Food Waste as a Resource:
Mapping Opportunities for Symbiosis on UCL's Campus

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Urban Symbiosis:

Urban symbiosis focuses on networks of resource partnerships and looping actions (reuse, recycling and recovery of resources) in the urban context. This form of systems integration involves the exchange of resources between organizations for the economic and environmental benefit of collaborators. Urban symbiosis attempts to create waste-to-resource loops with a goal of gradually integrating urban systems for greater efficiency (Vernay and Mulder, 2015).

Introduction

Cities cover just 2% of the world's land area yet currently represent 60-80% of global energy consumption, 75% of carbon emissions, and over 75% of natural resource consumption (Swilling et al, 2013). Demand for resources and production of wastes due to population growth and more resource-intensive lifestyles continue to increase; the United States National Intelligence Council expects demands for water, energy, and food to increase by 40%, 50%, and 35%, respectively, by 2030 (US NIC, 2012). Broader climate change threats such as decreased access to productive agricultural land and extreme weather events are posed to put a further strain on urban resources and threaten food, water, and energy security (Williams, 2019).

At the same time, one-third of food produced for human consumption is lost or wasted globally (FAO, 2011). Each year in the UK's Hospitality and Food Sector alone, food waste is equivalent to 1.3 billion uneaten meals (WRAP, 2019). This multiplicity of factors presents an urgent need to understand and adapt our urban food, water, and energy production systems to be more resilient and more efficient.

Systems thinking offers a potential solution to these complex problems. Efficient food waste-to-resource looping through inter-organizational cooperation can provide an opportunity to reduce demands on urban food systems, recover nutrients, valorise waste and byproducts, reduce greenhouse gas emissions and landfill usage, and generate renewable energy.

The objective of this research was to understand existing exchanges of food waste on UCL's campus, as well as to develop an understanding of what a local network of food waste reuse, recycling and recovery could look like.

The study used a mixed-methods approach involving semi-structured interviews and secondary source analysis in order to develop a set of system maps showing:

1. Ideal food waste pathways for an urban campus
2. Existing food waste flows (material-flow analysis)

3. Existing social networks amongst identified local partners (social network analysis)

The results show that UCL disposes of nearly 19 tonnes of food waste per month, nearly all of which is transported a great distance for treatment. A number of symbiotic relationships amongst local actors (for example the redistribution of uneaten prepared meals) already exist to handle food waste, but the quantity of waste processed locally is a very small proportion of total waste produced by the university.

UCL: A Hub of Action

Why build circularity into the infrastructure of UCL?

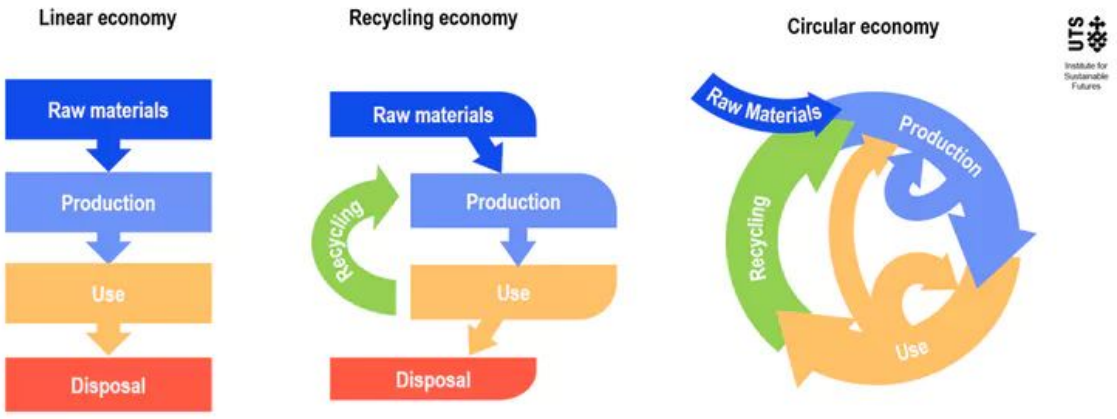
University College London (UCL) is a large public research university located in central London, UK. It is a member institute of both the University of London and the Russell Group. UCL operates 230 buildings (Transforming UCL, 2019), and is home to over 13,000 employees (UCL Human Resources, 2019) and nearly 40,000 students (About UCL, 2019). Most programs and facilities are located on the Bloomsbury campus, with an additional operational campus at *UCL at Here East* and a forthcoming campus at *UCL East*. UCL is co-located in the Bloomsbury district of London with several other institutions of higher learning (i.e. University of London, SOAS, Birkbeck University, The London School of Hygiene and Tropical Medicine), offering the potential to influence several similarly structured organizations.

In addition to its large physical footprint, UCL has strong international visibility as well as ambitions of being at the forefront of sustainable innovation, climate action, and integrated research. UCL's latest Sustainability Strategy involves a plan for circularity, showcasing institutional desire and political will for a circular transformation.

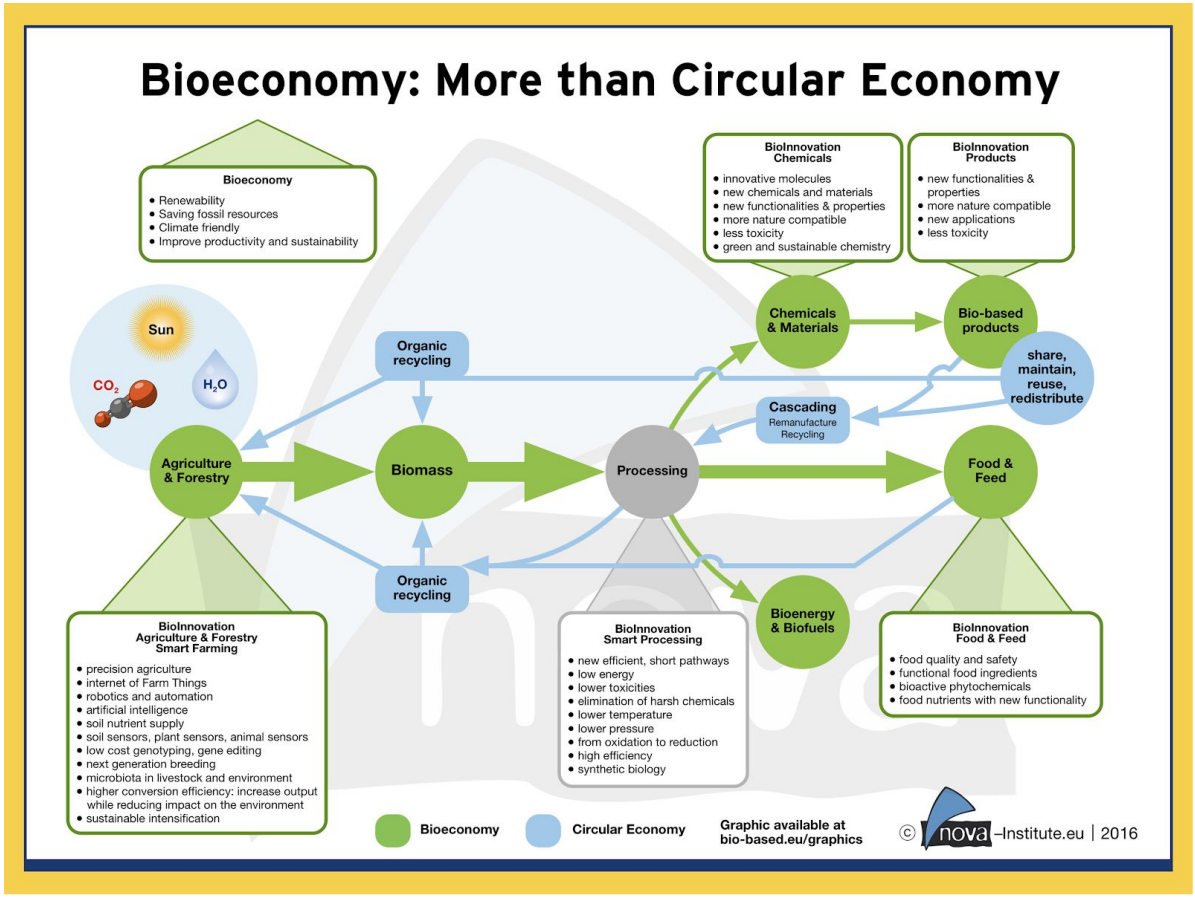
By the Numbers:

19 tonnes of food waste @UCL per month on average
128 tonnes of food waste @UCL from Jan 2019-July 2019
£14 million per annum in energy costs for UCL's estate and operations

Closing the Loop: Circular Urban Food Systems



A circular approach encourages the use of wastes and byproducts from production processes as resources for other processes, i.e. the closing of material and energy loops, to prevent waste and energy leakages (Camilleri, 2018). Closing waste and material loops such as those posed by food waste inefficiencies offer a way for urban areas to reduce their environmental impact while engaging with a diversity of organizations.



Case Study: An Exemplar Circular Food System in Milan

A strong case for the success of circular food systems comes from Milan, Italy. The system in Milan involves energy recovery through waste-to-energy via anaerobic digestion (AD), composting of food waste, surplus food redistribution and prioritization of local food procurement.

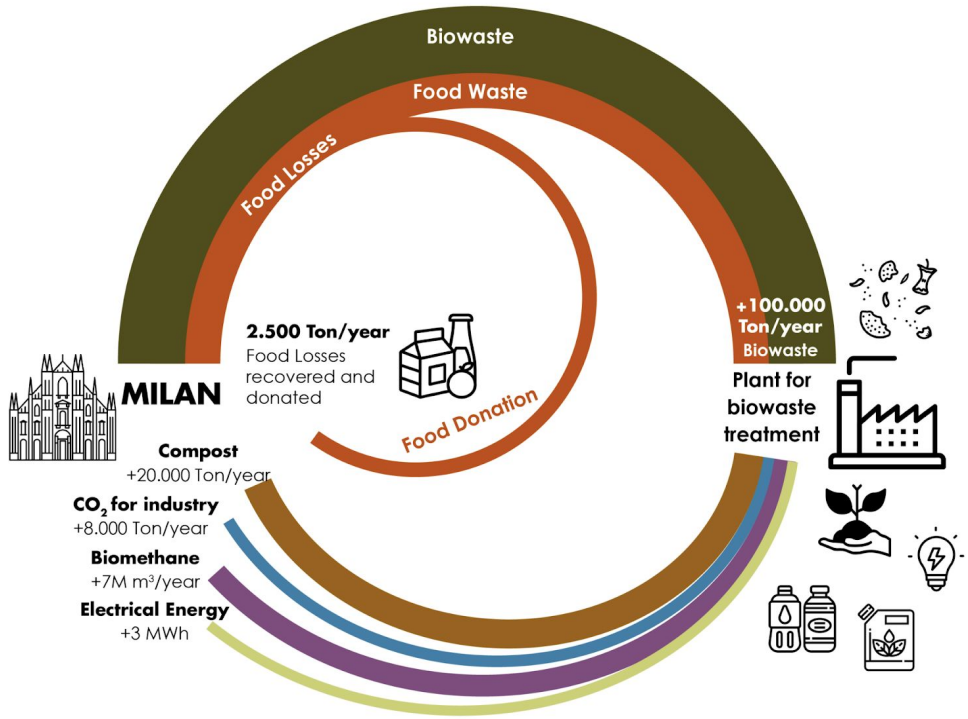


Figure 1: Milan's Circular Food System. Source: Ellen MacArthur Foundation

In 2011, the City of Milan launched a household food waste collection initiative, greatly improving the rate of recovery through educational campaigns and capacity building via its "Milano Recycle City" program. Collected household food waste, alongside commercial food waste (i.e. hotels, schools, etc) is taken for AD which yields biogas and compost. The biogas is used by the municipal gas grid, and compost is used for peri-urban farming. Locally produced food is prioritized to support local production and reduce food miles and transportation costs.

The circular nature of the system was strengthened in 2015 when the city government developed the Milan Food Policy to address food losses and waste. An important method for reducing food waste was the engagement of local actors, such as charities and food banks, who were tapped to help with food recovery and redistribution.The creation of relationships between these local actors was highlighted as one of the "Four Guidelines for Food Loss and Waste." Additionally, a "Local Food Waste Hub" was developed to aid the collection and

redistribution of donated surplus food from canteens, street markets, supermarkets, and non-profit organizations.

Diving In: How Can Food Waste Be Used, and By Whom?

In order to map the potential pathways of food waste symbiosis, a secondary source analysis and a series of interviews were conducted.

The Process:

1. Identify potentially **usable outputs, inputs, and byproducts** (e.g. Vegetable Waste, Used Cooking Oil) through review of existing literature on industrial and urban symbioses, waste hierarchy, bioenergy production, resource looping and bioeconomy
2. Identify **broad categories** of end-users who might potentially be able to use or process food waste
3. Identify specific **local** (central London-based) **end-users** who fit into each of those broader categories who could potentially be activated and brought into the food waste network through content analysis of company websites, press releases, etc.

Table 1: Types of food waste and potential end-users

Organization on Waste Hierarchy	Byproduct/ End-Use	End-User (Categories)	End-User (Examples)
Reuse	**Uneaten Meals**	Resale or Redistribution via Mobile App	Too Good to Go Olio
		Surplus Food Redistributor	FareShare UCL Zero Food Waste FoodCycle
		Community Fridge	Hubbub
Recycling	**Coffee Grounds**	Mushroom Farms	GroCycle Amendment 25
		Soap & Cosmetics production	UpCircle
	Used Cooking Oil (UCO)	Biodiesel Generation	N/A
	Starchy foods	Bio-ethanol Refinery	Biofuel Evolution
		Brewery	Toast Brewery

	Vegetable Waste, Egg Shells, Compost, Digestate	Local farms	Bentham's Farm Kentish Town Farm Freightliners Farm Spitalfields City Farm Hackney City Farm Vauxhall City Farm
		Local Community Gardens	Skip Garden King's Cross Castlehaven Horticultural Hub Culpepper Community Gardens Phoenix Garden Marchmont Community Garden
		Local Parks and Green Spaces	Bloomsbury Square Garden Russell Square Tavistock Square Gardens Gordon Square Woburn Square Garden Malet Street Gardens Bedford Square Euston Square Gardens Brunswick Square Gardens St. George's Gardens Regents Square Gardens St. Andrews Gardens Fitzroy Square Garden
		Local Allotments	Antrim Grove Branch Hill Fitzroy Park Westcroft Estate
Recovery	**Pre-consumer - not for human consumption** (i.e. moldy, carrot tops, etc.)	Local MicroAD	LEAP AD + Bloomsbury CHP or local CHP system
	Post-consumer	Local MicroAD	LEAP AD + Bloomsbury CHP or local CHP system

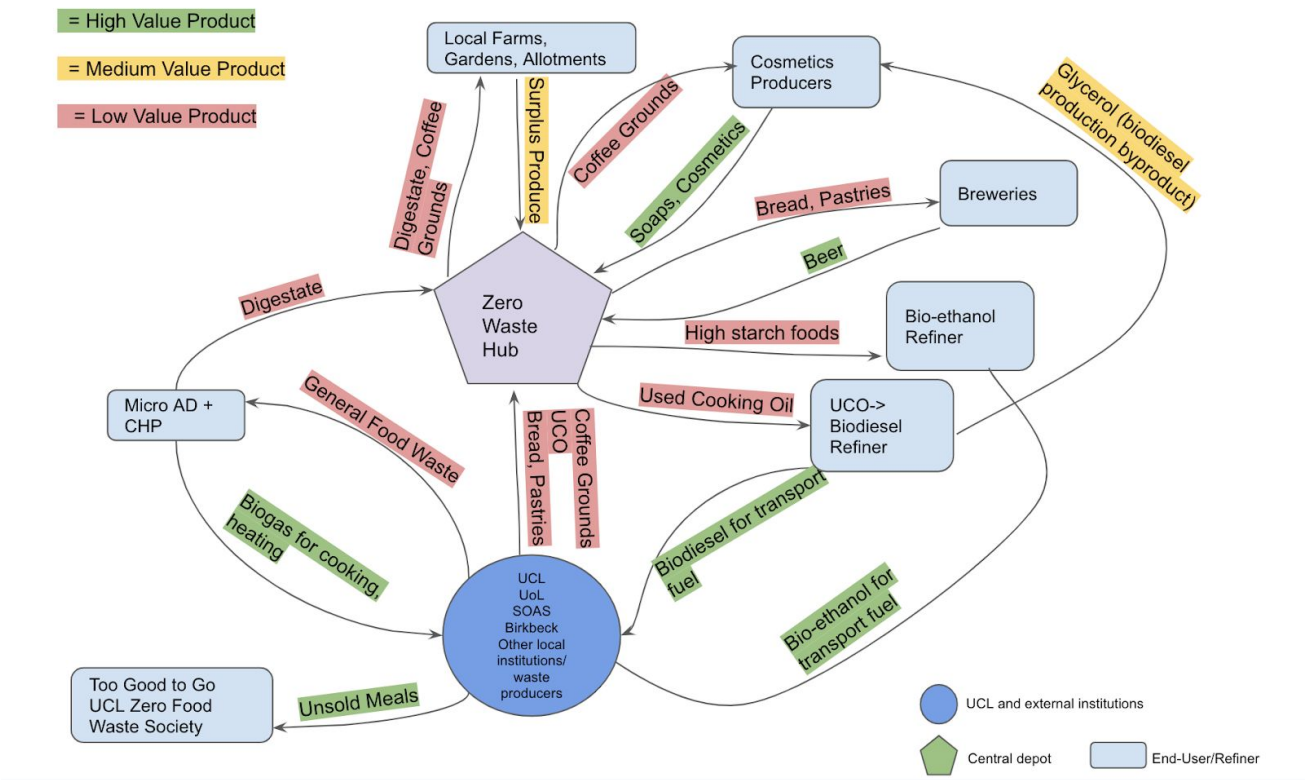


Figure 2: Generalized system diagram created to convey the circular nature of an ideal food waste system. Items in the waste stream are refined from low-value waste products to create higher-value products that remain in the system. A central Zero Waste Hub can be located at the existing waste pickup location, providing space for sorting usable byproducts and space for vendors to sell their new products to consumers.

Food Waste Hierarchy: Making Use of "Waste"

A "food waste hierarchy" is a tool to rank food waste management options based on what's best for the environment. Top priority is given to food waste prevention, followed by re-use, recycling and recovery. The least favourable way to handle food waste is disposal (e.g. landfill); unfortunately, a large chunk of food waste is unknowingly sent to landfill in most countries.

A WRAP report from 2019 showed that around 35% of food waste generated in the UK is sent to landfill, for incineration without energy capture, or to sewers.

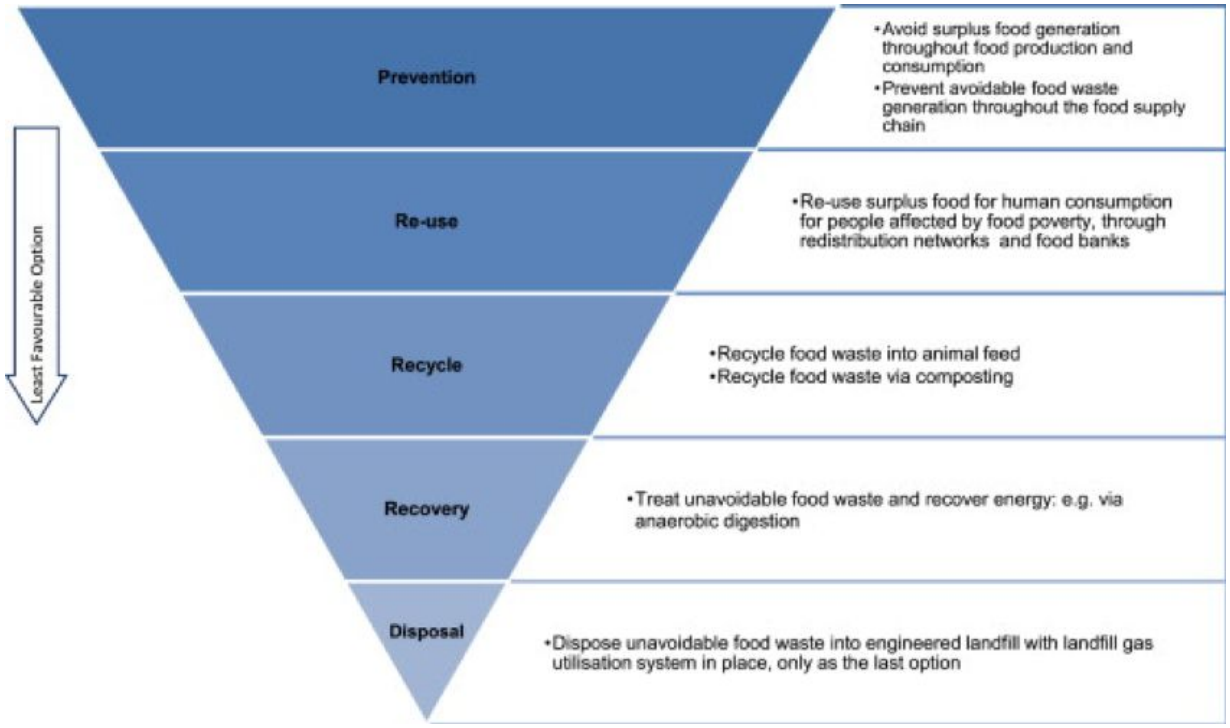


Figure 3: Food Waste Hierarchy. Source: WRAP

What's Going On: Mapping Existing Food Waste Flows at the Urban Campus/District Scale

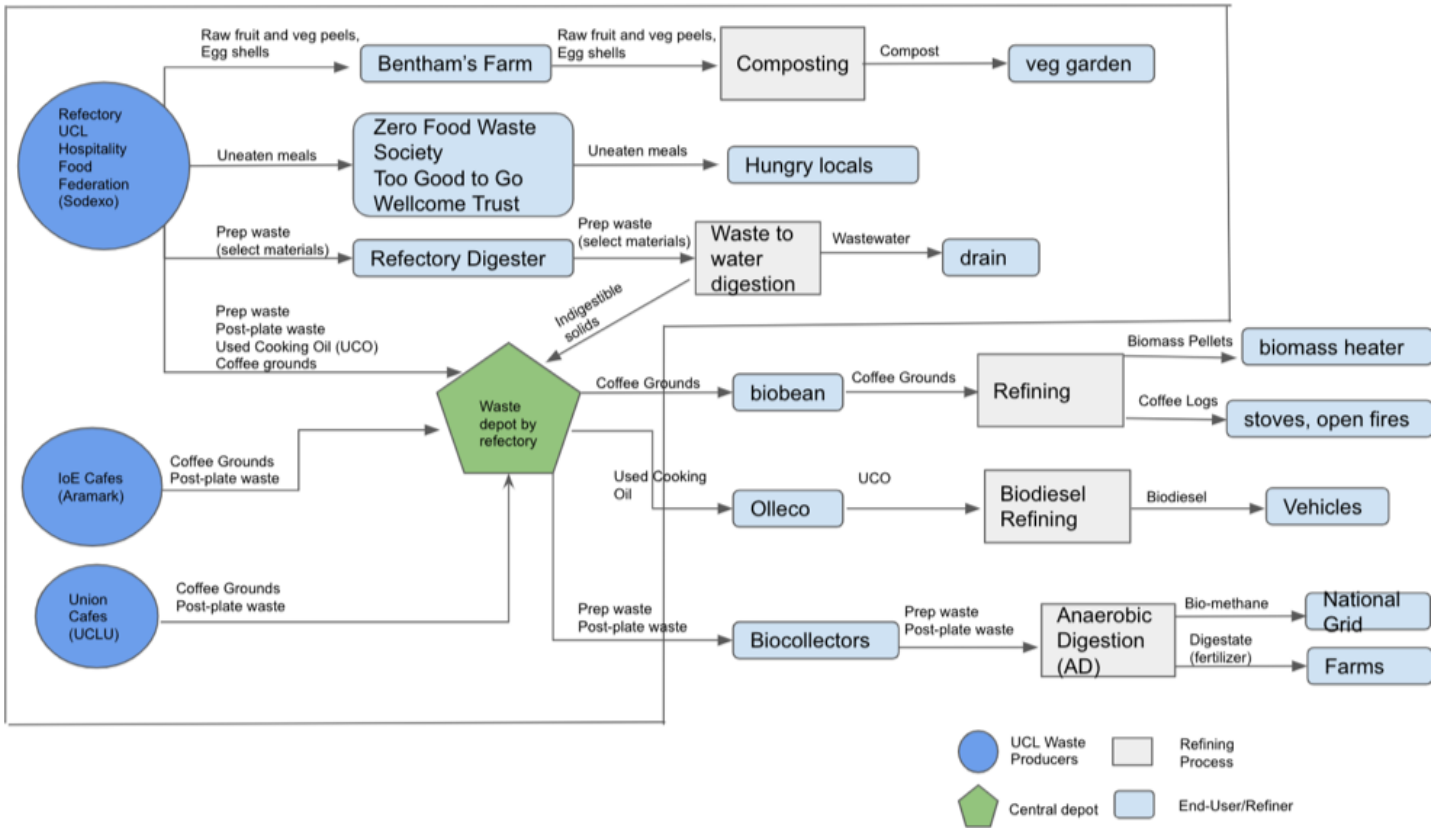


Figure 4: System diagram showing existing food waste disposal and reuse where available. Interviews with UCL's catering providers (Sodexo and Aramark) were used to develop a picture of the existing flow of food waste.

Takeaways:
On the whole, the volume of food waste handled locally is a very small proportion of total food waste; most food waste is processed outside of the system boundaries. The only local processing of food waste is undertaken by Sodexo; no other providers connect with local actors. There are three main local pathways: 1. compostable materials to Bentham's Farm; 2. uneaten meals to hungry people via the UCL Zero Food Waste Society, the Too Good to Go application, and the Wellcome Trust; and 3. Waste from food preparation to the drain via an on-site biodigester in the Refectory kitchen.

Sodexo has been working with Bentham's Farm, UCL's local small-scale agriculture project located at Ifor Evans Residence Hall. **Compostable materials**, like eggshells and fruit and vegetable peelings are provided for composting, which is used to fertilize the garden. Produce from the garden is then used to feed residents of the Ifor Evans student accommodations.

Photo of Bentham's Farm. Source: Bentham's Farm Facebook Page

Some percentage of **uneaten meals** are saved to feed Londoners. The majority of uneaten prepared meals are provided free of charge to Sodexo staff. UCL's Zero Food Waste Society transports meals to local charities. There was no data available quantifying these flows. The Too Good to Go application is a service which provides an avenue for prepared meals to be sold at the end of the day. Sodexo sells a maximum of 10 meals per day via the Too Good to Go app. Sodexo also transports prepared meals to the Wellcome Trust, where they are then passed along to the needy. The total number of meals saved via this pathway is quite small in relation to the total amount of food waste disposed of on campus.

The final pathway is through an **on-site digester** located on campus. Specific materials from the food preparation process can be digested into wastewater via the "Waste$_2$O" digester. According to the interview with Sodexo, the digester handles a very small amount of waste; this is due to its small capacity and inability to process many materials, such as pineapple and animal products. The primary benefit of the biodigester is to reduce landfill tipping costs.
The majority of food waste is handled outside the campus boundaries of UCL. As shown in the above diagram, off-site processing is done through three major refiners: bio-bean, Olleco, and Biocollectors. The locations of refineries have been mapped in Figure 9 below.

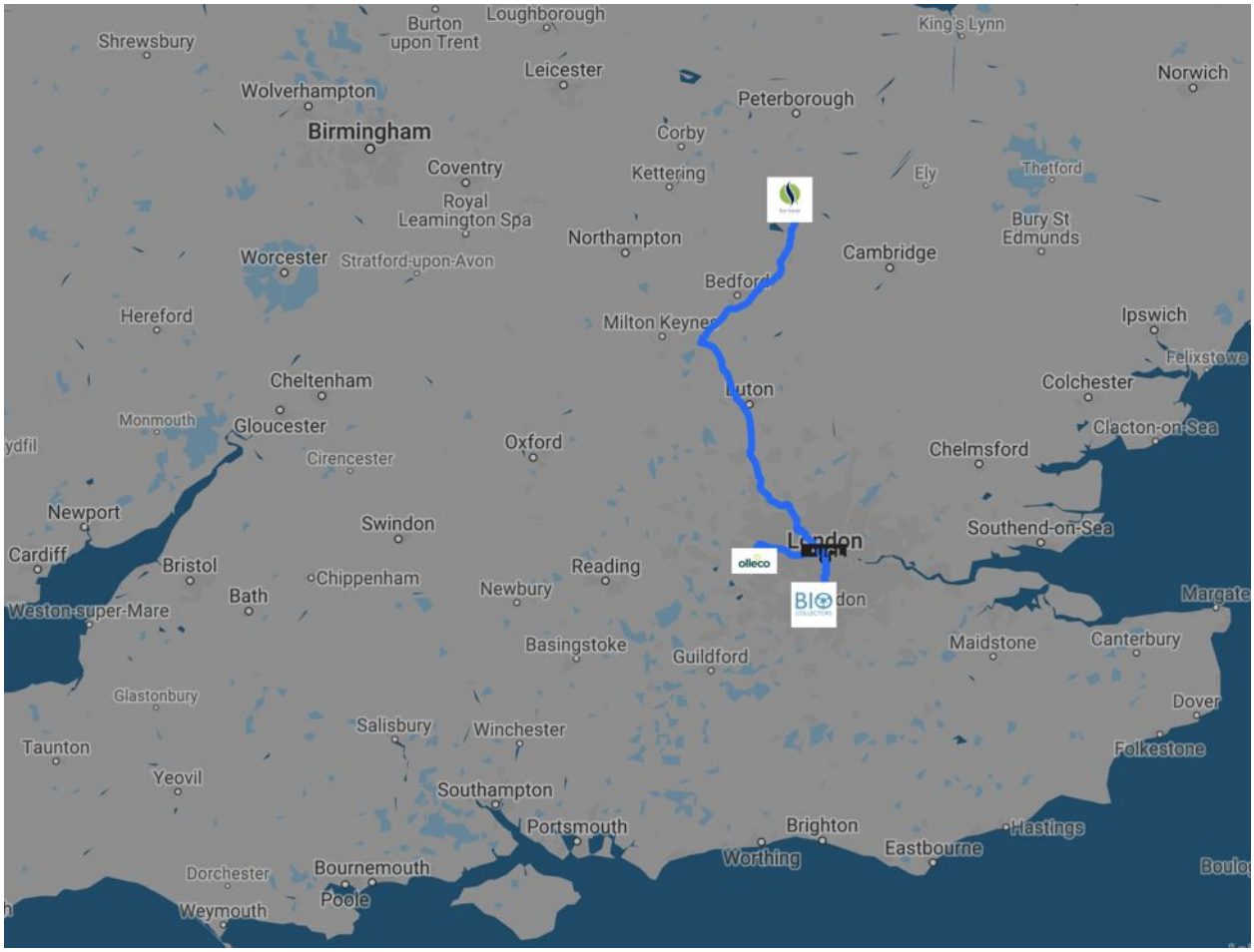


Figure 5: Map of England showing the distance food waste byproducts are transported to be refined. The majority of waste travels outside of central London for processing - incurring the additional financial and environmental costs associated with the transportation of materials.

Coffee grounds are transported by a third-party to bio-bean's facility in Cambridgeshire, 66 miles away from the UCL Student Centre. There the grounds are converted into coffee logs and biomass pellets. These are sold by bio-bean for use in biomass heaters and stoves; UCL does not purchase or use any bio-bean products. The total volume of coffee grounds removed from campus was 10 tonnes in the period from January to July 2019.

UCL pays for the pickup of **Used Cooking Oil (UCO)**, which is then transported to the Olleco facility located near Heathrow Airport in Southall, 16 miles away from the UCL Student Centre. There, it goes through a bio-diesel conversion process, yielding bio-fuel for transportation. Unfortunately, there was no available data on the total volume of UCO removed from campus.

The majority of food waste at UCL is handled through an **anaerobic digestion** pathway, which is second only to waste-to-landfill and waste-to-incineration as least preferable on the waste hierarchy (Papargyropoulou et al. 2014). Food waste is collected from the waste depot near the

Refectory and taken via a subcontractor to the Biocollectors plant in Mitcham, 12 miles from campus. The subcontractor comes 1-2 times per week to remove food waste. Once at the AD plant, food waste is processed for energy recovery producing usable biogas and digestate (a fertilizer). The total mass of food waste transported to the Biocollectors plant in the period from January to July was 128.76 tonnes, with an average of 18.39 tonnes per month. The cost of food waste disposal was not available at the time of research.

All of the value of the products that come from the used cooking oil, coffee ground refining, and AD is lost outside the local system.

Transportation: A Key Component

London-based startup Pedal Me provides logistics solutions in urban areas, using cargo e-bikes to transport passengers and materials. Source: pedalme.co.uk

Previous studies on circular cities and industrial ecology note the importance of co-localised firms and geographic proximity. Therefore, the ideal network incorporates local actors to reduce transportation losses and inefficiencies. The end-users selected in this project were all located within a 30-minute walking distance from UCL's campus. The hyper-local nature of this ideal system allows products and byproducts to be transported by foot or by bicycle, reducing the need for large vehicle pickups and deliveries on campus. Locally produced energy from waste such as biogas for CHP can be used in the local district heating network, providing low-cost, decentralized energy without transmission inefficiencies. New products and services such as Mobility-As-A-Service (MaaS) providers like Pedal Me in London offer potential solutions to problems of moving materials in the system area.

Who's Who?: Mapping Potential Actors in the Symbiotic Network

As part of the interview process, a list of local actors and stakeholders was distributed to interviewees. Participants were asked to mark a "K" for organizations they know about, and "W" for organizations with which there is an existing working relationship.

This information was used in the creation of Social Network Diagrams to understand the interactional ties ("works with") and cognitive ties (i.e. "knows about") amongst existing and potential actors in the local food waste network.

An important aspect in the development of symbiotic networks are the relationships and the social context from which networks develop. Trust, cooperation, and knowledge sharing are important drivers of synergistic resource exchange.

The social network diagram in Figures 6 indicates that many of the identified actors already work together in some regard, and know of each other at the least. Several relationships exist between various UCL departments and potential local network actors. It also indicates that Sodexo, UCL Sustainability (Procurement), and UCL Waste Management have a large number of existing ties. In network theory, this implies "preferential attachment" -- whereby nodes with a higher degree (number of ties) are more likely to receive a new tie (Zhu and Ruth, 2014). Therefore, the network can potentially grow through the facilitation of new ties through these actors.

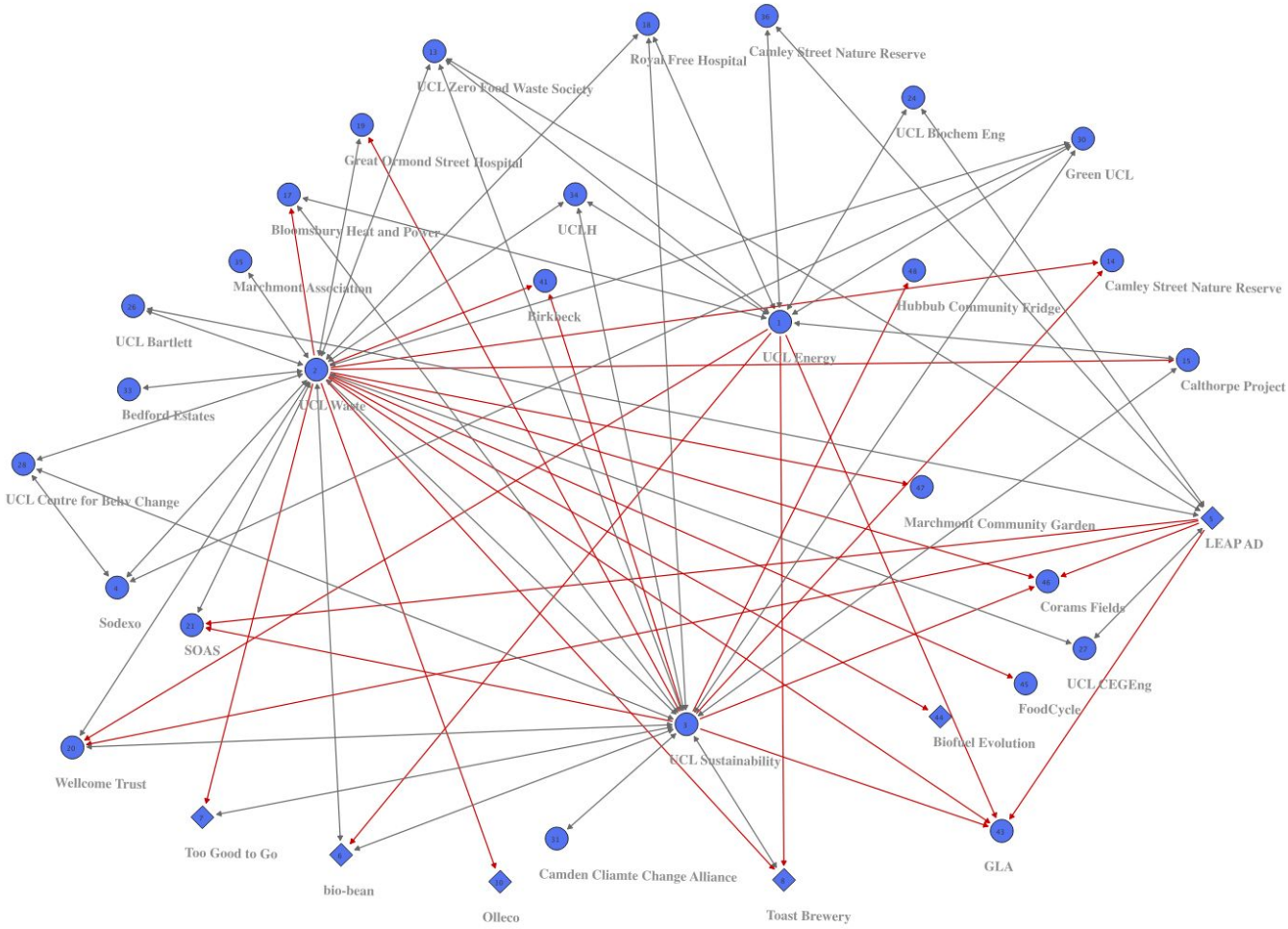


Figure 6: Social network diagram showing existing bidirectional working relationships (grey arrows) and unidirectional "knows of" (red arrows) relationships amongst identified actors (nodes). Diamonds indicate redistributors and refiners. Circles indicate UCL departments and external institutions.

Unveiling Symbiosis: Opportunities for a Cooperative Food Waste Network

When working with diverse, independently functioning systems such as those that exist on university campuses, there is always the possibility that opportunities are being missed due to siloed departments. Symbiosis benefits traditionally separate industries and fields via coordinated exchanges of resources - both material and informational. Through interviews with different departments and external actors alongside a secondary source analysis, this project yielded four previously unrecognized opportunities for developing symbiosis and resource looping.

Sustainable Restaurant Association Scheme

UCL is potentially moving towards a new sustainability certification scheme through the Sustainable Restaurant Association, which takes into account not only sustainable procurement but also building design, energy management, and waste. Both the representatives from Sodexo and UCL Sustainability mentioned this change. The proposed audit scheduled for October 2019 provides an opportunity for analysing the feasibility of an on-site biodigester and integrated CHP, for example.

UK Dementia Research Institute

The second opportunity that was discovered is the development of the new UK Dementia Research Institute hub at UCL, being built next door to the existing LEAP MicroAD plant in Calthorpe Gardens. The Dementia Research Institute is scheduled to break ground in 2020, and includes proposals for an on-site cafe. Integrating or testing on-site microAD offers an opportunity to reduce energy and waste removal costs. There is also potential to involve or develop the existing AD plant at Calthorpe Gardens to handle food waste from this new development.

UCL Sustainability Strategy 2019-2024

The third opportunity to further develop symbiosis on campus lies in UCL's new Sustainability Strategy. A copy of the forthcoming UCL Sustainability Strategy 2019-2024 was provided by UCL Sustainability. It includes several references to encouraging opportunities in student learning and research into sustainability topics, and using UCL as a living lab to test and showcase strategies: "Using UCL's research we will make the UCL campus a showcase of how a city-centre global institution can operate within planetary limits – using resources sustainably and leaving enough for current and future generations." (UCL Sustainability Strategy, 2019). Projects like microAD, on-site biodiesel generation, research into novel ways of extracting useful products from organic waste, and communication and behavioural change to create better waste segregation habits offer a new way to engage and educate students from a wide range of faculties, as well as work as a living lab on campus.

Additionally, there is an emphasis on connecting research and communities: "We will open a dialogue with the wider community to create, test and disseminate sustainability solutions; working with communities locally and globally to co-create solutions and providing informed and digestible science to the general public" (UCL Sustainability Strategy, 2019). As shown in the social network diagrams in Figures 10 and 11, many UCL departments already engage with potential food waste end-users or refiners in an ideal system to some extent. LEAPAD (microAD) works with UCL's Biochemical Engineering Department; Civil, Environmental, and Geomatic Engineering Department, and The Bartlett Faculty of the Built Environment. Biofuel Evolution (bio-ethanol refiner) works with the Chemical Engineering Department. UCL's Sustainability team currently work with the UCL Centre for Behavioural Change. Engaging these actors for the creation of local waste to resource and symbiosis research programs falls in line with the aims of UCL's Sustainability Strategy.

Use of Local Digestate or Compost - Greening Campaigns

One of the identified barriers and challenges to processing food waste locally via anaerobic digestion is the potential overproduction of digestate and lack of land space available for its use. However, two new campaigns might provide an avenue for handling the large amount of digestate that could come from local AD. Both involve urban greening campaigns, which might benefit from locally produced

fertilizers.

At a city-wide scale, London National Park City aims to "make the city greener, healthier, and wilder" (National Park City London, 2019). London was declared the world's first National Park City in July 2019. This new campaign is part of the Mayor of London's Sustainability Strategy, which also includes the goal of making London "50% of the city to be green by 2050" (London City Hall, 2019).

At a local scale, the forthcoming UCL "Wild Bloomsbury" campaign might provide potential institutional support for the use of locally produced fertilizer on and around UCL's campus. The project includes the development of a new masterplan, aimed at creating new green spaces as well as improving existing spaces. UCL aims to achieve 10,000m^2 of extra biodiverse space (UCL Sustainability Strategy, 2019); this area could be fertilized using compost and digestate from local AD and composting programs.

Conclusions

There is a large potential for symbiosis at a local scale, with many types of food waste byproducts and end uses potentially shared with entities that do not already engage with each other. The benefits of local processing of food waste and the development of local symbiosis on UCL's campus include:

- Potential for reduced energy requirements from the grid
- Potential for reduced production of greenhouse gases and air pollution from transport of materials and wastes
- Potential for increased value of items produced by local actors (keeping value in the economic system for longer)
- Opportunities for applied research and educational programs

For example, local food waste-to-energy projects such as micro-anaerobic digestion or UCO refining offer the opportunity to reduce the amount of transportation (and subsequent costs and carbon emissions) necessary to process food waste. It also provides an opportunity for collaboration and relationship building between Bloomsbury campuses (UofL, SOAS, Birkbeck) and local businesses. Another benefit of local symbiosis projects is that it can make waste more visible, providing students with the potential to get involved in the research and educational aspects of biochemical refining, alternative energy production, circular economy, behavioral change, and waste management.

Through the social network diagrams, it is clear that many organizations that would be needed to facilitate a transition to a more circular food system already work with one another in some capacity. Additionally, a large number of cognitive ties already exist. Cooperation and networking for symbiotic networks is dependent on a flow of information between firms. The existing social relationships between potentially cooperative actors suggests fewer informational barriers and an opportunity to begin exchanges of knowledge and eventually resources.

Finally, the interviews revealed four potential opportunities for collaboration and implementation of a circular food system at UCL - the forthcoming Sustainable Restaurant Association certification scheme, the development of the new UK Dementia Research Institute, the UCL Sustainability Strategy, and local and city-wide urban greening programs.

Last year, 4.1 million tonnes of food waste were sent straight to landfill in the UK alone; in London each year, around 19 million tonnes of CO2 emissions are generated from food waste (ReFood, 2019). This has far-reaching negative societal, environmental, and economic outcomes. Identifying alternative end-uses for food waste and engaging a variety of bioeconomy actors to develop symbiotic resource exchange and looping has the potential to greatly reduce landfill usage, greenhouse gas emissions, resource consumption, and energy costs, as well as to engage local communities and enable the creation of regenerative urban

environments. In line with what was argued by Chopra and Khanna (2014) regarding the multi-functionality of IS networks (see Chapter 2.3), further identification and promotion of these benefits can help encourage the development of urban symbiosis and innovative high value products from food waste, aiding the transition towards a circular bioeconomy and resilient closed-loop urban systems.