Summary report

Mapping Emissions and Waste Stream Profiles, and Opportunities for Achieving Net-Zero Circular Advanced Manufacturing

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Sustainable Business Network

Executive summary

This study supports the growth and resilience of Aotearoa New Zealand's advanced manufacturing sector. Advanced manufacturing makes up 10% of the economy ($24.1 billion GDP).

The goals were to:

- identify and map the sector's emissions and waste patterns
- find ways to adopt net-zero circular manufacturing practices within and across subsectors.

This strategy supports work underway - on New Zealand's Emissions Reduction Plans, Circular Economy and Bioeconomy, and Te Rautaki Para Waste Strategy.

We used quantitative and qualitative methods to map emissions and waste across the advanced manufacturing sector and its seven subsectors, using data from 2019 (the last pre-Covid year with robust data).

A combination of 'top-down' and 'bottom-up' approaches provided broad and detailed views of the current state of New Zealand's advanced manufacturing subsectors and potential opportunities. The project combined desktop research, stakeholder engagement, and reporting.

Context

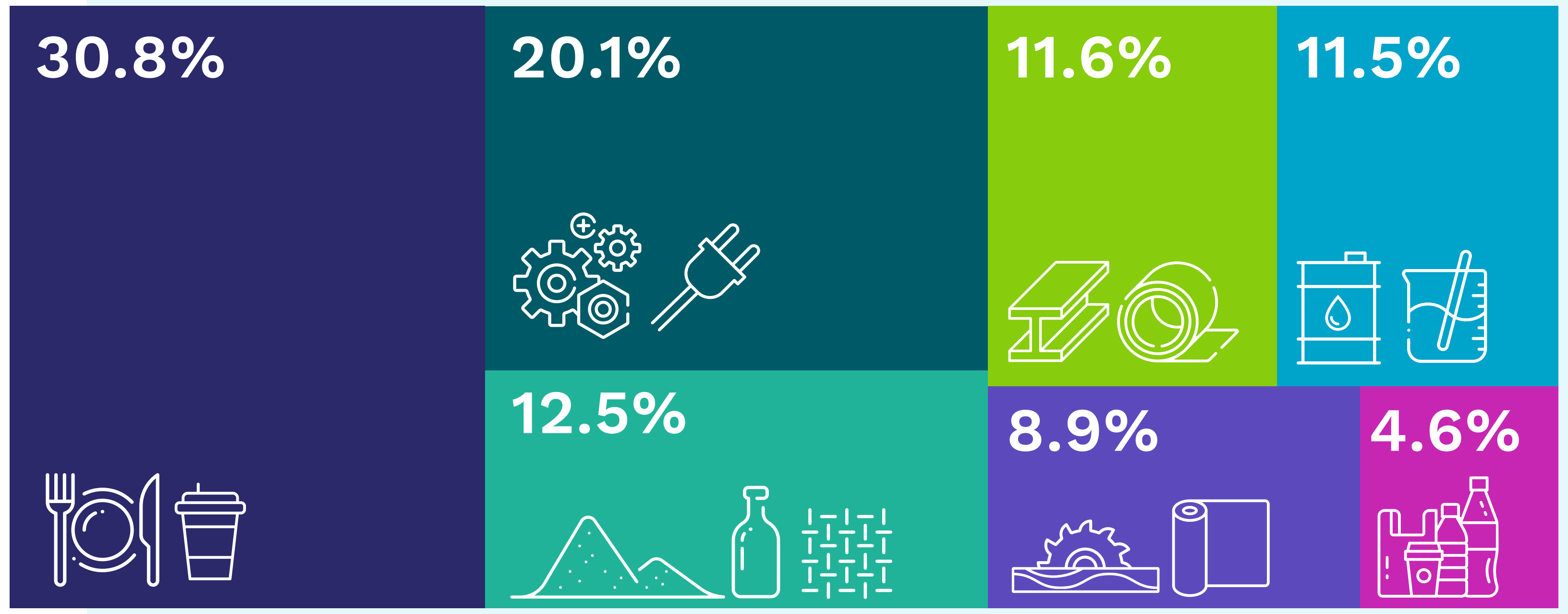
Net-zero practices aim to eliminate carbon emissions by cutting them entirely or reducing them to the point where the remaining emissions can be offset. These emissions typically stem from the energy we use and products we consume.

The circular economy seeks to decouple the economic value of goods and services from the impacts of extraction and waste production by designing out waste, keeping assets and materials at their highest value and regenerating nature. The circular economy is closely linked to the **Bioeconomy**, which uses renewable biological resources to produce food, products, and energy.

What we found

- Circular economy practices exist in New Zealand within and across manufacturing subsectors. Subsectors differ greatly. However, they are connected through resource flows and face similar challenges, particularly around waste.
- Features of New Zealand's national and regional economies, import and export dependencies and manufacturing sector influence opportunities for change, the barriers that limit change and the enablers that support it.

Figure 1. Main manufacturing subsectors and manufacturing GDP share (2020)



Subsector insights

Subsectors are in order of manufacturing GDP share (2020).

	Food and beverage	Machinery and equipment	Other manufacturing	Metal and metal products	Chemicals and refining	Wood and paper	Plastics and rubber
Features	→ $7,464 million → Strong export market → Significant employer	→ $4,864 million → Heavy import reliance → Enabling subsector	→ $3,029 million → Diverse → Heavy import reliance	→ $2,820 million → Significant change	→ $2,790 million → Significant change → Heavy import reliance	→ $2,147 million → Biogenic - 7.8% used towards energy	→ $1,120 million → Close links to other subsectors
Emissions hotspots	→ Dairy → Meat → Seafood	→ Minimal domestic manufacturing so supply chain emissions offshored	→ Cement/concrete → Lime → Glass → Textiles	→ Steel → Aluminium	→ Petroleum → Methanol → Fertilisers	→ Bio-energy has minimal emissions, but some facilities still use fossil energy	→ Minimal domestic → Supply chain emissions offshored
Waste flows	→ Organic waste → Mature co/by-product streams	→ Scrap currently exported	→ Highly variable based on product	→ Mature internal scrap recycling → End-of-life scrap currently exported	→ Potentially hazardous	→ Organic waste → Potentially hazardous → Established residue management	→ Problematic plastics → Mature internal plastics recycling
Opportunities	→ Process heat decarbonisation → Food loss reduction	→ Product stewardship → Product as a service → E-waste and vehicle recycling	→ Cement replacement → Recycled aggregates → Product stewardship	→ Electric arc furnace for onshore recycling → Longer-term decar-bonisation of virgin metal	→ Biorefining → Fleet transition	→ Process heat decarbonisation → Value add e.g. engineered timber	→ Design for reduction, recycling and reuse → Product stewardship → Onshore recycling
Data gaps	→ Waste → Packaging → More granular subsector emission factors	→ More granular subsector emission factors → Material stocks and flows → Critical minerals	→ Textile emission factors → Internal market flows → Material stocks and flows	→ More granular subsector emission factors → Non-ferrous metals → Critical minerals	→ More granular subsector emission factors → International emission factors	→ Water use → End of life waste → Slash management → More granular subsector emission factors	→ Litter and microplastics → Material stocks and flows → More granular subsector emission factors

Opportunities for net-zero circular advance manufacturing

Risks and costs

- Reduced risks (operational, market, regulatory, portfolio).
- Reduced costs (materials, supply chain, labour, logistics).
- Reduced cost per unit and/or increased productivity (more value from the same inputs).

Supply chain and production

- More resilient supply chains (less reliant on global supply).
- Higher domestic production (consumption of New Zealand-made products replaces imports).
- Better use of waste as inputs across manufacturing subsectors (industrial symbiosis).
- Meeting environmental demands from customers, particularly Scope 3 Emission Reporting and export markets with increasingly higher environmental import criteria eg EU.

Brand and marketing

- Improved brand recognition (due to differentiated products).
- Sustainability credentials that support marketing (e.g. lower carbon products).

Asset management

- Longer asset lives, deferred investment in new assets.
- Improved productivity (utilisation, reliability, availability).
- Reduced lifetime operating costs.

Relationships

- Social licence to operate.
- More skilled jobs (servicing assets rather than replacing them).

Barriers and enablers for manufacturers

Barriers

- Access to capital remains a significant hurdle alongside competition within organisations for funding for these projects.
- Businesses often prioritise other challenges over sustainability due to perceived or real risks associated with emerging technologies, processes and business models.
- Initiatives can be complicated by a lack of familiarity with circular business models and insufficient access to necessary supply chains, such as energy and dispersed assets.
- A lack of mandatory or standardised waste data reporting and a coordinated central repository for waste data impedes visibility.
- The scarcity of workforce knowledge, skilled staff and intellectual property challenges pose substantial obstacles.

Enablers

- Cross-sector and regional collaboration, alongside sector-specific guidance, helps minimise the technical and commercial risks of adopting 'higher risk' solutions.
- Accessible funding/financing is critical to support emerging technologies.
- Government policies and regulations, such as environmental reporting programmes, promote this shift.
- Enhancements currently underway by MfE in waste data gathering and visibility should enable greater transparency and targetted action.
- National and industry-specific targets for circularity and supporting innovations in bio-refining and digital technologies to make sustainable practices 'business as usual'.

Conclusions

1. Circular economy practices exist in New Zealand within and across manufacturing subsectors. Subsectors differ greatly. However, they are connected through resource flows and face similar challenges, particularly around waste.
2. Supply chain emissions are significant across all subsectors.
3. Most subsectors depend on imports and 'offshore' their emissions. As a result, some will be exposed to critical minerals risks (e.g., fertilisers, machinery, and equipment).
4. For import-dependent subsectors, circular economy models that reduce consumption by extending service lives, sharing access to products or creating jobs through reuse, remanufacturing or repair, may reduce supply risks and global emissions.
5. In some subsectors, opportunities exist to use more of what we produce locally. In some cases, this could make businesses more resilient and create skilled jobs. Clear policies on managing domestic versus global emissions need to guide these transitions.
6. Solutions that match companies' business needs (e.g. support market access) are more commercially attractive.
7. The industry is open to collaborating but needs support to overcome transparency and access to better data to support decision-making. This is currently considered a market failure.

Recommendations

- Continue to develop and update the data in this report with industry to understand trends and changes to manufacturing emissions and waste.
- Collaborate with industry to identify, prioritise, and realise opportunities to develop a decarbonised, circular manufacturing sector, understand resource flows, and investigate opportunities for industrial symbiosis to reduce and divert waste.
- Support adopting digital tools (e.g., GIS, digital product passports) to help the industry collect and communicate data. This will encourage product stewardship, help the industry track emissions, and support international trade.
- Investigate ways to make assets last longer (e.g. investment and depreciation levers).
- Investigate and address data gaps, limitations and assumptions further, including:
  - Consumption-based emissions (including from imported goods)
  - Stocks and flows (e.g. lifespans, durability, replacement scenarios)
  - Identify critical minerals links and circular economy strategies to improve resilience (link to New Zealand Critical Minerals List, to be published soon)
  - Waste data (e.g. volumes and flows)
  - Potentially hazardous' waste streams.

Contents

Subsectors are in order of manufacturing GDP share (2020)

About this report

This report summarises the findings of the project "Mapping Emissions and Waste Stream Profiles, and Opportunities for Achieving Net-zero Circular Advanced Manufacturing", an MBIE-funded initiative to support New Zealand's advanced manufacturing sector.

The project fits within a larger programme that aims to identify the "Impacts, barriers and enablers for a Circular Economy", feeding into government strategy on the circular economy and bioeconomy, including New Zealand's Emissions Reduction Plan (2022), developing a Circular Economy and Bioeconomy Strategy (2024) and the Te rautaki para Waste Strategy (2023). A full report and dataset have been provided to MBIE to form the basis for ongoing development.

For more information please visit the Circular economy and Bioeconomy MBIE web page.

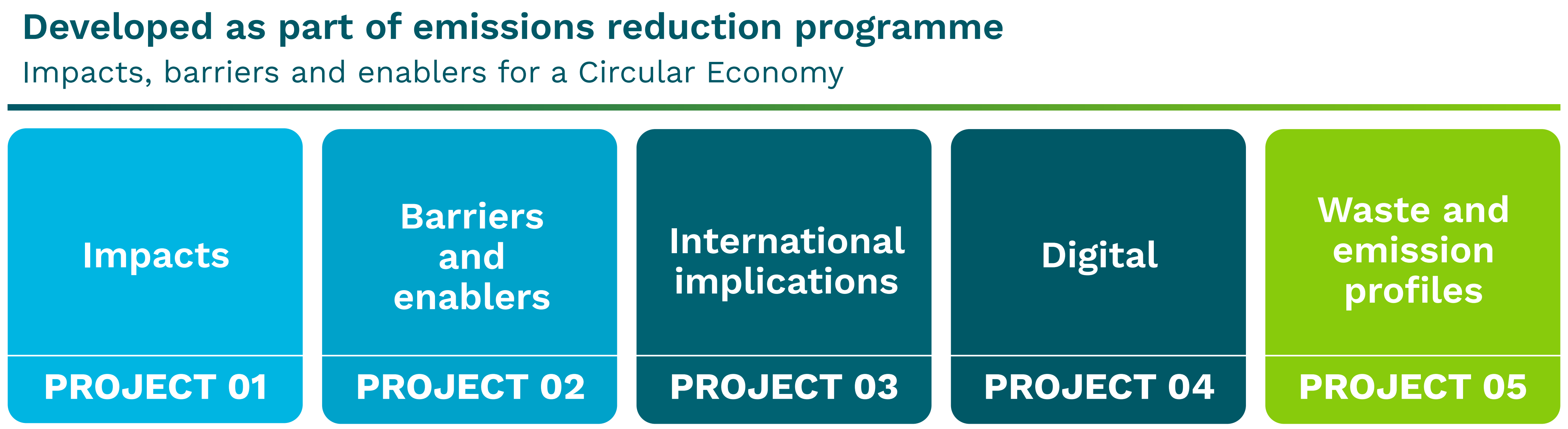


Figure 2. MBIE research programme and projects

About this report

The project has identified and mapped the emissions and waste patterns of the seven main advanced manufacturing subsectors to identify opportunities to adopt net-zero circular manufacturing.

This process was highly iterative and helped build a more accurate picture of the current state, knowledge gaps and interdependencies. Considerations also included manufacturing processes and activity location. Subsector specific emissions and waste data is valuable as it informs decisions at different scales and levels, helps prioritise transition activities and measure progress over time.

Although we were primarily interested in what is made in New Zealand, inclusion of both production and consumption related emissions was important - highlighting imports and exports and the role international trade plays.

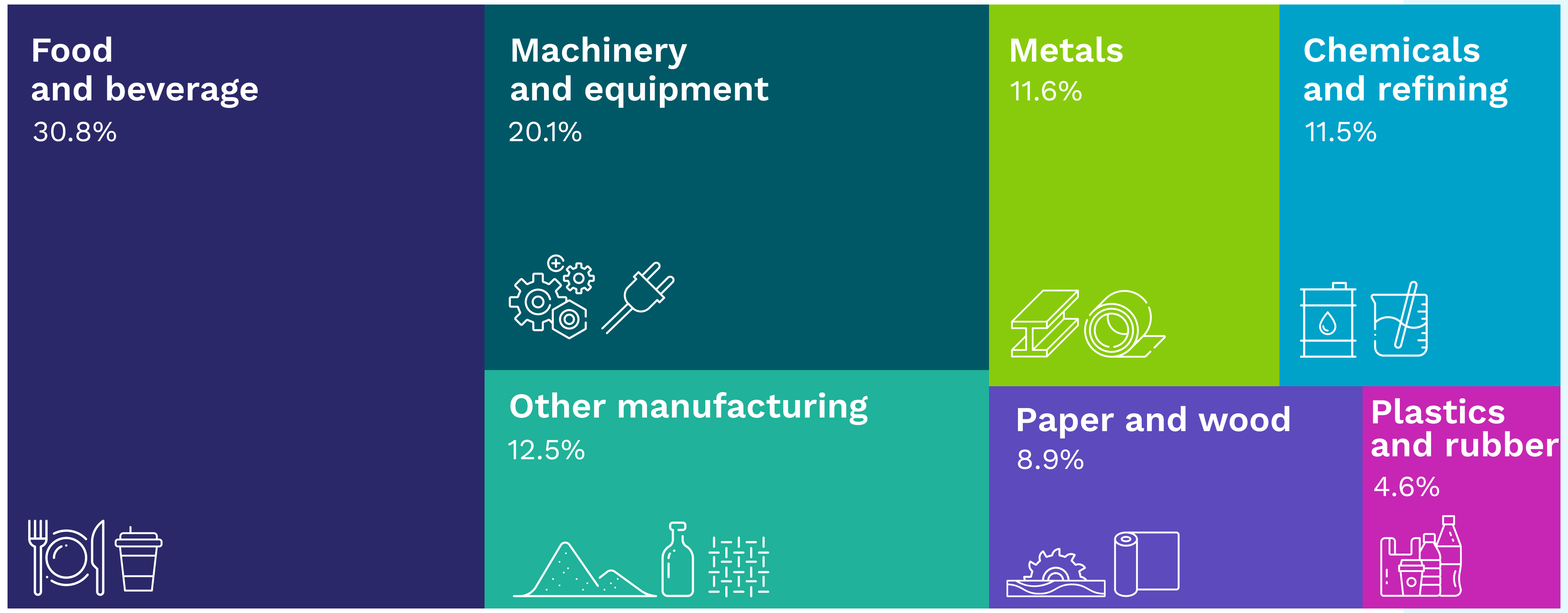


Figure 3. Main manufacturing subsectors and manufacturing GDP share (2020)

We used quantitative and qualitative methods to map emissions and waste across the advanced manufacturing sector and its seven subsectors, using data from 2019 (the last pre-Covid year with robust data).

A combination of 'top-down' and 'bottom-up' approaches provided broad and detailed views of the current state of New Zealand's advanced manufacturing sectors and potential opportunities. The project combined desktop research, stakeholder engagement, and reporting.

We gained insights through workshops, 1:1 interviews, and engaged with approximately 250 stakeholders over the duration of the project.

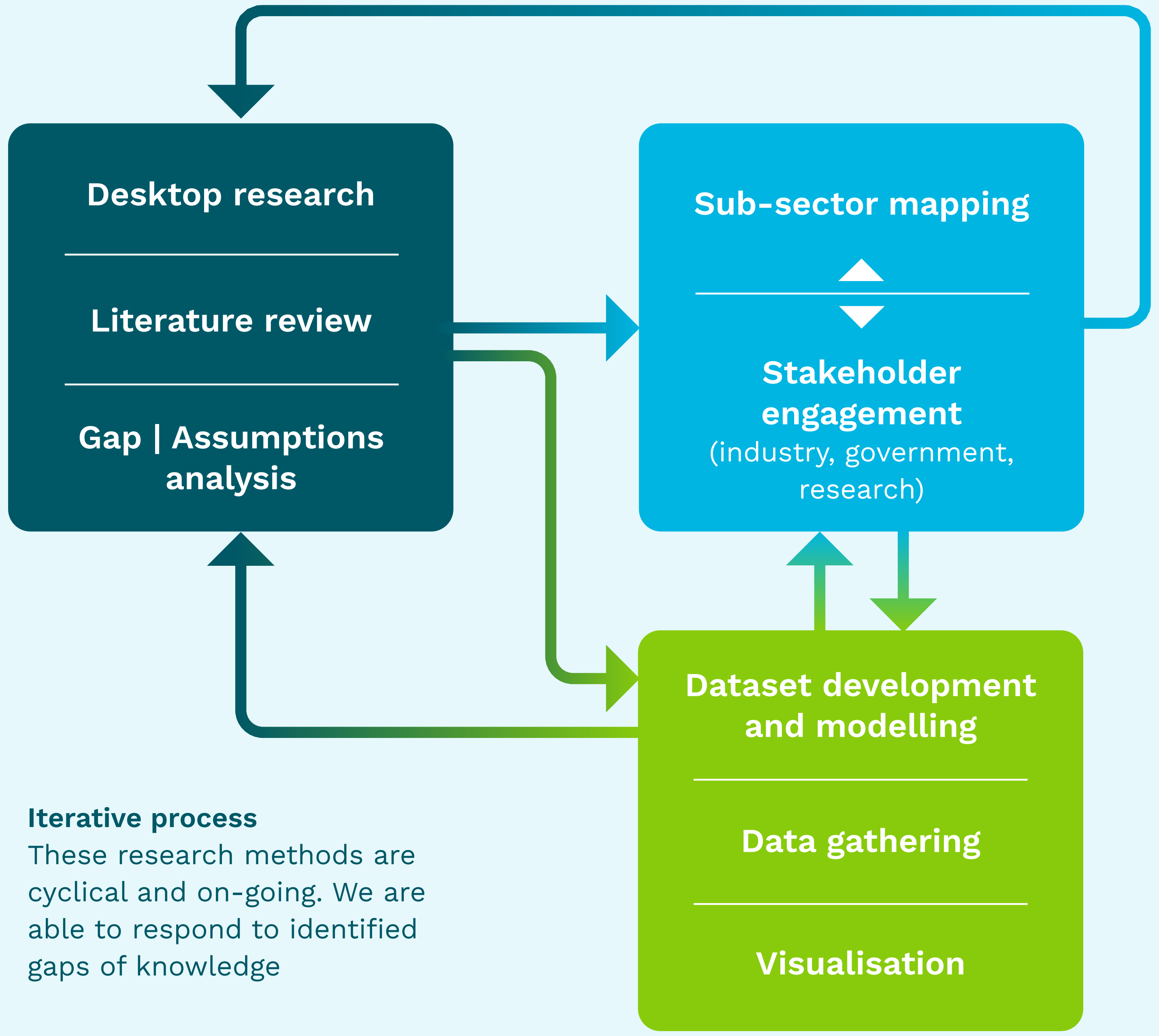


Figure 4. 'top-down' and 'bottom-up' approaches

Emissions

Annual emissions for the manufacturing sector (2019 baseline)

- Total **consumption-based emissions** were **24,900 ktCO₂e.** (38% of New Zealand gross greenhouse emissions in 2019)*
- Total **production-based emissions** were **12,900 ktCO₂e.** (16% of New Zealand gross greenhouse emissions in 2019)*

These figures exclude consumption emissions from end-use products like aerosols in cosmetics and refrigerant leakage from household heat pumps.

Imported emissions

For most advanced manufacturing subsectors, many impacts associated with manufacturing relate to materials and goods produced outside New Zealand and imported to support domestic production. Figure 5 shows that most subsectors have much higher consumption-based emissions than production-based emissions.

*See full report for assumptions

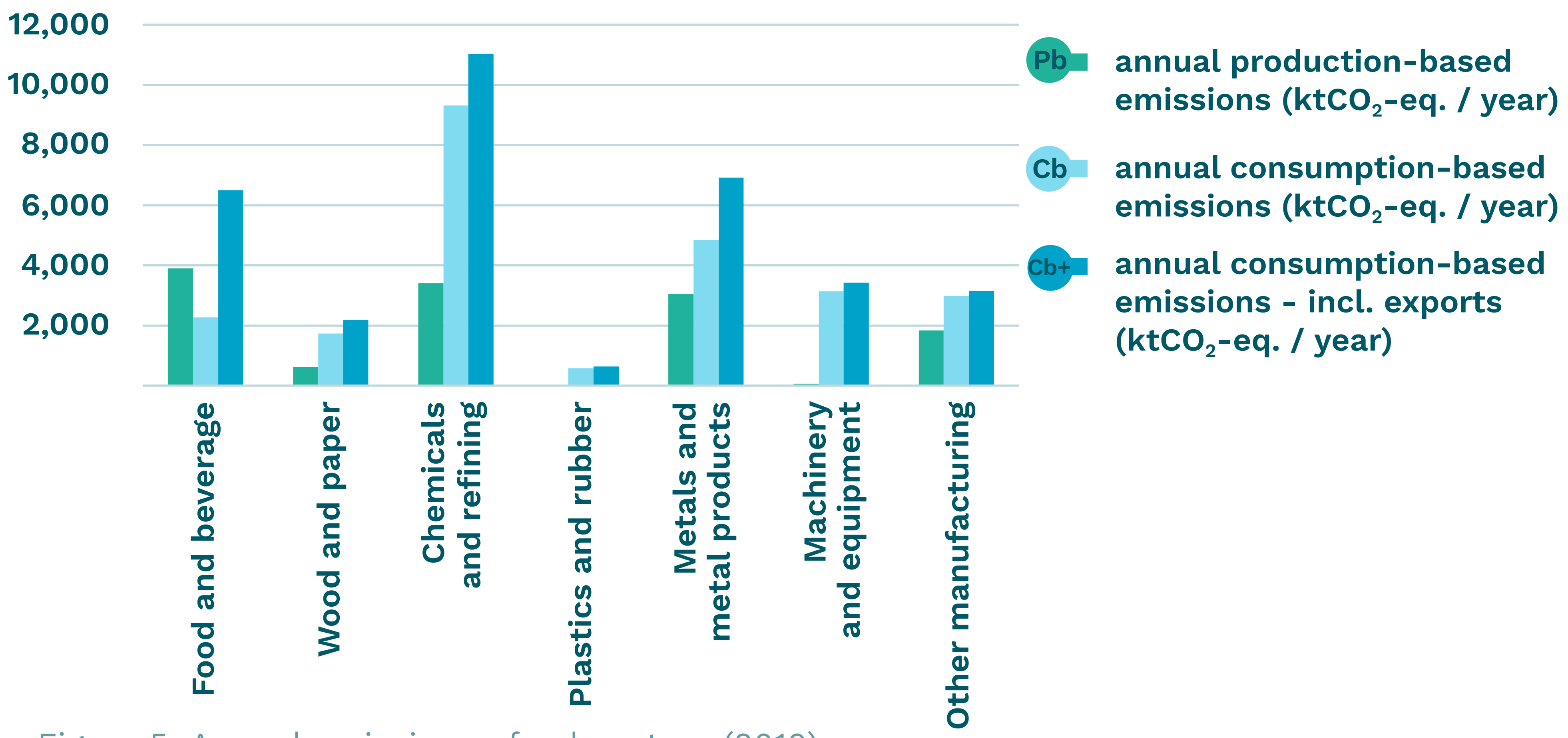
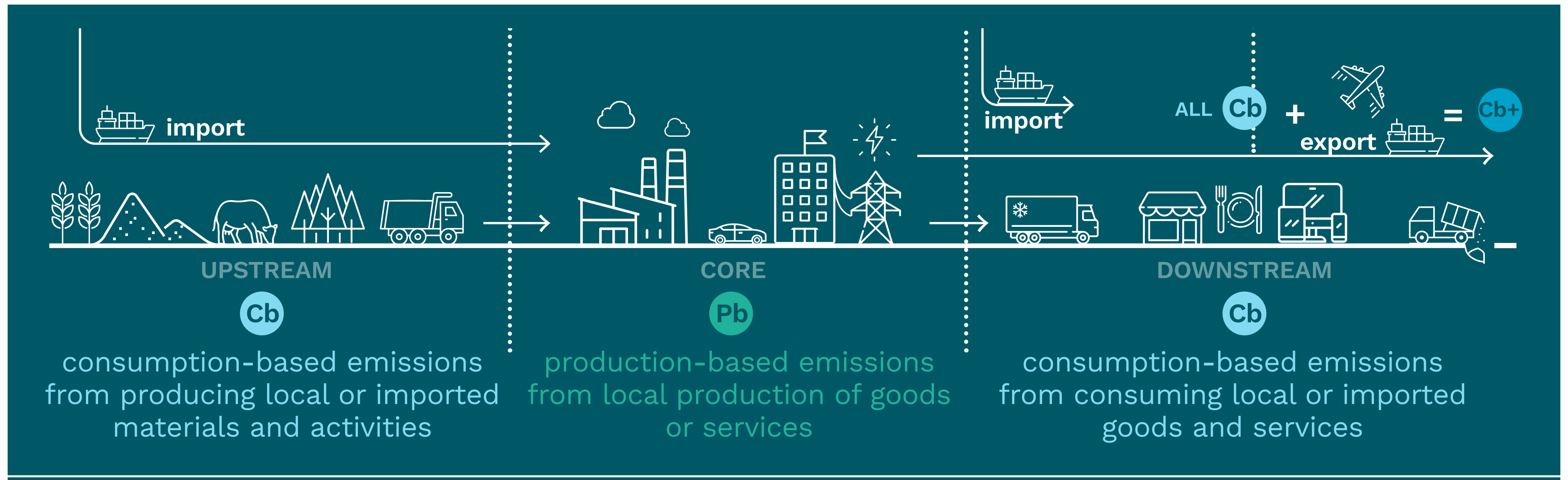


Figure 5. Annual emissions of subsectors (2019)



Pb Production-based emissions are those emitted within New Zealand and include anything we produce, regardless of whether we then consume it ourselves or export it elsewhere.

Cb Consumption-based emissions are associated with the goods and services New Zealand consumes, this can include just the things we produce for our own consumption or can be extended to include the things we import that are associated with the production emissions and transport related impacts (includes transport and refrigeration) of other regions.

Cb+ represents the total of all consumption-based emissions plus the emissions of exporting goods and services.

Opportunities to reduce emissions by producing locally

There may be opportunities to create local jobs and reduce overall emissions by producing domestically instead of importing materials and goods. If 'onshoring' production was successful, it would decrease global and likely increase New Zealand domestic emissions.

Food and beverage (particularly dairy production)

Even when supply chain emissions are accounted for, the subsector's consumption-based emissions are lower than production-based because so much dairy and meat is exported. If exports are included, the subsector's consumption-based emissions are larger than production-based emissions due to supply-chain emissions.

Chemicals and metals

These have relatively large production-based emissions, likely due to using coal and natural gas. Reducing these emissions may require the generation of significantly more low-carbon electricity or developing alternative fuels.

Industrial symbiosis

Circular economy initiatives using by-products or co-products across industries could reduce overall emissions. Providing local alternatives to imports could also reduce supply chain emissions and make markets more resilient.

Interdependencies

We identified major interdependencies (e.g. food and beverage emissions to agriculture/ horticulture and fertiliser chemicals). Reducing emissions in one industry may impact emissions in other subsectors.

Emissions intensity

Normalising emissions for revenues generated (Figure 6) shows that the chemicals and refining, and metals industries emit more for each dollar spent, especially when accounting for their supply chains.

The 2019 data does not account for the closing of the Marsden Point refinery in 2022. Consumption emissions would likely be higher and production emissions lower today.

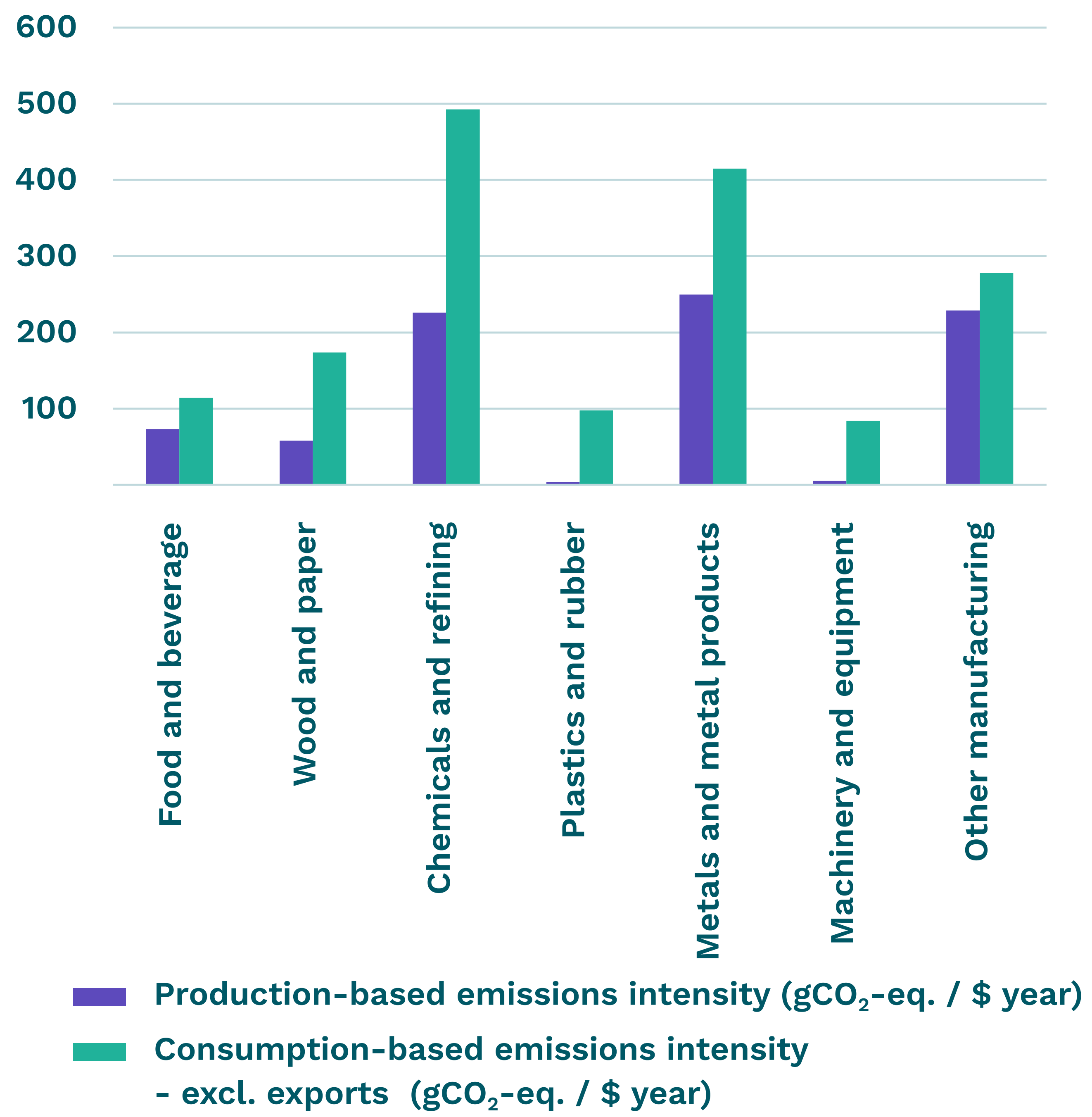
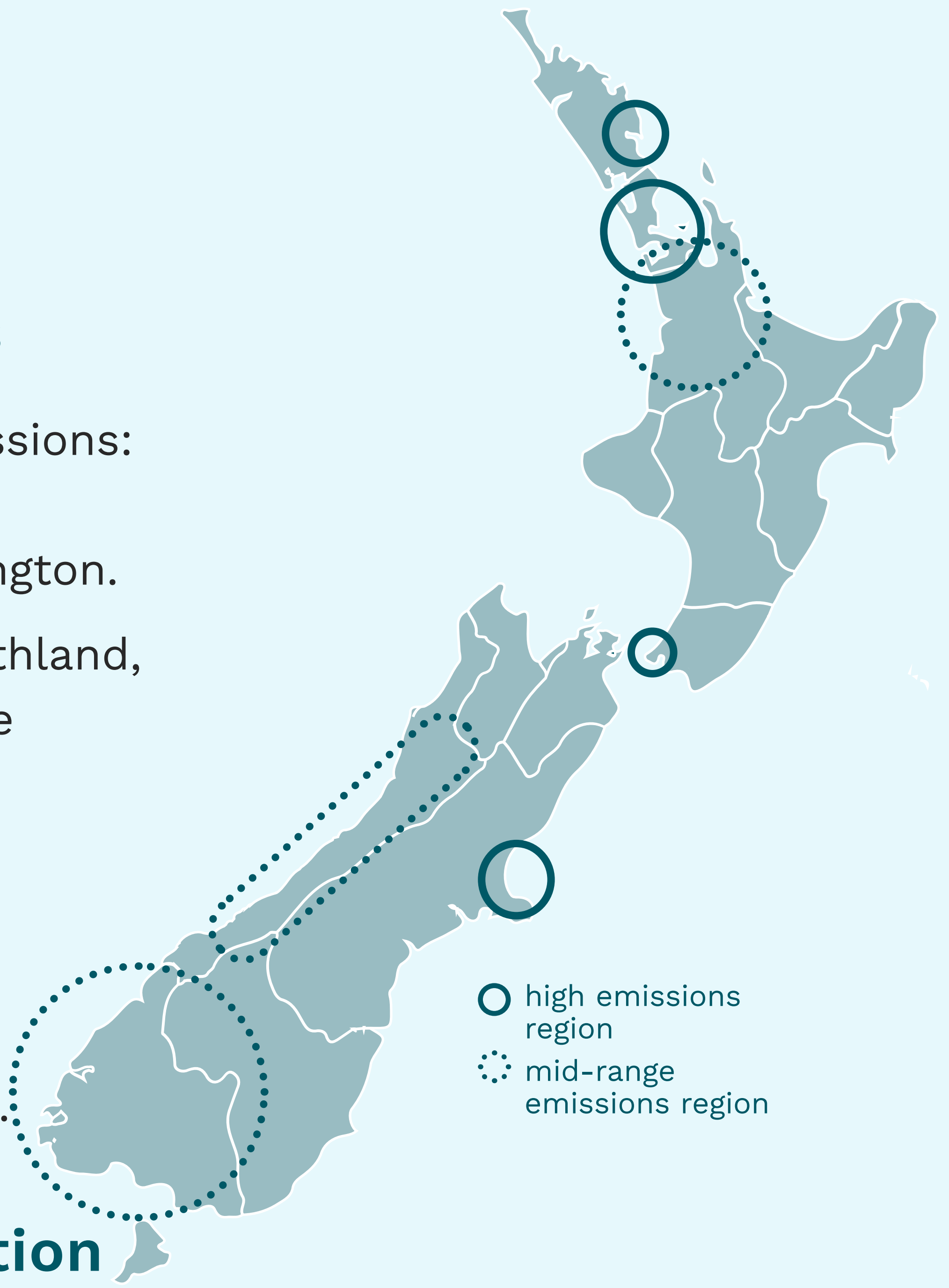


Figure 6. Production-based and consumption-based emissions intensity - all subsectors (2019)



Regional emissions

- Largest sources of emissions: Auckland, Whangārei, Christchurch and Wellington.
- Mid-range regions: Southland, the West Coast, and the Waikato.

The heatmap for consumption-based emissions mirrors the production-based one.

Impacts by population and industry

With Auckland, Christchurch, and Wellington representing New Zealand's largest population centres, the employment number-based approach may skew results. However, these are also expected to be large manufacturing centres.

As chemicals and refining contribute the most emissions, we expect Whangārei to be an emissions hotspot for the manufacturing sector. (This has since changed with the closure of Marsden Point Refinery in April 2022.)

Waste

Publicly available data on waste in New Zealand

Publicly available data on waste in New Zealand varies in consistency and quality. The most consistent source is MfE's reporting on the waste disposal levy. Although it is helpful to understand the composition of materials entering and being diverted from landfills at this point, it is challenging to link types and volumes of materials to sources such as manufacturing.

Another source of data: resource flow maps

We developed maps for major products in each subsector to help identify potential resource flows and waste streams we could not identify from waste data. An example for Meat, Wool and Leather (Figure 7) shows the links between manufacturing and waste that would otherwise be hidden. Figure 8 (page 11) show the results of this approach across the seven subsectors.

Resource recovery

Advanced manufacturing also plays an integral role in resource recovery and adding value. Currently, waste inputs from diversion activities are not well captured, limiting our ability to quantify existing resource recovery activities.

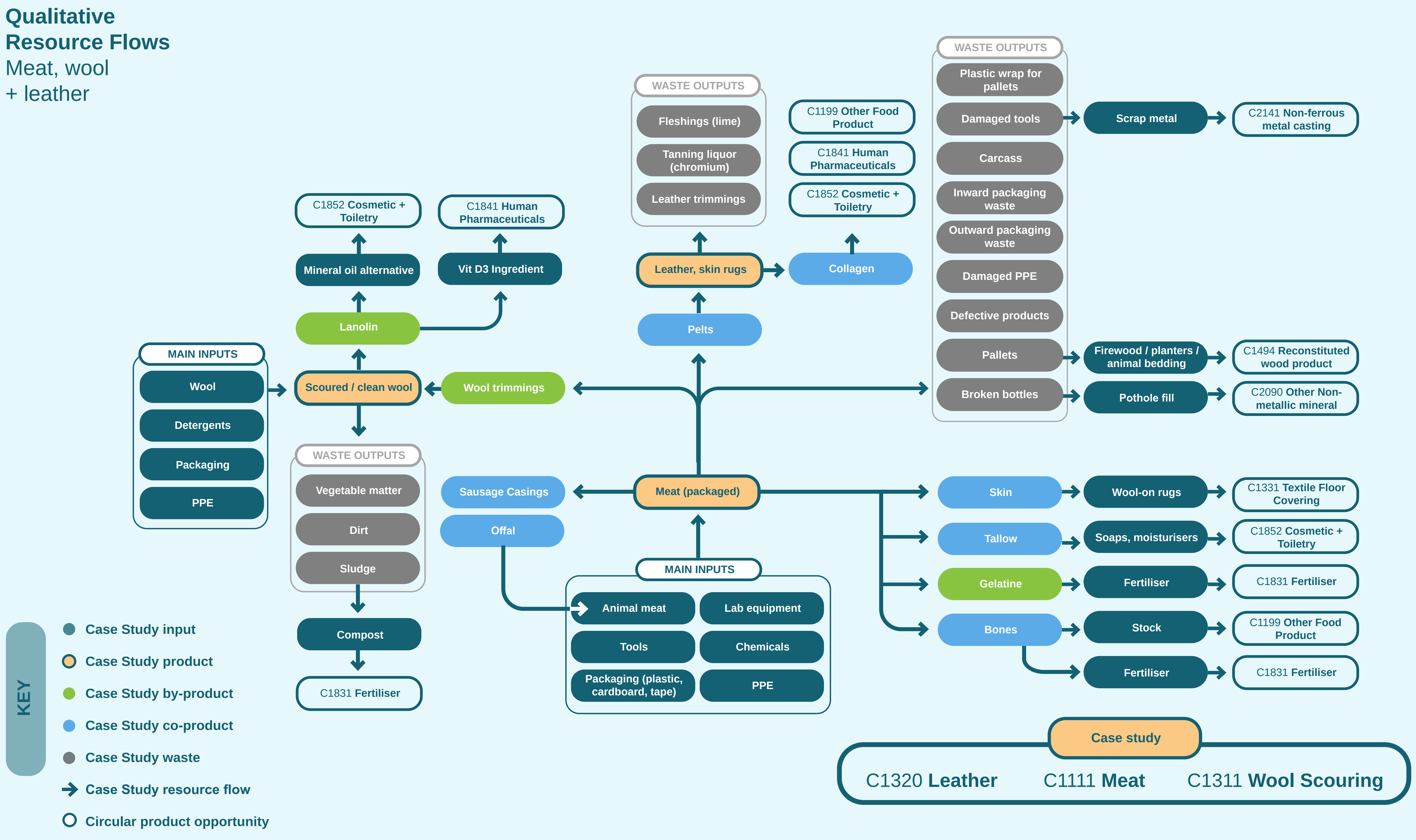


Figure 7. Material flows: Meat, wool and leather

Waste materials accross the seven subsectors

Waste Materials	Food and beverage	Machinery and equipment	Other manufacturing	Metal and metal products	Chemicals and refining	Wood and paper	Plastics and rubber
Organics	Food loss, fibrous biomass, defective product, spent grain, shells	from bio-based resource inputs	Scouring/retting vegetable matter	-	from bio-based resource inputs	slash, leaves	-
Cardboard and paper	Packaging	Packaging	Packaging	Packaging	Packaging	Offcuts, Packaging	Packaging
Timber	Packaging	Packaging	Offcuts, packaging	Packaging	Packaging	Offcuts, packaging	Packaging
Rubble/Concrete incl cleanfill	-	-	defective materials	-	-	-	-
Potentially hazardous	Expired or excess chemical sludge	Metal and chemical contaminated cleaning outputs, e-waste, dust, oils and lubricants, cleaning liquids	waste chemicals, dye/tanning liquor, scouring sludge, oils and lubricants, kiln dust, contaminated rags and wipes, resins	sludge waste, machinery oils and lubricants, casting material, oxidised product, acids from pickling/hydrochloric acid	Contaminated packaging, degraded/rejected product, unused/expired chemical	Pulp mill sludge, ink and de-inking sludge	solvents, unused/expired chemicals, used filters, pigments, recycling wash plant outputs, sludge waste
Plastic	Packaging	Packaging	defective parts, offcuts, foam, packaging,	Packaging	Packaging	Offcuts, Packaging	Offcuts, rejected product, packaging
Metals	Packaging	defective and corroded parts, offcuts	defective and corroded parts, offcuts	Offcuts and defective product, excess alloys, n.b. internal recycling practice observed	-	-	-
Textiles	PPE	PPE	defective product, samples, offcuts, PPE	PPE	PPE	PPE	PPE
Nappies and sanitary	PPE	PPE	PPE	PPE	PPE	PPE	PPE
Glass	Packaging	Defective parts, off cuts, fibreglass waste	defective parts, offcuts, fibre-glass	-	-	-	-
Rubber (incl tyres)	-	Tyres, defective machinery parts	defective product, offcuts	-	-	-	-

Figure 8. Results resource flow maps approach across the seven subsectors

About this report

Main observations for waste (date for New Zealand, 2019)

Overall:

- Of 17,288 kt of waste generated, 2019, 92% ended up in landfill.
- 1,371 kt (8%) of waste was recycled or exported.

Exports:

Two-thirds of all metal waste (547 kt) was exported to be processed outside New Zealand.

Recycling:

- 697 kt (4%) of all waste was recycled.
- 124 kt (18%) construction and demolition waste; 273 kt (39%) cardboard and paper; 102 kt (15%) glass; 13 kt (2%) metal ; 28 kt (4%) plastics; 141 kt (20%) organics; 15 kt (2%) tyres.

Landfill:

- 5,833 kt of rubble (34% of total).
- 1,824 kt of organics (10%+).
- Plastics: 1,315 kt (just under 8%).
- Timber: 1,380 kt (roughly 8%).
- Potentially hazardous waste: 807 kt (4.7%).
- Smaller quantities: paper (695 kt, 4%), textiles (395 kt, 2.3%), nappies and sanitary products (304 kt, 1.8%), metals (256 kt, 1.5%), glass (207 kt, 1.2%).
- Tyres: a minor fraction (17 kt, or 0.1%) possibly indicating a gap in the data.

New Zealand Waste Flows - 2019

Thousand tonnes (kt)

Sources: National Waste Generation and Recycling Snapshot (2023); Waste Managements Sustainability report (2020); MPI (2019); Plastic Packaging Stewardship Forum (2022); Plasback and Agrecovery (2020); Eunomia (2015)

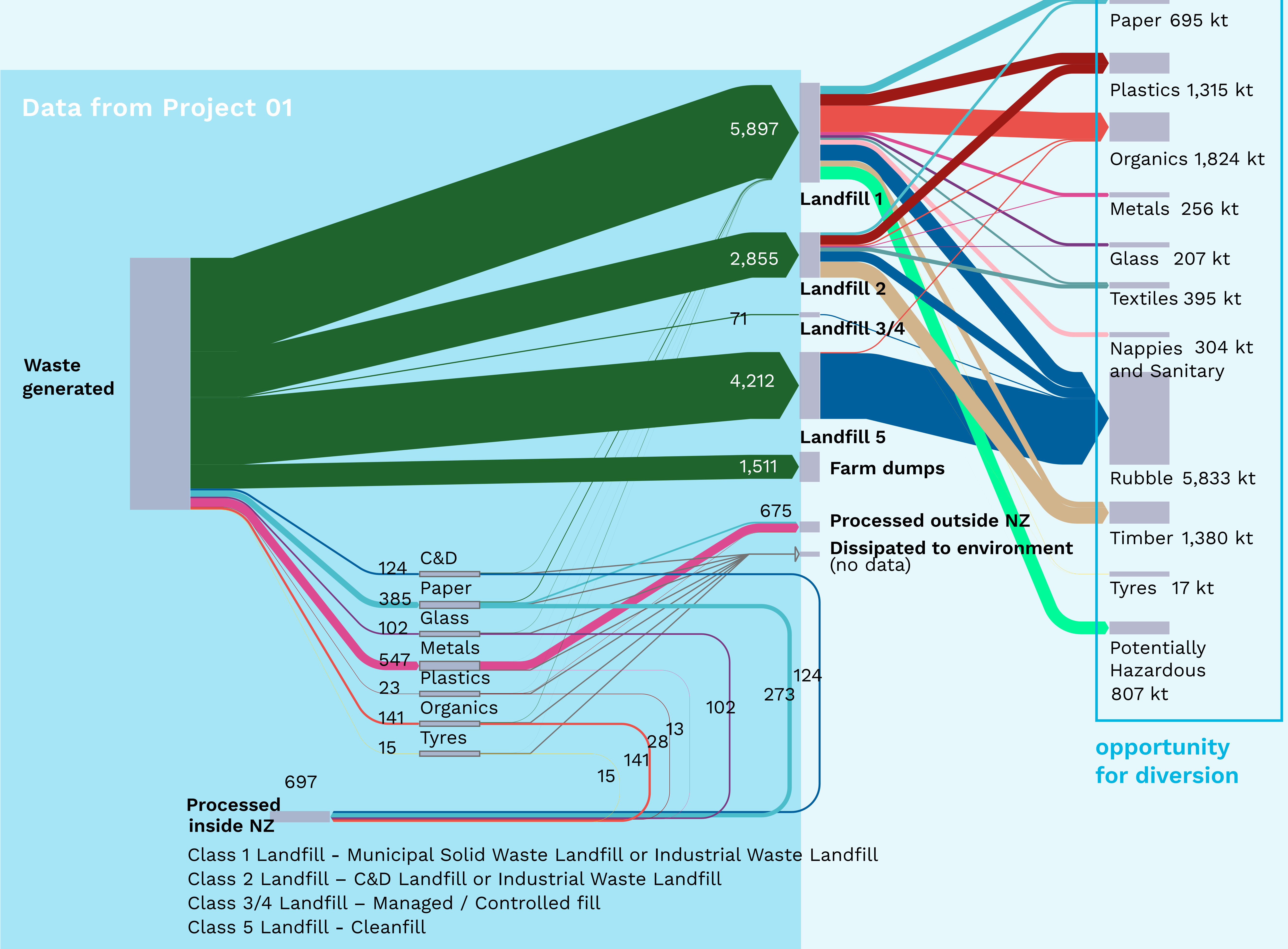


Figure 9. New Zealand waste flows (2019)

Food and beverage

The subsector represents a major part of advanced manufacturing: 32% of GDP, considerable employment, and the highest percentage of foreign direct investment.

A recent surge in investment has seen growth in the dairy sector, particularly in milk powder production for export.

New Zealand is largely self-sufficient in meat, dairy, seafood, fruit, and vegetables but relies heavily on imports for other goods, fertilisers, and packaging.

Emission hotspots (production-based) per annum

- **Dairy industry:** 3,037 $ktCO_2e$ (82% of subsector emissions)
- **Meat production:** 560 $ktCO_2e$
- **Seafood production:** 157 $ktCO_2e$

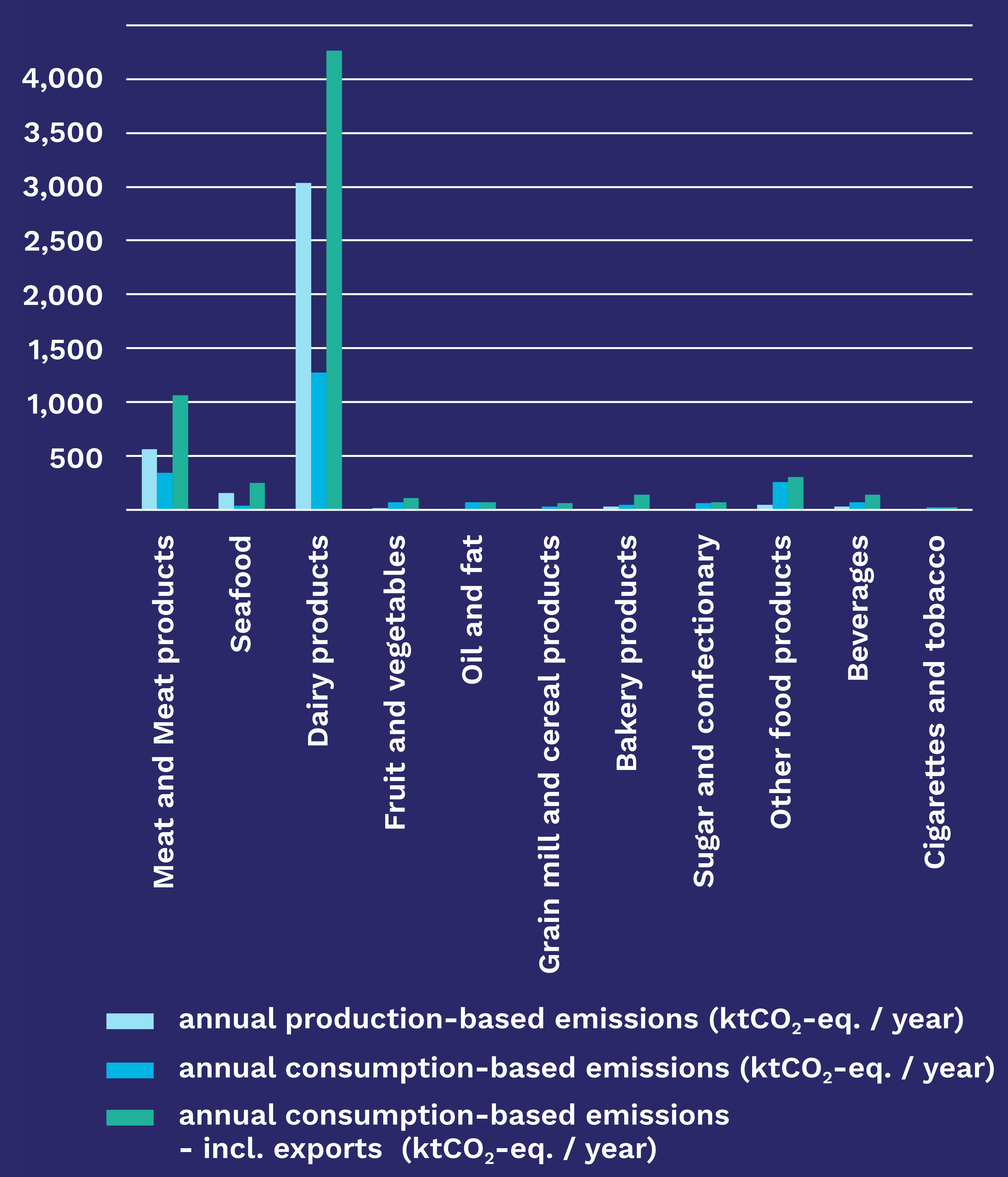


Figure 10. Food and beverage annual emissions (2019)

Subsector mapping

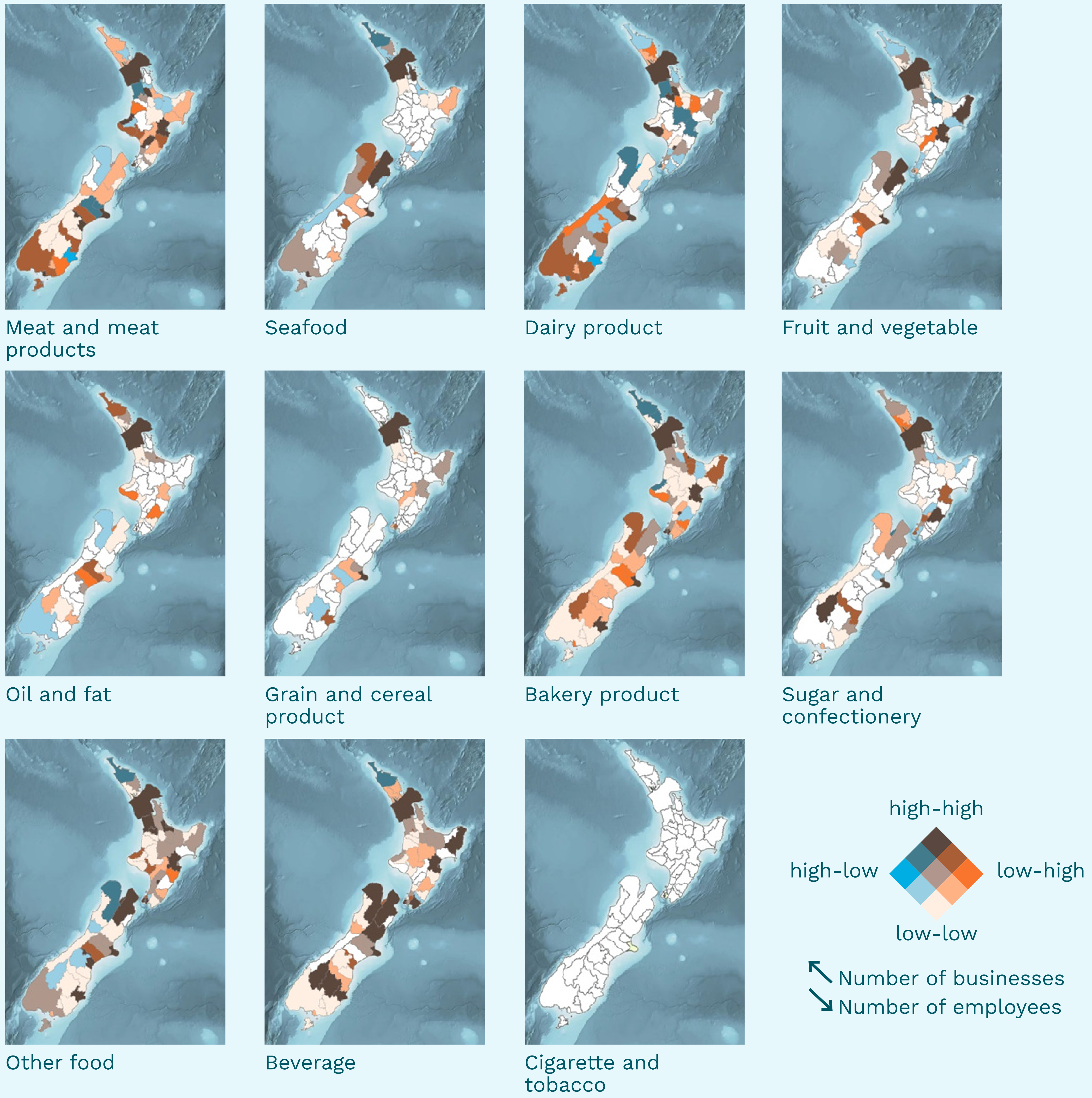


Figure 11. Food and beverage subsector | mapping number of businesses and employees (StatsNZ, 2019)

Emissions intensity: dairy sector

A large part of these impacts comes from consuming fossil fuels as energy for manufacturing. Milk powder production is the largest user of energy.

The largest share of emissions originated from animal-related sources, particularly enteric methane and managing manure. Other significant sources include land-use change, transporting animal feed and producing and transporting fertilisers.

Regional emissions

18% of manufacturing businesses in Auckland are in this sector. Other regional focal points include Gisborne (fruit and vegetable processing) and Canterbury (baked goods and meat).

The sector's impacts were highest in Auckland (20%), followed by southern districts and regions in the Waikato. This matches where much of New Zealand's agriculture is located.

Waste flows

We identified evidence of the extensive use of residues, co-products and by-products. While we found many examples, we could not find enough quantitative data to assess these flows. Similarly, we identified a strong link between the subsector and packaging (as material inputs and waste outputs) but need more data to assess this.

Carbon emissions of the dairy industry of New Zealand, 2019

Main sources: MPI, Dairy NZ, Fonterra, FAO
(unit in kt CO_2e-eq)

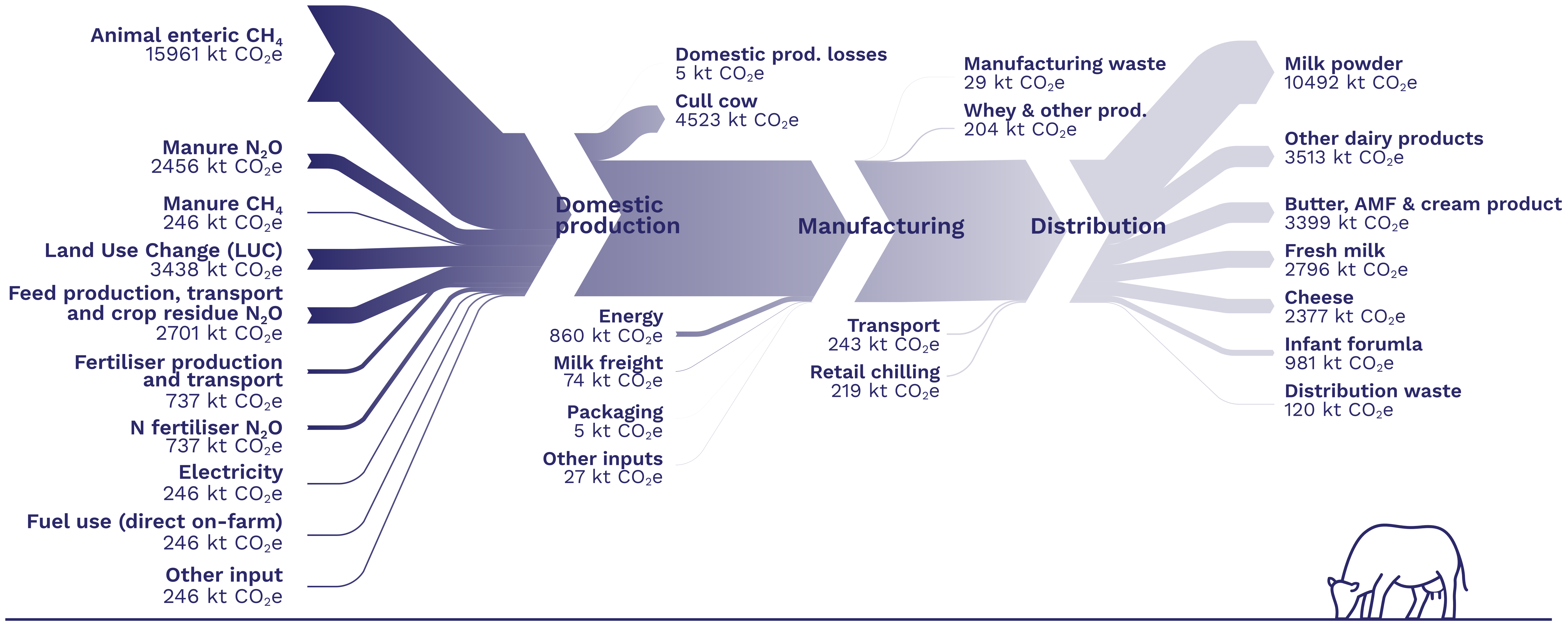


Figure 12. Carbon emissions od the dairy industry in New Zealand (2019)

Opportunities

We identified many case studies and low-carbon initiatives. While the subsector has relied on natural gas and coal for many years, it is decarbonising by replacing coal boilers, reducing emissions linked to fertiliser use, and electrifying transport. Decarbonising manufacturing needing higher temperatures, such as spray dryers, is a more significant challenge.

Data gaps

- Granular emissions data is lacking for some categories of goods, such as fruit and vegetables, bakery products, oils and fats. This resulted in uncertainties.
- A lack of granular production data meant we could not map emissions intensities as well as we would have liked. We used proxy data from other regions, resulting in inaccuracies.
- More data is needed to differentiate between manufacturing and administrative sites. The lack of data may have led to allocating activities to Auckland.
- There are gaps in waste streams associated with packaging.

Stakeholder views

- **Waste streams**
  The extensive use of waste streams reflects relationships in the agricultural sector. Challenges in composting and with trade waste remain.
- **Data**
  Granular data on dairy production, including inputs like imported feed and emissions, helped understand subsector-specific impacts. Stakeholders noted data gaps for waste and by-products, especially in sectors like wine and juice manufacturing, which have significant waste steams. The effect of imported goods on emissions is a data gap that industry engagement could help to fill. Stakeholders would like clearer, more up-to-date data to inform decision-making.
- **Knowledge**
  Stakeholders would like to understand more about supply chain emissions, waste streams and the potential for circular economy practices in their subsectors.
- **Reducing imports**
  Stakeholders were interested in shifting feed sources for aquaculture and livestock to reduce their reliance on imported feeds with high emissions.
- **Collaboration**
  The industry needs to collaborate to collect standardised data and reports. Measurement and management of waste, byproducts, and packaging are challenges.

Subsector

Machinery and equipment

This subsector has declined over the last few decades. It now represents 1.7% of GDP. Niche manufacturing and exports dominate the subsector. A few large players dominate financially, while most firms are smaller.

Auckland is the most significant region with a range of businesses. Other regions tend to be more specialised around agritech, oil and gas or electronics. The subsector has about 12,018 manufacturers and employs 83,556 workers.

Emission hotspots

As the subsector strongly depends on imports, consumption-based impacts are much higher than production-based impacts. Hotspots include imported motor vehicles and transport equipment.

Import reliance in this subsector means we must be aware of offshored impacts and international initiatives that may decrease access or increase costs to products and components.

As most impacts are currently offshored, demand-based solutions that extend the service life or use of products offer the main opportunity to influence them.

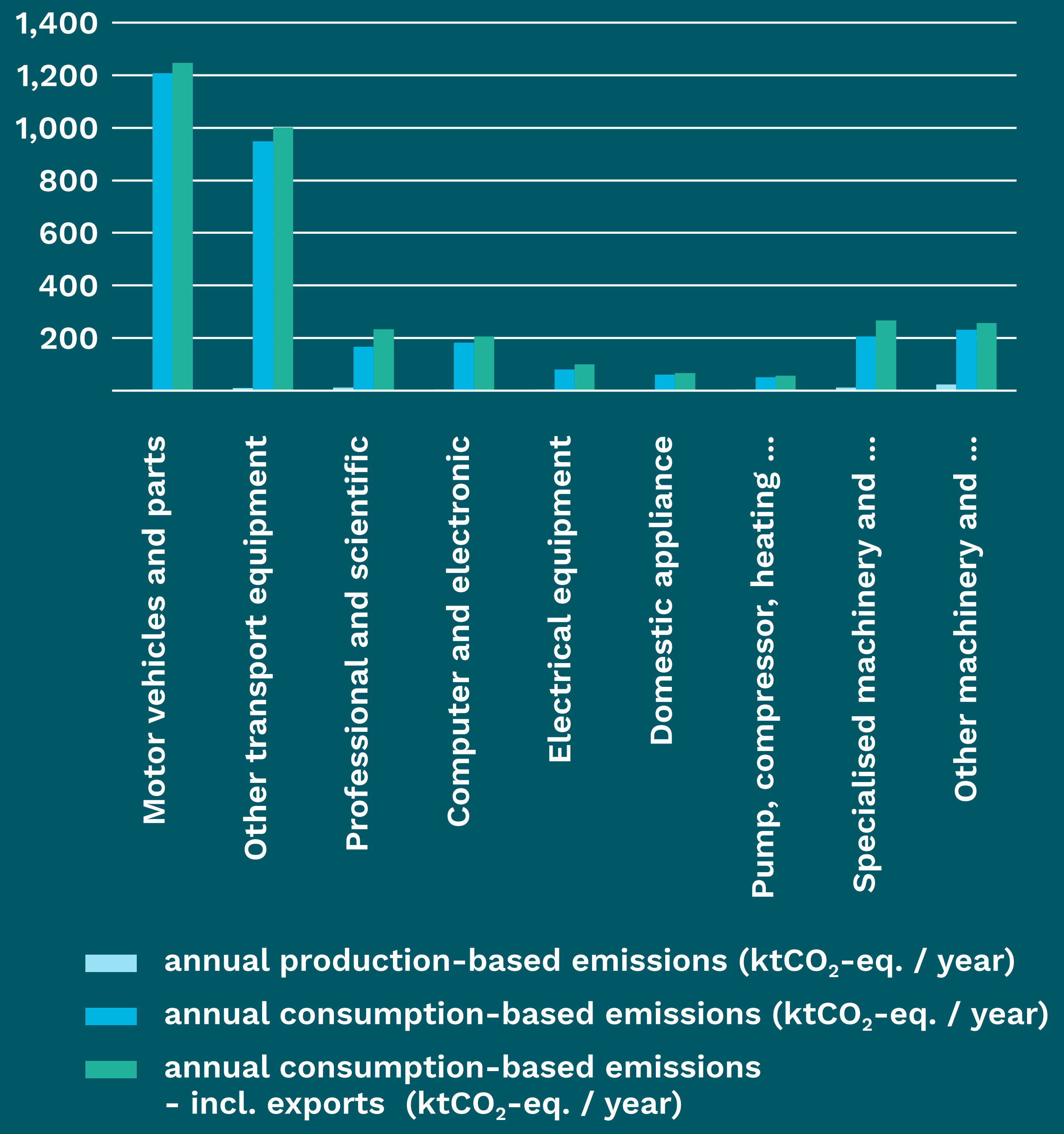


Figure 13. Machinery and equipment annual emissions (2019)

Subsector mapping

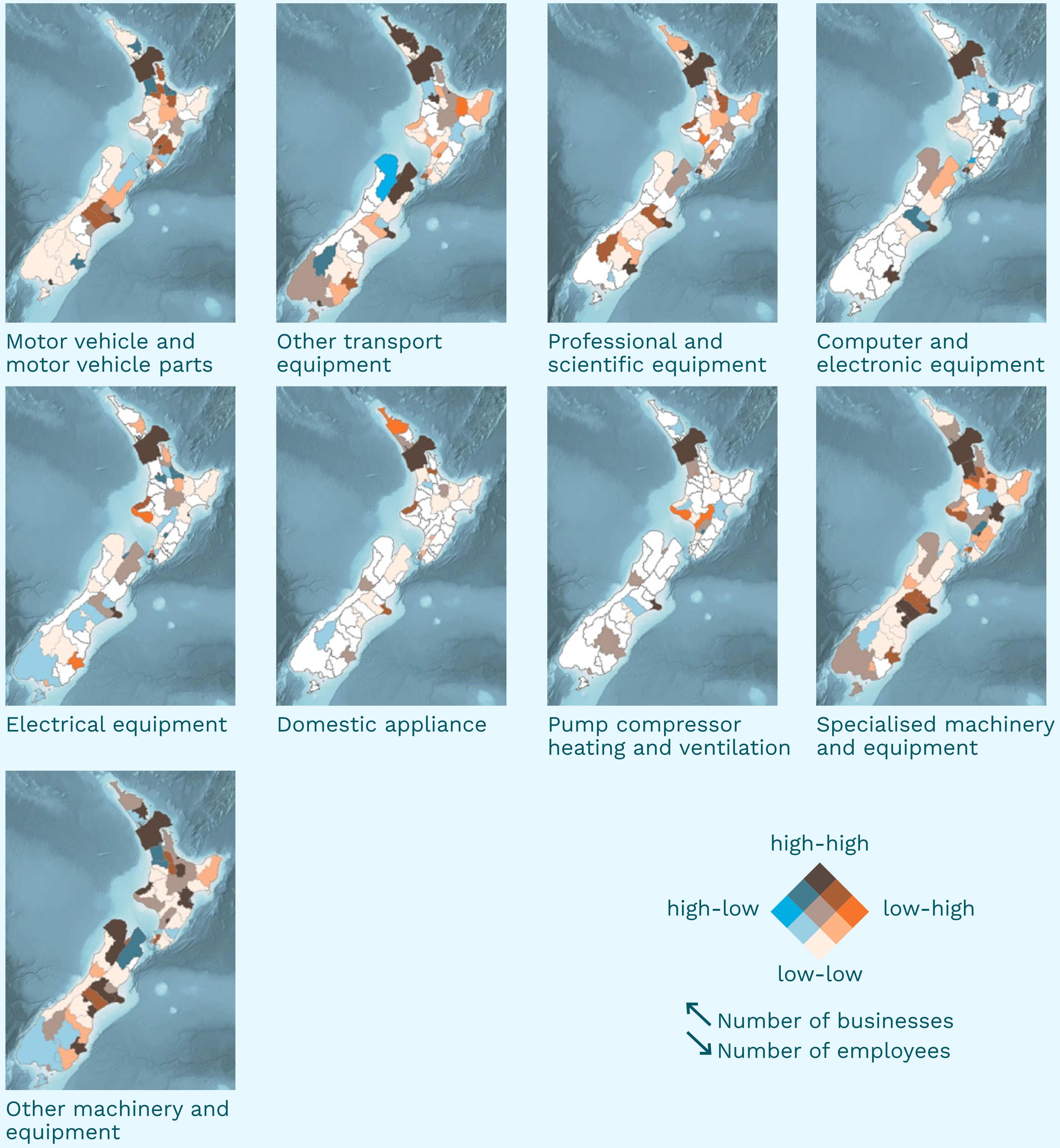


Figure 14. Machinery and equipment subsector | mapping number of businesses and employees (StatsNZ, 2019)

Waste flows

The subsector has a broad spectrum of practices, from innovative waste reduction and recycling to traditional disposal.

Machinery and equipment sector in NZ, 2019

Sources: National accounts
(million of NZD/year)

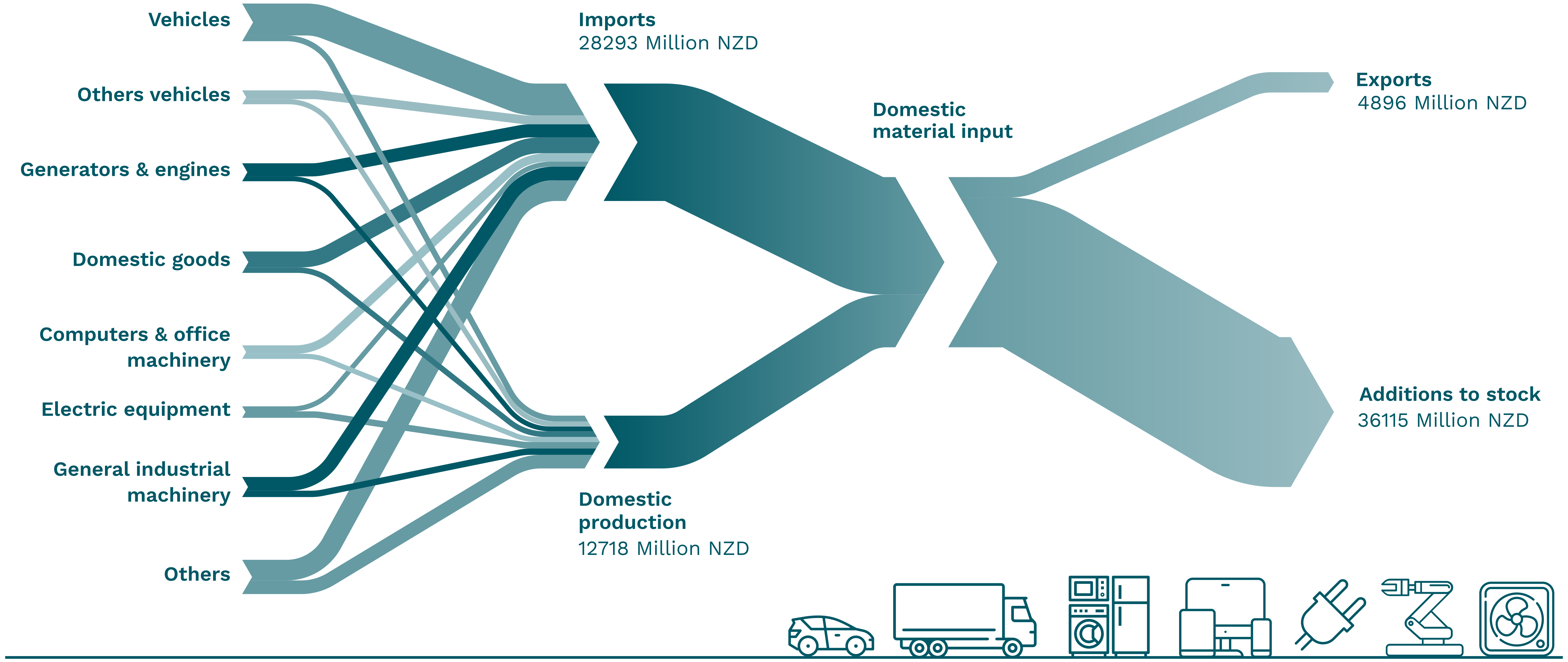


Figure 15. Machinery and equipment subsector in New Zealand (2019)

Stocks and flows

In 2019, we imported $28,293 m of machinery and equipment, and imported materials and components supported a further $12,718 m of domestic manufacturing.

Exports were relatively small ($4,896m) compared with imports. $36,115 million flowed into stocks within New Zealand. Vehicles, domestic goods and engines featured prominently. This flow of value into stocks implies that these materials persist in our economy and support longer-term economic activity.

Opportunities

- Opportunities for durable design, reuse, shared-use, remanufacturing, repair, recycling and 'design for disassembly' stand out. They could create high-quality employment and substantially reduce global price volatility and other critical minerals risks.
- Industry 4.0 technologies, including digital twins and AI, could help reduce emissions, make the subsector more efficient and minimise waste.
- The bioeconomy and innovative applications like e-waste recycling have potential.
- The subsector needs to improve stock management and explore circular economy principles to reduce waste and use internal materials.
- Collaborating within the industry is crucial to share best practices.
- When New Zealand Steel's electric arc furnace is operational, this will likely increase demand for scrap from used machinery and equipment.
- Focusing on manufacturing high-quality, low-carbon, durable goods will likely help differentiate our exports as other markets address critical minerals challenges and align with circular economy principles.

Data gaps

- A lack of data about where stocks are, how long they are likely to persist (e.g. replacement cycles for vehicles in the national fleet) and how they can benefit the economy when they exit service hinders attempts to plan or anticipate demand.
- A lack of granular data and appropriate emission intensities means we cannot fully resolve some resources and emissions, including those from imported goods.
- We lack knowledge about how to share data safely in a competitive market.
- We need further modelling to understand the impacts of increasing product repairs to reduce imports.

Stakeholder views

- **Opportunities**
  Although stakeholders were interested in product as a service models and modular and durable design, they currently lack confidence in their ability to adopt these models.
- **Data gaps**
  Stakeholders discussed the lack of data about the lifecycle of products once in use, including how long they are used and what happens to them at end-of-life. They also discussed whether it would be feasible to gather data within companies as a more practical approach. Competition was seen as a potential barrier to effective data sharing.
- **Collaboration**
  Individuals are motivated to champion sustainability, but some noted the need for in-house champions to drive greater systems change and support the gathering and sharing of data. Stakeholders would welcome a multi-disciplinary group to support repair and commercial investment.

Other manufacturing

This diverse category includes products like non-metallic mineral products, textiles, leather and footwear, furniture, jewellery, toys, sporting goods, recreational products, musical instruments, candles, and paintbrushes.

Non-metallic minerals represent the most significant flow. A few large businesses dominate the subsector, including Golden Bay Cement, Graymont Lime, and O-I Glass*. They supply many more concrete and glass product manufacturers. The subsector contributes $1.2 billion to GDP.

We import all the flat glass and two-thirds of the cement we use. Our production of non-metallic minerals is highly focused on the domestic market, with low exports.

Textiles contribute $600 million. Consumer spending on textiles was $6,156 million in 2019. $4,627 million of this was imported, and $1,529 was produced domestically. Exports of $1,356 million point to a strong export market and the potential for New Zealand to meet more of its own needs.

*Visy aquired O-I Glass's (Owens Illinois Glass) Australian and New Zealand division in 2020

Subsector mapping

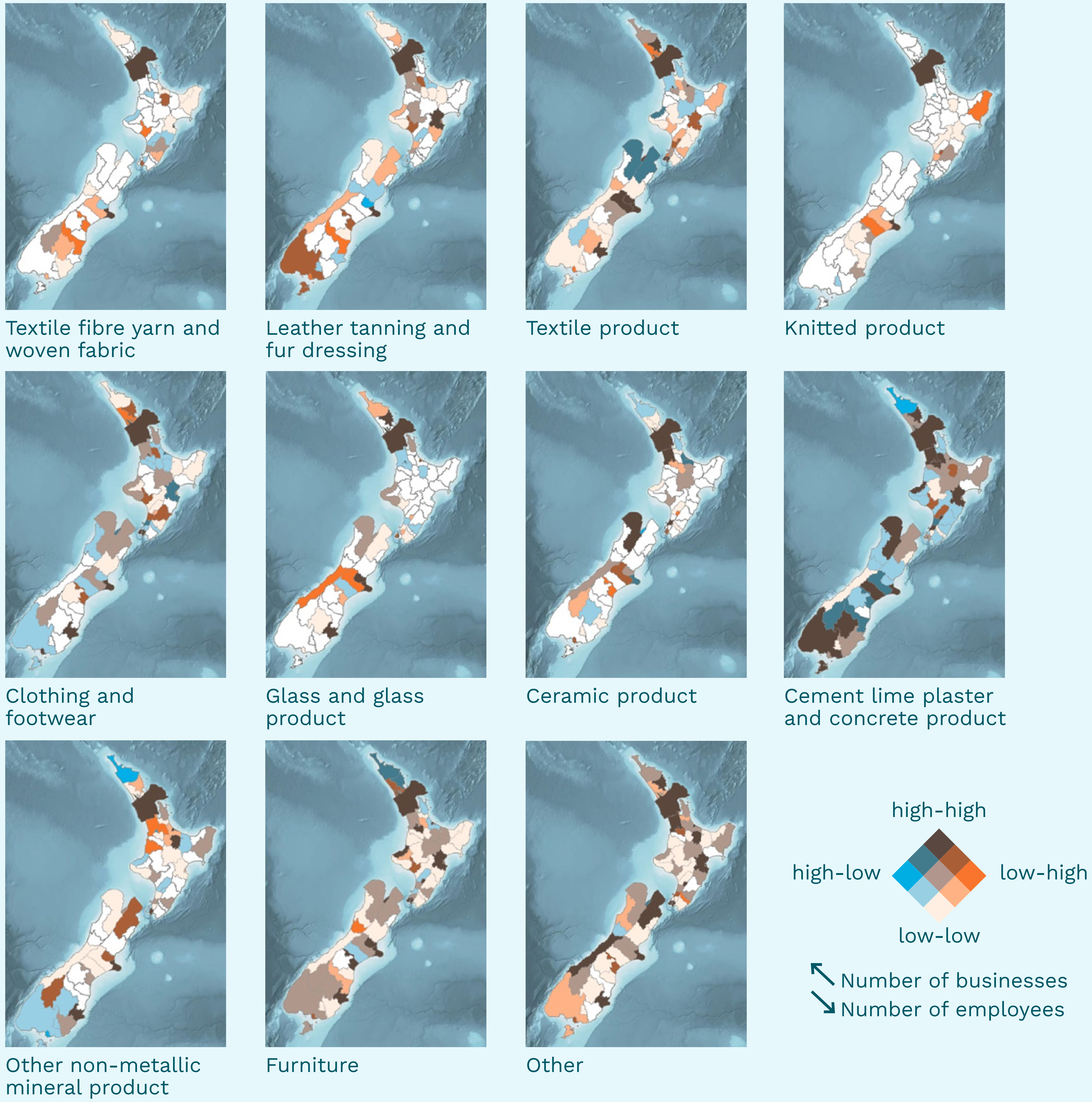


Figure 16. Other manufacturing subsector | mapping number of businesses and employees (StatsNZ, 2019)

Emission hotspots

The footprint of non-metallic minerals dominates. Primary production accounts for much of this footprint.

Despite consuming a large amount of clinker in concrete, the emissions caused by cement production are the most significant. Ready-mix concrete contributed 1,123 kt CO2e in 2019. Around half was used in residential buildings, with the rest split evenly between non-residential buildings and infrastructure. As these are substantial minerals flows into stocks, we must understand how long the buildings and infrastructure stay in service and when they will likely become waste. This is currently a data gap.

Geographically the impacts from non-metallic minerals and textiles tend to follow the most highly populated areas.

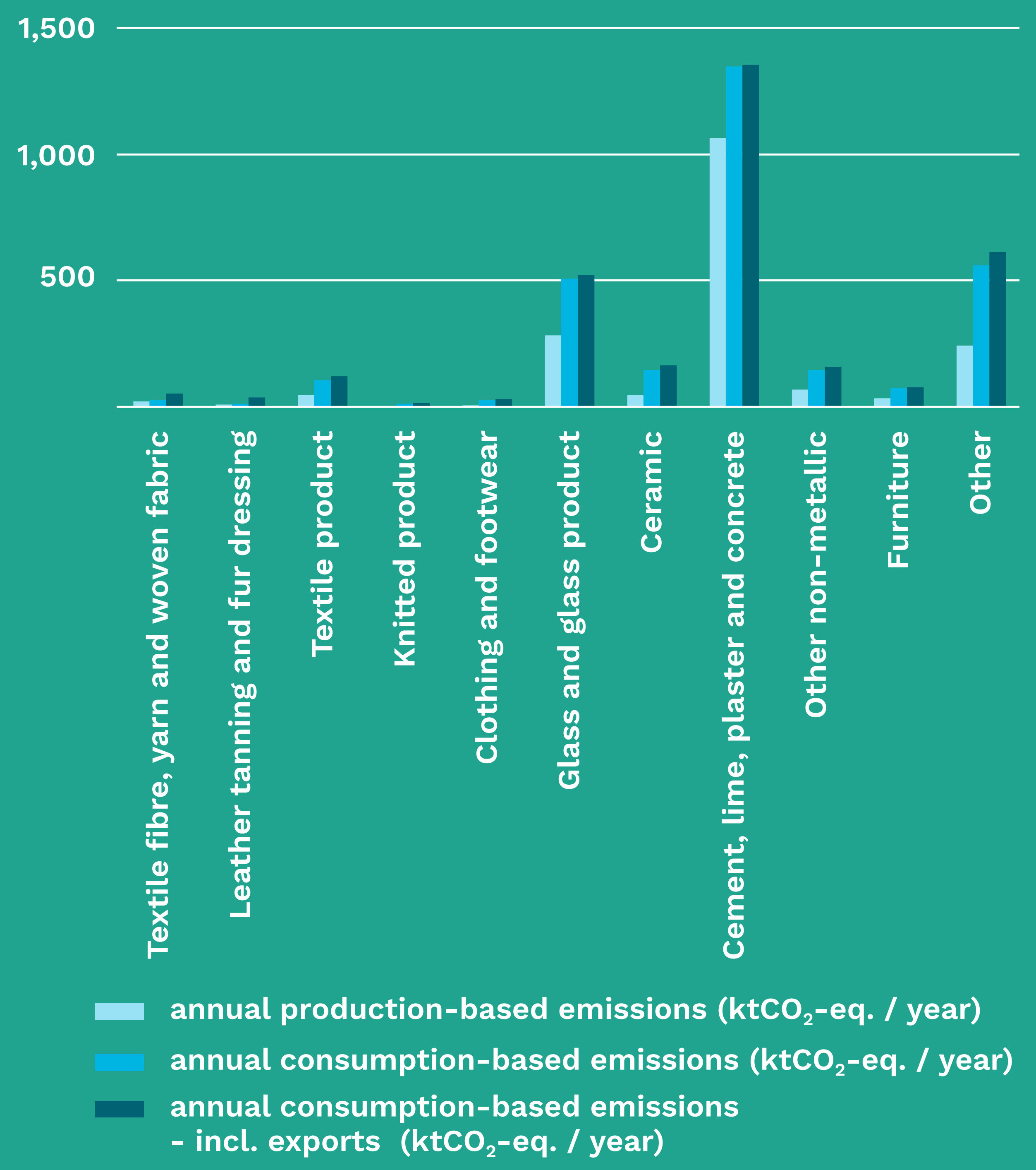


Figure 17. Other manufacturing annual emissions (2019)

Waste flows

Rubble is a significant flow into landfills around New Zealand. Using these materials as recycled aggregate is promising, but potential contamination from carbonated and chloride-contaminated cement may reduce the lifespan of reinforcing steel if used inappropriately.

Large construction companies like Fulton Hogan and Fletcher Building use other subsectors waste for their processing and production. Developing regulated, commercial recycling and product stewardship programmes helps businesses supply their waste products to be repurposed.

365 kt of textiles were sent to Class 1 or 2 landfills in 2019. This is likely to be mostly end-of-life textiles, but we lack the data to confirm it.

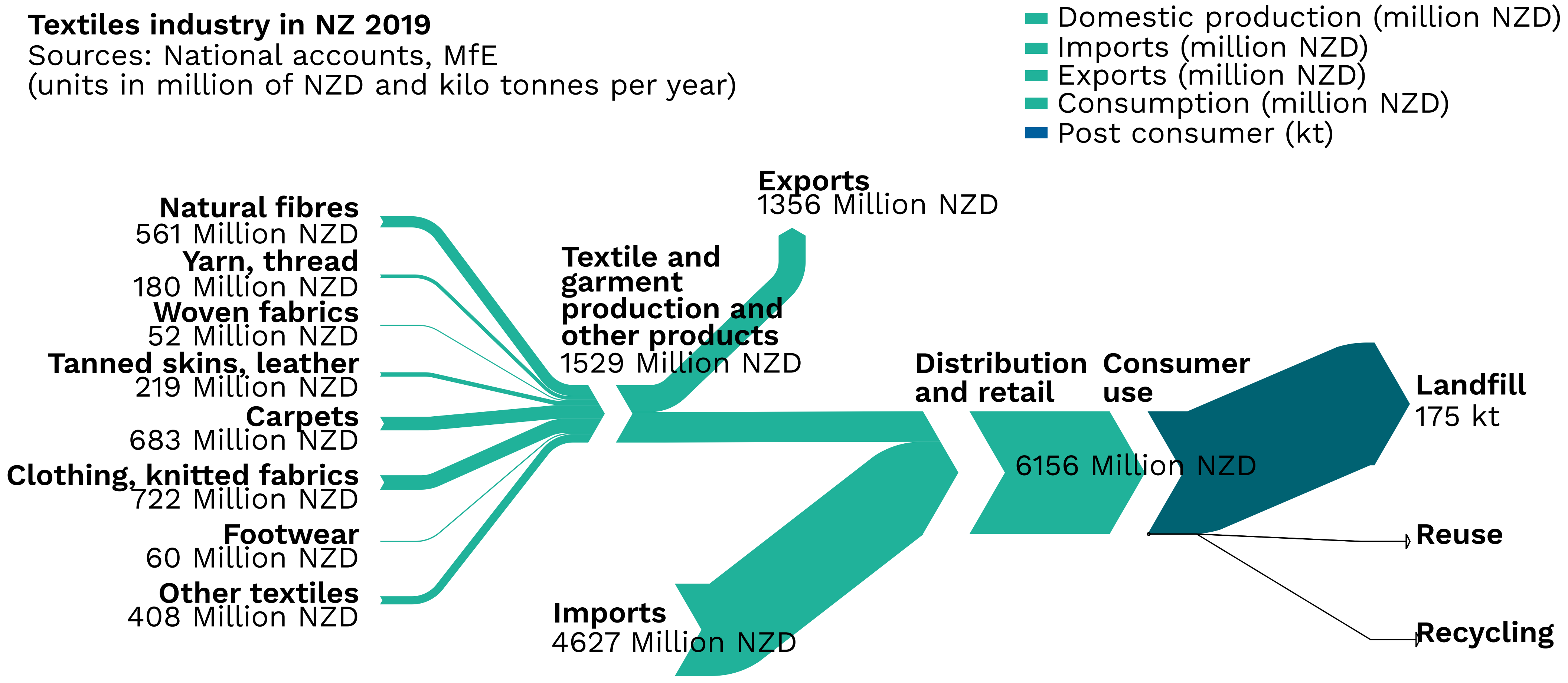


Figure 18. Textile industy in New Zealand (2019)

Waste flows

Carbon emission of Cement and concrete production in New Zealand, 2019
Source: EPD Australiasia, MBIE NZ, Stats NZ, thinkstep-anz
(unit kilo tonnes of CO_2-eq produced in 2019)

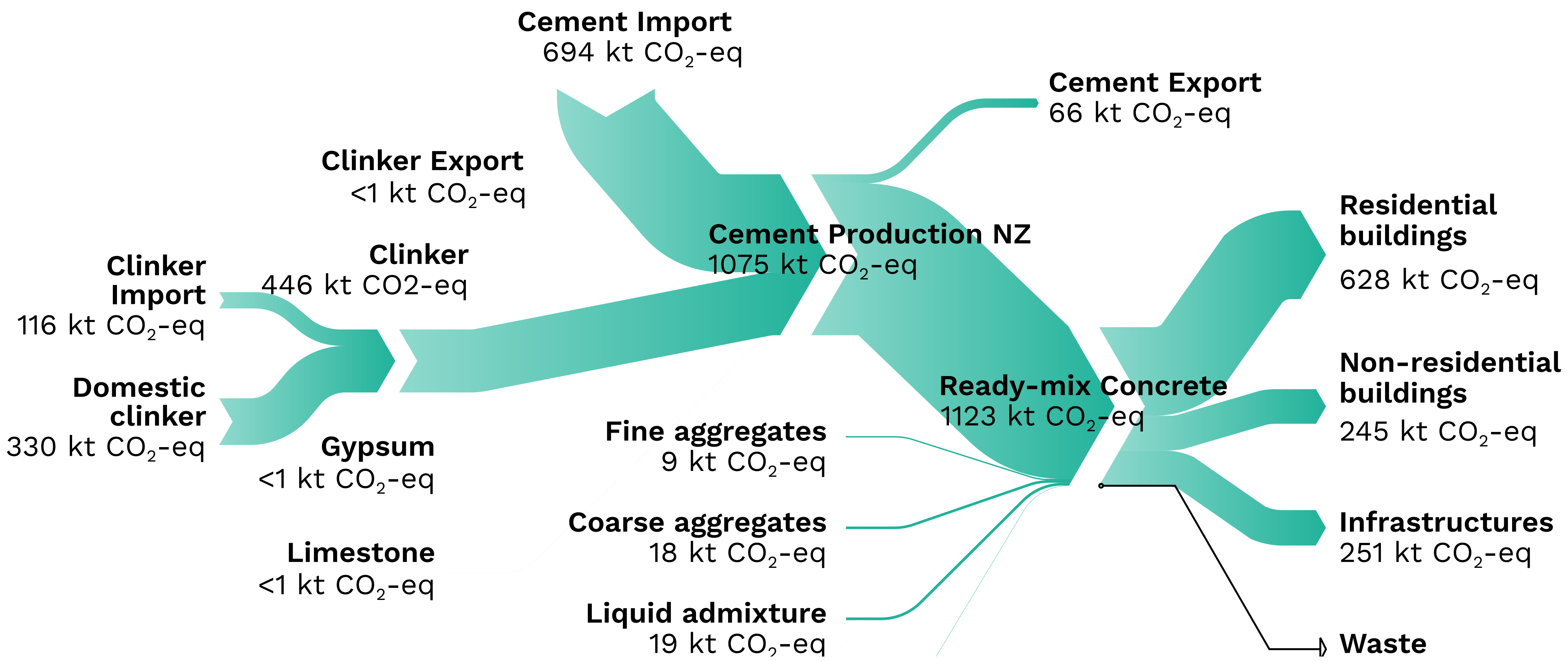


Figure 19. Carbon emission of cement and concrete production in New Zealand (2019)

Cement and concrete production in New Zealand 2019
Source: Stats NZ, thinkstep-anz
(unit tonnes of material used in 2019)

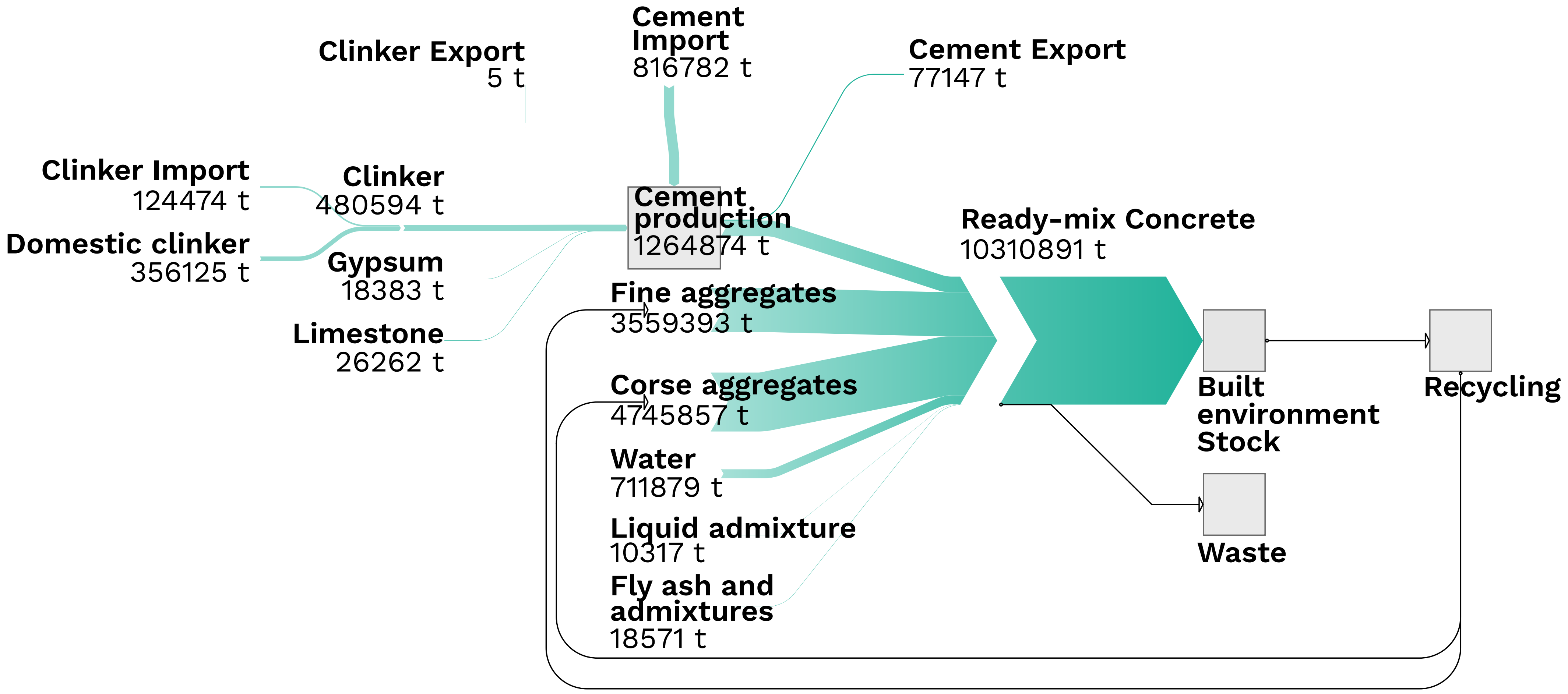


Figure 20. Cement and concrete production in New Zealand (2019)

Other manufacturing

Opportunities

- Cement and lime production are challenging to decarbonise but essential to develop domestic infrastructure. As we are highly dependent on imports, there are limited opportunities to influence the carbon footprint of the cement and lime we use.
- However, domestic production is highly centralised, and this may make it easier to implement lower-emission technologies as they become available. Using alternative and supplementary cementitious materials (SCM) for concrete is integral to the concrete industry's zero-emission roadmap. Phasing out coal power at Huntly will reduce local supplies of flyash; SCMs may increasingly be imported and we have not been able to evaluate the emissions impacts of this scenario. Natural pozzolans from volcanic ash may soon provide local alternatives.
- Despite the variety in this subsector, Other Manufacturing is delivering product stewardship programmes at pilot and commercial scales. Our stakeholder engagement showed the industry is engaging with supply chains to source sustainably and reduce impacts.
- Industry 4.0 technologies could help companies operate more efficiently and minimise waste.
- A lack of onshore processing options may limit the use of new technologies, such as fibre-to-fibre processing for textiles, resuting in landfill or export being the primary options. Industry-led working groups are driving change but need government investment and support to apply innovation at a commercial scale.

Data gaps

- Complex and variable data sources make understanding material flows and emissions difficult.
- We need better data on hazardous waste from various manufacturing processes, second-hand markets, and repair initiatives.
- Gaps include stocks associated with 'other manufacturing'. This data is relevant to the construction industry, asset base and construction and demolition waste.
- We lack data on textile emission intensities by fibre type.
- We need to investigate glass manufacturing and mattress production further.
- The industry has 'a long tail'. More work is needed to understand 'outliers' not represented in the other ANZSIC codes.

Stakeholder views

- **Data**
  Stakeholders talked about the challenges of translating financial data into physical quantities and needing to adopt standard reporting frameworks across sectors. They would like detailed information on products' end-of-life phases, particularly in recycling and re-manufacturing processes. Stakeholders suggested acquiring missing data through industry associations, from government and council data, and by exploring new ways to collect data. These could include standard reporting frameworks or technology-based solutions (e.g. GIS, remote sensing).
- **Emissions data**
  Stakeholders understood the need to consider the entire supply chain to measure emissions.
- **Circular economy initiatives**
  Stakeholders identified opportunities for more recycling and re-manufacturing of materials, particularly textiles and composites. They saw strong potential for product-as-a-service models and designing products to last and be repairable. This would extend product lifecycles and minimise waste.
- **Sustainability**
  Discussions emphasised government support and industry-wide efforts to become more sustainable.
- **Collaboration**
  Collaborating across sectors is crucial to advance circular economy goals.

Metal and metal product

Metals manufacturing is dominated by steel and aluminium production at Tiwai Point in Southland and Glenbrook near Auckland. Smaller producers of non-ferrous materials, including gold, copper, and brass, are located in Otago, Waihi and Auckland. Downstream product manufacturing is dispersed across New Zealand.

The New Zealand metal manufacturing subsector is worth $2.82 billion.

Emission hotspots

Emissions were concentrated in a few high-impact companies, emphasising primary/virgin metal production. Decarbonising these processes requires significant capital spending on emerging technologies and long-term strategic roadmaps to support them. This is especially challenging for NZAS aluminium production, given the commercial uncertainties it faces.

Using fossil fuels and producing feedstock contribute significantly to emissions in steel production.

The industry is reducing direct emissions by moving from gas to electricity.

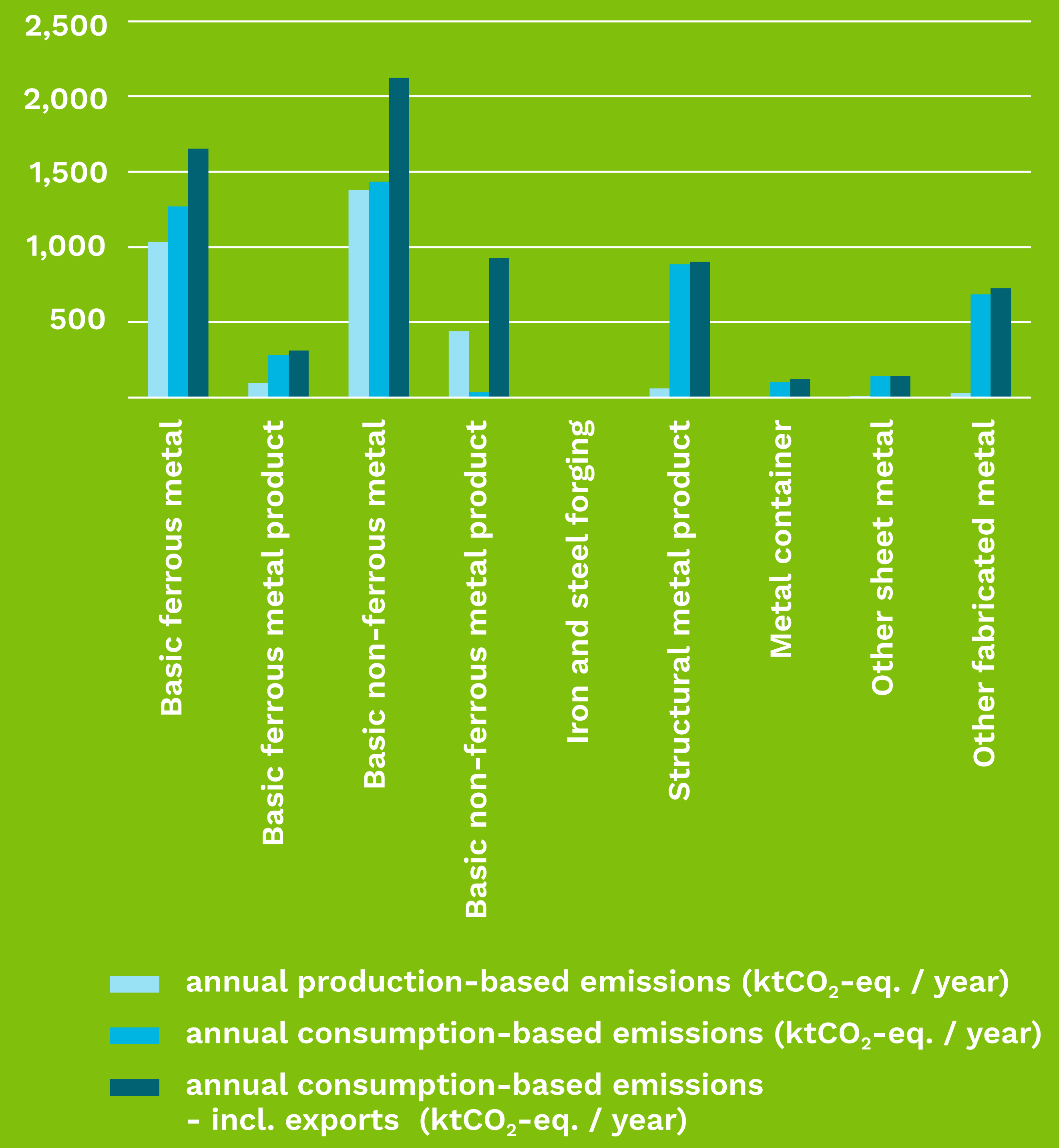


Figure 21. Metal and metal product annual emissions (2019)

Subsector mapping

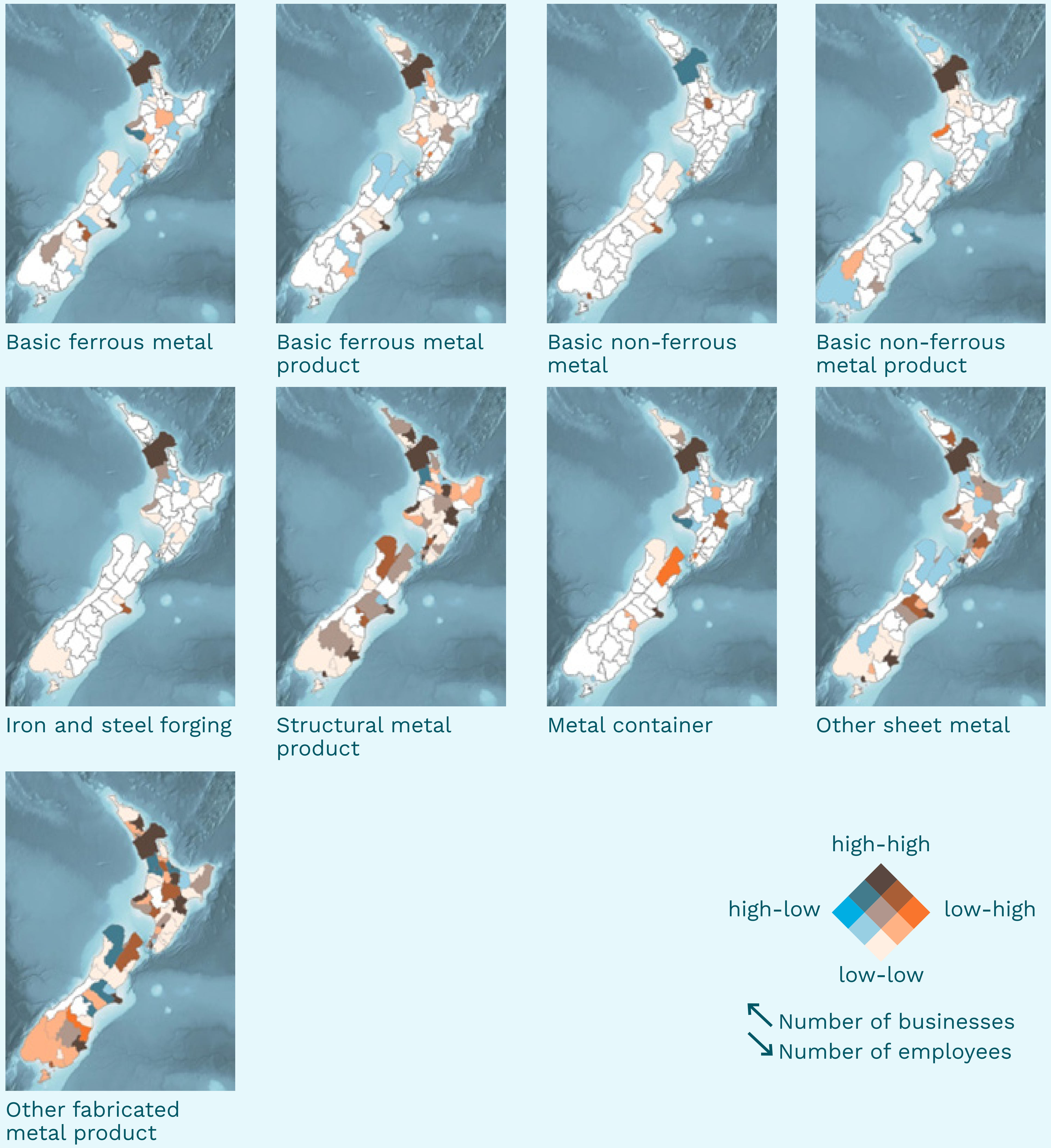


Figure 22. Metal and metal product subsector | mapping number of businesses and employees (StatsNZ, 2019)

Waste flows

Metal recycling is gearing up, particularly for steel. Glenbrook's electric arc furnace will come online in 2027 and increase domestic demand for scrap metal. Smaller recyclers are recycling smaller volumes of non-ferrous metals.

Unlike overseas, the New Zealand industry is not set up for large-scale product circularity. Common carrier metals (such as iron and aluminium) can be recycled many times without any material loss of quality. However, many alloying elements used in metals in New Zealand are critical minerals that are lost or diluted during recycling, suggesting the need for alternate strategies.

Wastes from metals production are used in low-value applications, such as melter slag for aggregate.

Carbon emissions and Mass of Primary Steel production New Zealand 2019

Sources: MfE, WorldSteel Association, AusLCI, JRC
Units in kilo tonnes of CO_2-eq (kt CO_2-eq) per year [emissions] (orange) and kilotonnes (kt) [mass] (blue)

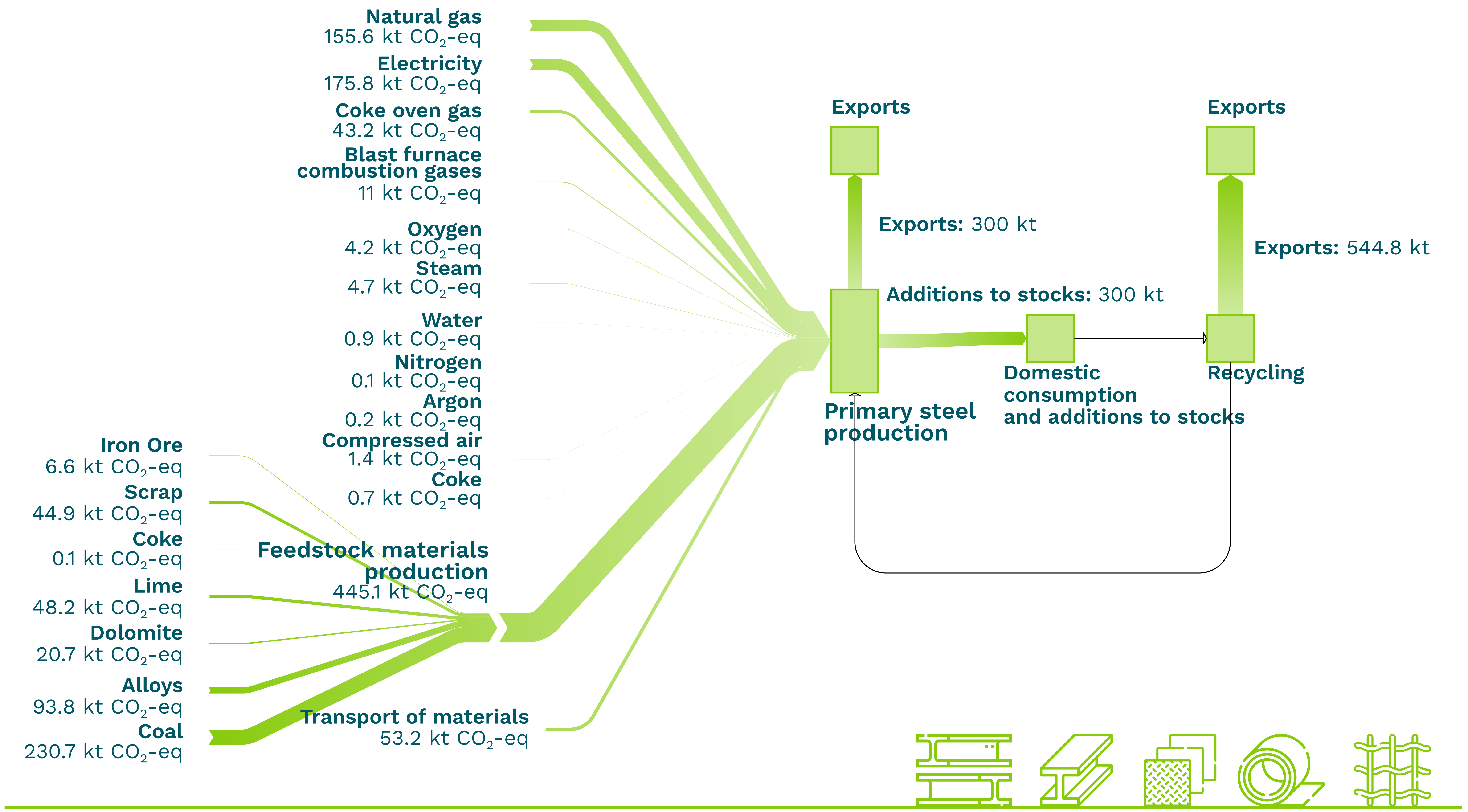


Figure 23. Carbon emissions and mass of primary steel production in New Zealand (2019)

Opportunities

New Zealand's critical minerals list will be published later in 2024. This will focus on managing supply risks for applications that include critical minerals and identifying circular economy opportunities to mitigate these risks. As critical minerals are often lost during recycling, improving 'segregation', extending service life, and encouraging reuse offer opportunities.

Increasing the circularity of metals will help New Zealand decarbonise and decouple from supply risks. However, the domestic vs global benefits have not been assessed for unintended consequences and will require further research. Unintended consequences include possible impacts on trade agreements, jobs and skills.

Suppliers of non-ferrous metals are already sourcing materials from recycled stocks. New Zealand Steel's electric arc furnace will support this strategy from 2027.

Opportunities exist to recover value from higher-priced commodities such as vanadium and titanium.

Data gaps

- Lack of current, granular data, especially for waste streams (e.g. recycling processes and destinations of recycled metals, both domestic and international).
- Lack of data on smaller industries such as copper-based alloy smelting, refining, and gold/silver smelting.
- Discrepancies in emissions data, particularly aluminium and steel, make it difficult to assess the subsector's emissions profile accurately.
- The industry needs more and better data to represent its environmental impact.
- Lack of data for subsectors outside ferrous metal production.
- No specific emissions intensity factors for subsectors.
- Data gaps make it difficult to link the subsector with other sectors (e.g. machinery and equipment manufacturing).

Stakeholder views

- **Data**
  Stakeholders are concerned about the lack of detailed data. Suggestions to bridge these gaps included using up-to-date industry surveys and customs data and working with organisations like Toitū Envirocare and the Sustainable Business Network.
- **Waste**
  Stakeholders were keen to understand domestic versus offshore recycling and the potential to improve domestic recycling.
- **Emissions**
  Stakeholders were interested in the emissions involved in manufacturing primary steel and the significant role coal and natural gas play in this process.
- **Metal circularity**
  The industry would like more explicit government policies and targets to encourage circular practices, address logistical challenges, and foster collaboration to improve circularity across the subsector.
- **Collaboration**
  The industry is keen to collaborate more within the subsector and with external recyclers.

Chemicals and refining

The chemicals and refining subsector covers the high-value manufacturing of fuels, polymers, fertilisers, pesticides, medicines, cosmetics, detergents, and industrial chemicals. Auckland, Wellington and Tauranga were key activity areas for this subsector.

The subsector shrank by 15.8% between 2018 and 2022. R&D expenditure fell by 13.67% over this time. This may reflect a longer-term decline in the subsector and a fall in the number of chemicals and refining businesses in New Zealand. The subsector relies heavily on imports ($6.4 billion of fuels and chemicals in 2019).

Between 2021 and 2022, the subsector captured 12% of manufacturing foreign direct investment, with pharmaceuticals and cosmetics growing.

The industry tracks carbon emissions across Scopes 1, 2, and 3 to minimise its carbon footprint.

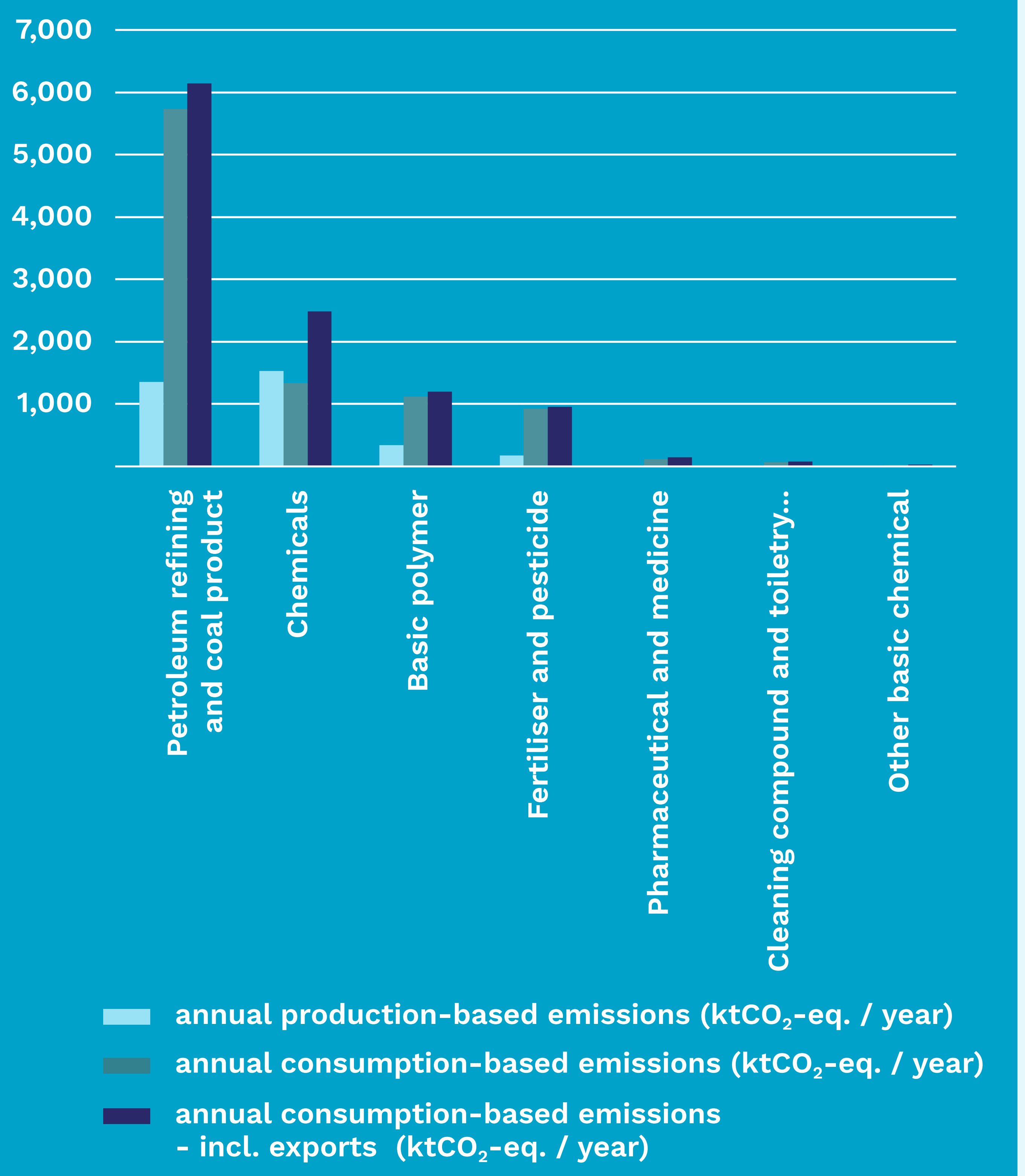


Figure 24. Chemicals and refining annual emissions (2019)

Emission hotspots

This subsector has the most significant emissions of all sectors, with consumption-based emissions linked to petroleum and coal. The 2019 data does not reflect the closing of the Marsden Point refinery in 2021. We expect an updated analysis using 2024 data would show negligible production-based emissions and a potential shift to more consumption-based emissions.

The most significant subsector for production emissions is basic chemical manufacture, dominated by Methanex.

Subsector mapping

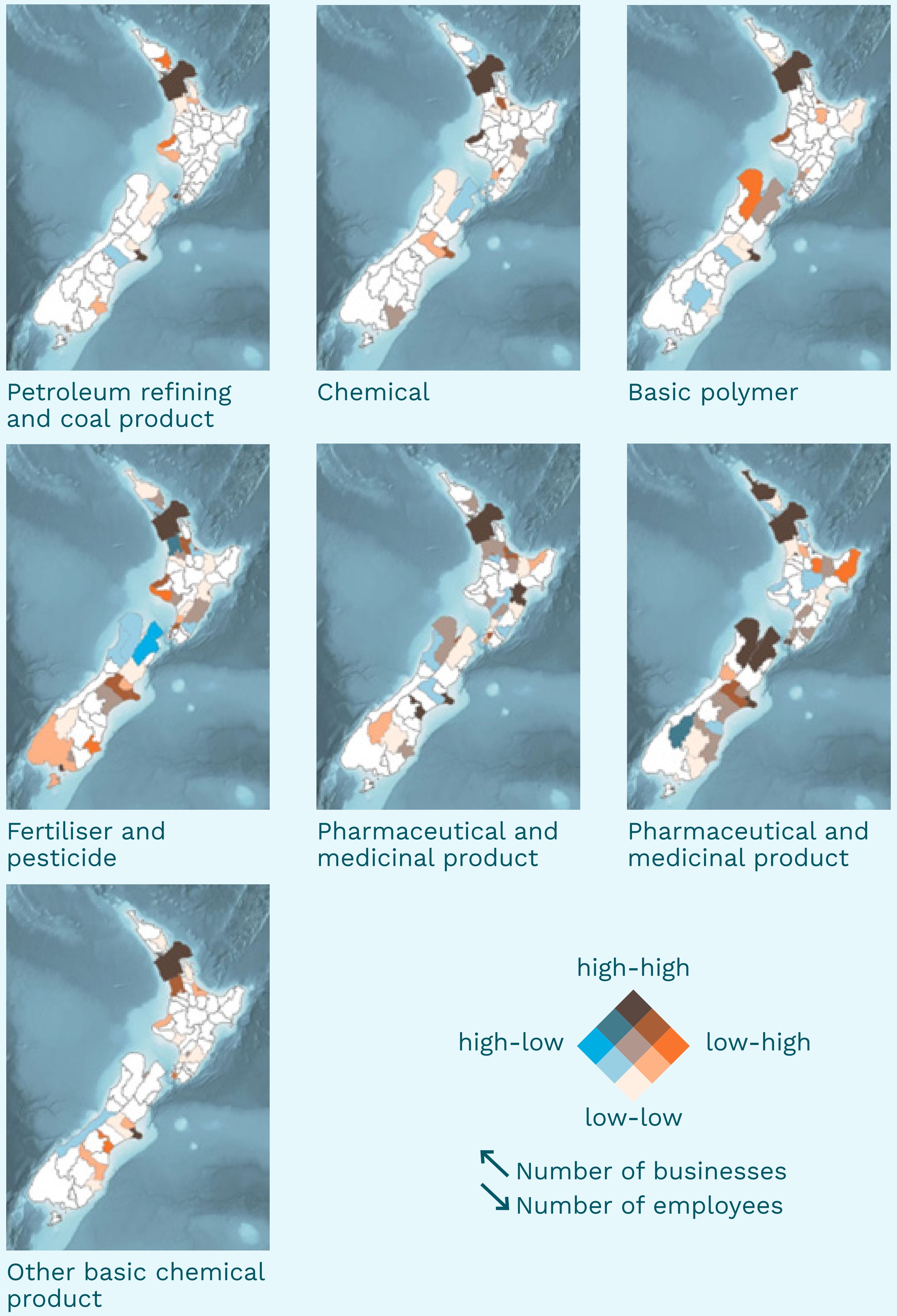


Figure 25. Chemicals and refining subsector | mapping number of businesses and employees (StatsNZ, 2019)

Waste flows

The subsector's diversity made this analysis difficult. Many 'potentially hazardous' waste streams and losses could occur through the environment, waterways, organic biowaste, and sludge. Disposing of contaminated packaging and unused chemical waste are likely sources of problematic waste.

The industry is working hard to reduce its environmental impact by reducing emissions, complying with regulations for disposing of and recycling chemical waste, and managing wash water.

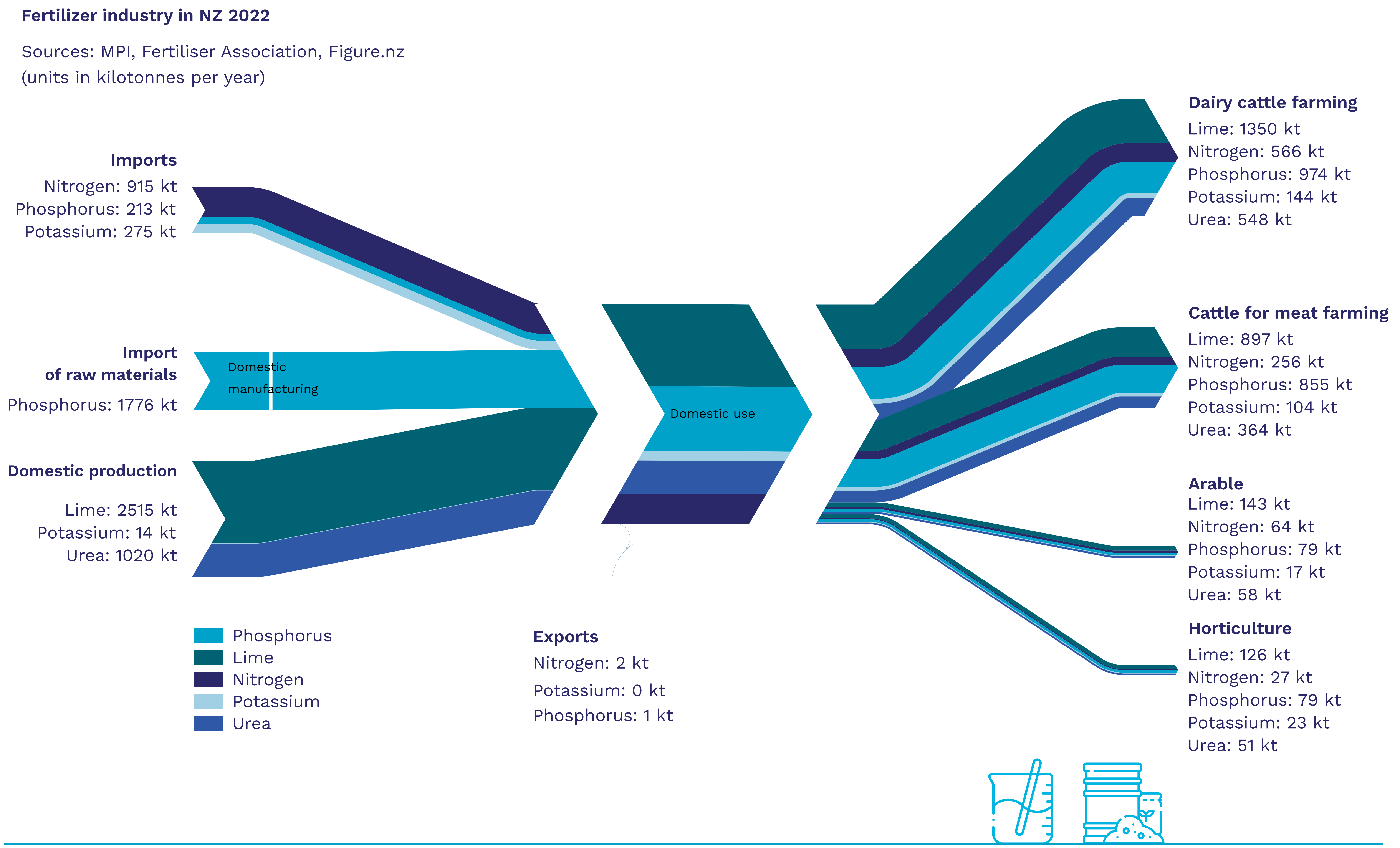


Figure 26. Fertilizer industry in New Zealand (2019)

Opportunities

There are opportunities to reduce imports by reshoring activities or expanding domestic production. This could decrease global emissions through reduced transportation, lower-carbon domestic production, creating jobs in New Zealand and decreasing our exposure to supply chain risks. It might also increase domestic emissions. In particular, the fertiliser industry was identified as depending heavily on imports of fertilisers and raw materials such as phosphorus and has strong links to the dairy and meat farming sectors.

The subsector could become more circular by improving recycling at source, developing business models that promote reusing chemical products, and exploring bio-based chemicals as sustainable alternatives.

Data gaps

- Data for different chemical and refining processes and aggregated data needs to be more granular and specific. It needs to cover recycling processes, managing waste of chemical by-products, and the environmental impacts of different disposal methods. Better data will make it easier to distinguish the impacts of different chemicals and measure emissions and waste streams.
- The industry lacks data for sectors other than fertiliser (e.g. basic polymer production, pharmaceuticals, and other basic chemical manufacturing).
- Gaps in data include detailed emissions data for Methanex.
- Data for fertilisers does not include emissions associated with producing and using it. As some products are based on fossil fuels and others on minerals, it is important to measure carbon emissions accurately.
- We could not identify quantitative data on waste from the chemical industry.

Stakeholder views

- **Imports**
  Stakeholders are concerned about how reliant the subsector is on imports.
- **Data**
  Stakeholders want better data (as above). They suggest using customs data for insights into chemical imports and working with organisations like Toitū Envirocare to gain lifecycle assessments.
- **Emissions**
  Stakeholders recognise that the industry is a heavy energy user, and reliance on coal and natural gas increases emissions.
- **Waste**
  The industry would value better domestic recycling options to mitigate Scope 3 emissions related to imported chemicals.
- **Circular economy**
  The industry needs clearer regulation, better data, and support for sustainable material R&D to move to a circular economy.
- **Collaboration**
  The industry is keen to collaborate and share non-competitive data, including by exploring decarbonisation pathways and sustainable production methods. There are also commercial sensitivities.

Subsector

Paper and wood

Forestry and wood products contributed 8.9% of the national GDP in 2020. They are New Zealand's third largest export after dairy and meat. Raw logs dominate, but New Zealand also exports a range of processed wood products. In recent years, paper production has declined due to falling demand for newsprint.

Auckland, Christchurch, Hastings, and Rotorua accounted for approximately 70% of the national emissions in the subsector.

Despite substantial domestic production, a large amount of paper, paperboard and timber panels is imported.

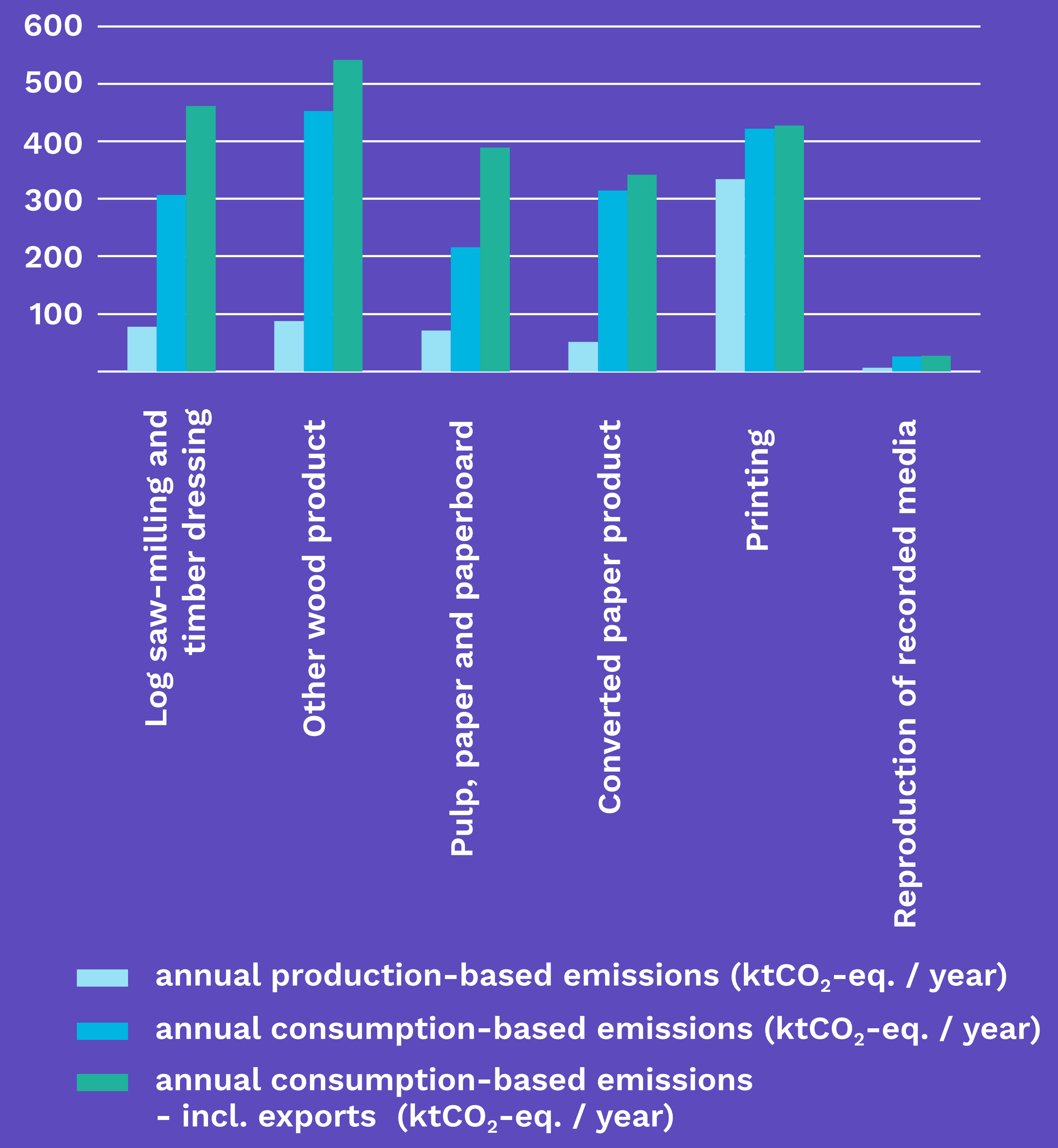


Figure 27. Paper and wood annual emissions (2019)

Emission hotspots

Our data suggested that forestry was responsible for most emissions within the subsector, with manufacturing contributing relatively little. However, our assessment included fossil fuels and did not consider biomass, an energy source often viewed as climate-neutral but worthy of inclusion.

Sustainable practices, including reusing sawmill by-products and exploring non-timber forest products, are important to reduce emissions.

Subsector mapping

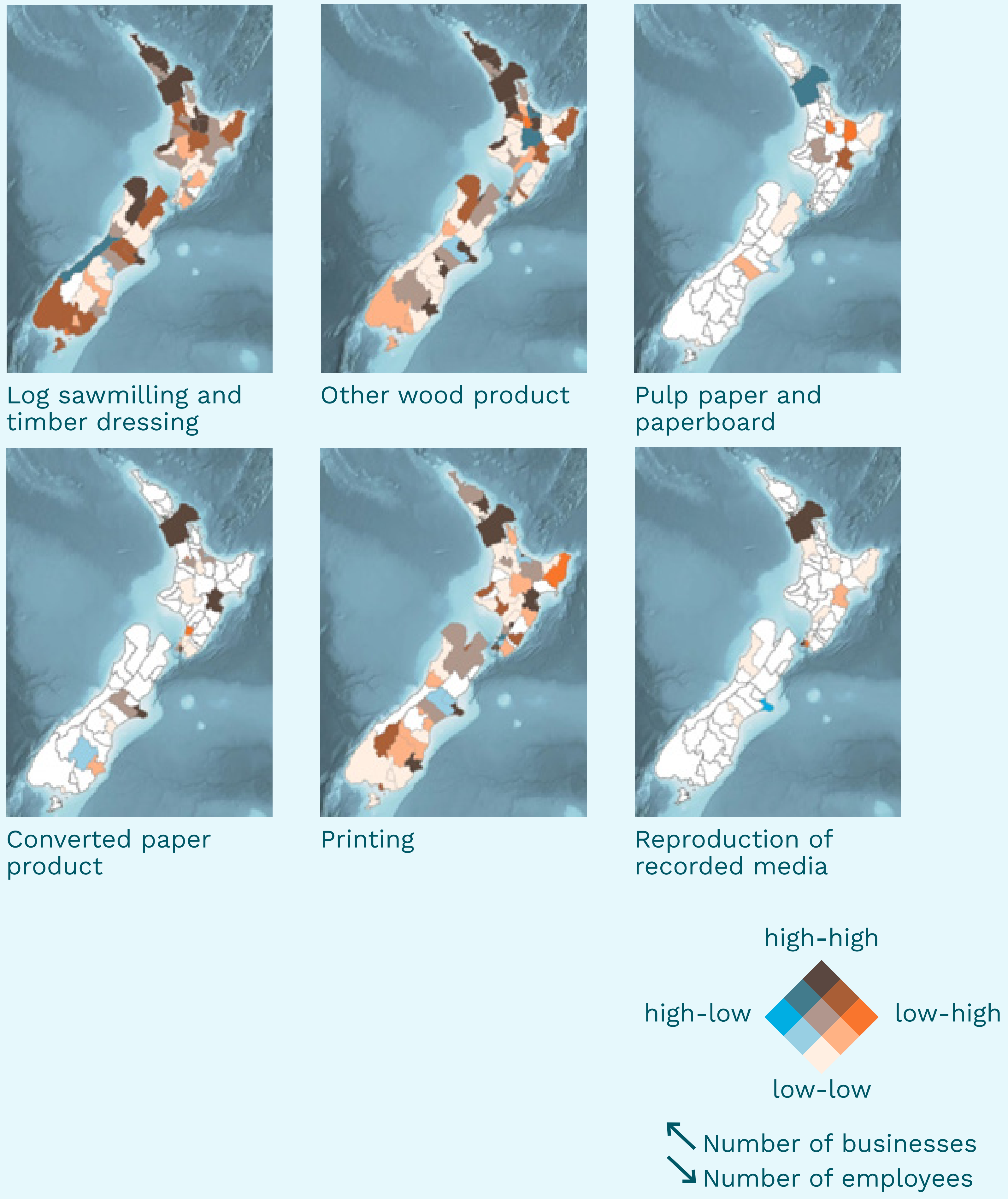


Figure 28. Paper and wood subsector | mapping number of businesses and employees (StatsNZ, 2019)

Emissions intensities

The emission intensities for wood and paper were relatively low compared with other sectors. Greater consumption-based intensities are linked to harvesting and transportation emissions. The substantial use of rail for transporting timber was suggested.

Printing and reproducing recorded media stood out for increased intensities. However, this may be due to the manufacturing process more than the materials.

Waste flows

The subsector has many waste streams. The main ones are organic. Others include inks, preservatives, plastics, adhesives, and byproducts such as ash and sawdust.

Timber by-products (e.g. harvest residue) are used for energy through wood pellets and biochar, Roughly 7.8% of roundwood removed was used as bioenergy in 2019.

Waste management represents a substantial aspect of the subsector’s operations, particularly handling harvest residue and bark.

The end-of-life fate of New Zealand wood and paper products was unclear. A large quantity is exported or ends up as stocks in the built environment. This means overall sequestration (storing) of biogenic carbon over time is hard to calculate.

Challenges include managing low-grade materials and finding markets for waste products.

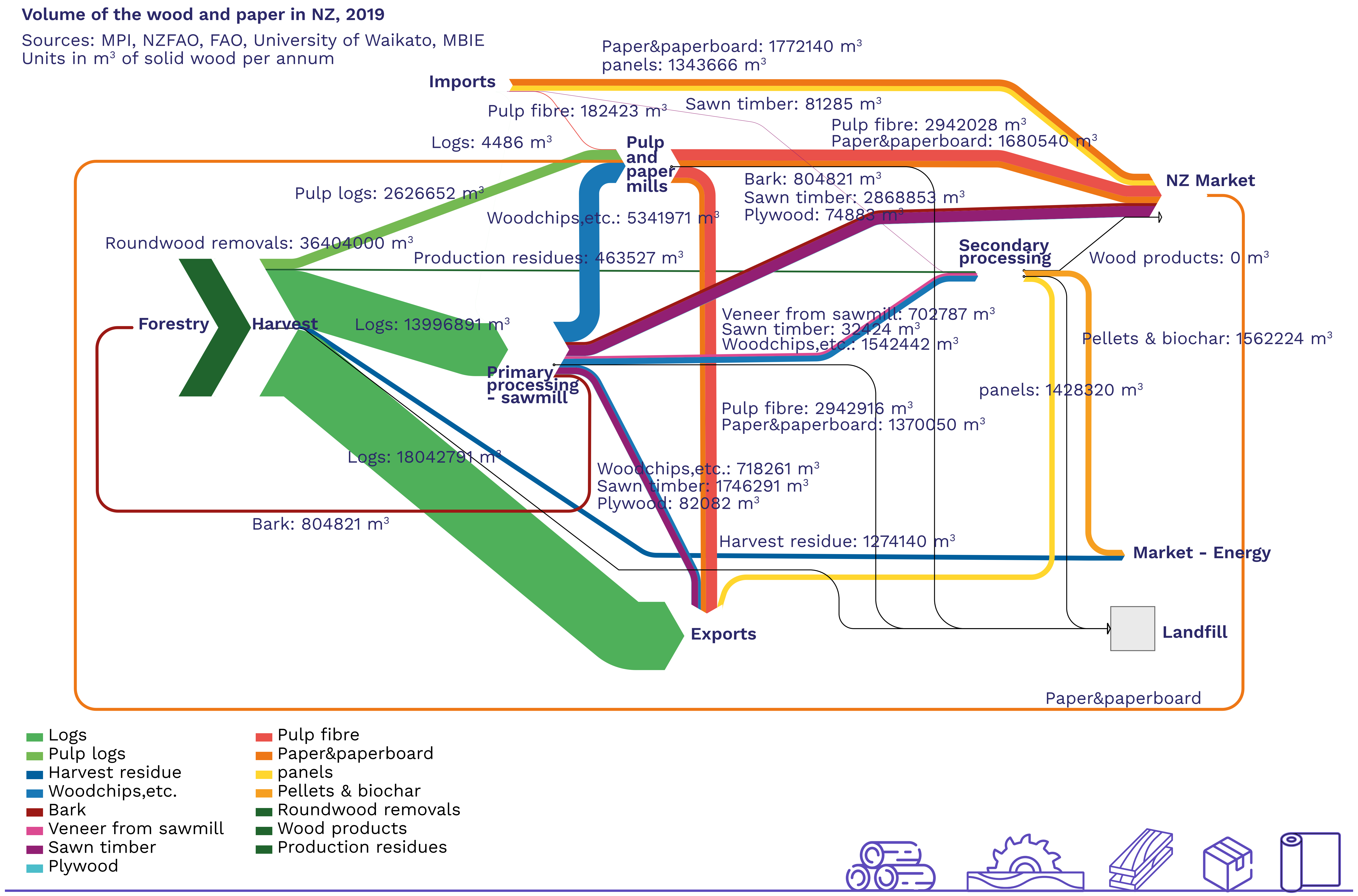


Figure 29. Volume of wood and paper in New Zealand (2019)

Opportunities

- Increase use of domestic wood and paper
- Use more engineered timber, timber products and bioenergy from waste.
- Continue to adopt innovative recycling and bioeconomy practices (particularly in bioenergy and bio-refining).
- Develop digital tools and platforms for data management and improve traceability across the supply chain.
- Support product development that reuses biotech waste.
- Cross-sector collaboration to support the circular economy.

Data gaps

- Granular emissions data is lacking for some categories of goods, such as fruit and vegetables, bakery products, oils and fats. This resulted in uncertainties.
- A lack of granular production data meant we could not map emissions intensities as well as we would have liked. We used proxy data from other regions, resulting in inaccuracies.
- More data is needed to differentiate between manufacturing and administrative sites. Lack of data may have led to allocating activities to Auckland.
- There are gaps in waste streams associated with packaging.

Stakeholder views

- **Data**
  The industry wants to use data more effectively to achieve sustainability goals. This includes having digital tools and platforms for data management.
- **Data**
  Stakeholders suggested obtaining missing data by engaging with industry groups, using trade and customs data more effectively, and exploring recent studies on carbon emissions and water flows through forests.
- **International vs domestic**
  They were interested in how efficient domestic production is compared to international alternatives and the potential to consume more domestic timber products

Subsector

Plastics and rubber

Although the sector is a small proportion of advanced manufacturing activity by GDP (4.6%), it has close links to other sectors. This includes using resin inputs from the chemicals and refining subsector and providing plastic packaging to the food and beverage subsector.

The main areas of activity are Auckland, Hamilton, Canterbury, and Wellington. The subsector faces pressures from consumers and the government to address plastic pollution.

Emissions

The industry is focused on reducing Scope 3 emissions associated with supply chains. It is also moving to sustainable electricity and making processes as low-carbon as possible.

Emission hotspots

Due to the size of domestic production, there are minimal production-based emissions. Consumption-based emissions come from imports. This makes it challenging to decarbonise the subsector: most emissions are associated with international supply chains.

Basic polymer production emissions in chemicals and refining are relatively high, contributing to supply chain emissions for polymer products.

More work is needed to allocate emissions to plastic and rubber accurately.

Auckland accounts for 50% of all emissions. Therefore, developing infrastructure and systems in Auckland can reduce emissions and waste output.

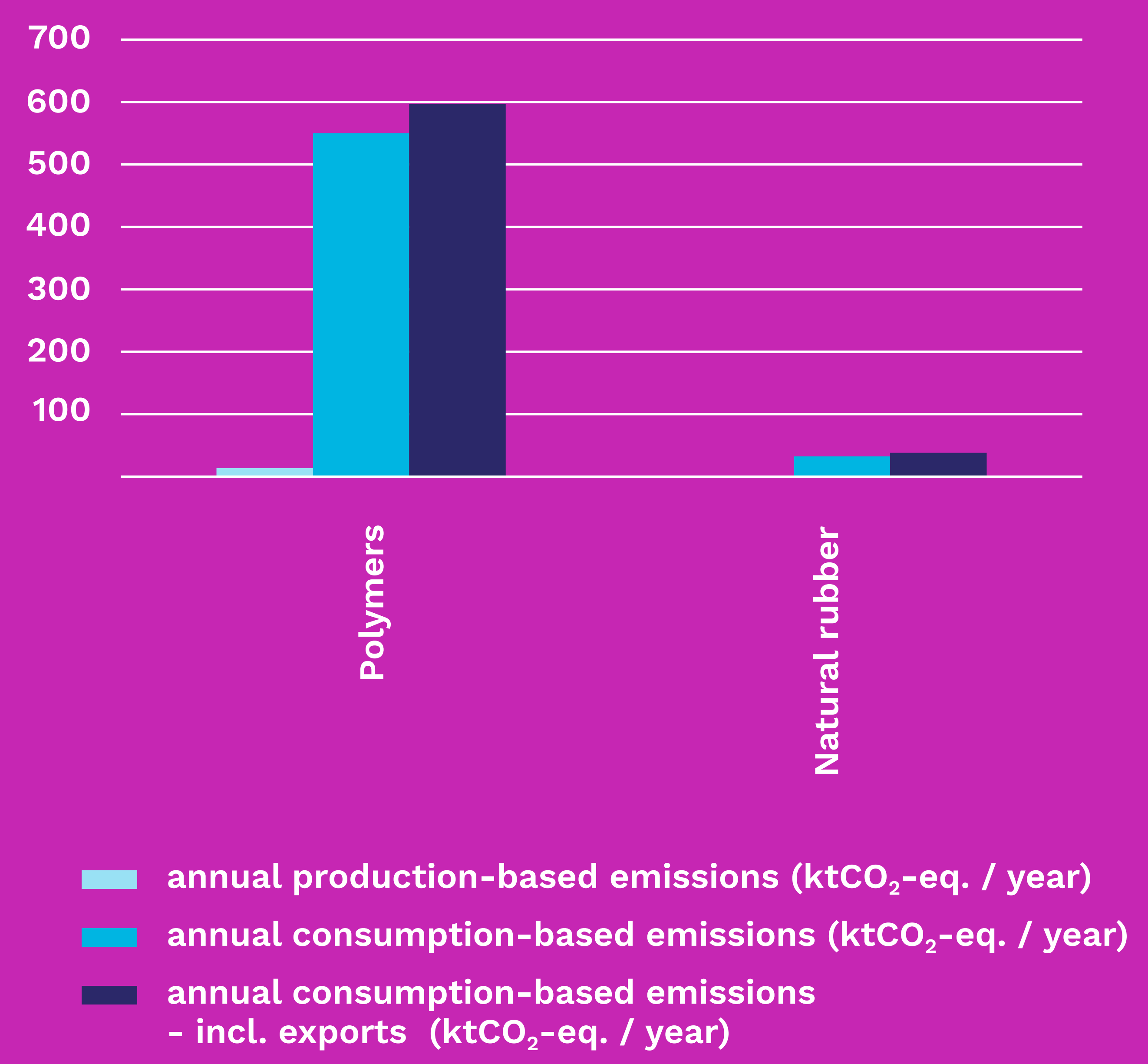


Figure 30. Plastic and rubber annual emissions (2019)

Subsector mapping

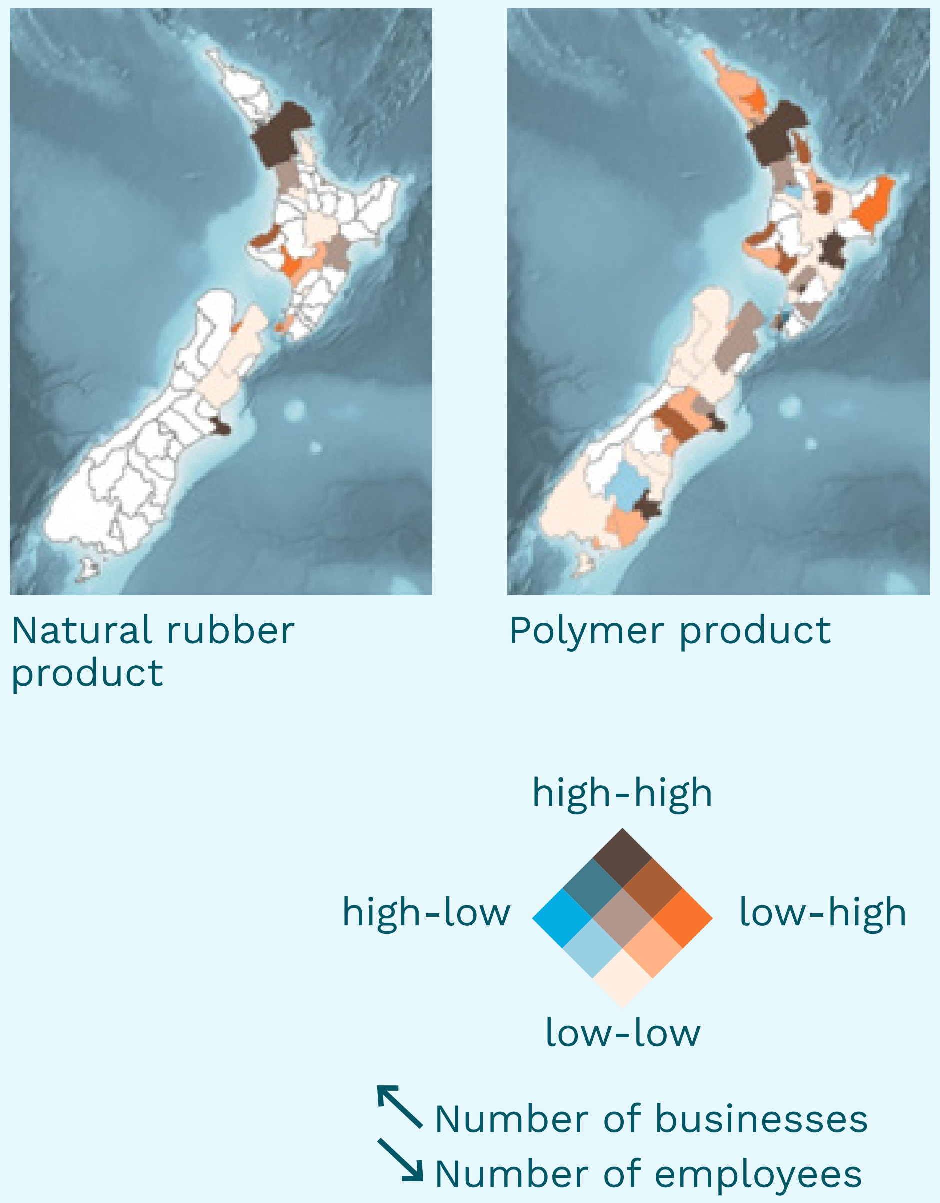


Figure 31. Plastics and rubber subsector | mapping number of businesses and employees (StatsNZ, 2019)

Emissions intensity

This is low relative to other subsectors.

Waste flows

Addressing waste during products' use and at end-of-life is critical and challenging to decouple from design and manufacturing. Potential waste streams relate to inputs, Personal Protective Equipment (PPE) and packaging. The product itself is considered problematic.

Certifications and partnerships with waste management companies are important. So, too, is developing internal systems to track and manage waste and recycling points.

We have identified internal circular loops, particularly around recycling. These need to be verified.

Plastic production in New Zealand 2020

Source: Auckland Council, MBIE NZ, ME NZ, Office of the Prime Minister's Chief Science Advisor, Stats NZ, thinkstep-anz
(unit tonnes of plastics produced in 2020)

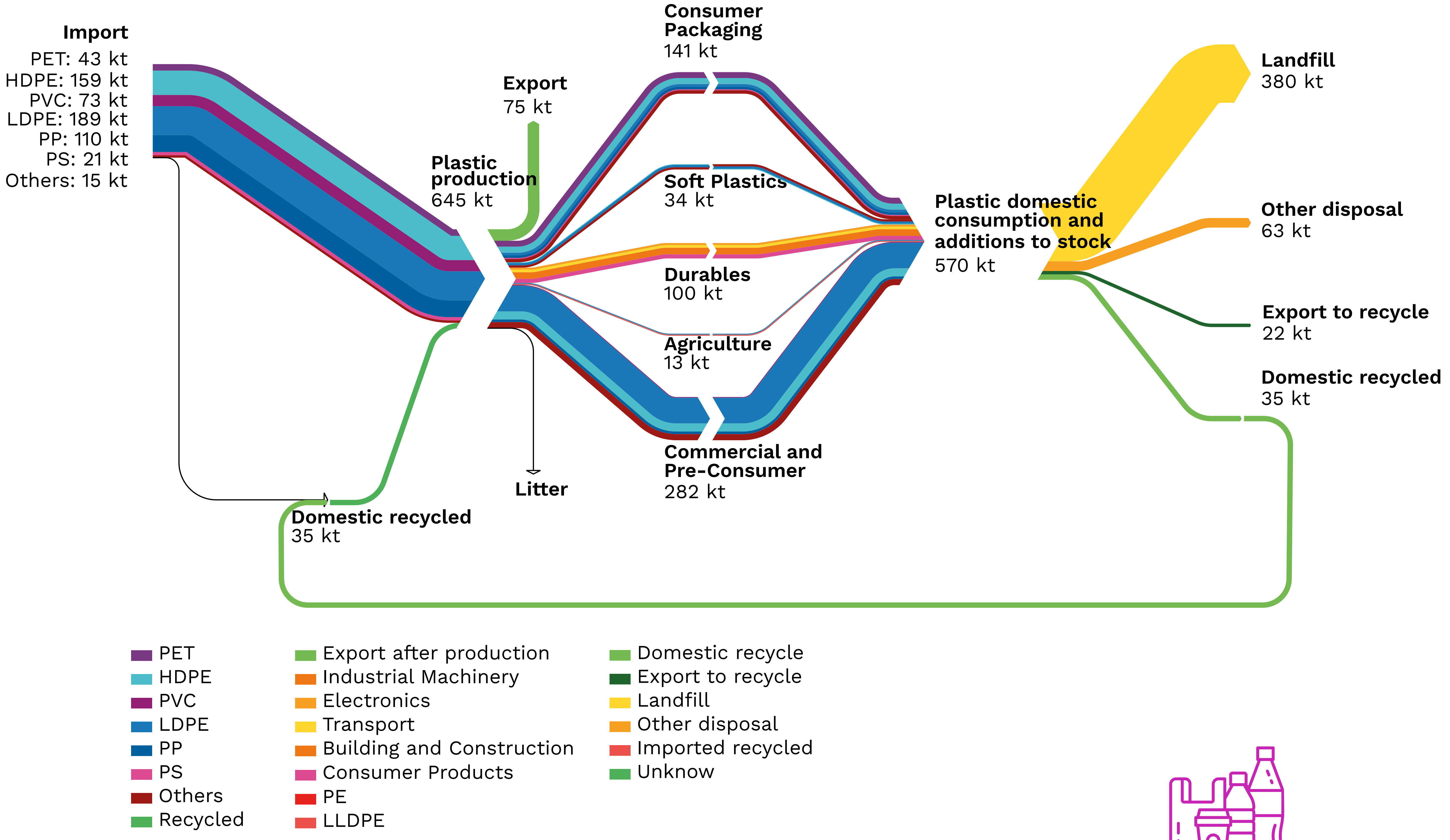


Figure 32. Plastic production in New Zealand (2019)

Opportunities

- There are opportunities for policies and incentives to improve recycling infrastructure and reduce plastic waste.
- The relatively small amount of plastic being recycled in New Zealand suggests opportunities to improve domestic recycling opportunities and raise public awareness. Introducing standard kerbside collections in February 2024 is a good example of the government intervening to phase out hard-to-recycle items and deliver high-quality recycled materials with higher resale value.
- Enhancing the ability to separate and recover value from plastics downstream through intelligent use and design will be essential to keep pace with domestic regulations and the fast-changing regulations of our trading partners.
- There are opportunities to reuse plastics, particularly in logistics and supply chain activities and lease/return systems involving repair and recycling. Examples include crates.
- Replacing single-use products with durable products could reduce waste and emissions but requires careful assessment.
- Incorporating wash facilities into manufacturing will help process pre and post-consumer waste streams.

Data gaps

- We lack data on the plastic litter associated with plastic products manufactured and imported into New Zealand.
- We need more data about links to Chemicals and Refining (sources of raw materials, particularly resin impacts and imported products) and to Food and Beverage (packaging).
- More public information about waste facilities would be useful to understand existing levels of circularity and value recovery and to target interventions based on data.

Stakeholder views

- **Data**
  Stakeholders recognise gaps in data, especially about types of plastics, the amount of waste they generate, and the origins of carbon footprints from imported resins. They also recognise that the industry needs this data to support recycling initiatives and reduce Scope 3 emissions. Stakeholders suggest analysing customs import data for information about imported resins and better information from waste facilities.
- **Circularity**
  Stakeholders identified increasing the use of recycled materials in manufacturing and exploring bio-based alternatives as crucial to making the subsector more sustainable and circular. They would welcome more explicit guidelines and stewardship models for waste management and recycling and a rating system to inform consumers.
- **Collaborating**
  This is important to the industry, as the partnerships and joint ventures with waste management organisations show. The industry is keen to collaborate further and share knowledge but may require assistance in establishing safe environments to collaborate.

Thank you

The authors wish to thank MBIE for commissioning this research and supporting collaboration with government agencies such as MfE, StatsNZ and EECA, fellow circular economy researchers and advanced manufacturing industry stakeholders who actively contributed through sharing of data and insights throughout the duration of this project.

This report is produced by:

Aurecon is a design, engineering and advisory company working across Aotearoa New Zealand, Australia and Asia on innovative sustainable systems transition and implementation initiatives.

Aurecon's circular economy team provides business, sector and regional level circular scans, material flow analysis and maturity assessments while integrating circular approaches across Aurecon's design and engineering work.

Aurecon works on some of Aotearoa's largest manufacturing and infrastructure decarbonisation projects. They measure, assess, and tackle direct and indirect emissions with technical, financial, risk, digital and carbon related expertise and decision support.

thinkstep-anz supports organisations to advance the circular economy through consulting and software solutions. This includes promoting sustainable use of resources, managing business risks, and reducing waste. Their approach is science-based, pragmatic and flexible. They help clients understand and apply critical circular economy indicators.

The multidisciplinary team includes certified Life Cycle Assessment (LCA) Practitioners, approved Environmental Product Declaration (EPD) verifiers and effective communicators. They work with clients, big and small, in many industries, to help them create business value and succeed sustainably.

The Sustainable Business Network (SBN) has worked to create a sustainable economy in Aotearoa New Zealand for more than 20 years in partnership with hundreds of organisations in all sectors nationwide.

Since 2014 circular economy principles have grounded all their work. This makes SBN uniquely experienced and wellpositioned to create 'pre-competitive' partnerships across value chains and sectors, and organisations – including partnerships with Māori, where SBN is weaving mātauranga Māori with western science.

Summary report

Mapping Emissions and Waste Stream Profiles, and Opportunities for Achieving Net-Zero Circular Advanced Manufacturing
May 2024 | Version 1.0