Kafsimo: recycling coffee waste into bioenergy

Implementing a circular waste management system: a case study of SCG

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Abstract

Initiated in 2019, kafsimo is a circular economy, community-based project carried out by 'InCommOn', a Greek non-profit organisation that promotes sustainable and participatory urban development. Kafsimo is a pilot project, its aim is to model a scalable, low-emissions logistics system for organic waste management, using spent coffee grounds as its case study, and to facilitate the transition to a circular economy through shifting public perception on waste. The purpose is to standardise this recycling model in order for it to be replicable in other geographical areas and adaptable to other organic waste streams. It is carried out in three phases; an experimentation phase; a scaled collection, transportation and storage phase, and; the examination of three alternatives for conversion into bioenergy. As part of the methodology, qualitative and quantitative data is collected during all stages which inform next steps and any necessary improvements to the model. Our findings indicate that treating spent coffee grounds through the kafsimo system results in local environmental, social and financial benefits, by reducing direct and indirect greenhouse gas emissions, creating awareness and acceptance of innovative strategies for dealing with waste and by creating local jobs. These results provide a strong case for scaling kafsimo nationally. In addition, the monitored environmental, social and financial impact demonstrates how kafsimo balances the socio-economic concerns and the utilization of valuable materials -former waste- while promoting the notion that environmental, economic and social issues are interrelated and require a common, holistic solution.

Keywords: spent coffee grounds, circular waste management, participatory, low-emissions logistics, bioenergy

Introduction

According to EUROSTAT (2020), Greece produces 524kg of urban solid waste per person per year, 407kg (78%) of which ends up in landfills while more than 40% of this waste is organic [1]. These high rates of landfilling are among the highest in the EU and fall far below EU targets. Simultaneously, the necessary precautionary measures for waste management instigated by the Greek state, such as effective separation at source and separate collection for re-use, are not in place yet despite the fact that EU policy already requires its Member States to significantly reduce their waste and achieve relatively high recycling rates. At the same time, Greece performs extremely poorly in terms of eco-innovation and urban waste recycling [2], which are prerequisites for the transition to a circular economy. In particular, Greece has the fourth worst recycling performance in Europe. Consequently, Greek urban centres face an acute problem not only of environmental degradation, but also of overall unsustainability - environmental, social and financial. Furthermore, in recent years, only 8.4% of Greeks over the age of 16 are considered active citizens. The corresponding EU average is 11.9%, an already extremely low rate [3].

In this context it is important to test alternative methods of collecting and processing waste streams in order to identify best practices for Greece that are scalable and can considerably improve the social and environmental impact of waste management in Greece. The project kafsimo (Greek: κάΦσιμο[1]) is a circular economy, community-based project which collects spent coffee grounds (SCG) from cafes in two cities of Northern Greece - Thessaloniki and Kilkis - and converts them into bioenergy. The added value of kafsimo is that all its processes are designed in such a way so as to have the least possible environmental footprint, and includes the design and implementation of an innovative low-emissions logistics system. Kafsimo's immediate aim is to reduce the amount of waste that ends up in the landfill by collecting and transforming an 'output' - SCG - that would otherwise be landfilled, into an 'input' - bioenergy -, closing the cycle of coffee. The long-term goal of kafsimo is to standardise this recycling model and make it scalable to other geographical areas and adaptable to other organic waste streams; to revolutionise the way in which waste is produced and discarded by working with coffee-shop owners, industries and at a policy level to move towards a circular model of reusing "waste" as an economic input rather than an end product to be discarded.

Equally importantly, the participatory aspect of kafsimo facilitates the mobilisation of citizens and communities, further promoting social circularity, while the project maintains a social dimension. Kafsimo is aligned with the principles of a fair and equitable economy and addresses issues such as social inclusion, high unemployment rates and environmentally-unfriendly consumption behaviours. An underlying aim of kafsimo is to raise awareness by promoting a sustainable practice of managing organic waste, and to facilitate a transition in the public perception that exists around waste by mainstreaming an alternative one whereby waste is seen as a valuable resource.

The project's multidimensional character - addressing simultaneously the environmental, social and financial aspects of waste management - is reflected in its '*3 +1 pillars*' foundation:

1. Community involvement and Training *[Society]*
2. Low-emissions logistics *[Environment]*
3. Product Utilization *[Economy]*

+1 Data Collection and Analysis

This paper presents an overview of the innovations associated with the 'kafsimo' model, its separate parts (low-emissions logistics, sustainable drying/processing and bioenergy production) and provides indicators for its social, environmental and financial impact.

[1] The name is a wordplay in Greek combining the words 'coffee' (καφές) and 'fuel' (καύσιμο) to make 'κάΦσιμο'.

Literature Review

In recent years, various initiatives have launched in various countries that aim to commercially 'recycle' SCG, such as Bio-bean in the UK[2], Ecobean in Poland[3] and Coffeebin in Greece[4]. Nevertheless, it remains unclear what the economic, environmental and social feasibility of coffee recycling projects are, to our knowledge there are no published studies that document this. The relevant literature generally indicates that there are a range of effective uses for SCG but that the challenge lies in developing applicable, efficient and sustainable collection and transportation systems to support the processes involved in recycling [4, 5].

Existing studies document multiple ways of treating and disposing of SCG, including landfilling, composting, bioenergy/biofuels and as absorbents and nutrients [6, 7]. From an environmental perspective, landfilling organic matter is the least desirable disposal method as it releases significant amounts of pollutants into the environment and greenhouse gases (GHG) directly into the atmosphere, especially methane, and is not a productive input into another process [8]. By contrast, composting is theoretically preferred as it is higher up on the waste hierarchy. Multiple studies, however, illustrate that in order to produce quality compost coffee waste needs to be mixed with other waste streams [9] and as such is not a desirable feedstock for composting in itself. In this context, there has been increasing interest in using SCG for bioenergy production.

In many ways, SCG is an ideal waste stream for energy production as it is a 'clean' waste product that needs no or minimal separation from other waste sources, and is therefore relatively easy to use for waste-to-energy systems. Kamil et al., (2019), Caetano et al. (2014) and Kwon et al. (2013) investigate and show that there are options for creating biodiesel and bioethanol from SCG [10–12]. Vitez et al. (2016) have looked at the potential of SCG for biogas production [4]. Various studies, including Nosek et al. (2020), Lisowski et al. (2019), and Kristanto & Wijaya (2018), have looked at the potential of turning SCG into pellets, all of which highlight that the SCG need to be mixed with other organic sources to produce high quality pellets [7, 13, 14]. Indeed, a study conducted by CERTH and Wroclaw University in 2017 showed that SCG are better suited as an additive to making pellets [15]. Matrapazi & Zabaniotou (2020) conduct an economic analysis of the potential of SCG pyrolysis in central Greece [16]. Rivera et al., (2020) conduct an environmental comparison of multiple ways of treating SCG [17]. These studies explore the advantages and disadvantages of the different end products but do not focus on the methods for implementing a full value chain of spent coffee grounds.

In this context, this study fills this gap by providing an overview of a transition from a linear waste management system to a circular, community-based project in a Mediterranean setting. Findings from this experience will allow us to assess the environmental, social and economic feasibility and potential of such an initiative as well as its capacity for scaling and replication. As the literature indicates that there is already wide research on turning coffee waste into bioenergy, kafsimo focuses less on the aspect of utilization but rather on the management of this product as a whole, from the moment it is discarded as 'waste' until it reaches the stage of processing prior to conversion into bioenergy. As such, this study gives emphasis on the logistics, including separation, collection, transportation and storage. Coffee waste is used as it is a 'clean' waste product (i.e. separated at source by default) by businesses and, until there is a comprehensive system of organic waste management in place, SCG provides an easy-to-handle waste to experiment with alternative ways of handling and managing waste as well as to prepare the community, including both businesses and consumers, for the transition to sustainable waste management practices within the emerging circular economy.

[2] Bio-bean Limited <https://www.bio-bean.com/>
[3] EcoBean <http://ecobean.pl/>
[4] CofeeBin <https://coffeebin.gr/>

Materials and methods

The project comprises of three phases, each of them building on the findings of the previous one; Phase 1 was an experimentation phase that consisted of a small scale collection of spent coffee grounds from cafes in Kilkis and several chemical analyses of the bio-product in collaboration with CERTH[5]; Phase 2 includes a full scale collection in Kilkis - a small town - and a pilot collection from several cafes in Thessaloniki - an urban centre -, and the transportation, storage and drying of the product, and; Phase 3 will result in identifying the best method of using the biomass for producing bioenergy, experimenting with several conversion methods and uses in order to define the optimal one, taking into account the feasibility of each for the Greek context. During all phases and stages of the project, both qualitative and quantitative data is collected, which allows us to monitor, evaluate and improve our processes and methods.

Phase 1

Phase 1 of kafsimo took place from May 2019 to May 2020 and included the following actions: networking with several local cafes in Kilkis to inform stakeholders about the project as well as to introduce them to the issue of the overproduction of organic waste and the importance of its appropriate management; a pilot collection in Kilkis with the participation of 39 coffee shops, during a weekday and a weekend day, in order to establish whether the quantity of the coffee waste produced differs between weekdays and weekends, and; a chemical analysis of samples from the collected SCG by CERTH to determine the calorific value, humidity content, amount of sulfur and ash, elemental, trace elements, and oil content analysis, and the particles size produced in the subsequent process.

Among the findings of Phase 1, upon which the next Phase was built, was that the majority of coffee shops were eager to participate, however a small percentage of cafes did not complete the in-store collection for several reasons, including the burden of separating SCG from other wastes, broken links in the communication between owners and employees and non-compliance with the waste separation by one or more members of staff. The pilot days of collection showed that the quantities of coffee waste are similar during weekdays and weekends. Finally, the main findings of the analyses carried out by CERTH were that: (a) SCG consist of 62.5% water, (b) when burned dry, the remaining ash was at 1.6%, and (c) dry volatile matter is 81.5%. These characteristics render the pelletisation of pure coffee waste equivalent to Class B pellets. As such, they are not desirable for use as the sole feedstock for pellets but are likely to be of higher quality when mixed with other organic additives. However, the analysis showed that SCG as biomass has the potential to become a high-energy, sustainable feedstock.

Phase 2

Following the experimentation phase, a small network of cafes was initially created, several pilot collection systems were tested and a few months of regular collection carried out. In the Spring of 2020, and with the support of the Green Fund, kafsimo entered its second phase, collecting from 70 coffee shops in both Thessaloniki and Kilkis. The second phase, which will run until October 2021, consists of the collection and transportation of the coffee waste to a specially designed greenhouse for storage and drying. There, the dried biomass undergoes several experiments regarding its conversion into bioenergy, which is part of Phase 3.

[5] CERTH - Center for Research and Technology (ΕΚΕΤΑ - Εθνικό Κέντρο Έρευνας & Τεχνολογικής Ανάπτυξης)

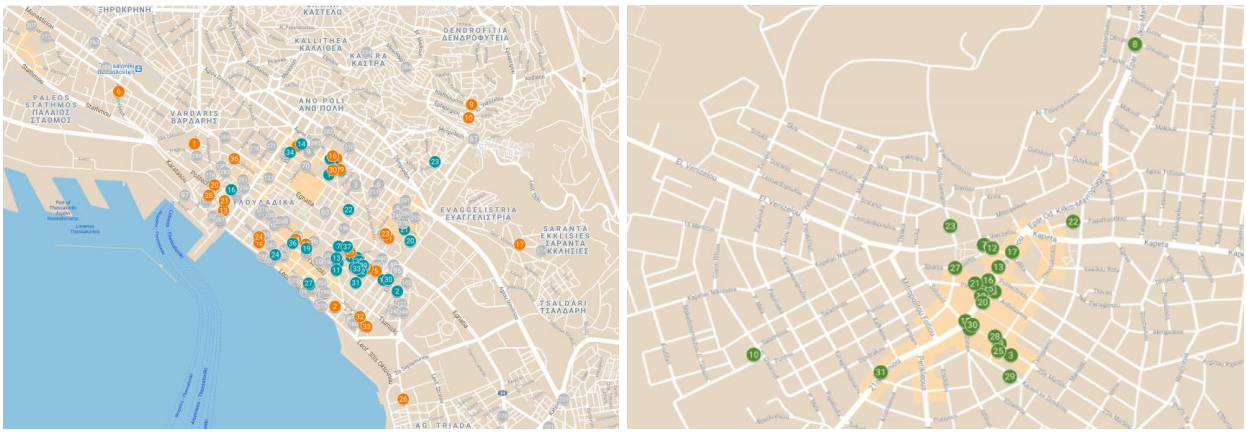
Collection & Transportation

The collection system that is currently being followed was developed in collaboration with the participating cafes, their owners and staff members. Through the active participation of all the parties involved, it was ensured that the collection process would be appropriate and tailored to the specific set up, conditions and needs of each of the cafes. The participatory planning of the collection also included training the staff on the separation of organic waste at source, and more specifically of the coffee waste. The training was aimed at optimising the time that employees will spend on separating the coffee waste into the special kafsimo collection bin, as well as the time it would take to be collected on the collection days.

Furthermore, the collection system that was developed took into consideration other temporal and spatial parameters, such as the space that the collected waste would take up in the collection vehicle as well as the processing time involved both in collecting and depositing the kafsimo bins at the storage facility. The collection bin is appropriate in size (10L), shape (squares can easily be stacked, stored and transported) and material for handling hot content, while the type of plastic used (Polypropylene) does not interact with the SCG and it can be efficiently cleaned and reused indefinitely by the partner stores. Nevertheless, it is imperative in terms of logistics to minimise the water content of the coffee waste as much as possible before collection, such as with the use of a self-drying mechanism installed in the bin. In optimising the collection processes, environmental impact was minimised, having as a long-term aim to develop a zero-emissions logistics system for all processes involved in kafsimo.

The amount and humidity of SCG produced by cafes is consistently weighed and monitored based on the typology of each business. Additionally, we mapped all relevant coffee waste producers (cafes) in Kilkis and central Thessaloniki (see Figure 1). The mapping activity consisted of both desk and field work, collecting and compiling lists of hospitality business from relevant bodies and cross-checking their validity, as the lists were found to be rather incomplete on their own. The resulting maps were used in the creation of the algorithm for the low-emissions logistics system.

Figure 1. Kafsimo's network in Thessaloniki (left) and Kilkis (right)



In order to minimise transportation-related GHGs, we use a 100% electric vehicle for the collection which follows an optimal route. To define the optimum collection route, we mapped the network of the participating cafes (see Figure 1, illustrated with orange in left map) and developed a Smart Algorithm - a tool individualized and adapted to the characteristics of the particular waste - taking into consideration several relevant parameters. In creating this tool, the most important factors were the location of the cafe, the amount (in weight) of daily production of SCG as well as the frequency of the collection visits. The data were adapted to the constant parameters (such as traffic and parking regulations) while the tool itself is evaluated and improved as more data is coming in.

Storage & Drying

At the end of each collection day, the coffee waste is transferred to our leased premises in Kilkis where a specially designed greenhouse has been installed. The greenhouse has the dual aim of storage space and for drying the product. The storage arrangements and the conditions of the greenhouse serve the purpose of naturally dehydrating the coffee grounds, replacing thus the need for an electricity-powered equipment. As such, this method reduces both the financial costs and the environmental impact that would otherwise be attached to drying process with the use of mechanical means. The greenhouse conditions and the product's physical properties are closely monitored and evaluated for further technique development.

The consistency and water-to-coffee ratio of the SCG at time of collection is dependent on the amount of time the SCG remains in the in-store collection bin before collection and, on average, is around 60% water and 40% coffee. The desired level of humidity that needs to be reached in preparation for converting the SCG into bioenergy is determined by the type of bioenergy. The findings from our own tests reveal that for biogas the desired water content is 34%, for pelletisation 12-15% and for incineration it is 20-25%.

Phase 3

Phase 3 of kafsimo is expected to be in full force in the next months and is in essence the last stage of the project before we can move to large-scale implementation of the system. The aim, by the end of this phase, is to have extensively tested and evaluated three alternative methods for energy production - incineration, pelletisation and biogas - in order to identify the optimal choice, taking into account the whole range of relevant parameters that are attached to this project, such as carbon footprint, the local economy needs, infrastructure available in the area.

The drying process by itself leads to a ready-to-use biofuel; the dried biomass can be incinerated to produce thermal energy to cover the needs of industrial facilities and at this stage we have sent samples of our product to two stakeholders to test the use of SCG as feedstock for their biomass incinerator. With regards to turning the SCG into biogas, our lab testing and analyses, performed by Delta Energy S.A.'s Qlab, showed that SCG meet the conditions for biogas production; the specific biomass contains 56.9% methane, which falls within the rough limit of 50-70% methane content for the production of biogas [18]. Our findings suggest that the theoretical gas yield per kilogram of dry matter is 388.2 litres of biogas, equivalent to 0.49kg.

Concerning the alternative of pelletisation, the dried biomass can be turned into pellets by a pellet machine with bespoke parts (as, to the best of our knowledge, there seem to be no factory-made machines for this specific feedstock). The resulting pellets can be burned for domestic use or for the heating purposes of a hospitality business, such as an outdoor pellet burner. Our initial experiments indicated that if pure SCG is used alone as a feedstock then the pellet machine needs to be adjusted, the die's temperature needs to be increased and the pellets need to be cooled down and significantly dried before transportation. The findings of our latest experiments, which were carried out by a partner in Finland, show that mixing SCG with other organic/agricultural wastes would allow forming granules of appropriate size and density and can yield high quality pellets, equivalent to Class A. Indicatively, we tested the combination of SCG with residues from a local straw variety from Kilkis which produced denser pellets, as opposed to the ones made from pure coffee waste. "If the pelleting process includes the coffee grounds and straw, there needs to be an external source of heating elements to achieve the required +90 C degree for the die." Further testing and experimentation carried out during Phase 3 will determine the final composition of the pellets.

Measuring Impact

In order to measure the environmental impact of kafsimo, we conduct a GHG analysis of the various systems of utilizing SCG. This GHG analysis takes into account the emissions associated over the life cycle of SCG going to the landfill (emissions associated with the production of the diesel truck, transportation, landfilling) and the emissions associated with SCG throughout the kafsimo waste management model (emissions associated with the production of the electric van, transportation using grid energy, incineration). Our analysis also accounts for the GHG saved by producing energy from incinerating SCG as compared to landfilling SCG and emissions associated with using Greek grid energy.

The social impact of kafsimo is measured using both quantitative and qualitative tools and it derives from the role it plays in raising awareness and promoting and supporting behavioral change with respect to coffee-drinking habits and sustainability in general. The estimates are based on: social media analytics (from Facebook where kafsimo is present); monitoring and reporting tools for events, seminars, workshops, etc. that kafsimo is present and/or is presented, such as attendance sheets; surveys and interviews with owners and employees of the participating cafes; direct contacting via available communication channels including social media accounts, emails, phone lines as well as face-to-face; the "snowball effect" deriving from kafsimo's presence in the media. The estimated number of people includes: the number of people that kafsimo has reached through its social media accounts; the number of people from around Greece who contact InCommOn to inquire about kafsimo or express their interest to participate, either as cafe owners, partners for collection and for utilization or as volunteers; kafsimo's presence in and exposure on traditional media, including radio shows, newspapers and TV programmes; the municipal authorities we have reached out to to inform about or promote kafsimo; the number of participants in the actions and activities organized as part of the project; the owners and employees of the participating cafes; the consumers of these cafes; the project's presence at conferences and events; the reach of kafsimo's visual communication.

Financial impact is measured by the amount of new jobs created and the number of people employed in the project. In addition, the ways in which kafsimo has positive spillover effect on the local economy are also discussed, including the development of new skills relevant to sustainable practices and the circular economy. Moreover, the benefits for the local economy and number of coffee shops reached are also considered.

Results

The results presented in this section are the product of careful monitoring of all processes and data collection, as the environmental, economic and social impact of the project is consistently measured. The tools used for monitoring and evaluating range from weighing the collected coffee waste at source and measuring its humidity, to GHG analyses and social media analytics. For the purposes of this paper, the results will be divided into environmental, social and financial. When possible, quantified findings will be presented.

Environmental Impact

By the end of phase 3, it is estimated that kafsimo will have collected, transported and stored 20 tonnes of SCG from 70 cafes in Kilkis and Thessaloniki. This amount of SCG will be diverted from the landfill, where it would otherwise have been disposed of. The results from our GHG analyses (see Table 1) show that for every kilogram of SCG that kafsimo diverts from the landfill and is incinerated, thereby also reducing fossil energy needs, up to 4.2 kilograms of CO_2equivalent (CO_2eq) emissions are saved. Overall, 60% less CO_2eq is emitted in this process as compared to the current alternative of transporting the waste with fossil fuel powered vehicles, mixed with other wastes and burying it in a landfill, and producing the equivalent amount of electricity according to the Greek grid energy mix.

Table 1: Summary of GHG Analyses

Process	**kg of CO_2eq emissions per kg of SCG**
Kilkis kafsimo – incineration [electric van]	2.14
Kilkis kafsimo – incineration [diesel van]	2.15
Thessaloniki kafsimo – incineration [electric van]	2.20
Thessaloniki kafsimo – incineration [diesel van]	2.28
Kilkis Landfill [diesel truck]	6.38

By preventing coffee from ending up in the landfill and reducing the local reliance on fossil fuels, kafsimo will save up to 84 tons of CO_2eq (depending on utilisation method) from being emitted into the atmosphere in its first year of operation. By using electromobility for coffee waste transportation, 50% less emissions are created as compared to using a standard waste truck over its entire life cycle. Diverting coffee waste from the landfill to produce energy creates 4 times less GHG emissions per unit of energy produced as compared to the alternative of producing energy from lignite while landfilling the coffee waste. Based on our results, we roughly estimate that if all coffee waste (around 40,000 tonnes of dry product per year) in Greece underwent a similar process as kafsimo as compared to currently landfilled, around 169,552 tons of CO_2eq would be saved annually.

Social Impact

This impact becomes more apparent with time, as kafsimo gains increasingly more visibility and acceptance by the community, both in the local sphere and beyond this, in the traditional media and in the social media. Indicatively, we get regular contact from individuals and businesses around Greece who are interested in implementing kafsimo in their areas. Currently, the number of people kafsimo has reached is estimated to be around 22,000. Kafsimo has been raising awareness about a wide range of ecological issues through every part of its operations: working with suppliers, consumers, policymakers (with regards to both waste management and in advocating for the use of electric vehicles), coffee-shop employees and the public to encourage participatory environmental “mentality change”, through the simple and relatable act of enjoying a cup of coffee.

Moreover, the owners and the employees of the cafes of the partner network have become themselves agents of change, augmenting the social impact of kafsimo. Through the education and training that they have received, as well as the active participation they have in the project and its processes, they become themselves cause-in-the-matter of raising awareness and promoting behavioural change, stating that the separation of SCG has become “second nature” to their everyday practices as 93% of the participating cafes report that separating coffee waste has become a habit and that they are “happy to be part of this network and introduce the project to inquiring customers.”

In qualitative terms, a range of visual tools that are used for communicating the project play an important role in raising awareness of the wider public, and especially as these visuals gain recognition. These include the identifiable electric van with its logos, the stickers on the windows of the participating cafes and the recognisable in-store collection bin. This visual recognition, albeit non-quantifiable, gives kafsimo an immaterial dimension that reaches beyond the spaces of its material implementation.

Financial Impact

The financial impact will be more visible later in the project and as larger amounts of SCG are collected and diverted from the landfill. The impact will be in the form of reduced costs and charges paid annually by the municipal authorities of Kilkis and Thessaloniki for the transportation and management of waste, as well as in the tax-payers' money saved from fines due to high landfill rates.

Nevertheless, the project has brought about short-term financial benefits for the community as it has created 3 new jobs, stimulating as such the local economy, and employs in total 9 people, either on a full- or part-time basis and including both paid and voluntary positions. Three people from vulnerable groups have successfully completed training on issues of circular economy and waste management. This not only supports the three individuals in increasing their potential for employment in the formal economy, but also their families and through their new knowledge, their own communities' capacity to engage in environmentally sustainable behaviour change.

Moreover, as more than 70 coffee shop owners and their employees are involved in turning waste into energy, their training on organic waste separation and smart collection schemes has provided them with employable skills, which are transferable to other businesses within the new circular economy that is forming in Greece.

Discussion

Successes and limitations

The project's success, which has exceeded our expectation, is attributed to its visibility and its holistic approach. The quick uptake of the procedures by the established network of cafes, the demand by other coffee shops - both from Thessaloniki and other parts of the country - to be part of the initiative, and the exposure that kafsimo received in the media, all demonstrate its attractiveness. The electric van moving around the two cities with its recognisable stickers and logos has also played an important role in raising curiosity and, consequently, awareness. However, a major success of kafsimo is that it demonstrates in practice that proper organic waste management is not about simply putting money into 'green issues' but rather that it has the potential to create jobs and to stimulate local economies, benefits which can be reaped by both the private sector and the municipal authorities.

The combination of sustainable technologies, practices and planning, with social and economic benefits is what makes kafsimo innovative, where complex socio-environmental issues gain visibility through creative, comprehensible and directly usable ways, allowing innovative science to have immediate impact in the public sphere. The socially and economically innovative aspects derive from the ability of the project to stimulate local communities as it employs local individuals and actively includes the local communities in its processes. This holistic model of a circular bio-economy is a means not only for creating a local circular economy, but also a way to shift public perception on resource-consumption and highlight the potential value of waste. Part of the reason behind the embrace of kafsimo by the participating network is that they place value on the fact that the waste they separate - their time and labour - is indeed utilised, in contrast to other recycling schemes that have come and gone or are still in place but without notable success.

The participatory aspect of kafsimo, which ensures the involvement of the community in all stages and procedures, including both planning and implementation, has played a crucial role in the effectiveness of the initiative and its acceptance by the affected community. Indicatively, decisions concerning the location of the collection bin inside the shops, the collection days and times, the method of collection as well as the marketing strategy to be followed for the partnerships, were a product of collaborative planning with the owners and employees of each of the participating cafes.

The collaborative planning had to be adjusted, due to COVID-related safety measures, to face-to-face visits instead of a collective decision-making with all members of the network that was initially planned.

With regards to using e-mobility for this waste management scheme, we encountered both benefits and drawbacks; apart from the reduction of the transportation-related emissions, a major benefit is the reduction of the costs involved in powering the vehicle (charging) as compared to a diesel-powered van. The most significant drawbacks were the scarcity of charging points, which are currently under development, and the limited autonomy of each charge.

The COVID-19 pandemic has affected most of the processes and activities of the project; the number of participating cafes varies throughout the restriction period of November 2020 - May 2021 (pending opening date), as some remained close during the lockdowns, or part of the lockdown period, while others shut down completely, and new partners entered the network later in the project; planned events involving the whole network of cafes were cancelled; workshops with the local community were cancelled or postponed. The immediate result of this was that the amount of SCG collected was less than initially expected, however it did not impact our ability to design, implement and test the model, which, at this stage, was the overarching aim of the project.

Scaling Potential

The innovative system of logistics has been developed in a way that makes it realistically applicable to any city or area. The model includes the collection, measuring, transportation and storage of the former waste and is based on an algorithm that is individualised for the specific network of cafes in the specific area. However, the algorithm is adjustable to any area or network of waste producers. This scaling potential maximizes the quantities of waste that can be diverted from the landfill and further facilitates the transition to a circular economy. In the future, the uptake of the model will also assist in the reduction of transportation-related emissions as the quantities of organic waste to be collected by municipal waste collection vehicles for disposal will be reduced.

The inherent replicability of the model has a further aspect; the potential for its application to other organic waste streams. The low-emissions logistics system has been designed in such a way so as to make it easily applicable to other organic waste streams, whether this is a ‘clean’ (i.e. easily separated at source) waste, such as coffee, or mixed organic waste produced by hospitality businesses, households, educational institutions or the municipality as a whole. And this replicability of its model is what makes kafsimo relevant, especially in light of the provisions of the new national waste legislation, the European Green Deal as well as the emerging 2021 Greek circular economy roadmap.

Policy Recommendations

The experience of developing and implementing kafsimo has allowed us to identify various policy recommendations that would aid in scaling kafsimo as well as in developing other sustainable waste management systems. In the long run, it is important that projects like kafsimo are financially sustainable; our initial research indicates that various policies such as the implementation of an effective landfill tax, and ‘pay as you throw’ schemes can both directly and indirectly financially support the development of sustainable waste management systems. We encountered numerous legislative and bureaucratic obstacles throughout the setting up of kafsimo which resulted in unexpected delays and financial costs. Policies that remove these obstacles will facilitate the creation of projects like kafsimo, these include the declassification of coffee waste as waste, streamlining the registration of waste collection vehicles, enforcing the simplification of the regulation governing waste storage requirements, making the VAT of biomass (currently at 24%) more competitive as compared to gas which currently stands at 6%, and facilitating and speeding up the installation of fast charging points on national highways and within urban centres for electric vehicles.

Conclusions

In conclusion, this paper has provided an overview of the project kafsimo as a case study of a transition from a linear waste management system to a circular, community-based project in a Mediterranean setting. We also identify a number of areas for policy improvement as well as future research. Monitoring the long-term impacts of kafsimo in future stages would allow us to draw further conclusions as to how innovative waste management strategies can be scaled.

It is important to note that at this stage in the project our findings indicate that the innovations associated can help drive Greece's transition to a circular economy. The inherent participatory nature of kafsimo, involving numerous stakeholders, drives compliance, behavioural change and involvement and is likely to support long term commitment even after the pilot period ends. The innovations around the low-emissions system illustrates the need for creating more sustainable logistics and collection systems and not just focusing on the end product.

Our results indicate that managing SCG through the kafsimo method has positive environmental, social and financial impacts; decreasing emissions, increasing the benefit to society by mobilising and "activating" its citizens, and creating local jobs under a circular economy model. The multidimensional character of kafsimo demonstrates the potential for dealing with waste management in a holistic way without segmenting the processes, giving equal importance to all the parts that make up a life cycle.

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