Consumption Emissions Modelling

March 2023

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Prepared for

Auckland Council

This document may be cited as: Market Economics Limited, 2023, Consumption Emissions Modelling, report prepared for Auckland Council.

Date of this version: March 2023

Report author(s): Dr Garry McDonald, Dr Nicola McDonald

ISBN 978-1-99-106001-3 (PDF)

www.me.co.nz

Executive Summary

National emissions reporting has to date focused primarily on production-based reporting by industry or per capita. Although useful, these approaches do not enable households to make a discerning assessment of their consumption patterns that potentially may mitigate/reduce Greenhouse Gas (GHG) emissions. In this report, we show how consumption-based emissions can be determined from data readily available from StatsNZ.

Consumption based emissions accounting focuses on calculating the emissions 'embodied' in the goods and services people consume. In other words, all emissions released directly and indirectly throughout the industrial supply chain that generated each good or service. To analyse embodied emissions, emissions intensities (i.e. tonnes of carbon dioxide equivalents (CO_2-e) per dollar of use) are generated for different commodity types. Using these intensities provides opportunities to study which components of household (or any other final consumer) expenditure offer the greatest opportunities for reduction. We also account for the emissions produced directly by consumers when using commodities e.g., when fuel is combusted in household vehicles.

To develop the emissions intensities, we rely primarily on StatsNZ's 2020 Inter-industry Study of the New Zealand Economy[1] and StatsNZ's 2019 Production-based GHG Emissions Accounts[2] for New Zealand. Using Supply-Use Tables, from the inter-industry study, we produce consumption emission intensities by 199 commodities which, in turn, can be linked to the Household Economic Survey; providing a direct link to commonly purchased household items. The approach here is based entirely on a top-down Input Output (IO) approach, rather than a bottom-up process-based Life Cycle Assessment (LCA) approach.

We have relied only on emissions data reported by StatsNZ, which was a pre-condition of the scope of this work. This means that we have used emission intensities calculated from domestic datasets only. In other words, it is assumed that goods and services purchased from outside of New Zealand generate the same quantities of emissions per dollar of expenditure as equivalent goods and services produced in New Zealand.

The emissions intensities and datasets generated by this project have other potential uses. This could include, for example, estimation of a carbon footprint for each Auckland Local Board and the breakdown of carbon footprints by household types covering demographic characteristics such as age, income, family type and ethnicity. The emission intensities may be applied, not only to identify interventions to reduce emissions attributed to household consumption, but also by businesses and government to identify emission reduction strategies, particularly around Scope 3 emissions. Furthermore, when matched with models that produce different economic future pathways, we can ask such questions as "how will different development trajectories and climate adaptation strategies impact on emission production?"

[1] This is for the financial year ending 31 March 2020, released 20 December 2021 (See Item 3 under Data sources).

[2] These are for the calendar year ending 2019, released 8 July 2021 (See Item 1 under Data sources).

Glossary of Acronyms

B20	Reserve Bank of NZ B20 Floating Interest Rate
CoPD	Census of Population and Dwellings
CGE	Computable General Equilibrium
CGPI – RB	Capital Goods Price Index – Residential Buildings
CO_2-e	Carbon Dioxide Equivalents
CPI	Consumer Price Index
EF	Ecological Footprint
GST	Goods and Services Tax
IO	Input-Output
IOT	Input-Output Table
IPD – GDE	Implicit Price Deflator – Gross Domestic Product Expenditure Series
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
HEC	Household Economic Classification
HES	Household Economic Survey
NZ CCC	New Zealand Climate Change Commission
StatsNZ	Statistics New Zealand
SUT	Supply Use Table

Acknowledgements

The authors would like to thank Anja Vroegop, Adrian Feasey and Adrien Bouzonville at Auckland Council for their patience, understanding and critique in development of this work. We would also like to thank Adam Tipper at StatsNZ for answering questions on the relationship between Ministry for the Environment's GHG emissions inventory and the StatsNZ's production and consumption-based emission accounts.

Contents

1 Introduction

National emissions reporting has to date focused primarily on production-based assessment by industry or per capita. Production-based accounts provide information on where emissions come from, while per capita emissions are only indicative of the magnitude of emissions, on average, for each person. Although useful, these approaches do not enable households to make a discerning assessment of their consumption patterns that potentially may mitigate Greenhouse Gas (GHG) emissions. In this report we show how consumption-based emissions can be calculated from data readily available from StatsNZ.

This work will be used by Auckland Council to generate a set of national emission intensities (tonnes of CO_2 equivalents per dollar of expenditure) by commodities aligned to the Household Economic Survey (HES). These commodity-based emission intensities are primarily generated using StatsNZ's 2020 Inter-industry Study of the New Zealand economy and 2019 industry and household production-based emissions data[3] (see respectively Item 3 and 1 under Data sources below). Input-output (IO) mathematics, based on the Supply-Use Table (SUT) Framework of the inter-industry study, is used to generate the commodity-based emission intensities.

Our commodity-by-industry approach facilities exact matching of household consumption categories (as per the HES) to StatsNZ's SUT commodities[4]. This enables us to produce an average household emission for every household consumption category and, in turn, facilitates the use of household characteristics (from the HES) to derive emissions for different household types (e.g., as defined by income, ethnicity, age-sex, family type etc.) and by spatial location.

Our work corroborates preceding work (e.g., McDonald and Patterson (2004), McDonald and Forgie (2006) and Romanos *et al.* (2014)) which note that important drivers of emissions are food (diet), transport, and energy. Although not explicitly generated for this report, further analysis has also revealed that the composition of emissions varies between regions based on income.

1.1 Previous New Zealand studies

Early studies that used an IO approach to estimate embodied resource (land, waste, energy) and residual (i.e., emissions) include Peet and Baines (1985) and McDonald (1995, 1997). Under the Ministry for the Environment's Sustainable Management Fund, the *Eco*Link project also produced multi-regional IO tables with embodied resource and residual intensities for Northland, Auckland, and Waikato regions (McDonald and Patterson, 1998; McDonald, LeHeron and Patterson, 1999; McDonald, LeHeron, Stockham and Patterson, 1999). This includes generating footprints for land, water, energy and for various emissions and

[3] This is for the calendar year ending 2019.

[4] Most studies use IO tables to calculate consumption emissions. These have an industry-by-industry structure. Each industry produces only one homogenous output. The 'sheep and beef cattle farming' industry, for example, produces a single product of 'sheep-beef cattle'. Under a commodity-by-industry approach (as used in this study) an industry can produce more than one product. Thus, 'sheep and beef cattle farming' can produce sheep, cattle, wool etc. This facilitates an exact matching of commodities consumed by households (as defined by the HES) with those included in SUTs (which have a commodity-by-industry structure).

pollutants. This work also included a forward-looking simulation model (using a dynamic IO table) that traced transition pathways under different economic development options.

Bicknell *et al*. (1998) produced New Zealand's first Ecological Footprint (EF) using IO analysis. McDonald and Patterson (2004) enhanced Bicknell et al.'s work by producing land and carbon footprints for all sixteen of New Zealand's regions. Emission intensities are derived from agriculture, energy and household data based on methodologies outlined in McDonald (2005). The footprints calculated are for the year ending March 1998. The carbon footprints are, in turn, converted to land equivalents using sequestration rates i.e., into the planted land needed to absorb the emissions. These are then added to embodied land estimates to provide an ecological footprint for each region. Comprehensive estimates are fully reported in Ministry for the Environment (2003) 'Ecological Footprints of New Zealand and its Regions'. McDonald and Patterson (2004) provide per capita assessment of carbon, land, and ecological footprints. They note key drivers of the footprints within each region, estimate ecological interregional and international balances of trade, and compare the footprints with the biocapacity of each region to determine if a region is in ecological surplus or deficit. They also critique the footprint approach and note that a critical determinant of footprinting through time is environmental regulation and land management practices at the point of resource extraction.

McDonald and Forgie (2006) calculate the embodied land, water, energy resources and GHGs/pollutant residuals consumed by household type. This is the first attempt within New Zealand to estimate consumption emissions by different household types. Moreover, McDonald and Forgie (2006) consider the potential impact of ageing on consumption emissions – asking the question "Will ageing processes offset the growth in New Zealand's footprints across time?" Using future projections of final demand (based on usually resident population projections developed by StatsNZ and econometric analysis of future exports and capital formation), they determine the emissions for each household type. They conclude that while household ageing will reduce footprints, this is not sufficient to offset the overall size of the footprint associated with future growth.

Creedy and Sleeman (2006) use StatsNZ's 1995-96 Inter-industry Study of the New Zealand Economy to generate emission intensities by industry and consider how price changes by industry change under various carbon tax policy options. Smith and McDonald (2007) provide an update of EF work undertaken by McDonald and Patterson (2004). The EFs calculated are for the year ending March 2004. They estimate the ecological, carbon and land footprints for New Zealand and its sixteen constituent regions. The results of the work are also presented in Ministry for the Environment's State of the Environment Report (2007).

Andrew and Forgie (2008) generated estimates of emissions for New Zealand under three different perspectives: consumption-based, production-based and a shared approach. Under their shared responsibility approach, they found that New Zealand producers are responsible for 44% of domestic emissions, New Zealand consumers appropriate 28%, while 27% of emissions are embodied in international imports.

Romanos *et al*. (2014) develops emission intensities using the 2007 Inter-Industry Study of the New Zealand Economy and 2007 New Zealand GHG Inventory. Like the preceding studies they generate emissions at an industry (rather than commodity) level which, in turn, are crudely matched to household expenditure survey consumption categories. Retail and wholesale margins are not separated out, nor are any adjustments made for price differences. Like most preceding studies they estimate the emissions embodied

in international imports based on New Zealand production recipes.[5] There are significant challenges that must be overcome before a United Nations-backed database of IO (and SUT) tables with aligned production-based emissions is developed. Key challenges include 1) consistency in emission accounting, 2) consistent use of commodity and industry definitions, 3) alignment of reporting years, and 4) agreement on post-processing algorithms that ensure each nations' tables are compatible. Chandrakumar *et al*. (2020) use consumption and production-based accounting approaches to provide different insights to support climate policymaking. They comprehensively assess the consumption based GHG emissions of the New Zealand economy, including using the EoRA (Lenzen *et al*., 2012; Lenzen *et al*., 2013) dataset, to capture emissions embodied in international trade.

StatsNZ also produces accounts of consumption emissions, these are derived using an industry-by-industry approach (the next (provisional) release of these is planned for 7 December 2022, for the calendar year ending 2020). The estimates are calculated at a greater industry resolution than available publicly (avoiding aggregation bias), but the results are then aggregated before being released. As above, they assume that emissions embodied in international imports reflect New Zealand production recipes.

A summary of the contributions made by these studies is provided in Table 1.

[5] This is discussed further in Section 5.

Table 1 Summary of Previous Studies

Author	Year	No. of Industries	No. of Commodities	Reporting Level for Emission Intensities	IOT or SUT	One homogenous product, or joint products, per industry	How are emissions embodied in imports accounted for?	Resources and residuals covered	Comments
Peet and Baines (1985)	Unknown	Unknown	Unknown		IOT	One	Not included	Energy	
McDonald (1995, 1997)	YE Mar 1995	23	NA	23 industries	IOT	One	Not included	Land, Water, Energy, Energy related emissions	
McDonald and Patterson (1998)	YE Mar 1998	48	NA	48 industries	IOT	One	Not included	Land, Water, Energy, Energy related emissions	
McDonald et al. (1999)	YE Mar 1998	48	NA	48 industries	IOT	One	Not included	Land, Water, Energy, Energy related emissions	
McDonald et al. (1999)	YE Mar 1998	48	NA	48 industries	IOT	One	Not included	Land, Water, Energy, Energy related emissions	
Bicknell et al. (1998)	YE Mar 1995	10	NA	10 industries	IOT	One	NZ intensities used for international trade	Ecological Footprint (Land, Energy land)	
McDonald and Patterson (2003, 2004)	YE Mar 1998	48	NA	48 industries	IOT	One	Actual intensities for interregional trade, NZ intensities used for international trade	Ecological Footprint (Land, Energy land)	Official EF, Ministry for the Environment
McDonald (2005)	YE Mar 1998	48	48	48 industries	SUT	Joint	Actual intensities for interregional trade, NZ intensities used for international trade	Land, Water, Energy, GHG emissions, Water pollutants, Waste, Ecosystem Services	

Table 1 Summary of Previous Studies (Cont.)

Author	Year	No. of Industries	No. of Commodities	Reporting Level for Emission Intensities	IOT or SUT	One homogenous product, or joint products, per industry	How are emissions embodied in imports accounted for?	Resources and residuals covered	Comments
McDonald and Forgie (2006)	YE Mar 1998	48	48	48 industries	SUT	Joint	Actual intensities for interregional trade, NZ intensities used for international trade	Land, Water, Energy, GHG emissions, Water pollutants, Waste	
Creedy and Sleeman (2006)	YE Mar 1995	Unknown	NA	Unknown	IOT	One	Unknown	GHG emissions	
Smith and McDonald (2007)	YE Mar 2004	48	NA	48 industries	IOT	One	Actual intensities for interregional trade, NZ intensities used for international trade	Ecological Footprint (Land, Energy land)	Official EF, Ministry for the Environment
Andrew and Forgie (2008)	Unknown	Unknown	Unknown	Unknown	IOT	One	Unknown	Unknown	
Ramanos et al. (2014)	YE Mar 2007	114	NA	114 industries	IOT	One	NZ intensities used for international trade	GHG emissions	
Chandrakumar et al. (2020)	YE Mar 2013	Unknown	Unknown	Unknown	IOT	One	EoRA for international trade	GHG emissions	
StatsNZ	YE Mar 2019	>109	>199	13 commodities	IOT	One	NZ intensities used for international trade	GHG emissions	
This study	YE Mar 2020	109	199	199 commodities	SUT	Joint	NZ intensities used for international trade	GHG emissions	

1.2 Understanding Input-Output Analysis

IOTs and SUTs show the relationship between industries, the goods and services (commodities) they produce, and who uses them. The tables comprehensively capture the flows of goods and services, in monetary terms, within an economy for a given period (typically one year). Production recipes provide a snapshot of not only expenditure on commodities, but also on primary inputs such as labour, capital, and imports. Sales of commodities to each industry and final demand (i.e., households, government, exports) are also recorded.

Industry-by-industry framework

IO tables[6] are presented in an industry-by-industry format with the rows providing details on the sales of industry output to other industries and final demand, while the columns provide details of the production recipe (including primary inputs such as labour and capital) of given industries. An IO table may be extended to incorporate information on resource inputs (e.g., land, energy, and water) and residual outputs (e.g., emissions, pollutants). Using matrix algebra these environmentally-extended IO tables can be used to determine not only the *direct*, but also *indirect* (i.e., embodied), appropriation of *resource inputs or residual outputs* to produce a unit worth of final demand.[7] Calculated on an industry basis, these embodied resource or residual (emission) intensities may be used to quantify the quantum of resources or residuals required to meet a given level of consumption.

While IO tables are presented in an industry-by-industry format are useful, they do have several limitations. Firstly, they assume that an industry produces only one homogeneous output (i.e., a weighted average of all commodities produced). For example, the 'sheep farming industry' produces 'sheep farming output'. Sheep farms however produce sheep for meat, milk, and wool – all very different commodities. Secondly, as they produce industry-based emissions intensities they are best suited to production-based industry assessments of emissions. Further IOT and SUT assumptions are thoroughly documented in Miller and Blair (2009).

[6] Each nation has its own approach to developing input-output tables. Most countries, in support of the United Nations System of National Accounts 2008 (United Nations, 2009), follow the guidance of the United Nations in developing these (United Nations, 2018). In New Zealand, the tables are produced by StatsNZ National Accounts division. Only summary documentation associated with the development of StatsNZ Inter-industry Study of the New Zealand economy is as available: https://www.stats.govt.nz/reports/user-guide-for-national-accounts-input-output-tables-year-ended-march-2020.

[7] Within this study, emissions are produced 'directly' by an industry or household if the emission is recorded against the respective industry or household category within StatsNZ's Production-based GHG Emissions Accounts, for year ending 31 December 2019 (See item 1 under Data sources). Indirect emissions are those that, while not produced directly by an industry in the production of its commodities, can be attributed to those produced commodities because the emissions were produced by other industries who were involved in the supply of goods and services also necessary to produce those commodities. For example, a restaurant may only produce emissions directly through natural gas cookers and in combusting transport fuel when purchasing supplies. However, in creating food for customers, the restaurant will purchase supplies from other industries such as wholesale traders who will also have used fuel for transportation. In turn, the wholesale trader will have purchased meat and dairy from farm suppliers, and emissions will also have been generated in producing those agricultural products (such as methane from stock). Each of these other emissions created in the upstream supply chain will be counted as an 'indirect' emission that are 'embodied' in the final restaurant services commodity.

Commodity-by-industry framework

These tables expand the IO framework distinguishing industries and commodities. Supply-Use Tables (SUTs), which are used in this study, are the most common representation of the commodity-by-industry framework. These consists of the following tables: (1) a Supply Table which shows the supply of commodities by industries within the economy, (2) a Use Table which records the use of commodities and primary inputs (e.g., labour and capital) by industries and final demand; and (3) an Imports into Industries and Final Demands Table which records the use of international imports.[8] The key advantage of SUTs over IOTs is that it allows joint production analysis, thus, an industry can produce more than one product i.e., the number of commodities (generally) exceeds the number of industries. Importantly, under various technology assumptions (which describe how commodities are made), it is also possible to derive an IOT from a SUT, but not vice versa. Most national statistical agencies, including StatsNZ generate SUTs and, in turn, derive IOTs from these.

[8] The 'Supply Table' is sometimes referred to as the 'Make Table', while the 'Use Table' is also known as the 'Absorption Table'.

2 Data sources

The following StatsNZ datasets were used in this study.

1. *Production-based GHG Emissions Accounts, for year ending 31 December 2019 (released 8 July 2021, updates are quarterly)*. These accounts cover 119 industries as defined by the New Zealand Standard Industrial Output Categories (NZSIOC). For household emissions, StatsNZ provides data for three categories: transport, heating, and other emissions. See supplementary material folder 'GHG CO2-e by 109 industries and households', workbook 'GHG Accounts at 109 Industries SNZ-based.xlsx', worksheet '2019 GHG Accounts SNZ' for full details.
2. *Household Consumption-based GHG Emissions Accounts, for year ending 31 December 2019 (released 17 December 2021, updates appear to be two yearly)*. These accounts cover 13 categories, namely: food and non-alcoholic beverages; alcoholic beverages, tobacco, and illicit drugs; clothing and footwear; housing and household utilities; health, transport, communication; recreation and culture; education; restaurants and hotels; miscellaneous goods and services; and imports of low value goods purchased directly by households. These emissions and their associated emission intensities (GHG CO_2 equivalents per $m of household expenditure) are only used for cross-checking purposes in our analysis (see Section 4).
3. *Inter-Industry Study of the New Zealand Economy, for year ending 31 March 2020 (released 20 December 2021, updates are irregular – the previous release was for 31 March 2013)*. This covers the New Zealand IO and SUT framework as produced by StatsNZ. We use the New Zealand SUT to generate a 'Total Requirements Matrix' to capture the direct and indirect (embodied) expenditure necessary to generate an additional unit of final demand on a commodity-basis. The New Zealand SUT describes supply and use of 199 commodities and seven primary inputs, by 109 industries and seven final demands.
4. *Household Economic Survey, year ending 30 June 2019 (released 2 July 2020, as downloaded on the 28 April 2022 from stats.govt.nz/large-datasets/csv-files-for-download/detailed-household-expenditure-year-ended-June-2019-csv.csv), updates are released every 3 years).* This StatsNZ dataset provides details on household expenditure by the New Zealand Household Economic Classification (NZHEC) covering >2,100 unique commodities.
5. *Consumer Price Index (CPI) for the quarter ending 30 June 2022 (released 18 July 2022, updated quarterly)*. This index is used to deflate current expenditure on 168 household items (Household Economic Classification (HEC) classes) to the year ending 31 March 2020. Deflation ensures that household expenditures on commodities are recorded in the same dollars used to estimate the consumption emission intensities. The Consumer Price Index does not account for the type of household, it simply tracks the prices of commodities that household typically purchase.
6. *Reserve Bank B20 Floating Interest Rate (B20) (released 19 March 2022, updated monthly)*. This index is used to deflate expenditure on mortgage interest payments (HEC class 13.1.01) recorded in the HES. The reason we use the B20 here is that mortgage interest payments are not covered by the CPI.
7. *Implicit Price Deflator GDP expenditure series (IPD–GDE) (released 17 March 2022, updated quarterly)*. This index is used to deflate the following household expenditures including interest payments on personal loans (HEC 13.1.02), credit sales (hire purchases) (HEC 13.1.03), other interest payments (HEC 13.1.04), contributions to savings (HEC 13.2.00), money given to others (excluding donations) (HEC 13.3.00), and fines (HEC 13.4.00). Again, the reason we use the IPD-GDE here is that these items are not covered by the CPI.

8. *Capital Goods Price Index – Residential Buildings (CGPI–RB) (released 18 February 2022, updated quarterly)*. This index is used to deflate expenditure on sales of property (HEC 14.2.01). Again, this item is not covered by the CPI.

3 Methodology

The key steps involved in our approach, to generate emission intensities (tonnes of CO_2 equivalents per dollar of expenditure) by commodities aligned to the HES, are outlined below in Figure 1.

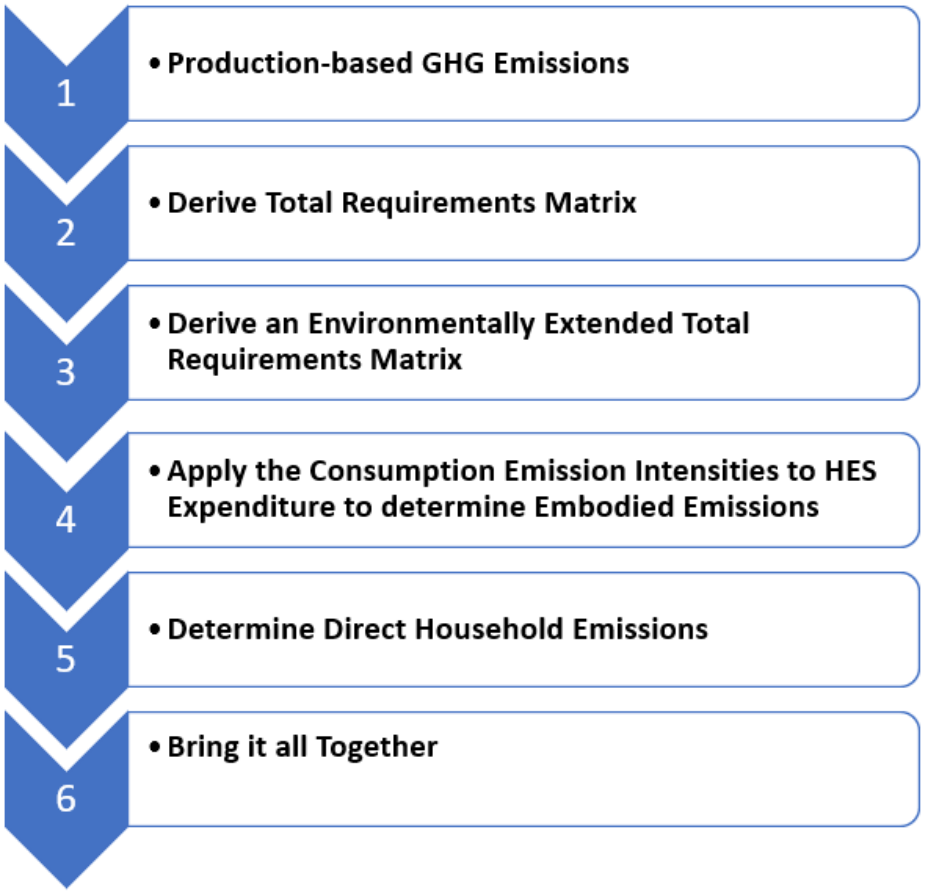


Figure 1 Sequence of steps followed to generate emission intensities by commodities aligned to the Household Expenditure Survey (HES)

Step 1: Production-based GHG Emissions

We start with StatsNZ's national-level[9] production-based GHG Emissions Accounts for the year ending 31 December 2019 by type of GHG measured in CO_2 equivalents covering 119 NZSIOC industries and for three household consumption categories (transport, heating and other) (Item 1 under Data sources). The production-based GHG emissions of the NZSIOC industries are aggregated to match exactly the 109 industries used in the New Zealand SUT (a concordance is provided in the supplementary material folder 'GHGH CO2-e by 109 industries and households', workbook 'GHG Accounts at 109 industries SNZ-based.xlsx', worksheet 'Concordances'). Finally, we divide each industry's production emissions (total GHG

[9] Data at regional scale or finer temporal resolution is not currently provided by StatsNZ.

CO_2 equivalents) by its corresponding gross output[10] (as measured in dollars), to derive a production-based direct emission intensity, vector $\boldsymbol{g}$(**1 x** $\boldsymbol{n}$, where $\boldsymbol{n}$ is the total number of industries considered) as measured in GHG CO_2-e (t) per $ of gross output[11].

Step 2: Derive Total Requirements Matrix

Next, we generate a Total Requirements Matrix[12] based on the IO mathematics laid out by Miller and Blair (2009, Chapter 5). This matrix represents the *direct* and *indirect* requirements ($) to produce an additional unit of commodity final demand ($). Based on StatsNZ's New Zealand SUT framework shown in Table 2 (Item 3 of the Data sources) we define the following matrices and vectors as per Table 3.

Table 2 The New Zealand Supply Use Table Framework, New Zealand dollars

	Commodities (1 … *m*)	Industries (1 … *n*)	Household Consumption	Other final demands	Exports	Total Use
Commodities (1 … *m*)		**U** Use Table		OFD	Exports	**q**
Industries (1 … *n*)	**V** Supply Table					**x**
Value Added		VA				
Imports	Imports					
Total Supply	**q'**	**x'**				

[10] Gross output for an industry is measure of the total sales by that industry. This includes sales to intermediate (other industries) and final demand (households, non-profit organisations servicing households, local and central government, exports, capital formation, and any changes in inventories).

[11] In input-output mathematics the intensities are always expressed in GHG CO_2-e (t) per $ of gross output. Note at an industry level, gross output equals gross input. Gross input is a measure of total expenditure by an industry, this includes expenditure on both intermediate inputs (i.e., inputs into the production recipe sourced from other industries) and value added (i.e., capital and labour inputs). Thus, using value added would not account for the intermediate inputs used in production.

[12] The commodity-by-industry 'Total Requirements Matrix' is the conceptual equivalent of the industry-by-industry 'Leontief Inverse Matrix', $(I - A)^{-1}$. Use of the Total Requirements Matrix produces results that are by commodity for each industry, while the Leontief Inverse Matrix produces results by a single homogenous product for each industry.

Table 3 Matrices, Vectors and Scalars as Derived from the New Zealand Supply Use Table Framework for this Study

Label	Matrix, Vector or Scalar	Dimensions	Units	Definition
m	Scalar	NA	No.	number of commodities
n	Scalar	NA	No.	number of industries
U	Matrix	(*m* x *n*)	$	Use table
V	Matrix	(*n* x *m*)	$	Supply table
x	Vector	(*n* x 1)	$	Total industry output by industry *n*
q	Vector	(*m* x 1)	$	Total commodity output by commodity *m*
i	Vector	(*m* x 1)	Non-applicable	Row summing vector
i, j	Indices	NA	Non-applicable	Used as indices to refer to elements in vectors and matrices
B	Matrix	(*m* x *n*)	No units[1]	Ordinary technical coefficients matrix
C	Matrix	(*m* x *n*)	No units[2]	Product mix matrix
D	Matrix	(*n* x *m*)	No units[3]	Market shares matrix
I	Matrix	(*m* x *m*)	Non-appliable	Identity matrix
g	Vector	(1 x *n*)	t (GHG CO_2-e)/$ (of industry expenditure)	Production-based direct emission intensity vector
h	Vector	(*m* x 1)	t (GHG CO_2-e)/$ (of commodity expenditure)	Consumption emission intensities vector

Notes: 1. Represents the value of commodity *j* input necessary to produce 1 additional unit of industry *i* output, 2. Represents the fraction of total industry *i* output that is in the form of commodity *j*, and 3. Represents the fraction of total commodity *j* output that was produced by industry *i*.

Matrix $\mathbf{U}$ (m x n, where n is the total number of industries considered) is the Use Table ($). This describes the use of commodities by industries. Matrix $\mathbf{V}$ (n x m) is the Supply Table ($). This describes the supply (production) of commodities by industries. Vector $\mathbf{x}$ is represents total industry output ($), while vector $\mathbf{q}$ represents total commodity output ($). From the data in the Use matrix, the total output of any industry is found by summing over all commodities produced by that industry. These totals are the row sums of matrix $\mathbf{V}$ (note that $\mathbf{i}$ is a column vector of dimensions m x 1, thus when multiplied by matrix $\mathbf{V}$ it effectively sums each row of matrix $\mathbf{V}$) i.e.,

$$x_j = v_{j1} + \ldots + v_{jm} \text{ or } \mathbf{x} = \mathbf{Vi} \quad \text{(Eq. 1)}$$

Similarly, the total output of any commodity can be found by summing over all industries that produce that commodity. These totals are the column sums of matrix $\mathbf{V}$ i.e.,

$$q_j = v_{1j} + \ldots + v_{nj} \text{ or } \mathbf{q} = (\mathbf{V}')\mathbf{i} \quad \text{(Eq. 2)}$$

Base matrices

To generate a Total Requirements Matrix (capturing not only the *direct*, but also the *indirect* requirements from other industries, necessary to produce an additional $ of commodity output in an industry) under the commodity-by-industry approach requires defining three base matrices $\mathbf{B}$, $\mathbf{C}$ and $\mathbf{D}$.

Matrix $\mathbf{B}$ (m x n) is like an ordinary IO technical coefficients table[13]. $\mathbf{B}$ is a commodity-by-industry table where each column j represents the value of inputs of each commodity per dollars' worth of industry j's output.

$$b_{ij} = u_{ij}/x_j \quad \text{(Eq. 3)}$$

$$\mathbf{B} = \mathbf{U}\hat{\mathbf{x}}^{-1} \quad \text{(Eq. 4)}$$

Matrix $\mathbf{C}$ (m x n) represents the commodity composition of industry outputs. $\mathbf{C}$ is often referred to as the Product Mix Matrix. c_{ij} denotes the fraction of total industry i output that is in the form of commodity j.

$$c_{ij} = v_{ij}/x_i \quad \text{(Eq. 5)}$$

$$\mathbf{C} = \mathbf{V}'\hat{\mathbf{x}}^{-1} \quad \text{(Eq. 6)}$$

Matrix $\mathbf{D}$ (n x m) represents the industry source of commodity outputs. It is often referred to as the Market Shares Matrix. d_{ij} denotes the fraction of total commodity j output that was produced by industry i.

$$d_{ij} = v_{ij} / q_j \quad \text{(Eq. 7)}$$

$$\mathbf{D} = \mathbf{V}\,\hat{\mathbf{q}}^{-1} \quad \text{(Eq. 8)}$$

[13] The technical coefficients table simply records the production recipe expressed as shares for each industry. See Miller and Blair (2009, p.22) for further details.

Industry-technology versus commodity-technology assumptions

A Total Requirements Matrix can be developed under different technology assumptions. Under an industry-technology assumption, industry input structures (the columns of matrix $\mathbf{B}$) are the basic data, and the commodity input structures are found as weighted averages of these columns. An alternative view, the commodity-technology assumption, is that a given commodity should have the same input structure in all industries that produce it. Under this technology assumption, commodity inputs to industry j production (elements in the j^{th} column of $\mathbf{B}$) may be viewed as weighted averages of commodity inputs to commodity production for each of the commodities that industry j makes, and the weights are the proportions of each commodity in industry j's total output.

The choice of which technology assumption to adopt has been contested over several decades. Miller and Blair (2009) conclude that there is no consensus as to which technology assumption better – citing an extensive literature base supporting, and rejecting, each alternative. The Eurostat Manual (Eurostat/European Commission, 2008), which provides the latest standards for data collection for European Union member nations, recommends use of the industry-technology assumption. To the best of the author's knowledge, StatsNZ provides no guidance on this matter. We note however that the New Zealand IO table, which is compiled from the New Zealand SUT, is generated under an industry technology assumption. For these reasons, we adopt this assumption to generate the Total Requirements Matrix.[14]

Total Requirements Matrix

The Total Requirements Matrix captures not only the *direct*, but also the *indirect* requirements from other industries necessary to produce an additional unit of commodity output in an industry. Note that if the number of commodities exceeds the numbers of industries (which is the case with StatsNZ's 2020 New Zealand SUT) then the commodity-by-industry system will be rectangular rather than square[15]. With household final demand for commodities the major driving force behind consumption, the Total Requirements Matrix, under an industry-technology assumption, may be calculated as follows:

$$\mathbf{D}\,(\mathbf{I} - \mathbf{BD})^{-1} \qquad \text{(Eq. 9)}$$

The Total Requirements Matrix is equivalent to the Leontief Inverse Matrix, $(\mathbf{I} - \mathbf{A})^{-1}$, commonly derived from a square industry-by-industry IOT.

Step 3: Derive an Environmentally Extended Total Requirements Matrix

[14] We note that use of the commodity-technology assumption can result in negative entries in the Total Requirements Matrix – a nonsensical possibility. For those interested in understanding fully the different technology assumptions, and how negative entries may be addressed, we direct readers to Smith and McDonald (2011).

[15] This reflects that more than one commodity can be produced by an industry. This is a major improvement over methods which use IOTs where each industry produces only one homogenous product. For example, under an IOT the 'meat processing industry' simply produces one product 'meat products', while under a SUT the 'meat processing industry' can produce 'fish', 'chicken', 'pork', 'beef', 'lamb', 'venison' and so on. Obviously, these products have very different footprints. So, breaking them down is useful.

We now generate an environmentally extended Total Requirements Matrix. This requires pre-multiplying the Total Requirements Matrix (Eq. 9) by a transposed g representing the production emission intensities by industry (as measured in CO_2 equivalents per $ of gross output, derived in Step 1 above), the result is the consumption emission intensities vector, h, with h' (1 x m), translating this to a column vector (for h', see supplementary material folder 'Consumption_Emissions_Model', sub-folder 'Output', worksheet 't_h.csv').

$$h = g' \text{ x } [\mathbf{D}\ (\mathbf{I} - \mathbf{BD})^{-1}] \qquad \text{(Eq. 10)}$$

Step 4: Apply the Consumption Emission Intensities to Household Economic Survey Expenditure to determine the Consumption Emissions

To estimate the emissions associated with household consumption we must multiply, for each commodity, its consumption emissions intensity (as derived in Step 3, Eq. 10) by a corresponding amount of household expenditure. The commodity-based definitions of the SUT facilitate this. The 199 commodities of the SUT can be concorded directly to the National Accounts 2006 Commodity Classification (NA06CC), and in turn, the NA06CC can be concorded with the New Zealand Household Economic Classification (NZHEC) (see supplementary material folder 'Household Expenditure Survey', workbook '2019 Household Expenditure Survey.xlsx', worksheet 'NZHEC to SUT' for a full concordance). The HES uses the NZHEC as its foundation. Diligence is required to account for:

- *Wholesale and retail margins and taxes (taken directly from the New Zealand SUT produced by StatsNZ)*. Commodity transactions in the SUT are measured in basic prices i.e., they exclude wholesale and retail margins and taxes. By comparison, HES expenditures are measured in purchaser's prices i.e., they include taxes and wholesale and retail margins. Thus, it is important to take out the margins and taxes associated with each HES commodity expenditure before multiplying by a corresponding emissions intensity (see supplementary material folder 'Household Expenditure Survey', workbook '2019 Household Expenditure Survey.xlsx', worksheet 'Margins & Taxes' for a full concordance). The shares of total cost that should be attributed to both taxes and margins is readily calculated from the New Zealand Supply Table. Note that the emissions attributed to margin purchases should be calculated by summing up retail and wholesale margin payments across all commodities, and in turn, multiplying total retail and wholesale trade margins by their corresponding wholesale and retail trade consumption emission intensity.
- *Price deflation*. Expenditure by HES commodity must be price adjusted. To deflate the current prices (dollars of today) to March 2020 equivalents requires the use of an appropriate set of deflators. Four deflator series were selected for this purpose, namely, the B20, CGPI – RB, CPI and IPD – GDE (Items 5-8 under Data sources). The key series is the CPI which is available quarterly and covers most of the HES commodities at the NZHEC class level (see supplementary material folder 'Deflators', workbook 'Deflators.xlsx', worksheet NZHEC_Class to Deflators' for a full concordance).

Step 5: Determine Direct Household Emissions

The focus of this report, thus far, has been on detailing a method employed to calculate embodied emissions associated with household consumption. Since households are the ultimate source of demand for the goods and services that they consume, households may be considered *indirectly* responsible for the emissions produced by industries during the production of these goods and services, along the entire upstream production chain. In other words, these emissions are 'embodied' in goods and services that households consume. Importantly, households also produce greenhouse gases *directly*, for example through combustion of fuel by household vehicles, or through burning natural gas for heating and cooking.

Emissions directly produced by households are reported as 9,828 kt of CO_2-e for 2019 in the Production Emission Accounts. This is equivalent to around 12% of StatsNZ's total Production Emissions Accounts. Since these emissions are a significant proportion of New Zealand's total emissions, it is worthwhile considering not only the way in which emission can be reduced by changing the pattern of consumption of goods and services by households (reducing *indirect* emissions), but also how emissions produced directly by households can be avoided[16].

The Production-based GHG Emissions Accounts (See Item 1 under Data sources) estimate the emissions produced directly be households at 686 kt CO_2-e from heating/cooling (e.g., gas fires, gas hot water heating, release of hydrofluorocarbons from air conditioning and refrigerators), 8,869 kt CO_2-e from transport (mainly from combustion of petrol and diesel in vehicles), and 272 kt CO_2-e from other sources (e.g., household waste composting and emissions released during other product use). During this project we developed the emissions factors in Table 4, these may be of assistance in estimating directly produced emissions from households. We note however that during the writing phase of this report the Ministry for the Environment also produced a set of emission factors for use by organisations wishing to monitor and report their greenhouse gas (GHG) emissions (Ministry for the Environment, 2022). We recommend using the Ministry for the Environment (2022) emission factors but have included Table 4 as an alternative.

The Ministry for the Environment (2022) emissions factors can be used to calculate emissions produced *directly* when households combust fuel or consume a product. Refer particularly to Ministry for the Environment's (2022) Table 1 Stationary combustion of fuels: Residential Use; Table 4: Transport fuels; Table 5: Biofuels; Table 7: Refrigerant use emission factors; Table 13 Passenger vehicle fleet; Table 14: Default private car emission factors. Note that emissions factors for purchased electricity, transmission and distribution losses of natural gas and public transport are already accounted for in the estimation of indirect emissions (as calculated in Step 2 above) and thus already covered by production emissions intensities (of Step 1).

[16] If waste is considered a direct emission by households in the New Zealand GHG inventory, it will be considered a direct emission in our study. On inspection of the GHG inventory tables for the Waste sector, waste emissions get allocated to the waste sector who manages the waste sites. Commodities produced by the waste sector (i.e., waste disposal services) will thus embody these emissions. In addition, there are categories for composting of waste (which are small) that would get allocated as a direct emission by households.

Table 4 Emission Factors for Combustion of Energy Commodities

	Energy per unit (GJ/l for liquid fuels, GJ/kwh for gas)[1]	Carbon emission factors							
		kg CO_2/ GJ[2]	kg CO_2/l	kg CO_2/kWh	kg CO_2/$[3,4]				
					Year ending 31 Dec 2017	Year ending 31 Dec 2018	Year ending 31 Dec 2019	Year ending 31 Dec 2020	Year ending 31 Dec 2021
Petrol	0.0350	65.90	2.30		1.20	1.08	1.08	1.18	1.02
Diesel	0.0378	68.69	2.60		2.20	1.81	1.79	2.15	1.76
Natural Gas	0.0036	53.21		0.19	1.49	1.33	1.33	1.35	1.33

Notes:

[1,3] Derived from MBIE. Energy Prices Data Tables. Revision Dec 20. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-prices/

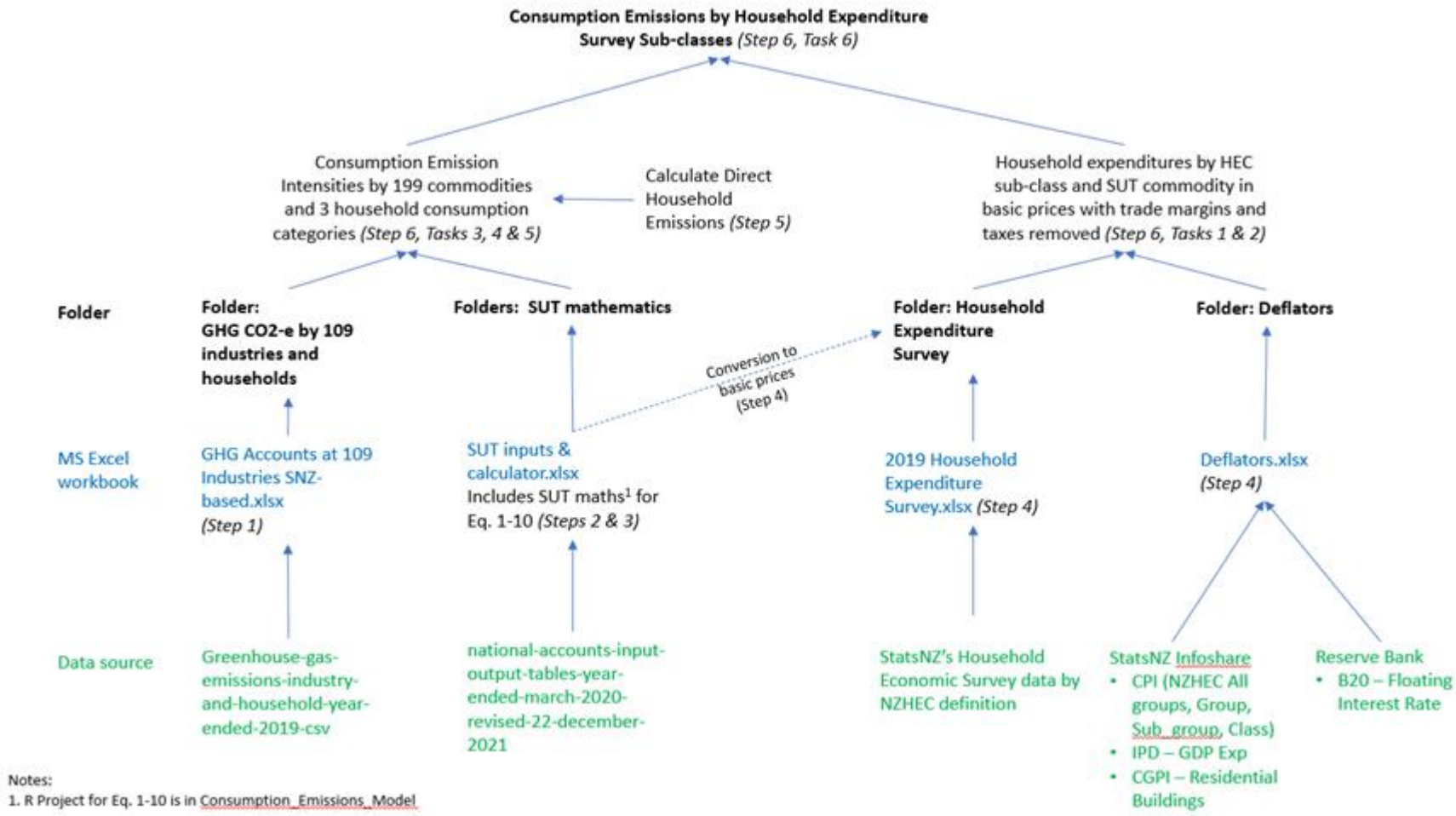
[2] See MBIE (2012) New Zealand Data Tables for Energy Greenhouse Gas Emissions http://www.med.govt.nz/sectors-industries/energy/energy-modelling/data/greenhouse-gas-emissions

[4] Nominal values, includes GST.

Step 6: Bring it all Together

Steps 1 to 5 focus mostly on how the consumption emissions intensities are calculated, creating the building blocks necessary for applications. We have however only touched briefly on how they should be applied. In this Step we provide guidance on this. We do this through a worked example by referring to the spreadsheets that accompany this report. The Council has its own logic intervention processes which must also be accounted for in how the consumption emissions for an entity will be derived. For this reason, the process outlined here is only indicative of that which will be followed. Figure 2 provides a schematic that shows data sources, supplementary material folders and their associated workbooks, and how these are linked (by the Steps identified above and the Tasks outlined below).

Figure 2 Schematic of Calculation Process for Consumption Emission by Household Expenditure Survey HEC Sub-classes



Total Consumption Emissions may be defined as, E, where:

$$E = \sum(\alpha, \beta, \gamma, \delta) \quad \text{(Eq. 11)}$$

where α is the embodied emissions associated with the consumption of commodities (see Task 3 below), β is the embodied emissions associated with wholesale trade margins (Task 4), γ is the embodied emissions associated with the retail trade margins (Task 5), and δ direct household emissions. See supplementary material folder 'Household Expenditure Survey', workbook '2019 Household Expenditure Survey.xlsx', worksheet 'Final Unit Values by NZHEC' for a fully worked example covering the Tasks outlined below. Note however this does not include Task 6, which would need to be undertaken separately.

Task 1: End user questions relating to household consumption

Under this task a web portal will be used to ask questions that relate to household consumption of commodities. These questions would solicit expenditure information coded to the NZHEC's class (covering 161 commodities) and sub-class groupings (covering 268 commodities). Firstly, this information must be deflated (see supplementary material folder 'Deflators', workbook 'Deflators.xlsx', worksheet 'Deflators'). Note that the deflators are only available at the NZHEC class level and thus sub-classes with be deflated at the same rate as their parent class. Secondly, we then multiply the share of each sub-class within each SUT commodity. These shares, which were derived directly for StatsNZ's HES dataset, are available in the spreadsheet (see supplementary material folder 'Household Expenditure Survey', workbook '2019 Household Expenditure Survey.xlsx', worksheet 'NZHEC to SUT' for a full concordance). For example, in the case of 'Apple and pears' (Sub-class = 01.1.01.3) 83% goes to 'Pome fruit (apple, pears)' (IO20_197Com_code = 4) and 17% goes to 'Other fruit and nuts' (IO20_197Com_code = 5). This will produce estimates of household expenditure by NZHEC sub-class by SUT commodity. A breakdown by SUT commodities would then be generated by simply summing across all SUT commodities.

Task 2: Remove Margins and Taxes

Under this task the taxes and margins associated with Task 1 would be separated out. This is achieved by multiplying the SUT commodity expenditures created in Task 1 by appropriate shares for whole and retail margins and taxes. These shares are available in the spreadsheet (see supplementary material folder 'Household Expenditure Survey', workbook '2019 Household Expenditure Survey.xlsx', worksheet 'Margins and Taxes'). This will result in four datasets covering all SUT commodities, namely: 1) household expenditure (in basic prices); 2) estimates of the wholesale trade margin; 3) estimates of the retail trade margin; and 4) estimates of tax. Note that we do not calculate the emissions associated with tax because these represent transfers to government over which households have no influence.

Task 3: Calculate the embodied emissions associated with the consumption of commodities, α

In this task the emissions embodied in the commodities purchased by households are calculated. This involves multiplying the household expenditure dataset derived in Task 2 by the emissions intensities

derived in Step 3, Eq. 10 above (see supplementary material folder 'Consumption_Emissions_Model', sub-folder 'Output', workbook 't_h.csv' for the consumption intensities by the 199 SUT commodities).

Task 4: Calculate embodied emissions associated with the wholesale trade margins, β

In this task the emissions associated with the wholesale trade margins are estimated. This involves summing up the expenditure on wholesale trade margins and, in turn, multiplying this, as per the dataset derived in Task 2, by the corresponding emission intensity for wholesale trade derived in Step 3, Eq. 10 above (see supplementary material folder 'Consumption_Emissions_Model', sub-folder 'Output', workbook 't_h.csv', average of Cells B199:B200).

Task 5: Calculate embodied emissions associated with the retail trade margins, γ

In this task the emissions associated with the retail trade margins are estimated. This involves summing up the expenditure on retail trade margins and, in turn, multiplying this, as per the dataset derived in Task 2, by the corresponding emissions intensity for retail trade derived in Step 3, Eq. 10 above (see supplementary material folder 'Consumption_Emissions_Model', sub-folder 'Output', workbook 't_h.csv', average of Cells B199:B200).

Task 6: Calculate direct household emissions, δ

A second set of questions would use the carbon emission factors such as presented by the Ministry for the Environment (2022) and in Table 4 above to generate estimates of the direct household emissions.[17] This would need to provide estimates for the direct household emission categories, namely: transport, heating and other (as referred to in Step 1 above).

[17] For the sake of clarity, we emphasise that for commodities such as petroleum, diesel, and natural gas there will be both an embodied emission as calculated under Tasks 1-3, as well as a direct emission calculated under Task 6. The embodied emissions are the emissions generated in the process of producing and delivering the commodity to the consumer (e.g., emissions related during mining, fugitive emissions in the transport of natural gas) while the direct emissions are those released when the fuel is combusted.

4 Generated emission intensities

The derived consumption emissions intensities are shown in Table 5. There are two sets of consumption emissions shown. The first set (on the left) are for the 199 commodities of the SUT framework (i.e., as calculated in Eq. 10 above), the second set (on the right) are for the 268 commodities for the HES (NZHEC) sub-classes. The latter consumption emission intensities were derived using national level HES data appropriately deflated and adjusted for margins and taxes – as per Eq.11, covering Tasks 2-5 above. These are the weighted average (by dollar of expenditure) of the 268 HES sub-classes mapped exactly to the 199 SUT commodities.[18] Importantly, these only cover embodied emissions i.e., they do not account for emissions produced directly by households as per Task 6 above.

A comparison was also made with StatsNZ consumption emissions accounts for New Zealand. Consumption emissions for New Zealand were generated by multiplying the SUT based consumption emission intensities vector (from Eq.10 above) by corresponding final demand category vectors. In this study, embodied consumption emissions for New Zealand's Household Consumption, NPISH, Central and Local Government final demand categories equated to 37,602Kt CO_2-e for the calendar year ending 2019. By comparison, StatsNZ consumption emissions (see Item 2 under Data sources) for the same final demand categories equated to 38,384Kt CO_2-e – a difference of 782Kt or 2.0% of the StatsNZ estimate. Once consumption emissions related to the Gross Fixed Capital Formation and Changes in Inventories final demand categories are also included, providing an estimate of the total consumption emissions for New Zealand, these figures improve further to 50,510Kt CO_2-e (this study) versus 50,699 (see Item 2 under Data sources) – a difference of only 189Kt CO_2-e or 0.4% of the StatsNZ estimate. Overall, the comparison shows that the emissions derived are extremely close. Although it is not possible within the scope of this work to precisely pinpoint the exact reasons for any discrepancies, likely reasons include:

- *Input-output tables*. The figures produced by StatsNZ are based on the 2013 Inter-industry Study of the New Zealand economy, while the figures produced in this report are based on the 2020 Inter-industry Study of the New Zealand economy. This certainly explains difference associated with Changes in Inventories final demand category and is likely to be key reason for any other discrepancies. Changes in Inventories can vary greatly year-to-year, in the 2013 Inter-industry Study of the New Zealand economy Changes in Inventories equated, in total, to $808m, while in the 2020 Inter-industry Study of the New Zealand economy the equivalent figure was $926m.
- *Industry-by-industry versus commodity-by-industry approach*. StatsNZ uses an industry-by-industry approach to derive the emissions embodied in consumption (using a Leontief Inverse Matrix), while the approach used here is based on a commodity-by-industry approach (using a Total Requirements Matrix). The latter approach, in which industries may produce more than one commodity, and where the number of commodities exceeds the number of industries, is less likely to be impacted by aggregation bias than the former approach where only one homogenous commodity is produced per industry. The StatsNZ approach is thus more likely to slightly overstate emissions than the approach used in this study.
- *Industry/commodity disaggregation*. As the national statistical office of New Zealand, StatsNZ holds non-publicly available data, that may have been used to further disaggregate industries and

[18] Using this approach, it is possible to provide consumption emission intensities for the HES (NZHEC) sub-item level – covering appropriately 4,000+ commodities.

commodities. Our discussion with StatsNZ, undertaken as part of this project, indicated that some disaggregation was undertaken, but only for few commodities/industries. This was done where disaggregated sub-industries had very different production emission intensities. This superior data approach will have produced more accurate emissions than the approach used in this study.

Table 5 Consumption Emission Intensities for the Year Ending 2019

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
1	Living plants, buds, seeds, spice, and aromatic crops	0.00041480	0.415	01.1.01.1	Citrus fruit (fresh or chilled)	0.00041572	0.416
2	Vegetables	0.00072957	0.730	01.1.01.2	Bananas (fresh or chilled)	0.00041572	0.416
3	Kiwifruit	0.00043162	0.432	01.1.01.3	Apples and pears (fresh or chilled)	0.00036515	0.365
4	Pome fruit (apples, pears)	0.00035452	0.355	01.1.01.4	Stone fruit (fresh or chilled)	0.00041572	0.416
5	Other fruit and nuts	0.00041572	0.416	01.1.01.5	Berry fruit, kiwifruit and grapes (fresh or chilled)	0.00042012	0.420
6	Forage products, fibres, sugar crops, unmanufactured tobacco	0.00204806	2.048	01.1.01.6	Other fresh or chilled fruit	0.00041572	0.416
7	Cereals	0.00243157	2.432	01.1.01.7	Dried fruit	0.00041524	0.415
8	Sheep	0.00276302	2.763	01.1.01.8	Canned, bottled and frozen fruit	0.00071179	0.712
9	Cattle	0.00267900	2.679	01.1.02.1	Leaf and stem vegetables (fresh or chilled)	0.00072957	0.730
10	Other livestock	0.00098188	0.982	01.1.02.2	Brassica (fresh or chilled)	0.00072957	0.730
11	Deer	0.00151097	1.511	01.1.02.3	Vegetables cultivated for their fruit (fresh or chilled)	0.00072957	0.730
12	Pigs	0.00108938	1.089	01.1.02.4	Root crops, bulbs and mushrooms (fresh or chilled)	0.00072957	0.730
13	Raw milk	0.00150003	1.500	01.1.02.5	Potatoes and other tuber vegetables	0.00072957	0.730
14	Wool	0.00278886	2.789	01.1.02.6	Other fresh or chilled vegetables	0.00072957	0.730
15	Other animal products	0.00111198	1.112	01.1.02.7	Dried vegetables	0.00030976	0.310
16	Wood and non-wood forest products	0.00022317	0.223	01.1.02.8	Frozen vegetables and other preserved or processed vegetables	0.00030976	0.310
17	Fish	0.00028585	0.286	01.2.01.1	Beef and veal (fresh, chilled or frozen)	0.00146977	1.470
18	Crustaceans	0.00028298	0.283	01.2.01.2	Pork (fresh, chilled or frozen)	0.00146977	1.470
19	Support services to agriculture (including animal husbandry)	0.00031547	0.315	01.2.01.3	Mutton, lamb and hogget (fresh, chilled or frozen)	0.00146977	1.470
20	Support services to forestry and logging	0.00022775	0.228	01.2.01.4	Poultry (fresh, chilled or frozen)	0.00146977	1.470
21	Fishing services	0.00024477	0.245	01.2.01.5	Other fresh, chilled or frozen edible meat	0.00146977	1.470
22	Coal, coke, and tar products	0.00167095	1.671	01.2.01.6	Preserved, prepared and processed meat	0.00141844	1.418
23	Crude petroleum	0.00039979	0.400	01.2.02.1	Fish (fresh or chilled)	0.00027340	0.273
24	Natural gas	0.00040788	0.408	01.2.02.2	Other seafood (fresh or chilled)	0.00027340	0.273
25	Iron ores, animal hides, and animal and vegetable oils and fats	0.00070217	0.702	01.2.02.3	Frozen, preserved or processed fish and other seafood	0.00027340	0.273

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
26	Gypsum, limestone, cement, and building stone	0.00032685	0.327	01.3.01.1	Bread	0.00030080	0.301
27	Sands, pebbles, gravel, clays, stone, and bitumen	0.00028784	0.288	01.3.01.2	Cakes and biscuits	0.00030080	0.301
28	Chemical, fertilizer minerals, and salt	0.00053711	0.537	01.3.01.3	Breakfast cereals	0.00029680	0.297
29	Precious metals and stones	0.00038564	0.386	01.3.01.4	Pasta products	0.00023547	0.235
30	Services incidental to mining and manufacturing	0.00043224	0.432	01.3.01.5	Pastry-cook products	0.00113881	1.139
31	Meat and offal	0.00146977	1.470	01.3.01.6	Other cereal products	0.00029241	0.292
32	Bacon, ham, and smallgood products	0.00137914	1.379	01.3.02.1	Fresh milk	0.00113364	1.134
33	Prepared fish	0.00027340	0.273	01.3.02.2	Preserved milk	0.00113364	1.134
34	Milk and cream in solid or processed liquid form	0.00113364	1.134	01.3.02.3	Yoghurt (fresh, frozen)	0.00113189	1.132
35	Other dairy products	0.00113189	1.132	01.3.02.4	Cheese	0.00113364	1.134
36	Prepared vegetables	0.00030976	0.310	01.3.02.5	Other milk products	0.00106011	1.060
37	Beer, soft drinks, and fruit juices	0.00031029	0.310	01.3.02.6	Eggs	0.00111198	1.112
38	Prepared fruit and nuts	0.00071179	0.712	01.3.03.1	Butter	0.00113364	1.134
39	Grain products	0.00029680	0.297	01.3.03.2	Margarine and other vegetable fats	0.00070217	0.702
40	Starches	0.00108094	1.081	01.3.03.3	Edible oils	0.00070217	0.702
41	Animal feed	0.00104144	1.041	01.3.03.4	Other edible animal fats	0.00070217	0.702
42	Bakery products	0.00030080	0.301	01.3.04.1	Sugar	0.00031338	0.313
43	Sugar, cocoa, chocolate and food products nec	0.00031338	0.313	01.3.04.2	Other sugar products	0.00069746	0.697
44	Macaroni and noodles	0.00023547	0.235	01.3.04.3	Sauces	0.00030905	0.309
45	Spirits and tobacco products	0.00021511	0.215	01.3.04.4	Salt, spices, culinary herbs and other condiments	0.00048814	0.488
46	Wines	0.00021533	0.215	01.3.04.5	Stocks, food colourings and flavourings	0.00031338	0.313
47	Natural and man-made textile fibres	0.00043109	0.431	01.3.04.6	Food additives nec	0.00031338	0.313
48	Yarn and thread	0.00080077	0.801	01.3.05.1	Chocolate	0.00031338	0.313
49	Woven fabrics	0.00081083	0.811	01.3.05.2	Confectionery products	0.00031338	0.313
50	Other textiles	0.00037091	0.371	01.3.05.3	Ice cream and edible ices	0.00112246	1.122

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
51	Tanned skins and leather; handbags and articles of leather	0.00082717	0.827	01.3.05.4	Nuts and edible seeds	0.00071179	0.712
52	Carpets	0.00050058	0.501	01.3.05.5	Snack foods	0.00031080	0.311
53	Clothing and knitted fabrics	0.00027626	0.276	01.3.06.1	Jams, marmalades and other spreads	0.00071992	0.720
54	Footwear	0.00023864	0.239	01.3.06.2	Soups	0.00031338	0.313
55	Wood	0.00021466	0.215	01.3.06.3	Prepared meals (fresh, frozen or dried)	0.00027337	0.273
56	Panels, boards, veneer sheets, and plywood	0.00022563	0.226	01.3.06.4	Canned baked beans, spaghetti and other canned meals	0.00029089	0.291
57	Building joinery	0.00020130	0.201	01.3.06.5	Desserts and dessert preparations (excluding milk based)	0.00031338	0.313
58	Wood containers and other wood products	0.00021611	0.216	01.3.06.6	Baby and invalid food	0.00031338	0.313
59	Pulp, paper, and paperboard	0.00025878	0.259	01.3.06.7	Other food and groceries nec	0.00031338	0.313
60	Basic chemicals; plaster and lime, other paper and paperboard products	0.00009826	0.098	01.4.01.1	Coffee	0.00031338	0.313
61	Books and other printed material	0.00009816	0.098	01.4.01.2	Tea	0.00031338	0.313
62	Newspapers and journals	0.00044320	0.443	01.4.01.3	Cocoa and other powdered hot drinks	0.00031232	0.312
63	Petrol	0.00044285	0.443	01.4.02.1	Soft drinks	0.00031029	0.310
64	Diesel	0.00048453	0.485	01.4.02.2	Mineral or spring waters	0.00031029	0.310
65	Other petroleum products	0.00047170	0.472	01.4.02.3	Fruit and vegetable juices	0.00031029	0.310
66	Other chemical products and man-made fibres, non-metal wastes and scraps	0.00105784	1.058	01.4.02.4	Drink concentrates and powders	0.00031308	0.313
67	Fertilisers and pesticides	0.00024722	0.247	01.4.02.5	Energy drinks	0.00031029	0.310
68	Plastics in primary forms	0.00143444	1.434	01.4.02.6	Non-alcoholic beverages nec	0.00031029	0.310
69	Pharmaceutical products	0.00018302	0.183	01.5.01.0	Restaurant meals	0.00016786	0.168
70	Soap and perfumes	0.00030614	0.306	01.5.02.0	Ready-to-eat food	0.00016063	0.161
71	Paints	0.00035089	0.351	01.5.03.0	Other food services	0.00000000	0.000
72	Rubber tyres and tubes	0.00023252	0.233	02.1.01.1	Beer consumed off licensed premises	0.00031029	0.310
73	Rubber	0.00037184	0.372	02.1.01.2	Beer consumed on licensed premises	0.00017658	0.177
74	Semi-manufactures of plastics	0.00046869	0.469	02.1.02.1	Wine consumed off licensed premises	0.00021533	0.215
75	Packaging products of plastics	0.00035462	0.355	02.1.02.2	Wine consumed on licensed premises	0.00017658	0.177

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
76	Other plastics products	0.00036241	0.362	02.1.03.1	Spirits and liqueurs consumed off licensed premises	0.00021511	0.215
77	Glass and glass products	0.00056881	0.569	02.1.03.2	Spirits and liqueurs consumed on licensed premises	0.00017658	0.177
78	Non-structural ceramic ware and clay products	0.00047776	0.478	02.1.04.0	Alcoholic beverages nec	0.00021511	0.215
79	Concrete, and other non-metallic mineral products	0.00058619	0.586	02.2.00.1	Cigarettes	0.00021511	0.215
80	Wastes and scraps	0.00038503	0.385	02.2.00.2	Cigars	0.00000000	0.000
81	Basic iron, steel, and other metals	0.00111754	1.118	02.2.00.3	Other tobacco products	0.00020639	0.206
82	Steel products, semi-finished metal products	0.00091505	0.915	02.2.00.4	E-cigarettes and refills	0.00017822	0.178
83	Structural metal products and other fabricated metal products	0.00031994	0.320	02.3.00.0	Illicit drugs	0.00000000	0.000
84	Prefabricated buildings	0.00018010	0.180	03.1.01.0	Clothing nfd	0.00027626	0.276
85	Metal containers and steam generators	0.00032193	0.322	03.1.02.0	Men's clothing (excluding headwear and neckwear)	0.00027941	0.279
86	Weapons and ammunition; accumulators, primary cells, and batteries	0.00017862	0.179	03.1.03.0	Women's clothing (excluding headwear and neckwear)	0.00031401	0.314
87	Motor vehicles, trailers, and semi-trailers; bodies (coachwork)	0.00016565	0.166	03.1.04.1	Boys' clothing (excluding headwear and neckwear)	0.00027626	0.276
88	Ships, pleasure, and sporting boats	0.00018070	0.181	03.1.04.2	Girls' clothing (excluding headwear and neckwear)	0.00027626	0.276
89	Other transport equipment and parts	0.00022065	0.221	03.1.04.3	Infants' clothing	0.00027626	0.276
90	Aircraft and spacecraft	0.00023014	0.230	03.1.05.0	Clothing accessories	0.00028472	0.285
91	Domestic appliances	0.00016887	0.169	03.1.06.0	Knitting and sewing supplies	0.00038562	0.386
92	Computers, parts, and office machinery	0.00008634	0.086	03.1.07.0	Clothing services	0.00007195	0.072
93	Electric motors, generators, and transformers	0.00017613	0.176	03.2.01.0	Footwear nfd	0.00023864	0.239
94	Other electrical equipment and parts thereof	0.00018692	0.187	03.2.02.0	Men's footwear	0.00023864	0.239
95	Television, cameras, and other electronic goods	0.00010347	0.103	03.2.03.0	Women's footwear	0.00023864	0.239
96	Medical equipment	0.00017493	0.175	03.2.04.0	Children's and infants' footwear	0.00023864	0.239
97	Photographic and scientific equipment	0.00014706	0.147	03.2.05.0	Footwear accessories and services	0.00014184	0.142
98	Engines	0.00027146	0.271	04.1.01.1	Actual rentals for housing	0.00004095	0.041
99	General industrial machinery	0.00025009	0.250	04.1.01.2	Educational accommodation	0.00014971	0.150
100	Agricultural and forestry equipment	0.00026281	0.263	04.1.02.0	Payments connected with renting	0.00005577	0.056

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
101	Other special-purpose machinery	0.00028029	0.280	04.2.01.1	Purchase of housing	0.00000000	0.000
102	Machinery for mining	0.00027295	0.273	04.2.01.2	Mortgage principal repayments	0.00000000	0.000
103	Machinery for food production	0.00032181	0.322	04.2.02.0	Materials for property alterations, additions and improvements	0.00030916	0.309
104	Furniture	0.00021671	0.217	04.2.03.0	Services for property alterations, additions and improvements	0.00017927	0.179
105	Jewellery	0.00086101	0.861	04.3.01.0	Property maintenance materials	0.00042013	0.420
106	Sports goods	0.00037116	0.371	04.3.02.0	Property maintenance services	0.00017318	0.173
107	Games and toys	0.00036271	0.363	04.4.01.0	Water supply	0.00024203	0.242
108	Electricity	0.00064961	0.650	04.4.02.0	Refuse disposal and recycling	0.00150718	1.507
109	Gas	0.00039743	0.397	04.4.03.1	Property rates	0.00019477	0.195
110	Water	0.00024203	0.242	04.4.03.2	Other payments to local authorities	0.00000000	0.000
111	Sewerage services	0.00028364	0.284	04.4.04.0	Other property related services	0.00007034	0.070
112	Waste disposal, recycling, and environmental protection services	0.00150718	1.507	04.5.01.0	Electricity	0.00064961	0.650
113	Residential building construction	0.00016922	0.169	04.5.02.1	Reticulated gas	0.00047170	0.472
114	Non-residential building construction	0.00021242	0.212	04.5.02.2	Bottled gas	0.00040788	0.408
115	Civil engineering services	0.00019350	0.194	04.5.03.0	Solid fuels	0.00036411	0.364
116	Pre-erection work	0.00016612	0.166	04.5.04.0	Liquid fuels	0.00047170	0.472
117	Other installation work	0.00017268	0.173	04.5.05.0	Domestic fuel nec	0.00161790	1.618
118	Electrical installation work	0.00016292	0.163	04.6.00.0	Other housing expenses	0.00008496	0.085
119	Plumbing and other installation services	0.00016455	0.165	05.1.01.0	Furniture and furnishings	0.00024413	0.244
120	Building completion work	0.00016899	0.169	05.1.02.0	Carpets and other floor coverings	0.00041057	0.411
121	Land and land improvements	0.00016863	0.169	05.1.03.0	Repair of furniture, furnishings and floor coverings	0.00007085	0.071
122	Wholesale trade	0.00007759	0.078	05.2.00.0	Household textiles	0.00027201	0.272
123	Accommodation	0.00014971	0.150	05.3.01.1	Refrigerators, freezers and fridge-freezers	0.00016887	0.169
124	Meal services	0.00016786	0.168	05.3.01.2	Clothes washing machines, clothes drying machines and dishwashing machines	0.00016887	0.169
125	Takeaways	0.00016060	0.161	05.3.01.3	Cookers	0.00016887	0.169

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
126	Beverage services	0.00017658	0.177	05.3.01.4	Heaters, air conditioners	0.00016887	0.169
127	Road transport freight services	0.00021601	0.216	05.3.01.5	Cleaning equipment	0.00016887	0.169
128	Road passenger transport	0.00023017	0.230	05.3.01.6	Sewing and knitting machines	0.00000000	0.000
129	Railway transport freight services	0.00028307	0.283	05.3.01.7	Other major household appliances	0.00016887	0.169
130	Railway passenger transport	0.00037718	0.377	05.3.02.0	Small electrical household appliances	0.00016887	0.169
131	Sea transport freight services	0.00032721	0.327	05.3.03.0	Repair and hire of household appliances	0.00007570	0.076
132	Passenger transportation by waterborne vessels	0.00052909	0.529	05.4.00.1	Glassware, tableware and cutlery	0.00046781	0.468
133	Air transport freight services	0.00075476	0.755	05.4.00.2	Kitchen and domestic utensils	0.00034740	0.347
134	Air passenger transport	0.00078778	0.788	05.5.01.0	Major tools and equipment for the house and garden	0.00024455	0.245
135	Travel arrangement and sightseeing transportation services	0.00009851	0.099	05.5.02.0	Small tools and accessories for the house and garden	0.00023787	0.238
136	Postal and courier services	0.00011823	0.118	05.6.01.1	Cleaning products	0.00029536	0.295
137	Cargo handling services	0.00024641	0.246	05.6.01.2	Other household supplies	0.00047311	0.473
138	Supporting services for road and rail transport	0.00007849	0.078	05.6.02.0	Other household services	0.00031151	0.312
139	Supporting services for water transport	0.00003537	0.035	06.1.01.0	Pharmaceutical products	0.00018302	0.183
140	Supporting services for air transport	0.00010008	0.100	06.1.02.0	Other medical products	0.00019999	0.200
141	Freight transport agencies and other supporting transport services	0.00005970	0.060	06.1.03.0	Therapeutic appliances and equipment (including repairs)	0.00014868	0.149
142	Storage and warehousing services	0.00012874	0.129	06.2.01.0	Medical services	0.00007285	0.073
143	Publishing, printing, and reproduction services	0.00033460	0.335	06.2.02.0	Dental services	0.00007285	0.073
144	Packaged software, tapes, audio, and video records	0.00011493	0.115	06.2.03.1	Medical laboratory and radiology services	0.00008006	0.080
145	Motion picture, radio, TV services	0.00006456	0.065	06.2.03.2	Other non-hospital services	0.00000000	0.000
146	Broadcasting, programming, and programme distribution services	0.00005975	0.060	06.3.00.0	Hospital services	0.00008141	0.081
147	Telecommunications services	0.00004037	0.040	07.1.01.0	Purchase of new motor cars	0.00016565	0.166
148	Digital imports to households	0.00005682	0.057	07.1.02.0	Purchase of second-hand motor cars	0.00016565	0.166
149	Internet telecommunications services and online content	0.00004486	0.045	07.1.03.0	Purchase of motorcycles	0.00019706	0.197
150	News agency, library, and archive services	0.00004108	0.041	07.1.04.0	Purchase of bicycles	0.00022065	0.221

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
151	Financial intermediation services	0.00002747	0.027	07.2.01.0	Vehicle parts and accessories	0.00021760	0.218
152	Life insurance	0.00001721	0.017	07.2.02.0	Petrol	0.00044285	0.443
153	Other insurance services	0.00001203	0.012	07.2.03.0	Other vehicle fuels and lubricants	0.00055929	0.559
154	Superannuation and individual pension services	0.00006856	0.069	07.2.04.0	Vehicle servicing and repairs	0.00012954	0.130
155	Services auxiliary to financial services	0.00002592	0.026	07.2.05.0	Other private transport services	0.00006976	0.070
156	Equipment hire services	0.00012139	0.121	07.3.01.0	Rail passenger transport	0.00037718	0.377
157	Licensing services for the right to use computer software and databases	0.00004010	0.040	07.3.02.0	Road passenger transport	0.00021210	0.212
158	Intellectual property licensing services	0.00007667	0.077	07.3.03.0	Domestic air transport	0.00078778	0.788
159	Capitalised exploration	0.00028667	0.287	07.3.04.0	International air transport	0.00000000	0.000
160	Leased residential property services	0.00004095	0.041	07.3.05.0	Sea passenger transport	0.00052909	0.529
161	Leased commercial property services	0.00006191	0.062	07.3.06.0	Combined passenger transport	0.00000000	0.000
162	Other real estate services	0.00009432	0.094	07.3.07.0	Other passenger transport costs	0.00010682	0.107
163	Owner - occupied dwellings	0.00003009	0.030	08.1.00.0	Postal services	0.00017233	0.172
164	Research and development	0.00013517	0.135	08.2.00.0	Telecommunication equipment	0.00010347	0.103
165	Architectural and engineering services	0.00006541	0.065	08.3.00.0	Telecommunication services	0.00004160	0.042
166	Other business services	0.00007342	0.073	09.1.01.1	Audio-visual equipment	0.00010434	0.104
167	Legal services	0.00002632	0.026	09.1.01.2	Other optical instruments	0.00000000	0.000
168	Accounting and taxation services	0.00002770	0.028	09.1.02.0	Computing equipment	0.00008197	0.082
169	Advertising and marketing services	0.00007783	0.078	09.1.03.0	Recording media	0.00011227	0.112
170	Management consultancy	0.00010086	0.101	09.1.04.0	Repair of audio-visual, photographic and information processing equipment	0.00007085	0.071
171	Veterinary services	0.00004863	0.049	09.2.00.1	Major durables for outdoor recreation	0.00020539	0.205
172	IT design and development related services	0.00006154	0.062	09.2.00.2	Musical instruments	0.00036271	0.363
173	IT infrastructure provisioning and network management services	0.00003894	0.039	09.2.00.3	Major durables for indoor recreation	0.00037116	0.371
174	IT technical consulting and support services	0.00004217	0.042	09.2.00.4	Maintenance and repair of other major durables for recreation and culture	0.00000000	0.000
175	Placement and supply of personnel	0.00006191	0.062	09.3.01.0	Games, toys and hobbies	0.00034295	0.343

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m
176	Cleaning	0.00020435	0.204
177	Other support services	0.00008909	0.089
178	Local government administration services	0.00019477	0.195
179	Central government administrative services	0.00006514	0.065
180	Investigation and security services	0.00007034	0.070
181	Preschool education	0.00004377	0.044
182	Primary education	0.00005346	0.053
183	Secondary education	0.00005952	0.060
184	Higher education	0.00006322	0.063
185	Other education services	0.00007158	0.072
186	Hospital and nursing care	0.00008141	0.081
187	Medical, dental, and other health services	0.00007285	0.073
188	Accommodation for the aged	0.00007812	0.078
189	Child care services	0.00007763	0.078
190	Other social services	0.00007757	0.078
191	Libraries, museums, and art	0.00004754	0.048
192	Sport and recreation services	0.00014153	0.142
193	Gambling services	0.00004181	0.042
194	Maintenance of domestic and office equipment	0.00007085	0.071
195	Maintenance of transport machinery and equipment	0.00012954	0.130
196	Maintenance of other equipment	0.00012079	0.121
197	Other personal and community services	0.00007235	0.072
198	Retail margin	0.00009285	0.093
199	Wholesale margin	0.00014196	0.142

Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
09.3.02.1	Equipment for sport and outdoor recreation	0.00035372	0.354
09.3.02.2	Equipment for camping	0.00031994	0.320
09.3.03.0	Plants, flowers and gardening supplies	0.00040793	0.408
09.3.04.1	Pets and domestic livestock	0.00000000	0.000
09.3.04.2	Food for pets and domestic livestock	0.00105027	1.050
09.3.04.3	Other supplies for pets and domestic livestock	0.00053785	0.538
09.3.04.4	Equipment for pets and domestic livestock	0.00036242	0.362
09.4.01.0	Recreational and sporting services	0.00012195	0.122
09.4.02.1	Admission charges to cinemas, theatres, concerts	0.00005432	0.054
09.4.02.2	Museums, zoological gardens and the like	0.00004732	0.047
09.4.02.3	Television and radio charges and hire of equipment	0.00006059	0.061
09.4.02.4	Other cultural services	0.00009837	0.098
09.4.03.0	Veterinary and other services for pets and domestic livestock	0.00006919	0.069
09.4.04.0	Games of chance	0.00004181	0.042
09.5.01.0	Books	0.00009259	0.093
09.5.02.0	Newspapers and magazines	0.00029749	0.297
09.5.03.0	Miscellaneous printed matter	0.00009816	0.098
09.5.04.0	Stationery and drawing materials	0.00017751	0.178
09.6.00.1	Domestic accommodation services	0.00014971	0.150
09.6.00.2	Overseas accommodation prepaid in New Zealand	0.00000000	0.000
09.9.00.1	Domestic Flights and Accommodation	0.00000000	0.000
09.9.00.2	International Flights and Accommodation	0.00000000	0.000
10.1.00.0	Early childhood education	0.00006057	0.061
10.2.00.1	Primary and intermediate education	0.00005435	0.054
10.2.00.2	Secondary education	0.00005952	0.060

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m

Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
10.3.00.0	Tertiary and other post school education	0.00006335	0.063
10.4.00.0	Other educational fees	0.00007158	0.072
11.1.01.0	Hairdressing and personal grooming services	0.00007879	0.079
11.1.02.0	Electrical appliances for personal care	0.00018692	0.187
11.1.03.1	Other appliances, articles and products for personal care	0.00034053	0.341
11.1.03.2	Articles for personal hygiene	0.00030614	0.306
11.1.03.3	Beauty products, perfumes and deodorants	0.00030813	0.308
11.1.03.4	Other personal care products	0.00013201	0.132
11.2.00.0	Prostitution	0.00000000	0.000
11.3.01.0	Jewellery and watches	0.00059577	0.596
11.3.02.1	Travel goods and other carriers	0.00082717	0.827
11.3.02.2	Other personal effects	0.00037588	0.376
11.4.01.0	Life insurance	0.00001721	0.017
11.4.02.0	Dwelling insurance	0.00001203	0.012
11.4.03.0	Contents insurance	0.00001203	0.012
11.4.04.0	Health insurance	0.00001203	0.012
11.4.05.0	Vehicle insurance	0.00001203	0.012
11.4.06.0	Combinations of insurance nec	0.00001203	0.012
11.4.07.0	Other insurance	0.00001203	0.012
11.5.01.0	Direct charges for deposits and loans	0.00002747	0.027
11.5.02.0	Financial intermediation services	0.00000000	0.000
11.6.01.0	Vocational services	0.00007235	0.072
11.6.02.0	Professional services	0.00002694	0.027
11.6.03.0	Real estate services	0.00000000	0.000
11.6.04.0	Other miscellaneous services nec	0.00007237	0.072

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
				13.1.01.0	Mortgage interest payments	0.00002747	0.027
				13.1.02.0	Interest payments on personal loans	0.00002747	0.027
				13.1.03.0	Interest payments on credit sales (hire purchases)	0.00002747	0.027
				13.1.04.0	Other interest payments	0.00002747	0.027
				13.2.00.0	Contributions to savings	0.00006762	0.068
				13.3.00.0	Money given to others (excluding donations)	0.00002747	0.027
				13.4.00.0	Fines	0.00006514	0.065
				14.1.01.1	Sales of clothing nfd	0.00027626	0.276
				14.1.01.2	Sales of men's clothing	0.00000000	0.000
				14.1.01.3	Sales of women's clothing	0.00000000	0.000
				14.1.01.4	Sales of boys' clothing	0.00000000	0.000
				14.1.01.5	Sales of girls' clothing	0.00000000	0.000
				14.1.01.6	Sales of infants' clothing	0.00000000	0.000
				14.1.02.1	Sales of men's footwear	0.00000000	0.000
				14.1.02.2	Sales of women's footwear	0.00000000	0.000
				14.1.02.3	Sales of children's and infants' footwear	0.00000000	0.000
				14.1.02.4	Sales of other footwear	0.00023864	0.239
				14.2.01.0	Sale of property	0.00000000	0.000
				14.2.02.0	Sales and trade-ins of materials for property improvement and maintenance	0.00000000	0.000
				14.3.01.0	Sales and trade-ins of furniture and furnishings	0.00021671	0.217
				14.3.02.0	Sales and trade-ins of major household appliances	0.00016887	0.169
				14.3.03.0	Sales of small electric household appliances	0.00000000	0.000
				14.3.04.0	Sales of glassware, tableware and household utensils	0.00056881	0.569
				14.3.05.0	Sales and trade-ins of tools and equipment for house and garden	0.00030547	0.305
				14.3.06.0	Sales and trade-ins of furnishings, household equipment nec	0.00000000	0.000

Table 5 Consumption Emission Intensities for the Year Ending 2019 (Cont.)

Code	Supply-Use Table Commodity Description	t CO_2-e per $	kt CO_2-e per $m	Code	Household Economic Survey Class Description	t CO_2-e per $	kt CO_2-e per $m
				14.4.00.0	Sales, trade-ins and refunds for health (excluding insurance claims)	0.00000000	0.000
				14.5.01.0	Sales and trade-ins of vehicles	0.00000000	0.000
				14.5.02.1	Sales of spare parts and accessories	0.00000000	0.000
				14.6.00.0	Sales and trade-ins for communication	0.00010347	0.103
				14.7.01.1	Sales and trade-ins of audio and visual equipment and accessories	0.00010347	0.103
				14.7.01.2	Sales and trade-ins of computing equipment	0.00008634	0.086
				14.7.01.3	Sales and trade-ins of recording media	0.00000000	0.000
				14.7.02.1	Sales and trade-ins of major durables for outdoor recreation	0.00016565	0.166
				14.7.02.2	Sales and trade-ins of musical instruments and major durables for indoor recreation	0.00036271	0.363
				14.7.03.0	Sales and trade-ins of other recreational equipment and supplies	0.00037116	0.371
				14.7.04.0	Returns from games of chance	0.00004181	0.042
				14.7.05.1	Sales of books	0.00009816	0.098
				14.7.05.2	Sales of newspapers and periodicals	0.00000000	0.000
				14.7.06.0	Sales, trade-ins and refunds for recreation and culture nec	0.00037116	0.371
				14.8.00.0	Refunds for education	0.00000000	0.000
				14.9.01.0	Sales and trade-ins of personal effects nec	0.00086101	0.861
				14.9.02.0	Cash receipts from insurance claims	0.00001203	0.012
				14.9.03.0	Other sales, trade-ins and refunds nec	0.00013929	0.139

5 Strengths and weaknesses

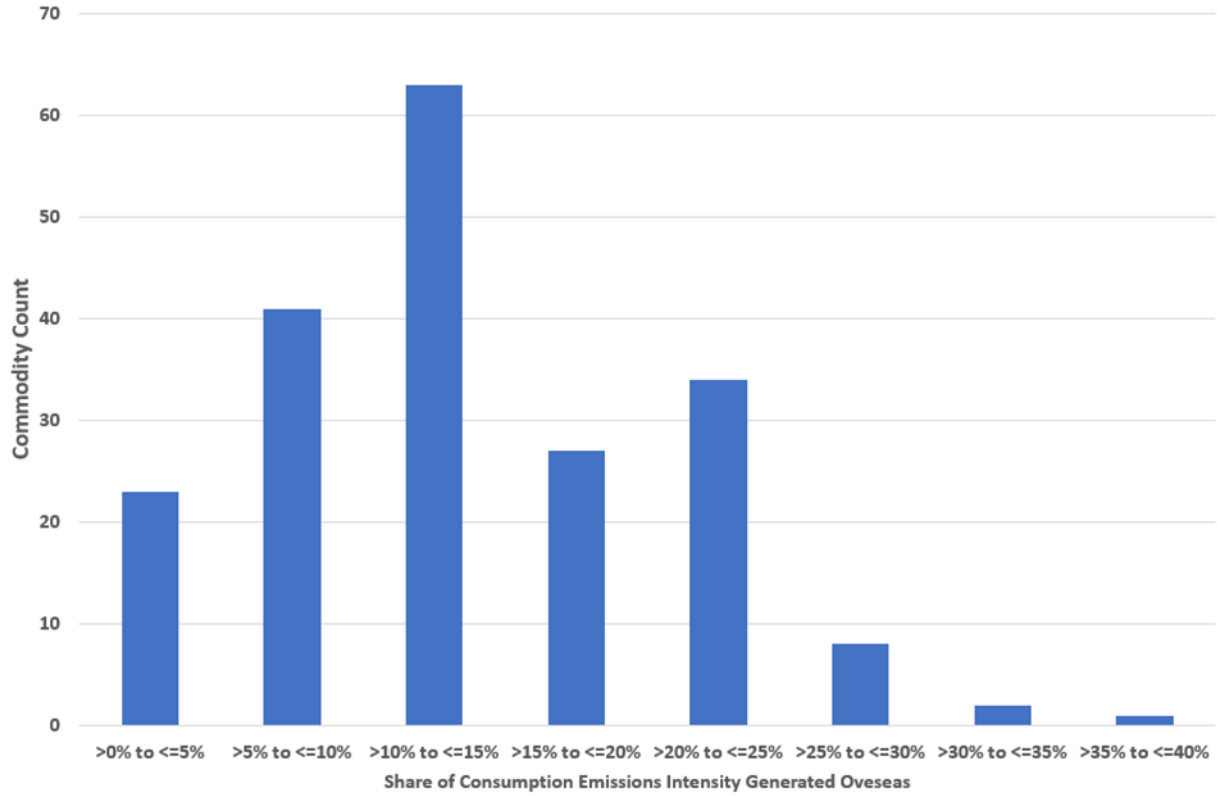
A key strength with adopting the commodity-by-industry SUT approach is that it allows for joint products i.e., each industry can produce more than one commodity. This differs from the industry-by-industry IO approach used in many previous New Zealand studies, where each industry produces only one homogenous commodity (effectively the weighted average of all its joint products). A further advantage of the commodity-by-industry approach is that it facilitates direct comparison with the NZHEC commodity classifications used in the HES.

There are however weaknesses associated with this approach:

Emissions embodied in international imports. We assume emissions embodied in international trade reflect domestic (New Zealand) production recipes. Auckland Council is however eager to ensure compatibility with StatsNZ approach – which also makes this assumption. This reflects many of the proceeding studies, for example, Romanos *et al*. (2014), Andrew and Forgie (2008), and McDonald (2004). Nevertheless, this is conceptually incorrect. A quick glance at New Zealand trade data reveals why this is a problem. Some manufactured commodities are completely imported with no production occurring in New Zealand. The emissions for these commodities are therefore not appropriately accounted for. Car manufacturing, for example, is a niche industry within New Zealand and, thus, not necessarily reflective of car manufacturing in Japan where many of New Zealand's vehicles originate from.

As mentioned above, no agreed method exists to estimate the emissions embodied in international trade. To better understand the extent of the issue we have calculated the % share of the SUT-based consumption emissions intensities generated overseas (Table 6). Note we assume that imported goods are produced in the same manner as domestic goods and thus generate the same level of emissions in production (directly and indirectly) per dollar of commodity. These results are also provided in the supplementary material folder 'Share of Commodity Emission Intensity Generated Overseas', workbook 'Share of Commodity Emission Intensity Generated Overseas.xlsx', worksheet '% of Cons Emm Int frm Overseas'. This crudely indicates that the bulk of the commodity intensities are generated within New Zealand. The histogram in Figure 3 provides a count of the commodities within different % emission intensity ranges that are generated offshore. We see, for example, that 23 out of 199 commodities have between 0-5% of their respective emission intensities generated offshore, and 63 out of 199 commodities have >10% but <=15% of their respective emission intensities generated offshore. Cumulatively, 196 out of the 199 commodities have <=30% of their emission intensities generated offshore, with the only one commodity generating 38% of its emission intensity offshore.

Figure 3 Histogram of Counts



It is worth noting that is not a relatively straightforward task to assess all upstream emissions including those embodied in international imports using proprietary datasets, including: (1) the EoRA dataset originally developed by the University of Sydney (Lenzen *et al*., 2012, 2013) and now maintained by KGM & Associates Pty, Ltd (https://worldmrio.com/); (2) the Global Trade Analysis Project (GTAP) database (https://www.gtap.agecon.purdue.edu/); (3) the OECD's IO tables; and non-proprietary datasets such as (4) the World IO Database (https://www.rug.nl/ggdc/valuechain/wiod/?lang=en). Nevertheless, concordance issues may exist in mapping imported commodities (as reported by StatsNZ) to the definitions in these datasets (i.e., one-to-many and many-to-many mappings may exist). Care also needs to be taken to avoid double counting of New Zealand emissions. Emissions associated with aluminium ingots produced in New Zealand is an example where double counting could occur. Ingots are sold to other countries, and in turn these countries use these to extruded aluminium products that are then sold back to New Zealand.

Further disaggregation of production emissions. As carbon footprints are heavily related to food consumption, energy use, and transport. It is important that nuances within the industries that produce these commodities be accurately captured. Ideally the 'Sheep, beef cattle and grain farming' industry should be further disaggregated into 'sheep farming', 'beef cattle farming' and 'grain farming'. Unfortunately, this is not a straightforward task as many farms operate as integrated systems i.e., mixed sheep and beef cattle farming, beef cattle and grain farming, sheep farming and grain farming, and so on. Thus, creating revenue and expenditure accounts for these will undoubtedly be based on 'representative' rather than 'actual' farm accounts. In our study, we have kept these industries aggregated, but because we use a SUT (i.e., a commodity-by-industry structure) to derive the Total Requirements Matrix, we significantly reduce aggregation issues as multiple commodities (rather than just one homogenous commodity under an industry-by-industry structure) can be produced by an industry.

Table 6 % of Consumption Emissions Intensity Generated Overseas

IO20_199Com_Name	%_comm_intensity_generated_overseas	IO20_199Com_Name	%_comm_intensity_generated_overseas	IO20_199Com_Name	%_comm_intensity_generated_overseas	IO20_199Com_Name	%_comm_intensity_generated_overseas
Sports goods	38%	Maintenance of transport machinery and equipment	19%	Other education services	14%	Other fruit and nuts	8%
Games and toys	35%	Precious metals and stones	18%	Libraries, museums, and art	14%	Prepared vegetables	8%
Plastics in primary forms	32%	Other chemical products and man-made fibres, non-metal wastes and scraps	18%	Fish	13%	Prepared fruit and nuts	8%
Air transport freight services	30%	Machinery for food production	18%	Spirits and tobacco products	13%	Grain products	8%
Air passenger transport	30%	Sands, pebbles, gravel, clays, stone, and bitumen	17%	Wines	13%	Bakery products	8%
Aircraft and spacecraft	29%	Prefabricated buildings	17%	Railway transport freight services	13%	Macaroni and noodles	8%
Cargo handling services	28%	Motor vehicles, trailers, and semi-trailers; bodies (coachwork)	17%	Freight transport agencies and other supporting transport services	13%	Carpets	8%
Rubber	27%	Computers, parts, and office machinery	17%	Packaged software, tapes, audio, and video records	13%	Meal services	8%
Semi-manufactures of plastics	27%	Pre-erection work	17%	Motion picture, radio, TV services	13%	Accommodation for the aged	8%
Jewellery	27%	Electrical installation work	17%	Broadcasting, programming, and programme distribution services	13%	Child care services	8%
Other plastics products	26%	Plumbing and other installation services	17%	Financial intermediation services	13%	Other social services	8%
Paints	25%	Land and land improvements	17%	Intellectual property licensing services	13%	Living plants, buds, seeds, spice, and aromatic crops	7%
Packaging products of plastics	25%	Equipment hire services	17%	Leased commercial property services	13%	Kiwifruit	7%
Weapons and ammunition; accumulators, primary cells, and batteries	25%	Maintenance of other equipment	17%	Advertising and marketing services	13%	Support services to forestry and logging	7%
Domestic appliances	25%	Footwear	16%	Veterinary services	13%	Chemical, fertilizer minerals, and salt	7%
Electric motors, generators, and transformers	25%	Residential building construction	16%	Central government administrative services	13%	Natural and man-made textile fibres	7%
Medical equipment	25%	Civil engineering services	16%	Higher education	13%	Takeaways	7%
Supporting services for air transport	25%	Other installation work	16%	Gambling services	13%	Beverage services	7%
Petrol	24%	Building completion work	16%	Wood	12%	Other real estate services	7%
Diesel	24%	Management consultancy	16%	Building joinery	12%	Cleaning	7%
Rubber tyres and tubes	24%	Maintenance of domestic and office equipment	16%	Wood containers and other wood products	12%	Wood and non-wood forest products	6%
Other transport equipment and parts	24%	Wholesale margin	16%	Railway passenger transport	12%	Support services to agriculture (including animal husbandry)	6%
Photographic and scientific equipment	24%	Books and other printed material	15%	Telecommunications services	12%	Iron ores, animal hides, and animal and vegetable oils and fats	6%
Other petroleum products	23%	Newspapers and journals	15%	Internet telecommunications services and online content	12%	Yarn and thread	6%
Basic chemicals; plaster and lime, other paper and paperboard products	23%	Non-residential building construction	15%	Superannuation and individual pension services	12%	Woven fabrics	6%
Basic iron, steel, and other metals	23%	Other insurance services	15%	Other business services	12%	Tanned skins and leather; handbags and articles of leather	6%
Engines	23%	Licensing services for the right to use computer software and databases	15%	Other support services	12%	Vegetables	5%
Other special-purpose machinery	23%	IT infrastructure provisioning and network management services	15%	Investigation and security services	12%	Other livestock	5%
Postal and courier services	23%	IT technical consulting and support services	15%	Preschool education	12%	Pigs	5%
Services incidental to mining and manufacturing	22%	Crustaceans	14%	Primary education	12%	Other animal products	5%
Glass and glass products	22%	Prepared fish	14%	Secondary education	12%	Gas	5%
Non-structural ceramic ware and clay products	22%	Panels, boards, veneer sheets, and plywood	14%	Sport and recreation services	12%	Sewerage services	5%
Concrete, and other non-metallic mineral products	22%	Pulp, paper, and paperboard	14%	Beer, soft drinks, and fruit juices	11%	Local government administration services	5%
Steel products, semi-finished metal products	22%	Pharmaceutical products	14%	Clothing and knitted fabrics	11%	Deer	4%
Metal containers and steam generators	22%	Wholesale trade	14%	Storage and warehousing services	11%	Sugar, cocoa, chocolate and food products nec	4%
Ships, pleasure, and sporting boats	22%	Travel arrangement and sightseeing transportation services	14%	Other textiles	10%	Animal feed	4%
Other electrical equipment and parts thereof	22%	Supporting services for road and rail transport	14%	Water	10%	Forage products, fibres, sugar crops, unmanufactured tobacco	3%
General industrial machinery	22%	Supporting services for water transport	14%	Accommodation	10%	Cereals	3%
Agricultural and forestry equipment	22%	Digital imports to households	14%	Sea transport freight services	10%	Meat and offal	3%
Machinery for mining	22%	News agency, library, and archive services	14%	Publishing, printing, and reproduction services	10%	Bacon, ham, and smallgood products	3%
Coal, coke, and tar products	21%	Life insurance	14%	Hospital and nursing care	10%	Starches	3%
Crude petroleum	21%	Services auxiliary to financial services	14%	Medical, dental, and other health services	10%	Sheep	2%
Natural gas	21%	Leased residential property services	14%	Other personal and community services	10%	Cattle	2%
Structural metal products and other fabricated metal products	21%	Owner - occupied dwellings	14%	Pome fruit (apples, pears)	9%	Wool	2%
Furniture	21%	Research and development	14%	Fishing services	9%	Milk and cream in solid or processed liquid form	2%
Fertilisers and pesticides	20%	Architectural and engineering services	14%	Wastes and scraps	9%	Other dairy products	2%
Soap and perfumes	20%	Legal services	14%	Road transport freight services	9%	Electricity	2%
Capitalised exploration	20%	Accounting and taxation services	14%	Road passenger transport	9%	Waste disposal, recycling, and environmental protection services	2%
Gypsum, limestone, cement, and building stone	19%	IT design and development related services	14%	Passenger transportation by waterborne vessels	9%	Raw milk	1%
Television, cameras, and other electronic goods	19%	Placement and supply of personnel	14%	Retail margin	9%		

6 Recommendations and next steps

As our work is being fed into several on-line calculators developed by Auckland Council, we have not presented any results here. Thus, opportunities exist to extend the framework further:

- *Consumption emission accounts for Auckland Region*. The most obvious extension of this work is to estimate consumption emission accounts for Auckland Region by multiplying the consumption emissions intensities by estimates of Auckland's household expenditure.
- *Distributional analysis of consumption emissions*. This would extend the above analysis by disaggregating Auckland's consumptions emission by household type. Household types, based on demographic variables (such as age-sex cohort, income, family type, and ethnicity), can be defined using the 2018 Census of Population and Dwellings (CoPD) and, in turn, multiplied by aligned HES data. This would allow a distributional analysis of consumption emissions to be performed. Delineating consumption emissions would enable households of different types to see where reductions in their carbon footprints could be made. It may also reveal how socio-economic disparities play out in footprint terms.
- *Spatial disaggregation of consumption emissions*. This would again extend the above analysis by mapping consumptions emission across Auckland e.g., by SA1, SA2, Ward of Local Board. Furthermore, this could be performed for the distribution analyses discussed in the previous bullet point.
- *Business and government rather than household consumption emissions*. The methodology developed in this report facilitates estimation of the consumption-based emissions for households, nevertheless it could equally be used to estimate the emissions associated with business, or even government and local government, consumption of final products. The potential for reduction of GHGs in Auckland Region businesses is significant. Simple choices are supplying industry could significantly reduce emissions. Resilience co-benefits are also possible here as careful consideration of business supply chains to reduce GHG emissions may also reduce potential impacts associated with disruptive events.
- *Assessment of policy options and tracing of dynamic transitions*. A gap in Auckland policy development is an ability to determine what future emissions might look like under different growth trajectories or scenarios. A Computable General Equilibrium (CGE) analysis, known as the C-PLAN model, of the future growth pathways to meet New Zealand's Climate Change Commission targets was released in 2021. Auckland Unlimited has recently developed a multi-regional version (consisting of Auckland Region and the rest of New Zealand) aligned to this model which could be coupled with the consumption emissions modelling undertaken in this project (Monge and McDonald, 2022). This model is fully compatible with the SUT framework developed here and could be used to assess the emissions associated with climate change mitigation and adaptation strategies. This would enable investigation of questions such as "Will climate change adaptation strategies reduce carbon emissions?", "Can we further reduce GHG emission by changing people behaviours and consumption?"

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