Steel Recycling Report

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List of Acronyms

ADP	Abiotic Depletion Potential
AP	Acidification Potential
BOS	Basic Oxygen Steelmaking
EAF	Electric Arc Furnace
EOL	End-of-Life
EP	Eutrophication Potential
EPD	Environmental Product Declarations
ETP	Potential Comparative Toxic Unit for ecosystems
ff	fossil fuels
fw	fresh water
GaBi	Ganzheitliche Bilanzierung (German for holistic balancing)
GHG	Greenhouse Gas
GWP	Global Warming Potential (Climate Change)
HTP	Potential Comparative Toxic Unit for humans
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
ODP	Depletion potential of the stratospheric ozone layer
PM	Potential incidence of disease due to PM emissions
POCP	Formation potential of tropospheric ozone

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Executive summary

HERA commissioned thinkstep-anz to quantify and articulate the benefits of recycling steel that is produced and used in Aotearoa New Zealand. The infinite recyclability of steel is used as a key part of its sustainability messaging. However, with no large-scale recycling capability within New Zealand, this is not immediately obvious to the local market.

This study aimed to identify the recycling rates of steel used in New Zealand

The aim of this study was to identify the recycling rates of the steel used in New Zealand so that the development of marketing claims and messaging of this important aspect can be supported. Some of the deliverables of this work included:

- collecting data to estimate how the steel produced and used in New Zealand is recycled at the end of life;
- calculating the benefits of recycling steel from New Zealand, including consideration of transport impacts; and
- presenting a sectoral analysis for the New Zealand building and infrastructure sector which is the largest steel using sector in the country.

Recycling steel scrap is beneficial overall

This report shows that recycling steel scrap produced in New Zealand provides significant environmental benefits, despite the need for transport to overseas recycling facilities.

The estimated steel scrap recovery rate is 74 percent, based on global data and New Zealand industry information for the calendar year 2020. This value is slightly lower than the estimated recovery rate for steel scrap in New Zealand based on the calendar year 2015, which was about 80 percent (Eunomia, 2017). Due to the higher proportion of New Zealand steel scrap generated from sectors with lower recovery rates (for example, domestic appliances), the estimated recovery rate for steel scrap is also lower than the global average recovery rate (85 percent).

When more steel scrap is recovered, the savings in global warming potential per tonne of steel scrap generated is higher. At 74 percent recovery, the savings in global warming potential per tonne of steel scrap generated in New Zealand was 1,085 kg CO_2-equivalent. If 100 percent recovery could be achieved, there is potential savings of 1,473 kg CO_2-equivalent. The 26 percent increase in additional steel recycling improves the overall potential savings by about 36 percent, due to the diversion of steel scrap disposed to landfill, which has environmental burdens.

Furthermore, the sectoral analysis found that the estimated steel scrap recovery rate in the New Zealand building and infrastructure sector is 85 percent, which is also slightly lower than the recovery rate of many developed countries. At 85 percent recovery, the savings in global warming potential per tonne of steel scrap generated in the sector was 1,249 kg CO_2-equivalent. If 100 percent recovery could be achieved, there is potential savings of 1,473 kg CO_2-equivalent.

The benefits from recycling are dependent on the amount of steel scrap collected

The results of this study show that the amount of steel scrap collected for recovery is critical to the overall benefits of the recycling system. Nevertheless, the current estimated collection rates are providing a significant benefit across the year — the collection of 545 kilotonnes of steel scrap every year is shown to provide a net benefit of 816 kilotonnes CO_2-equivalent. This would increase to 1,107 kilotonnes CO_2-equivalent per year if 100 percent of generated steel scrap were collected for recovery. Similar net benefits exist for steel scrap in the New Zealand building and infrastructure sector.

Recommendations to improve the steel scrap collection rate in New Zealand include:

- encouraging the design of products for recycling so that material disassembly and separation during the EOL phase is easier; and
- continuously improving the waste management and recycling infrastructure; adapting to the material recovery of complex end-of-life products made from a diverse range of materials.

Results are limited to the current data available

It is important to note that the results in this report are limited to the current data availability for steel scrap generated and produced in New Zealand. Although the New Zealand Waste Disposal Levy report (Eunomia, 2017) provided some insights into the estimated steel recovery in 2015, the data is outdated. Industry data was obtained to estimate the amount of steel generated in different sectors in New Zealand. This was combined with global data on steel recovery rates by sector to calculate the total amount of steel scrap in New Zealand. This report assumes that the proportion of steel scrap that is not recovered is lost to landfill. This is a conservative assumption since there is no indication of the fate of unrecovered steel scrap in New Zealand.

1 Introduction

HERA commissioned thinkstep-anz to quantify and articulate the benefits of recycling steel that is produced and used in Aotearoa New Zealand. The infinite recyclability of steel is used as a key part of its sustainability messaging. However, with no large-scale recycling capability within New Zealand, this is not immediately obvious to the local market.

This study aimed to identify the recycling rates of New Zealand steel

The aim of this study was to identify the recycling rates of the steel used in New Zealand so that the development of marketing claims and messaging of this important aspect can be supported. Some of the deliverables of this work included:

- collecting data to estimate how the steel produced and used in New Zealand is recycled at the end of life;
- calculating the benefits of recycling steel from New Zealand, including consideration of transport impacts; and
- presenting a sectoral analysis for the New Zealand building and infrastructure sector which is the largest steel using sector in the country.

The proportion of scrap recycled is based on approximation

In this study, the approach used to estimate the proportion of scrap recycled is based on approximation from the New Zealand metal industry and published data. The New Zealand Association of Metal Recyclers (NZAMR) confirmed that primary data is not currently available for New Zealand.

Only post-consumer steel scrap was considered in this study

The scope of this study is based on the Environmental Product Declaration (EPD) modules C2-C4 and module D.

The system boundary starts at the ‘end-of-life’ state when the steel is transported to a processing facility (C2). It is important to note that only post-consumer steel scrap (waste arising after consumer use of a product) was considered in this study. Pre-consumer steel scrap (waste from production or manufacturing) was excluded.

The waste processing stage (C3) includes the separation of steel from other materials and scrap processing (shredding activities, baling, shearing, etc.). Material that is not captured for recycling is assumed to be disposed to landfill (C4). Module D starts at the ‘end-of-waste’ state when the steel is no longer a product in its first life cycle and becomes a potential input for its second life cycle.

For steel, the “end of waste” state is generally reached when the scrap has been collected and sorted/pre-processed, and is available to be purchased by a recycling facility. This means that the ‘end-of-waste’ state is when the scrap has completed the waste processing (C3) stage. Module D gives a credit for the net recycling impact of steel.

The scope of the study

The scope of the study includes the:

- transport from collection to recyclers — the scrap processing facilities (C2);
- scrap processing operations including shredding, baling, shearing, gas-cutting, etc. (C3);
- transport to landfill for cases with steel lost to landfill (C4);
- operation of the landfill including leachate treatment for cases with steel lost to landfill (C4);
- transport from a scrap processing facility to the steel mill (Module D);
- steel mill operations in an Electric Arc Furnace (EAF) or Basic Oxygen Steelmaking (BOS) vessel (Module D); and
- production of primary steel via iron ore which is avoided (Module D).

The steel recycling benefits and environmental impacts were determined using the Life Cycle Assessment (LCA) method. The results from the assessment are not intended to support comparative assertions of different metal types, but to assist in understanding the benefits of capturing and recycling steel waste.

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2 Data collection & modelling approach

2.1 Data collection approach

The proportion of steel scrap produced in New Zealand and specifically in the building and infrastructure sector has been estimated based on:

- steel scrap export data obtained from the Harmonised Trade Statistics excluding 'new production' steel scrap data approximated by New Zealand Steel;
- steel scrap percentage by sector approximated by the NZAMR; and
- global literature on steel use and steel recovery rates by different sectors.

This study considers post-consumer steel scrap, defined as waste arising after consumer use of a product. Pre-consumer steel scrap was not considered in this study. Pre-consumer steel scrap is defined as the scrap produced during the manufacturing and production stages.

Sections 2.1.1 and 2.1.2 describe the data used to calculate the total post-consumer steel scrap generated in New Zealand and the proportion captured for recovery. Consideration is given to a comparison of steel recovery rate based on global data and the New Zealand Waste Disposal Levy report in Section 2.1.3. Section 2.1.4 shows how the transport distances of steel scrap to either recovery or disposal were estimated.

2.1.1 New Zealand post-consumer steel scrap export

New Zealand no longer recycles post-consumer steel scrap locally; New Zealand's only historic domestic steel recycler, Pacific Steel's Electric Arc Furnace at Otahuhu, closed in 2016.

As such, all post-consumer steel scrap is now exported to a range of countries, depending on demand in any given year. For the past five years, the amount of exported post-consumer ferrous waste and scrap in New Zealand has remained fairly consistent, despite the fluctuations in the global steel scrap price, as shown in Table 1. The amount of exported post-consumer ferrous waste and scrap excludes the 20 kilotonnes per year of 'new production' steel scrap captured in the n.e.c. (not elsewhere captured) under the scrap code's heading no. 7204. This volume of excluded pre-consumer scrap is based on an industry estimate provided by New Zealand Steel.

Year	Exported post-consumer ferrous waste and scrap (tonne)
2020	544,807
2019	547,327
2018	548,832
2017	536,232
2016	572,700

Table 1. Total exports of ferrous waste and scrap in New Zealand excluding 'new production' steel scrap captured in the n.e.c. under the scrap code's heading no. 7204 (Stats NZ, 2020).

Since the annual total of exported post-consumer steel scrap is relatively consistent, this study has been based on the exports of ferrous waste and scrap for the calendar year 2020. This data was retrieved from the New Zealand Harmonised Trade Statistics (Stats NZ, 2020), as shown in 2.1.2 Post-consumer . Only post-consumer ferrous waste and scrap was considered, hence the n.e.c. in heading no. 7204 scrap code excludes the small volume of 'new production' scrap from New Zealand Steel.

Ferrous waste and scrap type	Cast iron	Stainless steel	Alloy steel (excluding stainless)	Tinned iron or steel	n.e.c. in heading no. 7204	Total
Amount (kilotonnes)	2.17	31.3	57.0	20.5	434	**545**

Table 2. Total exports of ferrous waste and scrap in New Zealand for the 2020 calendar year (Stats NZ, 2020).

This data gives us the total amount of post-consumer steel scrap that was captured and exported for recovery in 2020. To understand the overall recovery rates of post-consumer steel scrap in New Zealand, we must also consider the sectors that scrap arises from in New Zealand and the average recovery rates, which are explored in the next section.

2.1.2 Post-consumer scrap generation and recovery

Primary data is not currently available for the quantity of steel scrap generation and recovery in New Zealand.

The World Steel Association provides global data for the proportion of steel used by sector and the average global recovery rates per sector. This data is provided in Appendix D for reference. The global steel recovery rates were assumed to be the steel collected for further recovery by sector since no further description was provided by the World Steel data.

The global data on the proportion of steel used by sector was not seen to be representative for New Zealand, so instead the proportion of steel scrap arising from each sector in New Zealand was used as a proxy. The New Zealand steel scrap sector percentages were based on initial data collection from the NZAMR members, industry knowledge, and awareness of recycling rates through local council collection services.

The total scrap generation was therefore estimated from:

- the proportion of steel scrap arising from each sector in New Zealand, approximated by the NZAMR, as shown in Table 3;
- recovery rates for the different sectors (World Steel Association, 2019), as shown in Table 3; and
- the total amount of post- consumer steel scrap exports, as provided in Table 2.

The difference in the amount of steel scrap produced and the total scrap exports was assumed to be material lost to landfill (refer to Figure 1). This is a conservative assumption since there is no available data for the unrecovered steel scrap flow. The amount of steel scrap exported is assumed to undergo further metallurgical processing (*i.e.* used as recycled input into steel production) in other countries.

Sector	Steel scrap (%)	Recovery rate (%)	Steel scrap produced (kilotonnes)
Building and infrastructure	50	85	332
Automotive	20	90	126
Metal products (mostly packaging)	10	82.5	68.5
Electrical equipment & domestic appliances	20	50	226
Total	**100**		**752**

Table 3. Estimated steel scrap produced based on different sectors and their respective recovery rates.

Based on the calculation, the amount of steel scrap collected for recovery or further metallurgical processing is 74 percent, and the remaining 26 percent of steel is assumed to be lost in landfill. The overall steel scrap produced in New Zealand for the calendar year 2020 is summarised in Figure 1.

2.1.3 Post-consumer scrap generation and recovery – New Zealand building and infrastructure sector

There is no primary data currently available for the New Zealand building and infrastructure sector; hence, the proportion of steel scrap arising from this sector was estimated (Table 4). It was assumed that the global data on the proportion of steel used by this sector was representative for New Zealand and the recovery rate for the sector (*i.e.* 85 percent) was the same across the different steel uses (World Steel Association, 2019).

Steel use	Steel use (%)	Recovery rate (%)	Steel scrap produced (kilotonnes)
Reinforcing bars	44	85	146
Structural sections	25	85	83
Sheet products, including those used in roofs, internal walls and ceilings	31	85	103
Total	**100**		**332**

Table 4. Estimated steel scrap produced in the New Zealand building and infrastructure sector based on different uses and their respective recovery rates.

Based on these assumptions, the amount of steel scrap collected from the New Zealand building and infrastructure sector for recovery or further metallurgical processing is 85 percent, and the remaining is assumed to be lost in landfill (Figure 1).

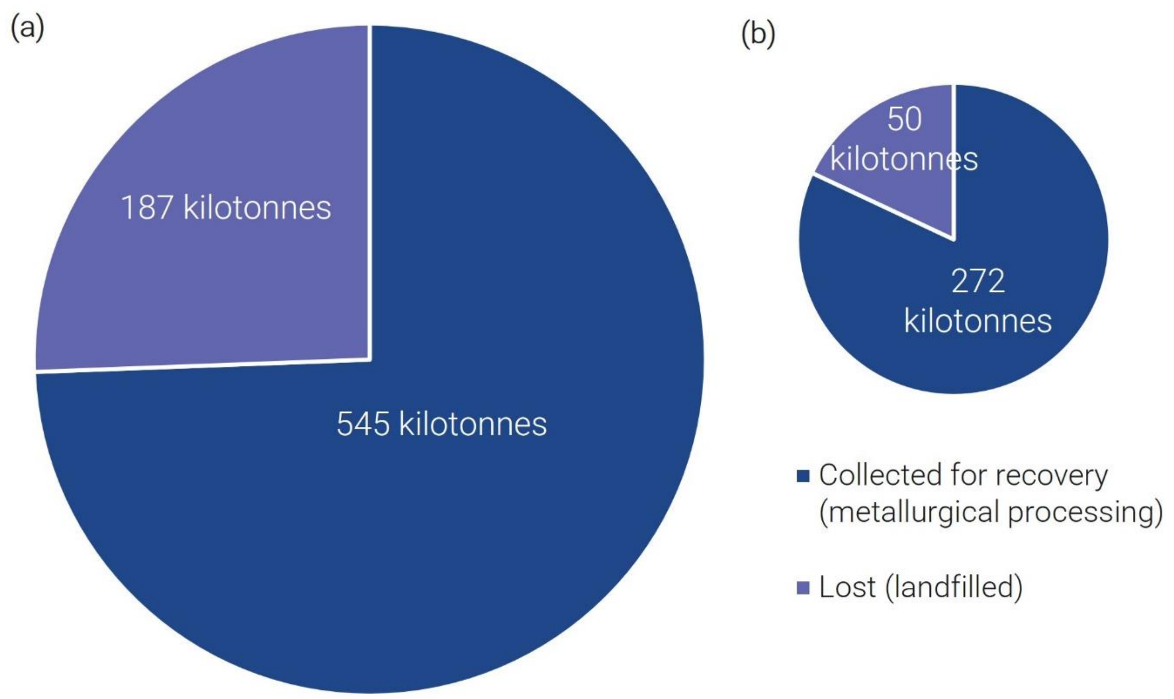

Figure 1. Estimated steel scrap produced in (a) New Zealand and (b) building and infrastructure sector, and their pathways for the calendar year 2020.

2.1.4 Steel recovery rate comparison

The proportion of steel scrap produced by sector is quite different in New Zealand compared to the global averages, with a much greater proportion of steel used for the electrical equipment, domestic appliances, and automotive sectors. The relatively low recovery rate for the electrical equipment and domestic appliances sector results in New Zealand's overall recovery rate being rather lower than the global average steel recovery rate of about 85 percent (refer Appendix D).

The estimated percentage of steel scrap produced in New Zealand is slightly lower than the steel recycling data in the New Zealand Waste Disposal Levy report based on the calendar year 2015 (Eunomia, 2017), which was about 80 percent (refer Appendix E). While the report provided the New Zealand-specific steel recycling data, the figures are outdated. Therefore, the estimated amount of steel scrap produced and recovered in New Zealand — based on the global recovery rates and New Zealand steel industry data of 2020 (Figure 1) — was used for the recycling benefits analysis for this study.

2.1.5 Steel scrap transport

The transport of the steel scrap to either landfill or recovery must be estimated in order to calculate the net benefits of recycling steel.
The steel scrap collected for recovery was assumed to be transported:

- 50 km by truck (50 percent utilisation) from the collection site to a recycler (scrap processing facility);
- 50 km by truck (50 percent utilisation) from the recycler (scrap processing facility) in New Zealand to the nearest large port;
- 10,649 km by sea (48 percent utilisation); and
- 50 km by truck (50 percent utilisation) to the receiving BOS and EAF facilities.

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The metal lost to landfill is assumed to be transported 50 km by truck (50 percent utilisation).

The sea freight distance was calculated as an export-weighted average of exports of ferrous waste and scrap for the calendar year 2020, based on New Zealand Harmonised Trade Statistics (Stats NZ, 2020). Individual sea freight distances were estimated from the Port of Auckland to a large port in the receiving country using http://portworld.com/map (S&P Global Platts, 2021), with detailed data available in Appendix A.

The total estimated transport distances are shown in Table 5.

Steel scrap produced	Road freight (km)	Sea freight (km)	Amount (kilotonnes)	Percentage (%)
Collected for recovery (metallurgical processing)	150	10,649	545	72
Lost (entering landfill)	50	-	207	28
		Total	**752**	**100**

Table 5. Estimated steel scrap flows in New Zealand and the distance travelled.

2.2 Modelling approach

The recycling model was based on the system boundary defined in Section 1. The recycling environmental impact and benefits were calculated based on an LCA model created in the GaBi Software system for life cycle engineering which was developed by Sphera (formerly thinkstep). The GaBi LCI Database 2020 (Sphera, 2020) provides the life cycle inventory data for several of the raw and process materials obtained from the background system. Most datasets have a reference year between 2016 and 2019. The specific reference year for the main background datasets used in this study can be seen in Table 6.

2.2.1 Recycling of New Zealand steel scrap

For steel products, the proportion of steel scrap collected for recovery through metallurgical processing was awarded a recycling credit based on World Steel's global average "Value of Scrap" dataset (*i.e.* the difference between primary and secondary steel production). The alloy mix has a negligible impact since steel scrap used in smelting processes has various mixes.

Based on the defined scope, the metal sent for recycling included domestic and international transportation. The model took a conservative approach and assumed that all metal lost (*i.e.* not collected for recovery) will be transported (50 kilometres) to an inert landfill.

The steel scrap processing (including shredding, baling, shearing, gas-cutting, etc.) was estimated based on the shredding process due to the lack of data for the different processes.

The steel scrap flow in New Zealand can be seen in Figure 2.

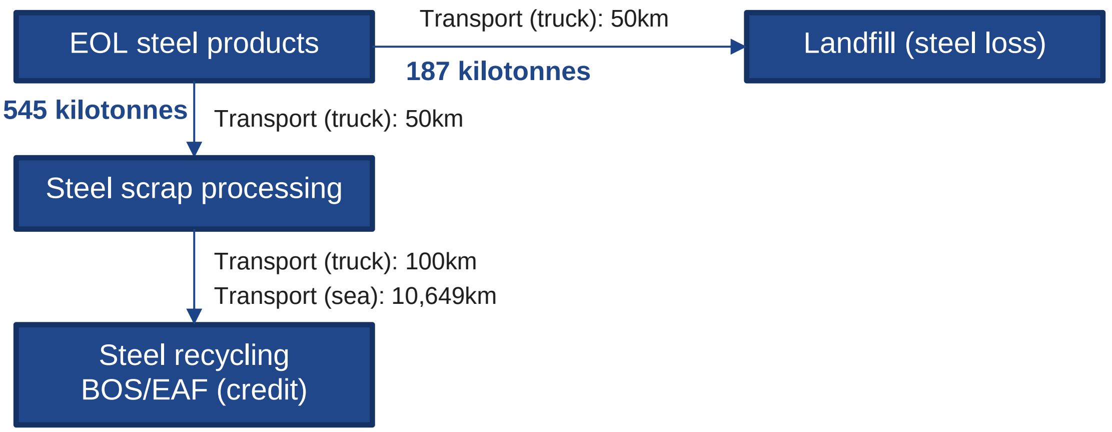

Figure 2. Steel scrap flow in New Zealand for the calendar year 2020.

2.2.2 Recycling model processes & datasets

The datasets used in calculating the environmental impact and recycling benefits are shown in Table 6.

Process	Dataset name	Source	Year	Geography
Transport				
Truck	Euro 0-6 mix, 20-26t gross weight/17.3t payload capacity	Sphera	2019	Global
	Diesel at refinery	Sphera	2016	Australia
Sea	Container ship, 5,000 to 200,000 dwt payload capacity, ocean going	Sphera	2019	Global
	Heavy fuel oil at refinery (1.0 wt.% sulphur)	Sphera	2016	Australia
Metal lost to landfill				
Steel loss	Inert matter (steel) on landfill	Sphera	2019	European Union
Collected metal for recovery				
Steel scrap processing	Metal shredding, baling, shearing, gas-cutting, etc. (estimated based on car shredding process)	thinkstep-anz	2019	New Zealand
	Electricity grid mix	Sphera	2016	New Zealand
Steel credit	Value of scrap	worldsteel	2019	Global

Table 6. Recycling processes and datasets.

2.2.3 Scenarios assessed

Two additional scenarios were also included to understand the impacts of the steel scrap pathways in New Zealand on the environmental impacts and recycling benefits. The scenarios used for comparison were:

- 100 percent steel scrap collected for recovery (100 percent steel scrap recycling; no transport to landfill or landfill operation); and

- No steel scrap collected for recovery (0 percent steel scrap recycling; all steel scrap lost to landfill including the transport impact to landfill and the landfill operation).

The proportion and volume of steel scrap collected for recovery for the different EOL scenarios included in this study are detailed in Table 7.

Scenarios	Steel recycling (72%)	Steel recycling (100%)	Steel recycling (0%)
Collected for recovery (kilotonnes)	545	732	0
Lost (entering landfill)	187	0	732
Total	**732**	**732**	**732**

Table 7. Estimated steel scrap flow in New Zealand based on the different EOL scenarios (amount of steel scrap collected for recovery through metallurgical processing).

Likewise, an EOL scenario assessment was undertaken for the New Zealand building and infrastructure sector. The scenarios are detailed in Table 8.

Scenarios	Steel recycling (85%)	Steel recycling (100%)	Steel recycling (0%)
Collected for recovery (kilotonnes)	272	322	0
Lost (entering landfill)	50	0	322
Total	**322**	**322**	**322**

Table 8. Estimated steel scrap flow in the New Zealand building and infrastructure sector based on the different EOL scenarios (amount of steel scrap collected for recovery through metallurgical processing).

3 Environmental impact & benefits

The environmental impacts of steel recycling were interpreted in accordance with EN 15804+A1 (CEN, 2013), the standard for construction product environmental product declarations (refer to Appendix B for the list of Life Cycle Impact Assessment (LCIA) indicators).

The most important environmental indicator for this study was the Global Warming Potential (GWP). Globally, the iron and steel sector is responsible for around 7 percent of all CO_2-equivalent (CO_2-eq) emissions (International Energy Agency, 2020). New Zealand Steel accounts for 2.2 percent of New Zealand's carbon emissions (Forsyth Barr, 2019). Hence, the GWP environmental impact indicator was chosen to further analyse the recycling impact of steel scrap in Section 3.1.

All other results according to EN 15804+A1 are provided in Appendix C. Most of the other environmental impact indicators followed a similar pattern to GWP with higher metal recycling rates leading to more credits, except for Acidification Potential of Soil and Water (AP) and Eutrophication Potential (EP) impacts. AP and EP showed higher environmental impacts associated with improved steel recycling rates due to the larger amount of scrap transported overseas leading to an increased amount of nitrogen oxide emitted to air during sea transport.

3.1 Assessment results

The potential environmental impacts and benefits per tonne of New Zealand steel scrap recycling for different EOL scenarios can be seen in Figure 3, based on the GWP environmental indicator.

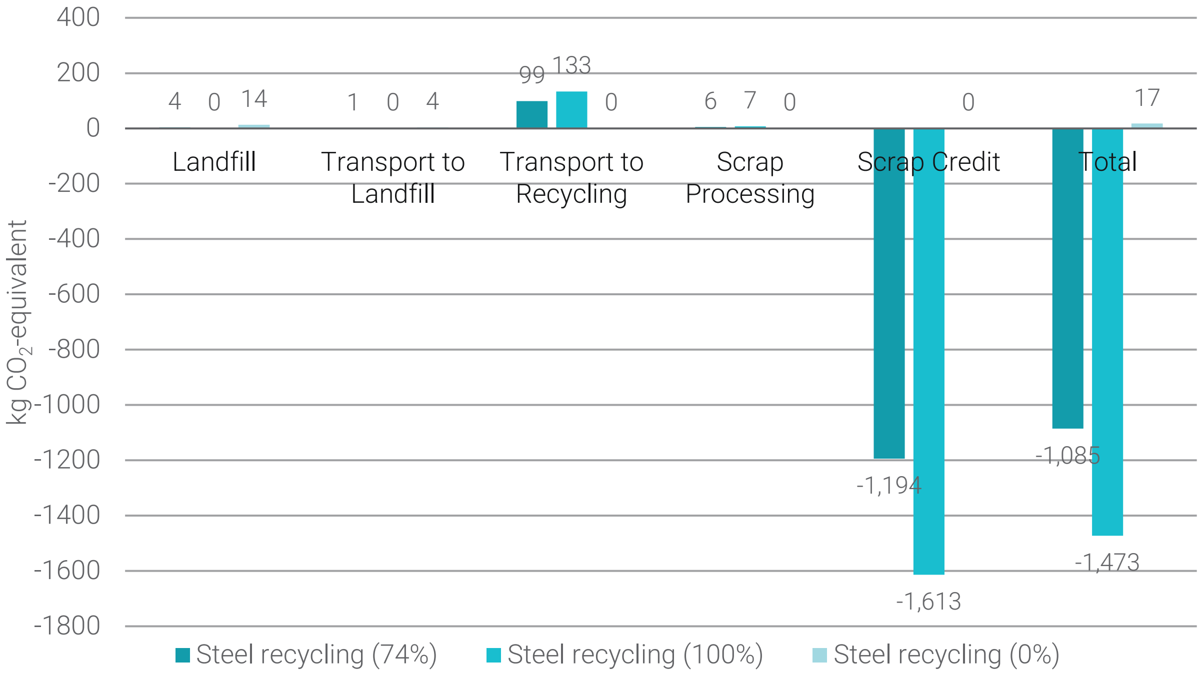

Figure 3. GWP per tonne of steel scrap recycling for different EOL scenarios in New Zealand.

The GWP impact results show that the scrap credit outweighed the burdens due to transport of the steel scrap and landfill of lost scrap for the 74 percent and 100 percent recycling scenarios.

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For the scenario with no recycling, the GWP impact was dominated by the transport to landfill and the landfill operation with no GWP credits.

The net impacts for each scenario are shown in Table 9, where a positive value denotes an overall burden, and a negative value denotes a credit. The 26 percent difference in recycling rate between the 74 percent and 100 percent scenarios leads to the net scrap GWP credit increasing by about 36 percent, due to the diversion of steel scrap disposed to landfill, which has environmental burdens.

EOL scenario	Net GWP impacts (kg CO_2-eq)
Steel recycling (0%)	17
Steel recycling (72%)	-1, 085
Steel recycling (100%)	-1,473

Table 9. Net GWP impacts for the collection of 1 tonne of steel scrap for different EOL recycling scenarios.

The main contributor to the GWP impacts for transport to recycling is the use of crude oil for sea shipping, about 92 percent. Although the impact of sea transport of steel scrap to other countries reduced the overall recycling benefits, it was still insignificant when compared to the steel scrap recycling credit.

3.2 Assessment results – New Zealand building and infrastructure sector

The potential GWP impacts and benefits per tonne of New Zealand building and infrastructure steel scrap recycling for different EOL scenarios can be seen in Figure 4.

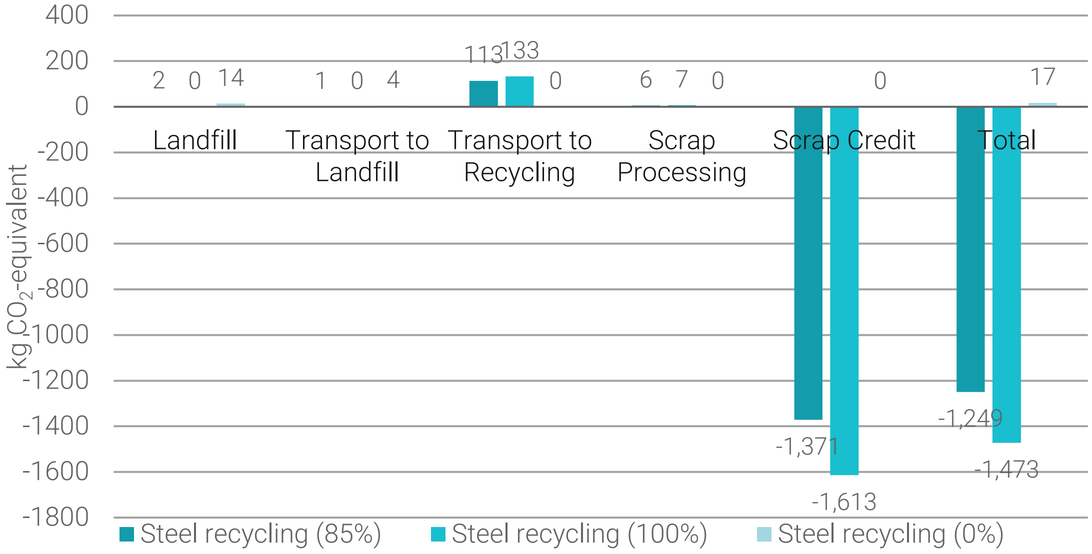

Figure 4. GWP per tonne of steel scrap recycling for different EOL scenarios in New Zealand building and infrastructure sector.

Overall, the results are similar to the results of New Zealand. The GWP impact results of this sector show that the scrap credit outweighed the burdens due to transport of the steel scrap and landfill of lost scrap for the 85 percent and 100 percent recycling scenarios. For the scenario with no recycling, the GWP impact was dominated by the transport to landfill and the landfill operation with no GWP credits.

The 15 percent difference in recycling rate between the 85 percent and 100 percent scenarios leads to the net scrap GWP credit increasing by about 18 percent, due to the diversion of steel scrap disposed to landfill, which has environmental burdens.

3.3 Overall annual impacts

The annual GWP impacts for steel scrap produced in New Zealand and in the building and infrastructure sector in 2020 are shown in Figure 5 and Figure 6 respectively.

The generation of 732 kilotonnes of steel scrap provides a net benefit of 816 kilotonnes CO_2-eq when 74 percent of the scrap is recycled as estimated. If all scrap were to be recycled, this net benefit would increase to 1,107 kilotonnes CO_2-eq, while the scenario with no recycling leads to a burden of 13 kilotonnes CO_2-eq.

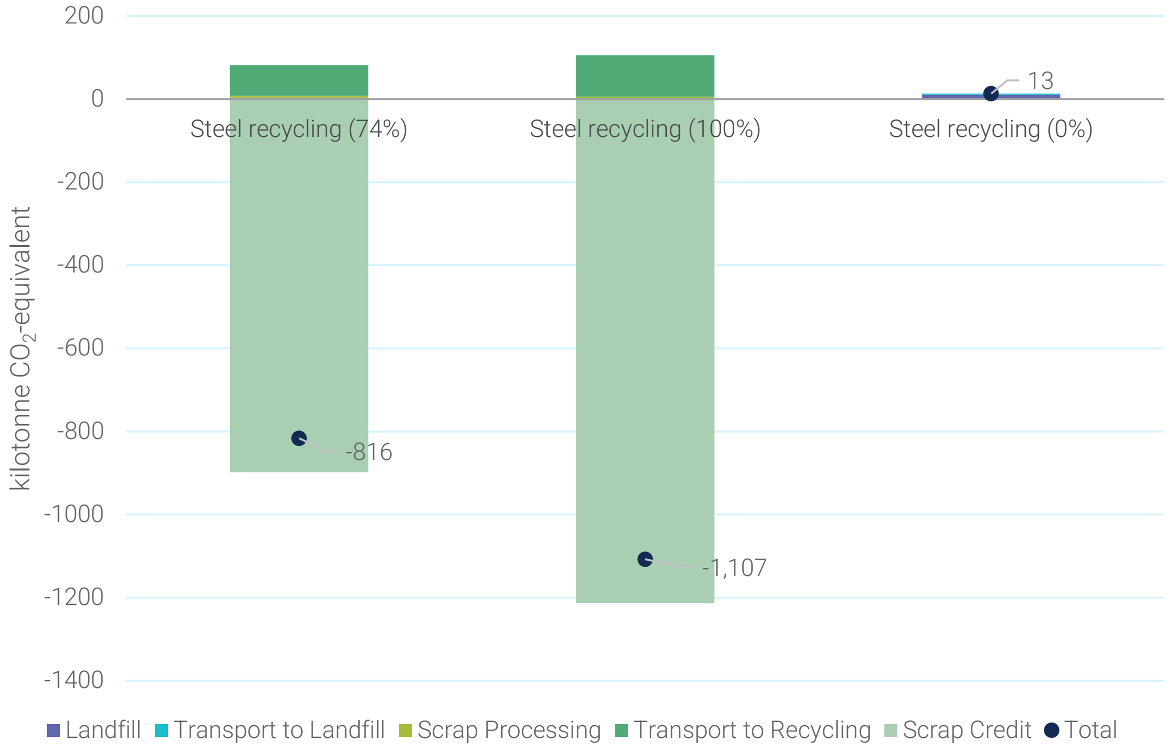

Figure 5. GWP credits for steel scrap for different EOL scenarios in New Zealand in the year 2020

Likewise, at the sector level, the generation of 322 kilotonnes of steel scrap provides a net benefit of 415 kilotonnes CO_2-eq when 85 percent of the scrap is recycled as estimated. If all scrap were to be recycled, this net benefit would increase to 489 kilotonnes CO_2-eq, while the scenario with no recycling leads to a burden of 6 kilotonnes CO_2-eq.

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The results showed that sending steel scrap for recycling provides a significant environmental benefit despite being exported for recycling in other countries. With the significant amount of steel scrap generated in New Zealand, the overall annual benefits of recycling are significant.

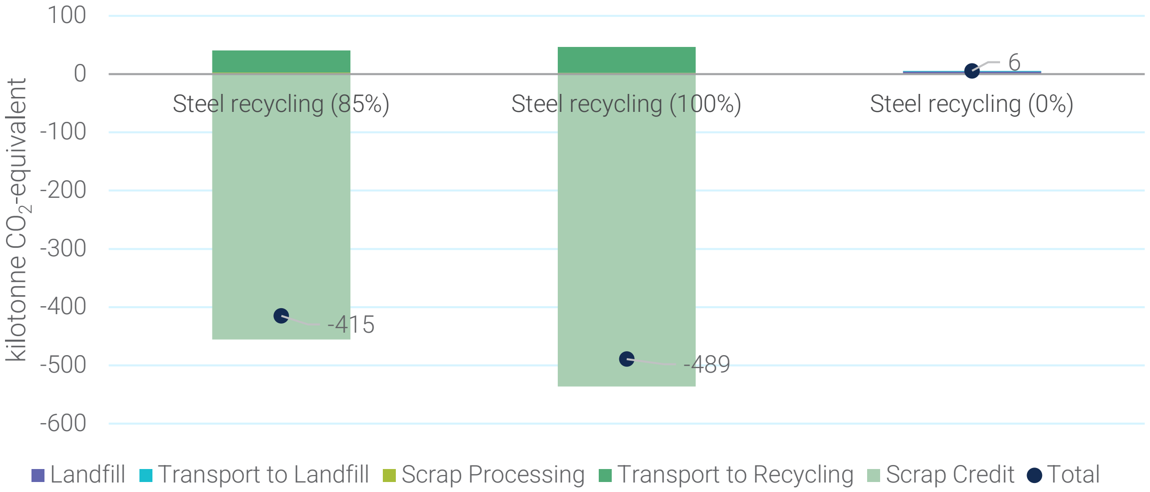

Figure 6. GWP credits for steel scrap for different EOL scenarios in New Zealand building and infrastructure sector in the year 2020

4 Conclusions & recommendations

Steel scrap in New Zealand was estimated to have a recycling rate of 74 percent. This value is slightly lower than the New Zealand waste report (80 percent), which is based on the calendar year 2015 (Eunomia, 2017). The estimated recovery rate for New Zealand steel scrap is also lower than the global average recovery rate (85 percent) due to the higher proportion of steel scrap generated from sectors with lower recovery rates (*e.g.* domestic appliances).

Similarly, steel scrap in the New Zealand building and infrastructure sector was estimated to have a recycling rate of 85 percent. It was noted that the estimated recovery rate for this sector is also lower than the recovery rate of many developed countries including the UK (95 percent).

Steel scrap credits far outweighed the transport and other impacts

The recycling of steel scrap provides significant environmental benefits despite the need for transport to overseas recycling facilities. As shown in Section 3.3, the steel scrap credits far outweighed the transport impacts (domestic and overseas) and the scrap lost to landfill impacts (for cases in which the steel scrap is not fully collected for recovery through metallurgical processing).

Although the scrap processing impacts may vary slightly due to the different processes, such as shredding, baling, shearing, gas-cutting, etc. which were not considered in this study, they are insignificant compared to the scrap recycling benefits.

There is potential to further improve the steel recycling benefits

The benefits from steel recycling could be improved by increasing the proportion of scrap collected for recovery and reducing the GWP impact of sea transport. The amount of steel scrap collected for recovery was critical to the overall system benefits, although the current estimated collection rates still provide a significant benefit across the year. The generation of 732 kilotonnes of New Zealand steel scrap with a scrap recycling rate of 74 percent in the calendar year 2020 provided a net benefit of 816 kilotonnes CO_2-equivalent. If 100 percent recycling rate was achieved, the net benefit would increase to 1,107 kilotonnes CO_2-equivalent. Similar net benefits exist for steel scrap in the New Zealand building and infrastructure sector - 415 and 489 kilotonnes CO_2-equivalent for 85 and 100 percent recycling rates, respectively.

Comparison of the different EOL recycling scenarios (recycling rate of 0 percent, 74 percent and 100 percent) showed that the scrap credit can be improved by increasing the collection rate of steel scrap for recovery and to minimise or prevent steel lost to landfill.

Recommendations to improve the steel scrap collection rate include:

- encouraging the design of products for recycling so that material disassembly and separation during the EOL phase is easier; and
- continuously improving the waste management and recycling infrastructure; adapting to the material recovery of complex end-of-life products made from a diverse range of materials.

More specific data is needed

At present, there is no available information on the actual amounts of steel scrap generated and the proportion collected by recyclers (scrap operation facilities) for recovery through steel mills operation (metallurgical processing). More specific data collection on the quantities and fates of steel scrap arising in New Zealand needs to be obtained to improve the accuracy of the interpreted steel scrap environmental benefits.

To improve the New Zealand steel data collection, recommendations include:

- gathering the data for steel collection rates in New Zealand in collaboration with the New Zealand Association of Metal Recyclers (NZAMR), which is currently trialling the data collection from their members; and
- updating national data on materials that are sent to landfill to provide insight into the lost opportunity for steel recycling and inform initiatives to reduce these losses.

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Appendix A: New Zealand export steel scrap recycling transport distance

Country	Value (NZD)	Share (%)	Sea (km)	Sea (weighted km)
Bangladesh	59,376,747	24.8	11,710	2,909
Australia	38,514,986	16.1	2,326	375
India	20,094,072	8.41	13,099	1,101
Singapore	19,635,018	8.21	8,969	737
United Arab Emirates	14,636,024	6.12	14,931	914
Thailand	13,993,626	5.85	9,999	585
Viet Nam	11,802,128	4.94	9,095	449
Pakistan	11,201,347	4.69	13,942	653
Saudi Arabia	10,848,099	4.54	17,344	787
Italy	9,824,264	4.11	21,422	880
Korea, Republic of	9,232,177	3.86	9,351	361
Hong Kong (Special Administrative Region)	8,428,729	3.53	9,282	327
Indonesia	6,063,828	2.54	8,423	214
United Kingdom	2,722,174	1.14	20,937	238
Malaysia	1,098,592	0.46	9,325	43
United States of America	487,886	0.204	10,495	21
Taiwan	384,197	0.161	8,806	14
China, People's Republic of	244,970	0.102	9,441	10
Canada	222,593	0.093	11,419	11
Netherlands	126,559	0.053	21,063	11
Jordan	91,366	0.038	18,370	7
Luxembourg	18,180	0.008	21,052	2
Fiji	3,540	0.001	2,134	0.03
Total	**239,051,102**	**100**		**10,649**

Table 10. New Zealand steel scrap export data.

Appendix B: Assessment indicators

Indicator	Abbreviation	Unit
Global warming potential	GWP	kg CO_2 eq.
Depletion potential of the stratospheric ozone layer	ODP	kg CFC 11 eq.
Acidification potential of soil and water	AP	kg SO_2 eq.
Eutrophication potential	EP	kg $(PO_4)^{3-}$ eq.
Formation potential of tropospheric ozone	POCP	kg C_2H_4 eq.
Abiotic depletion potential of elements	APDe	kg Sb eq.
Abiotic depletion potential of fossil fuels	ADPf	MJ

Table 11. EN 15804+A1 environmental impact indicators.

The following environmental parameters are based on the life cycle inventory (LCI). They describe the use of renewable and non-renewable material resources, renewable and non-renewable primary energy, and water, as shown in Table 12.

Indicator	Abbreviation	Unit
Renewable primary energy as energy carrier	PERE	MJ, net calorific value
Renewable primary energy resources as material utilization	PERM	MJ, net calorific value
Total use of renewable primary energy resources	PERT	MJ, net calorific value
Non-renewable primary energy as energy carrier	PENRE	MJ, net calorific value
Non-renewable primary energy as material utilization	PENRM	MJ, net calorific value
Total use of non-renewable primary energy resources	PENRT	MJ, net calorific value
Use of secondary material	SM	kg
Use of renewable secondary fuels	RSF	MJ, net calorific value
Use of non-renewable secondary fuels	NRSF	MJ, net calorific value
Use of net fresh water	FW	m^3

Table 12. Resources use indicators.

The waste materials and output flows, such as components for re-use and recycling, are shown in Table 13.

Indicator	Abbreviation	Unit
Hazardous waste disposed	HWD	kg
Non-hazardous waste disposed	NHWD	kg
Radioactive waste disposed	RWD	kg
Components for re-use	CRU	kg
Materials for recycling	MFR	kg
Materials for energy recovery	MER	kg
Exported electrical energy	EEE	MJ
Exported thermal energy	EET	MJ

Table 13. Waste material and output flow indicators**.**

Appendix C: Other assessment results

Indicator	Steel recycling (72%)	Steel recycling (100%)	Steel recycling (0%)
ODP (kg CFC 11 eq.)	-2.73E-12	-3.71E-12	7.49E-14
AP (kg SO_2 eq.)	9.55E-01	1.26E+00	9.16E-02
EP (kg $(PO_4)^{3}$- eq.)	2.26E-01	3.02E-01	1.10E-02
POCP (kg C_2H_4 eq.)	-4.57E-01	-6.19E-01	4.27E-03
APDe (kg Sb eq.)	-2.65E-03	-3.59E-03	1.38E-06
ADPf (MJ)	-9.91E+03	-1.35E+04	1.93E+02

Table 14. Other core environmental impact indicators for 1 tonne of steel scrap recycling for different EOL scenarios.

Indicator	Steel recycling (72%)	Steel recycling (100%)	Steel recycling (0%)
PERE (MJ)	1.29E+03	1.73E+03	2.61E+01
PERM (MJ)	0	0	0
PERT (MJ)	1.29E+03	1.73E+03	2.61E+01
PENRE (MJ)	-9.57E+03	-1.30E+04	1.99E+02
PENRM (MJ)	0	0	0
PENRT (MJ)	-9.57E+03	-1.30E+04	1.99E+02
SM (kg)	0	0	0
RSF (MJ)	0	0	0
NRSF (MJ)	0	0	0
FW (m^3)	-4.80E+00	-6.51E+00	5.02E-02

Table 15. Resources use indicators for 1 tonne of steel scrap recycling for different EOL scenarios**.**

Indicator	Steel recycling (72%)	Steel recycling (100%)	Steel recycling (0%)
HWD (kg)	3.95E-06	4.28E-06	3.03E-06
NHWD (kg)	3.92E+02	1.78E+02	1.00E+03
RWD (kg)	1.03E-03	6.02E-04	2.26E-03
CRU (kg)	0	0	0
MFR (kg)	0	0	0
MER (MJ)	0	0	0
EEE (MJ)	0	0	0
EET {MJ)	0	0	0

Table 16. Waste material and output flow indicators for 1 tonne of steel scrap recycling for different EOL scenarios.

Other assessment results – New Zealand building and infrastructure sector

Indicator	Steel recycling (85%)	Steel recycling (100%)	Steel recycling (0%)
ODP (kg CFC 11 eq.)	-3.14E-12	-3.71E-12	7.49E-14
AP (kg SO_2 eq.)	1.08E+00	1.26E+00	9.16E-02
EP (kg $(PO_4)^{3-}$ eq.)	2.58E-01	3.02E-01	1.10E-02
POCP (kg C_2H_4 eq.)	-5.26E-01	-6.19E-01	4.27E-03
ADPe (kg Sb eq.)	-3.05E-03	-3.59E-03	1.38E-06
ADPf (MJ)	-1.14E+04	-1.35E+04	1.93E+02

Table 17. Other core environmental impact indicators for 1 tonne of New Zealand building and infrastructure steel scrap recycling for different EOL scenarios.

Indicator	Steel recycling (85%)	Steel recycling (100%)	Steel recycling (0%)
PERE (MJ)	1.47E+03	1.73E+03	2.70E+01
PERM (MJ)	0	0	0
PERT (MJ)	1.47E+03	1.73E+03	2.61E+01
PENRE (MJ)	-1.10E+04	-1.30E+04	1.99E+02
PENRM (MJ)	0	0	0
PENRT (MJ)	-1.10E+04	-1.30E+04	1.99E+02
SM (kg)	0	0	0
RSF (MJ)	0	0	0
NRSF (MJ)	0	0	0
FW (m^3)	-5.52E+00	-6.51E+00	5.02E-02

Table 18. Resources use indicators for 1 tonne of New Zealand building and infrastructure steel scrap recycling for different EOL scenarios.

Indicator	Steel recycling (85%)	Steel recycling (100%)	Steel recycling (0%)
HWD (kg)	4.09E-06	4.28E-06	3.03E-06
NHWD (kg)	3.01E+02	1.78E+02	1.00E+03
RWD (kg)	8.51E-04	6.02E-04	2.26E-03
CRU (kg)	0	0	0
MFR (kg)	0	0	0
MER (MJ)	0	0	0
EEE (MJ)	0	0	0
EET {MJ)	0	0	0

Table 19. Waste material and output flow indicators for 1 tonne of New Zealand building and infrastructure steel scrap recycling for different EOL scenarios.

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Appendix D: Estimated average recovery rate for steel (global)

Sector	Use (%)	Recovery rate (%)
Building and infrastructure	52	85
Mechanical equipment	16	90
Automotive	12	90
Metal products (mostly packaging)	10	82.5
Other transport	5	90
Electrical equipment	3	50
Domestic appliances	2	50
Total average		**85**

Table 20. Estimated average recovery rate for steel (global) based on the use sector percentage and their respective recovery rates (World Steel Association, 2019; Word Steel Association, 2020).

Appendix E: Steel recycling data in the New Zealand Waste Disposal Levy report

In Eunomia's report, the amount of steel recovered and lost in landfill was calculated based on the different activities or source (refer Table 21).

Activity/source	Total waste in landfill (kilotonnes)	Steel lost to landfill (% of total waste)	Steel lost to landfill (kilotonnes)	Steel recovered (kilotonnes)
Domestic kerbside	1,110	2.1	23.3	9.09
Residential	206	12.6	26.0	90.0
Industrial, commercial and institutional sources	913	6.0	54.8	404
Landscape	117	1.0	1.17	0
Construction and demolition	579	4.8	27.8	50
Special (biosolids, infrastructure fill or industrial waste	185	0	0	0
Rural	110	4.2	4.63	7.34
Total	**3,221**		**138**	**560**

Table 21. Steel scrap recovered and lost in landfill based on the calendar year of 2015 (Eunomia, 2017).

Steel scrap produced	Amount (kilotonnes)	Percentage (%)
Collected for recovery (metallurgical processing)	560	80
Lost (entering landfill)	138	20
Total	**698**	**100**

Table 22. Estimated steel scrap flow in New Zealand in 2015 (Eunomia, 2017).

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