Coffee 4 Planet Ark

Final Report for the City of Sydney

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PLANET ARK™

Feasibility Study Report

This document reports the findings of a six-month feasibility study into the commercial viability of recycling spent coffee grounds from cafes and coffee shops within the City of Sydney. Planet Ark Environmental Foundation conducted the study through funding from the City of Sydney's Innovation Grant.

The names of all businesses and people consulted with for this study have been kept confidential. Please contact the authors if you require further information.

Definitions

Spent coffee grounds (SCG): Spent coffee grounds refer to coffee grounds after they have been used, they are the waste product of the espresso coffee extraction process.

Coffee grounds (CG): Coffee grounds refer to grounds that have not yet been used, i.e. the form they are in prior to the extraction of coffee.

Small café chain: A small café chain is defined as a chain of cafes with five or less cafes in total.

Large café chain: A large café chain is defined as a chain of more than five cafes.

Acknowledgements

We would like to thank all of the cafes, baristas and coffee shop patrons that participated in the surveys in this report. Support and information was also kindly provided from environmental and sustainability consultants, waste collection companies and fast food chains. An Australian University kindly shared data they had gathered from analysing spent coffee grounds, which was a great help in this study. Finally we would like to thank the City of Sydney for providing the funding to conduct this work.

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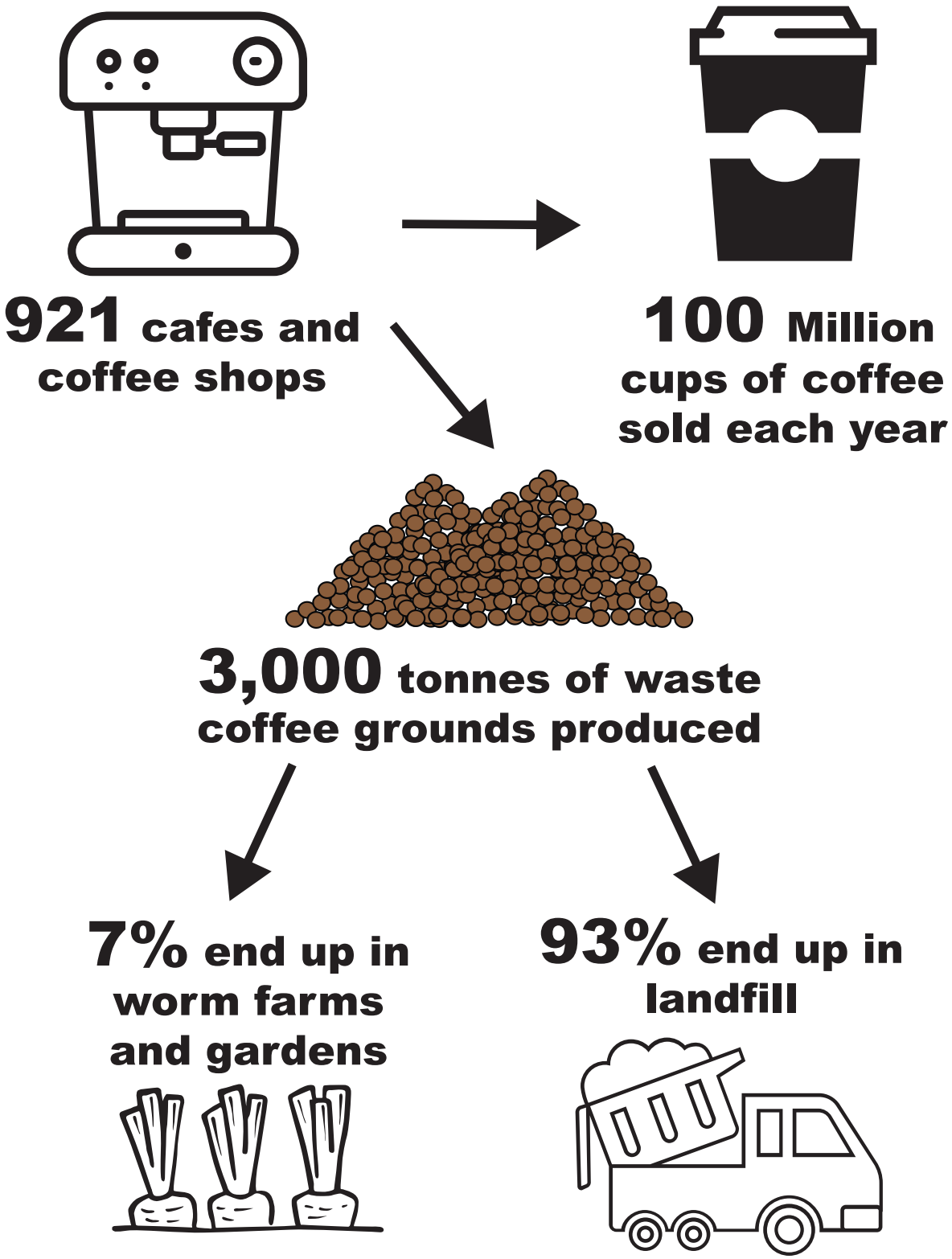
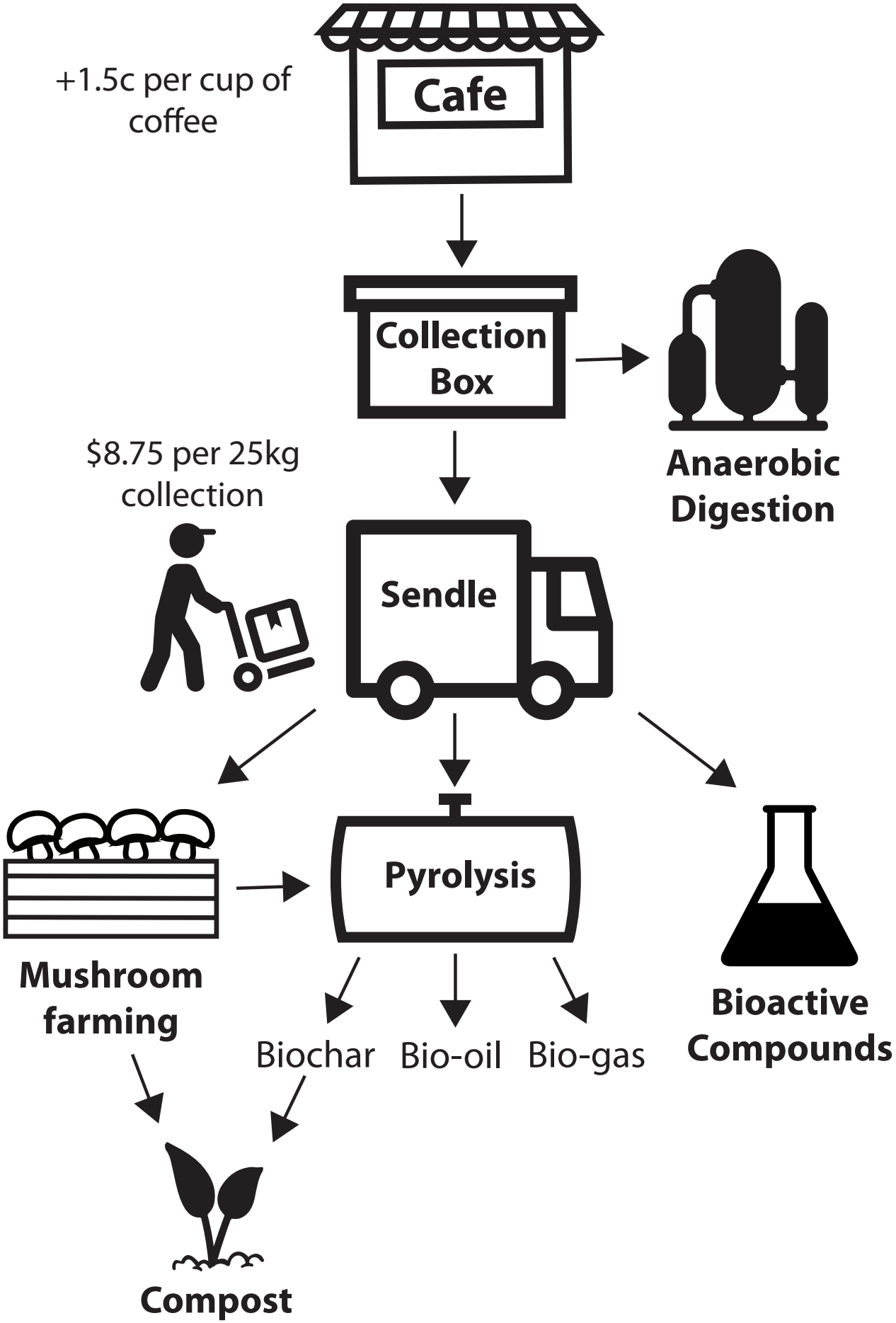
Executive Summary

Current linear system of coffee waste in the City of Sydney



Proposed spent coffee grounds collection system and end-uses



Aim of the Study

Planet Ark conducted this feasibility study in order to determine whether a collection and processing programme can be established for spent coffee grounds for the City of Sydney that is financially self-sustaining and develops an environmentally beneficial product.

Key areas addressed by this study include:

1. Determining the volume of spent coffee grounds produced by cafes within the City of Sydney and their current waste disposal methods.
2. Gauging the interest of cafes in participating in a coffee grounds recycling/landfill diversion programme.
3. Gauging the willingness of the general public to pay for their coffee grounds to be diverted from landfill and their level of concern for the environment.
4. Investigating the different collection services available and their cost.
5. Producing an economic model.
6. Determining the chemical composition of spent coffee grounds through laboratory testing.
7. Investigating the different processing and end use options that are possible for spent coffee grounds.
8. Engaging with potential stakeholders.

An average cafe uses 5.1kg of coffee grounds in one day

How Much Coffee Waste is in the City of Sydney?

In order to determine the quantity of spent coffee grounds (SCG) produced within the City of Sydney each year and identify where the waste is ending up, data was gathered from 65 cafes within the City of Sydney through face-to-face, phone and email correspondence. Cafes assessed include single businesses, small chains and a large fast food chain.

Coffee usage

The mean weight of coffee grounds (CG) used by a cafe in one business day is 5.1kg (Table 1). As the mean number of days a café is open for a week is 6.2 days (Table 2), an average café uses approximately 32kg of CG in a week.

Coffee grounds used per day (kg)	Number of cafes (%)
1-2.5	14
2.6-5	51
5.1-7.5	20
7.6-10	12
>10	3

Table 1. Quantity of coffee grounds used by cafes in a single business day.

Days open per week	Number of cafes (%)
5	17
6	45
7	38

Table 2. Number of days cafes are open for in a typical week.

Waste produced

Based on our measurements from cafes, the before and after extraction weight conversion of coffee grounds is 1.9, i.e. 1kg of new coffee grounds produces 1.9kg of spent coffee grounds. This value is in line with that obtained from other studies[1]. An average café using 32kg (5.1kg x 6.2 days) of CG in a week will therefore produce 60kg of SCG in a week.

The City of Sydney's 2012 Floor Space and Employment Survey[2] stated that there are 921 cafes in the City of Sydney (not including restaurants and hotels). It can therefore be estimated that within the City of Sydney Local Government Authority cafes alone produce nearly 3,000 tonnes of SCG a year.

Waste destination

93% of cafes (60 out of 65 cafes) currently have their send their SCG to landfill.

Of the five cafes that sent their waste somewhere else, three sent them to organic waste processors and two collected their coffee grounds for friends and customers to compost.

A clean waste stream

All cafes said that their SCG are collected at the counter in a dedicated bin. These bins are typically a tall cylinder with a bar across the top for the SCG to be tapped in, or a box that sits under a hole in the counter. Contamination is small, but largely consists of receipts.

92% of cafes within the city of Sydney currently send their SCG to landfill.

Cafe Participation

Interest by cafes in a coffee grounds recycling program was very positive, with 77% of cafes stating that they would like to participate in a Coffee 4 Planet Ark project.

Cafes interested in participating	Number of cafes (%)
Yes	77
No	20
Don't know	3

Table 3. Number of cafes that said whether or not they would be interested in participating in the Coffee 4 Planet Ark campaign

For the 13 cafes (20%) that said no, three said there is no room for an extra bin, nine said that they were not interested in anything that required more work, and one said that the coffee grounds would attract vermin unless collected everyday. As the majority of cafes who said no stated the reason was due to not wanting more work, if we are able to demonstrate a simple and easy collection system these cafes may change their mind about participating.

Reduction in general waste costs for cafes

Cafes, like all businesses, are required to pay for their waste to be collected and safely disposed of. Cafes and coffee shops that participate in a coffee ground collection program will have a reduction in the volume of general waste that they need to pay to be collected, either through a reduction in the number of bins required for the business or the frequency at which they are emptied. The value of this cost reduction identifies the potential fee that Coffee 4 Planet Ark could charge cafes to receive a SCG collection service with no net increase in waste disposal costs.

Waste collection

One out of five cafes (20%) empty their SCG into larger shared bins on a daily basis, with

waste collection incorporated into their rent or strata fees. These cafes will not have reduced general waste costs by participating in Coffee 4 Planet Ark, instead it will be the building owner that does. This opens up the possibility however of promoting participation in Coffee 4 planet Ark to building managers, especially where food courts and multiple coffee shops are present. As waste collection companies though often provide discounts to sites with large volumes of waste, the cost savings of a reduction in general waste would likely be smaller per kg than a typical cafe.

For the remaining 80% of cafes the most common frequency for their waste bins to be collected is daily (Table 4), with larger cafes having their waste bins collected more frequently than smaller cafes (Table 5).

Waste Collection rate	Number of cafes (%)
Daily	50
2-3 times a week	33
Weekly	17

Table 4. Number of cafes that have their waste bins collected daily, collected 2-3 times a week and collected weekly.

Waste collection rate	Mean daily NCG usage (kg)
Daily	6.9
2-3 times a week	4
Weekly	3.1

Table 5. Mean weight of coffee grounds used by cafes in a typical business day that have a daily, 2-3 a week and weekly collection of their bins.

Based on the weight to volume ratio of coffee grounds a 120litre bin can hold 48kg of dry coffee grounds, 67kg of wet coffee grounds and 86.5kg of packed wet coffee grounds[1]. Waste collectors however have weight limits for their bins, an average of 60kg per 120litre bin depending on the company and this includes the 9.8kg weight of the bin itself. The cost of waste companies collecting a 120litre general waste bin is on average $15 per collection (based on quotes obtained from Veolia, Suez and Transpacific). The cost per kg for SCG to be collected as general waste is therefore calculated as $15/50.2kg = 30c/kg

Potential reduction in general waste costs = Cost per kg of general waste collection x (Daily weight of CG used x CG to SCG weight conversion) x number of days open a year.

A typical café using 5.1kg of CG in a day that is open six days a week could have a reduction in general waste costs of up to:

($15/50.2kg) x (5.1 x 1.9) x 313 = $906 saved in general waste collection costs each year

This saving is based on waste being charged on a per kg basis, but many waste collectors charge per bin collection. For financial savings to be achieved, participating in Coffee 4 Planet Ark must result in a reduction in the frequency of general waste bin collection from cafes. How this occurs and any costs that may result from cafes participanting, such as additional staff time, will need to be tested in a pilot study.

The $906 per annum does however represent the potential opportunity cost for a collection system, with cafes able to pay to participate in the Coffee 4 Planet Ark without causing a net increase in their waste disposal costs.

Container commonly used by cafes to collect SCG.

Customer Participation

Other than potential cost savings, an important aspect of the program to incentivise cafes to participate is the level of interest by the general public and whether customers would be willing to pay extra for a cup of coffee if it meant that their coffee grounds were diverted from landfill.

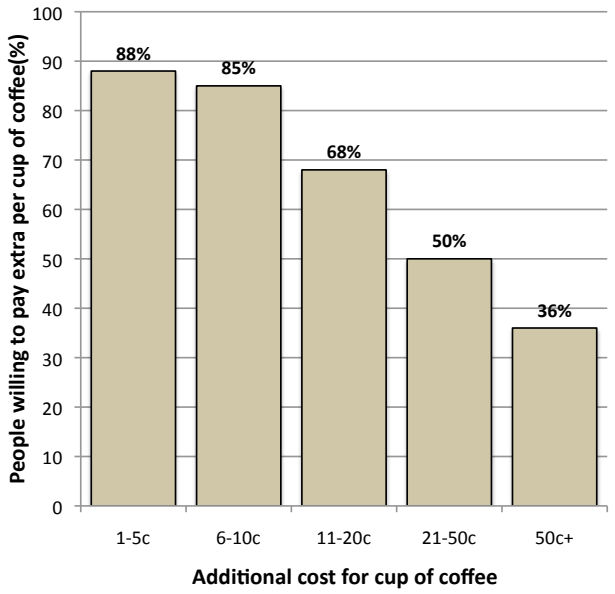


Figure 1. Percentage of survey participants willing to pay divert their waste coffee grounds from landfill.

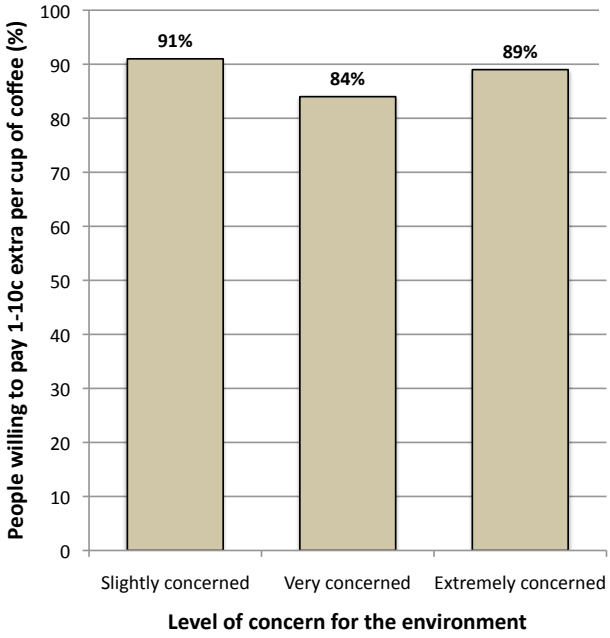


Figure 2. Percentage of people with differing levels of concern for the environment who are willing to pay up to 10c extra per cup of coffee in order to divert their waste coffee grounds from landfill. A forth option of 'no concern for the environment' was available but not selected by any survey participants.

An email survey was conducted on 302 Australians from all states and territories in December 2015. The results showed that nearly nine out of ten Australians are willing to pay 1-10c more per cup of coffee bought at a café if it meant that their grounds were diverted from landfill (Figure 1). This willingness to pay up to 10c extra was consistent across survey participants regardless of their level of concern for the environment (Figure 2) and annual income, though there was a slight decline in people with an annual household income below $25,000 (Figure 3).

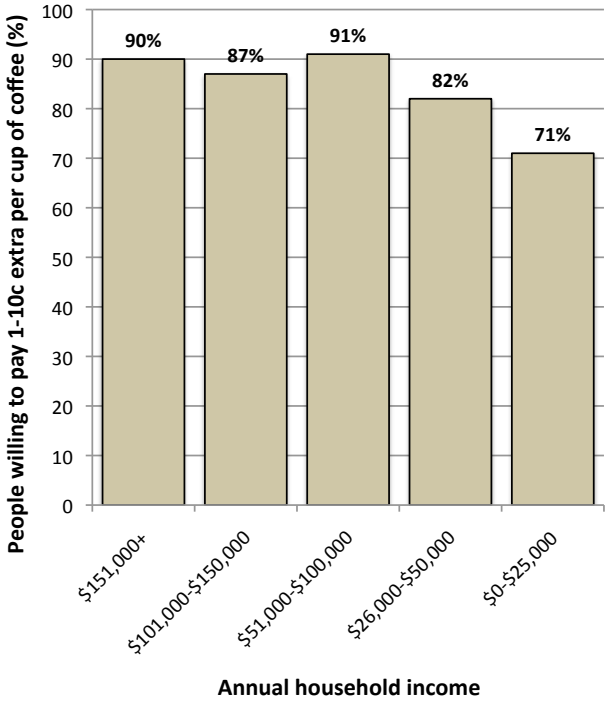


Figure 3. Percentage of people willing to pay up to 10c extra per cup of coffee in order to divert their waste coffee grounds from landfill, across a range of household incomes.

Nine out of ten Australians are willing to pay 1-5c extra per cup of coffee in order to have the SCG diverted from landfill.

Waste Collection

How SCG are collected from cafes and the cost of the process is a vital element of the program.

Of the six waste collectors contacted in this feasibility study, only two companies were able to provide an organic waste collection service on a scale suitable for cafes within the City of Sydney. For these collectors a dedicated coffee bin would be required.

Organic Recycling Group (ORG)

- $14.95+ GST for collection of a 120litre bin (up to 50kg)
- $22.50 +GST for 240litre bin (up to 80kg)

Veolia

- $20+ GST for collection of a 120litre organics bin (up to 60kg)
- $23+ GST for collection of a 240litre organics bin (up to 80kg)
- All bins have a $1 per week rental fee

Organic waste collected by the Organic Recycling Group is sent to EarthPower, an anaerobic digestion facility, and organic waste collected by Veolia is taken to a compost facility.

Sendle

Sendle is a parcel delivery service that will collect and deliver boxes up to 25kg within a city for $8.75 per collection. Coffee 4 Planet Ark would need to provide all boxes at an additional cost, but it allows the program to control the end destination of the coffee grounds. Sendle also allows for greater flexibility over collections, with the frequency and the time and day of collections able to be altered.

Due to limited space in cafes and their storage areas, 240L bins are likely to be too big.

Environmental impact of collection

The exact carbon emissions produced by Veolia and the Organic Recycling Group during collections is dependent on a number of variables, including the truck used, the number of collections per route and the distance from the cafes to the waste processing facility. This environmental impact is likely to be similar to that produced by the trucks that collect waste for landfill. All Sendle deliveries however are carbon negative, with each parcel carbon offset for the distance Brisbane to Perth despite only traveling within Sydney.

Economic Model

Knowing the cost of collecting SCG from cafes in order to divert the waste from landfill and how this breaks down to the additional cost that would need to be charged per individual cup of coffee is vital in determining the viability of the project.

Cost of collection

On average 22g of CG are used to make a large coffee in a café, and 12g to make a regular. This means that 1kg of CG can make 45 large cups of coffee and 83 regular cups of coffee.

In order to determine the additional cost per cup of coffee that would need to be charged by a café to divert the SCG from landfill we need to know:

-The cost per collection
-The total kg of SCG in each collection
-The kg of NCG that create the kg of SCG collected

Table 6 shows that in order to cover the cost of Sendle collections, a cafe would need to charge an extra 1.5c per large cup of coffee and an extra 0.8c per regular cup of coffee.

The cost that wholesale coffee suppliers charge cafes per kg of premium coffee grounds is on average around $30, depending on its origin and bean type[3]. If roasters pass on the full cost of 67c per kg to cafes to have their SCG collected and diverted from landfill, it will be an increase of 2.2% for the wholesale price of coffee grounds.

Additional costs

As Sendle does not provide collection boxes, an initial cost of purchasing suitable boxes and an ongoing cost of liners that hold the SCG when collected will also need to be accounted for. Initial research suggests that these liners will cost between 19c-50c each depending on the material. If the liners cost 50c each, the change to the additional cost per large and small cup of coffee sold by cafes is 0.1c.

This form of collection box, with a permanent box at the point of collection and liners containing the product that gets picked up, is very similar to that used by Cartridges 4 Planet Ark.

In addition to collection costs, the program will also need funding for promotion and general admin costs. Based on other programs run by Planet Ark, a further 25% on cost for promotion and coordination of the program appears to be a reasonable estimate. This will bring the additional cost per large cup of coffee to 1.9c and 1c per regular cup of coffee with Sendle collections.

'Cartridges 4 Planet Ark' places boxes in businesses and shops.

	Sendle	ORG	Veolia
Cost per collection	$8.75	$14.95	$20
kg of SCG in each collection	25kg	40.2kg	50.2kg
kg of CG used by cafes to produce SCG per collection	13.1kg	21.1kg	26.4kg
Additional cost per kg of CG sold to cafes to cover cost of collection	67c per kg	71c per kg	76c per kg
Additional cost per large cup of coffee	1.5c	1.6c	1.7c
Additional cost per regular cup of coffee	0.8c	0.9c	1c
Additional cost per kg of CG sold to cover cost of collection and 25% promotion	84c per kg	89c per kg	95c per kg
Plus 25% per large cup of coffee	1.9c	2c	2.1c
Plus 25% per regular cup of coffee	1c	1.1c	1.25c

Table 6. Table calculating the additional cost a cafe would need to charge customers per large and small cup of coffee in order to have the spent coffee grounds collected and diverted from landfill. 120litre bins were used for ORG and Veolia calculations, not 240litre bins, as cafes stated that space availability for the bin was their biggest concern. ORG= Organic Recycling Group.

Circular Economy

The goal of Coffee 4 Planet Ark is to not only divert SCG from landfill, but to have them become a value-added product where they are a resource that adds value to other processes. This system creates a circular economy, where the waste from one process is used as a resource by another. Within this setup the use of energies and materials are optimised, waste generation is minimised and there is an economically viable role for every product of a manufacturing process. A circular economy therefore supports sustainable development through the efficient use of resources, minimising environmental impacts while supporting economic success[4]. The potential uses for spent coffee grounds are not limited to just one, but may be able to be put through a cascade of processes to allow for maximum value.

This section will present the findings of laboratory analysis of SCG and discuss potential end uses.

On average, 22g of coffee grounds are used to make one large cup of coffee.

Composition of SCG

A sample of 100% Arabica SCG was sent to Food Laboratories Australia Pty Ltd in Victoria for analysis (Table 7).

Additionally, levels of carbon, nitrogen, hydrogen and moisture in five samples of SCG were provided by an Australian University (Table 8).

Ground type	Arabica
Moisture (%)	58.0
Ash (%)	0.8
Fat (%)	7.8
Protein (%)	5.7
Carbohydrate (%)	27.7
Peroxide value (meq O_2/kg)	10.2
Free fatty acids (%)	6.03

Table 7. Results from laboratory analysis of 100% Arabica spent coffee grounds.

Cafe ID	Sample	Grounds	Moisture (%)	Carbon (%)	Nitrogen (%)	Hydrogen (%)
1	1	Unknown	51.7	49.5	2.4	7.1
1	2	Unknown	53.5	50.3	2.3	7.1
2	3	Arabica	50.5	50	2.4	7.0
2	4	Arabica	50.0	49.9	2.4	6.9
3	5	Unknown	50.8	34	2.0	5.1

Table 8. Analysis of five samples of spent coffee grounds provided by an Australian University.

End Uses

Compost

One of the possible end-uses for SCG is as compost, with its currently under-utilised high nutrient and energy levels representing a potential niche market.

Composting is a bio-oxidative exothermic process where microbes metabolise fresh organic matter under idealised moisture, oxygen, pH, carbon and nitrogen conditions, transforming it into more stable, humified and non-phytotoxic compost[5,6]. Three composting technologies that have been examined with spent coffee grounds include vermicomposting, aerated static pile composting and mechanical in-vessel composting[6]:

Vermicomposting is the process of composting using worms. Worms play a significant role in aggregating nutrients in their casts, as well as playing a major role in mixing materials in the compost pile. Eisenia fetida earthworms are commonly used in vermicomposts due to their capacity to induce significant chemical and physical changes in organic matter.

Aerated static composting is the simplest and most cost effective method of composting organic matter, due to requiring minimal management once the compost pile has been established. The negative of this system though is the extended time required to generate a mature product, ranging from 6 to 12 months.

Mechanical in-vessel composting systems confine the organic material inside an enclosed container or sealed area that is controlled under uniform temperature and moisture conditions. These systems have a faster compost production time due to the greater control exerted over environmental conditions and the thorough mixing of the feedstocks.

A comparison of these three approaches with SCG found that the C:N ratios of the final composts were all in the optimum range of <25:1. There were key differences between the methods though, with in-vessel composting of coffee grounds with cardboard providing the fastest decomposition of organic matter but loosing the largest amount of nitrogen. Static aerated pile composting of coffee grounds with coffee filters on the other hand produced the largest increase in nitrogen content (75%). Although vermicomposting produced a suitable end product, survival of the worms was low, suggesting that mixing the SCG with other feedstocks will create a better composting system with worms.[6]

Several studies have shown the benefits of using compost derived from coffee, including enhancing soil nutrients[7] and resistance against pathogens[8]. Mixing spent coffee ground compost with peat in potted plants has also been shown to produce good growth rates, with quality indices similar to those obtained when using fertilisers and higher quality indices than when using peat alone. Peat moss is the principal organic component of growing media preparations, but bog-excavated peat is a non-renewable resource that is increasing in price as it becomes harder to access. The use of spent coffee ground compost could therefore be a sustainable substitute to reduce the usage and demand of peat.[5]

The potential negative of using SCG for compost is it not being a valuable enough resource that will fund the Coffee 4 Planet Ark collection program, due to the abundance of compost already being produced in Australia.

Aerated static composting is the simplest form of composting, but also takes the longest to generate a mature product

Composters

An Australian composting company has said that they will receive and compost SCG from us for free during a pilot study. The company supply landscaping and horticultural products and own several compost manufacturing facilities in NSW, including one at Badgerys Creek, Sydney, which produces over 600,000m^3 of organic compost annually.

A Dairy farmer has also shown interest in participating in a compost program for SCG and is willing to be the site for any tests of different composting conditions that may need to be carried out.

Mushroom growth medium

A second possible end-use for SCG is as a growth substrate for edible mushrooms.

Using SCG as the growth substrate for edible mushrooms is a relatively new process, with several studies conducted on its use but no large scale mushroom farms utilising SCG yet in operation.

Despite the lack of uptake in their use, studies have shown that the use of SCG as a growth substrate produces mushrooms with the same nutrient quality and yields as mushrooms cultivated on substrates that are already being used by the mushroom industry, such as straw[9]. Furthermore the mushrooms produced do not contain caffeine or tannins, with the fungus thought to partially degrade the toxins in the SCG[9,10].

The first urban mushroom farm to use SCG is being set up in Fremantle, WA.

One study did find that SCG were a good substrate for mycelia growth but not for mushroom production[11]. The study though was using maitake mushrooms and highlights how the sensitivity of fruiting can differ from species to species.

Oyster mushrooms appear to be the most suitable mushrooms for growing on SCG, being a relatively easy type to grow with more durability to differing environmental conditions[11-13]. Exact tonnage demand of SCG for mushroom growth would need to be determined in a pilot study.

Mushroom growers

Mushroom growers that we approached were not interested in trailing SCG as a growth substrate, as their mushroom growing facilities are already being fully utilised.

An Australian start up company in Fremantle, WA, however plans on being the first urban mushroom farm in Australia to use SCG. When the farm is fully running mushrooms will be sold to local restaurants, food outlets and markets, with home mushroom growing kits also available online.

This company is a potential excellent end destination for spent coffee grounds collected from cafes, as they will be using the waste to produce a valuable product. As it is not environmentally or economically suitable to send SCG collected in Sydney to Western Australia, this potential end-use will need to wait until the company have extended their production to the east coast, or Coffee 4 Planet Ark has begun collections in Fremantle. Based in this model there may be an opportunity to create a similar project within the City of Sydney.

> **"Cafes will love the opportunity to sell mushrooms to their customers grown on coffee grounds from their own café"**
>
> **(Café chain owner).**

Pyrolysis and Biochar

A third possible end-use for SCG is pyrolysis. Pyrolysis is a process that thermally decomposes organic materials through the application of intense heat in the absence of oxygen. Without oxygen the materials cannot combust and instead produce biogas, bio-oil and biochar.

Biogas and bio-oil have interesting waste to energy implications[14], and could help prevent the world fuel crisis turning into a food crisis. Falling oil prices though means they may not be the most stable option at present. At the time of writing this report (January 2016) shares in Australia's only national biodiesel company, Australian Renewable Fuels (ARF), have been stopped from trading whilst the company assesses the implications of another fall in world oil prices[15]. ARF have also indicated that they are after low moisture content, <5% free fatty acids and a peroxide value of <10. As the analysis of SCG that was conducted for this report found a moisture level of 58%, a free fatty acid level of 6.03% and a peroxie value of 10.2meq O_2/kg, it suggests that SCG may not be of suitable quality for the production of bio-fuels.

The third output from pyrolysis however, biochar, is drawing attention from the scientific community on whether it has potential to help mitigate climate change. The natural system of plants decaying and producing CO2 that other plants then absorb is carbon neutral, meaning that the overall amount of carbon dioxide in the atmosphere stays the same. The process of creating biochar through pyrolysis though actually reduces CO2 in the atmosphere because it takes organic matter that would have decayed and emitted CO2 and instead turns it into stable carbon structures that get stored in the ground for potentially hundreds or even thousands of years[16]. The production of biochar from pyrolysis is in essence mimicking the natural process that turned ancient plants into coal.

Studies suggest that the sustainable global implementation of pyrolysis has the potential

Biochar has potential to help mitigate climate change due to its ability to sequester carbon in soil.

to offset up to 12% of anthropogenic CO2e equivalent emissions (1.8 Pg CO2e per year of the 15.4 Pg CO2e emitted annually). Half of the avoided emissions are due to the net carbon sequestered as biochar, 30% to replacement of fossil fuel energy by bio-oil and biogas and 20% to avoided emissions of CH4 and N2O.[17,18] Even if bio-oil and biogas are not economically viable end products, as a minimum they can be used to power the pyrolysis process and remove the need for external energy sources.

Biochar is an important end product not only for its potential carbon sequestration in soil, but also for its use as a soil amendment. The very high surface area of biochar improves the water holding capacity of soil, soil aeration and microbial activity, stimulates nutrient dynamics and supresses nutrient leaching. These characteristics themselves have the potential to help tackle climate change[18]:

- Increased soil fertility stimulates plant growth, increasing CO2 intake.
- Improved nutrient dynamics and reduced leaching decreases the need for chemical fertilisers, eliminating the emissions associated with their manufacture.
- Enhanced microbial activity increases the volume of carbon stored in the soil.

A study that conducted slow pyrolysis on SCG after its lipids had been removed for biodiesel production, produced biochar that had the

potential to be a long-term storage of carbon for 27.6-28.6% of the initial carbon biomass. The biochar also had a higher energy density than the initial SCG and one comparable to solid fossil fuels, demonstrating the potential for biochar derived from SCG to be co-fired as a solid fuel.[19]

Pyrolysis systems

We have discussed with pyrolysis machine manufacturers and consultants the possibility of using SCG as the feedstock and they have confirmed its potential suitability. As very few studies have been conducted on the use of SCG in pyrolysis however further experiments would need to be conducted on the quality and use of the end products produced.

Bio-bean is a green energy company in the UK who is turning SCG into biomass pellets to heat buildings and plan to produce biodiesel at an industrial scale to power transport systems. Bio-bean is a commercial company though who have patented their technology and do not currently have plans to enter the Australian market.

Many health related chemicals found in coffee beans are left in SCG during the extraction process.

Bioactive compounds

A fourth possible end-use for SCG is as a source of bioactive compounds.

Coffee beans contain several classes of health-related chemicals, such as phenolic compounds, melanoidins, diterpenes, xanthines and vitamin precursors. For example chlorogenic acids, the main component of the phenolic fraction of green coffee seeds, have been shown to reduce atherosclerosis, diabetes and various types of cancer[20-22]. Melanoidins on the other hand, which are produced during the processing of coffee, have been demonstrated to modulate bacterial growth in the colon, exert anti-inflammatory and antiglycative effects and inhibit tumour growth and metastasis[22,23]. As these compounds are only partially extracted during brewing however, SCG represent a potentially valuable source of bioactive compounds that have a wide range of applications in the food and pharmaceutical industries.

Several studies have identified the presence and possible extraction of bioactive compounds from SCG, showing them to be a natural source of antioxidants[24] with high phenolic content[22]. One demonstrated extraction method has been to use fungal strains to grow and release phenolic compounds from SCG under solid-state conditions, a technique that has a positive environmental impact due the avoided use of solvents[25].

Spent coffee grounds also contain hemicelluloses, polysaccharides that have practical applications in a large variety of industrial processes such as in the production of edible films to coat food, thickening and stabilising agents in foods, films and gels for packaging, chemicals and even fuels. In order to be effectively used in bioconversion processes however, the hemicellulose polysaccharide needs to be separated from other structures that it is naturally found with, such as cellulose and lignin. Dilute acid hydrolysis is one extraction method from SCG that has been shown to be effective, producing a hydrolysate rich in the sugars flucose, arabinose, mannose

and galactose.[26]

The greatest challenge in using SCG collected by Coffee 4 Planet Ark as a source of bioactive compounds is that although their potential usage has been clearly demonstrated in studies, none of these strategies have yet been routinely implemented.

Anaerobic digestion

A fifth possible end-use for SCG is anaerobic digestion. Anaerobic digestion is the process of breaking down organic material by microorganisms in the absence of oxygen. The process produces a methane-rich biogas that can be used as a fuel, and a nutrient-rich fertiliser.[27]

One of the benefits of anaerobic digestion is that it can be conducted on both large and small scales. EarthPower is an anaerobic digestion facility in Camellia, Sydney, which has the capacity to convert enough green energy to power over 3,600 homes[28]. This is also the facility that ORG takes all collected organic waste to. In contrast it is also possible to have anaerobic digesters that are small enough to be kept under buildings to process the organic waste generated in the immediate facility. These small systems remove the cost of transporting waste.

An anaerobic digester has been set up in Federation Square, Melbourne. The system receives organic waste from local cafes and restaurants and can process one tonne per hour, continuously[29]. The biogas produced is fed into a dual fuel hot water system to provide hot water for the tenants, and the digestate is sold as a fertiliser. The cost of the pilot plant was $385,000.[30]

One draw back from this system is that SCG that are sent immediately to an anaerobic digester cannot then go through further end processes, preventing maximal end uses to be achieved. The energy obtained from anaerobic digestion is also greater when the feedstock is high in sugars and studies have not been conducted on the suitability of using SCG from cafes as the only input. One possibility is to expand the feedstocks accepted for the system to include all food waste from cafes and restaurants, especially if the processing potential of the anaerobic digester is greater than current SCG generation.

EarthPower allows organic waste collections to have up to 5% contamination.

EarthPower generates enough green energy to power 3,600 homes.

Discussion

Participation

The results of this study show that a SCG collection program from cafes within the City of Sydney is very feasible. Cafes and coffee shops are keen to join the program and customers are prepared to pay the additional cost of ensuring the grounds from their coffee is diverted from landfill. The willingness of cafes to participate in the program appears to be a combination of wanting to help the environment and the potential cost savings they may receive by diverting SCG from their general waste bins.

The positive response from the general public in paying for the waste coffee grounds to be diverted from landfill is a great outcome. The result was particularly encouraging as nine out of ten coffee drinkers stated that they would pay up to 5c extra per cup of coffee, but the economic model for the program shows the additional cost required to divert the SCG from landfill is less than 2c per large cup.

The multiple potential value added end uses for the SCG further suggests that after a pilot study has been conducted, the cost of the collection program may partially or fully be covered by the end products produced. Although not part of this feasibility study, early indications from some roasters suggest that the cost of the collection program may be funded for certain brands through a product stewardship scheme, creating another source of financial income for the project.

Collections

Sendle offer the cheapest collection service for SCG from cafes within the City of Sydney. The cost of collection per kg of SCG could have been cheaper with other waste collectors if larger bins were used, but this was not a suitable option as cafes had stated that their biggest concern for participating in the program was space availability for the bin.

Utilising the services of Sendle also has additional benefits beside cost: collections can be done on any day of the week, are collected within the café not from the street, can have the frequency of collections changed at any time, require no ongoing contract and are carbon offset. Standard waste collectors on the other hand set the day of collection, require bins to be put out on the street (possibly creating a source of contamination if pedestrians use the bins) and often require contracts for a set duration of time.

Sendle also allows for choice over the end destination instead of going to the default organic processer for the waste collection company. Controlling the destination of the collected SCG is important if we want them to be used to create a valuable end product to help finance the project.

Over 100 million cups of coffee are sold in the City of Sydney every year.

End uses

The possible end uses for SCG are not mutually exclusive, meaning that the grounds have the potential to go through a chain of several value added end processes.

At this stage no end use is clearly more suitable or financially viable than the others, with all options having both positive and negative aspects.

- Compost is a simple and easy option, with companies already discussing with us their willingness to engage in a pilot study. There is however an abundance of compost in Australia, lowering its financial value.

- Using SCG as a medium for growing mushrooms is a very promising end use, creating a valuable end product that can even be sold back to the cafes the grounds originated from. The first mushroom growers in Australia to use SCG however are still establishing their urban farm in Fremantle, so this end use will need to wait until the company has expanded or a mushroom farm using SCG is set up in Sydney.

- Pyrolysis has great potential as a source of biofuels and biochar to help tackle the fuel crisis and mitigate climate change. Pyrolysis systems however have large set up costs, which may be too great for a pilot stage. Biodiesel is also not currently the most economic solution due to the instability of oil prices and the analysis on the composition of SCG conduct in this study found it to not be a suitable quality of biofuels. This does not mean though that pyrolysis could not become a viable option further down the road, with enough bio-fuel still being produced to power the pyrolysis process.

- SCG has been shown to be a source of bioactive compounds that have value in food, pharmaceutical and manufacturing industries. None of these strategies have yet been routinely implemented however, with the systems needing to be established at the industrial level before we are able to find a company to work with.

- Anaerobic digestion is an interesting option, as the ability to set up local systems within the City of Sydney will greatly reduce transport costs. If an anaerobic digester is set up in a building with a large food court, the waste from these cafés could go straight into bins for the digester and remove the need to pay for a collection company to pick up and transport the waste. As anaerobic digesters are able to process nearly all types of food waste, it opens up the possibility of expanding the program to include all organic waste from cafes and restaurants.

The end destination that SCG go to can easily be altered at any stage of the project, with grounds potentially going to different facilities depending on the location of the cafe. The most important steps for a pilot study are establishing a workable collection program and a network of participating cafes, choosing an end destination that is reliable and easy to set up should therefore be the priority.

Future work

The next stage of Coffee 4 Planet Ark will need to be conducting a pilot study. This will allow us to work directly with a small number of cafes to develop and improve the collection system, by determining the best shape and material for the boxes, identify contamination levels, required frequency of collections and the best communication methods with cafes and owners. A pilot study will also highlight any unforeseen obstacles that need to be addressed and create real life case studies that can be used to promote the project and discuss product stewardship schemes with roasters. Planet Ark is keen to discuss opportunities for funding of the pilot program.

Once an effective and efficient collection program has been established, applying for funding for larger scale end uses, such as pyrolysis systems and anaerobic digesters, will be more greatly justified.

References

1. Reference Information: Ingredient Bulk Density Table. (Brabender Technologie, 2014).

2. Floor space and employment survey. (City of Sydney, 2012).

3. Bean prices plummet but no bargains for coffee drinkers. Good Food (2014). at <http://www.goodfood.com.au/good-food/drink/bean-prices-plummet-but-no-bargains-for-coffee-drinkers-20140104-30arn.html>

4. Corder, G. D., Golev, A., Fyfe, J. & King, S. The Status of Industrial Ecology in Australia: Barriers and Enablers. Resources 3, 340–361 (2014).

5. Ronga, D., Pane, C., Zaccardelli, M. & Pecchioni, N. Use of Spent Coffee Ground Compost in Peat-Based Growing Media for the Production of Basil and Tomato Potting Plants. Communications in Soil Science and Plant Analysis (2015).

6. Liu, K. & Price, G. W. Evaluation of three composting systems for the management of spent coffee grounds. Bioresource technology 102, 7966–7974 (2011).

7. Adi, A. J. & Noor, Z. M. Waste recycling: Utilization of coffee grounds and kitchen waste in vermicomposting. Bioresource technology 100, 1027–1030 (2009).

8. Sathianarayanan, A.Khan, AB. An eco-biological approach for resource recycling and pathogen (Rhizoctoniae Solani Kuhn.) suppression. Journal of Environmental Protection Science 2, 36–39 (2008).

9. Murthy, P. S. & Manonmani, H. K. Bioconversion of Coffee Industry Wastes with White Rot Fungus Pleurotus florida. Reearch Journal of Environmental Sciences 2, 145–150 (2008).

10. Leifa, F., Pandey, A. & Soccol, C. R. Production of Flammulina velutipes on coffee husk and coffee spent-ground. Brazilian Archives of Biology and Technology 44, 205–212 (2001).

11. Barreto, S. M., López, M. V. & Levin, L. Effect of cultue parameters on the production of the edible mushroom Grifola frondosa (maitake) in tropical weathers. World Journal of Microbiology and Biotechnology 24, 1361–1366 (2008).

12. Murthy, P. S. & Naidu, M. M. Sustainable management of coffee industry by-products and value addition: A review. Resources, Conservation and Recycling 66, 45–58 (2012).

13. Fan, L., Pandey, A., Mohan, R. & Soccol, C. R. Use of various coffee industry residues for the cultivation of Pleurotus ostreatus in solid state fermentation. Acta Biotechnologica 20, 41–52 (2000).

14. Li, X., Strezov, V. & Kan, T. Energy recovery potential analysis of spent coffee grounds pyrolysis products. Journal of Analytical and Applied Pyrolysis 110, 79–87 (2014).

15. Biodiesel maker braces for oil price pain. SBS (2016). at <http://www.sbs.com.au/news/article/2016/01/18/biodiesel-maker-braces-oil-price-pain>

16. Climate Change and Biochar. biochar-international.org/ at <http://www.biochar-international.org/biochar/carbon>

17. Woolf, D., Amonette, J. E., Street-Perrott, F. A., Lehmann, J. & Joseph, S. Sustainable biochar to mitigate global climate change. Nature communications 1, 56 (2010).

18. Biochar: Production, Characterization, and Applications. (CRC Press Taylor & Francis Group, 2015).

19. Vardon, D. R. et al. Complete utilization of spent coffee grounds to produce biodiesel, bio-oil, and biochar. ACS Sustainable Chemistry & Engineering 1, 1286–1294 (2013).

20. McCarty, M. F. A chlorogenic acid-induced increase in GLP-1 production may mediate the impact of heavy coffee consumption on diabetes risk. Medical hypotheses 64, 848–853 (2005).

21. Natella, F., Nardini, M., Belelli, F. & Scaccini, C. Coffee drinking induces incorporation of phenolic acids into LDL and increases the resistance of LDL to ex vivo oxidation in humans. The American journal of clinical nutrition 86, 604–609 (2007).

22. Panusa, A., Zuorro, A., Lavecchia, R., Marrosu, G. & Petrucci, R. Recovery of Natural Antioxidants from Spent Coffee Grounds. Journal of Agricultural and Food Chemistry 61, 4162–4168 (2013).

23. Moreira, A. S., Nunes, F. M., Domingues, M. R. & Coimbra, M. A. Coffee melanoidins: structures, mechanisms of formation and potential health impacts. Food & function 3, 903–915 (2012).

24. Ramalakshmi, K., Rao, L. J. M., Takano-Ishikawa, Y. & Goto, M. Bioactivities of low-grade green coffee and spent coffee in different in vitro model systems. Food Chemistry 115, 79–85 (2009).

25. Machado, E. M., Rodriguez-Jasso, R. M., Teixeira, J. A. & Mussatto, S. I. Growth of fungal strains on coffee industry residues with removal of polyphenolic compounds. Biochemical Engineering Journal 60, 87–90 (2012).

26. Mussatto, S. I., Carneiro, L. M., Silva, J. P. A., Roberto, I. C. & Teixeira, J. A. A study on chemical constituents and sugars extraction from spent coffee grounds. Carbohydrate Polymers 83, 368–374 (2011).

27. Anaerobic Digestion. Bio-gas info (2015). at <http://www.biogas-info.co.uk>

28. Creating Green Energy. EarthPower (2015). at <http://www.earthpower.com.au/creating_green_energy.php>

29. Active Research. KPMG (2015). at <http://www.kpmg.com/au/en/beyond/clients/pages/active-research.aspx>

30. EMRC Committee meeting minutes. (EMRC, 2012).