not found, the whole project can not be implemented. This area should be chosen according to specific regulations and "rules" of the local environment. If those do not exist, then they should be adapted from other locations, locally or around the world, where composting projects are running well.

2. Economic viability

   Showing economic viability in the quantitative analysis through the Benefit/Cost Index can help in motivating the municipality to implement the project. To maximize the Economic viability, a sensitivity analysis should be done in order to ensure the optimal conditions for the project's implemention.

3. Commitment and motivation to manage the project

   The current challenges in the waste management system are the drivers of the commitment and motivation to the project. Thus, in areas where the municipality has proplematic issues with waste, and specifically with organic waste, should be more motivated it to change the situation, especially if there is a general puplic interest for change in the community, which votes the municipality council and mayor into office.

It should be noted that the core competencies could be differently evaluated for different decentralized composting solution such (home composting, community composting or communal composting (Yunus, 2020*).

5.5.7 Feasibility Analysis

The feasibility analysis, also called a feasibility study, is an assessment of the practicality of a proposed plan or project, and should be based on both the quantitative and qualitative analyses.

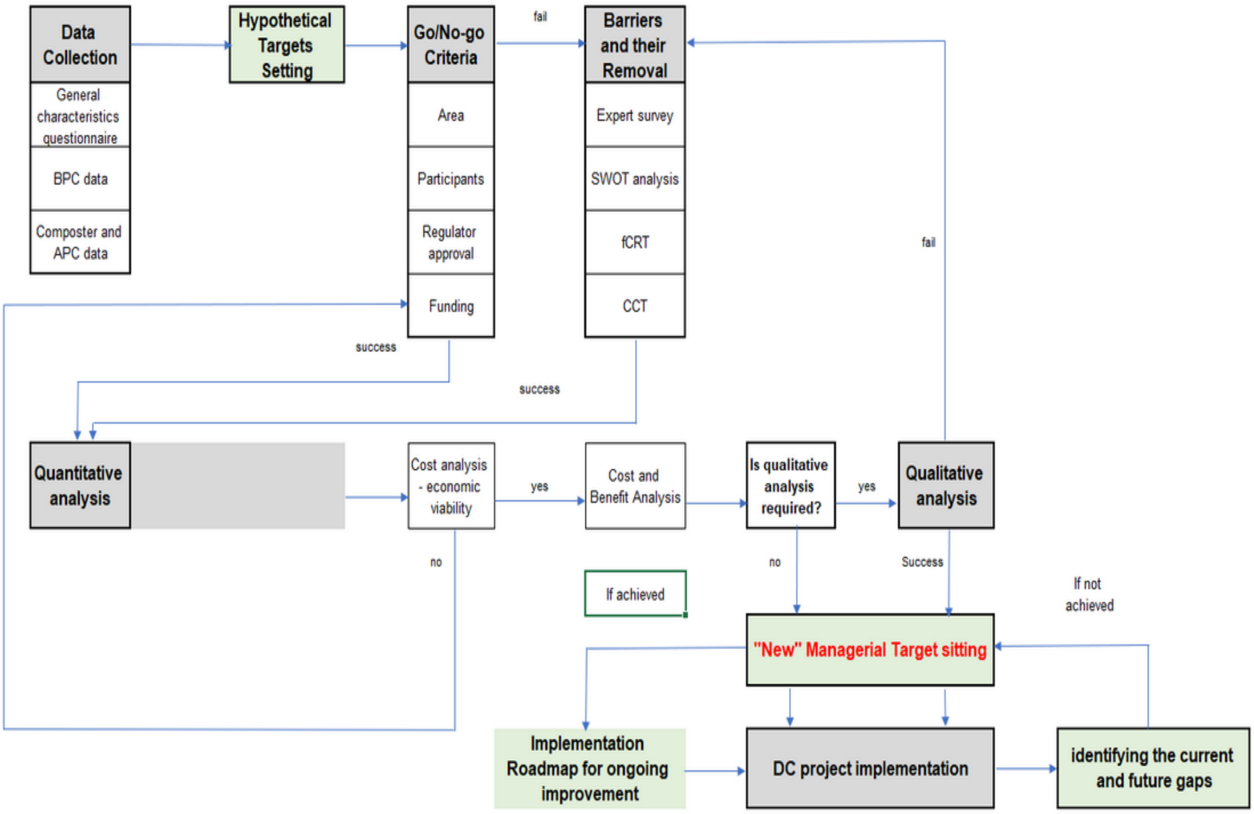
5.5.8 Target Setting

Target Setting Analysis should be done within the Replacability and Transferability Plan, in order to provide answers to questions such as “what to change”. This should be done in defined steps, relying on the rules in the Target Setting Theories. As such, target setting does not at all mean giving targets that were not discussed, or were “copied” from other case studies.

Target Setting should be done after the existing situation is well studied and analyzed, and a clear vision for the project is defined, so that questions like “why to change” and “what to change” can easily be answered. Within this stage, it is highly recommended to identify the potential future gaps and issues should the current situation not be changed.

For a DC project, a target can be the specific quantity of composted organic matter in a specific period of time. This can be tons of composted material per year, kilograms of waste per day, and anything in between. In addition, such a target may be specific, such as the goal of the DECOST Project.

Figure 15: Setting new waste manegment targets in a DC project



In addition to the importance of studying the existing situation, it is also recommended to consider other targets from similar projects, like the current indicator in the EU for food waste reduction as part of the Sustainable Development Goals (SDGs). According to that EU target, the reduction in food loss and waste (FLW) should be 30% by 2025, and 50% by 2030 (SDG 12.3 Food Waste Index).

At this stage, a hypothetical target can be suggested, meaning that it is not “the real target”, but a point from which to begin. Such a target, for example, can be "Composting 15% of the organic waste by 2025", based on the fact that 50% of food waste is avoidable, and can be either donated or treated as animal feed, and the remaining 50% can potentially be composted.

Having identified such a “hypothetical target”, it should be "highlighted and remembered" for the next stages of the Conflict and Constrains Analyses, as well as the SWOT Analysis.

After completing all of the above-mentioned analyses, a “managerial target” should be set. This target/goal should be based on the results of the SWOT Analysis, so that it concentrates on the "low hanging fruits" that were identified, and the motivational drivers/value accelerators that were determined. Moreover, it should follow the S.M.A.R.T. criteria, meaning **S**pecific, **M**easurable, **A**chievable (attainable), **R**elevant, and **T**ime-bound.

In order to achieve this goal, a road map with specific actions should be implemented, and gaps should be identified, while the project is running. It is also recommended to perform continuous monitoring of the gaps and the implemented actions to solve the constraints.

The goal of target setting is the ongoing improvement in order to achieve a better sustainable composting project, in all the aspects of sustainability: social, economical and environmental.

5.6 Decentralized Composting R&T Model - Summary

The DC R&T Plan provides a unique and innovative model and guidelines for examining the feasibility of the replicability and transferability of decentralized composting projects from one location to other locations. The model provides quantitative and qualitative methodological tools to support decision-making, including tools and guidelines for collecting relevant data and performing the calculations required to examine the economic viability and the cost-effectiveness of the project. The model takes into account economic, environmental, operational, social, and regulatory aspects.

The DC R&T model includes a comprehensive framework along with detailed processes including Go / No-go criteria, quantitative analysis, qualitative analysis, and a methodology for analyzing barriers and their removal.

6 Conclusions and Recommendations

Admittedly, it sometimes seems intuitive whether a composting project is worthwhile or not. Still, the R&T model analyzes the feasibility of DC projects through quantitative and qualitative analyses, in order to determine the worthiness of the composting project, and not make assumptions without performing a methodical analysis. The methodology is generic, and offers tools for each municipal authority anywhere to apply it locally. Further, the methodology allows a comparison between different scenarios for different authorities and/or different locations. With "worthwhile" projects, the authority can examine suggestions for expanding the project in the area where it is located, and/or in other areas.

Trust between the local authority and the residents is a crucial factor in the success of the DC project. Therefore, it is recommended to conduct a residents' satisfaction survey as a preliminary step in the implementation of the project. Sometimes, there is a gap between the authority's perception of the residents' trust and the actual trust situation, so it is recommended that the survey be performed by an external party or consultant to ensure that there is no bias.

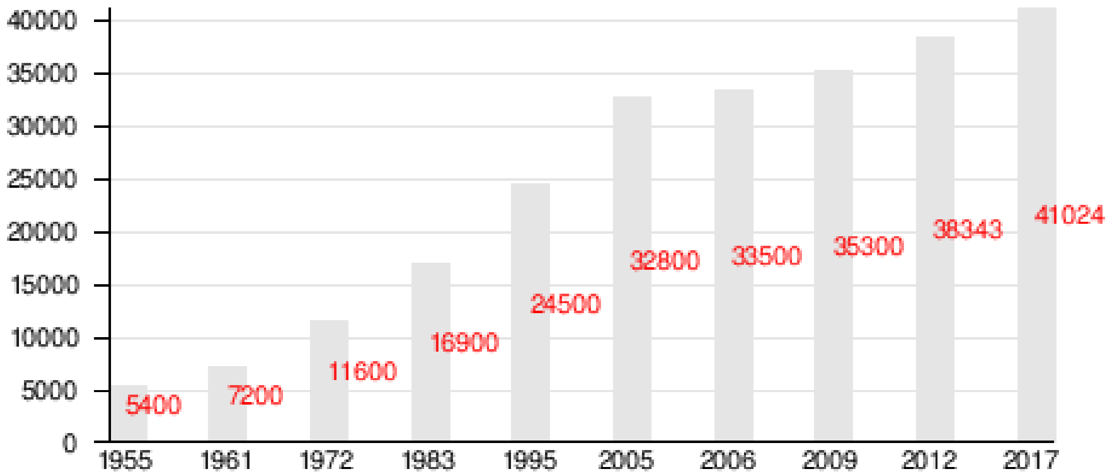
7 Simulations

The following simulations are case applications of the DECOST R&T model and guidelines, in order to present the implementation of the R&T framework. The cities of Shefa-Amr and Patras were chosen to represent home and commercial DC, respectively.

7.1 Shefa-Amr Simulation

Shefa-Amr is an Arab city in the Northern District of Israel located at the entrance to the Galilee region. In 2019, Shefa-Amr had a population of about 42 thousand residents (Israel Central Bureau of Statistics, 2020). Figure 16 presents the population growth in Shefa-Amr between 1955 to 2017.

Figure 16: The population in Shefa-Amr between 1955 and 2017

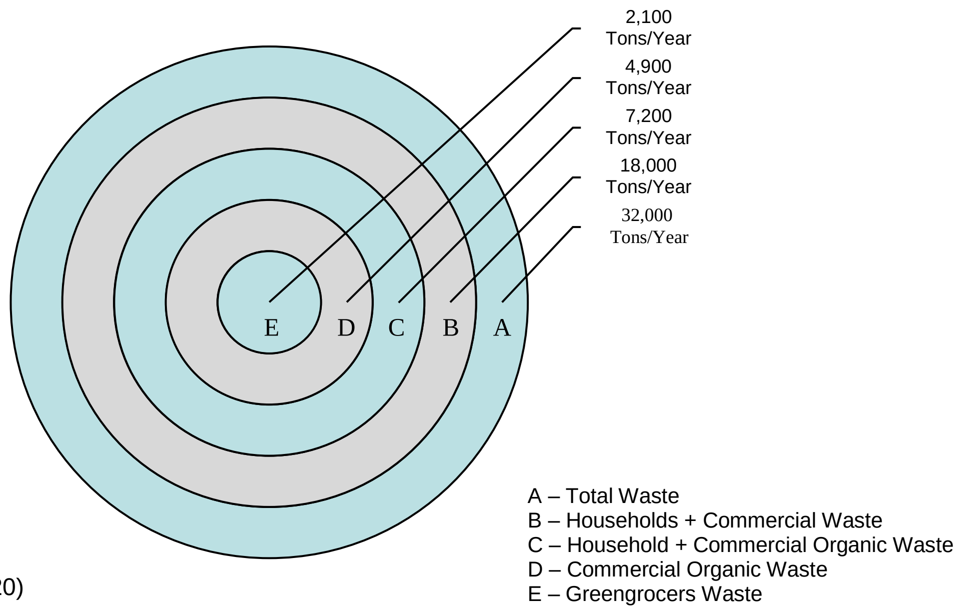


Various Sources (see Wikipedia https://en.wikipedia.org/wiki/Shefa-Amr#cite_note-51)

Of the approximately 32,000 tons of waste produced in Shefa-Amr each year, about 18,000 tons are classified, according to municipal records, as mixed household waste. That includes the waste collected from businesses located in the heart of the city and the residential neighborhoods (Asi, 2020).

Figure 19 presents the quantities of organic waste in the city of Shefa-Amr according to its sources.

Figure 17: Organic Waste in Shefa-Amr by Source



Source: Asi (2020)

7.1.1 Commercial composting

Project data and characteristics:

- 15 Greengrocers
- There is no direct waste collection fee for businesses[2]
- BPC:
    - 15 x 1,100 litre plastic bins (1 for each)
    - Mixed waste
    - 2/3 of the mixed waste is organic waste
    - The total amount of waste ~4.5 tons per day (~300 kg per greengrocer)
    - Total cost per ton is 606.29 ILS including 17% VAT
- APC:
    - HotRot 1811 composter

[2] There is a municipal property tax

- o Additional 360 litre bin for residual waste

Figure 18: 1,100 Litre plastic waste bin

Figure 19: 360 Litre plastic waste bin

Figure 20: HotRot 1811 composter

Source: http://www.waste-to-food.co.za/index.php/in-vessel-composting

The data for Shefa-Amr commercial composting, BPC and APC, are presented in Tables 8 and Table 9, respectively.

Table 8: Shefa-Amr Greengrocers data BPC

Waste properties		Waste collection									Waste treatment						
The source of the waste (Domestic / Commercial / Industrial)	Type of waste (Mixed / Organic separated at source/ Packaging separated at source/ Other)	Type of receptacle (Can / bin/ container / underground container)	Volume (Liters)	No. Of WCB	Weekly collection frequency	Total no. of monthly collections (average)	The cost of one-time collection from one receptacle (currency)	Total monthly cost (NIS)	Waste hauler (private/ municipal)	The payer (local authority/ business/ resident)	The name of the site that receives the waste	The distance of the site from the local authority / area of the project (km)	Tipping fee to the waste site (currency/ Ton)	Levy/ tax (NIS/ton)	Total cost per ton	Total Monthly amount (ton) - 4.5 ton/Day * 26 days	Total cost (According to total ton) NIS
BPC																	
Commercial	Mixed	Container	1100	15	6	387	75.58	29,250	Local authority	Local authority	Hiriya	100	140.2	128	268.2	117.00	31,379.4
The total monthly cost for each category								**29,250**									**31,379.4**
Total monthly cost																	**60,629**

Table 9: Shefa-Amr Greengrocers data APC

APC																	
Commercial	Organic	Container	1100	15	6	387	75.58	29,250	Local authority	Local authority	Hiriya	100	140.2	128	268.2	78.00	20,919.6
Commercial	Residual	Container	360	15	6	387	25.19	9,750	Local authority	Local authority	Hiriya	100	140.2	128	268.2	39.00	10,459.8
Compostation																	25,208.3
The total monthly cost for each category								**9,750**									**35,668.1**
Total monthly cost																	**45,418**

The monthly costs for Shefa-Amr commercial composting are presented in Table 10 (ILS) and Table 11 (Euro).

Table 10: Monthly cost results for Shefa-Amr (ILS)

	Collection	Treatment	Compostation	Total cost
BPC	29,250	31,379	0	**60,629**
APC	9,750	10,460	25,208	**45,418**

Table 11: Monthly cost results for Shefa-Amr (Euro)

	Collection	Treatment	Compostation	Total cost
BPC	7,405	7,944	0	**15,349**
APC	2,468	2,648	6,382	**11,498**

(Exchange rate = 3.95 ILS per Euro)

The amount of organic waste directed to composting in both options is 78 tons per month.

Table 12 shows the summary of monthly cost and benefit results for Shefa-Amr.

Table 12: Summary of monthly cost and benefit results for Shefa-Amr

	BPC	APC
Cost (C)	60,629	45,418
Benefit (B)	7.8	78.00
B/C index	0.0001	0.0017

7.1.2 Community composting

In this simulation, the alternative of community composting was examined. The data is presented in Tables 13 and 14. A participation rate of 15% is assumed, and a Euro-ILS rate of 3.75 was use, where applicable.

Table 13: Shefa-Amr community composting project characteristics

No.	Composter Type	Annual Composting Cost (ILS)	Buildings in the Area	Apartments in the Area	Population in the Area	OFMSW Amount ton/year)
1	CtTec - Bio - Bi I.3.X	15,625	15.15	29	29	18
2	CtTec - Bio - Bi I.5.X	31,250	186	53	53	32
3	CtTec - Bio - Bi I.5.X	31,250	176	50	50	31
4	CtTec - Bio - Bi I.5.X	31,250	170	48	48	30
Totals		**109,375**	**547.15**	**180**	**180**	**110**

Table 14: Shefa-Amr community composting BPC and APC data

Average Monthly Costs (ILS)

Component	BPC	APC	Difference
Collection, transfer and treatment	36,650	31,150	5,500
Compostation	0	9,115	-9,115
Total	36,650	40,265	-3,615

Savings through Composting of OFMSW / Diverting from Landfilling

Item	BPC	APC
Tons per year	73.3	172.3
Tons per month	6.1	14.4

Benefit/Cost Index Calculations

Item	BPC	APC
Costs (ILS)	36,650	40,265
Benefit (ton)	6.1	14.4
B/C Index	0.00017	0.00036

The results (0.00036 vs. 0.00017) show that the benefit/cost index is higher for the APC option (after placing the community composter). However, compared to commercial composting, the results show that the benefit/cost index of commercial composting is significantly higher than that of community composting, 0.00036 for community composting Vs. 0.0017 for commercial composting.

For more Details regarding the planning of community composting, see Appendix G.

7.1.3 Home composting

In this simulation, the alternative of home composting was examined. Data is presented in Table 15 and Table 16.

Table 15: Shefa-Amr home composting project characteristics

No.	Composter Type	Annual Composting Cost (ILS)	Buildings in the Area	Apartments in the Area	Population in the Area	OFMSW Amount ton/year)
	Home comsposters	1,440	15.15	29	117	20
		2,648	186	53	215	37
		2,505	176	50	203	35
		2,423	170	48	196	34
Totals		**9,015**	**547.15**	**180**	**731**	**126**

Participation rate 1 = 5%

Table 16: Shefa-Amr home composting BPC and APC data

Average Monthly Costs (ILS)

Component	BPC	APC	Difference
Collection, transfer and treatment	36,650	31,150	5,500
Compostation	0	751	-751
Total	36,650	31,901	-4,749

Savings through Composting of OFMSW

Item	BPC	APC
Tons per year	73.3	188.3
Tons per month	6.1	15.7

Benefit/Cost Index Calculations

Item	BPC	APC
Costs (ILS)	36,650	31,901
Benefit (ton)	6.1	15.7
B/C Index	0.00017	0.00049

7.1.4 Summary of C/B Analysis for Shefa-Amr

A summary of B/C Index calulations for the three aforementioned options is provided in the next table.

Table 17: Shefa-Amr Composting Options BPC and APC Data

	BPC	APC **COMMERCIAL COMPOSTING**	APC **COMMUNITY COMPOSTING**	APC **HOME COMPOSTING**
COST (ILS)	36,650	45,418	40,265	31901
BENEFIT (TONS)	6.1	78	14.4	15.7
B/C INDEX	0.00017	0.00172	0.00036	0.00049

The results show that the best B/C result is obtained for the commercial composting option, followed by home composting, then community composting.

7.2 Patras' area (Rio) simulation in Greece

Patras is the third-largest city in Greece, and the municipality of Patras has a population of 213,984 inhabitants (2011) and an area of 333.14 km^2. Patras is the regional capital of Western Greece, in the northern Peloponnese, 215 km west of Athens. The city is built at the foot of Mount Panachaikon, overlooking the Gulf of Patras. The study area selected for the community composting project in Patras is the Rio neighborhood. Rio is located on the Homonymous Cape, 8 km northeast of the city of Patras. It has an area of almost 98,000 acres and a population of 14,000 inhabitants (see Figure 23). The large area and the developing agriculture in the area of Rio make it a perfect neighborhood for community composting.

Figure 21: Rio Neighbourhood

<u>Patras' DC Project characteristics:</u>

- Domestic community composters
- Organic waste is approximately 50% of the mixed waste

The information presented below is based on the Local Waste Management Plan (LWMP) for the Municipality of Patras that was published in 2015. Unfortunately, more recent information was very difficult to find. All mixed waste bins (green bins) in the Municipality of Patras (MoP) have a capacity of 1,100 litres each. Small bins of significantly lower capacity (e.g. 250 litres) are not included in this analysis. There are 6,511 bins in the MoP, with 1,101 in the Rio area. The average waste collection frequency from the bins is 6 times per week (26 times per month).

To calculate the total annual cost for only the mixed waste collection, all the relevant annual costs from the Local Waste Management Plan were added, as presented in Table 18. Thus, the total annual cost for only the mixed waste collection was calculated as equal to 5,207,900.76€, resulting in a total monthly cost of 433,991.73€. The cost of a one-time collection from one receptacle was calculated as 433,991.73 ÷ 26 ÷ 6,511 = 2,564€. This is the cost for each and every bin in the Patras area. Therefore, for Rio, the total monthly cost, based on 1,101 bins, was calculated to be 2,564€ x 26 = 73,387.33€.

Table 18: Rio study area - BPC

Waste properties		**Waste collection**								
Source[1] of the waste	**Type of waste[2]**	**Type of receptacle[3]**	**Volume (Litres)**	**No. of WCB**	**Collection frequency per week**	**Average collections per month per receptacle**	**Cost (€)of one-time collection from one receptacle**	**Total monthly cost (€)**	**Waste hauler[4]**	**Payer[5]**
Domestic (all)	Mixed	Bin	1,100	6,511	6	26	2.564	433,992	Municipal	Local authority
Domestic (Rio)	Mixed	Bin	1,100	1,101	6	26	2.564	73,387	Municipal	Local authority
Domestic (Rio study area)	Mixed	Bin	1,100	122	6	26	2.564	8,132	Municipal	Local authority

1 Domestic / Commercial / Industrial
2 Mixed / Organic separated at source / Packaging separated at source / Other
3 Can / bin / container / underground container
4 Private / municipal
5 local authority/ business/ resident

	Waste treatment				
	Name of the site receiving the waste	**Distance of site from local authority / project area (km)**	**Tipping fee to the waste site (€/ton)**	**Total cost (€/ton)**	**Total cost € (based on total tons)**
Domestic (all)	Xerolaka	4.7	35.00	107.93	13,542,055.49
Domestic (Rio)	Xerolaka	6.4	35.00	107.93	1,227,889.35
Domestic (Rio - study area)	Xerolaka	7.4	35.00	107.93	136,060.40

The total monthly cost for waste collection in Rio was found to equal 8,131.93€. The proposed scenario is expected to decrease this cost.

The main proposed scenarios are focused on implementing either home composting or community composting. This “best practice” is applied through the DECOST Project, and offers many benefits beyond just organic waste collection bins. The biggest benefit is that no waste collection procedure will be followed, as the community composters will produce compost, which will be used by the residents and no collection will be needed.

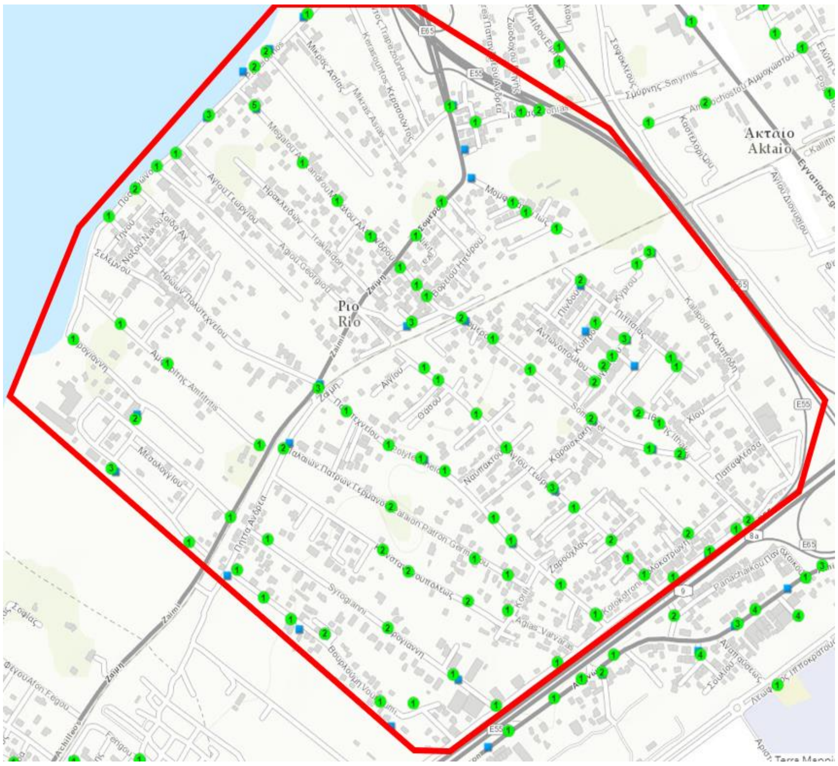
According to the LWMP for the Municipality of Patras, the average annual mixed waste production in Rio is 8,591.11 tons. Generally, for the Municipality of Patras, the average percentage of organic waste included in the mixed waste is 44.3% w/w. For the study area, the total organic waste has an annual volume of 324.4 m^3, as presented in Table 19.

Table 19: Annual volume and weight of mixed and organic waste for Rio and for the specific study area in Rio

No. of bins	Item	Annual volume (m^3)
1,101	Total mixed waste from Rio	6,608.55
1,101	Total organic waste from Rio	2,927.59
122	Total mixed waste for study area	732.28
122	Total organic waste for study area	324.40

Since there was information available only for a limited area in Rio, with 122 mixed waste collection bins, that area was selected as the study area. The chosen area covers 1,587 km^2. The initial screenshot is shown in Figure 24, with a red polygon delimiting the study area. The green circles indicate the positions of the green bins (bins for mixed waste), while the number in the green circle, from 1 to 3, indicates the number of green bins at the corresponding position.

Figure 22: The study area in Rio



7.2.1 First Proposed Scenario - Home Composting

The first proposed scenario focuses on the use of Home Composting in the study area. The number of households is required in order to determine the number of home composters that will be used in the study area. In the general Rio area, the number of bins is 1,101, and there are 14,000 inhabits. It is calculated that in Rio (only the study area) there are 122 bins, thus the number of residents in the area is extrapolated to be 14,000 ÷ 1,100 x 122 = 1,551, assuming that the same ratio of people-to-bins exists for the study area as for Rio. Another assumption of 4 inhabitats per household leads to a calculation of the number of households as 1,551 ÷ 4 = 388.

The proposed home composter is the COMPOSITOR ECO composter (28 litres) made by Garantia (Germany). It is a garden composter with adjustable air ducts, so that it is possible to change the air supply according to weather conditions in order to achieve ideal conditions of ventilation and humidity in the composter. The composter is shown in Figure 23, and has a diameter of 79 cm and a height of 84 cm. The cost of each composter is 67 €.

Figure 23: Compositor ECO composter

In order to fully determine the best case scenario for the use of these Home Composters, four use cases were examined based on two parameters: the transportation or collection costs and the investment costs.

In the first use case, the **Waste collection cost** (with composters) **doesn't change**, the waste collection takes place 6 times per week (same as current situation) and the **investment is paid per year (PMT).**

Scenario 1 Home Composting (1st Use case)

Composter capacity	0.28 m3
Number of composters	388
Price per composter	67 €
Composters cost (investment)	25,996 €
Composters cost (investment) per year (PMT)	3,367 €
Salaries per month	0
Salaries per year	0
Waste collection (with composters) 6 times per week	8,132 €

Waste collection (with composters) per year	97,572 €
Waste treatment per year	136,060 €

Table 20: Summary results for Rio study area (proposed scenario 1 –Use case 1)

	BPC	APC – Year 1
Cost	19,469 €	19,750 €
Benefit	0	162
B/C	0	0.0082

In the second use case, the **Waste collection cost** (with composters) **doesn't change**, the waste collection takes place 6 times per week (same as current situation) and the **investment is upfront the first year.**

Scenario 1 Home Composting (2nd Use case)

Composter capacity	0.28 m3
Number of composters	388
price per composter	67 €
Composters cost (investment)	25,996 €
Composters cost (investment) per year (PMT)	-
Salaries per month	0
Salaries per year	0
Waste collection (with composters) 6 times per week	8,132 €
Waste collection (with composters) per year	97,572 €
Waste treatment per year	136,060 €

Table 21: Summary results for Rio study area (proposed scenario 1 –use case 2)

	BPC	APC – Year 1
Cost	19,469 €	21,636 €
Benefit	0	162
B/C	0	0.0075

In the third use case, the **Waste collection cost** (with composters) **changes**, the waste collection takes place 3 times per week (instead of 6) and the **investment is paid per year (PMT).**

Scenario 1 Home Composting (3rd Use case)

Composter capacity	0.28 m3
Number of composters	388
Price per composter	67 €
Composters cost (investment)	25,996 €
Composters cost (investment) per year (PMT)	3,367 €
Salaries per month	0
Salaries per year	0
Waste collection (with composters) 3 times per week	4,066 €
Waste collection (with composters) per year	48,786 €
Waste treatment per year	136,060 €

Table 22: Summary results for Rio study area (proposed scenario 1 –use case 3)

	BPC	APC – Year 1
Cost	19,469 €	15,684 €
Benefit	0	162
B/C	0	0.0103

In the fourth use case, the **Waste collection cost** (with composters) **changes**, the waste collection takes place 3 times per week and the **investment is** the **investment is upfront the first year.**

Scenario 1 Home Composting (4th Use case)

Composter capacity	0.4 m3
Number of composters	68
Price per composter	1,572.5 €
Composters cost (investment)	106,930 €
Composters cost (investment) per year (PMT)	-
Salaries per month	3,600 €

Salaries per year	43,200 €
Waste collection (with composters) 6 times per week	4,066 €
Waste collection (with composters) per year	48,786 €
Waste treatment per year	113,028 €

Table 23: Summary results for Rio study area (proposed scenario 1–use case 4)

	BPC	APC – Year 1
Cost	19,469 €	17,570 €
Benefit	0	162
B/C	0	0.0092

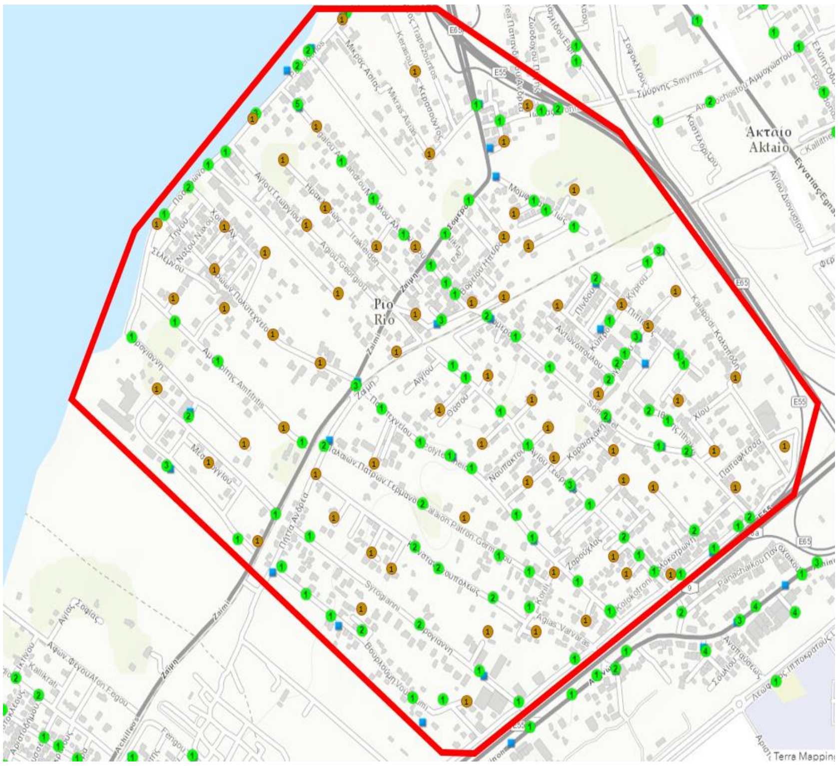
7.2.2 Second Proposed Scenario – Community Composting A

The proposed mechanical community composters are acquired from Veltiotiki G. Pappas. The model is JK 400, which dimensions are 1,400 mm x 800 mm x 1,300 mm, and has a capacity of 0.4 m^3. The composter needs a month to completely convert organic waste into compost.

Figure 24: JK 400 community composter

To deteremine the number of community composters (CCs) for the study area, an analysis of the organic waste production for that area is needed. The annual volume of the total organic waste from Rio (only for study area) is 324.40 m^3 (Table 21). The chosen CCs have a capacity of 0.4 m^3 each, and they need about a month to completely transform the organic waste into compost. Thus, to satisfy the need of 324.4 m^3 of organic waste, at least 68 CCs are needed (324.4 ÷ 12 ÷ 0.4 = 67.58). Locating the CCs took into consideration the home positions as shown in the map. These CCs will be placed on the side of the road, and will be property of MoP. These locations are presented in Figure 27 as brown circles. The number in the circle indicates the number of CCs per position.

Figure 25: Proposed positions of CCs in Rio for the first scenario



The starting point of the proposed solution is the initial investment cost, i.e. the cost of buying 68 community composters. With a price of 1,572.5 € per community composter, the total cost is 106,930 € for all the composters. In addition, it is estimated that 6 people (permanent staff of 2 teams with 3 people each) will be needed to check the composters, add material when needed, and stir the compost. The associated cost is 6 x 600 € per month = 3,600 € per month, or 43,200 € per year. Other annual costs should be taken into account for materials needed to fix and improve the compost, to deactivate smells and for dissemination activities for people's participation.

Moreover, as less mixed waste is disposed of at the Xeroka landfill, the waste treatment costs are expected to decrease. In particular, the total cost of mixed waste treatment is expected to be equal to 113,027.6 € per year, calculated as 136,060 - ((35 + 107.93) x 162), instead of 136,060 € per year, which is the cost in the current situation. The benefit is 162 ton per year (324 m^3 per year), assuming that 1 m^3 OFMSW = 0.5 ton OFMSW tons, that are directed to composting.

In order to fully determine the best case scenario for the use of these community composters, four use cases were examined based on two paratmeters: the transportation cost and the investment cost.

In the first use case, the **Waste collection cost** (with composters) **doesn't change** and the waste collection takes place 6 times per week (same as current situation) and the **investment is paid per year (PMT).**

Scenario 2 Community Composting A (1st Use case)

Composter capacity	0.4 m3
Number of composters	68
price per composter	1,572.5 €
Composters cost (investment)	106,930 €
Composters cost (investment) per year (PMT)	8,581 €
Salaries per month	3,600 €
Salaries per year	43,200 €
Waste collection (with composters) 6 times per week	8,132 €
Waste collection (with composters) per year	97,572 €
Waste treatment per year	113,027.6 €

Table 24: Summary results for Rio study area (proposed scenario 2 – Use case 1)

	BPC	APC – Year 1
Cost	19,469 €	21,865 €
Benefit	0	162
B/C	0	0.0074

In the second use case, the **Waste collection cost** (with composters) **doesn't change** and the waste collection takes place 6 times per week (same as the current situation) and the **investment is upfront the first year.**

Scenario 2 Community Composting A (2nd Use case)

Composter capacity	0.4 m3
Number of composters	68
price per composter	1,572.5 €
Composters cost (investment)	106,930 €
Composters cost (investment) per year (PMT)	-
Salaries per month	3,600 €
Salaries per year	43,200 €
Waste collection (with composters) 6 times per week	8,132 €
Waste collection (with composters) per year	97,572 €
Waste treatment per year	113,027.6 €

Table 25: Summary results for Rio study area (proposed scenario 2 – Use case 2)

	BPC	APC – Year 1
Cost	19,469 €	30,061 €
Benefit	0	162
B/C	0	0.0054

In the third use case, the **Waste collection cost** (with composters) **changes** and the waste collection takes place 3 times per week and the **investment is paid per year (PMT).** As the organic waste is almost half of the mixed waste in the current situation, the mixed waste bins, after the implementation of the proposed scenario, can be emptied every other day (3 times per week instead of 6). That way, the waste collection cost is expected to drop in half.

Scenario 2 Community Composting A (3rd Use case)

Composter capacity	0.4 m3
Number of composters	68

Price per composter	1,572.5 €
Composters cost (investment)	106,930 €
Composters cost (investment) per year (PMT)	8,581 €
Salaries per month	3,600 €
Salaries per year	43,200 €
Waste collection (with composters) 3 times per week	4,066 €
Waste collection (with composters) per year	48,786 €
Waste treatment per year	113,027.6 €

Table 26: Summary results for Rio study area (proposed scenario 2 – Use case 3)

	BPC	APC – Year 1
Cost	19,469 €	17,800 €
Benefit	0	162
B/C	0	0.0091

In the fourth use case, the **Waste collection cost** (with composters) **changes** and the waste collection takes place 3 times per week and the **investment is upfront the first year.**

Scenario 2 Community Composting A (4th Use case)

Composter capacity	0.4 m3
Number of composters	68
Price per composter	1572.5 €
Composters cost (investment)	106,930 €
Composters cost (investment) per year (PMT)	-
Salaries per month	3,600 €
Salaries per year	43,200 €
Waste collection (with composters) 6 times per week	4,066 €
Waste collection (with composters) per year	48786 €
Waste treatment per year	113027.6 €

Table 27: Summary results for Rio study area (proposed scenario 2 – Use case 4)

	BPC	APC – Year 1
Cost	19,469 €	25,995 €
Benefit	0	162

B/C	0	0.0062

7.2.3 Third Proposed Scenario – Community Composting B

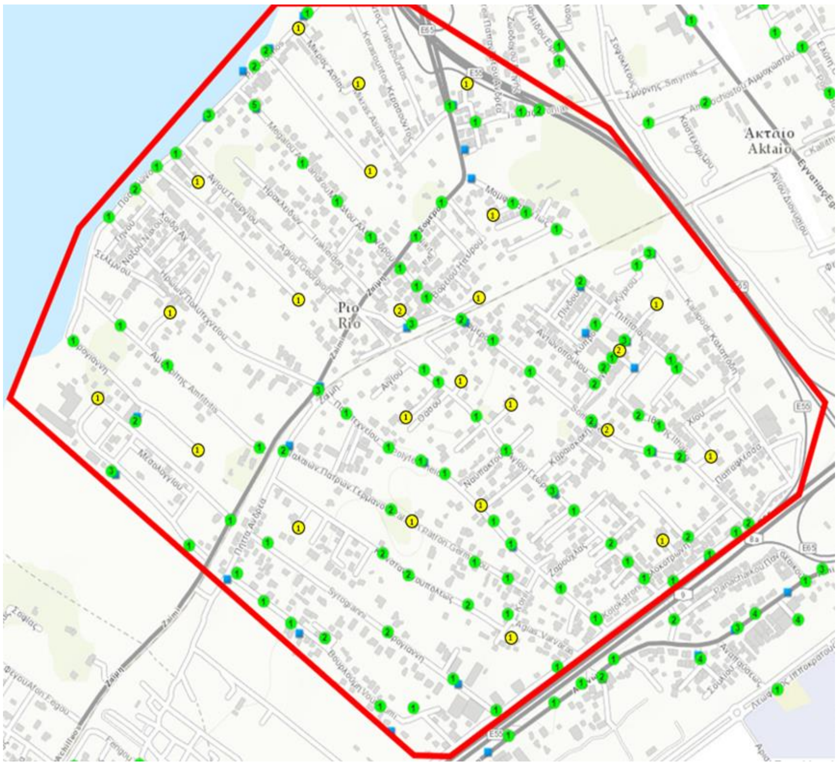
In the third proposed scenario, the Vermican modular composter is suggested. This composter is the market leader for community composters throughout the national territory. Vermican composters are used in the ambitious community composting program of the Pontevedra Provincial Council, Plan Revitaliza, in Spain. They are robust and offer a faster process that the traditional composting methods, while producing a high quality compost. Vermican designed the composters in a modular way. The composter is easy to install and is sized for each line of 3 composters to serve approximately 30 families.

Figure 26: Four Vermican modular composters in Santa Cilia, Spain

To determine the number of Vermican CCs needed in the study area, information regarding the organic waste production for that area is needed. As already mentioned, the average annual mixed waste production in Rio is 8,591.11 tons.

The Vermican CC has a capacity of approximately 0.08 ton/month (1 m^3). Thus, to satisfy the demand of 324.4 m^3 of organic waste produced in the study area (Table 21), at least 27 CCs (324.4 ÷ 12 ÷ 1) need to be implemented. Locating the CCs took into consideration the home positions as shown in the map. These CCs will be placed on the side of the road, and will be property of MoP. The positions are presented in figure 29 with yellow circles. The number in the circle indicates the number of CCs per position.

Figure 27: Proposed positions of CCs in Rio for the second scenario



The initial cost of the proposed solution is the investment cost, i.e. the cost for buying the 27 Vermican community composters. The price for the selected community composter is 670.00 €, so the total cost is 27 x 670 = 18,090 € for all composters. Moreover, since in this scenario the number of composters is lower than that in the second scenario, the staff cost has to be adjusted accordingly, thus the permanent staff will include a team of 3 people (21,600 € per year). Other annual costs can be considered for materials needed to correct the compost, to deactivate smells and for dissemination activities for people's participation.

Moreover, as less mixed waste will be disposed of at Xeroka landfill, the waste treatment costs are expected to decrease. The total cost of the mixed waste treatment is expected to be 113,027.60 € per year, and the benefit is 162 ton per year.

In order to fully determine the best case scenario for the use of these Community Composters, four use cases were examined based on two paratmeters: the transportation cost and the investment cost.

In the first use case, the **Waste collection cost** (with composters) **doesn't change** and the waste collection takes place 6 times per week (same as the current situation) and the **investment is paid per year (PMT)**.

Scenario 3 Community Composting B (1st Use case)

Composter capacity	1 m3
Number of composters	27
Price per composter	670 €
Composters cost (investment)	18,090 €
Composters cost (investment) per year (PMT)	1,743 €
Salaries per month	1,800 €
Salaries per year	21600 €
Waste collection (with composters) 6 times per week	8,132 €
Waste collection (with composters) per year	97,572 €
Waste treatment per year	113,027.60 €

Table 28: Summary results for Rio study area (proposed scenario 3 – use case 1)

	BPC	**APC – Year 1**
Cost	19,469 €	19,495 €

Benefit	0	162
B/C	0	0.0083

In the second use case, the **Waste collection cost** (with composters) **doesn't change** and the waste collection takes place 6 times per week (same as current situation) and the **investment is upfront the first year.**

Scenario 3 Community Composting B (2nd Use case)

Composter capacity	1 m3
Number of composters	27
Price per composter	670 €
Composters cost (investment)	18,090 €
Composters cost (investment) per year (PMT)	-
Salaries per month	1,800 €
Salaries per year	21600 €
Waste collection (with composters) 6 times per week	8,132 €
Waste collection (with composters) per year	97,572 €
Waste treatment per year	113,027.60 €

Table 29: Summary results for Rio study area (proposed scenario 3 – use case 2)

	BPC	**APC – Year 1**
Cost	19,469 €	20,857 €
Benefit	0	162
B/C	0	0.0078

In the third alternative, the **Waste collection cost** (with composters) **changes** and the waste collection takes place 3 times per week and the **investment is paid per year (PMT).** As the organic waste is almost half of the mixed waste in the current situation, the mixed waste bins, after the implementation of the proposed scenario, can be emptied every other day (3 times per week instead of 6). That way, the waste collection cost is expected to drop in half.

Scenario 3 Community Composting B (3rd Use case)

Composter capacity	1 m3
Number of composters	27
Price per composter	670 €
Composters cost (investment)	18,090 €
Composters cost (investment) per year (PMT)	1,743 €
Salaries per month	1,800 €
Salaries per year	21,600 €
Waste collection (with composters) 3 times per week	4,066 €
Waste collection (with composters) per year	48,786 €
Waste treatment per year	113,027.60 €

Table 30: Summary results for Rio study area (proposed scenario 3 – use case 3)

	BPC	APC – Year 1
Cost	19,469 €	15,430 €
Benefit	0	162
B/C	0	0.0105

In the fourth alternative, the **Waste collection cost** (with composters) **changes** and the waste collection takes place 3 times per week and the **investment is** the **investment is upfront the first year.**

Scenario 3 Community Composting B (4th Use case)

Composter capacity	1 m3
Number of composters	27
Price per composter	670 €
Composters cost (investment)	18,090 €
Composters cost (investment) per year (PMT)	-
Salaries per month	1,800 €
Salaries per year	21,600 €
Waste collection (with composters) 3 times per week	4,066 €
Waste collection (with composters) per year	48,786 €
Waste treatment per year	113,027.60 €

Table 31: Summary results for Rio study area (proposed scenario 3 – Use case 4)

	BPC	APC – Year 1
Cost	19,469 €	16,792 €
Benefit	0	162
B/C	0	0.0097

7.3 Comparison of the Different Scenarios

Simulation in Greece (Rio Patras)

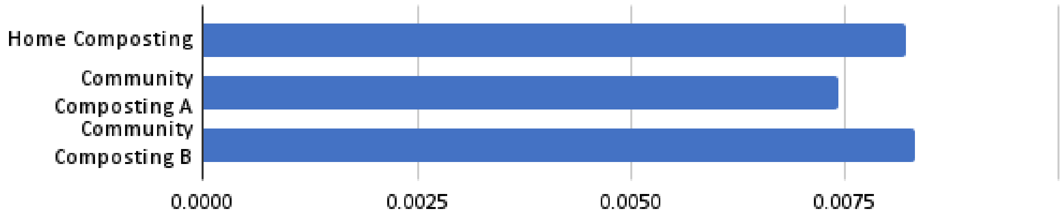
In the following tables and charts, the Benefit/Cost analysis for the three different scenarios (Home Composting, Community Composting A, Community Composting B) and each of the four use cases is summarised.

1st Use case

Table 32: Results for Rio study area (all scenarios comparison– Use case 1)

Use Case 1	Home Composting	*Community Composting A*	*Community Composting B*
Composter capacity	0.28	0.4 m^3	1 m^3
Number of composters	**388**	**68**	**27**
Price per composter	67	1,572.5	670
Composters cost (investment)	25,996	106,930	18,090
Composters cost (investment) per year (PMT)	3,367	8,581	1,743
Salaries per month	0	3,600	1,800
Salaries per year	0	43,200	21,600
Waste collection (with composters) 6 times per week	8,132	8,132	8,132
Waste collection (with composters) per year	97,572	97,572	97,572
Waste treatment per year	136,060	113,027.6	113,027.6

The Result	Scenario	APC -Year 1
The Benefit/Cost Index	Home Composting	0.0082
	Community Composting A	0.0074
	Community Composting B	**0.0083**

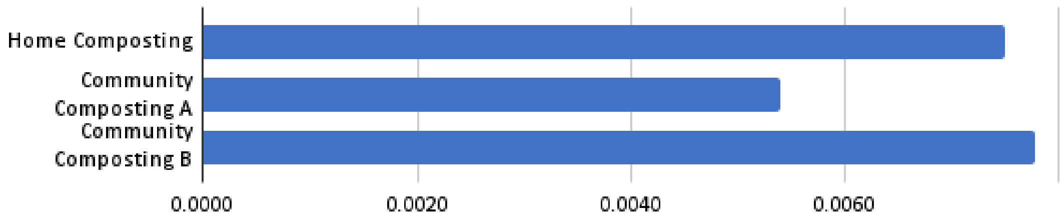


2nd Use case

Table 33: Results for Rio study area (all scenarios comparison– Use case 2)

Use Case 2	Home Composting	Community Composting A	Community Composting B
Composter capacity	0.28	0.4 m^3	1 m^3
Number of composters	**388**	**68**	**27**
Price per composter	67	1,572.5	670
Composters cost (investment)	25,996	106,930	18,090
Composters cost (investment) per year (PMT)	3,367	8,581	1,743
Salaries per month	0	3,600	1,800
Salaries per year	0	43,200	21,600
Waste collection (with composters) 6 times per week	8,132	8,132	8,132
Waste collection (with composters) per year	97,572	97,572	97,572
Waste treatment per year	136,060	113,027.6	113,027.6

The Result	Scenario	APC -Year 1
The Benefit/Cost Index	Home Composting	0.0075
	Community Composting A	0.0054
	Community Composting B	**0.0078**



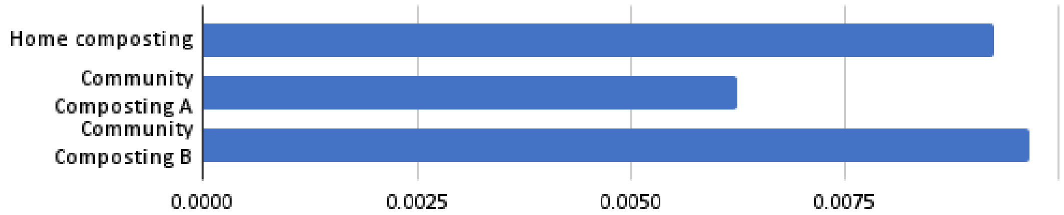
3rd Use case

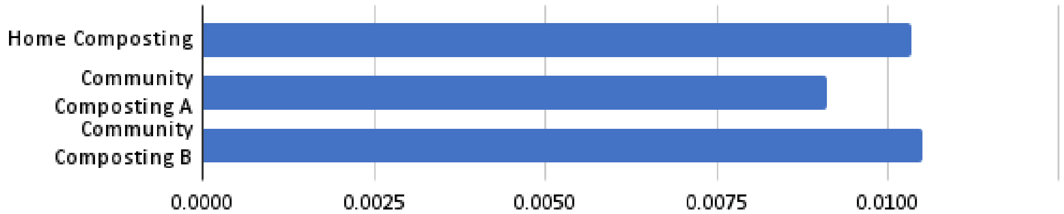
Table 34: Results for Rio study area (all scenarios comparison – Use case 3)

Use Case 3	Home Composting	Community Composting A	Community Composting B
Composter capacity	0.28	0.4 m^3	1 m^3

Number of composters	**388**	**68**	**27**
Price per composter	67	1,572.5	670
Composters cost (investment)	25,996	106,930	18,090
Composters cost (investment) per year (PMT)	3,367	8,581	1,743
Salaries per month	0	3,600	1,800
Salaries per year	0	43,200	21,600
Waste collection (with composters) 3 times per week instead of 6 (monthly)	4,066	4,066	4,066
Waste collection (with composters) per year	48,786	48,786	48,786
Waste treatment per year	136,060	113,027.60	113,027.60

The Result	Scenario	APC -Year 1
The Benefit/Cost Index	Home Composting	0.0103
	Community Composting A	0.0091
	Community Composting B	**0.0105**





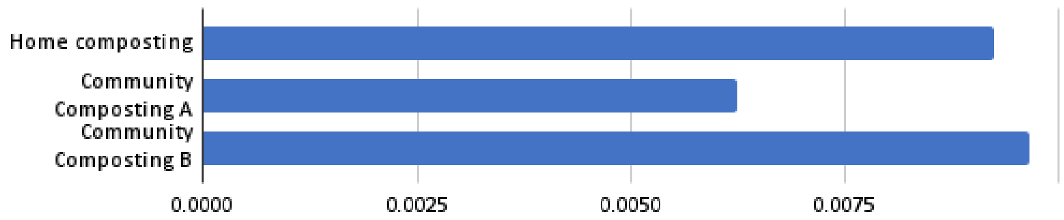
4th Use case

Table 35: Results for Rio study area (all scenarios comparison – Use case 4)

Use Case 4	*Home Composting*	Community Composting A	Community Composting B
Composter capacity	0.28	0.4 m^3	1 m^3
Number of composters	**388**	**68**	**27**
Price per composter	67	1572.5	670
Composters cost (investment)	25,996	106,930	18,090
Composters cost (investment) per year (PMT)	3,367	8,581	1,743
Salaries per month	0	3600	1800

Salaries per year	0	43200	21600
Waste collection (with composters) 3 times per week instead of 6 (monthly)	4,066	4,066	4,066
Waste collection (with composters) per year	48,786	48,786	48,786
Waste treatment per year	136,060	113,027.6	113,027.6

The Result	Scenario	APC -Year 1
The Benefit/Cost Index	Home Composting	0.0092
	Community Composting A	0.0062
	Community Composting B	**0.0097**



Based on the calculations for the three scenarios and the four different use cases, it is concluded that Community Composting B (with the Vermican modular composter) is the best option for this study area. Further, it is clear that the Home Composting is the second best option, and it could become the best option for this study area, if we were to take into account an investment cost increase (the price of the community composter), and/or should salaries increase.

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Appendix A: DECOST General Characteristics Questionnaire

The following questions relate to the participants in the Decentralised Composting project and the characteristics of the area where the project takes place

1. Country/State: _____________
2. Region/City/Town: _____________
3. Name of Neighburhood (if applicable): ________ ___ _ ___ ____
4. Area characteristics: Living area (neighborhood) / Commercial area / Industrial ares / Other: ______
5. The size of the area in square meters: ___________
6. National socio-economic status: High / Medium / Low / Other: ______________
7. Household waste: Yes / No
8. Commercial waste: Yes / No
9. No. of businesses: _____
10. No. of households: _____
11. Average number of persons per household: ___________
12. No. of high-rise building: _____ / ______ % of total participants
13. No. of single-homes: _____ / ______ % of total participants
14. Mode of waste management payment by households: in general municipal taxes/ any mode of Pay as you Throw/ other: ________________
15. Mode of waste management payment by businesses: in general municipal taxes/ any mode of Pay as you Throw/ other
16. Waste <u>collection</u> payment method: per bin or container hauling/ per ton / Other: _____
17. Waste <u>treatment</u> payment method: tipping fee per ton / Other: ___________
18. Landfill levy: Yes / No
19. No. of composters designed or implemented in the project: ________________No. of composters designed or implemented in the project: ________________
20. Composter location: Coupled with each household / Community composter in public areas / Other: _
21. Allocated area for each composter: _______m^2
22. Operational responsibility for the organic waste transportation: Residents / businesses / Local authority / Other: _______
23. Operational responsibility for composting: Residents / Businesses / Local authority / Other: _______
24. Collecting the organic waste: bins / plastic bags / paper bags / bio-plastic bags / Other: ___
25. The monthly amount of organic waste directed to composting: __ _ __ tons
26. Composter type: _____________

Appendix B: BPC data

The table below is a tool for collecting the relevant data and calculating the costs BPC.

DECOST Cost-Benefit Feasibility Model

Instructions:
Please fill in all the information regarding the waste collection bins (WCB) of the pilot participants
A separate row is required for each type of WCB/weekly collection frequency

																		Fill this part in case the local authority bears the cost of waste collection and treatment but charges a direct fee/payment (businesses/PAYT/other)		
Waste properties		Waste collection									Waste treatment							Fee / other related payments		
The source of the waste (Domestic / Commercial / Industrial)	Type of waste (Mixed / Organic separated at source/ Packaging separated at source/ Other)	Type of receptacle (Can / bin/ container / underground container)	Volume (Liters)	No. Of WCB	Weekly collection frequency	Total no. of monthly collections (average)	The cost of one-time collection from one receptacle (currency)	Total monthly cost (NIS)	Waste hauler (private/ munucipal)	The payer (local authority/ business/ resident)	The name of the site that receives the waste	The distance of the site from the local authority / area of the project (km)	Tipping fee to the waste site (currency/ Ton)	Levy/ tax (NIS/ton)	Total cost per ton	Total Monthly amount (ton)	Total cost (According to total ton) NIS	The service provider (local authority / contractor) Name of the local authority / contractor	A fee is charged for service by the local authority Yes/No	The fee per Ton (currency)
BPC																				
The total monthly cost for each category								0									0.0			
Total monthly cost																	0			

Appendix C: Composter data

The table below is a tool for collecting the relevant data, and calculating the costs of placing the composter.

General properties										Investment Cost				O & M cost					Total cost	Benefit
#	Composter provider	Model	Link	Capacity (tons per year/day)	Dimensions	Volume	Area size required for placing the composter	Property rights on the land	Lifetime (Years)	The price of the composter (currency)	Site development and construction cost (currency)	Biofilter cost	Total monthly cost	Ongoing operation and maintenance cost (currncy per month)	Transporting cost (currency per ton)	Loading cost (currency per ton)	Cost of application/s for access & control (currency)	Biofilter cost	Total monthly cost	Monthly amount of organic waste directed to composting (ton)

Appendix D: APC data

The DC project can be evaluated according to different characteristics, alternatives, and scenarios as detailed in section 5.5. The tables below are tools for collecting the relevant data, and calculating the costs of the various options (two or more).

Waste properties		Waste collection									Waste treatment							Fee / other related payments		
The source of the waste (Domestic / Commercial / Industrial)	Type of waste (Mixed / Organic separated at source/ Packaging separated at source/ Other)	Type of receptacle (Can / bin/ container / underground container)	Volume (Liters)	No. Of WCB	Weekly collection frequency	Total no. of monthly collections (average)	The cost of one-time collection from one receptacle (currency)	Total monthly cost (NIS)	Waste hauler (private/ municipal)	The payer (local authority/ business/ resident)	The name of the site that receives the waste	The distance of the site from the local authority / area of the project (km)	Tipping fee to the waste site (currency/ Ton)	Levy/ tax (NIS/ton)	Total cost per ton	Total Monthly amount (ton)	Total cost (According to total ton) NIS	The service provider (local authority / contractor) Name of the local authority / contractor	A fee is charged for service by the local authority Yes/No	The fee per Ton (currency)
APC - Option 1																				
	Organic																			
Compostation																				
The total monthly cost for each category								0									0.0			
Total monthly cost																	0			

APC - Option 2																				
	Organic																			
	Residual																			
Compostation																				
The total monthly cost for each category								0									0.0			
Total monthly cost																	0			

Appendix E: Waste and recycling legislation in Israel, 1984-2017

The following table is an example of mapping legislation in Israel and identifying the relevant regulation for a DC project.

Year	Legislation	Purpose	Source	Relevance to Decentralized Composting
1984	Maintenance of Cleanliness Law	"Prohibits littering or the disposal of waste, building debris, and vehicle scrap in the public domain."	IMoEP, 1984	-
1993	Collection and Disposal of Waste for Recycling Law	"Provides the principles and the legal framework for recycling in Israel. It authorizes local authorities and obliges them, when required by the Minister of Environmental Protection, to allocate sites for recycling centers and to install recycling facilities and containers."	IMoEP, 1993	+
1998	The obligation of Waste Disposal for Recycling- Regulations	"These regulations require local authorities to reduce their waste for disposal through recycling, under graduated recycling targets as per the following timetable: at least 10% by December 1998; 15% by December 2000; 25% by December 2007."	IMoEP, 1998	+
1999	Deposit on Beverage Containers Law	"Required manufacturers, importers, and retailers to collect a deposit on beverage containers larger than 0.1 liters and smaller than 1.5 liters, except for bags or paper containers. A recycling corporation was established under the law to institute a refund, bottle collection, and recycling system, which was required to comply with graduated targets for collecting empty beverage containers."	IMoEP, 1999	-
2007	Amendment to Maintenance of Cleanliness Law, 2007: Landfill Levy	"In effect since July 1, 2007; requires landfill operators to pay a levy for every ton of waste landfilled. The aim is to internalize the full and real costs of waste treatment and disposal."	IMoEP, 2007a	+
2007	Tire Disposal and Recycling Law	"Aims to reduce the environmental nuisance caused by improper tire disposal in Israel, while promoting tire recycling. The law makes tire	IMoEP, 2007b	-

Year	Legislation	Purpose	Source	Relevance to Decentralized Composting
		producers and importers responsible for the disposal and recycling of used tires at graduated rates each year, with recycling replacing disposal after July 2013."		
2011	Packaging Law	"This law imposes direct responsibility on manufacturers and importers in Israel to collect and recycle the packaging waste of their products."	IMoEP, 2011	-
2012	Electrical and Electronic Equipment and Batteries Law	"Environmental treatment of electrical and electronic equipment and of batteries and accumulators, to encourage the reuse of electrical and electronic equipment, reduce the quantity of waste created from electrical and electronic equipment and from batteries and accumulators, prevent the burial of such waste, and mitigate the negative environmental and health effects of electrical and electronic equipment, of batteries and accumulators, and of the waste from these products."	IMoEP, 2012	-
2016	The Law for the Reduction of the Use of Disposable Carrying Bags	"Reducing the use of carrying bags to reduce the amount of waste generated by their use and the negative environmental effects of this waste, inter alia by restricting the distribution of disposable bags by dealers without payment and by imposing a duty to sell them."	IMoEP, 2016	-
2017	The criteria for collecting basic waste and excess waste from businesses		IMoI, 2017	+

+ Applicable (Quantitative/Qualitative), - Not Applicable

Source: Daskal et al. (2020)

Appendix F: Composters at the Pilot Sites

DECOST Pilot Site	Kufur Ruman	Sama Rousan	VIC Spain	Potenza Italy	Atella Italy	Anabta
	Home composting		Community composting			
Composter provider	local Subcontractor (Al-Arda steel Manufacturer) for home composters	India	VERMICAN	CtTec	CtTec	not available yet for community composter
Model	manually controlled dual chambers home composter	Aerobin	Modular composter	Bio - Bi I.3.X	Bio - Bi I.9.X	$5m^3$ community composter, electrically operated
Link						
#	92	80	62	2	1	5
Capacity (tons per year)	0.5	0.6	1	17.5	80	66
Composter Volume (m^3)	0.32	0.5	1	3.5	15	5

DECOST Pilot Site	Kufur Ruman	Sama Rousan	VIC Spain	Potenza Italy	Atella Italy	Anabta
	Home composting		Community composting			
Dimensions (m)	Length = 100 cm Diameter = 64 cm	0.5 x 0.5 x 0.5 m	1x1x1	width:1,790 - heigth: 2,150 - length:3	width:2 - heigth: 2,50 - length:7	1.3 m x 4.0 m
Area size required for placing the composter (m2)	2	1	1.7	10	14	50
Property rights on the land	For house owners	?	Properties are public	Public area managed by Legambiente	Cafaro Platform	Anabta municipality
Potential Users	7	10	75	117	626	
Lifetime (Years)	5	5	15			10
The price of the composter	400	130 JDs	670 €/unit	2 x 25,000 €	65,000 €	20,000 €
Site development and construction cost	0	20 JDs	600 €/site			25,000 €
Biofilter cost (€)	0	none	No biofilter but smart lock of 285 €/unit. Installed 14, one per each composting site	Included in the price	Included in the price	0

DECOST Pilot Site	Kufur Ruman	Sama Rousan	VIC Spain	Potenza Italy	Atella Italy	Anabta
	Home composting		Community composting			
Ongoing operation and maintenance cost (€/month)	200 €	none	Aprox. 585 € (technician dedicated part-time)	Included in the price for 18 months	Included in the price for 12 months	1,900 €
Transporting cost (€/ton)	0	10 JDs	17 €/ton	0	114	800 € /month
Loading cost (per ton)		5 JDs		0	Included in the price	
Cost of application/s for access & control	0	5 JDs	10 €/month/composter so a total of 140 €/month for all the smart locks installed in the municipality	Included in the price	-	
Biofilter cost (€/year)	0	none		67	133	
Quantity of compost	25-40 tons/year	0.5 m3 per 4 months	We don't have compost yet, but we could count on 50% of the raw product, maybe 2.0-2.5 t/month? No info yet	2 x (4 - 6 tons/year)	15 - 25 tons/year	100-300 tons/year

Appendix G: Example of Community Composting Planning

<u>PLANNING COMMUNITY COMPOSTING</u> (City of Shefa-Amr as an Example)

In order to identify suitable location alternatives for the establishment of community composting systems / facilities, it is important to establish the criteria to identify and select such potential locations. The relevant criteria were defined on the basis of data extracted from the GovMap site, an available governmental planning site, in addition to using AutoCAD with regard to the Old Centre of the City of Shefa-Amr, and include:

- Population: 4,860 people (GovMap)
- Zone area: 660 dunums (with AutoCAD help)
- Number of households: 632 (with AutoCAD help)
- Density
- Number of schools (GovMap)
- Land ownership types: (GovMap)
- Land designation
- Land uses

Defined Criteria

A. <u>Number of Households within 400 m</u>
This distance was defined according to a study from Chicago in which planning the community composters relied on the willingness of residents to walk 400 m from their houses to a public transportation station. The assumption was that the willingness to use public transportation was equivalent to the willingness to walk to a community composter. That said, some studies have suggested a distance of 100 m, noting that 400 m was deemed to be "too far".

B. <u>Available Possible Spaces for Composters</u>
Large space means unlimited space, *Sufficient* space means limited but enough space, and *Limited* space means restricted space to some extent.

C. Land Ownership Types

Ownership type helps in determining the suitability of the land for a composting facility. For example, privately owned land, sacred lands or lands with unknown owners are considered not suitable for the establishment of a composting facility. This issue is quite important and critical in Arabic municipalities in Israel, because of the political situation and the historical conflict over land issues. For example, a lot of Land ownerships are classified as "mixed", which can make such lands impossible to use.

D. Land Uses

The designated land use, similar to ownership type, also helps in determining the suitability of the land for a composting facility. Examples of uses of a particular land include residential areas, industrial and handicraft areas, commercial and office areas, transportation areas, and open spaces. For example, land owned by a local authority that is designated for kindergarten use is obviously not recommended for the construction of a composition facility.

For each criterion, three (3) conditions were assigned (traffic light model). The most suitable condition for designing a community composting facility was given a green color, and the least suitable one was given a red color. Table 7 below summarizes the defined criteria and the assigned "traffic light" colors.

Table 36: Traffic Light Model for the Criteria for Planning a Community Composting System

Number of Households within 400 m	0-100	101-250	251-400
Available space	Limited	Sufficient	Large
Land use	Residential	Agricultural / Public building	Open public space
Land ownership type	Private ownership	Israel Land Administration	Local authority ownership

For each criterion, the alternative option receives one point for each defined criterion, according to the descriptions in Table 7 above. Since there are four (4) defined criteria, the total points that each alternative can obtain is four, with the priority being to obtain the four points under the green color.

For example, if an alternative has 300 households within 400 m, it receives a point in the green block. If the available space in that alternative is defined as "Large", then the alternative receives another point in the green block. Now, if the alternative is defined as "privately owned land", then it receives a point, but in the red block, and so on. The summary of the scores of the various alternatives can be seen in Table 8.

Table 37: Summary of Criteria for Planning a Community Composting System in the Old City

Alternative 1	1	2	1
Alternative 2	1	2	1
Alternative 3	1	2	1
Alternative 4	0	2	2
Alternative 5	1	1	2
Alternative 6	1	1	2
Alternative 7	0	0	4
Alternative 8	0	1	3
Alternative 9	0	2	2
Alternative 10	0	0	4
Alternative 11	0	2	2
Alternative 12	0	0	4
Alternative 13	0	2	2
Alternative 14	1	2	1
Alternative 15	2	2	0

To start, we have divided the old city into three (3) areas:

- Area 1: South-west part of the old city, and contains alternatives 1-3
- Area 2: Central part of the old city, and contains alternatives 4-6
- Area 3: North-east part of the old city, and contains alternatives 7-15

Through a quantitative comparison only, we can see that alternatives 7, 10 and 12 have the highest number of green criteria (green = most suitable), and at the same time have the lowest number of red criteria (red = least suitable). Therefore, these three alternatives are found to be the most suitable for the construction of composting facilities.

Following the criteria we set for the construction suitability of composting facilities, and according to the obtained ranking, alternatives 4, 8, 9, 11 and 13, rank next, after the aforementioned alternatives.

Since the planning refers to a walking distance of up to 400 m from a resident's home to the community composter, it is important to choose the combination of alternatives that allows the widest "coverage" of composters within that walking distance.

Therefore, after gathering information and conducting discussions, we have decided to set up composts in Alternative 12, which covers most of Area 3, and Alternative 4, which covers about 3/4 of Area 2, but for the rest of the Old City area (especially Area 1), no suitable alternatives were found.

Therefore, as a complementary solution, we looked for alternatives that allowed the construction of composting facilities around the Old City area (outside the defined border), which can also serve the residents within the Old City, and we came up with three alternatives that met our requirements, as summarized in Table 9 below.

Table 38: Summary of Criteria for Planning a Community Composting System Around the Old City

Alternative 16	2	1	1
Alternative 17	0	1	3
Alternative 18	0	2	2

Through a quantitative comparison, it can be seen that alternatives 17 and 18 have the highest number of green criteria. As such, these alternatives were deemed the most suitable for the construction of community composting facilities, as a complementary solution to the alternatives we have chosen at the beginning. Alternative 17 covers about half of Area 1, and alternative 18 covers most of Area 1. Please see Figure 28, which can clearly be seen in Appendix G.

Figure 28: Locations of the alternatives selected for the planning of community composter facilities

The color of the alternative describes the use of the land that is planned for the construction of the composter in it: green - open public areas, yellow - agricultural land, and blue - school (through the use of AutoCAD software).

Amounts of Organic Waste Produced by Residents in Each Alternative

Initial calculation of the amount of organic waste produced in the various alternatives (see Table 10) was made according to the number of persons within a radius of 400 m for each alternative. We took into account that there was an overlap between the alternatives, and lowered the households in common between the two alternatives. The number of persons is calculated by counting the households for each alternative within a radius of 400 m (done with the help of AutoCAD), multiplied by the average housing density for each household, which is equal to 1.9, and multiplied again by the average number of persons per household, which is equal to 4.05.

The housing density is calculated by dividing the Units within a Household by the number of Households, and the persons' ratio per household unit is obtained by dividing the number of persons by the number of households. Applying this logic to Alternative 18, as an example, housing density = 192 ÷ 101 = 1.900 or 1.9, and persons per household unit = 777 ÷ 192 = 4.047 or 4.05.

The amount of organic waste produced in each alternative was calculated based on the coefficient of waste generation per person per day, which is 1.25 times the percentage of organic waste from all the waste, that being 33% (https://old.cbs.gov.il).

Table 39: Quantities of Organic Waste Produced in Each Selected Alternative

Alternative	Households	Units within Household	Persons	General Waste kg/day	Organic Waste kg/day	Organic Waste ton/year
18	101	192	777	971	321	117
4	186	353	1,431	1,789	590	215
17	176	334	1,354	1,693	559	204
12	170	323	1,308	1,635	540	197

The future participation rate of the residents in the community composter project greatly affects the estimate of the generation of organic waste. Participation rates of 10-40% are considered acceptable in the literature, based on which, the estimates were made in Table 11 below.

Table 40: Amounts of Organic Waste Generated in Each Alternative for Different Participation Rates

Amount of Organic Waste (tons/year per selected alternative)					
Total (ton/year)	Alternative 12	Alternative 17	Alternative 4	Alternative 18	Participation Rate
733	197	204	215	117	100%
293	79	82	86	47	40%
110	30	31	32	18	15%
73	20	20	22	12	10%

Determining Type of Community Composting Facility Suitable for Each Alternative

The appropriate size and type of the composting facilities can be determined by calculating the amount of organic waste produced by a certain percentage of participation for each selected alternative. In addition, it should be taken into account that additional quantities of pruning and/or tree trimmings may be added to improve compost production. Therefore, the selection of the facilities is made using approximately double the amount produced according to Table 11, assuming the addition of pruning in the same amount as organic waste.

Further, in order to reduce "environmental nuisances", we focused on choosing IN-VESSEL facilities so as to minimize the problem of odors, keeping in mind that the cost of setting up these facilities is significantly higher. Using 15%, which is a realistic percentage of participation, we selected composters with suitable capacities. The types of selected facilities are shown in Table 12, and their characteristics can be seen in Appendix H.

Table 41: Types of Composting Facilities Selected for Each Alternative

Alternative	Organic Waste * (ton/year)	Type of Facility	Capacity (ton/year)	Dimensions (m)
18	18	CtTec -Bio - Bi I.3.X	15-20	1,790 x 2,150 x 3,000
4	32	CtTec - Bio - Bi I.5.X	30-32	1,790 x 2,150 x 5,000
17	31	CtTec - Bio - Bi I.5.X	30-32	1,790 x 2,150 x 5,000
12	30	CtTec - Bio - Bi I.5.X	30	1,790 x 2,150 x 5,000

* Amount of organic waste (ton/year per alternative), assuming 15% participation rate

Selection of Potential Sites for Decentralized Community Composting, Using GIS Tools, in the City of Shefa-Amr

Contribution by

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Abstract

The crisis of solid waste accumulation in large quantities has become a worldwide issue, due to the accelerated development in different economic activities and changing lifestyles. This leads to increased pollution and significant impact on human health and the environment. As a result, sustainable management of solid waste has become a necessity in all communities worldwide. This management entails reducing, reusing and recycling of sloid waste.

This project is identifying and evaluating potential sites for composting of organic waste, to be recycled and used in agriculture in the City of Shefa-Amr. This will help to achieve sustainability by preserving the environment and resources for future generations. The project involves a multi-criteria decision-making strategy, through which the necessary criteria for selecting suitable sites for composting is identified, evaluated and analyzed, in order to obtain a final decision about the most suitable sites. For the evaluation, a hierarchical analysis strategy is employed, in which we assigned different weights to the criteria and components. Then we used the Model tool in the Geographic Information System to form a hierarchy and sequencing of data and criteria, giving the largest quantitative value to the criteria with the most impact, and the smallest value to criteria with minimal or no impact, on selecting the most suitable compost sites.

The Model tool, and the applicable analytical tools in the Geographic Information System, facilitate the process and remove the complexity of integrating multiple criteria to arrive at the best potential sites for composting in a decentralized manner. The steps involve defining the criteria, identifying the related data required for the criteria, assigning weights to the data components and criteria, then using the GIS Model tool, and finally selecting the sites based on the weighted results of the proposed sites, in this case 21 sites in the City of Shefa-Amr.

The sites are further evaluated in terms of density of food waste generation sites, in addition to the Location-Allocation model analysis, using three problem types, namely Minimize Facility, Minimize Impedance, and Maximum Coverage. Based on this analysis, 11 sites were selected from the previously chosen 21 sites for composting.

It is possible, and actually recommended, to implement this project in other communities and cities, in the efforts to properly dispose of organic waste and achieve sustainability using the same criteria, process and tools in the GIS program, as explained in this study, obviously with the relevant information for each community, as well as the nature and characteristics of the region.

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Section 1: Introduction

1.1 Goals

Achieving sustainability, using and applying new environmental technologies, as well as the related planning processes, have faced many challenges in our modern age, one of which is the selection of sites for composting, and the related processes, in order to recycle organic waste and prevent its associated problems.

This project aims to identify the process steps and tools for selecting potential sites for the placement of composters within city communities, by using the GIS methodology. This methodology is explained in the next section, and answers the following questions:

- What are the modern strategies and techniques for organizing the work steps?
- What is composting, including its types, and what is the potential for its application in cities and communities?
- What is the possibility of applying the compost site selection process in all communities, using the same steps and method?
- What are the criteria for selecting a compost site?
- How can GIS program tools and solutions be used in the site selection process?
- What is location allocation, and how can it be used in the site selection process?
- How to ensure that the sites are distributed logically, as and where needed, and not randomly?
- What is the relationship between the variables of the criteria?

1.2 Strategy

The project relies on the GIS-based Multi Criteria Decision Analysis (MCDA), also known as Multi Criteria Decision Making (MCDM). It is defined as a strategy that transforms and combines geographical data (map criteria) and value judgments (decision-makers' preferences and uncertainties), to obtain relevant and useful information for decision making. The main reason behind integrating GIS and MCDM is that these two distinct areas of research can complement each other. GIS, Geographic Information System mapping, is commonly recognized as a powerful and integrated tool with unique capabilities for storing, manipulating, analyzing and visualizing spatial data for decision making. Its correlated part, MCDM provides a rich collection of procedures and algorithms for structuring decision problems, designing, evaluating and prioritizing alternative decisions [1].

Analytic Hierarchy Process (AHP) is among the most wildly used techniques for GIS–MCDM [2]. AHP has a high ability to solve complex problems during the process of decision-making in different fields, and it is used to determine the consistency of weightings for criteria through constructing a matrix of pair-wise comparisons[3].

Because of the practical nature of the AHP, and its suitability for solving complex problems, it has gained the attention of many researchers, and has wide applications in many fields and areas of decision-making. The application of this method towards site selection in solid waste management entails the following general steps: [2], [4]

- Preliminary study, which includes reviewing of the previous literature
- Database collection and construction, including digital maps within GIS software for the study area
- GIS-based AHP, which includes the determination of the weightings for the sub-criteria and the criteria, and integrating these weighings into the GIS system

Determination of a suitability index to apply to candidate sites The sensitivity analysis is used to determine the equilibrium of the results through the sensitivity analysis test “what happens if”, in the event of a change in the priorities of the criterion.

The “Model Builder” tool in the GIS program can be applied in the AHP technique, as it analyzes the data of the specific criteria for the sites, determines their prioritization, and assigns weights to them that explain their importance and priority. The results of the analysis are then studied and analyzed to determine the importance of each criterion in choosing the site and influencing the decision.

The above-noted strategy was applied in this project, as it involves choosing appropriate sites for composters in the city of Shefa-Amr. The strategy can be applied to any other community or project. Choosing appropriate sites is a complex idea in itself due to the presence of many criteria that must be met with respect to proportions, quantities, values or specific descriptions. This is the case in selecting composter site, as the composting process takes place in stages, hierarchies, and certain processes as well, such as the process of converting waste into organic compost, so choosing the site must be appropriate for all these stages without any negative effects. For example, one of the stages of the composting process is waste collection, which has requirements for the composting sites, such as being close to the source of waste production in public and private buildings, and other locations, as well as having easy access for transporting waste to them.

1.3 The City of Shefa-Amr – Introduction

Shefa-Amr is a Palestinian-arab city located in the Lower Western Galilee region, in the Northern District of Israel. It has an area of 22 km^2 and an elevation of 137-215 m above the Mediterranean Sea, according to Shefa-Amr Master Plan 2015, found in the Environment and landscape annex (https://drive.google.com/file/d/17HrH7YPbwbZn9_3ILxdmb6md6QUMN-wh/view?usp=share_link)

According to the Master Plan, Shefa-Amr is 13 km inland from the sea, and 20 km from each of the cities of Haifa, Acre and Nazareth. It is one of the central cities in the Galilee due to its strategic location, being at the meeting point of the plains with the mountains of Galilee. It is located on seven hills, which is why it is called "Little Rome".

Shefa-Amr has a population of 43,452 people, according to estimates by the Israel Central Bureau of Statistics to October 2022. It has approximately 8,800 buildings, with a population density of 2200/km^2, while the population density in the residential land area is approx. 7500/km^2. Its population is approximately 61% Muslims, 25% Christians and 14% Druze (For further information, additional data can be accessed on the official website of the Israeli Central Bureau of Statistics (CBS): https://is.gd/RFDRfe.

Several uses are assigned to the land within the city of Shefa-Amr, such as residential, commercial, agricultural, public, institutional, industrial and infrastructure uses. Large amounts of organic waste are collected from all these areas, and sent to the central waste landfill site in the city, which was established in 2018 by the municipality in order to reduce random dumping.

Section 2: Composting - Theoretical Introduction

This Section explains the theoretical side of the project, including what composting is, types of composting, the GIS program, Model Builder tool, Location Allocation problems and solutions.

2.1 Community Composting

The concept of "green development" is becoming more and more popular throughout the world. It involves promoting economic growth while reducing waste, pollution, and greenhouse gases. It also calls for managing natural resources sustainably and protecting biodiversity. Among the main areas that green development can be applied to is solid waste management, which includes “composting” as one of the green alternatives to landfilling.

2.1.1 Definitions and Aims

Composting is optimization of the decomposition process that occurs naturally in the presence of atmospheric oxygen. It is a biological process, essentially a controlled and accelerated version of the natural process. Only decomposable organic waste can be composted, that includes natural materials such as hay, firewood, leaves and plants. The process is driven by microorganisms (microbes), like bacteria and fungi, which break down organic materials, by eating the organic parts and leaving behind compost, which is rich in inorganic components such as nitrogen, phosphorus and potassium, all good for the soil. Creating ideal conditions for the microbes involves Oxygen and aeration, Carbon to Nitrogen ratio, sufficient moisture content, suitable particle size, optimum temperature, and enough time[5], [6].

Compost is the dark, crumbly, earthy-smelling and humus-rich material produced by the natural aerobic decomposition of organic materials such as garden trimmings and food scraps. Added to soil, it improves the soil's biological, chemical, and physical characteristics, and makes the soil better for plants and beneficial soil organisms. Although composting can be achieved at different levels; backyard, block, neighborhood, schoolyard, community, and regional, there are special benefits to community composting that includes:[7]

- Raising awareness among community members and educate them about the benefits of composting
- Benefitting the environment through providing a material that adds needed organic matter to soil, sequesters carbon in soil, improves plant growth, conserves water, reduces reliance on chemical pesticides and fertilizers, and helps prevent nutrient runoff and soil erosion.
- Benefitting the community through local activities and Supporting locally-grown, healthy food production
- Benefitting the local government by reducing the burden of landfilling or incineration
- Benefitting the local economy through job creation and supporting local small-scale enterprises

2.1.2 Hierarchy to Reduce Organic Waste

The process of reducing household waste, of which food waste constitutes a large percentage, involves several levels that highlight the importance of locally based composting solutions as a priority over large-scale regional solutions. These levels are listed below [8]:

- Source reduction: activities on the household level to reduce the generation of organic waste
- Edible food rescue: donating extra food to hungry people
- **Home composting: composting in the backyard to avoid collection cost**
- **Small-scale, decentralized composting**
- **Medium-scale, locally-based composting**
- **Centralized composting or anerobic digestion**
- Mechanical biological mixed waste treatment
- Landfill and incirator

Centralized and Decentralized Composting

There are two types of composting, *centralized* at the level of the region or a group of communities, and *decentralized*, which is a network at the local level to convert organic waste to compost in a specialized environment, and is a strategic solution for urban waste management.

The table presents the differences between centralized and decentralized composting systems, as summarized in the referenced article:[9]

Table 1 – Difference Between Centralized and Decentralized Composting Systems

Centralized Composting	Decentralized Composting
Advanced/mechanized technology intensive, low labor	labor intensive, simple technology
Large capital cost and imported equipment	Low capital cost and locally available materials
High operation and maintenance costs and high specialized skills required	Less maintenance costs and Low level skills required
Less interaction and involvement of the community	The community is highly involved
High transportation costs	Low transportation costs
Low quality of compost (largely unseparated waste)	High quality of compost (separated waste)

2.1.3 The Component Needed for Composting

According to Brolis and Platt, the four components needed for a good compost are: greens (raw vegetables, green leaves etc.), browns (leaves, twigs, straw, etc.), air and water [8].

2.1.4 Composting Process Steps

The process of recycling waste into organic compost passes through several stages, as listed below, starting from the collection of waste to the production of compost and its distribution to the local markets: [6]

- Reception of bio-waste
- Mixing and improvement of the initial conditions
- Fermentation
- Maturation
- Screening and storage
- Atmospheric emissions
- Leachates management
- Facility maintenance
- Process monitoring

The Process Monitoring stage includes basic analytics and the equipment for the monitoring in the market.

2.2 GIS Technology

GIS (Geographic Information System) is a spatial multi-component environment, used to create, manage, visualize, analyze and map all types of data. It is important to note that most datasets you will encounter in your lifetime can all be assigned a spatial location whether on the Earth's surface or within some arbitrary coordinate system [10].

In GIS, there are two models that are used to map spatial data: vector features and rasters. Each of these models has its own advantages and disadvantages. The vector model uses points and line segments to identify locations on the Earth, while the raster model uses a series of cells to represent those locations [10].

Vector data / graphics are comprised of vertices and paths. The three basic symbol types for vector data are points, lines, and polygons (areas). Vector points are simply XY coordinates. Generally, they are latitude and longitude. When features are too small to be represented as polygons, points are used.

Vector lines connect each vertex with paths. When a set of vertices are joined in a particular order and closed, this is now a vector polygon feature [11]. A line must connect at least two points that represent the start and end line, meaning the line represents anything of length, such as: highways and rivers. Polygons can represent anything that has boundaries such as political, administrative and natural areas.

Raster data, by comparison, is made up of pixels (also referred to as grid cells). They are usually regularly spaced and square but they don't have to be. Raster models are useful for storing data that varies continuously [11].

Each cell in the raster model contains only one value of data and each group of cells containing the same value is related to a record in the attribute table.

People working in many different fields use GIS technology and tools, as they can be used for scientific investigations, resource management, development planning, and site selection, as well as saving and/or explaining data by maps, making mathematical processes in data, and more.

2.3 The Model Builder Tool

The Model Builder Tool is one of the Analysis GIS tools used to automate work flow, and keep track of geo-processing tasks. A model may consist of one process, but more commonly contains multiple processes strung together, with each process consisting of one tool and its parameter values. It is a mathematical and digital structure for representing phenomena over the Earth. Data models represent various aspects of these phenomena by means of geographic data, including spatial locations, attributes, change over time, and identity.

The most important thing to note here is that models are just tools, and they behave exactly like all other tools. Model tools run the GIS workflow to generate new outputs.

GIS Models facilitate the process of selecting the composting site as a result of arranging the data hierarchy, and collecting all the data and analytical tools used in one exit. The following are some of the analysis tools, and their uses in the process:

- Editing: edit existing data or for draw new data and attribute table.
- Feature to Point: transfer the type of data from polygon to points.
- Clip: cut out a piece of one dataset, using features in another dataset.
- Symbology: show the categories of fields in maps with symbols or colors.
- Feature to Raster: transfer vector data to raster data in 2D.
- Topo to Raster: transfer vector data to raster data in 3D.
- Buffer: create buffer areas (polygons) with around input features to specified distances.
- Euclidian Distance: provide the distance from each cell in the raster to the closest source.
- Terrain analysis (slope): transfer contour lines (elevations) or TIN to slope values (3D).
- Aspect (3D): determine the direction of a slope.
- Kernal Density: calculate the density of features (eg. buildings) in a neighborhood.
- Reclassify: reclassify (or change) the values in a raster, eg. categories of data fields from 10 to 1, or from high to low importance.
- Plus: add (sum) the values of two rasters on a cell-by-cell basis.

2.4 Location Allocation Models

GIS can be used to model the interaction between facilities that provide services, such as composting sites, and locations that have demand for those services. These models are often used to identify which areas are currently served by a certain facility, and which are not, in order to select the location for a new facility that will best meet the demand, or to predict the level of demand for any facility [12].

Location allocation is often considered the most important factor affecting the success of private or public sector organizations. Private-sector organizations can profit from good locations, be they small coffee shops with local clientele, or a multinational networks of factories with distribution centers and a worldwide chain of retail outlets. Public-sector facilities, such as schools, hospitals, libraries, fire stations, composters and emergency response services (ERS) centers, can provide high quality services to the community at low costs when a good location is chosen. (ESRI website)

The uses of location allocation models [12]**:**

- One set of the models allocates demand from locations to the closet facility, within specified parameters, such as the maximum distance a location can be from a center.
- Another set of models attempts to determine to which facility people at each location will travel, given the choice of facilities and the cost of getting to each one, thus modelling peoples' preferences for one facility over others.

To define the parameters of the model and choose the appropriate methods [12]**:**

- Define the problem to be addressed and the information needed for the model.
- Identify the characteristics of the facility and the demand points.
- Define the factors that influence the interaction, including costs, distance, travel time and cost, travel direction (demand point to facility or facility to demand point).

2.4.1 The Process Steps for Location Allocation

The process of allocating demand to centers is noted in the table below [12]:

Table 2 – Process of Allocating Demand to Facilities

Process Steps	Description
Define the solution needed	There are many types of problems to solve with location allocation: ▪ Allocating demand to existing facilities or locating new ones? ▪ How many facilities are needed? ▪ Minimize transportation costs? ▪ Constraints on how far demand points are from the facilities? ▪ Is travel from the facilities to the demand point or vice versa?

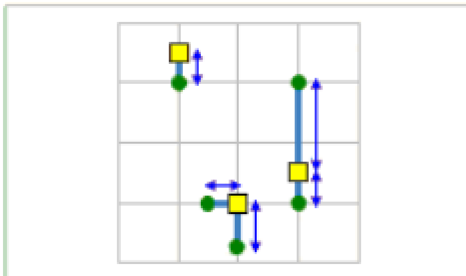
Set up the network	Location allocation models require a transportation network, usually the streets. Each edge in the network must have an attribute representing impedance.
Identify the facilities	Facilities are represented as point features in the GIS. If the intent is to choose the best location for new facilities, these will be created as point feature. But when the facility cover a large area (polygon), it needs to be converted to point feature by using “Feature to Point” tool in GIS.
Specify the demand points	The demand points are the locations served by the facility, and may be represented as point features.
Run the model	Specify the type of location allocation problem/issue to be solved. These types have the same underling method used to reach a solution, but with variables such as distance. In fact, depending on the data and parameters used, different solutions may produce the same results. Typical solutions include: ▪ Maximize demand ▪ Maximize coverage ▪ Maximize facilities ▪ Match demand to available supply at a facility ▪ Maximize demand that diminishes with distance ▪ Minimize all overall transportation cost
Evaluate the results	The results of the analysis are contained in the attribute tables for the facilities and demand points.
Display and apply the results	The results in the location allocation model are displayed in a number of ways: ▪ by selecting the feature using fields in the attribute table for the facilities, demand points and interaction lines. ▪ by using the attribute values to symbolize the feature

2.4.2 Location Allocation Problem Types

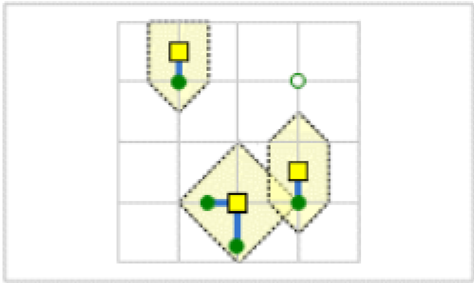
There are many types of location allocation problems can be used to make models for locate a new facility or define the demand point related to each facility, with take distance, time, number of facilities and the capacity of facility in consideration [12]:

Table 3 – Location Allocation Problem Types

Problem Type	Description
Minimize Impedance (P-Media)	This problem type is traditionally used to locate a facility, for example composters, so as to reduce the overall transportation costs, since Minimize Impedance reduces the overall distance that the public needs to travel to the chosen facility. The minimize impedance problem without an impedance cutoff is ordinarily regarded as more equitable than other problem types for locating

	certain public-sector facilities such as compost sites, regional airports, museums, motor vehicles offices, and health clinics. Facilities are located such that the sum of all weighted costs between demand points and solution facilities is minimized. The arrows in the graphic below highlight the fact that the allocation is based on the distance among all demand points.  Minimize Impedance chooses facilities such that the sum of weighted impedances (demand allocated to a facility multiplied by the impedance to the facility) is minimized. The following list describes how the minimize impedance problem type handles demand: ▪ If a facility impedance cutoff point is set, then any demand point outside that is not allocated. ▪ A demand point inside the impedance cutoff of one facility has all its demand weight allocated to that facility. ▪ A demand point inside the impedance cutoff of two or more facilities has all its demand weight allocated to the nearest facility only. **Inputs**: demand point, facilities (points), number of facilities needed. **Outputs**: each demand point will be allocated to the closest facility.
Maximize Coverage	Maximize Coverage is frequently used to locate emergency services or any services usually required to arrive at all demand points within a specified response time. An example of this is identifying the potential compost sites so that they service all the buildings, such that each person can reach the compost site within the same time and distance, so that there is no building that cannot reach the compost site.

<table>
<tr><td></td><td>Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff.



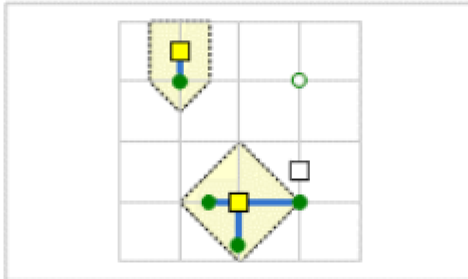
Maximize Coverage chooses facilities such that as much demand as possible is covered by the impedance cutoff of facilities. In this graphic, the solver was directed to choose three facilities.

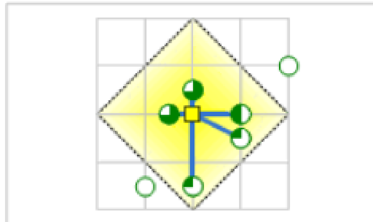
The following list describes how the Maximize Coverage problem handles demand:
▪ Any demand point outside all the facilities' impedance cutoffs is not allocated.
▪ A demand point inside the impedance cutoff of one facility has all its demand weight allocated to that facility.
▪ A demand point inside the impedance cutoff of two or more facilities has all its demand weight allocated to the nearest facility only.

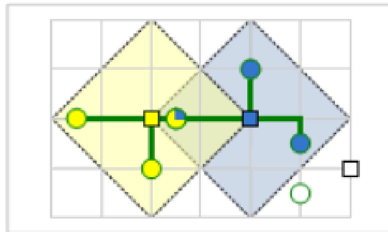
Inputs: demand point, facilities (points), distance from facility (meters).
Outputs: facilities should be located to maximize the number of buildings within 500 meters of the facility.</td></tr>
<tr><td>Maximize Capacitated Coverage</td><td>Maximize Capacitated Coverage allows the location of facilities such that all or the greatest amount of the demand can be served without exceeding the capacity of any facility. It is similar to Minimize Impedance or Maximize Coverage, but with the added constraint of capacity.

Maximum capacity coverage can be used to create areas that include a certain number of people or companies, or to define compost sites with the ability to accommodate a limited amount of waste from a limited number of demand points.</td></tr>
</table>

	Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff. Additionally, the weighted demand allocated to a facility cannot exceed the facility's capacity. The following list describes how the Maximize Capacitated Coverage problem handles demand: ▪ Unlike Maximize Coverage, Maximize Capacitated Coverage does not require an impedance cutoff. However, when an impedance cutoff is specified, any demand point outside all the facilities' impedance cutoffs is not allocated. ▪ An allocated demand point as all or none of its demand weight assigned to a facility; that is, demand is not apportioned with this problem type. ▪ If the total demand within the impedance cutoff of a facility is greater than the capacity of the facility, only the demand points that maximize total captured demand and minimize total weighted impedance are allocated. **Inputs**: demand points, facilities (points), the capacities of facilities. **Outputs**: facilities should be located to maximize the number of buildings within the capacity of the facility.
Minimize Facilities	Minimize Facilities is the same as Maximize Coverage, but with the exception of the number of facilities to locate, which is determined, in this case, by the solver. Facilities are located such that as many demand points as possible are allocated to a minimum number of solution facilities, within the given impedance cutoff.

	 Minimize Facilities chooses facilities such that as many demand points as possible are within the impedance cutoff of facilities. Additionally, the number of facilities required to cover all demand points is minimized. In this graphic, the solver was able to cover all demand points with only two facilities. The following list describes how the Minimize Facilities problem handles demand: ▪ Any demand point outside all of the facilities' impedance cutoffs is not allocated. ▪ A demand point inside the impedance cutoff of one facility has all its demand weight allocated to that facility. ▪ A demand point inside the impedance cutoff of two or more facilities has all its demand weight allocated to the nearest facility only. **Inputs**: demand points, facilities (points), distances from facilities (meters), number of facilities needed. **Outputs**: minimum number of facilities needed to service all demand points with 500 meters of a facility.
Maximize Attendance	Maximize Attendance assumes that the farther people have to travel to reach the facility, the less likely they are to use it. This is reflected in how the level of demand assigned to facilities diminishes with distance. Facilities are chosen such that as much demand weight as possible is allocated to facilities, with the assumption that the demand weight decreases in relation to the distance between the facility and the demand point.

	 Maximize Attendance chooses facilities such that as much demand weight as possible is allocated to facilities while assuming the demand weight decreases with distance. The demand points, represented by pie charts in this graphic, show how much of their total demand is captured by the facility. The following list describes how the Maximize Attendance problem handles demand: ▪ Demand outside the impedance cutoff of all facilities is not allocated to any facility. ▪ When a demand point is inside the impedance cutoff of one facility, its demand weight is partially allocated according to the cutoff and impedance transformation. The demand points in the graph above have pie charts to represent the ratio of their total demand weight that was captured by the chosen facility. ▪ The weight of a demand point covered by more than one facility's impedance cutoff is allocated only to the nearest facility.
Maximize Market Share	The Market Share problem types require the most data because not only the weighting of own facilities is needed, but also that need to know that of the competitors’ facilities. The same types of facilities that use the Maximize Attendance problem type can also use Market Share problem types, given that they have comprehensive information that includes competitor data. A specific number of facilities is chosen such that the allocated demand is maximized in the presence of competitors. The goal is to capture as much of the total market share as possible with a specified number of facilities. The total market share is the sum of all demand weights for valid demand points.

	 Maximize Market Share chooses facilities such that the largest amount of allocated demand is captured in the presence of competitors. You specify the number of facilities you want it to choose.
Target Market Share	Target Market Share locates the minimum number of facilities necessary to capture a specific percentage of the total market share, in the presence of competitors. The total market share is the sum of all demand weights for valid demand points. The entity sets the desired percent of the market share to reach, and lets the solver locate the smallest number of facilities necessary to meet that threshold.

Section 3: Site Selection by GIS Model Building for Establishing Decentralized Compost in the City of Shefa-Amr

The project involves locating composting station sites for groups of buildings in the city of Shefa-Amr, with composting at the medium level. The idea is that the waste of a group of buildings in the defined geographical area is converted into compost through the exploitation of vacant lands or those with specific uses such as open public lands, agricultural lands, or public buildings, as composting stations. Organic materials are recycled at those stations through designated methods and equipment for composting. This has an associated low cost due to saving transportation costs compared to central composting stations.

3.1 Methodology of Site Selection by Model building

The process to determine the best potential sites for the establishment of decentralized composting stations, which transform organic waste into organic compost, passes through several stages that are listed below, and will be explained in detail later:

- Determining the criteria of an appropriate location for the composting station.
- Determining the geospatial and non-spatial data needed for the criteria.
- Classifying the data and indicating its type, and determining the weights needed to evaluate the sites, from 1 (worst) to 10 (best), and to choose the best site.
- Determining the necessary tools during the model building process in GIS.
- Building the model in GIS and obtaining a layer that contains an evaluation of all the sites in Shefa-Amr, specifically the best sites.
- Selecting the best locations for the compost stations, and creating a map showing this in the form of points and polygons.

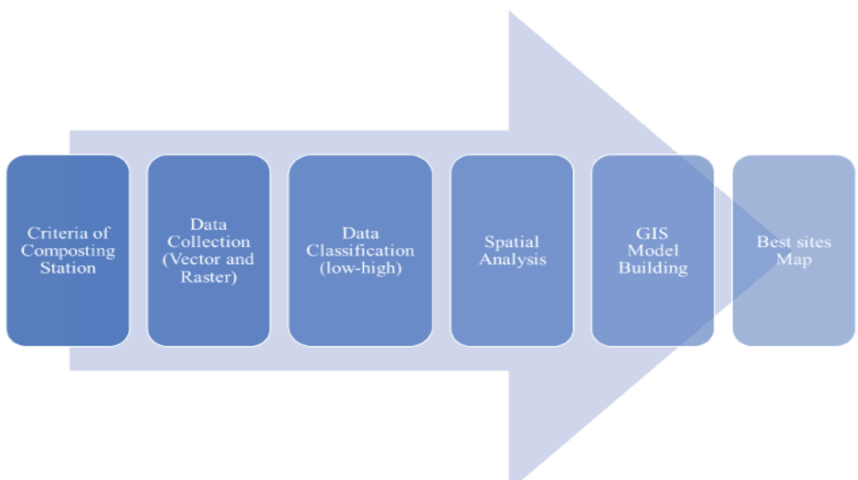


Figure 1 – Methodology of Site Selection by Model Building

3.2 Model Building in the GIS Program

Criteria and Needed Data

The first step in the model building is identifying the criteria and necessary data for the project. This is one of the most accurate stages in the work, and needs much effort and time. The criteria is summarized in Table 4 below. All layers of the data must be similar in their coordinate systems.

The process generates accurate geographical location coordinates, and has the ability to compute and display information from a database, in the manner that the researcher wants. This information is real, credible and comprehensive for the area to be studied, which comprehensiveness allows a general view that is specialized for the specified area (geological, environmental, tourist, agricultural, educational, etc.). It also enables a comparison between the nature of developments and the prevailing conditions in a particular area from time to time, based on observing the extent of the differences and similarities of the phenomena for a geographical area, through the overlay of multiple layers. This facilitates finding geographical relationships between various phenomena, with the layers matching each other correctly and without displacement, thus obtaining final results with high accuracy, and selecting points for the final locations with the same coordinates for all data. For this project, we have used the "Israel TM Grid" coordinates system.

Table 4 below summarizes the criteria, data needed, and data type, as well as the criteria sources. The needed maps were acquired from [13]

Table 4 – Criteria of Decentralized Community Composting Sites

Criteria	Importance for Site	Data Needed	Data Type & Description	Resource
(1) Site area > or = 2500 ft^2 or about 230 m^2	Provide enough space for all departments of composting	Parcel	Vector (Polygon)	[14]
(2) Land use: vacant, residential, commercial, public, government, gardens, public parks	Land and buildings designated for public use are preferable for locating composting stations, in order to allow the use of the area to collect waste by everyone without any restrictions or obstacles	Master Plan	Vector (Polygon)	[14]
(3) Buildings use: residential, commercial, public use, school or university		Building	Vector (Polygon)	[7]
		Public Building	Vector (Point)	
(4) Land slope 5% - 20%	The slope range for the best site should not be flatter than 5% and or steeper than 20%, to make it easier to collect the	Slope	Raster	[14], [15]

	black sap of water in point and dry it			
(5) Land exposure to wind direction and with high moisture	Select areas with high moisture content and little heat, in order to provide a suitable environment for compost, and are downstream from the city, to minimize / prevent the impact of bad smells and pollutant	Aspect	Raster	[14], [16]
(6) Population density areas	Areas with high population density produce the most amounts of organic waste	Density	Raster	---
(7) Availability of road network access to the site of composting	Ensure easy access to the site, provide transportation lines for the collected waste to the site	Road	Vector (Line)	[15]

Data Reclassification

The second step in the model building is to reclassify to categories in the data field to determine the required and less required by digitizing it to numbers from 1 to 10.

Table 5 below describes, for each criterion, the data, attributes, category and reclassification weights, as well as the transferability from vector to raster by using the Feature-to-Raster tool.

Table 5 – Criteria and Reclassify of Data Categories

Criteria Per Table 4 Above	**Data**	**Feature to Raster**	**Attribute (field name)**	**Categories**	**Reclassify (1-10)**
(1)	Parcel	✓	Shape Area	Area 24-229 square m	1
				Area 230-3000 square m	9
				Area 3000-4750 square m	5
(2)	Master Plan	✓	Land Use	Public open area	8
				Residential, mixed use	9
				Commercial, offices	7
				Forests, gardens	9
				Other uses	1
(3)	Building	✓	F-type	Residential	9
				Commercial	9
				Greenhouses	8
				Other	1

	Public Building		USG-group	Education, old care center, kindergarten, school, college, entertainment use, clinic, hospital, industrial, agriculture	9
				Government, police, municipality, religious, mall center, playground	5
				Fair station, social center, library, pharmacy	3
				Others	1
(4)	Contour	transfer contour line to raster by use (Topo to Raster) then tool Slope from 3D Analysis tools			
	Slope	✗	Slope	0-5 %	1
				5-10 %	9
				10-15 %	9
				15-20 %	9
				20-27 %	1
(5)	Aspect	✗	Value	North (0-22.5)	1
				Northeast (22.5-67.5)	1
				East (67.5-112.5)	9
				Southeast (112.5-157.5)	7
				South (157.5-202.5)	9
				Southwest (202.5-247.5)	3
				West (247.5-292.5)	1
				Northwest (292.5-337.5)	1
				North (337.5-360)	1
(6)	Density	✗	Kernel Density	0-200	1
				200-700	5
				700-1200	7
				1200-2300	9
				Grass	3
				Shrubbery	5
				Agricultural area, olive tree	7
				Garden, park, forest	9
(7)	Road	✓	Euclidian Distance	0-100	9
				100-200	8
				200-300	6
				300-400	5
				400-500	4
				500-600	3
				600-700	2
				700-800	1

Spatial Analysis

The adopted methodology depends on certain spatial and statistical methods of data analysis and processing, something that GIS has the possibility to conduct objectively. It should be noted that the analysis process includes the use of many analytical tools, especially since the data in the study has two styles, Vector and Raster.

The following is a list of some of these tools (explained before):

- Model tool
- Editing tool
- Feature to Point
- Clip tool
- Symbology
- Feature to Raster
- Topo to Raster
- Buffer tool
- Euclidian Distance
- Terrain analysis (slope
- Aspect (3D
- Kernal Density
- Reclassify
- Plus tool

ArcGIS Model

Figure 2 below shows the entire model with all the criteria, data and tools.

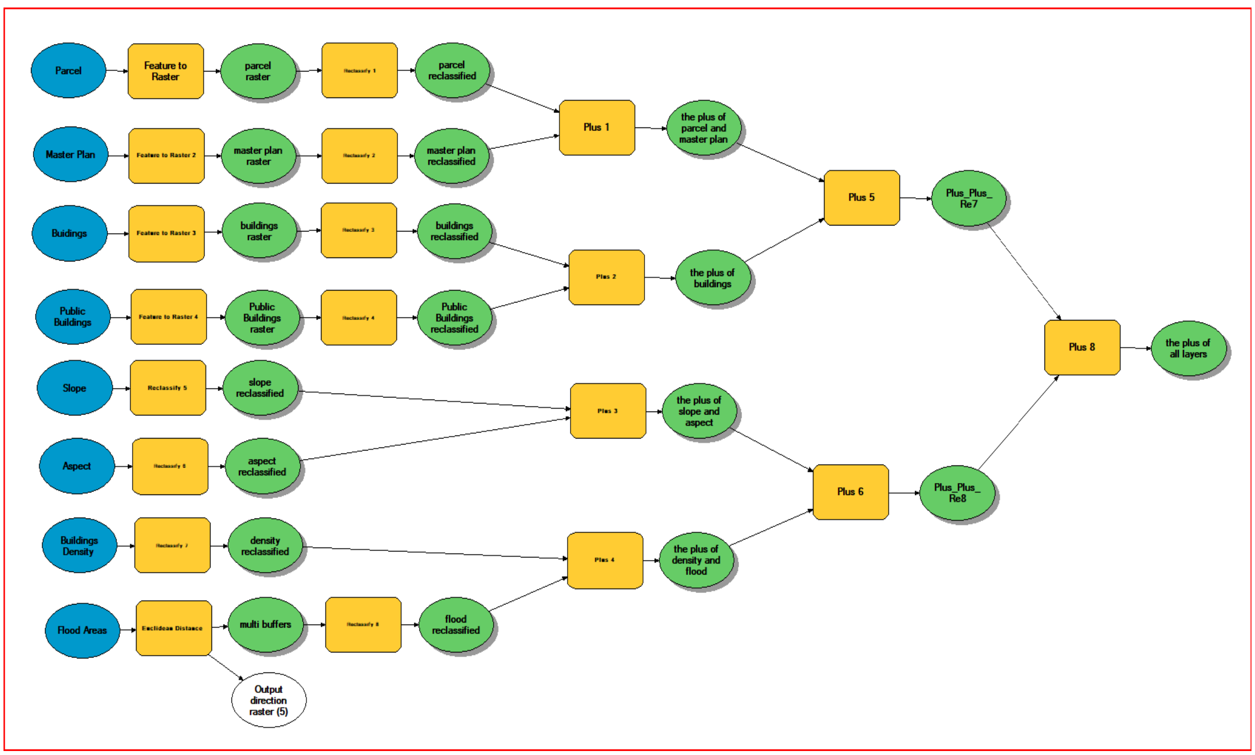


Figure 2 – GIS Model for Site Selection for Community Composting for Shefa-Amr(Available on link: https://is.gd/4DMmj5)

3.3 Best Potential Sites for Composting

Otential

The City of Shefa-Amr is divided into several blocks with various assigned land uses. After determining the potential areas with the highest evaluations (preferably 10, but also 9 and 8), some sites were identified for the establishment of potential local compost stations. The sites were then tested within each block according to three things: first, the weight of the model result; second, the median center* of the blocks containing more than three food waste generation sources; and third, the density of buildings.

* The median center, which is a measure of central tendency in GIS, is a location representing the shortest total distance to all other features in a study area, thus it identifies the location that minimizes travel from it to all other features in the dataset [12].

After evaluation, the suggestion sites were selected in the median of the block or nearest to it with the weights 10 and in high dens area, the sites that were suggested were divide into two types: the large type which accommodates a more than one cubic meter of waste and the small type which accommodates smaller quantities (Future research will explore the optimal quantities for "large" composters situated within urban areas).

Table 6 shows the evaluation of the potential sites. Figure 5 is a map that shows the density of food waste generation sites in Shefa-Amr city, while figures 6 and 7 show maps with the final results for the sites that were proposed, the distances from the buildings to the sites (500 m maximum walking distance) and the site locations on a street map.

Table 6 – Analysis of Community Composting Potential Sites

Potential Site Number	**The Evaluation**				
	Value 10	**At Median Center**	**Nearest to Median Center**	**Farthest from Median Center**	**Density Value for Area**
1	✓	-	✓	-	High
2	✓	-	-	✓	High
3	✓	-	-	-	High
4	✓	-	-	-	High
5	✓	-	-	✓	High
6	✓	-	-	-	High
7	✓	-	-	-	High
8	✓	-	-	-	High
9	✓	-	-	-	High
10	✓	-	-	-	Moderate
11	✓	-	-	✓	Moderate
12	✓	-	-	-	High
13	✓	-	✓	-	Moderate
14	✓	-	-	✓	Moderate

15	✓	-	-	✓	Moderate
16	✓	-	-	-	High
17	✓	-	-	-	Moderate
18	✓	-	✓	-	Moderate
19	✓	-	-	-	Moderate
20	✓	-	-	-	High
21	✓		-	-	Moderate

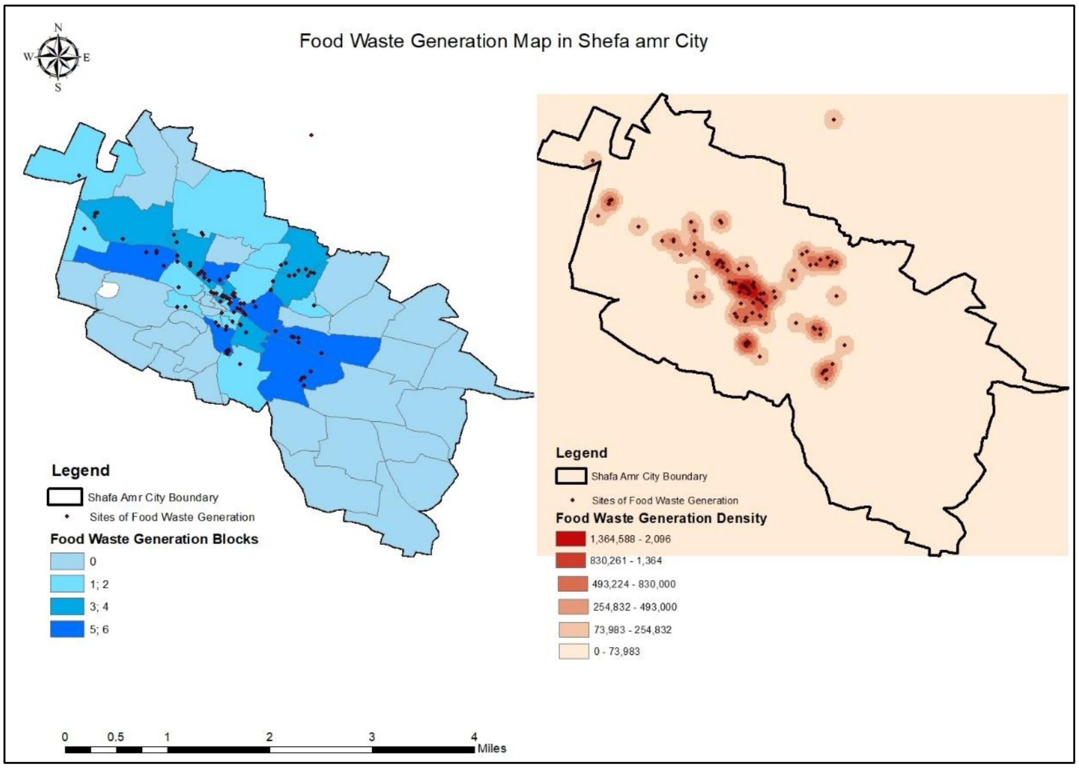


Figure 3 – Food Waste Generation Sources in Shefa-Amr

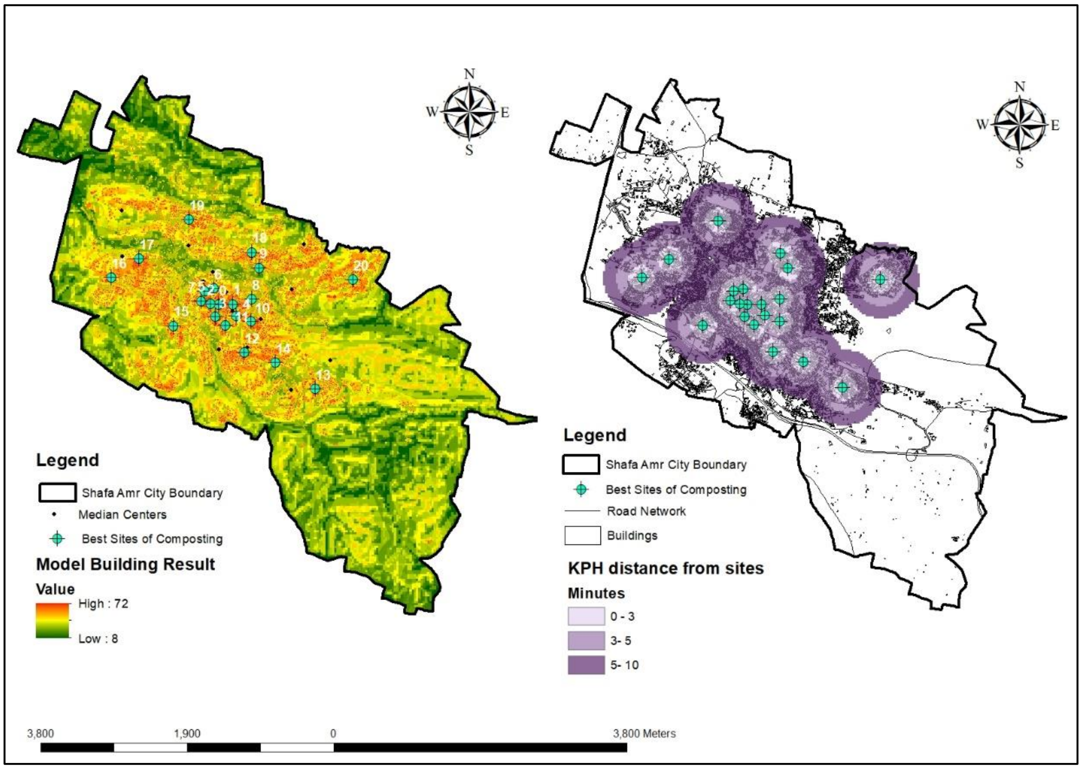


Figure 4 – Final Results for Potential Sites

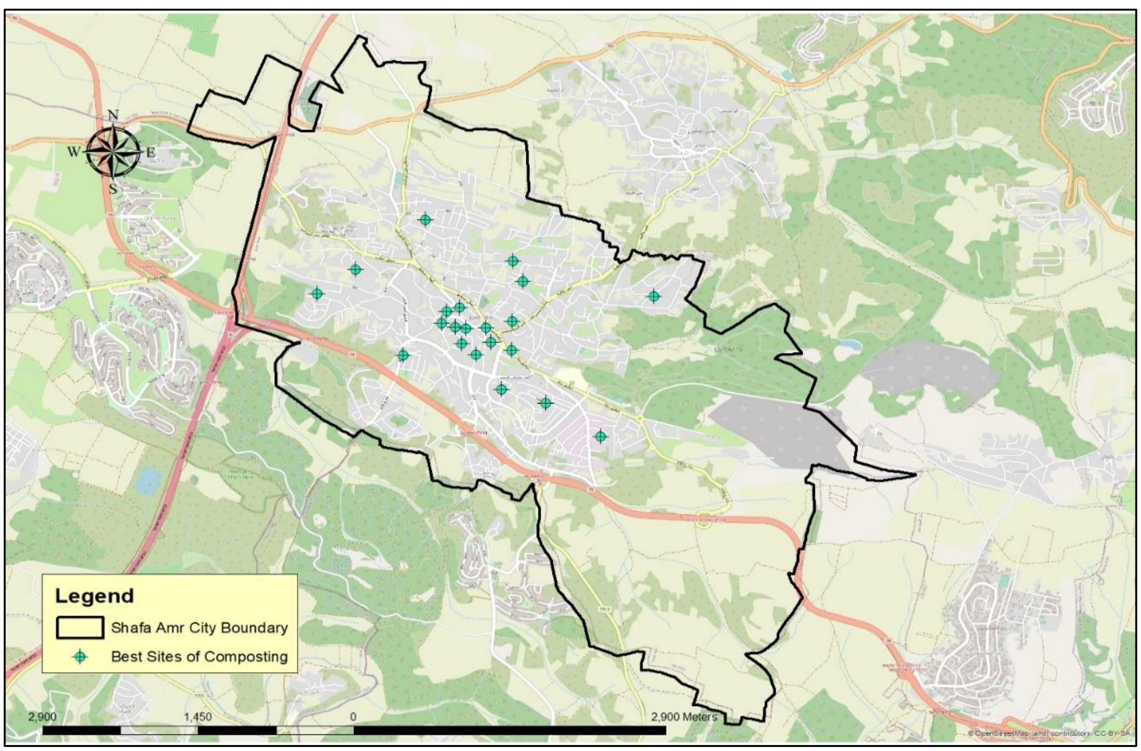


Figure 5 – Potential Sites in an Open Street Map of Shefa-Amr

Section 4: Location Allocation Models

Network Analyst is an extension of the ESRI’s ArcGIS ArcMap application, that provides a set of tools which allow for analyzing networks. In this session, we will look at the location allocation analysis, with the aim of explaining this analysis, what can be done with it, and how to go about doing it, in some detail.

In this project, we will use the following problem types to prepare a model for choosing the best location for composters in the city.

1. **Minimize Facilities** to provide the minimum number of compost stations needed for all building points within 500 m (pedestrian and bicycles) of the composter, and also to obtain which building points should be assigned to any given composter.
2. **Minimize Impedance** to identify the composter locations in order to minimize the total weighted distance (Facilities are located such that the sum of all weighted distance between demand points and solution facilities is minimized), and each building point will be allocated to its closest compost.
3. **Maximize Coverage** to determine where to locate composters with the highest reclassification ratings (10, but also 9 and 8) in order to maximize the number of buildings within 500 m of a composter.

4.1 Create a Road Network

We first need to define the network before moving on to the analysis, as "networks" are used in many different settings and ways. In this project, we have used the transportation network (roads). The network will consist of a set of links connecting a set of nodes, and the GIS software will use the spatial coincidences of nodes and links to define the connectivity of the network.

Step 1: Add data of Road Network to GIS.

To add road network data, a shapefile format of the network must be added into the layout

Step 2: Create a new network dataset.

Creating a new network dataset is important to run the Network Analyst extension and all its features. The travel distance data found in the attributes of the roads shapefile is used as a “cost” in the model.

4.2 Location Allocation Analysis

Before beginning the analysis, the built OSM (OpenStreetMap) network is added to the layout, and any other network added previously is removed. It is suggested to display only the network and to hide the junctions.

The Location Allocation tool can be used to solve several related, but distinct, kinds of problems. There are two stages to solving these problems. First, a number of facilities must be located from a set of feasible locations, and second, demand must be allocated to these facilities. These steps are the same in all problem models, but depending on what sort of problem being solved, the rules for locating the facilities will vary.

The following five steps are the same for all problem solution models in location allocation, and made once at the beginning only.

Step 1: Add data.

The first step is to add all data needed.

1. Facilities: community compost suggestion sites
2. Demand point: buildings points (feature building from polygon to point)
3. Road network (network data base)

Step 2: Add a new location allocation layer.

Use the Network Analyst toolbar to add a New Location Allocation layer to the layout.

The location-allocation analysis layer also appears in the table of contents as a composite layer containing six corresponding feature layers: Facilities, Demand Points, Lines, Point Barriers, Line Barriers, and Polygon Barriers. Each of the six feature layers has default symbology that can be modified in the respective Layer Properties window.

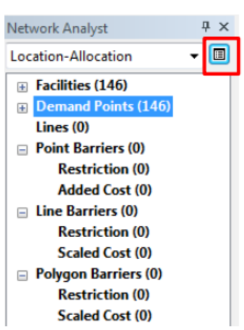
Step 3: Load facilities.

The locations of potential composters should be loaded into the Facilities, noting that these are not the real locations of the facilities, but the possible/feasible locations.

Step 4: Load demand points.

Next, load the locations of the demand points, the assumption being that every building is a demand point.

Step 5: Finally, make sure that impedance is set to meter



With these steps completed, the models for this case can be applied, as noted above, namely:

1. Minimize Facilities
2. Minimize Impedance
3. Maximize Coverage

4.2.1 Minimize Facility Problem Type

In this model, "Minimize Facilities" should be selected, because the aim is to identify every building within 500 m of a composter, and set the Impedance Cutoff to 500, then click on OK.

After solving the problem, the result is a map showing the minimum number of composters needed to have all demand points (buildings) with 500m of a composter, and also how the buildings are assigned to composters, as shown in Figure 6.

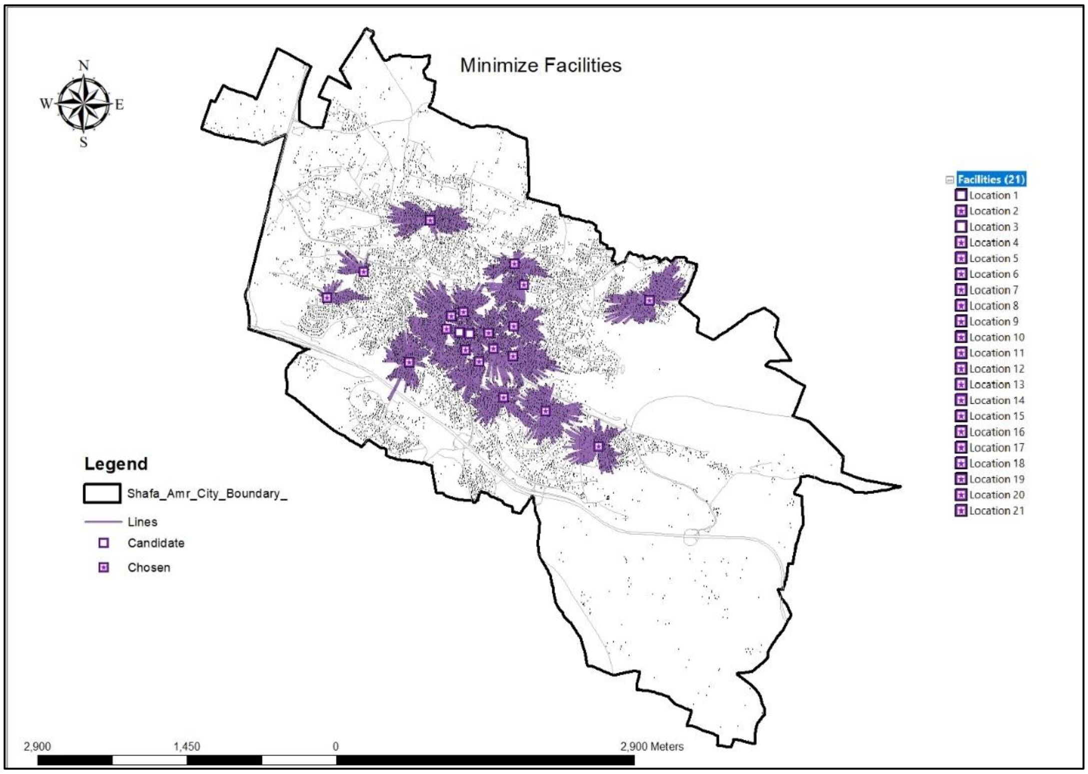


Figure 6 – Minimize Facilities Problem type model

4.2.2 Minimize Impedance Problem Type

Rather than maximizing the number of people within 500 m of a composter, in this model the goal is to minimize the weighted distance from each building to each compost.

After solving the problem, the result this time is a map with the locations of potential composters in order to minimize the total weighted distance, and each building will be allocated to its closest compost, as shown in Figure 7.

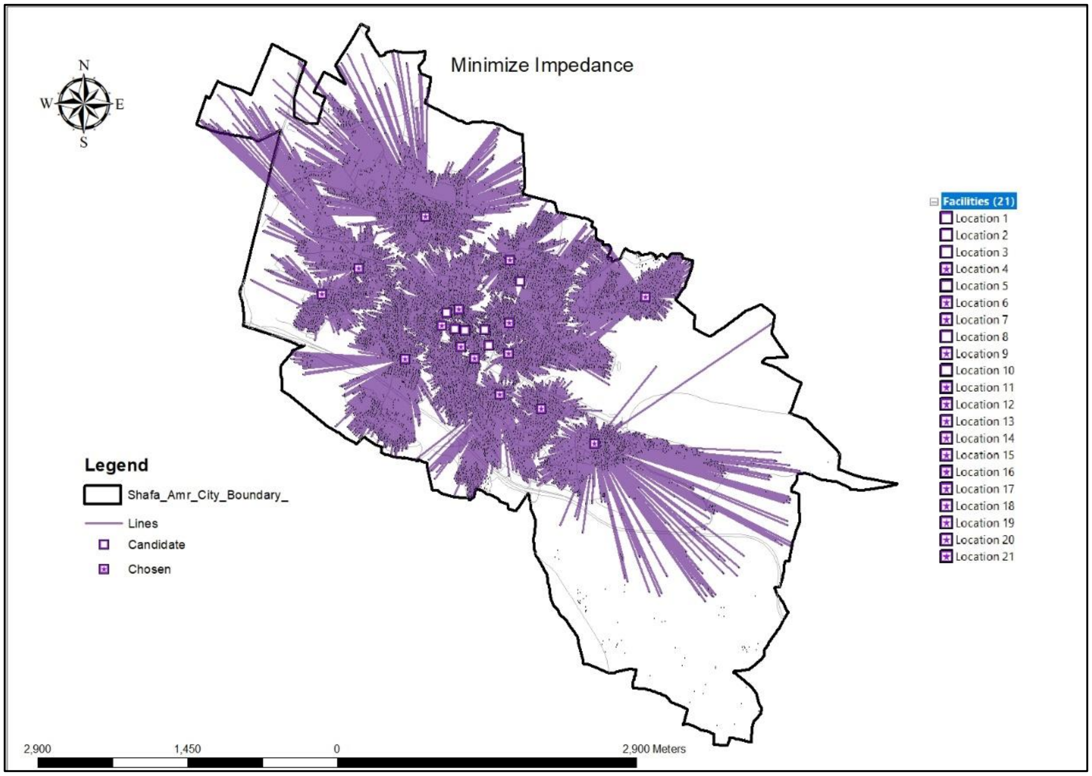


Figure 7 – Minimize Impedance Problem type model.

4.2.3 Maximum Coverage Problem Type

Consider now a related problem. Imagine that there is a budget for 15 compost facilities, and the goal is to identify where to locate them.

the goal here is to “Maximize Coverage”, i.e. to maximize the number of buildings within 500 m of a composter.

After solving the problem, the result is a map showing where the 15 composters should be located in order to maximize the number of buildings within 500 m of a composter, as shown in Figure 8.

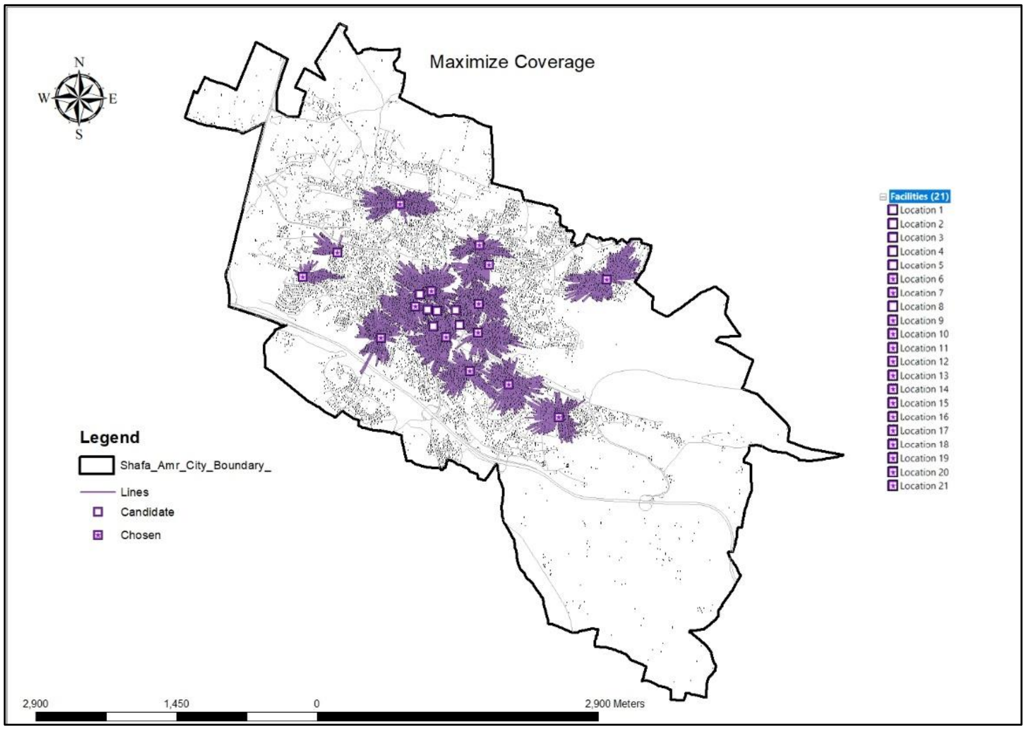


Figure 8 – Maximize Coverage Problem Type Model

Section 5: Final Results and Summary

The following table is based on the previous analysis with different methods and tools, and shows the evaluation of the potential sites in the model building stage. The results of the models' location allocation were added to the evaluation, and the final evaluation was calculated to select 10-15 potential sites for composters. The total score, out of 6, is the combination of several components: evaluation value of 10, being at or nearest to the median centers, high density, be among the selected sites based on the results of the location allocation. Models 1, 2 and 3 relate to Minimize Facilities (Mn Fac), Minimize Impedance (Mn Imp) and Maximize Coverage (Mx Cov), respectively.

Table 7 – Evaluation of Potential Sites

Potential Sites	**The Evaluation**								**Final Result * (total 6)**
	Value 10	**Median Center**			**Density Value**	**Model 1 Mn Fac**	**Model 2 Mn Imp**	**Model 3 Mx Cov**	
		At	**Nearest**	**Farthest**					
1	✓	-	✓	-	High	×	×	×	**3**
2	✓	-	-	✓	High	✓	×	×	**3**
3	✓	-	-	-	High	×	×	×	**2**
4	✓	-	-	-	High	✓	✓	×	**4**
5	✓	-	-	✓	High	✓	×	×	**3**
6	✓	-	-	-	High	✓	✓	✓	**5**

7	✓	-	-	-	High	✓	✓	✓	**5**
8	✓	-	-	-	High	✓	×	×	**3**
9	✓	-	-	-	High	✓	✓	✓	**5**
10	✓	-	-	-	Moderate	✓	×	✓	**3**
11	✓	-	-	✓	Moderate	✓	✓	✓	**4**
12	✓	-	-	-	High	✓	✓	✓	**5**
13	✓	-	✓	-	Moderate	✓	✓	✓	**5**
14	✓	-	-	✓	Moderate	✓	✓	✓	**4**
15	✓	-	-	✓	Moderate	✓	✓	✓	**4**
16	✓	-	-	-	High	✓	✓	✓	**5**
17	✓	-	-	-	Moderate	✓	✓	✓	**4**
18	✓	-	✓	-	Moderate	✓	✓	✓	**5**
19	✓	-	-	-	Moderate	✓	✓	✓	**4**
20	✓	-	-	-	High	✓	✓	✓	**5**
21	✓		-	-	Moderate	✓	✓	✓	**4**

* Legend: Good Moderate Bad

The study identified 11 potential sites for the establishment of decentralized local composting stations in Shefa-Amr, and we divide the compost into two sizes: one large size that accommodates one cubic meter of waste, or the equivalent of one thousand liters, per day, to be located in the city center (high density area), and 10 small size with a capacity of 700 liter per day, to be located throughout the city, with the decentralized characteristic, in order to achieve sustainability in distribution.

The map below (Figure 9) shows the final results for compost station locations in Shefa-Amr.

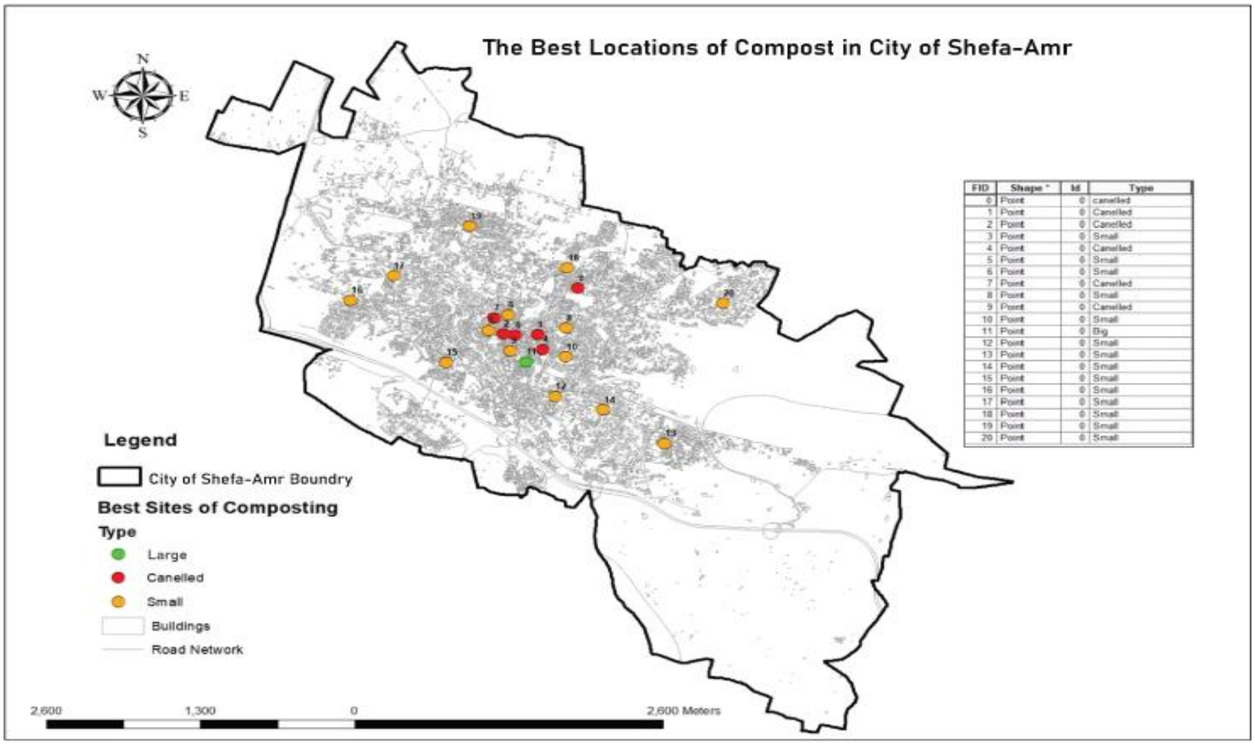


Figure 9 – Final Results for Composter Locations in Shefa-Amr

The next table shows the XY coordinates for the potential composting sites (point), and the name of street where the site is, according to the street map website. Al layers used in the different processes have the same coordinates.

Table 8 – XY Coordinates of Potential Composting Sites and Names of Related Streets

Compost Point	Coordinates XY		Street Name
	X	Y	
1	216277.881033	745661.386243	n/a
2	216464.99474	745664.772916	Ibrahim Nemir Hussien Street
3	216178.820835	745671.546263	n/a
4	216237.240951	745504.752596	n/a
5	216507.328158	745518.29929	n/a
6	216053.513917	745709.646339	n/a
7	216219.460916	745868.819991	n/a
8	216097.540672	745834.106588	n/a
9	216705.871889	745732.576941	Nearest to Amer Al-Sa’sa’ani Street
10	216807.93776	746138.173419	n/a
11	216699.804099	745440.123578	Tawfik Ziad Street
12	216368.5892	745391.351953	n/a
13	216610.122517	745040.959663	n/a

14	217532.528007	744564.920378	n/a
15	217017.315743	744905.529851	Street 140
16	217017.315743	745385.253824	Nearest to Street 450
17	214889.599805	746012.685857	n/a
18	215250.280526	746259.06635	n/a
19	216713.196452	746339.457511	n/a
20	215894.750371	746762.227245	n/a
21	218026.194928	745984.789899	n/a

After reviewing the final results of the potential composter sites in the City of Shefa-Amr, a simple study was made of the road network that connects the buildings, being the demand points, with the composter sites, being the facilities. The aim is to determine and map the routes to the facilities in the road network in order to identify the easiest access and the least possible distance between the buildings and the proposed composting facilities.

We have overlaid the road network with the results from each of the three problem types. The resulting maps are shown below.

1. Minimize Facility

In this problem type, with a required distance of 500 m, we have selected the demand points that are within a distance of 500 m of the composter site (measured according to Minimize the road network that has been defined), thus obtaining the following map (Figure 10).

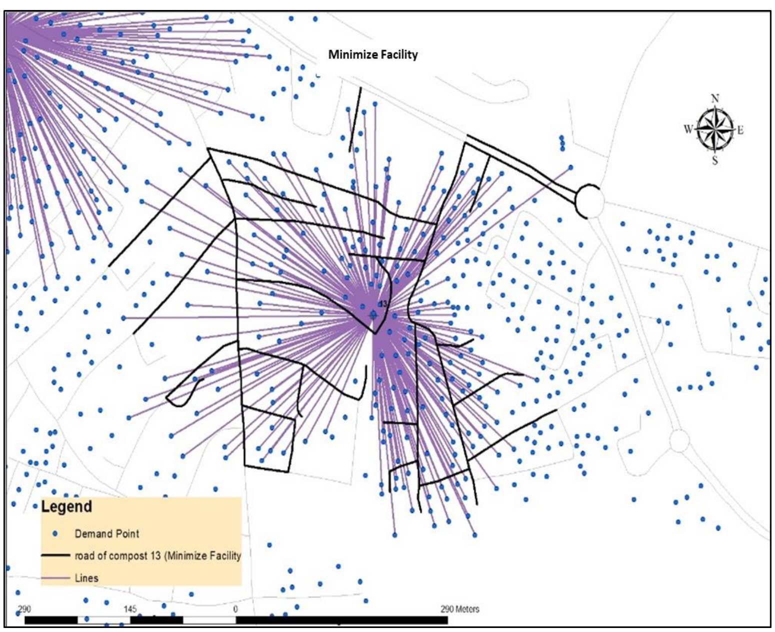


Figure 10 – Minimize Facility Road Network for Compost Sites

2. Minimize Impedance

For this problem type, we have only considered the number of potential composter sites for the entire city, therefore effort was directed to covering the demand points (buildings) as much as possible from the selected site, thus obtaining the next map.

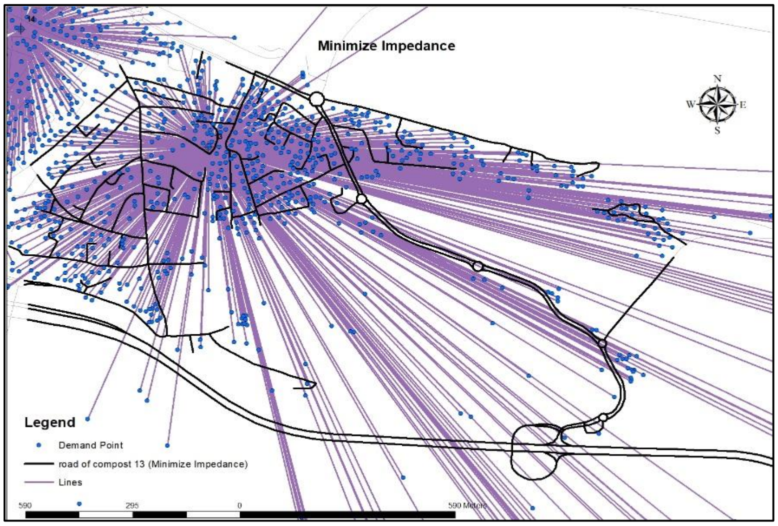


Figure 11 – Minimize Impedance Road Network for Compost Sites

3. Maximize Coverage

Here, the number of potential composter sites has been input for the entire city, so effort has been directed to covering the demand points (buildings) as much as possible from the facility, in addition to keeping the distance between the buildings and the facility below 500 m, thus obtaining the following map (Figure 12).

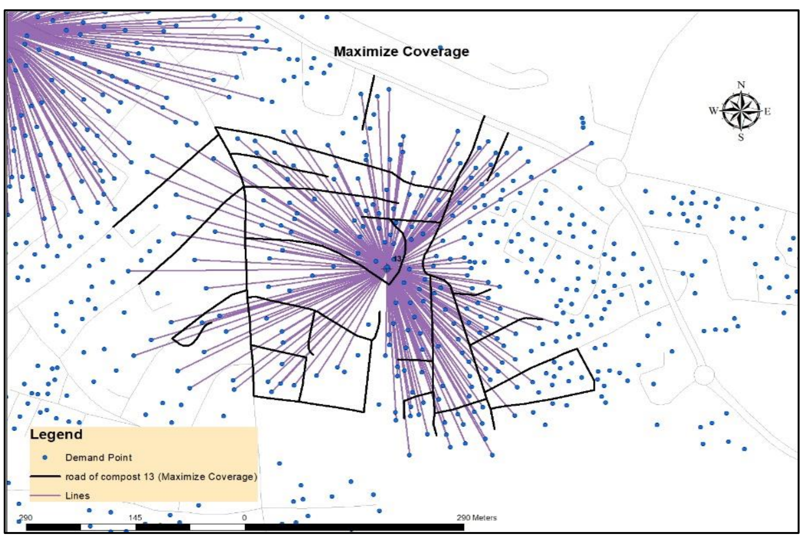


Figure 12 – Maximize Coverage Road Network for Compost Sites

Section 6: Recommendations

This section provides general recommendations, though not necessarily based on the results above.

1) Encourage officials in the fields of environment and planning to follow health principles and standards in planning, so as to dispose of organic waste in the community, and use it to preserve the environment and achieve sustainability.
2) Develop legislation and laws in the field of solid and organic waste to clarify the responsibilities and roles of each part in the waste management process.
3) Increase public awareness of composting and the community involvement in it.
4) Encourage researchers and research centers to conduct similar studies in other local communities and cities, and apply this process in its entire steps, criteria and processes, taking into account the differences in data classifications and formulation of concepts from one region to another.

Section 7: Limitations

This section lists the Limitations (difficulties) faced in performing the study and preparing the report.

1) Unavailability of some data except from online resources.

Differences in the format of data between Palestine and Israel.

References & Resources

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Appendix – Data Collection Tool

This appendix describes programming the plug-in to automatically collect data, where a person enters a specific area, and the tool extracts the required data, through OSMnx.

The OSMnx library is a Python package that allows the download of geospatial data from Open Street Map (OSM), then model, visualize and analyze real-world street networks. It also allows downloading and working with other types of infrastructure, amenities, points of interest, buildings, building footprints, elevation data, street bearings, directions, speed/time of travel. (https://osmnx.readthedocs.io/en/stable/)

The first task in the tool is to call the necessary OSMnx library, as shown in the command below.

```
In [1]: import osmnx as ox
```

Next, create a code function called **getting_locations**, which has two inputs. The first input is the name of the location from which it is intended to obtain the sites, including restaurants, cafes, markets, vegetable and fruit stores, parks, green areas and agricultural areas. The second input is the conservation path.

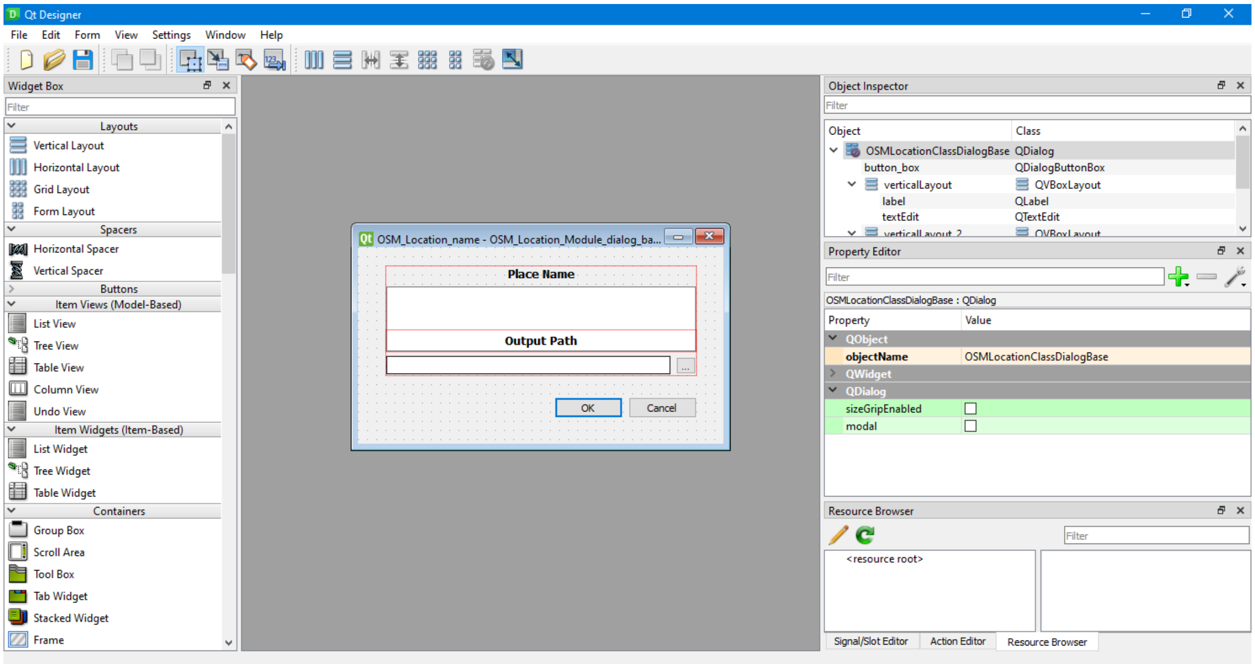
This is shown in the following command sequence.

```python
In [1]: import osmnx as ox
```

```python
In [2]: def getting_locations(place_name,path):
            '''

                a function to getting data from OSM
                parametrs are|
                1-place_name is a name of place that you want getting data its
                2-path|path that the data will be in

            '''
            # Amenity
            amenity_list  = ['fast_food','restaurant','ice_cream','pub','cafe','bar','marketplace','bbq']

            # building
            building_list = ['supermarket']

            # shop
            shop_list = ['supermarket','greengrocer']

            # landuse
            landuse_list = ['greenfield','recreation_ground','farmland','forest','meadow','orchard','vineyard']

            #getting with osmnx
            geom = ox.geometries_from_place(place_name,
                                            {'amenity':amenity_list,'building':building_list,'shop':shop_list,'landuse':landuse_list})
            geom.reset_index(inplace=True)
            geom = geom[['element_type','osmid','name','name:ar','geometry']]
            #create folder

            path_ = os.path.join(path)
            if os.path.isdir(path):
                try:
                    shutil.rmtree(path,ignore_errors=True)
                    os.mkdir(path)
                    print('Folder Created')
                except:
                    print('Opps...There Is An Error During Folder Creation')
            else:
                os.mkdir(path)
                print('Folder Created')
            #saaving data
            try:
                for i in geom['geometry'].geom_type.unique():
                    name = str(i)+'.shp'
                    path_ = os.path.join(path,name)
                    geom.loc[geom['geometry'].geom_type==i].to_file(path_,encoding='utf-8')
                return 'Done Successfully'
            except:
                return 'Opps...There Is An Error During Data Saving'
```

Now, integrate the above code work with the QGIS plug-in, by applying the four steps below, as shown in the diagrams following the steps:

1. Build a new QGIS plug-in; do not do any job with Plugin Builder inside QGIS.
2. Use the plug-in interface through Qt Designer, a program for QGIS, to enter the requirements of the getting_locations function.
3. Employ the plug-in by associating it with the function getting_locations to get the required data.
4. Install the Plugin via Install From ZIP as mentioned in the video.




```
In [ ]: def run(self):
            """Run method that performs all the real work"""
            if self.first_start == True:
                self.first_start = False
                self.dlg = OSMLocationClassDialog()
            self.dlg.show()
            result = self.dlg.exec_()

            if result:
                try:
                    global ox
                    import osmnx as ox
                except ImportError:
                    import_path = os.path.join(self.plugin_dir, 'packages')
                    sys.path.insert(0, import_path)
                    global ox
                    import osmnx as ox
                ##################

                place_name = self.dlg.textEdit.toPlainText()

                path = self.dlg.mQgsFileWidget.filePath()

                getting_locations(place_name,path)

                ##################
                print('Made By | YasserIsmail©2022')
                pass
```

Notes

- One of the features of the plug-in is that the libraries used will be downloaded automatically when the plug-in is used for the first time, so the first time may take longer than other times.
- Prepare an analysis to find the best waste collection path out of about 100 points so that we should find how to collect the largest amount of waste (load Garbage truck: 8-10 tons) from the fewest points

This analysis was done using several libraries specialized in spatial analyses, and some libraries related to machine learning in general, such as pandas, network, shape, geopandas, osmnx, sklearn, resulting in many functions getting programmed to do the analysis.

```
In [ ]: def get_nearest(src_points, candidates, k_neighbors=1):
            """Find nearest neighbors for all source points from a set of candidate points"""

            # Create tree from the candidate points
            tree = BallTree(candidates, leaf_size=15, metric='haversine')

            # Find closest points and distances
            distances, indices = tree.query(src_points, k=k_neighbors)

            # Transpose to get distances and indices into arrays
            distances = distances.transpose()
            indices = indices.transpose()

            # Get closest indices and distances (i.e. array at index 0)
            # note: for the second closest points, you would take index 1, etc.
            closest = indices[0]
            closest_dist = distances[0]

            # Return indices and distances
            return (closest, closest_dist)
```

```
In [ ]: def get_perfect_node(gdf,limit):
            gdf['x'] = [po.x for po in gdf.geometry]
            gdf['y'] = [po.y for po in gdf.geometry]
            Paths =[]
            for iii in gdf.index:
                point = gdf.loc[[iii]]
                line_node =[]
                drop_list =[]
                quantity_list =[]
                x = point.iloc[0].x
                y = point.iloc[0].y
                line_node.append(point.iloc[0].geometry)
                drop_list.append(point.index[0])
                quantity_list.append(point.iloc[0].descriptio)
                for i in gdf.index:
                    if (gdf.drop(drop_list).shape[0]>0) and (sum(quantity_list)<=limit):
                        src = nearest_neighbor(point,gdf.drop(drop_list))
                        x = src.iloc[0].x
                        y = src.iloc[0].y
                        line_node.append(src.iloc[0].geometry)
                        drop_list.append(gdf.loc[(gdf['x']==x)&(gdf['y']==y)].index[0])
                        quantity_list.append(src.iloc[0].descriptio)
                        point = src
                Paths.append([LineString(line_node),LineString(line_node).length])
            columns = ['path','length']
            df = pd.DataFrame(Paths,columns = columns)
            return gpd.GeoDataFrame(df[['length']],geometry=df['path'],crs=4326)
```

```
In [ ]: def nearest_neighbor(left_gdf, right_gdf, return_dist=False):
            left_geom_col = left_gdf.geometry.name
            right_geom_col = right_gdf.geometry.name
            right = right_gdf.copy().reset_index(drop=True)
            left_radians = np.array(left_gdf[left_geom_col].apply(lambda geom: (geom.y * np.pi / 180, geom.x * np.pi / 180)).to_list())
            right_radians = np.array(right[right_geom_col].apply(lambda geom: (geom.y * np.pi / 180, geom.x * np.pi / 180)).to_list())
            closest, dist = get_nearest(src_points=left_radians, candidates=right_radians)

            # Return points from right GeoDataFrame that are closest to points in left GeoDataFrame
            closest_points = right.loc[closest]

            # Ensure that the index corresponds the one in left_gdf
            closest_points = closest_points.reset_index(drop=True)

            # Add distance if requested
            if return_dist:
                # Convert to meters from radians
                earth_radius = 6371000  # meters
                closest_points['distance'] = dist * earth_radius

            return closest_points
```

```python
In [ ]: def get_streets(gdf):
            gdf = gdf.buffer(0.01)
            minx, miny, maxx, maxy = gdf.total_bounds
            streets = ox.graph_from_bbox(maxy,miny,maxx,minx,network_type='all')
            return streets
```

```python
In [ ]: def near_nodes(waste_path,nodes):
            geom = [Point(po[0],po[1]) for po in list(waste_path.geometry.iloc[0].coords)]
            waste_nodes = gpd.GeoDataFrame(geometry=geom,crs=4326 )
            req_node = []
            target = nodes.reset_index()[['osmid','geometry']]
            for i in range(waste_nodes.shape[0]):
                data = nearest_neighbor(waste_nodes.loc[[i]],target).iloc[0]
                req_node.append([data['osmid'],data['geometry']])
            columns = ['osmid','geom']
            df = pd.DataFrame(req_node,columns=columns)
            return gpd.GeoDataFrame(df[['osmid']],geometry=df['geom'],crs=4326)
```

```python
In [2]: def get_perfect_edge(nodes,roads,g):
            roads = roads.reset_index()
            lst = []
            for i in range(nodes.shape[0]):
                if i == nodes.shape[0]-1:
                    break
                edge = roads.loc[(roads['u']==nodes.iloc[i]['osmid'])&(roads['v']==nodes.iloc[i+1]['osmid'])]
                if edge.shape[0]==0:
                    new_nodes = nx.shortest_path(g,nodes.iloc[i]['osmid'],nodes.iloc[i+1]['osmid'])
                    if len(new_nodes) > 1:
                        for i_2 in range(len(new_nodes)):
                            if i_2 == len(new_nodes)-1:
                                break
                            edge = roads.loc[(roads['u']==new_nodes[i_2])&(roads['v']==new_nodes[i_2+1])]
                            lst.append(edge.iloc[0]['geometry'])
                else:
                    lst.append(edge.iloc[0]['geometry'])
            return lst
        def get_line_node(geom):
            geom = [Point(po) for po in waste_path.iloc[0]['geometry'].coords]
            return gpd.GeoDataFrame(geometry=geom,crs=4326)
```

Please note that the results of the previous codes are already presented in section 4

References to libraries and software used:

https://www.qt.io

https://qgis.org/en/docs/index.html

https://pandas.pydata.org/docs

https://geopandas.org/en/stable/docs.html

https://shapely.readthedocs.io/en/stable/manual.html

https://osmnx.readthedocs.io/en/stable/

https://networkx.org/documentation/stable/

https://scikit-learn.org/stable/user_guide.html

https://matplotlib.org

https://numpy.org

DECOST

DECOST additions to R&T plan

Exploring the Key Factors Affecting Composting Behavior in Greece

Study by U Patras

Contents

Figures

Tables

1. Scope of the study - Exploring the Key Factors Affecting Composting Behavior

This study aims to investigate the opinion, awareness and readiness of residents in Greece to compost. At the first part of this report the situation in Greece regarding composting is summarized and the factors affecting the willingness to compost in Greece are analyzed. Furthermore, several waste management models that can be used to simulate the composting of organic waste in Greece.

The next part of this report focuses on the study investigating the opinion, awareness, and readiness of residents in Greece to compost. This study should include mixed-methods approach, combining both quantitative and qualitative data collection methods. After the simulation analysis that was concluded using use cases and different factor in specific scenarios in the previous part of this report, this part of the report focuses on the analysis based on questionnaires.

The first step of this study was the development of a questionnaire. A questionnaire was created that assesses residents' opinions, awareness, and readiness to compost. The questionnaire included questions about the residents' existing waste management practices, their knowledge of composting, their attitudes towards composting, and their willingness to start composting. The following step was to conduct the survey. The questionnaire was administered to a sample of residents to collect quantitative data on the level of awareness, attitudes, and readiness of residents towards composting. Furthermore, as a next step the data collected from the survey had to be analyzed. This helped to identify common themes, trends, and patterns in the data. As a final step was the reporting of the findings. The findings could be used to design targeted education and outreach programs to raise awareness and encourage more residents to start composting, as well as to develop policies and programs that address barriers to composting and make composting more accessible to more people.

2. Willingness to compost in Greece

2.1 Composting in Greece

In Greece, composting has gained popularity in recent years as a means of reducing waste and promoting environmental sustainability. The Greek government has been promoting composting initiatives through educational campaigns, financial incentives, and the development of composting facilities. In Greece, there are around 514 kilograms of municipal waste produced per person year, according to official data released by the authorities (NWMP, 2020-2030). The waste is composed of biodegradable fractions, such as paper and garden and food waste, making up 66.5% of the municipal waste. Garden and food waste make up roughly 44% of the municipal bio-waste overall (NWMP, 2020-2030).

In Greece, landfilling is still the most common method of disposing of municipal waste. Composting is the most natural and oldest method of recycling organic waste. It can be done individually in gardens or yards, collaboratively in appropriate and pre-selected locations within a settlement, or in composting plants that accept deliveries of previously separated organic waste. Organic waste is an excellent raw material for making compost for soil conditioning. European citizens are working to reduce the amount of waste sent to landfills in accordance with European waste management policies.

The new National Waste Management Plan 2020-2030 in Greece specifies future reductions in landfilled municipal waste; it anticipates that by 2030, Greece will have achieved its goal of 10% or less of total generated municipal waste being disposed of in landfills, while the amending 2018/850 Landfill Directive, which will be transposed into national legislation, imposes additional restrictions by prohibiting the landfilling of municipal waste that has been separately collected.

Composting, as explained above, is a process that converts organic waste into a nutrient-rich soil amendment known as compost. It is an important practice for managing organic waste, reducing the amount of waste disposed at landfills, and improving soil quality. Compost can be used as a soil conditioner and fertilizer in agricultural and gardening applications, and it can also be used in landscaping and erosion control. Overall, while data on the end uses of compost in Greece is limited, it appears that compost is primarily used for soil conditioning and fertilization.

There are several types of composting practices in Greece, including household composting, community composting, and commercial composting. Household composting involves the composting of organic waste in individual homes, while community composting involves the composting of organic waste in shared spaces, such as community gardens or parks. Commercial composting is the composting of organic waste by businesses and institutions.

2.2 Factors influencing willingness to compost

Various factors must be carefully considered in order to determine the best composting approach. In this chapter, we examine the factors that influence people's decisions in Greece between home composting and community composting, with the goal of encouraging sustainable waste management practices. The amount of organic waste generated is an important consideration when deciding on the best composting method. For smaller amounts of organic waste, home composting can be a viable option, whereas community composting is more efficient for larger volumes of waste.

Another critical factor to consider is the availability of space. Composting at home takes up little space for a compost bin, making it ideal for those with limited outdoor space. In contrast, community composting necessitates larger spaces for public composting bins or dedicated facilities. The availability of resources, such as funding, equipment, and personnel, is an important consideration when deciding on a composting strategy. Home composting typically requires few resources, making it more accessible to individuals and households. Community composting, on the other hand, necessitates sufficient resources to establish and maintain public composting infrastructure.

Composting initiatives rely heavily on public perception and participation. If there is a high level of public interest and willingness to participate in composting, community composting may be the best option because it fosters a sense of collective responsibility and cooperation.

The legal framework surrounding composting practices should also be considered. Local waste management and composting laws and regulations can influence the feasibility and implementation of both approaches. Compliance with legal requirements ensures that composting initiatives are consistent with local policies and environmental standards.

Cost is an important consideration in the decision-making process. Composting at home is generally less expensive because it requires less equipment and materials. Community composting, on the other hand, may have higher initial costs due to the establishment of composting facilities or public infrastructure. However, community composting can generate revenue through the sale of compost, potentially offsetting some costs over time.

A thorough evaluation of these factors is required before deciding whether to implement home or community composting. It is critical to involve stakeholders, such as residents, businesses, and local governments, in order to consider the community's specific circumstances and priorities. Collaborative discussions and consultations with relevant stakeholders will aid in decision-making. Finally, composting, both individually and communally, holds great promise for managing organic waste and promoting environmental sustainability in Greece. Informed decisions about the implementation of home or community composting initiatives can be made by assessing factors such as waste quantity, space availability, resource allocation, public perception, legislative considerations, and cost implications.

3. Questionnaire Analysis

3.1 Importance of Questionnaires

Questionnaires are an essential tool for collecting information about people's attitudes, behaviors, and experiences related to a particular topic. When it comes to composting, a well-made questionnaire can be a useful tool for determining the degree of awareness, interest, and obstacles to composting in a particular region, like Greece.

By conducting a questionnaire, we can gain insight into how popular composting is in Greece and how likely residents are to start composting. With the aid of this information, we can create outreach and education initiatives that are specifically aimed at increasing composting awareness and participation.

A questionnaire can also assist in identifying the major barriers that prevent people from composting, such as a lack of space, a lack of knowledge, or concerns about odors or pests. We can develop programs and policies that make composting more accessible to more people by addressing these barriers.

Furthermore, a questionnaire can reveal how residents in Greece think about waste and waste management, as well as how composting fits into their overall approach to waste reduction and environmental sustainability. This data can help us understand waste management attitudes and behaviors, as well as develop policies and programs that promote composting and other sustainable waste management practices.

Moreover, the information gathered from a questionnaire can be used to help shape policies and programs that promote composting and other sustainable waste management practices. We can increase the likelihood of these programs being effective in promoting behavior change by tailoring them to the needs and preferences of the local community.

Overall, questionnaires can provide valuable insights and information that can help inform the development and implementation of composting programs, including home and community composting.

3.2 Questionnaire for composting

For the purpose of this study, a questionnaire was developed to assess the opinions, awareness, and readiness of Greek residents to engage in composting. The questionnaire aimed to gather valuable insights and data on various aspects related to composting practices and attitudes among households in Greece. The questionnaire consisted of three parts: Knowledge and current situation, Factors influencing the willingness to compost, and General information. It comprised a total of 35 questions designed to elicit information about respondents' composting behavior, knowledge level, attitudes toward composting, perceived barriers, and general demographic details.

To ensure a comprehensive understanding of composting practices, the questionnaire explored whether respondents were familiar with the concept of circular economy, and if they had prior knowledge of home composting or community composting. It further assessed respondents' understanding of composting, their current composting practices (if any), and the types of organic waste typically generated at home. Additionally, the questionnaire aimed to gauge respondents' self-assessed knowledge level of composting, awareness of community composting initiatives in their area, past participation in such initiatives, and whether they had received any education or training on composting.

The second part of the questionnaire delved into the factors that influence individuals' willingness to engage in composting. It sought respondents' views on starting home composting, participating in community composting initiatives, and their opinions on the benefits of composting for waste reduction, soil improvement, and environmental sustainability. The questionnaire also explored respondents' perceptions of the difficulty level of composting and identified potential barriers such as space constraints, time limitations, and lack of knowledge or necessary equipment.

The final part of the questionnaire focused on collecting general information about the respondents, including their age, gender, education level, employment status, marital status, household size, approximate income, and residence type.

The questionnaire was distributed online in Greek over a period of two months. The survey was conducted among a convenience sample of 100 households in Greece. The questionnaire is available in annex 1. The use of online forms facilitated easy access and participation for respondents, allowing for a larger and more diverse sample size. The convenience of the online format also enabled respondents to complete the questionnaire at their own convenience and reduced the need for physical data collection.

By analyzing the responses obtained through the questionnaire, this study aims to gain a comprehensive understanding of the composting behaviors, attitudes, and challenges faced by households in Greece.

3.3 Statistical analysis of questionnaire and results

In this chapter, we present the statistical analysis and results obtained from the questionnaire administered to households in Greece. The analysis was conducted using Microsoft Excel and SPSS software. The questionnaire consisted of three parts, covering knowledge and current situation, factors influencing willingness to compost, and general information.

Part 1: Knowledge and Current Situation

The chart below illustrates the respondents' awareness of the concept of circular economy:

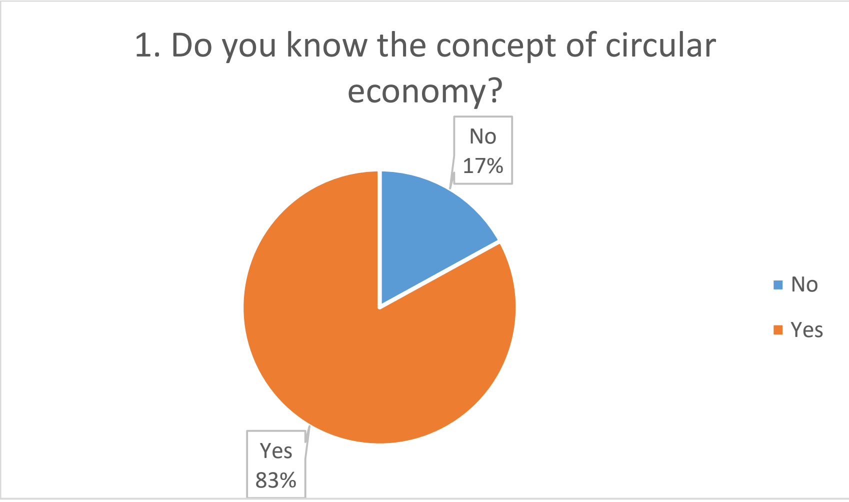


Figure 1: Awareness of the Concept of Circular Economy

The results indicate that out of the total respondents, 17 individuals (17%) were not aware of the concept of circular economy, while 83 individuals (83%) demonstrated knowledge of circular economy. This suggests a relatively high level of awareness regarding circular economy among the surveyed households in Greece.

The following chart displays the respondents' familiarity with home and community composting:

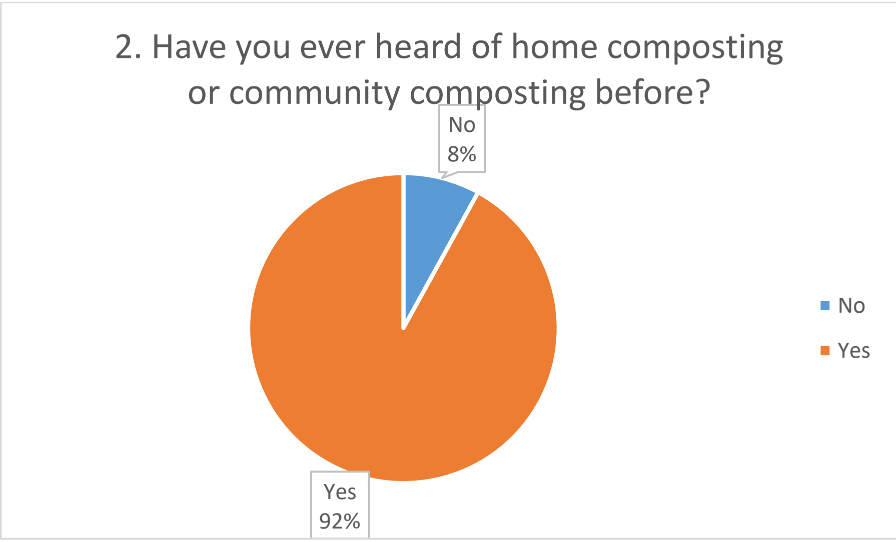


Figure 2: Awareness of Home Composting and Community Composting

The majority of respondents (92%) reported having heard of home composting or community composting before, indicating a relatively high level of awareness about these composting methods among the surveyed population.

The chart below presents the respondents' understanding of composting:

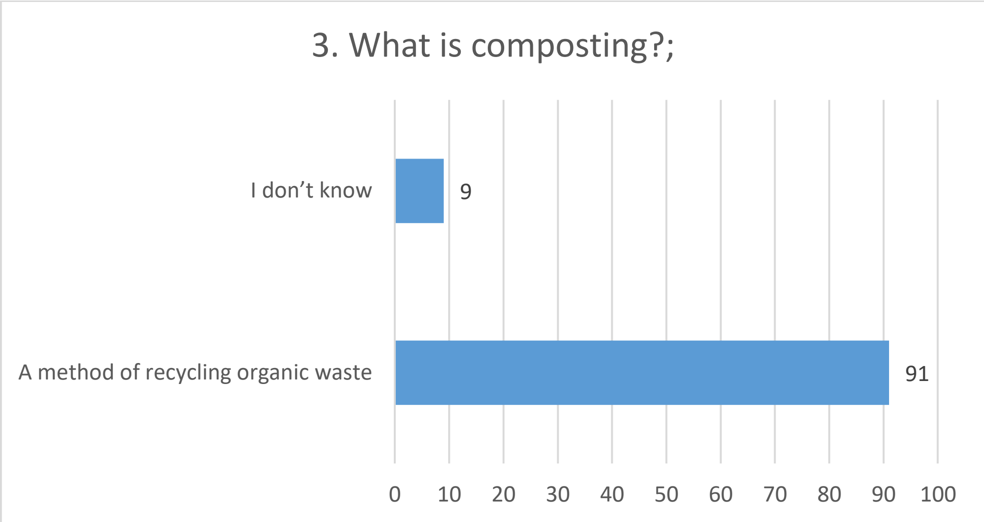


Figure 3: Knowledge of Composting

Based on the results, 91% of respondents correctly identified composting as a method of recycling organic waste. Interestingly, a small percentage (9%) of respondents were unsure about the concept of composting, with no one selecting other options such as recycling paper, plastics, or glass as the definition of composting.

The following chart represents the respondents' current composting practices:

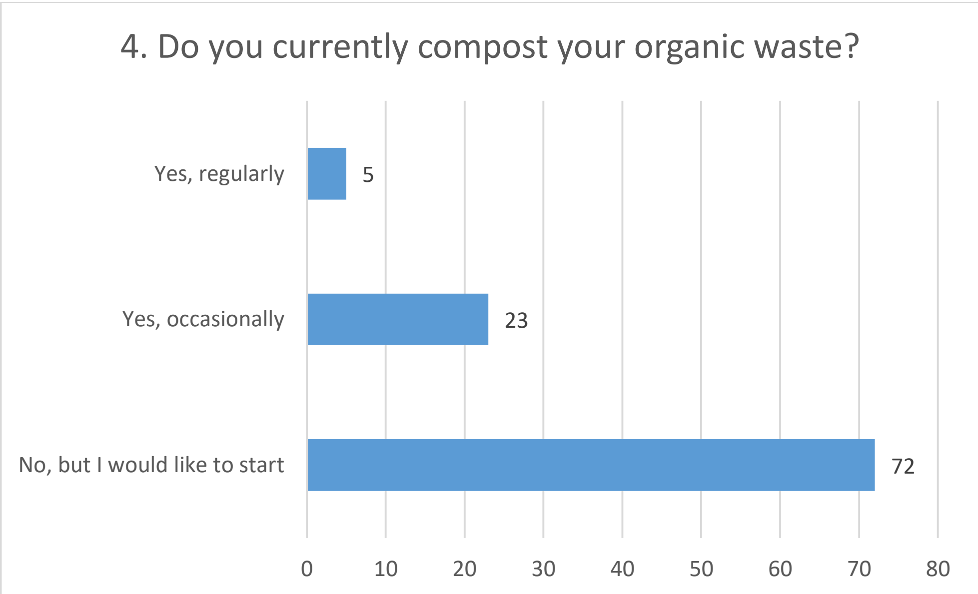


Figure 4: Current Composting Practices for Organic Waste"

The results indicate that a majority of respondents expressed an interest in starting composting, with 72% stating their willingness to begin composting their organic waste. This suggests a potential opportunity to promote and encourage composting practices among households. Additionally, the low percentage (5%) of respondents who reported composting regularly suggests that there is room for improvement in terms of increasing regular composting behavior.

The chart below illustrates the breakdown of the respondents' organic waste generation:

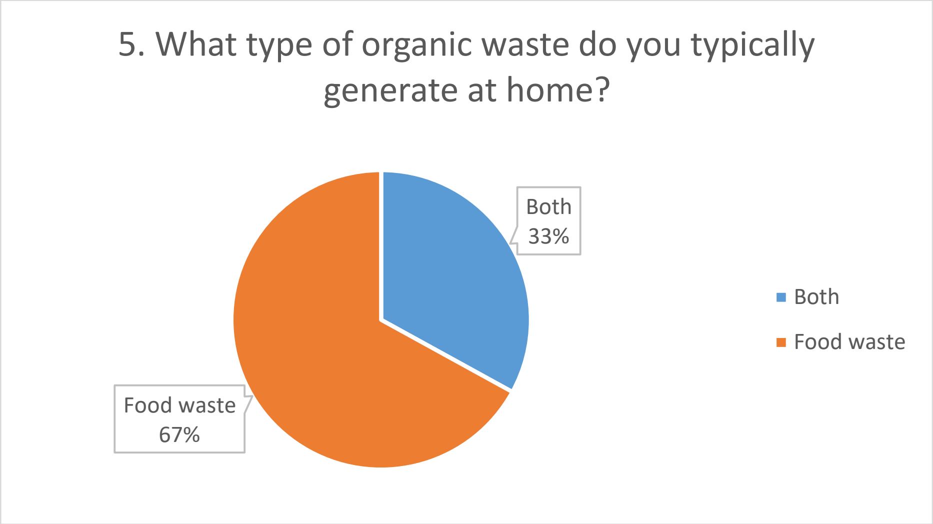


Figure 5: Types of Organic Waste Generated at Home

The results indicate that 67% of respondents typically generate food waste at home, while 33% mentioned generating both food waste and yard waste. This suggests that food waste is a more prevalent type of organic waste among households surveyed.

The following chart displays the frequency of composting among the respondents:

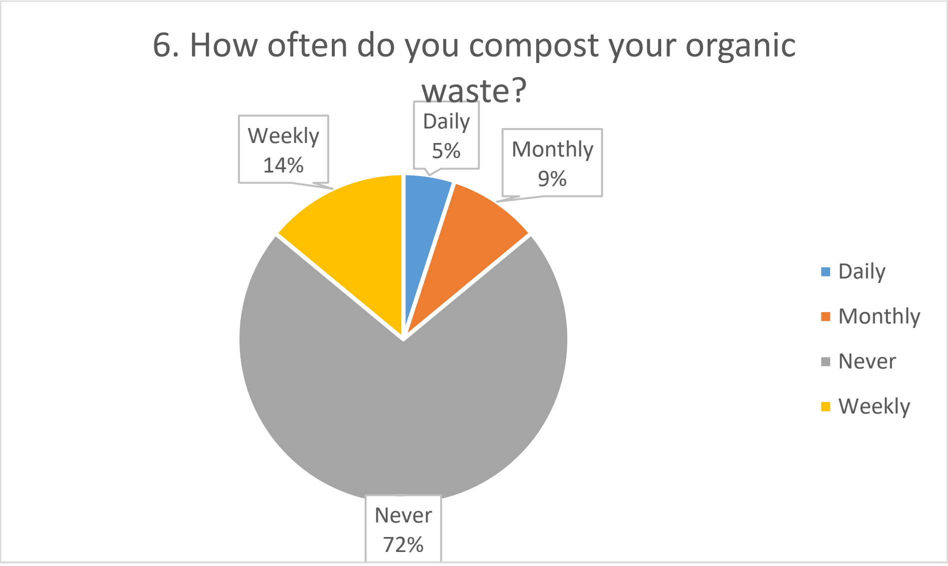


Figure 6: Frequency of Composting Organic Waste

The results indicate that among the respondents, the majority (72%) do not compost their organic waste. A small percentage (5%) compost their waste daily, while 14% compost on a weekly basis. Only a few respondents (9%) reported composting their organic waste monthly.

These findings suggest that there is a significant opportunity to promote more frequent composting practices among households.

The chart below demonstrates the respondents' self-assessment of their composting knowledge:

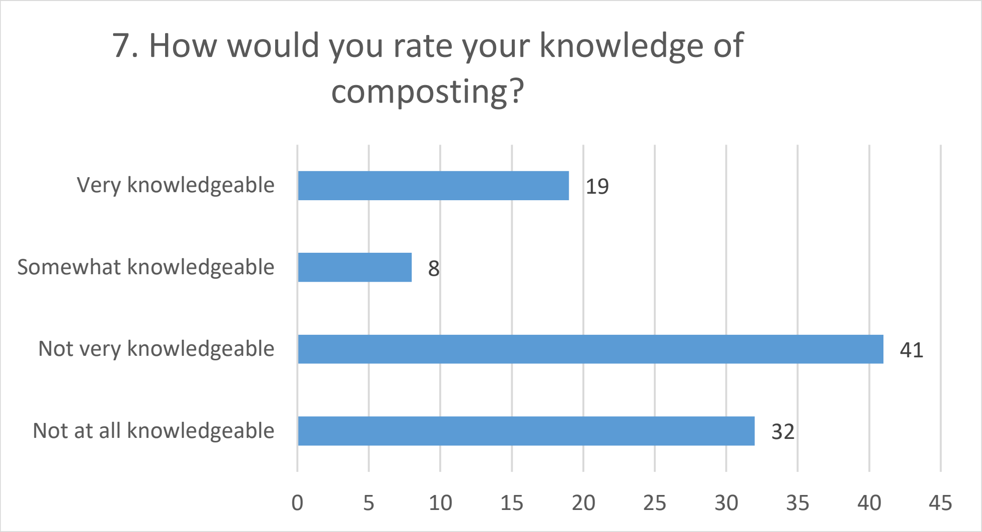


Figure 7: Knowledge of Composting Level Among Respondents

The results indicate that a significant portion of respondents do not consider themselves knowledgeable about composting, with 32% stating they have no knowledge and 41% indicating low knowledge. Only 8% of respondents feel somewhat knowledgeable, while 19% believe they are very knowledgeable about composting. This suggests that there is a need for educational initiatives and awareness-raising campaigns to improve understanding and knowledge about composting among the surveyed population.

The following chart presents the respondents' awareness of community composting initiatives:

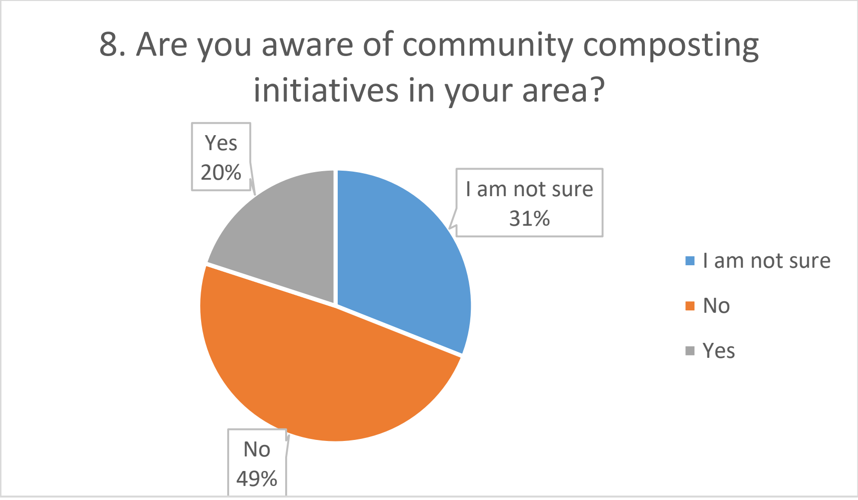


Figure 8: Awareness of Community Composting Initiatives in the Area

Based on the survey responses, it was found that 20% of the respondents are aware of community composting initiatives in their area, while 49% answered negatively and 31% were unsure. This indicates a relatively low level of awareness regarding community composting initiatives among the participants.

The chart below shows the respondents' participation in previous community composting initiatives:

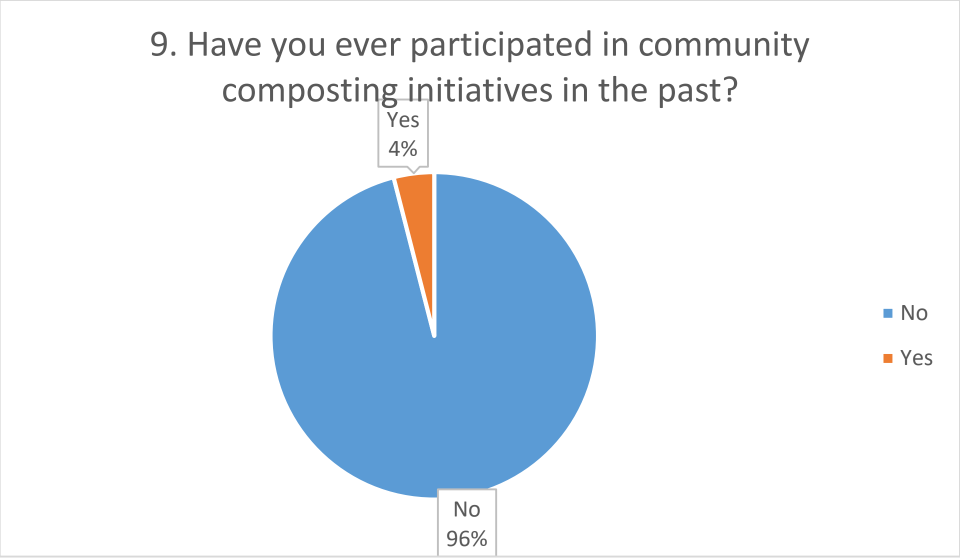


Figure 9: Participation in Community Composting Initiatives

The results indicate that a majority of respondents (96%) have not participated in community composting initiatives in the past, while a small percentage (4%) have. This suggests a potential opportunity to increase community engagement and participation in composting initiatives.

The following chart represents the respondents' previous education or training on composting:

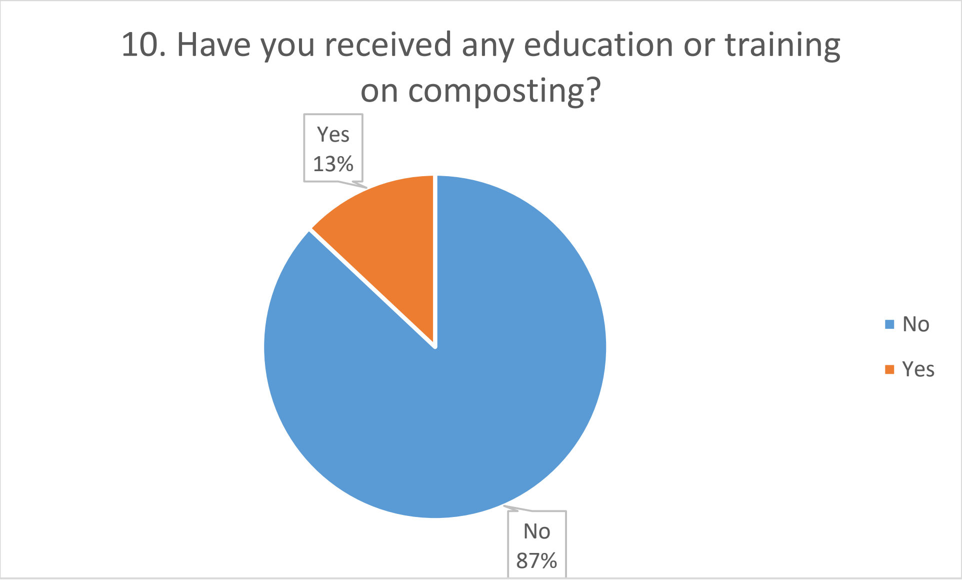


Figure 10: Education or Training on Composting

The majority of respondents (87%) have not received any education or training on composting, while a smaller percentage (13%) have received such education or training. This suggests that there is a potential opportunity to provide more composting education and training to promote awareness and knowledge among the participants.

Part 2: Factors Influencing the Willingness to Compost

The chart below indicates the respondents' willingness to start home composting:

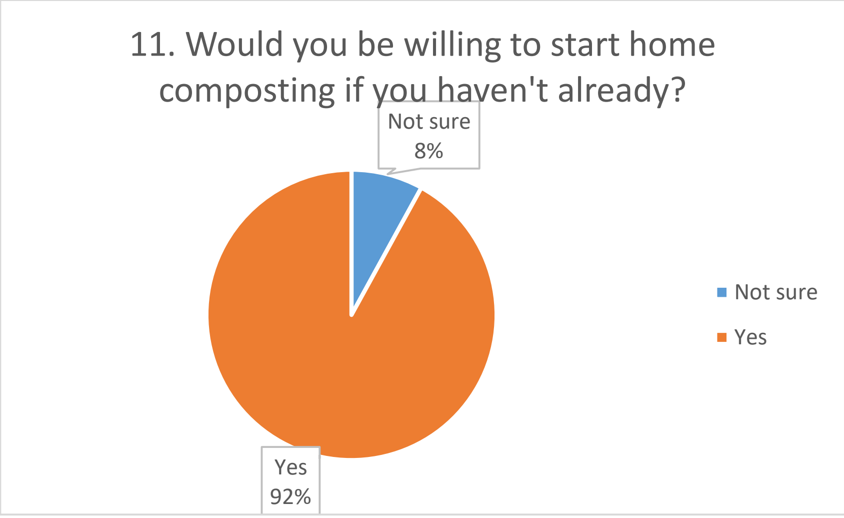


Figure 11: Willingness to Start Home Composting

It can be observed that a significant majority of respondents (92%) express a willingness to start home composting if they haven't already. This indicates a positive attitude towards adopting composting practices among the surveyed population. Additionally, a small proportion (8%) of respondents are unsure about their willingness to start composting, suggesting the potential for further awareness-raising efforts to address any uncertainties.

The following chart displays the respondents' interest in future community composting participation:

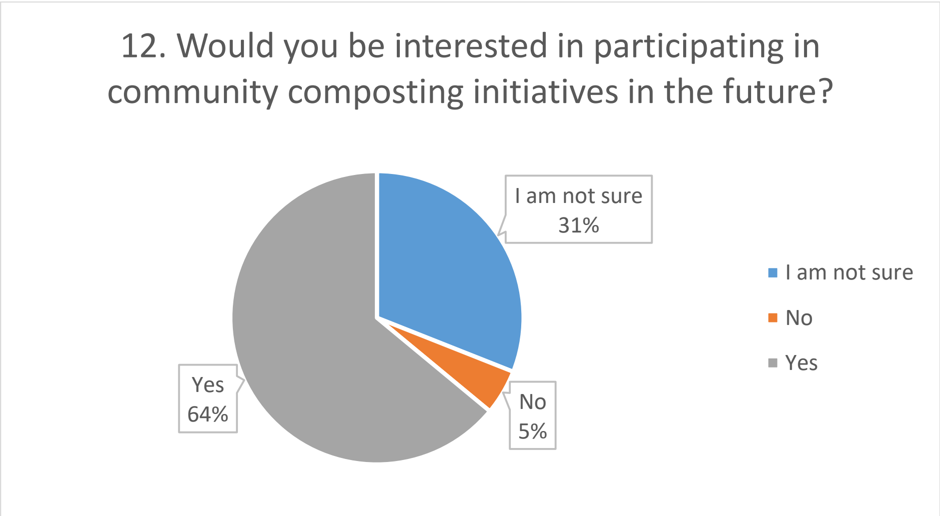


Figure 12: Interest in Participating in Community Composting

A significant portion of respondents (64%) expressed interest in participating in community composting initiatives in the future. This indicates a potential willingness to engage in collaborative composting efforts. However, a notable portion (31%) indicated uncertainty regarding their interest, suggesting the need for further information and awareness-building regarding the benefits and opportunities associated with community composting. Only a small percentage (5%) expressed a lack of interest in participating.

The chart below illustrates the respondents' preferences for the benefits of composting:

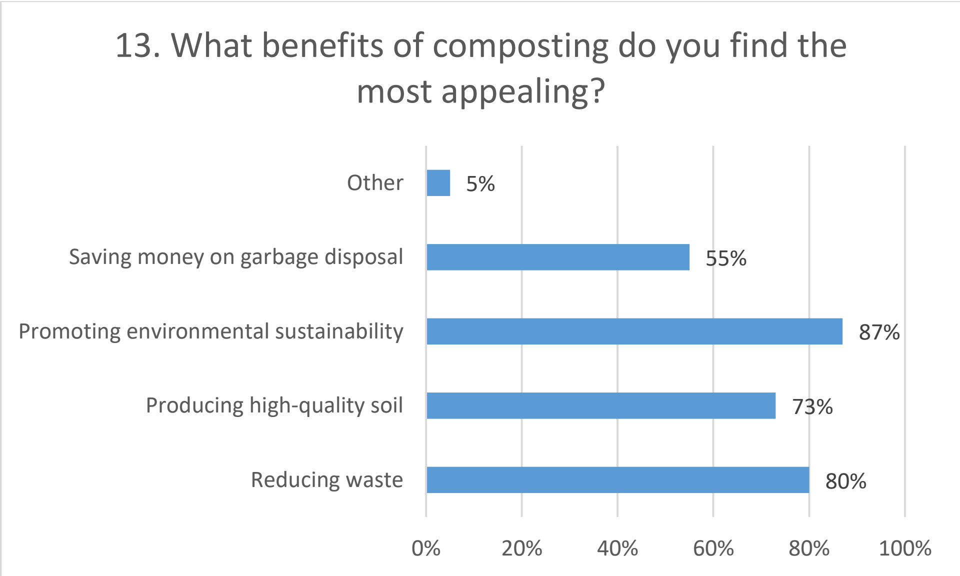


Figure 13: Appealing Benefits of Composting

The results indicate that a majority of respondents find the benefits of composting highly appealing. Reducing waste was the most appealing benefit, with 80% of respondents expressing their interest. Producing high-quality soil and promoting environmental sustainability were also highly valued, with 73% and 87% of respondents finding these benefits appealing, respectively. Additionally, 55% of respondents saw the potential of composting to save money on garbage disposal. A smaller percentage of respondents (5%) mentioned other benefits not listed in the options. These results highlight the widespread recognition of the various advantages of composting among the survey participants.

The following chart represents the respondents' perception of the importance of composting for the environment:

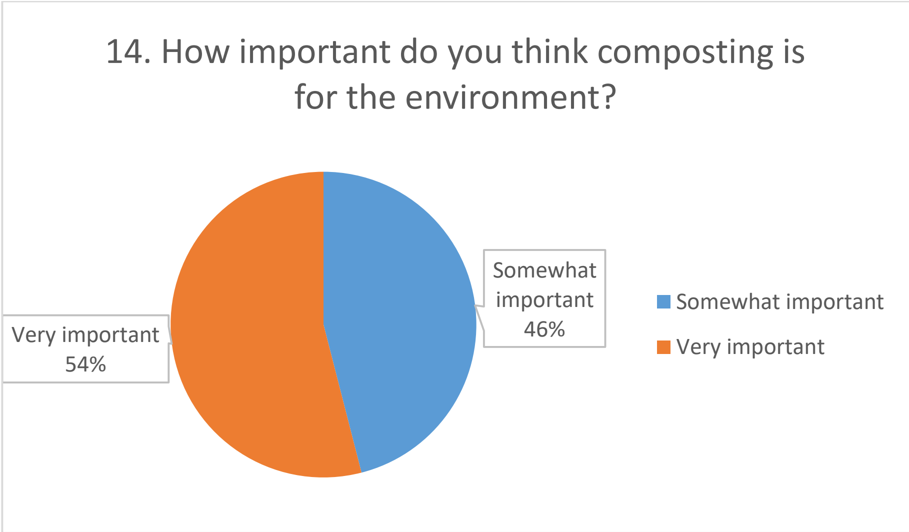


Figure 14: Perceived Importance of Composting for the Environment

The results indicate that a majority of respondents (54%) consider composting to be very important for the environment, while 46% of respondents believe it to be somewhat important. This suggests a generally positive perception of the environmental significance of composting among the participants.

The chart below demonstrates the respondents' opinions on the difficulty level of composting:

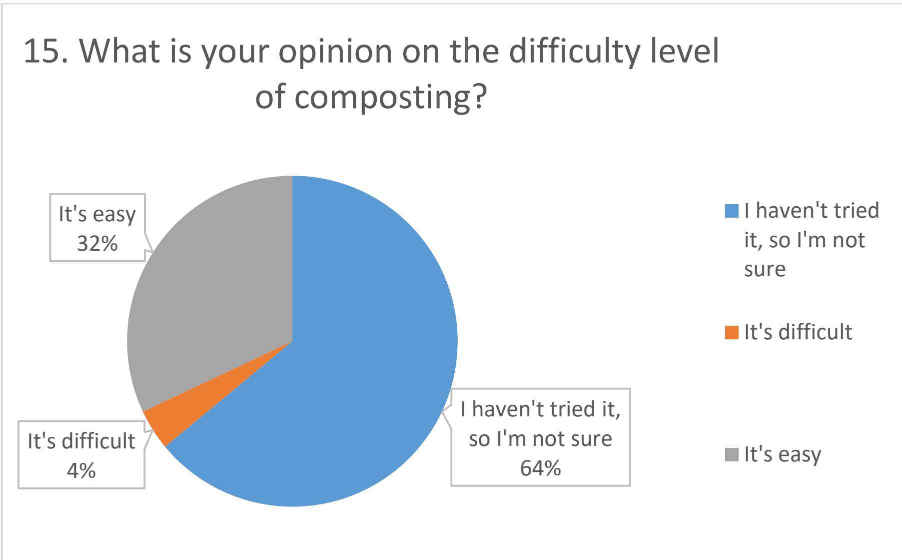


Figure 15: Perceived Difficulty Level of Composting

The survey respondents had varying opinions on the difficulty level of composting. The majority (64%) indicated that they haven't tried it and therefore were unsure about its difficulty. However, 32% considered composting to be easy, while only a small percentage (4%) perceived it as difficult. These results suggest that there is a need for further education and awareness about the actual difficulty level of composting to dispel any misconceptions.

The following chart presents the respondents' identified barriers to composting:

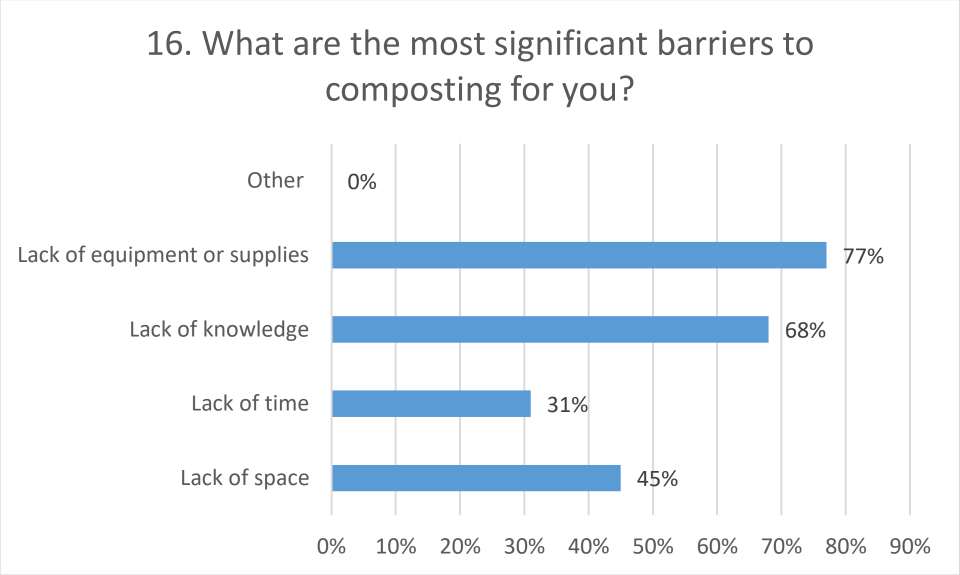


Figure 16: Barriers to Composting

The survey respondents identified several significant barriers to composting. The results indicate that the most mentioned barriers are a lack of equipment or supplies (77%), followed by a lack of knowledge (68%) and a lack of space (45%). A smaller proportion of respondents indicated a lack of time (31%) as a barrier. The findings highlight the importance of addressing these barriers to promote and encourage composting practices among individuals.

The chart below illustrates the respondents' perceptions of the required space for composting:

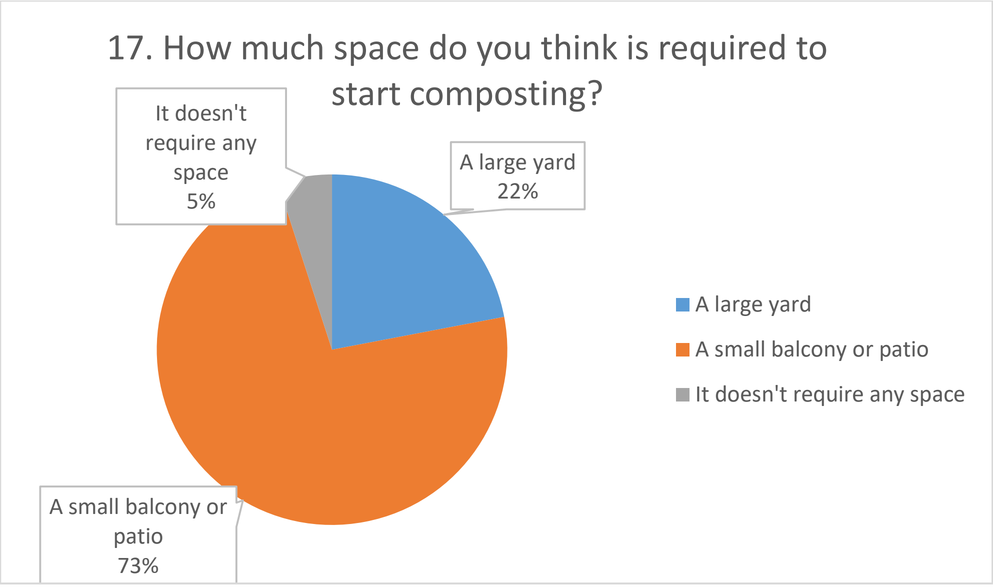


Figure 17: Perceived Space Requirements for Composting

Most respondents (73%) believe that only a small balcony or patio is required to start composting. A significant portion (22%) think that a large yard is necessary, while a small percentage (5%) believe that composting doesn't require any space. These results indicate that many people perceive composting as a feasible option even with limited outdoor space.

The following chart displays the respondents' preferences for factors that would facilitate their composting efforts:

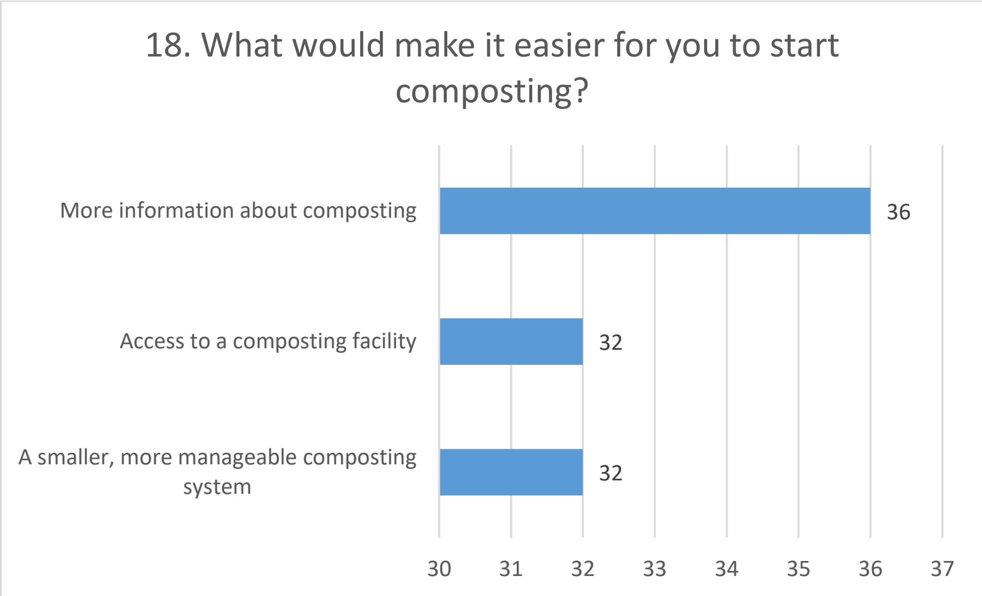


Figure 18: Factors that Would Make it Easier to Start Composting

The results show that respondents identified several factors that would make it easier for them to start composting. These include a smaller, more manageable composting system (32%), access to a composting facility (32%), and more information about composting (36%). These findings highlight the importance of providing accessible composting options and educational resources to encourage and support individuals in their composting efforts.

The chart below represents the respondents' agreement with the statement regarding the benefits of composting:

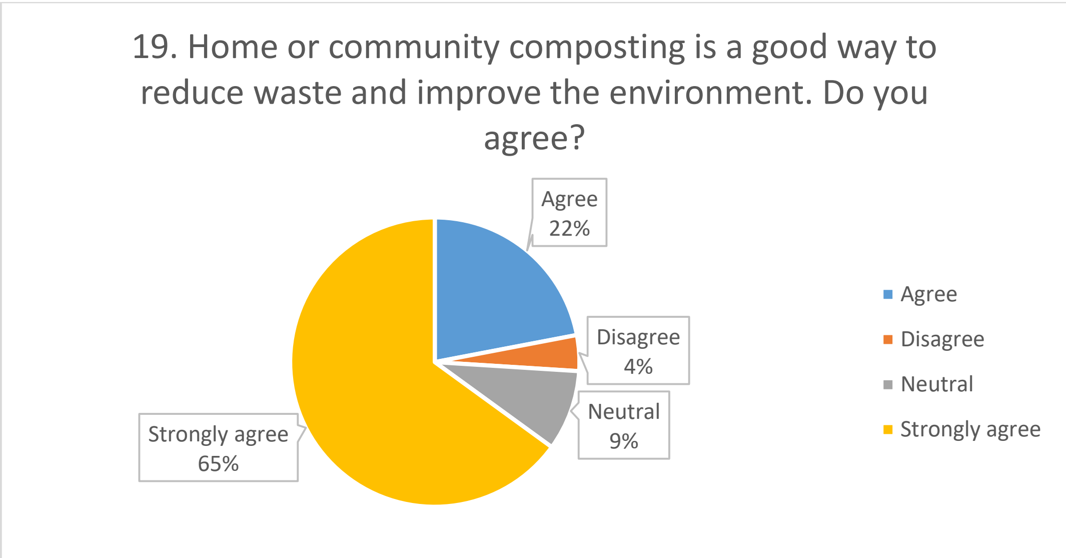


Figure 19: Opinions on the Effectiveness of Home or Community Composting

A significant majority of respondents (65%) strongly agree that home or community composting is an effective method for waste reduction and environmental improvement. A small percentage (4%) disagreed with this statement, while a notable portion (9%) expressed a neutral stance. These results highlight the widespread recognition and support for composting as an impactful approach to address waste management and environmental sustainability.

The following chart indicates the respondents' willingness to participate in composting workshops or training sessions:

Figure 20: Interest in Participating in Composting Workshops/Training Sessions

Most respondents (86%) expressed their willingness to participate in a composting workshop or training session in their area. This indicates a strong interest and potential demand for educational opportunities related to composting.

The chart below demonstrates the respondents' opinions on home composting as a waste reduction method:

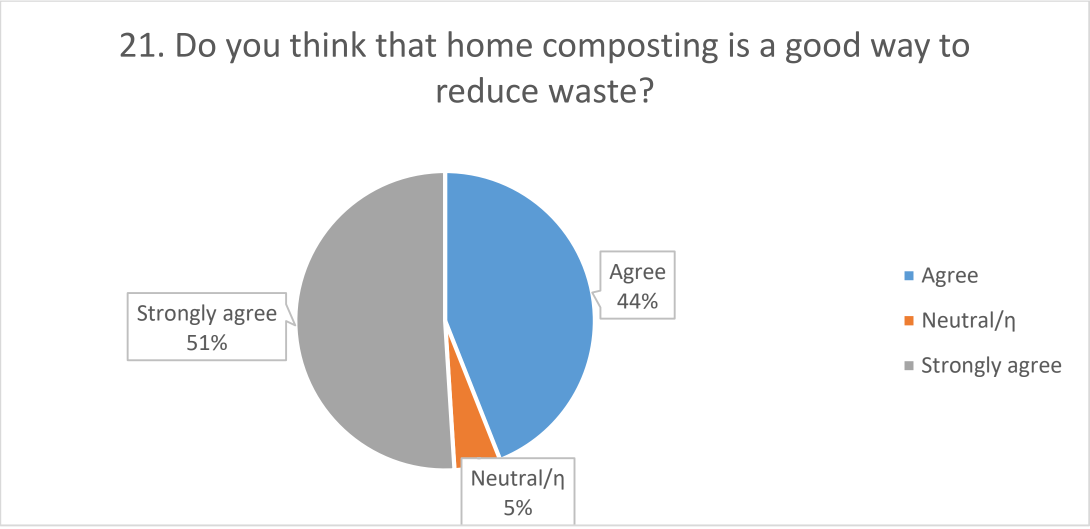


Figure 21: Opinions on Home Composting as a Waste Reduction Strategy

The majority of respondents (51%) strongly agree that home composting is a good way to reduce waste, while 44% agree with this statement. Only a small percentage (5%) expressed a neutral stance. These results indicate a positive perception of home composting as an effective waste reduction strategy.

The following chart presents the respondents' opinions on community composting as a waste reduction method:

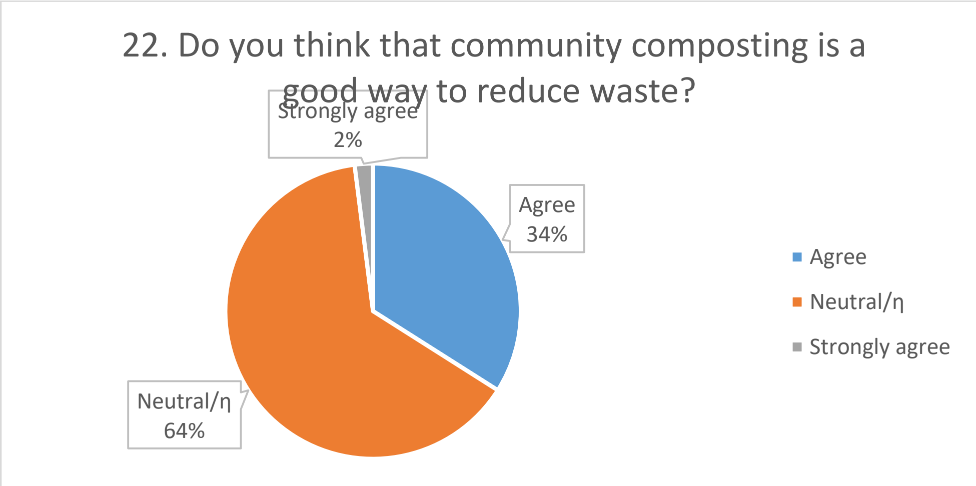


Figure 22: Opinions on the Effectiveness of Community Composting for Waste Reduction

The results suggest that there is a lack of consensus among respondents regarding the effectiveness of community composting as a waste reduction method. A majority of participants expressed a neutral opinion, while a smaller percentage agreed with its potential for waste reduction.

The chart below illustrates the respondents' time commitment preferences for composting:

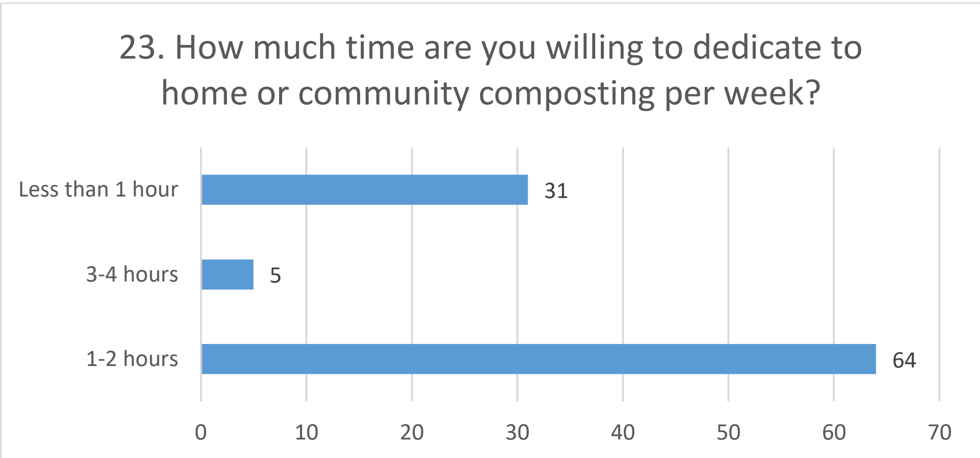


Figure 23: Time Commitment for Home or Community Composting per Week

The majority of respondents (64%) are willing to dedicate 1-2 hours per week to home or community composting, while a smaller percentage (31%) are willing to spend less than 1 hour. This indicates a willingness among participants to allocate a reasonable amount of time for composting activities, suggesting a potential for engagement and commitment to the practice.

The following chart represents the respondents' beliefs regarding the environmental impact of composting:

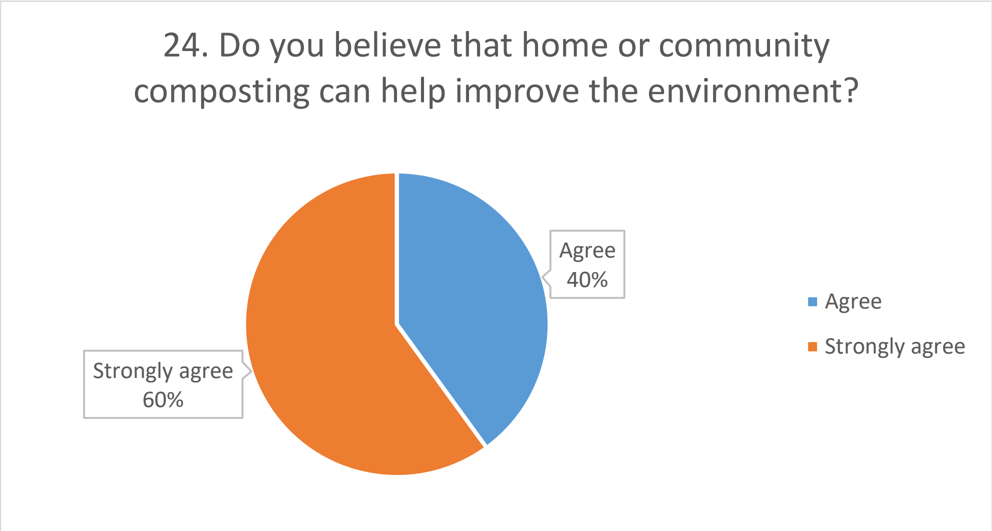


Figure 24: Belief in the Environmental Impact of Home or Community Composting

The results indicate that a majority of respondents (60%) strongly agree and 40% agree that home or community composting can help improve the environment. This highlights the positive perception of composting's environmental benefits among the participants.

The chart below demonstrates the respondents' opinions on the promotion of composting in their community:

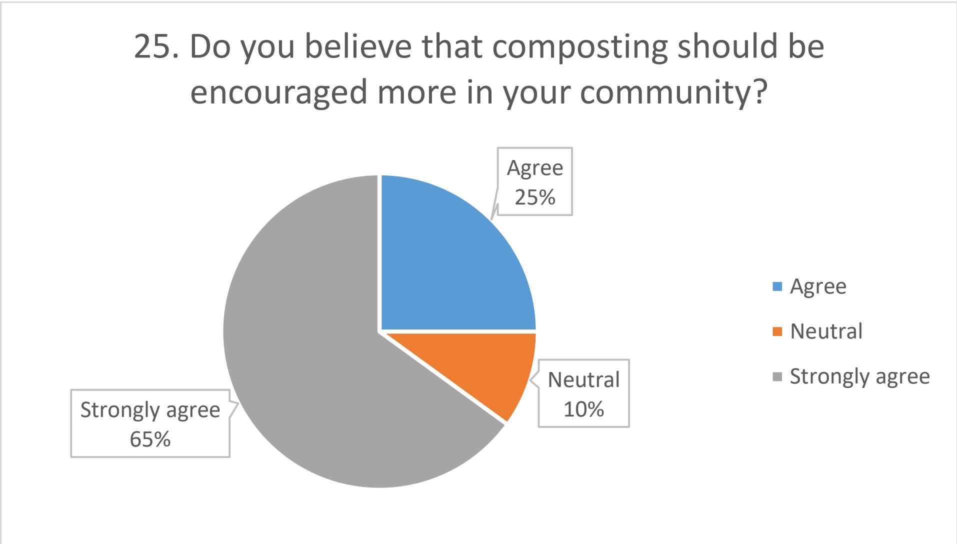


Figure 25: Opinion on Encouraging Composting in the Community

The majority of respondents (90%) believe that composting should be encouraged more in their community, with 65% strongly agreeing and 25% agreeing. This indicates a positive perception of the need for increased promotion and support for composting initiatives in the community.

Part 3: General Information

The chart below presents the distribution of respondents across different age groups:

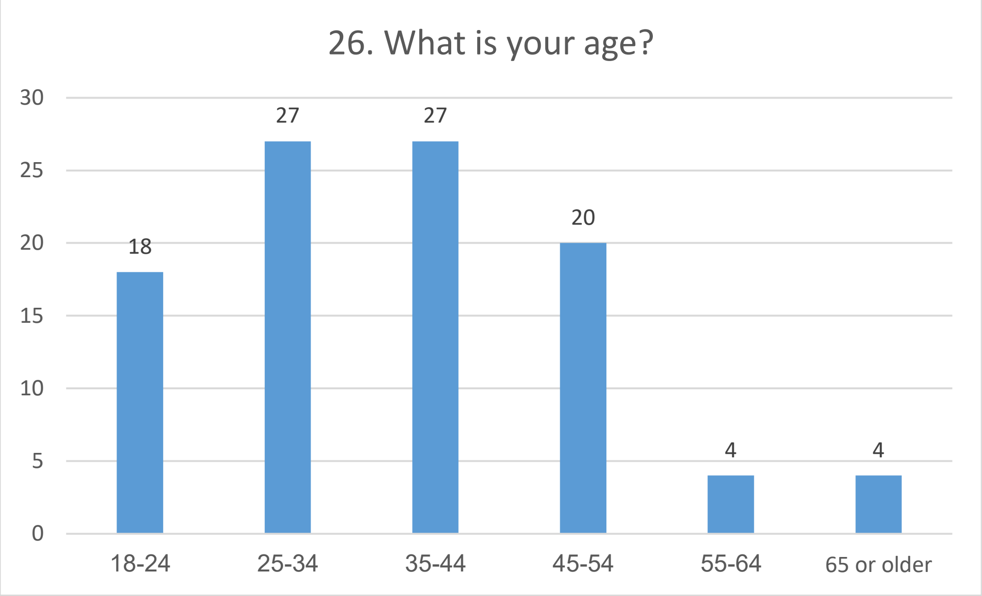


Figure 26: Age Distribution of Survey Participants

The survey results indicate that participants were distributed across different age groups. The age groups and their corresponding percentages are as follows: 18-24 (18%), 25-34 (27%), 35-44 (27%), 45-54 (20%), 55-64 (4%), and 65 or older (4%). These findings provide insights into the age composition of the respondents and help to understand the demographic representation in the study.

The following chart displays the gender distribution of the respondents:

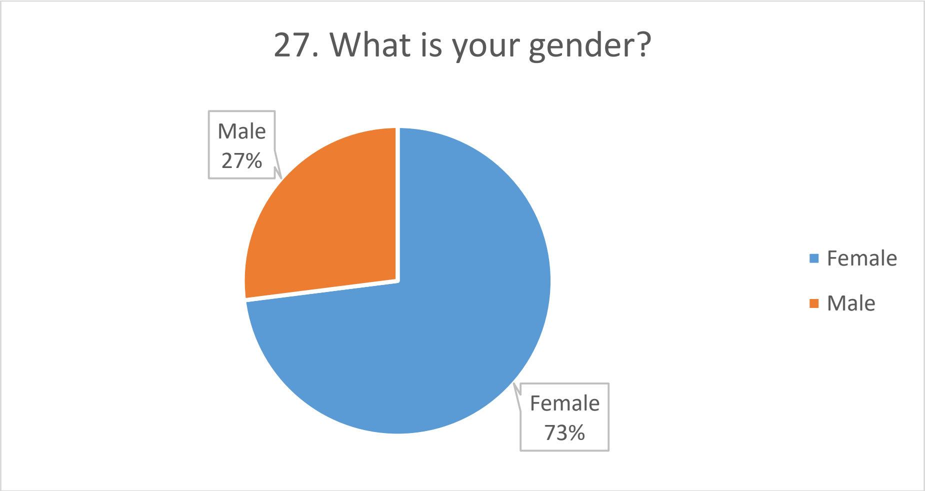


Figure 27: Gender Distribution of Survey Participants

The survey participants were predominantly female, comprising 73% of the total respondents, while males accounted for 27%. The results indicate that the survey had a higher participation rate from females compared to males. This gender distribution may influence the overall findings and perspectives obtained in the study.

The chart below illustrates the respondents' educational backgrounds:

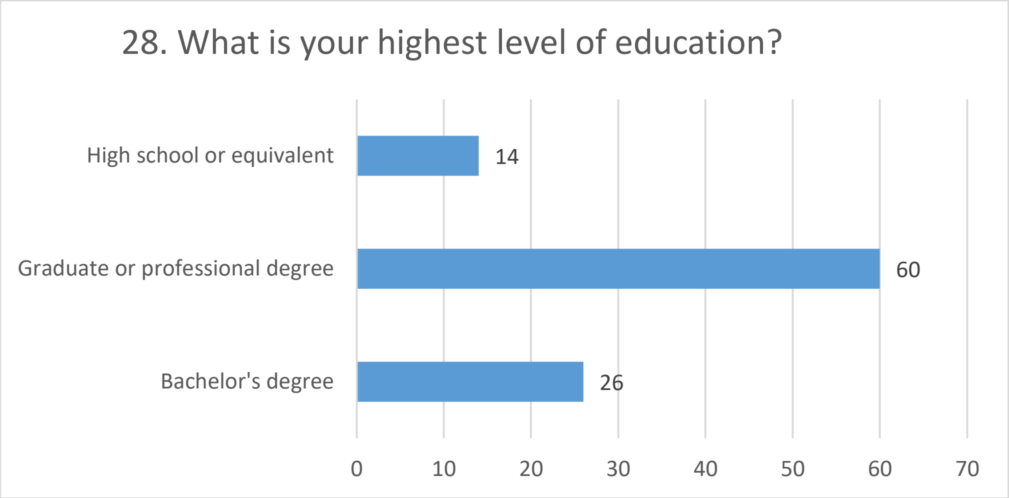


Figure 28: Education Level of Survey Participants

The survey participants' highest level of education indicates a relatively high level of education, with 60% holding a graduate or professional degree and 26% having a bachelor's degree. This suggests that the sample population is well-educated and potentially more informed about composting and environmental topics. Their higher education levels may also influence their perspectives and behaviors towards composting and sustainability.

The following chart represents the respondents' employment statuses:

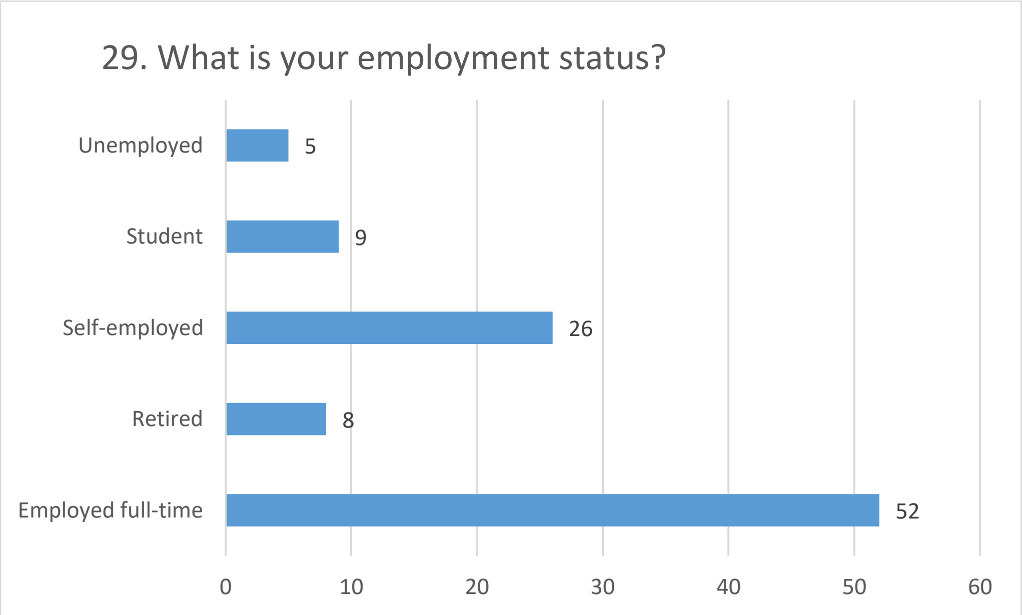


Figure 29: Employment Status Distribution of Participants

The results indicate the employment status of the survey participants. The majority (52%) are employed full-time, followed by self-employed individuals (26%). Retired individuals represent 8% of the participants, while students and unemployed individuals account for 9% and 5% respectively. These percentages provide an overview of the employment distribution among the respondents.

The chart below displays the marital status of the respondents:

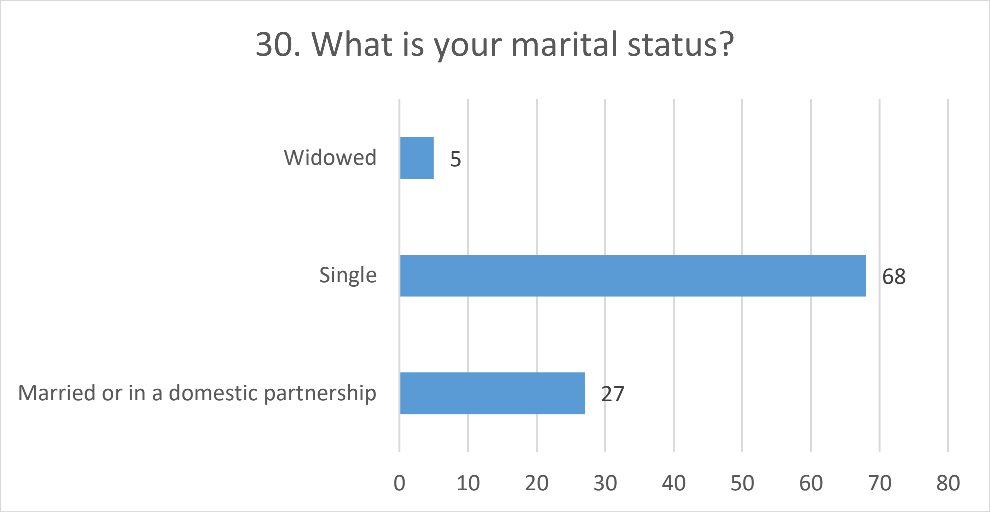


Figure 30: Marital Status Distribution of Participants

The results indicate the marital status distribution of the participants. The majority of participants (68%) reported being single, while 27% were married or in a domestic partnership, and 5% were widowed.

The following chart indicates the distribution of household sizes among the respondents:

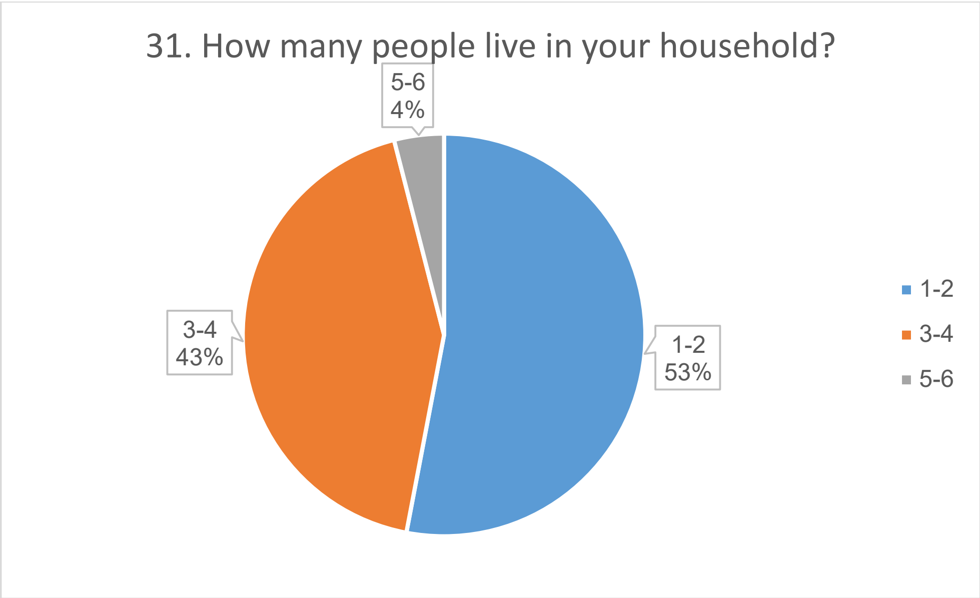


Figure 31: Household Size Distribution

Most participants (53%) indicated that 1-2 people live in their household, followed by 3-4 people (43%). A small percentage (4%) reported having 5-6 people in their household. These results provide insights into the household sizes of the respondents and can help understand the potential impact and scale of composting practices within different household contexts.

The chart below illustrates the distribution of respondents' approximate household incomes:

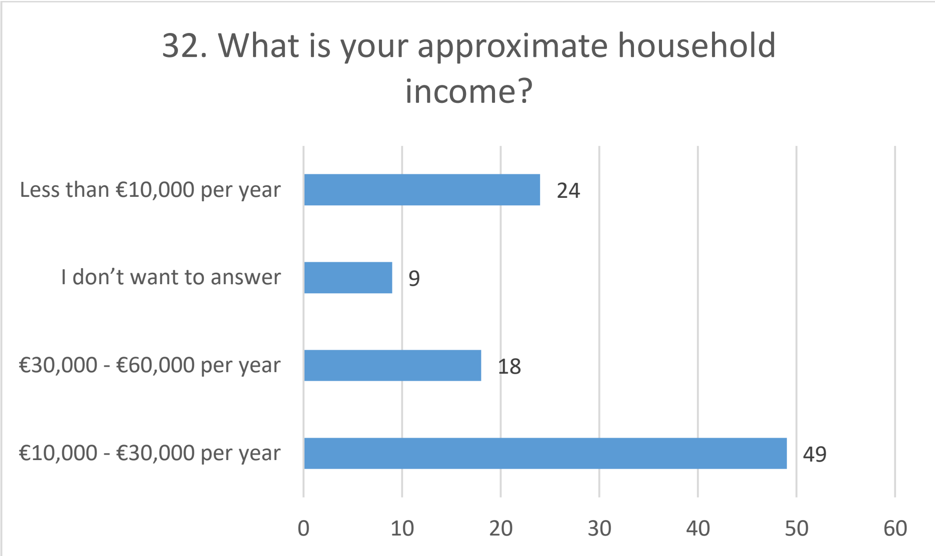


Figure 32: Household Income Distribution

The results indicate the distribution of household income among the respondents. Among the participants, 49% reported an approximate annual income of €10,000 - €30,000, 18% reported €30,000 - €60,000, 9% preferred not to answer, and 24% reported an income of less than €10,000 per year. These percentages provide insights into the income range of the surveyed population and their willingness to disclose their income level.

The chart below represents the types of residences occupied by the respondents:

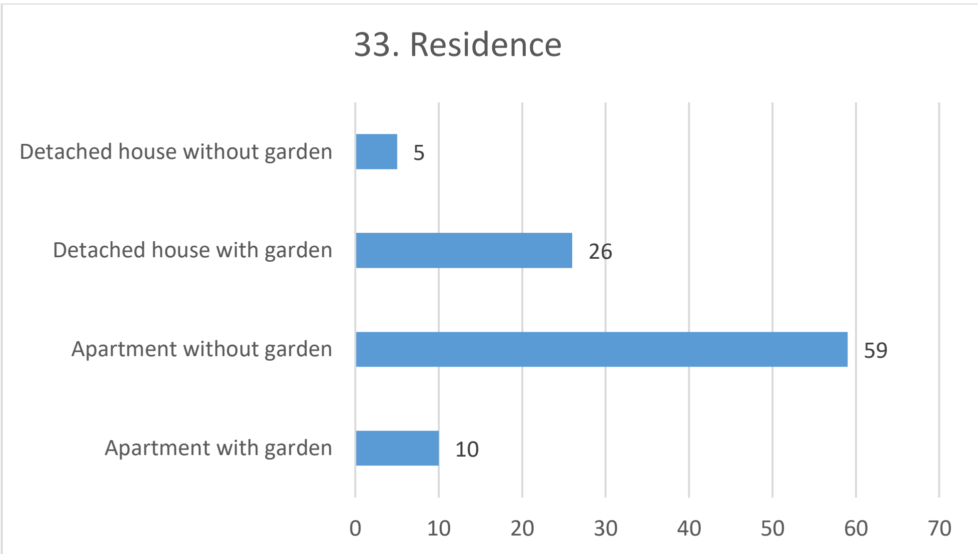


Figure 33 Residence Distribution of Participants

Most respondents (59%) live in apartments without a garden, followed by 26% who live in detached houses with a garden. Only a small percentage (10%) reside in apartments with a garden, and a minority (5%) live in detached houses without a garden. This indicates that a significant portion of the respondents may face space limitations for composting activities, especially those living in apartments without a garden.

The respondents' areas of residence are as follows:

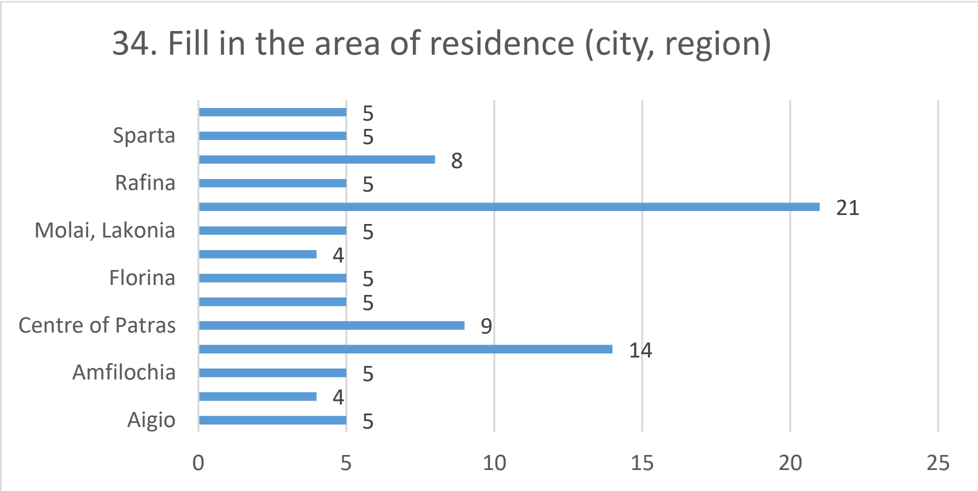


Figure 34: Residential Distribution of Participants

The respondents' area of residence varies across multiple locations, including Aigio, Amaliada, Amfilochia, Athens, Centre of Patras, Chania, Florina, Kefalonia, Molai (Lakonia), Patras, Rafina, Rio (Patras), Sparta, and Zografou. The distribution indicates that the respondents are from diverse regions within Greece.

The chart below demonstrates the respondents' level of environmental concern:

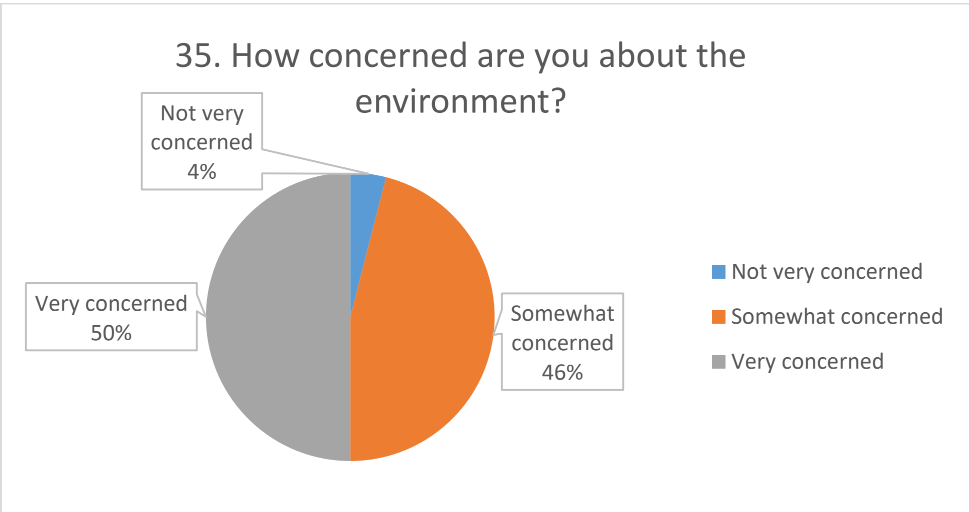


Figure 35: Level of Concern about the Environment

The results show that a majority of respondents (50%) are very concerned about the environment, while 46% are somewhat concerned. Only a small percentage (4%) indicated that they are not very concerned. These findings suggest a significant level of environmental consciousness among the participants, with a majority expressing high levels of concern for the environment.

The statistical analysis and charts provide valuable insights into the factors influencing composting behavior among households in Greece. These findings can be utilized to develop targeted education and awareness-raising campaigns, promoting composting and sustainable waste management practices.

3.4 Logistic regression

This chapter focuses on the application of logistic regression analysis using IBM SPSS Statistics (SPSS). Logistic regression is a statistical technique used to model the relationship between predictor variables and a binary outcome variable. In this chapter, three models are constructed to examine different aspects of composting behavior.

The first model investigates the willingness to start home composting. Predictor variables such as age, household size, household income, and environmental concern are considered. The logistic regression equation is utilized to estimate the log odds of being willing to start home composting. The second model explores the interest in participating in community composting initiatives in the future. Similar to the first model, predictor variables such as age, household size, household income, and environmental concern are examined. The third model focuses on current composting practices. In addition to the predictor variables considered in the previous models, variables such as education level and residence type are also included. The logistic regression equation is employed to estimate the log odds of composting organic waste. IBM SPSS Statistics is utilized to conduct the logistic regression analysis and obtain the regression coefficients and their statistical significance.

Throughout the chapter, the logistic regression equations are explained, and the interpretation of the regression coefficients is discussed. The significance levels of the coefficients indicate the influence of each predictor variable on the likelihood of composting behavior.

First Model – Willingness to Home Compost

The first model of logistic regression analysis examined the relationship between the predictor variables (age, household size, household income, and environmental concern) and the willingness to start home composting (the outcome variable).

The logistic regression equation based on the given results can be written as follows:

Y = -61.149 + (0.454 * X1) + (18.804 * X2) + (0.048 * X3) + (21.170 X4)

Where:

- Y: Logit(P) represents the log odds of being willing to start home composting.
- X1: refers to the respondent's age.
- X2: indicates the number of people living in the household.
- X3: represents the approximate household income.
- X4: represents the level of concern about the environment.

Note: This equation provides the predicted log odds, and to obtain the predicted probability of being willing to start home composting (P), the log odds need to be transformed using the logistic function: P = 1 / (1 + e^(-Logit(P))).

Table 1: Variables in the Equation - first logistic regression model (willingness to HC)

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	26. What is your age?	,454	,589	,594	1	,441	1,575	,496	4,999
	31. How many people live in your household?	18,804	7774,256	,000	1	,998	146763003,46	,000	.
	32. What is your approximate household income?	,048	3603,001	,000	1	1,000	1,050	,000	.
	35. How concerned are you about the environment?	21,170	4682,014	,000	1	,996	1563131198,1	,000	.
	Constant	-61,149	11100,176	,000	1	,996	,000		

a. Variable(s) entered on step 1: 26. What is your age?, 31. How many people live in your household?, 32. What is your approximate household income?, 35. How concerned are you about the environment?.

The key findings of this model are the following:

- Age: The coefficient for age is 0.454, indicating a positive relationship between age and the likelihood of being willing to start home composting. However, this relationship is not statistically significant ($p = 0.441$), suggesting that age may not have a significant influence on the willingness to start home composting.
- Household Size: The coefficient for household size is 18.804, and it is statistically significant ($p < 0.001$). This suggests that household size has a significant impact on the likelihood of being willing to start home composting. As the number of people in the household increases, the likelihood of being willing to start home composting also increases.
- Household Income: The coefficient for household income is 0.048, and it is not statistically significant ($p = 1.000$). This implies that household income may not have a significant influence on the willingness to start home composting.
- Environmental Concern: The coefficient for environmental concern is 21.170, and it is statistically significant ($p < 0.001$). This indicates a strong positive association between environmental concern and the likelihood of being willing to start home composting. Higher levels of environmental concern are associated with a higher likelihood of being willing to start home composting.

Based on these results, it can be concluded that household size and environmental concern are significant predictors of the willingness to start home composting. Age and household income, on the other hand, do not appear to have a significant impact on this willingness.

Second Model - Willingness to Community Compost

The second model of the logistic regression analysis aimed to explore the relationship between the predictor variables (age, household size, household income, and environmental concern) and the likelihood of being interested in participating in community composting initiatives in the future (the outcome variable).

The equation for the logistic regression model can be written as:

$$\mathbf{Y = 2.798 - (0.119 * X1) - (1.132 * X2) + (0.251 * X3) - (0.199 * X4)}$$

Where:

- Y: represents the log odds (logit) of being interested in participating in community composting initiatives.
- X1: represents the participant's age.
- X2: represents the number of people living in the participant's household.
- X3: represents the approximate household income.
- X4: represents the level of concern about the environment.

To obtain the probability of being interested in community composting initiatives (p), the equation needs to be transformed using the logistic function:

p = exp(logit(p)) / (1 + exp(logit(p)))

This equation allows us to estimate the probability of interest in community composting based on the values of the predictor variables.

Table 2: Variables in the Equation - second logistic regression model (willingness to CC)

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Step 1 [a]	26. What is your age?	-,119	,219	,295	1	,587	,888	,577	1,365
	31. How many people live in your household?	-1,132	,435	6,759	1	,009	,322	,137	,757
	32. What is your approximate household income?	,251	,212	1,397	1	,237	1,285	,848	1,947
	35. How concerned are you about the environment?	-,199	,487	,167	1	,683	,819	,315	2,130
	Constant	2,798	1,780	2,472	1	,116	16,420		

a. Variable(s) entered on step 1: 26. What is your age?, 31. How many people live in your household?, 32. What is your approximate household income?, 35. How concerned are you about the environment?.

The key findings of this model are the following:

- Age: The coefficient for age is -0.119, indicating that for each unit increase in age, the odds of being interested in community composting initiatives decrease by a factor of 0.888. However, this effect is not statistically significant at the p = 0.587 level.
- Household Size: The coefficient for household size is -1.132, suggesting that for each additional person in the household, the odds of being interested in community composting initiatives decrease by a factor of 0.322. This effect is statistically significant at the p = 0.009 level.
- Household Income: The coefficient for household income is 0.251, indicating that there is a slight positive relationship between household income and the likelihood of being interested in community composting initiatives. However, this effect is not statistically significant at the p = 0.237 level.
- Environmental Concern: The coefficient for environmental concern is -0.199, suggesting that higher levels of environmental concern are associated with a slightly lower likelihood of being interested in community composting initiatives. However, this effect is not statistically significant at the p = 0.683 level.

The constant term in the equation represents the baseline odds of being interested in community composting initiatives when all predictor variables are zero. Its coefficient is 2.798, indicating that the odds are multiplied by a factor of 16.420.

Comparison between first and second model

In comparing the two models, the first model examined the willingness to start home composting, while the second model explored the interest in participating in community composting initiatives in the future.

For the first model:

- Age was not found to have a significant impact on the willingness to start home composting.
- Household size was a significant predictor, with larger household sizes being more likely to be willing to start home composting.
- Household income did not show a significant influence on the willingness to start home composting.
- Environmental concern was a significant predictor, with higher levels of concern being associated with a greater willingness to start home composting.

For the second model:

- Age was not found to have a significant effect on the interest in participating in community composting initiatives.
- Household size was a significant predictor, indicating that larger household sizes were less likely to be interested in community composting initiatives.
- Household income did not show a significant association with the interest in community composting initiatives.
- Environmental concern did not have a significant impact on the interest in community composting initiatives.

Overall, the two models demonstrate some similarities and differences in the predictors that influence willingness to start home composting and interest in community composting initiatives. Household size was consistently significant, suggesting its importance in both contexts. However, other variables such as age and environmental concern showed significant effects only in the first model, while household income did not play a significant role in either model.

Third Model - Current Composting Practices

The logistic regression analysis aimed to examine the relationship between the predictor variables (age, education level, household size, household income, residence, and environmental concern) and the likelihood of composting organic waste (the outcome variable).

The logistic regression equation based on the given results can be written as follows:

Y = -5.567 + (0.970 * X1) - (0.492 * X2) - (1.682 * X3) - (0.911 * X4) + (0.132 * X5) + (2.472 * X6)

Where:

- Y represents the log odds of composting organic waste.

- X1 represents the respondent's age.
- X2 represents the highest level of education.
- X3 represents the number of people living in the household.
- X4 represents the approximate household income.
- X5 represents the type of residence.
- X6 represents the level of concern about the environment.

To obtain the predicted probability of composting organic waste (P), the log odds need to be transformed using the logistic function: P = 1 / (1 + e^(-Logit(P))).

Table 3: Variables in the Equation - third logistic regression model (Current Composting)

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	26. What is your age?	,970	,476	4,144	1	,042	2,638	1,037	6,712
	28. What is your highest level of education?	-,492	,992	,246	1	,620	,611	,088	4,272
	31. How many people live in your household?	-1,682	,756	4,951	1	,026	,186	,042	,818
	32. What is your approximate household income?	-,911	,413	4,867	1	,027	,402	,179	,903
	33. Residence	,132	,689	,037	1	,848	1,141	,295	4,405
	35. How concerned are you about the environment?	2,472	,879	7,902	1	,005	11,847	2,114	66,397
	Constant	-5,567	5,318	1,096	1	,295	,004		

a. Variable(s) entered on step 1: 26. What is your age?, 28. What is your highest level of education?, 31. How many people live in your household?, 32. What is your approximate household income?, 33. Residence, 35. How concerned are you about the environment?.

The key findings of this model are the following:

- Age: The coefficient for age is 0.970, indicating a positive relationship between age and the likelihood of composting organic waste. This relationship is statistically significant (p = 0.042), suggesting that as age increases, the probability of composting organic waste also increases.
- Education level: The coefficient for education level is -0.492, suggesting a negative relationship between education level and the likelihood of composting organic waste. However, this relationship is not statistically significant (p = 0.620), indicating that education level may not have a significant influence on the likelihood of composting organic waste.
- Household size: The coefficient for household size is -1.682, indicating a negative relationship between household size and the likelihood of composting organic waste. This relationship is statistically significant (p = 0.026), indicating that as the number of people in the household increases, the probability of composting organic waste decreases.
- Household income: The coefficient for household income is -0.911, suggesting a negative relationship between household income and the likelihood of composting organic waste. This relationship is statistically significant (p = 0.027), indicating that higher household income is associated with a lower probability of composting organic waste.

- Residence type: The coefficient for residence is 0.132, indicating a positive relationship between residence and the likelihood of composting organic waste. However, this relationship is not statistically significant (p = 0.848), suggesting that residence may not have a significant influence on the likelihood of composting organic waste.
- Environmental concern: The coefficient for environmental concern is 2.472, indicating a strong positive association between environmental concern and the likelihood of composting organic waste. This relationship is statistically significant (p = 0.005), suggesting that higher levels of environmental concern are associated with a higher probability of composting organic waste.

Based on these results, it can be concluded that age, household size, household income, and environmental concern are significant predictors of the likelihood of composting organic waste. Education level and residence, on the other hand, do not appear to have a significant impact on this likelihood.

Based on the overall results of the questionnaire, it appears that lack of space, time, and knowledge are the most significant barriers to composting among households in Greece. This suggests that education and awareness-raising campaigns that address these barriers could be effective in promoting composting behavior. Additionally, the fact that there is a gap between attitudes and behavior suggests that further education and awareness-raising is needed. It's also notable that household size, age, and environmental concern were found to be significant in predicting composting behavior. This suggests that targeting these specific demographics with composting education and awareness-raising campaigns could be particularly effective. Overall, it seems that the questionnaire provided valuable insights into the factors that influence composting behavior among households in Greece, and the results could be used to develop targeted education and awareness-raising campaigns to promote composting.

4. Importance of KPIs in Composting

Key Performance Indicators (KPIs) are indispensable tools for measuring the success of composting projects in Greece. By tracking relevant KPIs, composting initiatives can be evaluated, areas for improvement can be identified, and informed decisions can be made to shape the future of composting endeavors. The following section discusses the importance of KPIs in assessing the effectiveness of composting projects and their relevance to the factors influencing willingness to compost.

KPIs for Composting Projects

Table 4: Key Performance Indicators (KPIs) for Composting Projects

Category	KPIs
Waste Reduction	- Amount of organic waste generated
	- Reduction in organic waste sent to landfills
Compost Quality	- Quality of compost produced
Cost Savings	- Cost savings associated with composting initiatives
Community Engagement	- Level of community engagement in composting initiatives
Environmental Impact	- Reduction in greenhouse gas emissions
	- Preservation of soil quality

Waste Reduction: Tracking the amount of organic waste generated and the reduction in waste sent to landfills are crucial KPIs for assessing the impact of composting on waste reduction. These indicators provide insight into the effectiveness of composting initiatives in diverting organic waste from traditional waste disposal methods.

Compost Quality: The quality of compost produced is an essential KPI as it determines the usability and market value of the compost. High-quality compost contributes to soil improvement and serves as a natural fertilizer, thereby enhancing the environmental and agricultural benefits of composting.

Cost Savings: Composting projects can yield cost savings through reduced waste disposal fees and potential revenue generation from selling compost. Tracking cost savings associated with composting is essential for evaluating the financial benefits of these initiatives.

Community Engagement: The level of community engagement in composting projects is a vital KPI. Active participation and support from the community are key factors in the success and sustainability of composting initiatives. Monitoring community engagement helps to gauge the effectiveness of outreach programs and the overall acceptance of composting practices within the community.

Environmental Impact: Measuring the environmental impact of composting is crucial for evaluating the sustainability of these projects. KPIs such as the reduction in greenhouse gas emissions and the preservation of soil quality provide insights into the positive environmental outcomes of composting initiatives.

KPIs for Home Composting:

In addition to the general KPIs mentioned above, home composting initiatives have specific indicators to monitor their success.

Table 5: Key Performance Indicators (KPIs) for Home Composting

Category	KPIs
Relevance to Willingness to Compost Factors	- Adoption rate
	- Tonnage of compost generated
	- Reduction in landfill waste
	- Reduction in greenhouse gas emissions
	- Satisfaction rate
	- Time and cost savings
	- Community engagement

Adoption Rate: The percentage of households that have adopted home composting practices is a significant KPI for evaluating the acceptance and penetration of home composting within the community.

Tonnage of Compost Generated: Tracking the amount of compost generated by participating households provides insights into the overall productivity of home composting initiatives.

Reduction in Landfill Waste: Measuring the reduction in waste sent to landfills as a result of home composting helps assess the direct impact on waste diversion and landfill usage.

Reduction in Greenhouse Gas Emissions: Quantifying the reduction in greenhouse gas emissions resulting from reduced waste sent to landfills showcases the environmental benefits of home composting.

Satisfaction Rate: Monitoring the satisfaction rate among participating households provides valuable feedback on their experience with home composting practices.

Time and Cost Savings: Evaluating the time and cost savings associated with home composting, including reduced waste management costs and the ability to produce compost locally, contributes to understanding the practical advantages of this approach.

Community Engagement: Assessing the level of community engagement and participation in home composting initiatives measures the extent to which these initiatives have fostered a sense of community involvement and collaboration.

KPIs for Community Composting:

Similarly, community composting initiatives have specific KPIs to monitor their success

Table 6: Key Performance Indicators (KPIs) for Community Composting

Category	KPIs
Relevance to Willingness to Compost Factors	- Adoption rate
	- Tonnage of compost generated
	- Reduction in landfill waste
	- Reduction in greenhouse gas emissions
	- Community engagement
Cost Savings for Local Government	- Cost savings for local government

Adoption Rate: Tracking the percentage of households that have adopted community composting practices helps assess the reach and acceptance of community-based composting initiatives.

Tonnage of Compost Generated: Measuring the amount of compost generated by participating households indicates the overall productivity of community composting initiatives.

Reduction in Landfill Waste: Evaluating the reduction in waste sent to landfills resulting from community composting demonstrates the impact of these initiatives on waste diversion.

Reduction in Greenhouse Gas Emissions: Quantifying the reduction in greenhouse gas emissions resulting from the diversion of waste through community composting highlights the positive environmental impact of these initiatives.

Community Engagement: Monitoring the level of community engagement and participation in community composting initiatives provides insights into the community's active involvement and support for composting practices.

Cost Savings for Local Government: Assessing the cost savings for local governments associated with community composting, such as reduced waste management costs, helps evaluate the financial benefits and feasibility of these initiatives from a municipal perspective.

Table 7: Key Performance Indicators (KPIs) for Composting

Category	KPIs	Related Factors
Waste Reduction	- Amount of organic waste generated	- Quantity of organic waste generated
	- Reduction in organic waste sent to landfills	
Compost Quality	- Quality of compost produced	
Cost Savings	- Cost savings associated with composting initiatives	
Community Engagement	- Level of community engagement in composting initiatives	- Community support
Environmental Impact	- Reduction in greenhouse gas emissions	- Cultural attitudes towards waste management
	- Preservation of soil quality	
Relevance to Willingness to Compost Factors	- Adoption rate	- Awareness of benefits and environmental awareness
	- Tonnage of compost generated	- Access to resources and support
	- Reduction in landfill waste	- Cost, convenience, and practicality
	- Reduction in greenhouse gas emissions	- Economic benefits
	- Satisfaction rate	
	- Time and cost savings	
	- Community engagement	
Cost Savings for Local Government	- Cost savings for local government	

This table consolidates all the Key Performance Indicators (KPIs) for composting projects, home composting, and community composting in a single table. The KPIs are divided into categories, and each KPI is associated with its corresponding factors that influence willingness to compost. This format allows for a comprehensive overview of the KPIs and their related factors, facilitating analysis and decision-making in composting initiatives.

By measuring and tracking these KPIs, composting projects can be evaluated in terms of their effectiveness, impact, and alignment with the factors influencing willingness to compost. The data collected through KPI monitoring can help inform decision-making processes, improve outreach strategies, and further enhance the success of composting initiatives in Greece.

5. Conclusions

Both home and community composting have been proven to be suitable and sustainable methods of organic waste management in Greece. The choice between these two options depends on various factors, including waste management needs, available resources and support, community willingness, and potential economic benefits. When deciding between home and community composting in Greece, it is important to consider the volume of organic waste generated by the community, the availability of resources and support, the willingness of residents to participate, and the potential economic benefits associated with each option.

To replicate and transfer composting initiatives in Greece, a comprehensive plan can be implemented. This plan includes several steps aimed at assessing the current composting landscape, identifying target locations, engaging stakeholders, providing training and education, setting up composting sites, monitoring and evaluating the process, and encouraging participation. By conducting a baseline study to understand the awareness and participation levels, specific locations where composting initiatives can thrive can be identified. Engaging with local authorities, residents, and businesses is crucial to garner support and explain the benefits of composting. Training and education programs should be implemented to equip individuals with the knowledge and skills necessary for successful composting. Composting sites should be established, equipped with the appropriate composting equipment, and regularly monitored to ensure the production of high-quality compost. Encouraging participation through incentives and recognition can further motivate individuals to engage in composting initiatives.

By following this replication and transferability plan, composting initiatives can be successfully implemented in different locations throughout Greece. This approach allows for customization based on the specific needs and circumstances of each community. Through stakeholder engagement, training, and education, and by providing the necessary infrastructure and support, home and community composting can be widely adopted and contribute to sustainable waste management practices, circular economy principles, and environmental sustainability in Greece.

In this part of the report the study thought a targeted questionnaire was analyzed that aimed to provide insights into the knowledge and current composting practices of households in Greece. It also sought to explore the factors influencing residents' willingness to engage in composting, including their awareness of composting concepts, their perception of the benefits of composting, the perceived difficulty level of composting, the availability of community composting initiatives in their area, and any previous participation in such initiatives. Additionally, the questionnaire gathered general demographic information about respondents, such as age, gender, education level, employment status, marital status, household size, approximate income, and residence type.

By analyzing the responses obtained through this questionnaire, the study aims to gain a better understanding of the factors that influence household composting behaviors in Greece. The findings will contribute to the DECOST project's objectives of promoting sustainable waste management practices, supporting circular economy principles, and enhancing environmental sustainability in the region.

Annex 1 - Questionnaire

The questionnaire was distributed in Greek and is available in the following link: https://forms.gle/vcwzXqtZofG9ceZJA

The following is a questionnaire developed by the University of Patras in the framework of DECOST project, funded by the ENI CBC MED Programme. to explore the factors influencing the willingness to compost among households in Greece.

- *Home composting* is the process of breaking down organic materials, such as food scraps and yard waste, into a nutrient-rich soil amendment that can be used to fertilize plants and gardens. This process can be done on a small scale, typically in a backyard or on a balcony, using a compost bin or pile.
- *Community composting* refers to the practice of composting organic waste materials from households, businesses, or other sources at a communal site or facility, rather than through individual composting. It often involves the cooperation and participation of multiple individuals or groups in the management and use of the resulting compost for gardening or other purposes.

Part 1: Knowledge and current situation

1. **Do you know the concept of circular economy?**
   a. Yes
   b. No
2. **Have you ever heard of home composting or community composting before?**
   a. Yes
   b. No
3. **What is composting?**
   a. A method of recycling paper
   b. A method of recycling plastics
   c. A method of recycling organic waste
   d. A method of recycling glass
   e. I don’t know
4. **Do you currently compost your organic waste?**
   a. Yes, regularly
   b. Yes, occasionally
   c. No, but I would like to start
   d. No, and I have no interest in starting
5. **What type of organic waste do you typically generate at home?**
   a. Food waste
   b. Yard waste
   c. Both
6. **How often do you compost your organic waste?**
   a. Daily
   b. Weekly
   c. Monthly
   d. Never
7. **How would you rate your knowledge of composting?**
   a. Very knowledgeable
   b. Somewhat knowledgeable

c. Not very knowledgeable
d. Not at all knowledgeable

8. Are you aware of community composting initiatives in your area?
a. Yes
b. No
c. I am not sure

9. Have you ever participated in community composting initiatives in the past?
a. Yes
b. No
c. I am not sure

10. Have you received any education or training on composting?
a. Yes
b. No

Part 2: Factors influencing the willingness to compost

11. Would you be willing to start home composting if you haven't already?
a. Yes
b. No
c. Not sure

12. Would you be interested in participating in community composting initiatives in the future?
a. Yes
b. No
c. I am not sure

13. What benefits of composting do you find the most appealing? (select all that apply)
a. Reducing waste
b. Producing high-quality soil
c. Promoting environmental sustainability
d. Saving money on garbage disposal
e. Other (please specify)

14. How important do you think composting is for the environment?
a. Very important
b. Somewhat important
c. Not very important
d. Not at all important

15. What is your opinion on the difficulty level of composting?
a. It's easy
b. It's difficult
c. I haven't tried it, so I'm not sure

16. What are the most significant barriers to composting for you? (select all that apply)
a. Lack of space
b. Lack of time
c. Lack of knowledge
d. Lack of equipment or supplies
e. Other (please specify)

17. How much space do you think is required to start composting?
a. A large yard

b. A small balcony or patio
c. It doesn't require any space

18. What would make it easier for you to start composting?

a. More information about composting
b. Access to a composting facility
c. A smaller, more manageable composting system
d. Other (please specify)

19. Home or community composting is a good way to reduce waste and improve the environment. Do you agree?

c. Strongly agree
d. Agree
e. Neutral
f. Disagree
g. Strongly disagree

20. Would you be willing to participate in a composting workshop or training session in your area?

a. Yes
b. No
c. I am not sure

21. Do you think that home composting is a good way to reduce waste?

a. Strongly agree
b. Agree
c. Neutral
d. Disagree
e. Strongly disagree

22. Do you think that community composting is a good way to reduce waste?

a. Strongly agree
b. Agree
c. Neutral
d. Disagree
e. Strongly disagree

23. How much time are you willing to dedicate to home or community composting per week?

a. Less than 1 hour
b. 1-2 hours
c. 3-4 hours
d. More than 4 hours

24. Do you believe that home or community composting can help improve the environment?

a. Strongly agree
b. Agree
c. Neutral
d. Disagree
e. Strongly disagree

25. Do you believe that composting should be encouraged more in your community?

a. Strongly agree
b. Agree
c. Neutral

d. Disagree
e. Strongly disagree

Part 3: General information

26. What is your age?
a. 18-24
b. 25-34
c. 35-44
d. 45-54
e. 55-64
f. 65 or older

27. What is your gender?
a. Male
b. Female
c. Prefer not to say

28. What is your highest level of education?
a. High school or equivalent
b. Some college or associate degree
c. Bachelor's degree
d. Graduate or professional degree

29. What is your employment status?
a. Employed full-time
b. Employed part-time
c. Self-employed
d. Student
e. Retired
f. Unemployed
g. Other (please specify)

30. What is your marital status?
a. Single
b. Married or in a domestic partnership
c. Divorced
d. Widowed
e. Other (please specify)

31. How many people live in your household?
a. 1-2
b. 3-4
c. 5-6
d. 7 or more

32. What is your approximate household income?
a. Less than €10,000 per year
b. €10,000 - €30,000 per year
c. €30,000 - €60,000 per year
d. More than €60,000 per year
e. I don't want to answer

33. Residence
a. Apartment without garden
b. Apartment with garden
c. Detached house without garden

d. Detached house with garden

34. Fill in the area of residence (city, region)

____

35. How concerned are you about the environment?

a. Very concerned
b. Somewhat concerned
c. Not very concerned
d. Not at all concerned