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SCG Analyzer: A web platform that strengthens the use of Spent Coffee Grounds as potential renewable source of green energy for pellet production

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled **SCG Analyzer: A web platform that strengthens the use of Spent Coffee Grounds as potential renewable source of green energy for pellet production** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague, 22.04.2023

……………………………

Oscar René Montano Ramírez

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Abstract

The industrialization and commercialization of coffee produce a huge amount of waste around the world, much of this waste is Spent Coffee Grounds (SCG) which ends up in landfills contaminating the environment. SCGs contain great energy potential as a solid fuel. The literature on the use of SCG as solid fuel more specifically SCG-based pellets is extensive, however, depending on the objectives of the study, some aspects and/or key characteristics of these are examined and others are not, with no reference framework stablished specifically for SCG-based pellets. Through this study, a bibliographic search and summarization of the current information was carried out, thus, the values reported for each of the main characteristics of the SCG-based pellets have been collected, and the average/standard values were found out. According to the calculations, the standardized characteristics of SCG-based pellets are: Initial moisture content (IMC) 57.08 % (wet basis), Optimal moisture content (OMC) 10.53 % (wet basis), Net calorific value (NCV) 16.66 MJ kg^{-1} (wet basis), Net calorific value (NCV) 20.33 MJ kg^{-1} (dry basis), Gross calorific value (GCV) 24.79 MJ kg^{-1} (dry basis), Mechanical durability 76.23 %, Bulk Density (BD) 909.25 kg m^3 (wet basis), Ash content 1.71 % (dry basis), Economic value 0.12 EUR kg^{-1} and the dimensions as 15 mm long, 8 mm in diameter. In this study, the hypothesis was raised that the SCG-based fuel pellets were comparable to those made of wood-based, with the results obtained in the reference framework, it is concluded and confirmed the hypothesis that the energy potential contained in the SCG-based fuel pellets is comparable with those of wood-based according to the standard established by The British Standards Institution (2014). With the established frame of reference, this study created a web platform (https://scg-analizer.info) seeking to help calculating the energy potential contained in a specific amount of SCG in order to provide a broader picture of their use as a renewable energy resource, in addition to facilitating access to information, which could be useful for different target groups.

Key words: coffee residues, waste biomass, solid biofuels, waste-to-energy, web application, fuel-energy properties, energy potential calculator.

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List of the abbreviations used in the thesis.

SCG – Spent coffee grounds.

CS – Coffee silver skin.

DF – Dietary fibre.

SDF – Soluble dietary fibre.

TP – Thermal power.

CPC – Coffee parchment.

GHG – Greenhouse gas.

COD – Chemical oxygen demand.

CV – Calorific value.

GCV – Gross calorific value.

NCV – Net calorific value.

BD – Bulk density.

MC – Moisture content.

IMC – Initial moisture content.

OMC – Optimal moisture content.

WSCG – Wet spent coffee grounds.

DSCG – Dry spent coffee grounds.

RES – Renewable Energy Sources

wb. – Wet basis

db. – Dry basis

1. Introduction and Literature Review

1.1. Introduction

Given the growing problem about the depletion, use and exploitation of fossil fuels, the use of renewable energies such as biomass represents a viable energy resource in the future, being this one of the main resources available to satisfy the energy demand that year after year is increasing worldwide (Larson & Kartha 2000).

Coffee is one of the most traded commodities in the world, the industrialization and commercialization of coffee produce a huge amount of waste around the world and much of this waste is in form of Spent Coffee Grounds (SCG) which normally ends up in landfills contaminating the environment. SCG residues contain great energy potential as a biomass solid fuel (Atabani et al. 2022b). The literature on the use of SCG as fuel source is extensive but being more specific for the production of SCG-based pellets for heating generation is still large but depending on the objectives of the studies, some aspects and/or key characteristics are examined and others are not, with no reference framework stablished specifically for SCG-based pellets this master thesis aimed to summarize all the reported values for the key characteristics of the SCG-based fuel pellets and stablish a reference framework in order to be able to give a broader picture of their energy potential.

The use of digital technologies, such as web platforms, in order to exchange or access to information can contribute to improving agricultural practices with direct effects on productivity, calculation of production costs and risks, among others. The information accessed through digital channels represents a source of knowledge that can help to be able to learn and apply new practices, that are sustainable and moreover contribute to reducing the impact of these agricultural and industrial practices on the environment (Hidalgo et al. 2023).

Being coffee the third most consumed beverage in the world, its consumption is increasing together with the population worldwide, and so the residues generated by its production and commercialization (FAO 2021). Establishing reference values based on the available literature regarding to the key characteristics of the fuel pellets based on the residues produced by the industrialization of coffee, more specifically the Spent Coffee Grounds (SCG) settled the bases for the creation of the proposed web platform by this study. The web platform sought to represent in a dynamic and precise way the potential contained in the residues generated by the commercialization of coffee, being not only an easily accessible source of information but also a point of reference for future research on the use of SCG as solid fuels. This study is a theoretical and technical approach that helps to calculate and visualize the energy potential contained in the SCG-based fuel pellets.

1.2. Literature review

Energy sources have been a constant topic of debate in relation to human development, until the last few decades fossil fuels such as coal, oil and natural gas have played and continue to play an important role in the global energy system (Ritchie et al. 2022). Thanks to technological developments in recent years, there are many ways in which the energy around us can be stored for our benefit. Understanding how and finding sustainable, non-perishable energy sources is a constant challenge. Energy resources have been categorised into 2 groups: Non-Renewable and Renewable sources (Rosen & Farsi 2022).

Fossil fuels are mostly used for heat and power generation, and as fuel for means of transport, contributing to around 80.00 % of the Greenhouse Gas (GHG) emissions produced globally (Antar et al. 2021). The world's population currently stands at approximately 8.05 billion; according to data recorded by (www.macrotrends.net 2022) the last 5 years the population increase is maintained at an average of 0.89 % each year, it is estimated that by 2040 the world population could reach up to a total of 9.20 billion inhabitants, and in parallel with the increase in population, the demand for energy increases.

With Global Warming being one of the greatest threats facing modern man, the substitution of fossil fuels as the main source of energy is crucial. The emission of GHG due to the consumption of fossil fuels and their non-renewable character encourage and promote the search for new sources of clean and renewable energy (Bonilla-Hermosa et al. 2014). Investment in Renewable Energy types such as biomass is gaining importance as a solution to combat Global Warming and ensure a clean alternative energy source.

Biomass is one of the largest Renewable Energy Sources (RES) today (Rosen & Farsi 2022), its use has gained special interest in recent years due to the increasing depletion of conventional fossil fuels and global warming.

1.2.1. Biomass characterisation

Biomass is the oldest primary energy source used by humans as it is mostly unprocessed and naturally occurring in the environment. Biomass refers to all organic material existing in the biosphere based on plants, this material can be obtained from crop residues, forest residues, grasses and/or algae grown for this purpose, firewood farms, urban waste such as wood and/or food waste and animal waste (U.S. Department of Energy 2016), in addition to any organic material obtained by a natural or artificial process (Perea-Moreno et al. 2019).

Biomass is also defined by the United Nations Framework Convention on Climate Change (UNFCCC 2005) as:

"(a) Non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. This shall also include products, by-products, residues and waste from agriculture, forestry and related industries as well as the non-fossilized and biodegradable organic fractions of industrial and municipal wastes. Biomass also includes gases and liquids recovered from the decomposition of non-fossilized and biodegradable organic material."

The main process by which biomass is formed is through photosynthesis, defined by Pérez & Carril (2009) as: "*Physicochemical process by which plants, algae and photosynthetic bacteria use the energy of sunlight to synthesis organic compounds*", where plants, by means of such an electro-chemical process, capture and store the carbon contained in the CO_2 in the air. It is important to mention that the outstanding characteristic of biomass is that the raw materials consumed such as carbon, hydrogen, nitrogen, potassium and phosphorus, as well as the energy from photosynthesis, are renewable (Rodríguez Valencia et al. 2010).

According to the European Committee for Standardization, biomass can be classified by the variety of resources it comes from, identifying 2 main groups, as shown in Table 1 (Basu 2013).

Table 1: Biomass main groups and their subdivisions. Source: (Basu 2013)

Group	Origin	Subclasiffication
A. Virgin Biomass	A.1 Terrestrial Biomass	1. Forest Biomass 2. Grasses 3. Energy Crops 4. Cultivated Crops
	A.2 Aquatic Biomass	1. Algae 2. Water plant
B. Waste Biomass	B.1 Municipal waste	1. Municipal Solid Waste 2. Biosolids, sewage 3. Landfill gas
	B.2 Agricultural solid waste	1. Livestock and manures 2. Agricultural crop residue
	B.3 Forestry residues	1. Bark, elaves, floor residues
	B.4 Industrial Waste	1. Demolition Wood, sawdust 2. Waste oil/fat

Biomass can be considered as the most viable option to supply and secure energy demand in the future. Biomass accounts for between 3.00 % and 4.00 % of energy production in industrialized countries (Larson & Kartha 2000), however, the rural population in developing countries, which represents about 50.00 % of the world population, relies on biomass as an energy source, raising the use of it as a primary energy source to 14.00 % worldwide (Demirbas 2000).

Biomass utilization can be categorized into four different groups of processes: utilization through direct combustion (burning) processes, thermochemical processes (conversion to produce solid, gaseous and liquid fuels), chemical processes (conversion to produce liquid fuels) and biological processes (conversion to produce gaseous and liquid fuels). The first category being the most widely used worldwide to convert biomass into useful energy (U.S. Energy Information Administration 2022).

1.2.2. Coffee as biomass resource

The genus *Coffea* spp. (Coffee) belonging to the kingdom *Plantae* from *Rubiaceae* family being a group of “photosynthesizers” they store energy and convert it into organic material, thus representing a viable and renewable energy source (Pallardy 2008; Nigam & Singh 2014; Massaya et al. 2019). Depending on the waste obtained it can be classified as “Terrestrial biomass”, “Municipal waste”, “Agricultural solid waste” or “Industrial waste” according to the classification of biomass shown above in Table 1.

Coffee is the third most consumed beverage in the world, only after water and tea and one of the most highly traded products globally. The coffee market is growing due to an increase in consumption thanks to interest in specialty coffee and product innovation in developed countries (FAO 2021).

According to the United States Department of Agriculture (2022) and Sybil Agri International (2022), global coffee production for the period 2022/23 was estimated at 172.80 million 60.00 kg bags, resulting in a global total of 10.37 billion kilograms. The most common and widely cultivated coffee species in the world are *Coffea arabica* and *Coffea canephora* known as Arabica and Robusta coffee, respectively (Hamdouche et al. 2016). Coffee trees grow in the tropics, mainly in the tropics between Cancer and Capricorn, with abundant rainfall, warm temperate climate (average temperature 21 °C) and a mean altitude of 2000 m sea level and above. Coffee trees take about 5 years to reach their first full harvest and their productivity reaches about 15 years (Nigam & Singh 2014).

Arabica and Robusta are traded globally, with Arabica accounting for about 60.00 % of the coffee traded on the international market (Suarez Agudelo & Cardona Jaramillo 2012). Arabica is an autogamous specie, meaning that it is self-pollinating (Krug & Carvalho 1951). The Arabica variety is the most predominant variety produced throughout all over the world representing the 75.00 % of the coffee produced and the subject of this study (Dattatraya Saratale et al. 2020).

1.2.3. Morphological structure of the coffee fruit

This section presents the morphological structure of the coffee fruit, in order to visually understand how it is constituted and from which part the residues that are obtained with the drying process come from see Figure 1 and Figure 2.

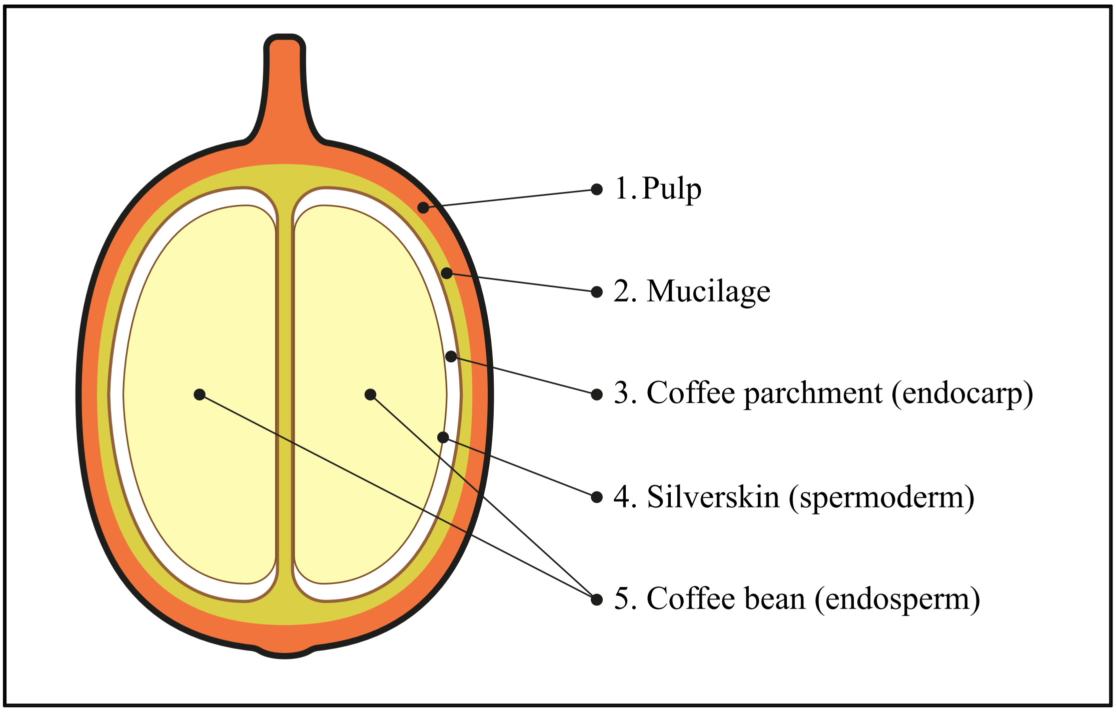

Figure 1: Morphological structure of the coffee fruit.

Cross-sectional view of a coffee bean

Source: (Bhushan et al. 2003) **Illustration:** by the Author

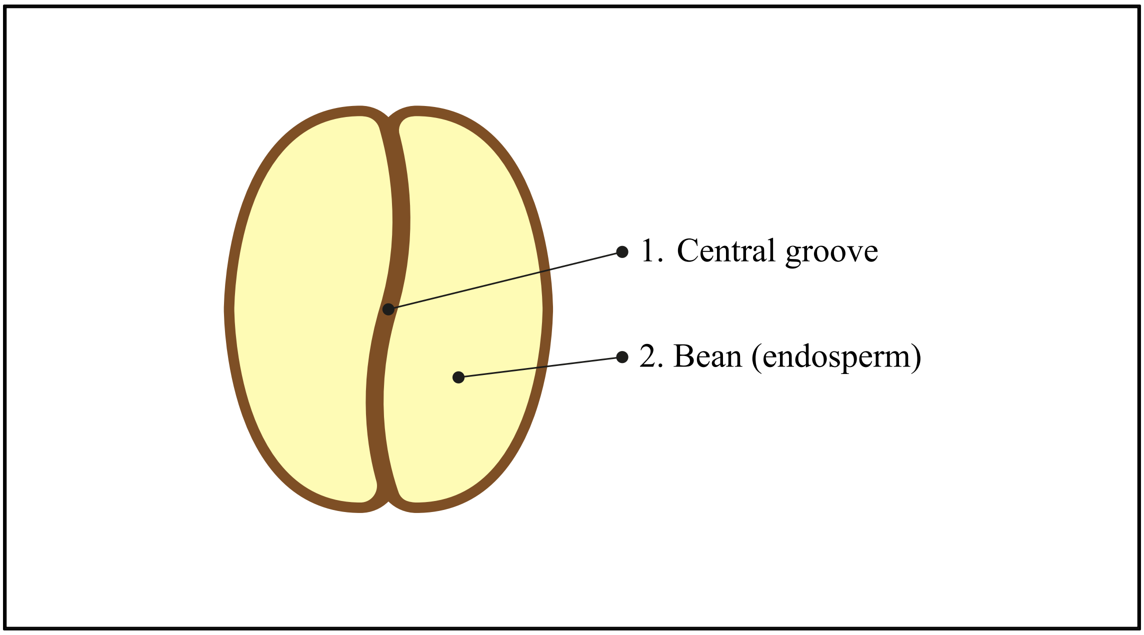

Figure 2: Structure of the coffee seed.

Inside-up view of a coffee bean seed showing central groove-embedded

Source: (Bhushan et al. 2003) **Illustration:** by the Author

1.2.4. Description of the post-harvesting process of coffee

The ripe coffee fruit, once detached from the bush, is a perishable organic material, which means that it must be processed immediately to obtain the dry bean in order to keep its organoleptic characteristics intact (de Hacienda et al. 2015) besides to reduce the microorganism, mycotoxin and mould development.

The coffee processing is made up by several sequential steps in order remove the external layers of the cherry and prepare the seeds for exportation, followed by diversified processing steps such as roasting, decaffeination, extraction for the preparation of instant coffee, and finally beverage preparation (Vieira et al. 2015). Coffee processing should be started immediately after the harvesting of the fresh fruit to prevent the pulp from fermenting and stop deteriorating the bean. There are different practices for post-harvest processing of the coffee fruit to remove external layers and preserve the intrinsic quality of the coffee, these can be divided into three main processes: i) natural (dry) process which is usually applied to *Coffea canephora* or Robusta coffee, ii) washing (wet) process which is applied to *Coffea arabica* or Arabica coffee, the wet process mainly results in a better-quality coffee, and iii) honey process, this is a combined method between natural and washed method, this results in the coffee brews characterized with lower body comparing the same as natural processed beans, but it has a cleaner profile, more similar to washed-processed (Vieira et al. 2015; Quintero et al. 2017; Hejna 2021).

Natural (dry) process: in this process, the whole fruit (pulp, mucilage and seed) obtained from the coffee bushes is dried under the sun wich can take on average about 3-4 weeks or in mechanical dryers (ovens), the time in the ovens may change depending on the temperature used (Taeixeira et al. 1995; Santos et al. 2021), followed by a dehulling step where the husk composed by the remaining pulp, parchment and skin are removed (Heeger et al. 2017).

Semi-wet (honey) process: this process is an intermediate between the natural process and the washing process and has been used in Brazil since the early 1990s. It is a hybrid process where the fruit is pulped and the parchment coffee is dried while still covered by mucilage. Fermentation for mucilage removal is not used in this process (Taeixeira et al. 1995; Duarte et al. 2010; Heeger et al. 2017).

Washing (wet) process: this process is more expensive, difficult to execute, and its environmental impact is higher comer to the others due the amount of water that is needed to carry it out. This process is typically used for coffee Arabica (Santos et al. 2021), this consists in separate ripe from unripe fruits in water; ripe fruits sink to the ground meanwhile the unripe coffee cherries remain on the surface. The ripe fruits are pulped mechanically using a pulper and then the mucilage is removed from the parchment by fermentation (Heeger et al. 2017). Fermentation takes place in tanks at room temperature, which involves the presence of microorganisms and usually lasts between 12 to 36 hours. The total mass of coffee fruits may or may not be covered by water, both processes are used under different circumstances, however, the use of water for fermentation slows down the process, this step finishes with a washing process which remove entirely the mucilage, then the parchment is dried following by the removal of all seeds' surrounding layers. The residues obtained from this process are pulp, mucilage, contaminated washing water, parchment and coffee silverskin (Taeixeira et al. 1995; Kleinwächter et al. 2015; Santos et al. 2021).

In a study done by Quintero et al. (2017) named "Analysis of Good Practices in the Coffee Milling Process: Study Experience in the Municipality of Viotá (Cundinamarca, Colombia)" are pointed out 2 different washing processes. The first one "Traditional coffee processing" where the mucilage is removed by natural fermentation and "Ecologic coffee processing" where the mucilage is removed mechanically, both with 6 stages (Quintero et al. 2017). Figure 3 summarizes the stages of both processes.

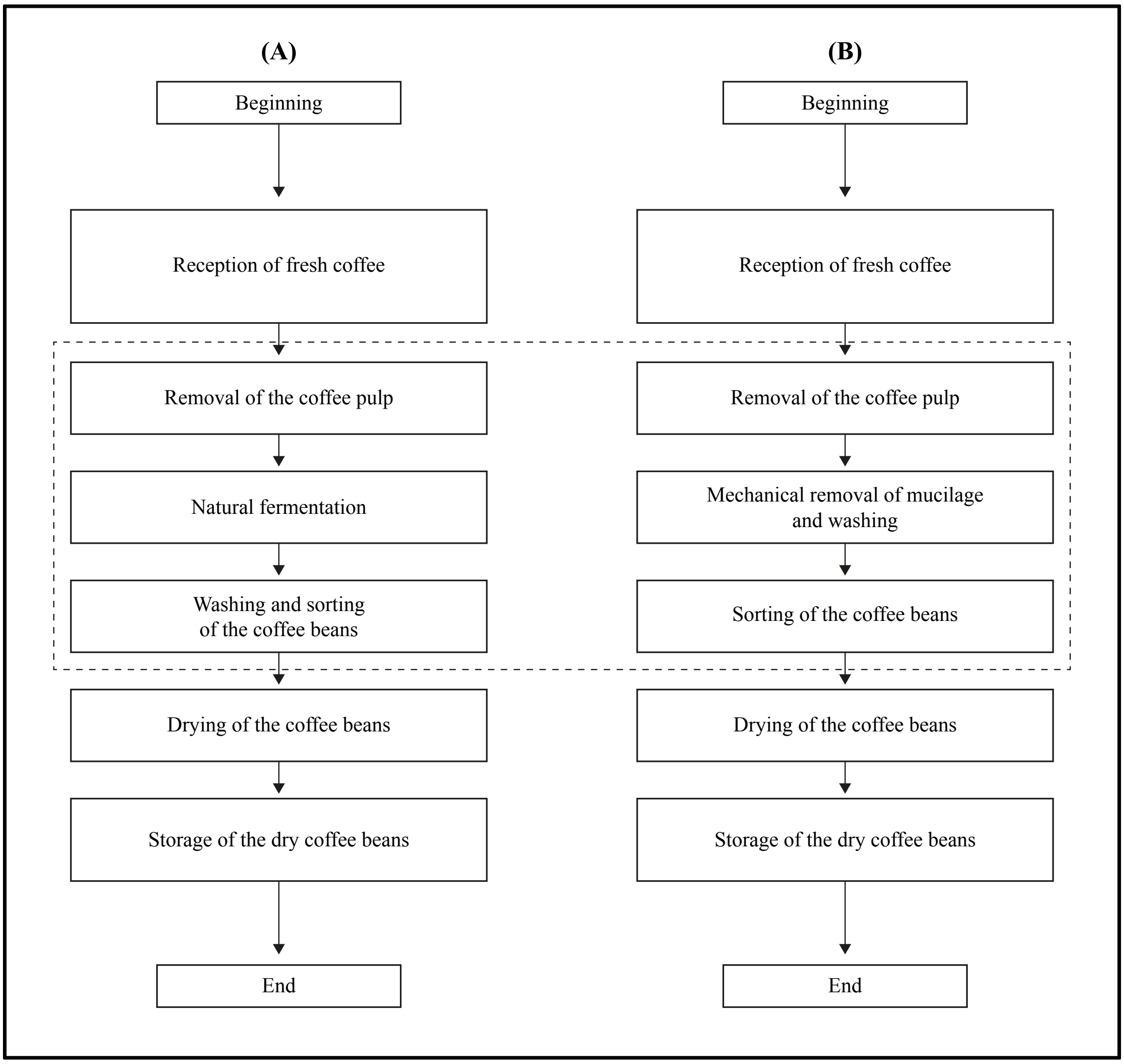

Figure 3: Flowchart of the traditional and ecologic coffee washing processing.

In the figure the traditional coffee processing is indicated with (A) and the ecologic coffee processing is indicated with (B)

Source: (Quintero et al. 2017) **Diagramming: by the Author**

In the traditional process (A), the removal of the mucilage is done by means of natural fermentation, a process that can take between 10:00 to 18:00 hours depending on the amount of coffee to be processed, temperature and the shape and material of the tank or deposit where it accumulates (CENICAFE 1999; Paola et al. 2013). Once the fermentation process is finished, the coffee is washed, approximately 40.00 litres of water are needed per kilogram, and the organic matter that becomes contained in the remaining water of the process generates a contamination of 115.10 g of Chemical Oxygen Demand (COD) per kilogram of fresh coffee fruit (this represents the amount of oxygen necessary to decontaminate the water) (Mejía-González et al. 2007). Therefore, the ecological coffee process (B) is more accepted in order to be able to reduce the pollution generated in obtaining the residues through the coffee processing, since the mechanical de-mucilaginating process uses less than one litre of water per kilogram of dry parchment coffee (Paola et al. 2013).

1.2.5. Description of the by-products obtained from coffee industrialization and commercialization and their potential use

The coffee residues also called coffee by-products can be divided depending on the stage where they are produced and/or obtained. In resume the washing processing of coffee generates husk, while the natural processing of coffee generates pulp, mucilage, parchment and contaminated water. These by-products can be categorized as pre-roasting by-products, while the coffee silverskin and spent coffee grounds can be categorized as port-roasting by-products (Hejna 2021).

Pre-roasting by-products

Pulp: this is the first by-product or residue obtained from the honey or washing coffee processing, which accounts for 39.00 % of the weight of the fresh fruit (wet basis) (Arturo et al. 2008). The average pulp yield per million 60.00 kg bags of raw coffee produced is a total of 162,900 tons of fresh pulp (Rodríguez Valencia et al. 2010), which, if not properly used and/or processed, produce pollution equivalent to that of 868,736 inhabitants in excrement and urine. Coffee pulp contains of organic material that is removed when it comes into contact with water and represents one of the two most important sources of contamination (Rodríguez Valencia & Rodilla Alamá 2009). For every 2 tonnes of green coffee produced, about 1 tonne of pulp is obtained. The pulp is essentially very rich in carbohydrates, proteins, fats and minerals, and contains large amounts of tannins, polyphenols and caffeine (Blinová et al. 2017b). The pulp obtained has been studied as a reuse proposal for mushroom production, composting, food use, biogas production, bioethanol and conversion and compaction into briquettes and pellets as solid fuel due to its calorific value, wich is 15.88 MJ kg^{-1} when the pulp is dry (Rodríguez Valencia et al. 2010; Blinová et al. 2017b; Manasa et al. 2021).

Mucilage: this residue is obtained normally in the fermenting piles during the washing coffee process and is completely removed in the washing step. Mucilage represents approximately 17.00 % of the coffee fruit. For every million 60.00 kg bags of raw coffee produced, an estimated 55,500 tons of fresh mucilage is generated (Arturo et al. 2008). Because little water is used during the demucilagination process, it leaves the possibility of being able to use such waste industrially to produce methane gas, otherwise, if left untreated, it will produce pollution equivalent to that of 310,000 inhabitants in excrement and urine (Rodríguez Valencia & Rodilla Alamá 2009; Rodríguez Valencia et al. 2010). Mucilage is rich in carbohydrates and nitrogen, and is composed of about 84.20 % water, 8.90 % protein, 2.50 % reducing sugars, 1.60 % non-reducing sugars and 1.00 % pectin, which postulates that mucilage has a great potential to be used as fertiliser, compost, animal feed, as well as a carbon and nitrogen resource for biotechnological processes in the production of organic acids such as lactic acids (Neu et al. 2016). Other uses of mucilage for bioethanol production have been proposed. Bioethanol is produced by the alcoholic fermentation of simple sugars, a study carried out by Pérez-Sariñana (2014) showed that the yield of mucilage for bioethanol production was optimal, it should be noted that through a fermentation process the yeast contained therein converts the reducing sugar into ethyl alcohol, its calorific value when it is used for biomass production is about 2.00 MJ kg^{-1}, while when it is used for bioethanol production is about 1.23 MJ kg^{-1} (Rodríguez Valencia et al. 2010; Yadira et al. 2014).

Parchment: this residue is obtained when it is separated from the coffee bean, this process is carried out in the dehulling machine. The parchment represents about 7.00 % of the coffee fruit (Arturo et al. 2008). Its most notable characteristic is its calorific value, which provides the equivalent of 17.58 MJ kg^{-1} of weight. Furthermore, its physical and chemical characteristics make it an excellent fuel for use in the ovens of coffee drying machines (Arturo et al. 2008; Rodríguez Valencia et al. 2010). It is estimated that for every 60.00 kg bag of coffee, the equivalent of approximately 11.00 kg of coffee parchment is obtained, which is one of the least studied coffee by-products to date. Coffee parchment is rich in phenolic compounds and dietary fibre (Mirón-Mérida et al. 2019). Phenolics linked to dietary fibre are not absorbed in the small intestine, these compounds arrive unprocessed in the colon where they are fermented, producing metabolites and antioxidants that can provide extra protection to human well-being, for such reasons this residue is taken into account as a complementary ingredient in the food industry (Mirón-Mérida et al. 2019; Benitez et al. 2019).

Husk: the major by-product of the dry method is husk, which is composed of the dried pulp and parchment. It represents approximately 12.00 % of the weight of the dried fruit. For every tonne of fresh coffee produced, 0.18 tonnes of husk are obtained, producing between 150.00 and 200.00 kg of green coffee ready to be marketed (Blinová et al. 2017b). Many studies have already been proposed on the reuse and potential of coffee husk, applications as a substrate for biogas production (Dananto Ulsido et al. 2016), bioethanol production (Gouvea et al. 2009), more labour-intensive applications such as biosorbents for cyanide (Mebrahtom Gebresemati et al. 2017), biosorbents for the removal of heavy metals from aqueous solutions (Oliveira et al. 2008), biosorbents for removal of dyes from aqueous solutions (Ahalya et al. 2014), biosorbents for water defluorination (Getachew et al. 2015), biosorbents for lead (Taddesse et al. 2015), as a substrate for the production of edible mushrooms (Alemu 2015), as compost (Anh Dzung et al. 2013; Shemekite et al. 2014), converted into pellets as solid fuel (Setter et al. 2020), as a functional ingredient in food production, the high concentration of caffeine and tannins which are generally seen as a threat to the environment can be used as key ingredients in the development and production of energy drinks and although their high Dietary Fiber (DF) content represents a problem of its own in the production of the drinks, this fibre can be used in the production of energy bars as a food supplement (Bondesson & Koch 2015).

Coffee waste (contaminated) water: the contamination of water used for wet and semi-wet processing of coffee is considerable. This water, which is loaded with organic material, microbial degradation results in a reduction of the oxygen level in the water, which makes aquatic life impossible in the polluted water bodies. The amount of water required varies from process to process, but is between 1.00 m^3 and 20.00 m^3 per ton of green coffee produced. Because there is no viable use for this waste and because the organic load exceeds the self-purification of natural watercourses, it is necessary to understand and evaluate in each case the composition of the wastewater in order to design a treatment system that is feasible and reduces the impact on the environment (Blinová et al. 2017b).

Post-roasting by-products

Silverskin: this residue is generated during the roasting process of the coffee bean, the bean has a silvery coating (spermoderm) which is strongly adhered to the bean which is also responsible for the generation of this residue when exposed to high temperatures (van Dam & Harmsen 2010). This is the most highly produced residue from the coffee roasting industry and having no commercial value, it has been discarded as solid waste and could represent an impact with negative effects on the environment, requiring an appropriate management of this resource (Rodrigues et al. 2015). For years research has been carried out on how to use this residue and/or potential applications, due to its high concentration of Soluble Diet Fiber (SDF) it has been proposed to be used as a complementary food ingredient or in other industries related to skin care (Acevedo et al. 2013; Bessada et al. 2018; Santos et al. 2021) but up to date most of the waste generated is used as direct combustion fuel, fertiliser or landfilled. Being the main by-product of the coffee roasting industries significant efforts have been made to characterize its chemical composition and develop new potential applications. Several publications have emerged suggesting the incorporation of coffee silverskin in beverages because of their high level of DF, proteins, minerals and fats (Borrelli et al. 2004; Bessada et al. 2018), also suggested for its potential as an ingredient in a new drink to reduce body fat accumulation (Martinez-Saez et al. 2014), bakery products such as bread with high fibre content (Bessada et al. 2018), or even studies which propose that it has the ability to block sunlight harmful to human skin, and has therefore been used in the cosmetics industry (Acevedo et al. 2013; Santos et al. 2021).

Spent Coffee Grounds: During the final processing of the beverage, selected compounds are extracted from the coffee beans, the industry generates a large amount of waste after processing, exclusively SCG. During the coffee milling process, for every tone of green coffee, an estimated 650.00 kg of ground coffee is produced (Dattatraya Saratale et al. 2020), and for every 1.00 kg of coffee powder, around 2.00 kg of wet ground coffee are produced (Santos et al. 2021). SCG are the solid residues that remain after the treatment of ground coffee with hot water for the preparation of the coffee beverage. These residues are fine-grained, have a high load of organic materials such as polysaccharides, tannins, lipids, amino acids, minerals, aliphatic acids, polyphenols, proteins, alkaloids, oligosaccharides, melanidines, trigonelline and phenolics, lignin, volatile compounds and moisture content (Jiménez-Zamora et al. 2015; Prihadi & Maimulyanti 2020; Atabani et al. 2022a). The SCG are the main residues of the coffee industry and represent about the 45.00 % of the material generated in coffee beverage and instant coffee preparation. According to the literature in the period 2004/2005 approximately 6.00 million tonnes of SCG were produced worldwide (Tokimoto et al. 2005; Mussatto et al. 2011a; Echeverria & Nuti 2017).

The final residue obtained represents about 5.00 % of the fresh fruit. Given that the residues that remain are made up of various compounds that are harmful to the environment, as they require a high demand for oxygen to degrade (Silva et al. 1997), the vast majority of this organic material is disposed of in landfills and burned as waste rather than being used for any other purpose (McNutt & He 2019; Forcina et al. 2023) resulting in a large emission of carbon dioxide into the atmosphere (Tokimoto et al. 2005).

The composition of SCG depends on a number of factors, such as brewing methods used, type of coffee, growing conditions, among others, but for the most part SCG are expected to have a composition similar to that of the coffee bean (Ballesteros et al. 2014).

Unlike the waste obtained in the previous processes, this particular waste has more practical applications. Some uses have been identified and reported as mixed fertilizers, soil improvement, recipes for animal feed or feedstock for fermentation and substrates for mushroom production, biodiesel production (Kondamudi et al. 2008), generation of electricity and heat through the production and burning of pellets due to its calorific value of about 29.01 MJ kg^{-1} (Rodríguez Valencia et al. 2010; van Dam & Harmsen 2010; Rajabi Hamedani et al. 2022), or as a feedstock for the bioethanol (Kondamudi et al. 2008). Some of the proposed uses such as the use of SCG as fertilizer were discarded as not economically viable, the case of the fertilizer in particular was discarded because of its low nitrogen content and high acidity (Silva et al. 1997). Another abandoned use was the use of SCGs as animal feed. An analysis of the amino acids contained in SCG protein showed that half of the essential amino acids were absent, and a high concentration of caffeine and phenols limited their digestibility (Hejna 2021). However, other uses such as the production of biodiesel, bioethanol and pellets as a solid fuel are widely accepted.

Bioenergy derived from SCG has gained much attention in recent years because coffee residues possess two main advantages that differentiate them from other agroindustrial biomasses: the first being the absence of seasonality and the second their wide distribution. It has been demonstrated by several studies that due to their gross calorific value, as an antioxidant resource material or as a source of polysaccharides with immunostimulatory activity, SCG can be used for the production of biodiesel and pellets (Mussatto et al. 2011a). The use of SCG as an energy resource by thermochemical and biochemical processes represents a solution to counteract the problems related to the disposal of such waste (Rajabi Hamedani et al. 2022). Figure 4 shows the process by which the result of the use of coffee waste is arrived:

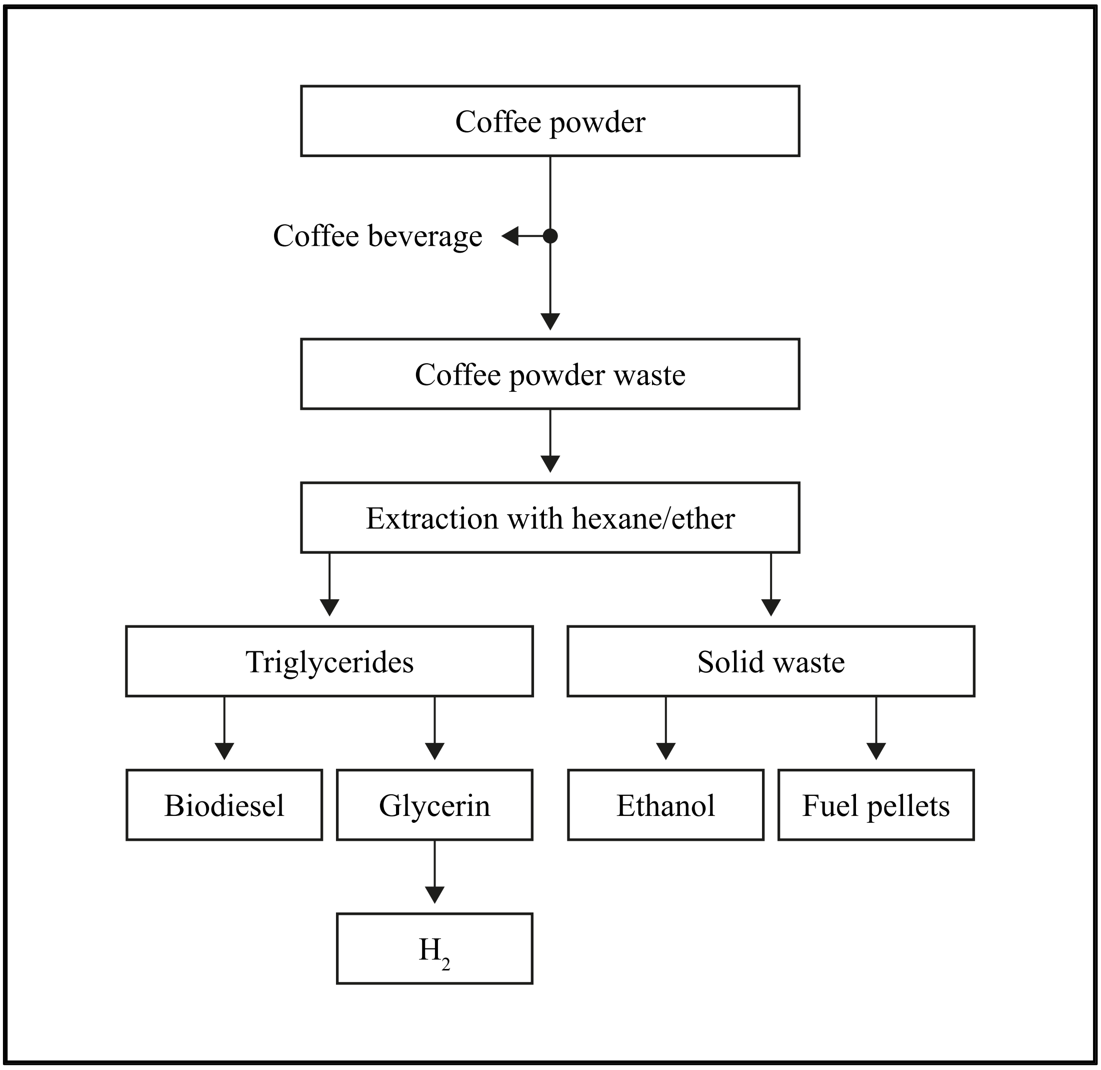

Figure 4: Flow chart of SCG-based biofuel production.

Source modified from: (Kondamudi et al. 2008)

The residues obtained from the coffee processing are not the only residues that remain in its production, in addition to the pulp, mucilage, parchment, silverskin or also husk (when pulp and parchment are together), stems, shreds, deteriorated coffee and spent coffee grounds are also obtained, which in general terms they maintain the same chemical composition as the coffee that is marketed (de Hacienda et al. 2015). The following residues are not directly related to coffee processing but are still coffee harvest residues that were included in this study as additional information to have a better overview of the total waste generated by the coffee industry.

Stems: the stems are obtained through the practice of pruning. The stems are offshoots or shoots of a coffee plant just after being cut at 30.00 cm from the stems, and which after about 18 months begin to produce a new bush with fruit (Rodríguez Valencia et al. 2010). This is one of the two practices known as coffee plantation rehabilitation, which means less investment and lower costs for coffee farmers, together with renovation by sowing, which refers to the removal of old bushes and the sowing of new seeds to produce new bushes, because over time coffee bushes cannot be rehabilitated to obtain adequate yields and need to be replaced (USAID Bureau for Food Security 2017); practices that are fundamental to the productivity of coffee plantations.

All the stems obtained from this practice are the result of the stalks of old bushes, generally used for cooking food and as fuel in the coffee drying ovens, stems are a source of energy used as direct fuel, its calorific value is around 19.75 MJ kg^{-1}. In addition, this residue can also be used for the production of bioethanol. This is one of the residues whose frequency is very low as usually the renovation and/or rehabilitation of coffee plantations takes place once every 5 years (Rodríguez Valencia et al. 2010).

Damaged coffee: this residue is obtained when the coffee bean is separated from the external layers like the skin or parchment. The residues are mostly small coffee beans, broken beans and imperfect beans. Although all these beans have the same chemical composition as the beans accepted and desired for commercialisation, the beverage obtained from them is of a much lower quality, therefore, they are extracted and not commercialized. Like the stems, these residues can be used as direct fuel and/or in the creation of biodiesel, they maintain a calorific value of 15.60 MJ kg^{-1} (Rodríguez Valencia et al. 2010).

According to a study carried out by Cenicafé (National Coffee Research Center of Colombia created by the National Federation of Colombian Coffee Growers) in 2010, less than 5.00 % of the organic material generated was used for the preparation of the beverage, the remaining approximately 95.00 % of the material remains in residual form (Rodríguez Valencia et al. 2010)

The following table (Table 2) shows an approximation of the residues obtained after the coffee processing:

Table 2: Residues obtained from coffee processing per 1,000 grams of coffee.
Adapted from: (Rodríguez Valencia et al. 2010)

Process	Lost (grams)	Residue obtained
Pulping	394	Pulp
Fermentation	216	Mucilage
Dehulling	35	Parchment or husk
Drying	171	Water
Roasting	22	Volatiles, silversking
Beverage preparation	104	SCG
Total lost:	942	

Figure 5 shows visually the residues produced by the coffee processing.

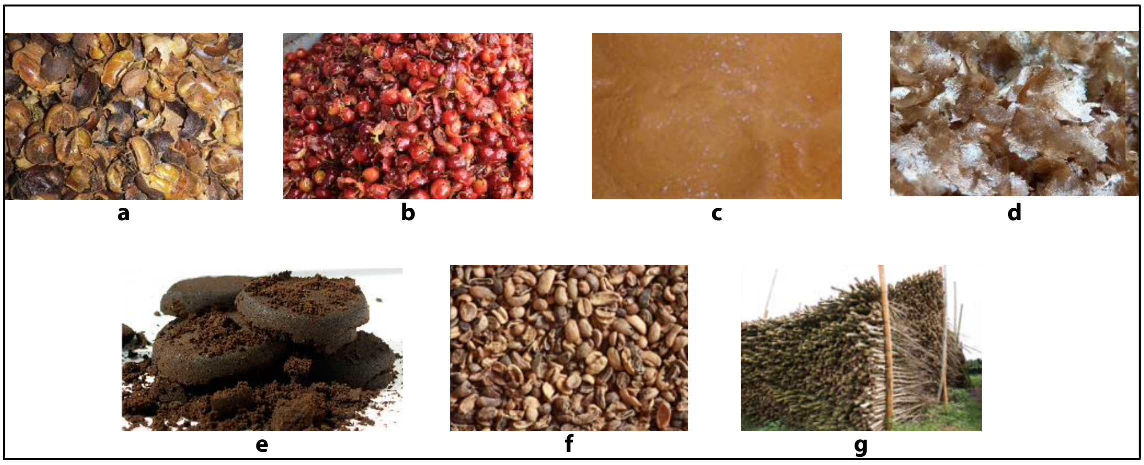

Figure 5: Visualization of the residues produced by coffee processing.
A) Husk; b) Pulp; c) Fresh Mucilage; d) Silverskin; e) SCG; f) Damaged coffee; g) Stems. Adapted from: (Rodríguez Valencia et al. 2010; Blinová et al. 2017b)

In Figure 6, a summary of the life cycle of coffee is shown, highlighting the cycles where the largest amount of waste is produced. A large amount of contaminated water is produced together with the wastes mentioned above. Depending on the process used for coffee processing, different by-products can be obtained. The applications of the residues or by-products, depending on their composition, have different uses and/or applications that vary from use as fuel to application in cosmetics and preparation of alcoholic beverages. The following is a summary of the uses that are currently given or can be given to the by-products obtained based on the stage at which they are produced.

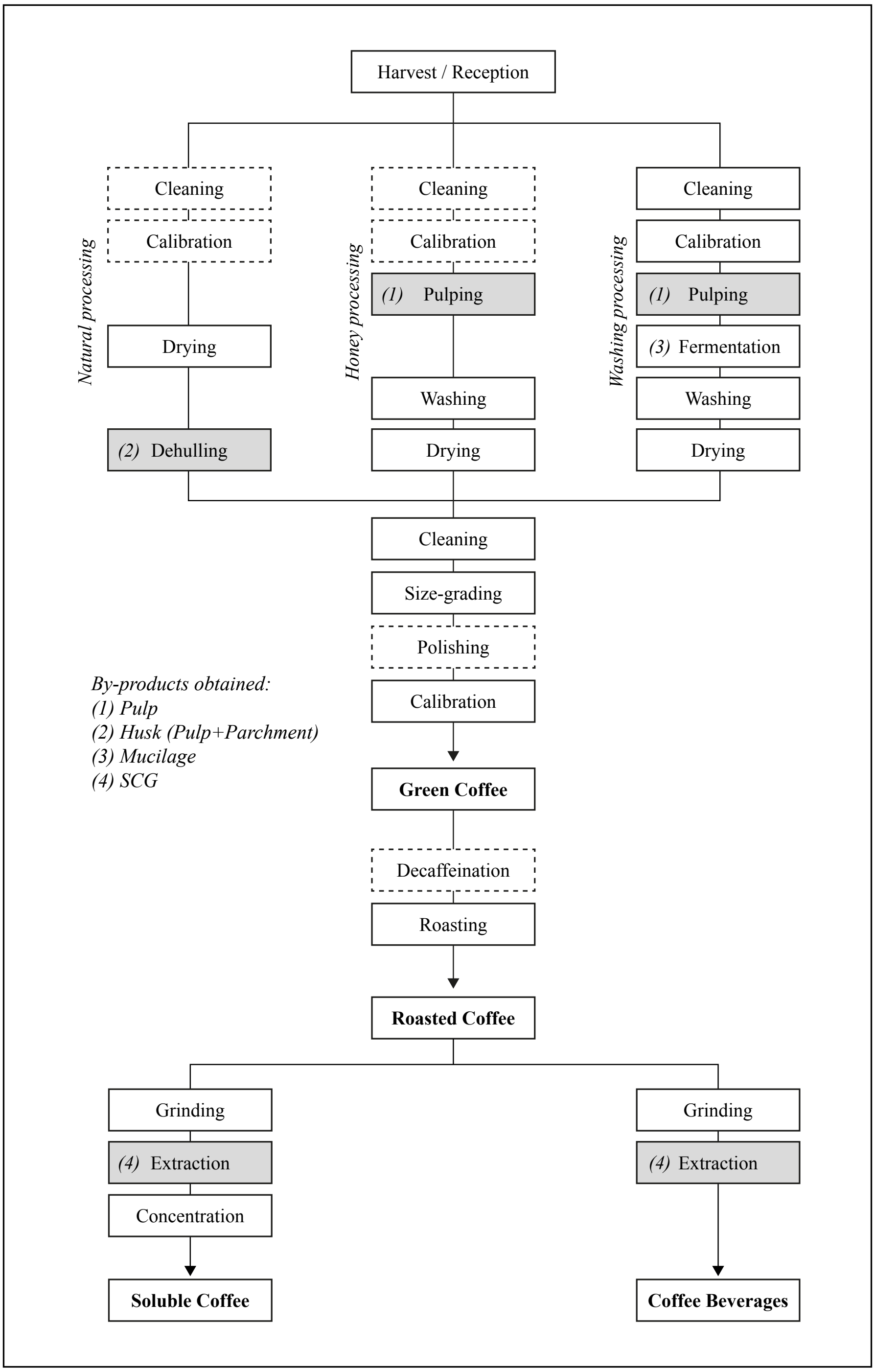

Figure 6: Flow diagram of the coffee life cycle.

(Boxes marked with grey are where most of the waste is obtained).

Modified from: (Quintero et al. 2017; Blinová et al. 2017b)

Many governments around the world are currently generating political and social pressure with the aim of reducing pollution from industrial activities. The amount of coffee waste produced in relation to the amount of organic material used is therefore significant. It is necessary to focus on finding a way to exploit the waste generated in a feasable and beneficial way, thus reducing the pollution generated by them and providing an alternative source of energy and possibly a contribution to the economy.

Tables 3 and 4 summarizes the possible uses and applications proposed in recent years for the by-products obtained from the coffee processing process.

Table 3: Summary: Uses of pre-roasting by-products.

Coffee processing

By-product	Uses	References
Pulp	Mushroom production, Compost, Bioethanol, Biogas, Briquettes, Pellets production	(Blinová et al. 2017b; Manasa et al. 2021)
Mucilage	Fertilizer, Compost, Animal feed, Bioethanol	(Yadira et al. 2014; Neu et al. 2016)
Parchment	Food complement as DF	(Mirón-Mérida et al. 2019; Benitez et al. 2019)
Husk	Biogas, Bioethanol, Biosorbents applications, Pellets production, Mushrooms production, Composting, Functional ingredient in food	(Oliveira et al. 2008; Gouvea et al. 2009; Anh Dzung et al. 2013; Ahalya et al. 2014; Shemekite et al. 2014; Alemu 2015; Bondesson & Koch 2015; Taddesse et al. 2015; Getachew et al. 2015; Dananto Ulsido et al. 2016; Mebrahtom Gebresemati et al. 2017; Setter et al. 2020)

Table 4: Summary: Uses of post-roasting by-products.

While roasting and after the beverage preparation		
By-product	**Uses**	**References**
Silverskin	Complement ingredient in beverages, Complement ingredient in bread, Main ingredient in cosmetics	(Borrelli et al. 2004; Martinez-Saez et al. 2014; Bessada et al. 2018; Santos et al. 2021)
SCG	Biodiesel, Ethanol, Pellets, Briquettes	(Kondamudi et al. 2008; van Dam & Harmsen 2010; Rajabi Hamedani et al. 2022)

1.2.6. Use of SCG as a renewable energy source

The SCG is the most widely generated and distributed residue of all coffee industrialisation and commercialisation, it represents an opportunity for its application as source of renewable energy. The approach of using SCG for the production of pellets as a solid fuel derives from the fact that the technologies for their production and accessibility of materials are more easily accessible compared to the other residues raised in this paper. The process of pelleting is commonly employed to decrease the size of various thermoplastic materials, such as raw polymers and blended composites. It is the most popular technique for achieving this type of size reduction (Drobny 2014).

In recent years, small-scale biomass thermal energy production has shown a clear trend towards densified biofuels (pellets) (Garcia-Maraver 2015). The production and consumption of pellets is mainly concentrated in Europe and North America, specifically in the cold areas and with an increase consumption during the cold seasons. Pellets are considered a clean and environmentally friendly fuel, which would also contribute to power generation and, in turn, help to replace the percentage of fossil fuels consumed in power plants (de Souza et al. 2020). It is estimated according to BIOENERGY EUROPE that world pellet production increased by 14.00 % from 2017 to 2018 from approximately 48.00 to 55.00 million tons produced worldwide, with the European continent accounting for around 36.00 % of global production (Calderón et al. 2019).

Characterization of biomass pelleting

In general, densified biofuels such as pellets are produced through the pelleting process, also known as the agglomeration method. This consists of gathering or grouping fine solid particles of prime matter to form larger elements such as spheres, bricks or cylindrical granules as in the case of pellets (Accredited Research Centre (Centre de Recherche Agréé – CRA) n.d.; Garcia-Maraver 2015).

Waste management is usually affected by the costs associated with the treatments required for the disposal of such waste. The use of such wastes for energy production by means of densified biofuels such as pellets reduces the costs associated with the handling, storage and transport (Garcia-Maraver 2015).

1.2.7. Use and evaluation of SCG-based pellets

In a study conducted by Allesina et al. (2017) in Modena in southern Italy, the performance of the production of SCG-based pellets was evaluated, about 20.00 kg of SCG were collected and mixed in different quantities with spruce sawdust to increase the mechanical strength. The types of pellets produced were: "Pellets d) with 100.00 % Coffee", "Pellet c) with 70.00 % Coffee and 30.00 % Sawdust", "Pellet b) with 50.00 % Coffee and 50.00 % Sawdust", in addition a pure coniferous wood pellet "Pellet a)", certified EN plus A1, was also used for the tests in order to have a point of comparison. The visual representation is in Figure 7. After its production, the pellets were used as fuel by direct combustion in a furnace.

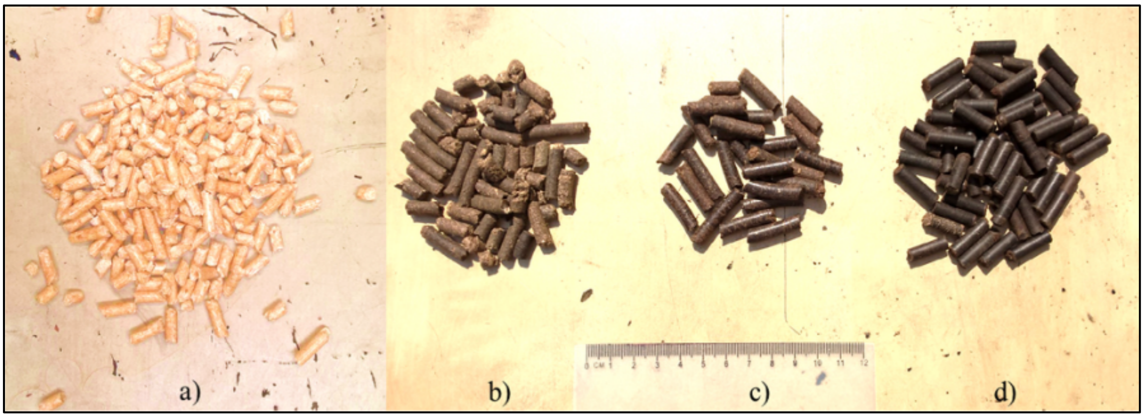

Figure 7: Pellets comparison.

a) Sawdust; b) 50.00 % Sawdust 50.00 % SCG; c) 30.00 % Sawdust 70.00 % SCG; d) 100 % SCG.
Source: (Allesina et al. 2017)

Each type of pellet was tested for a period of 1 hour and then the Gross calorific value (GCV) of the dry fuel and the thermal power generated were calculated, both practices proposed by Prabir Basu in his book *Biomass Gasification, Pyrolysis, and Torrefaction* (Basu 2013).

The results of the trial showed that "Pellet b) with 50.00 % Coffee and 50.00 % Sawdust" had a better performance in the combustion test in relation to the wood pellets, due to its gross calorific value of 18.94 MJ k^{-1}, generated thermal power (TP) of 8.86 kW consuming about 4.09 kg h^{-1} of material, where the control wood pellets reached respective measures of 17.39 MJ kg^{-1}, 8.02 kW and a consumption of 4.41 kg h^{-1}. The experiment showed that pellet b) is 3.50 % more efficient than the control pellet. Table 5 identifies the GCV (db.) of each of the evaluated pellet samples in more detail while in Table 6 can be seen the comparison of the efficiency and consumption of each of the pellet samples.

The increased amount of SCG in the pellet production also increased the problems in combustion performance issues, causing both pellets "Pellets d) with 100.00 % Coffee", "Pellet c) with 70.00 % Coffee and 30.00 % Sawdust" an unstable combustion, probably due to an increase in the amount of ash generated by the coffee (Allesina et al. 2017).

Table 5: Average of GCV (db.) & Thermal Power of SCG and Sawdust pellets.

Pellet	**Base**	Average GCV_{dry}	Average TP
"a)"	Wood (Control)	17.39 MJ kg^{-1} (4.83 kWh kg^{-1})	8.02 kW
"d)"	100.00 % Coffee	20.48 MJ kg^{-1} (5.69 kWh kg^{-1})	3.61 kW
"c)"	70.00 % Coffee & 30.00 % Sawdust	19.55 MJ kg^{-1} (5.43 kWh kg^{-1})	5.39 kW
"b)"	50.00 % Coffee & 50.00 % Sawdust	18.94 MJ kg^{-1} (5.26 kWh kg^{-1})	8.86 kW

Table 6: Average Efficiency & Consumption of SCG and Sawdust pellets.

Pellet	**Base**	Consumption	Efficiency
"a)"	Wood (Control)	4.41 kg h^{-1}	37.70 %
"d)"	100.00 % Coffee	3.31 kg h^{-1}	19.20 %
"c)"	70.00 % Coffee & 30.00 % Sawdust	3.35 kg h^{-1}	29.70 %
"b)"	50.00 % Coffee & 50.00 % Sawdust	4.09 kg h^{-1}	41.20 %

1.3. Web platform and technologies

The web as we know it has a bit more than 30 years of existence, over all these years it has experienced many changes and enhancements. According to The World Wide Web Consortium [W3C] (2021) the 60.00 % of the world population is online, accessing to the web everyday, it is the main source of information nowadays. Web platforms is another terminology for websites, these platforms provide a medium to access in detailed to information of interest, the web platforms are not only useful but aim to attain process efficiency and get real-time data, interactive information sharing and facilitating the access to it, besides to facilitate the development of numerous applications for the optimization and use of available resources, applications for Waste management, data analysis, logistic systems among others.

To ensure sustainable agriculture, it is necessary to bring about a significant transformation in the current agricultural system that can aid farmers in enhancing their yields, minimizing waste, and making improved management choices (Nyoman Kutha Krisnawijaya et al. 2022).

The use of digital technologies, such as web platforms, dedicated software and precision technologies are changing the farming as it is known, with the inclusion of wireless communication, data analytics and some other numerous application the exchange and/or access to information is contributing to improve agricultural practices, farmers, producers, retailers, final customers and practically any person have access to a huge volumes of information from the display screens on their cell phones, knowledge that can help actively to learn how to apply new practices, that are sustainable and moreover contribute to reducing the impact of the agricultural and industrial practices on the environment (Clapp & Ruder 2020; Hidalgo et al. 2023).

2. Aims of the Thesis

The Thesis aims to summarize and analyse the available scientific information related to the SCG-based fuel pellets and their key characteristics in order to establish reference framework of the optimal values for the production of pellets with SCG residues. The second main objective is to create a web platform that helps calculating the energy potential of SCG-based fuel pellets, as well as facilitating access to the information on coffee residues and pellets production process, giving the broader picture possible about their energy potential as a green energy source.

2.1. Specific objectives

1. Describe the processing of coffee and all residues obtained by the process.
2. Analyse the uses of coffee residues, and specifically pellets production from the spent coffee grounds.
3. Identify the key characteristics for the evaluation of SCG-based pellets.
4. Collect and standardize the values of each characteristic property of the SCG-based pellets.
5. Propose a web platform that helps automate the calculation of the energy potential of the SCG pellets.
6. Facilitate access to information related to the SCG and pellet production through the web platform.

2.2. Hypotheses

i. The calorific value property of SCG-based fuel pellets are comparable to that from woody pellets.

3. Research methodology

The research methodology and practical application of this study was based on three main steps. Step number 1 was to identify and establish a reference framework with reported values, creating an average for each of them in order to standardize each value of each of the characteristics of the SCG-based pellets; step number 2 was to classify the characteristics and the values obtained; Step number 3 was to identify the mathematical operations necessary to calculate the energy potential of the SCGs; Step number 4 was to design and establish the form and use of the proposed web platform in order to identify the elements and technologies necessary for its creation; Step number 5 was platform construction where the structure of the platform was done and the established mathematical operations are applied and results are obtained based on the chosen technologies plus the creation of the platform itself; and, as final step number 6 was to test based on a control sample to verify if the number and potential energy calculated by the platform coincided with that established with the mathematical operations in this document.

3.1. Data collection

The literature on the use of SCG as solid fuel more specifically SCG-based pellets is extensive, however, depending on the objectives of the study, some aspects and/or characteristics of these are examined and others are not, with no reference framework stablished specifically for SCG-based pellets. Through this study, a bibliographic search of the past years was done, looking for the available publications and/or studies carried out in recent years where the creation, comparison and/or evaluation of SCG-based pellets is studied and discussed, taking into account only those that mention pellets with at least 80.00 % SCG in their composition. The bibliographical review was carried out identifying each important characteristic and its value registered in each one of the publications and/or studies. Each value of each characteristic mentioned was recorded. After obtaining as many of the reported values as possible, we proceeded to make an average of each one of them. For reported values where a range was established, the number was obtained by adding the lowest number and the highest number and dividing by two. The mean of each of the values was established as a standard for that characteristic.

In order to identify and establish what characteristics and/or values are necessary for an optimal process of creating pellets, the following structure for the research was established.

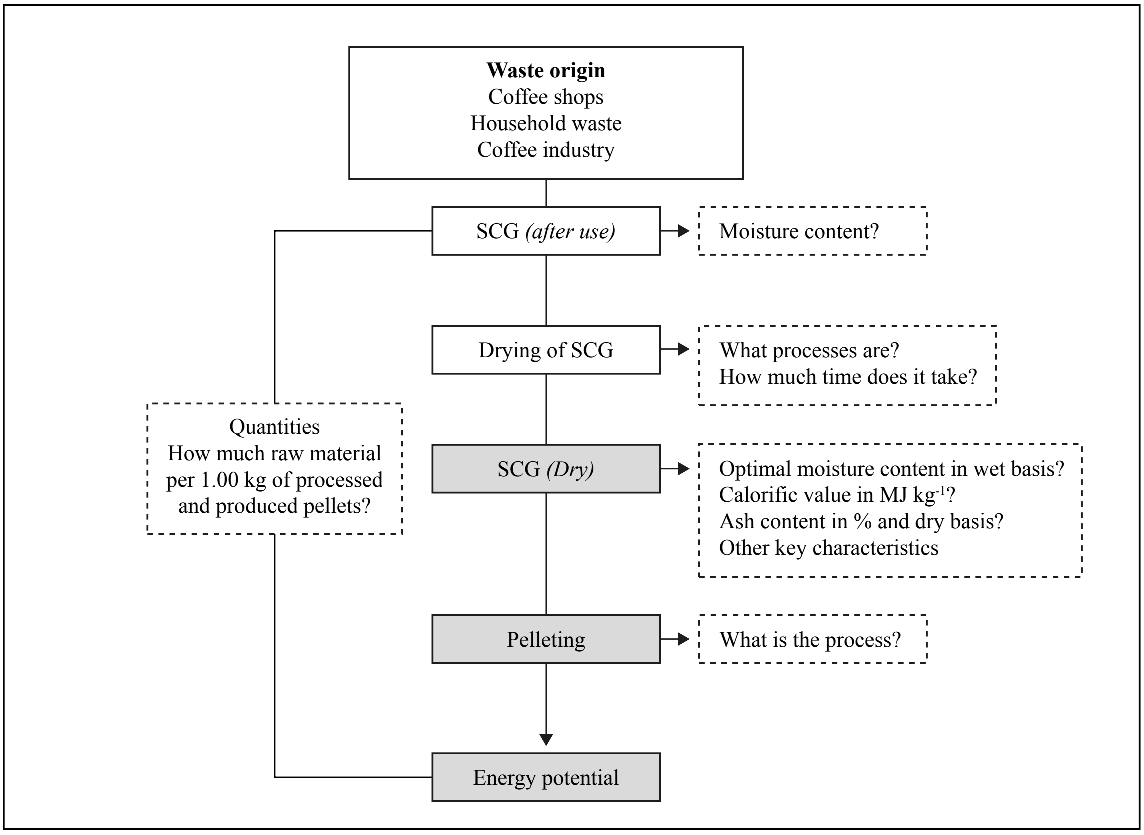

Figure 8: Initial structure of how to proceed with the research of the characteristics for the pellet creation. Source: by the author.

3.2. Data classification

The characteristics depending on their provenance were classified into two groups; being group number 1 called "SCG Energy Potential" and group number 2 called "SCG Physic and Economic", established in this way to be able to better identify those exclusive characteristics referring to energy potential and those characteristics referring to physical and economic aspects.

3.3. Mathematical calculations

Based on the theoretical framework, the residues can be obtained on a wet basis or dry basis, in each case a mathematical operation was identified in order to always transform the residues to a dry basis. Once the amount of waste in dry basis is obtained, the following operations are to multiply each value obtained based on one kilogram of SCG by the number of kilograms of SCG to be calculated. An operation was established for each of the characteristics of the reference framework.

3.4. Web platform design and technologies

The technologies to be used are focused on web development, since the platform proposed by this study is web-based. In order to standardize and streamline the reading of such a platform to the widest number of devices, common technologies were used in the creation of web platform. Technologies such as: HTML (Hypertext Markup Language - Platform structure); CSS (Cascading Style Sheets - Style sheets for the visual proposal); Javascript (Reaction to user actions/Dynamic page). which are organized in several components that give the platform the capacity to adapt the view, process and shows information at the most popular devices like smartphones, tables and PC, allows the user to process the information in real time. Such technologies enable visual design, dynamic interaction, and information processing.

The proposed web platform is operating in client-side mode, the browser of the user device acquires, process and shows information all in the same device, in this case the information format is specifically designed to be more focused on energetic values and key characteristic of the energy potential of SCG. The approach of using a web-based platform has many advantages:

- There is no need to install any extra software locally in the device, more than the browser itself.
- The web platform allows the development, upgrade and constant maintainance of the tool.
- The access to the web platform is easy and free from any device with internet access.

The platform was designed, structured, and as a decision-making the platform contains two main components: 1) The first core in a way of a form where the inputs are placed, such as: type of residues (SCG with a high moisture content or SCG with a reduced moisture content), number of residues, and unit of measure. With this information, the energy values and other key characteristics can be obtained and calculated, as well as their energy potential, which is the main calculation sought by the platform. 2) The second core is the collected literature in this document with the objective of facilitating access to information, the processes by which the information was collected, evaluated, classified and standardized were reflected in the platform.

3.5. Web platform structuration, inputs and outputs

In order to understand the flow of information, the following diagram was established (Figure 9) where the structure by which mathematical operations are performed on the platform is visually represented.

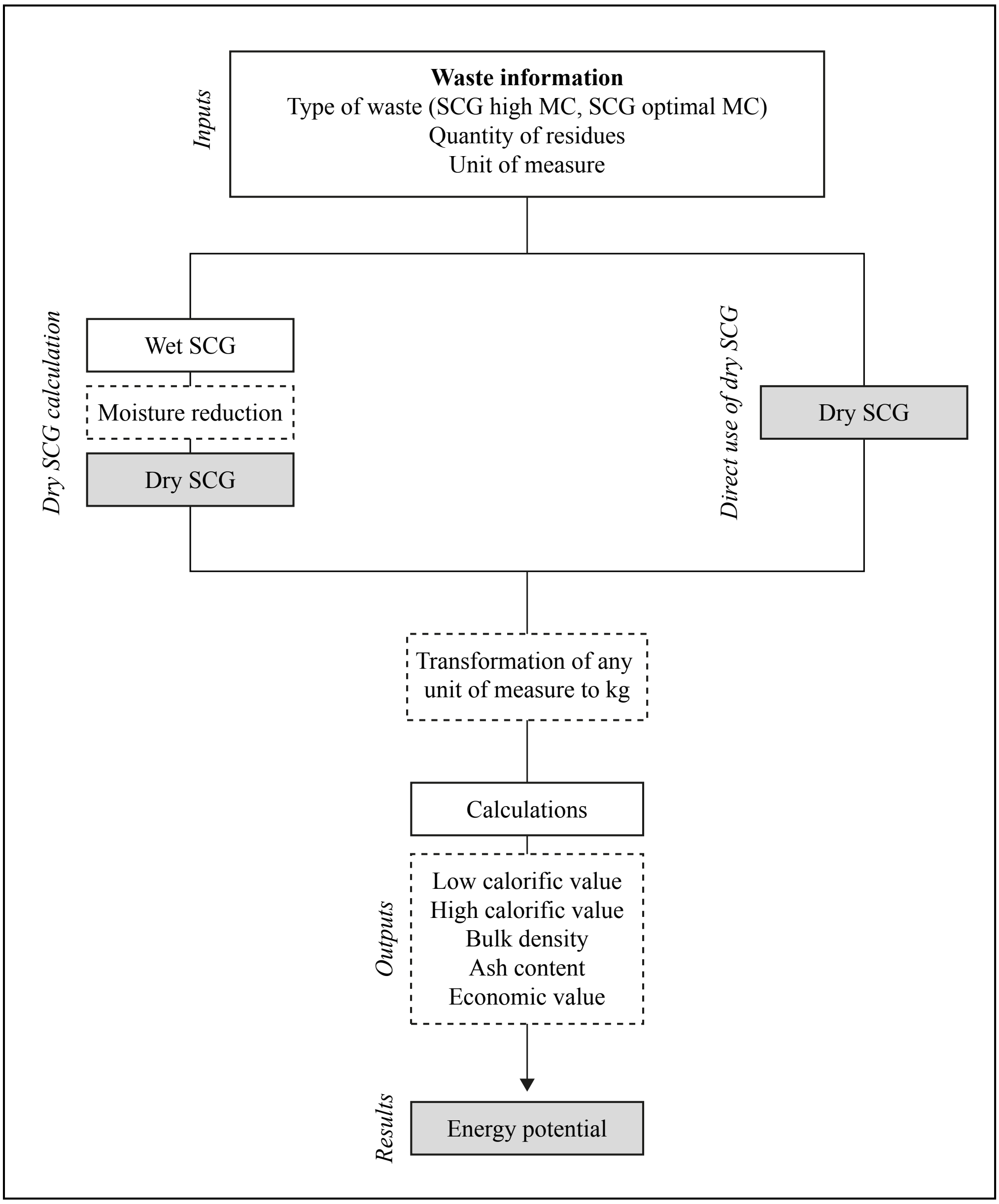

Figure 9: Structure of how platform performs calculations to obtain the SCG energy potential. Source: by the author.

3.6. Web platform testing

For the testing of the platform, a residue number was established, based on previous reports on SCG production worldwide. Mathematical operations were applied to each of the characteristics of the reference frame. The number and/or values obtained were the reference point with which the numbers obtained by the platform were compared.

4. Results

4.1. Step 1: Data set and standardizing

Pelletizing process

Right after the preparation of the coffee beverage, the SCG obtained contains high level of moisture, around 60.00 % in wet basis, so it is important that storage condition and time are idoneal before its utilization with energy purposes, it is necessary to process the residues as soon as possible, the moisture may or may not favour the proliferation of microorganisms that can affect the yield of the residues when they are used as biofuel (Colantoni et al. 2021). It is necessary to mention that two of the biggest advantages of the SCG are: one, the grinding process is already done as the raw material for the preparation of the beverage and two the residues are widely distributed all over the world, in most of the cases the residues are already in the place where they can be processed.

After the preparation of the coffee beverage the SCG requires the pre-treatment for the correct use. When the raw material is ready, this is used in so called Pelletizing process, this is a densification technique (compaction) used to transform fine materials such as powders, dusts, and other small particles into small, dense pellets that can be used for a variety of applications, including fuels based in biomass, animal feed, and more. Pelletizing is an effective method for transforming SCG into a more useful and versatile form (Drobny 2014). The pelletizing process for SCG typically involves the following steps:

1. **Collection and drying:** there are different ways which the removal of the moisture from the SCG can be done, this process is important in order to get the desirable moisture content, the SCG can be dried either in an Oven drying process where the SCGs are placed inside an oven at temperatures from 75 ˚C to 105 ˚C, the time reference is between 8 h and 24 h, in a Solar drying process this depends of a wide range of factors, the capacity of the dryer, the efficiency, weather conditions, between others, or in an Open air sun drying process this process happens by placing the trays in open air, under the sun, no electrical consumption is required, the drying times depend on various external factors that may or may not be controlled, therefore this document only mentions them without

establishing such times. The efficiency of each of the options also depends on its execution (Tun et al. 2020; Woo et al. 2021). The moisture of the raw material need to be reduced to between 10.00 % and 20.00 % wet basis to ensure the production of high-quality pellets (Garcia-Maraver 2015).

2. **Raw material preparation:** This may involve grinding, mixing, conditioning or other types of processing to ensure that the material has the right particle size and consistency for pelletizing. Once the coffee grounds are dry, they are typically ground into a fine powder using a hammer mill or other grinding equipment. This step helps to create a consistent particle size and ensures that the coffee grounds will form into pellets properly (Garcia-Maraver 2015). However, this step sometimes may not be necessary depending on how the SCG were processed.
3. **Pelletizing:** The ground coffee is fed into a pelletizing machine, which compresses the coffee powder under high pressure to form small, dense, and uniform pellets. Depending on the application, different binders such as corn starch or lignin could be added to help the pellets hold their shape. This machine typically consists of a rotating drum or disc that uses centrifugal force to compress the material into small, uniform pellets, the material is compacted by a pressure of 195 MPa for about 15 minutes (Kristanto & Wijaya 2018). Normally every 100 horsepower have the capacity to produce around 1 ton of pellets per hour (Garcia-Maraver 2015).
4. **Drying:** After the pellets have been formed, they are typically sent through a drying process to remove any remaining moisture, if the moisture is higher than 20 % bacteria growth might occur (Garcia-Maraver 2015). This is important to ensure that the pellets do not degrade or spoil during storage or transport.
5. **Cooling and screening:** After the pellets are formed, they are typically cooled and screened to remove any undersized or oversized pellets, as well as any fines or dust that may have been generated during the pelletizing process. The cooling process is critical for pellet strength and durability of pellets, when the pellets come out from the extruder they are hot and soft, they are gradually air cooled to allow a lightning solidify and strengthen the pellets (Garcia-Maraver 2015).
6. **Packaging and storage:** Finally, the coffee pellets are packaged and stored until they are ready for use. The typical way to packaging the SCG pellets are in bags. The weight of a spent coffee grounds pellets bag in the market can vary depending

on the manufacturer and the intended use of the pellets. Generally, bags of spent coffee ground pellets for use as fuel are available in weights ranging from 1.00 kg (2.20 lbs) to 20.00 kg (44.09 lbs) or more.

There is an abundant literature review on the production of pellets as biofuels, in the last years the SCG have been studied in many ways to understand its potential as biofuel in the production of pellets, and if it is feasible or not. Important characteristics to take into account in order to produce optimal pellets from SCG according to Atabani et al. (2022b) are:

Particle Size Distribution (PSD)

In order to create and enlarge pellets during the pelleting process, cohesive forces between particles are crucial. Therefore, having an appropriate particle size distribution is important to optimize the process. If the particles are too big, they won't stick together, and if they are too similar in size, the bond may not be strong enough, which would result in weak pellets. A study conducted by (Kang et al. 2017) showed that the **SCG particles size was between 100 and 850 µm**, this difference far to affect could be beneficial for the construction of pellets.

Initial Moisture content (IMC)

The presence of moisture is critical for particle aggregation and retention during pellet formation. When there is insufficient moisture, the pellets cannot develop, whereas excessive moisture can lead to material behaving like mud. The SCG right after the preparation of the coffee beverage have a high level of moisture, according to some studies carried out on the past years the moisture content range reported after the preparation of the drink was from **38.00 % to 85.00 %** in wet basis, this range was stablished for this study as reference. The details about the reported moisture content in wet basis over the last years are summarized in Table 7.

Table 7: Reported Initial Moisture Content of SCG in wet basis.

SCG Initial Moisture Content	Reported by
50.00 % to 85.00 %	(Garcia & Kim 2021)
62.00 % to 75.00 %	(Vakalis et al. 2019)
67.00 %	(Kristanto & Wijaya 2018)
65.70 %	(Caetano et al. 2014; Dattatraya Saratale et al. 2020)
60.00 %	(Blinová et al. 2017a)
45.00 % to 55.00 %	(Nosek et al. 2020)
50.00 %	(Mojapelo et al. 2021)
38.00 % to 48.00 %	(Bejenari et al. 2021)
42.00 %	(Colantoni et al. 2021)

Optimal Moisture Content (OMC)

The optimal moisture content (OMC) is the desired moisture for the optimal formation of the pellets. The moisture content of SCG right before its usage is critical for the pelletization process, still an amount of moisture is needed to hold particles together, the desirable range based on the data collected detailed in Table 8, is from **5.00 % and lower than 20.00 %** of moisture in wet basis. This is very important for the optimization of efficiency during the pelleting.

Table 8: Reported Optimal Moisture Content of SCG wet basis for pelleting.

SCG Optimal Moisture Content	Reported by
< 20.00 %	(Tun et al. 2020)
15.00 % to 17.00 %	(Woo et al. 2021)
5.00 % to 15.00 %	(Park et al. 2021)
10.00 % to 14.00 %	(Kristanto & Wijaya 2018)
11.80 %	(Lisowski et al. 2019)
11.78 %	(Jeguirim et al. 2014)
5.00 % to 10.00 %	(Vakalis et al. 2019)
10.0 %	(Rajabi Hamedani et al. 2022)
≤ 10.00 %	(Colantoni et al. 2021)
9.40 %	(Caetano et al. 2014)
8.10 %	(Li et al. 2014)
7.50 %	(Jeguirim et al. 2016)
6.81 %	(Kan et al. 2014)
6.50 %	(Nosek et al. 2020)

Pellet size and weight

The length (L) and diameter (⌀) for pellets is $L \leq 32$ mm and ⌀=5-25 mm, however the normalized values are around **$L \leq$ 15.0 mm and ⌀=4.5-9.0 mm** (Mussatto et al. 2011a;

Jeguirim et al. 2016; Lisowski et al. 2019; Woo et al. 2021). Due to the lack of the secondary data regarding to the weight of 1 fuel SCG standard pellet, this was compared to 1 fuel wood standard pellet, due to the fact that the mass contained in the compactation is the same. The average weight for 1 fuel wood pellet with *L*=13.0-15.0 mm and ⌀=8.0-9.0 mm is **5 grams** (Dinu 2006). According to the data collected an approximated of **200 SCG fuel pellets are produced for every 1.00 kg of dried material**.

Mechanical durability (MD)

This has as objective to evaluate the resistance to the impacts, the retention of their shape and withstand mechanical stress or abrasion during the handling and transportation processes, these results are highly affected by the storage conditions where the pellets were stored at (Woo et al. 2021), the parameter stablish is the probability that pellets will not crumble. All the values reported are detailed in Table 9.

Table 9: Reported mechanical durability for SCG pellets.

MD	Reported by
85.90 %	(Park et al. 2021)
84.70 %	(Kristanto & Wijaya 2018)
70.00 %	(Woo et al. 2021)
64.30 %	(Lachman et al. 2022)

Calorific value (CV)

This is defined as the amount of energy obtained from the combustion of a unit mass per kilogram when burnt with an excess of oxygen in a calorimeter (Carvill 1993), it is usually measured in kcal kg^{-1}, kJ kg^{-1} or MJ kg^{-1}, for purposes of this study, it has been standardized the measure to MJ kg^{-1}, all references that have a different measure has been converted. The Calorific value is one of the most important properties to evaluate the optimal production and yield of pellets (Kang et al. 2017). In many studies this value is referred also as Heating Value (HV). With the purpose of standardize the terminology all these values will be referred as Calorific Value (CV). The CV has two values when it is evaluated, the first one referred as Net calorific value (NCV) this is recognized when H_20 is present in the products of combustion as a vapour form; the second one referred as gross calorific value (GCV) this is recognized when H_20 is present in the products of combustion as a liquid form which is as well the higher of both (Carvill 1993). The reference of calorific value for SCG pellets **NCV range from 19.00 MJ kg^{-1} to 23.14 MJ kg^{-1}** dry basis, meanwhile for **GCV range from 21.10 MJ kg^{-1} to 29.01 MJ kg^{-1}** dry basis. In the other hand for the wet basis just NCV was reporter, having a range from **8.40 MJ kg^{-1} to 20.00 MJ kg^{-1}**.The details are in Table 10 and Table 11.

Table 10: Reported gross and net calorific value of SCG pellets on dry basis.

SCG NCV	SCG GCV	Reported by
	29.01 MJ kg^{-1}	(Rodríguez Valencia et al. 2010)
19.74 MJ kg^{-1}		(Jeníček et al. 2022)
19.71 MJ kg^{-1}	28.99 MJ kg^{-1}	(Kristanto & Wijaya 2018)
19.00 MJ kg^{-1}	26.90 MJ kg^{-1}	(Lisowski et al. 2019; Dattatraya Saratale et al. 2020)
19.30 MJ kg^{-1}	24.90 MJ kg^{-1}	(Nosek et al. 2020)
20.10 MJ kg^{-1}	23.80 MJ kg^{-1}	(Woo et al. 2021)
	23.20 MJ kg^{-1}	(Li et al. 2014)
23.14 MJ kg^{-1}		(Park et al. 2021)
20.73 MJ kg^{-1}		(Tun et al. 2020)
21.26 MJ kg^{-1}	22.83 MJ kg^{-1}	(Lachman et al. 2022)
	22.36 MJ kg^{-1}	(Rajabi Hamedani et al. 2022)
19.97 MJ kg^{-1}	22.24 MJ kg^{-1}	
	21.10 MJ kg^{-1}	(Sakuragi et al. 2016)

Table 11: Reported net calorific value of SCG pellets on wet basis.

SCG NCV	Reported by
20.00 MJ kg^{-1}	(Kang et al. 2017)
19.30 MJ kg^{-1}	(Atabani et al. 2019)
18.11 MJ kg^{-1}	(Jeguirim et al. 2014)
17.52 MJ kg^{-1}	(Jeguirim et al. 2016; Lisowski et al. 2019)
8.40 MJ kg^{-1}	(Nosek et al. 2020)

Bulk density (BD)

The Bulk density helps to understand and estimate the space required for transportation and storage of the pellets produced. This is expressed in weight, that fills the volume of a specific container (Woo et al. 2021) as it is shown in Table 12.

Table 12: Reported Bulk Density for SCG pellets.

Bulk Density	Reported by
1,211.00 kg m^3	(Jeguirim et al. 2014; Lisowski et al. 2019)
1,153.00 kg m^3	(Lisowski et al. 2019)
710.00 kg m^3	(Woo et al. 2021)
563.00 kg m^3	(Park et al. 2021)

Ash content

The ash content represents the leftovers after a sample of biomass is completely burnt (Sarkar 2015). The SCG ashes usually are constituted by several minerals such as potassium (3.5 mg g^{-1}), phosphorus (1.5 mg g^{-1}), magnesium (1.3 mg g^{-1}) and calcium (0.8 mg g^{-1}) (Mussatto et al. 2011b; Jeguirim et al. 2014) all the reported values are presented in detail in Table 13.

Table 13: Reported Ash content for SCG pellets dry basis.

Ash %	Reported by
3.12 %	(Chen & Chen 2021)
2.19 %	(Rajabi Hamedani et al. 2022)
1.90 %	(Sakuragi et al. 2016)
1.82 %	(Jeguirim et al. 2014)
1.70 %	(Li et al. 2014)
1.78 %	(Kan et al. 2014)
1.65 %	(Caetano et al. 2014)
1.60 %	(Lisowski et al. 2019)
1.50 %	(Park et al. 2021)
1.47 %	(Lachman et al. 2022)
0.10 %	(Kristanto & Wijaya 2018)

Market price

The price stablished in the market can vary depending on the composition of the pellets; according to Woo et al. (2021) the pellets from SCG taking as reference market: Italy, the prices analysed based in several factors like transportation, collection and production are: "*0.10 EUR kg^{-1} for SCG 50.00 % pellets (50.00 % pine sawdust (PS) blended) and 0.05 EUR kg^{-1} for 98.00 % SCG pellets (2.00 % starch blended)*", the prices in 2011 of Pellets from SCG are lower, about a 40.00 % compare to the wood pellets. The pellets normally are sold in bags, the weight of the bags can vary but in general these bags are coming in 40.00 lb or 18.14 kg weight, in the United States the cost per bag is between 3.00-4.00 USD each [2.76-3.68 EUR] resulting a total of 0.17-0.22 USD kg^{-1} [0.15-0.37 EUR kg^{-1}] (Office of Energy Efficiency & Renewable Energy - U.S. Department of Energy n.d.).

Table 14: Reported economic value by 1 kg of SCG pellets.

Original currency	EUR	Reported by
0.05 EUR kg^{-1}	0.05 EUR kg^{-1}	(Woo et al. 2021)
0.061 USD kg^{-1}	0.056 EUR kg^{-1}	(Atabani et al. 2019)
0.17 to 0.22 USD kg^{-1}	0.15-0.37 EUR kg^{-1}	(Office of Energy Efficiency & Renewable Energy - U.S. Department of Energy n.d.)

Averaging and standardizing of collected data

For the averaging and standardization of all the data, it was established a mean for every characteristic. The mean was calculated by adding up all values collected and dividing that total value by the number of values in the data set. For those who specified a range of data, the middle point of the range was taken for the calculation of the mean detailed on Table 14.

The standard value for each characteristic was stablished, for the IMC 57.08 % wb., OMC 10.20 % wb., NCV 20.33 MJ kg^{-1} db., GCV 24.79 MJ kg^{-1} db., MD 76.23 %, BD 909.25 kg/m^3, Ash content 1.71 % db., Economic value 0.12 EUR kg^{-1}. For the length (*L)* 15 mm, diameter (⌀) 8.0 mm and weight of 5.0 g was not stablished as a mean but a reported value by (Jeguirim et al. 2016; Woo et al. 2021).

Table 15: Mean values for SCG fuel pellets key characteristics.

	Measure	*Lower Value*	*Higher value*	Mean
IMC	%	*38.00*	*85.00*	57.08
OMC	%	*5.00*	*< 20.00*	10.20
NCV (wb.)	MJ kg^{-1}	*8.40*	*20.00*	16.66
NCV (db.)	MJ kg^{-1}	*17.52*	*23.14*	20.33
GCV (db.)	MJ kg^{-1}	*22.36*	*26.90*	24.79
MD	%	*70.00*	*85.90*	76.23
BD	kg m^3	*563.00*	*710.00*	909.25
Ash	%	*0.10*	*3.12*	1.71
Economic value	EUR kg^{-1}	*0.05*	*0.22*	0.12
Length (*L)*	mm	*n/a*	*n/a*	15.00
Diameter (⌀)	mm	*n/a*	*n/a*	8.00
Weight	g	*n/a*	*n/a*	5.00

4.2. Step 2: Classification of characteristic

The characteristics depending on their provenance were classified into two groups; being group number 1 called "SCG Energy Potential" and group number 2 called "SCG Physic and economic" as shown in Table 16.

Table 16: Key characteristic classification.

Group	Characteristics
SCG Energy Potential	Initial moisture content Optimal moisture content Net calorific value Gross calorific value Ash content Mechanical durability Bulk density
SCG Physic and economic	Average length Average weight Standard diameter Economic value

4.3. Step 3: Calculations

Required inputs for calculations

In order to carry out the calculations in the proposed platform, to calculate the energy contained and how much it is equivalent in practical terms of its use, two types of inputs were required: type of residues, whether it is wet SCG or dry SCG, and gross quantity of residues in kilograms (kg), pounds (lb), grams (g) or tons (t) as shown in Table 17.

Table 17: Inputs required for calculations.

Inputs	Description
Type of residue	SCG with high moisture content or SCG with reduced moisture content (around 10.20 %)
Gross quantity of residues	in kg, lb, g, t

Once all the required data is gathered, calculating the NCV (Net Calorific Value), GCV (Higher Calorific Value), bulk density, ash content, pellets quantity, and economic value is an essential aspect of evaluating the efficiency and sustainability of SCG used as biomass pellet fuels. These calculations help determine the amount of heat energy that can be produced by a given quantity of residues and a broader panorama of the potential of using SCG as fuel. Such calculations were established as detailed below.

IMC reduction to OMC

Equation (*1*). The dry spent coffee grounds (DSCG) can be used without any treatment therefore the value can be used as it is, they must have around the 10.20 % of moisture (wb.), with any pre-transformation. In the other hand wet spent coffee grounds (WSCG) according to the standard stablished the IMC is around the 50.08 % (wb.), it must lose a percentage of moisture until reaching the standard OMC of around 10.9 %, this loss of moisture also represents a loss of weight, therefore the weight of the wet residues will be less once they reach the OMC after the process of drying. In order to calculate the approximate weight of the residues after the drying process, the following equation was used:

Equation 1: Initial moisture content reduction.

$$\mathrm{W}f = \frac{Wi - (Wi * IMC)}{1 - OMC}$$

Where:

Wf = *Dried final mass weight in kg*

Wi = Initial mass weight in kg

IMC = Initial moisture content in %

OMC = Optimal moisture content in %

NCV calculation

Equation (*2*). The amount of NCV by kg of SCG is already defined in this document as 16.66 MJ kg^{-1} (wb.) and 20.33 MJ kg^{-1} (db.), in order to obtain the total NCV of the undefined residues, the mass of residues needs to be multiply by the standard NCV, this apply to both either (wb.) or (db.) as it is shown in the following equation:

Equation 2: Net calorific value calculation.

$$\mathrm{E}l = \mathrm{W}f * NCV$$

Where:

El = *Net calorific value in MJ kg*$^{-1}$

Wf = *Dried final mass weight in kg*

NCV = Standard net calorific value in MJ kg^{-1}

GCV calculation

Equation (*3*). The amount of GCV by kg of SCG is already defined in this document as 24.79 MJ kg^{-1}, and in order to obtain the total GCV of the undefined residues, the mass of residues needs to be multiply by the standard GCV as it is shown in the following equation:

Equation 3: Gross calorific value calculation.

$$\mathrm{E}h = \mathrm{W}f * GCV$$

Where:

Eh = *Gross calorific value in MJ kg*$^{-1}$

Wf = *Dried final mass weight in kg*

GCV = Standard Gross calorific value in MJ kg^{-1}

Ash content calculation

Equation (*4*). The percentage of leftovers of SCG is already defined in this document as 1.71 % and in order to obtain the total ash content the number of undefined residues, needs to be multiplied by 0.0171.

Equation 4: Ash content calculation.

$$\mathrm{A}r = \mathrm{W}f * Asc$$

Where:

Ar = *Ash final residues in %*

Wf = *Dried final mass weight in kg*

Asc = Ash standard content in %

Economic value calculation

Equation (*5*). The standard economic value for SCG pellets by kg is 0.12 EUR kg^{-1}. The following equation shows how to calculate the approximated economic potential value of the total amount of residues:

Equation 5: Approximation of the potential economic value calculation.

$$Ev = Wf * Sev$$

Where:

Ev = *Total economic value in EUR* kg^{-1}

Wf = *Dried final mass weight in kg*

Sev = *Standard economic value in EUR* kg^{-1}

Heating potential

According to the Fuels Pellets Institute (FPI) in average 24 hours of heating can be obtained from one bag of 40 lb or 18.14 kg. The estimated total may vary depending on inhouse living habits or temperature setting, size and efficiency of the stove, quality of the pellets, climate, among others.

4.4. Step 4: Design, structure and technologies

Introduction of the proposal

The proposed platform available on (https://scg-analizer.info) had as an objective to facilitates the access to information and helps to have a broader picture of the energy potential of SCG as renewable energy source. The platform was designed to provide an overview of the energy potential of SCG as a solid fuel in the form of pellets and to bring together all available information on the characterization of SCG-based pellets in the published literature. The reason for creating a web platform is to optimize search time and streamline the calculation of the potential of SCG as a source of green energy. Many studies have been carried out but not all of them mention all the characteristics of the SCG, therefore another objective of the platform was to gather available information in one place, such as the dry mass of spent coffee grounds after the drying process, gross calorific value total, net calorific value total, ash content and economic value of a undefined quantity of residues, providing valuable and scientifically referenced information, which can serve as a reference for future research or applications based on the use of such residues as an energy source.

In the last years many studies were conducted on the uses of SCG as an energy source, the literature on the use of SCG as fuel pellets is extensive, but depending on the specific objectives of the studies only some characteristics of SCG-based pellets are mentioned or not besides that some of the characteristics have been more studied than others. Since a specific frame of reference for SCG-based pellets has not yet been established, this platform seeks to create a reference framework for the creation of pellets, based on an extensive bibliographical review on the studies carried out for each of the most important characteristics that SCG-based pellets must meet, and show them through their practical application and gathering all the information in one place.

Designing and construction of the web platform

As a first step, the structure of the platform was defined, two sections were established as the main core, the first section, section A named "SCG Analyzer" containing a form where first the information on the number of residues to be analysed is collected, either the residues with eather a high or reduced moisture content, and second the reference measurement of mentioned quantity, these values were used to calculate the total values of each one of the characteristics of the total pellets. This section contains all equations established in this document, and they were applied to the undefined amount of residues collected by the form. In order to meet one of the objectives of the platform, the entire process and calculations are available in detail, always seeking to have easy access in section A.

The second section, section B consists of a small literature review divided and structured according to topics of interest related to the production of SCG and fuel pellets. This section is divided by topic and seeks to provide easy access to all the information collected on the studies carried out in recent years regarding SCGs, which are also the scientific support that gives reference to the calculations made by section one with their respective references.

Other sections such as Header, Introduction and Footer were included as a complement to the platform, to provide a little more information about the approach, provenance, and authors of the platform. Figure 10 shows the placement of each of the sections and the general structure of the platform in more detail.

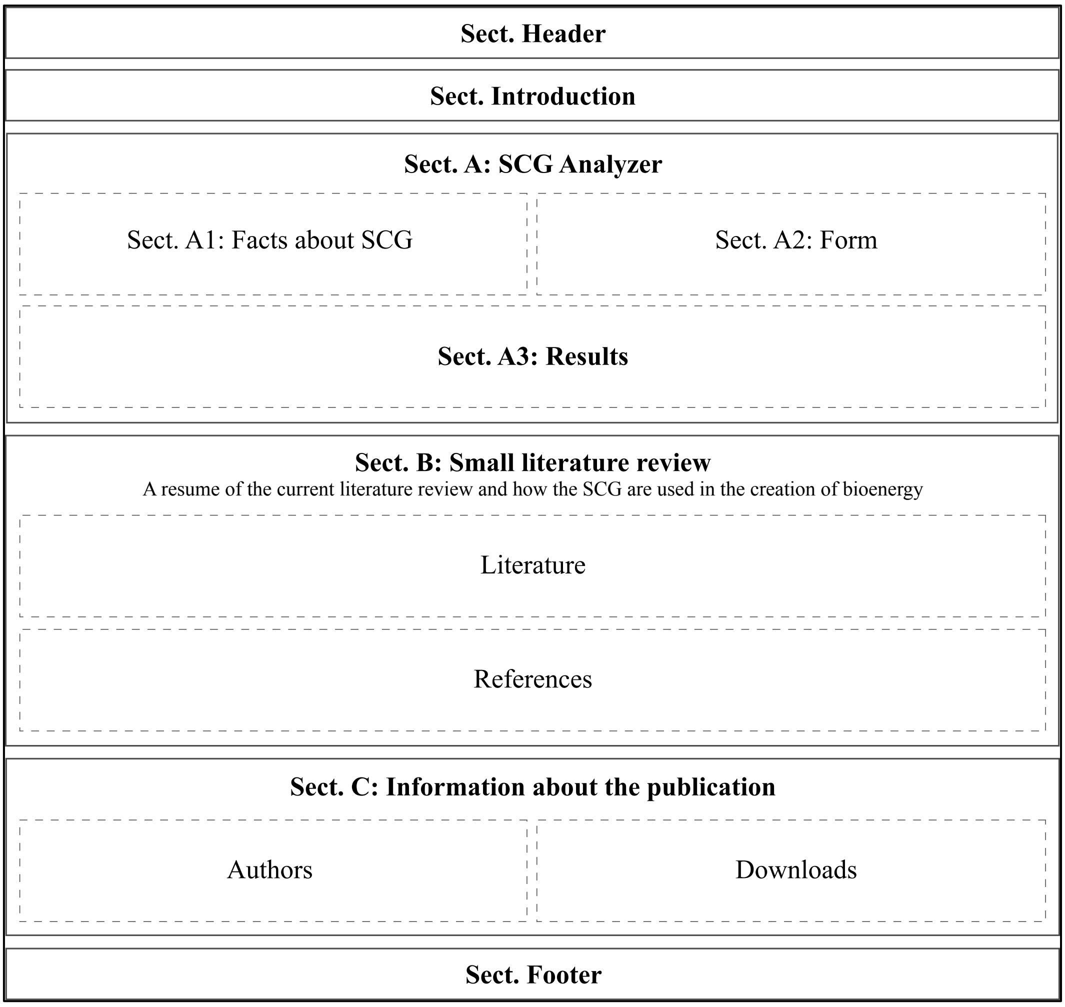

Figure 10: Structure of the web platform.

Source: by the author.

The general design follows specific guidelines so the graphic and interaction elements are easily accessible, easy to understand and facilitate their corresponding actions in this case, the calculations, taking into account a set of principles based on the usability of the platform; principles such as readability (text and graphics should be clear and precise with the use of a distinguishable font style), visual contrast (the symbols used on the screen such as buttons, alerts, and results must be clear and distinguishable), information architecture (presented information must be structured and organized in an easy way to facilitate the reading) and gestalt principles that refers to a perceptual organization of visual elements pointing to a unified approach in structuring and presentation of the information, that in general terms refers to the humans nature to perceive objects as organized patterns and unified smaller objects as one . This helps to focus attention on certain points on the platform to help the user find the information they are looking for (Lupton & Cole Phillips 2008; Poulin 2011).

Description of the used technologies

The platform was built using HTML, CSS, PHP and JavaScript.

The Hypertext Markup Language (HTML) is a text system used to describe how content is structured within an HTML file. This markup is used to create headings, paragraphs, lists, tables, and other structural elements. This system is the one that maintains the structure of the platform and establishes the elements that compose it.

The Cascading Style Sheets (CSS) is a programming language that describe to browser how the HTML elements are to be displayed on screen, this is used to define styles for the web-platform pages, including the design, layout, and variations in display for different devices and screen sizes or viewports.

JavaScript is an object-oriented computer programming language, which means that work directly with elements, like HTML tags, this is commonly used to create interactive effects and give functionality within web browsers and web pages. This programming language was chosen and used in this platform to perform the calculations once the information on the number of residues is collected, in addition to organizing and displaying the results obtained from such residues.

The platform was built by combining these technologies. HTML provides the basic structure of the platform; CSS allowed it to style it and JavaScript added interactivity and functionality.

4.5. Step 5: Platform construction

The platform creation process was started by creating an HTML file and adding the elements (HTML tags) and the necessary structure for the whole platform, such as the main container, sections, the main form, display area, and buttons including the calculate button (see Table 18), that in this case is so important because is the button which deployed the calculations based on what has been defined in the main form.

```
<div id="SEC1">
        <div id="SEC1A" class="">

          <!—Structure for the slide that contains the facts of SCG residues on the left side -->
          <div class="SLIDER semititle font-i">
            <div id="slide"></div>
          </div>

          <id id="timebar"></id>

        </div>
        <div id="SEC1B" class="">

          <!—Introduction to the section -->
          <font class="font-i semititle">How much energy by SCG's waste weigh</font>
          <br><br>
          <font class="font-i">
                Calculate the energy contained in and the quantity of Spent Coffee Grounds (SCG) fuel pellets
                that can be produced based on the weight of residues.
          <br><br>
                Simply enter the weight of the residues you have.
           </font>
          <br><br>

          <!—Input type "select" this defines the type of residues to be analyzed -->
          <select name="TOR" id="TOR">
                <option value="WSCG">SCG with high moisture content</option>
                <option value="DSCG">SCG with reduced moisture content (dry)</option>
          </select>

          <!—Alert. Optimal moisture content -->
          <font id="A-DSCG">
                The optimal moisture content for SCG's fuel pellets must be around 10.20 % (wb.).
          </font>

          <!— Input. Here is defined the number of residues to be analyzed -->
          <input name="QOR" id="QOR" type="number" placeholder="Total amount of residues. E.g.30.00">

          <!—Input type "select" this defines the unit of weight -->
          <select name="TOM" id="TOM">
            <option value="grams">grams (g)</option>
            <option value="pounds">pounds (lb)</option>
            <option value="kilograms" selected>kilograms (kg)</option>
            <option value="tons">tons (t)</option>
          </select>

          <!—Calculate buttom -->
          <div id="calculate" onclick="calculate()">Calculate</div>

          <br><br>

          <!—Extra link -->
          The information is processed according to standard values. To see the list of standard values
          <a href="hcm.php" class="link">click here</a>.
        </div>
      </div>
```

Figure 11: HTML structure for the SCG Analyzer section.

Source: by the author.

The CSS was used to style all the elements placed before, such as the general container, all the sections, the main form, header, footer and results of the SCG Analyzer section. The CSS style sheet made it look visually appealing, this has included setting the font, colours and size of the display area, fonts and width of elements, as well as adding borders, shadows, and other visual details as well as hover effects to the *calculate* button. The CSS code used can be found entirely in the appendices of this document, appendix: “general.css (General stylesheet)”. For the design of the platform, since the main elements were the information collected by the literature review and the results of the processed residues, it was sought to give major importance to the text/information, a scientific publication and/or article style was chosen.

The preview of the web platform can be seen in more detail in Figure 11 for the "SCG Analyzer" section where the elements like the form and the buttons can be identified.

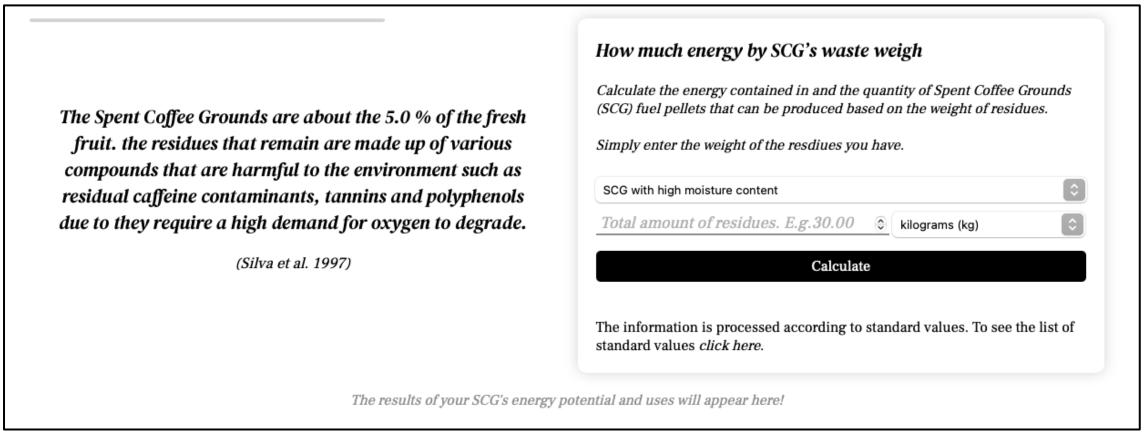

Figure 12: Web platform screenshot for the section SCG Analyzer.

Source: by the author.

In order to create the "SCG Analyzer" section, JavaScript was used to provide functionality and interactivity when performing the calculations required to display results. All the mathematical equations presented earlier in this document should have been adequate and applied, in addition to the averages already obtained in the data collection stablished as the reference framework.

For the interactivity and back-end data processing of the information JavaScript was used. This allowed capture the number of residues, value typed in the input of the form and the type of residues selected from the selection box as it can be identified in the Figure 13, and perform the appropriate calculations. In order to calculate all the results a function was created "*function calculate()*", a function in JavaScript can be defined as a procedure or a set of statements that performs a task or calculates a value, to be able to do this, it should take one input or more, and return an output, the inputs are taken from the main form, the inputs required were stipulated early in the document on Table 16. All standard reference values to be used were identified and adequate for the calculation as shown in Table 19, the function as well had the capacity of updating the display area with the result of each calculation, the Javascript code used for the calculations is in detail in Figure 13.

Table 18: Adequacy of the means for the web platform calculations.

	Original value	***Transformed***
Initial moisture content	57.08 %	0.5708
Optimal moisture content	10.20 %	0.102
Net calorific value mean (wb.)	16.01 MJ kg^{-1}	16.66
Net calorific value mean (db.)	20.33 MJ kg^{-1}	20.33
Gross calorific value mean	24.79 MJ kg^{-1}	24.79
Ash content mean	1.73 %	0.0173
Economic value mean	0.12 EUR kg^{-1}	0.12

```
function calculate(){

  // Standard values
  var IMC = 0.5708; // Initial moisture content (57.08 %)
  var OMC = 0.102; // Optimal moisture content (10.20 %)
  var SLCVW = 16.66; // Standard net calorific value wb. (16.66 MJ kg-1)
  var SLCV = 20.33; // Standard net calorific value db. (20.33 MJ kg-1)
  var SHCV = 24.79; // Standard gross calorific value db. (24.79 MJ kg-1)
  var SASC = 0.0171; // Standard ash content (1.71 %)
  var SECV = 0.12; // Standard economic value (EUR kg-1)
  var STBD = 909.25; // Standard bulk density (kg m3)
  var SWPP = 5; // Standard pellet weight (g)

  // Here the information from the main form is gotten
  var TOR = document.getElementById('TOR').value; // Specified type of residues
```

```
var QOR = document.getElementById('QOR').value; // Specified number of residues
var TOM = document.getElementById('TOM').value; // Specified unit of measure

// This section transforms the chosen weight units to kilograms
switch(TOM){
   case 'grams': var TAR = QOR/1000; var measure = 'g'; break;
   case 'pounds': var TAR = QOR/2.205; var measure = 'lb'; break;
   case 'kilograms': var TAR = QOR; var measure = 'kg'; break;
   case 'tons': var TAR = QOR*1000; var measure = 't'; break;
}

// Here the calculations are done
switch(TOR){

// In the case that the SCG residues have a high moisture content, the dry mass need to be calculated with a optimal moisture content of (10.20 %)
   case 'WSCG':

      // Mesage after results title
      document.getElementById('A-DSCG').style.display = "none";
      document.getElementById('A-WSCG').style.display = "block";
      var RTOR = 'SCG with high moisture content';
      var QORO = (QOR-(QOR*IMC))/(1-OMC);
      var DSCG = (TAR-(TAR*IMC))/(1-OMC);
      var LCV = DSCG*SLCV;
      var LCVW = DSCG*SLCVW;
      var HCV = DSCG*SHCV;
      var ASC = DSCG*SASC;
      var ECV = DSCG*SECV;
      var TPP = DSCG*(1000/SWPP);
      var BAG = DSCG/18.1437;
      var NHD = (DSCG*24.00)/18.1437;

   break;

// In the case that the SCG residues have a reduced moisture content of around (10.20 %). The value can be used as it was especified by the user.
   case 'DSCG':

      // Mesage after results title
      document.getElementById('A-DSCG').style.display = "block";
      document.getElementById('A-WSCG').style.display = "none";
      var RTOR = 'SCG with reduced moisture content';
      var QORO = QOR*1;
      var DSCG = TAR*1;
      var LCV = DSCG*SLCV;
      var LCVW = DSCG*SLCVW;
      var HCV = DSCG*SHCV;
      var ASC = DSCG*SASC;
      var ECV = DSCG*SECV;
      var TPP = DSCG*(1000/SWPP);
      var BAG = DSCG/18.1437;
      var NHD = (DSCG*24.00)/18.1437;

   break;

}
```

Figure 13: Calculations with Javascript of the SCG Analyzer section.

Source: by the author.

The preview of the web platform can be seen in more detail in Figure 12 for the "Results" section. This section shows once the calculations are done, having all the total values for each of the key characteristic identified in this document, such as SCG with reduced moisture content mass, NCV(wb.), NCV (db.), GCV (db.), ash content (db.), MD (wb.), BD (wb.) and economic value, beside some other useful information like standard diameter, average length, an approximation of how many pellets can be produced, an approximation of how many bags of 40.00 lb each can be obtained and to the left side an approximation of how many houses can be heated for a period of 24 hours based in the literature reviewed and collected in this document.

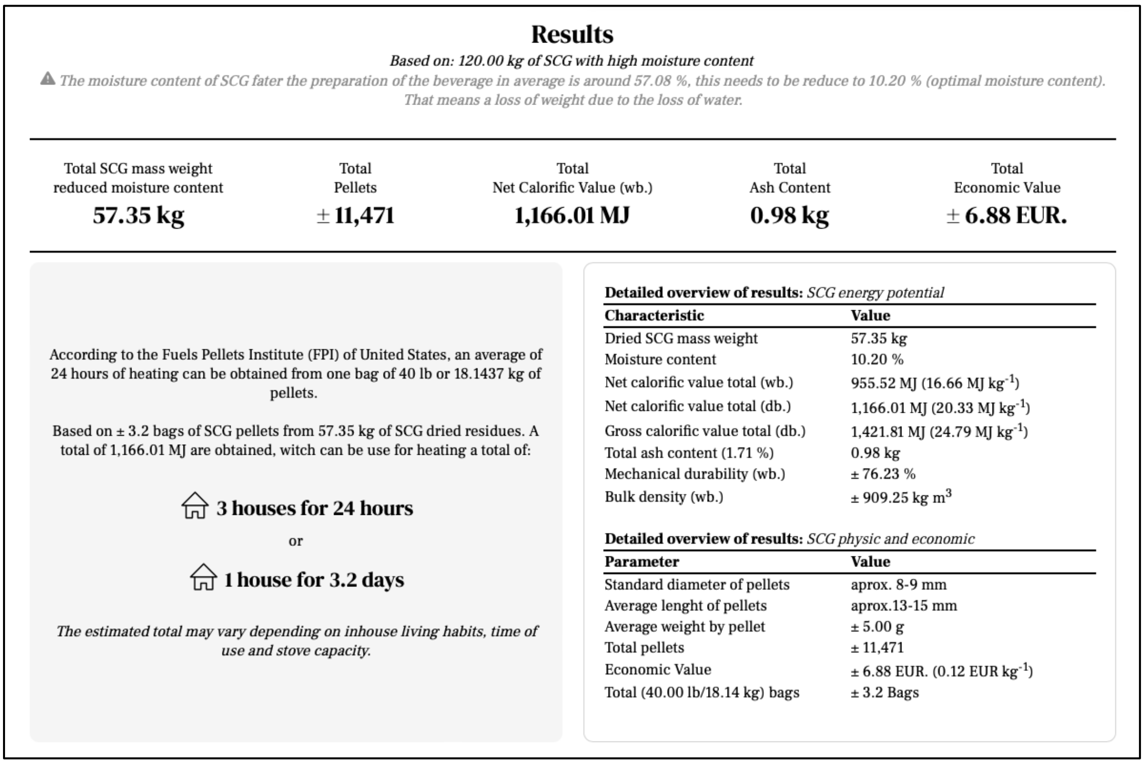

Figure 14: Web platform screenshot for the Results section.

Source: by the author.

The creation process of this section is similar to the one used for the "SCG Analyzer" section, the HTML structure was established, a table was created to organize the results and have a better visualization of each one of them. The HTML structure of the table for the results is found in more detail in Figure 15. The results were placed in their corresponding HTML tags by the “*function calculate()*” once the calculations were done.

```
<div id="SEC2">

    <div id="SEC2A"> </div>

        <div id="SEC2B">
          <table class="DOOR">
            <tr>
              <td colspan="2">
              Detailed overview of results: <font class="TDES">SCG energy potential</font>
              </td>
            </tr>
            <tr>
              <td>Characteristic</td>
              <td>Value</td>
            </tr>
            <tr>
              <td>Dried SCG mass weight</td>
              <td><font id="D-DSCG"></font> kg <font id="O-DSCG"></font></td>
            </tr>
            <tr>
              <td>Moisture content</td>
              <td>10.20 %</td>
            </tr>
            <tr>
              <td>Net calorific value total (wb.)</td>
              <td><font id="D-LCV-W"></font> MJ (<font id="SLCV-W"></font>)</td>
            </tr>
            <tr>
              <td>Net calorific value total (db.)</td>
              <td><font id="D-LCV"></font> MJ (<font id="SLCV"></font>)</td>
            </tr>
            <tr>
              <td>Gross calorific value total (db.)</td>
              <td><font id="D-HCV"></font> MJ (<font id="SHCV"></font>)</td>
            </tr>
            <tr>
              <td>Total ash content</td>
              <td><font id="D-ASC"></font> kg</td>
            </tr>
            <tr>
              <td>Mechanical durability</td>
              <td>± 76.23 %</td>
            </tr>
            <tr>
              <td>Bulk density</td>
              <td>± 909.25 kg m<sup>3</sup></td>
            </tr>
          </table>
          <table class="DOOR">
            <tr>
              <td colspan="2">
              Detailed overview of results: <font class="TDES">SCG physic and economic</font>
              </td>
            </tr>
            <tr>
              <td>Parameter</td>
              <td>Value</td>
```

```
            </tr>
            <tr>
              <td>Standard diameter of pellets</td>
              <td>aprox. 8-9 mm</td>
            </tr>
            <tr>
              <td>Average lenght of pellets</td>
              <td>aprox.13-15 mm</td>
            </tr>
            <tr>
              <td>Average weight by pellet</td>
              <td>± 5.00 g</td>
            </tr>
            <tr>
              <td>Total pellets</td>
              <td>± <font id="D-TPP"></font></td>
            </tr>
            <tr>
              <td>Economic Value</td>
              <td>± <font id="D-ECV"></font> EUR. (0.012EUR kg<sup>-1</sup>)</td>
            </tr>
            <tr>
              <td>Total (40.00 lb/18.14 kg) bags</td>
              <td>± <font id="D-BAG"></font> Bags</td>
            </tr>
          </table>
        </div>

    </div>
```

Figure 15: HTML structure for the results section.

Source: by the author.

Together to HTML tags and CSS specification, the JavaScript was used to display the result in the correct format. The entire JavaScript code used for the “SCG Analizer section” and “Results section” can be found in the appendices of this document, appendix: “calculations.js (Calculations function)”.

The preview of the web platform for the "Small literature review" section can be seen in more detail in Figure 16. In this section, all the information reviewed and collected in the literature review of this document was included. The information collected for the standardization of the values of each of the key characteristics of the SCG-based fuel pellets identified in this document was included as a guideline and added as am extra section of the platform, in addition to the equations and the process of the calculations made by it. The section was divided into several pages to better organize the information and meet one of the objectives of this platform, which is to facilitate access to information related to the topic of interest.


#Coffee_residues #Coffee_as_biomass #Characterization_and_composition_of_SCG #Use_of_SCG_and_practical_applications #Pelletizing_process #SCG_pellets #SCG_as_potential_source_of_renewable_energy

Pelletizing process of SCG

Right after the preparation of the Coffee Beverage, the SCG obtained have a high level of moisture, so it is important that storage condition and time are idoneal before its utilization with energy purposes. Due to its high level of moisture, it is necessary to process the residues as soon as possible, the moisture may or may not favour the proliferation of micro-organisms that can affect the yield of the residues when they are used as biofuel (Colantoni et al. 2021). It is necessary to mention that one of the biggest advantages of the SCG is that the grinding process is already done as the raw material for the preparation of the beverage, moreover the residues are widely distributed all over the world, in most of the cases the residues are already in the place where they can be processed.

After the preparation of the coffee beverage the SCG requires of the pre-treatment for the correct use. When the raw material is ready, this is used in a called Pelletizing process, this is a densification technique (compactation) used to transform fine materials such as powders, dusts, and other small particles into small, dense pellets that can be used for a variety of applications, including fuels based in biomass, animal feed, and more. Pelletizing is the most common method for size reduction of many thermoplastic materials, including raw polymers and mixed compounds (Drobny 2014). This is an effective method for transforming SCG into a more useful and versatile form. The pelletizing process for SCG typically involves the following steps:

1. Collection and drying: The moisture content for the SCG after the preparations of the coffee beverage is too high, so it is necessary to pre-treat the raw material for an optimal use of this in the pelletizing process. There are different ways which can be held to remove the moisture of the SCG, this process is important in order to get the desirable moisture content, the SCG can be dried either in an Oven drying process where the SCGs are placed inside an oven at temperatures from 75 ˚C to 105 ˚C, the time reference is between 8 h and 24 h, in a Solar drying process this depends of a wide range of factors, the capacity of the dryer, the efficiency, weather conditions, between others, or in an Open air sun drying process this process happens by placing the trays in open air, under the sun, no electrical consumption is required, the drying times depend on various external factors that may or may not be controlled, therefore this document only mentions them without establishing such times. The efficiency of each of the options also depends on its execution (Tun et al. 2020; Woo et al. 2021). The moisture of the raw material need to be reduce to between 10 % and 20 % to ensuare the production of high quality pellets (Garcia-Maraver 2015).
2. Raw material preparation: This may involve grinding, mixing, conditioning or other types of processing to ensure that the material has the right particle size and consistency for pelletizing. Once the coffee grounds are dry, they are typically ground into a fine powder using a hammer mill or other grinding equipment. This step helps to create a consistent particle size and ensures that the coffee grounds will form into pellets properly (Garcia-Maraver 2015). However this step sometimes may not be necesary depending on how the SCG were processed.
3. Pelletizing: The ground coffee is fed into a pelletizing machine, which compresses the coffee powder under high pressure to form small, dense and uniform pellets. Depending on the application, different binders such as corn starch or lignin could be added to help the pellets hold their shape. This machine typically consists of a rotating drum or disc that uses centrifugal force to compress the material into small, uniform pellets, the material is compacted to a pressure of 195 megapascals (MPa) for about 15 minutes (Kristanto & Wijaya 2018). Normally every 100 horsepower have the capacity to produce around 1 ton of pellets per hour (Garcia-Maraver 2015).
4. Drying: After the pellets have been formed, they are typically sent through a drying process to remove any remaining moisture, if the moisture is higher to 20 % bacteria growth might occur (Garcia-Maraver 2015). This is important to ensure that the pellets do not degrade or spoil during storage or transport.
5. Cooling and screening: After the pellets are formed, they are typically cooled and screened to remove any undersized or oversized pellets, as well as any fines or dust that may have been generated during the pelletizing process. The cooling process is critical for pellet strength and durability of pellets, when the pellets come out from the extruder they are hot and soft, they are gradually air cooled to allow a lightning solidify and strengthen the pellets (Garcia-Maraver 2015). 6. Packaging and storage: Finally, the coffee pellets are packaged and stored until they are ready for use. The tipical way to packaging the SCG pellets are in bags. The weight of a spent coffee grounds pellets bag in the market can vary depending on the manufacturer and the intended use of the pellets. Generally, bags of spent coffee ground pellets for use as fuel are available in weights ranging from 1kg (2.2 lbs) to 20kg (44 lbs) or more.

There is an abundant literature review on the production of Pellets as biofuels, in the last years the SCG have been studied in many ways to understand its potential as biofuel in the production of Pellets, and if it is feasible or not.

References

Colantoni A, Paris E, Bianchini L, Ferri S, Marcantonio V, Carnevale M, Palma A, Civitarese V, Gallucci F. 2021. Spent coffee ground characterization, pelletization test and emissions assessment in the combustion process. Scientific Reports 11. Nature Research.

Drobny JG. 2014. Processing Methods Applicable to Thermoplastic Elastomers. Pages 33–173 Handbook of Thermoplastic Elastomers2cond edition. Elsevier.

Garcia-Maraver A. 2015. Biomass Pelletization Process. Pages 53–66.

Tun MM, Raclavská H, Juchelková D, Růžičková J, Šafář M, Štrbová K, Gikas P. 2020. Spent coffee ground as renewable energy source: Evaluation of the drying processes. Journal of Environmental Management 275. Academic Press.

Woo DG, Kim SH, Kim TH. 2021. Solid fuel characteristics of pellets comprising spent coffee grounds and wood powder. Energies 14. MDPI AG.

Figure 16: Web platform screenshot for the small literature review section.

Source: by the author.

All the codes, such as HTML, CSS and JavaScript can be found in their entirety in the appendices section of this document. At the time of writing this document, version 1.0 of the platform was published.

4.6. Step 6: Control and value testing

When it comes to web developing, testing is an essential part of the process. A well-designed test ensures that the platform works as intended and helps prevent bugs and errors. The test was made with the purpose of doing any necessary adjustments to ensure that it is working correctly for all types of calculations. In order to carry out the test, a reference value was used, the value that has been taken into account is the amount of SCG residues produced annually, according to (Tokimoto et al. 2005) around 6,000,000 tons of SCG are generated worldwide. This value was taken as the amount of residues to carry out the reference calculations for the platform test. In order to reduce the figures and make them easier to understand, the total number of annual residues was reduced to weekly residues, giving a total of ± 125,000 tons per week worldwide.

As a first step, all standard reference values to be used were identified previously in Table 19, other values like BD and MD are not shown because calculation with these values are not carried out, the values are just representatives. Since the reference values regarding the amount of energy obtained are referenced by kilograms, it was proceeded to calculate the kilograms contained in 125,000 tons, giving a total of 125,000,000 kg. This material must still be dried and processed before it can be used for the production of pellets. Its moisture content must be reduced to a desired 10.20 % (wb.).

In order to calculate the value of the dry mass of the SCG, the equation (1) was used, where the number of reference residues was replaced as follow:

$$Wf = \frac{125{,}000{,}000 - (125{,}000{,}000 * 0.5708)}{1 - 0.102}$$

$$Wf = \frac{125{,}000{,}000 - 71{,}350{,}000}{0.898}$$

$$Wf = \frac{53{,}650{,}000}{0.898}$$

$$Wf = 59{,}743{,}875.28$$

<u>Residues with optimal moisture content (10.20 %wb.) = 59,743,875.28 kg</u>

In the case that the residues are established as reduced moisture content residues, then it is not necessary to carry out the moisture reduction calculation, the raw gross value is used. Once the reference value for the material with the OMC is obtained, the amount in kg is multiplied by each one of the standard references' values.

For the calculation of the CV of the obtained number of residues the equations number (2) and (3) were used, each one for the NTC and GCV respectively in dry basis.

For the calculation of the NCV (wb.) the equation (2) was used as follow:

$$El = 59{,}743{,}875.28 * 16.66$$

$$El = 995{,}332{,}962.16$$

NCV(wb.) = 995,332,962.16 MJ kg^{-1}

For the calculation of the NCV (db.) the equation (2) was used as follow:

$$El = 59{,}743{,}875.28 * 20.33$$

$$El = 1{,}214{,}592{,}984.44$$

NCV(db.) = 1,214,592,984.44 MJ kg^{-1}

For the calculation of the GCV the equation (3) was used as follow:

$$Eh = 59{,}743{,}875.28 * 24.79$$

$$Eh = 1{,}481{,}050{,}668.19$$

GCV = 1,481,050,668.19 MJ kg^{-1}

For the calculation of the ash content the equation (4) was used as follow:

$$Ar = 59{,}743{,}875.28 * 0.0171$$

$$Ar = 1{,}021{,}620.27$$

The total amount of ash residual (1.73 %db.) = 1,021,620.27 kg

For the calculation of the economic value the equation (5) was used as follow:

$$Ev = 59{,}743{,}875.28 * 0.12$$

$$Ev = 7{,}169{,}265.03$$

The total economic value of the total moaun of residues (0.12EUR kg^{-1}) = 7,169,265.03 EUR

The results of the energy potential for a total of 125,000 tons of SCG with a high moisture content of around 60.00 % produced per week worldwide are as shown in Table 19.

Table 19: Total energy potential of 125,000,000 kg of SCG with a high initial moisture content (wb.).

	Measure unit	*Reference*	*Measure unit*
Initial weight of SCG (wb.)	*% | kg*	IMC 57.08	125,000,000.00
Reduced weight of SCG (wb.)	*% | kg*	OMC 10.20	59,743,875.28
Net calorific value (wb.)	*MJ kg^{-1}*	16.66	995,332,962.16
Net calorific value (db.)	*MJ kg^{-1}*	20.33	1,214,592,984.44
Gross calorific value (db.)	*MJ kg^{-1}*	24.79	1,481,050,668.19
Ash content (db.)	*% | kg*	1.73	1,021,620.27
Economic value	*EUR kg^{-1}*	0.12	7,169,265.03

Once the reference values coincided with the data provided by the platform shown on Figure 17, the development and testing process was concluded.

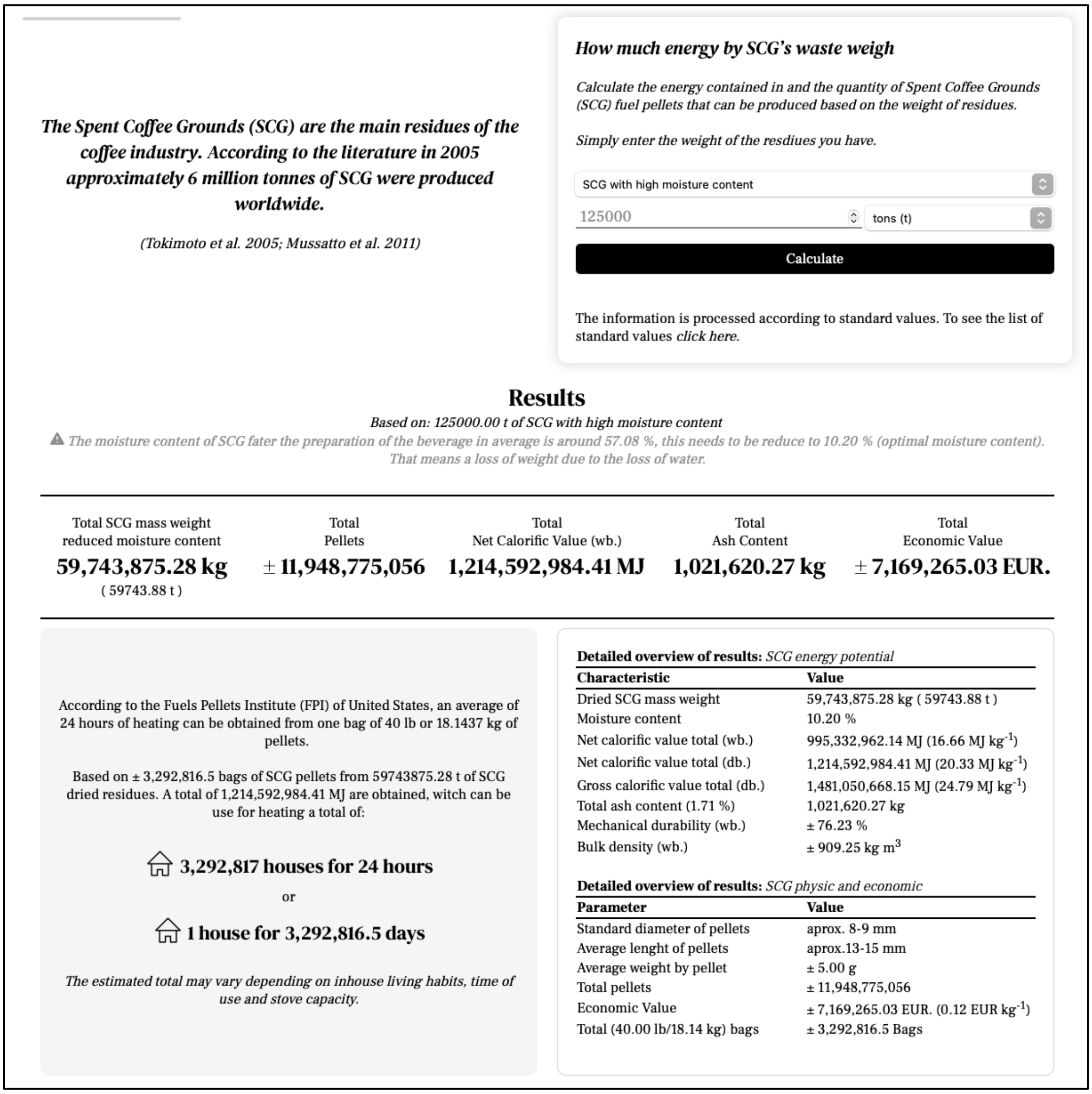

Figure 17: Web platform results of calculation based on 125,000 tons of SCG.

Source: by the author.

5. Discussion

Based on the studies and/or publications reviewed during the creation of this thesis, a reference framework was established in order to unify the values reported of SCG-based fuel pellets in past years, since not all the studies mention all the characteristics that make up the SCG-based pellets, this study sought to put all the information available together.

Although the literature is extensive, there are few studies focused on evaluating, through practical experimentation, some of the characteristics such as bulk density, ash content, economic value and MD. The most outstanding characteristics such as net calorific value (16.66 MJ kg^{-1} wb. and 20.33 MJ kg^{-1} db.) and gross calorific value (24.79 MJ kg^{-1} db.), although their mention in the reviewed literature are recurrent, not all studies mention both values as well as if they are in wet or dry basis, so during the process of creating this thesis special importance was given to identify and establishing these values, given that they are what characterize the potential of the SCG as a source of green energy.

It is already well known that the potential of the SCG and its utilization as refuse derived fuel is optimal, due the gross calorific value, however, in a study carried out in 2022, it's emphasized that the production of pellets with 100.00 % SCG is not feasible, first due to the fact that still a binder component is needed, some studies uses starch at 2.00 % to help the SCG to bind (Colantoni et al. 2021) but more commonly SCG-based pellets are manufactured by the addition of pine sawdust, because this improves densification, cohesiveness of pellets (Tun et al. 2020); the high emissions of nitrogen oxide, in addition to a drop in the temperature due to inefficient combustion, leads to low boiler combustion and increases carbon monoxide emissions (Atabani et al. 2022b).

Moreover, the addition of other residues obtained from the coffee processing can be used to reduce nitrogen oxide emissions and control combustion. The addition of coffee silverskin, this being the second most obtained residue and having a morphological structure similar to that of sawdust, being lighter and having a high combustion index, it can be used as a mixture to improve the production of pellets (Kristanto & Wijaya 2018).

Based only on the main composition of the SCG, since most of the pellets are made up of more than 90.00 % of these, the data standardized in the reference framework established by this document in comparison with those standards given by The British

Standards Institution (2014). For all those solid biofuels graded non-woody pellets characteristics, the vast majority were identified as grade A, except for MD, which was below the established standard. All the details of the comparison of the SCG-based fuel pellets with the non-woody graded pellets characteristics can be seen in more detail in Table 20, only available features were compared.

Table 20: Comparison of SCG-based fuel pellets with graded non-woody pellets produced from herbaceous biomass, fruit biomass, aquatic biomass and blends and mixtures.

	Measure	**Graded A**	**Graded B**	**SCG**
OMC (wb.)	*%*	≤ 12.00	≤ 15.00	10.20
NCV (wb.)	*MJ kg^{-1}*	≥ 14.50	≥ 14.50	16.66
MD	*%*	*≥ 97.50*	*≥ 96.00*	*76.23*
BD	*Kg m^3*	≥ 600.00	≥ 600.00	909.25
Ash (db.)	*%*	≤ 6.00	≤ 10.00	1.71
Length (*L*)	*mm*	3.15-40.00	3.15-40.00	15.00
Diameter (⌀)	*mm*	6.00-25.00	6.00-25.00	8.00

In the other hand, the same values from the SCG-based fuel pellets were compared to the woody graded pellets standard given by The British Standards Institution (2014). For all those solid biofuels graded woody pellets characteristics, the vast majority were identified as graded B. The OMC and MD were under the standard of the graded woody pellets. In the other hand the Bulk density and the NCV (wb.) correspond to Graded A1. All the details of the comparison of the SCG-based fuel pellets with the woody graded pellets characteristics can be seen in more detail in Table 21, only available features were compared.

Table 21: Comparison of SCG-based fuel pellets with graded woody pellets produced from herbaceous biomass, fruit biomass, aquatic biomass and blends and mixtures.

	Measure	**Graded A1**	**Graded A2**	**B**	**SCG**
OMC (wb.)	*%*	*≤ 10.00*	*≤ 10.00*	*≤ 10.00*	*10.20*
NCV (wb.)	*MJ kg^{-1}*	≥ 16.50	≥ 16.50	≥ 16.50	16.66
MD	*%*	*≥ 97.50*	*≥ 97.50*	*≥ 96.50*	*76.23*
BD	*Kg m^3*	≥ 600.00	≥ 600.00	≥ 600.00	909.25
Ash (db.)	*%*	≤ 0.70	≤ 1.20	≤ 2.00	1.71
Length (*L*)	*mm*	3.15-40.00	3.15-40.00	3.15-40.00	15.00
Diameter (⌀)	*mm*	6.00-25.00	6.00-25.00	8.00	8.00

According to the bibliographic review carried out in this document, the key characteristics of SCG-based pellets are comparable to those of pellets made from wood both in wet basis, therefore the energy potential contained in this residue is promising to be a renewable source of energy. In the other hand, based in all the secondary data review in this master thesis, has been remarked that the calorific value in dry basis is superior to those made from wood. Based in all this information, here is confirmed the hypothesis that the SCG-based fuel pellets are comparable to the standard stablished by The British Standards Institution (2014) for the woody pellets, moreover the SCG-based fuel pellets are comparable even with a greater potential compared to those non-woody graded pellets.

The collected and standardized information used in the creation of the web platform proposed in this document gives a broader picture of the great potential contained in SCGs, brings together all the necessary information to have a general idea of how SCGs are obtained and processed and facilitates access to said information, which will be a starting point and reference for future research and/or as a resource for people, institutions that seek to expand their knowledge in relation to the use of SCG as a source of green energy.

6. Conclusions

The spent coffee grounds have great potential to be used as a source of renewable energy for the creation of biofuels, more specifically pellets. As already demonstrated in this study, although the potential of the residue by itself is promising, an additive such as sawdust or starch is still needed in a minimal amount in order to meet the necessary requirements and the non-wood pellet standard. The SCG also have some advantages that other materials do not have, such as its wide distribution throughout the world, being such a commercialized, distributed and desired good, residues do not have to travel long distances to be processed, since most of it is already in a place.

Currently, there are many initiatives to be able to process SCG and reuse it for other purposes so that it does not end up in landfills, generating pollution to the environment. Due to its large amounts generated worldwide, it is a concern that is becoming increasingly important. For the most part of SCG the lack of information on how to process them means that more than half of the residues produced mostly by coffee shops and coffee processing factories ends up in landfills, and although the information on its potential uses is extensive, it is not easily accessible and is also very focused on experimental uses and specific results.

This study concludes that with proper knowledge, SCGs can become a promising renewable energy source in the future. This study has resorted to the use of web technologies to propose a platform that helps to calculate the energy potential contained in the residues obtained from the commercialization of coffee, in addition to facilitating access to information in order to be used as a point of reference for future research.

This study also concluded and emphasized the importance of having a broader picture of all the characteristics that make up the SCG, characteristics identified in this document as: initial moisture content, optimal moisture content, net calorific value, gross calorific value, ash content, bulk density, mechanical durability and economic value; all together give an idea of the value contained and the product to be produced. The platform proposed by this thesis is just a helpful tool that can provide a convenient and flexible way for researchers, coffee producers, coffee shops and pellet producers that want to know more about the SCG-bassed fuel pellets, having an access to all the material reviewed in this document.

7. References

Accredited Research Centre (Centre de Recherche Agréé – CRA). (n.d.). Pelletizing Processes. Available from https://www.ctp.be/en/expertise/mineral-processing/pelletizing-processes/ (accessed February 6, 2023).

Acevedo F, Rubilar M, Scheuermann E, Cancino B, Uquiche E, Garcés M, Inostroza K, Shene C. 2013. Spent coffee grounds as a renewable source of bioactive compounds. Journal of Biobased Materials and Bioenergy **7**:420–428.

Ahalya N, Chandraprabha MN, Kanamadi RD, Ramachandra T v. 2014. Adsorption of Fast Green on to Coffee Husk. Page Journal of Chemical Engineering and Research. Available from http://www.deltonbooks.com.

Alemu F. 2015. Cultivation of Shiitake Mushroom (Lentinus edodes) on Coffee Husk at Dilla University, Ethiopia. Journal of Food and Nutrition Sciences **3**:63. Science Publishing Group.

Allesina G, Pedrazzi S, Allegretti F, Tartarini P. 2017. Spent coffee grounds as heat source for coffee roasting plants: Experimental validation and case study. Applied Thermal Engineering **126**:730–736. Elsevier Ltd.

Anh Dzung N, Trung Dzung T, Thi Phuong Khanh V. 2013. Evaluation of coffee husk compost for improving soil fertility and sustainable coffee production in rural Central Highland of Vietnam. Resources and Environment **3**:77–82. Available from https://www.researchgate.net/publication/262182346.

Antar M, Lyu D, Nazari M, Shah A, Zhou X, Smith DL. 2021, April 1. Biomass for a sustainable bioeconomy: An overview of world biomass production and utilization. Elsevier Ltd.

Arturo E, Flores A, Mariel K, Zamora M, Optar P, De AT. 2008. Propuesta para el aprovechamiento de los subproductos del beneficiado del café como una alternativa para la diversificación de la actividad cafetalera y aporte de valor a la cadena productiva. San Salvador.

Atabani AE, Ali I, Naqvi SR, Badruddin IA, Aslam M, Mahmoud E, Almomani F, Juchelková D, Atelge MR, Khan TMY. 2022a. A state-of-the-art review on spent coffee ground (SCG) pyrolysis for future biorefinery. Chemosphere **286**. Elsevier Ltd.

Atabani AE, Al-Muhtaseb AH, Kumar G, Saratale GD, Aslam M, Khan HA, Said Z, Mahmoud E. 2019. Valorization of spent coffee grounds into biofuels and value-added products: Pathway towards integrated bio-refinery. Fuel **254**. Elsevier Ltd.

Atabani AE, Mahmoud E, Aslam M, Naqvi SR, Juchelková D, Bhatia SK, Badruddin IA, Khan TMY, Hoang AT, Palacky P. 2022b. Emerging potential of spent coffee ground valorization for fuel pellet production in a biorefinery. Environment, Development and SustainabilityDOI: 10.1007/s10668-022-02361-z. Springer Science and Business Media B.V.

Ballesteros LF, Teixeira JA, Mussatto SI. 2014. Chemical, Functional, and Structural Properties of Spent Coffee Grounds and Coffee Silverskin. Food and Bioprocess Technology **7**:3493–3503. Springer Science and Business Media, LLC.

Basu P. 2013. Biomass Gasification, Pyrolysis and Torrefaction. Practical Design and Theory - Second Edition.

Bejenari V, Marcu A, Ipate AM, Rusu D, Tudorachi N, Anghel I, Şofran IE, Lisa G. 2021. Physicochemical characterization and energy recovery of spent coffee grounds. Journal of Materials Research and Technology **15**:4437–4451. Elsevier Editora Ltda.

Benitez V, Rebollo-Hernanz M, Hernanz S, Chantres S, Aguilera Y, Martin-Cabrejas MA. 2019. Coffee parchment as a new dietary fiber ingredient: Functional and physiological characterization. Food Research International **122**:105–113. Elsevier Ltd.

Bessada SMF, Alves RC, Costa ASG, Nunes MA, Oliveira MBPP. 2018. Coffea canephora silverskin from different geographical origins: A comparative study. Science of the Total Environment **645**:1021–1028. Elsevier B.V.

Bhushan B, Bhat R, Rao BYK, Ahmad R, Bongirwar DR. 2003. Electron spin resonance studies on γ-irradiated coffee bean parts. International Journal of Food Science and Technology **38**:11–16.

Blinová L, Bartošová A, Sirotiak M. 2017a. Biodiesel Production from Spent Coffee Grounds. Research Papers Faculty of Materials Science and Technology Slovak University of Technology **25**:113–121. Walter de Gruyter GmbH.

Blinová L, Sirotiak M, Bartošová A, Soldán M. 2017b. Review: Utilization of Waste From Coffee Production. Research Papers Faculty of Materials Science and Technology Slovak University of Technology **25**:91–101. Walter de Gruyter GmbH.

Bondesson E, Koch K. 2015. A nutritional analysis on the by-product coffee husk and its potential utilization in food production-A literature study. Available from http://stud.epsilon.slu.se.

Bonilla-Hermosa VA, Duarte WF, Schwan RF. 2014. Utilization of coffee by-products obtained from semi-washed process for production of value-added compounds. Bioresource Technology **166**:142–150. Elsevier Ltd.

Borrelli RC, Esposito F, Napolitano A, Ritieni A, Fogliano V. 2004. Characterization of a New Potential Functional Ingredient: Coffee Silverskin. Journal of Agricultural and Food Chemistry **52**:1338–1343. American Chemical Society.

Caetano NS, Silva VFM, Melo AC, Martins AA, Mata TM. 2014. Spent coffee grounds for biodiesel production and other applications. Clean Technologies and Environmental Policy **16**:1423–1430. Springer Verlag.

Calderón C, Colla M, Jossart J. 2019. Statistical report 2019 - Report pellets. Available from www.bioenergyeurope.org.

Carvill J. 1993. Thermodynamics and heat transfer. Pages 102–145 Mechanical Engineer's Data Handbook. Elsevier. Available from https://linkinghub.elsevier.com/retrieve/pii/B978008051135150008X.

CENICAFE. 1999. Cap. 3 Beneficio Ecológico del Café.

Chen YC, Chen LY. 2021. Pelleting spent coffee grounds by waste utensils as binders of biofuels. Journal of Environmental Chemical Engineering **9**. Elsevier Ltd.

Clapp J, Ruder SL. 2020. Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. Global Environmental Politics **20**:49–69. MIT Press Journals.

Colantoni A, Paris E, Bianchini L, Ferri S, Marcantonio V, Carnevale M, Palma A, Civitarese V, Gallucci F. 2021. Spent coffee ground characterization, pelletization test and emissions assessment in the combustion process. Scientific Reports **11**. Nature Research.

Czech Statistical Office. 2020, December 18. Statistical Yearbook of Prague - 2020. Available from https://www.czso.cz/csu/czso/maps-and-cartograms-xzou8oj90p (accessed February 1, 2023).

Dananto Ulsido M, Zeleke G, Li M. 2016. Biogas potential assessment from a coffee husk: an option for solid waste management in gidabo watershed of ethiopia.

Dattatraya Saratale G et al. 2020, October 1. A review on valorization of spent coffee grounds (SCG) towards biopolymers and biocatalysts production. Elsevier Ltd.

de Hacienda M et al. 2015. Beneficio del café en Colombia.

de Souza HJPL, Arantes MDC, Vidaurre GB, Andrade CR, Carneiro A de CO, de Souza DPL, Protásio T de P. 2020. Pelletization of eucalyptus wood and coffee growing wastes: Strategies for biomass valorization and sustainable bioenergy production. Renewable Energy **149**:128–140. Elsevier Ltd.

Demirbas A. 2000. Biomass resource facilities and biomass conversion processing for fuels and chemicals. Available from www.elsevier.com/locate/enconman.

Dinu R. 2006. Wood pellets combustion with rich and diluted air in HTAC furnace. The Royal Institute of Technology - Stockholm, Stockholm.

Drobny JG. 2014. Processing Methods Applicable to Thermoplastic Elastomers. Pages 33–173 Handbook of Thermoplastic Elastomers2cond edition. Elsevier.

Duarte GS, Pereira AA, Farah A. 2010. Chlorogenic acids and other relevant compounds in Brazilian coffees processed by semi-dry and wet post-harvesting methods. Food Chemistry **118**:851–855.

Echeverria MC, Nuti M. 2017. Valorisation of the Residues of Coffee Agro-industry: Perspectives and Limitations. The Open Waste Management Journal **10**:13–22. Bentham Science Publishers Ltd.

FAO. 2021. Markets and Trade - Coffee.

Firmy.cz. 2023, January. Enrolled Coffee Shops in Prague. Available from https://www.firmy.cz/Restauracni-a-pohostinske-sluzby/Kavarny/kraj-praha (accessed February 1, 2023).

Forcina A, Petrillo A, Travaglioni M, di Chiara S, De Felice F. 2023. A comparative life cycle assessment of different spent coffee ground reuse strategies and a sensitivity analysis for verifying the environmental convenience based on the location of sites. Journal of Cleaner Production **385**. Elsevier Ltd.

Garcia C V., Kim YT. 2021, August 1. Spent Coffee Grounds and Coffee Silverskin as Potential Materials for Packaging: A Review. Springer.

Garcia-Maraver A. 2015. Biomass Pelletization Process. Pages 53–66.

Getachew T, Hussen A, Rao VM. 2015. Defluoridation of water by activated carbon prepared from banana (Musa paradisiaca) peel and coffee (Coffea arabica) husk. International Journal of Environmental Science and Technology **12**:1857–1866. Center for Environmental and Energy Research and Studies.

Gouvea BM, Torres C, Franca AS, Oliveira LS, Oliveira ES. 2009. Feasibility of ethanol production from coffee husks. Biotechnology Letters **31**:1315–1319.

Hamdouche Y, Meile JC, Nganou DN, Durand N, Teyssier C, Montet D. 2016. Discrimination of post-harvest coffee processing methods by microbial ecology analyses. Food Control **65**:112–120. Elsevier Ltd.

Heeger A, Kosińska-Cagnazzo A, Cantergiani E, Andlauer W. 2017. Bioactives of coffee cherry pulp and its utilisation for production of Cascara beverage. Food Chemistry **221**:969–975. Elsevier Ltd.

Hejna A. 2021, February 15. Potential applications of by-products from the coffee industry in polymer technology – Current state and perspectives. Elsevier Ltd.

Hidalgo F, Quiñones-Ruiz XF, Birkenberg A, Daum T, Bosch C, Hirsch P, Birner R. 2023. Digitalization, sustainability, and coffee. Opportunities and challenges for agricultural development. Agricultural Systems **208**:103660. Available from https://linkinghub.elsevier.com/retrieve/pii/S0308521X23000653.

Jeguirim M, Limousy L, Dutournie P. 2014. Pyrolysis kinetics and physicochemical properties of agropellets produced from spent ground coffee blended with conventional biomass. Chemical Engineering Research and Design **92**:1876–1882. Institution of Chemical Engineers.

Jeguirim M, Limousy L, Fossard E. 2016. Characterization of coffee residues pellets and their performance in a residential combustor. International Journal of Green Energy **13**:608–615. Taylor and Francis Inc.

Jeníček L, Tunklová B, Malaťák J, Neškudla M, Velebil J. 2022. Use of Spent Coffee Ground as an Alternative Fuel and Possible Soil Amendment. Materials **15**. MDPI.

Jiménez-Zamora A, Pastoriza S, Rufián-Henares JA. 2015. Revalorization of coffee by-products. Prebiotic, antimicrobial and antioxidant properties. LWT **61**:12–18. Academic Press.

Kan T, Strezov V, Evans T. 2014. Catalytic pyrolysis of coffee grounds using NiCu-impregnated catalysts. Pages 228–235 Energy and Fuels.

Kang SB, Oh HY, Kim JJ, Choi KS. 2017. Characteristics of spent coffee ground as a fuel and combustion test in a small boiler (6.5 kW). Renewable Energy **113**:1208–1214. Elsevier Ltd.

Kondamudi N, Mohapatra SK, Misra M. 2008. Spent coffee grounds as a versatile source of green energy. Journal of Agricultural and Food Chemistry **56**:11757–11760.

Kristanto GA, Wijaya H. 2018. Assessment of spent coffee ground (SCG) and coffee silverskin (CS) as refuse derived fuel (RDF). Page IOP Conference Series: Earth and Environmental Science. Institute of Physics Publishing.

Krug CA, Carvalho A. 1951. The Genetics of Coffea.

Lachman J, Lisý M, Baláš M, Matúš M, Lisá H, Milčák P. 2022. Spent coffee grounds and wood co-firing: Fuel preparation, properties, thermal decomposition, and emissions. Renewable Energy **193**:464–474. Elsevier Ltd.

Larson ED, Kartha S. 2000. Expanding roles for modernized biomass energy. Energy for Sustainable Development **4**:15–25. Elsevier.

Li X, Strezov V, Kan T. 2014. Energy recovery potential analysis of spent coffee grounds pyrolysis products. Journal of Analytical and Applied Pyrolysis **110**:79–87. Elsevier B.V.

Lisowski A, Olendzki D, Świętochowski A, Dąbrowska M, Mieszkalski L, Ostrowska-Ligęza E, Stasiak M, Klonowski J, Piątek M. 2019. Spent coffee grounds compaction process: Its effects on the strength properties of biofuel pellets. Renewable Energy **142**:173–183. Elsevier Ltd.

Lupton E, Cole Phillips J. 2008. Graphic Design the New Basics.

Manasa V, Padmanabhan A, Anu Appaiah KA. 2021. Utilization of coffee pulp waste for rapid recovery of pectin and polyphenols for sustainable material recycle. Waste Management **120**:762–771. Elsevier Ltd.

Martinez-Saez N, Ullate M, Martin-Cabrejas MA, Martorell P, Genovés S, Ramon D, del Castillo MD. 2014. A novel antioxidant beverage for body weight control based on coffee silverskin. Food Chemistry **150**:227–234. Elsevier Ltd.

Massaya J, Prates Pereira A, Mills-Lamptey B, Benjamin J, Chuck CJ. 2019. Conceptualization of a spent coffee grounds biorefinery: A review of existing valorisation approaches. Food and Bioproducts Processing **118**:149–166. Institution of Chemical Engineers.

McNutt J, He Q (Sophia). 2019, March 25. Spent coffee grounds: A review on current utilization. Korean Society of Industrial Engineering Chemistry.

Mebrahtom Gebresemati, Nigus Gabbiye, Sahu O. 2017. Sorption of cyanide from aqueous medium by coffee husk: Response surface methodology. Journal of Applied Research and Technology **15**:27–35. Universidad Nacional Autonoma de Mexico, Centro de Ciencias Aplicadas y Desarrollo Tecnologico.

Mejía-González CA, Carlos Oliveros-Tascón, E Sanz-Uribe, Juan R Moreno-Cárdenas, Edilson Luis, Rodríguez-Hurtado A. 2007. Evaluation of the technical and environmental performance of a coffee demucilaginer with rod rotor. Page 122 Cenicafé.

Mirón-Mérida VA, Yáñez-Fernández J, Montañez-Barragán B, Barragán Huerta BE. 2019. Valorization of coffee parchment waste (Coffea arabica) as a source of caffeine and phenolic compounds in antifungal gellan gum films. LWT **101**:167–174. Academic Press.

Mojapelo N, Mollagee M, Muzenda E, Mguni LL. 2021. Effect of Moisture Quantity on Non-Distillation Oil Extraction from SCG using MethanolDOI: 10.15242/IJRCMCE.E1113564. Available from http://dx.doi.org/10.15242/.

Mussatto SI, Carneiro LM, Silva JPA, Roberto IC, Teixeira JA. 2011a. A study on chemical constituents and sugars extraction from spent coffee grounds. Carbohydrate Polymers **83**:368–374.

Mussatto SI, Machado EMS, Martins S, Teixeira JA. 2011b, July. Production, Composition, and Application of Coffee and Its Industrial Residues.

Neu AK, Pleissner D, Mehlmann K, Schneider R, Puerta-Quintero GI, Venus J. 2016. Fermentative utilization of coffee mucilage using Bacillus coagulans and investigation of down-stream processing of fermentation broth for optically pure l(+)-lactic acid production. Bioresource Technology **211**:398–405. Elsevier Ltd.

Nigam PS, Singh A. 2014. Cocoa and Coffee Fermentations. Pages 485–492 Encyclopedia of Food Microbiology: Second Edition. Elsevier Inc.

Nosek R, Tun MM, Juchelkova D. 2020. Energy utilization of spent coffee grounds in the form of pellets. Energies **13**. MDPI AG.

Nyoman Kutha Krisnawijaya N, Tekinerdogan B, Catal C, Tol R van der. 2022, April 1. Data analytics platforms for agricultural systems: A systematic literature review. Elsevier B.V.

Office of Energy Efficiency & Renewable Energy - U.S. Department of Energy. (n.d.). Choosing and Installing Wood- and Pellet-Burning Appliances. Available from https://www.energy.gov/energysaver/wood-and-pellet-heating (accessed April 1, 2023).

Oliveira WE, Franca AS, Oliveira LS, Rocha SD. 2008. Untreated coffee husks as biosorbents for the removal of heavy metals from aqueous solutions. Journal of Hazardous Materials **152**:1073–1081.

Pallardy S. 2008. Physiology of Woody Plants (Third Edition):107–1067.

Paola J, Usaquén P, Juan ;, Uribe RS, Carlos ;, Tascón EO. 2013. Handling mechanically demucilaginated coffee.

Park S, Jeong HR, Shin YA, Kim SJ, Ju YM, Oh KC, Cho LH, Kim D. 2021. Performance optimisation of fuel pellets comprising pepper stem and coffee grounds through mixing ratios and torrefaction. Energies **14**. MDPI AG.

Perea-Moreno MA, Samerón-Manzano E, Perea-Moreno AJ. 2019. Biomass as renewable energy: Worldwide research trends. Sustainability (Switzerland) **11**. MDPI.

Pérez E, Carril U. 2009. Fotosíntesis: Aspectos Básicos. Reduca (Biología). Serie Fisiología Vegetal **2**:1–47.

Poulin R. 2011. The language of graphic design: an illustrated handbook for understanding fundamental design principles. Rockport Publishers.

PRAGUE CASTLE President of the CR. 2001, March. About the Czech Republic. Available from https://www.hrad.cz/en/czech-republic/about-the-czech-republic (accessed February 1, 2023).

Prihadi AR, Maimulyanti A. 2020. Chemical Compounds of Coffee Ground and Spent Coffee Ground for Pharmaceutical Products.

Quintero JJG, Mendez CDN, Vianchá Sánchez Z. 2017. Análisis de buenas prácticas en el proceso de beneficio del café: experiencia de estudio en el municipio de Viotá (Cundinamarca, Colombia). Ingeniería Solidaria **13**:121–136. Universidad Cooperativa de Colombia- UCC.

Rajabi Hamedani S, Colantoni A, Bianchini L, Carnevale M, Paris E, Villarini M, Gallucci F. 2022. Environmental life cycle assessment of spent coffee ground pellet. Energy Reports **8**:6976–6986. Elsevier Ltd.

Rodrigues F, Pereira C, Pimentel FB, Alves RC, Ferreira M, Sarmento B, Amaral MH, Oliveira MBPP. 2015. Are coffee silverskin extracts safe for topical use? An in vitro and in vivo approach. Industrial Crops and Products **63**:167–174. Elsevier.

Rodríguez Valencia N, Antonio D, Franco Z. 2010. National coffee fund the by-products of coffee: source of renewable energyDOI: 10.38141/10779/0393. Available from https://doi.org/10.38141/10779/0393.

Rodríguez Valencia N, Rodilla Alamá M. 2009. Study of an integrated biosystem for the post-treatment of coffee wastewater using aquatic macrophytes. Universidad Politecnica de Valencia, Valencia.

Rosen M, Farsi A. 2022. Sustainability and sustainable energy. Pages 107–132 Sustainable Energy Technologies for Seawater Desalination. Elsevier.

Sakuragi K, Li P, Otaka M, Makino H. 2016. Recovery of bio-oil from industrial food waste by liquefied dimethyl ether for biodiesel production. Energies **9**. MDPI.

Santos ÉM dos, Macedo LM de, Tundisi LL, Ataide JA, Camargo GA, Alves RC, Oliveira MBPP, Mazzola PG. 2021, May 1. Coffee by-products in topical formulations: A review. Elsevier Ltd.

Sarkar DK. 2015. Fuels and Combustion. Pages 91–137 Thermal Power Plant. Elsevier.

Setter C, Borges FA, Cardoso CR, Mendes RF, Oliveira TJP. 2020. Energy quality of pellets produced from coffee residue: Characterization of the products obtained via slow pyrolysis. Industrial Crops and Products **154**. Elsevier B.V.

Shemekite F, Gómez-Brandón M, Franke-Whittle IH, Praehauser B, Insam H, Assefa F. 2014. Coffee husk composting: An investigation of the process using molecular and non-molecular tools. Waste Management **34**:642–652.

Silva MA, Nebra SA, Silva MJM, Sanchez CG. 1997. The use of biomass residues in the brazilian soluble coffee industry.

Suarez Agudelo JM, Cardona Jaramillo MIDC. 2012. Use of solid waste from coffee processing in the municipality of Betania Antioquia: uses and applications.

Sybil Agri International. 2022. Global coffee market report in february 2022.

Taddesse AM, Hailu AM, Berhe S, Ayele D, Tadesse A, Mulu A. 2015. Adsorption Efficiency of Coffee Husk for Removal of Lead (II) from Industrial Effluents: Equilibrium and Kinetic Study. International Journal of Scientific and Research Publications **5**. Available from www.ijsrp.org.

Taeixeira AA, Brando CHJ, Thomazielo RA, Viano R, Illy A. 1995. Espresso Coffee - The Science of Quality - Second Edition. ELSEVIER:110–113.

The British Standards Institution. 2014. BSI Standards Publication Solid biofuels-Fuel specifications and classes.

The World Wide Web Consortium [W3C]. 2021, August 6. 30 years on from introducing the web to the world. Available from https://www.w3.org/blog/2021/08/30-years-on-from-introducing-the-web-to-the-world/ (accessed April 20, 2023).

Tokimoto T, Kawasaki N, Nakamura T, Akutagawa J, Tanada S. 2005. Removal of lead ions in drinking water by coffee grounds as vegetable biomass. Journal of Colloid and Interface Science **281**:56–61.

Tun MM, Raclavská H, Juchelková D, Růžičková J, Šafář M, Štrbová K, Gikas P. 2020. Spent coffee ground as renewable energy source: Evaluation of the drying processes. Journal of Environmental Management **275**. Academic Press.

UNFCCC. 2005. Clarifications on definition of biomass and consideration of changes in carbon pools due to a cdm project activity.

United States Department of Agriculture. 2022. Coffee: World Markets and Trade. Available from http://www.ico.org/coffee_prices.asp.

U.S. Department of Energy. 2016. Bioenergy Basics. Available from https://www.energy.gov/eere/bioenergy/bioenergy-basics (accessed February 1, 2023).

U.S. Energy Information Administration. 2022, June. Biomass—renewable energy from plants and animals.

USAID Bureau for Food Security. 2017. Renovation & Rehabilitation for Resilient Coffee Farms: A Guidebook for Roasters, Traders and Supply Chain Partners. Available from www.sustaincoffee.org.

Vakalis S, Moustakas K, Benedetti V, Cordioli E, Patuzzi F, Loizidou M, Baratieri M. 2019. The "COFFEE BIN" concept: centralized collection and torrefaction of spent coffee grounds. Environmental Science and Pollution Research **26**:35473–35481. Springer.

van Dam JEG, Harmsen P. 2010. Coffee residues utilization Literature survey In commission of Agentschap NL and KNVKT. Available from www.wur.nl.

Vieira T, Cunha S, Casal S. 2015. Mycotoxins in Coffee. Pages 225–233 Coffee in Health and Disease Prevention. Elsevier Inc.

Woo DG, Kim SH, Kim TH. 2021. Solid fuel characteristics of pellets comprising spent coffee grounds and wood powder. Energies **14**. MDPI AG.

www.macrotrends.net. 2022. World Population 1950-2023. Available from https://www.macrotrends.net/countries/WLD/world/population (accessed February 4, 2023).

Yadira PSB, Sergio ST, Fernando SEL, Sebastian PJ, Eapen D. 2014. Bioethanol production from coffee mucilage. Pages 950–956 Energy Procedia. Elsevier Ltd.

Yuri K. (n.d.). Calcular la equivalencia de megajoule [MJ] <—> kilocaloría (IT) [kcal (IT), kcal]. Available from https://www.translatorscafe.com/unit-converter/es-ES/energy/3-27/megajoule-kilocalorie%20(IT)/ (accessed February 2, 2023).

Appendices

List of the Appendices:

Appendix 1: general.css (General stylesheet)

Appendix 2: calculations.js (Calculations function)

Appendix 3: index.php (HTML code for the main page)

Appendix 1: general.css (General stylesheet)

```
/* -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
Author(s): Oscar Montano
Version: 1.0

Actual file:
general.css
-- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- */

body {
   margin: 0;
   padding: 0;
   font-family: 'Frank Ruhl Libre', serif;
}

input {
   padding: 0 0 0 5px;
   color: chocolate;
   border: none;
   border-bottom: 2px solid chocolate;
   font-family: 'Frank Ruhl Libre', serif;
   font-size: 1.1em;
} input::placeholder {
   font-style: italic;
   color: #E29F6F;
} input:focus {
   outline: 0;
}

select {
   font-size: 1.3em;
   margin: 5px 0;
}

/* -- CONTAINERS -- */
#coffeeimgtop {
   width: 100vw;
   height: 10vh;
   max-height: 80px;
   background-image: url(../imgs/img-dec-1.jpg);
   background-size: cover;
   background-position: center;
}

#blackband {
   width: 100vw;
   height: auto;
   padding: 5px;
   background-color: black;
   color: white;
   font-size: 0.8em;
   font-style: italic;
   text-align: center;

   box-sizing: border-box;
}

.general_container {
   width: 100vw;
   max-width: 1200px;
```

```
    height: auto;
    margin: 0 auto;
    padding: 10px;

    box-sizing: border-box;
}

/* -- FONTS -- */
.title {
    font-size: 1.7em;
    font-family: 'DM Serif Display', serif;
}

.semititle {
    font-size: 1.3em;
    font-family: 'DM Serif Display', serif;
}

.font-i {
    font-style: italic;
}

/* -- INPUTS -- */
#TOR {
    width: 100%;
}

#QOR {
    width: 59%;
}

#TOM {
    width: 39%;
}

/* -- SECTIONS -- */
#logo {
    width: 150px;
    height: 100px;
    margin: 0 auto;
    background-image: url(../imgs/SCG-Analyzer.png);
    background-position: center;
    background-size: contain;
    background-repeat: no-repeat;
}

#introduction, #description {
    width: 100%;
    height: auto;
    margin: 0;
    padding: 20px;
    box-sizing: border-box;
}

#introduction {
    text-align: center;
    border-bottom: 2px solid lightgray;
}

#description {
    text-align: justify;
}
```

```
#SEC1 {
   width: 100%;
   height: auto;
   margin: 0;
   padding: 0;

   display: flex;
   flex-direction: row;
} #SEC1A, #SEC1B {
   flex-basis: 49%;
   padding: 20px;
   border-radius: 10px;
   box-sizing: border-box;
} #SEC1A {
   margin: 0 1% 0 0;
   position: relative;

   display: flex;
   flex-direction: column;
   justify-content: center;
   align-items: center;
} #SEC1B {
   margin: 0 0 0 1%;
   box-shadow: 0 0 15px lightgray;
}

#SEC2 {
   width: 100%;
   height: auto;
   margin: 0;
   padding: 0;

   display: flex;
   flex-direction: row;
} #SEC2A, #SEC2B {
   flex-basis: 49%;
   padding: 20px;
   border-radius: 10px;
   box-sizing: border-box;
} #SEC2A {
   margin: 0 1% 0 0;
   background-color: whitesmoke;
   position: relative;

   display: flex;
   flex-direction: column;
   justify-content: center;
   align-items: center;
} #SEC2B {
   margin: 0 0 0 1%;
   border: 1px solid;
   border-color: lightgray;
}

/* -- BOTONES -- */
#calculate {
   margin-top: 10px;
   padding: 7px;
   border-radius: 5px;
   background-color: black;
   color: white;
```

```
    display: block;
    cursor: pointer;
    text-align: center;
} #calculate:hover {
    background-color: chocolate;
}

/* -- RESULTS -- */
#N-results {
    padding: 10px;
    margin: 10px 0;
    text-align: center;
    font-style: italic;
    color: chocolate;

    box-sizing: border-box;
}

#C-results {
    padding: 20px;
    text-align: center;

    display: none;

    box-sizing: border-box;
}

#A-DSCG, #A-WSCG {
    color: chocolate;
    font-style: italic;
    display: none;
}

#RES {
    width: 100%;
    height: auto;
    margin: 10px 0;
    padding: 20px 0;
    border-top: 2px solid black;
    border-bottom: 2px solid black;

    display: flex;
    flex-direction: row;
    flex-wrap: nowrap;

    box-sizing: border-box;
}
.RESI {
    flex-basis: 20%;

    display: flex;
    flex-direction: column;
    justify-content: flex-start;
    align-items: center;
}

.RESI-T {
    display: block;
    font-weight: 300px;
}

.RESI-V {
```

```
  font-size: 1.65em;
  font-family: 'DM Serif Display', serif;
}

.DOOR {
  width: 100%;
  margin: 0 auto 20px auto;
  text-align: left;
  border-collapse: collapse;
}

.DOOR tr:first-child {
  font-weight: 600;
}

.DOOR tr:nth-child(2) {
  font-weight: 600;
} .DOOR tr:nth-child(2) td {
  border-top: 2px solid black;
  border-bottom: 2px solid black;
}

.DOOR td {
  text-align: left;
} .DOOR td:first-child {
  width: 50%;
}

.DOOR .TDES {
  font-weight: 200;
  font-style: italic;
}

/* -- FIGURATIVE RESULTS -- */
.FIGRES {
  width: auto;
  margin: 10px 0;
  display: block;
  font-size: 1.4em;
  font-family: 'DM Serif Display', serif;
}

#M1B, #L1B {
  display: none;
}

/* -- SLIDER -- */
.SLIDER {
  text-align: center;
  position: relative;
}

#slide p {
  display: block;
  margin-top: 20px;
  font-family: 'Frank Ruhl Libre', serif;
  font-style: italic;
  font-size: 0.8em;
}

#timebar {
  width: 0%;
```

```
    height: 4px;
    border-radius: 2px;
    background-color: lightgray;
    animation-name: timebar;
    animation-duration: 15s;
    animation-iteration-count: infinite;
    animation-timing-function: linear;

    position: absolute;
    top: 0;
    left: 0;
} @keyframes timebar {
  from {width: 0%;}
  to {width: 100%;}
}

/* -- Recurrent classes -- */
.block-link {
    padding: 10px;
    margin: 10px 0;
    text-align: center;
    font-style: italic;
    display: block;
    text-decoration: none;
    color: black;

    box-sizing: border-box;
} .block-link:hover {
    text-decoration: underline;
}

.link {
    text-align: center;
    font-style: italic;
    text-decoration: none;
    color: black;
} .link:hover {
    text-decoration: underline;
}

/* -- Small Literature Review -- */
#SmaLitRev {
    width: 100vw;
    height: auto;
    margin: 10px 0;
    padding: 20px;

    background-color: whitesmoke;

    display: flex;
    flex-direction: column;
    justify-content: center;
    align-items: center;

    box-sizing: border-box;
}

.text-columns {
    width: 100%;
    max-width: 1200px;
    -webkit-columns: 3;
    -moz-columns: 3;
```

```
    columns: 3;
    text-align: justify;
}

.SLR-item {
    margin: 0 5px;
} .SLR-item:hover {
    color: chocolate;
    font-weight: 400;
    cursor: pointer;
}

.SLR-item-selected {
    margin: 0 5px;
    color: chocolate;
    font-weight: 400;
}

#literature-refs {
    width: 100%;
    max-width: 1200px;
    font-style: italic;
    padding-left: 20px;
    text-indent: -20px;

    box-sizing: border-box;
}

.s-ref {
    color: chocolate;
    cursor: pointer;
}

.senalando {
    animation-name: timeref;
    animation-duration: 5s;
    animation-timing-function: linear;
} @keyframes timeref {
    0% {color: chocolate;}
    60% {color: chocolate;}
    100% {color: black;}
}
```

Appendix 2: calculations.js (Calculations function)

```
function calculate(){

   // Standard values
   var IMC = 0.5708; // Initial moisture content (57.08 %)
   var OMC = 0.102; // Optimal moisture content (10.20 %)
   var SLCVW = 16.66; // Standard net calorific value wb. (16.66 MJ kg-1)
   var SLCV = 20.33; // Standard net calorific value db. (20.33 MJ kg-1)
   var SHCV = 24.79; // Standard gross calorific value db. (24.79 MJ kg-1)
   var SASC = 0.0171; // Standard ash content (1.71 %)
   var SECV = 0.12; // Standard economic value (EUR kg-1)
   var STBD = 909.25; // Standard bulk density (kg m3)
   var SWPP = 5; // Standard pellet weight (g)

   // Here the information from the main form is gotten
   var TOR = document.getElementById('TOR').value; // Specified type of residues
   var QOR = document.getElementById('QOR').value; // Specified number of residues
   var TOM = document.getElementById('TOM').value; //Specified unit of measure

   // This section transforms the chosen weight units to kilograms
   switch(TOM){
      case 'grams': var TAR = QOR/1000; var measure = 'g'; break;
      case 'pounds': var TAR = QOR/2.205; var measure = 'lb'; break;
      case 'kilograms': var TAR = QOR; var measure = 'kg'; break;
      case 'tons': var TAR = QOR*1000; var measure = 't'; break;
   }

   // Here the calculations are done
   switch(TOR){

// In the case that the SCG residues have a high moisture content, the dry mass need to be calculated with a optimal moisture content of (10.20 %)
      case 'WSCG':

         // Mesage after results title
         document.getElementById('A-DSCG').style.display = "none";
         document.getElementById('A-WSCG').style.display = "block";

         var RTOR = 'SCG with high moisture content';

         var QORO = (QOR-(QOR*IMC))/(1-OMC);

         var DSCG = (TAR-(TAR*IMC))/(1-OMC);
         var LCV = DSCG*SLCV;
         var LCVW = DSCG*SLCVW;
         var HCV = DSCG*SHCV;
         var ASC = DSCG*SASC;
         var ECV = DSCG*SECV;
         var TPP = DSCG*(1000/SWPP);
         var BAG = DSCG/18.1437;

         var NHD = (DSCG*24.00)/18.1437;

      break;

// In the case that the SCG residues have a reduced moisture content of around (10.20 %). The value can be used as it was especified by the user.
      case 'DSCG':

         // Mesage after results title
```

```
        document.getElementById('A-DSCG').style.display = "block";
        document.getElementById('A-WSCG').style.display = "none";

        var RTOR = 'SCG with reduced moisture content';

        var QORO = QOR*1;

        var DSCG = TAR*1;
        var LCV = DSCG*SLCV;
        var LCVW = DSCG*SLCVW;
        var HCV = DSCG*SHCV;
        var ASC = DSCG*SASC;
        var ECV = DSCG*SECV;
        var TPP = DSCG*(1000/SWPP);
        var BAG = DSCG/18.1437;

        var NHD = (DSCG*24.00)/18.1437;

      break;

   }

}

   document.getElementById('R-DSCG').innerHTML = (QOR*1).toFixed(2)+" "+measure;
   document.getElementById('R-TOR').innerHTML = RTOR;

   if( measure != "kg" ){
      document.getElementById('D-DSCG-T-O').innerHTML = "( "+QORO.toFixed(2)+" "+measure+" )";
      document.getElementById('O-DSCG').innerHTML = "( "+QORO.toFixed(2)+" "+measure+" )";
   } else {
      document.getElementById('D-DSCG-T-O').innerHTML = "";
      document.getElementById('O-DSCG').innerHTML = "";
   }

   document.getElementById('D-DSCG-T').innerHTML = DSCG.toLocaleString("en-US", {maximumFractionDigits: 2,
minimumFractionDigits: 2});
   document.getElementById('D-TPP-T').innerHTML = TPP.toLocaleString("en-US", {maximumFractionDigits: 0});
   document.getElementById('D-LCV-T').innerHTML = LCV.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-ASC-T').innerHTML = ASC.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-ECV-T').innerHTML = ECV.toLocaleString("en-US", {maximumFractionDigits: 2});

   document.getElementById('D-DSCG').innerHTML = DSCG.toLocaleString("en-US", {maximumFractionDigits: 2,
minimumFractionDigits: 2});
   document.getElementById('D-LCV').innerHTML = LCV.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-LCV-W').innerHTML = LCVW.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-HCV').innerHTML = HCV.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-ASC').innerHTML = ASC.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-ECV').innerHTML = ECV.toLocaleString("en-US", {maximumFractionDigits: 2});
   document.getElementById('D-TPP').innerHTML = TPP.toLocaleString("en-US", {maximumFractionDigits: 0});
   document.getElementById('D-BAG').innerHTML = BAG.toLocaleString("en-US", {maximumFractionDigits: 1});

   document.getElementById('SLCV').innerHTML = SLCV+" MJ kg<sup>-1</sup>";
   document.getElementById('SLCV-W').innerHTML = SLCVW+" MJ kg<sup>-1</sup>";
   document.getElementById('SHCV').innerHTML = SHCV+" MJ kg<sup>-1</sup>";
   document.getElementById('NOB').innerHTML = BAG.toLocaleString("en-US", {maximumFractionDigits: 1});

   document.getElementById('TAOR').innerHTML = DSCG.toFixed(2)+" "+measure;

   document.getElementById('MJO').innerHTML = LCV.toLocaleString("en-US", {maximumFractionDigits: 2})+" MJ";

   // Hidding and Showing divs
```

```
    document.getElementById('N-results').style.display = "none";
    document.getElementById('C-results').style.display = "block";

    if ( DSCG < 18.1437 ){
        document.getElementById('M1B').style.display = "none";
        document.getElementById('L1B').style.display = "block";
        document.getElementById('NHD').innerHTML = NHD.toLocaleString("en-US", {maximumFractionDigits: 0});
    } else {
        document.getElementById('L1B').style.display = "none";
        document.getElementById('M1B').style.display = "block";
        document.getElementById('NOD').innerHTML = BAG.toLocaleString("en-US", {maximumFractionDigits: 1});
        document.getElementById('NOH').innerHTML = BAG.toLocaleString("en-US", {maximumFractionDigits: 0});
    };

};
```

Appendix 3: index.php (HTML code for the main page)

```
<?php

// Creating session
session_start();

   // Conecting to database
   // require ("DataBaseConnection.php");
   // $conexion = conectar();

   // Setting timezone
   date_default_timezone_set('Europe/Prague');

   // Calling file repetitive texts
   require("includes/texts.php");

   // Setting variables
   $pag_actual = 'Home';
   $titulo = $pag_actual." | ".$rept["headertitle"]." ".date("Y");

?>

<!DOCTYPE html>
<html lang="en">
   <head>
      <meta charset="utf-8">
      <meta name="viewport" content="width=device-width, user-scalable=no, initial-scale=1.0, maximun-scale=1.0,
minimun-scale=1.0">
      <title><?php echo $titulo; ?></title>

      <!-- Styles / CSS -->
     <link rel="stylesheet" type="text/css" href="css/vars.css">
     <link rel="stylesheet" type="text/css" href="css/general.css">

     <!-- Javascript -->
     <script src="https://code.jquery.com/jquery-3.2.1.js"></script>
     <script src="js/general.js"></script>
     <script src="js/calculations.js"></script>

     <!-- Fonts -->
     <link rel="preconnect" href="https://fonts.googleapis.com">
     <link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
     <link
     href="https://fonts.googleapis.com/css2?family=DM+Serif+Display:ital@0;1&family=Frank+Ruhl+Libre:wght@3
     00;400;800&display=swap" rel="stylesheet">

   </head>
   <body>

      <div id="coffeeimgtop"><!-- This DIC contains the image of the coffee at the top of the page --></div>
      <div id="blackband">PLATFORMA V. 1.0. Online since 30.03.2023</div>

      <div class="general_container">
         <div id="introduction">
            <div id="logo"></div>
            <font class="title">SCG Analyzer: A platform that strengthens the use of Spent Coffee Grounds as potential
renewable source of green energy for pellet production.</font><br>
            <br>
            <font class="font-i">SCG’s based fuel pellets analyzer.</font> <br>
            <br>
```

```html
<font class="font-i">Montano O., Ivanova T., Duque E. <br>
Department of Sustainable Technologies, Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague <br>
Kamýcká 129, Prague - Suchdol 16500, Czech Republic <br>
Published online: the 22<sup>nd</sup> March, 2023</font>

</div>
<div id="description">

The industrialization and commercialization of coffee produce a huge amount of waste around the world, much of this waste is Spent Coffee Grounds (SCG) which ends up in landfills contaminating the environment. SCGs contain great energy potential as a solid fuel. The literature on the use of SCG as solid fuel more specifically SCG-based pellets is extensive, however, depending on the objectives of the study, some aspects and/or key characteristics of these are examined and others are not, with no reference framework stablished specifically for SCG-based pellets. Through this study, a bibliographic search and  summarization of the current information was carried out, thus, the values reported for each of the main characteristics of the SCG-based pellets have been collected, and the average/standard values were found out. According to the calculations, the standardized characteristics of SCG-based pellets are: Initial moisture content (IMC) 57.08 % (wet basis), Optimal moisture content (OMC) 10.53 % (wet basis), Net calorific value (NCV) 16.66 MJ kg<sup>-1</sup> (wet basis), Net calorific value (NCV) 20.33 MJ kg<sup>-1</sup> (dry basis), Gross calorific value (GCV) 24.79 MJ kg<sup>-1</sup> (dry basis), Mechanical durability 76.23 %, Bulk Density (BD) 909.25 kg m<sup>3</sup> (wet basis), Ash content 1.71 % (dry basis), Economic value 0.12 EUR kg<sup>-1</sup> and the dimensions as 15 mm long, 8 mm in diameter. With the established frame of reference, this study created a web platform seeking to help calculating the energy potential contained in a specific amount of SCG in order to provide a broader picture of their use as a renewable energy resource, in addition to facilitating access to information, which could be useful for different target groups<br>

<br>
<font class="font-i">#coffee residues #waste biomass #solid biofuels #waste-to-energy #web application #fuel-energy properties #energy potential calculator</font>

</div>
<div id="SEC1" calss="">

   <div id="SEC1A" class="">

      <div class="SLIDER semititle font-i">
         <div id="slide"></div>
      </div>
      <id id="timebar"></id>

   </div>
   <div id="SEC1B" class="">

      <font class="font-i semititle">How much energy by SCG’s waste weigh</font>
      <br><br>
      <font class="font-i"> Calculate the energy contained in and the quantity of Spent Coffee Grounds (SCG) fuel pellets that can be produced based on the weight of residues.
      <br><br>
      Simply enter the weight of the resdiues you have.</font>
      <br><br>

      <!-- In this section is the heart of the platform -->
      <select name="TOR" id="TOR">
         <option value="WSCG">SCG with high moisture content</option>
         <option value="DSCG">SCG with reduced moisture content (dry)</option>
      </select>
      <font id="A-DSCG">
         <svg xmlns="http://www.w3.org/2000/svg" width="16" height="16" fill="currentColor" class="bi bi-exclamation-circle-fill" viewBox="0 0 16 16"> <path d="M16 8A8 8 0 1 1 0 8a8 8 0 0 1 16 0zM8 4a.905.905 0 0 0-.9.995l.35 3.507a.552.552 0 0 0 1.1 0l.35-3.507A.905.905 0 0 0 8 4zm.002 6a1 1 0 1 0 0 2 1 1 0 0 0 0-2z"/></svg>
         The optimal moisture content for SCG's fuel pellets must be around 10.20 %.
      </font>
```

```
    <input name="QOR" id="QOR" type="number" placeholder="Total amount of residues. E.g.30.00">
    <select name="TOM" id="TOM">
      <option value="grams">grams (g)</option>
      <option value="pounds">pounds (lb)</option>
      <option value="kilograms" selected>kilograms (kg)</option>
      <option value="tons">tons (t)</option>
    </select>
    <div id="calculate" onclick="calculate()">Calculate</div>

    <br><br>
    The information is processed according to standard values. To see the list of standard values
    <a href="" class="link">click here</a>.

  </div>

</div>

<div id="N-results">The results of your SCG's energy potential and uses will appear here!</div>

<div id="C-results" class="">
  <font class="title">Results</font><br>
  <font class="font-i">Based on: <font id="R-DSCG"></font> of <font id="R-TOR"></font></font>
  <br>
  <font id="A-WSCG">
    <svg xmlns="http://www.w3.org/2000/svg" width="16" height="16" fill="currentColor" class="bi bi-
exclamation-triangle-fill" viewBox="0 0 16 16"> <path d="M8.982 1.566a1.13 1.13 0 0 0-1.96 0L.165 13.233c-
.457.778.091 1.767.98 1.767h13.713c.889 0 1.438-.99.98-1.767L8.982 1.566zM8 5c.535 0 .954.462.9.995l-.35
3.507a.552.552 0 0 1-1.1 0L7.1 5.995A.905.905 0 0 1 8 5zm.002 6a1 1 0 1 1 0 2 1 1 0 0 1 0-2z"/> </svg>
    The moisture content of SCG fater the preparation of the beverage in average is around 57.08 %, this
needs to be reduce to 10.20 % (optimal moisture content). That means a loss of weight due to the loss of water.
  </font>
  <br>
  <div id="RES">
    <div class="RESI">
      <font class="RESI-T">Total SCG mass weight<br>reduced moisture content</font>
      <font class="RESI-V"><font id="D-DSCG-T"></font> kg</font>
      <font class="RESI-T" id="D-DSCG-T-O"></font>
    </div>
    <div class="RESI">
      <font class="RESI-T">Total<br>Pellets</font>
      <font class="RESI-V">± <font id="D-TPP-T"></font></font>
    </div>
    <div class="RESI">
      <font class="RESI-T">Total<br>Net Calorific Value (wb.)</font>
      <font class="RESI-V"><font id="D-LCV-T"></font> MJ</font>
    </div>
    <div class="RESI">
      <font class="RESI-T">Total<br>Ash Content</font>
      <font class="RESI-V"><font id="D-ASC-T"></font> kg</font>
    </div>
    <div class="RESI">
      <font class="RESI-T">Total<br>Economic Value</font>
      <font class="RESI-V">± <font id="D-ECV-T"></font> EUR.</font>
    </div>
  </div>

  <div id="SEC2">

    <div id="SEC2A">
      According to the Fuels Pellets Institute (FPI) of United States, an average of 24 hours of heating can be
obtained from one bag of 40 lb or 18.1437 kg of pellets.
      <br><br>
```

```
<font>Based on ± <font id="NOB"></font> bags of SCG pellets from <font id="TAOR"></font> of SCG dried residues. A total of <font id="MJO"></font> are obtained, witch can be use for heating a total of:</font>
<br>

<!-- If the total amount of residues are less than the control one, print this -->
<div id="L1B">
  <div class="FIGRES">
    <svg width="35" height="35" class="svg-icon" viewBox="0 0 20 20" style="margin-bottom: -7px;">
      <path d="M18.121,9.88l-7.832-7.836c-0.155-0.158-0.428-0.155-0.584,0L1.842,9.913c-0.262,0.263-0.073,0.705,0.292,0.705h2.069v7.042c0,0.227,0.187,0.414,0.414,0.414h3.725c0.228,0,0.414-0.188,0.414-0.414v-3.313h2.483v3.313c0,0.227,0.187,0.414,0.413,0.414h3.726c0.229,0,0.414-0.188,0.414-0.414v-7.042h2.068h0.004C18.331,10.617,18.389,10.146,18.121,9.88 M14.963,17.245h-2.896v-3.313c0-0.229-0.186-0.415-0.414-0.415H8.342c-0.228,0-0.414,0.187-0.414,0.415v3.313H5.032v-6.628h9.931V17.245z M3.133,9.79l6.864-6.868l6.867,6.868H3.133z"></path>
    </svg>
    1 house for ± <font id="NHD" class="icon icon-house"></font> hours
  </div>
</div>

<!-- If the total amount of residues are more than the control one, print this -->
<div id="M1B">
  <div class="FIGRES">
    <svg width="35" height="35" class="svg-icon" viewBox="0 0 20 20" style="margin-bottom: -7px;">
      <path d="M18.121,9.88l-7.832-7.836c-0.155-0.158-0.428-0.155-0.584,0L1.842,9.913c-0.262,0.263-0.073,0.705,0.292,0.705h2.069v7.042c0,0.227,0.187,0.414,0.414,0.414h3.725c0.228,0,0.414-0.188,0.414-0.414v-3.313h2.483v3.313c0,0.227,0.187,0.414,0.413,0.414h3.726c0.229,0,0.414-0.188,0.414-0.414v-7.042h2.068h0.004C18.331,10.617,18.389,10.146,18.121,9.88 M14.963,17.245h-2.896v-3.313c0-0.229-0.186-0.415-0.414-0.415H8.342c-0.228,0-0.414,0.187-0.414,0.415v3.313H5.032v-6.628h9.931V17.245z M3.133,9.79l6.864-6.868l6.867,6.868H3.133z"></path>
    </svg>
    <font id="NOH" class="icon icon-house"></font> houses for 24 hours
  </div>
  or
  <div class="FIGRES">
    <svg width="35" height="35" class="svg-icon" viewBox="0 0 20 20" style="margin-bottom: -7px;">
      <path d="M18.121,9.88l-7.832-7.836c-0.155-0.158-0.428-0.155-0.584,0L1.842,9.913c-0.262,0.263-0.073,0.705,0.292,0.705h2.069v7.042c0,0.227,0.187,0.414,0.414,0.414h3.725c0.228,0,0.414-0.188,0.414-0.414v-3.313h2.483v3.313c0,0.227,0.187,0.414,0.413,0.414h3.726c0.229,0,0.414-0.188,0.414-0.414v-7.042h2.068h0.004C18.331,10.617,18.389,10.146,18.121,9.88 M14.963,17.245h-2.896v-3.313c0-0.229-0.186-0.415-0.414-0.415H8.342c-0.228,0-0.414,0.187-0.414,0.415v3.313H5.032v-6.628h9.931V17.245z M3.133,9.79l6.864-6.868l6.867,6.868H3.133z"></path>
    </svg>
    1 house for <font id="NOD"></font> days
  </div>
</div>

<br>
<font class="font-i">The estimated total may vary depending on inhouse living habits, time of use and stove capacity.</font>
</div>

<div id="SEC2B">
  <table class="DOOR">
    <tr>
      <td colspan="2">Detailed overview of results: <font class="TDES">SCG energy potential</font></td>
    </tr>
    <tr>
      <td>Characteristic</td>
      <td>Value</td>
    </tr>
    <tr>
```

```html
        <td>Dried SCG mass weight</td>
        <td><font id="D-DSCG"></font> kg <font id="O-DSCG"></font></td>
      </tr>
      <tr>
        <td>Moisture content</td>
        <td>10.20 %</td>
      </tr>
      <tr>
        <td>Net calorific value total (wb.)</td>
        <td><font id="D-LCV-W"></font> MJ (<font id="SLCV-W"></font>)</td>
      </tr>
      <tr>
        <td>Net calorific value total (db.)</td>
        <td><font id="D-LCV"></font> MJ (<font id="SLCV"></font>)</td>
      </tr>
      <tr>
        <td>Gross calorific value total (db.)</td>
        <td><font id="D-HCV"></font> MJ (<font id="SHCV"></font>)</td>
      </tr>
      <tr>
        <td>Total ash content (1.71 %)</td>
        <td><font id="D-ASC"></font> kg</td>
      </tr>
      <tr>
        <td>Mechanical durability (wb.)</td>
        <td>± 76.23 %</td>
      </tr>
      <tr>
        <td>Bulk density (wb.)</td>
        <td>± 909.25 kg m<sup>3</sup></td>
      </tr>
    </table>
    <table class="DOOR">
      <tr>
        <td colspan="2">Detailed overview of results: <font class="TDES">SCG physic and economic</font></td>
      </tr>
      <tr>
        <td>Parameter</td>
        <td>Value</td>
      </tr>
      <tr>
        <td>Standard diameter of pellets</td>
        <td>aprox. 8-9 mm</td>
      </tr>
      <tr>
        <td>Average lenght of pellets</td>
        <td>aprox.13-15 mm</td>
      </tr>
      <tr>
        <td>Average weight by pellet</td>
        <td>± 5.00 g</td>
      </tr>
      <tr>
        <td>Total pellets</td>
        <td>± <font id="D-TPP"></font></td>
      </tr>
      <tr>
        <td>Economic Value</td>
        <td>± <font id="D-ECV"></font> EUR. (0.12 EUR kg<sup>-1</sup>)</td>
      </tr>
      <tr>
```

```
                        <td>Total (40.00 lb/18.14 kg) bags</td>
                        <td>± <font id="D-BAG"></font> Bags</td>
                    </tr>
                </table>
            </div>

        </div>

        <a href="" class="block-link">How calculations are made?</a>
    </div>
</div>

<div id="SmaLitRev">
    <font class="font-i">
        <font id="SLR-0" class="SLR-item" onclick="ChangeSLR(0)">#Topic_0</font>
        <font id="SLR-1" class="SLR-item" onclick="ChangeSLR(1)">#Topic_1</font>
        <font id="SLR-2" class="SLR-item" onclick="ChangeSLR(2)">#Topic_2</font>
        <font id="SLR-3" class="SLR-item" onclick="ChangeSLR(3 )">#Topic_3</font>
    </font>
    <br>
    <font id="literature-title" class="title">Title of the topic</font>
    <br>
    <div id="literature-text" class="text-columns">
         <!—Literature review -->
    </div>
    <br>
    <font class="title">References</font>
    <br>
    <div id="literature-refs">

    </div>
</div>

  </body>
</html>
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