Options for long-term waste reduction and management in the Australian Capital Territory

A report drafted for

Conservation Council, ACT Region

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Executive Summary

As the Australian Capital Territory endeavours to control increasing waste volumes with diminishing landfill space, it has become vital to find new methods for waste system management. A waste to energy facility has been proposed, however would be expensive and may be rendered unviable in future, with commitments to higher territory waste reduction targets.

The following report produced a feasibility study, highlighting alternative waste management practices to reduce initial system input. Suggested initiatives focused on three major hierarchical levels of government, business and community. Initiatives presented included product regulation, pre-development audits for businesses, improved data management processes and engaging outside actors to deal with ACT waste.

The report concluded that the initiatives recommended were viable, having been previously employed in other locations or recently deliberated by local stakeholders. These initiatives are immediately implementable, providing long-term methods to reduce the waste stream input and deal with the waste generated.

Acknowledgements

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List of Abbreviations

°C	Degrees Centigrade
%	Percent
ACT	Australian Capital Territory
CWDD	Capital Works, Design and Delivery
EfW	Energy from Waste (see also WTE)
EPS	Expanded Polystyrene
GIS	Geographic Information Systems
HNRV	Highest Net Resource Value
MBT	Mechanical and Biological Treatment
MDF	Medium-Density Fibreboard
MRF	Materials Recovery Facility
MW	Megawatt
NIMBY	'Not in My Back Yard'
NSW	New South Wales
Syngas	Synthetic Gas
WTE	Waste to Energy (see also EfW)

Chapter 1: Introduction

Waste management processes are vital in modern cities, with proper methods minimising risks to society and the environment. This is accomplished through disposal or storage of all waste categories using perceived safe and long-term methods (Unilever 2010). Strategies to manage waste have traditionally included collection for landfills, processing of recycling and education campaigns to reduce consumerism behaviour. However, waste levels in the Australian Capital Territory (ACT) are rapidly increasing, and with limited space available for landfill in future (Crawford and Westcott, 2014), infrastructure for the conversion of waste to energy (WTE) is undergoing exploration.

1.1 Research Topic and Scope

This report highlights alternative waste management practices to WTE. These alternatives aim to reduce initial system input prior to infrastructure commitment and achieve a reduction in current ACT waste levels, recorded as 2.6 tonnes per capita (Blue Environment, 2013).

Suggested initiatives will be implementable by the government, and target three major hierarchical levels; government, business and community. This top-down approach to the report reflects the need for the ACT Government to be the crucial driver in the current waste debate.

Research scope is limited to major alternatives which could be implemented immediately. This ensured completion within timeframe and sizing requirements. Economic feasibility estimates are excluded due to complications with valuing environmental targets.

1.2 Methodology and Structure

Research took a mixed-method approach, collaborating quantitative and qualitative data. A literature review provided context, focusing on the current ACT waste system and WTE proposal. To determine potential initiatives, interviews and case study comparisons were employed.

Chapter 2: Background

The literature review explains the state of the ACT waste system and the WTE proposal. It briefly highlights current waste initiatives, establishing areas of opportunity for further exploration.

2.1 Current ACT Waste System

Since 1995, waste levels in the ACT have grown by approximately 5 percent (%) per year (ACT Government, 2011). Trends illustrated that landfill space would be full at end of 2015 (Purdon Associates Pty Ltd, 2012), however this has been alleviated with the interim measure of reopening the West Belconnen Resource Management Centre, while proposing extensions to the Mugga Lane facility (Crawford and Westcott, 2014). This will only extend landfill life by a short period (Purdon Associates Pty Ltd, 2012), and it is imperative to find solutions to deal with future waste levels.

In 2009 - 10, the total amount of waste generated in the ACT was 817,000 tonnes, with 25% ending in landfills (ACT Government, 2011). The total figure has since increased, and although a goal has been to ensure 'the growth in ACT waste generation is less than the rate of population growth' (ACT Government, 2011), this target has not been achieved. Increases to ACT population and waste generation (Figure 2.1) show that the growth rate of waste generation is greater than of population size.

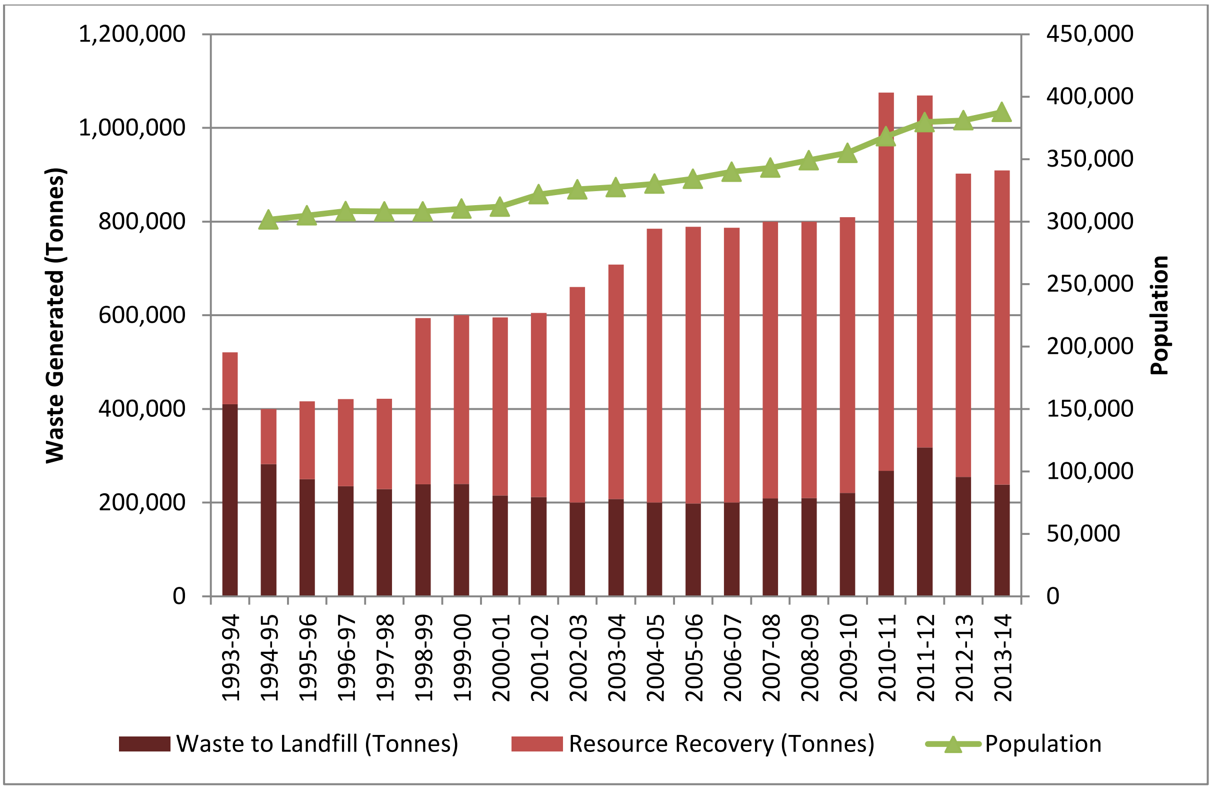


Figure 2.1: The total waste generation and population in the ACT (adapted from OCSE, 2011, to reflect current figures).

1996 saw the first ambitious waste policy in the ACT, '*No Waste by 2010*' (ACT Government, 1996), which aimed to achieve 'a waste free society by 2010' (ACT Government, 1996). The newest replacement '*ACT Waste Management Strategy 2011-25*' (ACT Government, 2011), lists four key outcomes of having less waste generated, ensuring full resource recovery, promoting a clean environment and establishing a carbon-neutral waste sector (ACT Government, 2011).

Aligned with this desire of a carbon-neutral waste sector, the 2015-16 ACT Budget allocated $2.8 million over two years to 'undertake a feasibility study to investigate long-term options for the management and treatment of waste in the ACT, including the development of a full business case for a waste to energy facility' (ACT Government, 2015b).

2.2 Waste to Energy (WTE) Proposal

The ACT and surrounds already possess some WTE capabilities, with the Mugga Lane landfill featuring a three megawatt (MW) power plant since 2005 (OCSE, 2007). Retrofitted wells in the buried landfill capture gases produced and redirect them to a combustion engine, generating electricity to be fed into the local grid network (OCSE, 2007). Outside the ACT, the Woodlawn Eco-Precinct at Tarago imports 20% of Sydney's waste (Veolia Energy, 2014a) and uses the same method to produce eight megawatts, with plans of 25 MW capabilities in future (Anonymous, d. 2015).

The Budget proposal for the ACT WTE facility did not specify which process will be employed to extract energy. Traditional processes of extraction include incineration, anaerobic digestion or landfill gas capture. Simon Corbell, ACT Minister Environment and Sustainable Development, had previously highlighted extraction methods under consideration, including 'gasification, pyrolysis or plasma gasification' (Parkinson, G. 2014). These six processes differ in terms of energy input and end products, compared in Table 2.1. End products listed are subject to variation, depending on initial waste composition.

Table 2.1: A description of the available WTE processes, including expected end products.

PROCESS NAME	BRIEF DESCRIPTION	PRODUCTS
Plasma Gasification	Converts organic waste into synthetic gas using a commercial plasma torch at temperatures greater than 3900°C (URS Australia Pty Ltd, 2010)	- Synthetic gas ('Syngas') - Ash - Emissions (if combusted)
Gasification	Converts organic waste into synthetic gas by heating to temperatures of 700 - 1400°C, in the absence of oxygen (URS Australia Pty Ltd, 2010)	- Syngas - Solid waste ('Slag') - Ash - Emissions (if combusted)
Pyrolysis	Thermal decomposition of organic material by heating to temperatures of 400 - 900°C, in the absence of oxygen (URS Australia Pty Ltd, 2010)	- Syngas - Tar or oil, for fuel - Biochar - Pyrolysis ash or char - Emissions (if combusted)
Landfill Gas Capture	Wells drilled into buried landfill deposits to capture gases produced (OCSE, 2007)	- Gas - Emissions (if combusted)
Incineration	Controlled burning at high temperatures to reduce landfill and extract energy as heat (GAIA, 2012)	- Gas - Ash - Slag - Emissions (during incineration and later if combusted) - Scraps/ materials not burned
Anaerobic Digestion	Use of microorganisms to break down biodegradable material. This material is converted to organic acids, then to gas (Chynoweth *et al*, 2000)	- Gas - Emissions (if combusted) - Compost or organic product

2.3 Current Initiatives and Suggested Inclusions

The ACT system of waste management incorporates kerbside garbage bin collection, drop-off repositories and a bulky waste collection system (Hyder Consulting Pty Ltd, 2011). Education initiatives extend to targeted awareness programs, publically accessible literature and award schemes promoting participation particularly in the business sector (Hyder Consulting Pty Ltd, 2011).

While these methods deal with the current intake of waste, the system lacks any impetus to reduce input and ease pressure on services, or to plan for future waste levels. This report highlights methods which could be introduced immediately to the system, aiming to decreasing initial input to the waste streams and provide management options.

Chapter 3: Adaptations to Current Waste Management Processes

The ACT Government are responsible for producing waste policies, maintaining collection and disposal, and regulation enforcement. Prior to outlay for WTE infrastructure there are initiatives which should be employed at governmental level, to reduce waste stream input and manage current waste levels.

3.1 Data Collection: Better Practice Methods

While the waste system appears efficient, there are arguments the territory has not employed its 'best' methods. In this case, the term 'better practice' methods will be used as it is impossible to note when 'best' level is achieved. Better practice approaches link directly to ensuring full and correct attainment of waste data.

During the NoWaste era, data collection methods included few sources. Recycling volumes were self-reported by recycling facilities using a prefabricated survey, and landfill collection was weighed at point-of-entry into the Mugga Facility (Anonymous, b. 2015). Alongside these regular methods, waste composition data was gathered through occasional landfill audits, Hume Materials Recovery Facility (MRF) assessments were undertaken to quantify incorrectly placed material, and intermittent kerbside audits of household bins were conducted (Anonymous, b. 2015). While these methods were simple, sampling was ongoing during the NoWaste period, providing useful data for understanding of waste systems.

Between 2011 and 2014, ACT waste data appears difficult to locate or not publicly available. Upon Conservation Council communications with a waste system stakeholder, it was recognised that waste data has not been well recorded since 2008 and there is now a need to establish a new data baseline (Anonymous, a. 2015). It is not possible for the ACT to plan for the future when the current state is not well known.

3.2 Outcome Focused, not Task Focused

In 1996, the NoWaste team aimed to achieve a completely waste free society based on the major outcome outlined in '*No Waste by 2010*' (ACT Government, 1996). The policy did not reach this goal, however pushed ACT communities from recovering 22% of waste generated, to recovering 74% of waste generated (Wright Corporate Strategy, 2008). Following on, the '*ACT Waste Management Strategy 2011-25*' (ACT Government, 2011) lists four major objectives, rather than a clear-cut goal.

An overarching outcome is a clearer strategy of addressing territory waste issues. While an outcome presents an obvious finalisation point, having objectives and tasks leaves room for manoeuvrability and no clear idea of standards needing to be achieved.

3.3 Product Regulation

Another method to be employed at a governmental level to reduce waste stream input is the regulation of products entering the territory. In 2011, the ACT Government banned plastic bags due to their slow breakdown rates, which caused unnecessary environmental and landfill stress (ACT Government, 2015a). The next regulated product could be expanded polystyrene (EPS), including all take-away containers, loose-fill packaging and box packing sheets.

Figure 3.1: A sample of polystyrene build-up in landfill (Clean Water Action, 2014).

In 2006-07, approximately 33,000 tonnes of foam were generated in Australia (Clean Up Australia Ltd). Foam is ‘single-use’; it is not easily recycled due to expansive formation processes and it possesses no after-market uses (BBC News, 2015). It fills landfill rapidly and remains for long time periods. Foam is also lightweight and mobile, escaping landfill and littering the landscape, creating further environmental concerns (BBC News, 2015).

The feasibility of regulating polystyrene can be demonstrated briefly by a recent case study in New York City, which has recently become the largest city to prohibit the sale, possession and distribution of polystyrene foam (Hogue, C. 2015). New York City Council implemented a ban on 1 July 2015 which stopped companies from buying, using or making polystyrene products, equipped with a six month grace period to adopt alternative products. While new regulations caused some dispute among actors, the city now joins more than 70 locations, including San Francisco, Seattle and Washington DC (Solis, M. 2015), who have banned polystyrene and switched to biodegradable or recyclable products. It stands to reason then, that Canberra could follow the same process of regulation.

In future, additional products to undergo regulation include household chemicals, plastic drink bottles and other ‘hard to dispose of’ items.

3.4 Business Regulation and Audits

Alongside product regulation is the need to regulate daily processes of businesses operating in the ACT. Businesses are currently regulated by the ACT Government using licences, permits, approvals and codes of practices (ABLIS, 2015), with set standards and guidelines for all (ABLIS, 2015).

Businesses are required to complete paperwork relating to foreseen issues when dealing with hazardous or clinical waste, however there are no checks requiring thought about any ‘normal’ waste generation (Anonymous, c. 2015). Suggested is an audit, requiring businesses to consider their potential waste generation across their lifecycle and all processes. This would be completed prior to being granted establishment permission or development approval, allowing for an overhaul of reported waste processes if government foresee an issue.

Such an audit may have been useful in the case of the long-awaited launch of IKEA at Majura Park, which will be saving locals from undertaking the ritualistic weekend trek to Sydney stores. The Swedish-born furniture giant boasts the Canberra store will open ‘with the full range of 8500 products’ (Gorrey, M. 2015), peaking community excitement with a completed catalogue drop of 194,000 households (Gorrey, M. 2015).

While the public eagerly await this opening, it is important to assess the introduction of easily-accessible flat-pack furniture to the ACT waste system. Flat-pack furniture is not as durable or long-lasting as traditional wooden household furniture (Flat Pack Mates, 2013). Joints are held simply with screws tightened by Allen keys and timber has been replaced with weaker medium-density fibreboard (MDF), meaning replacement of furniture will happen more often with broken items sent to landfill. The other issue is flat-pack furniture is inexpensive and follows trends. As the latest styles and shapes are released seasonally, the public feel less guilt when disposing of the last cheap purchases and replacing them with new fashions. This cyclic flow of furniture will dramatically increase waste levels in the ACT.

3.5 Recommendations

At a governmental level, there are multiple initiatives which could be employed to reduce waste stream input and better manage the landfill. Proposals about the future of waste in the ACT cannot be made without correct knowledge about current state. It is crucial to establish baseline data for waste levels, and implement new processes to ensure data is collected ongoing from present. This data needs to be transparent; accessible and available to public enquiries. In years where collection processes did not follow better practice protocols, the lack of or limitations of data need highlighting.

Better practice methods for setting targets and achieving them were seen in the NoWaste era, where the policies were outcome focused, rather than task based. An overarching outcome allows everyone to reach for the same final point, and current waste policies should be altered to include final goals.

Regulation is a crucial responsibility of the ACT Government. Certain products could be regulated immediately to negate unnecessary landfill. Businesses entering the ACT should be reviewed and have to undertake an application process, part of which outlines their expected waste streams and mitigation strategies, ensuring alignment with the territory's sustainable development goals.

Chapter 4: Responsibility on Outside Actors

As an alternative to investing in WTE infrastructure, placing additional responsibility on business or whole community actors could reduce the input to waste streams and ease pressure on ACT Government. Redirecting responsibility highlights opportunities such as community composting facilities or interactions with private companies to assist in waste disposal.

4.1 Community Responsibility and Involvement

Unfortunately, within communities there is often a NIMBY ('not in my backyard') attitude towards waste processing. Prior suggestions have been to allocate transfer stations or resource facilities within each suburb, or across groupings of suburbs, to regain responsibility of waste processing on a much smaller scale. This reduced scale would prove easier to process waste, gather data and monitor household participation. However, this solution is costly and requires multiple sites of available land and new infrastructure.

A simpler method of handing partial responsibility to communities is to establish community-based composting. This would create a method of handling the green and organic waste heading to landfill unnecessarily. Approximately 39% of the waste sent to landfill in the ACT is scrap food, and a further 6.6% is garden waste (APC, 2009), shown in Figure 4.1 below.

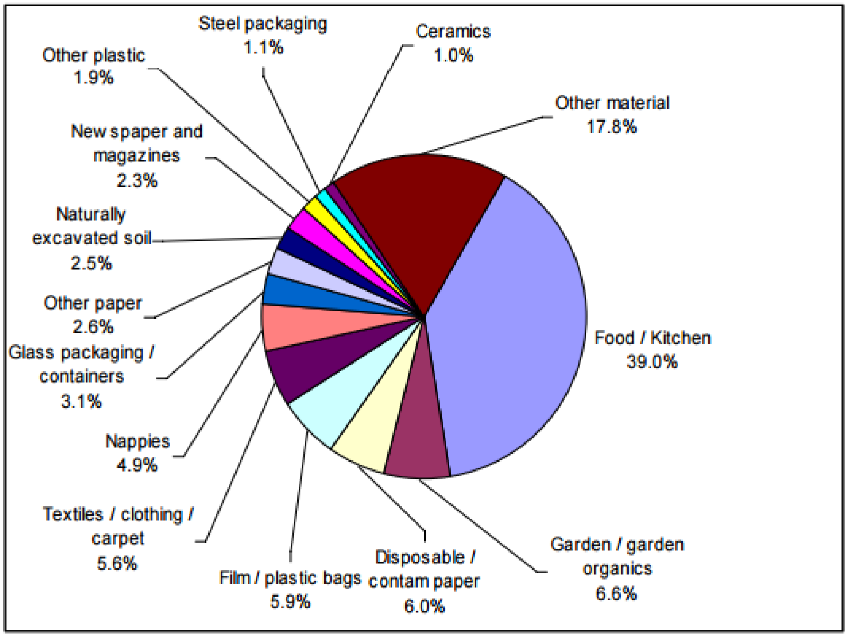


Figure 4.1: Composition of the ACT landfill, determined from kerbside audits (APC, 2009).

A community composting system would involve government working alongside communities to allocate space and assist in infrastructure development. This infrastructure could range from a large shed or designated warehouse area, to kerbside composting using specially designed receptacles (as seen in Grayson, R. 2011). Community-formed groups or government employees could care-take and educate about the composting. The product should then be available for residents or small-scale business pursuits. This composting proposal could stop the majority of organic and green waste streams from entering landfill, as the ACT has not adopted a ‘green’ bin system like New South Wales (NSW) and other states.

Many case studies are available around the world, demonstrating the success of community-based composting. In 2013, the city of Austin, Texas, began a year-long trial of kerbside composting after the local council determined that nearly half of the waste sent to local landfills could be composted instead (Statesman News, 2013), not dissimilar to the ACT’s situation. The Austin composting trial cost US$485,000 (Statesman News, 2013), which covered costs for all new infrastructure, collection, maintenance and educational programs (Statesman News, 2013). Composting locations were evenly spread for ease of total community access (Figure 4.2). Future plans for the compost produced include private companies processing it and selling as high-quality fertiliser (Statesman News, 2013).

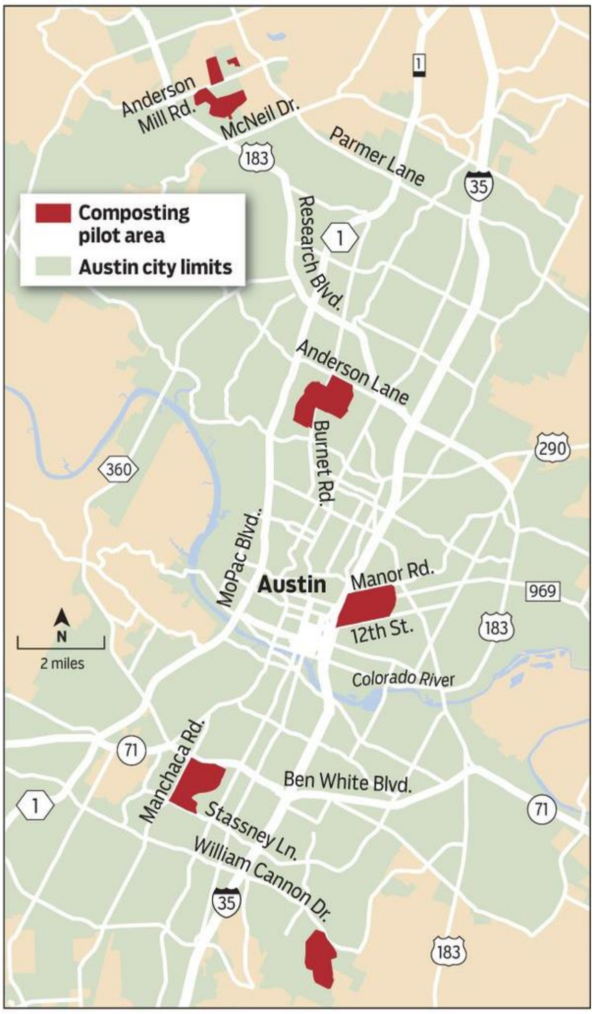


Figure 4.2: The areas in Austin, Texas, designated for community composting purposes (Statesman News, 2013).

In Australia, some Sydney-based local councils have installed community-composting stations on their streets, which have now been adopted into local waste practices (Grayson, R. 2011). While ACT Government may remain apprehensive about the idea, it is important to remember that prior to the NoWaste era there were no established household recycling practices. Local residents remain able and ready to adapt practices for a more sustainable future.

4.2 Woodlawn Bioreactor

Another method of the ACT Government redirecting waste processing responsibility onto an individual actor would include the opportunity to involve the private company Veolia to take ACT waste at its ‘Woodlawn Eco-Precinct’.

The Woodlawn Eco-Precinct is located in Tarago NSW, a mere 25 minutes from the ACT border. Once the site of an open-cut and underground mining operation, Veolia took over the site in 2002 and began importing waste in 2004, alongside ongoing mine-site rehabilitation (Veolia Energy, 2014a). The major facility drawcard is a bioreactor, where 20% of all Sydney's landfill is stored and methane produced is captured, combusted and fed as electricity back into the grid network (Veolia Energy, 2014b). The facility also features the beginnings of aquaculture and horticulture pursuits, where the waste heat from energy generation is used to farm barramundi and hydroponic systems filter water required (Veolia Energy, 2014b). On surrounding land, large herds of cattle and sheep are grazed for wool and meat, and Infigen Energy operates a 50MW (27 turbine) windfarm (Veolia Energy, 2014b).

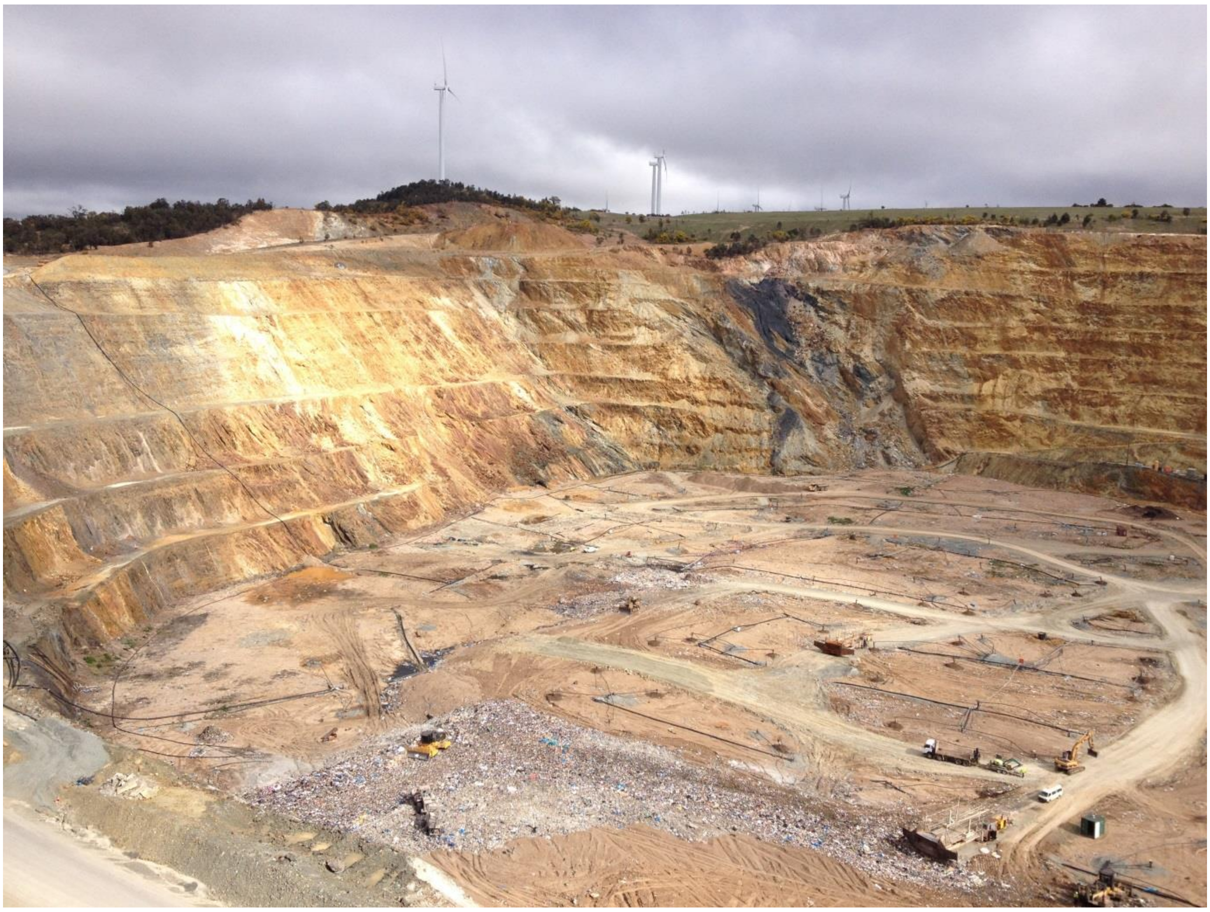


Figure 4.3: The Woodlawn mine site, now bioreactor (de Waal, L. 2015).

The suggestion is the ACT would send almost the entirety of their landfill to the Tarago site. Veolia has an already-established facility, negating the need for the ACT Government to commit large sums of money to WTE infrastructure. Utilising existing rail or road links, the transfer of landfill could happen almost immediately.

However, while Veolia has laid foundations of a sustainable facility, some plans are not yet established. For instance, there are six generators installed at present to combust the methane, each producing approximately 1.33 MW of power (Anonymous, d. 2015). Veolia plans to install a total of 24 generators, one every 18 months, to finally power 37,500 homes annually coupled with the Infigen Energy turbines (Veolia Energy, 2014b). Should the waste input into the mine outweigh the methane collection abilities, then the scheme might be releasing unwanted greenhouse gases.

A soon-to-be-commissioned component is the Mechanical Biological Treatment (MBT) facility, which has been designed to extract organic content from the mixed waste stream (Veolia Energy, 2014b). Landfill brought to the facility will be placed in slowly rotating drums, separating the organics from the total waste (Veolia Environmental Services, 2014). These organics will be treated and matured into compost, assisting in mine-site rehabilitation projects (Veolia Environmental Services, 2014). Veolia expects that this scheme would divert approximately 60% of material from the landfill (Veolia Environmental Services, 2014). The drums were on site on September 8 2015, however the facility has not yet started construction (Anonymous, d. 2015).

4.3 Recommendations

Community composting seems a novel idea when minimising initial waste stream input. However, the simplest and most instant solution to deal with the rising waste issues would be to arrange transport of all future waste to the Woodlawn Eco-Precinct.

Before commitment, this idea needs to be carefully analysed. A scheme like this fosters a lifestyle where ACT Government and residents are not dealing with their own waste, alleviating all pressure to reduce system input. Communities and businesses would no longer have an incentive to reconsider high levels of consumerism behaviour. Waste initiatives or education strategies would be rendered unnecessary, due to this ‘out of sight, out of mind’ situation. Costs and access would also be subject to external decision-makers such as the NSW Government.

Connotations of transferring waste to Woodlawn would be that WTE scheme was no longer required in the ACT. While transfer stations may still remain viable, the ACT would no longer have use for landfills. This may have a trickle-down effect of job losses in ACT Government waste management employed positions.

Veolia would need to consider if accepting the ACT's waste is a practical business decision. Deliberation is vital regarding the impact of additional waste on the lifespan of the mine. At the current rate, the site can support waste disposal for more than 50 years (Calculation in Appendix 7.1). This lifespan would reduce to approximately 38 years, given a situation where Woodlawn accepts the entirety of the ACT landfill. However, Veolia state that they were granted approval in 2012 to increase annual waste input from Sydney (Veolia Energy, 2014b), planning to accept close to 50% of Sydney's total landfill in future. This, coupled with the total landfill from the ACT, would reduce the mine's lifespan to a mere 20 years. Veolia needs to consider if this partnership with the ACT is detrimental to the future of their facility.

This then demonstrates a case where the Woodlawn 'solution' presents as more of a 'techno-fix', one that would last no more than 38 years for the ACT, before the territory faces a major issue with lack of planning or space for waste disposal. It is recommended that Woodlawn is not a solution for the future of waste management in the ACT, as any solution committed to needs to be viable for at least 50 years. Instead, smaller scale practices like community composting should be utilised in ACT waste solutions.

Chapter 5: Education and Engagement

Further education provided by the government at an individual level could see a reduction to the waste stream input, and should be considered prior to the commitment to WTE facilities. To reduce waste at this level, a much stronger focus on fostering and developing community commitment to, and understanding of, waste management is necessary.

5.1 Changes to the Waste Hierarchy

Previous discussions have found the traditional waste hierarchy taught as 'reduce, reuse, recycle' omits options on which the public should be educated. The hierarchy is important not only because it is embedded in waste management policy, underpinning objectives and outcomes, but also because it is adopted in lifestyle waste practices when taught to residents.

An updated hierarchy was presented in the newest waste management strategy as 'reduce, reuse, recycle, recover, landfill' (ACT Government, 2011).

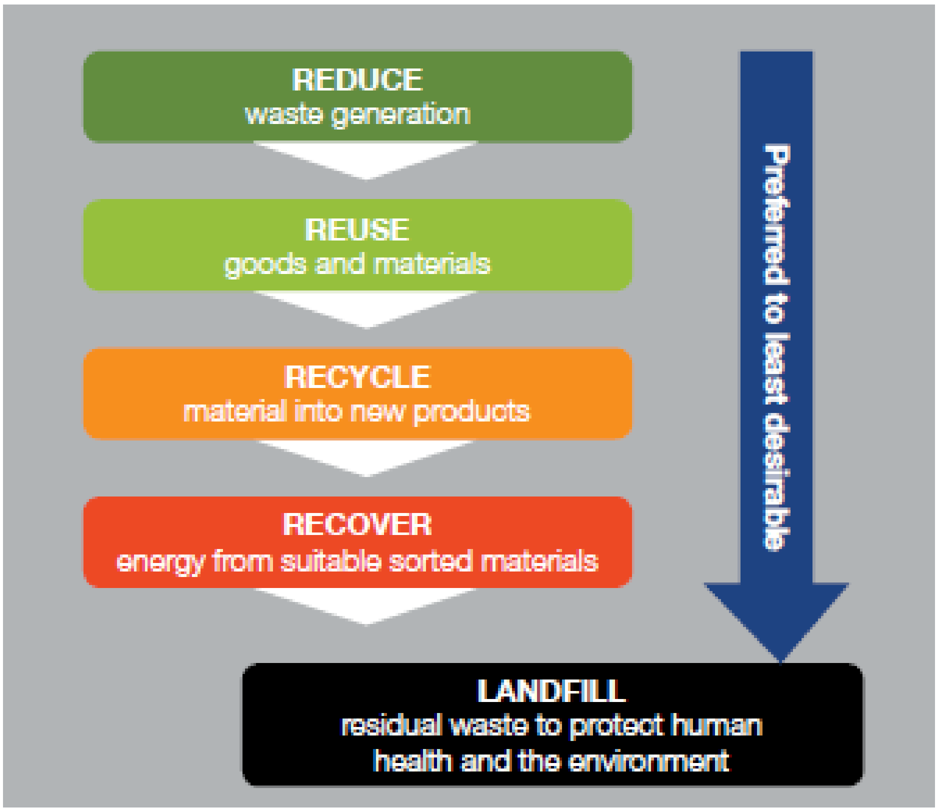


Figure 5.1: The current ACT waste hierarchy (ACT Government, 2011).

However, this hierarchy still leaves out important stages which would promote maximum material recovery. It is suggested that a superior hierarchy for the ACT would comprise ‘refuse (reject), reduce, reuse, recycle, recover, landfill’, pictured below (Figure 5.2).

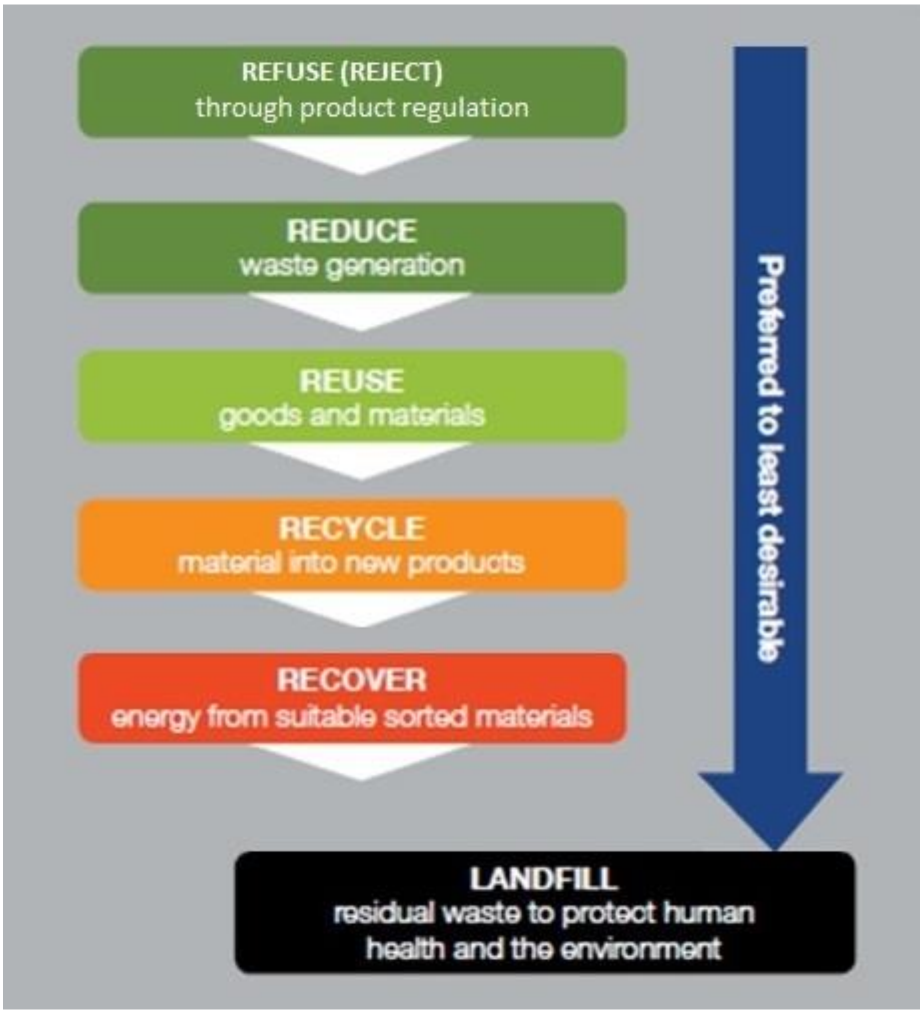


Figure 5.2: The suggested waste hierarchy (altered from ACT Government, 2011).

It has been suggested that future waste hierarchies could also include a ‘reprocessing’ stage, where waste heading to landfill is sent back through all stages again, to remove objects missed the first time. Obviously, this step would have to occur prior to the ‘recover’ stage, where energy is drawn from resources. This reprocessing might incur large costs, which is why it has not been included in the immediate waste hierarchy, as a cost analysis would have to be undertaken to determine feasibility.

5.2 Gaining Community Consent

Before ACT Government can commit to WTE infrastructure, it is imperative to gain community consent for such a scheme. The term 'community' in this case refers to all stakeholders surrounding the WTE scheme.

The Waste Management Association of Australia has released a Sustainability Guide for Energy from Waste Projects and Proposals (2003). This guide presents a code of practice when initiating and establishing such a facility. The guide recognises how crucial the role played by the community is (WMAA, 2003), and that such a scheme requires a 'community licence' to operate (WMAA, 2003). Suggested is a process and framework for interaction, beginning with the need to provide information, then stimulating involvement and lastly to maintain a transparent and accountable process (WMAA, 2003). This importance is further highlighted in the iterative roadmap in Figure 5.3, which includes 'communicate and consult' as a key factor throughout the process, and the 'community licence to operate' as the final stage before scheme commitment.

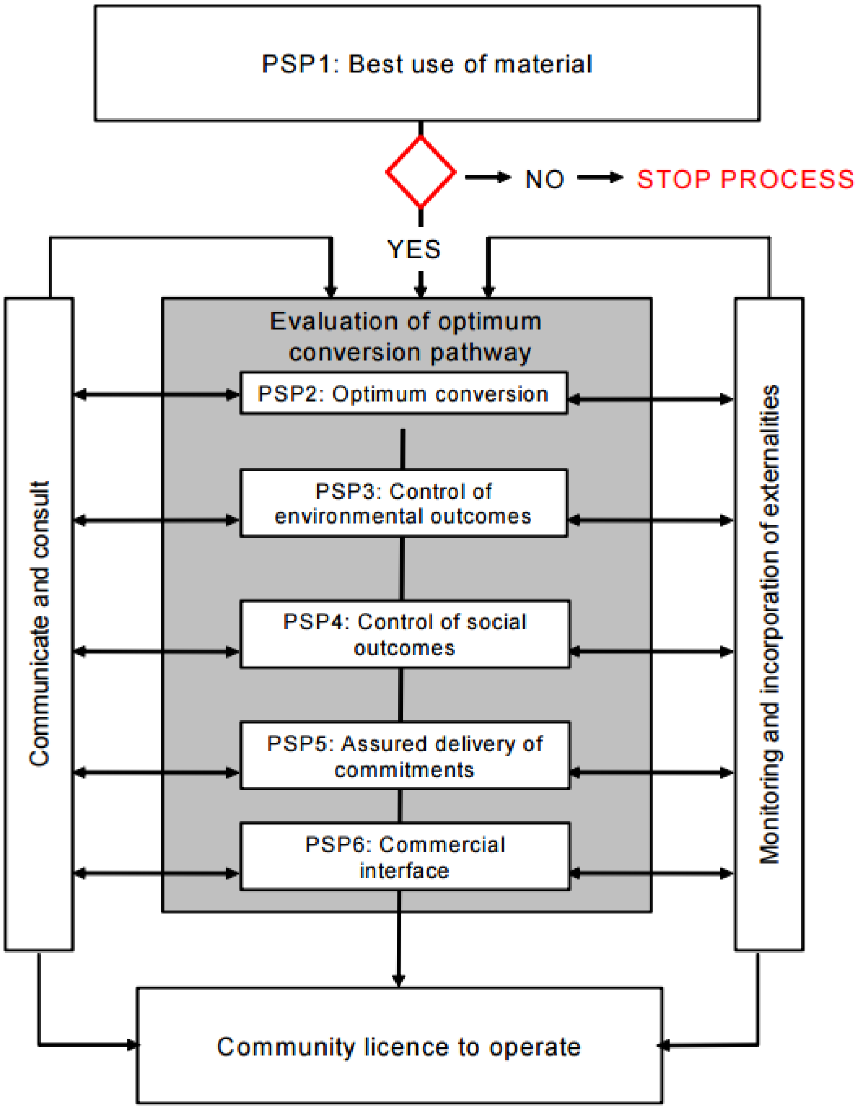


Figure 5.3: Assessment roadmap of scoping principles for WTE schemes (WMAA, 2003).

Engaging the community in this case would reap additional benefits, as community understanding of waste generated would be enhanced by engagement. The ACT Government could expect a reduction in waste generation from this involvement. Finally, the development of engagement schemes may see better communication between governmental departments.

5.3 Recommendations

Education processes highlighting a new waste hierarchy and the potential development of a WTE scheme are important for engaging local residents. The government should immediately adapt the waste hierarchy to include ‘refuse (reject)’, to promote the highest net resource value (HNRV), where communities are challenged to rethink the value of resources and ensure materials exit waste streams at their ‘highest value’.

The notion of gaining consent is applicable particularly to the team within ACT Government undertaking the current feasibility study and business case. They need to ensure they are responsive, transparent, accessible and truthful to the community and all stakeholders. Community consultation should not be mistaken for community consent.

Chapter 6: Conclusion

The waste to energy proposal in the newest ACT budget will come at a large expense to the ACT Government and local community. There are a variety of initiatives recommended across the three major hierarchical levels, which would reduce input to the waste stream and manage the current waste generated. It is important to note that there are many other initiatives which could be discussed in this context. However, those suggested are immediately implementable, and the reduction they encourage could impact the viability of such large WTE infrastructure over time.

The waste levels in the ACT will require ongoing monitoring and constant reassessment through better data collection to make certain better practice approaches are employed, ensuring the sustainable future of the territory.

Appendices

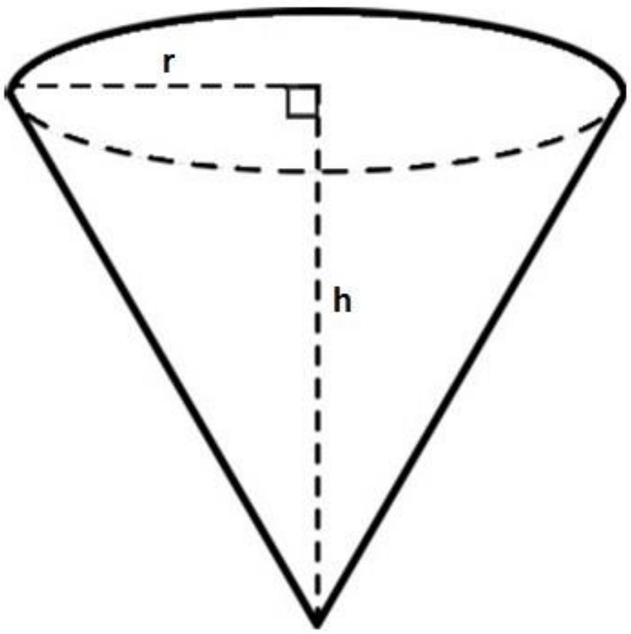
7.1 Woodlawn Bioreactor – Ballpark Analysis of Lifespan

This ballpark analysis provides an estimate for the volume of the Woodlawn Bioreactor, and uses this information along with gathered waste data to predict the lifespan of the facility. The calculation estimates the volume of the mine, the rate at which it is being filled and the lifespan of the facility based on different scenarios of supply of materials from both the ACT and the Sydney urban area.

Lifespan extensions due to separation, compaction or break-down processes were estimated, rather than calculating location-specific amounts. It makes approximations of tonnage based on an idealised conversion of household waste density from weight to volume. Figures used were provided by employees, found online or estimated based on typical mine-infrastructure statistics.

Step 1: Area of Mine - Total

To estimate the lifespan of Woodlawn, original capacity was estimated using the volume of a cone, which represents the shape of a typical open-cut mine and reflects the shape seen in photographs of the Woodlawn site at the end of its life as a mine. The Woodlawn site diameter is approximately 1 kilometre, and a depth of 200 metres. Therefore, the radius (r) is assumed as 500 m, and height (h) as 200 m.



Total capacity of this mine can then be found using the formula for volume of a cone

$$V_{TOTAL} = \pi r^2 \frac{h}{3}$$

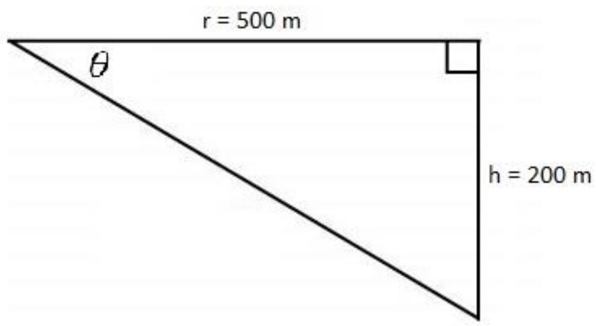
$$V_{TOTAL} = \pi 500^2 \frac{200}{3}$$

$$V_{TOTAL} = 52.4 x 10^6 m^3 \approx 52{,}359{,}878 m^3$$

Step 2: Area of Mine – Already Used

Next, the amount of used space in the mine can be estimated. Waste already in the mine is at a height of approximately 85 m.

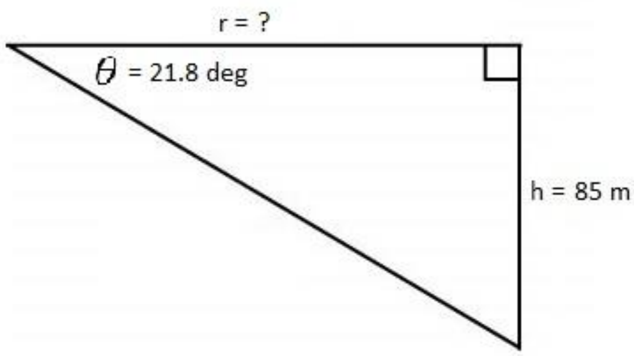
Radius was estimated using trigonometry, assuming proportional decrease and consistent angle.



$$\tan\theta = \frac{200}{500}$$

$$\theta = \tan^{-1}\frac{200}{500}$$

$$\therefore \theta = 21.8°$$



$$\tan 21.8° = \frac{85}{r}$$

$$r = \frac{85}{\tan 21.8}$$

$$\therefore r \approx 212.5\ m$$

From here, capacity already full can be calculated using the volume formula again

$$V_{USED} = \pi r^2 \frac{h}{3}$$

$$V_{USED} = \pi\ 212.5^2 \frac{85}{3}$$

$$V_{USED} = 4.02\ x\ 10^6 m^3 \ \approx 4{,}019{,}439\ m^3$$

Step 3: Area Remaining

The space remaining in the mine is then

$$V_{REMAINING} = V_{TOTAL} - V_{USED}$$

$$V_{REMAINING} = 52{,}359{,}878\ m^3 - 4{,}019{,}439\ m^3$$

$$V_{REMAINING} = 48{,}340{,}439\ m^3$$

Step 4: Lifespan at Current Rate (20% Sydney Waste)

Household waste density can be estimated as 0.481 tonnes per cubic metre (Aqua-Calc, 2015). Veolia’s website states that the Woodlawn Bioreactor was accepting approximately

500,000 tonnes per year until 2012, which is approximately 20% of Sydney's total annual landfill generation (Veolia Energy, 2014b). This figure will be used as the current input rate.

This predicted yearly tonnage can be converted to a volume equivalent

$$V_{YEARLY} = \frac{Tonnes\ per\ year}{0.481}$$

$$V_{YEARLY} = \frac{500{,}000\ tonnes\ per\ year\ (SYD)}{0.481}$$

$$V_{YEARLY} = 1{,}039{,}501 \frac{m^3}{yr}$$

Assuming that the yearly volume (V_{YEARLY}) represents the proportion of Sydney's waste entering the landfill annually from now onwards, the lifespan of the mine can be determined

$$Lifespan = \frac{V_{REMAINING}}{V_{YEARLY}}$$

$$Lifespan = \frac{48{,}340{,}439\ m^3}{1{,}039{,}501 \frac{m^3}{yr}}$$

$$Lifespan \approx 46.5\ years$$

However, compaction and breakdown processes have a profound impact on the lifespan of a landfill holding. It is estimated that compaction and breakdown using heavy machinery can extend a lifespan by at least 20%. A clearer figure is landfill specific, depending on the unit weight of municipal solid waste and a variety of treatment factors (Zekkos *et al.* 2006). For this ballpark analysis, the lifespans will be extended by 20% to account for all breakdown and compaction processes.

$$Lifespan \approx 46.5\ years * 120\%$$

$$Lifespan \approx 56\ years$$

Therefore, the actual lifespan if the Woodlawn Bioreactor continues to accept 20% of Sydney's landfill is **56 years.**

Step 5: Lifespan at Current Rate including ACT Waste (100% ACT Waste, 20% Sydney Waste)

There are discussions of the ACT sending all landfill to the Woodlawn Bioreactor for processing. This would add approximately 240,000 tonnes annually, not factoring in potential ACT waste growth rates, and would reduce the Woodlawn Bioreactor lifespan as the yearly input volume increases

$$V_{YEARLY} = \frac{Tonnes\ per\ year}{0.481}$$

$$V_{YEARLY} = \frac{500{,}000\ tonnes\ per\ year\ (SYD) + 240{,}000\ tonnes\ per\ year\ (CBR)}{0.481}$$

$$V_{YEARLY} = 1{,}538{,}462\,\frac{m^3}{yr}$$

The lifespan then reduces to

$$Lifespan = \frac{V_{REMAINING}}{V_{YEARLY}} * 120\%$$

$$Lifespan = \frac{48{,}340{,}439\ m^3}{1{,}538{,}462\,\frac{m^3}{yr}} * 120\%$$

$$Lifespan \approx 38\ years$$

Therefore, the reduced lifespan if the Woodlawn Bioreactor continues to accept 20% of Sydney's landfill, and 100% of the ACT's landfill, is **38 years.**

Step 6: Lifespan at Forecasted Rate incl. ACT Waste (100% ACT Waste, 50% Sydney Waste)

Veolia state on their website that in 2012 they were granted approval to increase the annual waste input rate to 1.13 million tonnes per year, accounting for almost 50% of Sydney's current landfill amounts (Veolia Energy, 2014b). Again, not including increases in waste growth rates, the lifespan can be calculated

$$V_{YEARLY} = \frac{Tonnes\ per\ year}{0.481}$$

$$V_{YEARLY} = \frac{1{,}130{,}000\ tonnes\ per\ year(SYD) + 240{,}000\ tonnes\ per\ year(CBR)}{0.481}$$

$$V_{YEARLY} = 2{,}848{,}233\,\frac{m^3}{yr}$$

The lifespan then reduces to

$$Lifespan = \frac{V_{REMAINING}}{V_{YEARLY}} * 120\%$$

$$Lifespan = \frac{48{,}340{,}439\ m^3}{2{,}848{,}233\,\frac{m^3}{yr}} * 120\%$$

$$Lifespan \approx 20\ years$$

Therefore, the reduced lifespan if the Woodlawn Bioreactor accepts 50% of Sydney's landfill, and 100% of the ACT's landfill, is **20 years.**

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