SECTION 3. FEEDSTOCK RESOURCES

Pictured: Waste containers in Sydney before New Year's Eve.
Credits: Maroual, 2009.

twe

efficiency | renewables | innovation

City of Sydney LGA

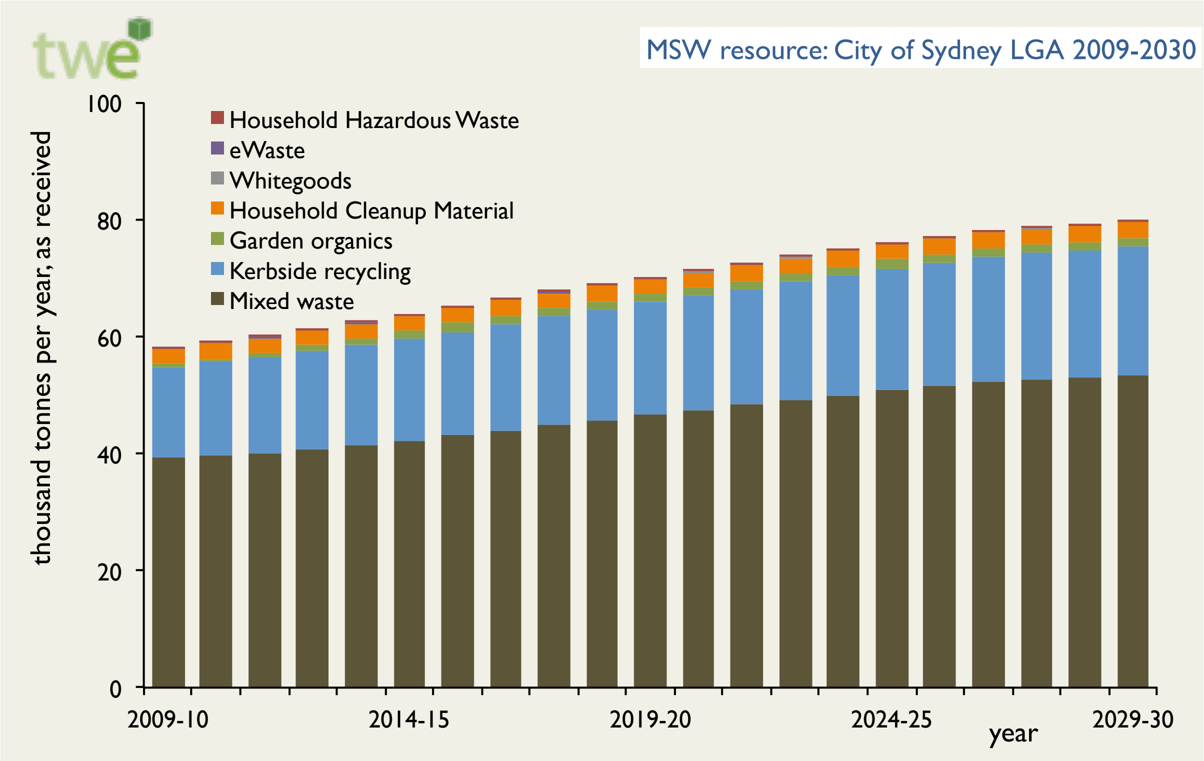
Domestic waste

Waste collection

The diagram below illustrates current and projected quantities of domestic waste generated within the City of Sydney LGA, broken down by collection method.

In 2010-11, the total amount of waste collected from domestic customers was 59,121.2 t, a quantity projected by City of Sydney to increase to just below 80,000 t in 2029-30. At 67% of total waste collected in 2010-11, mixed waste represents the largest fraction of the domestic waste stream, followed by kerbside recycling, accounting for 27% of the total collected in the same year.

Figure 24. Domestic waste quantities collected, City of Sydney LGA, 2009-30.

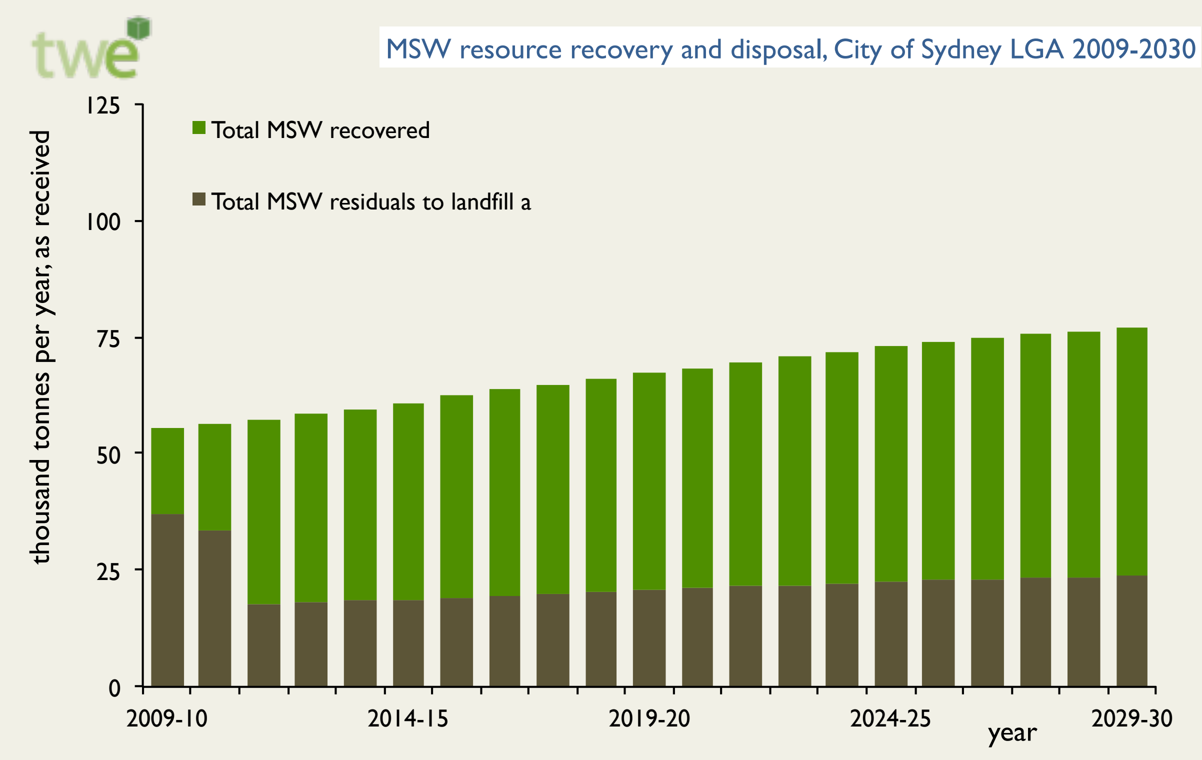


Recovery, treatment and disposal

Resource recovery within the City LGA has been historically limited to source-separated materials (kerbside recycling and garden organics), accounting for a resource recovery rate of 24.95% in 2008-09. This figure increased to 49.05% in 2010-11 through diversion of 20,437 t of domestic waste to the ArrowBio Alternative Waste Treatment (AWT) facility operated by WSN Environmental Solutions at Jacks Gully, near Camden.

From 2011-12 onwards, domestic waste residuals have been diverted to another AWT facility operated by SITA Environmental Solutions, as a transitional measure prior to final decisions on the City's own SfW processing solution.

Figure 25. Domestic waste – resource recovery and disposal, City of Sydney LGA, 2009-30.



This transitional arrangement allows for about 98% of mixed waste collected to be diverted to the SITA AWT facility. With about 40,000 t to be diverted in 2011-12, the resource recovery rate increased to 66%, meeting the state-wide target set by the NSW Government two years ahead of the target year of 2014.

The SITA facility has a waste processing efficiency of over 50%, with the remainder of the diverted material to be returned to landfill as AWT residual.

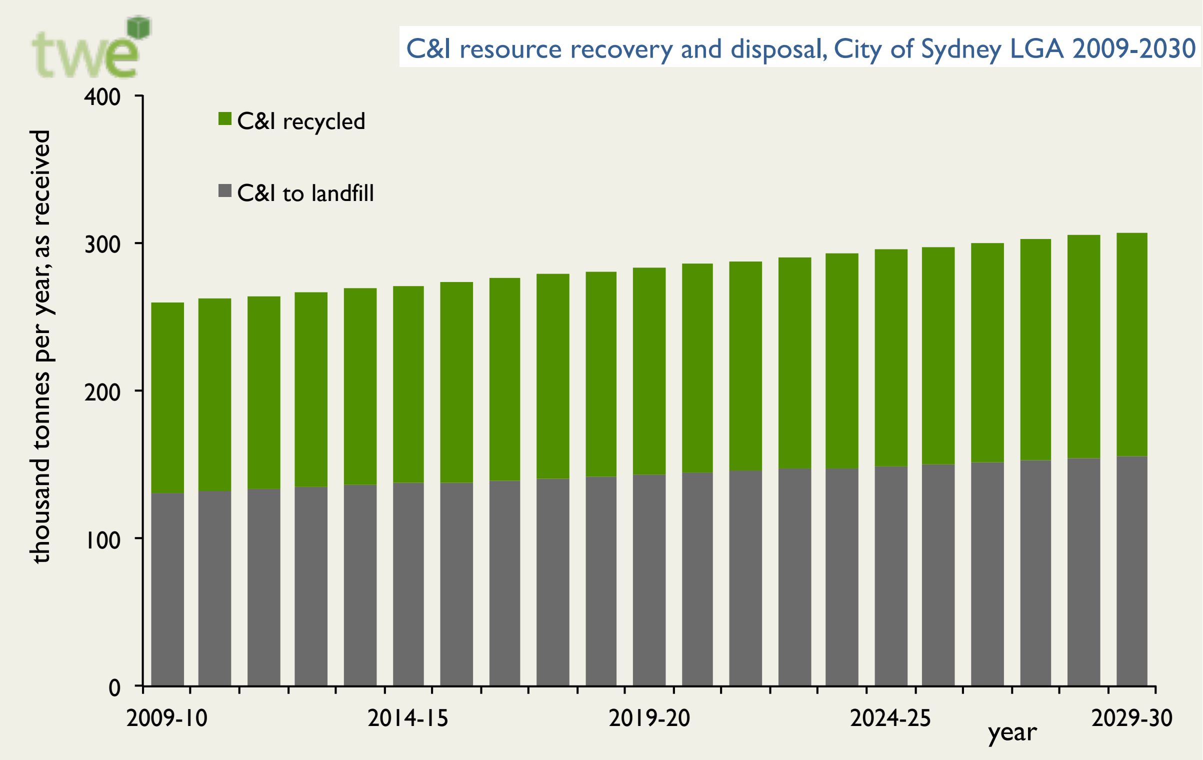
Commercial and Industrial Waste

Management services for Commercial and Industrial (C&I) wastes generated across the Sydney region are provided through private contractors.

In a disposal-based survey conducted in 2008, the NSW Department of Environment, Climate Change and Water (DECCW) estimated the fraction of C&I waste collected within the City of Sydney LGA at 7% of total collected across the Sydney metropolitan area (DECCW 2010). Resource recovery rates were estimated by the same source at 42% in that year.

Based on these figures and projections developed by Hyder Consulting for the City of Sydney (Hyder Consulting 2011), total C&I waste collected across the City of Sydney LGA is estimated at 261,749.4 t in 2010-11, a quantity projected to grow up to 307,153.7 t in 2029-30, as summarized in the diagram below.

Figure 26. Commercial and Industrial waste – resource recovery and disposal, City of Sydney LGA, 2009-30.



The assessment of residual waste resources available within the region surrounding Sydney is based on a detailed resource assessment presented under Appendix A.

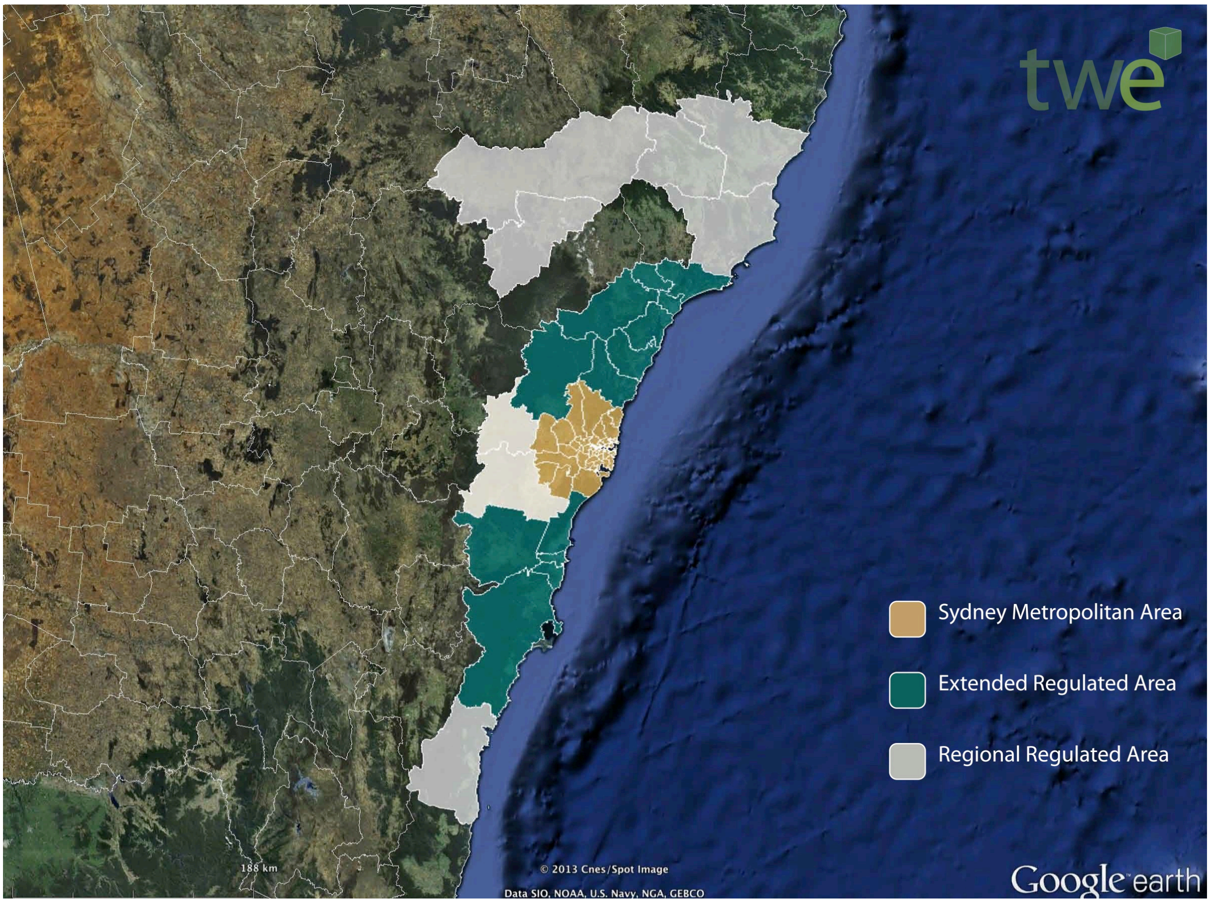
Beyond the City

Regulated areas

The NSW EPA defines four regulated waste and resource recovery (WARR) regulated areas:

- the **Sydney Metropolitan Area (SMA)**, including local government areas (LGAs) in the greater Sydney region;
- the **Extended Regulated Area (ERA)**, including LGAs in the Newcastle, Central Coast and Illawarra Regions;
- the **Regional Regulated Area (RRA)**, including the Hunter Region, and the Blue Mountains, Wollondilly and Eurobodalla LGAs; and
- the **Non Regulated Area (NRA)**, including the rest of New South Wales.

Figure 27. Regulated waste management areas, New South Wales



Domestic waste resources

Generation, recovery, treatment and disposal

The table below reports the latest available data on domestic waste (MSW) generation, recycling and disposal from the regulated areas of NSW, as published by the NSW Department of the Environment, Climate Change and Water (DECCW 2011b).

The two regions focus of this assessment, SMA and ERA, accounted in 2008-09 for 50.05% and 21.08% of the total MSW generated in New South Wales, respectively. In the same year, resource recovery rates across the two areas were 50.61% for the SMA and 43.50% for the ERA.

Use of alternative waste treatment (AWT), through mechanical-biological conversion (MBT or composting), is more advanced in the SMA, with 10.62% of the post-MRF residuals diverted to these facilities, compared to 2.82% in the ERA.

Table 11. domestic waste generation, recycling and disposal – NSW 2008-09, by regulated area

	Domestic waste (MSW) - 2008-09			
	SMA	ERA	RRA/NRA	NSW
MSW generated, t	2,126,000	895,500	1,226,500	4,248,000
Resource Collection				
Kerbside				
Source-separated (recyclables)	1,004,562	380,798	389,091	1,774,451
Mixed waste (non recyclables)	1,121,438	514,702	837,409	2,473,549
Resource Recovery, Treatment and Disposal				
Recycled materials	1,004,562	380,798	389,091	1,774,451
MSW residuals to landfill	1,121,438	514,702	837,409	2,473,549
Delivered to AWT	119,063	14,503	14,849	148,415
AWT residual to landfills [a]	47,625	5,801	5,940	59,366
Total MSW recovered	1,076,000	389,500	398,000	1,863,500
Total MSW residuals to landfill	1,050,000	506,000	828,500	2,384,500
Resource Recovery performance				
Resource recovery rate, %	50.61%	43.50%	32.45%	43.87%
Post MRF residues to AWT	10.62%	2.82%	1.77%	6.00%

SOURCE: adapted from (DECCW 2011b), Table B2, p.5

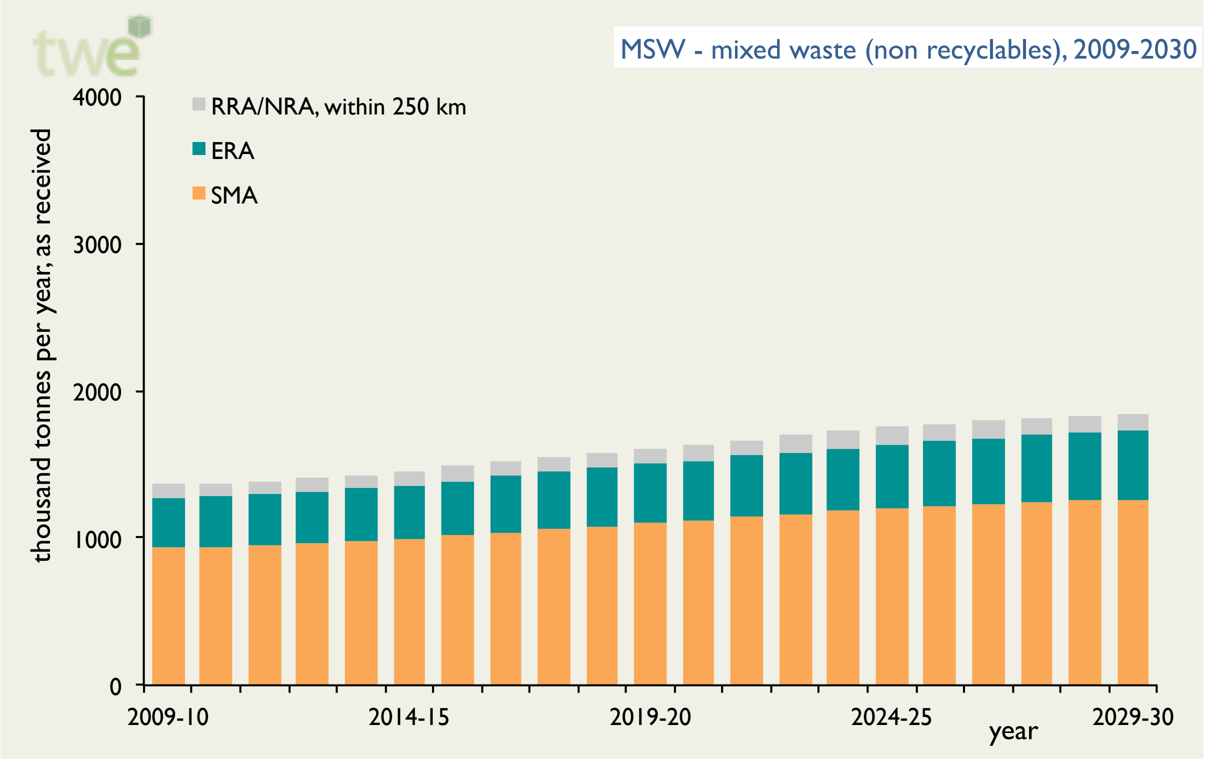
[a] AWT resource recovery efficiency 60% (Hyder Consulting 2012)

Within the scope of this Study, Talent with Energy has developed a set of projections for this resource, providing an estimate of total waste generated, resource recovery and residual MSW delivered to landfills through to 2029-30.

Target resource

Thermal conversion is a treatment option more advanced than mechanical-biological treatment under both a waste management and energy recovery perspective. For this reason we assume that Syngas from Waste facilities, once in operation, will replace MBT as the preferred Alternative Waste Treatment (AWT) option for Councils in the catchment region. Accordingly, the target feedstock resource considered within this study is the fraction of waste generated that is not source-separated for downstream resource recovery, eg. the *mixed waste* stream from kerbside collection activities. The chart below illustrates the projected evolution of this resource through the 2009-2030 timeframe.

Figure 28. MSW – mixed waste (non recyclables), 2009-2030

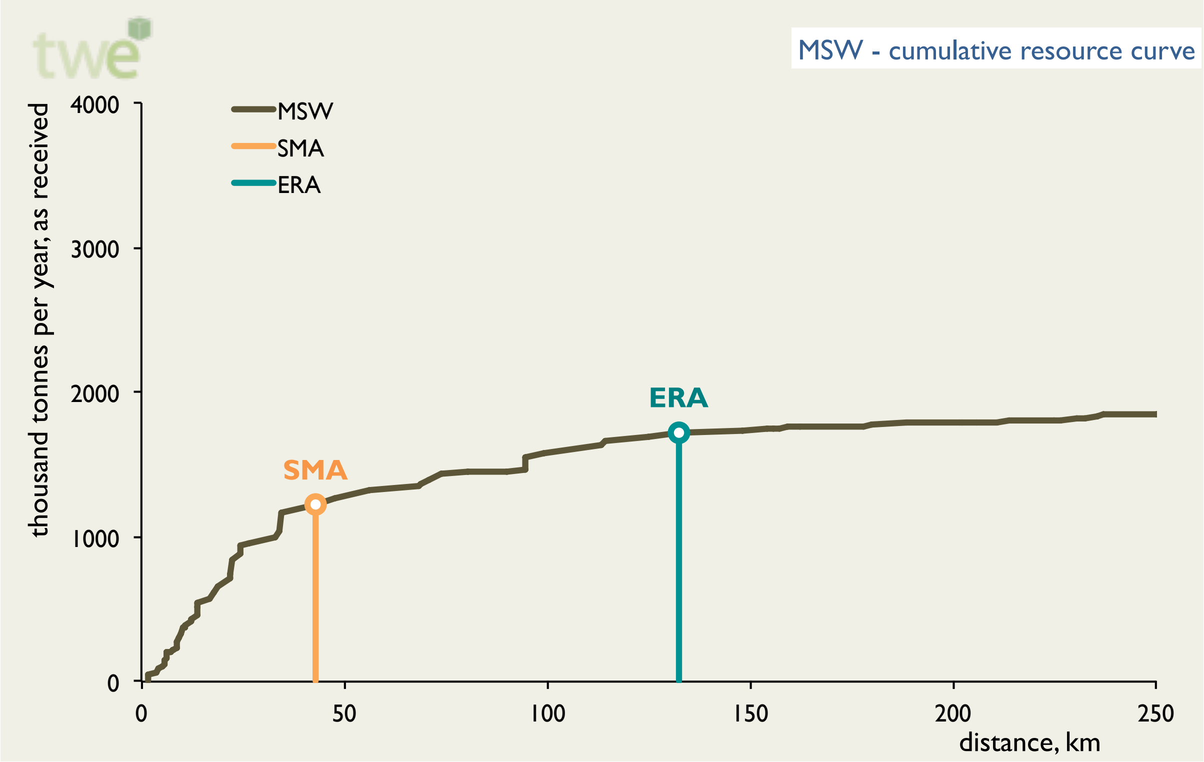


The total residual MSW resource available within a 250-km radius from the City of Sydney LGA is projected to grow 35.52% over this timeframe, from 1.381 million tonnes per year in 2009-10 to 1.871 million tonnes per year in 2029-30.

Resource distribution

The 2029-30 *cumulative resource curve*, below illustrates the distribution of the available resource with regard to its distance from the City.

Figure 29. MSW non recyclables – cumulative resource curve, 2029-30



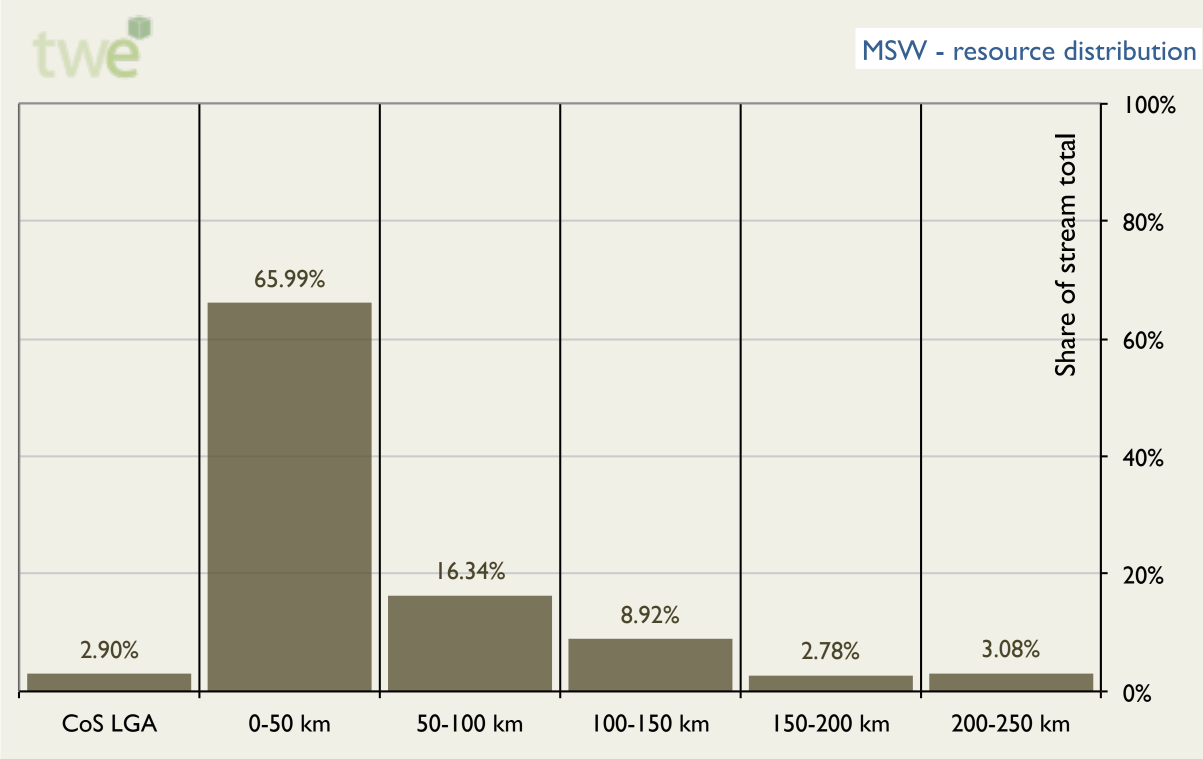
The two vertical lines indicate the boundaries of the SMA and ERA regions, set at 34.66 km (Camden SLA) and 106.97 km (Port Stephens SLA) from the City of Sydney LGA, respectively.

Collectively, the SMA and ERA regions accounts for 1.723 million tonnes per year or 92.1% of the total, 1.871 million tonnes per year, available in 2029-30 within a 250-km radius from the City of Sydney LGA.

This is illustrated further in the diagram below, where the available resource within a 250-km radius from the City is broken down in 50-km resource bands.

The densely populated areas in the region surrounding Sydney contribute the majority of this resource, with 70.7% of the total resource available within a 50-km radius from the City. Other significant contributions derive from the Wollongong, Newcastle and Central Coast areas, with a further 19.77% available between 50 and 100 km from the City.

Figure 30. MSW non recyclables – resource distribution, 2029-30



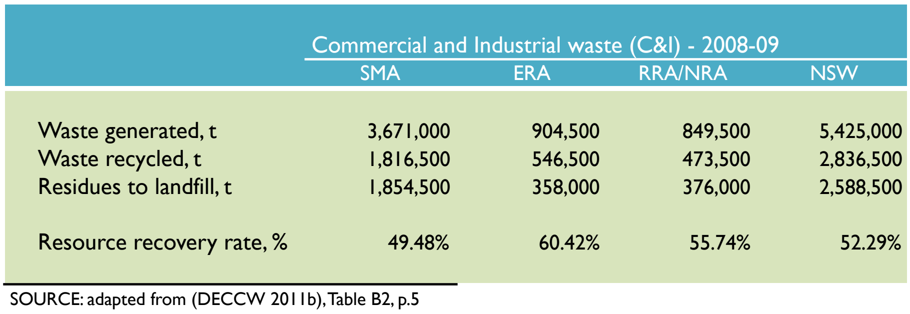
Commercial and Industrial waste resources

Generation, recovery, and disposal

New South Wales

The table below reports the latest available data on commercial and industrial (C&I) waste generation, recycling and disposal from the regulated areas of NSW, as published by the Department of the Environment, Climate Change and Water (DECCW 2011b).

Table 2. Commercial and Industrial waste generation, recycling and disposal – NSW 2008-09, by regulated area



	Commercial and Industrial waste (C&I) - 2008-09			
	SMA	ERA	RRA/NRA	NSW
Waste generated, t	3,671,000	904,500	849,500	5,425,000
Waste recycled, t	1,816,500	546,500	473,500	2,836,500
Residues to landfill, t	1,854,500	358,000	376,000	2,588,500
Resource recovery rate, %	49.48%	60.42%	55.74%	52.29%

SOURCE: adapted from (DECCW 2011b), Table B2, p.5

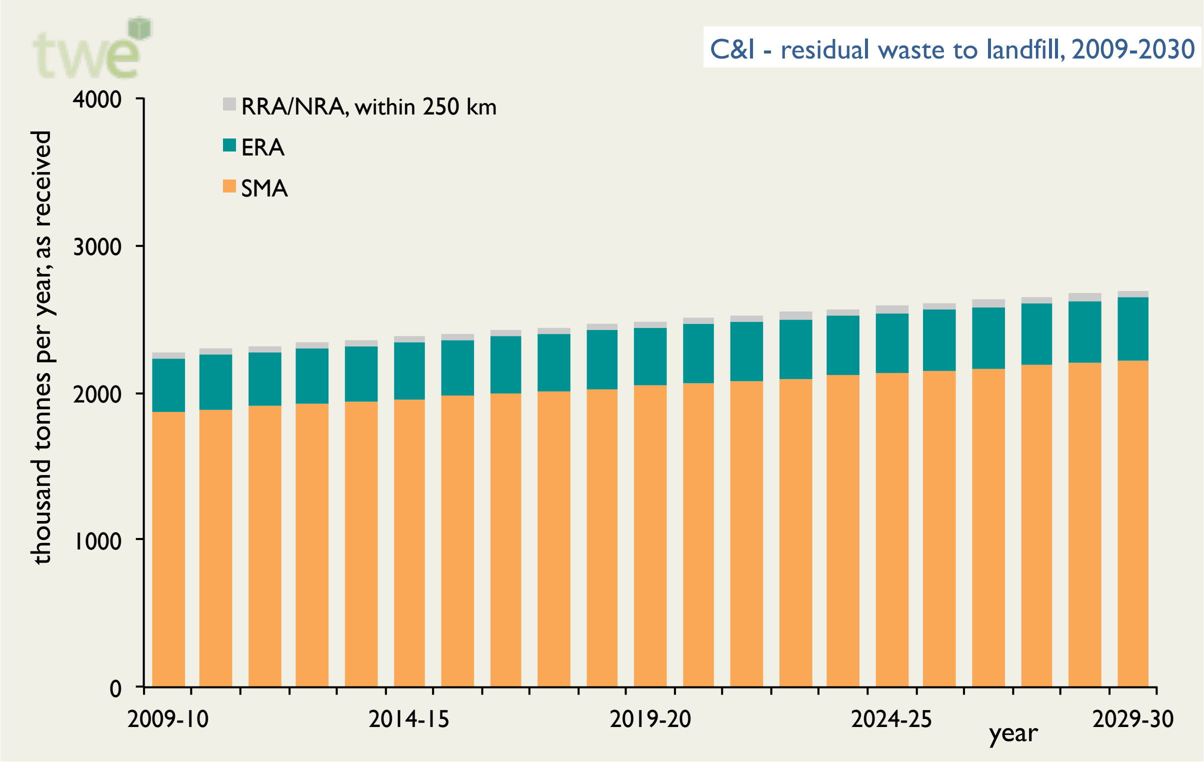
As for MSW, Talent with Energy has developed a set of projections for this resource, providing an estimate of total waste generated, resource recovery and residual C&I to landfills through to 2029-30.

Target resource

The target resource considered for this stream is the residual C&I waste delivered to landfill downstream of resource recovery activities. The chart below illustrates the projected evolution of this resource through the 2009-2030 timeframe.

The total residual C&I resource available within a 250-km radius from the City of Sydney LGA is projected to grow 21.79% over this timeframe, from 2.286 million tonnes per year in 2009-10 to 2.707 million tonnes per year in 2029-30.

Figure 31. C&I – residual waste to landfill, 2009-2030

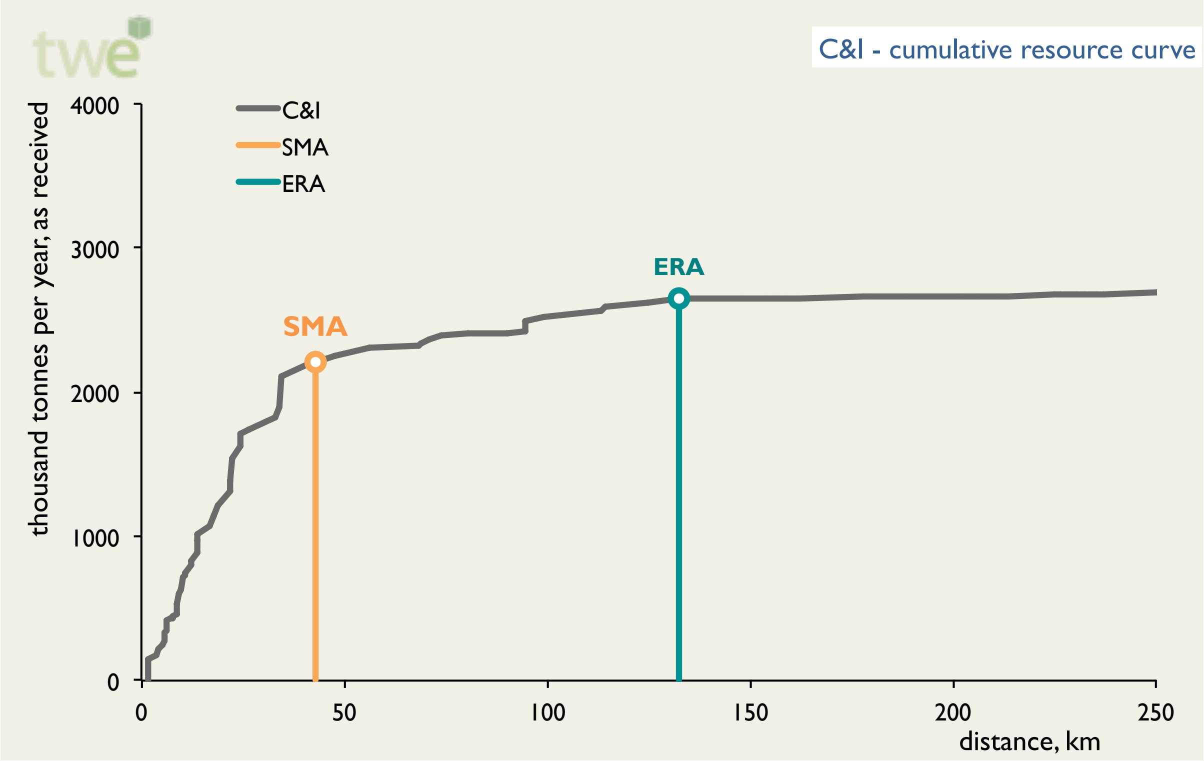


Resource distribution

For this resource stream, the contribution from the SMA and ERA region to the total resource available within 250 km - 2.707 million tonnes per year available in 2029-30 – is 2.645 million tonnes per year, or 97.7% of the total. This higher prpoportion than that observed for MSW reflects the higher degree of concentration of commercial and industrial activities in these metropolitan areas, when compared to the rest of the catchment region.

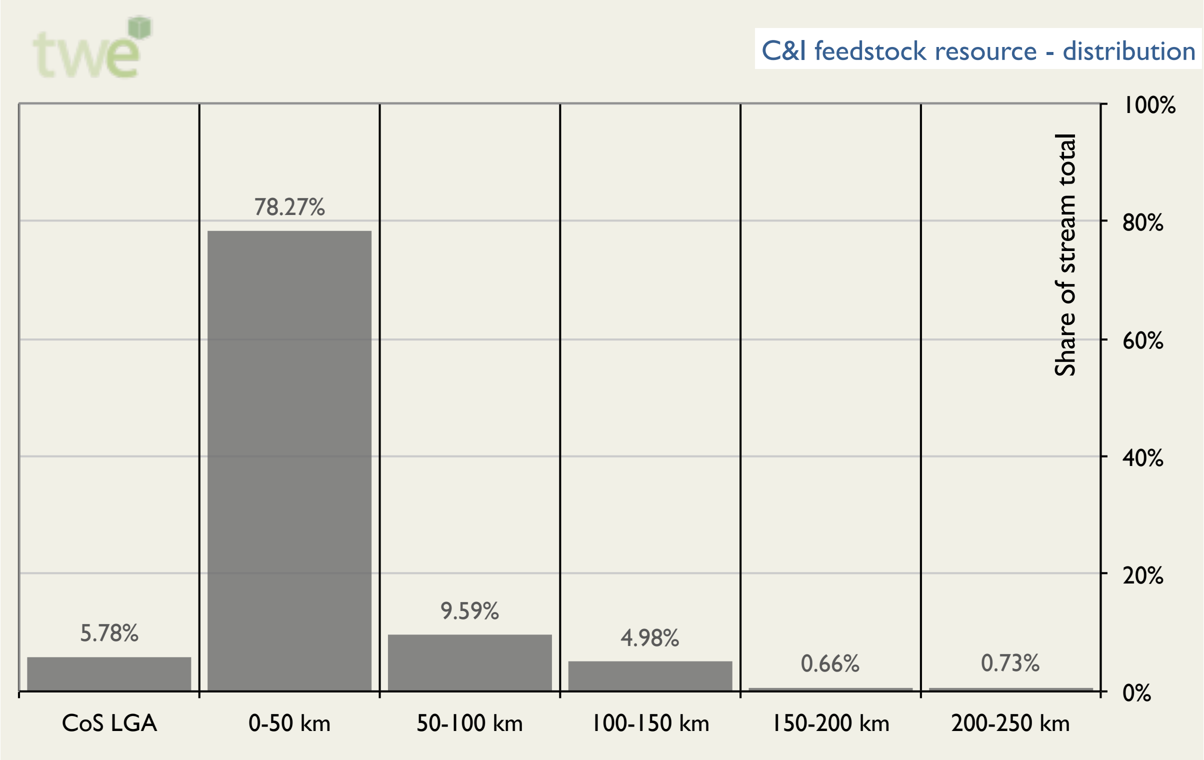
The 2029-30 *cumulative resource curve* for residual C&I is illustrated below.

Figure 32. C&I residues to landfill – cumulative resource curve, 2029-30



This is illustrated further in the diagram below, where the available resource within a 250-km radius from the City is broken down in 50-km resource bands.

Figure 33. C&I residues to landfill - resource distribution, 2029-30



The densely populated areas in the region surrounding Sydney contribute the majority of this resource, with 85.1% of the total resource available within a 50-km radius from the City. Other significant contributions derive from the Wollongong, Newcastle and Central Coast areas, with a further 11.69% available between 50 and 100 km from the City.

Resource characterization

Within the scope of this study, Talent with Energy has established a detailed feedstock resource characterization framework for residual waste to landfill from the MSW and C&I resource streams. The framework is described in detail in *Appendix A. Waste resource assessment and characterization*, we present here the key data of relevance to the modelling activities described further in this report, these include:

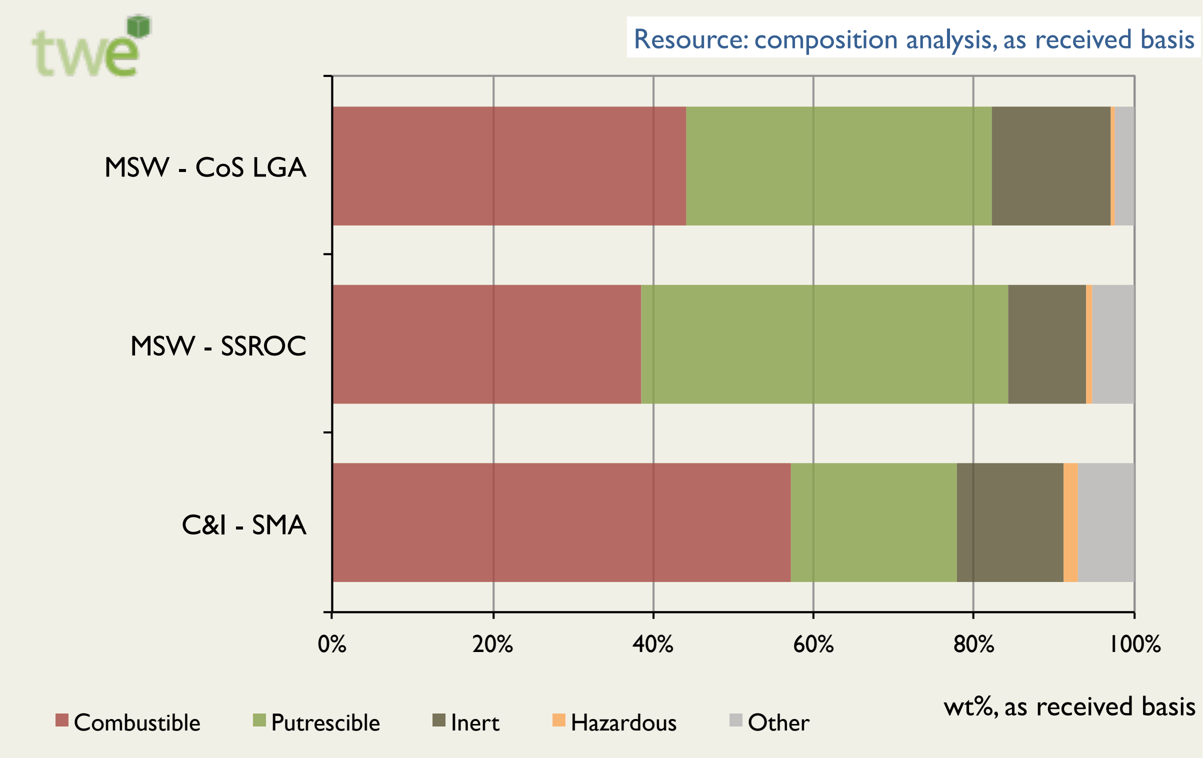
- waste stream composition
- feedstock elemental analysis and energy content;
- feedstock renewable fraction analysis.

Waste stream composition

The diagram below summarizes the resource composition data for this analysis, these are based on results from the following audit activities:

- **Domestic wastes**, collected within the City of Sydney LGA, and the SSROC region, sourced from (APC 2011a), and (APC 2011b), respectively; and
- **Commercial and Industrial wastes**, collected within the Sydney Metropolitan Area (SMA), sourced from (DECCW 2010).

Figure 34. Waste resource – composition analysis



Feedstock elemental analysis and energy content

Based on the matrix of processable fractions, the resource characterization framework presented in Appendix A enables to establish the following feedstock characteristics;

- the **elemental analysis**, or its chemical composition expressed in terms of its content, by weight, of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), inorganic compounds (Ash) and water content (Moisture); and
- the **energy content**, calculated from the feedstock elemental analysis data on the basis of an empirical correlation published in (Channiwala & Parikh 2002).

The four charts below present the resulting elemental analysis and energy content data for the two categories of LTC/HTC and HTCM feedstocks.

LTC/HTC feedstocks

Figure 35. LTC/HTC waste feedstocks – elemental analysis, as received basis

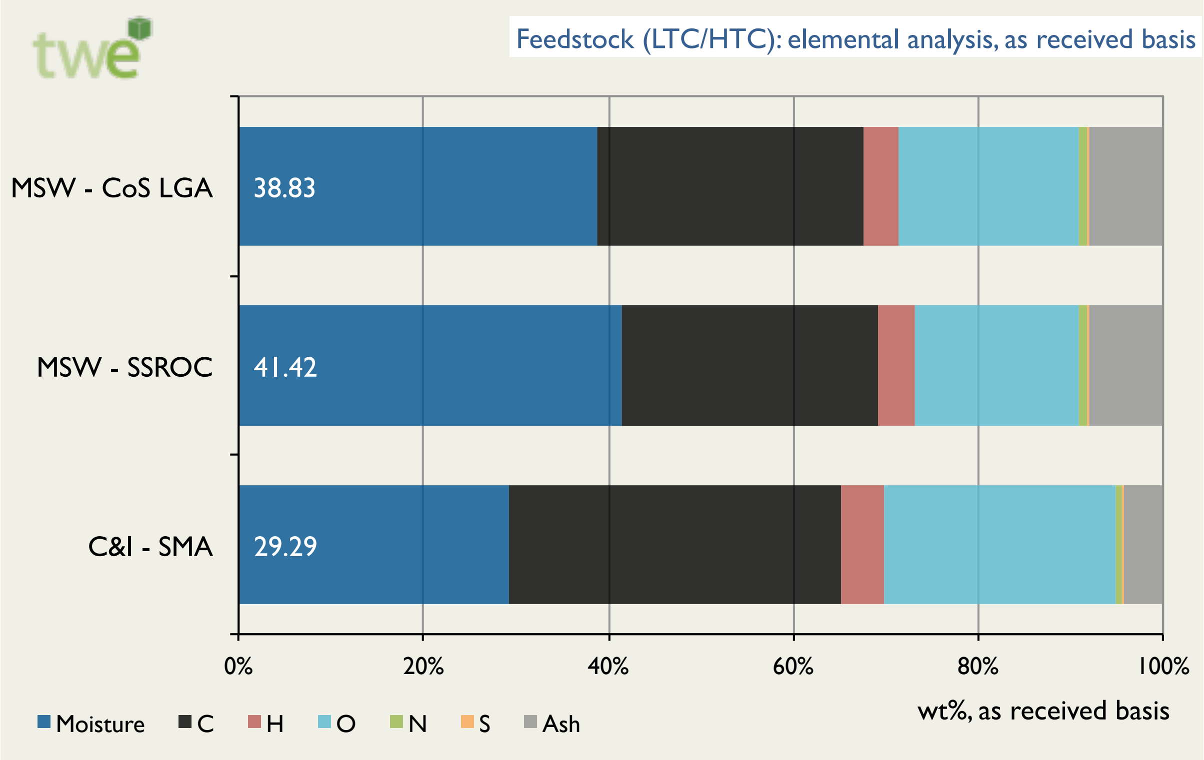
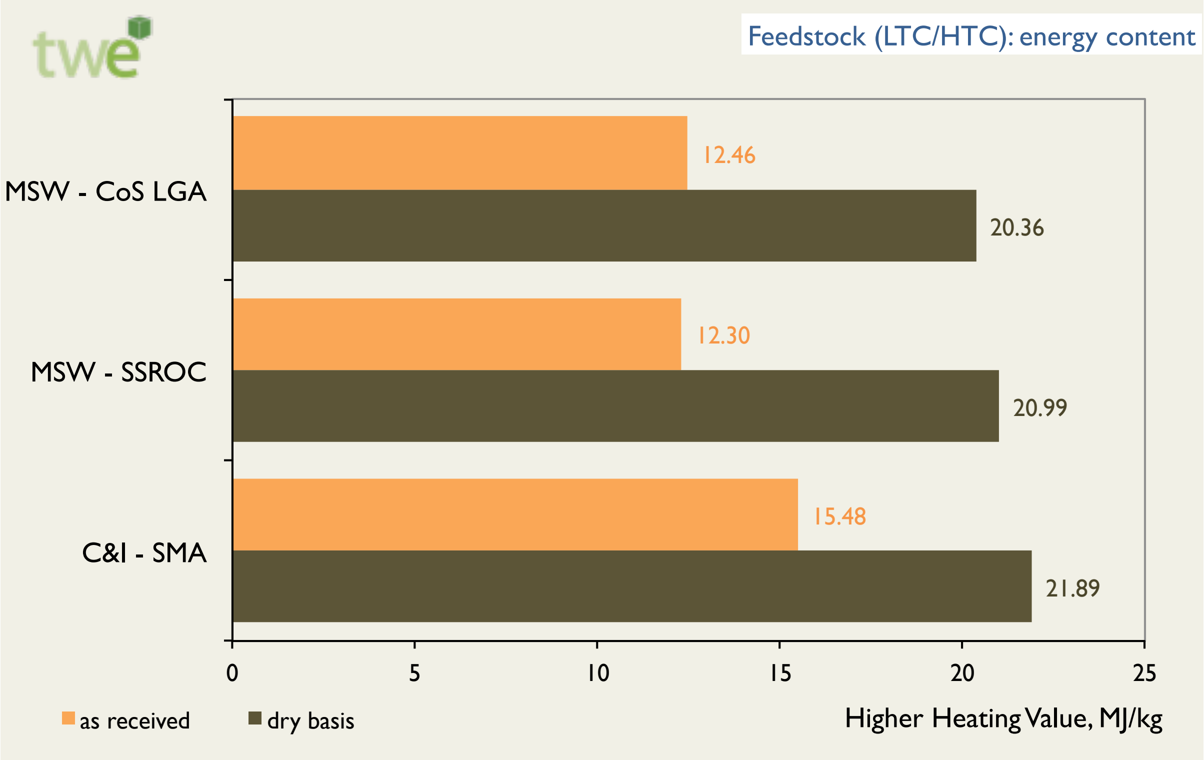


Figure 36.LTC/HTC waste feedstocks – energy content, HHV basis



HTCM feedstocks

Figure 37.HTCM waste feedstocks – elemental analysis, as received basis

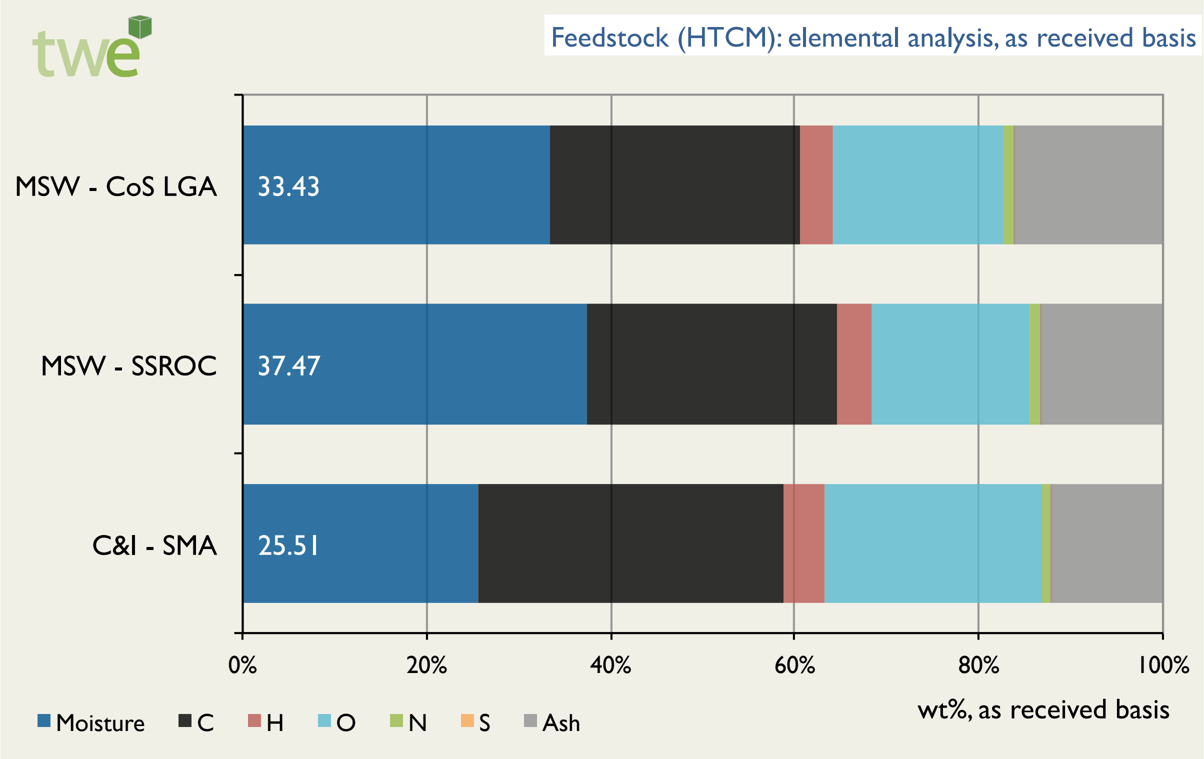
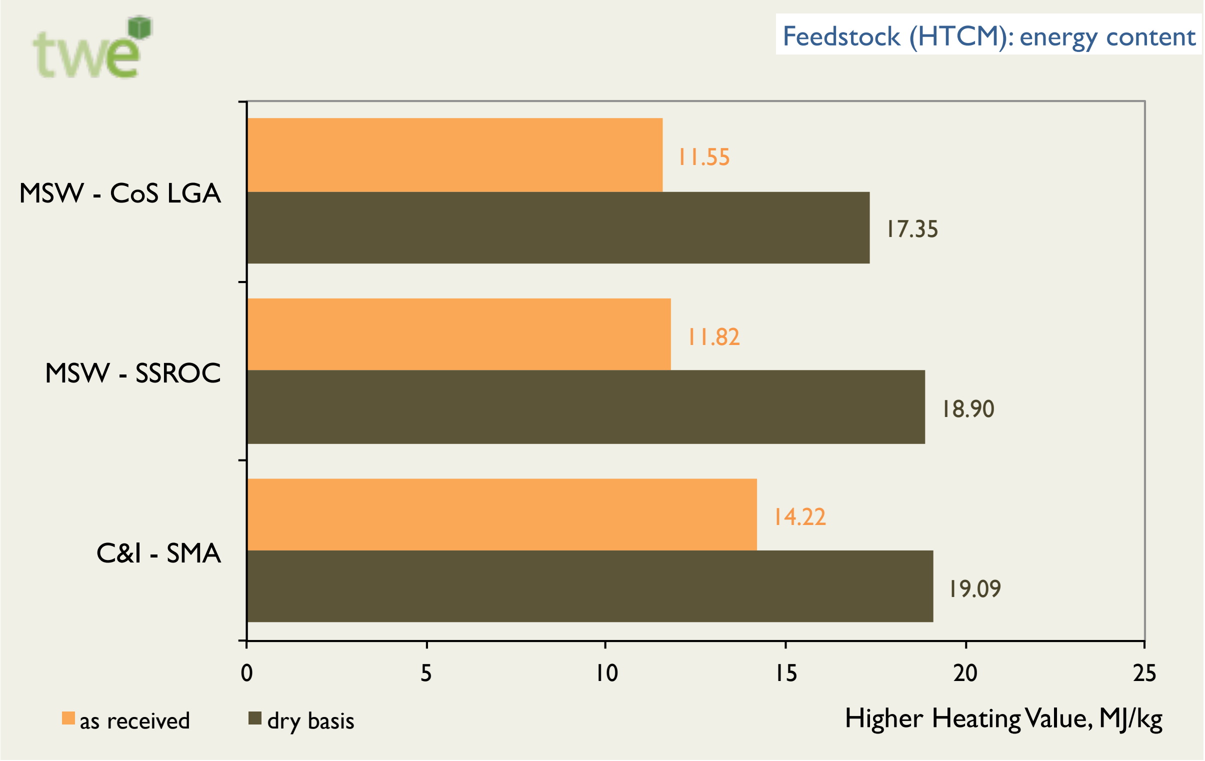


Figure 38. HTCM waste feedstocks – energy content, HHV basis



Feedstock renewable fraction analysis

For the purpose of this study we consider the renewable fraction of residual waste resources on the basis of its organic, or biomass fractions, in accordance with methods prescribed in the National Greenhouse and Energy Reporting (NGER) guidelines (DCCEE 2012) and the consolidated general methodology ACM0022 *Alternative Waste Treatment Porcesses* published under by the UNFCCC Clean Development Mechanism (CDM EB 2012) these are[16]:

- **Biomass fractions:** Food, paper, green waste, wood, textile, leather and rubber;
- **Non-biomass fractions:** oils, plastic, construction and demolition waste, glass and metal, hazardous fractions and other (e-waste, whitegoods, shredder residues, etc.)

Feedstock biomass content

The biomass content (BC) is the ratio of the combined weight of the biomass fractions, to the weight of the incoming waste feedstock, both calculated on an as received basis.

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[16] the guidelines for evaluation of eligibility of energy recovery from waste (including combustion, gasification and pyrolysis) under the Large-scale Generation Certificates under the Renewable Energy Ac, as set out in (Nolan-ITU 2001) exclude leather and textiles from eligibility, in situations where the synthetic (non renewable) contamination in these materials can not be determined. Within the context of this study we have considered the entire amount of wastes from the leather, rubber and textiles categories as eligible for consistency with the methods prescribed under (CDM EB 2012), and (DCCEE 2012).

Figure 39. LTC/HTC waste feedstocks – biomass content, as received basis

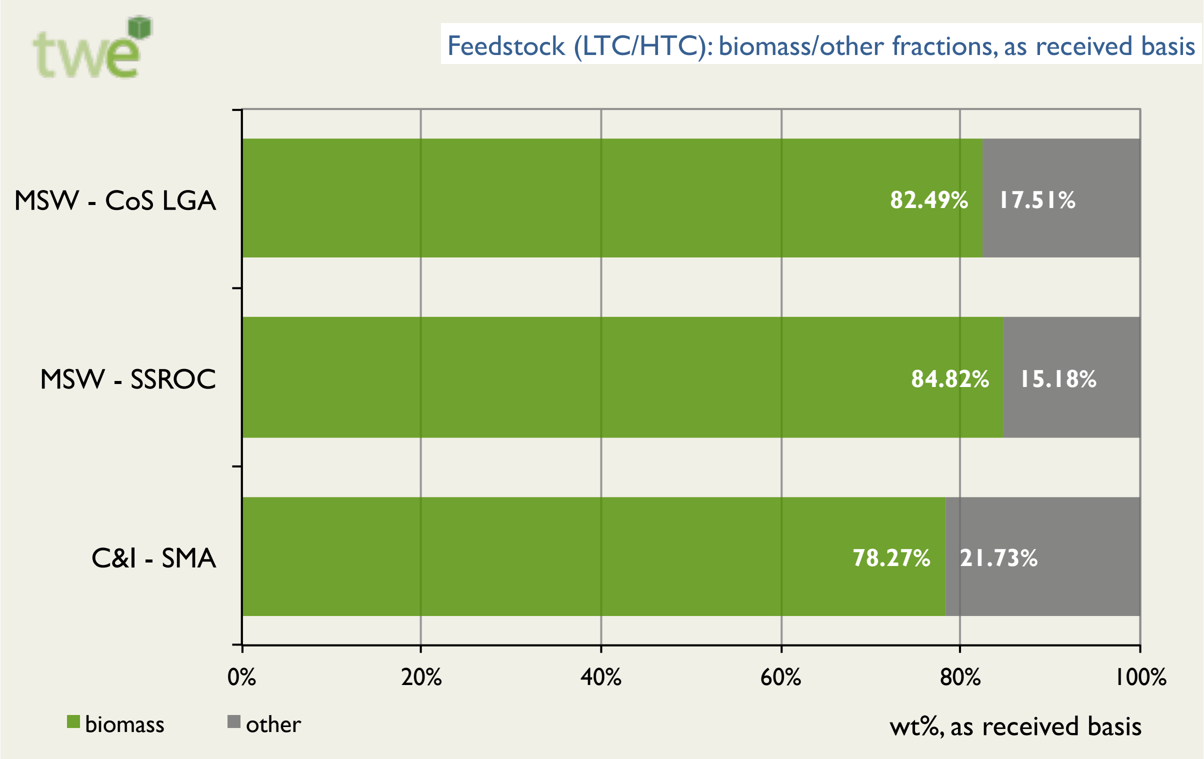
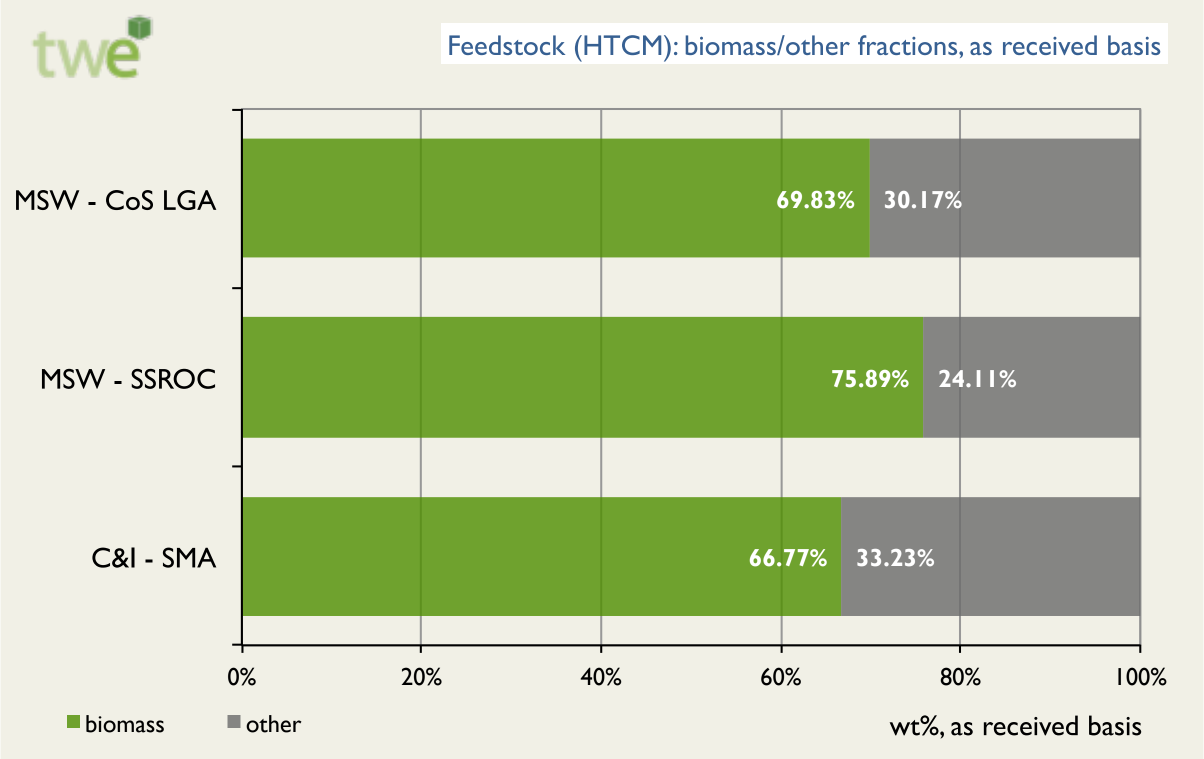


Figure 40. HTCM waste feedstocks – biomass content, as received basis



The addition of the inert fraction to the feedstock mix contributes to lower overall biomass contents for HTCM feedstocks across the three different feedstock resources considered.

Renewable energy content

The renewable energy content (REC) of the feedstock, is the ratio of the combined energy content of the biomass fractions, to the energy content of the incoming waste feedstock, both calculated on an as received, higher heating value (HHV) basis.

The variability observed in the renewable energy content between LTC/HTC and HTCM feedstocks is lower than that observed for the biomass content, as the low energy contents associated with the inert fraction (ranging between 0.70 and 2.72 MJ/kg, HHV as received) have a smaller impact on the total feedstock resource energy content.

The renewable energy content (REC) of the feedstock, adjusted for the introduction of any non-renewable auxiliary thermal input (e.g. from fuel combustion) in the conversion reactor, is used to determine the renewable energy content of the syngas generated, a key performance parameter in the analysis presented in the following section.

Figure 41. LTC/HTC waste feedstocks – renewable energy content, HHV as received basis

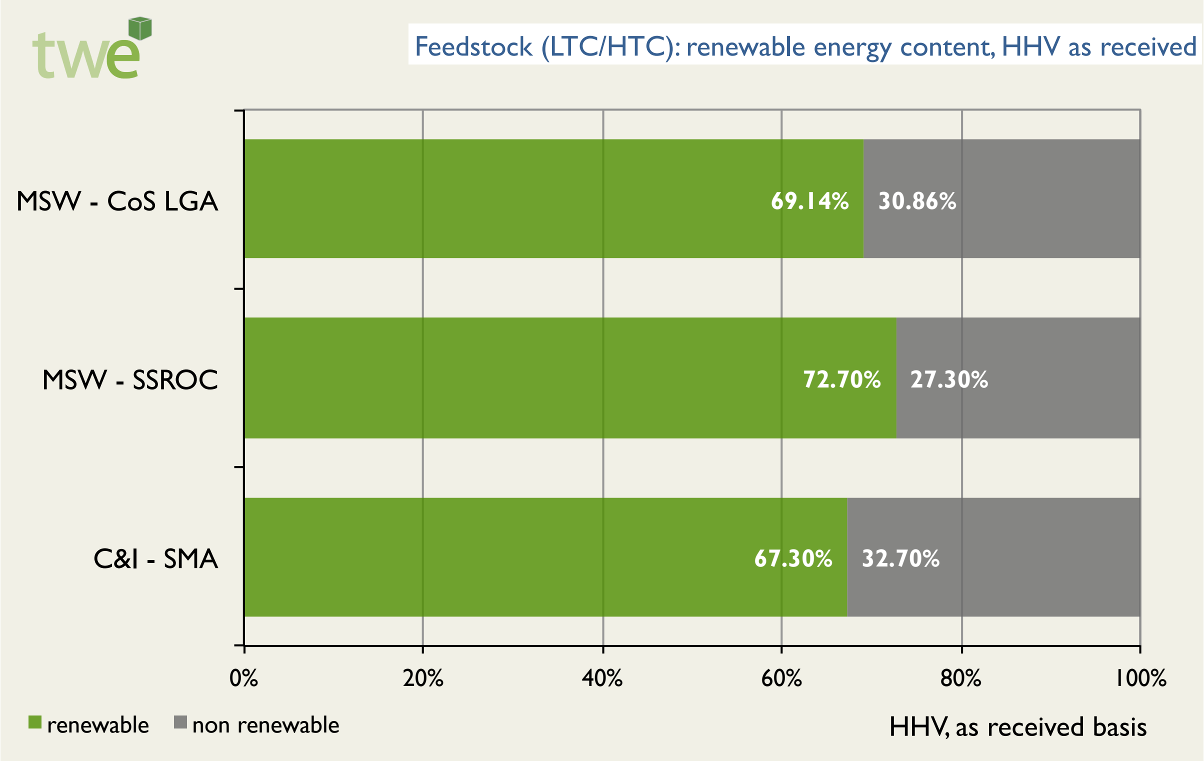
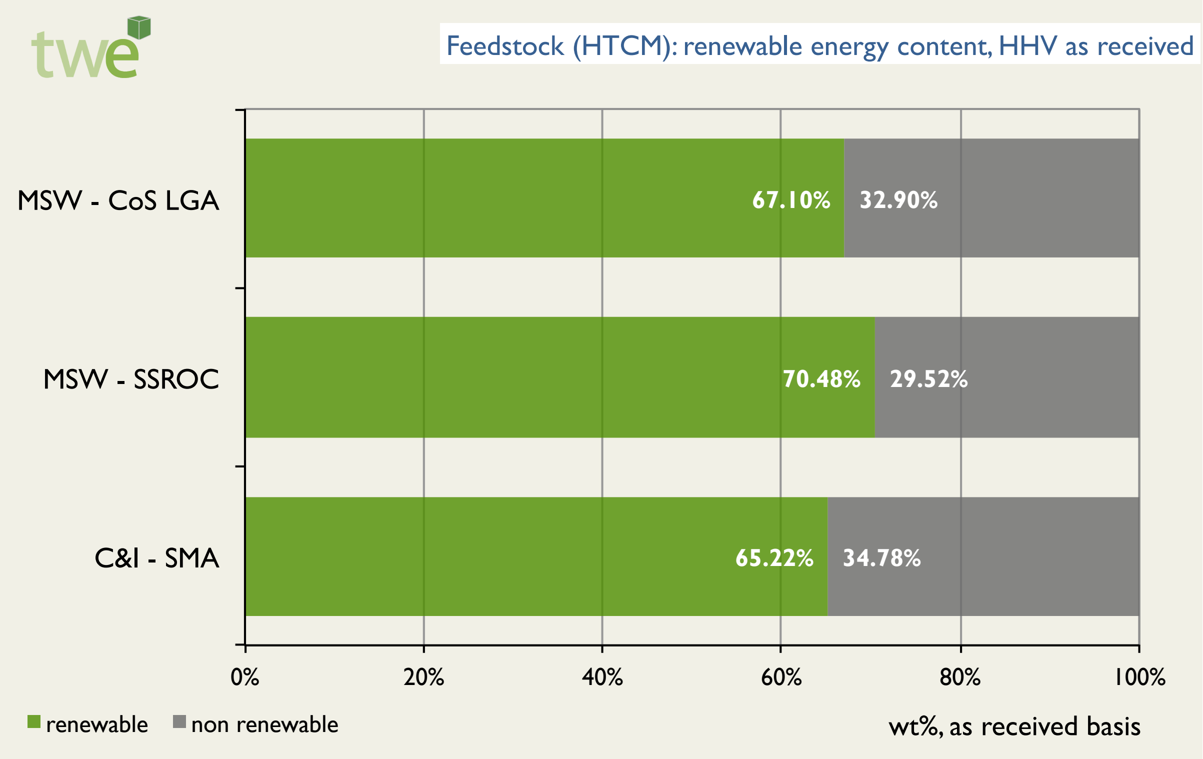
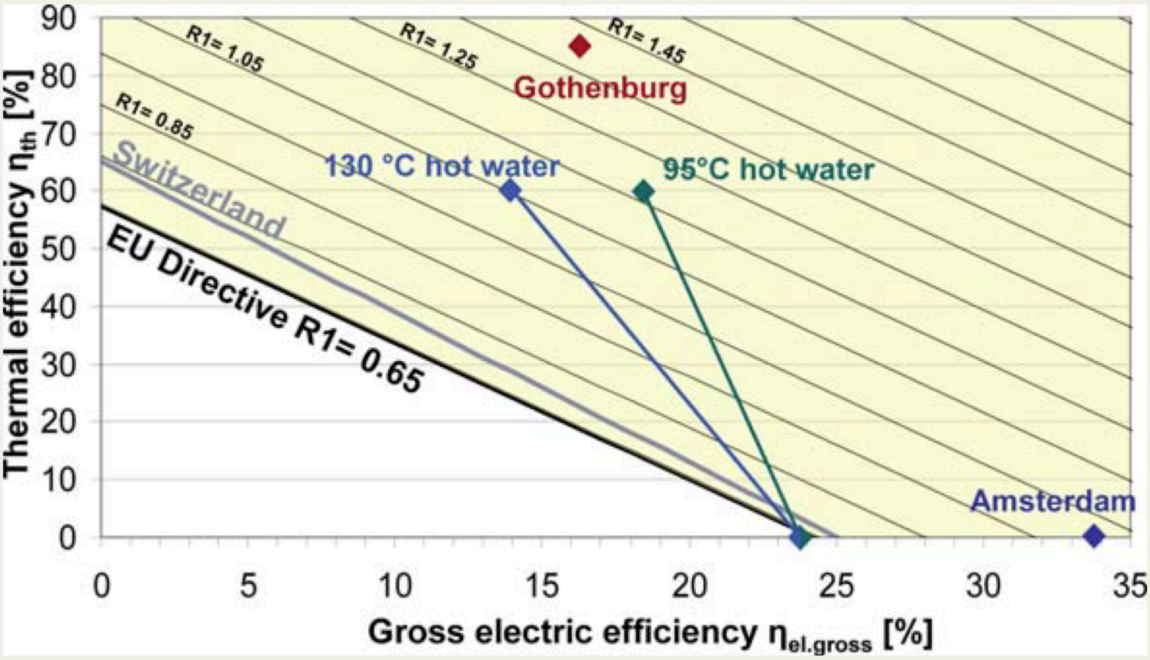


Figure 42. HTCM waste feedstocks – renewable energy content, HHV as received basis



Box 1. The EU WID Energy Efficiency Criterion

European legislation, originally developed in Italy (for the CIP6 green certificates) and Germany (for the country's feed-in tariff programs), and later integrated in the EU Commission Waste Directive, assumes instead energy recovered from waste resources to be *assimilable to renewables* for all energy from waste recovery plants, provided that the combined heat and electricity recovery from energy from waste (EfW) conversion schemes, is above the 'best practice' combined heat and power performances of fossil-fuel generation, through a test also known as the R1 criterion, conducted by means of the gross electric-efficiency/heat recovery rate diagram, shown below for a number of facilities.



The line labeled "EU Directive R1 = 0.65" marks the minimum requirement a plant must fulfil to get the recovery status, and thus access the set of incentives (green certificates or feed-in tariffs) available in the single Member States.

The energy efficiency criterion shifts the focus from the feedstock resource being renewable, to the waste to energy scheme achieving an improvement to the existing fleet of power and heat generation facilities. It also extends the notion of non-renewable resource to the landfills, thus emphasizing the waste management, and associated environmental benefits associated with energy from waste schemes.

It should be noted how, the coupling of advanced gasification with advanced tri-generation systems, far exceeding the average efficiency of electricity, heating and cooling generation, has the potential to outperform, under the energy efficiency criterion, even the most advanced EfW schemes operating.

Biogenic carbon content

The biogenic carbon content (BCC) for waste feedstocks is a key metric used to determine Scope 1 emission factors for the Syngas from Waste SNG.

This is calculated for each resource stream, conversion strategy and catchment region, as the ratio between the carbon content for the biomass fractions and the total feedstock resource stream (both on an as received basis) on the basis of elemental analysis data for each individual waste fraction.

Feedstocks for Low- and High-Temperature Conversion technologies have the highest biogenic carbon contents, ranging from 80.9% (wt%, as received) for MSW feedstocks sourced from the SMA (excluding the Inner Sydney catchment) and ERA regions, to 74.4% (wt%, as received) for C&I feedstocks.

For HTCM feedstocks biogenic carbon contents are lower, ranging from 79.5% (HHV, as received) for MSW to 71.8% (wt%, as received) for C&I feedstocks.

As for renewable energy content, the variability observed between LTC/HTC and HTCM feedstocks for the biogenic carbon content is lower than that observed for the biomass content, as the low carbon contents associated with the inert fractions (ranging between 5.9% and 10.3%, wt% dry basis) have a smaller impact on the total feedstock resource carbon content.

Figure 43. LTC/HTC waste feedstocks – biogenic carbon content, as received basis

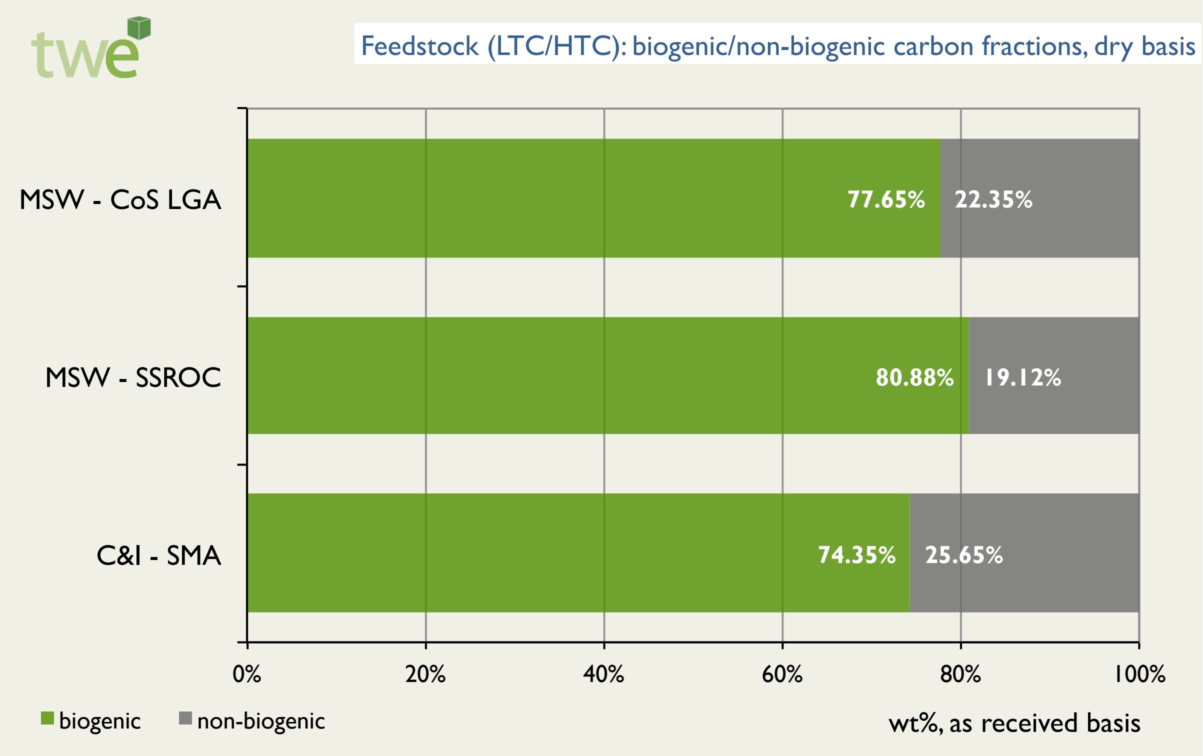
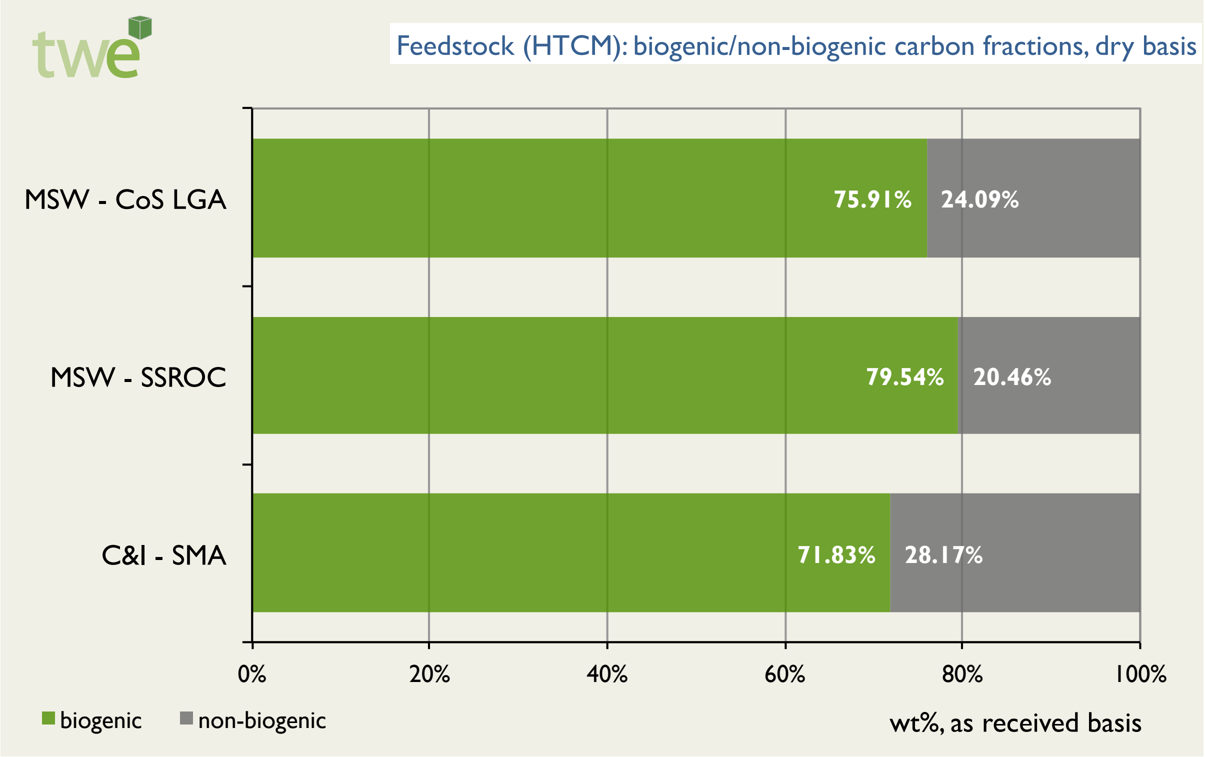


Figure 44. HTCM waste feedstocks – biogenic carbon content, as received basis



SECTION 4. ADVANCED WASTE TREATMENT SCENARIOS

Pictured: Conveyor at Malagrotta 2 gasification facility Rome,
Credits: Co.La.Ri., 2012

Overview

In this section we assess the potential for the establishment of a Syngas from Waste (SfW) facility to supply pipeline-quality substitute natural gas (SNG) to the City's proposed decentralised energy network.

The feedstock considered for the facility is the residual fraction from the mixed domestic (MSW) and commercial and industrial (C&I) waste streams collected within the City of Sydney Local Government Area (LGA) and the LGA from the Southern Sydney Regional Organization of Councils (SSROC).

The assessment presented here, based on typical conversion and energy recovery performances for a set of mature conversion technologies, representative of the 9 technology groupings introduced in *Section 1. Synthesis Gas Generation from Residual Waste Resources*, is focused on the scheme performances in two key areas:

- **waste conversion,** or the ability to contribute further to the City's resource recovery efforts and further reduce the amount of residual waste (including AWT residuals) that is sent to landfill; and
- **energy recovery,** or the ability to cover projected gas demand from the City's proposed network of trigeneration facilities.

The scenarios presented here identify the preferred conversion strategy to be adopted by the City of Sydney and inform the development of an initial shortlist of key commercially mature technologies of interest in regard to future procurement activities outlined in *Section 6. Enabling Actions*.

Syngas from Waste scenarios

A set of scenarios have been developed within the scope of this study to provide the City of Sydney with an initial estimate of the potential energy recovery, waste management and environmental performances associated with the implementation of a syngas-from-waste (SfW) facility within the City of Sydney LGA or in its close proximity.

Scenario framework

A nested scenario framework, summarized in the table below, has been developed to conduct this assessment, designed to highlight the key planning dimensions of:

1. **conversion strategy**, describing three alternative applications for the proposed SfW facility and its role in determining the future of waste collection, recovery, treatment and disposal operations across the City LGA;
2. **conversion technologies**, describing the range of available thermo-chemical technologies to match each of the three SfW-based waste management strategies;
3. **feedstock resource** describing the quantities, mix and characteristics of waste feedstock resource available as potential feedstocks for the proposed SfW facility from the MSW and C&I waste streams; and
4. **implementation approach**, describing alternative strategies for development of the proposed SfW facility based on single-, or two-stage implementation.

Table 12. Syngas from Waste scenarios - analysis framework

Level 1. STRATEGY	Level 2. TECHNOLOGIES	Level 3. RESOURCES	Level 4. IMPLEMENTATION
Low-Temperature Conversion (LTC)			
	Fixed-Bed Gasification	MSW	LGA (MSW)
	Slow Pyrolysis	C&I	LGA (MSW+C&I)
			SSROC (MSW)
			SSROC (MSW+C&I)
High-Temperature Conversion (HTC)			
	Fluid Bed Gasification	MSW	LGA (MSW)
	Pyro-Gasification	C&I	LGA (MSW+C&I)
			SSROC (MSW)
			SSROC (MSW+C&I)
High-Temperature Conversion + Melting (HTCM)			
	Pyro-Gasification + Melting	MSW	LGA (MSW)
	Fluid Bed Gasification + Melting	C&I	LGA (MSW+C&I)
	Plasma Gasification		SSROC (MSW)
			SSROC (MSW+C&I)

Baseline scenario

As the baseline scenario, the framework adopts the current waste management model operating within the City of Sydney – with the interim delivery of the mixed waste stream of MSW to a mechanical-biological treatment (MBT) facility, summarized by the diagram in the following page.

City of Sydney LGA

The two tables below present recent data for waste and resource recovery activities in the LGA, for the domestic (MSW) and commercial and industrial (C&I) resource streams.

Table 13. City of Sydney LGA – MSW collection, recovery, treatment and disposal, 2006-12

	Year					
	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12[b]
MSW - City of Sydney LGA						
Residential population	165,596.0	170,173.0	173,444.0	177,920.0	180,679.0	183,567.0
Resource Collection						
Mixed waste	36,864.7	37,815.7	39,378.2	39,453.2	40,209.0	40,081.2
Kerbside recycling	14,261.0	14,815.3	15,080.8	15,294.9	15,962.0	16,346.7
Garden organics	231.7	339.0	452.9	549.0	744.3	780.2
Household Cleanup Material	2,353.0	2,413.8	2,513.5	2,518.3	2,478.7	2,543.5
Whitegoods	280.0	287.6	222.0	268.5	126.5	110.3
eWaste	n/a	n/a	28.0	36.0	53.0	78.7
Household Hazardous Waste	n/a	n/a	n/a	16.2	15.0	16.2
TOTAL Collected	53,990.4	55,671.3	57,675.4	58,136.0	59,588.5	59,956.9
Resource Recovery, Treatment and Disposal						
Source-separated materials [a]	13,351.8	13,969.0	14,327.2	14,620.3	15,429.3	15,819.2
Delivered to AWT	0.0	0.0	0.0	7,386.5	20,437.0	39,652.8
AWT residual to landfills	0.0	0.0	0.0	3,693.2	8,603.3	15,861.1
Total MSW recovered	13,351.8	13,969.0	14,327.2	18,313.5	27,263.0	39,610.9
Total MSW residuals to landfill [a]	38,005.6	39,000.9	40,584.7	36,983.5	29,652.3	17,597.2
Resource recovery rate, %						
Actual	25%	25%	25%	32%	46%	66%

SOURCE: City of Sydney

[a] assuming 8% contamination of recycling into landfill

[b] projected levels from this date based on historic data, anticipated waste processing and population increases

Table 14. City of Sydney LGA – C&I waste collection, recovery, treatment and disposal, 2006-12

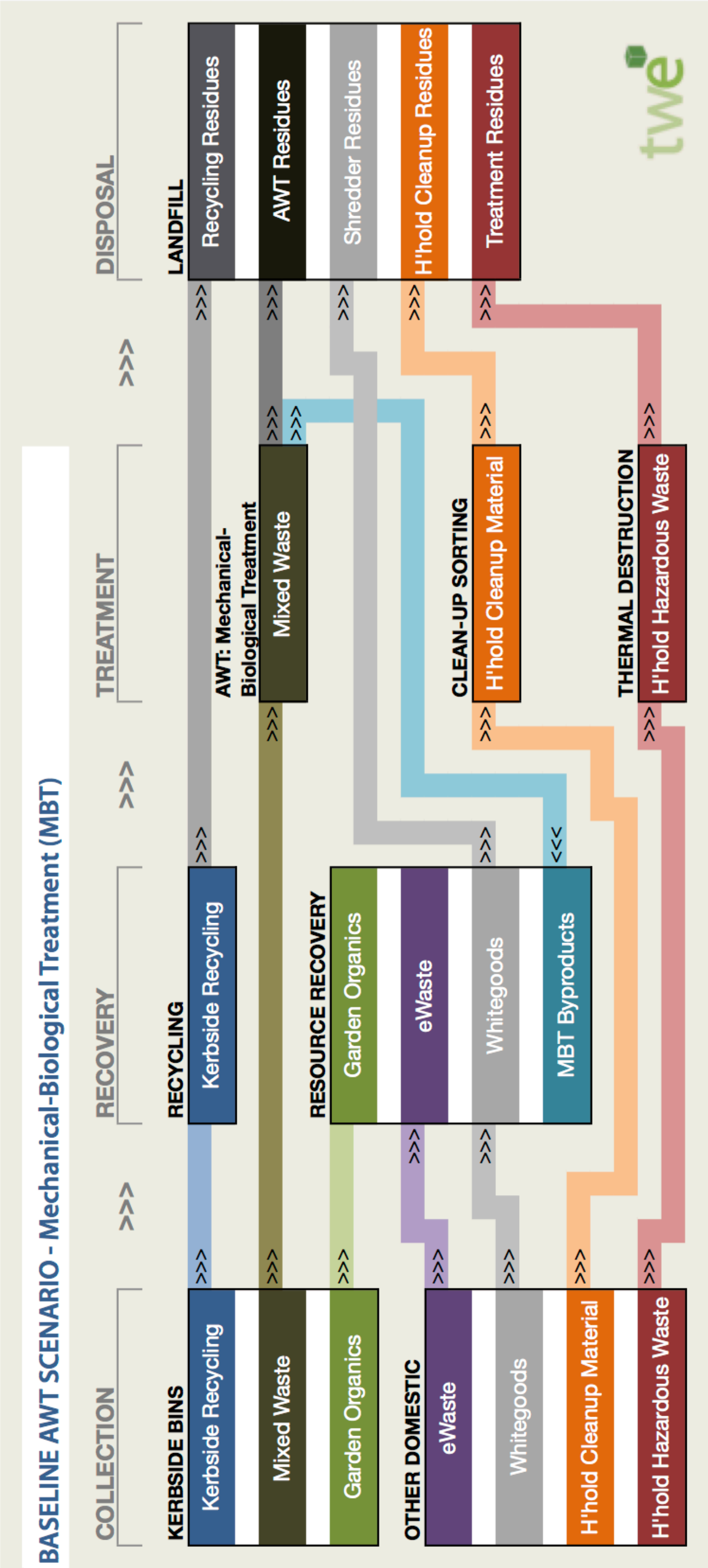
	Year					
	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
C&I - City of Sydney LGA						
Residential population	165596.0	170173.0	173444.0	177920.0	180679.0	183567.0
Waste Collection	252,190.6	254,580.3	256,970.0	259,359.7	261,749.4	264,139.1
Waste treatment/disposal						
C&I recycled	105,920.1	106,923.7	127,148.8	128,331.2	129,513.6	130,696.0
C&I to landfill	146,270.5	147,656.6	129,821.2	131,028.5	132,235.8	133,443.1
Resource recovery rate (b)	42.00%	42.00%	49.48%	49.48%	49.48%	49.48%

SOURCE: (Hyder Consulting 2011), (DECCW 2010).

(a) adapted from Council projections of employment within the City of Sydney LGA

(a) as reported in (DECCW 2010) for year 2007-08, and (DECCW 2011b) for year 2008-09

Figure 45. Baseline AWT scenario



Conversion strategies

The development of an syngas-from-waste (SfW) facility focused on one of the conversion technologies described earlier offers an opportunity to develop further energy and material recovery activities from waste generated within the City of Sydney's LGA and to increase resource recovery and landfill diversion rates.

Thermal conversion AWT scenarios

A set of three overarching *conversion strategy scenarios* have been developed to identify the key changes in the waste management model for the City of Sydney that would result from the implementation of an SfW facility based on one of the following strategies:

- **Low Temperature Conversion (LTC)**,
- **High Temperature Conversion (HTC)**, and
- **High Temperature Conversion + Melting (HTCM)**.

Low Temperature Conversion

Under this scenario, the interim delivery of mixed wastes to the MBT facility, will cease with the commissioning of an SfW facility based on low temperature conversion technologies such as slow pyrolysis or fixed-bed gasification.

High Temperature Conversion

Under this second scenario, the new EfW facility will be based on high temperature conversion technologies (fluid-bed gasification, pyro-combustion or pyro-gasification).

High Temperature Conversion + Melting

The third conversion strategy considers the implementation of an EfW facility based on high temperature technologies with ash melting capability, such as plasma gasification, fluidized bed gasification + melting, and pyro-gasification + melting.

The choice of these technologies offers the highest processing, and therefore resource recovery/landfill diversion potential, accepting mixed wastes and other streams with minimal or nil pre-processing requirements. In addition to the mixed waste stream, In addition, post-sorting bulky waste items arising from household clean-up and illegal dumping activities, will also be delivered to the new facility.

The hazardous and shredder residues fractions can be also processed by HTCM technologies, but have been excluded from this assessment as, based on experience with the City of Sydney domestic waste streams, they are delivered to specialized alternative waste treatment facilities.

Figure 46. LTC/HTC AWT scenario

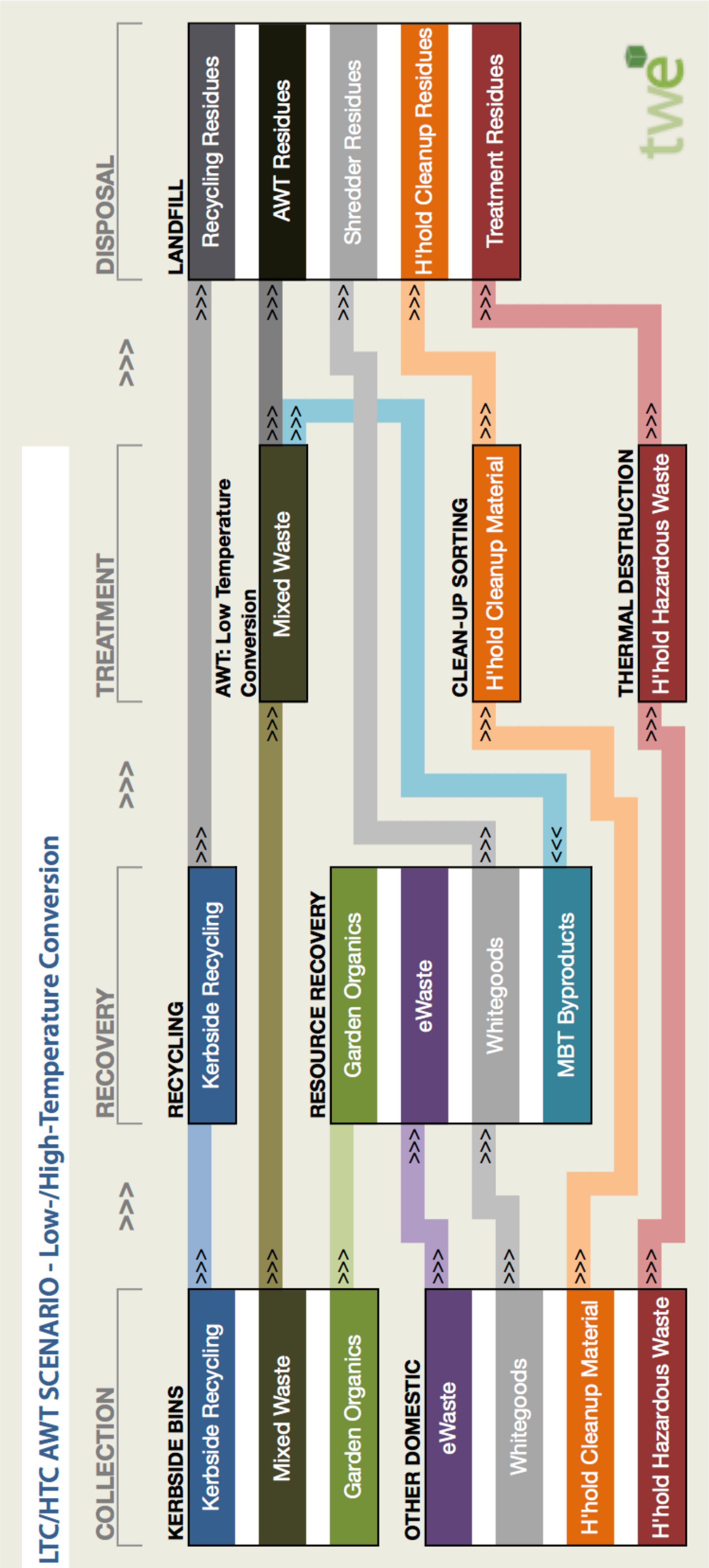
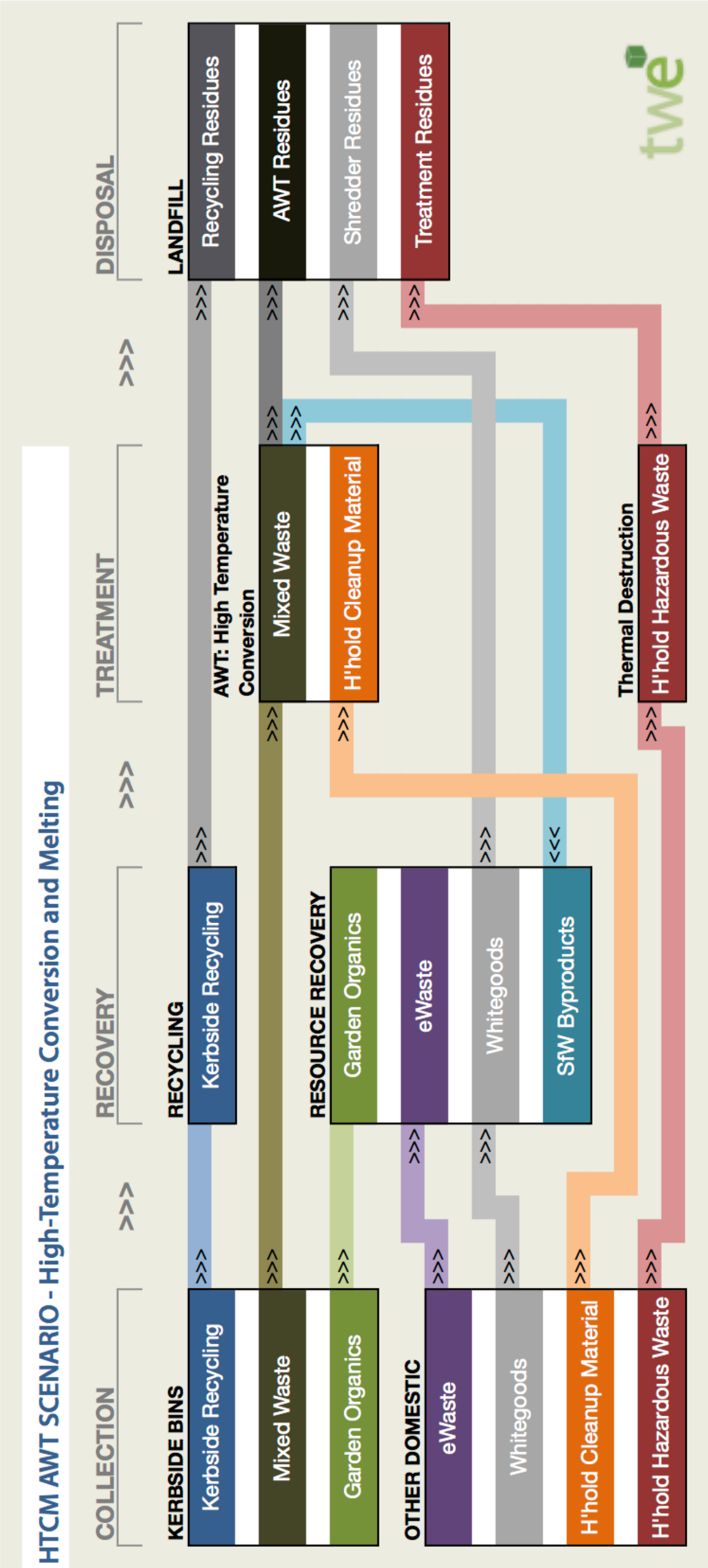


Figure 47. HTCM AWT scenario



Conversion technologies

In this section we present a set of representative conversion technologies that have been selected from our proprietary database as a proxy for each of the technology groups, on the basis of the following set of criteria:

- commercial maturity;
- plant throughput;
- feedstock processing capability;
- process type; and
- energy recovery and syngas processing capability; and
- emissions performance

Selection criteria

Commercial maturity

Technology and operational risk are key considerations in the successful commissioning and operation of energy from waste facilities. For the purpose of the developments of interest to the City of Sydney, we have selected only technologies that can be considered mature with at least one commercial-scale facility operating, and classified as either:

- **demonstrated** with at least one reference facility operating successfully at a commercial-scale;
- **proven** with at least one reference facility in continued, full-commercial operation; or
- **commercial or fully proven** with several reference facilities in continued, full commercial operation.

Plant throughput

In addition to commercial maturity, plant throughput is a key criterion for the selection of suitable conversion technologies.

Our review of technologies and the set of case studies presented in Appendix F have highlighted the risks associated with the scale-up of technologies from demonstration plants to first and subsequent generations of commercial concepts. Selection of suitable technologies should be based on the plant being demonstrated, proven or fully commercial at the scale of interest.

Reactor capacity, or throughput, is expressed in (metric) tonnes per day (tpd). Consistent with established industry practice – see for example (Juniper 2009)Juniper 2009, we adopt the following classification:

- **small-scale facilities** with plant throughput smaller than 25 tpd;
- **medium-scale facilities** with plant throughputs between 25 and 250 tpd; and
- **large-scale facilities** with plant throughputs in excess of 250 tpd.

In the analysis presented below under the *EfW Scenarios* chapter we have identified the potential for development of a medium- to large-scale EfW facility with daily plant throughputs ranging from 144.2 tpd – or 43,802.0 tonnes per year at 85% capacity factor – (MSW feedstock, low-temperature conversion technology) to 487.6 tpd – or 150,248.7 tonnes per year at 85% capacity factor – (mixed MSW and C&I feedstock, high-temperature conversion and melting).

Based on these considerations we have included in the short list technologies with reactor or processing size available in the medium and large-scale ranges, with the required throughputs achievable through development of multiple processing line facilities.

Feedstock processing capability

The key feedstocks of interest for the proposed EfW facility are mixed waste streams from domestic and commercial and industrial sources, with other waste streams (such as shredder residues, sewage sludge and industrial wastes) being considered for co-processing.

The selection has focused on technologies with proven processing capability for these waste stream, either un-processed, or post separation in material recovery facilities (post-MRF) or as a processed refuse derived fuel (RDF).

Conversion technology

Consistent with the set of *Conversion Strategy* scenarios presented below under *EfW Scenarios*, available conversion technologies have been grouped in the following categories:

- **Low Temperature Conversion (LTC)** for technologies operating conversion at temperatures below 750 °C, including slow pyrolysis and fixed-bed gasification technologies;
- **High Temperature Conversion (HTC)** for technologies operating conversion at temperatures at or above 750 °C, including pyro-combustion, pyro-gasification and fluidized bed gasification technologies; and
- **High Temperature Conversion + Melting (HTCM)** for technologies integrating a ultra-high temperature *melting* zone (above 1500 °C) where minerals (ashes) and metals present in the waste stream are brought above their fusion temperature and

recovered respectively as vitrified slag and molten granulates. These include plasma gasification, pyro-gasification + melting and fluidized bed gasification + melting technologies.

Energy recovery and syngas processing capability

The ability to generate a high quality synthesis gas that could be upgraded and delivered off-site to a network of trigeneration installations is a key requirement for the activities the City of Sydney is aiming to develop under its Green Infrastructure Strategy.

Although some technology providers do integrate syngas upgrading concepts in their current designs it should be noted how the configuration of the energy recovery section for EfW plants are typically defined to maximize returns from energy recovery based on the underlying market conditions for heat and power in the region where a plant operates.

Following established practice for waste to energy (WTE) facilities based on mass-burn or fluidized bed combustion, the majority of EfW facilities based on pyrolysis or gasification have historically integrated energy recovery sections designed for direct combustion of the raw synthesis gas (eg without upgrading) and recovery of heat and power in steam generators and steam turbine assemblies.

Increasingly, EfW facilities are designed to integrate intermediate syngas cleaning and upgrading sections, to generate a high-quality clean synthesis gas that can be used in high efficiency conversion technologies (such as gas engines, gas turbines and fuel cells), resulting in flexible operations, and overall improved energy recovery and environmental performance.

The concepts brought forward by the City of Sydney, of developing a market for renewable gases through establishment of a network of trigeneration facilities, is innovative and can be considered in all respects a game-changer in the market for EfW technologies.

While the delivery of clean synthesis gas off-site to industrial facilities (see for example the case study on the Thermoselect Chiba facility, with delivery of syngas to a nearby metalworks furnace via pipeline) or the upgrading and distribution of SNG from upgraded biogas to refuelling stations (see for example emerging C-SNG, or bio-methane refuelling networks in Sweden and Denmark as an example) have had some applications, the platform emerging from the integration of the Renewable Energy and Trigeneration components of the City’s Decentralized Energy Master Plans, with the development of an integrated gas supply chain for generation of synthesis gas, upgrade to SNG and delivery to a network of distributed trigeneration facilities represents a further innovation in the use and integration of renewable and synthesis gases.

The review of technologies and the set of case studies presented under the AWT and REMP sections (Appendixes F and G), have identified syngas upgrading and conversion technologies as fully commercial concepts that can be flexibly integrated with thermal conversion technologies as a variation to currently proposed configurations for syngas conditioning/upgrading, energy recovery and air pollution control sections.

In order to provide a representative comparison of syngas yields across the different set of technologies considered, irrespective of the energy recovery configurations, this study has considered the *cold-gas efficiency* (or the ratio of energy in the raw syngas, to energy in the feedstock waste and other auxiliary energy inputs) as the key performance parameter.

At this stage the City of Sydney should consider all technologies matching the set of criteria described above and put forward its requirements for syngas cleaning and upgrading as a key element of its market approach strategy (see below under *Enabling Actions*).

Emissions performance

The ability of thermal conversion and energy recovery technologies to operate within regulated air pollutant emission limits is a key consideration for successful commissioning and operation of EfW facilities. Failure to comply with such limits could result in significant commissioning delays, require costly retrofits to any Air Pollution Control (APC) systems and cause environmental authorities to force continued shutdowns of the facility, all ultimately affecting economic viability.

This review of conversion technologies has confirmed the ability of operating EfW facilities with suitably designed APC systems to operate well within the air pollutant emission standards in force in Europe, the USA and Japan, and the inherent advantages of conversion technologies with intermediate gas clean-up technologies in terms of more compact and less costly APC trains when compared to similar capacity facilities based on incineration. All commercially mature technologies reviewed comply with the relevant emission regulations.

Selected technologies

The table below presents the resulting selection of representative mature conversion technologies that have been adopted for the modelling efforts presented in this section.

Table 15. Representative AWT technologies

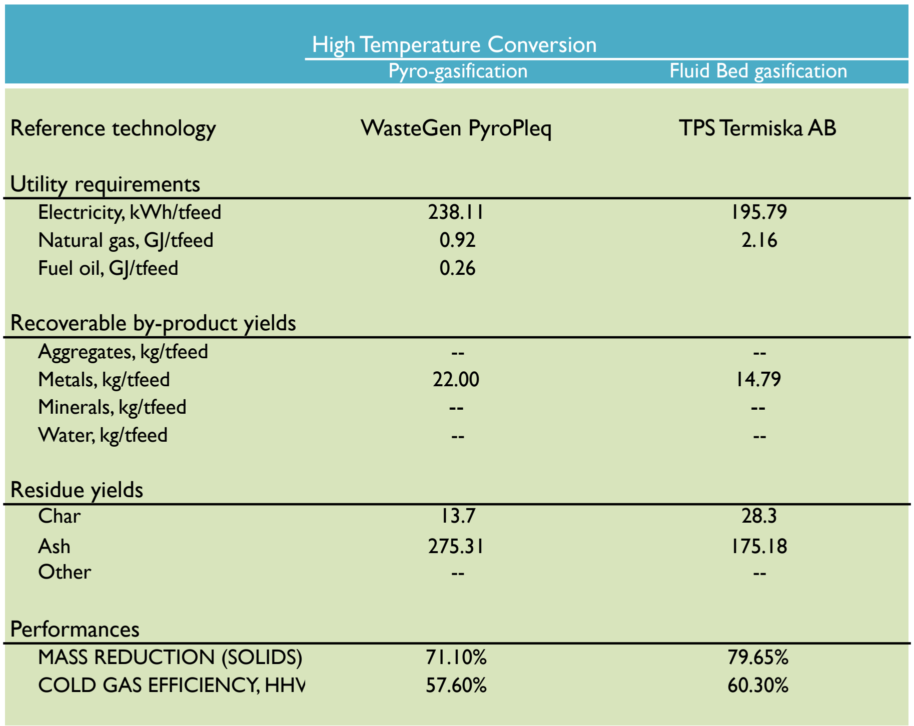
	Technology				
Supplier	Name	Type	Scale	Maturity	Application
Low-Temperature Conversion (LTC)					
Thide Environmental	EddiTh	Slow pyrolysis	small-medium	proven	MSW, industrial
IES	APS	Pyro-combustion	medium	demonstrated	MSW, industrial
Entech-RES	WtGas	Fixed-bed gasification	small-medium	commercial	MSW, sludge
High-Temperature Conversion (HTC)					
WasteGen	Pyropleq	Pyro-gasification	small-medium	proven	MSW, sludge
TPS	Termiska AB	Fluid-bed gasification	small-medium	proven	MSW, RDF
High-Temperature Conversion + Melting (HTCM)					
AlterNRG	PGVR	Plasma gasification	medium-large	proven	MSW, SR, RDF
Ebara TwinRec	TFiG	Fluid-bed gasification + melting	medium-large	commercial	MSW, SR
Thermoselect	HTR	Pyro-gasification + melting	medium-large	commercial	MSW

The tables below presents typical conversion and energy recovery performances for the representative technologies in each of the three conversion strategies, sourced from a proprietary TWE database of performances, costs and emissions for thermal conversion technologies.

Table 16. Low Temperature Conversion technologies – performance data

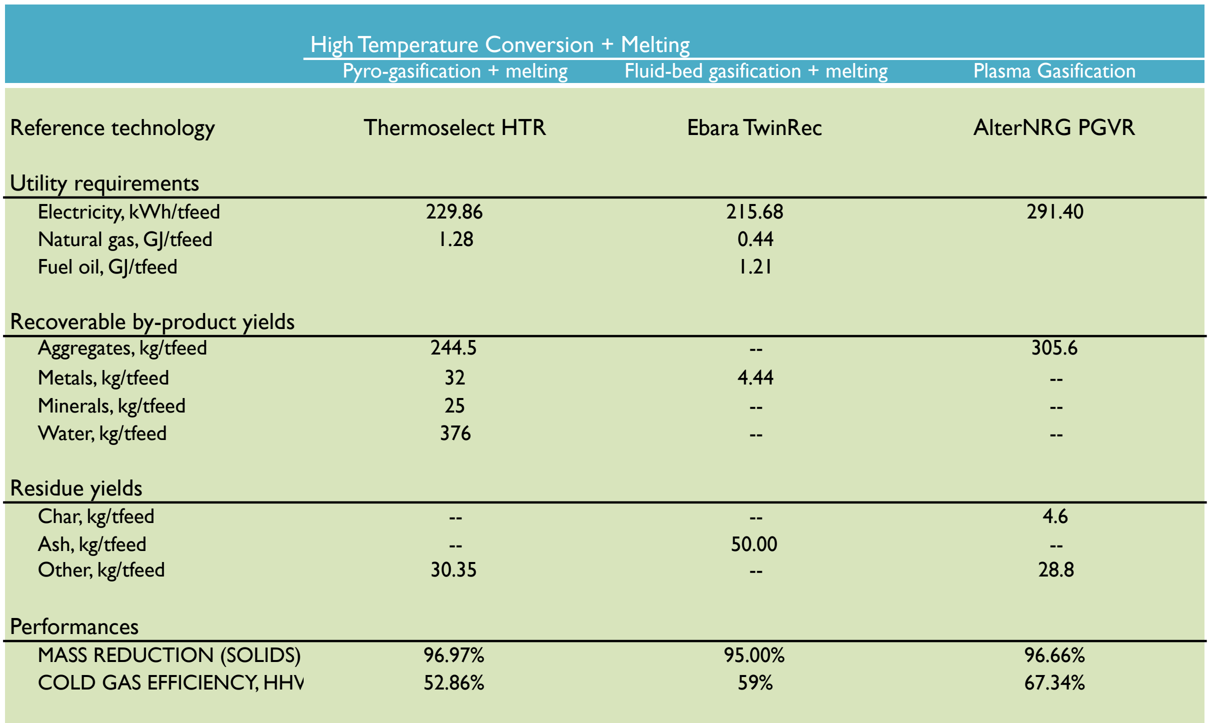
	Low Temperature Conversion		
	Pyrolysis	Pyro-combustion	Fixed bed gasification
Reference technology	Thide - EddiTh	IES - APS	Entech-RES - WtGas
Utility requirements			
Electricity, kWh/tfeed	188.40	48.95	33.14
Natural gas, GJ/tfeed	1.23	1.436	
Fuel oil, GJ/tfeed			
Steam, GJ/tfeed			0.83
Recoverable by-product yields			
Aggregates, kg/tfeed	--	--	--
Metals, kg/tfeed	27.00	--	--
Minerals, kg/tfeed	--	--	--
Water, kg/tfeed	--	38.4	--
Residue yields			
Char	--	119.99	--
Ash	343.10	223.45	40.00
Other	--	--	
Performances			
MASS REDUCTION (SOLIDS)	65.69%	65.66%	96.00%
COLD GAS EFFICIENCY, HHV	51.30%	56.97%	56.69%

Table 17. High Temperature Conversion technologies – performance data



	High Temperature Conversion	
	Pyro-gasification	Fluid Bed gasification
Reference technology	WasteGen PyroPleq	TPS Termiska AB
Utility requirements		
Electricity, kWh/tfeed	238.11	195.79
Natural gas, GJ/tfeed	0.92	2.16
Fuel oil, GJ/tfeed	0.26	
Recoverable by-product yields		
Aggregates, kg/tfeed	--	--
Metals, kg/tfeed	22.00	14.79
Minerals, kg/tfeed	--	--
Water, kg/tfeed	--	--
Residue yields		
Char	13.7	28.3
Ash	275.31	175.18
Other	--	--
Performances		
MASS REDUCTION (SOLIDS)	71.10%	79.65%
COLD GAS EFFICIENCY, HHV	57.60%	60.30%

Table 18. High Temperature Conversion + Melting technologies – performance data



	High Temperature Conversion + Melting		
	Pyro-gasification + melting	Fluid-bed gasification + melting	Plasma Gasification
Reference technology	Thermoselect HTR	Ebara TwinRec	AlterNRG PGVR
Utility requirements			
Electricity, kWh/tfeed	229.86	215.68	291.40
Natural gas, GJ/tfeed	1.28	0.44	
Fuel oil, GJ/tfeed		1.21	
Recoverable by-product yields			
Aggregates, kg/tfeed	244.5	--	305.6
Metals, kg/tfeed	32	4.44	--
Minerals, kg/tfeed	25	--	--
Water, kg/tfeed	376	--	--
Residue yields			
Char, kg/tfeed	--	--	4.6
Ash, kg/tfeed	--	50.00	--
Other, kg/tfeed	30.35	--	28.8
Performances			
MASS REDUCTION (SOLIDS)	96.97%	95.00%	96.66%
COLD GAS EFFICIENCY, HHV	52.86%	59%	67.34%

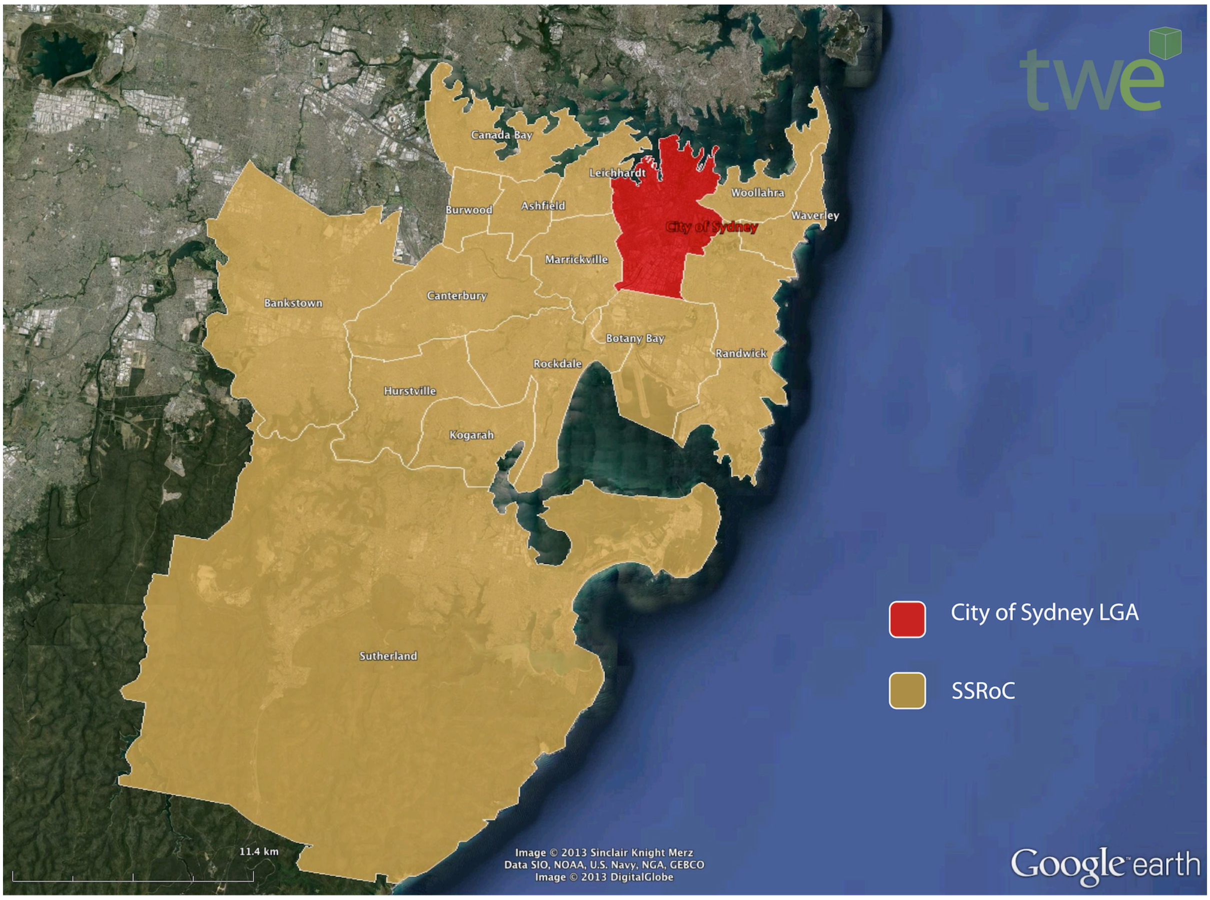
Resource scenarios

Resource catchments

The analysis presented here considers two resource catchments:

- **City of Sydney LGA**; and
- **SSROC region,** covering the LGAs within the Southern Sydney Regional Organization of Councils (SSROC)[17], including the City of Sydney.

Figure 48. Syngas from Waste scenarios - resource catchments



Target resource

Thermal conversion is a treatment option more advanced than mechanical-biological treatment under both a waste management and energy recovery perspective.

For this reason we assume that Syngas from Waste facilities, once in operation, will replace MBT as the preferred Alternative Waste Treatment (AWT) option for Councils in the catchment regions. Accordingly, the target feedstock resource considered within this study is the fraction of waste generated that is not source-separated for downstream resource

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[17] including Ashfield, Bankstown, Botany Bay, Burwood, Canada Bay, Hurtsville, Kogarah, Marrickville, Randwick, Rockdale, Sutherland, Sydney, Waverley and Wollahra

recovery, eg. the *mixed waste* from the domestic and commercial and industrial waste streams. The charts below present projections of these resources for the two catchments.

Figure 49. MSW – mixed waste (non recyclables), 2009-2030

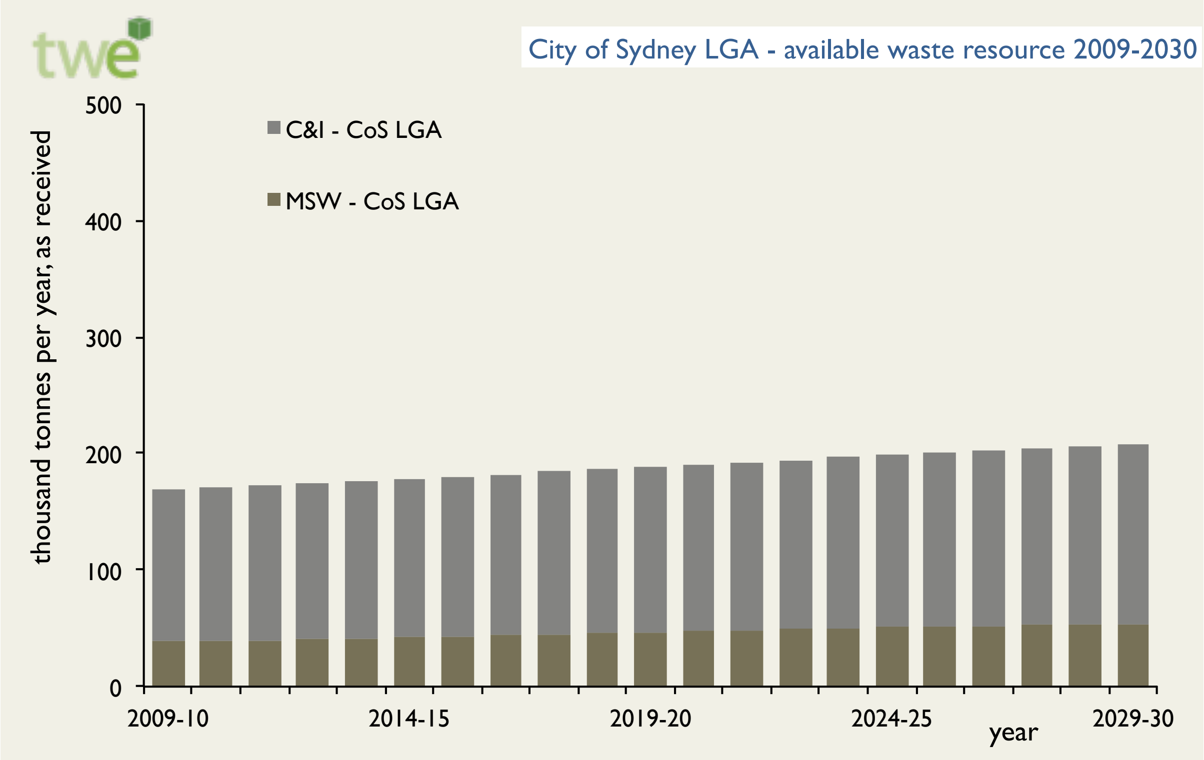
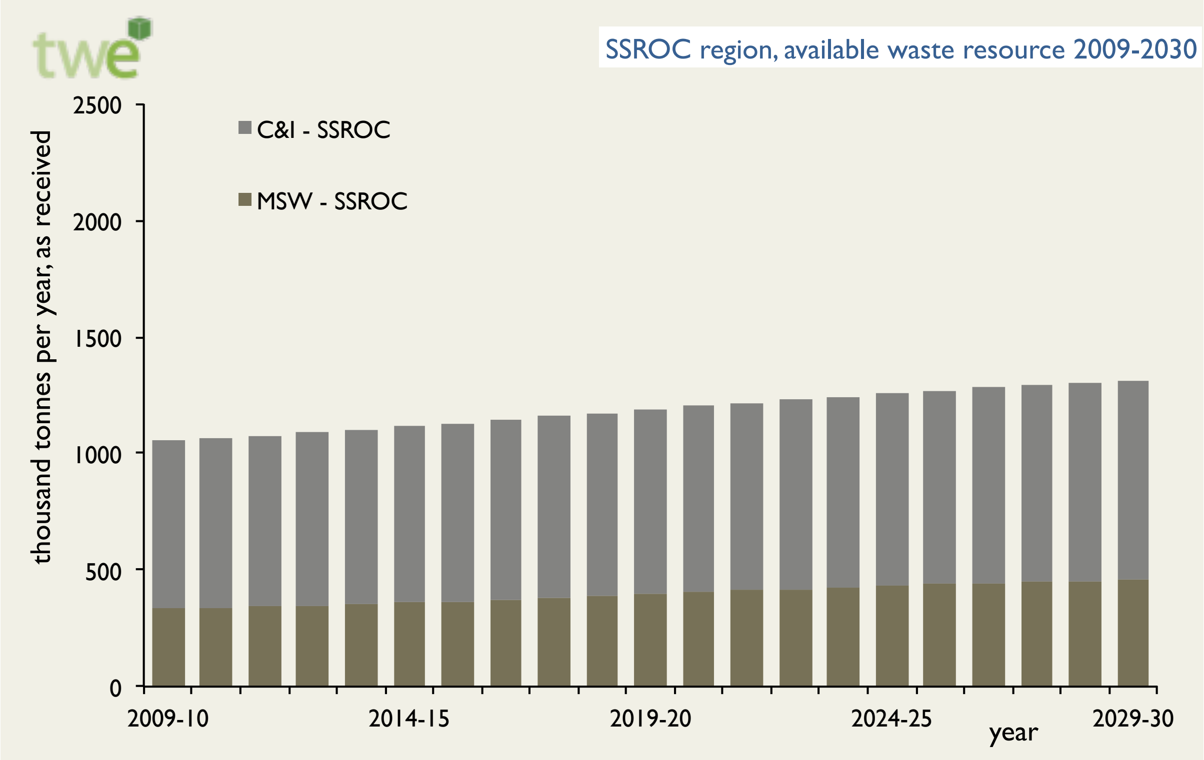


Figure 50. MSW – mixed waste (non recyclables), 2009-2030



Implementation scenarios

The scenario framework initially considers four alternative feedstock mix scenarios:

- **City of Sydney LGA – MSW**, considering the amount of mixed waste from domestic sources collected within the City of Sydney LGA;
- **City of Sydney LGA – MSW + C&I**, considering the amount of mixed waste from the domestic, commercial and industrial sources collected within the City of Sydney LGA;
- **SSROC – MSW**, considering the amount of mixed waste from domestic sources collected within the City of Sydney LGA;
- **SSROC – MSW + C&I**, considering the amount of mixed waste from the domestic, commercial and industrial sources collected within LGAs of the SSROC region.

Feedstock resource throughputs

The table below summarizes the processable fractions for each conversion technology.

Table 19. Syngas from Waste conversion technologies – waste fractions processed, by conversion strategy

	Mixed Waste Fractions					
STRATEGY/TECHNOLOGY	Combustible	Inert	Putrescible	Hazardous	Other	SR [a]
Low-Temperature Conversion (LTC)						
Pyro-Combustion	✓	✕	✓	✕	✕	✕
Slow Pyrolysis	✓	✕	✓	✕	✕	✕
Fixed-Bed Gasification	✓	✕	✓	✕	✕	✕
High-Temperature Conversion (HTC)						
Fluid Bed Gasification	✓	✕	✓	✕	✕	✕
Pyro-Gasification	✓	✕	✓	✕	✕	✕
High-Temperature Conversion + Melting (HTCM)						
Pyro-Gasification + Melting	✓	✓	✓	(✓)	✕	(✓)
Fluid Bed Gasification + Melting	✓	✓	✓	(✓)	✕	(✓)
Plasma Gasification	✓	✓	✓	(✓)	✕	(✓)

[a] Shredder Residues from Whitegoods processing at resource recovery facility

Within the scope of this study, Low-and High-Temperature Conversion technologies are considered to process the combustible and the putrescible fractions of the incoming residual waste stream. High-Temperature Conversion + Melting technologies, by virtue of the high-temperatures reached immediately downstream (for pyro-gasification + melting and fluid-bed gasification + melting) or inside (for plasma gasification) the main reactor, have the ability to process the inert fraction of the residual waste stream[18].

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[18] The hazardous and shredder residues fractions can be also processed by HTCM technologies, but have been excluded from this assessment as, based on experience with the City of Sydney domestic waste streams, they are delivered to specialized alternative waste treatment facilities.

Waste resource data for 2029-30, composition analysis and the matrix of processable fractions, are used to determine feedstock resource throughputs presented below.

Figure 51. MSW – City of Sydney LGA, annual feedstock throughputs, by conversion strategy

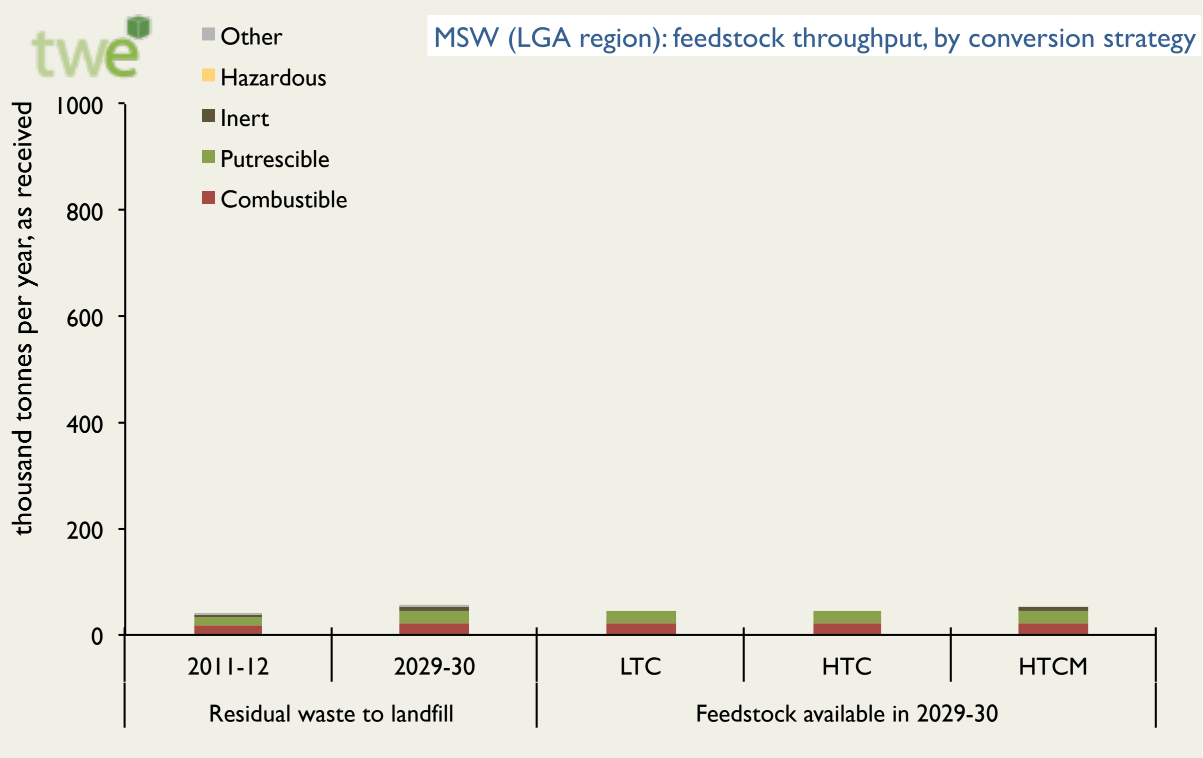


Figure 52. C&I – City of Sydney LGA, 2029-30 annual feedstock throughputs, by conversion strategy

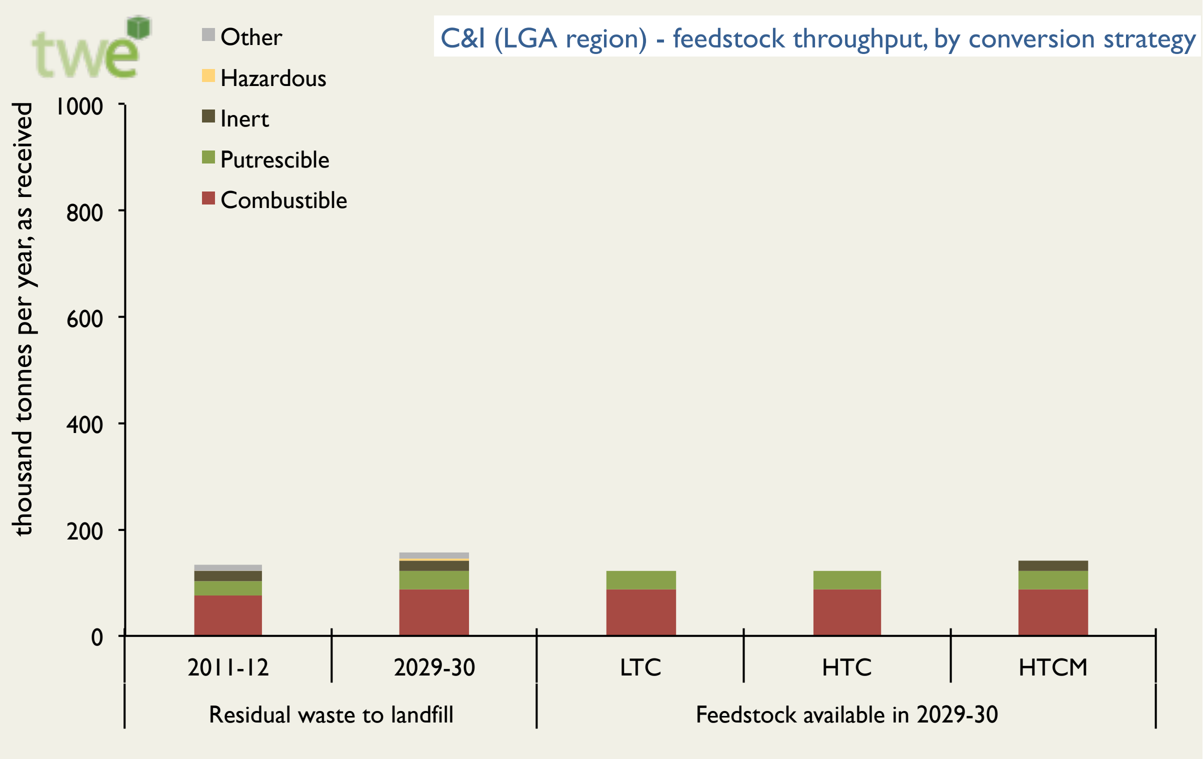


Figure 53. MSW – SSROC region, annual feedstock throughputs, by conversion strategy

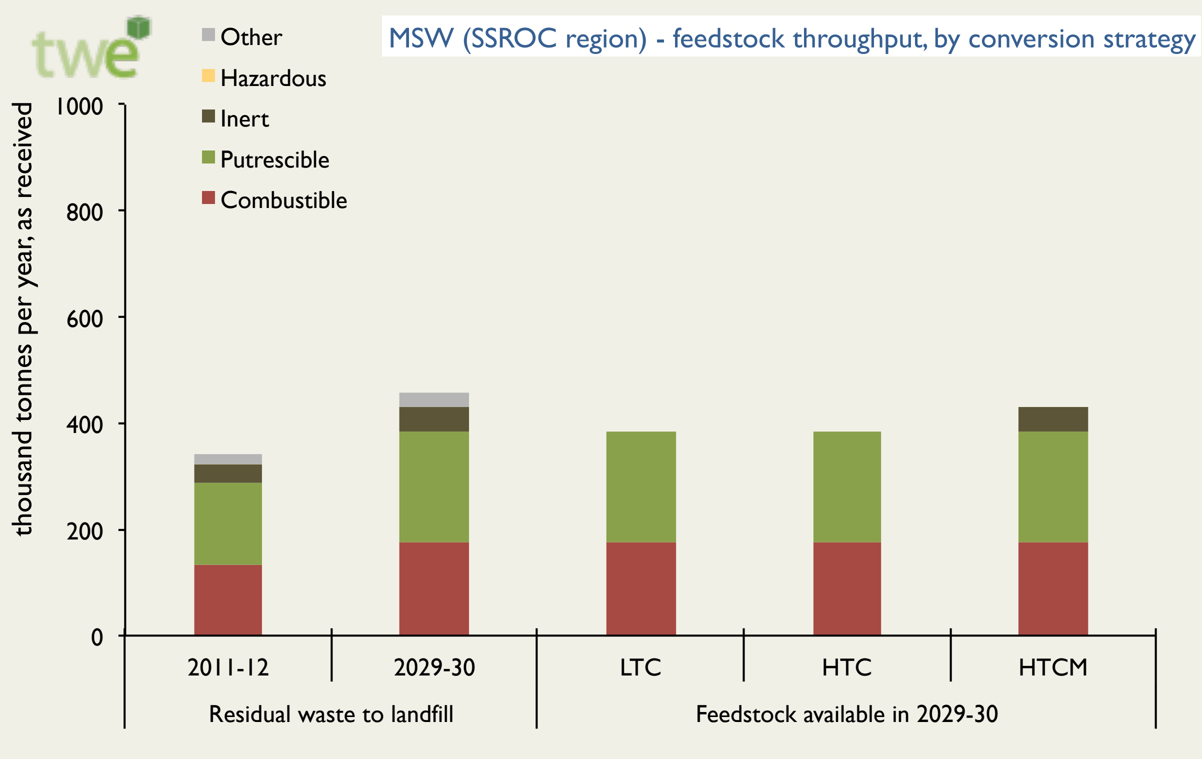
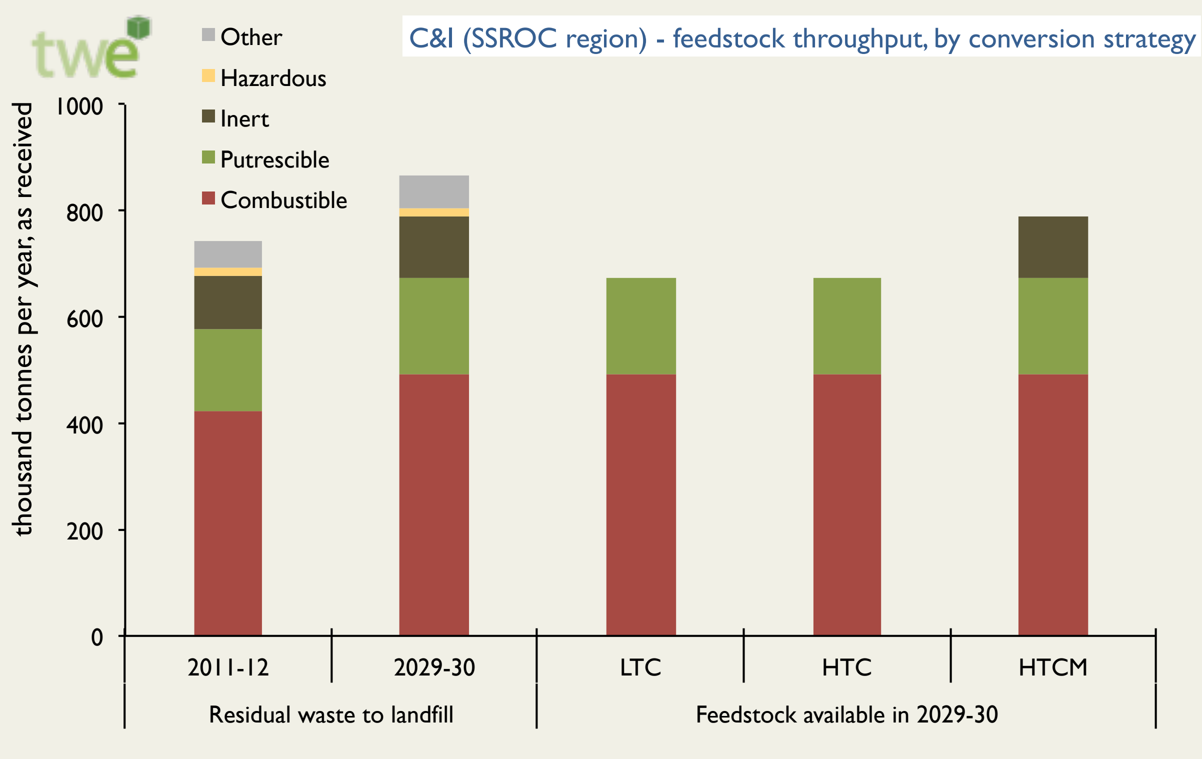


Figure 54. MSW – SSROC region, 2029-30 annual feedstock throughputs, by conversion strategy



Scenario analysis

In this section we present modelling results across the set of Syngas from Waste scenarios in terms of the following key performances:

- **raw syngas yield**, in petajoules per year (PJ/y, HHV basis) estimated, along with an assessment of the renewable energy fractions, for each conversion technology and implementation scenario;
- **net delivered SNG**, where the amount of SNG delivered to the City, net of own use and losses along the upgrading (SNG generation from raw syngas) and delivery chain is estimated;
- **waste diversion from landfill,** or the ability to contribute further to the City's resource recovery efforts and further reduce the amount of residual waste (incl. AWT residuals) that is sent to landfill, in tonnes per year (t/y, as received), by 2029-30.

Raw syngas yield

The raw syngas yield is estimated on the basis of the performance parameters presented earlier, on the basis of the following steps:

1. **design plant throughput**
2. **plant thermal input**
3. **syngas thermal output**
4. **syngas yield**
5. **renewable fraction**

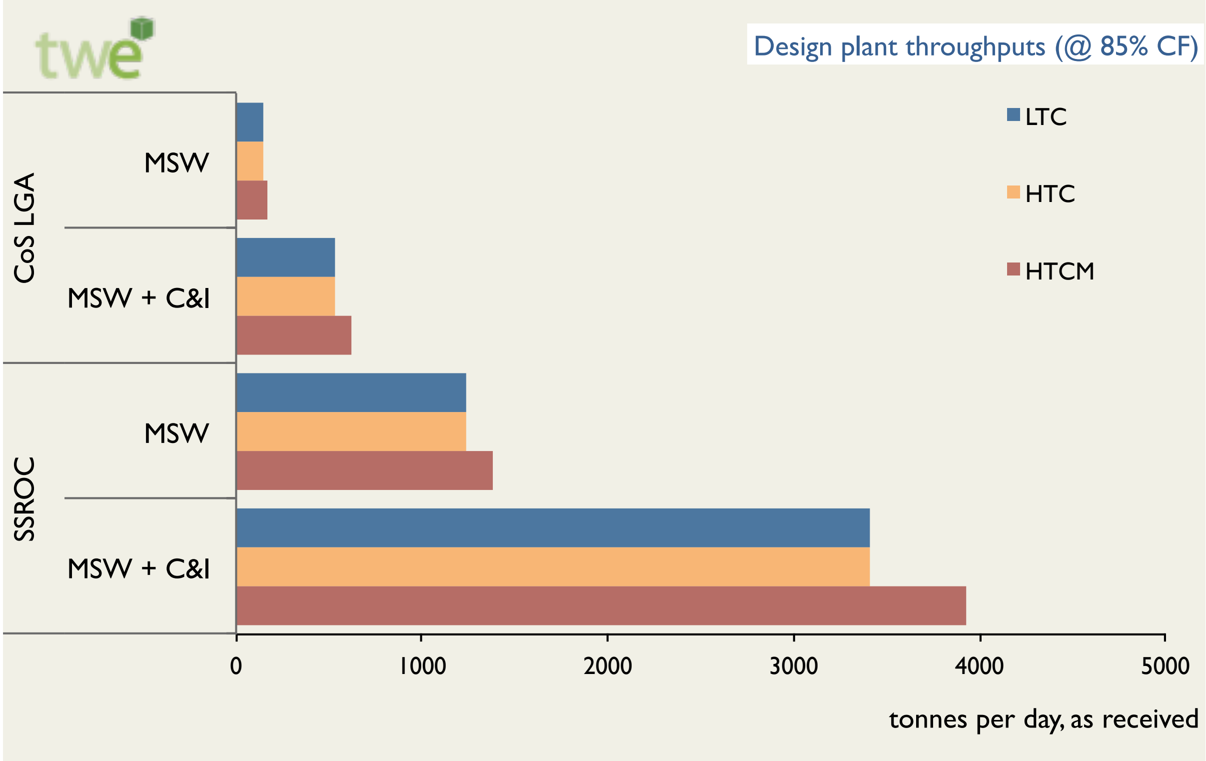
Design plant throughput

The first step is to determine the design plant throughput, in tonnes per day, required under each scenario has been determined based on the waste resource available in 2029-30 (design year) and assuming a capacity factor of 85%.

The resulting figures, also summarized in the diagram below, are:

- **City of Sydney LGA – MSW,** from 141.7 (LTC/HTC) to 167.4 (HTCM) tpd;
- **City of Sydney LGA – MSW + C&I,** from 530.8 (LTC/HTC) to 623.6 (HTCM) tpd;
- **SSROC region – MSW,** from 1,237.0 (LTC/HTC) to 1,382.6 (HTCM) tpd; and
- **SSROC region – MSW + C&I,** from 3,406.5 (LTC/HTC) to 3,925.7 (HTCM) tpd.

Figure 55. Syngas from Waste – design plant throughputs, by conversion strategy and implementation scenario



Plant thermal input

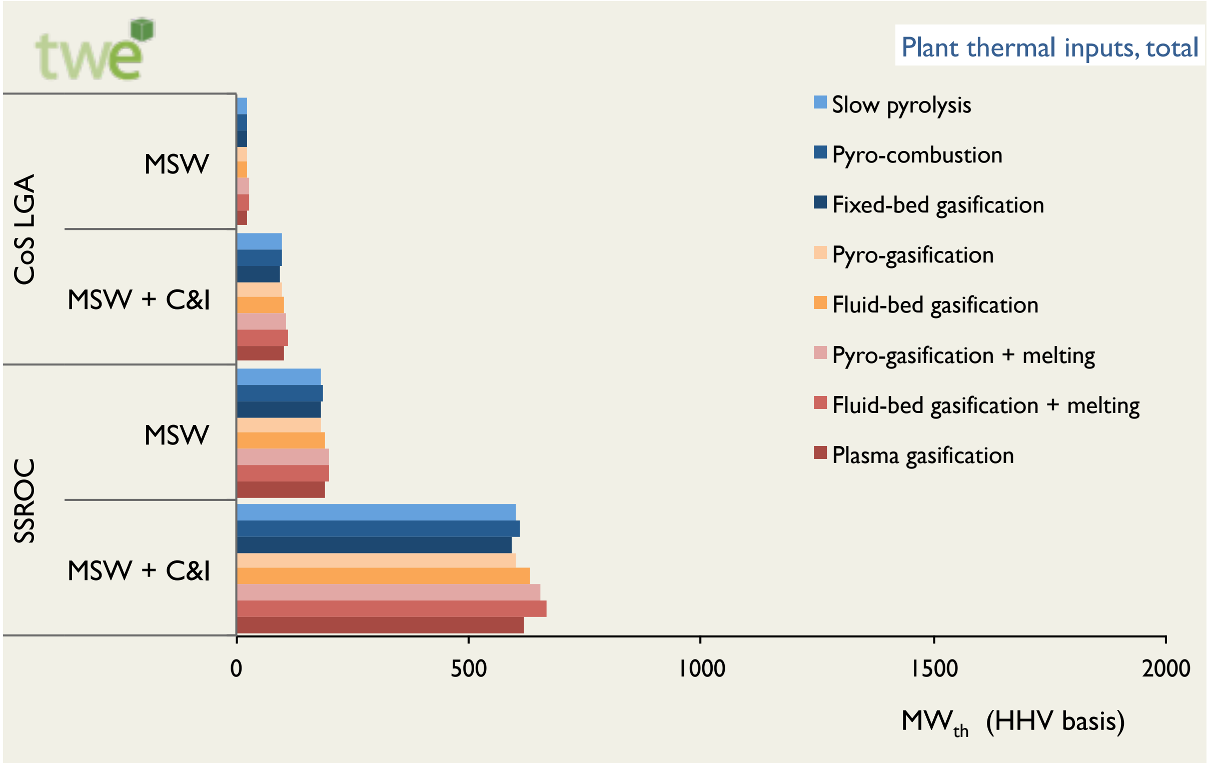
The plant thermal input – expressed in MW_{th} (HHV basis) – is a combination of the following:

- the *thermal energy content of the feedstock*, calculated on the basis of the design plant throughputs presented earlier, and the estimated energy contents (HHV basis) presented under *Section 3. Feedstock* Resources;
- the *auxiliary thermal input*, calculated on the basis of the design plant throughputs presented earlier, and the auxiliary fuel requirements for each of the conversion technologies considered.

The resulting figures, also summarized in the diagram below, are:

- **City of Sydney LGA – MSW,** ranging from 21.5 MW_{th} for LTC – fixed bed gasification, to 26.1 MW_{th} to HTCM – pyro-gasification + melting;
- **City of Sydney LGA – MSW + C&I,** ranging from 95.0 MW_{th} for LTC – fixed bed gasification to 109.9 MW_{th} to HTCM – pyro-gasification + melting;
- **SSROC region – MSW,** ranging from 181.0 MW_{th} for LTC – fixed bed gasification to 199.9 MW_{th} to HTCM – pyro-gasification + melting; and
- **SSROC region – MSW + C&I,** ranging from 590.4 MW_{th} for LTC – fixed bed gasification to 667.0 MW_{th} to HTCM – pyro-gasification + melting.

Figure 56. Syngas from Waste – plant thermal inputs, by conversion technology and implementation scenario



Raw syngas yield

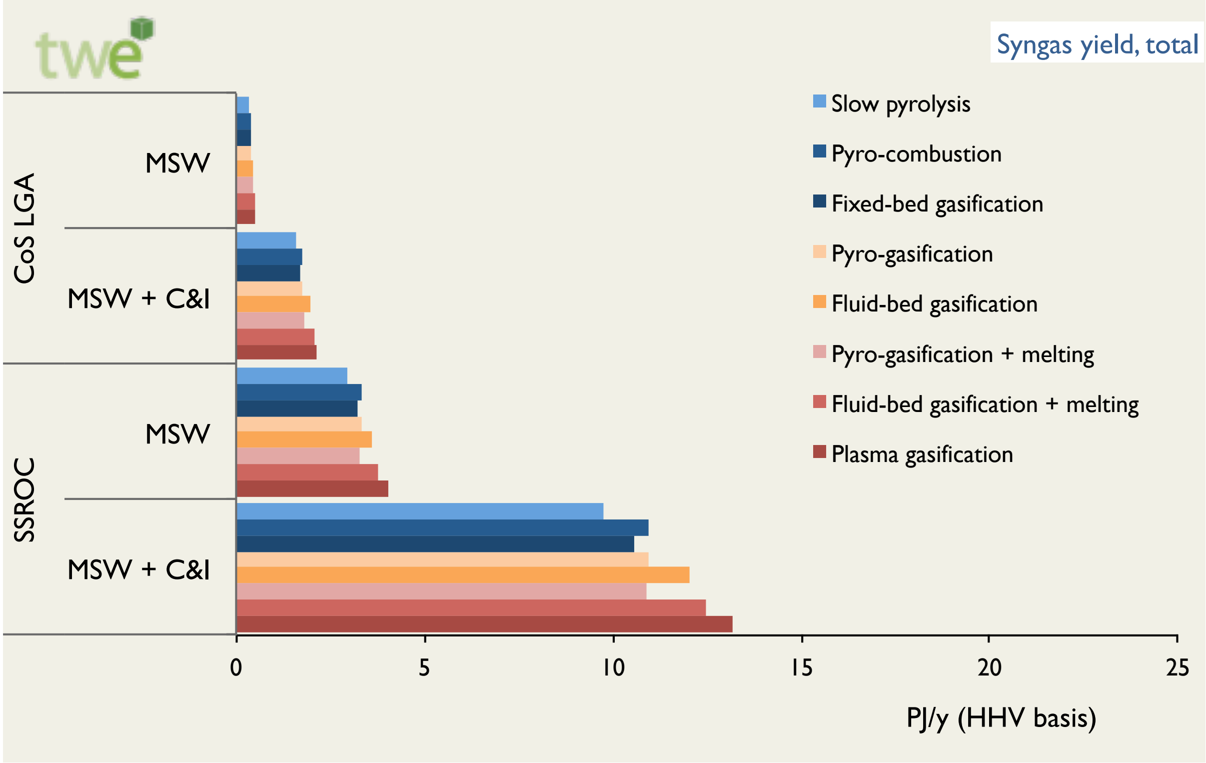
The raw syngas yield – expressed in petajoules per year (PJ/y, HHV basis) – is a calculated from the plant thermal inputs by applying the following:

- *Cold Gas* Efficiency (CGE) figures presented earlier for each of the thermal conversion technologies considered; and
- a *design capacity factor* of 85%.

The resulting figures, also summarized in the diagram below, are:

- **City of Sydney LGA – MSW,** ranging from 0.36 PJ/y for LTC – slow pyrolysis, to 0.50 PJ/y to HTCM – plasma gasification;
- **City of Sydney LGA – MSW + C&I,** ranging from 1.58 PJ/y for LTC – slow pyrolysis, to 2.13 PJ/y to HTCM – plasma gasification;
- **SSROC region – MSW,** ranging from 2.97 PJ/y for LTC – slow pyrolysis, to 4.06 PJ/y to HTCM – plasma gasification; and
- **SSROC region – MSW + C&I,** ranging from 9.75 PJ/y for LTC – slow pyrolysis, to 13.16 PJ/y to HTCM – plasma gasification.

Figure 57. Syngas from Waste – raw syngas yields, by conversion technology and implementation scenario



Renewable syngas yield

The renewable energy content of the syngas – calculated as the renewable energy content of the total energy input into the conversion reactor, by adjusting renewable energy content feedstock figures presented under *Section 3. Feedstock Resources*, to account for the auxiliary energy requirements for each of the conversion technologies – is presented below:

- **slow pyrolysis –** 62.9% (LGA – MSW), 67.4% (SSROC – MSW), 62.3% (C&I – all regions);
- **pyro-combustion –** 61.9% (LGA – MSW), 66.5% (SSROC – MSW), 61.6% (C&I – all regions);
- **fixed-bed gasification –** 65.3% (LGA – MSW), 69.4% (SSROC – MSW), 64.3% (C&I – all regions);
- **pyro-gasification –** 63.1% (LGA – MSW), 67.6% (SSROC – MSW), 62.5% (C&I);
- **fluid-bed gasification –** 58.8% (LGA – MSW), 63.8% (SSROC – MSW), 59.1% (C&I – all regions);
- **pyro-gasification + melting –** 60.5% (LGA – MSW), 64.6% (SSROC – MSW), 59.8% (C&I – all regions);
- **fluid-bed gasification + melting –** 58.9% (LGA – MSW), 63.2% (SSROC – MSW), 58.4% (C&I – all regions); and

- **plasma gasification –** 65.3% (LGA – MSW), 68.9% (SSROC – MSW), 63.7% (C&I – all regions);

Figure 58. Syngas from Waste – syngas renewable energy content, LTC technologies, by resource

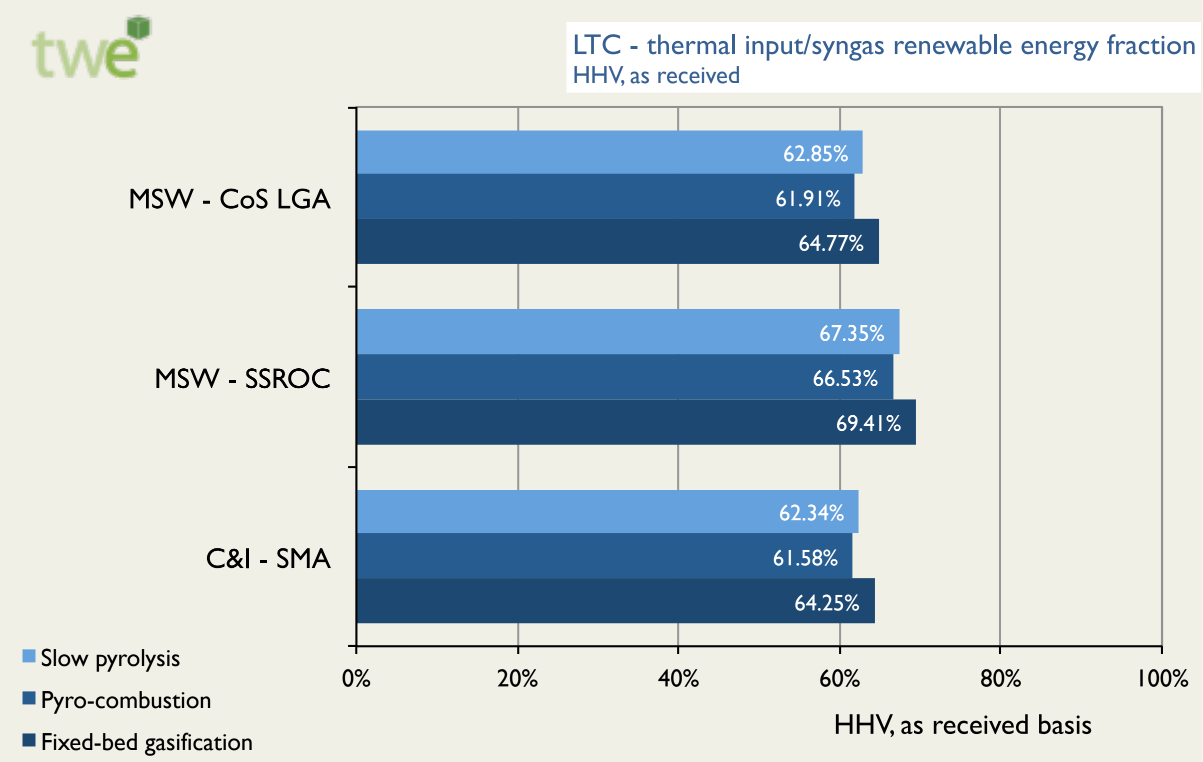


Figure 59. Syngas from Waste – syngas renewable energy content, HTC technologies, by resource

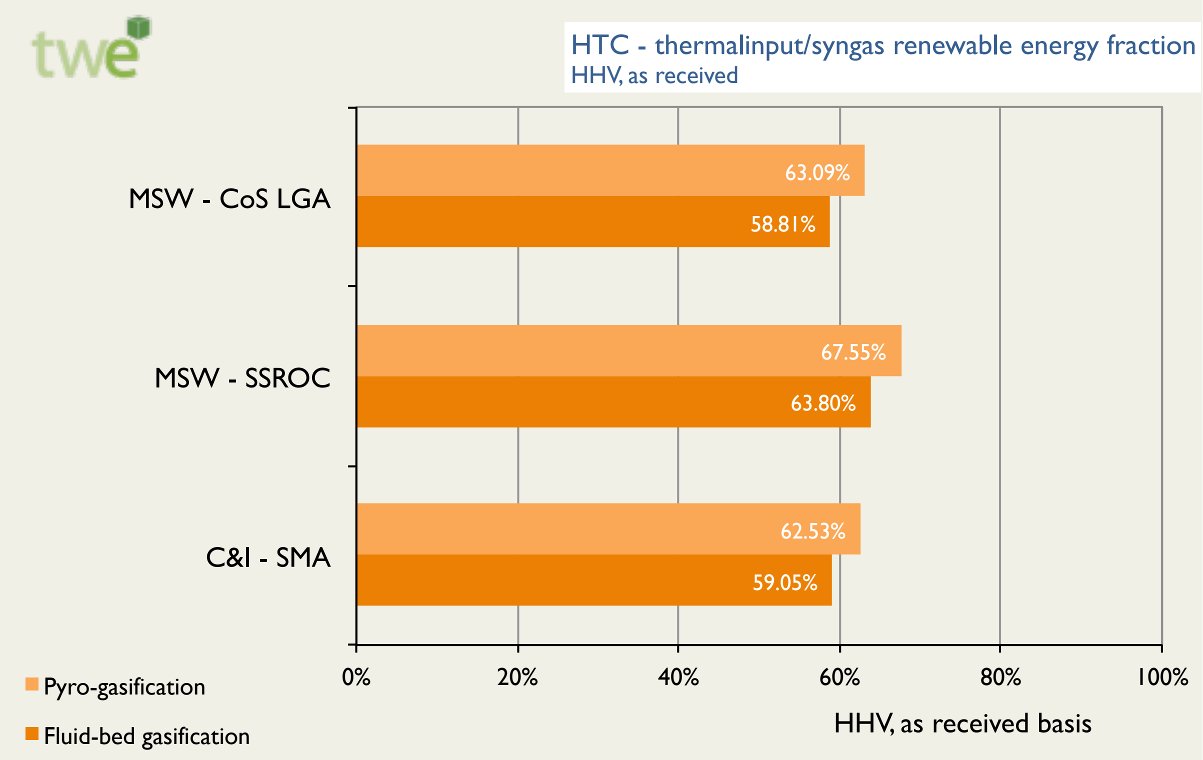
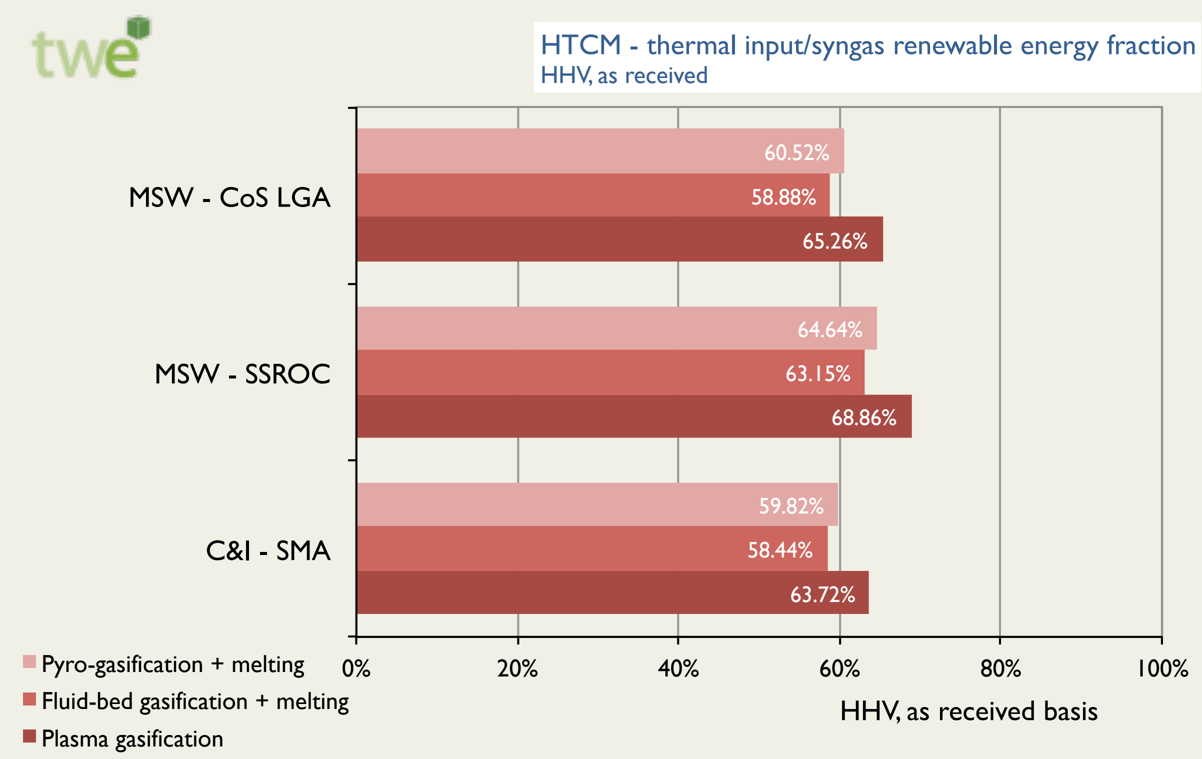
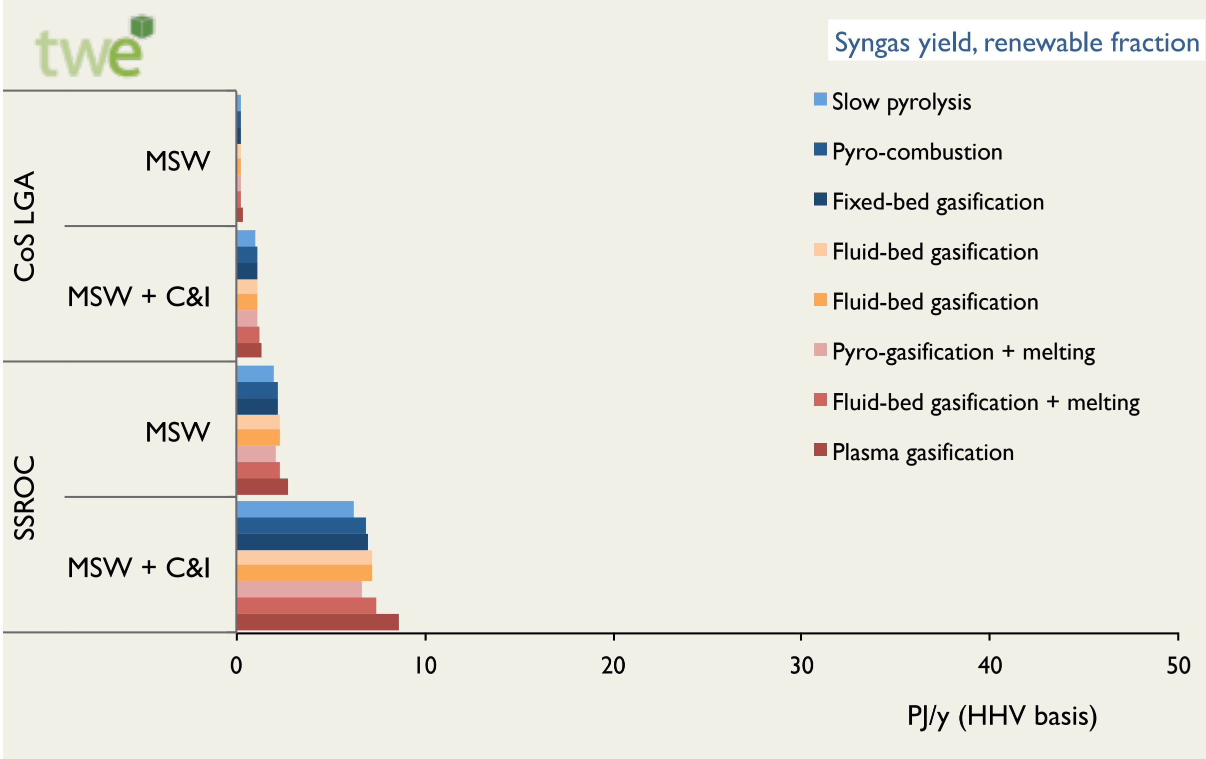


Figure 60. Syngas from Waste – syngas renewable energy content, HTCM technologies, by resource



The resulting renewable syngas yield figures are summarized in the diagram below.

Figure 61. Syngas from Waste – raw syngas yields, by conversion technology and implementation scenario



- **City of Sydney LGA – MSW,** ranging from 0.23 PJ/y for LTC – slow pyrolysis, to 0.33 PJ/y to HTCM – plasma gasification;
- **City of Sydney LGA – MSW + C&I,** ranging from 0.98 PJ/y for LTC – slow pyrolysis, to 1.37 PJ/y to HTCM – plasma gasification;
- **SSROC region – MSW,** ranging from 2.00 PJ/y for LTC – slow pyrolysis, to 2.80 PJ/y to HTCM – plasma gasification; and
- **SSROC region – MSW + C&I,** ranging from 6.23 PJ/y for LTC – slow pyrolysis, to 8.59 PJ/y to HTCM – plasma gasification.

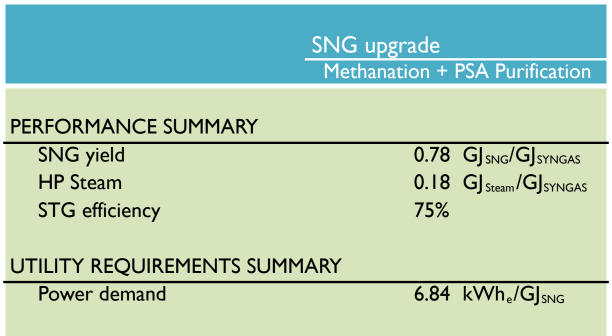
Net delivered SNG

Syngas upgrading

The raw syngas from the Syngas from Waste facility can be upgraded to substitute natural gas (SNG) through a methanation followed by a purification step based on pressure swing adsorption (PSA).

The key performance and operational assumptions for this process, based on the TREMP™ process are summarized in the table below.

Table 20. Upgrading - technology performances and utility requirements



	SNG upgrade Methanation + PSA Purification	
PERFORMANCE SUMMARY		
SNG yield	0.78	GJ_{SNG}/GJ_{SYNGAS}
HP Steam	0.18	GJ_{Steam}/GJ_{SYNGAS}
STG efficiency	75%	
UTILITY REQUIREMENTS SUMMARY		
Power demand	6.84	kWh_e/GJ_{SNG}

As discussed earlier in *Section 2. Syngas Utilization and Upgrading*, syngas upgrading to SNG via methanation yields 78% of the energy content in the incoming raw syngas stream as SNG. The process is highly exothermic, with the balance of the raw syngas energy released as heat. Based on commercial practice, we assume this heat to be recovered in a heat recovery steam generator (HRSG), with typical recovery efficiencies of 80%. This steam could be used upstream to support the gasification process, or for electricity generation in a steam turbine generator (STG) assembly.

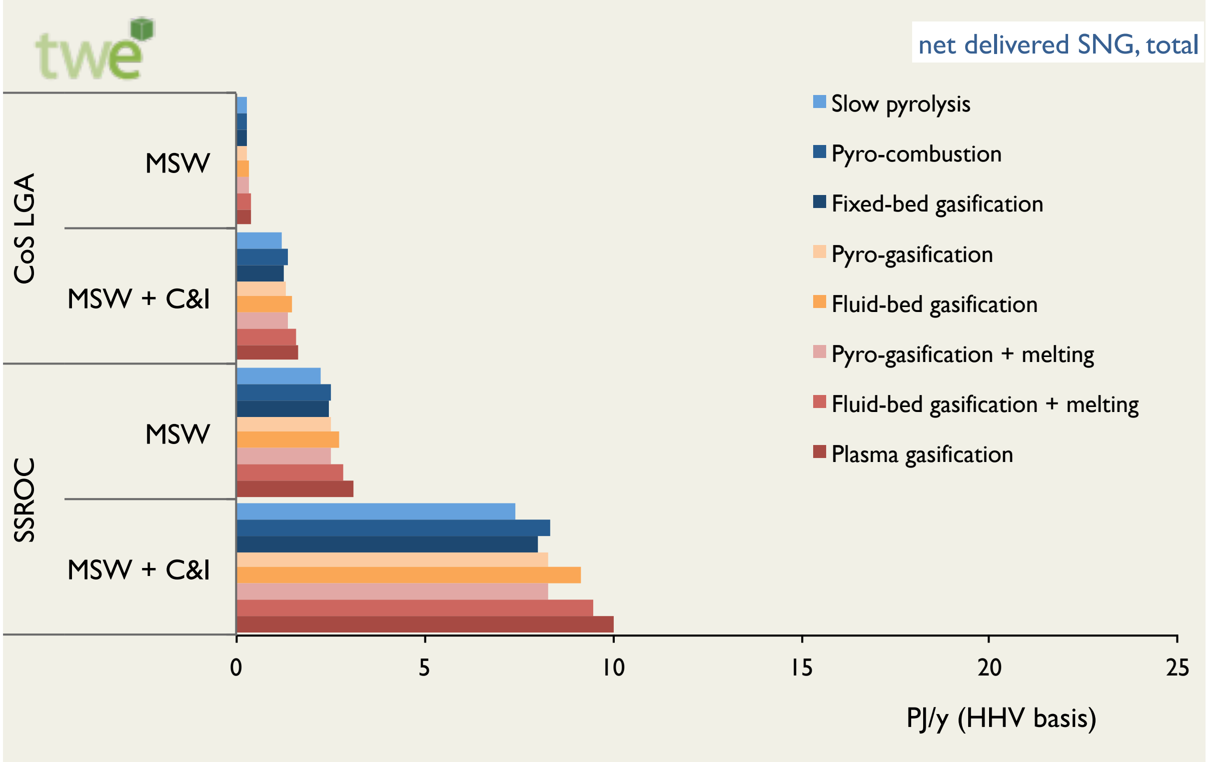
SNG delivery

The net delivered SNG for this pathway is calculated for each supply resource on the basis of the *unaccounted-for gas* (UAG) metric, published annually by the New South Wales Government.

The UAG, defined as the ratio of the annual gas output from the network, to the annual inflow, is a global measure accounting for fugitive losses and own consumption along the pipeline network. The latest reported figure, for 2010-11, was 2.45% (NSW TI 2012).

The resulting figures for net, delivered SNG are presented below.

Figure 62. Syngas from Waste – net, delivered SNG, by conversion technology and implementation scenario



- **City of Sydney LGA – MSW,** ranging from 0.27 PJ/y for LTC – slow pyrolysis, to 0.38 PJ/y to HTCM – plasma gasification;
- **City of Sydney LGA – MSW + C&I,** ranging from 1.20 PJ/y for LTC – slow pyrolysis, to 1.62 PJ/y to HTCM – plasma gasification;
- **SSROC region – MSW,** ranging from 2.25 PJ/y for LTC – slow pyrolysis, to 3.09 PJ/y to HTCM – plasma gasification; and
- **SSROC region – MSW + C&I,** ranging from 7.42 PJ/y for LTC – slow pyrolysis, to 10.01 PJ/y to HTCM – plasma gasification.

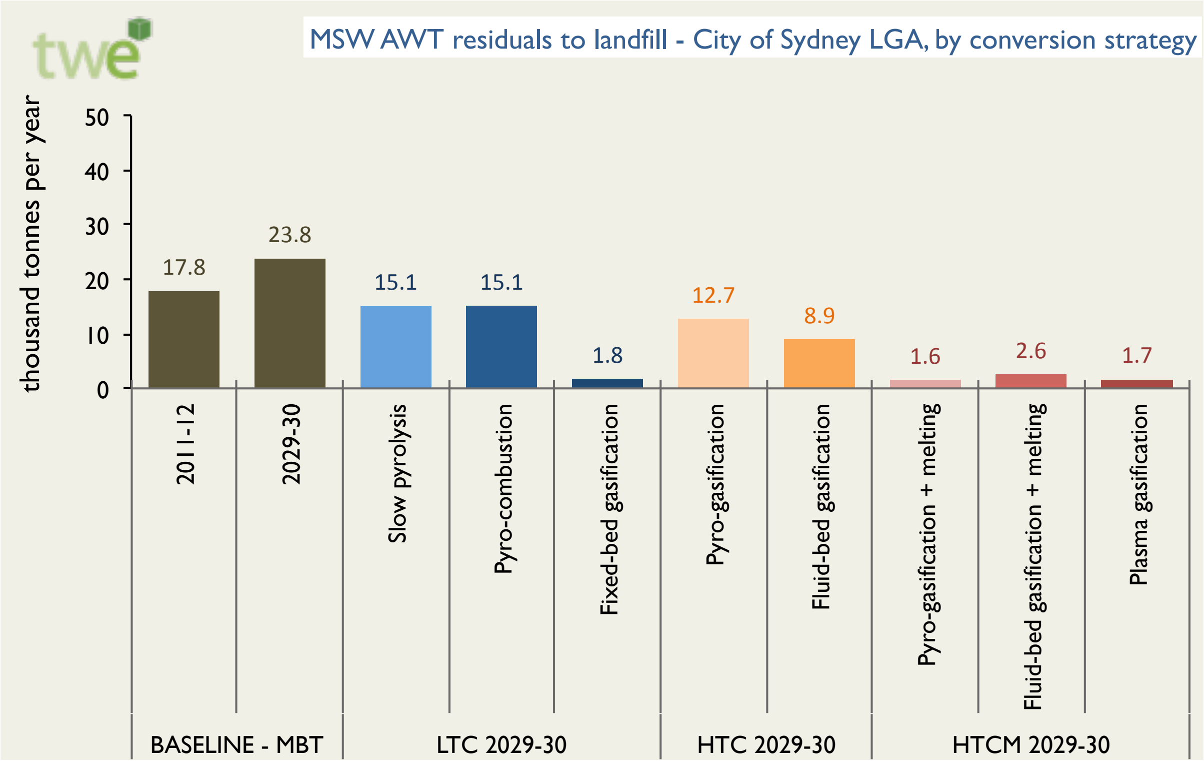
Diversion from landfill

In this section we present results of the total diversion from landfill achieved by 2029-30 for each technology for the domestic waste stream collected within the City of Sydney LGA.

AWT residuals to landfill

The amount of residues delivered to landfill in 2029-30 is reported in the diagram below for each of the conversion technologies, alongside with the amounts of AWT residuals delivered to landfill under the baseline solution (98% of post-MRF residuals delivered to mechanical-biological treatment).

Figure 63. AWT residuals to landfill - MSW, City of Sydney LGA



- **mechanical-biological treatment (baseline) –** from 17,281.2 tonnes per year in 2011-12, up to 23,783.6 tonnes per year by 2029-30;
- **slow pyrolysis –** 15,080.3 tonnes per year by 2029-30;
- **pyro-combustion –** 15,095.4 tonnes per year by 2029-30;
- **fixed-bed gasification –** 1,758.2 tonnes per year by 2029-30;
- **pyro-gasification –** 8,305.4 tonnes per year by 2029-30;
- **fluid-bed gasification –** 10,701.7 tonnes per year by 2029-30;
- **pyro-gasification + melting –** 1,575.9 tonnes per year by 2029-30;
- **fluid-bed gasification + melting –** 2,596.2 tonnes per year by 2029-30; and
- **plasma gasification –** 1,734.6 tonnes per year by 2029-30.

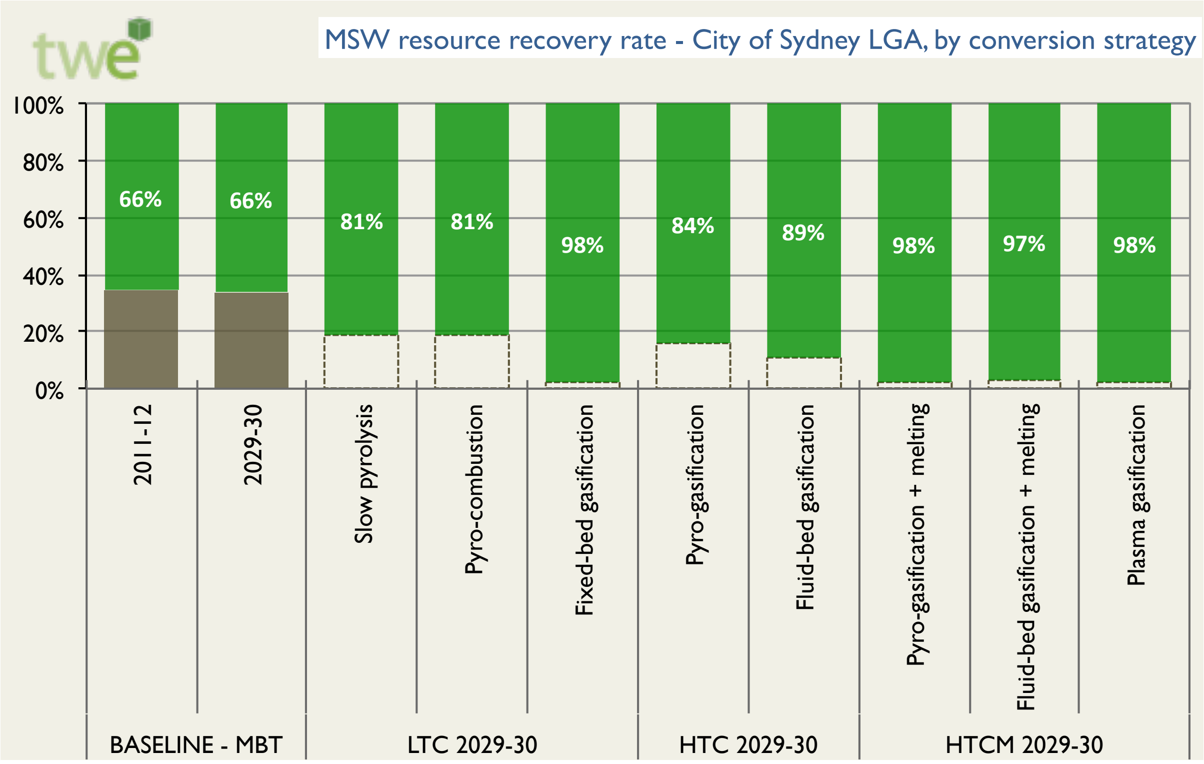
Resource recovery

In order to evaluate total diversion from landfill, we combine the AWT residuals to landfill figures with figures from other resource recovery activities, to obtain the resource recovery rate for the MSW component of waste collected within the City of Sydney LGA, across each conversion technology scenario.

All the technologies bring significant benefits against the baseline scenario with mechanical-biological treatment, bringing resource recovery rate from 66% in the baseline scenario, up to between 87% (slow pyrolysis) and 98% (fixed bed gasification, pyro-gasification + melting and plasma gasification).

The results are summarised in the diagram below.

Figure 64. AWT residuals to landfill - MSW, City of Sydney LGA



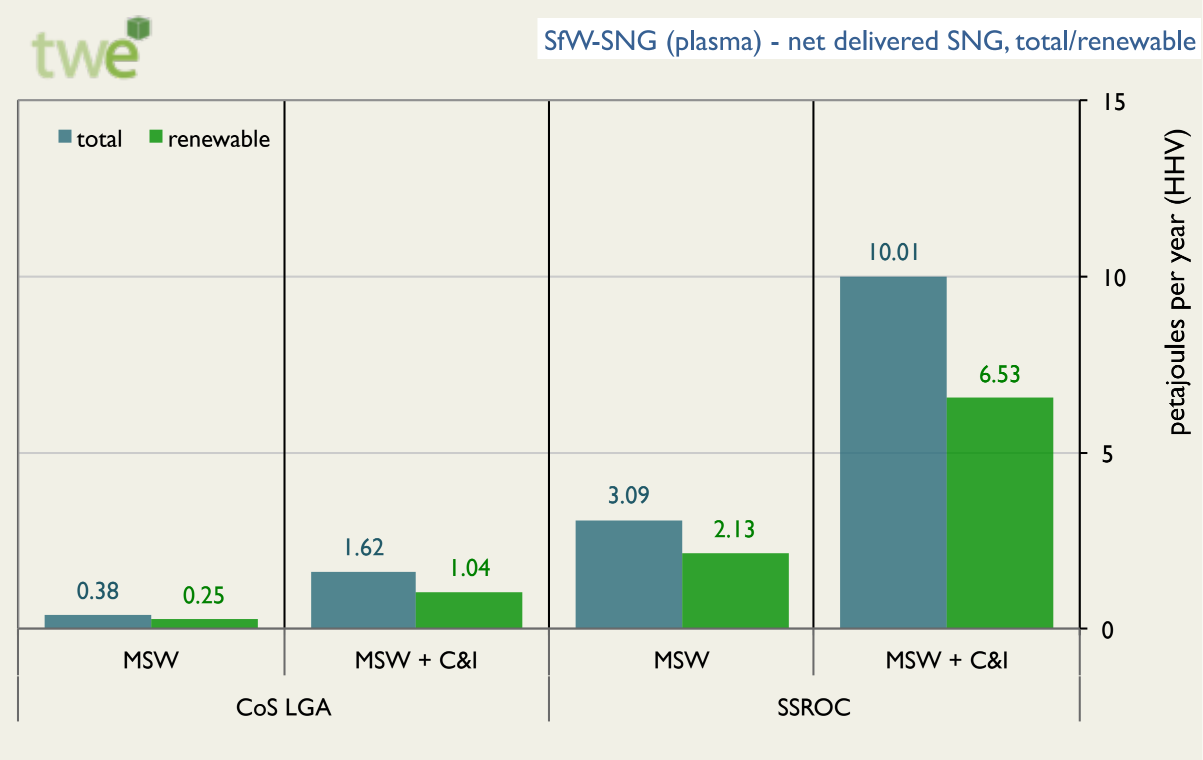
Conclusions

The modelling presented has shown how High-Temperature Conversion + Melting (HTCM) technologies deliver the highest energy recovery and waste management benefits, enabling the City to divert the highest amount of materials to a Syngas from Waste AWT facility and to achieve resource recovery rates in excess of 97%.

Energy recovery is also maximised with these three families of technologies, with the highest net, delivered SNG yields obtained via plasma gasification, with up to 10.01 PJ/y

(6.53 PJ/y renewable), recoverable from the SSROC region, as summarized in the diagram below.

Figure 65. SfW-SNG (plasma) – net, delivered SNG, total/renewable.



It is recommended that the HTCM conversion strategy, with the ability to process inert materials and metallic and inert contaminants in the mixed waste resource stream, form the basis of procurement activities, as described in *Section 6. Enabling Actions*.

An initial technology shortlist for these activities is provided in the table below.

Table 21. HTCM technology shortlist

Supplier	Technology				
Name	Name	Type	Scale [a]	Application	Maturity
AlterNRG	PGVR	Plasma Gasification	medium-large	MSW, SR,RDF	commercial
Ebara	TwinRec	Fluid Bed Gasification + Melting	medium-large	MSW, SR	commercial
Entech-RES	WtGas	Fixed bed Gasification	small-medium	MSW, sludge	proven
Nippon Steel	DMS	Fix Bed Gasification + Melting	medium-large	MSW, sludge	commercial
Plasco	PGP	Plasma Gasification	medium-large	MSW	proven
Advanced Plasma Power	GasPlasma	Plasma Gasification	small-medium	MSW, SR, RD	demonstrated
JFE/Thermoselect	HTR	Pyro-Gasification + Melting	medium-large	MSW	commercial
Toshiba	PKA	Pyro-Gasification + Melting	small-medium	MSW	proven
Metso Power	Metso CFBG	Fluid Bed Gasification	medium-large	MSW, RDF	proven

[a] small-scale <25 tpd; medium scale 25-250 tpd; large-scale >250 tpd