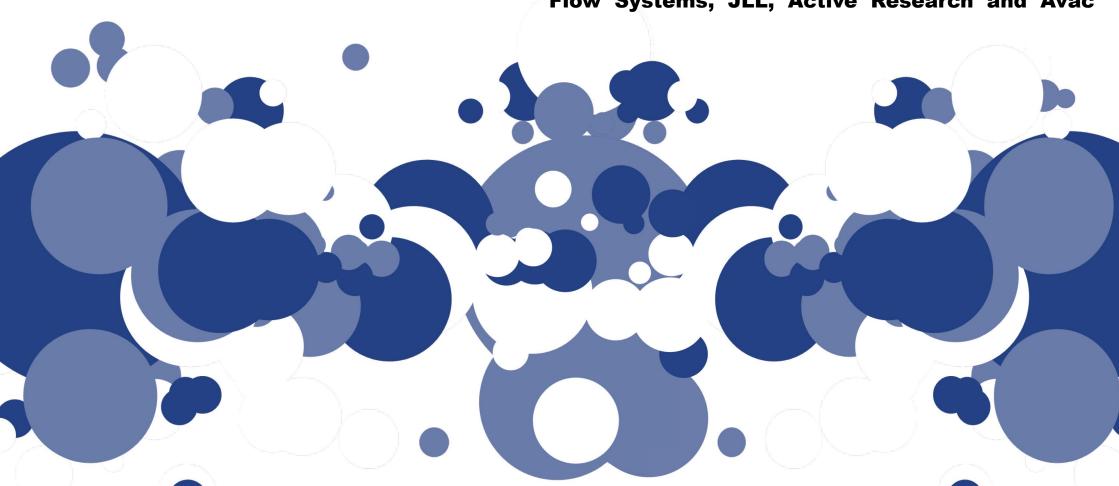


Central Park Precinct Organics Management Feasibility Study

Institute for Sustainable Futures
in collaboration with
Flow Systems, JLL, Active Research and Avac



About The Authors

The Institute for Sustainable Futures (ISF) was established by the University of Technology Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human wellbeing and social equity. For further information visit: www.isf.uts.edu.au

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About The Research

The 'Central Park Precinct Organics Management Feasibility Study' has been prepared by the Institute for Sustainable Futures (ISF), University of Technology Sydney (UTS). The research, conducted by ISF, was funded through a City of Sydney (CoS) Innovation Grant (2016) and Flow Systems (Flow) in collaboration with JLL (retail managers at Central Park), Active Research (anaerobic digestion specialists) and Avac (vacuum system specialists).

The project supports various state and local government initiatives. The project strongly aligns with the NSW Waste Avoidance and Resource Recovery Strategy (WARR) 2014-2021, by providing background information and data on the viability of innovative organic waste management systems and the potential for new markets for recycled materials. By including an analysis of the feasibility of recycling organic food waste (combined with organics in wastewater and trade waste), this project explicitly supports WARR's goal of diverting 75% of waste from landfill and increasing recycling rates for municipal solid waste (MSW) and commercial and industrial waste to 70% by 2021-22, of which organic food waste is a critical component. The project also provides direct benefits to the CoS, by supporting the City to meet its strategic goals. These benefits are related to the 2030 Sustainable Sydney Strategy and the Master Plans developed to support that Strategy (especially the Decentralised Water Master Plan, in which ISF was centrally involved (with GHD)) and the Advanced Waste Treatment Master Plan.

Disclaimer

The authors have used all due care and skill to ensure the material is accurate as at the date of this report.

INSTITUTE FOR SUSTAINABLE FUTURES

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Abbreviations

ABS Australian Bureau of Statistics ML

AD Anaerobic digester (or digestion) MJ

A\$ Australian dollars MS

BAU Business as usual MU

C&D Construction and Demolition
C&I Commercial and Industrial

CBD Central Business District

CoS City of Sydney

CTEP Central thermal electricity plant

CUB Carlton United Brewery

FOG Fats, oils and grease

FW Food Waste

GHG Greenhouse gas

GO Garden Organics

Ha Hectare

Internet of Things

ISF Institute for Sustainable Futures

JLL Jones Lang LaSalle

kg Kilograms
kL Kilolitres

km Kilometres

_ Litres

m Metres

ML Megalitres

MJ Megajoules

MSW Municipal Solid Waste

MUDs Multi unit dwellings

NSW EPA New South Wales Environment Protection Authority

P Phosphorus

PUP Pyrmont-Ultimo precinct

SWC Sydney Water Corporation

t Tonnes

TW Trade waste

UCO Used cooking oil

URM United Resource Management

UTS University of Technology Sydney

WARR Waste Avoidance and Resource Recovery



EXECUTIVE SUMMARY



Introduction

The 'Central Park Precinct Organics Management Feasibility Study' has involved conducting a high level assessment of the feasibility of organic waste management using anaerobic digestion (AD) at One Central Park, Sydney.

The newly developed One Central Park site has been specifically chosen due to the significant potential to incorporate an AD system within its existing recycled water plant facility, the site's connection to the tri-generation central energy plant, and the ISF's direct involvement and experience in research in organic waste management.

Flow Systems manages the A\$13million, 1 ML/day, water recycling plant at One Central Park, the largest water recycling facility in the basement of a residential building in the world.

As a private utility pioneer, Flow Systems is interested in pursuing the feasibility of energy generation through a building scale AD to assist in on-site organic waste management and expansion of their private multi-utility business model.

As the utility manager of One Central Park, Flow Systems are uniquely placed to investigate a building scale AD system in a dense urban setting in combination with their existing world leading on-site water recycling facility and central energy plant. They are keen to investigate the feasibility of piloting an AD plant at Central Park to demonstrate on-site organics management and associated socio-cultural and technological innovations such as minimising contamination of food waste streams through vacuum systems and the generation and utilisation of energy on-site.

There are currently very few successful examples of organic waste management (e.g. food waste, sewage and trade waste) systems at a single large building/precinct scale using AD. While technologies already exist to manage organics in more sustainable and beneficial ways, significant gaps in knowledge exist in closing the loop on organic waste streams through on-site AD in a dense urban setting. These gaps include, for example, identifying the:

- volume and type of organics available for an on-site AD plant in a mixed-use dense urban setting,
- volume and type of organics required for such a system to operate efficiently,
- range of costs and benefits of AD to residential and commercial customers,
- preferred technical options for Central Park in particular.

FINDINGS AT A GLANCE

OR

ENERGY GENERATION

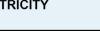
POTENTIAL ENERGY from treatment of the organics on-site can supply up to:



upto **20%**

ELECTRICITY







upto 50%

HOT WATER needs



AVOIDED COSTS

Treatment of the organics on-site has the **POTENTIAL TO AVOID**:



upto 85k/annum

WASTE REMOVAL





upto 80k/annum

ELECTRICITY 'or' **HOT WATER**

costs



Based on estimated upfront capital costs and avoided costs PAYBACK PERIODS



could be as early as

5 years

ADDITIONAL BENEFITS

Significant ENVIRONMENTAL BENEFITS can be harnessed by:



avoiding over 10,000km/annum

TRUCK & RAIL movement

With Sydney expected to grow from 5 to 8 million people over the next 30 years, on-site treatment of organic waste using anaerobic digestion (AD) unlock significant potential in both retrofit and new developments.

Waste Management at One Central Park

The Central Park precinct is built on the former Carlton United Brewery (CUB) site next to Central Station on the southern edge of Sydney's CBD and directly adjacent to Ultimo, currently, the densest urban area in Australia, with some 15,100 people/km2 (ABS 2016). One Central Park, on the western edge of the development, with its distinctive East and West towers draped in green vegetation, is the focal point of this feasibility study.

For the feasibility study, current waste management systems and practices were investigated for both the residential and commercial areas at One Central Park. Figure 1 below illustrates the various waste streams along with the management and treatment of each waste stream, including garden organics (GO), food waste (FW) (residential & commercial/retail), UCO, FOG, sewage and trade waste (TW). A more detailed assessment of the volume of waste containing organics was developed to assist in assessing the potential of an AD system on-site at One Central Park. Volumes of individual streams containing organic waste are shown in Figure 2. Figure 3 shows the current waste stream routes and destinations highlighting the fragmented nature of organic waste management and significant potential

3,351 kL/annum Residential Municipal Solid Waste (MSW) Commercial/Retail Solid Waste 4.106 kL/annum **Woolworths Food Waste** 194 kL/annum **Woolworths Solid Waste** 883 kL/annum **Used Cooking Oil (UCO)** 12 kL/annum Fats Oil and Grease (FOG) 300 kL/annum **Waste Water Sewage** 62,050 kL/annum (diverted to sewer bypassing the recycled water plant) Trade Waste sludge (TW) 4,380 kL/annum (discharged to sewer from the recycled water plant) Garden Organics (GO) 333 kL/annum (from green walls and parks at Central Park)

Figure 2

One Central Park waste streams (excl. recyclables) containing organics in kL/annum based on 2017 data (through assumed and actual data collection)

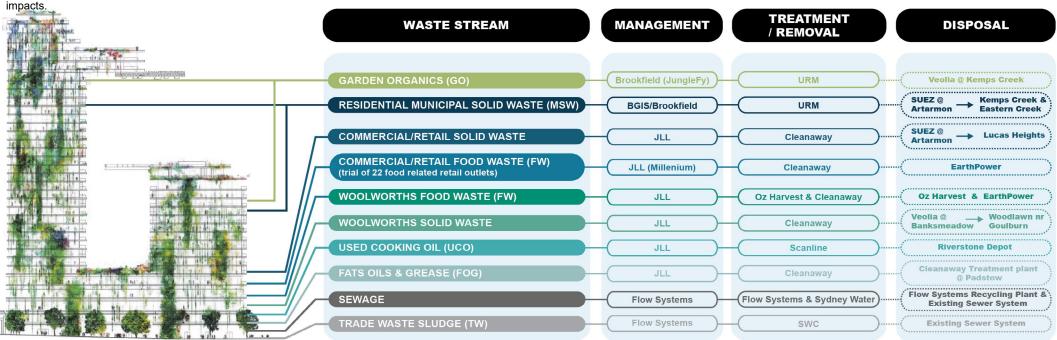
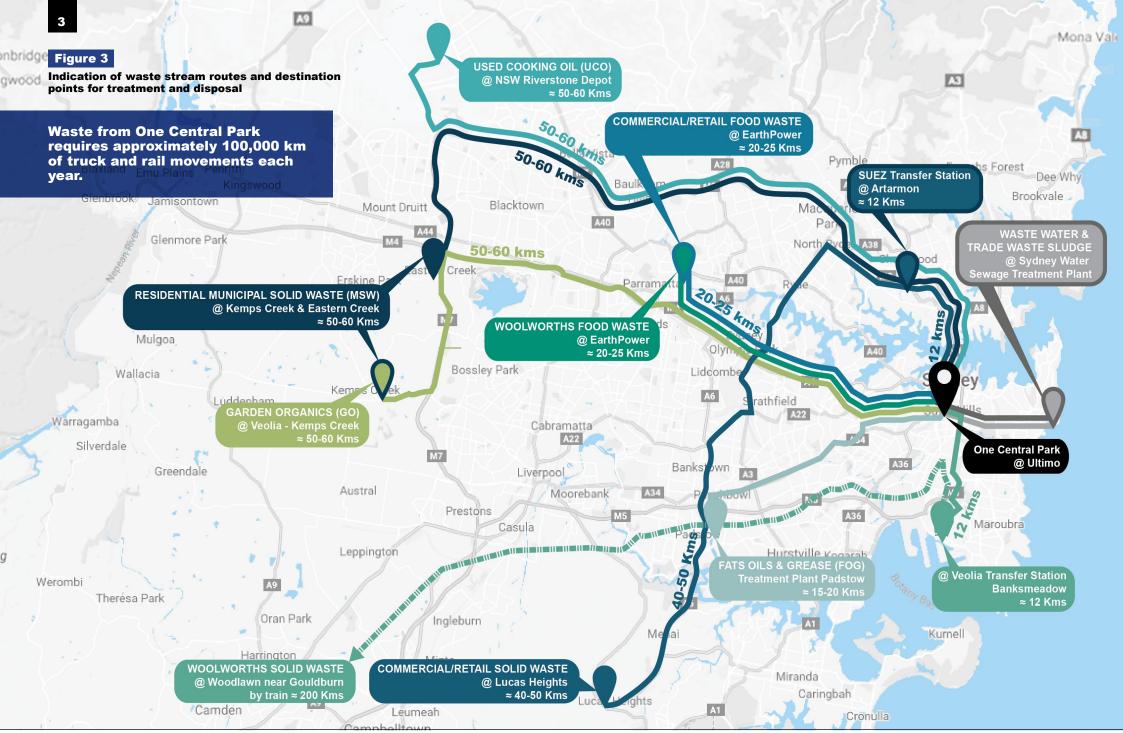


Figure 1

Waste streams and management at One Central Park (excl. recyclables)





Technological Options

A total of six potential options were identified for assessment which took into consideration a spectrum of opportunities relevant to retrofitting One Central Park but also new precinct scale developments.

The study revealed that there is currently limited food waste and other organics source separation occurring at One Central Park, yet there are potentially significant volumes of organic waste available and, if captured and combined, can be used as a feedstock for an on-site AD system. Such opportunities are amplified due to the specific characteristics of the site, including sludge produced from the on-site waste water recycling plant and potential connection to the central energy plant. Figures 4 & 5 show estimated organics available with and without sewage and trade waste sludge while Figure 6 shows the organics vs. potential energy production for each of the options.

All options include commercial/retail food waste, Woolworth's food waste, UCO, and FOG but excludes GO.

Options 1 to 4 include varying volumes of residential food waste (from 15% to 75%) from the 623 flats at One Central Park plus all trade waste sludge.

Option 5 excludes residential food waste and includes only 50% of trade waste sludge.

Option 6 excludes both residential food waste and trade waste sludge representing a more commercial/retail focused example of precinct scale development.

The options were analysed for potential biogas production revealing that Options 3 and 4 provide the highest energy potential.

The potential energy versus the quantum of organics needed to generate the energy highlights the significant opportunities of waste streams such as food waste, UCO, and FOG compared to trade waste sludge

Figure 6

Organics vs. Potential energy production for each option.

Res FW - 2270 Kg/Week

Com FW (part) - 786 Kg/Week

Wol FW - 1188 Kg/Week

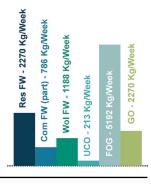
UCO - 213 Kg/Week

FOG - 5192 Kg/Week

TW - 105,000 Kg/Week

Figure 5

Estimated Organics waste streams w/o Trade Waste Sludge



Potential Energy Generation in MJ/annum (millions)
Organics in tons/annum

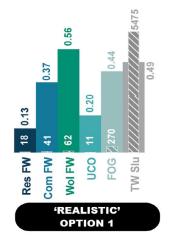
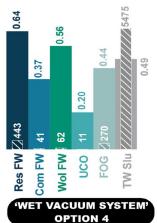


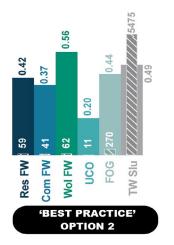
Figure 4

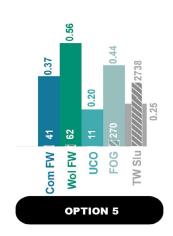
Estimated organics

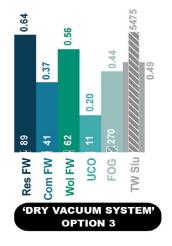
waste streams with

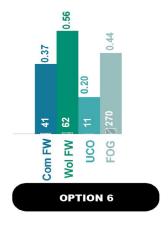
Trade Waste Sludge













As the Central Park precinct has a tri-generation central energy plant located on-site, there is the opportunity to use the energy generated from the AD plant to either contribute towards the needs of electricity **or** hot water for the residential flats on-site. Figure 7 provides a comparison summary of the six options.

Options 3 and 4 have the potential to capture the largest volume of organic waste on-site which could provide sufficient renewable energy for about 20% of the 623 flats at One Central Park for electricity or approximately 50% of flats for hot water per annum.

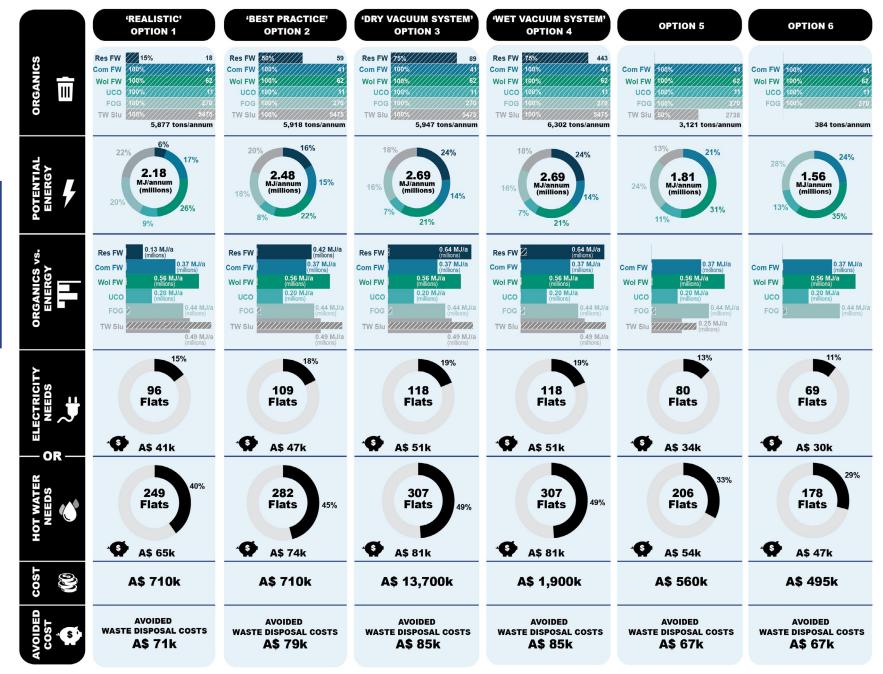


Figure 7

Comparison Summary of the six technological options

Capital Costs & Potential Benefits

Whilst the costs of incorporating AD and the associated collection/ transportation systems at One Central Park vary, the potential for annual avoided cost benefits are significant. This combined with grant funding opportunities and the involvement of a progressive private multi-utility business such as Flow Systems, provide a major opportunity to set up a world leading AD system at One Central Park.

The estimated upfront/capital costs of the retrofit systems are summarised in Figure 8. These costs are high level estimates and require further detailed assessment. (Note with both Woolworths and the commercial/retail areas already separating food waste through kitchen caddies and bins, no additional costs have been considered.)

The costs of the options vary significantly with Option 3 - 'dry vacuum system' high compared to the other options with little or no additional organics capture compared to Options 1,2, and 4. If wet vacuum systems were retrofitted for residential and commercial/retail or fitted in a new build, major cost savings could be made.

Whilst dry vacuum costs are high, well designed wet vacuum systems in new buildings have real potential. All the non vacuum retrofit options assessed have a viable business case with a payback period of approx. 5 years.

The AD system costs do not vary significantly despite the size differences between the Options. A large component of the cost of the system is for pre-treatment, that is, removal of plastics and metal contamination to protect the AD plant and minimise maintenance issues.

Estimated benefits are also summarised in Figure 8. These are high level estimates and require more detailed assessment. There are significant quantifiable annual benefits, including the avoidance of approx. 20% of current BAU waste management costs and production of renewable energy leading to reduced costs for hot water OR electricity costs for flats. Non-quantifiable annual benefits include, for example, reduced greenhouse gases from truck movements and landfill.

Figure 8

Summary of AD and estimated upfront capital costs and annual avoided costs excluding operational costs.

	'REALISTIC' OPTION 1	'BEST PRACTICE' OPTION 2	'DRY VACUUM' OPTION 3	WET VACUUM' OPTION 4	OPTION 5	OPTION 6
ORGANICS	112,720	113,515	114,082	120,893	59,879	7,379
	Kg/week	Kg/week	Kg/week	Kg/week	Kg/week	Kg/week
AD	56k	56k	56k	56k	22k	10k
VOLUME	Litres	Litres	Litres	Litres	Litres	Litres
AD SIZE	3.8 m x 5 m	3.8 m x 5 m	3.8 m x 5 m	3.8 m x 5 m	2.5 m x 4.5 m	1.8 m x 4 m
	Dia x Ht	Dia x Ht	Dia x Ht	Dia x Ht	Dia x Ht	Dia x Ht
ESTIMATE OF Digestate	1,000 Kg/day	1,000 Kg/day	1,000 Kg/day	1,000 Kg/day	500 Kg/day	65 Kg/day

_				(G).				
				ESTII	MATE OF UP FR	ONT / CAPITAL (COST	
	4	CAMPAIGN	A\$ 40,000	A\$ 40,000	A\$ 40,000	A\$ 40,000		
	Z	CADDIES	A\$ 10,000	A\$ 10,000				
	RESIDENTIAL	WET VACUUM				A\$ 1,200,000		
	Y	DRY Vacuum			A\$ 13,000,000			
		INPUT PIPES/CON	A\$ 25,000	A\$ 25,000	A\$ 25,000	A\$ 25,000	A\$ 25,000	A\$ 25,000
	TREATMENT	PRE TREATMENT	A\$ 100,000	A\$ 100,000	A\$ 100,000	A\$ 100,000	A\$ 100,000	A\$ 100,000
		AD UNIT	A\$ 450,000	A\$ 450,000	A\$ 450,000	A\$ 450,000	A\$ 350,000	A\$ 300,000
ŀ	AD TR	POST TREATMENT	A\$ 35,000	A\$ 35,000	A\$ 35,000	A\$ 35,000	A\$ 35,000	A\$ 35,000
	4	OUTPUT PIPEWORK	A\$ 50,000	A\$ 50,000	A\$ 50,000	A\$ 50,000	A\$ 50,000	A\$ 50,000
	3	TOTAL	A\$ 710,000	A\$ 710,000	A\$13,710,000	A\$ 1,900,000	A\$ 560,000	A\$ 495,000
1				S ES	TIMATE ANNUA	L AVOIDED COS	STS	
	D	WASTE DISPOSAL	A\$ 71k	A\$ 79k	A\$ 85k	A\$ 85k	A\$ 67k	A\$ 67k
	Н	FLAT OT WATER	A\$ 64k	A\$ 73k	A\$ 80k	A\$ 80k	A\$ 53k	A\$ 46k
	EL	OR —— FLAT ECTRICITY	A\$ 64k	A\$ 73k	A\$80k	A\$ 80k	A\$ 53k	A\$ 46k
		TOTAL	A\$ 135k	A\$ 152k	A\$165k	A\$ 165k	A\$ 120k	A\$ 113kt
		PAYBACK ERIOD YRS.	5.3	4.7	83	11.5	4.7	4.4

Issues for Consideration & Recommendations

In assessing the volume of organics available on-site and the associated costs and benefits of introducing an AD system at One Central Park, this feasibility study has highlighted a range of challenges, opportunities and issues for considerations.

These have been assessed using a social, technological, environmental, economic and political (STEEP) analysis. While the STEEP analysis provides insights specifically for One Central Park many of the insights can be considered more broadly for managing organic waste and developing AD systems in dense urban settings. Figure 9 provides a summary of the issues for consideration and associated recommendations.

issues for consideration

Ongoing buy-in from retail outlets to separate & collect food waste

Lack of precedents of AD systems in dense urban Australian settings

Fragmented collection & management of organics waste streams on-site

Behaviour change to separate & collect food waste & minimise contamination

SOCIAL

Modify all retailer leasing arrangements to mandate food waste collection

Collate lessons learned on urban AD examples locally & internationally Negotiate contract arrangements with current waste management providers

Conduct a residential food waste trial on-site and evaluate lessons learned from the current retail food waste trial

recommendations

issues for consideration

Smart/Internet of Things (IOT) Technology opportunities

Remote management & operational control requirements

Retrofitting an existing building vs installing AD in a new building

Adaptive AD system to deal with variations in quality & quantity of substrates

TECHNICAL

Investigate opportunities to use smart/IOT Technology

Conduct due diligence on appropriate AD (& vacuum) systems

Conduct detailed feasibility assessment into the various AD, vacuum, energy and digestate reuse options

Conduct laboratory testing of the various substrates

recommendations

issues for consideration

Capturing nutrient opportunities

Energy and greenhouse gas trade offs

Management of potential odour & vector issues

ENVIRONMENTAL

Collate national & international information on AD digestate use & regulations

Conduct detailed assessment of operational energy requirements & greenhouse gas emissions for all options including BAU

Conduct detailed feasibility/design assessment of management of potential odour & vector issues

recommendations

issues for consideration

Non-quantifiable benefits

Varying costs of vacuum system options

Vacuum systems for wastewater & organic waste

Financial incentives for waste-to-energy systems

Lack of transparency & availability of data on waste volumes & costs

ECONOMICAL

S

Use appropriate decision-making framework as part of the detailed feasibility study to capture quantifiable & non quantifiable costs & benefits

Conduct full assessment of costs of AD & vacuum options taking into consideration retrofit vs new build development

Investigate & advocate the potential for combined food/organic waste & wastewater vacuum systems

Seek potential national, state and local government grant funding for AD (& vacuum) system pilot

Conduct detailed assessment of costs & benefits of options against BAU as part of detailed feasibility/design study

recommendations

issues for consideration

Regulatory barriers

Increasing awareness & support for food waste management

POLITICAL

ш

Actively share knowledge on the current study findings and future detailed feasibility study/design & pilot

Work closely with regulators such as the NSW EPA

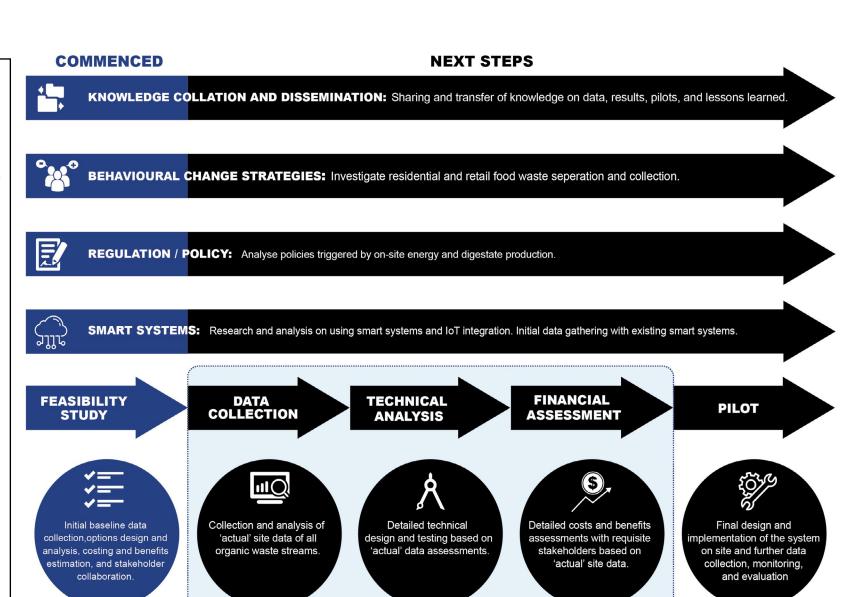
recommendations

Figure 9

Summary of Issues for Consideration and Recommendations

Project Roadmap

There is currently significant opportunity and momentum to trial and demonstrate AD in Sydney, specifically at One Central Park. By using a collaborative approach, leveraging the research conducted to date, and conducting further investigations as indicated, the CoS, Flow Systems, and other project partners involved have the opportunity to provide national and international leadership on AD Organics Management.



DETAILED FEASIBILITY / DESIGN PHASE

Figure 10

Project Roadmap

CONTENTS

			5	POTENTIAL OPTIONS	17
EXECU	TIVE SUMMARY	ii	5.1	Socio-technical options	17
			5.2	Renewable energy options	19
ABBRE	EVIATIONS	iv	_		
4	INTRODUCTION	4	6	COSTS AND BENEFITS	21
1		1	6.1	Business as usual costs	21
1.1	Aim	1	6.2	Option costs	22
1.2	Background	1	6.3	Benefits	23
1.3	Project partners	2			
1.4	Layout of the report	2	7	DISCUSSION AND RECOMMENDATIONS	25
1.5	Approach	3	7.1	Discussion	25
			7.1.1	Socio-cultural dimensions	25
2	THE WASTE CHALLENGE	4	7.1.2	Technological dimensions	25
2.1	The challenge	4	7.1.3	Environmental dimensions	26
2.2	Potential solutions	4	7.1.4	Economic dimensions	27
	- otoritian obligations	·	7.1.5	Political/institutional dimensions	28
3	OVERVIEW OF CENTRAL PARK	7	7.2	Recommendations	28
3.1	The Central Park precinct	7	8	REFERENCES	30
3.2	One Central Park	7			
3.3	Current waste management at One Central Park	8	APPEN	DICES	31
3.3.1	Residential	8	Append	dix A – Site plans & typical cross sections of One Central Park	32
3.3.2	Commercial/retail	8		, , , , , , , , , , , , , , , , , , ,	
3.3.3	Used cooking oil (UCO)	8	Append	dix B – Organics waste stream assumptions	33
3.3.4	Fats, oils and grease (FOG)	8			
3.3.5	Wastewater and trade waste	8	Append	dix C – AD technology & vacuum & caddy collection & transportatio	
3.3.6	Garden organics (GO)	9	system	S	34
3.3.7	Pet waste	9	Ana	erobic digestion	34
3.3.8	Summary	9		euum systems	35
4	ORGANIC WASTE STREAMS	11		ddies	36
4.1	Overview of organic waste streams at One Central Park	11	_		
4.2	Data on organic waste streams	13	Append	dix D – Australian food load test	37
4.2.1	Full potential scenario	13	Append	dix E – Knowledge sharing, transfer and dissemination	38
4.2.2	Data and assumptions	13	• • •	<u> </u>	

1 INTRODUCTION

This project the "Central Park Precinct Organics Management Feasibility Study" has been developed by the Institute for Sustainable Futures (ISF), part of the University of Technology Sydney (UTS), in collaboration with Flow Systems, JLL, Active Research and Avac. The project has been funded under the City of Sydney (CoS) Environmental Performance - Innovation Grants program¹ (2016-17 Round 4).

1.1 Aim

The aim of the study has been to investigate innovative approaches to the management of organics waste streams in the heart of Sydney. Specifically, the study focusses on determining the feasibility of using vacuum and anaerobic digestion (AD) technology to transport and process food waste and other organic waste materials (i.e. used cooking oil, fats, oils and grease from grease traps and sewage sludge from the recycled wastewater treatment plant) on-site at Central Park to generate:

- biogas as a renewable energy for use on-site; and
- nutrient rich digestate for beneficial reuse to land.

Due to the sheer size and complexity of the Central Park precinct development, the investigation has focused on the main building, One Central Park, which first opened at the end of 2013. This main building sits within the 5.8 hectare Central Park precinct development which encompasses a total of 11 buildings. Construction of the entire development will be completed by the end of 2018.

By investigating the Central Park precinct development, the study aims to inform (where feasible based on available data) the potential for both retrofitting existing buildings and incorporating innovative organic waste management systems and practices in new buildings. This includes investigation of:

- different types and volumes of organic waste streams;
- organic waste treatment;
- biogas, energy and digestate generation and usage;
- management arrangements; and
- costs, benefits and pricing arrangements.

1.2 Background

This project stemmed from discussions within the Smart Locale² initiative, which brings together agencies, organisations and businesses in the Pyrmont-Ultimo precinct (PUP) with an interest in implementing sustainability initiatives in the Pyrmont-Ultimo corridor, which encompasses the iconic Central Park. Smart Locale organisations include for example: UTS, Flow Systems, JLL, the City of Sydney (CoS), Sydney Water Corporation (SWC), the Pyrmont Ultimo Chamber of Commerce, TAFE, the Total Environment Centre, Sydney Fish Markets, the Powerhouse Museum and the Star (casino and entertainment hub).

Several of the organisations within the Smart Locale initiative were involved in the SWC and NSW EPA funded project, "Pyrmont-Ultimo Precinct (PUP) Scale Organics Management Scoping Study" (Turner et al 2017), which investigated the range and volume of organic waste streams within the PUP corridor and potential innovative options for managing these waste streams more sustainably. On completion of the PUP scoping study, Smart Locale members, in particular, Flow Systems and the CoS, were interested in progressing a feasibility study to investigate AD to manage organic waste and produce energy on-site at Central Park with the ultimate aim of installing a pilot/demonstration site at One Central Park in the future.

¹ http://www.cityofsydney.nsw.gov.au/community/grants-and-sponsorships/environmental-grants/innovation-grant (accessed 27/02/18

² https://www.smartlocale.com.au (accessed 27/02/18)

1.3 Project partners

The key partners in the project are summarised in Table 1.1.

Table 1.1 - Project partners

Project responsibilities	Organisation	Details
Project funder	City of Sydney (CoS)	Funder under Environmental Performance - Innovation Grants program http://www.cityofsydney.nsw.gov.au/com munity/grants-and- sponsorships/business-grants/innovation- grant
Research consultants and project managers (data collection and analysis)	Institute for Sustainable Futures (ISF), University of Technology Sydney (UTS)	https://www.uts.edu.au/research-and- teaching/our-research/institute- sustainable-futures
Project funders, manager of on-site water recycling plant and data provider	Flow Systems	https://flowsystems.com.au
Manager of commercial retail outlets and data provider	JLL	http://www.jll.com.au/australia/en-au
Anaerobic digestion specialist	Active Research	http://www.activeresearch.com.au
Vacuum system specialist	Avac	http://www.avac.com.au

1.4 Layout of the report

The report layout is as follows:

Introduction

Provides a summary of the aims and objectives of the project, background information on the feasibility study, an overview of the partners involved, their roles and responsibilities in the study and the overall study approach/methodology.

The waste challenge

This section provides a brief background on the waste challenge in Sydney and the potential for innovative waste management solutions, originally identified in the PUP scoping study.

Overview of Central Park

A brief overview of the Central Park precinct development is provided concentrating on One Central Park as the focus of the investigation. Current waste management arrangements are also discussed in this section.

Organic waste streams

An overview of waste management and specifically organic waste streams and volumes at One Central Park is represented including used cooking oil (UCO), fats, oils and grease (FOG), food waste (FW) - residential and commercial/retail, garden organics (GO) and trade waste (TW).

Potential options

Based on the modelling of organic waste streams conducted in this project, a suite of potential options have been identified.

Costs and benefits

A high level analysis of the quantifiable and non-quantified costs and benefits of the suite of options identified is presented.

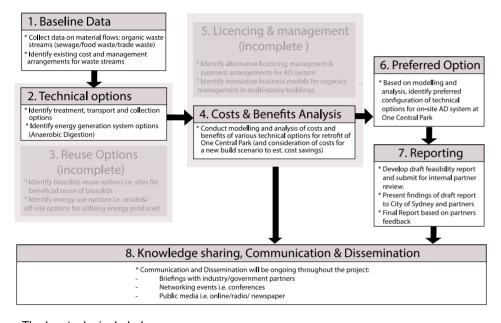
Discussion and recommendations

Finally, a short discussion on the final outcome of the project and recommendations on the feasibility of AD in a dense urban setting is presented with reference to Social, Technical, Environmental, Economic and Political considerations.

1.5 Approach

The approach adopted for this study required an inception meeting and eight discrete and overlapping areas of inquiry, with two tasks unable to be completed within the project timeline (refer to Figure 1.1)

Figure 1.1 - Study approach/methodology



The key tasks included:

An inception meeting with all partners was conducted at the commencement of the project and team meetings scheduled at key milestones throughout.

1. Baseline data collection

- <u>Organic waste flows:</u> Existing and assumed data on volumes of organic waste streams at Central Park was collected. This included investigating volumes of food waste (residential & commercial/retail), UCO, FOG, trade waste sludge, sewage and GO.
- <u>Costs and management arrangements:</u> In parallel to collecting data on organic waste flows, the project aimed to identify the costs and management arrangements of each organic waste stream. Where possible, the organisation involved in managing the waste stream and costs were identified.

- 2. Technical options: The project proposed to:
 - <u>Identify treatment, transport and collection options:</u> Based on data collected
 in the previous task, a suite of potential options was identified.
 - <u>Identify energy generation system options based on AD:</u> Calculations were conducted on the potential energy generated from the suite of options.
- **3. Reuse options (incomplete):** While the original proposal aimed to identify potential reuse options both for (1) digestate created from AD and (2) energy use options for utilising energy produced through AD (both on-site and off-site), this task was not achieved within the timeframe of the project. The significant amount of time required to identify actual and assumed volumes of organic waste streams at Central Park and the costs and management arrangements of these waste streams meant these tasks were only partially achieved this is an opportunity for further research.
- **4. Costs and benefits**: A preliminary high level assessment of the quantifiable and non-quantifiable costs and benefits was conducted for the suite of technical options identified (see: Task 2). This task was limited by the data available.
- **5. Licensing and management (incomplete):** The original proposal aimed to identify alternative licensing and management arrangements and potential business models to support AD as an approach to manage organic waste streams on-site at Central Park. In reality, gaining insight into the costs and licensing arrangements of waste contractors was an unexpected hurdle and meant this task was unable to be completed within the project timeline.
- **6. Preferred options**: Based on the modelling and analysis of costs and benefits, a preferred configuration of technical options for Central Park was identified.
- **7. Final reporting:** Presentation of project results was provided to the CoS with draft and final reporting submitted after feedback from the CoS.
- **8. Knowledge sharing, communication and dissemination:** A key requirement of this project is knowledge sharing, communication and dissemination. At the end of the report an overview of the communications, workshops and conference presentations undertaken both in Australia and internationally, which demonstrate sharing the results of this research, is provided. Further sharing will occur, after the project has been completed, through various fora. In addition, to these research outputs the final stage of the project involved surveying the project team to determine lessons learned throughout the project. Refer to Appendix F for details on knowledge sharing and the project team survey results.

2 THE WASTE CHALLENGE

2.1 The challenge

Sydney currently has a population of over 5 million (ABS 2016). This is expected to grow to over 8 million by the middle of the century, predominantly through urban densification (GSC 2017). With the city growing at such a rapid pace, it will be essential to transition from the highly siloed and traditionally centralised, linear model of water and waste service provision, where resources are imported into the city and waste exported out, towards a more circular economy that includes more decentralised systems of waste management. That is, a system where waste is considered a resource and where waste streams generated locally are recovered, treated and reused locally where it makes sense to do so.

A key issue of concern facing the city is the generation of organic waste streams. Millions of tonnes of organic waste are currently generated every year by the residential and commercial sectors. The majority of this material is sent to landfill producing leachate and methane gas, a greenhouse gas (GHG) estimated to be 25 times more damaging to the atmosphere than carbon dioxide (Parliament of Australia 2008), resulting in significant environmental impacts.

In an attempt to curb waste generation and increase avoidance of waste and recycling rates, the NSW government have committed to the NSW EPA Waste Avoidance and Resource Recovery (WARR) Strategy. The latest WARR Strategy 2014 - 2021 defines clear actions and targets to 2021 (NSW EPA, 2014) including:

- avoiding and reducing the amount of waste generated per person in NSW;
- increasing recycling rates to 70% for both Municipal Solid Waste (MSW) and Commercial and Industrial (C&I) waste and 80% for Construction and Demolition (C&D) waste; and
- increasing the volume of waste diverted from landfill to 75%.

To support these objectives, the NSW EPA uses proceeds from the landfill levy, currently A\$ 141/tonne³, to provide funds and incentives for waste management initiatives. The 'Waste Less, Recycle More' fund specifically targets organic waste diversion, incentivising new technology and behaviour change programs⁴ that support councils and the private sector to manage food waste more sustainably and to create new markets for processed outputs.

2.2 Potential solutions

In 2016/17, ISF modelled and mapped the volumes of food waste (and other organic waste streams) in the PUP corridor and conducted a comprehensive review of national and international innovative organic waste management solutions that could potentially be used to manage organic waste streams in the precinct. The study "*Pyrmont-Ultimo Precinct (PUP) Scale Organics Management Scoping Study*" (Turner et al 2017) was funded by SWC and the NSW EPA and therefore, not only focused on reducing food waste from the residential and commercial sectors sent to landfill, but also, took into consideration other potential organic waste streams in the urban environment including:

- Food Waste (FW);
- Used Cooking Oil (UCO);
- Fats, Oils and Grease (FOG) from grease traps at commercial sites;
- Sewage;
- Trade Waste (TW); and
- Garden Organics (GO).

This holistic view of organic waste streams in the city enabled consideration of innovative solutions for local capture, treatment and use of organic materials to not only divert organic waste such as food waste from landfill but to also provide opportunities for various scales of treatment and reuse. Table 2.1 lists some of the potential management solutions, or "illustrative" options, considered in the PUP project. Figure 2.1 indicates the intensity of organics in the PUP and specific locations where the illustrative options could be implemented in the precinct.

Building on the PUP project, the aim of this study has been to specifically explore the feasibility of AD in a dense urban setting. Whilst AD is a common process in the wastewater sector, and has been trialled for food waste in various locations, such as Federation Square (Turner et al 2017; Victoria State Government 2016) and the Pixel Building (Sustainability Victoria, 2012) in Melbourne, AD located in the basement of an urban building is still an unexplored opportunity for managing organics waste in urban Sydney. Such localised collection and treatment provides an opportunity for the CoS to investigate new waste management solutions for the increasing challenges associated with bin space availability due to urban densification.

³ https://www.epa.nsw.gov.au/your-environment/waste/waste-levy (accessed 13/08/18)

https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/waste-less-recycle-more (accessed 25/05/18)

Table 2.1 – Illustrative organics waste options identified in the PUP study (Turner et al, 2017)

No	Focus	Waste	Scale	Collection>transport	Treatment
1	Low rise residential	Food waste	Neighbourhood	Kitchen caddies > door pick-up by bike with trolley	Localised: pre-processing (compost, decomposer, dehydrator or AD) Centralised: AD
2	Low rise residential & commercial cafes	Food waste	Neighbourhood	Kitchen caddies & small commercial bins > door pick-up by bike with trolley	Localised: pre-processing or AD Centralised: AD
3	Low & high rise MUDs & commercial	Food waste	Whole of precinct	One waste contractor for residential & commercial properties	Centralised: AD
4	High rise multi-unit dwellings (MUDs)	Food waste	Building	Kitchen caddies > chutes > basement	On-site: pre-processing or AD Centralised: AD
5	High rise MUDs	Food & pet waste	Building	Kitchen caddies & pet waste bags > chutes > basement	On-site: AD Localised: AD Centralised: AD
6	High rise MUDs (NEW)	Food waste	Precinct	In-sink-erator in kitchen > pipe to basement	On-site: AD Centralised: AD
7	High rise MUDs (NEW)	Food waste & sewage	Precinct	Kitchen bench food waste vacuum + vacuum toilet > vacuum to basement	On-site: AD
8	Commercial cafes	Food waste avoidance	Neighbourhood	Café > App > collection by end user	Food waste avoidance & redistribution
9	Commercial cafes	Food waste	Neighbourhood	Small commercial bins > door pick-up by bike with trolley	Localised: pre-processing or AD Centralised: AD
10	All commercial	Food waste	Whole of precinct	Policy: Zero food waste to landfill	Various methods
11	Commercial cafes	Food waste	Precinct	Café vacuum inlet > vacuum to basement	On-site: AD Localised: AD Centralised: AD
12	Commercial cafes/market (NEW) Fish Markets	Food waste	Precinct	Café vacuum inlet > vacuum to central location on-site	On-site: AD Localised: AD
13	Education centre	Food waste avoidance	Neighbourhood	Students with spare food/meal > App > students share meal	Food waste avoidance & redistribution/sharing
14	Education centres	Food waste	Neighbourhood	Cafes > commercial bins	On-site: decomposer/dehydrator
15	Education & large government organisations	Food waste	Neighbourhood	One waste contractor for multiple sites	Centralised: AD
16	Council Parks	Pet waste	Council parks	Owners use bags > deposit in park collection point	Localised: AD

Figure 2.1 – Mapping of the organics waste and illustrative options developed as part of the PUP study (Turner et al, 2017)

Total surveyed organic flows at mesh block scale [kg]

Option 3 - Mixed Use 700000 Option 16 - Institutional Single waste contractor for low-rise household & commercial food waste Parks animal waste collection for on-site AD (Central Park also) Option 4 - Residential MUDs Household food waste for onsite 600000 treatment or tank to off-site AD Option 5 - Residential MUDs Food waste + animal waste for onsite AD or tank to off-site AD Option 1 - Residential Low Rise 500000 Food waste bike collection Option 6 - Residential MUDs (New build) Insinkerator & tank to offsite AD Option 2 - Mixed use Residential & commercial food Option 7 - Residential MUDs 400000 waste bike collection (New build) Vacuum food & sewage waste to on-site AD Option 12 - Commercial Sydney Fish Markets (new build) vacuum & on-site AD 300000 Option 8 - Commercial Cafes food waste avoidance App 200000 Option 10 - Commercial Zero food waste to landfill policy Option 13 – Institutional Option 14 – Institutional 100000 UTS student housing food share App UTS+TAFE shared dehydrator Option 15 – Institutional Option 9 - Commercial 500m UTS + TAFE + ABC joint tender Cafes food waste bike collection for waste contractor Option 5 - Residential MUDs Option 11 – Commercial Central Park food waste & animal Central Park vacuum to on-site AD waste for onsite AD (Pyrmont also)

3 OVERVIEW OF CENTRAL PARK

This section provides a brief overview of the Central Park precinct development, the context for this study. This includes, the layout of the site, the specific area being investigated and current waste management arrangements.

3.1 The Central Park precinct

The Central Park precinct is built on the former Carlton United Brewery (CUB) site next to Central Station on the southern edge of Sydney's CBD and directly adjacent to Ultimo, currently the densest urban area in Australia, with some 15,100 people/km² (ABS 2016). Refer to Figure 3.1.

Figure 3.1 – Central Park precinct development (Frasers Property Australia & Sekisui House)





The A\$ 2 billion, 5.8 hectare, 5 star Green Star development, when finished in 2018, will have 11 buildings, 33 heritage items, a 6,400 m² public park and 1,200 m² of green walls consisting of 35,000 plants from 350 different species. The 255,500 m² gross floor area covers residential (58%), commercial (30%) and retail (12%) with approximately 5,300 residents and 1,750 workers (White et al 2018). Figure 3.2 shows the extent of the precinct.



⁵ https://apac.bgis.com/au/about-us.htm (accessed 22/05/2018)

Figure 3.2 – Site map of the Central Park precinct development



3.2 One Central Park

One Central Park, on the western edge of the development, with its distinctive East and West towers draped in green vegetation, is the focal point of this feasibility study.

One Central Park has over 600 apartments, managed by BGIS⁵, a subsidiary of Brookfield, on behalf of the original developers Frasers and Sekisui House. There are currently over 50 active retail spaces with over half allocated as food establishments ranging in size from a large supermarket (Woolworths) on the lower ground floor to smaller food outlets and restaurants spanning several levels of the retail area and food court. The new Palace Cinema on Level 3, with food supplied from within One Central Park, opened in late 2017. The retail space and general food outlets are managed by the retail manager JLL.

Within the basement of One Central Park resides a A\$ 13 million, 1 ML/day capacity water recycling plant, currently the largest in the basement of a residential building in the world (White et al, 2018). Flow Systems, the private utility managing the plant, part owned by Brookfield, provide water, wastewater and water recycling services across the entire Central Park precinct development. Enwave also owned by Brookfield, provide the energy services through the on-site A\$ 80 million tri-generation central energy plant located in the basement beneath the old brewery yard adjacent to One

Central Park. The highly efficient plant provides both electricity as well as hot water and chilled water for cooling to the residential flats and commercial/retail buildings adjacent including the large refrigeration units within the supermarket (White et al 2018).

Refer to Appendix A for site plans and typical cross sections of One Central Park.

3.3 Current waste management at One Central Park

The multiple waste streams, from both residential and commercial sites at One Central Park are managed by a range of different organisations.

3.3.1 Residential

The waste for the 623 apartments at One Central Park is managed by BGIS/Brookfield. Bin rooms are located on each floor for depositing recyclables and providing access to the municipal solid waste (MSW) chutes. The bin rooms are managed by a cleaning contractor on behalf of BGIS/Brookfield. All residential waste goes to the two main east and west bin rooms on level B1. The Sky penthouse residents have an additional separate main collection bin room.

Food waste is not currently separated or collected from the residential apartments and is, therefore, currently disposed of as MSW which is collected and transported off-site by the contractor, URM, three days a week as part of the Council of the CoS obligations. This material is transported to the SUEZ Transfer Station at Artarmon and then to the Alternative Waste Treatment facility and landfill site at Kemps Creek or Eastern Creek, some 50 km west of Central Park.

Recyclables are currently collected by URM once a week.

3.3.2 Commercial/retail

The waste from the main retail space and food outlets is managed by a cleaning contractor through a contract with the retail manager JLL. Two bin rooms are located on Level B1. There is currently no official food waste separation for the retail food outlets except for a trial instigated as part of this feasibility study (refer to Section 4.2.2 for details) to assist with more accurate data collection. The waste contract for the commercial/retail solid waste and recyclables is currently with Cleanaway. The commercial/retail solid waste is removed daily and typically taken to the SUEZ Transfer Station at Artamon (pers com Cleanaway representative) and then on to Lucas Heights for final disposal, some 35 km to the south of Central Park.

The retail space includes Woolworths supermarket which manages its own waste streams in a separate waste collection area on Level B1. Food waste is currently separated from commercial/retail solid waste and recyclables. Woolworths also has an arrangement with Oz Harvest to collect and distribute edible food waste as part of its commitment to eliminate food waste sent to landfill by 2020⁶. Unavoidable food waste is currently collected by Cleanaway three days a week and transported off-site to EarthPower, 25 km west of Central Park, where it is treated via large scale AD to generate green renewable energy and nutrient rich digestate which is used as a fertilizer by the agricultural and horticultural sectors⁷. Woolworths' commercial/retail solid waste is collected by Cleanaway and transported to the Veolia Banksmeadow Transfer Station and then onto the Woodlawn facility, near Goulburn, by train, 200 km to the south of Central Park. Recyclables are also collected by Cleanaway.

3.3.3 Used cooking oil (UCO)

UCO is transported by individual retail outlets to Level B1 where it is stored in a holding tank ready for collection and the individual oil tins crushed on-site. UCO is collected each month by Scanline, a NSW EPA approved and licensed UCO manager. It is taken to their NSW Riverstone Depot, over 55 km north west of Central Park, where depending on the quality of the material, it is processed and recycled for biodiesel, stockfeed and/or pet products⁸ on-site or at other appropriate treatment facilities. Waste by-products generated as part of the treatment processes are used for agricultural soil injection where appropriate (pers com Scanline representative).

3.3.4 Fats, oils and grease (FOG)

There are three 15,000 L and one 5,000 L grease traps for One Central Park. The grease traps are emptied approximately every two months by Cleanaway and treated off-site at the Cleanaway Treatment Plant at Padstow, over 20 km to the south west of Central Park, where the grease waste is dewatered and the concentrated grease sent to the agricultural sector for soil injection, and the water component discharged to sewer for further treatment before discharge (pers com JLL representative).

3.3.5 Wastewater and trade waste

In the basement of One Central Park, the 1 ML/day capacity wastewater recycling plant, managed by the private utility Flow Systems (part owned by Brookfield), treats both residential and commercial/retail wastewater flows.

For the residential component, the plant treats standard end uses (i.e. toilets, showers, washing machines and bathroom and kitchen sinks). The plant treats the wastewater, returning high quality recycled water for toilet flushing and cold water washing machine use (White et al 2018).

⁶https://www.woolworthsgroup.com.au/page/media/Latest News/Woolworths to send zero food wast e to landfill with OzHarvest partnership (accessed 13/08/18)

⁷ https://earthpower.com.au/the-technology/ (accessed 07/05/18)

⁸ http://www.aeoscanline.com.au (accessed 11/03/18)

For the commercial/retail customers, the plant treats the wastewater from the toilets and bathroom and kitchen sinks etc. The treated recycled water is used for flushing toilets, cooling towers and irrigation of the precinct parks and green walls (White et al 2018).

A by-product of the wastewater recycling plant process is the generation of sewage sludge. This is discharged by Flow Systems to the existing sewer system managed by SWC through a trade waste agreement. The volume of sludge currently produced will increase as the plant treats recycled water for the entire Central Park development when completed at the end of 2018. On completion, recycled water will be exported to UTS and used for toilet flushing and the cooling towers in a new campus building currently being constructed (White et al 2018). During the interim period excess sewage, together with the sludge from the water recycling plant, is discharged to sewer for treatment by SWC.

3.3.6 Garden organics (GO)

The green walls and planters installed at the Central Park precinct development, including One Central Park, produce significant volumes of GO. All GO produced onsite is maintained by JungleFy⁹¹⁰ through a management contract with Brookfield (who facilitate the contract on behalf of Central Park Strata, Parklane 1, 3, 5, 8 and The Mark Strata and JLL). The public park situated at the centre of the Central Park precinct development has been handed back to the CoS and is managed by a maintenance contractor (pers coms JungleFy representative). Waste from maintenance of the 1,200 m² vertical green walls and One Central Park planter boxes is collected fortnightly by the CoS contractor, URM, and transported to a designated composting facility managed by Veolia at Kemps Creek, 50 km west of Central Park, and processed for compost.

3.3.7 Pet waste

Residents at Central Park are permitted to have pets (i.e. up to two cats or two dogs or a combination with a combined weight of up to 20 kg). Pets must be registered with BGIS/Brookfield under the strata management agreement. There are currently 47 registered pets at One Central Park (pers com BGIS representative).

The waste from domestic animals is not collected separately and is therefore assumed to be within the MSW in residential bins and general waste bins situated in the public park at the centre of the Central Park precinct development. This material currently goes to MSW through the residential and park waste streams respectively. Some animal waste may be disposed of by residents in apartment toilets. This requires further investigation.

3.3.8 Summary

In summary, this project has identified the current waste management arrangements for multiple waste streams in both the residential and commercial/retail sectors. Figure 3.3 (a) and (b) summarise the organisations currently managing these various waste streams.

Figure 3.3 – Organisations currently managing waste streams at One Central Park

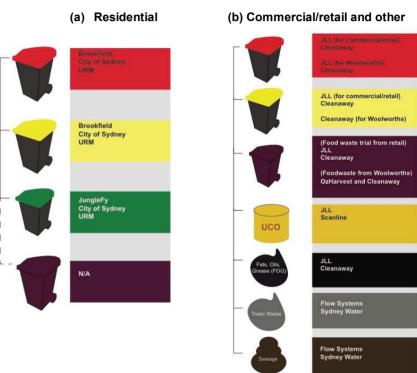


Figure 3.4 provides a visual summary of the organic waste streams from One Central Park and their current destinations for treatment and or disposal, highlighting the highly fragmented treatment/disposal arrangements and significant transport distances covered, in some cases on a daily basis.

⁹ https://junglefy.com.au (accessed 11/03/18)

¹⁰ https://www.dailytelegraph.com.au/news/peregrine-falcons-frogs-and-bees-move-into-sydneys-central-park-in-unprecedented-natural-growth/news-story/268cbde1fde18b4ce4b4d69d2322b113 (accessed 11/03/18)

Figure 3.4 - Indication of waste stream routes and destination points for treatment/disposal



4 ORGANIC WASTE STREAMS

This section analyses the volumes/weights of organic waste streams generated at One Central Park to assess the potential of an on-site AD plant and the associated sizing, costing and potential energy and digestate production.

Volumes/weights of food waste and other organic waste streams are rarely collected and considered in a holistic way. When data is collected, for example for food waste, this is typically conducted using a visual assessment (i.e. Bin Trim audits for the C&I sector¹¹). For this study, where actual volumes/weights of organic waste streams onsite are known, this data has been used to assist in the calculations. Where unknown, the best available data and assumptions have been used.

4.1 Overview of organic waste streams at One Central Park

To assist in assessing the potential of an AD system on-site at One Central Park individual streams of organic waste have been calculated. These streams are illustrated in Figure 4.1, inclusive of garden organics (GO), food waste (FW) (residential & commercial/retail), used cooking oil (UCO), fats oils and grease (FOG), trade waste and sewage.

Table 4.1 provides an indication of the volumes of waste streams collected/discharged from One Central Park in 2017 based in litres/annum (L/annum), excluding recyclables but including MSW and commercial solid waste in which a proportion of organic waste will be contained. These volumes are converted to weights using appropriate conversion factors in subsequent sections of the report. Table 4.1 provides a snap shot and comparative scale of various waste streams. Figures 4.2 and 4.3 provide a graphic representation of these volumes. Figure 4.3 has been represented without the significant volumes of sewage and sludge discharged via sewer, to enable comparison of the other smaller streams of waste.

Figure 4.1 – Organic waste streams managed, treated/removed at One Central Park



¹¹ https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/business-government-recycling/bintrim (accessed 25/05/18)

Table 4.1 – Overview of volumes of waste streams collected/discharged from One Central Park in 2017

Waste stream	2017 L/annum	Comments
Residential		
Municipal Solid Waste (MSW)	3,350,880	Approx. estimate of total volume of 240 L & 660 L red bins collected in 2017 (i.e. volume of actual waste will be less)
Commercial/ retail		
Food Waste (FW)		Retail food waste contained within red bin commercial solid waste figure below (except for recent trial commencing in mid December 2017).
Commercial Solid Waste	4,105,860	Approx. estimate of total volume of 660 L red bins collected over 2017 (i.e. volume of actual waste will be less)*
Woolworths Supermarket		
Food Waste (Oz Harvest)		Data not provided
Unavoidable Food Waste (EarthPower)	193,740	Approx. estimate of total volume of 240 L and 660 L bins removed in 2017 (i.e. volume of actual food waste will be less)
Commercial Solid Waste	882,400	Approx. estimate of total volume of 1,100 L and 240 L (organics contaminated) bins removed in 2017 (i.e. volume of actual waste will be less)
Used Cooking Oil (UCO)	12,000	Approx. 1,000 L of UCO collected every month (actual volumes per month recorded)
Fats Oils & Grease (FOG)	300,000	Approx. 3 x 15,000 L and 1 x 5,000 L of FOG collected from the grease trap tanks every 2 months. Figure includes total volume removed (i.e. concentrated FOG, water and food waste detritus caught in the system)
Wastewater System		
Wastewater (discharged/ diverted)	62,050,000	Currently approx. 75% of wastewater is treated through the on-site water recycling plant (i.e. 500 kL/day treated & & 170 kL/day discharged/diverted). Excess wastewater discharged to sewer will decrease in future when the plant is fully operational & treating greater levels of wastewater for recycled water end uses at the completed Central Park development & new UTS building opposite.
Trade Waste (sludge discharged)	4,380,000	Approx. estimate of 12 kL/day of sludge is discharged to the sewer. This volume is likely to increase in future when the plant is fully operational.
Garden Organics (GO)	332,800	Approx. estimate of 35 x 240 L & 4 x 1,100 L bins collected every 2 weeks (i.e. volume of actual waste will be less)

Figure 4.2 – Estimated volumes of waste streams containing organics (L/annum) for 2017

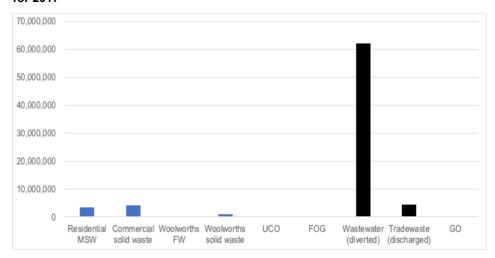
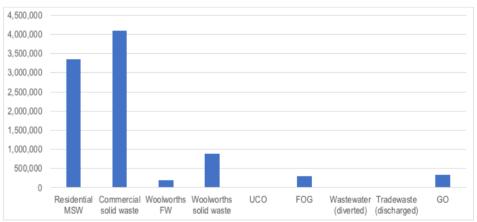


Figure 4.3 – Estimated volumes of waste streams containing organics (L/annum) for 2017 excluding wastewater and sludge discharged via sewer



As shown in Table 4.1 and represented in Figure 4.2, a large proportion of the wastewater collected from the Central Park development is currently diverted before it is treated by the on-site water recycling plant. This wastewater passes straight to sewer. This large volume of wastewater has not been included in the investigations, as it is anticipated that most of this stream of organic waste will eventually be treated by the Central Park water recycling plant when the new adjacent UTS building is completed and additional recycled water is exported to UTS in 2019 (refer to Section 4.2.2 for details).

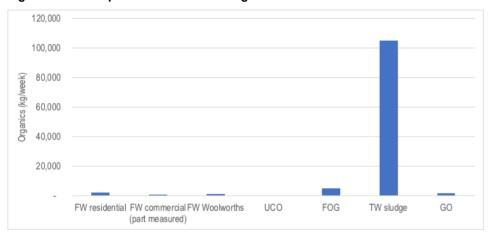
4.2 Data on organic waste streams

4.2.1 Full potential scenario

To determine the feasibility of on-site AD at One Central Park, the volume and availability of each organic waste stream has been calculated (excluding the excess diverted wastewater passing straight to sewer).

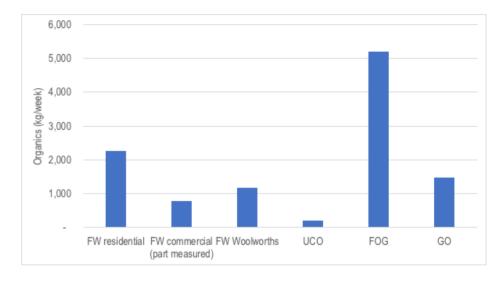
Figure 4.4 provides an overview of the range of organics waste streams generated in kg/week. The "full potential" scenario assumes that all organics waste generated onsite could potentially be used for an AD plant not withstanding existing contracts, collection logistics (i.e. how much food waste/organic waste can realistically be obtained from the residential sector) or combined treatment feasibility (i.e. compatibility of various waste streams in an on-site AD plant).

Figure 4.4 – "Full potential" scenario in kg/week



As identified, trade waste sludge generated from the water recycling plant dominates the data. Figure 4.5 therefore provides an overview of the full potential scenario, excluding trade waste from the graph to assist in providing insight into the availability and proportion of the other smaller organic waste streams.

Figure 4.5 – Organic waste streams under full potential scenario in kg/week (excluding trade waste)



4.2.2 Data and assumptions

The volumes/weights of each organic waste stream collated for this study use a combination of measured and assumed data. Details are provided below. For more detailed assumptions and calculations, refer to Appendix B.

Residential food waste

Actual volumes/weights of food waste from the 623 apartments within One Central Park is not available as this waste stream is currently combined with general MSW. Therefore, an estimate has been made as to the assumed weight of food waste in the MSW bins.

Based on assumptions (refer to Appendix B), residential food waste in the CoS area is 113 kg/person/annum. Therefore, the total volume of food waste for the estimated population of 1,045 residents at One Central Park is assumed to be 118 t/annum (2,270 kg/week).

Commercial/retail food waste

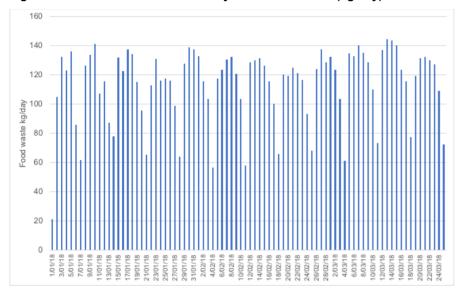
There are approximately 50 retail outlets at One Central Park with currently approximately 25 generating food waste.

The food waste component of the data collected has been separated into:

- Food waste commercial
- Food waste Woolworths

A Bin Trim assessment of the retail outlets at One Central Park (excluding Woolworths supermarket) was conducted in 2015 (Cleanaway 2015). This included a visual inspection of food waste within the commercial solid waste bins assessed. Due to the significant volumes of food waste identified in the Bin Trim assessment, estimated at over 281,000 kg/annum (770 kg/day) during the Bin Trim assessment period, a food waste measurement trial was set up as part of this feasibility study to help validate the Bin Trim data. Figure 4.6 provides daily weights of the food waste collected from the participating retail outlets (excluding Woolworths) during the food waste trial.

Figure 4.6 – Food waste trial total daily measured results (kg/day)



Twenty two of the 27 retail food outlets operational at One Central Park participated in the trial, which commenced in mid-December 2017. One additional retail outlet was vacated part way through the food waste assessment trial. Food waste from Woolworths supermarket was excluded from the trial as it is collected separately (see Section 3.3.2). The five retail outlets that did not participate in the trial have the potential to contribute significant volumes of food waste but have not been documented. Therefore, the weights collected in the trial are an underestimate of the potential food waste collected from the retail outlets at One Central Park. The average weight of organic waste collected during the trial from the stable period at the beginning of January to 25th March 2018 was on average, approximately 115 kg/day. Based on the average volumes documented, it is assumed that there is the potential to collect approximately 42 t/annum (802 kg/week).

With UTS campus located directly opposite One Central Park, it is expected that University terms and holiday periods will influence the volume of food waste collected over the period assessed. In March, when the autumn semester commenced, there was approximately a 10% increase in food waste collected compared to the January and February period.

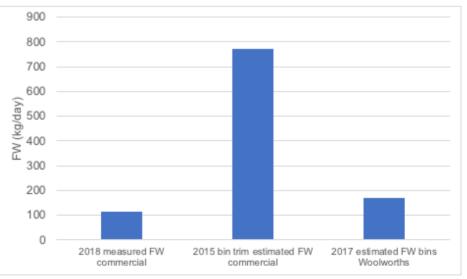
A common weekly pattern can be observed in the food waste collected with the least amount of food waste generated on Sundays.

The trial only measured the weight of pre-plated food waste occurring in the preparation of food generated within the kitchens of each of the retail outlets studied. This stream of food waste was identified as relatively uncontaminated compared to post-plated food waste which is commonly associated with higher contamination rates.

Figure 4.7 provides a comparison of the 2018 measured retail food waste (FW commercial), 2015 Bin Trim estimates and estimates of food waste from the Woolworths supermarket (FW Woolworths). As identified, the Bin Trim data is high compared to the food waste measured from the retail food waste trial. This is likely to mean a combination of:

- an over-estimation of food waste in the Bin Trim visual assessment:
- an over-estimation of the weights of food waste calculated in the Bin Trim assessment;
- the Bin Trim assessment may have been successful in behaviour change by the retailers involved thereby assisting in reducing retail food waste after the 2015 Bin Trim assessment;
- a significant portion of food waste is in the general waste bins.

Figure 4.7 – Measured versus Bin Trim assessed food waste together with Woolworths estimated food waste (kg/day)



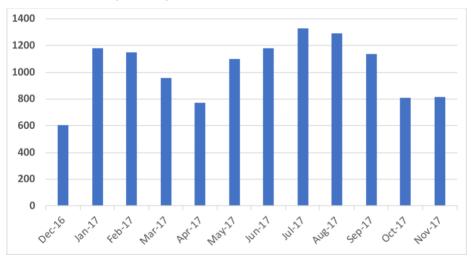
As of mid 2018 JLL, the retail manager of the commercial/retail space at Once Central Park, is also considering how it might expand the trial to capture additional commercial/retail food waste (i.e. collection of additional post-plated food waste in the food court).

As discussed previously, the food waste generated by Woolworths supermarket is collected separately but not measured. From 2017 records, the total number of bins of unavoidable food waste from Woolworths (in L) has been factored at 75% of bins (i.e. the food waste bins will not be full) and multiplied by a standard food waste density conversion factor (refer to Appendix B). The estimated 2017 weight of Woolworths food waste collected and taken to EarthPower is approximately 62 t/annum (1,188 kg/week). This excludes food waste recovered through donation to Oz Harvest for which data is not currently available.

Used cooking oil (UCO)

UCO, collected by Scanline, was measured to be approximately 11 t/annum (213 kg/week) in 2017. Figure 4.8 provides a monthly profile of oil collected, predominantly over 2017, showing the seasonal profile and maximum collection during the winter months.

Figure 4.8 – UCO collected from December 2016 to November 2017 showing seasonal variation (L/month)



Fats, oils and grease (FOG)

At One Central Park there are three 15,000 L and one 5,000 L grease traps. The total volume of FOG removed by Cleanaway per year (on a regular two monthly cycle) is approx. 270 t/annum (5,192 kg/week). This is a significant quantity of FOG. However, due to the potential over sizing of the grease traps the proportion of fats, oils and grease assumed to be within the materials collected (i.e. concentrated FOG, water and food waste detritus) has been factored down for this study. That is, the proportion of water is assumed to be higher than typical estimates in order not to overestimate the possible biogas potential.

Wastewater

Approximately 25% of the total wastewater generated on-site is not treated by the on-site water recycling plant at Central Park but rather discharged to the sewer. While this excess wastewater is not accurately measured, it equates to approximately 62,050 t/annum (1,190,000 kg/week).

The Central Park precinct development will be completed by the end of 2018. The water recycling plant will then provide recycled water up to 1 ML/day to the precinct. By the end of 2019 the new campus building at UTS opposite Central Park will be complete with recycled water exported to the UTS building for end uses such as toilet flushing and use in cooling towers.

As the wastewater discharge is likely to be reduced when these remaining developments are connected, the diverted wastewater stream has been excluded from the feasibility study at this stage. It should be noted, however, that as the capacity of the recycled water plant increases from current levels, the sludge generated will also increase (see further details below).

Trade waste (TW)

As identified in Figure 4.4, the volume of trade waste generated on-site is significant. Trade waste is currently discharged to sewer under a trade waste agreement with SWC. The sludge discharged is not measured, however, estimates by Flow Systems indicates that approximately 12 kL/day of sludge is discharged to sewer. This equates to approximately 4,380 t/annum (84,000 kg/week). At full potential (i.e. when the plant is fully operational), this volume is likely to increase. The 12 kL/day sludge estimate is based on the water recycling plant running at approximately half capacity (0.5 ML/day). Estimated capacity in the near future (i.e. by 2019) will be approximately 0.7 ML/day when the Central Park precinct development and UTS building are on-line (i.e. still not the full 1 ML/day capacity of the recycling plant). This will equate to approximately 15 kL/day of associated sludge (pers com Flow Systems representative). Therefore, it has been assumed that the trade waste sludge discharged to sewer by the end of 2019 will be approximately 5,475 t/annum (105,000 kg/week).

Garden organics (GO)

GO from planter boxes and trimmings from vertical walls at One Central Park is not measured. The volume of the green GO bins removed on a fortnightly cycle by URM has, therefore, been used to establish a GO estimate for this study. Approximately 77 t/annum (1,478 kg/week) of GO was removed in 2017 using a standard GO density conversion factor (refer to Appendix B).

The relatively large volume/weight of GO produced at One Central Park is in part due to the characteristics of the site. Therefore, this waste stream has been excluded from the final analysis of feasibility of AD at Central Park. This is, in part, due to the exceptional characteristics of the site compared to other similar precincts, which do not include green walls and a precinct public park, but also as GO is less effective in AD due to the cellulose and lignin characteristics of the waste stream. Such waste lends itself more to traditional composting approaches.

Pet waste

There are approximately 47 registered cats and dogs at One Central Park (pers com Strata Manager, BGIS). The public gardens surrounding the Central Park precinct development are a popular inner-city space for dog owners to walk their dogs and, therefore, there are likely to be many additional dogs visiting the site on a daily basis in addition to the 47 registered animals living on-site.

While animal waste has not been measured, a rough estimate of the registered animals alone would indicate that approximately 4.3 t/annum (82 kg/week) of animal waste is produced. Whilst significant in terms of weight, this waste stream has not been included in the analysis as further research is required (i.e. determining the numbers of dogs frequenting the public park at Central Park) and because it is a relatively small waste stream compared to the other organic waste streams on-site.

This kind of waste stream lends itself to particular strategies such as educational AD plants located in parks/dog parks where the energy from the waste has the potential to be used in a specialised AD plant with for example an attached street lamp to provide education on biogas and energy generation from organic waste. Such examples can be found in the UK, Canada and the US (Turner et al 2017). This is a recommended strategy to be explored.

5 POTENTIAL OPTIONS

As identified in the previous section, there is currently limited food waste separation occurring at One Central Park, yet there are potentially significant volumes that could be captured from both the residential and commercial/retail areas. There are also significant volumes of other organics waste streams currently managed by a range of contractors through various management arrangements that if combined with available food waste could provide the opportunity to be a feedstock for an on-site AD system at Central Park. Such opportunities are amplified due to the specific characteristics of the site, including sludge produced from the on-site water recycling plant. This study, to determine the feasibility of AD at One Central Park, is not generalisable but potential options have been chosen to assist in making the research relevant to both Central Park in terms of a retrofit and other precinct scale sites in dense urban settings (both retrofit and new developments). Potential opportunities are discussed below in terms of socio-technical, renewable energy and digestate reuse options.

5.1 Socio-technical options

The options presented in this project take into consideration both technical and social dimensions associated with the feasibility of an AD system. The underlying premise of 'socio-technical thinking' is that the design of a system should take into account both the social "and" technical factors that influence the functionality and use of that system.

Appendix C provides a brief description of AD technology and provides reference to both social and technical options for implementing a functional AD system. For example, this includes the collection and transport of the food waste streams reliant on either kitchen caddies (a socially dependent option to transport food waste) or dry or wet vacuum systems (a technically dependent option to transport food waste). A brief description of these transport systems is also provided in Appendix C.

The suite of socio-technical options analysed for this study are summarised in Table 5.1.

None of the options include GO or excess wastewater (as discussed in Section 4). GO is excluded due to the currently atypical context of green walls at One Central Park and because such materials are less compatible with smaller scale AD (as discussed in Section 4). The excess wastewater has also been excluded due to the scale of wastewater produced on-site and its high water content. (Further discussion on wastewater opportunities are available in Section 7).

Table 5.1 also summarises estimated volumes, sizing and digestate production for each of the Options considered. As can be seen the size of the AD plant varies depending on the substrates used as feedstock. For example, halving or removing

trade waste sludge (Options 5 and 6 respectively) as a feedstock significantly reduces the size of the AD plant required. In comparison, the proportion of residential food waste included as feedstock makes relatively little difference to the sizing of the system. Decisions on which substrates to include is highly dependent on the costs, benefits and feasibility/logistics (as discussed in Sections 6 and 7).

It should be noted that Option 4 is assumed to use a wet vacuum system for food waste transport to the AD plant. It assumes the use of an 'in-sink-erator'¹². Such technology is normally linked to the sewer system, however, in this option it is assumed it links as a separate system directly to the AD plant. This, of course, would be highly expensive and logistically difficult to consider as a retrofit but should be considered for new buildings as discussed in Section 7.

The in-sink-erator requires 4 L of water to be flushed through the system for every kg of food waste. Therefore, the volumes for food waste in this option have been factored into the sizing of the AD system to allow for the additional water component. Tests conducted by Avac Australia (project collaborator) in 2018 determined that the in-sink-erator, as a kitchen top pumping mechanism connected to a wet vacuum system, needs approximately 3 L of water to pass 1 kg of food waste in approximately 60 seconds. Avac recommendations have been to allow 4 L/kg for conservative calculations (see Australian Food Load Test by Avac in Appendix D).

and require water to assist in the maceration and drainage process. The waste is normally discharged to the wastewater system but can be directed to a separate system for collection.

¹² In-sink-erators or kitchen waste disposal units are devices installed in the kitchen sink that are used to macerate food before discharge to a drainage system. Such systems are typically electrically powered

Table 5.1 – Summary of options

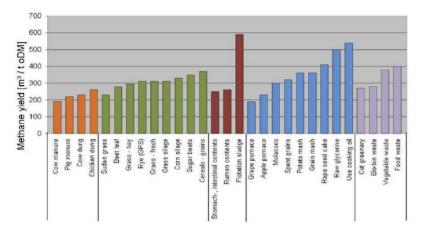
	Streams included in option	AD volume	AD size	Digestate	Comments
Options & waste streams		required (L)	dia. (m), height (m)	produced each day kg/day	
Option 1 (realistic)*		(=)		rigrady	
FW residential	15% of residential FW	56,000	D=3.8	1,000	Option 1 targets all viable waste streams at One
FW commercial (part measured)	Yes	30,000	H=5	1,000	Central Park and assumes a "realistic" volume of
FW Woolworths	Yes		11 0		food waste can potentially be collected from
UCO	Yes				residential apartments based on studies in Sydney
FOG	Yes				using caddy systems (i.e. Randwick and Leichhardt
TW sludge	Yes				Councils – refer to Appendix B).
Option 2 (best practice)*	103				,
FW residential	50% of residential FW	Similar to Option 1	Similar to Option 1	Similar to Option 1	Similar to Option 1 but assumes that 50% of food
FW commercial (part measured)	Yes	Cirrilar to Option 1	ommar to option i	Cirinar to Option 1	waste is recoverable from residential apartments
FW Woolworths	Yes				through 'best practice' with residents using caddy
UCO	Yes				systems as the transportation mechanism for food
FOG	Yes				waste. Based on study in Milan – refer to Appendix
TW sludge	Yes				B)
Option 3 (vacuum – dry)*	1.00				
FW residential	75% of residential FW	Similar to Option 1	Similar to Option 1	Similar to Option 1	Similar to Option 1 but assumes a higher volume of
FW commercial (part measured)	Yes	Cirrilar to Option 1	ommar to option i	Cirinar to Option 1	food waste recoverable from residential apartments
FW Woolworths	Yes				by using a dry vacuum system as a transport
UCO	Yes				mechanism for food waste.
FOG	Yes				
TW sludge	Yes				
Option 4 (vacuum – wet)*					
FW residential	75% of residential FW	Similar to Option 1	Similar to Option 1	Similar to Option 1	Similar to Option 1 but assumes a higher volume of
FW commercial (part measured)	Yes	•	•	'	food waste is recoverable from residential
FW Woolworths	Yes				apartments by using a wet vacuum system as the
UCO	Yes				transport mechanism for food waste.
FOG	Yes				
TW sludge	Yes				
Option 5					
FW residential	No	22,000	D=2.5	500	Option 5 excludes residential food waste as a feed
FW commercial (part measured)	Yes	,	H=4.5		stock due to the potential for high rates of
FW Woolworths	Yes				contamination at One Central Park. Option 5 also
UCO	Yes				assumes only 50% of trade waste sludge is used as
FOG	Ye				feedstock to test the potential of reducing AD plant
TW sludge	50%				size and associated costs.
Option 6					
FW residential	No	10,000	D=1.8	65	Option 6 excludes residential food waste and trade
FW commercial (part measured)	Yes	·	H=4		waste sludge and is more aligned to the
FW Woolworths	Yes				characteristics of precinct developments which may
UCO	Yes				not have residential apartments or a water recycling
FOG	Yes				plant onsite.
TW sludge	No				

^{*} with respect to residential waste with assumptions on percentages of food waste potentially collected and collection/transportation mechanism for food waste

5.2 Renewable energy options

The biogas and associated energy produced from substrates used as feedstock for AD can vary significantly. Figure 5.1 illustrates the significant variation of energy produced from various organic waste streams.

Figure 5.1 – Example of biogas produced from various waste substrates (Al Seadi et al, 2008)



To assess actual biogas potential of various substrates, laboratory testing should be undertaken. Laboratory testing is outside the scope of this feasibility study therefore, available literature and expert knowledge have been used to estimate possible biogas production and associated renewable energy potential.

Figure 5.2 provides an indication of the estimated annual renewable energy potential for each substrate for Option 1 together with the relative annual organics volume to produce that energy. The graph illustrates the significant differences between each substrate. For example, despite the trade waste sludge being such a large volume, the value of that substrate, in terms of energy potential, is less than the food waste produced by Woolworths supermarket.

Figure 5.2 - Organic waste and potential energy generation for Option 1

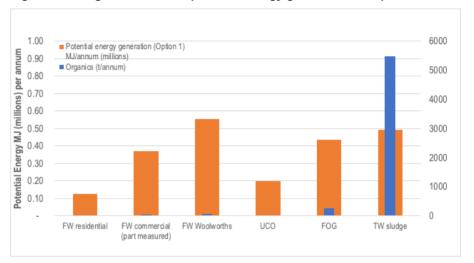


Figure 5.3 provides estimated renewable energy for each substrate for Option 4. This graph illustrates how by using a wet vacuum system for food waste the volume of organics increases due to the additional water content in the substrate. Assuming a vacuum system assists in attaining a higher waste capture rate for the residential apartments, this substrate increases from the lowest to highest potential energy contributor.

Figure 5.3 – Organics waste and potential energy generation for Option 4

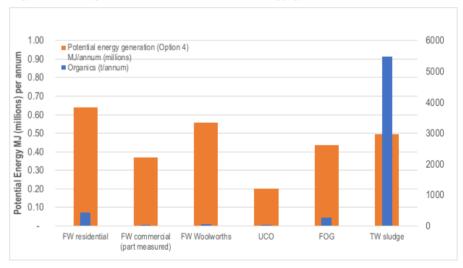


Table 5.2 summarises the estimated organics, biogas production and energy production for each substrate for each of the six options considered.

Table 5.2 - Summary of organics, biogas and energy generation for each option

	Organics kg/week	Organics (t/annum)	Biogas (m3/t)	Biogas (m3)	Potential energy generation MJ/annum (millions)
Option 1	Kg/week	(vaiiiuiii)	(IIIS/L)	(IIIO)	(millions)
FW residential	341	18	200	3.542	0.13
FW commercial (part measured)	786	41	250	10,249	0.37
FW Woolworths	1,188	62	250	15,439	0.56
UCO	213	11	500	5.545	0.20
FOG	5,192	270	45	12,150	0.44
TW sludge	105,000	5.475	3	13,688	0.49
1 VV Slouge	112,720	5,877	-	60,612	2.18
Option 2	112,120	0,011		00,012	2.10
FW residential	1,135	59	200	11,805	0.42
FW commercial (part measured)	786	41	250	10.249	0.37
FW Woolworths	1,188	62	250	15,439	0.56
UCO	213	11	500	5.545	0.30
FOG	5.192	270	45	12,150	0.20
TW sludge	105.000	5.475	3	13,688	0.49
1 vv sludge	113,515	5,918		68.875	2.48
Option 3	110,010	0,010		00,010	2.40
FW residential	1,703	89	200	17,708	0.64
FW commercial (part measured)	786	41	250	10,249	0.37
FW Woolworths	1.188	62	250	15,439	0.56
UCO	213	11	500	5,545	0.20
FOG	5.192	270	45	12,150	0.44
TW sludge	105,000	5,475	3	13,688	0.49
TWOODGO	114,082	5,947		74,778	2.69
Option 4	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	0,011	-		2.00
FW residential	8.513	443	40	17,708	0.64
FW commercial (part measured)	786	41	250	10,249	0.37
FW Woolworths	1,188	62	250	15,439	0.56
UCO	213	11	500	5.545	0.20
FOG	5,192	270	45	12,150	0.44
TW sludge	105,000	5,475	3	13,688	0.49
	120,893	6,302		74,778	2.69
Option 5	7/2-14	- i i			-
FW residential					
FW commercial (part measured)	786	41	250	10,249	0.37
FW Woolworths	1,188	62	250	15,439	0.56
UCO	213	11	500	5,545	0.20
FOG	5,192	270	45	12,150	0.44
TW sludge	52,500	2,738	3	6,844	0.25
Service Application of the Control o	59,879	3,121		50,226	1.81
Option 6	100 100				
FW residential					
FW commercial (part measured)	786	41	250	10,249	0.37
FW Woolworths	1,188	62	250	15,439	0.56
uco	213	11	500	5,545	0.20
FOG	5,192	270	45	12,150	0.44
TW sludge					
- Accessor and the	7,379	384		43,383	1.56

* Note: In Option 4, food waste, organics and biogas have been factored to take into account the extra volume of water required of a wet vacuum system (i.e. 4 L of water per kg of food waste).

Options 3 and 4 provide the highest energy potential with an estimated 2.70 million MJ/annum produced. Option 6 which excludes both the residential food waste and trade waste sludge provides the lowest energy potential with an estimated 1.6 million MJ/annum produced.

As the Central Park precinct has a central energy plant located on-site, there is the opportunity to use the energy generated from the AD plant to either contribute towards the needs for electricity or hot water for residential apartments on-site.

Table 5.3 presents the approximate energy potential of each option and how this energy might contribute to the supply of either electricity <u>or</u> hot water for the equivalent number of flats at One Central Park.

Table 5.3 – Equivalent number of flats that can be provided for by the potential AD energy produced

Option	Potential energy generation MJ/annum (millions)	Equivalent no. of flats (electricity)	% of flats (electricity)	Equivalent no. of flats (hot water)	% of flats (hot water)
1	2.18	96	15	249	40
2	2.48	109	18	282	45
3	2.69	118	19	307	49
4	2.69	118	19	307	49
5	1.81	80	13	206	33
6	1.56	69	11	178	29

Assumes each flat uses on average 2,400 kWh/annum for electricity and 8,778 MJ/annum for gas for hot water.

Options 3 and 4 have the potential to capture the largest volume of organic waste onsite which could provide sufficient electricity for approximately 20% of the flats or hot water for approximately 50% of flats at One Central Park per annum.

6 COSTS AND BENEFITS

To implement any new technology, assessment of the costs and benefits of that system, both quantifiable and non-quantifiable, compared to business as usual (BAU), is essential. This section aims to begin to assess the costs and benefits of the AD systems considered in order to inform decision-making on whether to further investigate AD at Central Park and if so what the preferred option/s might be. Due to difficulty in obtaining data, this has been challenging.

6.1 Business as usual costs

As identified throughout this report, the acquisition of data has been difficult. Therefore, establishing the BAU situation has only been conducted at a cursory level and requires more detailed assessment with the correct stakeholders involved.

The BAU considers current:

- Residential MSW bin rental and lift costs
- Commercial/retail solid waste bin rental and lift costs for both the retail area and Woolworths
- Food waste bin rental and removal costs for Woolworths and the new commercial/retail trial
- GO bin rental and lift costs
- UCO removal costs
- FOG removal costs
- Trade waste sludge discharge costs.

The BAU costs based on 2017 figures are summarised in Table 6.1 along with the assumptions for bin numbers, sizes, collection frequency etc. which have been drawn from multiple sources. The bin rental and lift rates are not specifically based on the Central Park contracts, but an average rate, drawn from several similar contracts. This is also the case for the FOG collection rate. The trade waste sludge fee, which is not based on a volumetric rate, is directly sourced from Flow Systems.

The cost of removing various waste streams from One Central Park in 2017 was around A\$ 380k. With the new commercial/retail food waste trial sending food waste to EarthPower, waste removal at One Central Park will be closer to A\$ 400k/annum going forward. These costs do not include the significant cost associated with the recycled water plant (except the sludge disposal component) nor the cost of discharging the excess sewage to sewer.

The sewage sludge disposal charges, in the case of Central Park, are low due to the special arrangements made with SWC due to the novelty of the water recycling system

when it was first implemented. This "grandfathering" arrangement is no longer available for new developments. Hence, for new developments with such a water recycling system, considering the use of AD for combined treatment of food waste/organics and sewage sludge, there are likely significant cost savings to be made in reducing discharge to sewer. Whilst these savings are not available to One Central Park they need to be determined in any assessment of cost and benefits for future developments.

Due to the shifting policy environment, the BAU is likely to change in the medium term. For example, as part of the Sustainable Development Goals (SDG), SDG 12 indicates a target of halving food waste by 2030 (UN undated). In Australia, the Federal Government has committed to halving food waste by 2030 (Commonwealth of Australia 2017) and many Councils, including the CoS (CoS 2017), are setting strategies and action plans towards zero waste to landfill by 2030. Hence, current BAU may only be possible in the short-term. Therefore, the BAU costs of waste management at One Central are likely to increase over time, especially if there is a move to set more stringent targets or even ban organics passing to landfill through regulation as in many other jurisdictions internationally (Turner et al 2017).

Table 6.1 - Summary of estimated BAU waste management costs

Item	Bin hire A\$	Collection/ treatment/ disposal A\$/pick-up	Bins/collection frequency	Estimate d cost for 2017 A\$
Residential				
- MSW (bin hire & collection/treatment/di	A\$ 1/ week/bin	A\$ 15/240L bin	20 x 240L bins 3 times/week	47,840
sposal)		A\$ 25/660L bin	18 x 660L bins 3 times/week	71,136
Commercial				
- FW (bin hire & collection/treatment/di	A\$ 1/ week/bin	A\$ 20/120L bin	1 x 120L bins 5 times/week	5,252
sposal)*	W0010 DIII	A\$ 27/240L bin	2 x 240L bins 5 times/week	14,144
- commercial solid	A\$ 1/	A\$ 25/660L bin	6.221 total in 2017	156,253
waste (bin hire & collection/treatment/ disposal)	week/bin		-,··	,
Woolworths				
- FW (bin hire &	A\$ 1/	A\$ 27/240L bin	40 x 240L bins	1,184
collection/treatment/di	week/bin	A # 00/0001 1:	total in 2017	40.704
sposal)		A\$ 60/660L bin	277 x 660L bins total in 2017	16,724
- commercial solid waste (bin hire & collection/treatment/ disposal)	A\$ 1/ week/bin	A\$ 40/1,100L bin	818 x 1,100L bins total in 2017	32,928
GO	A\$1 / week/bin	A\$ 10/240L bin	36 x 240L bins fortnightly	11,232
		A\$ 25/1,100L bin	4 x 1,100L bins fortnightly	2,808
uco		Zero cost as collected for free		0
FOG		0.10 c/L	300,000L total collected in 2017	30,000
Sludge		Trade waste sludge fee A\$ 9,000 per year	5,475,000 L/a by end 2018	9,000
Total				379,105

^{*} The retail/commercial food waste trial became operational in mid-December 2017. It has not been included in the 2017 costs but will be a BAU cost from 2018.

6.2 Option costs

Six organic waste management options involving AD and transportation systems (i.e. caddies or wet or dry vacuum for food waste and pipe networks for other organics) have been considered in this feasibility study.

Option costs include:

- Estimated costs for transport mechanisms (i.e. caddies or wet or dry vacuum systems).
- Estimated cost of the AD system and associated pre-treatment (i.e. metal and plastics screening), electronics, basic odour control, AD vessel and posttreatment.
- Estimated additional costs such as linkage to the central energy plant for beneficial reuse of the biogas produced.

The costs do not include the additional costs of managing an on-site system in terms of both the cleaners on-site who will be required to assist in organics waste collection each day or the running and maintenance of the AD (or vacuum system). These will need to be assessed at the detailed feasibility/design stage.

The estimated up-front/capital costs of the retrofit systems are summarised in Table 6.2. Note with both Woolworths and the commercial/retail areas already separating food waste through kitchen caddies and bins, no additional costs have been considered.

Table 6.2 - Summary of estimated up front/capital costs

	Estimated up front/capital costs (A\$)							
Item	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6		
Residential - collection/trans port								
- campaign	40,000	40,000	40,000	40,000				
- caddies	10,000	10,000						
- wet vac				1,200,000				
- dry vac			13,000,000					
Commercial & Woolworths - collection/trans port								
- caddies/bins								
- wet vac								
- dry vac								
AD Treatment								
- input pipework/conn ections	25,000	25,000	25,000	25,000	25,000	10,000		
- pre-treatment	100,000	100,000	100,000	100,000	100,000	100,000		
- AD unit	450,000	450,000	450,000	450,000	350,000	300,000		
- post- treatment	35,000	35,000	35,000	35,000	35,000	35,000		
- output pipework (gas)	50,000	50,000	50,000	50,000	50,000	50,000		
Total	710,000	710,000	13,700,000	1,900,000	560,000	495,000		

As can be seen the costs of the options vary significantly with the residential dry vacuum system (Option 3) being an extremely high cost compared to the other options with little or no additional assumed increase in organics capture compared to Options 1, 2, and 4. However, benefits could be potentially accrued to other waste management systems (i.e. recycling). If vacuum systems were retrofitted as a combination system (i.e. residential and commercial/retail) or in a new build development significant savings could be made. Refer to Table 6.3 for comparisons.

Table 6.3 – Estimated cost comparisons between wet and dry vacuum systems and retrofits versus new developments (Avac)

	Type of Use	Vacuum system (wet) cost estimate (A\$)	Vacuum system (dry) cost estimate (A\$)
One Central Park (retrofit)	Residential	1,210,000	13,000,000
One Central Park (retrofit)	Commercial	700,000	3,000,000
One Central Park (retrofit)	Residential & commercial	1,600,000	14,000,000
New development (623 apartments)	Residential	1,000,000	12,000,000
New development (similar retail space to One Central Park)	Commercial	450,000	2,500,000
New development (623 apartments & similar retail space to One Central Park)	Residential & commercial	1,200,000	13,000,000

If a wet vacuum system combined food waste collection with sewage collection in a new development (not considered here), further significant waste transportation and treatment savings could be harnessed. Refer to Section 7 for further discussion.

In Table 6.2. the AD system costs do not vary significantly across the options despite the size differences between Options 1 to 4 and Options 5 and 6 which are much smaller. A large component of the cost of the system is for pre-treatment, that is, plastics and metal contamination removal to protect the AD plant. The addition of this technology is primarily due to experience relating to the AD plant at Federation Square in Melbourne, which was decommissioned after three years due to unresolved contamination issues (pers com Active Research representative) causing ongoing maintenance issue to the AD plant.

6.3 Benefits

The benefits of the six organics management options considered will be both quantifiable and non-quantifiable. These have been assessed at a cursory level to aid decision making (refer to Table 6.4). Option benefits, which accrue to various stakeholders include:

- Avoided waste disposal costs
- Avoided trade waste disposal costs
- Energy generation for on-site electricity or hot water use to offset residential energy costs or alternatively operational energy costs of the water recycling plant
- · Capture and recycling of nutrients
- Reduced greenhouse gas emissions

Table 6.4 – Estimated annual avoided costs and benefits of the options considered

	Estimated annual benefits (A\$)					
Item	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Avoided waste and trade waste disposal costs						
Residential - collection/transport	3,480	11,640	17,440	17,440	N/A	N/A
Commercial & Woolworths - collection/transport						
- retail/commercial	19,396	19,396	19,396	19,396	19,396	19,396
- Woolworths	17,908	17,908	17,908	17,908	17,908	17,908
GO	N/A	N/A	N/A	N/A	N/A	N/A
UCO	0	0	0	0	0	0
FOG	30,000	30,000	30,000	30,000	30,000	30,000
TW sludge*	0	0	0	0	0	N/A
Sub total	70,784	78,944	84,744	84,744	67,304	67,304
Avoided apartment hot water costs	65,461	74,385	80,760	80,760	54,244	46,853
(OR)						
Avoided apartment electricity costs	64,489	73,281	79,561	79,561	53,439	46,158
Other non-quantifiable benefits						
Capture & recycling of nutrients	ſ	ſ	ſ	Λ	ſ	ſ
Greenhouse gas emissions from vehicle movements	1	1	↓	Ų	1	↓
Greenhouse gas emissions from landfill	↓	↓	ħ	↓	↓	ħ

^{*} Assumes TW discharge to sewer is still required for other wastes from the water recycling plant such as brine when the new AD plant is installed. Due to grandfathering arrangements for Central Park, these costs (and thus opportunities for avoided costs) are negligible in the case of Central Park but likely to be significant for other new developments.

As is evident from this brief assessment there are significant potential annual benefits, both quantifiable and non-quantifiable, of incorporating AD at Central Park. These costs and benefits will require more detailed assessment and verification in consultation with the stakeholders involved during a detailed feasibility/design study to find the preferred option and move towards piloting.

The benefits of avoided organics waste and trade waste disposal (refer to Tables 6.1 and 6.4) indicate that the avoided costs are approximately 20% of current BAU waste disposal costs and depend on the option considered. Adding the benefits of avoided apartment electricity or hot water costs significantly increase the benefits of incorporating AD on site, although operational costs need to be considered. Other benefits such as the value of capturing and recycling nutrients, reduced greenhouse gases from waste vehicle emissions and landfill, are more difficult to assess, but, have the potential to provide additional major quantifiable and non-quantifiable benefits. Many can be quantified with further detailed assessment and consultation with appropriate stakeholders.

The costs of incorporating AD and the associated collection/transportation systems at One Central Park vary considerably (refer to Table 6.2). However, with the potential annual avoided cost benefits, highlighted in Table 6.4, potential current funding opportunities through, for example, CoS and NSW EPA grants, and involvement of a progressive private multi-utility such as Flow Systems, there is real potential to set up an AD system at Central Park. This is despite the system potentially having a relatively long payback period, which will be dependent on more detailed assessment of costs and benefits, how those costs and benefits accrue to individual stakeholders and opportunities for grant contributions.

With Central Park already providing an international exemplar of sustainable urban development and demonstration site for the largest water recycling plant in the basement of a residential building in the world, there is a major opportunity to test and demonstrate the feasibility of AD in a precinct scale development at Central Park. However, a decision on whether to proceed and which is the preferred option requires consideration of factors beyond the costs and benefits. Other factors such as social and technical barriers are equally important. These along with other challenges and opportunities are discussed in the following section along with recommendations for next steps.

7 DISCUSSION AND RECOMMENDATIONS

7.1 Discussion

In assessing the management arrangements of waste at One Central Park (Section 3), volumes of organics available (Section 4), potential options and biogas production (Section 5) and associated costs and benefits of introducing an AD system on-site (Section 6), this feasibility study has unveiled a range of challenges, opportunities and considerations. These are discussed below using a STEEP (Social, Technological, Environmental, Economic and Political) analysis. While the STEEP analysis is context specific and provides insights specifically on the research findings from Central Park, many of the issues raised can be considered more broadly in managing organic waste and developing AD systems in urban settings.

7.1.1 Socio-cultural dimensions

The social and cultural dimensions determining the feasibility of AD at Central Park are associated with the complex arrangements for different organics waste streams and the need for changes in socio-cultural practices in effectively managing such waste streams. Socio-cultural behaviours and practices relate to individual residents and retailers, to centralised management, and to the issue of broader knowledge transfer of AD within Australia. These issues are discussed below.

Need for behaviour change to separate and collect food waste and minimise contamination

To collect uncontaminated food waste from residential and retail sites requires significant changes in behaviour and practices. For residents, this includes their behaviour and practices along with: the creation of a supportive system that takes into consideration socially acceptable collection vessels for food waste (i.e. caddies) designed for everyday practices; engaged and well-trained cleaning and operations staff removing the waste on a daily basis; and a strategic, long term communication and education campaign to ensure residents are aware of the value of alternative waste collection and treatment options. Similar issues are relevant for the commercial/retailers on site. With a culturally and linguistically diverse community residing and working at One Central Park, with relatively high turnover of staff and residents, socio-cultural practices in food waste management will need specific consideration. However, there are numerous best practice residential examples in Australia and internationally to turn to, and with respect to the retailers, those at One Central Park have already demonstrated that it is feasible to collect uncontaminated food waste (with the assistance of JLL, Cleanaway and Millennium - the cleaning contractor).

Requirement for ongoing buy-in from retail outlets to separate and collect food waste

Retail outlets change and vary in response to varying economic conditions and trends. Within the timeframe of this project, there were two major changes in occupancy of the retail outlets studied: (1) the opening of the Palace Cinema; and (2) the closing of a bakery, which had the potential to create significant volumes of bread waste and therefore biogas. While a consistent volume of food waste from retail outlets can never be guaranteed, a first step in ensuring that as much food waste is collected as possible, is to ensure leasing arrangements mandate food waste collection from all retail outlets in new leases at Central Park, in line with other progressive retail precincts such as Barangaroo. JLL are already considering modifying the leasing arrangements at One Central Park to mandate food waste collection.

Fragmented collection and management of organics waste streams As identified throughout this project there are an array of different organisations and contractors managing each organic waste stream with their own collection, transport and treatment/disposal arrangements. This fragmented collection and management of the waste streams together with lack of transparency in regard to the volumes/weights of waste generated and the costs of collecting, transporting and treating each waste stream is a major barrier to assessing the viability of onsite AD treatment and associated reuse. With organisations such as the CoS and JLL paying for waste services, there is significant opportunity for these large organisations to require, as part of ongoing contracts with waste service providers, the transparent and accurate measurement and costing of waste to assist in assessing the viability of AD on-site compared to BAU at One Central Park.

• Lack of precedents of AD systems in dense urban Australian settings
AD has been extensively used in the wastewater industry sector internationally, in
wastewater and food waste treatment in Australia, and for specific food waste
applications. It is technically feasible for AD to treat multiple organic waste
substrates in a dense urban setting, however, there are a lack of longitudinal case
studies in Australia, and more importantly, a lack of in-depth evaluation of failed
systems. For example, both the Pixel Building and Federation Square in
Melbourne have implemented AD (Turner et al 2017; Turner and White 2017).
However, neither system is now in operation and there are no documented
evaluations or lessons learned to assist in improving such systems. Such case
studies and the associated post implementation evaluations are invaluable in
aiding AD to overcome multiple barriers and become more acceptable as a
distributed system within a dense urban environment.

7.1.2 Technological dimensions

Even though AD systems have been used extensively both nationally and internationally for both food waste and wastewater applications for several decades, the lack of small scale, onsite systems in Australia and in dense urban settings internationally presents several technological challenges to overcome.

Retrofitting an existing building versus installing AD in a new building
Figure 7.1 (a) shows a small building-scale AD plant and Figure 7.1 (b) shows the
top floor of the existing water recycling room at One Central Park (which is directly
beneath one of the main bin rooms in Central Park) and in which an AD plant
could potentially be located. In this particular situation, the scale of AD plants
being considered for One Central Park (refer to Table 5.1) can potentially fit within
the existing water recycling plant room due to the significant head room available
and logistical issues already considered for the existing water recycling plant (i.e.
large plant access doors). However, consideration of the associated
interconnecting pipework, pre and post-treatment equipment and the structural
integrity of the floor will need to be assessed. The size and weight of the largest
AD system option (Option 4) may not be feasible structurally or may require
investment in structural modifications of the plant room.

Figure 7.1 – (a) Building scale AD plant formerly located at Federation Square in Melbourne (Active Research) and (b) Top floor of the water recycling room at One Central Park (Flow Systems)



Adaptive AD systems to deal with variations in both the quality and quantity of substrates

The nature of collecting organic waste streams from the residential and leased commercial/retail areas means that there will be potential variations over time in both the quality and quantity of substrates collected. This is particularly the case for the retail areas. For example, within the period of this feasibility study, there have been retail outlets that have newly opened (i.e. Palace Cinema), and closed, (i.e. a bakery) at Central Park. As retail outlets open and close over time they may not only produce varying quality and quantity of food waste but also varying volumes of UCO and FOG which may potentially influence the biogas potential and efficiency of the AD system installed. Therefore, any AD system installed will need to have the capacity to deal with variations in substrate quality and quantity. To assist in sizing an AD plant, laboratory testing of available substrates would be necessary during the next detailed feasibility/design stage to assess viability and quality of potential biogas. In addition to accessing food waste from Central Park,

there is also the potential of accessing food waste, UCO and FOG from adjacent sites such as Spice Alley consisting of over 30 food retail outlets. Tapping into such a concentration of potential additional food/organic waste could increase the financial viability of AD at Central Park.

• Remote management and operational control requirements

As is now typical with modern distributed systems the existing water recycling plant is unmanned and has a sophisticated SCADA¹³ systems to aid in that remote management. Hence any AD system installed would also need remote control functionality if installed at Central Park. Such functionality is now common practice for equipment such as AD, however, the skills to manage the system if a fault is detected are less common. Back-up systems and maintenance and fault crew will need to be carefully considered.

Smart/Internet of Things (IOT) Technology opportunities

In the Smart Locale area encompassing Central Park, there is significant opportunity to use advanced technology, such as the Internet of Things (IoT) using low power wide area network systems (e.g. LoRaWAN) to collect data. With Flow Systems staff leading the Open Cities ¹⁴ initiative, there is also significant opportunity to use Central Park to take advantage of such technologies to advance the capture and analytics of water, energy and waste streams to improve sustainability outcomes. These converging opportunities need further exploration.

7.1.3 Environmental dimensions

Environmental issues also need to be considered.

Management of potential odour and vector issues

The final system installed to collect, transport and treat organic waste, in particular food waste, will need to be designed to ensure odour and vector issues are effectively managed. One potential option is to manually collect waste from residential and retail sites through a caddie system on each residential floor and food court area of Central Park. For this option to be viable over the long term, collection and transport of food waste would need to be managed daily, if not twice daily, which would increase the costs of cleaning and operations staff. In addition, odour and vector control in the water recycling centre needs to be considered and potentially mitigated. Flow Systems have taken specific steps to manage odour within the water recycling centre, as have several water recycling centres within urban buildings in recent years, such as the Darling Quarter scheme in Sydney (ISF 2013). As the Central Park water recycling centre is used as an exemplar of water recycling for international visitors, odour control associated with food waste and other organic waste streams passing to the AD system will need to be carefully managed.

¹³ Supervisory control and data acquisition (SCADA)

¹⁴ http://www.opencities.net.au/about.html (accessed 25/05/18)

• Energy and greenhouse gas trade offs

As with many local smaller-scale technologies, an AD plant at Central Park would need energy to run the plant, which will need to be taken into consideration in the overall costs and benefits of the system during the next more detailed assessment of options. In the case of vacuum systems, to potentially increase food waste collection opportunities, this would also need to be considered, noting that dry systems, due in part to the diameter of the transport network system, typically use more energy than the wet system alternative. In any existing or new development, the scale of food and organic waste material available to produce biogas versus the energy intensity and greenhouse gas implications of collecting, transporting and treating that waste needs to be considered against BAU.

Capturing nutrient opportunities

AD digestate has the potential to provide valuable nutrients for agriculture, including phosphorus and nitrogen, depending on the substrates input, the type of AD process used and post handling methods. Depending on the bioavailability of those nutrients and application processes used these nutrients have the potential to provide significant benefits to plants as shown in Figure 7.2. The nutrient potential and most appropriate post handling methods used will need to be investigated as part of the next more detailed stage of assessment.

Figure 7.2 – An example of cover crops with and without digestate use¹⁵.



7.1.4 Economic dimensions

As with the implementation of any new technology, the economic viability of that technology against BAU is essential to take into account as well as the non-monetisable benefits

As a result of a lack of transparency on volumes of organic waste streams generated and costs for managing these waste streams, an accurate calculation of the costs and benefits of AD for Central Park has not been possible within the timeframe of the study. A high-level preliminary assessment has been made of the upfront capital costs, potential energy generation benefits and possible waste avoidance costs. However, further detailed measurement of individual waste streams (with appropriate automated measuring technologies), subsequent analysis and involvement of all relevant stakeholders to ensure the most viable options are considered and assessed against BAU is required along with assessment of accrual of costs and benefits to various stakeholders. So too are the implications of grandfathering costs for existing developments versus new developments (i.e. grandfathering of trade waste sludge discharge costs reduces the viability of tapping into avoided costs when the sludge is added to a potential AD system at Central Park).

Varying costs of vacuum system options

While vacuum systems installed in both residential and commercial sites have the potential to be cost prohibitive, this study has offered a range of options. In calculations for installing vacuum systems at Central Park, costs differed significantly (i.e. A\$ 700k for a retrofit of the commercial outlets (wet vac) to A\$ 14 million for the retrofit of both the commercial and residential sites (dry vac)). There are obvious cost savings with planning for vacuum in new buildings as opposed to a retrofit such as Central Park. The configurations and costs between wet and dry vacuum systems differ considerably as detailed in Table 7.1 below.

Although the costs for retrofit in Central Park are prohibitive, it is worth considering an option including the use of a lower cost wet vacuum system in the commercial areas and/or some of the lower floors of the residential apartments to act as a pilot/demonstration site in a high profile building for potential knowledge transfer opportunities.

Central Park has been the lack of transparency on both volumes/weights of organics and current costs for managing/treating/removing organic waste streams. The majority of data on organic waste streams collected throughout the project was assumed by waste contractors, rather than accurately measured or calculated through weight-based/volume-based calculations (as discussed in Section 4), with existing quality, accuracy and overall accessibility of this data lacking. One way this project sought to access "actual" data for commercial/retail food waste was to conduct a trial to weigh the commercial/retail food waste produced at One Central Park (see Section 4 for further details).

¹⁵ https://www.slideshare.net/EasternOntarioCropConference/christine-brown-spoils-for-soils (accessed 16/08/18)

Table 7.1 – Spectrum of costs for wet and dry vacuum systems for retrofit and new development applications for a site similar to One Central Park

	Type of Use	Vacuum system (wet) cost estimate (A\$)	Vacuum system (dry) cost estimate (A\$)
One Central Park (retrofit)	Residential	1,210,000	13,000,000
One Central Park (retrofit)	Commercial	700,000	3,000,000
One Central Park (retrofit)	Residential & commercial	1,600,000	14,000,000
New development (623 apartments)	Residential	1,000,000	12,000,000
New development (similar retail space to One Central Park)	Commercial	450,000	2,500,000
New development (623 apartments & similar retail space to One Central Park)	Residential & commercial	1,200,000	13,000,000

Vacuum systems for wastewater and organic waste

Whilst the retrofit of a combined wastewater and food waste vacuum and AD system is not a viable option for Central Park, such systems have the potential to revolutionise waste management in new precincts. In urban areas undergoing significant urban densification, such as that under the jurisdiction of the CoS, there is a real opportunity for councils to take leadership and advocate the use of such systems with developers of new precinct developments being considered.

Financial incentives for waste-to-energy systems

Due to current policy support of waste-to-energy technologies, discussed further in "political/institutional dimensions" below, there is currently significant government funding to assist new niche technologies such as AD to be trialled in Australia and specifically in Sydney, NSW. Whilst such incentives may detract from the long-term viability of AD in dense urban contexts, they provide the bridge needed to assist new technologies to go through initial "teething problems" and fund demonstration sites to assist in knowledge transfer of lessons learned. These current national, state and local government funds available for technologies such as AD make it an ideal time to invest in the Central Park AD plant.

Non-quantifiable benefits

Many of the environmental benefits discussed in "environmental dimensions" above, such as reduced greenhouse gases, are difficult to monetise due to their associated externalities but are essential to take into consideration when deciding whether to progress new alternative systems such as AD and vacuum. So too are the benefits to a business such as Flow Systems and a Council such as the CoS taking the progressive steps needed to install an AD plant on-site in a precinct scale development which, as with the existing water recycling plant, showcases a new and emerging system of waste management and application. In terms of industry leadership, this is invaluable. To assist in decision-making of the options/preferred options both the quantifiable and non quantifiable costs and

¹⁶ http://www.un.org/sustainabledevelopment/sustainable-consumption-production/ (accessed 28/08/2017)

benefits need to be considered in a suitable decision-making framework for the various stakeholders involved.

7.1.5 Political/institutional dimensions

As with many of the other STEEP dimensions, political/institutional dimensions can provide both significant barriers and opportunities.

Increasing awareness and support for food waste management The increasing awareness and policy support for food waste management at multiple levels of government provides a major opportunity for co-digestion of organic waste streams using AD. Nationally this has been in the form of the Australian National Food Waste Strategy, a framework to support collective action towards halving Australia's food waste by 2030. The strategy contributes toward global action on reducing food waste by aligning with Sustainable Development Goals in which a sub aim is to halve food waste by 2030¹⁶. At state and local levels, the NSW EPA and many council policies and associated investment is being focused on diversion of food waste and garden organics from landfill. This current policy environment has meant significant interest in the findings of this project and potential opportunities for AD from a wide range of stakeholders from

Regulatory barriers

vacuum systems.

On the other hand whilst policy supports innovation such as AD, regulations around using the resulting digestate may prove to be a barrier due to the novelty of the material produced, its various potential uses and risks associated with potential pathogens and human contact etc. This will require research into digestate use in international case studies, laboratory testing and application to land.

technology providers to state government representatives, providing a supportive

"window of opportunity" for piloting emerging technologies such as AD and

7.2 Recommendations

Through this project it has become apparent that various recommendations for further action are required across multiple dimensions and scales. Using the STEEP framework these recommendations are summarised below and aim to help fill knowledge gaps to assist in transitioning to the next phase of inquiry, detailed feasibility/design of precinct scale AD (and potentially vacuum), and piloting precinct scale AD in Sydney. Key recommendations include:

Socio-cultural

- SC#1 Conduct a residential food waste trial at One Central Park ensuring social practices across the entire system (i.e. residents, cleaners, strata managers, contractors) are taken into consideration, including collation of best practice national and international examples and actual measurement of food waste generated. To minimise costs the trial could be conducted on a restricted number of floors in the building.
- SC#2 Evaluate lessons learned from the current retail food waste trial and collate best practice examples nationally and internationally to assist in industry knowledge transfer and continuous improvement for the retailers at One Central Park.
- SC#3 Modify all retailer leasing arrangements at One Central Park to mandate food waste collection including separation and collection of pre and post plate food waste.
- SC#4 Negotiate contract arrangements with current waste management providers to include more transparent and accurate measurement and costing of waste to be able to compare alternatives like AD with BAU
- SC#5 Collate lessons learned on urban AD examples locally and internationally to improve and support industry knowledge transfer, and avoid repeating mistakes.

Technological

- > T#1 Conduct detailed feasibility assessment into the various AD, vacuum, energy and digestate reuse options taking into consideration detailed assessment of the interconnecting pipework, pre and post-treatment equipment and the structural integrity of the water recycling plant room.
- T#2 Conduct laboratory testing of the various substrates to inform detailed feasibility/design and assist in more accurate assessment of the potential biogas production and flexibility to deal with variations in substrate quality, quantity and compatibility including the potential of using the Active Research mobile AD system or similar.
- T#3 Conduct due diligence on appropriate AD (and vacuum) systems in Australia and appropriate remote monitoring, maintenance and back-up systems and crew for emerging technologies.
- T#4 Investigate opportunities to use smart/Internet of Things (IOT) Technology due to physical accessibility to the local LoRaWan and Flow Systems connection to the Open Cities initiative.

Environmental

- > En#1 Conduct detailed feasibility/design assessment of management of potential odour and vector issues from collection and transport through to treatment within the water recycling plant room and production of digestate.
- En#2 Conduct detailed assessment of operational energy requirements and greenhouse gas emissions for all AD and vacuum options to compare against detailed BAU assessment.
- En#3 Collate national and international information on relevant AD digestate use and regulations to assess the most appropriate post handling

methods to maximise nutrient recovery and beneficial use (including discussions with the NSW EPA).

Economic

- Ec#1 Conduct detailed assessment of costs and benefits of options against BAU as part of detailed feasibility/design study including detailed measurement of individual waste streams (using appropriate automated measuring technologies), accurate assessment of BAU, waste avoidance costs, capital and operating costs of all options and potential energy generation benefits with full assistance from all stakeholders (i.e. signing of a Memorandum of Understanding or similar).
- Ec#2 Conduct full assessment of costs of AD and vacuum options taking into consideration retrofit versus new build development and the specific additional costs associated with retrofitting (and piloting a new emerging technology) to assist in potential grant funding assistance.
- Ec#3 Investigate and advocate the potential for combined food/organic waste and wastewater vacuum systems in new dense urban developments through discussions with developers – CoS/Flow Systems
- Ec#4 Seek potential national, state and local government grant funding as well as private collaborator funding to assist in the detailed feasibility and piloting of AD (and potentially vacuum) at One Central Park to provide a demonstration site for knowledge transfer.
- Ec#5 Use an appropriate decision-making framework as part of the detailed feasibility study that enables both quantifiable and non quantifiable costs and benefits to be taken into consideration, not just the financial costs and benefits, and assess the accrual of costs and benefits to various stakeholders to assist in sharing of those costs and benefits.

Political/institutional

- P#1 Actively share knowledge on the current study findings and future detailed feasibility study/design and pilot broadly at national, state and local fora with a broad spectrum of stakeholders to assist in knowledge transfer and the opportunity to achieve higher policy aims of halving food waste by 2030.
- P#2 Work closely with regulators such as the NSW EPA during the detailed feasibility stage to work through potential regulatory barriers such as the local use of digestate to land.

As can be seen, there is currently significant opportunity and momentum to trial and demonstrate AD in Sydney, specifically One Central Park. By using a collaborative approach, leveraging the research conducted to date and conducting further investigations as indicated, the CoS, Flow Systems and others involved in One Central Park have the opportunity to provide national and international leadership in AD. This will further contribute to much needed knowledge on innovation in organics management as we grapple with how to manage organic waste streams in our growing cities and maximise beneficial use.

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APPENDICES

Appendix A – Site plans and typical cross sections of One Central Park

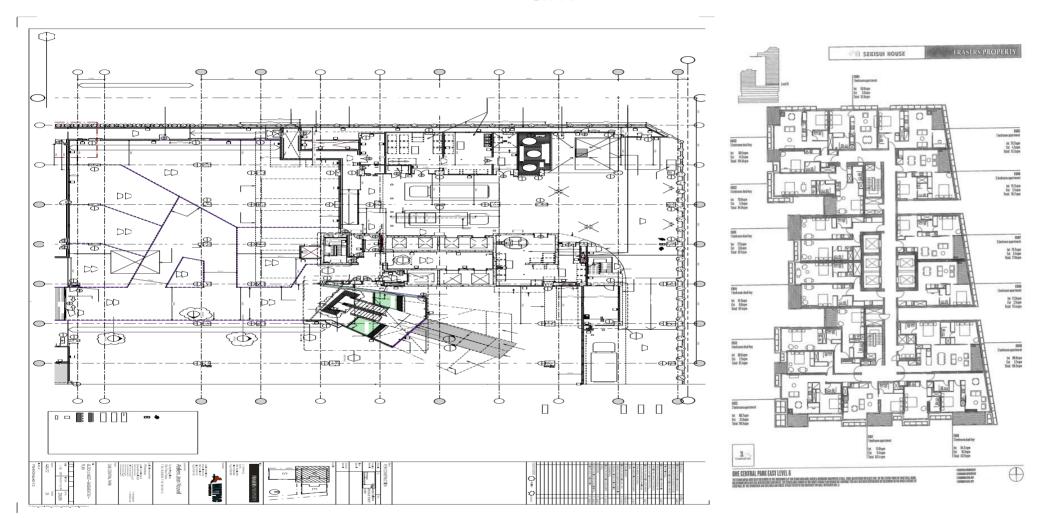
Appendix B - Organics waste stream assumptions

Appendix C – AD technology and vacuum and caddie transportation systems

Appendix D – Australian food load test (Avac)

Appendix E – Knowledge sharing, transfer and dissemination

Appendix A – Site plans & typical cross sections of One Central Park



Appendix B – Organics waste stream assumptions

Residential food waste

- 623 apartments at One Central Park, 1005 bedrooms (pers com Frasers representative)
- Assumed population 1045 based on CoS occupancy rates¹⁷
- Food waste per person assumed to be 113 kg/person/annum based on NSW EPA 2014/2015 kerbside report Appendix A¹⁸

Commercial/retail food waste

 Standard food waste density factor = 0.425 kg/L (Zero Waste SA: Solid waste and recycling reporting template)

Used cooking oil

- UCO collected at Central Park is approximately 1027 L/month
- Standard density factor for oil = 0.9 kg/L¹⁹

Fats, oils and grease

- According to SWC data for the Pyrmont-Ultimo area only approx. 16% of the material removed from grease traps is grease and 17% is solids (pers com SWC representative)
- Due to anticipated oversizing of the grease traps at One Central Park an estimate of 5% grease and 10% food waste/solids has been used (pers com FOG/UCO industry representative)
- Standard density factor for FOG = 0.9 kg/L

Wastewater

Density conversion factor = 1kg/L

Trade waste

Density conversion factor = 1kg/L

Garden organics

 Standard garden organics waste density factor = 0.231 kg/L (Zero Waste SA: Solid waste and recycling reporting template)

Pet waste

- Assume half the registered pets at Central Park are dogs and half cats
- Average dog poo per day = 0.33 kg/day²⁰
- Assume average cat poo per day equals half = 0.17 kg/day

¹⁷ http://www.cityofsydney.nsw.gov.au/ data/assets/pdf file/0017/259001/Occupancy-rates-to-determine-net-population-increase.pdf (accessed 21/08/18)

¹⁸ http://www.cityofSydney.nsw.gov.au/ data/assets/pdf file/0017/259001/Occupancy-rates-to-determine-net-population-increase.pdf (accessed 21/08/18) (accessed 21/08/18)

¹⁹ http://www.environment.gov.au/system/files/resources/a16491f5-6697-4f1b-bba0-074963e78957/files/hazardous-waste-unit-conversion-factors.pdf (accessed 21/08/18)
²⁰ http://www.poopower.com.au/index.html_and_https://www.petpooskiddoo.com/blog/showing-muchanimals-poop-fruit/ (accessed 21/08/18)

Appendix C – AD technology & vacuum & caddy collection & transportation systems

Anaerobic digestion

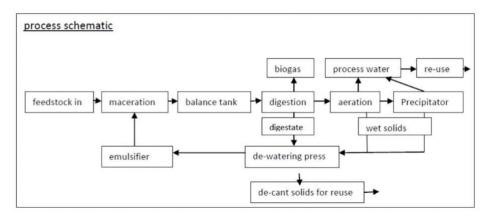
Anaerobic digestion (AD) is a process involving the breakdown of organic matter into carbon dioxide, methane and water by microorganisms and bacteria in the absence of oxygen. It has been used extensively in the wastewater industry for several decades, especially in Europe and more recently to treat food waste in isolation or combination with wastewater/sludge. The two main types of AD are thermophilic (reaching temperatures of up to 60 deg C) and mesophilic (typically 35 to 40 deg C). The process produces biogas, a mixture of methane and carbon dioxide, that can be used for energy production. The biogas can be burned to produce heat and electricity or the methane injected into the gas grid or used as a vehicle fuel. Additional by-products of the process are water and digestate, rich in nitrogen and phosphorus, that can be used as a fertiliser. 2122

AD is less common in Australia but is being used by wastewater utilities, private waste contractors and food waste manufacturers. For example, Sydney Water Corporation was the first utility to implement a waste-to-energy trial (in 2016) using locally sourced food waste to assist in powering a wastewater treatment plant²³. EarthPower was the first Australian regional food waste-to-energy facility, opened in 2003, now processing up to 50,000 t/annum of food waste and organics. Also, large food manufacturers such as Warrnambol, producing cheese and butter in Victoria, process their organics waste and generate heat.²⁴

There are limited examples of AD being used in the urban environment on a small scale in Australia. Active Research²⁵ designed and ran the 5,000 L AD unit at Federation Square in the heart of Melbourne from 2014 to 2017. The plant shown below, with a 5,000 L AD reactor, was located in a loading dock. The plant which operated 24/7 treated up to 800 kg of food waste per day from the precinct's restaurants and cafes producing up to 14,400 L of gas per day used as an energy source to heat boilers (Victorian Government 2016; pers com Active Research representative).



The technology used by Active Research at Federation Square and similar AD systems is a high rate fixed film anaerobic digestion, enhanced reactor technology including constant mix, insulated reactors, scum removal, heating, retentive thickening and remote management capability through the utilisation of best practise electronic monitoring equipment. A typical process schematic is shown below (Active Research).



²¹ http://adbioresources.org/about-ad/what-is-ad/ (accessed 10/06/18)

²² http://www.wrap.org.uk/content/anaerobic-digestion-1 (accessed 10/06/18)

²³ http://wastemanagementreview.com.au/utility-first-food-waste-to-energy-plant/ (accessed 10/06/18)

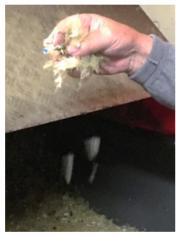
²⁴ https://batchgeo.com/map/2fb1cc9f27a39cb7b37562b95c32bcf4 (accessed 10/06/18)

²⁵ http://www.activeresearch.com.au/index.htm (accessed 10/06/18)

A key feature of the system is the rapid retention time (i.e. a hydraulic retention time (HRT) of only 7 days versus the typical 30 days in European systems with larger footprints). In addition, other key features include: the maceration and emulsification which reduce the particle size of the feedstock to enable the rapid access of the microbes to the substrate; and a slightly higher operating temperature which facilitates rapid HRT and higher biogas yields. An additional benefit of the rapid HRT, and additional oxygen injection at an appropriate point in the process, enables a reduction in the production of hydrogen sulphide and odour (pers com Active Research representative).

An important part of the pre-treatment process which has become evident is the removal of metal objects such as cutlery which can be removed by magnets and plastic bags and packaging which can be removed by technology currently sourced from Europe. The plastics removal technology and product produced, which in Europe is used as a boiler fuel feed stock, are depicted below (Active Research).





The digestate produced at the end of the process, depending on the feedstock, can be high in nutrients such as nitrogen and phosphorus. De-watered digestate post digestion is shown in the figure below together with illustrative photos of crops grown with and without digestate (Active Research).

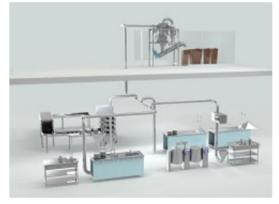




Vacuum systems

Vacuum systems have been used for sewage/wastewater transportation extensively in the aeronautical and marine environments since the 1960s. They have also been used in correctional facilities since the 1990s and in locations with difficult topography and high water tables for decades (Felix J 2016). Such "wet" systems are also used to transport food waste in food production sites such as poultry and fish processing and large professional kitchens and supermarkets. A typical "wet" system for food waste is shown in the figure below including kitchen station food waste funnel and associated vacuum system²⁶.





²⁶ www.taifun.fi/vacuum conveying/index.php.en/ (accessed 21/08/18)

In Europe vacuum systems have also been used for solid waste removal, with Hammerby, in Sweden²⁷, being an example of a "dry" vacuum system where waste is deposited by householders in individual inlets at central points, which then transport combustible waste, organic waste and newspaper underground to central sorting areas. This is illustrated in the figure below.



Most stationary systems supplied today are designed for source separation.

1. Waste is disposed off into ordinary refuse chutes. One for each fraction. 2. The waste is stored for a short while on a

valve, which opens when the computer-cor trolled emptying process starts. One fraction is emptied and collected at a time.

All waste fractions are transported through the same pipe system at a speed of 70 km/h

5. The waste is guided to the correct contains 6. The transport air is cleaned through filters The largest fractions are compressed

4. Fans create the partial vacuum that sucks the

waste to the collection station

Despite numerous examples of vacuum systems being used in Europe for both wet and dry systems for sewage and food and other organic waste there has been limited application in Australia. Vacuum systems have been used for difficult terrains for sewage but only in limited mainstream residential and commercial applications in food waste or for "dry" solid waste removal. In 2011, the nine-storey Melbourne Water Headquarters in the Docklands was opened with 72 vacuum toilets, using only 0.8 I/flush, servicing 1,100 people (Vacuum Toilets Australia n.d). In Sydney, vacuum technology has been used for toilets in the conversion of a heritage listed property. Legion House (Vacuum Toilets Australia n.d). A key example of a dry system in Australia, the first of its kind installed in a CBD, is the A\$ 21 million, 6.5 km system being installed in the Maroochydore City Centre with the first phase to be completed by the end of 2018.28

Caddies

Kitchen caddies are used both in the residential and commercial sectors, typically to collect and store food waste during the food preparation process. They can be used within the kitchen environment as a low cost and convenient means of collecting and storing waste for a variety of treatment processes. For example:

- home worm farms and composters²⁹,
- local council food organic (FO) services such as in parts of Inner West Council³⁰ or food organic garden organic (FOGO) collection services such as provided in Byron³¹.
- commercial scale rapid food waste decomposers/dehydrators such as at UTS32.
- city scale food waste collection for AD as implemented in Milan, Italy³³

There are an array of sizes and styles of caddy (i.e. vented and non-ventilated) and associated liners (i.e. paper, compostable)³⁴.



Avoidance of potential odour and vector issues is dependent on many socio-technical practices such as frequency of removal of the food waste, the type and use of liners, frequency of cleansing etc. Such issues are also highly dependent on ambient and seasonal temperatures.

Projects/Automated-Waste-Collection-System (accessed 10/06/18)

https://compostrevolution.com.au/?gclid=EAlalQobChMltaz5vej 3AlV1qcqCh3m6A9ZEAAYASAAEqJ5 Y D BwE (accessed 21/08/18)

http://www.wrap.org.uk/sites/files/wrap/HH food waste collections guide section 4 caddies and liner s.pdf (accessed 21/08/18)

²⁷ http://www.solaripedia.com/files/719.pdf (accessed 10/06/18)

²⁸ https://www.sunshinecoast.qld.gov.au/Council/Planning-and-Projects/Infrastructure-

³⁰ https://www.innerwest.nsw.gov.au/live/waste-and-recycling/less-waste/food/food-waste-and-recycling-service (accessed 21/08/18)

³¹ https://www.epa.nsw.qov.au/-/media/epa/corporate-site/resources/wastegrants/18p0682-byron shirefogo-case-study.pdf (accessed 21/08/18)

³² https://www.uts.edu.au/research-and-teaching/our-research/institute-sustainable-futures/ourresearch/food-futures/food (accessed 21/08/18)

³³ https://pocacito.eu/sites/default/files/FoodWasteRecycling Milan.pdf (accessed 21/08/18)

Appendix D – Australian food load test

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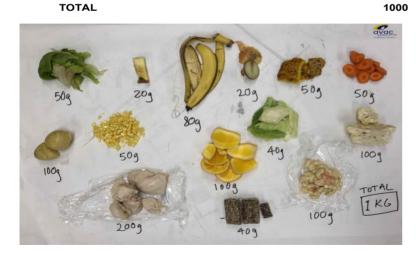


Australian Food Load

For the purposes of consistency in testing Avac Australia developed an "Australian Food Load" to be used in consistent testing and sizing calculations for waste pipeline systems and associated equipment interface.

Specification

Item	Description	Weight (g)
1 2 3 4 5 6 7 8 9 10 11	Chicken Breast (cooked) Potato (cooked) Orange Peel Pasta Salad Cauliflower (raw) Banana skin Pineapple skin Iceberg lettuce Carrot (raw) Corn kernels (raw) Cabbage rough cut (raw) Lamington	200 100 100 100 100 80 50 50 50 40
13 14	Onion ends (raw) Apple Core	20 20



Appendix E – Knowledge sharing, transfer and dissemination

The project aimed to enhance knowledge of the feasibility of AD and various collection/transports systems (e.g. vacuum, source separation) to manage organic waste (i.e. food waste, sewage and trade waste) in a large mixed-use commercial-residential multi-storey building to produce energy and biosolids for:

- project partners (CoS, private retailer, building operations manager, AD & vacuum suppliers)
- extended project partners (e.g. Smart Locale group and EPA)
- selected businesses in the Smart Locale area through the Pyrmont-Ultimo Chamber of Commerce (Smart Locale partner)
- broader industry audience

These goals were achieved and demonstrated through two main pathways:

- Publication and presentation of research & results through local, national and international forums, and
- Surveying project partners to determine new knowledge gained from the project which is expected to be shared with associated networks.

Publication and presentation of research & results 35

The list below details the range of conferences and public media outlets where the research has been published targeting multiple audiences including industry and business partners in the local precinct.

Waste Water Summit 2018 (October, 2018)

Andrea Turner & Dena Fam 'Convergence of the waste & water sectors' (Invited presentation), Wastewater Expo 2018, Melbourne Convention and Exhibition Centre, 3rd & 4th October 2018

https://www.wasteexpoaustralia.com.au (expected participation by 1,500 participants)

 South Sydney Region of Councils (SSROC) – Food Waste Forum (June, 2018)

Andrea Turner and Dena Fam, 'Collecting Food Waste on a Precinct Scale – The Pyrmont-Ultimo Precinct & Central Park Studies' Wednesday 13th June, 9.30-2.00, Redfern Community Centre (approx. 35 participants - waste experts, sustainability managers and council representatives)

• Waste 2018 Conference (May, 2018)

Andrea Turner & Dena Fam, 2018, 'Innovation in precinct scale food and organic waste management: Opportunities for the future...', Opal Cove Resort, Coffs Harbour, NSW, 8-10 May 2018 (approx. 650 participants)

• TWENTY65: Bringing the water sector together – Conference (April, 2018)
Dena Fam & Andrea Turner, 2018, 'Water and beyond: Innovation and the convergence of the water and waste sectors', TWENTY65: Bringing the water sector together, 17-18 April 2018, Hilton Hotel Manchester, UK. (approximately 120 participants)

Alt Media (November 2017)

Article by Anna Freeland 'Bright idea for leftovers' http://www.altmedia.net.au/brightidea-for-leftovers/128548 (Altmedia has a readership of approx. 25,000 residents from Inner West of Sydney)

ISF Newsletter (October 2017)

Dena Fam and Andrea Turner: Central Park Precinct Organics Management Feasibility Study, October 2017. https://www.uts.edu.au/research-and-teaching/our-research/institute-sustainable-futures/our-research/resource-futures-43?utm source=newsletter&utm medium=email&utm campaign=october 2017 wrap &utm content=central park organics (the ISF newsletter is sent out to approximately 3000 individuals, organisations and businesses)

Surveying project partners - Lessons learned

In addition to the communications and knowledge transfer listed above team members for this project actively sought to collate the lessons learned through an end of project survey, identifying knowledge gained throughout the project, unexpected insights and experiences that were seen as important to share with others planning on implementing AD systems in multi-storey buildings (see below for survey questions and answers by the research team)

The survey questions for this research are based on the inquiry into the feasibility of AD at One Central Park and a requirement of the CoS (i.e. to survey project partners to determine how knowledge has been enhanced as a result of the feasibility study of AD and various collection/transports systems (e.g. vacuum, source separation) to manage organic waste (i.e. food waste, sewage and trade waste) at Central Park).

Questions for partner/participants in the Central Park Organics Management Feasibility Study

- 1. What knowledge have you gained as a result of being involved in the Central Park Feasibility Study? How does this knowledge relate to:
 - a. **Operations and management** required for AD? i.e. policies, costs, behavioural change to support source separation etc.
 - b. **Collection/transport systems** for AD? i.e. vacuum systems, residential and commercial food waste collection etc.
 - Processing systems for AD? i.e. the feasibility of technological components of the system

³⁵ Further communications will be conducted at the completion of the project including an academic journal article, local/national radio programs (i.e. 2SER and Radio National) and national waste industry magazines (i.e. Waste Management Review)

- d. **Beneficial reuse of processed waste** from AD? i.e. for the production of energy and/or soil conditioner
- 2. Were there any unexpected insights gained into the feasibility of AD systems at Central Park throughout the project?
- 3. What other insights would you like to share with others involved in planning, designing and/or implementing AD in multi-storey mixed-use sites such as Central Park?
- 4. Were there any other comments you'd like to share about the project and knowledge gained?

Key themes emerging from the survey

Illustrative quotes are presented to provide context for the themes highlighted below which range from the practicalities of purchasing small scale AD systems and ancillary components in Australia to the political/regulatory environment enabling the emergence in innovation in organic waste management.

LACK OF AVAILABLE INFORMATION ON AD SYSTEMS IN AUSTRALIA

People don't understand AD, what it is and the volumes needed for a plant. It is therefore needed when installing AD to help people have a better understanding what AD is and volumes needed because it is so unclear.

INDUSTRY & GOVERNMENT SUPPORT IS REQUIRED TO GROW THE AD MARKET

The difficulty is there is nowhere you could buy the AD equipment in Australia, the systems are imported from the EU. There is a need for a roundtable with EPA and Sydney Water to discuss small scale AD systems and how they might be supported...It's an untapped market...

MYTHS ABOUT ACCEPTABLE CONTAMINATION RATES FOR AD SYSTEMS

Common attitude is that no contaminants are needed in organic waste streams to be used in AD systems. Mixed organic waste can be processed with the packaging so contaminants are fine and not a problem. Myths are a big problem. This is the biggest myth....

REDUCING COSTS THROUGH AD

There is a huge potential of AD to reduce costs associated with carparks and cost reduction will have a massive impact and flow through to housing affordability because it's something developers struggle with. Carpark and infrastructure costs are huge e.g. cement, ventilation and space for waste storage and collection. There is also much better amenity if you have automated central collection which is away from everything instead of huge bin rooms which create potential for pests and rodents.

In a retail market, any offtake into the sewer is a real driver to find a solution for the nutrient load for a waste recycled water scheme. If it didn't cost anything to do that there isn't incentives for AD...

What was exciting was that the AD system and kit is 90% the same infrastructure, so for Flow immediately there is a synergy already, we haven't found out the details yet but its all there! That was a basic but exciting operational revelation and how [AD] gets combined is a systems solution and that could be integrated with costs savings!

ACCESSIBLITY AND AVAILABLITY OF WASTE DATA IS KEY

It continues to surprise me that good data is difficult to find. Data is the key. Even in other fields as well i.e. solar. There's always a struggle with data, even people collecting the waste don't know the data on volumes collected.

The 'Dark arts' aren't good enough. We need to track our waste and know a lot more about what's in there, volumes and what's not accounted for, it's not understood and therefore we don't know the full range of opportunities for us...

EARLY PLANNING IS NEEDED

It has to be done from the onset, you can't do retrofits for AD but on the flipside, it would be a walk in the park if you installed AD from the beginning and would not be any different from putting in your plumbing. The costs wouldn't be prohibitive if you see the benefits.

Get onto it early! Going back into Central Park to install AD as a retrofit presents cost hurdles

PLANNING WITHIN EXISTING GREEN PRECINCTS SUCH AS CENTRAL PARK

The Central Park community, business and rentals, JLL, owners and the body corporate are all engaged in the benefits of green infrastructure. They are looking to make it better and you can do that when you build from scratch and can adapt to the culture in a precinct such as CP rather than one single building...

Once you've got, multiple green engineered solutions that are working together then it's easier to get community engaged.

AD COULD BE SUPPORTED THROUGH CO-FUNDED BUSINESS MODELS

For developers, they will need to collaborate with organizations like Flow who could sell the gas and we could recoup the capital for the AD plant through the sale of the gas and electricity. It's hard for developers to justify the costs but a co-funded structure would work i.e. similar for what's happening in solar.

AD REQUIRES REGULATORY DRIVERS

We need councils to get on board with this, to support source separation, it's not a big thing for them to stipulate, but it would be a key driver helping to get AD off the ground

There are 2 ways to deal with the [prohibitive] cost of AD and vacuum systems:

- 1. Penalize food waste to landfill with legislation and apply pressure to legislators to make this happen and
- 2. We need to come up with a cheaper solution

UNEXPECTEDLY HIGH ENERGY PRODUCTION FROM THE FEASIBLITY STUDY

Originally I was sceptical of the gas produced but the numbers say it's a justifiable quantity and there's enough there to warrant a step to putting this system in...Overall the more I got involved the more I realised how big this idea of AD for waste is for Australia to manage our waste...

A DEMONSTRATION SITE IS NEEDED FOR MANAGING WASTE, WATER & ENERGY VIA AD

There's a real opportunity for water and waste management, the synergies are great and infrastructures should work for organic waste as well as water/sewage. We need to give priority for that. A city(s) should be committed to get these integrated systems up [and installed].

Let's design a theoretical project from a clean slate with the cheapest money possible and be clear about what the goal is...What is the real goal that sits behind decision making so we need to be more open and transparent.

DEVELOPERS NEED TO BE OPEN & TRANSPARENT ABOUT ACCEPTABLE COSTS FOR AD

Business perspective need to talk to developers about how the business case stacks up at the beginning of the conversation, they need to monetise what they think can work...They are usually guarded about expenditure and any business case. People aren't open enough to share costings. You can change the world by thinking outside the box but it's not an open discussion...

Openness is the key