UNIVERSITÀ DEGLI STUDI DI PADOVA

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MASTER'S THESIS

"CIRCULAR FOOD WASTE VALORIZATION: THE CASE OF SPENT COFFEE GROUNDS"

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CHAPTER 4: HOW TO VALORIZE SPENT COFFEE GROUNDS

This chapter begins with the presentation of a coffee vending machines company, Riviera Distributori. The analysis of the company revealed their commitment to sustainability and CE; however, to further implement conscious practices, they want to valorize a seemingly marginal by-product, spent coffee grounds. In the second part of the chapter, a literature review on spent coffee grounds is conducted to explore the potential applications of this by-product, providing illustrative examples, and discussing advantages and challenges. Finally, an in-depth analysis of the findings and discussions was conducted to determine the optimal solution that seamlessly fits the needs and vision of Riviera Distributori.

4.1 Riviera Distributori: the Company, CE Commitment and the Future Path

Figure 14: Riviera Distributori's logo and location

Source: https://www.rivieradistributori.com/

Riviera Distributori[1] is a small family business in the province of Venezia and has emerged as a pivotal player in the snack and beverage vending industry since its establishment in 1972. The company has consolidated its presence in the industry with 225 vending machines distributed between the provinces of Venezia and Padova, it is now expanding to the Treviso area. It distinguishes itself by offering customized, rapid, and environmentally sustainable services. In addition to vending machines, they offer other services such as break area creation. Their vending machines offer options for hot, cold, and snack beverages, all enclosed in modern and operationally efficient designs. At the end of the year 2022, the company's turnover reached approximately 776.221 euros, a 35% increase when compared with the previous year's data, 2021[2]. After the

[1] https://www.rivieradistributori.com/
[2] Data gathered from the AIDA Database

COVID-19 pandemic, they decided to undertake a twofold transition that characterized their entrepreneurial journey: digital and ecological. Their decision to embrace sustainability was not swayed by transient trends, but rooted in a transition that began long before, manifesting itself as an intentional deviation from prevailing patterns. This commitment to sustainability is underscored by their recognition of individual contributions to environmental preservation and overall quality of life, leading to various initiatives, listed in chronological order below:

- partnership with the "Too Good To Go" app;
- efficient vending machines;
- partnerships with Rete Clima (Portel Parà REDD+ Project and Ghani Solar Renewable Power Project);
- partnership with Foresta Italia (Valle di Anterselva and Tribano, Italy).

The first initiative involves addressing social issues, with a particular focus on food waste. Through a partnership with the "Too Good To Go[3]" app, Riviera Distributori connects with consumers, offering products in *Magic Boxes* at discounted prices, and reducing food waste while promoting accessibility to quality products. Tangible results from this collaboration are illustrated in the subsequent Figure (15), featuring data updated until the end of 2023.

Figure 15: Data of Riviera Distributori from the partnership with "Too Good To Go"

Source: https://www.rivieradistributori.com/impronta-verde/too-good-to-go/ (last access 27/12/2023)

Simultaneously, Riviera Distributori invested in its vending machines, upgrading them to Class A. This qualification represents energy efficiency and technological quality. Beyond energy considerations, their commitment extends to conscientious vending machine accessories such as paper cups and eco-friendly kits; moreover, the products are sourced from environmentally friendly enterprises.

[3] https://www.toogoodtogo.com/it

In 2022, Riviera Distributori established a crucial partnership with Rete Clima[4], engaging in projects aimed at environmental preservation. Rete Clima is a non-profit organization, that promotes and supports companies that decide to undertake Corporate Social Responsibility (CSR), sustainability, and decarbonization actions. Riviera Distributori participated in different projects, including the *Portel Parà REDD+ Project* in Brazil, focusing on safeguarding the Amazon Rainforest. Furthermore, they participated in the reforestation of the Valle di Anterselva in Italy, contributing to the national afforestation campaign *Foresta Italia*[5]; as part of the same Italian campaign, they also planted 50 trees in the Tribano area in the province of Padova (Italy). Additionally, they participated in the *Ghani Solar Renewable Power Project* in India demonstrating their commitment to clean energy.

Thanks to Rete Clima, Riviera Distributori ensures customers that choosing their products means indulging in carbon-neutral coffee. Achieving decarbonization, they obtained Carbon Neutrality in 2022 and the Label Climate Plus in 2023, signifying their commitment to exceeding carbon reduction goals.

Pictured below are the labels obtained by Riviera Distributori over the years.

Figure 16: Labels obtained: Carbon Neutrality, Climate Plus, Partner of Foresta Italia

Source: https://www.rivieradistributori.com/

Looking forward, Riviera Distributori aspires to reuse Spent Coffee Grounds from its vending machines from a CE perspective. In recent years, Riviera Distributori has strategically focused on exploring possible applications to effectively harness the potential of such coffee waste. Its efforts have embraced several avenues, including the production of pellets from coffee grounds, the development of soil fertilizers, forays into the cosmetics industry, and attempts to grow mushrooms. All these experiments will be explored in depth in the last part of this chapter. Despite these trials, it has not been possible to implement any of the previously mentioned alternatives effectively; therefore, the company is determined to find the most suitable solution.

[4] https://www.reteclima.it/
[5] https://www.forestaitalia.it/

In this context, Riviera Distributori's commitment to the CE, compared with the principles of CE discussed in the previous chapters, is evident. The ultimate goal is to create a CSC through the implementation of activities designed to ensure its success. The company aims to reduce its environmental impact and create meaningful synergies within its sector and with other sectors. This chapter focuses on the valorization of coffee grounds, which is not limited to production alone. The company consistently integrates sustainable solutions to fight food waste in innovative ways, as demonstrated by its partnership with Too Good to Go. These initiatives are possible due to the company's committed corporate sustainability strategy[6].

Figure 17: Riviera Distributori's coffee vending machines

Source: https://www.rivieradistributori.com

[6] All the information and data discussed regarding the company were gathered through an interview with the administrative manager of Riviera Distributori and the company's website (https://www.rivieradistributori.com/). The key aspects of the Interview with Riviera Distributori are in the table below.
Source: Own elaboration

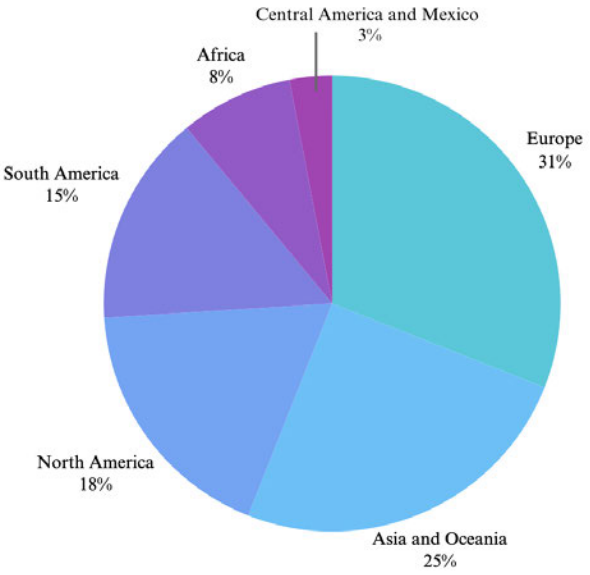
Respondent's position	Method	Date	Duration
Administrative Officer	Online meeting	13/12/2023	60 min

4.2 Spent Coffee Grounds Scenario

Coffee is the second most traded commodity in the world –surpassed only by oil– underscoring its significant market position (Murthy & Naidu, 2012). From the analysis conducted in 2022 by the International Coffee Organization (ICO), the production of coffee beans reached 10 million tons, corresponding to an annual worldwide consumption of approximately the same quantity[7]. Global daily coffee intake exceeds 3 billion cups on a worldwide scale (Santos et al., 2023).
Approximately, from an ICO estimation, one-third of the world's coffee consumption occurs in Europe (31%), with Asia and Oceania coming next at a 25% market share, followed by North America (18%), South America (15%), Africa (8%), and Central America and Mexico (3%) (ICO, 2023). These data are illustrated through the graph on the following page (Figure 18), which provides a clear and immediate visual representation of the information analyzed.
Coffee production globally generates an amount between 8 to 10 million tons of waste annually (Echeverria & Nuti, 2017; Saratale et al., 2020). The waste produced encompasses husks, pulp, mucilage, silverskins, and spent coffee grounds. These by-products originate from various stages of the coffee supply chain, including harvesting, processing, roasting, and brewing (Lestari et al., 2022). Notably, among these waste materials, spent coffee grounds stand out as the most abundant residue, amounting to 0.6/0.65 ca. tons per ton of coffee (Janissen & Huynh, 2018). In the context of spent coffee management, a graph similar to the one in Figure 18 on consumption can be conceived to show the trend and distribution of coffee grounds closely related to consumption levels.

[7] International Coffee Organization; https://www.icocoffee.org/documents/cy2022-23/cmr-0423-e.pdf

Figure 18: Consumption of coffee worldwide, 2022



Source: Own elaboration from https://www.icocoffee.org/documents/cy2022-23/cmr-0423-e.pdf

Spent Coffee Grounds –commonly abbreviated as SCGs– are solid remnants resulting from the preparation of coffee as a beverage (Bevilacqua et al., 2023). As stated before, SCGs are a large amount of coffee waste that causes storage and disposal issues (Fu et al., 2022). SCGs are organic composites, and their composition is contingent upon factors such as the variety of coffee beans, extraction processes, and roasting conditions. The constituents of SCGs are mainly grouped as follows: (i) oil fraction, (ii) crude fiber, and (iii) various elements including protein, alkaloids, and others.

The multiple potential applications of SCGs across various sectors underscore their versatility and different studies have investigated them. Thus, they can serve as antioxidants in different applications. Additionally, SCGs can be employed for the production of bioproducts such as biodiesel, bioplastic, biopolymers, biogas, bioethanol, biochar, adsorbents, cosmetics, compost, and fertilizers (Bevilacqua et al., 2023). This multifaceted utilization aligns with the principles of the CE and supports sustainability practices.

These examples represent only a fraction of the potential applications for coffee grounds, which, depending on the context, may be applied directly or necessitate intermediate activities before the integration into novel processes.

The objective of the subsequent literature review is to identify the best opportunities for enhancement, both from a general and specific perspective of comprehensive applications in the context of Riviera Distributori. Aiming at answering the questions:

a) *What can be the possible applications for SCGs valorization in the context of CE?*

b) *In the field of SCG valorization, what alternative strategic options emerge within a collaborative framework?*

Nevertheless, the complete valorization of SCGs' potential remains untapped. Opportunities abound for advanced research, particularly in exploring the environmental and economic advantages within the fields of agriculture, bioenergy, sustainable materials, and cosmetics. Challenges emerge in scaling up SCGs collection, determining optimal processing methods, accounting for chemical variations based on coffee types –for the purpose of this research, SCGs are treated in a general sense–, and ensuring cost-effective utilization.

4.2.1 Research Methodology

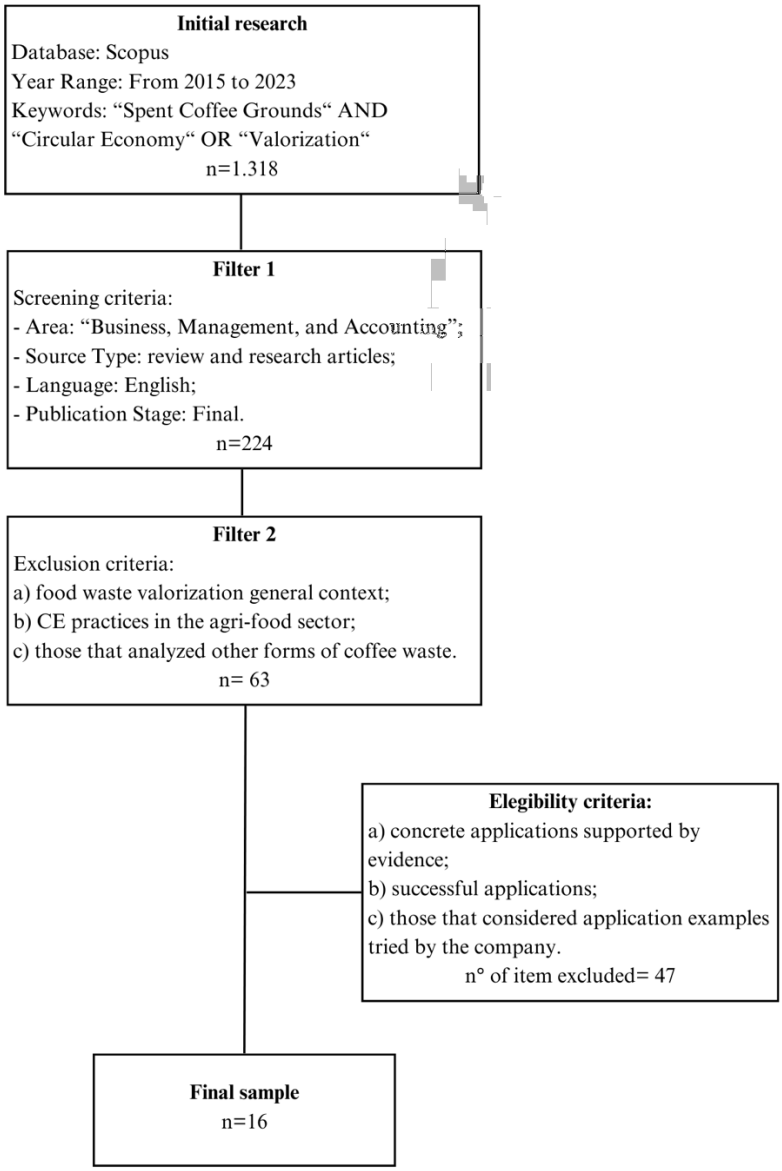
This section will explore the main applications of SCGs to promote the implementation of CE practices and their existing examples. Then the benefits and criticalities of the applications will be discussed to determine the optimal solution that a company such as Riviera Distributori can adopt, which requires a thorough analysis to identify the most effective strategy to apply.

In order to develop a comprehensive review on the valorization of SCGs, this analysis encompasses an examination of works over the past decade, spanning from 2015 to 2023. By restricting the timeframe to this specific temporal window, the objective is to provide an in-depth and updated analysis of the evolving theme of SCGs. The year 2015 was selected as the starting year because one of the first systematic reviews on coffee grounds was conducted in that year. That review, entitled "*Spent Coffee Grounds: A review on current research and future prospects*" by Campos-Vega et al. (2015). Furthermore, research on SCGs has gained increasing interest in recent years, 90% of the studies are concentrated from 2010 onward.
It should be pointed out that two distinct forms of literature review exist: the Narrative or Traditional Literature Review and the Systematic Literature Review, often abbreviated as SLR. For the purpose of this study, the SLR approach was employed due to its more meticulous and well-defined methodology for scrutinizing the literature within a specific domain. This approach facilitates a thorough examination and critical analysis of articles within the relevant study area (Cronin et al., 2008).

Scopus has been used as a database for the research because it is considered one of the largest archives of peer-reviewed scientific literature globally. So, its use ensures a comprehensive examination of the current state of the art on SCGs valorization (Arias et al., 2023). The search was meticulously conducted using specific keywords such as “Circular Economy” and “Valorization” in combination with “Spent Coffee Grounds”. Starting from a base of 1.318 items, only those written in English and reaching the final stage of the writing process were taken into consideration. This search yielded a substantial sample of 312 scientific articles in the area of “Business, Management, and Accounting”. To refine the dataset, a judicious approach was employed filtering exclusively “review articles” and “research articles”, other types of publications were not considered because their research rigor is lower and they may not be subjected to a conventional peer-review procedure (Adams et al., 2017; Levy & Ellis, 2006; Webster & Watson, 2002). This process resulted in a refined sample of 224 papers, ensuring a robust foundation for a well-informed and scientific exploration of potential applications. Articles were found in various journals reflecting a range of academic fields that address topics related to SCGs. The first three journals, based on the number of articles, are the “Journal of Cleaner Production”, “Resources, Conservation and Recycling”, and “Waste Management”.

The significance of the chosen articles was assessed through a manual review process, in which those deemed misleading were excluded. Exclusion criteria included articles that discussed (a) food waste valorization in a general context, (b) CE practices in the agri-food sector, or (c) those that discussed other forms of coffee waste (e.g., silver skin, husks, etc.) unrelated to coffee grounds. Thus, a total of 161 items were removed, with a remaining sample of 63 articles. Through the evaluation of these remaining articles, were considered those that dealt with (a) concrete applications supported by evidence; (b) applications that demonstrated actual success; and (c) those that, at least in part, considered some of the application examples tried by Riviera Distributori. After this stage, a total of 16 articles pertinent to the topic remained. The number of articles seems small compared to other reviews; according to Rojon et al. (2021) and Überbacher (2014), many scholars believe that a comprehensive literature review can provide a deeper understanding of the research context. However, it is equally, if not more, important to consider the quality and relevance of sources rather than just their quantity. It is imperative to maintain objectivity and avoid subjective evaluations. Nevertheless, the crucial aspect of a review seems to lie not in the mere quantity of literature analyzed, but rather in the quality of the papers included. This is because high-quality papers enhance robust and confident conclusions. The SLR process is summarized in Figure 19.

Figure 19: Selection process of the studies for the SLR



Source: Own elaboration

To support this SLR, a critical analysis of gray literature in the coffee sector has been conducted. This analysis focused on reports, analyses, and press reviews from unofficially published sources. The relevance of this gray literature is particularly evident in the careful and targeted selection of specialized industry websites, which constitute the main source of information. The methodology used involved carefully selecting sites based on specific criteria, such as the analysts' authority, information completeness, and content specificity regarding key aspects of the coffee sector. This targeted selection phase was crucial to ensure the reliability and relevance of the sources used for the analysis. In addition, gray literature is a valuable complement to the information found in

scientific papers, providing a broader context and a more comprehensive understanding of the dynamics of the coffee industry. The convergence of scientific data and information from gray literature helps to consolidate the robustness and completeness of the analysis (Paez, 2017).

4.2.1.1 Preliminary investigation

Leveraging both the resources of the University's network and the expertise of the thesis supervisor, a company involved in Research and Development activities –particularly focused on new materials and innovative technologies– was identified and interviewed[8]. This company is MaTech[9], engaging with this agency was useful to explore their studies and experiences related to potential applications of SCGs and for obtaining additional guidance in identifying the most promising areas for spent coffee utilization and limitations of such applications. Valuable insights were gleaned from the discussions with this organization.

4.2.2 Findings

Generally, the chosen studies indicate a limited and scarce body of international literature on the topics related to SCGs, even if they are of high quality. Utilizing the selection of 16 articles sourced from the international Scopus database, a comprehensive analysis of the different applications of SCGs has been conducted. In each article, the specific names associated with SCGs applications were identified (i.e., biodiesel, biogas, fertilizer, sunscreen, skincare, dyes, and so on); while when details were presented only identifying the industry of application, the relevant field was considered. Subsequently, all these data about SCGs applications have been categorized into distinct groups according to the sectors, as illustrated in the figure in the next pages.
The order followed in identifying, and then discussing, the different areas of application of SCGs is determined according to the perceived importance during the examination of the selected items.

As previously discussed, after conducting a comprehensive investigation of the selected articles and meticulously categorizing the sectors of applications, a thorough examination of implemented examples –in the specific sectors– was undertaken to substantiate and fortify the findings of these studies. This approach not only ensured a comprehensive understanding of the identified sectors but also provided concrete evidence through real-world instances, thereby reinforcing the credibility

[8] Key aspects of the interview with MaTech – Source: Own elaboration

Respondent's position	Method	Date	Duration
Technical Manager	Online meeting	13/12/2023	40 min

[9] https://www.matech.it/

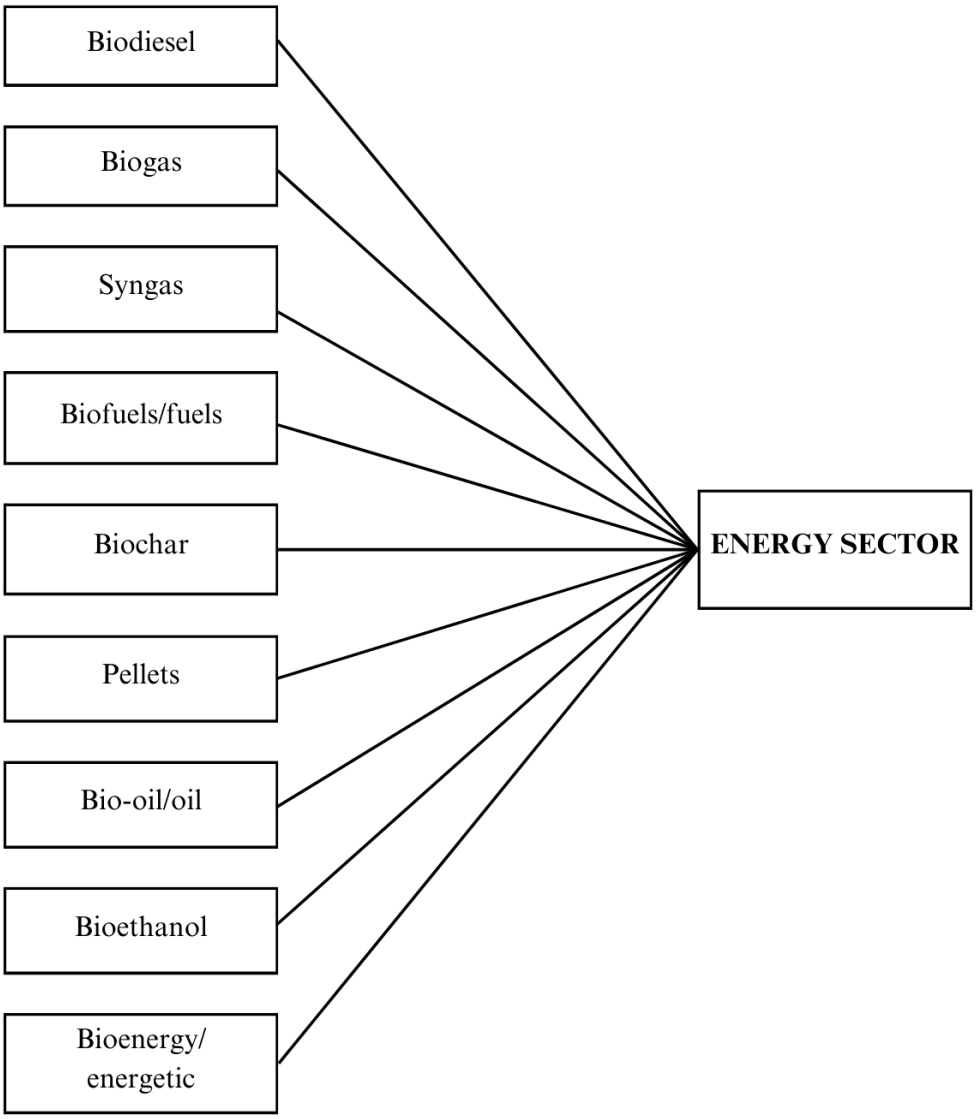
and potential applicability of the research. These examples have been individuated through the website of the European Vending and Coffee Service Association[10] and reports by big players of the coffee market –Nespresso, Lavazza, and so on–, in the pursuit of solely obtaining accurate information.

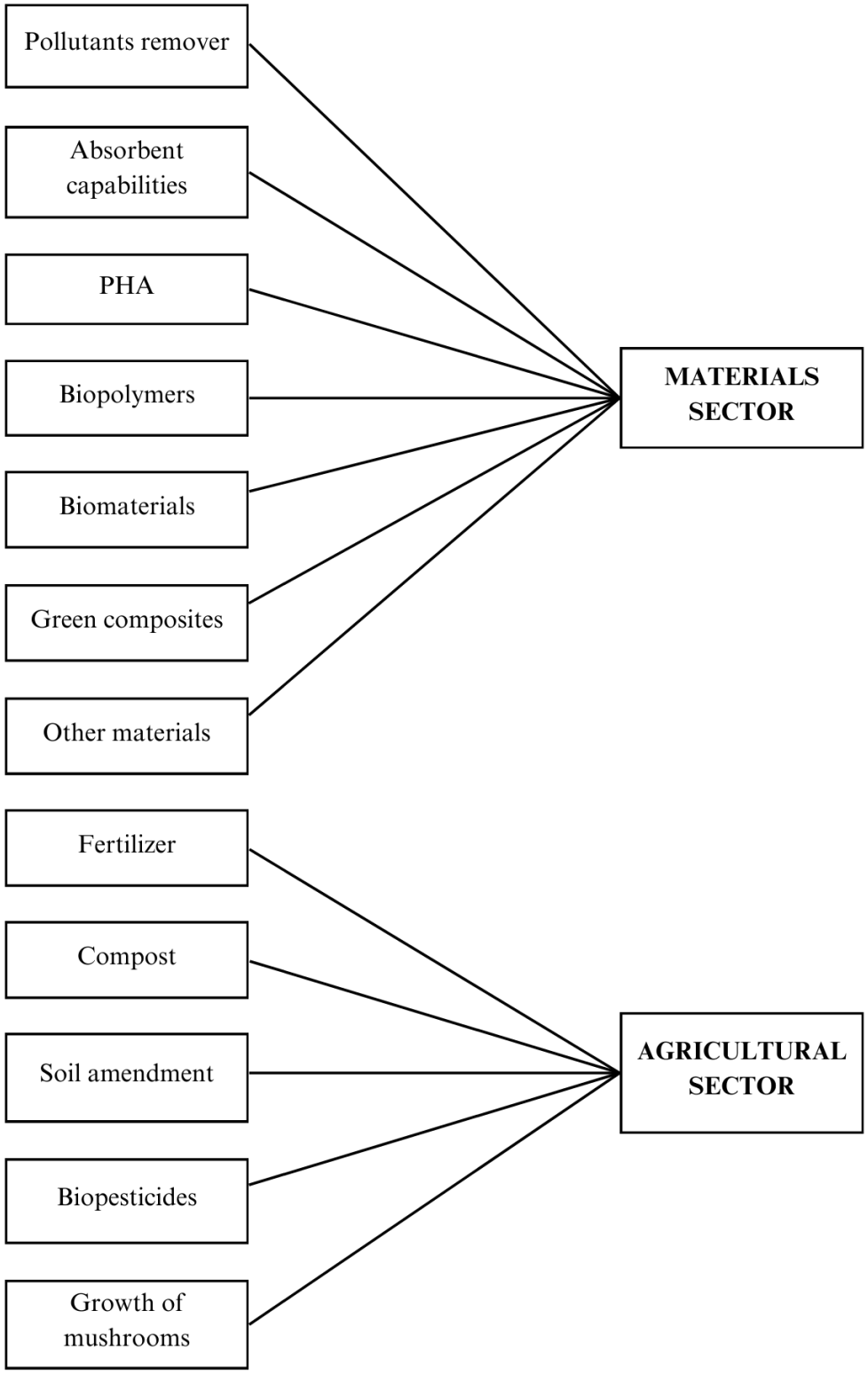
For the scope of this research, certain industries such as construction, pharmaceuticals, and food, have not been incorporated. This omission stems from the presence of conflicting and occasionally inconclusive findings in the studies analyzed about the applications within these sectors. Additionally, there were no discernible examples of practical applications within companies or similar entities that can substantiate and support such studies. Furthermore, as suggested by Yusufoğlu et al. (2023), additional studies are required to fully comprehend the potential of SCGs in these fields, as they are only in their early stages.
Throughout this analysis, all the different types of coffee were treated uniformly without considering their differences; therefore, the analysis focused on the overall coffee as a whole, without specific distinctions among its variants.

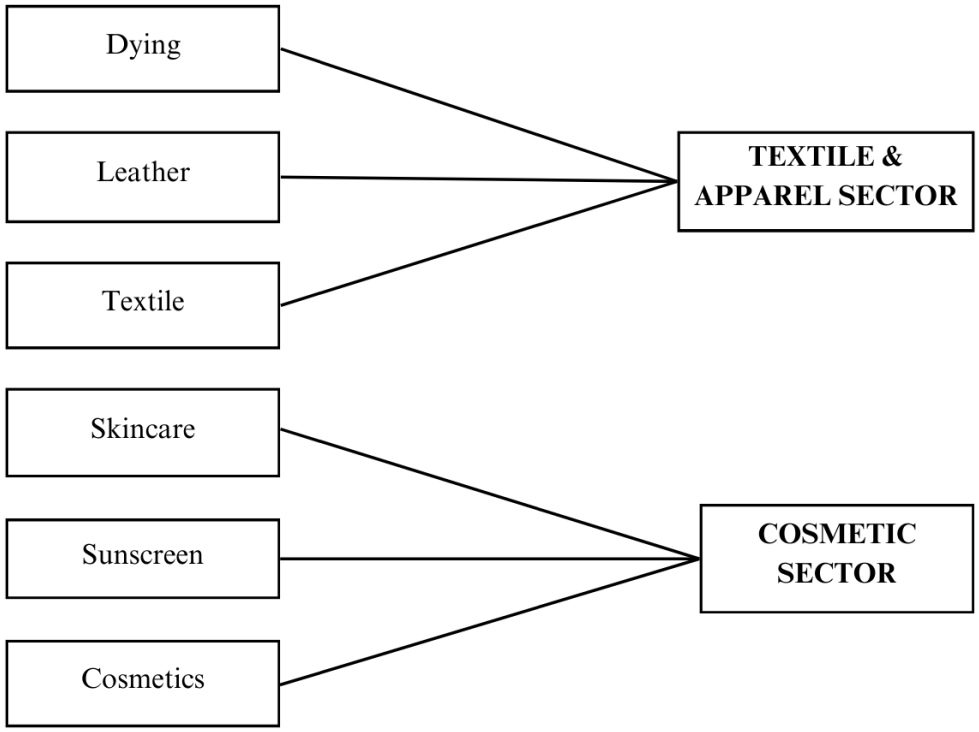
As previously discussed, SCGs have different components, these are extracted through specialized processes. However, it is noteworthy that SCGs can also find direct application without undergoing any extraction procedures (Kovalcik et al., 2018) despite this the cases of direct use are limited. Coffee grounds can undergo biorefining processes in order to extract and enhance their nutrients. According to Sousa and Ferreira (2019), coffee grounds in landfills can pose a big challenge due to the risk of excessive production of pollutants emissions; this can be environmentally harmful. Coffee grounds are donated by producers to those who intend to valorize them. The case studies analyzed illustrate this distinctive feature.

[10] https://www.vending-europe.eu/

Figure 20: SCGs applications sectors




Pollutants remover
Absorbent capabilities
PHA
Biopolymers
Biomaterials
Green composites
Other materials
MATERIALS SECTOR
Fertilizer
Compost
Soil amendment
Biopesticides
Growth of mushrooms
AGRICULTURAL SECTOR



Source: Own elaboration from data of the sample's articles

4.2.2.1 SCGs in the Energy Sector

The energy sector stands as the most frequently cited domain in the discourse surrounding SCGs, with all 15 papers sampled emphasizing the potential of extracting energy from this source. The specific extraction mechanisms employed for SCGs, particularly their oil content, present an opportunity for transformation into biodiesel and, more broadly, various biofuels such as biogas, biochar, and others. Research indicates that the high calorific value of coffee grounds, comparable to other agro-food waste, underscores their viability in this sector (Kang et al., 2017; Mata et al., 2018).

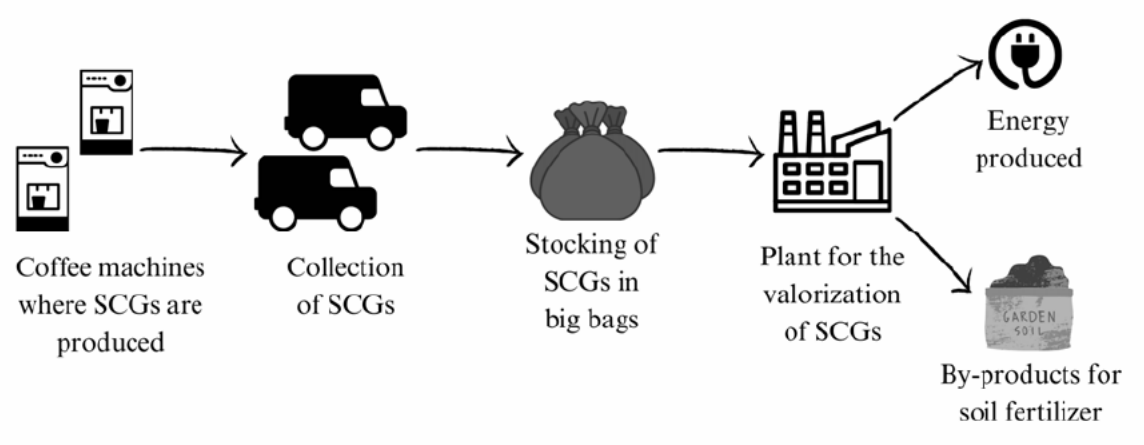
According to Atabani and Al-Rubaye (2020), 10% of the world's energy comes from bioenergy, with 80% of it being sourced from renewable inputs. This is important as the global shift away from fossil fuels keeps going. SCGs have shown potential as a substrate for biogas production, through the collection of spent coffee and then the treatment in biogas plants. Through this obtaining energy and by-products to use in soil fertilizers.

Extensive studies on energy derived from SCGs have paved the way for the exploration of different biofuels, including biogas, biodiesel, biochar, bioethanol, and pellets, as highlighted by Kourmentza et al. (2018) and McNutt (2019). The versatility of coffee grounds is further exemplified by the production of biomass pellets, as just mentioned, capable of powering boilers, offering an additional

path for resource utilization (Colantoni et al., 2021).
The extraction of fuels and energy from coffee grounds not only introduces the era of renewable energy sources but also addresses the pressing concerns of waste management. Moreover, this process leverages a low-cost raw material, contributing to the economic feasibility of such endeavors. The integration of biofuels into a CE system provides cost advantages, aligning with sustainable practices.

Several businesses have been actively engaged in developing sustainable applications for SCGs, aiming to generate 100% renewable energy from this resource. Big companies, like Nespresso[11], have invested in projects focused on producing energy from SCGs in biogas facilities powering 1500 households and the final by-product of this process is a high-quality natural soil fertilizer[12]. Noteworthy examples also emerged in the vending sector, exemplified by [redacted] a market leader in Italy that nowadays has been acquired by the [redacted], and [redacted] Automatica[14], a medium-family business located in the province of Venezia.
[redacted] initiated its venture into SCGs utilization with a pilot project named "[redacted] Ambiente" in 2015, showcasing a commitment to environmental sustainability. In contrast, [redacted] entered the scene in 2020. The operational model for both companies involves the collection of spent coffee from their vending machines, storing the by-product in big bags, and subsequently sending these SCGs to biogas facilities for the production of renewable energy. This process, aside from energy generation, yields by-products that can be utilized in the formulation of soil fertilizers. Figure 21 exemplifies the general process of producing energy and then soil fertilizers in the vending sector.

Figure 21: Energy transformation process of SCGs



Source: Own elaboration from data collected

In the table below, the data outlining [redacted] Distribuzione Automatica's (Venezia, Italy) forecasts that highlight the potential energy that can be derived from the SCGs produced by their vending machines, there is no information about the timeframe of collection. Due to the acquisition of [redacted] by the [redacted] Group (Milano, Italy), it has proven challenging to access specific data regarding the pilot project. However, considering the dissimilarities in size –[redacted] is bigger than [redacted] Distribuzione–, it is reasonable to assume that the scale of the project would have been more extensive.

Table 10: Forecasts of [redacted] Distribuzione Automatica

SCGs collected	Renewable Energy Created
40 ton	25.000 KWhe[15]

Source: Own elaboration [redacted]ia-circolare-dai-fondi-di-caffe-ricaviamo-energia-pulita/

4.2.2.2 SCGs in the Materials Sector

In the materials industry, various applications of SCGs have been explored, with a particular emphasis on polyhydroxyalkanoates (PHA) as a promising alternative to petrochemical plastics (Kovalcik et al., 2018). PHA is a biocompatible and biodegradable type of polyester sourced from microorganisms. The biodegradable nature of PHA aligns with CE principles, offering

[15] kilowatt-hours electric

environmental and societal benefits. Traditional polymers have started a transition toward these innovative biopolymers (Kourmentza et al., 2018).
Scholars have not limited their research on incorporating SCGs solely in PHA; they have also explored other materials, such as composites, commonly referred to as green composites. Composite means combining different high-quality materials to obtain a new material with higher mechanical properties. These composites, enriched with SCGs as additives, demonstrate improved performances and increased biodegradability. For example, Wu et al. (2016) found that SCGs in composites reinforce mechanical and thermal properties, enhancing water resistance. Moreover, Lee et al. (2019) explored nanocomposites combining polyvinyl alcohol and coffee, resulting in a material with superior strength compared to traditional carbon-based counterparts. These SCG-infused composites find applications in various contexts, including interior decorating materials and non-wearable products like cups. While some studies suggest limitations in certain sectors because of the resilience demanded, successful cases like Coffeefrom and Co.ffee Era showcase the transformative potential of SCGs.

Coffeefrom[16] is a socially oriented start-up born as a spin-off of a cooperative. It produces recycled, thermoplastic, and bio-based materials from spent coffee, introducing innovative products like coffee cups with a material composition of 30% spent coffee.
Co.ffee Era[17] similarly contributes to SCGs valorization by creating design products, ranging from organizers to lamps, through a local CE initiative in Milan. These initiatives not only divert SCGs from landfills but also contribute to ecosystem preservation, exemplifying sustainable practices at the grassroots level.
These projects support IS by fostering the sharing of resources and knowledge. Additionally, they actively collect coffee waste –Coffeefrom claims to collect coffee grounds from the food industry (reaching up to 200 tons), and Co.ffee Era from cafes and restaurants in selected neighborhoods. The integral role of product designers is acknowledged as an essential component of this symbiotic relationship.
To sum up, they take circularity to another level, reducing the SCGs in landfills by diverting them from this conventional path. They promote an innovative approach toward transforming them into design products.
Figure 22 depicts the process of manufacturing products from SCGs-based materials.

[16] https://coffeefrom.it/
[17] https://www.coffee-era.net/

Figure 22: Process of manufacturing products from SCGs-based materials

Source: Own elaboration

4.2.2.3 SCGs in the Agricultural Sector

In the context of SCGs valorization, there is growing attention to the agricultural sector, particularly in biobased fertilizer production, composting, and related applications. Before delving into this topic, it is crucial to understand the difference between compost and fertilizer; compost is aimed at improving soil structure, while organic fertilizer is specifically formulated to enrich plants with nutrients. Residues derived from coffee production can play a significant role due to their rich nutrient composition and can be used as soil conditioners or fertilizers for plants, as stated previously (Mayson & Williams, 2021).

Spent coffee finds great use in organic farming due to its high mineral content (Cruz et al., 2012; Ribeiro et al., 2017). According to Santos et al. (2017) and Ronga et al. (2016), the use of SCGs as compost or fertilizer can only occur after there has been pre-treatment; it cannot be done directly. Hardgrove and Livesley (2016) and Cervera-Mata et al. (2021) conducted studies on plant and flower growth with direct use of SCGs as fertilizer that showed worse results. Kovalcik et al., 2018, suggest that only minor modifications are needed to achieve better results; one possibility would be to mix spent coffee with other materials to achieve remarkable results (Santos et al., 2017; Ronga et al., 2016). Such treatments reduce the potential toxicity of spent coffee.

Several studies show the benefits of using compost with a percentage of SCGs, for example, in growing vegetables, showing improvements in colors and vitamins, making them more pleasant to consumers' eyes. In addition, there have been conducted studies that have recognized the importance of using coffee grounds in pesticides, commonly recognized as biopesticides (Yusufoğlu et al., 2023). Furthermore, it has also been reported that the use of SCGs affects crop growth, controls undesirable herb proliferation, and improves soil quality such as making it more capable in water absorption (Cervera-Mata et al., 2019).

The use of SCGs in fertilizers is a choice that increases the implementation of CE and provides sustainable options and can be complementary to the transformation of SCGs in energy, as discussed before.

Another interesting application of coffee by-products in agriculture is the cultivation of edible mushrooms. In this case, coffee grounds do not undergo any treatment prior to mushroom cultivation. Coffee grounds, rich in minerals and nutrients, serve as substrate for mushroom growth. The mycelia, or the 'seed' of the mushrooms, are placed in the SCGs, and a period of about 20-25 days is waited for the mushrooms to appear (Carrasco-Cabrera et al., 2019).

During the first part of this period, the necessary nutrients are absorbed into the mycelia. In the second part of the time, the actual growth of the mushrooms begins. The type of mushrooms grown in these coffee grounds is mostly *Pleurotus*, which is known for its edibility and adaptability to different substrates (Murthy & Naidu, 2012).

An advantageous feature of this practice is that it does not require pasteurization, as the coffee powder is pasteurized during the brewing process at high temperatures. This results in significant energy savings. Once the nutrients in the coffee grounds are depleted, the residues are used as compost.

In Italy, there are two major CE projects dedicated to growing mushrooms using SCGs. In 2014, the Funghi Espresso project was born in the province of Florence, now part of Circular Farm. In 2016, "cooperativa Il Giardinone", previously mentioned for the Coffeefrom project, launched Fungo Box in Milan.

Funghi Espresso[18] collects coffee grounds from bars in the Florence area, subsequently, these SCGs are used to grow mushrooms. Bars are selected close to the production site, favoring environmentally friendly means of transportation, a key element in terms of both IS and CE. Once mushroom harvesting is completed, the spent substrate is destined for composting. They have a well-defined chain of what happens to the coffee grounds once the mushrooms are harvested.

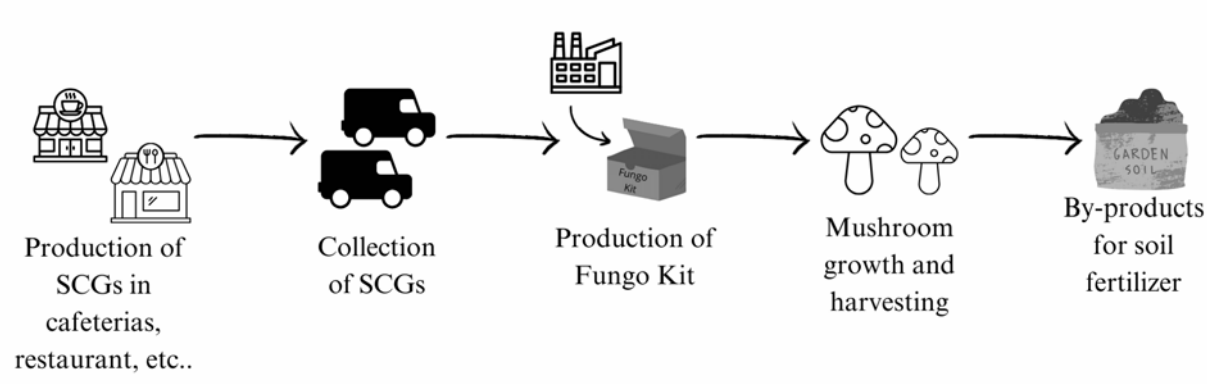
Fungo Box[19] is the result of a collaboration between Il Giardinone, Novamont and, Lavazza[20]. The last two collect coffee grounds mainly from bars and deliver them to Il Giardinone. To minimize unnecessary travel, the collection takes place only for quantities over 100 kg and is limited to northern Italy –with some limitations–, thus reducing the ecological footprint. Fungo Box offers

[18] https://www.funghiespresso.com/
[19] https://www.fungobox.it/
[20] Before partnering with Il Giardinone, Novamont and Lavazza collaborated in 2015 to create a compostable MATER-BI capsule under Lavazza's patent. This collaboration aims to promote a circular model that enables the collection and industrial composting of used capsules and coffee, transforming them into natural fertilizer to reduce waste and greenhouse gas emissions.

mushroom growing kits, emphasizing the possibility of obtaining up to three harvests with the same kit, although subsequent harvests are less abundant. A single harvest provides one serving for two people.

Figure 23, below, represents the production process of mushrooms from SCGs.

Figure 23: Process of producing mushrooms from SCGs



Source: Own elaboration

4.2.2.4 SCGs in the Cosmetics Sector

Within the cosmetic sector, SCGs find extensive utilization, due to their valuable and high-quality characteristics as antioxidants –that increase as coffee is brewed–, emollient, and UVB protectors. The particular appeal of these two characteristics makes incorporation into cosmetic products highly desirable (Kovalcik et al., 2018). According to the studies of Ribeiro et al. (2013), the oil extracted from SCGs serves as an additive in cosmetics formulations, enhancing skin sebum and hydration properties. However, subsequent research in 2016 proposed SCGs' oil as a low-cost component in sunscreen formulations, offering higher protection against the harmful impacts of ultraviolet radiation (Choi et al. 2016; Marto et al., 2016). From the extraction of residual caffeine in SCGs it is possible to develop skincare formulations for its ability to reduce swelling and enhance circulation (Mayson & Williams, 2021).

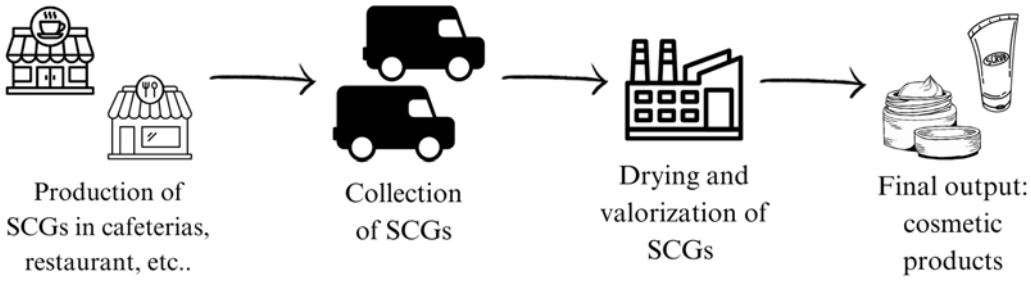
Despite the significance of these studies, SCGs are commonly employed in artisanal cosmetics and skincare products. Spent coffee is directly used, without any treatment, in homemade exfoliating scrubs or masks, revitalizing the skin.

In 2016, UpCircle[21] was founded by a visionary duo Anna and Will with the goal of fostering sustainability in the cosmetic industry. Recognized as pioneers in using food waste to create high-

[21] https://eu.upcirclebeauty.com/

performance cosmetic products, particularly scrubs and exfoliating creams derived from coffee waste, the company actively collaborates with a growing portfolio of cafes in London. Through this partnership, UpCircle collects SCGs, highlighting a collective engagement with the community in fostering sustainable practices. Recently, UpCircle has expanded its influence globally through various stockists and has further solidified its commitment to sustainability by introducing its own refill program, exemplifying a holistic approach to minimizing environmental impact.
Figure 24 depicts the process of using SCGs in the cosmetics industry.

Figure 24: Process of using SCGs in cosmetics



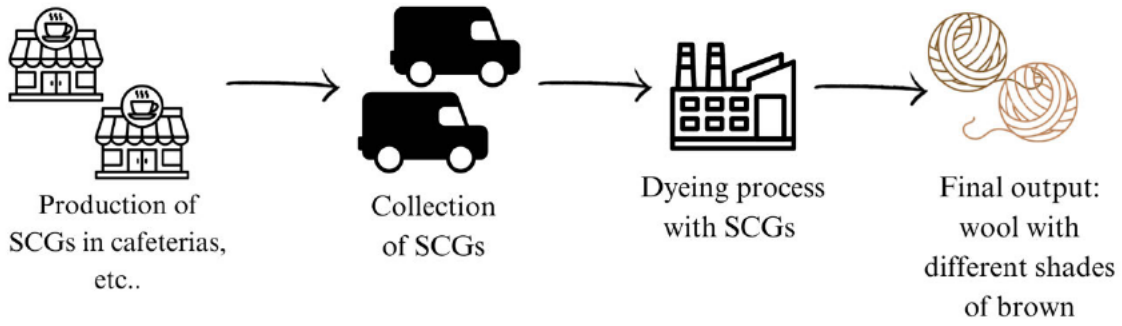
Source: Own elaboration

4.2.2.5 SCGs in the Textile and Apparel Sector

In the textile and apparel sector, SCGs can offer versatile applications, contributing to a more sustainable textile industry through the use of non-toxic materials (Campos-Vega et al., 2015; Yusufoğlu et al., 2023). According to research conducted by Tian et al. (2022), the potential to create a non-polluting water-based synthetic leather using SCGs as fillers in the composite has been investigated, presenting it as an eco-friendly alternative to leather with chemical solvents. Following a meticulous testing phase, this SCGs-based synthetic leather successfully meets the standards of waterborne synthetic leather commonly used in apparel and luggage. This advancement not only streamlines the production process, making it more energy-efficient and environmentally friendly but also introduces an innovative and sustainable product poised for future application in the apparel industry.
Furthermore, SCGs contain a large number of pigments, especially tannins which are the most important components in dyeing wool and cotton to brown shades color (Janani et al., 2014). Moreover, a study was performed examining the feasibility of dyeing fabrics with SCGs and showing that utilizing spent coffee as a dyeing material is not only viable but also yields durable results. This approach not only imparts color to textiles but also introduces supplementary functionalities to the apparel.

[redacted] Bottoli[22], a wool manufacturing facility situated in the province of Treviso (Veneto, Italy), has engaged in a strategic collaboration with [redacted]t[23] to elevate the sustainability of its esteemed apparel dyeing processes. In an interview with [redacted] some key aspects of this collaboration emerged[24]. Within this partnership, [redacted] systematically collects spent coffee from its cafeterias (about 200 kg) and donates them to [redacted] who subsequently harnessed them in an innovative dyeing method for their fabrics. The richness and vibrancy of the resultant colors are linked to the quantity of SCGs used in the dyeing process. This cooperative endeavor not only underscores a distinctly Italian initiative, given the shared origin of both companies but also underscores their mutual dedication to sustainable practices. Especially in the promotion of CE and the reduction of chemical dyeing agents. Furthermore, it emphasizes the importance of local partnerships in advancing environmental responsibility. Beyond geographical proximity –both are located in Treviso–, this collaboration can be identified as an IS marked by shared resources, knowledge exchange, and a collective commitment to sustainable innovation.
Figure 25 illustrates the process of dyeing fabrics with SCGs-based materials.

Figure 25: Process of dyeing fabrics with materials based on SCGs



Source: Own elaboration

After a thorough literature review that identified several application sectors and specific applications for SCGs, the focus was on presenting representative real-world examples for each category. This selection of examples is intended to illustrate the diversity and breadth of applications within each sector. It is evident from the analysis that certain areas present more

[redacted]

Respondent's position	Method	Date
Head of Administration	Asynchronous interview	01/01/2024

straightforward opportunities for employing coffee grounds in valorization, while others involve a more onerous process. Consequently, Table 11 aims to summarize these examples, showcasing the sector in the first column, the specific application in the second column, the case studies in the third column, and, finally, in the fourth column, providing a personal assessment of the perceived complexity in employing them for valorization. This is categorized as follows:

- Low complexity: Signifying that coffee grounds require minimal processing for valorization.
- Moderate complexity: Involving some degree of processing, yet still feasible on a large scale.
- High complexity: Requiring conformity to standards that may not always be applicable and can impede the application.

Table 11: Summary of the applications examples analyzed

Sector	**Specific application**	**Case studies**	**Complexity**
Energy	Biogas	-[redacted] Distribuzione Automatica	Low complexity
Materials	SCGs-based materials	-Coffeefrom, -Co.ffee Era	Moderate complexity
Agricultural	Growth of mushrooms	-Funghi Espresso, -Fungo Box	Moderate complexity
Cosmetic	Scrub and exfoliant	-UpCircle	High complexity
Textile and Apparel	Dyeing fabric	-[redacted] Bottoli	Moderate complexity

Source: Own elaboration

4.2.3 General Discussion of Benefits and Challenges in Using SCGs

The findings previously presented have emerged from the analysis of the articles within the sample. This enables the exploration of the benefits and criticalities of these applications for the valorization

of SCGs and facilitates the identification of the feasible options that Riviera Distributori can consider; these will be subsequently analyzed from a critical perspective.

First and foremost, it is crucial to enumerate the potential general advantages that any of the aforementioned applications in the energy, materials, agricultural, cosmetics, and textile and apparel sectors can offer. While there are benefits specific to each industrial application, they can still be categorized within these major domains. Nevertheless, these specifications will be clarified in subsequent explanations.

The examined implementation examples across various sectors consistently demonstrate the potential advancement of IS through the valorization of waste within supply chains. The use of by-products as raw materials in another, different, supply chain exemplifies a tangible manifestation of circularity. Furthermore, the sharing of knowledge and resources contributes to the establishment of symbiotic relationships. Despite this, geographical proximity or distance emerged as a key consideration when deciding on symbiosis.

Another common benefit showcased by all the applications examined is the reduction of SCGs in landfills. Although at different levels, all applications divert a significant amount of SCGs from landfills. Consequently, the implementation of waste management practices transforms these waste materials into valuable resources.

Connected to sustainable waste management practices is the benefit of cost saving in disposal. This implies that the implementation of efficient recycling or reutilizing processes for SCGs' valorization results in lower costs related to waste disposal. Once something becomes waste, it incurs a disposal cost. The money saved can be reinvested to enhance the circularity implementation process.

Furthermore, always from an economic perspective, it is important to note that coffee grounds are mostly donated by those who produce them to those who valorize and repurpose them. However, it can be expected that in the future they will be sold due to the potential profitability associated with their use.

Coffee grounds possess a significant calorific value, denoting the potential for deriving substantial energy through their valorization in the appropriate facilities along with the transformation into pellets. It is estimated that pellets crafted from coffee grounds exhibit a greater heating capacity compared to traditional wood-based pellets.

Furthermore, there are opportunities to save on emissions. For instance, in the energy sector, producing energy in a biogas plant allows savings in CO_2 emissions. Additionally, sustainable means of transportation can be employed in SCGs collecting activities, as highlighted by Fungo Box and Funghi Espresso. Suppliers are chosen based on their proximity to facilities, a practice also

observed in UpCircle, a pioneer in the cosmetic industry. [redacted], both located in Veneto, also exemplify the importance of geographic proximity in establishing beneficial relationships.

Moreover, subjecting coffee powder to high-temperature brewing enables the pasteurization of the SCGs, leading to significant energy savings. However, it is essential to point out that the advantages of pasteurization are contingent upon the timely collection and rapid drying of SCGs. Prolonged intervals during the collection process elevate the risk of contamination and the potential development of fungi or mold. For example, in the cosmetics industry, the selection of raw materials is governed by strict cleaning and purification standards. If SCGs suffer contamination and harbor mold or fungi during the collecting process, they become ineligible for use in cosmetic formulations (Kovalcik et al., 2018). Hence, limitations within this range of applications can manifest in various ways.

Before going on discussing the limitations, it is fundamental to highlight the fact that, despite the initial utilization of coffee grounds in a specific application such as the growth of mushrooms or the conversion of energy, if they produce by-products in the process, they can find purpose in an alternative manner like soil fertilizers, thereby facilitating a complete reuse of resources, amounting to 100%, fostering the implementation of circular practices and the development of symbiotic relationships.

Several challenges or critical issues can arise when valorizing SCGs. In addition to adhering to cleaning standards for SCGs –particularly in the context of cosmetic product formulation–, a pivotal consideration concerns the required volume of coffee waste per specific application. While this concern remains relatively unnoticeable within the energy sector –as exemplified by the conversion of spent coffee into energy through biogas plants– it takes on increased significance when contemplating the specific transformation of by-products into, for instance, pellets. The issue of quantity surfaces in almost all the scenarios of processing SCGs discussed in the previous sections. Quantity issues appear to be primarily focused on insufficient by-products in most cases. Hence, it becomes evident that the collection of coffee grounds should not be restricted to a singular activity (i.e., bar, cafeteria, restaurant) but extends across multiple activities. Across the diverse examples presented, the SCGs collecting activities are a widespread practice that includes more bars, cafeterias, and so on, with the exception being instances involving suppliers capable of providing substantial quantities alone, such as [redacted] –although they collect spent coffee in many [redacted] venues.

Despite the possibility of creating favorable conditions for the implementation of IS, and respecting

among the key principles the one of proximity, a hurdle that needs to be overcome can emerge: the costs associated with the transfer of SCGs from the place of production to the valorization sites. With a view to local-scale implementation (i.e., selected neighborhood), it is easy to identify low-impact transportation solutions that often involve low costs. However, in situations where the production and valorization locations for spent coffee are distant, the logistical costs associated with transporting these residues must be taken into account. Thus, the situation can have several consequences. On one hand, the management of such costs can be smooth, enabling efficient recovery. On the contrary, circumstances can arise where such costs are high, making the successful implementation of various applications complicated. Therefore, it is critical to conduct a careful selection of coffee grounds suppliers, taking into consideration various factors, including the actual distance between the two locations.

Different scenarios of application have emerged within the materials industry, primarily based on the incorporation of SCGs into polymers, endowing them with biodegradable and sustainable properties. However, this integration is an innovative path for sure, but hinders some problems, as the infusion of SCGs renders polymers more fragile, thereby precluding their use in various products (McNutt, 2019). Despite that, in many cases, it appears to enhance the mechanical properties of the resulting material. Extensive research within the eyewear sector, for instance, proved unsuccessful, with the new material failing to meet the industry's stringent standards. Consequently, a definitive conclusion was reached, indicating that SCGs-infused polymers are unsuitable for wearable products, excluding clothing from the analysis.
It is imperative to note that the polymer composition cannot be exclusively composed of SCGs; rather, only a percentage incorporates these grounds. This strategic formulation has, nonetheless, paved the way for the success of SCGs-based materials in alternative applications, particularly in the domain of design products as discussed before (Kovalcik et al., 2018).

Table 12: General benefits and criticalities of the applications analyzed

Benefits	**Criticalities**
> Implementation of IS > Waste Reduction > High Heat Value > Cost Savings > Lower Pollution > Energy Savings	> Cleaning and Purification Standards > Variability in the Quantity of SCGs > Logistic costs of SCGs > Variability in the Strength of SCGs-based Materials

Source: Own elaboration

To conclude, the use of coffee grounds in different sectors shows significant potential to deliver environmental, economic, and innovative benefits. The sustainable approach of reusing SCGs as an energy resource, composite material, fertilizer, cosmetic ingredient, and natural textile dye offers a promising prospect for resource management and waste reduction. Most importantly, highlighting reduced pollution and lower disposal costs. However, it is critical to carefully consider the associated challenges, including the variability in the availability level of SCGs, storage procedures, and differences in strength of SCGs-based materials. Balancing the benefits and criticalities will be essential in determining the long-term effectiveness and sustainability of using coffee grounds in the various applications presented. Further insights and investment in R&D are crucial to maximize the benefits and address the challenges, paving the way for wider and more efficient use of SCGs in the various areas mentioned.

4.2.4 Limitations of the Study

Despite the efforts made to do a comprehensive investigation and the adoption of a recognized method, the analysis presents some limitations. First of all, the limited availability of literature on the topic represents a first hurdle; however, it was possible to identify the main sectors for SCGs' valorization. Nonetheless, some of them have been excluded due to the poor base of research and the lack of practical applications in companies or similar entities. Furthermore, despite filtering the

articles by the category “Business, Management, and Accounting”, the explanations provided were limited in recognizing the economic benefits of these applications due to their chemical nature. Thus, this hinders the possibility of making overarching conclusions derived from this study. However, it is imperative to highlight that this review was deliberately structured to prioritize the exploration of the potential portfolio of solutions for Riviera Distributori. Subsequently, with the goal to identify the most suitable solution for their specific needs. Another limitation arises from the fact that in the example sought in the gray literature for supporting the studies, there is no exact data. This circumstance can be attributed to the impossibility of accessing sensitive and detailed data of the companies investigated.

The topic of Spent Coffee Grounds valorization is recognized as an emerging and still in the developmental phase theme. This research emphasizes the growing interest in SCGs practices intending to implement CE.

4.3 Towards SCGs Valorization in Riviera Distributori: General Strategic Options

After identifying the potential applications of SCGs and understanding their various benefits and limitations, it is possible to draw conclusions about the potential solution that can provide the greatest strategic value to Riviera Distributori. The following assessment takes as a starting point various experiments conducted by the company to valorize coffee grounds in 2022, unfortunately yielding negative results. The table on the next page presents the series of experiments, who they contacted, and delineates the reasons that stopped the implementation based on specific peculiarities of the company.

Table 13: Riviera Distributori experiments on SCGs

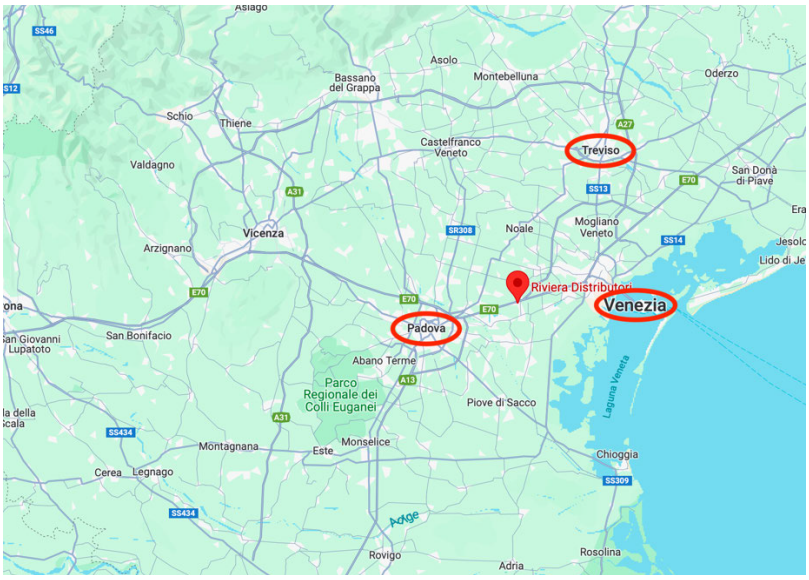
	Sector	Contact	Type of application	Constraints related to the company
1.	Energy	Experts	Coffee pellets	From an economic point of view, the operation was deemed unsustainable due to the need to market pellets at a significantly higher price than the market average
2.	Agricultural	Farm in the Venezia area	Compost/Fertilizer	The amount of coffee grounds proposed exceeds the needs of the farm
3.	Agricultural	Fertilizer company in the Venezia area	Compost/Fertilizer	The amount of coffee grounds proposed was insufficient according to the needs of the company
4.	Agricultural	Gardener of a town near Venezia	Found a start-up to grow mushrooms	The absence of expertise, combined with insufficient external support, restricts the availability of resources required to establish a specialized R&D office to oversee a project of this type
5.	Cosmetic	Cosmetic company in the Veneto region	Cosmetic line with SCGs	Strict health regulations prohibit the use of mold and bacteria-contaminated products, even if they are harvested weekly

Source: Own elaboration based on the interview with Riviera Distributori

Based on the information gathered during the interview with Riviera Distributori's Administrative Officer, it appears that the amount of available SCGs was a significant challenge, as shown in the table above. Three out of five experiments highlight this issue.

At this stage, having comprehended the barriers encountered by Riviera Distributori in valorizing SCGs, in order to formulate a solution more closely aligned with reality and trying to avoid quantity constraints, a database obtained from AIDA was utilized. This database encompasses companies identified by the ATECO 2007 code: 47.99.20, titled "*Trade carried out by means of automatic vending machines*[25]". From the database results 48 companies trading through vending machines in the Veneto region. Subsequently, the analysis was limited to three provinces in the region, using as a starting point the location of Riviera Distributori in Venezia and then looking for the nearby provinces which result being Padova and Treviso as can be seen in the Figure below; the selected provinces are the one in the red circle. Thus, sustaining one of the fundamental principles of IS: proximity, as demonstrated by the reviewed examples. The filtering according to three provinces reduced the number to 20; moreover, the small sample size allowed for a quick investigation of their websites to determine if they had coffee vending machines. Out of the 20 companies found, two were excluded as they dealt with products different from coffee, despite operating in the vending machines trade. Hence, the final sample is constituted of 18 coffee vending machines companies distributed in Venezia, Padova, and Treviso, including Riviera Distributori.

Figure 26: Selection of provinces according to geographical proximity



Source: https://www.rivieradistributori.com/

In order to understand the better solution, it is necessary to have a look at the data of Riviera Distributori. Each year Riviera Distributori produces approximately 4.800-5.200 kg of coffee grounds. This estimate was obtained based on a yearly average purchase of approximately 8.000 kg

[25] Commercio effettuato per mezzo di distributori automatici

of coffee beans from the company. The studies analyzed show that for every 1.000 kg of coffee, 600 to 650 kg of grounds are produced after brewing (Janissen & Huynh, 2018). Therefore, by multiplying this ratio by eight, it was possible to estimate a range of 4.800 to 5.200 kg of SCGs. To simplify the discussion, the average of this range was taken as 5.000 kg. For the purposes of this study, the companies in the sample, while varying in size, were considered equivalent to Riviera Distributori in terms of production capacity, each with an annual potential of 5.000 kg of coffee grounds –this can turn out as a downward estimate. This approach results in a cumulative production of 90.000 kg of coffee grounds for the entire sample, around 90 tons per year, cautious forecast.

The following paragraphs will delve into discussing the option that, after considering all these premises, Rivera Distributori, and more generally, the 18 vending machine companies, can collectively consider. The order in which potential solutions are presented is determined based on an estimate of success in application in this particular area of the Veneto region, from the most likely to succeed to less likely to succeed.

Option 1: Applications in the energy sector - biogas plants

According to the results from the review and the experiments of Riviera Distributori, the valorization of SCGs in the energetic sector can be a practicable alternative. In the case of coordination between the 18 companies of the sample, the production of coffee pellets seems to be a feasible option in collaboration with a specialized business or by setting up a novel corporate entity. The foundation of a start-up, as thought by Riviera Distributori, shows to be a feasible option but the creation of a start-up requires additional investments, and it is uncertain whether they will be recovered. In this case, the uncertainty is of a higher level compared to applications in the materials or agricultural sector. Instead, the collection of SCGs from the vending machines, the subsequent stocking in big bags, and then sending them to biogas plants to produce energy and soil fertilizers with the by-products of the process, this combined solution seems to be a plausible one.

In the Veneto area, there are several biogas facilities, including the ones belonging to waste management companies and agricultural enterprises. Biogas plants are pretty much uniformly distributed in the Region, enhancing the creation of an IS Network. The synergy between the companies, based on the forecasts of a collection of 90 tons of SCGs –according to the data analyzed–, permits the production of around 55.000 KWhe[26] (time frame not specified).

[26] The relationship between 40 tons and 25.000 kWhe (See table 10) is proportionally equivalent to that of 90 tons and x, expressed as $x = \frac{25.000\ KWhe * 90\ tons}{40\ tons} \rightarrow x = 56.250$ KWhe that for facilitate the discussion has been approximated to 55.000 KWhe

Leveraging on biogas facilities for the production of energy can drive multiple benefits. Starting by diverting SCGs from landfills, otherwise, as time goes by, the natural decomposition of such organic waste in landfills can produce methane (Campos-Vega et al., 2015), a potent greenhouse gas. The production of energy from SCGs in biogas facilities per se reduces the amount of CO_2 emissions. As discussed at the beginning of this chapter, Riviera Distributori is a CO_2 free company; hence, this will reinforce its sustainability company image. The production of soil fertilizers from the by-products encapsulates the essence of a circular supply chain by closing the loop. Moreover, from an economic point of view, the disposal costs, which can be huge, are avoided or significantly reduced. Biogas plants can generate revenue for vending machine companies through the production of energy from SCGs that can be sold to the electricity grid or used internally in headquarters to reduce energy costs.

Option 2: Applications in the textile sector - dyeing fabrics

Another option that should be considered is the textile sector. Riviera Distributori did not consider this sector during its multiple experiments in 2022. However, in the Veneto production landscape, particularly in the selected area, numerous textile companies stand out, with some employing dyeing methods that can be interested in incorporating coffee grounds as a dyeing agent. Selected companies already use other by-products of the food industry, such as pomegranate peels and onion peels, for similar purposes. Generally, all textile companies can adopt this innovative dyeing technique. Following the example set by [redacted] in collaboration with [redacted] this application appears feasible. As in the other options, it is important to develop and adopt an efficient plan for collecting and transporting spent coffee. Afterward, individual textile companies would be responsible for the fabric dyeing process. This partnership is characterized by geographical proximity, the promotion of innovation through novel dyeing techniques, the avoidance of disposal costs, and the reduction of environmental impact facilitates the establishment of an IS network.
In order to guarantee the success of this application and collaboration, textile companies must demonstrate a clear interest in obtaining coffee grounds to be used as a coloring agent. However, the use of food waste as a raw material significantly reduces the overall amount of waste –including SCGs– that ends up in landfills; thus, contributing to the reduction of emissions generated over time. By diverting this waste from the landfill, companies can reduce their disposal costs; moreover, over time, as collaboration strengthens, it is conceivable that coffee grounds may no longer be donated (this is the case of the collaboration between [redacted] and [redacted] instead, companies might shift to selling their coffee grounds and profit from the sale of spent coffee.

Option 3: The use of matchmaking platforms – becoming a circular supplier

Another strategic perspective to consider is the use of matchmaking platforms as intermediaries for industrial by-products or waste, such as coffee grounds, to be purchased as raw materials by other actors. These platforms promote new collaborative partnerships, fostering the circularity of the economy through the creation of IS networks. Thanks to these platforms, companies can take a step forward in closing the supply chain and valorizing by-products that, in landfills, would have created pollution. On matchmaking platforms, suppliers indicate their geographical location; thus, companies can operate in adherence to the proximity principle that characterizes IS. Moreover, for suppliers of such by-products, this practice can result in a twofold advantage. On one hand, it results in savings on disposal costs. On the other hand, it represents an opportunity to generate profits through the exchange process on these specific platforms. In this circumstance, companies that place their by-products in the platform do not have to worry about the subsequent management of these materials and to find the right partner. If companies use platforms like *Circularity*, they only need to register the types of by-products they have and wait for the platform to match them with entities interested in utilizing them. Additionally, they do not need to worry about transportation since the platform connects them with a company available for transporting the by-products. Their responsibility is limited to a simple business transaction to gain economic benefit and contribute to value creation through the alternative reuse of materials otherwise sent to landfills. The downside associated with this option is the time-consuming nature of the process to find the right partnership. This is due to the challenge of accurately estimating the duration, which can lead to the degradation of the spent coffee and the loss of its intrinsic properties for some applications.

Option 4: Applications in the agricultural sector - growth of mushrooms and fertilizers production

Looking at the experiments done by Riviera Distributori, going on for agricultural applications can be feasible in the east area of the Veneto region thanks to the presence of several farmers. Despite the complications underlined during the interview about the quantity, this is still a problem for sure, because if the level of SCGs produced by one company was excessive, then the amount of coffee grounds produced by almost twenty companies would exceed their needs too. However, it is important to note that this was a consideration based on the opinion of only one farmer. A potential solution would be for the 18 vending machine companies to establish relationships with more farmers in their areas in order to sell the SCGs to a larger portfolio of farmers. The latter can be feasible, but it is important to note that coffee-based fertilizer cannot be used in all crops as highlighted by Kourmentza et al. (2018).

Furthermore, considering the partnership between the firms, selling the SCGs to fertilizer companies can offer a viable alternative, the quantity is higher, and they can provide an eco-friendly solution to their clients. In both cases –sell the SCGs to farmers and/or fertilizer companies–, there is an economic advantage of generating revenue from the selling and, at the same time, avoiding waste disposal costs. Nevertheless, it is crucial to develop a well-defined collection and transportation plan for SCGs to minimize emissions and costs of delivery. These economic benefits and the need for a collection and transportation plan characterized all the possible options. Although, in certain circumstances, substantial investments are required such as setting up a start-up committed to preparing and selling mushroom growing kits from SCGs or the foundation of a separate corporate entity. From the interview with Riviera Distributori emerged that for this type of solution, an investment in an R&D team is crucial. Even though the financial burden associated with creating an R&D division, in the case of the companies together, can be distributed. In the team are required sector specialists who know how to effectively utilize SCGs in this particular application. These specialists often operate outside the area of vending machine companies, manifesting the requirement for a higher investment and more time to individuate them. In terms of SCGs' quantity, it should be noted that a mushroom kit from Funghi Espresso or Fungo Box typically weighs around 1,5 kg concerning SCGs. Considering that the 18 companies collectively generate approximately 90.000 kg of SCGs, they have the potential to produce around 60.000[27] mushroom kits. In this context, it appears that quantity is not a limiting factor. Nevertheless, the expenses associated with the production of these boxes may pose a potential challenge; however, these costs may be recuperated through subsequent sales. Despite obstacles that can undermine the effectiveness of this application, the use of food waste as an input offers significant advantages in overcoming a critical issue: the disposal of organic waste –especially waste that can have harmful consequences on the environment. Coffee grounds, among the most common wastes, can be used in this process to reduce the amount going to landfills; thus, resulting in mitigation of emissions generated over time from spent coffee. Once the mushrooms have been harvested, if a second harvest is not possible, the remaining contents of the box can be used as fertilizer. From an economic perspective, the implementation of this practice would result in a reduction of disposal costs and –as mentioned earlier– can generate revenue through the sale of the by-products in an innovative way.

[27] 90.000 kg of SCGs; 1,5 kg per kit $\rightarrow \frac{90.000\ kg}{1{,}5\ kg} = 60.000\ kits$

Option 5: Applications in the materials sector - SCGs-based material

Certain scenarios necessitate substantial investments such as in the establishment of a start-up dedicated to manufacturing products with SCGs-based material; this is another field in which Riviera Distributori did not do any experiments. The production of SCGs-based materials requires specific expertise and preliminary investment, particularly in establishing a dedicated R&D division. One potentially successful strategy can be to create a corporate entity separate from vending machine companies. Then, vending companies can entrust the coffee grounds collected from vending machines to this entity. At this stage, it would be appropriate to engage professionals who specialize in creating innovative materials and conducting experiments to develop products based on polymers derived from SCGs. If well managed, the investment can be profitable in the long run. However, another challenge that needs to be addressed in the case of the materials industry is quantity –the principal issue. Companies like Coffefrom claim to collect 200 tons of spent coffee yearly, and the SCGs usage projections of these companies together are 90 tons yearly. So, less than half, and it would still come back to the problem of uncertainty about the recovery of the investment made.

Option 6: Applications in the cosmetics industry

Valorizing coffee grounds within the cosmetics industry can be challenging without implementing a daily collecting process in the vending businesses –if the premises were different, as in the case of UpCircle, it would have been possible, given that the economic structure of the Veneto region includes several cosmetics companies.
Different premises like daily transportation with low environmental impact and suitable storage facilities to meet the strict industry standards for safety are crucial to be considered. However, no feedback was received regarding cosmetics companies in the Veneto Region that use spent coffee in beauty products. Thus, from the point of view of the Veneto market structure, it seems feasible; despite that, from the point of view of the raw material and the required standards, it is not feasible. Hence, the cosmetics industry in this assessment has been excluded a priori due to the low likelihood of success.

In conclusion, the analysis of the various alternatives for valorizing coffee grounds within the operational scope of Riviera Distributori - and, more generally, of the vending companies in the selected area of the Veneto region - provides an exhaustive overview of the opportunities and challenges associated with this process, given the quantities involved (yearly: 5.000 kg for one company; 90.000 kg for all 18 companies). The appropriate strategy should be selected through a

comprehensive analysis, considering various factors such as available resources, synergies with other business activities, as well as economic and environmental considerations. Additionally, the ultimate decision should not only take into account the available resources and business objectives, but also carefully consider the development and implementation of the most efficient collection and transportation plan from the coffee grounds collection points to the processing plant, both in terms of costs and sustainability. The selection of the specific areas of Venezia, Padova, and Treviso for the analysis and consequent choice is critical due to proximity, which leads to lower costs and reduced emissions compared to other areas in the Veneto region. Based on the analysis performed and the assumptions made, *options 1*, *2,* and *3* appear to be the most likely to succeed in the short run, while *options 4* and *5* can show a higher rate of success in the long run. *Option 6* is less likely to succeed unless there are changes and the implementation of an efficient collection and delivery method. This is only a preliminary assessment that does not considered all the factors of success or failure. Thus, the valorization of SCGs presents interesting opportunities to improve the environmental and economic sustainability of Riviera Distributori and other vending companies in the selected Veneto area. This would contribute significantly to reducing the overall environmental impact and generating added value under the CE principles.

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