

Life Cycle Assessment and Environmental Footprinting of Sectors and Products in the New Zealand Economy



Murray Patterson

John Kim

Garry McDonald

Duncan Grimson

Nicola McDonald

Juan Monge

Life Cycle Assessment and Environmental Footprinting of Sectors and Products in the Zealand Economy

Professor Murray Patterson ¹

Joon-Hwan (John) Kim ²

Dr Garry McDonald ²

Duncan Grimson ²

Dr Nicola McDonald ²

Dr Juan Monge ²

¹ School of People, Environment and Planning, Massey University, Palmerston North

² Market Economics Ltd, Auckland

© Patterson, Kim, McDonald, Grimson, McDonald, Monge 2024

Published by Massey University

Private Bag 11 222

Palmerston North

New Zealand

While the authors have exercised all reasonable skill and care in researching and reporting this information, they accept no responsibility for the opinions expressed or the accuracy or completeness of the contents of this document. The authors will not be liable in contract, tort, or otherwise howsoever, for any loss, damage or expense (whether direct, indirect or consequential) arising out of the provision for the information contained in the report or its use.

ISBN 978-0-473-70134-5

Executive Summary

This section of this publication **summarises** and **updates** the data contained in the main body of this publication. Readers are encouraged to examine the main body of the report particularly in regard to the detailed life-cycle assessment diagrams it contains.

Motivation and Rationale for the Analysis

Industries and sectors in the economy depend on natural resources either directly or indirectly. The environment is also important in terms of processing wastes that result from economic activity. Governments worldwide are struggling to come to terms with how to best manage the economy so as to reduce the negative impacts of exploiting natural resources and pollution whilst not compromising the achievement of other policy goals such as maintaining incomes and employment.

Environmental policies rewarding the efficient use of natural resources as well as limiting current levels of pollutant are both profitable alternatives and costly constraints to some of New Zealand's major economic contributors. Hence, more emphasis is being placed on identifying the sectors that are either the most efficient users of the nation's precious natural resources or the most polluting ones contributing to both local problems like lake eutrophication and globally to challenges such as climate change.

This publication contributes to our understanding of these issues, by undertaking input-output based life cycle assessment and environmental footprinting of 32 sectors in the New Zealand economy. This covers utilisation of natural resources (energy, land, freshwater, ecosystem services) and the pollutants (nitrogen, phosphorus, greenhouse gases, wastewater, landfill wastes). In total, 335 life-cycle assessment diagrams that quantify the direct and indirect natural resources or pollutants emitted from each sector. As well as being of practical use to life-cycle assessment and footprinting practitioners, these LCA diagrams should help better visualise the indirect impacts on the environment of sectors in New Zealand economy.

By identifying the use of resources and emissions of all sectors within New Zealand, a comprehensive understanding of the major polluters and consumers of key resources within the economy, and their interconnectedness through value chains, can be ascertained. These resources and emissions are measured in the forms of total energy usage, electricity usage, fossil fuel usage, land usage, water inputs, landfill waste, wastewater, phosphorous emissions, CO₂ emissions and ecosystem services.

Practical Use of the Compendium of Data

In practical terms, it is hoped that this comprehensive analysis of sectors and their products in the New Zealand economy, will provide a compendium of data for life-cycle assessment (LCA) of products. Particularly, it is hoped that in future life-cycle assessment exercises, that the data and LCA diagrams presented in this publication: (1) will be used in hybrid (process and input-output) based life-cycle assessment of sectors and their products; (2) at the very least, the data in the life-cycle assessment diagrams presented in this publication, will help scope out indirect environmental footprints of products and sectors, particularly those sectors that are often overlooked because singularly they are not important and/or often diffuse, but cumulatively they are significant.

Eco-Efficiency¹ of Sectors in the New Zealand Economy

Table ES1 (2004) and Table ES2 (2019)² summarises these eco-efficiency indicators for sectors such as agriculture and manufacturing – that is, the environmental footprint (energy, land, water, landfill wastes, phosphorus, carbon dioxide) per tonne of product sector. It's important to note that for each of the eco-efficiency indicators reported in Table ES1 there is a detailed Life Cycle Assessment (LCA) diagram that appears in the main body of the report. These LCA diagrams reveal that the environmental footprint of producing sector products, is not just the direct on-site impacts, but also importantly the indirect impacts that are embodied in the products and services that the sector purchases.

Table ES1 accordingly indicates that the most eco-efficient sector is “mining and quarrying” followed by “forestry and logging”, across most of the indicators. “Dairy cattle farming” is the third most eco-efficient sector across most of the indicators, although it must be recognised that methane emissions from the sector are not taken account of in these indicators, which is significant avenue for further research. The least eco-efficient production sectors, are those sectors that produce products further down the value chain – “printing, publishing and recorded media” is the least eco-efficient, with larger environmental footprints per tonne of product, followed the second and third least eco-efficient sectors being “furniture and other manufacturing” and “textiles and apparel manufacturing”. All of these sectors have the highest environmental footprints for energy and carbon dioxide emissions, when normalised in terms of tonnes of sector output produced.

It's important to realise that the eco-efficiency indicators summarised by Tables ES1 (2004) and Table ES2 (2019) also include an estimate of their environmental footprints incurred by imported products. This is an important factor which is often overlooked, whereby import substitution of manufactured products like importing low-cost furniture, is shifting ecological footprints and impacts from New Zealand to other countries.

Apart from the eco-efficiency indicators of production and manufacturing sectors summarised by Tables ES1 and ES2, the service sectors in the economy also have significant eco-efficiency even though they don't produce physical products. Paper for example or computer equipment required by service sectors have noteworthy environmental footprints – refer to Tables ES3 and ES4. It should also be noted of the sectors covered by Table ES3 and ES4 that the “Road Transport” generally has the poorest performing eco-efficiency indicators, particularly in regard to its energy and carbon dioxide environmental footprints per \$1,000 of output.

Eco-efficiency indicators measure changes in the relative decoupling of environmental footprints from economic production. In this regard, there is good evidence that the eco-efficiency of the production and manufacturing sectors, have improved (lower environmental footprints relative to tonnes of product made) from 2004 to 2019. This is the case with energy, solid wastes from landfill, water inputs, water wastes and nutrients in this waste stream. However, due to the intensification of agriculture

¹ In the main body of the report and instead of using the terminology “eco-efficiency” we used the terminology “direct intensities”, “indirect intensities” and “total intensities”. The measurement of “total intensity”, is exactly the same as the measurement of eco-efficiency reported in Tables ES1 to ES4 where the environmental footprints are measured either in terms of their weight (tonnes) of output in the production and manufacturing sectors, or in terms of \$1,000 worth of output in service, construction and transport sectors. Refer to the following publication for the rationale behind using this “eco-efficiency” metric: Jollands, N., Lermitt, J., Patterson, M. 2004. Aggregate Eco-Efficiency Indices for New Zealand — A Principal Components Analysis. *Journal of Environmental Management* 293-305 73:4

² The eco-efficiency indicators for our estimated 2019 from the 2004 data, by taking it into account changes in inflation, and known and/or implied changes in the underlying technical efficiency of the eco-efficiency indicator.

there is good evidence that for some sectors, that their land footprints have increased relative to tonnes produce.

Environmental Footprints of the Zealand Economy

Although the environmental footprints of each of the 32 sectors for 2019³, were not calculated in the main body of the report, they can easily be estimated by multiplying the eco-efficiency indicator by the mass output of the sector or \$1,000 worth of sector output (as well as adjusting the data for inflation) – refer to Table ES5.

It's important to note that the environmental footprints unlike eco-efficiency indicators, measure the total environmental impacts with no normalisation or reference to the level of production of goods and services by a particular sector. Arguably, such environmental footprints are preferable indicators, if the purpose of the analysis is to ascertain how much impact a sector has on reaching environmental limits, environmental thresholds and/or policy goals – for example, ascertaining how the environmental footprint of a sector contributes to reaching the threshold for eutrophication in a lake.

Such environmental footprints are indicators of 'absolute decoupling' of environmental impacts from economic production of goods and services, with a decrease in these indicators over time indicating a movement towards decoupling.

Making the Indirect Effects Visible

An important contribution of this publication, by way of life-cycle assessment diagrams, is making visible the indirect resource inputs and indirect pollutants of each sector, normalised in terms of tonnes of sector output or \$1,000 worth of sector output. In contrast, usually in input-output analysis "ecological multipliers" (total footprint per output divided by direct footprint per output) are reported as single numbers, perhaps leaving the reader wondering how the number is arrived at terms of the sum total of the direct and the indirect footprints.

For example, Figure ES1 demonstrates how a life cycle assessment diagram, records the direct and indirect fossil fuel (megajoules) required to produce \$1,000 output for the construction sector. Of the total fossil fuel requirements of the construction sector the LCA diagram shows that the direct fossil fuel inputs (316.2 MJ/\$,1000) are only 17% of the total fossil fuel inputs (1,864.2). There are significant first round indirect inputs some of which exceed the direct fossil fuel inputs, such as from the fossil fuels embodied in "wood products" (e.g. dressed timber, particleboard), "non-metal products" (e.g. glass, cement, plaster) and the "metal products (e.g. aluminium, steel) all of which are required for construction primarily of buildings and houses. A significant strength of the input-output analysis algorithm is that it tracks indirect inputs, in this case fossil fuels, up the supply chains to a set point where they become insignificant – usually, as can be seen from Figure ES1 this means measuring the indirect inputs back to the third or fourth round. Another strength of the input-output methodology employed in the study, is that it measures not only the 'depth' of inputs back up the supply chains, but it also comprehensively measures the 'width' of inputs encapsulating inputs such as "finance insurance and business services" which is often overlooked in process-based life cycle assessment exercises.⁴

³ The environmental footprints of all sectors for 2004 are documented in each chapter of this publication, as well as summarised being as well as being summarised by Tables ES1 and ES2.

⁴ It needs to be acknowledged that although input-output analysis comprehensively measures the the full depth (and width) of supply chains, this needs to be balanced against the aggregation error of input-output analysis compared with LCA process analysis , and this is one of the reasons why a hybrid approach is often advocated.

Figure ES2 provides another of visualising the results presented in Tables ES1 and ES2. Although such graphics are useful in conveying the results of the eco-efficiency analysis at an aggregate level, such graphics need to be carefully interpreted and contextualised.

Future Research

Although the data can be updated to 2019, by using Statistics New Zealand's inflation indices, change of output for each sector, and other data such as from EECA Energy End Use Database, there is an urgent need to update the base data when it comes to the direct environmental footprints of each sector – this not only means that the direct environmental footprints of each sector is measured, but it also means that the indirect environmental footprints can then be calculated for 2019 by using input-output analysis.

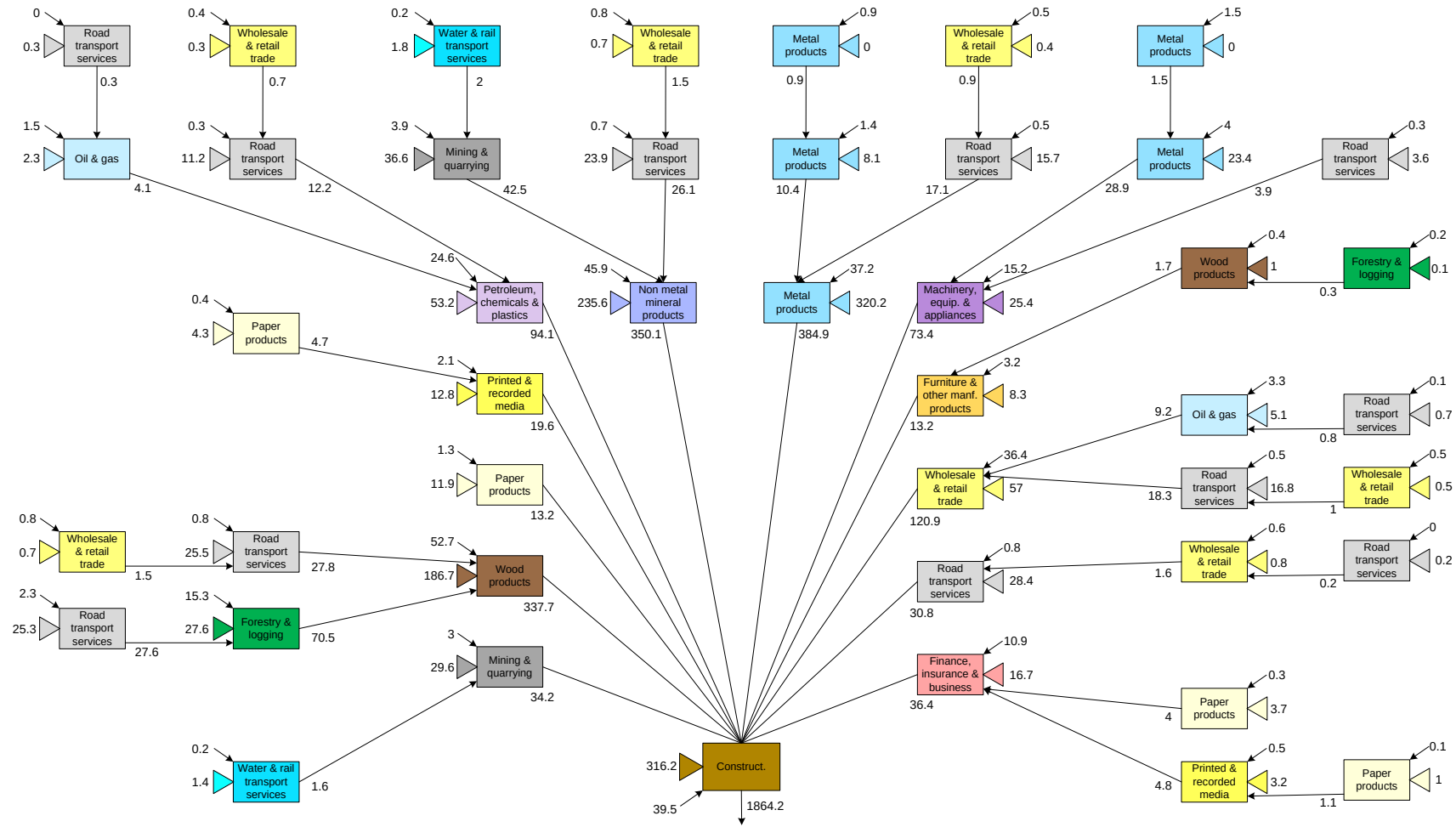
A significant amount of the base data used in this publication to calculate the eco-efficiency and environmental footprint indicators, was derived from the *EcoLink* project funded by the Ministry for the Environment and a participating Regional, City and District Councils, based on mining Regional Councils consents and monitoring databases. These base data were updated in a New Zealand economy physical input output table which was constructed in a PhD thesis (McDonald, 2005)⁵.

Even though in this publication, there has been some comparison of our input-output based results, with results published in the Life Cycle Assessment literature, more research is required to compare these results, and to explain any differences.

The most urgent need is to incorporate methane emissions into the input-output analysis. Without this, some of carbon footprints (from energy use) are incomplete particularly as they don't take account of methane emissions from ruminant animals, such as cattle and sheep. This is important because it is known at an aggregate level, in terms of global warming potential, methane emissions from agriculture are close to levels of carbon dioxide emissions from energy use.

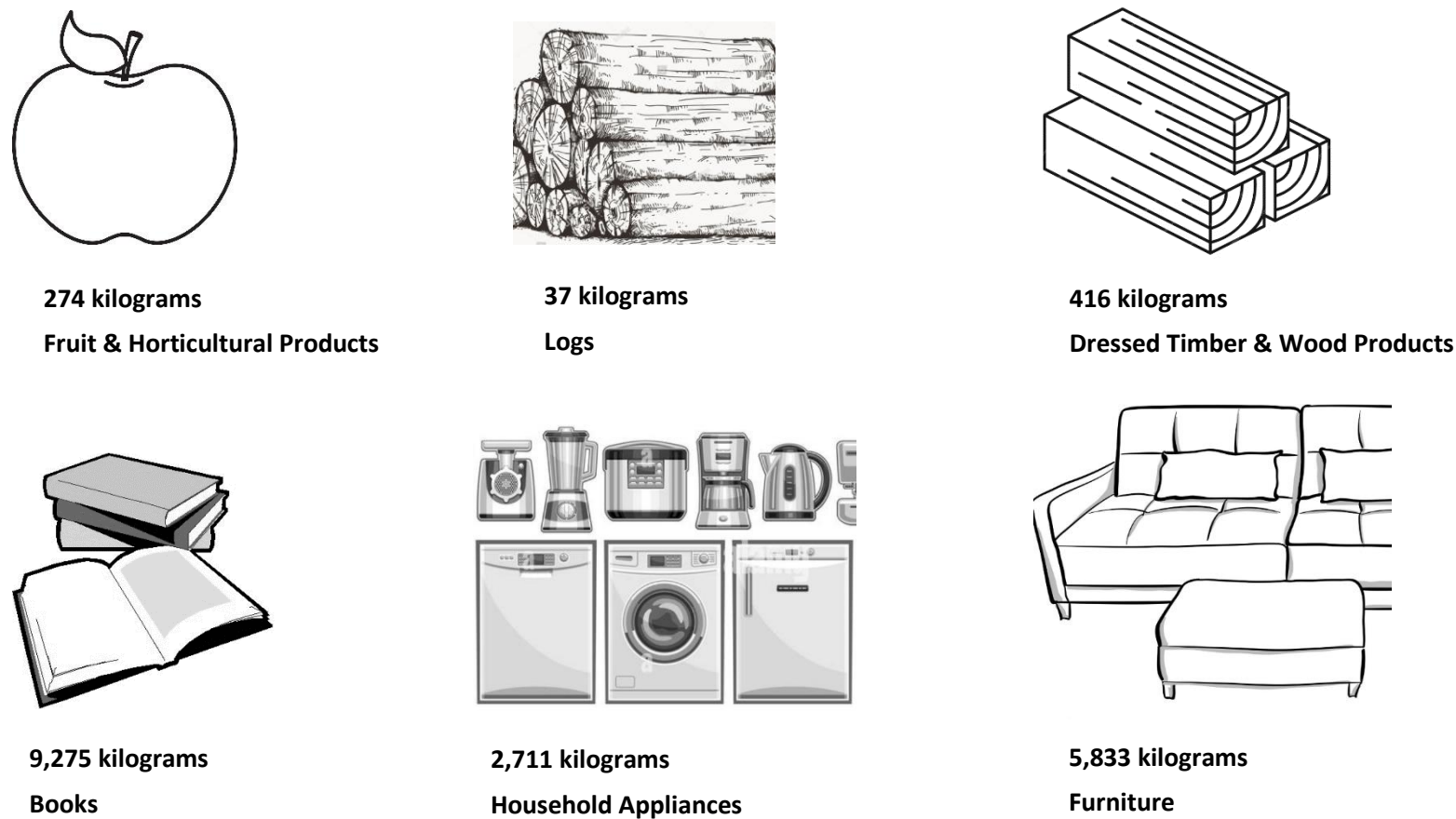
⁵ McDonald, G. 2005. Integrating Economics and Ecology: A Systems Approach to Sustainability In the Auckland Region. PhD Thesis, Massey University, Palmerston North, New Zealand.

Figure ES1 Direct and Indirect Fossil Fuels (Megajoule), to Produce of \$1,000 of Construction Sector Output, 2004



Triangle = Direct Fossil Fuel Inputs (Megajoules) A , Rectangle = Indirect Fossil Fuel Inputs (Megajoules) B , Inward Arrow with no Rectangle = Unspecified Indirect Fossil Fuel Inputs (Megajoules) C
Total Output of Sector D = A + B + C (Megajoules)

Figure ES2 Kilograms of Carbon Dioxide Emissions Needed to Make One Tonne of Product⁶



⁶ Direct and Indirect Inputs Carbon Dioxide Emissions Required to Make 1 Kilogram of Product, Across the Entire Supply Chain, in 2019. These are only Carbon Dioxide Emissions that result from energy use in the economy. Refer to last column in Table ES 2. These Carbon Dioxide Emissions are Representative of One of the Main Products of Each Sector.

Table ES1 Eco-efficiency Indicators: Direct and Indirect Resources and Pollutants, per Tonne of Product, of Sectors in the New Zealand Economy, 2004

Sectors	Total Energy ¹	Fossil Fuel	Electricity	Land inputs	Water Inputs ²	Landfill Wastes	Water Wastes ³	Phosphorus Wastes	CO ₂ from Energy ⁴	Main Products ⁵
	MJ per tonne	MJ per tonne	MJ per tonne	m ² per tonne	litres per tonne	grams per tonne	litres per tonne	grams per tonne	grams per tonne	
Horticulture and Fruit Growing	3,737	3,100	638	924	28,184	10,657	16,131	97	326,387	Apples
Livestock and Crop Farming	4,869	4,172	698	46,563	14,491	16,821	28,861	5,680	358,626	Sheep, Beef Cattle
Dairy Cattle Farming	1,277	986	291	1,960	8,477	4,065	9,738	206	92,120	Raw Milk
Forestry and Logging	644	542	102	13,712	145	1,140	1,133	17	44,369	Rough Sawn Timber
Mining and Quarrying	445	360	85	31	10,641	344	35,276		31,241	Coal, Ironsand
Meat and Meat Product Manufacturing	15,883	12,976	2,907	74,999	84,436	61,636	109,126	9,506	1,129,426.3	Beef, Lamb & Mutton
Dairy Products Manufacturing	11,908	9,776	2,132	6,895	6,259	49,303	75,337	775	848,351	Processed Milk, Butter
Beverage, Malt and Tobacco Manufacturing	5,572	4,075	1,497	1,098	12,027	33,283	15,998	134	446,130	Soft Drinks, Beer, Wine
Textile and Apparel Manufacturing	31,666	24,478	7,187	40,551	58,589	185,690	93,313	5,121	2,169,658	Textiles, Processed Wool
Wood Product Manufacturing	4,975	4,078	897	1,642	308	45,630	6,104	30	494,971	Dressed Timber
Paper and Paper Product Manufacturing	8,107	3,424	4,683	490	13,597	37,045	39,010	8	1,919,183	Paper Products
Printing, Publishing and Recorded Media	98,979	80,828	18,151	1,417	26,204	240,434	118,925		11,041,924	Newspapers, Books
Petroleum, Plastic, Rubber, Industrial Chemicals	4,246	3,083	1,163	230	44,760	79,281	53,169	23	297,633	Petroleum, Chemicals
Non-Metallic Mineral Product Manufacturing	2,565	2,194	372	56	6,422	9,024	26,654		202,434	Glass, Cement, Plaster
Basic, Structural and Fabricated Metal	18,242	10,007	8,235	140	29,845	27,374	89,545		1,288,620	Aluminium, Iron & Steel
Transport Equipment Manufacturing	12,419	9,245	3,174	1,117	30,816	72,261	50,171		960,013	Motor Vehicles & Parts
Machinery and Other Equipment	44,753	29,300	15,453	1,225	40,539	211,216	125,410		3,227,115	Household Appliances
Furniture and Other Manufacturing	63,307	55,175	8,133	4,456	56,620	365,430	155,463		6,943,840	Furniture

Notes

1. Only Includes commercial energy forms and wood. Does not include solar energy.
2. As consented. Does not include precipitation or water used for irrigation.
3. Point Source Discharge.
4. Divide by 1,000,000 to get '1 kg of CO₂ per 1 kg of Product'. The latter is a commonly used indicator,
5. Main Products in terms of tonnes.

Table ES2 Eco-efficiency Indicators: Estimated¹ Direct and Indirect Resources and Pollutants, per Tonne of Product, of Sectors in the New Zealand Economy, 2019

Sectors	Total Energy ²	Fossil Fuel	Electricity	Land inputs	Water Inputs ³	Landfill Wastes	Water Wastes ⁴	Phosphorus Wastes	CO ₂ from Energy ⁵	Main Products ⁶
	MJ per tonne	MJ per tonne	MJ per tonne	m ² per tonne	litres per tonne	grams per tonne	litres per tonne	grams per tonne	grams per tonne	
Horticulture and Fruit Growing	3,625	3,007	618	970	25,366	6,479	14,518	74	274,165	Apples
Livestock and Crop Farming	4,723	4,046	677	46,563	13,042	10,227	25,975	4,301	301,246	Sheep, Beef Cattle
Dairy Cattle Farming	1,239	957	282	2,156	7,629	2,471	8,764	156	82,908	Raw Milk
Forestry and Logging	625	526	99	13,712	130	693	1,020	13	37,270	Rough Sawn Timber
Mining and Quarrying	432	349	83	32	9,577	209	31,748		26,243	Coal, Ironsand
Meat and Meat Product Manufacturing	14,389	11,755	2,634	82,498	75,992	37,474	98,213	7,197	948,564	Beef, Lamb & Mutton
Dairy Product Manufacturing	10,788	8,856	1,931	10,342	5,633	29,976	67,803	587	712,615	Processed Milk, Butter
Other Food Manufacturing	5,819	5,217	602	592	3,556	31,063	7,015	53	372,298	Grocery Foods
Beverage, Malt and Tobacco Manufacturing	5,048	3,691	1,356	1,208	10,824	20,236	14,398	102	374,750	Soft Drinks, Beer, Wine
Textile and Apparel Manufacturing	28,688	22,176	6,511	44,606	52,730	112,898	83,981	3,877	1,822,513	Textiles, Processed Wool
Wood Product Manufacturing	4,507	3,694	813	1,806	277	27,743	5,493	23	415,776	Dressed Timber
Paper and Paper Product Manufacturing	7,344	3,102	4,242	538	12,237	22,523	35,109	6	1,612,114	Paper Products
Printing, Publishing and Recorded Media	89,671	73,227	16,444	1,558	23,584	146,183	107,033		9,275,216	Newspapers, Books
Petroleum, Plastic, Rubber, Industrial Chemicals	3,846	2,793	1,054	253	40,284	48,202	47,852	17	250,011	Petroleum, Chemicals
Non-Metallic Mineral Product Manufacturing	2,324	1,987	337	61	5,779	5,487	23,989		170,045	Glass, Cement, Plaster
Basic, Structural and Fabricated Metal	16,526	9,066	7,460	154	26,860	16,643	80,591		1,159,758	Aluminium, Iron & Steel
Transport Equipment Manufacturing	11,251	8,376	2,876	1,229	27,734	43,935	45,153		806,411	Motor Vehicles & Parts
Machinery and Other Equipment	40,544	26,544	14,000	1,348	36,485	128,418	112,869		2,710,777	Household Appliances
Furniture and Other Manufacturing	57,354	49,986	7,368	4,902	50,958	222,180	139,917		5,832,825	Furniture

Notes

1. Estimated based on known and implied changes in the technical eco-efficiency indicators from 2004.
2. Only includes commercial energy forms and wood. Does not include solar energy.
3. As consented. Does not include precipitation or water used for irrigation.
4. Point Source Discharge.
5. Divide by 1,000,000 to get '1 kg of CO₂ per 1 kg of Product'. The latter are commonly used units in carbon emissions accountancy.
6. Main Products in terms of tonnes.

Table ES3 Eco-efficiency Indicators: Direct and Indirect Resources and Pollutants per \$1,000 of Product of Sectors¹ in the New Zealand Economy, 2004⁵

Sectors	Total Energy ²	Fossil Fuel	Electricity	Land inputs	Water Inputs ³	Landfill Wastes	Water Wastes ⁴	Phosphorus Wastes	CO ₂ from Energy	Main Products
	MJ per \$ 000	MJ per \$ 000	MJ per \$ 000	m ² per \$000	litres per \$000	grams per \$000	litres per \$000	grams per \$000	grams per \$000	
Construction Services	3,472	2,671	801	408	4,516	38,761	17,768		281,352	Buildings and Houses, Roads
Wholesale and Retail Trade	4,262	3,398	865	848	37,880	19,725	13,257		347,926	Retail & Wholesale Products
Accommodation, Restaurants and Bars	4,439	2,679	1,760	1,692	5,979	36,084	7,521	213	295,388	Accommodation, Restaurants
Road Transport	13,017	12,779	238	114	4,609	15,533	4,973		901,240	Road Freight, Bus, Taxi
Water and Rail Transport	7,968	7,045	922	217	3,406	6,650	4,923		544,631	Rail Freight, Shipping
Air Transport, Services to Transport & Storage	4,748	4,350	398	118	3,955	0	4,191		299,079	Passenger Air Transport
Communication Services	837	573	264	26	750	2,071	1,141		61,821	Telco Services, Internet
Finance, Insurance & Business Services	953	620	333	121	1,330	2,993	3,844		85,065	Banking, Insurance, Finance
Central Government Administration & Defence	2,867	2,146	721	350	4,252	10,033	9,104		208,520	Central Government Services
Local Government Administration Services	1,941	1,278	663	44	2,699	10,656	15,316		140,739	Council Services
Education and Training Services	1,261	911	349	54	4,078	5,722	5,702		106,107	Primary & Secondary Schools
Health and Community Services	970	758	212	15	218	9,361	7,571	22	72,880	Medical Services, Dentists
Cultural and Recreational Services	474	289	185	1,279	6,300	3,414	2,763	12	31,833	TV & Radio Broadcasting
Personal and Other Community Services	2,095	1,327	767	153	6,260	9,016	316,121	1,347	156,446	Personal Care, Sewage Treatment

Notes

1. With the exception of Construction and Transport Sectors, these are Service Sectors that primarily do not make physical products.
2. Only includes commercial energy forms and wood. Does not includesolar energy.
3. As consented. Does not include precipitation or water used for irrigation.
4. Point Source Discharge.

Table ES4 Eco-efficiency: Estimated¹ Direct and Indirect Resources and Pollutants per \$1,000 of Product of Sectors² in the New Zealand Economy, 2019

Sectors	Total Energy ³	Fossil Fuel	Electricity	Land inputs	Water Inputs ⁴	Landfill Wastes	Water Wastes ⁵	Phosphorus Wastes	CO ₂ from Energy	Main Products
	MJ per \$ 000	MJ per \$ 000	MJ per \$ 000	m ² per \$000	litres per \$000	grams per \$000	litres per \$000	grams per \$000	grams per \$000	
Construction Services	2,184	1,680	504	257	2,841	24,378	11,175		176,951	Buildings and Houses, Roads
Wholesale and Retail Trade	3,335	2,659	677	664	29,640	15,434	10,373		272,243	Retail & Wholesale Products
Accommodation, Restaurants and Bars	3,330	2,010	1,320	1,270	4,485	27,070	5,642	160	221,596	Accommodation, Restaurants
Road Transport	8,296	8,145	151	73	2,937	9,900	3,169		574,404	Road Freight, Bus, Taxi
Water and Rail Transport	5,078	4,490	588	138	2,171	4,238	3,137		347,120	Rail Freight, Shipping
Air Transport, Services to Transport & Storage	3,441	3,152	289	85	2,866	0	3,037		216,724	Passenger Air Transport
Communication Services	601	412	190	18	539	1,488	820		44,411	Telco Services, Internet
Finance, Insurance & Business Services	639	416	223	81	891	2,006	2,576		57,014	Banking, Insurance, Finance
Central Government Administration & Defence	2,060	1,542	518	251	3,055	7,208	6,540		149,799	Central Government Services
Local Government Administration Services	1,394	918	476	32	1,939	7,655	11,003		101,105	Council Services
Education and Training Services	906	655	251	39	2,929	4,110	4,097		76,226	Primary & Secondary Schools
Health and Community Services	680	531	148	10	153	6,560	5,305	15	51,072	Medical Services, Dentists
Cultural and Recreational Services	341	208	133	919	4,526	2,452	1,985	9	22,868	TV & Radio Broadcasting
Personal and Other Community Services	1,505	953	551	110	4,497	6,477	227,098	968	112,390	Personal Care, Sewage Treatment

Notes

1. Estimated from the 2004 data taking into account: (1) changes in technical eco-efficiency indicators, (2) inflation.
2. With the Exception of Construction and Transport Sectors, these are Service Sectors that do not produce physical products.
3. Only Includes commercial energy forms and wood. Does not included solar energy.
4. As consented. Does not include precipitation or water used for irrigation.
5. Point Source Discharge.

Table ES5 Estimated¹ Environmental Footprints² of Sectors in the New Zealand Economy, 2019

Sectors	Total Energy	Fossil Fuel	Electricity	Land inputs	Water Inputs ³	Landfill Wastes	Water Wastes ⁴	Phosphorus Wastes ¹	CO ₂ from Energy
	PJ	PJ	PJ	hectares	Gigalitres	tonnes	Gigalitres	tonnes	kilotonnes
Horticulture and Fruit Growing	9.4	7.8	1.6	238,951	66	17,884	25	204	628
Livestock and Crop Farming	14.6	12.5	2.1	14,391,945	40	33,741	47	14,239	825
Dairy Cattle Farming	16.2	12.5	3.7	2,568,463	100	34,573	48	2,191	899
Forestry and Logging	17.2	14.4	2.7	37,645,248	4	20,312	28	385	907
Mining and Quarrying	19.3	15.6	3.7	149,776	428	9,978	14	0	1,038
Meat and Meat Product Manufacturing	23.5	19.2	4.3	18,394,679	124	65,406	91	12,606	1,375
Dairy Product Manufacturing	29.1	23.9	5.2	2,791,454	15	86,365	120	1,696	1,705
Beverage, Malt and Tobacco Manufacturing	3.0	2.2	0.8	72,185	6	12,912	18	65	199
Textile and Apparel Manufacturing	5.8	4.5	1.3	903,576	11	24,411	34	841	327
Wood Product Manufacturing	26.2	21.5	4.7	1,050,402	2	172,218	239	142	2,143
Paper and Paper Product Manufacturing	23.7	10.0	13.7	173,553	39	77,490	107	22	4,606
Printing, Publishing and Recorded Media	28.4	23.2	5.2	49,292	7	49,356	68	0	2,600
Petroleum, Plastic, Rubber, Industrial Chemicals	30.8	22.3	8.4	202,423	322	411,487	571	150	1,772
Non-Metallic Mineral Product Manufacturing	17.1	14.6	2.5	44,891	42	43,064	60	0	1,108
Basic, Structural and Fabricated Metal	59.0	32.4	26.6	55,090	96	63,415	88	0	3,425
Transport Equipment Manufacturing	2.4	1.8	0.6	26,521	6	10,121	14	0	154
Machinery and Other Equipment	14.7	9.6	5.1	48,782	13	49,621	69	0	870
Furniture and Other Manufacturing	15.2	13.3	2.0	130,163	14	62,977	87	0	1,373

Notes

1. Estimated from 2004 data taking into account: (1) changes in sector outputs, (2) changes in technical eco-efficiency; (3) inflation.
2. Only Includes Primary and Secondary Sectors.
3. Includes Direct and Indirect Footprints.
4. Only includes commercial energy forms and wood. Does not include solar energy.
5. As consented. Does not include precipitation or water used for irrigation.

Glossary

ANZSIC Code. The Australian and New Zealand Standard Industrial Classification (ANZSIC) code is a standardized classification of industry used within Australia and New Zealand. Entities are classified to an industry based on their main economic activity.

Capital (in Economics). Capital has a number of similar, but not necessarily the same meanings, in Accountancy, Commerce, Economics and Finance. Conventionally in Economics, 'Capital' is considered to be one of the main factors of production along with Labour, Land and Information. Capital's distinguishing feature is that although it contributes to production, it is *not used up immediately in the process of production*, unlike raw materials or intermediate goods. That is, other than a small amount of depreciation, it endures across time and generations. In traditional economic models only **physical** and **financial capital** were usually considered, but in more recent years other forms of capital have been developed, including for example **human capital**, **natural capital** and **social capital**. Capital is a central concept in economic analyses of **sustainability** issues, which is explained in a further entry in this glossary.

Carbon Dioxide Equivalents. 'Carbon dioxide equivalents' measure greenhouse gas emissions that are standardised in terms of their 'global warming potential'. In these terms, one tonne of carbon dioxide equals 25 tonnes of methane and 298 tonnes of nitrous oxide based on a 100-year time horizon. Carbon dioxide equivalents are abbreviated to: CO₂e.

Direct Intensity. The amount of natural resource directly used, or wastes/emissions directly produced, per unit of useful output from a given sector. The useful output can be measured in tonnes, litres, tonne-kilometres or monetary units. This does not include natural resources or wastes/emissions embodied in products that are used as inputs by a given sector – refer to **Indirect Intensity** and **Total Intensity**.

Double Counting. When aggregating data or indicators, they can be counted twice or even more than twice. This occurs because individual indicators, to some extent overlap with each other and/or are not totally independent of each other. When double counting is not eliminated (or adjustments not made for it) during the aggregation process, this can lead to an overestimation of an aggregate indicator.

Environmental Footprint. An environmental footprint represents the quantity of ecological assets that are required to support people or the economy, such as producing natural resources to consume or to absorb its wastes such as carbon emissions. Accordingly, for example, a **Water Footprint** measures the amount of water used to produce goods and operate services. There are three classifications of water footprint. Firstly, a **Green Water Footprint** measures the water from precipitation stored in the root zone for the soil and evaporated, transpired or incorporated by plants, this is particularly relevant for agricultural, horticultural, and forestry-related sectors. A **Blue Water Footprint** which measures the amount of water from surface or groundwater resources that is either evaporated, incorporated into a product, or taken from one body of water and returned to another catchment at a different time. Finally, a **Grey Water Footprint** measures the amount of freshwater required to assimilate pollutants to meet specific water quality standards.

Eco-efficiency. It is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution. Operationally, eco-efficiency can be measured as the ratio between useful outputs of a sector or process, relative to the amount of natural resource used or pollution/wastes produced by that given sector or process.

Economies of Scale. In microeconomic theory, economies of scale refers to the cost advantages earned by firms or industries as their scale of production increases. Production becomes more efficient and the cost per unit of output decreases.

Environmental Multiplier. A vector (row of numbers) that quantify the direct and indirect natural resources required to produce a given amount of economic output, or the direct and indirect emissions/wastes/residuals that result from producing a given amount of economic output. Such 'environmental multipliers' are determined by using input-output based matrix algebra techniques.

Ecosystem Service. An ecosystem process, function or quantity that is beneficial to humans and has a positive impact on human well-being. It is measured as a **flow**. Typically, ecosystem services are derived from natural capital which is a **stock**. Examples of ecosystem services include; climate regulation, water purification, processing of industrial wastes, provisioning of food and fibre, the habitat of valued species, buffering from storm events, and pollination.

Emergy. The measurement of energy that takes into account differences in energy quality, when energy quality is measured from a systems perspective of the transformation of energy inputs to energy outputs.

Energy Efficiency and Conservation Authority (EECA). A New Zealand Government agency responsible for improving the energy efficiency of NZ homes and businesses, while encouraging the uptake of renewable energy. As part of these objectives, EECA have produced their **Energy End Use Database**. This database estimates national end use energy consumption broken down by different categories.

Exclusive Economic Zone (EEZ). The area over which a coastal state has jurisdiction over the exploration and exploitation of marine resources in its adjacent section of the continental shelf, taken to be a band extending 200 miles from the shore.

Emissions Trading Scheme (ETS). This is the NZ Government's main tool for meeting climate change targets. As businesses must purchase enough units to cover their emissions, setting a price on these greenhouse gas emissions encourages the reduction of greenhouse gas emissions.

Externality. A consequence of economic activity that has no market price but impacts negatively or positively on well-being. An example of a negative externality (cost externality) is industrial greenhouse gas emissions that contribute to climate change, which has a number of well documented negative impacts on human well-being. An example of a positive externality (benefit externality) could be a farmer planting riparian margins to improve the water quality of a stream in the farmer's property – but downstream users also benefit from the improved water quality without incurring any financial cost.

Flows. A flow variable is measured over an interval of time. Therefore, a flow is measured as a 'quantity' per 'unit of time' – for example, 20 tonnes of aluminium produced per day. **Stocks**, on the other hand, are the measurement of a quantity, at a certain point in time – for example, the volume of water in Lake Taupo at 12 noon 1 December 2018. Economists and system modellers often refer to 'stocks and flows'.

Gross Domestic Product (GDP). The total market value of the final goods and services produced by a national economy in a given year. The most widely used measure of national economic performance. Dividing this value by the nation's population gives the **Per Capita** level of GDP, which is appropriate metric in comparing the GDP performance of different nations particularly when there is significant difference in their populations.

Indirect Intensity. The amount of natural resources or wastes/emissions embodied in inputs used by a given sector, per unit of useful output produced by that sector. The useful output can be measured in tonnes, litres, tonne-kilometres or monetary units.

Industry. In this publication, the term 'industry' is usually use synonymously with the term 'sector'. Refer to the definition of a 'sector' in this glossary.

Life Cycle Assessment. A technique used to examine the inputs and outputs of materials and energy, including the associated environmental impacts directly attributable, used in the functioning of a good or service throughout its life cycle. These flows can be represented graphically in the form of a **Life Cycle Assessment Diagram**, a guide to interpret these diagrams can be found at the end of the methodology section.

Sector. A branch of the economy producing similar products by usually similar processes. In this publication the term 'sector' is usually used interchangeably term 'industry'. Sometimes the term industry is avoided as it can sometimes referred to 'manufacturing' or 'processing' sectors, which is potentially confusing.

Sustainability. There is no one unequivocal measure of 'sustainability'. Its meaning can vary according to its academic and policy context – refer to **Sustainability (Economics)**, **Sustainability (Ecological)**, and **Sustainability (Policy and Planning)**.

Sustainability (Ecology). Ecological systems are always in a state of change, which presents challenges in defining what sustainability may mean from an ecological perspective. That said, sustainability in ecology means maintaining an ecological system so it can persist and be resilient over time. If the systems 'ecological limits' are exceeded, then the system is irreversibly changed, ceases to exist, or there is a regime shift to another relatively stable system.

Sustainability (Economics). In economics, it can be defined as 'strong' or 'weak' sustainability. 'Strong' sustainability refers to at least maintaining the same aggregate level of natural capital stock across generations. 'Weak' sustainability, refers to at least maintaining the same aggregate level of capital stock across generations, adding up all the capitals (manufactured, natural and so forth). That is, under 'weak sustainability' natural capital can decline from generation to generation, as long as it is at least matched by an increase in the aggregate stock of the other capitals (particularly manufactured capital). In this publication, unless otherwise stated, when using the term 'sustainability' we are referring to 'weak sustainability'. 'Weak sustainability' assumes that there is substitutability between the different forms of capital.

Sustainability (Policy and Planning). The attempt often used in policy analysis and planning to 'balance' the different dimensions of sustainability (economic, social, environmental) in order to develop and implement policies to achieve the 'best' overall outcomes for a community or for a country. There is no *a priori* assumption that any one of these dimensions of sustainability is more or less important than any other dimension – as opposed to the Russian-doll model of sustainability, which has the following implicit hierarchy of importance: environmental > social > economic.

Technical Eco-Efficiency. Technical eco-efficiency refers to the physical relationship between natural resource inputs (or pollutants/emissions/wastes) relevance of the output of a process or sector.

Total Intensity The total amount of natural resources or wastes/emissions embodied in the inputs used by a sector, per unit of useful output produced by that sector. The useful output can be measured in tonnes, litres, tonne-kilometres or monetary units . The total intensity is arithmetically the **direct intensity** plus the **indirect intensity**. In this publication the terms 'eco-efficiency' and 'total intensity' are calculated in the same way and these terms can be used interchangeably.

Measurement Units

Energy Units⁷

J = 1 Joule

kJ = 1 kilojoule = 1,000 joules

MJ = 1 Megajoule = 1,000,000 joules

GJ = 1 Gigajoule = 1,000,000,000 joules

TJ = 1 Terajoule = 1,000,000,000,000 joules

PJ = 1 Petajoule = 1,000,000,000,000,000 joules

MJ_{OE} = Megajoule = Megajoules measured in Oil Equivalents. 1 MJ_{OE} = 10,000 MJ_{SE} (emergy units)⁸

MJ_{SE} = Megajoule = Megajoules measured in Solar Equivalents. MJ_{SE} = 0.0001 MJ_{OE}

MJ_H Megajoule = Megajoules measured in heat content.

Other Units

g = gram

kg = kilogram = 1,000 grams

tonne = 1,000 kilograms = 1,000,000 grams

L = litre

ML = Megalitre = 1,000,000 litres

GL = Gigalitre = 1,000,000,000 litres

CO₂e = Carbon Dioxide Equivalents. Refer to the Glossary.

m² = square metre of area

ha = hectare = 10,000 m²

⁷ Unless stated all energy units measured in this report are measured in terms of heat content, which is conventional practice.

⁸ So that different energy types can be validly aggregated that they are first of all normalised in terms of their energy quality by converting them to emergy units (solar equivalents or oil equivalents). We prefer oil equivalents because of the inaccuracies involved in converting commercial energy forms back to solar inputs. Refer to Table 1 in Patterson (2012). Patterson, M.G. 2012. Are All Processes Equally Efficient from an Emergy Perspective? Analysis of Ecological and Economic Networks Using Matrix Algebra Methods. *Ecological Modelling* 77-91 226:

Contents

Executive Summary

Glossary

Measurement Units

1.	Introduction	1
2.	Methodology.....	11
3.	Data sources.....	26
4.	Horticulture and Fruit Growing.....	30
5.	Livestock and Crop Farming.....	44
6.	Dairy Cattle Farming	59
7.	Forestry and Logging.....	73
8.	Mining and Quarrying	87
9.	Meat and Meat Product Manufacturing.....	100
10.	Dairy Product Manufacturing	114
11.	Beverage, Malt and Tobacco Manufacturing.....	129
12.	Textile and Apparel Manufacturing	143
13.	Wood Product Manufacturing	157
14.	Paper and Paper Product Manufacturing	171
15.	Printing, Publishing and Recorded Media.....	185
16.	Petroleum, Plastic, Rubber and Industrial Chemical Manufacturing.....	197
17.	Non-Metallic Mineral Product Manufacturing	211
18.	Basic, Structural and Fabricated Metal Manufacturing	223
19.	Transport Equipment Manufacturing	236
20.	Machinery and Other Equipment Manufacturing	248
21.	Furniture and Other Manufacturing	260
22.	Construction Services.....	272
23.	Wholesale and Retail Trade	284
24.	Accommodation, Restaurants and Bars.....	296
25.	Road Transport	309
26.	Water and Rail Transport.....	321
27.	Air Transport, Services to Transport and Storage.....	333
28.	Communication Services.....	344

29.	Finance, Insurance, Property and Business Services	356
30.	Central Government Administration and Defence	368
31.	Local Government Administration Services.....	381
32.	Education and Training Services	394
33.	Health and Community Services	407
34.	Cultural and Recreational Services	420
35.	Personal and other Community Services.....	434
36.	Ecosystem Services	476
37.	Bibliography	462

1. Introduction

There is a rising global concern regarding the negative environmental impacts associated with the production and consumption of products. New Zealand has a high level of greenhouse gas emissions per person, already having wide-ranging impacts on the natural and man-made world.⁹ Similar trends have been seen around the world.¹⁰ This has led to the development of methods to better understand and address these impacts, one notable technique that has been developed is Life Cycle Assessment (LCA).

This publication is intended as a resource to help further guide and develop Life Cycle Assessment of sectors, products and services in New Zealand.

What is Life Cycle Assessment?

Definition

LCA is an analytical approach used to assess the environmental impacts of a chosen good, service, or manufacturing process. Also known as “cradle-to-grave” analysis, it tracks all inputs such as raw materials, energy, and land used in production and the corresponding outputs such as waste products. As a result of this holistic approach, LCA allows for the estimation of the environmental burden resulting from all stages in a product’s lifecycle, providing an extensive picture of the environmental impact of goods, services, or sectors from production through to disposal.¹¹ The International Organization for Standardization (ISO) define LCA as “a technique for assessing the environmental aspects and potential environmental impacts, such as the use of resources, throughout a product’s life cycle from raw material acquisition through production, use, end-of-life treatment, recycling, and final disposal.”¹²

As part of an LCA study, there are four phases; 1) the goal and scope definition phase; 2) the inventory analysis phase; 3) the impact assessment phase; 4) the interpretation phase.¹³

Approaches/Methodologies

Various approaches and adaptations have been developed to conduct LCA. Two notable approaches are process-based, which provides data relevant to specific materials and processes, and Input-Output (IO) based methods, which provides an aggregate, economy-wide view.

The process-based methodology focusses on a specific manufacturing process or product. In this approach, the environmental impact of inputs and outputs of the production process are initially estimated, which includes the raw materials required for production and wastes/emissions discharged into the environment. Following this, the environmental impacts of both the upstream and downstream activities associated with the initial production process are estimated. Again, these include activities that cover the whole lifecycle of the specific production process from the extraction

⁹ Ministry for the Environment. (2019). *Environment Aotearoa 2019 Summary*. Wellington, New Zealand: Ministry for the Environment. Retrieved from <https://www.mfe.govt.nz/environment-aotearoa-2019-summary>

¹⁰ World Bank Group. (2014). *Turn Down the Heat : Confronting the New Climate Normal*. Washington, DC: World Bank. Retrieved from <https://openknowledge.worldbank.org/handle/10986/20595>

¹¹ Scientific Application International Corporation. (2006). *Life Cycle Assessment: Principles and Practice*. Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRML&dirEntryId=155087

¹² ISO. (2007). *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework*. Geneva, Switzerland: ISO. Retrieved February 7, 2020, from <https://www.iso.org/standard/37456.html>

¹³ Ibid.

of the raw material to the disposal of the final product.¹⁴ This provides a detailed estimate of the entire environmental impact associated with the specific production process or product, giving a deep understanding of the environmental impacts of a single production process. Furthermore, a detailed breakdown of the entire production process allows for the identification of areas for process improvements. The ability to identify where most negative environmental impacts are generated allows for the improvement in these specific activities.¹⁵

While the detail and depth of analysis of a single production process is a benefit, limits or boundaries need to be placed subjectively as to how detailed the analysis will be. Production processes can be delineated to a very fine level, often causing the scope of the analysis to spiral out of control.¹⁶ These chosen boundaries may omit environmental impacts or lifecycle stages from the analysis leading to a truncation error and a potential underestimation of the environmental impacts caused by the manufacturing process.¹⁷ Secondly, while a detailed estimation of the environmental impact of a single production process is obtained, this approach provides a very limited analysis of the environmental impact of the economy as a whole. Therefore, analysis of interconnectivity of industries and their effects on the environment is lacking using this approach.

The minimal breadth of the process-based methodology provides a significant drawback when requiring an analysis of the entire economy. A second, most notable approach to this problem is the use of an IO-based methodology. This approach illustrates linkages between sectors rather than a specific process or product, representing the transactions between all industry sectors and providing an illustrative look at the economy as a whole.¹⁸ To achieve this, products and manufacturing chains are aggregated resulting in units such as agricultural output rather than individual commodities, such as tomatoes, as would be the case under a process-based LCA. An IO-based methodology takes a top-down approach, using the whole economy as the boundary, rather than the subjective choice of boundary when implementing a process-based approach.¹⁹ Implementing an IO table, which is a static representation of how much sectors buy from each other for each unit produced in each sector, allows for the estimation of the environmental impacts created by the upstream supply chain to produce each unit from a given sector. As sectors are aggregated these estimations are given as an industry average.²⁰

In contrast to the process-based approach, the IO-based approach covers a wider *breadth of analysis*, providing information on environmental impacts from all sectors of the economy. However, the drawback of IO approach is the *aggregation problem* – as processes²¹ and commodities are aggregated, there is limited understanding and uncertainty concerning their component processes and their environmental impacts. Given the aggregated nature of the IO data, the accuracy of this estimation depends on the level of homogeneity of products and processes in relation to other

¹⁴ Jensen, A. A., Christiansen, K., Elkington, J., Hoffman, L., Møller, B. T., Schmidt, A., & van Dijk, F. (1998). *Life cycle assessment (LCA) - a guide to approaches, experiences and information sources*. Copenhagen, Denmark: European Environment Agency. Retrieved from https://www.researchgate.net/publication/299446257_Life_cycle_assessment_LCA_-_a_guide_to_approaches_experiences_and_information_sources

¹⁵ Carnegie Mellon University Green Design Institute. (2020). *Economic Input-Output Life Cycle Assessment*. Retrieved February 7, 2020, from <http://www.eiolca.net/>

¹⁶ Hendrickson, C., Horvath, A., Joshi, S., & Lave, L. (1998). Economic Input-Output Models for Environmental Life-Cycle Assessment. *Environmental Science & Technology*, 32(7), 184A-191A. DOI: 10.1021/es983471i

¹⁷ Lave, L. B., Cobas-Flores, E., Hendrickson, C., & McMichael, F. C. (1995). Using input-output analysis to estimate economy-wide discharges. *Environmental Science and Technology*, 29(9), 420A-426A. DOI: 10.1021/es00009a748

¹⁸ Carnegie Mellon University Green Design Institute. (2020). *Economic Input-Output Life Cycle Assessment*. Retrieved February 7, 2020, from <http://www.eiolca.net/>

¹⁹ Joshi, S. (1999). Product Environmental Life-Cycle Assessment Using Input-Output Techniques. *Journal of Industrial Ecology*, 3(2-3), 95-120. doi:10.1162/108819899569449

²⁰ Hendrickson, C., Lave, L. B., Matthews, H. S., Horvath, A., Joshi, S., McMichael, F. C., . . . Bergerson, J. A. (2006). *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach*

²¹ Sector x Commodity input output tables are used in this analysis. 'Sectors' are an aggregation of 'Processes'. For accurate results, 'processes' that are here aggregated into sectors, should have similar inputs and outputs and similar mixes of inputs and outputs.

products or processes in the same aggregated industry sector. The less homogenous, the less accurate the estimation is likely to be.²²

Furthermore, a range of information regarding international imports is also needed to accurately estimate the impact of industries. Often this information is unavailable, or it requires significant cost or time to obtain. Because of this, alternative measures or assumptions need to be made. Often these foreign imports are “domesticated”, meaning these international inputs follow the same production process as if they were produced domestically. This assumption can limit the accuracy of the estimations due to the difference in industry structures domestically and internationally not being accounted for.^{23 24}

Due to the strengths and weaknesses of both process- and IO-based LCAs, there is an opportunity to combine the two methods resulting in new hybrid approaches. Hybrid LCA approaches are widely applied nowadays as they bridge the gap between the two aforementioned approaches. Hybrid approaches have been pioneered by Moriguchi et al. (1993),²⁵ who analyse the main processes using a process-based approach while analysing remote, far upstream flows using an IO-based approach. Similarly, using a hybrid approach, Pairotti et al. (2015)²⁶ evaluate the environmental sustainability of a range of different diets, namely their energy and carbon footprints. Here, the hybrid method used is based on the lifecycles of products from specific product categories, in which some stages of the cycle are accounted through standard LCA and others via IO. Further examples of hybrid approaches are given by, but not limited to, Hendrickson et al. (2006),²⁷ Bilec et al. (2006),²⁸ Lenzen and Crawford (2009),²⁹ and Crawford (2014).³⁰ Suh and Huppes (2005),³¹ provide a comparison of the two different approaches with a range of hybrid approaches. They found that while not one method is superior to all others, methods excel in different areas and decisions can be made to select the best method depending on the goal, scope, and available resources.

²² Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., . . . Suh, S. (2009). Recent developments in Life Cycle Assessment. *Journal of Environmental Management*, 91(1), 1-21. doi:10.1016/j.jenvman.2009.06.018

²³ Carnegie Mellon University Green Design Institute. (2020). *Economic Input-Output Life Cycle Assessment*. Retrieved February 7, 2020, from <http://www.eiolca.net/>

²⁴ Patterson, M. G., McDonald, G. W., & Smith, N. J. (2011). Ecosystem Service Appropriation in the Auckland Region Economy: An Input-Output Analysis. *Regional Studies*, 45(3), 333-350. doi:10.1080/00343400903241451

²⁵ Moriguchi, Y., Kondo, Y., & Shimizu, H. (1993). Analyzing the life cycle impact of cars: The case of CO₂. *Industry and Environment*, 16(1-2), 42-45.

²⁶ Pairotti, M. B., Cerutti, A. K., Martini, F., Vesce, E., Padovan, D., & Beltramo, R. (2015). Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA-IO method. *Journal of Cleaner Production*, 103, 507-516. doi:10.1016/j.jclepro.2013.12.082

²⁷ Hendrickson, C., Lave, L. B., Matthews, H. S., Horvath, A., Joshi, S., McMichael, F. C., . . . Bergerson, J. A. (2006). *Environmental Life Cycle Assessment of Goods and Services: An Input-Output*

²⁸ Bilec, M., Ries, R., Matthews, H. S., & Sharrard, A. L. (2006). Example of a Hybrid Life-Cycle Assessment of Construction Processes. *Journal of Infrastructure Systems*, 12(4). doi: 10.1061/(ASCE)1076-0342(2006)12:4(207)

²⁹ Lenzen, M., & Crawford, R. (2009). The Path Exchange Method for Hybrid LCA. *Environmental Science & Technology*, 43(21), 8251-8256. doi:10.1021/es902090z

³⁰ Crawford, R. H. (2014). Post-occupancy life cycle energy assessment of a residential building in Australia. *Architectural Science Review*, 57(2), 114-124. doi:10.1080/00038628.2013.819556

³¹ Suh, S., & Huppes, G. (2005). Methods for Life Cycle Inventory of a product. *Journal of Cleaner Production*, 13(7), 687-697. doi:10.1016/j.jclepro.2003.04.001

What is Environmental Footprinting?

Another way of interpreting the results presented in this publication is through the concept of environmental footprints. Originally, Wackernagel and Rees (1996)³² developed the concept of 'ecological footprint' in the early 1990s. The ecological footprint measures the total amount of land required to support an economy, city, community, business or individual person. Then this 'total amount of land' required by these entities or activities, is compared with the total amount of biologically productive land which is available (termed biocapacity), and if the former exceeds the latter, then these activities are deemed to be 'unsustainable'. Ecological footprints in this way are widely used around the world in sustainability assessments.

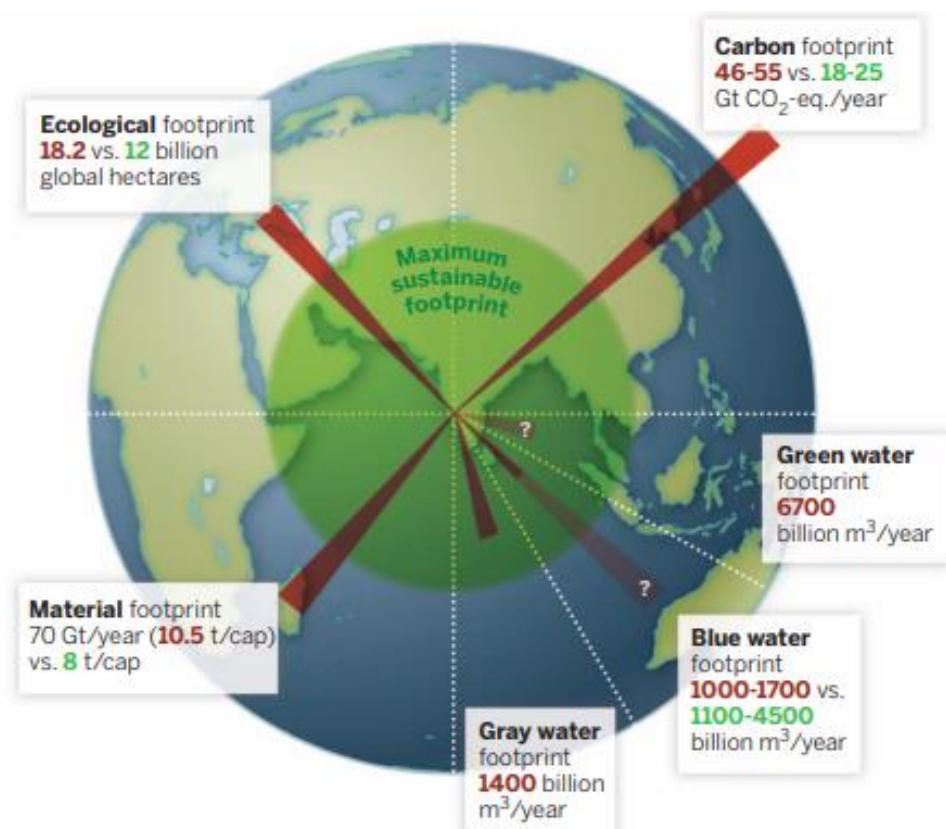


Figure 1.1 Global Environmental Footprints and their Maximum Sustainable Level

(Source: Hoekstra and Wiedmann, 2014)

One criticism of the ecological footprint is that it ultimately measures sustainability in terms of the single metric of land and its availability³³. As pointed out by several authors (Hoekstra and Wiedmann,

³² Wackernagel, M., Rees, W.E., 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers, Philadelphia.

³³ Proponents of ecological footprint argue that other resources (e.g. energy) and wastes (e.g. carbon dioxide) are taken into account in ecological footprinting as: (1) the land required to produce a resource (e.g. land required to produce energy) is as measured; (2) the land required to absorb wastes (e.g. land required to plant trees to absorb carbon dioxide) is measured. This approach however is open to criticism, as this is 'imputed' or 'virtual' land rather than actual land. Interestingly, this concept of 'virtual land' is similar to the concept of 'ghost acreage' previously developed by Borgstrom (1967,1973) which is also advocated by Catton (1982) in his landmark book:

Borgstrom, G., 1967. *The Hungry Planet*. McMillan, New York, USA.

Borgstrom, G., 1973. *Harvesting the Earth*. Abelard-Schuman, New York

Catton, W.R., 1982. *Overshoot: The Ecological Basis of Revolutionary Change*. University of Illinois Press, Urbana

2014³⁴; Tukker et al., 2014³⁵), land is not the only environmental limit to human activities – availability of water, energy and mineral resources impose global and local limits to human activities, and there are limits to the ability of the environment to absorb and process pollutants such as greenhouse gases, nutrients and toxins. Hoekstra and Wiedmann (2014) point out that the global limits of some of these resources and pollutants have already been exceeded, or are close to being exceeded (refer to Figure 1.1). Therefore, in this publication quantitative measures for the ‘environmental footprints’ of sectors and products in the New Zealand economy are systematically covered. These include ‘environmental footprints’ of land, energy separating out electricity and fossil fuels, water, landfill wastes, water wastes, greenhouse gases and ecosystem services. Hence, the data presented in this report is in terms of the broader concept of ‘environmental footprints’ as opposed to the narrow concept of ‘ecological footprint’.

Patterson et al. (2017)³⁶ argues that there is considerable overlap between the methods of ‘life-cycle assessment’, ‘ecological footprints’ and ‘environmental footprints’ as commonly calculated by using input-output analysis. That is, all of these methods have a focus on environmental accounting and sustainability assessment, they all measure direct and indirect impacts through network analysis (either process based, or using input-output analysis), they all encounter similar if not identical methodological problems including the joint production problem, weighting, commensuration of different resources and pollutants, double counting and boundary setting. As Patterson et al. (2017)³⁶ concludes not all these methods are perfect and they all have their methodological strengths and weaknesses, so therefore it is sensible to use a mix of these methods, if at all possible, and certainly analysts should acknowledge the limitations of each method when using them.

Definition

An environmental footprint represents the quantity of environmental assets that are required to support people or the economy, such as producing natural resources to consume or to absorb its waste such as carbon emissions.

Structure/Outline

This publication is structured as follows. First, a conceptual framework of the IO-based approach is provided and followed by a description of the methodological sequence, consisting of 5 phases and 12 steps, to create the economy-wide LCA of New Zealand.

Following this, the data sources used to derive environmental multipliers and Input-Output tables, such as supply use tables, emissions data, and land use data are listed, described, and referenced.

Next, each of the 32 aggregated sectors (i.e. 18 commodity-producing plus 14 service sectors) are then described through their respective ANZSIC codes and commodities produced. An economic overview of each sector is also given, identifying the relative sizes (employment and GDP contribution) as well as the structure of each sector (e.g. key historical moments and players). Following this, production and export trends are produced for each sector with a brief interpretation.

³⁴ Hoekstra, A.Y., Wiedmann, T.O., 2014. Humanity's Unsustainable Environment Footprint. *Science* 344, 1114–1117, <http://dx.doi.org/10.1126/science.12483>

³⁵ Tukker A, Bulavskaya T, Giljum S, de Koning A, Lutter S, Simas M, Stadler K, Wood R, 2014. *The Global Resource Footprint of Nations: Carbon, Water, Land and Materials Embodied in Trade and Final Consumption*. The Netherlands Organisation for Applied Scientific Research, Delf. ISBN: 978-3-200-03637-6

³⁶ Patterson, M.G., McDonald, G., Hardy, D. (2017) Is There More in Common Than We Think? Convergence of Ecological Footprinting, Emergy Analysis, Life Cycle Assessment and Other Methods of Environmental Accounting. *Ecological Modelling* 19-36 362:

LCA diagrams are provided and interpreted for each sector at the end of each chapter. An explanation as to how to interpret these diagrams can be found at the conclusion of the Methodology section. Most sectors are analysed with the following 9 measures: total energy inputs, electricity inputs, fossil fuel inputs, land, water inputs, landfill wastes, wastewater, phosphorous waste, and energy-related CO₂ emissions.

Sector Products and Services

Life-cycle assessment has a focus on the environmental impact of producing a **product or service (commodity)**. Whereas, the data presented in this report first of all focuses on the environmental impact of a **sector**. Fortunately, however the **commodity x sector** physical input output tables used in this analysis, organises sectors in terms of similar products or services which means they have similar environmental impacts (resource use, production of wastes/pollutants).

Care needs to be taken in interpreting the LCA diagrams (Chapter 4 to 36), to imply amounts of resource use and production of wastes of various products or services produced in the economy. Generally speaking, the environmental impact of the production of each commodity listed in the second column of Table 1.1, are close to the environmental impact determined for each sector listed in the first column. This is because a sector is essentially the aggregation of processes that make up the sector that produce the same or similar products.

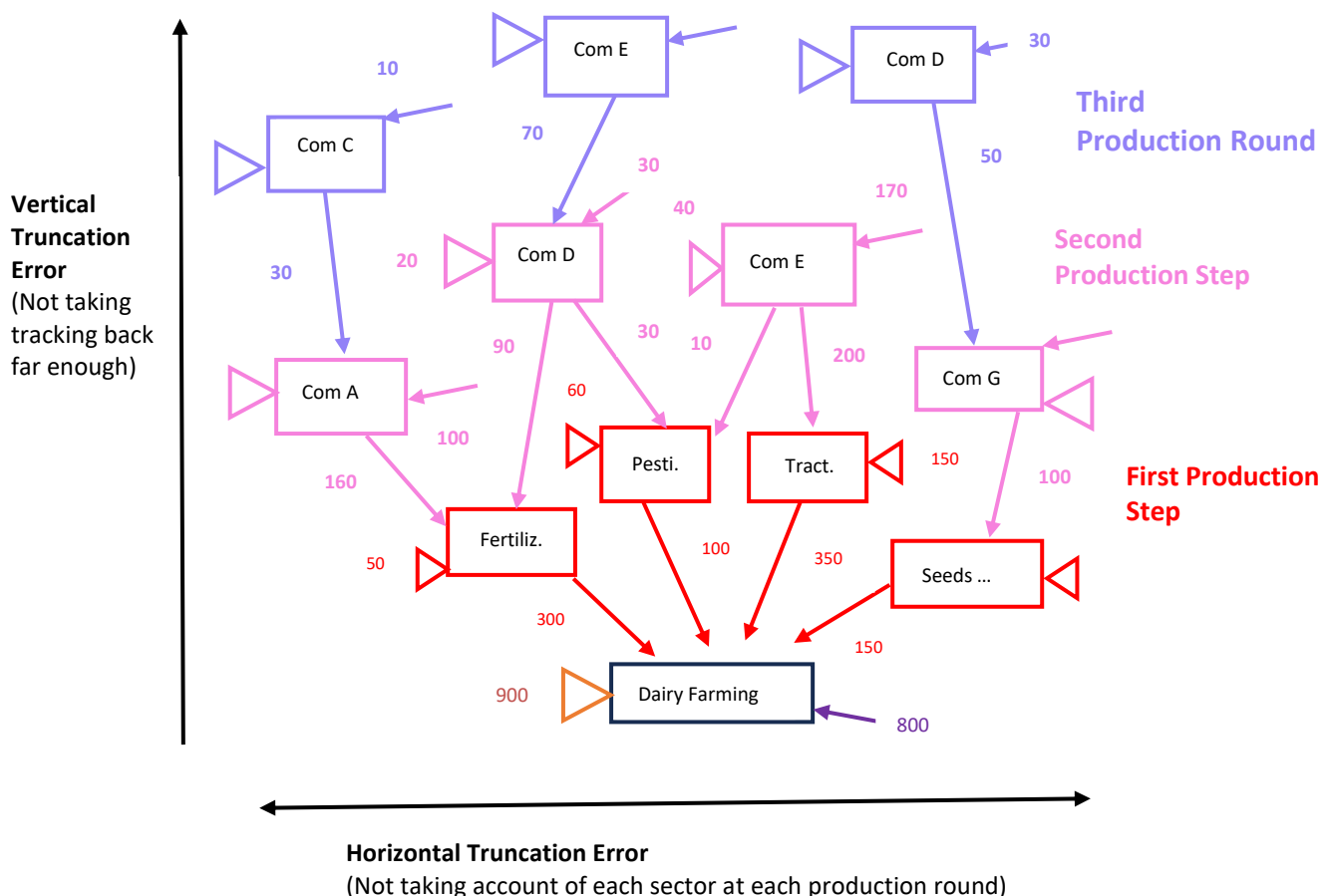


Figure 1.2 Schematic Depiction of Vertical and Horizontal Truncation Error in Lifecycle Assessment

Table 1.1 Commodities Produced by Sectors

Sectors	Commodities ¹	Units
Horticulture and Fruit Growing	Apples , Kiwifruit, Grapes, Other Fruit	tonnes
Livestock and Crop Farming	Sheep, Beef Cattle , Wool, Wheat, Other Grains, Vegetables	tonnes
Dairy Cattle Farming	Raw Milk	000 litres
Forestry and Logging	Rough Sawn Timber , Roundwood	tonnes
Fishing and Aquaculture	Fish , Shellfish, Rock Lobster	tonnes
Mining and Quarrying	Coal , Ironsand, Limestone	tonnes
Meat and Meat Product Manufacturing	Beef Meat, Lamb & Mutton , Deer Meat, Chicken Meat	tonnes
Dairy Product Manufacturing	Processed Milk , Cheese, Butter	tonnes ²
Other Food Manufacturing	Grocery Foods , Processed Fruit, Bread, Confectionary	tonnes
Beverage, Malt and Tobacco Manufacturing	Soft Drinks , Beer, Wine	tonnes ²
Textile and Apparel Manufacturing	Textiles , Processed Wool, Leather Products, Clothing	tonnes
Wood Product Manufacturing	Dressed Timber , Plywood, Wood Chips	tonnes
Paper and Paper Product Manufacturing	Paper Products , Paper, Cardboard, Paper Bags	tonnes
Printing, Publishing and Recorded Media	Newspapers , Books	tonnes
Petroleum, Plastic, Rubber, Industrial Chemicals	Petroleum , Rubber, Chemicals, Plastics	tonnes ²
Non-Metallic Mineral Product Manufacturing	Glass , Cement, Plaster, Ceramics	tonnes
Basic, Structural and Fabricated Metal	Aluminium, Iron & Steel	tonnes
Transport Equipment Manufacturing	Motor Vehicles & Parts , Aircraft, Ships, Engines	tonnes
Machinery and Other Equipment	Household Appliances, Computers , Heating Equipment	tonnes
Furniture and Other Manufacturing	Furniture , Prefabricated Buildings	tonnes
Construction Services	Buildings and Houses , Roads, Bridges, Civil Engineering	\$ 000
Wholesale and Retail Trade	Retail Products , Wholesale Products	\$ 000
Accommodation, Restaurants and Bars	Accommodation , Restaurants, Bar Services, Takeaway Foods	\$ 000
Road Transport	Road Freight , Bus, Taxi	\$ 000
Water and Rail Transport	Rail Freight , Rail Passengers, Shipping	\$ 000
Air Transport, Services to Transport & Storage	Passenger Air Transport , Freight Air Transport	\$ 000
Communication Services	Telecommunications & Internet , Postal Services, Couriers	\$ 000
Finance, Insurance & Business Services	Banking , Insurance, Finance, Legal Services, Real Estate	\$ 000
Central Government Administration & Defence	Central Government Services , Police, Defence, Corrections	\$ 000
Local Government Administration Services	Council Services , Environmental Management, Civil Defence	\$ 000
Education and Training Services	Primary & Secondary Schools , Universities, Pre-School	\$ 000
Health and Community Services	Medical Services , Dentists, Aged Care, Veterinarian	\$ 000
Cultural and Recreational Services	TV & Radio Broadcasting , Creative Arts, Libraries, Museums	\$ 000
Personal and Other Community Services	Personal & Community Services , Sewage Treatment	\$ 000

Notes:

1. Main commodities for each sector are listed. This is not a comprehensive list of commodities.

2. Largest commodity for each sector is in bold (in terms of tonnes, litres or \$₂₀₁₉ 000).

3. For liquid products (milk, soft drinks, beer, wine) 1 tonne ≈ 1,000 litres

Take for example the sector “Textiles and Apparel Manufacturing” (first column of Table 1.1) which is an aggregation of processes that produce either “Textiles”, “Processed Wool” or “Clothing Products” (second column of Table 1.1.). The assumption made here, for any given sector, is that **all products** within that sector have for example the **same resource inputs** (e.g., energy inputs) or produce the **same wastes/pollutants** (e.g. carbon dioxide emissions) – this is the **homogeneity assumption**.

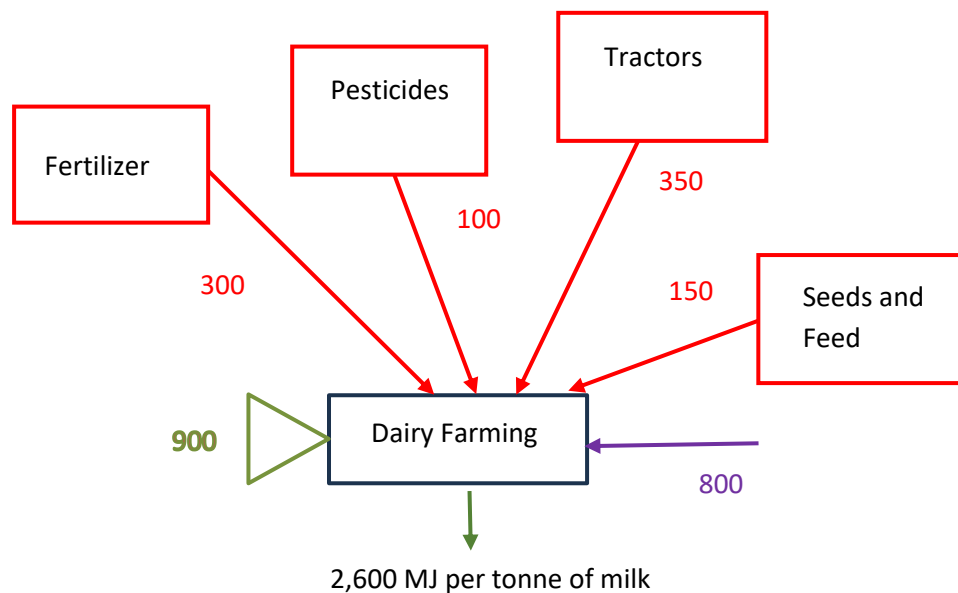
There will be errors in the calculation of the resource inputs and waste/pollution outputs for most of the products and services listed in Table 1.1, as the homogeneity assumption is only an approximating assumption. That said, these errors due to the violation of homogeneity assumption are relatively small, in most cases, and these errors need to be balanced against the improved accuracy of input output analysis in eliminating ‘vertical truncation errors’ and ‘horizontal truncation errors’ that often

occur in LCA analysis – that is: (1) **vertical truncation errors**, as Lenzen and Dey (2000)³⁷ point out, refers to LCA analyses not tracking the resource inputs/wastes back far enough in the supply chain; (2) **horizontal truncation errors** refer to not taking account of all of the sector resource inputs/wastes at any given production step in the supply chain, with typically service sector resource inputs/wastes not being taken account of in many LCA analyses – refer to Figure 1.2.

Finally, it should be noted that although there are 129 commodities in Table 1.1 the input output data used in this analysis contains potentially 210 commodity types which can be related to sectors in Table 1.1.³⁸ Most of these more detailed-level commodities (210) are listed at the beginning of Chapters 4 to 35.

Reading an LCA Diagram

The direct and indirect energy used by the the dairy farming sector can be depicted in terms of the following simplified LCA diagram:



All of the data is expressed in terms of energy inputs (MJ) per unit of mass (tonnes) of milk produced by the dairy farming sector. In these terms:

- the **green triangle** represents the **direct energy inputs** (MJ) into dairy farming – in terms of the dairy farming sector this is mainly electricity to run the milking shed and associated equipment such as refrigeration, and diesel/petrol to run farm machinery such as tractors.
- the **red arrows** represent **indirect energy embodied** in direct (first round) inputs into this simplified dairy farming sector. For example, there is indirect energy required to produce the final product of ‘milk’: fertilizer inputs (300 MJ per tonne of raw milk produced), and pesticide inputs (100 MJ per tonne of milk produced). These direct first-round inputs correspond to the inputs that would appear on a dairy farmer’s balance sheet prepared by his/her accountant.

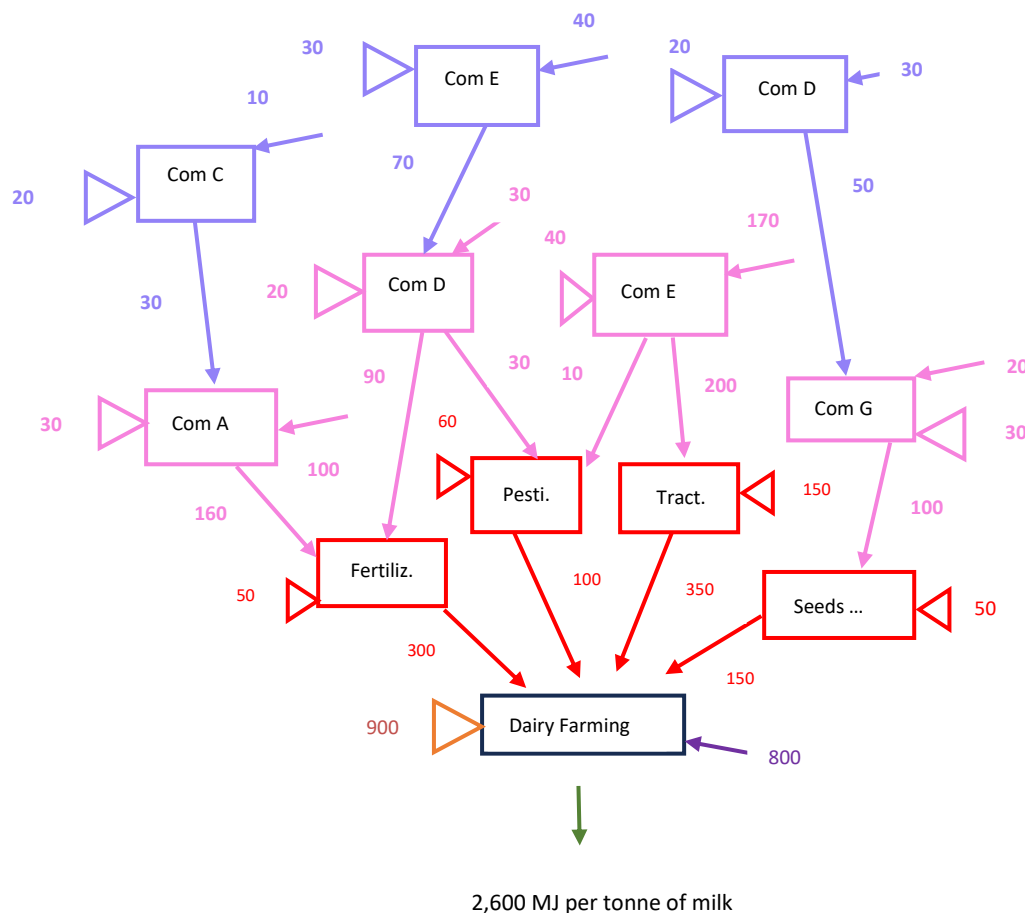
³⁷ Lenzen, M., Dey, C. 2000. Truncation Error in Embodied Energy Analyses of Basic Iron and Steel Products. *Energy* 25:6 577-585. Using the case study of the Australian steel industry Lenzen and Dey (2000) demonstrate that vertical truncation error was in the order of 50%.

³⁸ Refer to Table E.4 in McDonald (2005):

McDonald, G.W. 2005. *Integrating Economics and Ecology. A Systems Approach to Sustainability In the Auckland region*. PhD thesis, Massey University, Palmerston North

- the **purple arrow** represents the indirect energy that are non-specified. That is, given our dataset, there are up to 32 potential first-round inputs, but it is impossible to draw them all on the LCA diagram, so the smaller first round inputs are aggregated and denoted by this purple arrow that has no rectangle associated with it simply because these inputs don't come from one particular rectangle/sector. In this simplified example, the non-specified inputs account for 800 MJ per tonne of milk production.
- the **green arrow** represents the **total** (direct + indirect energy) required to produce one tonne of milk. By definition, the 'total' energy inputs which must equal the sum total of all of direct energy and the indirect energy: $900 + 300 + 100 + 350 + 150 + 808 = 2,600$

The **second step** involves reading the second round, third round and subsequent rounds in the LCA diagram, using the diagram below for dairy farming, is an illustrative example:



The **first round impacts** are denoted by **red rectangular boxes** for each sector/commodity – as noted above for the final step in the production chain (milk production), the sum of of the inputs for each rectangular box must equal the sum of the outputs. For example, take the first round, sector/commodity fertilizer production, with direct energy inputs of 50, and with energy embodied in commodity A inputs (160) and energy embodied in commodity D inputs (90), which sums to total inputs of 300, which by definition must equal the output of fertilizer production of 300.

The **second round impacts** are denoted by **pink rectangular boxes** for each sector/ commodity. Again, the sum of the inputs into each sector/commodity must equal the sum of the outputs – for example, sector D has inputs of $20 + 70 + 30 = 120$ which equals the outputs of sector D of $90 + 30 = 120$

The **third round impacts** are denoted by **mauve rectangular boxes** for each sector/ commodity. Again, the sum of the inputs into each sector/commodity must equal the sum of the outputs – for example sector E has inputs $30 + 40$ which equals the output of sector E in the third round of 70.

The production chain can be tracked back even further but usually no more than four or five rounds yields significant inputs, as there are diminishing marginal inputs at each round. In this publication we usually proceed round by round tracking back to the inputs into each round/production step no more than three or four rounds, before the inputs become insignificant. Usually there is an algorithm that can be applied beyond which the inputs are tracked back to a set amount – say for example > 2 MJ per tonne. Ultimately, if the analyst wants to obtain a very accurate result, the production must be tracked back to a point where only direct inputs appear – because ultimately all the embodied (indirect) energy inputs logically must be derived from direct inputs.

Important Note on Energy Units

Energy inputs in this report are reported in two ways:

- *Heat content or Heat equivalents.* This is the conventional way of measuring energy units, which is used in official energy statistics such as those maintained by the Ministry of Business, Innovation and Enterprise (MBIE). In this report this is denoted by the symbols J (for joules) and the MJ (megajoules which is 1 million joules)
- *Emergy or Oil Equivalents.* This is a measurement of energy that takes account of energy quality. It is argued in the report that it's methodologically incorrect to add up joules (measured in terms heat content) as this doesn't take account of the differing energy quality of the constituent energy sources – that is, one megajoule of energy of coal (measured in terms of a content), is not as useful as one megajoules of electricity (measured in terms of a content). In this report, 'total energy' is therefore measured in terms of 'oil equivalents' which is an emergy measurement as it takes account of energy quality by multiplying a quantity energy by its transformity (a measurement of energy quality) – refer to Table 1.2. Emergy is denoted by MJ_{OE} when it measured in 'Oil Equivalents'. Emergy can also be measured in terms of 'solar equivalents' by using the transformity values listed in Table 1.2 .

Table 1.2 Transformities of Energy forms in the New Zealand Economy, 2019

Energy Form	Transformity [MJ (Emergy) / MJ (Heat Equivalents)]	
	Solar = 1	Oil = 1
Electricity	22,600.00	3.05
Oil Products	7,400.00	1.00
Natural Gas	6,900.00	0.93
Coal	4,000.00	0.54
Wood	3,100.00	0.42
Geothermal	9,100.00	1.23
Black Liquor	5,000.00	0.68
Solar	1.00	0.0001

Data Source: Calculated for 2019 based on the Singular Value Decomposition Method Developed by Patterson (2012)

2. Methodology

Conceptual Framework

This section outlines the steps used to examine environmental resource appropriation in the New Zealand economy. The starting point for this analysis is a commodity-by-industry³⁹ input-output model similar to that proposed originally by Stone (1961, 1966),^{40 41} and later used by Victor (1972)⁴² in analysing environment-economy interactions. The matrix structure, depicted in Figure 1 below, is also compatible with the supply-use framework recommended for national accounting by the United Nations (1999).⁴³ It consists of a system of seven sub-matrices (***U***, ***V***, ***W***, ***X***, ***Y***, ***Z*** and ***E***) and six vectors (***o***, ***v***, ***w***, ***x***, ***y*** and ***z***). The matrix components of primary concern for this analysis are the two sub-matrices ***U*** ($n \times m$) and ***V*** ($m \times n$), commonly referred to as the ‘use’ and ‘supply’ matrices respectively, and a matrix, ***E***, pertaining to resource/residual inputs/outputs. The remaining components of Figure 1 complete the financial accounting framework and have been included simply for conceptual illustration.

		Commodities 1... <i>n</i>	Industries 1... <i>m</i>	Final Demands		Total use
				Other Final Demands 1... <i>q</i>	Exports 1... <i>r</i>	
Commodities 1... <i>n</i>			U Use	Y Other Final Demands	X Exports	o Gross Commodity Outputs
Industries 1... <i>m</i>		V Supply				v Gross Industry Outputs
Primary Inputs	Value Added 1... <i>s</i>		W Value Added			w Value Added
	Imports 1... <i>t</i>	Z Imports				z Imports
Total Supply		o' Gross Commodity Outputs	v' Gross Industry Inputs	y Other Final Demands	x Exports	
Environmental Resource Inputs			E Environmental Resource Inputs			

Figure 2.1 - Commodity-by-Industry Financial Flow Matrix

³⁹ In this publication the term “industry” and “sector” are used interchangeably.

⁴⁰ Stone, R. (1961). *Input-output and National Accounts*. Paris: Organization for European Economic Cooperation.

⁴¹ Stone, R. (1966). *Mathematics in the social sciences, and other essays*. Cambridge, Massachusetts: M.I.T. Press.

⁴² Victor, P. A. (1972). Input-Output Analysis of Economic and Environmental Interactions. *Economics of Pollution*, 55-72. doi:10.1007/978-1-349-01531-3_4

⁴³ United Nations. (1999). *Handbook of Input-Output Table Compilation and Analysis. Handbook of National Accounting: Studies in Methods. Series F, No. 74*. New York: United Nations.

Beginning with matrix $\mathbf{U}$ ($n \times m$), it describes the commodity inputs into the New Zealand economy, with an element $u_{ij} \in \mathbf{U}$ representing, in monetary terms, the value of commodity i used by industry j ($i = 1 \dots n; j = 1 \dots m$), within the relevant financial year. Sub-matrix $\mathbf{V}$ ($m \times n$), captures the production relationships within the New Zealand economy, with an element $v_{ji} \in \mathbf{V}$ representing, again in monetary terms, the output of commodity i , produced by industry j within the same year. Appended to the Industries column in Figure 1 is the matrix of environmental inputs, $\mathbf{E}$ ($n \times m$). An element e_{ij} of this vector quantifies, in monetary terms, the value of direct environmental resource input i required by industry j within the financial year.

Methodological Sequence

Using the conceptual framework set out above, we now describe a five-phase, twelve-step method for tracing environmental resource/residual appropriation chains.

In steps 1 to 3, the supply table and environmental data are adjusted by ‘domesticating’ international imports. In step 4, the ecological multiplier is determined. In steps 5 to 8, the environmental resource appropriation chains are calculated. In steps 9 and 10, the environmental resource appropriation chains for imports are calculated. In step 11, the environmental resource appropriation chains for domestic and imports are calculated. In step 12, the environmental resource appropriation chains are converted from the total economy to per-tonne and per-thousand-dollar bases.

Phase 1: Environmental Supply-Use Table Adjustments

Step 1 Adjust the use table for international imports.

The supply table contains the domestic supply of commodities by industries, while the use table contains industries’ use of domestic and international commodities. The use table must be adjusted to exclude the use of international (i.e. imported) commodities by domestic industries if ecological multipliers are to be developed that identify the domestic environmental effects. The use table was adjusted by subtracting the international imports commodity-by-industry use matrix, $\mathbf{U}_{Imports}$, from the total (domestic and international imports) commodity-by-industry use matrix, $\mathbf{U}_{Total}$, to generate a domestic commodity-by-industry use matrix, $\mathbf{U}_{Domestic}$.

$$\mathbf{U}_{Domestic} = \mathbf{U}_{Total} - \mathbf{U}_{Imports} \quad (1)$$

The 2003-04 commodity-by-industry import-use matrix, $\mathbf{U}_{Imports}$, was constructed by multiplying the vector representing the use of imported commodities in 2003-04, $\mathbf{Z}$, against the commodity-by-industry matrix of import-use ratios, $\mathbf{U}_{Imports\ Ratio}$, which was calculated from Statistics New Zealand’s 1995-96 commodity-by-industry import-use table.

$$\mathbf{U}_{Imports\ 2003-04} = \mathbf{Z} \times \mathbf{U}_{Imports\ Ratio\ 1995-96} \quad (2)$$

Step 2 Aggregation of industries and commodities.

To avoid the derivation of negative environmental multipliers, industries and commodities were aggregated. Negative environmental multipliers are conceptually incorrect as an output must use, or produce, positive amounts of environmental resources or wastes. In addition, the utility sectors, which mainly use natural resources to generate outputs, have been excluded. This was done to avoid double-counting, as the utility sector's outputs are included in the environmental accounts. Lastly, the number of industries and commodities must be equal (i.e. the supply-use table must be 'square') to be able to generate a matrix inverse.

After excluding utilities and aggregating the industries and commodities, 37 industries and 37 commodities remained out of an initial total of 48 industries/commodities. Both supply and use matrices and environmental accounts were aggregated according to the new concordance.

Phase 2: Determining Environmental Multipliers

Step 3 Calculating environmental multipliers.

In this step, we describe how the supply-use framework may be used to generate an ecological multiplier, ε_i , representing total embodied environmental resource inputs, measured in monetary terms, per unit of commodity i . To calculate the vector of environmental multipliers for all commodities, we begin by noting that for each industry, the value of environmental resource appropriation embodied in commodity outputs must be equivalent to the value of environmental resources appropriated directly by the industry, plus the value of environmental resources embodied in the industry's commodity inputs,

$$e_{ij} + \sum_{i=1}^n \varepsilon_i u_{ij} = \sum_{i=1}^n \varepsilon_i v_{ij} \quad (3)$$

In matrix notation for all industries, this becomes,

$$\mathbf{E} + \varepsilon \mathbf{U} = \varepsilon \mathbf{V}^T \quad (4)$$

If the number of commodities equals the number of industries (i.e. $n = m$), equation 4 can be solved for the vector of ecological multipliers, ε , simply as

$$\varepsilon = \mathbf{E}(\mathbf{V}^T - \mathbf{U})^{-1} \quad (5)$$

The matrix $(\mathbf{V}^T - \mathbf{U})$ in Equation 5, is referred to as the 'net matrix', $\mathbf{N}$, with an element $n_{ij} \in \mathbf{N}$ representing the net output (total output less total input) of commodity i by industry j .

Phase 3: Calculating Domestic Environmental Resource Appropriation Chains

Step 4 Calculating the first-round chain of commodity input to industry output.

Greater insight into the ecological multiplier may be gained by decomposition into first, second, and subsequent round impacts. However, before we calculate chains by commodity, we first need to work out commodity ratios (the ratio of other commodities required to produce a unit of a given commodity). This is undertaken by calculating the value of environmental resources embodied in commodity inputs at each point in the production chain. To begin, the first-round environmental resource requirements for every industry may be determined by defining a matrix $\boldsymbol{\theta}$ ($n \times n$),

obtained by diagonalising the vector ε , and then post-multiplying by the net matrix, N , to obtain an 'evaluated' matrix, Q ($n \times m$), containing the first-round impacts in dollar terms:

$$Q = \Theta N \quad (6)$$

The first-round impacts for industry 1 are presented in the first column of the evaluated matrix, Q , while the first-round impacts for industry 2 are presented in the second column, and so forth. Any positive (negative) element of Q (i.e. q_{ij}) represents the total direct and indirect value of environmental resources embodied in the net output (input) of commodity i by (into) industry j . We then summed up positive values on each row (i.e. commodity) to calculate tq for each industry, total environmental resources (or wastes) required (produced) by each producing industry in the New Zealand economy.

$$tq_j = \sum_i q_i, \text{ where } q_i = \text{all elements of } Q \text{ which are greater than 0, for all } j \quad (7)$$

Step 5 Calculating second-round chain of commodity input to industry output.

In this step, the second-round impacts for a given column industry of the evaluated matrix Q are generated. To trace the second-round impacts we need to select a given column industry from the matrix Q for further analysis. Here we select, as an example, the second-round impacts associated with the first-round input of commodity 2 into industry 1. In other words, our example will decompile element $q_{2,1}$ from the evaluated matrix into its constituent second-round impacts.

Having selected element $q_{2,1}$ for further analysis, the first task is to determine the industries that are responsible for producing the value of commodity 2 inputs supplied to industry 1. This requires the definition of three new row vectors, b , g and k . Starting with b ($n \times m$), this is a vector defined simply as the row elements for commodity 2 within the evaluated matrix Q . Vector k has the same dimensions and elements as b , except that any negative elements (net inputs) are set to zero. The row sum of k , k_T , is equivalent to the total value of environmental resources embodied in outputs of commodity 2. Finally, we calculate the vector g , which has the same dimensions as vector b , by inverting each element of the vector k for every element that is not zero and zero for the rest.

$$\begin{aligned} g_i &\in g \\ \forall k_i \neq 0, g_i &= \frac{1}{k_i} \text{ and,} \\ \forall k_j = 0, g_i &= 0 \end{aligned} \quad (8)$$

where, if it is assumed that the proportion of industry 1's input of commodity 2 that is supplied from industry j is the same as the proportion of the total net output of commodity 2 in the economy supplied from industry j , we can obtain the equation,

$$p = \left(\frac{-q_{2,1}}{k_T} \right) k \quad (9)$$

where p is a vector ($1 \times m$) defining the value of environmental resources embodied in commodity 2 inputs into industry 1 by producing industry j .

The second task is to define a new matrix of net commodity inputs and outputs, M ($n \times m$), relating only to the production of commodity 2, and the associated inputs required by each producing industry

for that production. This is undertaken by first defining two new matrices, $\mathbf{R}$ ($n \times m$) and $\mathbf{S}$ ($n \times m$), that are derived from the evaluated matrix $\mathbf{Q}$, and relate to the value of environmental resources embodied in net commodity inputs and net commodity outputs, respectively. The matrix $\mathbf{R}$ is constructed by setting all non-positive elements in the matrix $\mathbf{Q}$ as elements of the matrix $\mathbf{R}$ and zero otherwise. Additionally, the matrix $\mathbf{S}$ is constructed by setting all non-negative elements in the matrix $\mathbf{Q}$ as elements of the matrix $\mathbf{S}$ and zero otherwise.

$$r_{ij} \in \mathbf{R} \quad (10)$$

$$\forall q_{ij} < 0, r_{ij} = q_{ij} \text{ and,}$$

$$\forall q_{ij} \geq 0, r_{ij} = 0$$

$$s_{ij} \in \mathbf{S} \quad (11)$$

$$\forall q_{ij} > 0, s_{ij} = q_{ij} \text{ and,}$$

$$\forall q_{ij} \leq 0, s_{ij} = 0$$

We also define a vector f and a matrix $\mathbf{F}$ ($m \times m$) where the vector f is the column sum of the matrix $\mathbf{S}$ inverted and the matrix $\mathbf{F}$ is constructed by diagonalising the vector f .

$$f_j \in f \quad (12)$$

$$f_j = \sum_i \frac{1}{s_{ij}}$$

$$\hat{f}_{ij} \in \mathbf{F}$$

$$\forall \hat{f}_{ij} \text{ where } i = j, \hat{f}_{ij} = f_j \text{ otherwise } \hat{f}_{ij} = 0$$

(i.e. diagonalising the vector f)

Now, we define a vector h ($1 \times m$) and a matrix $\mathbf{H}$ ($m \times m$) where the vector h is calculated by matrix multiplication of the vector k and the matrix $\mathbf{F}$, and the matrix $\mathbf{H}$ is constructed by diagonalising the vector h .

$$h = k\mathbf{F} \quad (13)$$

$$\hat{h}_{ij} \in \mathbf{H}$$

$$\forall \hat{h}_{ij} \text{ where } i = j, \hat{h}_{ij} = h_j \text{ otherwise } \hat{h}_{ij} = 0$$

(i.e. diagonalising the vector h)

Next, we define a matrix $\mathbf{K}$ ($n \times m$), where all elements are set to zero except for the row pertaining to commodity 2 inputs, which is equivalent to the vector k .

$$\hat{k}_{ij} \in \mathbf{K} \quad (14)$$

$$\forall \hat{k}_{ij} = \text{same } j \text{ as } k, \hat{k}_{ij} = k_i,$$

$$\hat{k}_{ij} = 0 \text{ otherwise}$$

Matrix $\mathbf{M}$ can now be calculated as,

$$\mathbf{M} = \mathbf{RH} + \mathbf{K} \quad (15)$$

Now, we define $\mathbf{G}$ ($m \times m$), a matrix obtained by diagonalising the vector g , and similarly $\mathbf{P}$ ($m \times m$), a matrix obtained by diagonalising the vector p .

$$\hat{g}_{ij} \in \mathbf{G} \quad (16)$$

$$\forall \hat{g}_{ij} \text{ where } i = j, \hat{g}_{ij} = g_j \text{ otherwise } \hat{g}_{ij} = 0$$

(i.e. diagonalising the vector g)

$$\hat{p}_{ij} \in \mathbf{P}$$

$$\forall \hat{p}_{ij} \text{ where } i = j, \hat{p}_{ij} = p_j \text{ otherwise } \hat{p}_{ij} = 0 \quad (17)$$

(i.e. diagonalising the vector p)

It is now possible to calculate a new evaluated matrix pertaining to the second-round impacts, $\hat{\mathbf{Q}}$ ($n \times m$) by matrix multiplication of matrices $\mathbf{M}$, $\mathbf{G}$, and $\mathbf{P}$.

$$\hat{\mathbf{Q}} = (\mathbf{MG})\mathbf{P} \quad (18)$$

To calculate a scalar z_i , the total commodity input by total commodity output, we add every industry together by commodities.

$$\hat{q}_{ij} \in \hat{\mathbf{Q}}$$

$$z_i = \sum_{j=1}^m \hat{q}_{ij} \quad (19)$$

Finally, we create the commodity ratio l_i by dividing z_i with $q_{2,1}$.

$$l_i = \frac{z_i}{q_{2,1}} \quad (20)$$

This results in a vector of ratios of commodity chains, which shows, for each dollar of commodity output how much of inputs are from other commodities.

The procedure that is described here for evaluating the second-round impacts resulting from the first-round impact of commodity 2 input to industry 1 may also be used to calculate the second-round impacts of other commodity inputs in industry 1.

In order to achieve mass balance in the Supply-Use table, the derived physical goods from the Physical Input-Output table, the resource usage, and the residuals were all included in the Physical Input-Output table (refer to McDonald, G.W. & Patterson, M.G, 2006).⁴⁴ These data subsequently were used to derive the environmental multipliers used in this analysis.

Step 6 Calculating the first-round chain of commodity input to commodity output.

To calculate the first-round chains by commodity inputs to commodity output for a selected commodity 1, we multiply tq_j , total environmental resources or wastes required to produce a selected commodity in the New Zealand economy as calculated in step 4, with the commodity chain ratio for commodity 1, l_1 ,

$$c_1 = tq_j \cdot l_1 \quad (21)$$

Positive elements within c_1 define the value of environmental resources embodied in commodity outputs, while negative elements define the value of environmental resources embodied in commodity inputs. Also, the value of direct environmental-resource inputs to each industry can be calculated by subtracting the sum of all elements in c_1 from zero.

$$\text{Direct ecosystem service} = 0 - \sum c_1 \quad (22)$$

Step 7 Calculating second-round chain of commodity input to commodity output.

In this step, we combine a vector of commodity chains for every commodity to form a chain ratio matrix L .

$$L = [l_1, \dots, l_n] \quad (23)$$

We then multiply a vector of first-round chains by chain ratio matrix, calculating C_2 , second-round chain matrix by commodity inputs to commodity outputs.

$$C_2 = c_1 L \quad (24)$$

As with the evaluated matrix for the first-round impacts, positive elements within C_2 define the value of environmental resources embodied in commodity outputs of each commodity, while negative elements define the value of environmental resources embodied in commodity inputs. As with the first-round calculations, the value of direct environmental resource inputs to each industry can be calculated by adding an additional row to the matrix C_2 that balances each column sum to zero.

Step 8 Calculating third and subsequent round chain of commodity input to commodity output.

Each column of the second-round chain matrix, C_2 , represents a vector of second-round commodities chains for commodity i .

$$C_2 = [c_1, \dots, c_i, \dots, c_n] \quad (25)$$

⁴⁴ McDonald, G., & Patterson, M. (2006). Development of a New Zealand Physical Input-Output Table. *Intermediate Input-Output Meetings on Sustainability, Trade & Productivity*. Sendai, Japan.

To calculate the third-round chains for a given commodity, we multiply each vector of second-round chains (i.e. $c_1, \dots, c_n$) by transposed chain ratio matrix L . This calculates $C_{3,i}$, the third-round chain matrix for a given second-round commodity i .

$$C_{3,i} = c_i L \quad (26)$$

Subsequent round chains for a given commodity can be calculated exactly the same as calculating the third-round chain.

Phase 4: Calculating Import Environmental Resource Appropriation Chains

Step 9 Calculating the first-round chain of commodity import to industry output.

To gain further insights into how the economy as a whole affects environmental resources, we also need to consider international imports use as well as domestic production and domestic use. From the assumption above about our model, we use the same environmental multiplier for international imports as domestic.

To calculate the commodity imports required to produce a given commodity we first need to identify the proportion of each industry's output made up of each commodity. This is calculated by each element in the supply matrix divided by the horizontal sum in the same row of the supply matrix. This creates a matrix $\hat{A}$ with the exact same dimensions as the supply matrix.

$$\hat{a}_{ij} \in \hat{A} \quad (27)$$

$$\hat{a}_{ij} = a_{ij} / a_i$$

Then, we matrix multiply this matrix with the national imports use matrix, creating a matrix I which lists imports required for the production of commodities in dollar terms.

$$I = U_{Imports} \hat{A} \quad (28)$$

Finally, we matrix multiply the diagonalised environmental-resource multiplier for a chosen environmental resource with the imports requirement matrix to produce $\hat{Q}$, a matrix of the first-round chain of commodity import to industry output.

$$\hat{Q} = \theta I \quad (29)$$

Step 10 Calculating the coefficient tables for imports for each commodity.

To estimate a matrix $\hat{L}$, the commodity imports required to produce a dollar of output of a selected commodity, we divide each element in the first-round chain of commodity import to industry output by the vertical sum in the same column.

$$\hat{L}_{ij} \in \hat{L} \quad (30)$$

$$\hat{L}_{ij} = \hat{Q}_{ij}/\hat{Q}_j$$

This creates the coefficient table for each commodity, which calculates how much a unit of environmental resource of a given commodity requires of imported environmental resource of a given commodity.

Phase 5: Transforming Calculated Chain for our Purpose

Step 11 Calculating the domestic and import chains.

To calculate the total domestic and import chains, we first need to create an imports chain matrix for each round after the first. This is calculated exactly the same as domestic chains in steps 7 and 8 except it uses the coefficient table for imports rather than the coefficient table for domestic.

To create Q_T , the total domestic and import chain matrix, we add elements in the same commodity and industry specification for both domestic and import chains together for every element except diagonal elements which will be just import chain elements for the given commodity. The diagonal elements were not summed with domestic chains because we need to introduce imports of a given commodity to produce the same commodity.

$$\dot{Q}_{ij} \in Q_T \quad (31)$$

$$\dot{Q}_{ij} = Q_{ij} + \hat{Q}_{ij} \quad \forall i \neq j$$

$$\dot{Q}_{ij} = \hat{Q}_{ij} \quad \forall i = j$$

Step 12 Converting from a chain by the total economy to per tonne and \$000s.

To interpret the data for our purpose, we must convert from output/residual of a chain by the total of a given commodity to output/residual of the chain on a per tonne and \$000s basis of the output of the given commodity.

In order to convert the total of a given commodity to per tonne output of the commodity, we need to work out the average price of a given commodity per tonne. Here we make an important assumption; the domestic prices of commodities are equal to the world prices of commodities. We make this assumption since calculating the price-per-tonne ratio in the domestic market is very hard due to the lack of data. But in terms of international trade activities, the weight quantities and the values of commodities are recorded every time the commodity enters or leaves the country. Hence, we average out the imports trade sector and then use its average as a price-per-tonne value to calculate the total tonnage of a given commodity in the economy.

On the other hand, chains in terms of \$000s are calculated by dividing the total amount by a factor of a thousand dollars.

Domestication of International Imports

A significant proportion of the appropriation of resources occurs by way of international imports. To theoretically calculate the resources and emissions embodied in their production we need the following information:

- (a) The inputs of imported commodities into each New Zealand industry,
- (b) The foreign industries responsible for producing international imports,
- (c) The input-output structure of each foreign economy that produces commodities that make up international imports, and
- (d) The resources/emissions required by each foreign industry in order to produce the commodities that make up international imports.

The domestic use matrix includes the use of all commodities in the New Zealand economy (i.e. inputs of domestically produced commodities and imported commodities), thus providing us with information for (a). But since the domestic supply matrix only includes domestic outputs, we do not have other information for (b), (c), and (d).

There are three possible approaches to this problem. The ideal approach would be to use a multi-regional input-output table; this would capture the complexity of production chains with many imports and exports across the globe. Even if we were able to obtain a suitable input-output structure, we would then require environmental accounts for each relevant foreign country.

A less-perfect solution would be to use the input-output tables of our major trading partners to determine the production chains of the most important imports to New Zealand. Once again, even if we were able to derive an appropriate input-output framework (requiring significantly additional time and costs), the problem is that we would still require foreign environmental accounts.

The final approach is to 'domesticate' New Zealand's imports. Here we derive the information for (b), (c) and (d) by simply assuming that the patterns of production of foreign commodities (i.e. the industries' responsible for producing the commodities, the industries' input structures and the required resources/emissions) are the same as in New Zealand. There are obvious difficulties with this assumption, notably, commodities will not be produced overseas in the same manner as New Zealand (i.e. production overseas will have economies of scale, thus more efficient, while domestic products are more likely to have diseconomies of scale, i.e. less efficient). The clear advantage of this approach, however, is in saving time and costs.

We have essentially gone with the third option. In order to determine the industries responsible for producing commodity imports, we used domestically derived ecological multipliers to produce imports' environmental linkages.

Numerical Example of the Calculation of LCA Diagrams

A simple example of how to calculate an LCA diagram from input-output data is provided as follows:

Step1 Assumed data⁴⁵

It is assumed that the following data is available in vector and matrix format^{46, 47}

Water Inputs **E**

Sector 1	Sector 2	Sector 3
500	200	2

The input of water into each sector, in terms of litres or megalitres of water, is recorded across the row.

Outputs **V^t**

	Sector 1	Sector 2	Sector 3
Commodity 1	380	0	0
Commodity 2	0	770	0
Commodity 3	0	0	360

This matrix is for the situation where there is one output per sector⁴⁸.

Inputs **U**

	Sector 1	Sector 2	Sector 3
Commodity 1	30	300	10
Commodity 2	100	20	100
Commodity 3	50	50	360

The input of each sector measured in tonnes is recorded down the columns.

Step 2 Calculation of the Environmental Multiplier The following manipulations are required to calculate the embodied water (direct plus indirect inputs) per tonne of sector output:

Outputs - Inputs **V^t - U**

	Sector 1	Sector 2	Sector 3
Commodity 1	350	-300	-10
Commodity 2	-100	750	-100
Commodity 3	-50	-50	0

⁴⁵ The **E** matrix must always be measured in physical terms. The outputs **V^t** and inputs **U** matrices can however be measured in monetary terms which was the case in our study, but alternatively they can be measured in physical terms.

⁴⁶ It is assumed in this simple numerical example that the international imports have been incorporated into the water inputs vector **E**, outputs matrix **V^t** and the inputs matrix **U**. This assumes that the water use and input output structure that applies for the New Zealand economy also applies for imports from other countries

⁴⁷ The term “industry” and “sector” are used interchangeably in this publication.

⁴⁸ The output of each sector is measured in tonnes that appears on the diagonal. Some input output data allow for the possibility of multiple outputs per sector, which means that in the output matrix **V^t** there are non-diagonal entries that record non-dominant outputs for each sector. This situation of multiple outputs sometimes means that there are negative elements in the solution which quantifies the environmental multiplier ϵ – there are various methods, some of which means that the commodity-by-commodity matrix has diagonal entries similar to the above outputs matrix **V^t**.

	$(V^t - U)^{-1}$		
	Sector 1	Sector 2	Sector 3
Commodity 1	0.0037	0.002	0.0023
Commodity 2	0.0008	0.0018	0.0019
Commodity 3	0.0023	0.0019	0.0121

	Solution Vector	$\epsilon = E(V^t - U)^{-1}$	
Embodied Water	1.95	1.16	1.3817

The total (direct and indirect) inputs of water in megalitres per tonne of sector output, and this read across the row in the vector ϵ .

Step 3 Calculation of the Data for the Lifecycle Assessment Diagram

The environmental multiplier can be decomposed so as to provide diagrammatic understanding of the web of inputs of water (direct and indirect) required to produce 1 tonne of sector output. For example, for Sector 1, the inputs of water can be depicted across three rounds in the production chain. Similar diagrams can be drawn for Sectors 2 and 3. The following calculations need to be undertaken:

Diagonalise $\epsilon = \delta$
(Embodied Water)

1.95	0	0
0	1.16	0
0	0	1.3817

This diagonalisation is required for the next calculation: $W = \delta(U - V)$:

Commodity 1	685.6627	-705.253	-19.5904
Commodity 2	-116.5783	874.3373	-116.578
Commodity 3	-69.0843	-69.0843	138.1687
Water Input	-500	-100	-2

Column 1 represents the **Round 1** direct (grey shading) and indirect inputs of water from sector 2 (blue shading) and sector 3 (brown shading) – refer to Figure 2.2. The total embodied water for each sector appears on the diagonal.

Rounds 2 and 3 inputs for sector 1 can be undertaken by the calculation outlined below:⁴⁹

Sector 1 (Round 1) to Sector 2 (Round2)	
Total input = 116.578	
From Sector 1 (Round 3)	$116.5783 * (705.253/874.3373) = 94.0037$
From Sector 3 (Round 3)	$116.5783 * (69.0843/874.3373) = 9.2112$
Direct	$116.5783 * (100/874.3373) = 13.3333$

⁴⁹ Direct and indirect inputs, for sectors 2 and 3, can be calculated by undertaking similar calculations. The results of these calculations can be used to construct LCA diagrams for Sectors 2 and 3 of similar to the LCA diagram constructed for Sector 1 on the next a page.

Sector 1 (Round 1) to Sector 3 (Round2)

Total input = 69.0843

From Sector 1 (Round 3) $69.0843 * (19.5904/138.1687) = 9.7952$

From Sector 2 (Round 3) $69.0843 * (116.578/138.1687) = 58.2891$

Direct $69.0843 * (2/138.1687) = 1.0000$

This process can be repeated for subsequent rounds (4,5,6) until all the embodied water is tracked back to direct inputs of water. Usually however after about 3 or 4 rounds the direct and indirect inputs of water become insignificant in terms of their numerical magnitudes.

Based on the above illustrative calculations undertaken in Step 3, a LCA diagram for sector 1 for 3 rounds can be constructed – refer to to Figure 2.2.

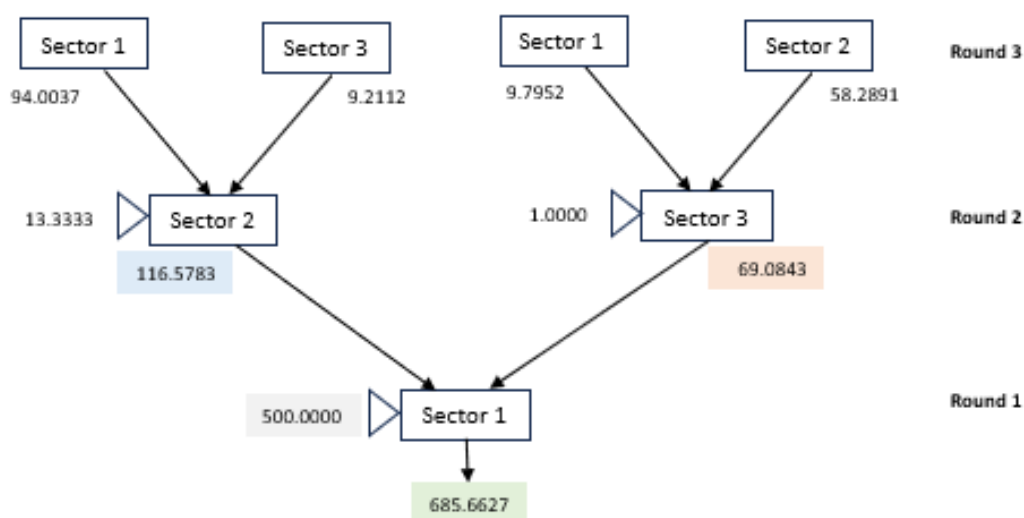


Figure 2.2 Calculation Lifecycle Assessment Diagram for Sector 1 (Rounds 1,2 ,3)

Interpretation of an LCA Diagram

LCA diagrams can be developed with the results generated from the 12 steps mentioned above. These diagrams: (1) are provided at the end of each chapter, along with their respective interpretations: (2) cover a range of resource uses, wastes/emissions and ecosystem services. Regarding resource usage: electricity, fossil fuels, land, water, and total energy are all measured. Regarding wastes/emissions: landfill waste, wastewater, phosphorous, and CO₂ emissions are all measured. These diagrams track a range of different usages and emissions for the 32 sectors studied, as well as the backward linkages to their respective supply chains, allowing for the identification of resource usage and emissions across various supply chains in the New Zealand economy.

For an interpretation of LCA diagrams, refer to Figure 2.3, which is used as an example. This diagram measures the total energy inputs, in megajoules (MJ), required to produce one tonne of raw milk products. This diagram is repeated in Chapter 6.

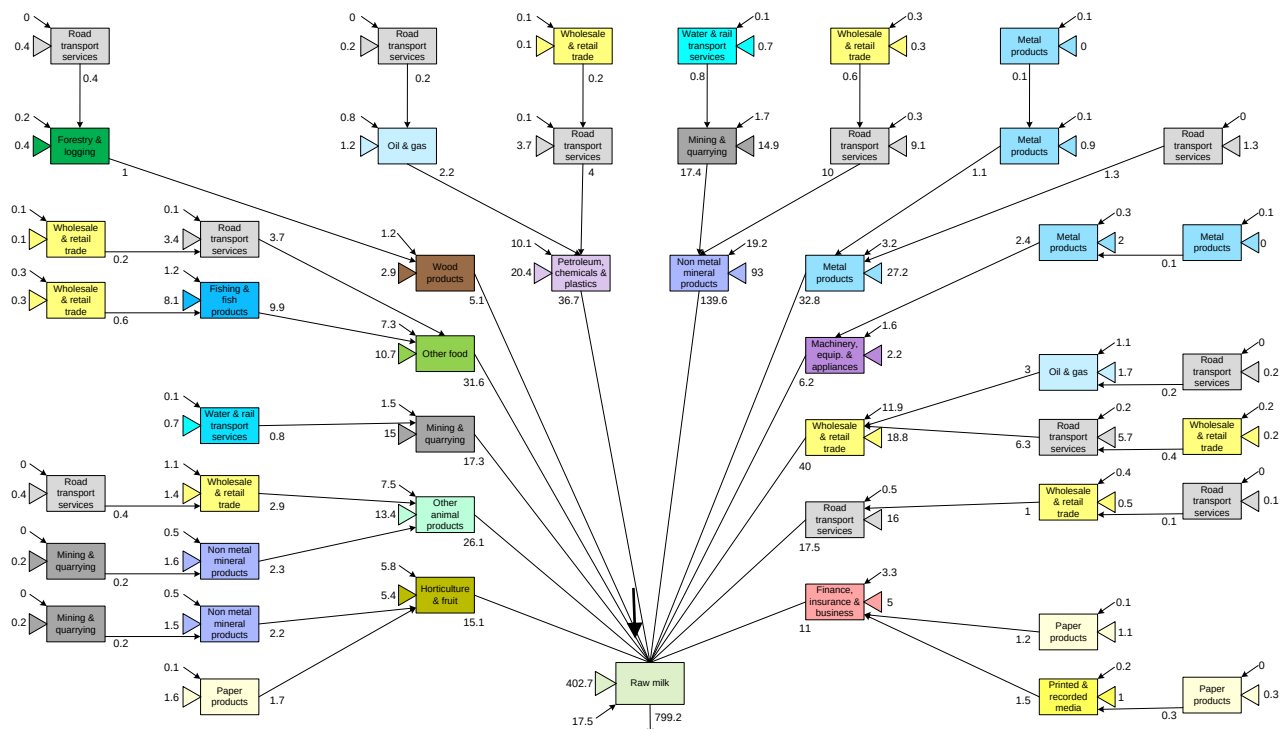


Figure 2.3 - Total Energy Inputs Required to Produce One Tonne of Raw Milk Products, 2003-04 (MJ_e, Oil Equivalents)

Emissions generated or resources used by the industry itself are its direct inputs. In terms of dairy cattle farming, the energy used in activities such as operating farm bikes to herd cows, running electric fences, and the energy used to light milking sheds would contribute to the dairy cattle farming's direct energy use. In Figure 2.3, direct energy use is represented by the triangle adjacent to the commodity or industry being studied, with a numerical value identifying the size of the respective resource use or emission. Depending on the resource measured, the direction of the triangle will face towards or away from the sector or commodity. If resource inputs are measured, the triangle will face towards the industry or commodity being studied. If emissions are being measured, this triangle faces away from the industry or commodity. Here it shows that 402.7 MJ of total energy is used directly as inputs by the dairy cattle farming sector to produce one tonne of raw milk.

Indirect inputs come from the activities and production processes of the chosen sector's backward linkages. These backward linkages produce inputs that feed into the analysed sector, contributing with indirect inputs to the production process of the chosen sector. Continuing with the example of the total energy embodied in dairy cattle farming, the energy used to produce the fertilisers applied to the dairy cattle pastures would be included. Graphically, these are represented as arrows from industries upstream feeding into the next chain of the production process.

Following one of these backwards linkages, we see that 139.6 MJ of total indirect energy comes from the sector producing non-metallic minerals. Indirect inputs may also be traced back further with 17.4 MJ and 10 MJ of the energy used to produce non-metallic mineral products, which in turn are used to produce raw milk, coming indirectly from the 'mining and quarrying' and 'road transport services' sectors, respectively. It should be noted that while production processes can be traced back multiple steps, only the first-level backward linkages of the sector being analysed are included in the sector's indirect component.

Smaller, non-major contributors to the industry's indirect inputs or emissions are summated. These are graphically shown as the small arrow pointing to the industry being studied. In Figure 2.2, 17.5 MJ of total energy used in raw milk production comes from the summation of other smaller indirect

sources, such as construction, communication, and government services. Individually, these sectors only make up a small component of dairy cattle farming's total energy use.

Combining the direct, indirect (by major industries) and other indirect (summed) components, results in the total embodied inputs or wastes for every unit of output produced by the industry in question. In Figure 2.2, all three components for production of raw milk sum to the total 799.2 MJ: 402.7 MJ coming from direct inputs, 379 MJ coming from major indirect inputs, and 17.5 coming from other, minor indirect inputs.

3. Data Sources

Resources, Wastes and Ecosystem Services Data

Resources, wastes and ecosystem services data which was used in the calculation of the environmental multipliers and the associated LCA diagrams were obtained from the following sources:

- *Land-Use data.* These data are gathered from Quotable Value New Zealand (2004),⁵⁰ Agriquality New Zealand's Agribase (2004),⁵¹ Ministry of Agriculture and Forestry (2006),⁵² and Works Consultancy Services Ltd (1996).⁵³
- *Energy Input Data and Energy-related CO₂ emissions.* These estimates are derived from the Energy Efficiency and Conservation Authority's (2004) Energy Database.⁵⁴
- *The national ecosystem services data.* The estimates for 1997-98 were calculated by identifying spatial land coverage from Terralink's LCDB (Land Cover Database)⁵⁵ and multiplying them by ecosystem's multiplier from an overseas study.⁵⁶ The data was then converted to 2003-04 estimates by multiplication with the Producer's Price Index (PPI) Output ratio.
- *Resources and Wastes/Residuals.* Resources are inputs into the economy from the biophysical environment such as water, minerals, biological resources, energy and so forth. Wastes or what is sometimes referred to as *residuals*, are emitted from the economy back into the biophysical environment. Table 3.1 specifies the *resources* and *wastes/residuals* analysed in the LCA diagrams in this publication: (1) *Resources* include categories: electricity, fossil fuels total energy inputs⁵⁷ (sum total of fossil fuels and electricity electricity) land and water; (2) *Wastes and residuals* categories: landfill waste, non-point source phosphorus, wastes, carbon dioxide from energy use, methane from energy use, nitrous oxide from energy use, recycled 'wastes', metal wastes, glass wastes, paper wastes and plastic wastes⁵⁸.
- *Ecosystem Services.* In addition to these resources and wastes, as can be ascertained from Table 3.1 the LCA diagrams are constructed in terms of the direct and indirect inputs of selected *ecosystem services* including: climate regulation, disturbance regulation, water regulation, erosion control, waste treatment, nutrient cycling and raw materials. The

⁵⁰ Quotable Value New Zealand. (2004). *Regional Land Use Estimates by Land Use Code*. Auckland: Quotable Value New Zealand.

⁵¹ Agriquality New Zealand. (2004). *Regional agricultural land use by farm type, as taken from Agribase*. Wellington: Agriquality New Zealand.

⁵² Ministry of Agriculture and Forestry. (2006). *2004 National Exotic Forest Description*. Wellington: Ministry of Agriculture and Forestry.

⁵³ Works Consultancy Services Ltd. (1996). *Transit New Zealand National Traffic Database. Contents and Operation of Database*. Wellington: Transit New Zealand.

⁵⁴ Energy Efficiency Conservation Authority (EECA). (2004). *Energy End-Use Database 2001-02*. Wellington: Energy Efficiency Conservation Authority.

⁵⁵ Terralink. (2004). *Land Coverage Database (LCDBII)*. Wellington: Terralink.

⁵⁶ Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., . . . van den Belt, M. (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature*, 387, 253-260. doi:10.1038/387253a0

⁵⁷ In general terms, only energy that forms part of the national energy accounts such as those maintained by MBIE are analysed, which is generally restricted to energy forms that have a market value. This means for example, that solar energy inputs, which are important to agriculture and forestry are not analysed.

⁵⁸ Not all of these 'wastes' are analysed and depicted in the LCA diagrams in this publication, but are available on the CD which can be obtained from the authors – refer to Table 3.1.

ecosystem services data was drawn from Patterson and Cole (2013)⁵⁹ based on using economic valuation methods and hence is measured in monetary terms.

New Zealand Supply-Use Tables

New Zealand Supply-Use Tables were developed by updating national supply and use tables from the 1996 inter-industry study of the New Zealand economy⁶⁰ to the year ending 2004. Readers are referred to McDonald (2005)⁶¹ for full details of this process. The tables from the 1996 study cover 126 economic industries and 210 economic commodities. They were updated for volume, price and productivity changes. The physical (tonnes or litres) output of first 20 sectors (Chapter 4 to Chapter 21) were obtained from the New Zealand Physical Input Output Table (PIOT) which was constructed by McDonald and Patterson (2008).^{62,63}

In order to achieve mass balance in the Supply-Use tables, the derived physical goods from the Physical Input-Output table, the resource usage, and the residuals were all included in the Physical Input-Output table (refer to McDonald and Patterson 2006).⁶⁴ These data subsequently were used to derive the environmental multipliers used in this analysis, by using the methodology outlined in Chapter 2.

Base Year

In almost all cases the data outlined above was available for the calendar year 2004, so this was used as a base year for the environmental multipliers and LCA diagrams presented in this publication. In some cases, price data needed to be adjusted for inflation, and as a first priority the appropriate industry group and the Producer Price Index (outputs) was used for this purpose, and when that this was not available⁶⁵ as a second priority the GDP deflator was used. Some of the data in the LCA diagram and elsewhere were converted to 2019 prices, so that they could be compared with prices close to current day prices – we deliberately avoided converting prices to 2020, 2021 to 2022 prices due to anomalies brought about by COVID pandemic. In the Executive Summary, some of the Eco-Efficiency⁶⁶ and Environmental Footprint indicators were converted to 2019 terms, by using known or implied changes to the technical efficiency which in most cases decreased the amount of resources used and/or wastes/emissions produced, as well as adjustments for price inflation from 2004 to 2019.

⁵⁹ Patterson, M.G. and Cole, A.O. 2013. 'Total Economic Value' of New Zealand's Land-Based Ecosystems and their Services. In, *Ecosystem Services in New Zealand: Conditions and Trends*. Dymond, J.R. (Editor) pp 496-510. Manaaki Whenua Press, Lincoln, New Zealand.

⁶⁰ Statistics New Zealand. (2001). *Harmonised System Statistics 2001*. Wellington: Statistics New Zealand.

⁶¹ McDonald, G. (2005). *Integrating economics and ecology : a systems approach to sustainability in the Auckland region*. Palmerston North: Massey University. Retrieved from <http://hdl.handle.net/10179/1776>

⁶² McDonald, G. O., and Patterson, M.G. (2008) *Development of a New Zealand Physical Input Output Table*. New Zealand Centre for Ecological Economics Monograph Series No. 10. Massey University, Palmerston North, New Zealand. ISBN 978-0-9582782-6-3

⁶³ The remaining 14 sectors (Chapter 22 to 35) mainly produced 'services' so their outputs were measured in monetary units (\$000).

⁶⁴ McDonald, G., & Patterson, M. (2006). Development of a New Zealand Physical Input-Output Table. *Intermediate Input-Output Meetings on Sustainability, Trade & Productivity*. Sendai, Japan.

⁶⁵ Some service sectors such as "Central Government Administration and Defence" don't have output prices and therefore are not measured by the Producer Price index (output prices) produced by Statistics New Zealand.

⁶⁶ Eco-efficiency indicators measure useful output (\$), relative to the amount of natural resource used or residuals/wastes/emissions produced by that given sector. These are operationally the same as 'direct intensities', 'indirect intensities' and 'total intensities'.

Measurement Units in the LCA Diagrams

Precise definition of the measurement units used in the LCA diagrams contained in Chapter 4 to 36 are specified in Table 3.1 .

Table 3.1 Measurement Units Used in the LCA Diagrams

Category	Units ¹	Chapter or CD ²
<u>Resources</u>		
Total Energy Inputs ³	MJ _{OE} /tonne or MJ _E /\$1,000	Chapters 4-35
Total Energy Inputs ⁴	MJ _H / tonne or MJ/\$1,000	Chapters 4-35
Fossil Fuel Inputs ⁴	MJ _H / tonne or MJ/\$1,000	Chapters 4-35
Electricity ⁴	MJ _H / tonne or MJ/\$1,000	Chapters 4-35
Land	m ² /tonne or m ² /\$1,000	Chapters 4-35
Water Inputs	litres/tonne or litres/\$1,000	Chapters 4-35
Ecosystem Services ^{5,6}	\$ecosystem services /tonne	Chapter 36
Ecosystem Services ^{5,7}	\$ecosystem services /\$1,000 or tonne	Available ²
<u>Wastes/Residuals</u>		
Landfill Wastes	grams/tonne or grams/\$000	Chapters 4-35
Phosphorus into Water Bodies and Land	grams/tonne or grams/\$000	Chapters 4-35
Water Wastes	litres/tonne or litres/\$1,000	Chapters 4-35
Carbon dioxide from energy use	grams/tonne or grams/\$1,000	Chapters 4-35
Methane from energy use	milligrams/tonne or milligrams/\$1,000	Available ²
Nitrous oxide from energy use	milligrams/tonne or milligrams/\$1,000	Available ²
Recycled Wastes	grams/tonne or grams/\$1,000	Available ²
Metal Solid Wastes	grams/tonne or grams/\$1,000	Available ²
Glass Solid Wastes	grams/tonne or grams/\$1,000	Available ²
Paper Solid Wastes	grams/tonne or grams/\$1,000	Available ²
Plastic Solid Wastes	grams/tonne or grams/\$1,000	Available ²

Notes

1. Numerator = resource or waste; Denominator = Either: (1) tonnes of commodities produced by sector; Or: (2) market value (\$1,000) of commodities produced by sector, usually necessary for service sectors
2. Not in this publication. Contact Authors.
3. Measured in terms of emergy units (oil equivalents). Methodologically incorrect to add up energy inputs measured in 'heat content' units – refer to the text. To convert 'oil equivalents' to the more conventional 'solar equivalents' multiply by 7,400.
4. Measured in terms of heat units – refer to the text
5. Ecosystem Services classified as a 'resource'. However, some ecosystem services (e.g.waste treatment & nutrient cycling) process wastes.
6. These Ecocystem Services include: climate regulation , disturbance regulation, water regulation, erosion control & waste treatment.
7. These Ecocystem Services include: nutrient cycling, raw materials

On the *resource* side, the LCA diagrams measure how much resource directly and indirectly it takes to produce a given amount of product or service. This measure can be seen as a ratio with the numerator measuring the 'amount of resource required ' and the denominator measuring the 'amount of product produced,' either as 'per tonne' of physical product or 'per \$1,000' for a service .

On the *waste or residual* side , the LCA diagrams measure how much wastes/residuals are generated in producing either a tonne of physical product or \$1,000 for a service .

The LCA diagrams also provide information on the amount of *ecosystem services* required to produce a physical product or service (Chapter 36). Because the base data were utilised in our calculations drawn from Patterson (2013) the 'amount of ecosystem services' is measured in monetary terms, although in principle the amount of ecosystem services could also be measured in terms of physical units.

4. Horticulture and Fruit Growing

Description

ANZSIC Codes covered:

- 011 – Nursery and Floriculture Production
- 012 – Mushroom and Vegetable Growing
- 013 – Fruit and Tree Nut Growing

Main commodities supplied (hectares in 2007):

- Kiwifruit (13,250), grapes (29,616), avocados (4,004), apples (9,247), blackcurrants (1,275)⁶⁷
- Indoor vegetables such as capsicum, cucumber and tomatoes (2,397,468), outdoor vegetables such as broccoli, carrots and lettuce (49,779)
- Indoor crops such as flowers, bulbs and nursery plants (2,058,680)⁶⁸

GDP 2016 = \$1.833 billion

Rank = 22nd

Average annual growth rate

2006 to 2016 = 7.46%

Rank = 7th

Employment 2016 = 35,523

Rank = 15th

Economic Overview

Although pastoral farming dominates land use in New Zealand, over the last 20 years there have been significant increases in areas planted in horticulture and fruit. Overall, the horticulture and fruit growing sector was the 7th fastest growing sector in the economy over the period from 2006 through to 2016. Horticultural crops were traditionally grown mainly for the home market, but horticulture exports have been increasing to become New Zealand's sixth-largest export industry, with fruit, vegetables and flowers being exported to 121 different countries in 2007. Kiwifruit is New Zealand's largest horticultural export by value. ZESPRI, the single desk exporter, manages approximately 30% of internationally traded kiwifruit and supplies 53 countries,⁶⁹ with the three major markets being Continental Europe (28%), China (25%), and Japan (21%) and developing markets- which include the domestic market, as well as Australia, South-East Asia, the Indian Ocean Region, and Far East Russia.⁷⁰

Three-quarters of the fruit produced is consumed domestically, with peaches, nectarines and plums produced mainly for domestic consumption, while the majority of apricots and cherries are exported.⁷¹ Horticulture in NZ occupies more than 120,000 hectares of land, producing more than 60 different vegetables, and employing 60,000 people,⁷² although roughly 80% of these are short-term, seasonal workers.⁷³ However, when Kiwifruit is taken out of the equation, New Zealand's fruit and

⁶⁷ Statistics New Zealand. (2008). New Zealand Official Yearbook 2008. Auckland, New Zealand: David Bateman Ltd. (pp. 372–73)

⁶⁸ Statistics New Zealand. (2007). *Agricultural Census*.

⁶⁹ Horticulture New Zealand. (2018). *Fresh Facts*. Auckland: The New Zealand Institute for Plant and Food Research Ltd.

⁷⁰ Zespri Group. (2018). *Boldly Moving Forward: Annual Review 2017/18*. Tauranga: Zespri Group

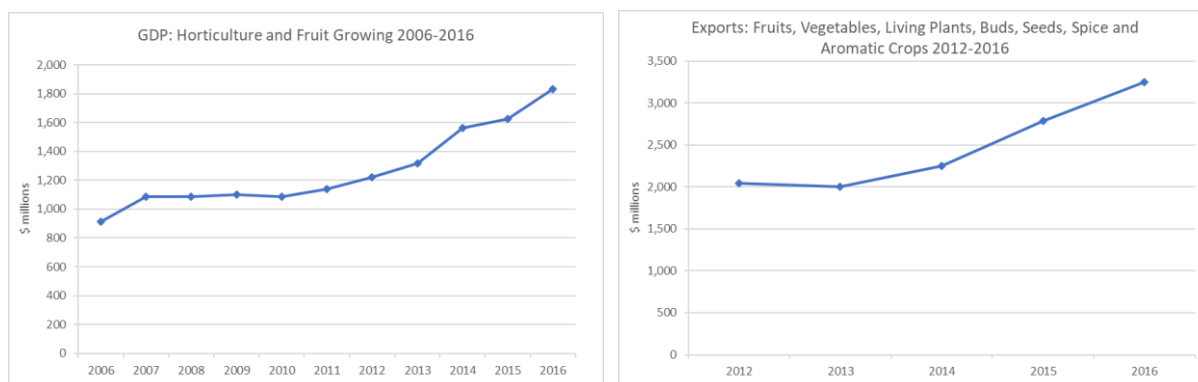
⁷¹ Statistics New Zealand. (2008). New Zealand Official Yearbook 2008. Auckland, New Zealand: David Bateman Ltd. (pp. 370–71)

⁷² Horticulture New Zealand. (2018). *A Food Story: Annual Report 2018*. Wellington. Retrieved February 5, 2020, from <https://www.hortnz.co.nz/assets/Annual-Report/HortNZ-Annual-Report-2018.pdf>

⁷³ Timmins, J. (2009). *Seasonal Employment Patterns in the Horticultural Industry*. Wellington: Statistics New Zealand. Retrieved February 5, 2020, from http://archive.stats.govt.nz/browse_for_stats/income-and-work/employment_and_unemployment/LEED-reports/seasonal-employment-patterns-in-the-horticultural-industry.aspx

vegetable exports make up a relatively small percentage of international trade, rendering the country a small player on the international market. Because approximately half of the total horticulture and fruit production in New Zealand is exported, the sector is highly vulnerable to fluctuations in the exchange rate. This means producers must take the price dictated by highly competitive world market forces, and thus have limited ability in passing on exchange rate costs to consumers.

Sector Trends



Production

Production in this sector grew steadily at an average annual growth rate of 5.2% from \$911 million in 2006 to \$1.22 billion in 2012. In more recent times, however, growth in production appears to have accelerated as levels rose by 39.2% between 2013 (\$1.32 billion) and 2016 (\$1.83 billion). Favourable weather conditions, growing domestic demand, and high commodity prices are the main driving forces behind this continued and accelerated growth.

Exports

The accelerated growth in recent years is matched by the accelerated uptake of horticulture exports. As illustrated above, prior to 2014, the value of horticulture exports remained relatively constant at around \$2 billion. However, in 2016 value grew by 62.3% to \$3.25 billion and it appears that this trend might persist in the coming years. The strong upward trend in exports is most likely due to continued growth in global demand for New Zealand fruit and vegetables. Further free trade agreements will continue to help domestic producers, as entry to overseas markets are made easier.⁷⁴

Life Cycle Assessment Diagrams

Energy (Figure 4.1, Figure 4.2, Figure 4.3)

Horticultural products were found to have a total energy intensity of 2,355.9 MJ_E per tonne of horticultural product (2.336 MJ_{OE}). Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand Horticulture and Fruit Growing sector is 3.26 MJ_H/kg. This

⁷⁴ Horticulture New Zealand. (2019). Our Food Future. Wellington.

is in a similar order to reported energy intensities for other similar products: New Zealand apples at 2.98 MJ_H/kg, New Zealand onions at 2.89 MJ_H/kg,⁷⁵ and New Zealand kiwifruit at 2.42 MJ_H/kg⁷⁶

Direct energy use was 31% of the total energy intensity, measuring MJ_{OE} 738 per tonne of horticultural produce. Direct energy uses includes energy for horticultural equipment (tractors, picking machines), some for horticultural irrigation equipment such as pumps, storage shed energy use and increasingly for heating indoor cropping facilities particularly tomatoes – the EECA in use database reports that 3,3016 TJ of energy was used for indoor cropping in 2006/07. *Indirect energy use* was 69% of the total energy intensity, measuring 2,356 MJ_{OE} per tonne of horticultural product. *The main indirect energy uses were; (i) energy embodied in non-mineral products at 421.2 MJ_{OE}/tonne; (ii) energy embodied in paper products at 325.9 MJ_{OE}/tonne, which includes the energy embodied in cardboard and paper packaging materials for horticultural products; (iii) energy embodied in other animal products at 204.2 MJ_{OE}/tonne; (iv) energy embodied in road transport at 182 MJ_{OE}/tonne, which includes the energy to transport horticultural produce from the farm gate usually to storage facilities.*

It should be noted that the total energy intensity (2,336 MJ_{OE}/tonne) for horticultural products is the fifth-lowest of the 20 product-producing sectors covered in this publication, but it is relatively high amongst the other primary-sector products considered (mineral products, raw milk, non-metal and mineral products, wood products). It can, therefore, be considered that horticultural products are relatively energy-intensive, for primary sector products.

Land (Figure 4.4)

Surprisingly, horticultural products do not have such a large footprint compared to other product producing sectors, with a total land intensity of 924.1 m² per tonne of product produced; ranking 14th out of the 20 product producing sectors covered by this publication. The land footprint of horticultural products is considered very low when compared to the three highly ranked sectors: 74,998 m² of land per tonne of meat products, 46,563 m² of land per tonne of livestock and crops products, and 40,651 m² of land per tonne of textile and apparel products.

Direct land use made up 67% of all embodied land used to produce horticultural products measuring 619 m² per tonne of horticultural produce. Direct land use is the total land used to grow horticultural produce. *Indirect land use* was 33% of all embodied land used to produce horticultural products, measuring 305.1 m² per tonne of horticultural produce. *The major indirect land uses in the production of horticultural produce came from; (i) land embodied in livestock and crops at 172.8 m² per tonne of produce; (ii) land embodied in other animal products at 32.7 m² per tonne of produce; (iii) land embodied in wholesale and retail trade at 26.5 m² per tonne of produce; (iv) land embodied in non-metal mineral products at 14.8 m² per tonne of produce.*

Water Inputs (Figure 4.5)

Not surprisingly, horticulture and fruit produce require large water inputs with 28,183.9 litres per tonne of product produced, ranking the sector 9th out of the 20 product producing sectors. Other reported amounts of water inputs for various fruit and vegetables include: pears 95,508 m³ ton⁻¹ (97,040,608 litres per tonne), kiwifruit 170,695 m³ ton⁻¹ (173,434,127 litres per tonne), and apples

⁷⁵ Saunders, C., Barber, A., Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry (Research Report No.285)*. Christchurch, New Zealand: Lincoln University

⁷⁶ Hall, P., Jack, M. (2008). *Bioenergy Options for New Zealand: Pathways Analysis*. Rotorua, New Zealand: Scion Energy Group.

135,134 m³ ton⁻¹ (137,302,483 litres per tonne).⁷⁷ These figures are substantially higher than the figure given in the LCA diagram. A possible reason for this is that the reported figures above are global averages, suggesting New Zealand horticultural produce requires less blue water inputs due to geographical differences, relying more on green water inputs (rainwater) which are not taken into account in these figures.

Water inputs are made up mostly of *direct water inputs* into horticultural products at 70%, measuring 19,898.1 litres per tonne of horticultural produce. Direct water inputs come mainly from irrigation and post-harvest washing of fruit and vegetables – As at 30 June 2012, the area of irrigable land increased 17% from 2007 to 721,700 hectares.⁷⁸ *Indirect water inputs* are a much smaller share of total water use at 30%, measuring 8,285.8 litres per tonne of horticultural produce. *The main indirect water inputs into the horticulture and fruit produce sector came from; (i) water inputs embodied in non-metal mineral products at 2,753 litres per tonne; (ii) water inputs embodied in wholesale and retail trade at 2,221 litres per tonne; (iii) water inputs embodied in mining and quarrying at 1,382 litres per tonne; (iv) water inputs embodied in other animal products at 872 litres per tonne.*

Landfill Wastes (Figure 4.6)

The horticultural and fruit produce sector was found to generate 10,656.9 grams (10.6 kg) of landfill waste per tonne of product. *Landfill waste directly* generated by horticultural products was only 4% of total waste produced or 423.6 grams per tonne of horticultural and fruit produce. This is likely because most horticultural product waste can decompose naturally. *Landfill waste indirectly* generated by horticultural products was a massive 96% of total waste produced or 10,233.3 grams per tonne of horticultural produce. *The main sources of indirect landfill waste came from; (i) landfill wastes embodied in non-metal mineral products at 3,153 grams per tonne; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 2,003 grams tonne; (iii) landfill wastes embodied in other animal products at 1,016 grams per tonne.*

It should be noted that landfill waste (10,656.9 grams per tonne) for horticultural products is the fifth lowest out of the 20 product producing sectors covered in this publication. This is relatively similar for other primary sector products considered such as livestock and crops, raw milk, forestry and logging. It can, therefore, be considered that horticultural products, like other primary sectors, produce relatively low levels of landfill waste.

Water Wastes (Figure 4.7)

The horticultural and fruit produce sector was found to produce 16,130.8 litres of wastewater per tonne of product, ranking the sector 15th highest out of the 20 product producing sectors covered in this publication. *Wastewater directly* generated by horticultural produce was only 2% of total waste produced at 271.8 litres per tonne of horticultural product. *Water wastes indirectly* generated by horticultural products made up the majority of the total at 98% or 15,859 litres per tonne of product.

The main sources of indirect wastewater from horticultural and fruit produce came from (i) wastewater embodied in non-metal mineral products at 7,393 litres per tonne of horticultural product produced; (ii) wastewater embodied in mining and quarrying at 3,433 litres per tonne of horticultural product produced; (iii) wastewater embodied in paper products at 1,283.5 litres per tonne of

⁷⁷ Mekonnen, M.M. and Hoekstra, A.Y. (2011). The green, blue and grey water footprint of crops and derived crop products, *Hydrology and Earth System Sciences*, 15(5): 1577-1600.

⁷⁸ Statistics New Zealand. (2013, May 13). Agricultural Production Statistics: June 2013 (final). Retrieved from http://www.stats.govt.nz/~media/Statistics/Browse%20for%20stats/AgriculturalProduction_final/HOTPJun12final/AgriculturalProduction_finalJun12finalHOTP.pdf

horticultural product produced; (iv) wastewater embodied in other animal products at 1,052 litres per tonne of horticultural product produced.

Phosphorus Wastes (Figure 4.8)

The horticultural and fruit produce sector was found to produce 97.4 grams of phosphorus waste per tonne of product. *Phosphorus waste directly* generated by horticultural products was only 22% of total waste produced at 21.7 grams per tonne of horticultural product. *Phosphorus waste indirectly* generated by horticultural products made up the majority of the total at 78% or 75.7 grams per tonne of horticultural product. *The indirect phosphorus waste from the production of horticultural and fruit produce was mostly made up of (i) phosphorus waste embodied in other animal products at 44.3 grams per tonne of product; (ii) phosphorus waste embodied in other livestock and crops at 21.1 grams per tonne of product; (iii) phosphorus waste embodied in wholesale and retail trade at 3.7 grams per tonne of product; (iv) phosphorus waste embodied in other non-metal mineral products at 2.1 grams per tonne of product.*

Energy Greenhouse Gases (Figure 4.9)

In terms of CO₂ greenhouse gas emissions, the horticultural and fruit produce sector was found to emit 326,386.9 grams of energy-related CO₂ per tonne of product produced. This is in a similar order of magnitude to reported CO₂ greenhouse gas emissions produced by various horticultural products: New Zealand Apples at 60,100 grams per tonne.⁷⁹

Energy-related CO₂ directly generated by horticultural products was only 25% of total waste produced at 12,726.4 grams per tonne of product. *Energy-related CO₂ indirectly generated* by horticultural products made up the majority of the total at 75% or 244,660.5 grams per tonne of product. *The indirect energy-related CO₂ was mostly made up of (i) energy-related CO₂ embodied in Non-metal mineral products at 73,796.1 grams per tonne of horticultural product produced; (ii) energy-related CO₂ embodied in paper products at 65,318.6 grams per tonne of horticultural product produced; (iii) energy-related CO₂ embodied in other animal products at 23,204.2 grams per tonne of horticultural product; (iv) energy-related CO₂ embodied in road transport services at 21,479.8 grams per tonne of horticultural product; energy-related CO₂ embodied in wholesale and retail trade at 15,461.9 grams per tonne of horticultural product.*

Energy-related CO₂ emissions (326,386.9 grams/tonne) from horticultural products are ranked 15th out of the 20 product producing sectors covered in this publication. A low level of energy-related CO₂ emissions in horticultural products is consistent with other primary sectors products considered such as livestock and crops (14th), raw milk (18th), forestry and logging (19th), and mining and quarrying (20th).

⁷⁹ Saunders, C., Barber, A., Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry* (Research Report No.285). Christchurch, New Zealand: Lincoln University.

Figure 4.1 - Total Energy Inputs Required to Produce One Tonne of Horticulture and Fruit Products, 2004 (MJ_E, Oil Equivalents)

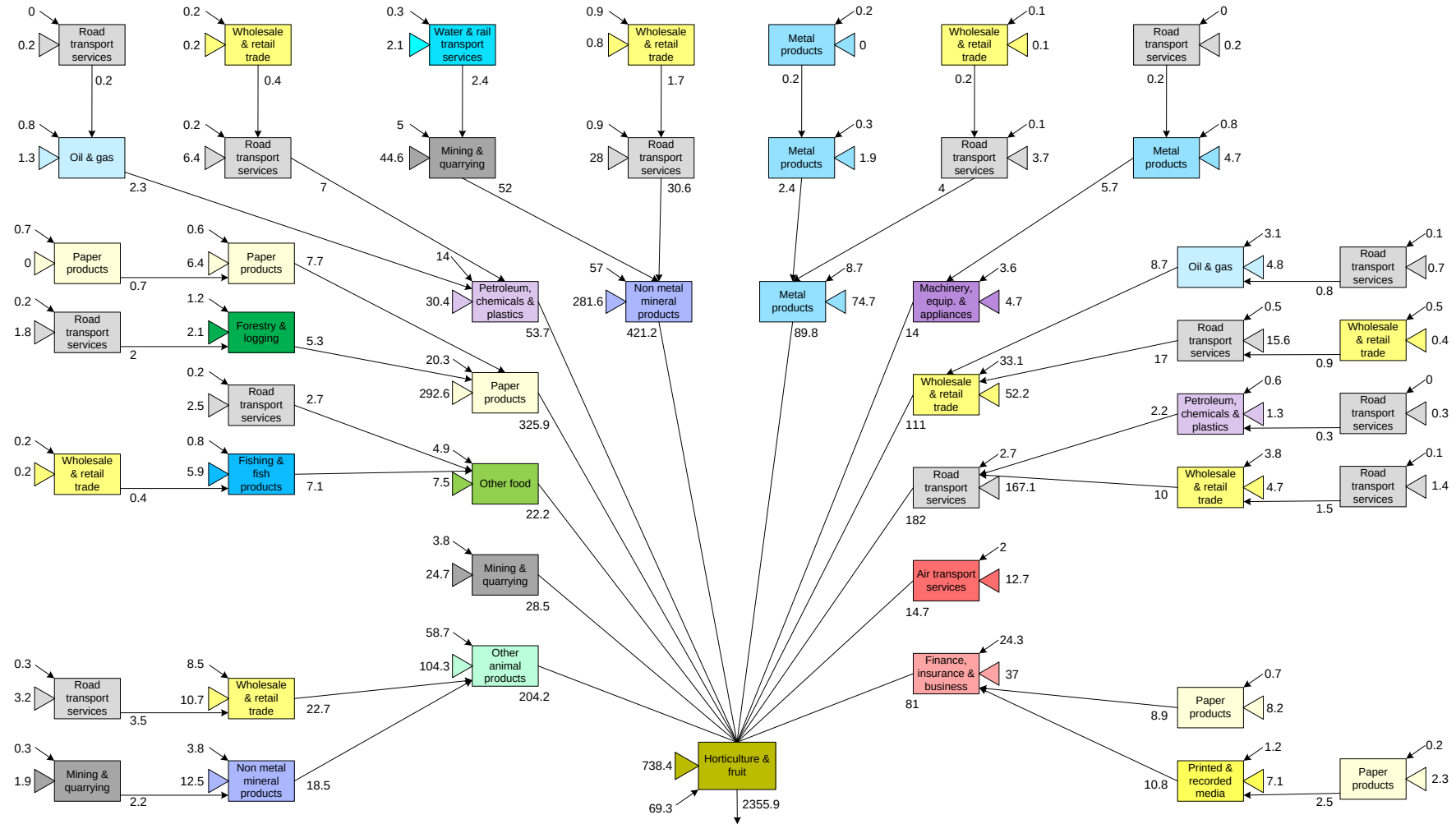


Figure 4.2 - Electricity Inputs Required to Produce One Tonne of Horticulture and Fruit Products, 2004 (MJ, Heat Equivalents)

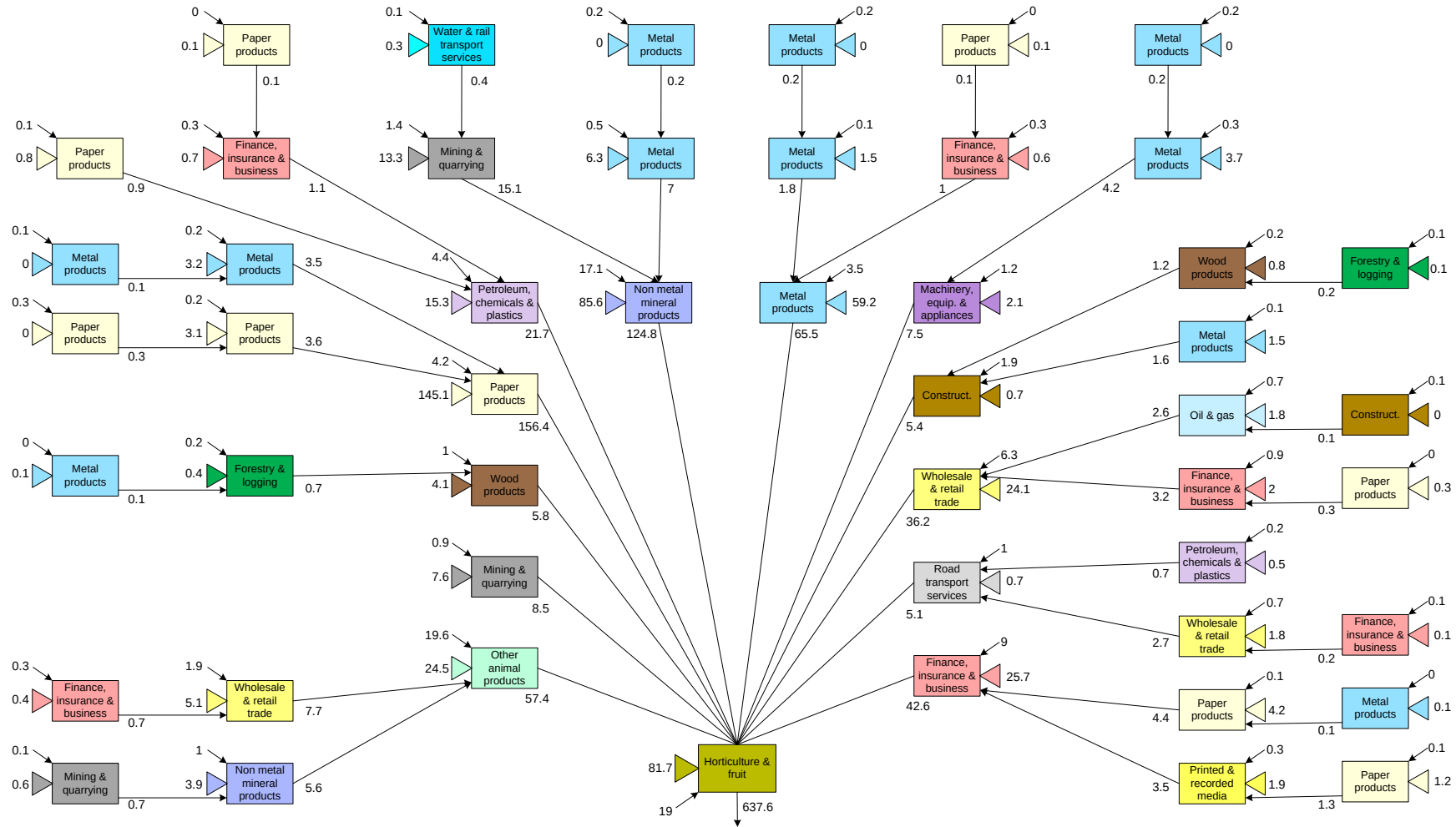


Figure 4.3 - Fossil Fuel Inputs Required to Produce One Tonne of Horticulture and Fruit Products, 2004 (MJ, Heat Equivalents)

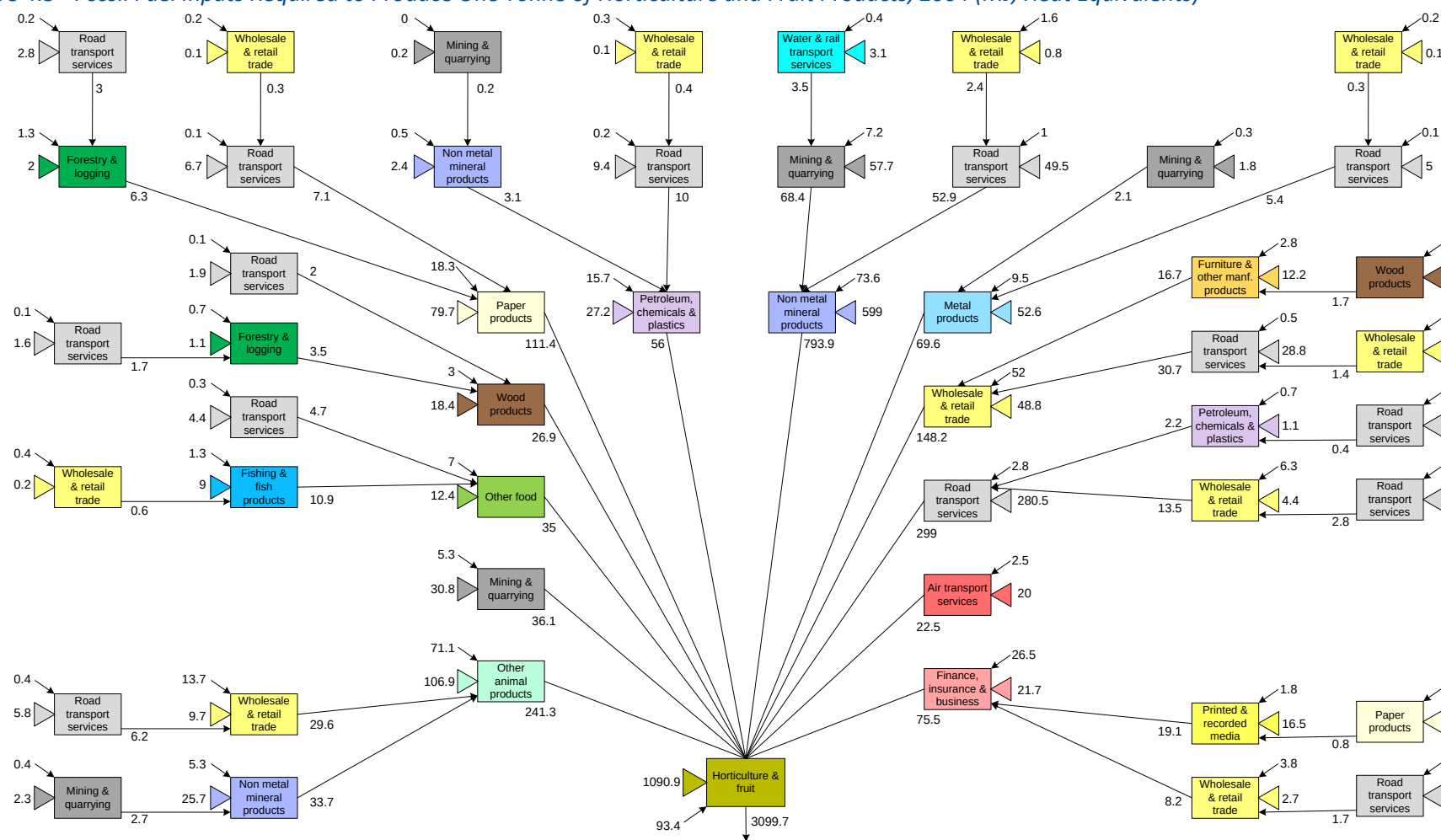


Figure 4.4 - Land Required to Produce One Tonne of Horticulture and Fruit Products, 2004 (m²)

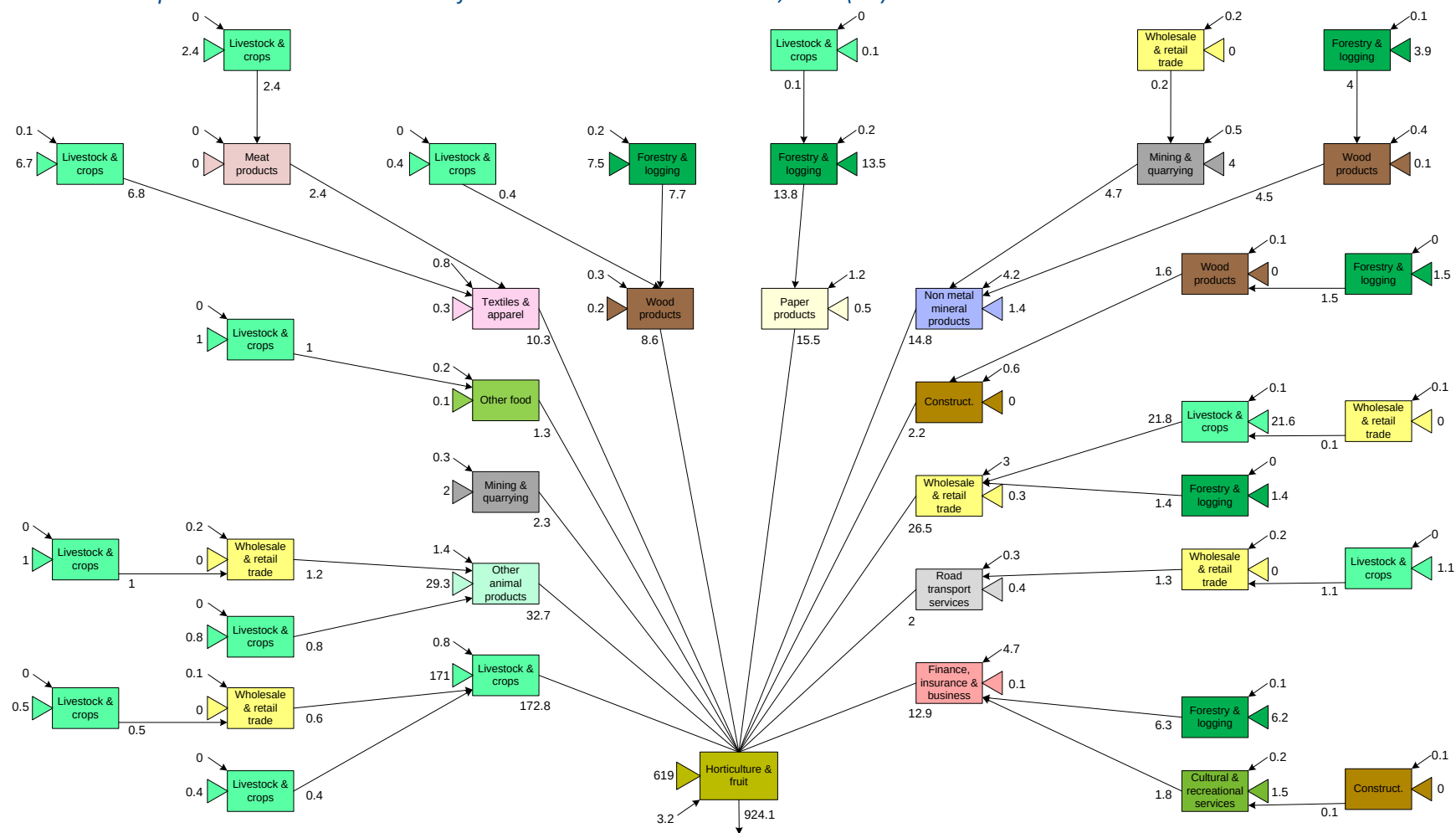


Figure 4.5 - Water Inputs Required to Produce One Tonne of Horticulture and Fruit Products, 2004 (Litres)

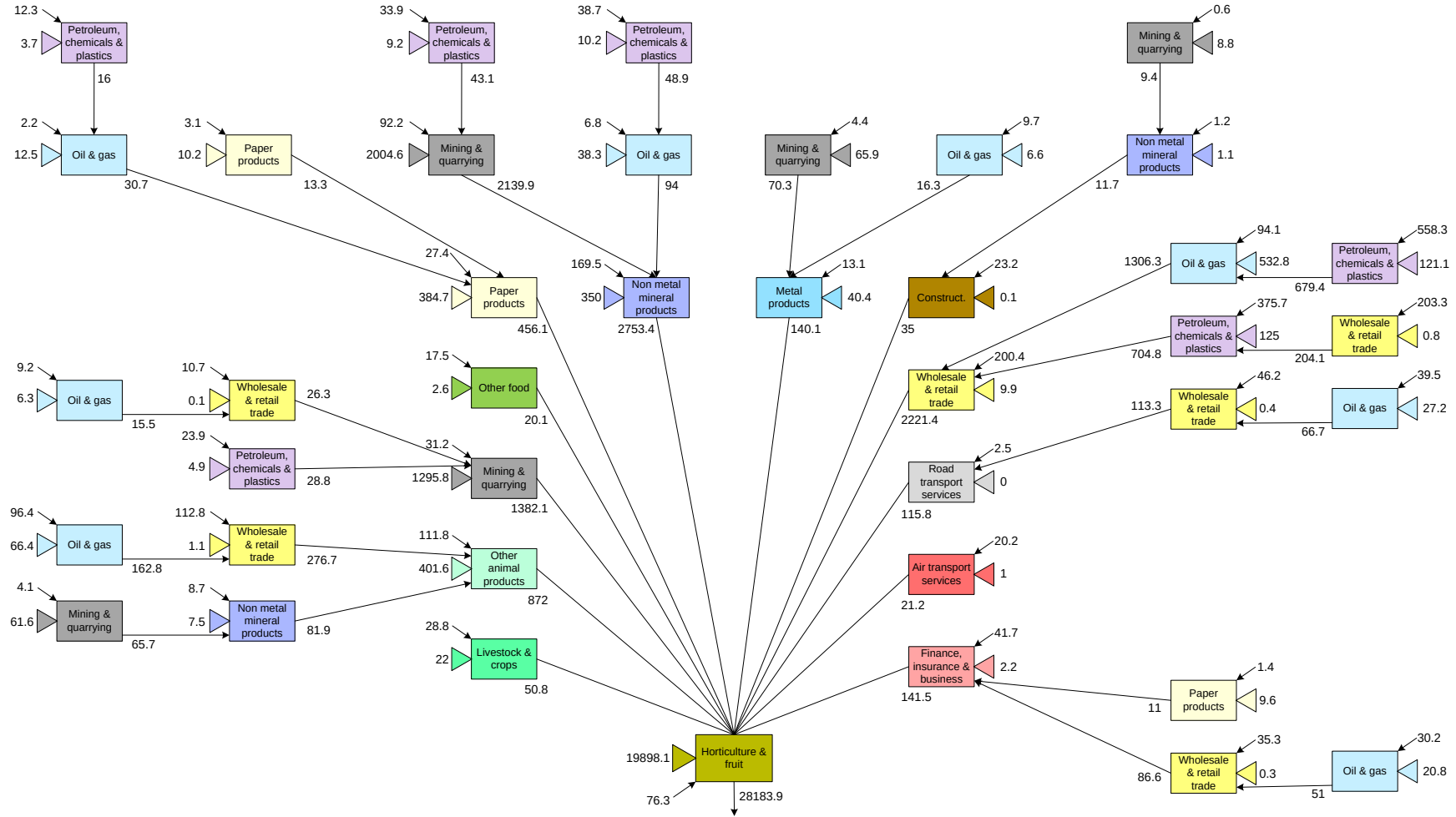


Figure 4.6 - Landfill Waste Generated in Producing One Tonne of Horticulture and Fruit Products, 2004 (Grams)

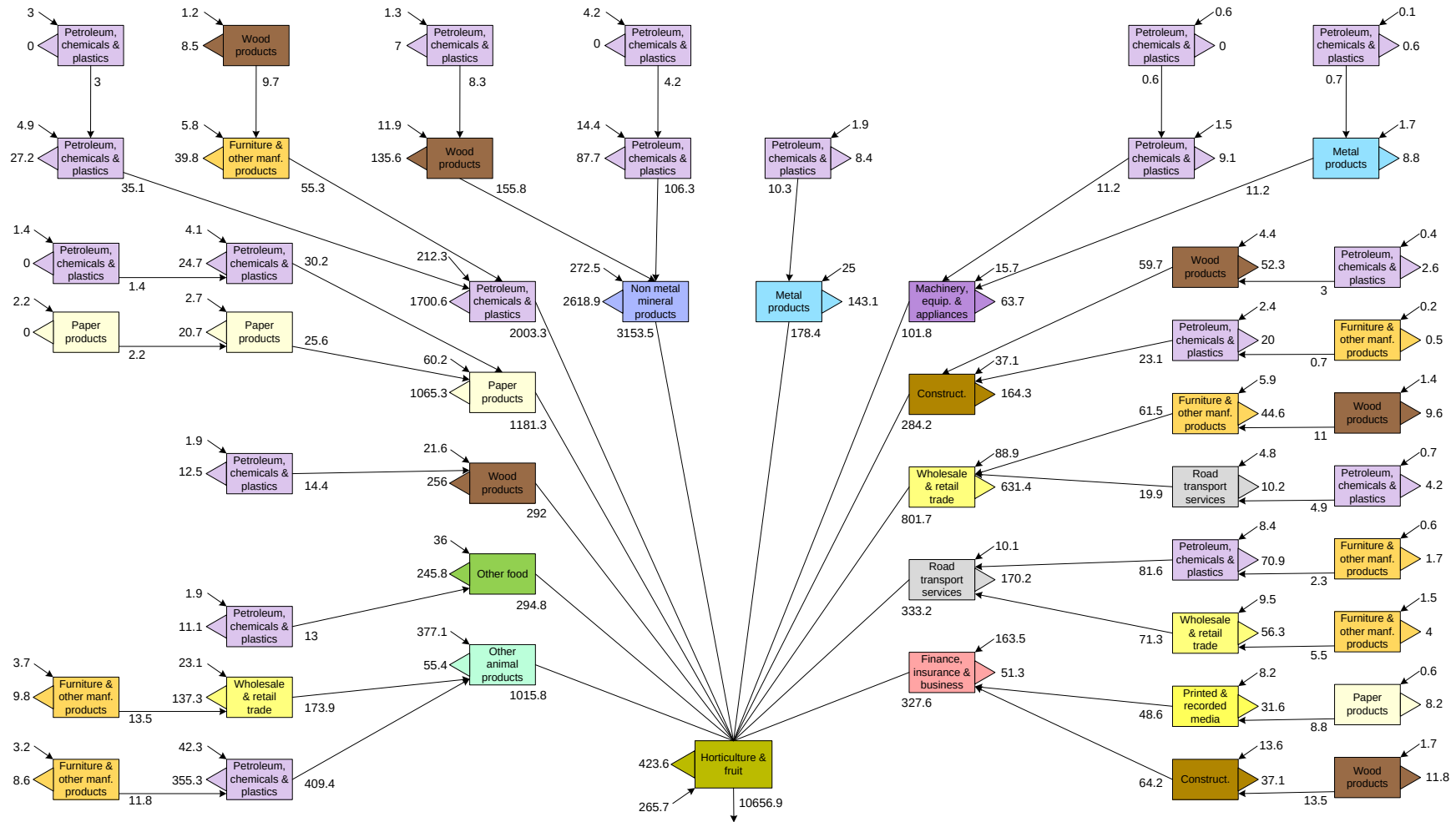


Figure 4.7 - Water Waste Generated in Producing One Tonne of Horticulture and Fruit Products, 2004 (Litres)

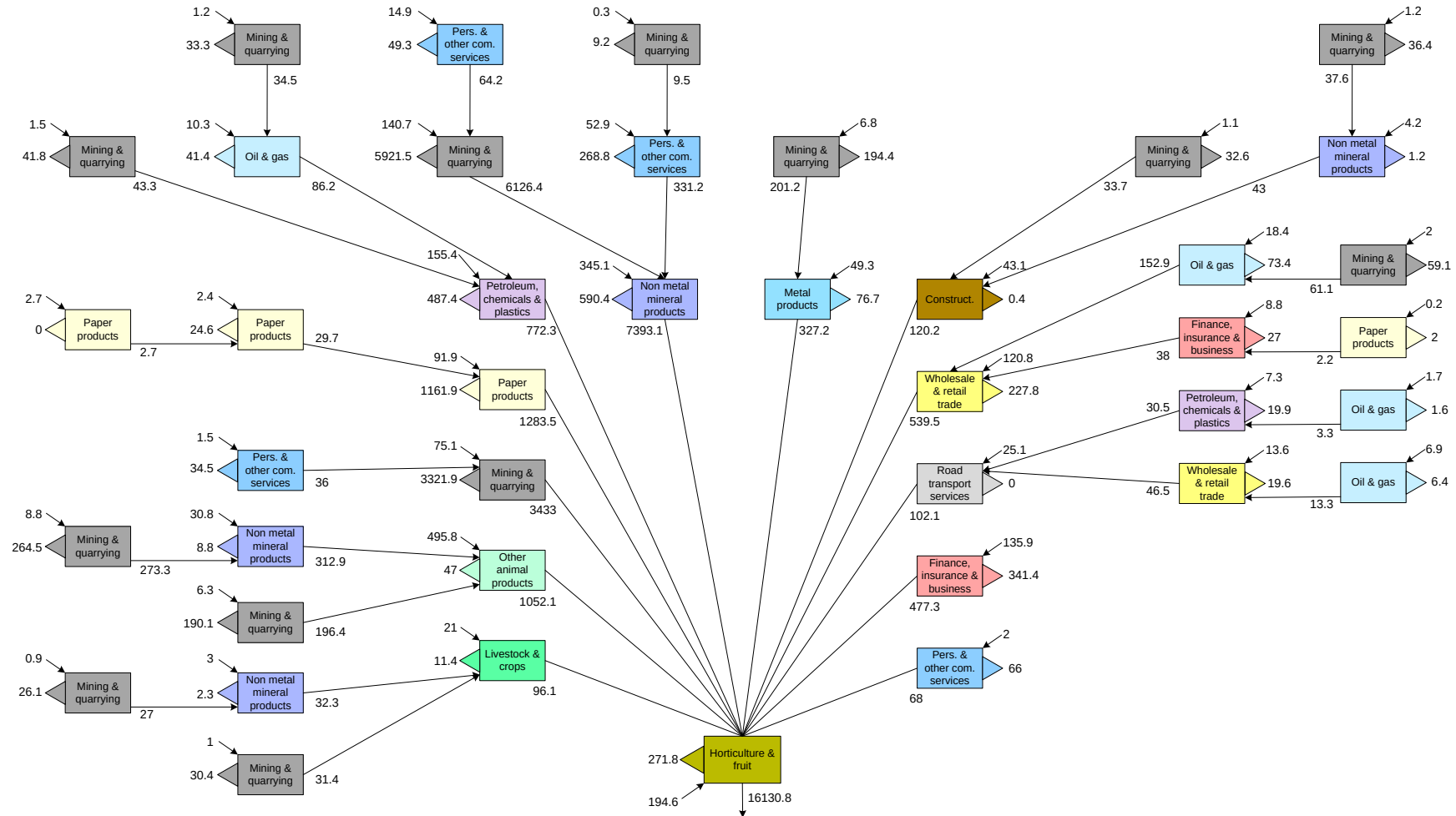


Figure 4.8 - Phosphorus Waste Generated in Producing One Tonne of Horticulture and Fruit Products, 2004 (Grams)

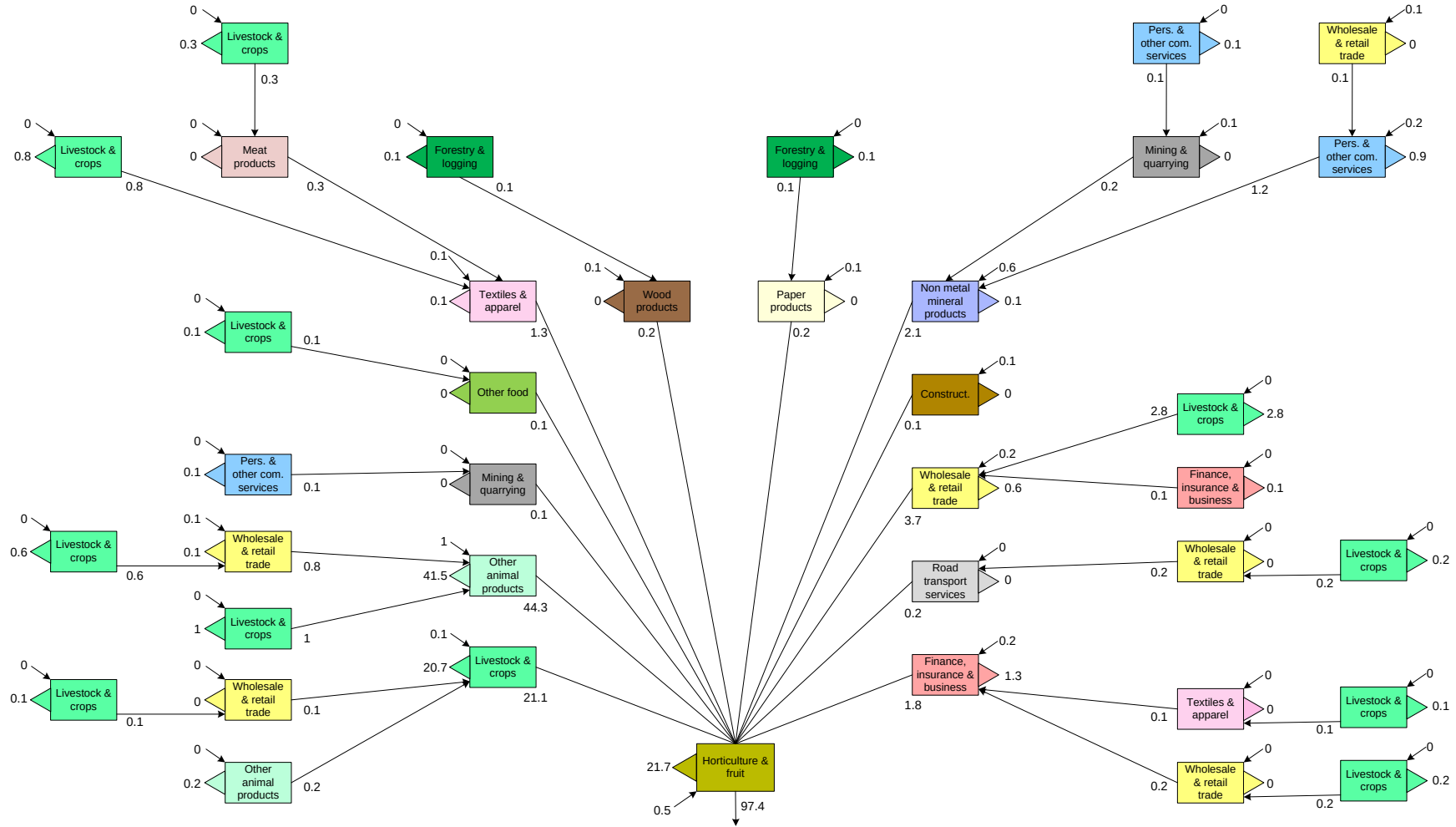
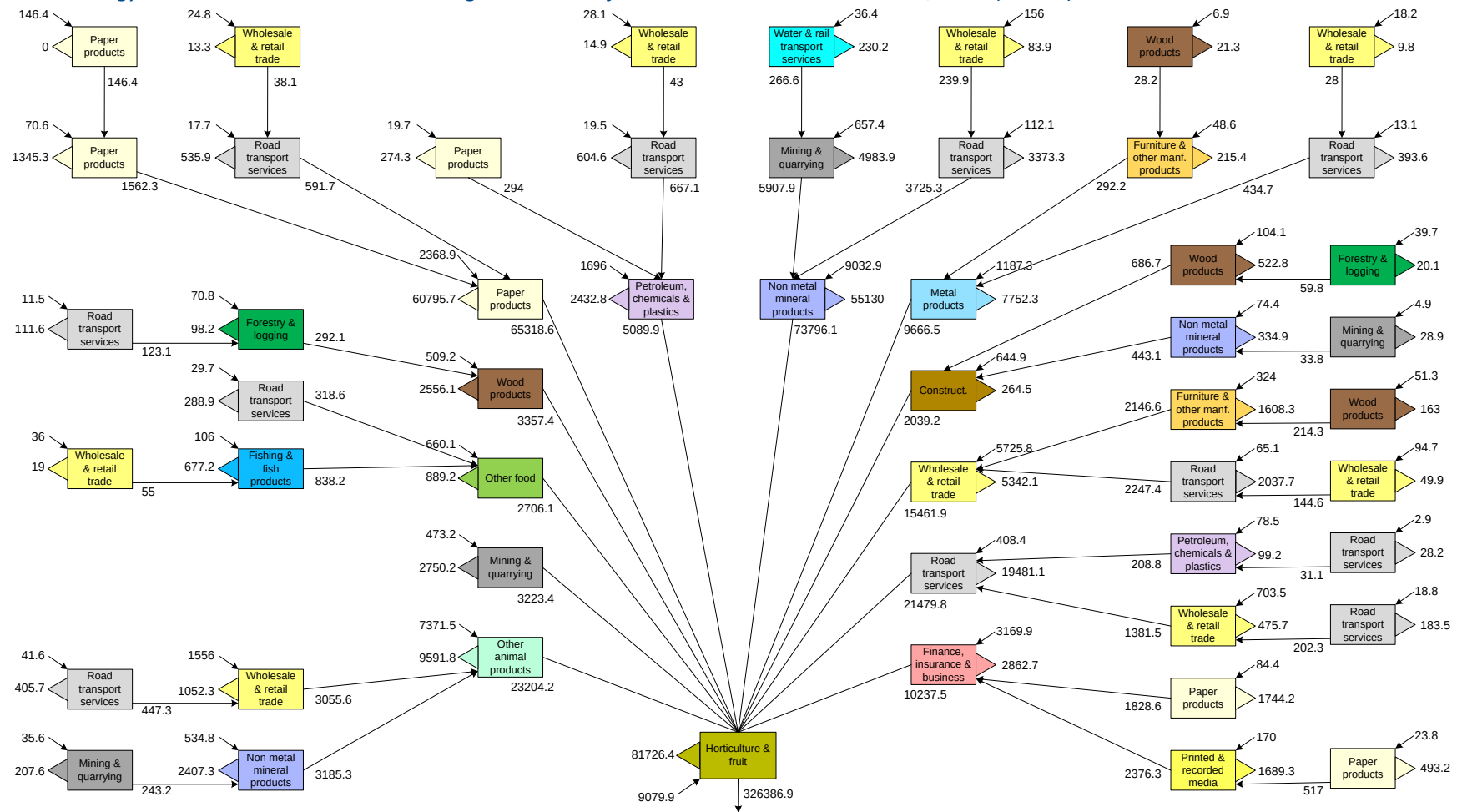


Figure 4.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Horticulture and Fruit Products, 2004 (Grams)



5. Livestock and Crop Farming

Description

ANZSIC Codes covered:

- 0141 – Sheep Farming
- 0142 – Beef Cattle Farming
- 0143 – Beef Cattle Feedlots
- 0144 – Beef-Sheep Farming
- 0145 – Grain-Sheep or Grain-Beef Cattle Farming
- 0146 – Rice Growing
- 0149 – Other Grain Growing
- 0151 – Sugar Cane Growing
- 0152 – Cotton Growing
- 0159 – Other Crop Growing

GDP 2016 = \$2.79 billion
Rank = 16th

Average annual growth rate
2006 to 2016 = 4.26%
Rank = 17th

Employment 2016 = 40,016
Rank = 14th

Main commodities supplied:

- Livestock (Numbers in 2007): Sheep (38.5 million), beef cattle (4.39 million), wool (164,000 tonnes)⁸⁰
- Grain (Tonnes in 2005): barley (300,000), wheat (310,000), and maize (205,000)⁸¹

Economic Overview

Well over half of New Zealand's total land area is devoted to the grazing of livestock on pasture, cropping or is fallow, making livestock and crop farming the dominant land use in New Zealand, accounting for 11.1 million of the total 14.4 million hectares in agriculture in 2012.⁸² It was the 16th largest sector in the economy in 2016, contributing \$2.79 billion to GDP. Climatic conditions, soil type, type of stock carried, and land contours determine stocking rates for New Zealand farms. Trends in livestock numbers included in this sector are largely determined by world market prices for meat and wool, but New Zealand has an advantage in this area, being able to combine properties and shift land use from one activity to another in response to shifting market returns.

Probably New Zealand's best-known statistic is that it once had more than 20 times as many sheep as people; however, by 2018 the ratio was down to 5.6 sheep for every person.⁸³ The sheep population in NZ declined dramatically from 70.3 million in 1982 to 27.3 million in 2018. The beef cattle population fell 20.97% over the same period to reach 3.72 million in 2018.

⁸⁰ Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. Auckland, New Zealand: David Bateman Ltd. (pp. 359–61)

⁸¹ Te Ara, *The Encyclopaedia of New Zealand, Grain production, 1905–2005*.

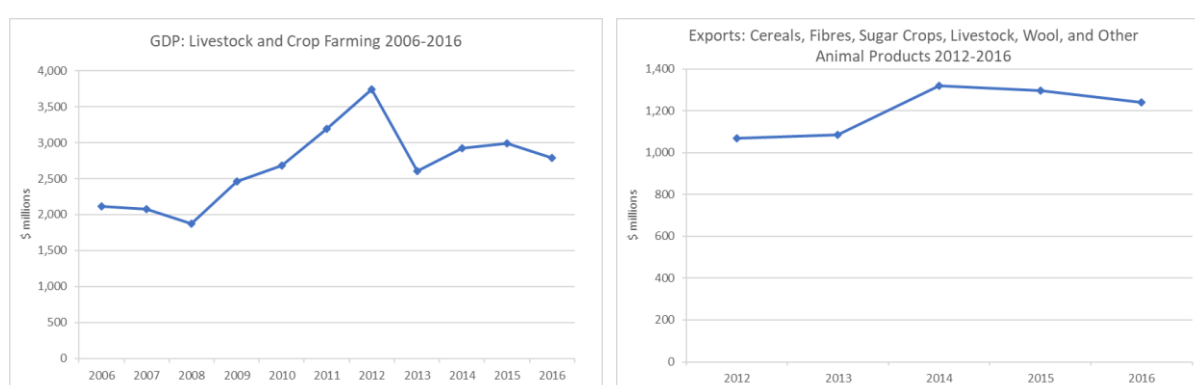
⁸² Statistics New Zealand. (2012). *2012 Agricultural Census Tables*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/2012-agricultural-census-tables/land-use.aspx#

⁸³ Rae, S. (2019). *Now 5.6 sheep for each NZer*. Retrieved from Otago Daily Times: <https://www.odt.co.nz/rural-life/red-meat/now-56-sheep-each-nzer>

Wool has historically been the most significant commodity in this sector, but while in 1988 exports of wool were worth \$1.8 billion, they have been continuously declining to reach only \$635 million in 2007, following an end to government subsidies in 1984, a switch to synthetic fibres, and falling global wool prices and adverse exchange rates. Illustrating the decreasing contribution of wool to the New Zealand economy. Additionally, an increasing price in lamb has resulted in a shift away from wool exportation to sheep meat exportation,⁸⁴ as well as increasing dairy returns incentivising farmers to switch from sheep to dairy farming.

New Zealand produces a small amount of the world's grain production, with exports falling from \$15.3 million in 1988 to \$2.6 million in 2007. While New Zealand exports livestock, with a surge in exports in 2019,⁸⁵ there are calls to ban the practice, largely due to animal welfare concerns.⁸⁶

Sector Trends



Production

Overall production in the livestock and crop farming sector has increased from \$2.11 billion in 2006 to \$2.79 billion in 2016, growing at an average annual rate of 4.3%. While this 33% increase over a 10-year period could be considered rather modest, it is worthy to note that this sector experienced strong growth between 2008 and 2012, with production levels peaking at \$3.74 billion in 2012. Not only does this upward trend signal the sector's strong recovery following the global financial crisis (GFC) of 2007-08, but it also highlights New Zealand as an ideal place to farm livestock given the country's temperate climate, fertile soils, absence of predators, an abundance of space, and low disease rates. In 2013, however, production in this sector declined significantly by 70% to \$2.6 billion, this is a result of the 2012-2013 drought experienced throughout New Zealand.⁸⁷ Since then, production reached another peak at \$3 billion in 2015.

Exports

Between 2013 and 2014, the value of exports increased noticeably by 17.9%, from \$1.08 billion up to a peak of \$1.32 billion. Outside of this growth, exports appear to be relatively stagnant, with exports having tailed off slightly through to 2016 by \$80 million. A likely reason for the stagnant pattern of growth is down to New Zealand's proximity to the global wool and livestock market. The geographical

⁸⁴ Statistics New Zealand. (2012). *Wool at a Glance*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/wool-at-a-glance-2011-infographic.aspx

⁸⁵ Taunton, E. (2019, 10 17). *Live cattle exports climb despite continued calls for a halt to trade*. Retrieved from <https://www.stuff.co.nz/business/farming/116653286/live-cattle-exports-climb-despite-continued-calls-for-a-halt-to-trade>

⁸⁶ Ministry for Primary Industries. (2020). *Review of livestock exports*. Retrieved from <https://www.mpi.govt.nz/news-and-resources/consultations/review-of-livestock-exports/>

⁸⁷ NIWA. (2013). *The 2012-13 drought: an assessment and historical perspective*. Wellington: Ministry for Primary Industries

isolation of NZ in comparison with other countries in South America and Asia reduces the country's ability to remain competitive, mainly due to the logistical difficulty of exporting livestock, meaning producers are focusing on targeting domestic consumers instead.

Life Cycle Assessment Diagrams

Energy (Figure 5.1, Figure 5.2, Figure 5.3)

Livestock and crop products were found to have a total energy intensity of 2.80 MJ_{OE}/kg of product. Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand livestock and crop farming sector is 4.87 MJ_H/kg. It is difficult to compare this figure with literature data, because of the aggregation in our publication of the categories "livestock" and "crops", whereas the literature only reports one category at a time. However, Patterson and Earle (1985)^{88, 89} reports wheat production having a total energy intensity of between 1.1 and 1.6 MJ_H/kg for New Zealand, and Slessor and Wallace (1981)⁹⁰ reports a total energy intensity of 1.4 to 2.1 MJ_H/kg for wheat production in the European Union. Given: (1) these low literature energy intensity data for "crops", (2) given the higher total energy intensity for this sector in our study, and (3) given known relative volumes of outputs of "crops" versus "livestock", then it can be algebraically implied that the energy intensity for livestock must be higher than crops in our New Zealand data.

Direct energy use was 34% of the total energy intensity, measuring 962.9 MJ_{OE} per tonne of livestock and crop product. Direct energy uses includes energy for crop harvesting equipment (tractors), some for crop irrigation equipment such as pumps, storage shed energy use, energy use from farm vehicles for shifting stock, sheep shearing, and farm utility sheds – the EECA in use database reports that 2,203.758 TJ of energy was used for the non-dairy agriculture sector in 2006/07. *Indirect energy use* was 66% of the total energy intensity, measuring 1,834.9 MJ_{OE}/tonne of livestock and crop product.

The main indirect energy uses were; (i) energy embodied in non-metal mineral products at 577.7 MJ_{OE} per tonne; (ii) energy embodied in wholesale and retail trade at 209.6 MJ_{OE} per tonne; (iii) energy embodied in other animal products at 204.4 MJ_{OE} per tonne; (iv) energy embodied in road transport at 178.5 MJ_{OE} per tonne, which includes the energy to transport livestock between grazing locations, and transporting crop produce once harvested from the farm gate to storage facilities.

It should be noted that the total energy intensity (2,336 MJ_{OE} per tonne) for livestock and crop products is ranked 14th out of the 20 product producing sectors covered in this publication, but it is relatively high amongst the other primary sectors products considered such as horticulture and fruit (15th), raw milk (18th), forestry and logging (19th), mining and quarrying (20th). Therefore, it can be considered that livestock and crop products are relatively energy-intensive for primary sector products.

Land (Figure 5.4)

As expected, livestock and crop products had the second-largest land footprint when compared to other product producing sectors, with a total land intensity of 46,563.3 m² per tonne of product

⁸⁸ Patterson, M.G. and Earle, M.D. (1985). Energy Use in the New Zealand Food System. New Zealand Energy Research and Development Committee Report Number 110. New Zealand Energy Research and Development Committee Report, University of Auckland, Auckland.

⁸⁹ More recently Saunders, Barber and Taylor (2006) report that the total energy, *New Zealand onions* at 2.89 MJ_H/kg, and *New Zealand potatoes* at 1.20 MJ_H/kg.

⁹⁰ Slessor, M. and Wallace, F. (1981). Energy Consumption Per Tonne of Competing Agricultural Products Available to the EC. Commission of the European Communities Report Number 85. Commission of the European Communities, Belgium.

produced. *Direct land use* made up 98% of all embodied land used to produce livestock and crop products measuring 45,709.3 m² per tonne of product produced. Direct land use is the total land used to graze livestock and grow crops. *Indirect land use* only made up 2% of all embodied land used to produce livestock and crop products, measuring 854 m² per tonne of product produced.

The major indirect land uses came from; (i) land embodied in livestock and crops at 442.1 m² per tonne of product produced; (ii) land embodied in wholesale and retail trade at 188 m² per tonne of product produced; (iii) land embodied in other animal products at 45.5 m² per tonne of product produced; (iv) land embodied in non-metal mineral products at 31.8 m² per tonne of product produced.

Water Inputs (Figure 5.5)

Livestock and crop products require 14,490.8 litres of water inputs product per tonne of product produced, ranking the sector 11th out of the 20 product producing sectors. Other reported amounts of water inputs for various livestock and crop products include barley – 80,268 litres per tonne, maize (corn) – 82,300 litres per tonne, and rye – 25,401 litres per tonne.⁹¹ These figures are substantially higher than the figure given in the LCA diagram. A possible reason for this is that the reported figures above are global averages and suggest New Zealand livestock and crop produce requires less blue water inputs due to geographical differences, relying more on green water inputs (rainwater) which are not taken into account in these figures.

Direct water inputs into livestock and crop products are 40% of total water inputs, measuring 5,752.5 litres per tonne of production. Direct water inputs would come mainly from irrigation and water for troughs – As at 30 June 2012, the area of irrigable land increased 17%, from 2007 to 721,700 hectares.⁹² *Indirect water inputs* are a much smaller share of total water use at 60%, measuring 8,738.3 litres per tonne of product.

The main indirect water inputs came from; (i) water inputs embodied in non-metal mineral products at 2,753 litres/tonne; (ii) water inputs embodied in wholesale and retail trade at 2,221 litres per tonne; (iii) water inputs embodied in mining and quarrying at 1,382 litres per tonne; (iv) water inputs embodied in other animal products at 872 litres per tonne.

Landfill Wastes (Figure 5.6)

Livestock and crop products were found to generate 16,820.7 grams (16.82 kg) of landfill waste per tonne of product. *Landfill waste directly generated* by Livestock and crop products was only 3% of total waste produced or 462.2 grams per tonne of production. *Landfill waste indirectly generated* by Livestock and crop products was a massive 97% of total waste produced or 16,358.5 grams per tonne of production. *The main sources of indirect landfill waste came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 5,488.6 9 grams per tonne; (ii) landfill wastes embodied in non-metal mineral product at 4,559.49 grams per tonne; (iii) landfill wastes embodied in wholesale and retail trade at 1,656.9 grams per tonne; (iv) landfill wastes embodied in other animal products at 1,016.9 grams per tonne.*

It should be noted that landfill waste (10,657 grams per tonne) for livestock and crop products is 15th out of the 20 product producing sectors covered in this publication. Even though this is relatively low, it is, however, the highest-ranking waste producer out of the primary product producing sectors such

⁹¹ Mekonnen, M.M. and Hoekstra, A.Y. (2011). The green, blue and grey water footprint of crops and derived crop products, *Hydrology and Earth System Sciences*, 15(5): 1577-1600.

⁹² Statistics New Zealand. (2013, May 13). Agricultural Production Statistics: June 2013 (final). Retrieved from http://www.stats.govt.nz/~media/Statistics/Browse%20for%20stats/AgriculturalProduction_final/HOTJun12final/AgriculturalProduction_finalJun12finalHOTP.pdf

as horticulture and fruit (16th), raw milk (18th), forestry and logging (19th), and mining and quarrying (20th).

Water Wastes (Figure 5.7)

Livestock and crop products were found to produce 28,861 litres of wastewater per tonne of product produced. *Wastewater directly generated* by livestock and crop products was only 8% of total waste produced at 2,369.1 litres per tonne. Wastewater indirectly generated by livestock and crop products made up the majority of the total at 92% or 28,861.1 litres per tonne. *The indirect wastewater of livestock and crop products was mostly made up of (i) wastewater embodied in non-metal mineral products at 10,826.3 litres per tonne; (ii) wastewater embodied in mining and quarrying at 8,958.2 litres per tonne; (iii) wastewater embodied in petroleum, chemicals and plastics at 2,154.2 litres per tonne; (iv) wastewater embodied in other animal products at 1,129.1 litres per tonne.*

The amount of wastewater produced by livestock and crop products is ranked 13th out of the 20 product producing sectors covered in this publication. It is the largest producer of wastewater out of the primary product producing sectors like horticulture and fruit (15th), raw milk (17th), forestry and logging (19th), and mining and quarrying (20th).

Phosphorus Wastes (Figure 5.8)

Livestock and crop products were found to produce 5,680.2 grams (5.6 kg) of phosphorus waste per tonne. This is in a similar order of magnitude to reported phosphorous waste produced by various other products. *Phosphorus waste directly generated* was 97% of total phosphorous waste at 5,520.4 grams per tonne of livestock and crop products. *Phosphorus waste indirectly generated* was only 3% of the total, at 159.8 grams per tonne of livestock and crop products produced.

The indirect phosphorus waste in livestock and crop products was mostly made up of (i) phosphorus waste embodied in other animal products at 62.2 grams per tonne; (ii) phosphorus waste embodied in other livestock and crops at 53.8 grams per tonne; (iii) phosphorus waste embodied in wholesale and retail trade at 24.4 grams per tonne; (iv) phosphorus waste embodied in non-metal mineral products at 4.2 grams per tonne.

Energy Greenhouse Gases (Figure 5.9)

In terms of CO₂ greenhouse gas emissions, livestock and crop products were found to emit 358,625.6 grams of energy-related CO₂ per tonne of product produced. This is in a similar order of magnitude to reported CO₂ greenhouse gas emissions produced by various New Zealand livestock and crop products including lambs at 45,000,000 grams of energy-related CO₂ per tonne; pigs at 35,000,000 grams of energy-related CO₂ per tonne; Poultry at 500,000 grams of energy-related CO₂ per tonne,⁹³ wheat at 340,000 grams of energy-related CO₂ per tonne; maize grain at 190,000 grams of energy-related CO₂ per tonne.⁹⁴

From previous studies and reports, livestock generally has a much higher level of CO₂ greenhouse gas emissions than the figure from the LCA diagram, while crops generally emit a much lower level of emissions.

⁹³ Ministry for Primary Industries. (n.d). *Agriculture in the New Zealand Emissions Trading scheme: Emissions factors (agriculture)*. Retrieved December 13, 2013 from <http://www.mpi.govt.nz/Portals/0/Documents/agriculture/agri-ets/agets-emissions-factors.pdf>

⁹⁴ Barber, A., Pellow, G., Barber, M. (2011). *Carbon Footprint of New Zealand Arable Production – Wheat, Maize Silage, Maize Grain, and Ryegrass seed*. Retrieved from <http://www.fedfarm.org.nz/Files/2011-MPIGrainCarbon.pdf>

Energy-related CO₂ directly generated by horticultural products was only 29% of the total waste produced at 105,061.4 grams per tonne. Energy-related CO₂ indirectly generated by livestock and crop products made up the majority of the total at 71% or 253,564.2 grams per tonne. The indirect energy-related CO₂ from the livestock and crop products sector was mostly made up of (i) energy-related CO₂ embodied in non-metal mineral products at 100,339 grams per tonne of product; (ii) energy-related CO₂ embodied in wholesale and retail trade at 28,559 grams per tonne of product; (iii) energy-related CO₂ embodied in other animal products at 23,076 grams per tonne of product; (iv) energy-related CO₂ embodied in road transport services at 20,839.7 grams per tonne of product.

Energy-related CO₂ emissions (326,386.9 *grams* per tonne) from livestock and crop products is ranked 14th out of the 20 product producing sectors covered in this publication. Livestock and crop products are however the highest of the primary product sectors in terms of energy-related CO₂ emissions.

Figure 5.1 - Total Energy Inputs Required to Produce One Tonne of Livestock and Crop Products, 2004 (MJ_E, Oil Equivalents)

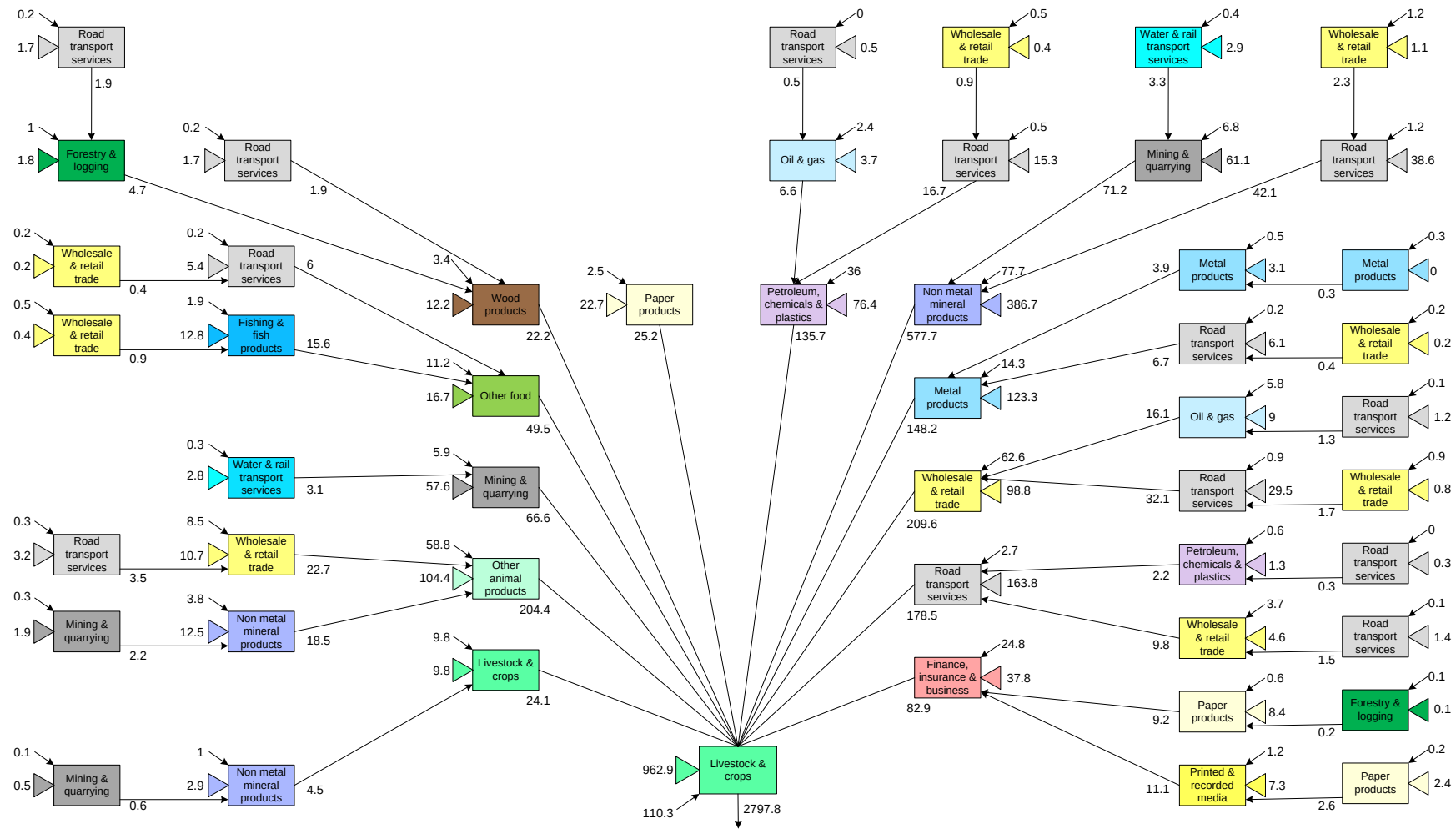


Figure 5.2 - Electricity Inputs Required to Produce One Tonne of Livestock and Crop Products, 2004 (MJ, Heat Equivalents)

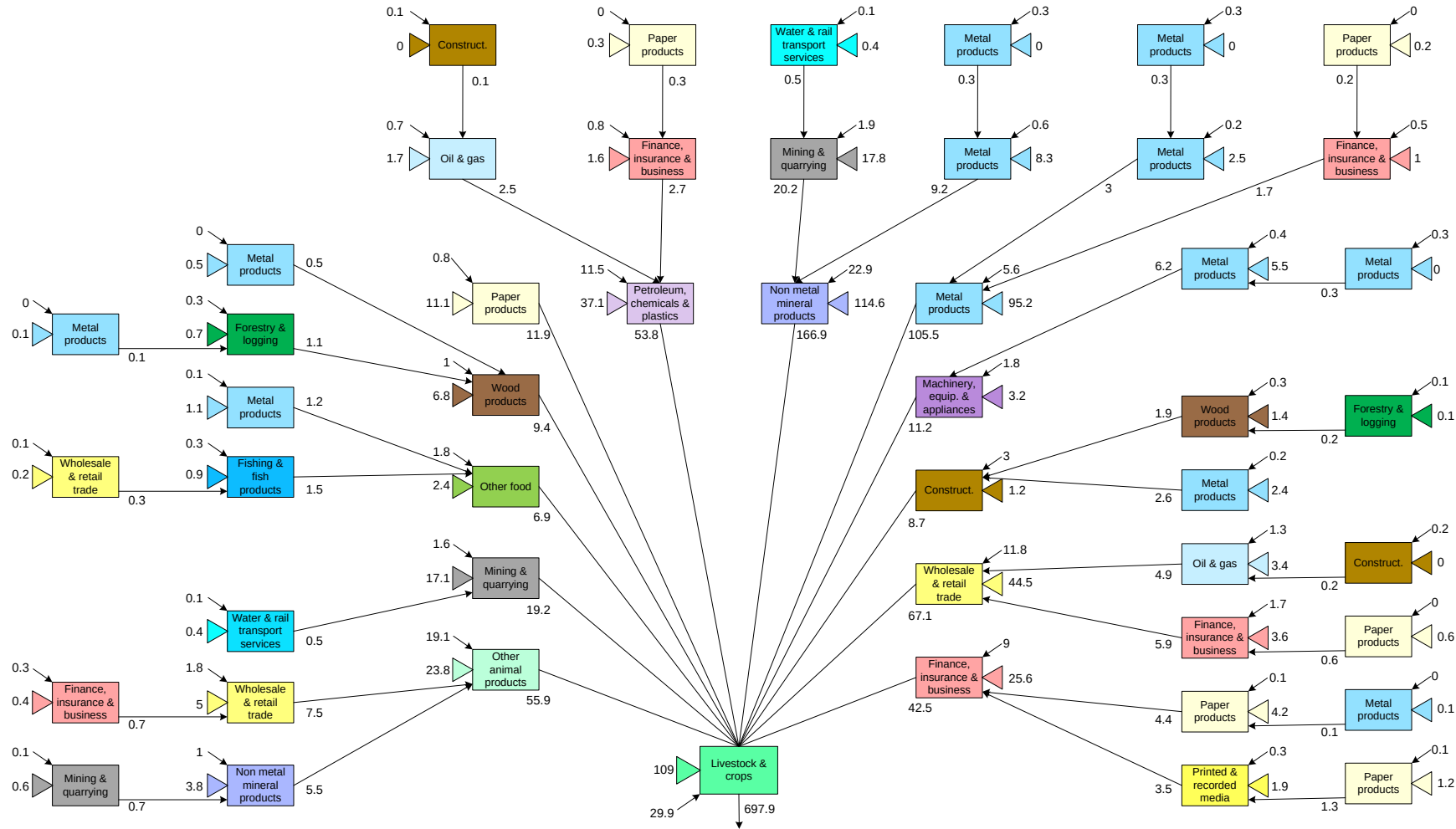


Figure 5.3 - Fossil Fuel Inputs Required to Produce One Tonne of Livestock and Crop Products, 2004 (MJ, Heat Equivalents)

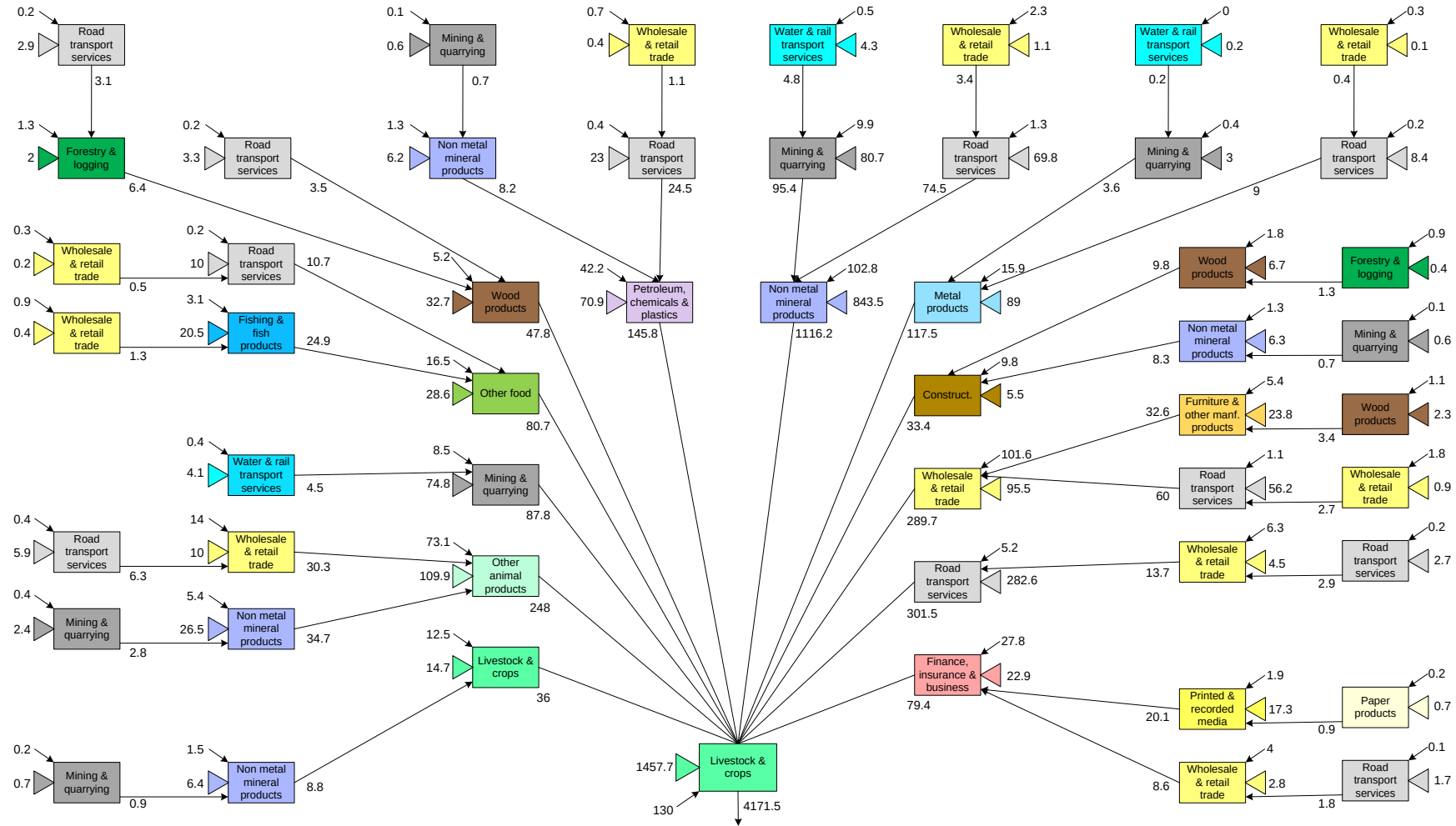


Figure 5.4 - Land Required to Produce One Tonne of Livestock and Crops Products, 2004 (m²)

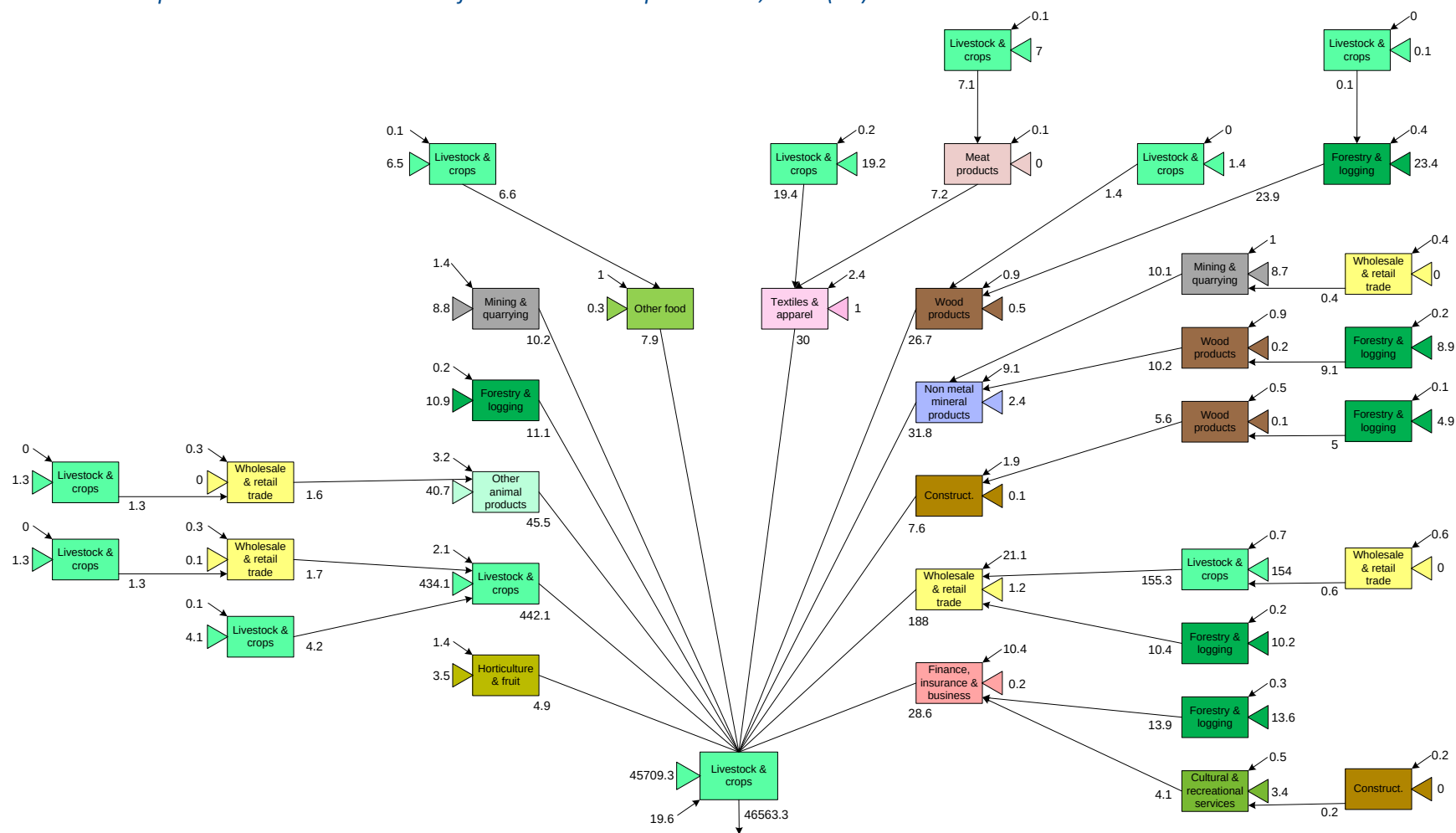


Figure 5.5 - Water Inputs Required to Produce One Tonne of Livestock and Crop Products, 2004 (Litres)

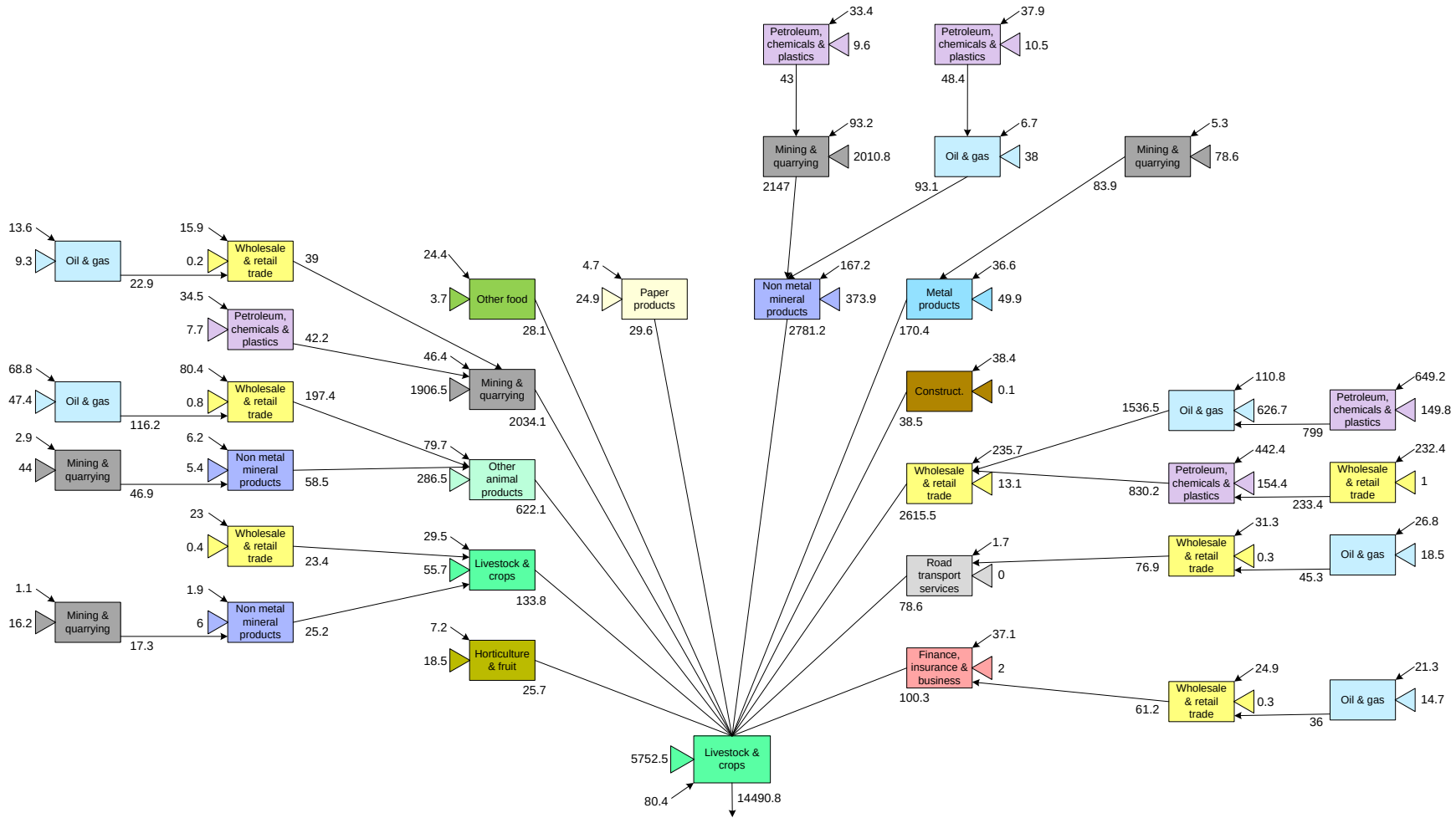


Figure 5.7 - Water Waste Generated in Producing One Tonne of Livestock and Crop Products, 2004 (Litres)



Figure 5.8 - Phosphorus Waste Generated in Producing One Tonne of Livestock and Crop Products, 2004 (Grams)

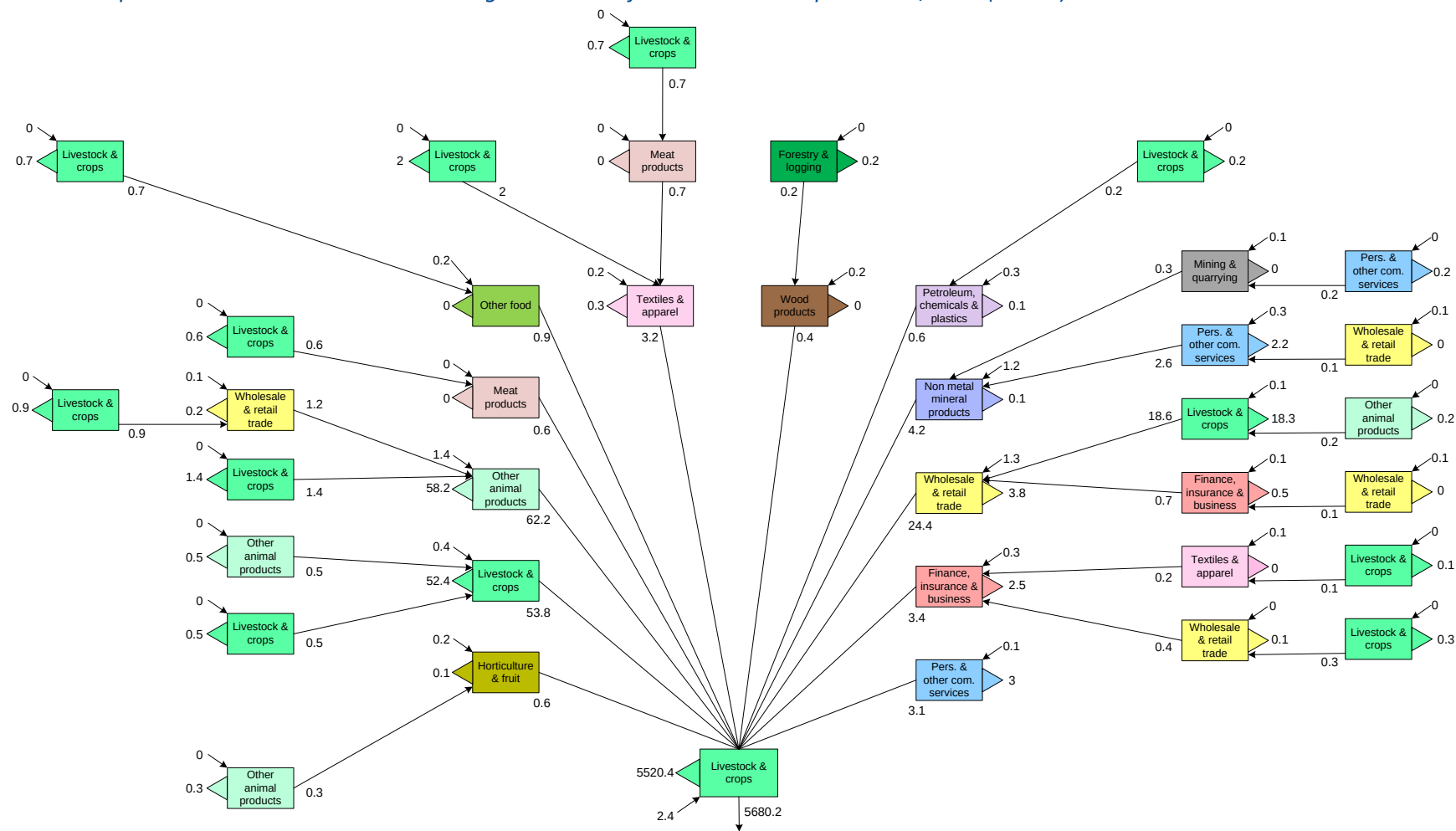
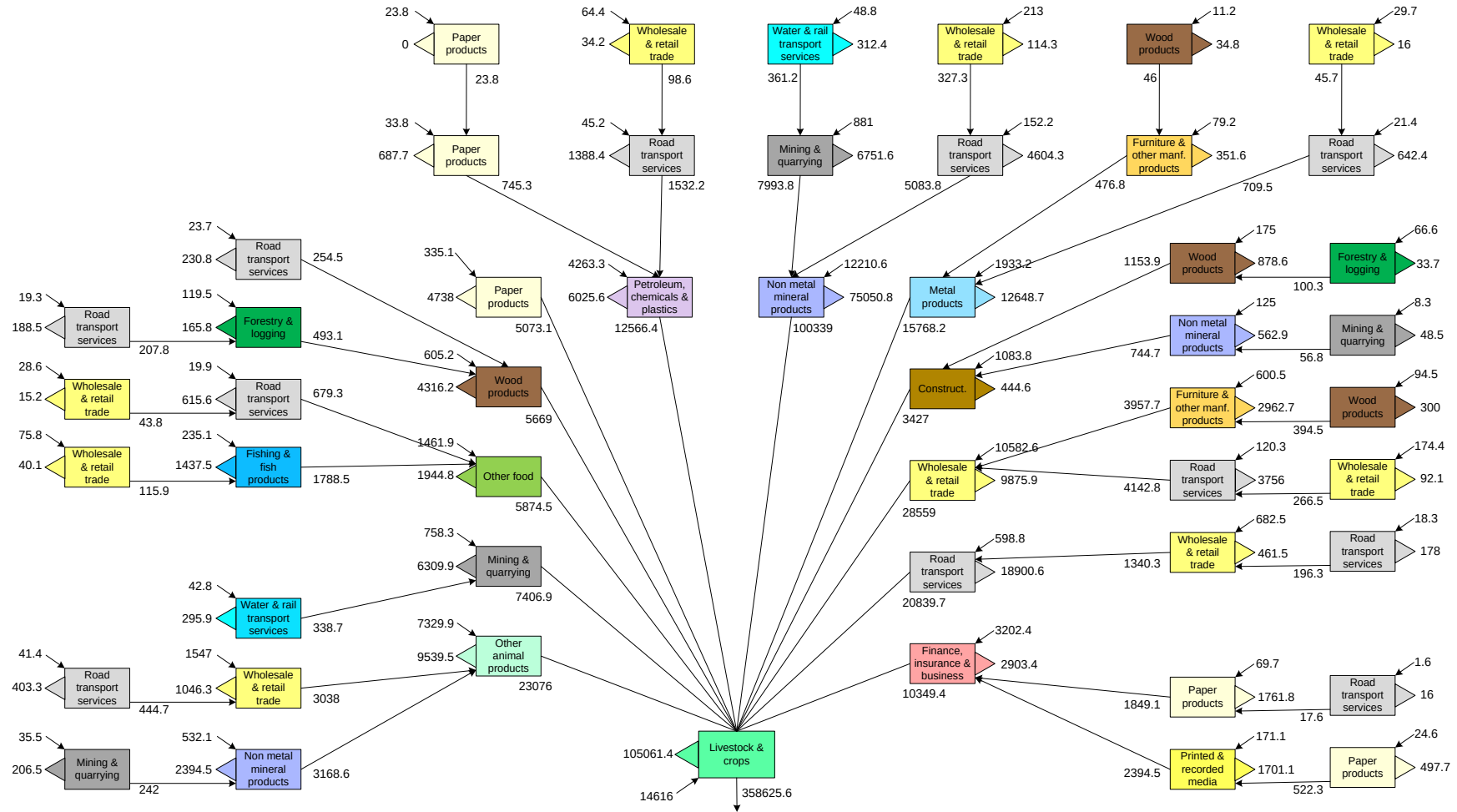


Figure 5.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Livestock and Crop Products, 2004 (Grams)



6. Dairy Cattle Farming

Description

ANZSIC Codes covered:

- 0160 – Dairy Cattle Farming

Main commodity supplied:

- Raw milk

GDP 2016 = \$2.532 billion
Rank = 20th

Average annual growth rate
2006 to 2016 = 13.57%
Rank = 2nd

Employment 2016 = 40,979
Rank = 13th

Economic Overview

The dairy industry in New Zealand is a highly important contributor to GDP, with production valued at \$2.532 billion in 2016 making it the 20th largest sector in the economy. Dairying has been expanding since 1996 in response to product price signals, with many farms converting to dairying and increasing in size. In 2018 there were 4.99 million dairy cattle on 8,380 dairy farms, with an average farm size of 151 ha. 72% of dairy herds are in the North Island. The Waikato region has the most herds in NZ with 33% of the country's dairy farms. Dairy cattle numbers increased by 17.84% from 4.1 million in 1995 to 4.99 million in 2018, supporting the figure in the above box, which shows between 1991 and 2016 the dairy cattle farming sector was the 2nd fastest growing sector in the economy.⁹⁵ In 2007, the national herd was made up of breeds Holstein-Friesian (47%, although declining), Jersey (15%), and Ayrshire (2%).⁹⁶

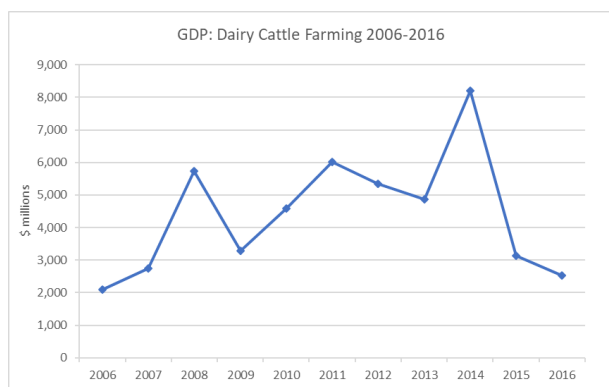
Historically important for the efficiency of dairy cattle farming, was the mechanising of the milking shed to maximise throughput of cows per operator and streamline the milking process. The large-scale automation of the milking process has led the industry in New Zealand to achieve economies of scale, making it a highly profitable industry. In 2019, Fonterra set the midpoint price of milk solids at \$7.05 per kg, following strong international demand for milk powder.⁹⁷ The main end-use sector purchasing from the dairy cattle farming sector is evidently the dairy product manufacturing sector. The cooperatively owned dairy company, Fonterra, is the major processor of milk in New Zealand and processes 94.8% of all milk solids from dairy farms.

⁹⁵ Dairy NZ. (2019). *QuickStats about dairying*. Retrieved from <https://www.dairynz.co.nz/media/5791052/quickstats-about-dairying-new-zealand-2019.pdf>

⁹⁶ Stringleman, H., and Scrimgeour, F., *Dairying and dairy products - Dairy cattle breeds*, Te Ara, the Encyclopaedia of New Zealand. Retrieved 15/02/13, from <http://www.TeAra.govt.nz/en/dairying-and-dairy-products/6>

⁹⁷ Hargreaves, D. (2019, October 22). *Fonterra gives new milk price range for the season of \$6.55-\$7.55 per kilogram of milk solids; says it has been achieving 'good prices' for its milk so far*. Retrieved February 5, 2020, from Interest: <https://www.interest.co.nz/rural-news/102236/fonterra-gives-new-milk-price-range-season-655-755-kilogram-milk-solids-says-it>

Sector Trends



Production

Production in this sector appears to have been rather volatile between 2006 and 2016, with a number of peaks and troughs observed over the 10 years considered. Surprisingly, during the GFC, production rose 74.1% to \$5.72 billion in 2008, but then subsequently fell by 57.6% to \$3.3 billion the following year. Production in this sector reached its highest peak in 2014, with levels recorded at \$8.21 billion, a strong recovery from two years of sustained contraction in production, in which the 2012-2013 drought was experienced. In the following year, production fell considerably by 61.2% to \$3.12 billion. This downward trend continued in 2016 as production declined further to \$2.53 billion. Indeed, the volatility of production can be attributed to the reliance on conditions in the international markets for milk products.

Exports

No raw milk is exported.

Life Cycle Assessment Diagrams

Energy (Figure 6.1, Figure 6.2, Figure 6.3)

Raw milk products were found to have a total energy intensity of 799.2 MJ_E per tonne of product (0.799 MJ_E/kg). It should be noted that the total energy intensity (799.2 MJ_E per tonne) for raw milk products is one of the lowest, ranking 18th out of the 20 product producing sectors covered in this publication. This represents a total energy intensity of 0.644 MJ_H/kg for raw milk when using conventional units of energy. Saunders and Barber (2007)⁹⁸ report a total energy intensity of 1.00 MJ_H/kg for raw milk for New Zealand dairy farms, calculated by taking account of direct and indirect physical inputs (litres, kilowatt-hours, kg of input). This is increased to 1.10 MJ_H/kg when capital items⁹⁹ (e.g. metres of fence line, hectares of water supply) are factored into the calculations.

⁹⁸ Saunders, C. and Barbour, A. 2007. Comparative Energy and Greenhouse Gas Emissions of New Zealand's and the UK's Dairy Industry Research Report No. 297 Agribusiness and Economics Research Unit, Lincoln University, Canterbury.

⁹⁹ Capital items are often excluded from energy analysis and footprinting exercises, because of the methodological assumptions that need to be made about allocating impacts (resources, pollutants) across years – e.g. the energy embodied in the production of a fenceline which lasts for a lifetime of perhaps 50 years needs to be annualised across each of the 50 years that the fence lasts. The simplest approach is to divide the embodied energy amount by 50 years to get an annual figure, which is problematic for some economists as this assumes a zero discount rate.

Direct energy use was 50% of the total energy intensity, measuring 402.7 MJ_{OE} per tonne of raw milk products. Direct energy uses includes energy for farm bikes for herding the cows, electric fences, milking equipment such as pumps, and milking shed energy use through lighting – the EECA in use database reports that 4,088.312 TJ of energy was used in the dairy agriculture sector in 2006/07. *Indirect energy* use made up the other half of total energy intensity at 50%, measuring 396.2 MJ_{OE} per tonne of raw milk product.

The main indirect energy uses from the raw milk products sector were from; (i) energy embodied in non-metallic mineral products at 139.6 MJ_E per tonne of product; (ii) energy embodied in wholesale and retail trade at 40 MJ_{OE} per tonne of product; (iii) energy embodied in other petroleum chemicals & plastics at 36.7 MJ_{OE} per tonne of product; (iv) energy embodied in metal products at 32.8 MJ_{OE} per tonne of product.

Land (Figure 6.4)

Raw milk products require a relatively large footprint compared to other product producing sectors, with a total land intensity of 1,959.7 m² per tonne of product produced, ranking 7th out of the 20 product producing sectors. This is in a similar order of magnitude to reported land footprints for other products: Yet the land footprint of raw milk products is considered comparatively low when compared to the three highest-ranking sectors 74,998 m² of land per tonne of meat products, 46,563 m² of land per tonne of livestock and crops, and 40,651 m² of land per tonne of textile and apparel.

Direct land use for the production of raw milk products was 97% of all embodied land used to produce horticultural products measuring 1,915.5 m² per tonne of product. Direct land use is the total land used to graze the cows, milk the cows, and manufacture the raw milk products. *Indirect land use* only made up 3% of all embodied land used to produce raw milk products, measuring 44.2 m² per tonne of product.

The major indirect land uses came from; (i) land embodied in wholesale and retail trade at 10.7 m² per tonne of raw milk product; (ii) land embodied in livestock and crops at 5.2 m² per tonne of raw milk product; (iii) land embodied in horticulture and fruit products at 5.1 m² per tonne of raw milk product; (iv) non-metal mineral products at 4.9 m² per tonne of raw milk product.

Water Inputs (Figure 6.5)

Raw milk products require 8,477 litres of water inputs per tonne of product produced, ranking the sector 15th out of the 20 product producing sectors. Other estimates include 14,400 litres of water per tonne of total milk solids in milk, in Victoria, Australia.¹⁰⁰ The International Dairy Federation estimates that roughly 9.5 litres of water are used in the production of 1 kg of milk (9,500 litres per tonne).¹⁰¹

Water inputs are made up mostly of *direct water inputs* into raw milk products at 69%, using 5,869.8 litres per tonne of product produced. Direct water inputs come mainly from irrigation and washing down of cow sheds after milkings. *Indirect water inputs* are a much smaller share of total water use at 31%, using 2,607.2 litres per tonne of raw milk product.

The main indirect water inputs came from; (i) water inputs embodied in non-metal mineral products at 832.2 litres per tonne; (ii) water inputs embodied in mining and quarrying at 692.4 litres per tonne;

¹⁰⁰ Ridoutt, B. G., Williams, S. R., Baud, S., Fraval, S., & Marks, N. (2010). Short communication: The water footprint of dairy products: Case study involving skim milk powder. *Journal of Dairy Science*, 93(11), 5114-5117. doi:10.3168/jds.2010-3546

¹⁰¹ Guignard, C., Verones, F., Loerincik, Y., & Joillet, O. (2009). Environmental / Ecological Impact of the Dairy Sector. *Bulletin of the International Dairy Federation*, 436. Retrieved from <http://www.ukidf.org/documents/Bulletin436.pdf>

(iii) water inputs embodied in wholesale and retail trade at 648.4 litres per tonne; (iv) water inputs embodied in other animal products at 107.4 litres per tonne.

Landfill Wastes (Figure 6.6)

Raw milk products were found to generate 4,064.6 grams (4.06 kg) of landfill waste per tonne of product. It should be noted that landfill waste (4,064.6 grams per tonne) for raw milk products is relatively low compared to the other 20 product producing sectors covered in this publication, ranking 18th. *Landfill waste directly generated* by raw milk products was only 3% of total waste produced or 137.6 grams per tonne of product. This is likely because waste from the production of raw milk products is mostly organic waste material which can easily break down into the ground without needing to be taken to a landfill. *Landfill waste indirectly generated* by raw milk products was the majority of total landfill waste produced at 97%, or 3,927 grams per tonne of product produced.

The main sources of indirect landfill waste for raw milk products came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 1,428 grams per tonne of product; (ii) landfill wastes embodied in non-metal mineral products at 1,060.6 grams per tonne of product; (iii) landfill wastes embodied in other food products at 435.5 grams per tonne of product; (iv) landfill wastes embodied in wood products at 120.1 grams per tonne of product.

Water Wastes (Figure 6.7)

Raw milk products were found to produce 9,737.7 litres of wastewater per tonne of product. The amount of wastewater produced by the raw milk products sector is relatively low when compared to other product producing sectors covered by this publication, ranking 17th out of 20.

Wastewater directly generated by raw milk products was 33% of total waste produced at 3,257.9 litres per tonne of product. The direct wastewater generated by raw milk products is likely a result of the water used to wash down the milking sheds. *Wastewater indirectly generated* by raw milk products make up the majority of the total at 67% or 6,479.8 litres per tonne of product.

The indirect wastewater from raw milk production is mostly made up of (i) wastewater embodied in non-metal mineral products at 2,625.4 litres per tonne of product produced; (ii) wastewater embodied in mining and quarrying at 2,348 litres per tonne of product produced; (iii) wastewater embodied in petroleum, chemicals & plastics at 573.4 litres per tonne of product produced; (iv) wastewater embodied in other animal products at 148.2 litres per tonne of product produced.

Phosphorus Wastes (Figure 6.8)

Raw milk products were found to produce 206.1 grams of phosphorus waste per tonne of product produced. *Phosphorus waste directly generated* by raw milk products made up the majority (95%) at 196.4 grams per tonne of product. On the other hand, *Phosphorus waste indirectly generated* by raw milk products made up only 5% of the total phosphorus waste produced at 9.7 grams per tonne of product. Indirect phosphorus waste from the production of raw milk products was mostly made up of (i) phosphorus waste embodied in other animal products at 5.5 grams per tonne of product produced; (ii) phosphorus waste embodied in other wholesale and retail trade at 1.4 grams per tonne of product produced; (ii) phosphorus waste embodied in other wholesale and retail trade at 1.4 grams per tonne of product produced.

Energy Greenhouse Gases (Figure 6.9)

In terms of CO₂ greenhouse gas emissions, raw milk products were found to emit 92,119.9 grams (92.1 kg) of energy-related CO₂ per tonne of product produced. This is relatively low among the other product producing sectors covered in this publication, ranking 18th out of 20. It can, therefore, be considered that raw milk production is a relatively low CO₂ producing sector.

Energy-related CO₂ directly generated by raw milk products was only 41% of total CO₂ greenhouse gas emissions at 37,471.8 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by raw milk products was 59% or 54,648.1 grams per tonne of product produced.

The indirect energy-related CO₂ from the production of raw milk products was mostly made up of (i) energy-related CO₂ embodied in non-metal mineral products at 24,014.7 grams per tonne of product produced; (ii) energy-related CO₂ embodied in wholesale and retail trade at 5,340.9 grams per tonne of product produced; (iii) energy-related CO₂ embodied in other food products at 3,678.8 grams per tonne of product produced; (iv) energy-related CO₂ embodied in metal products at 3,472.9 grams per tonne of product produced.

Figure 6.1 - Total Energy Inputs Required to Produce One Tonne of Raw Milk Products, 2004 (MJ_E, Oil Equivalents)

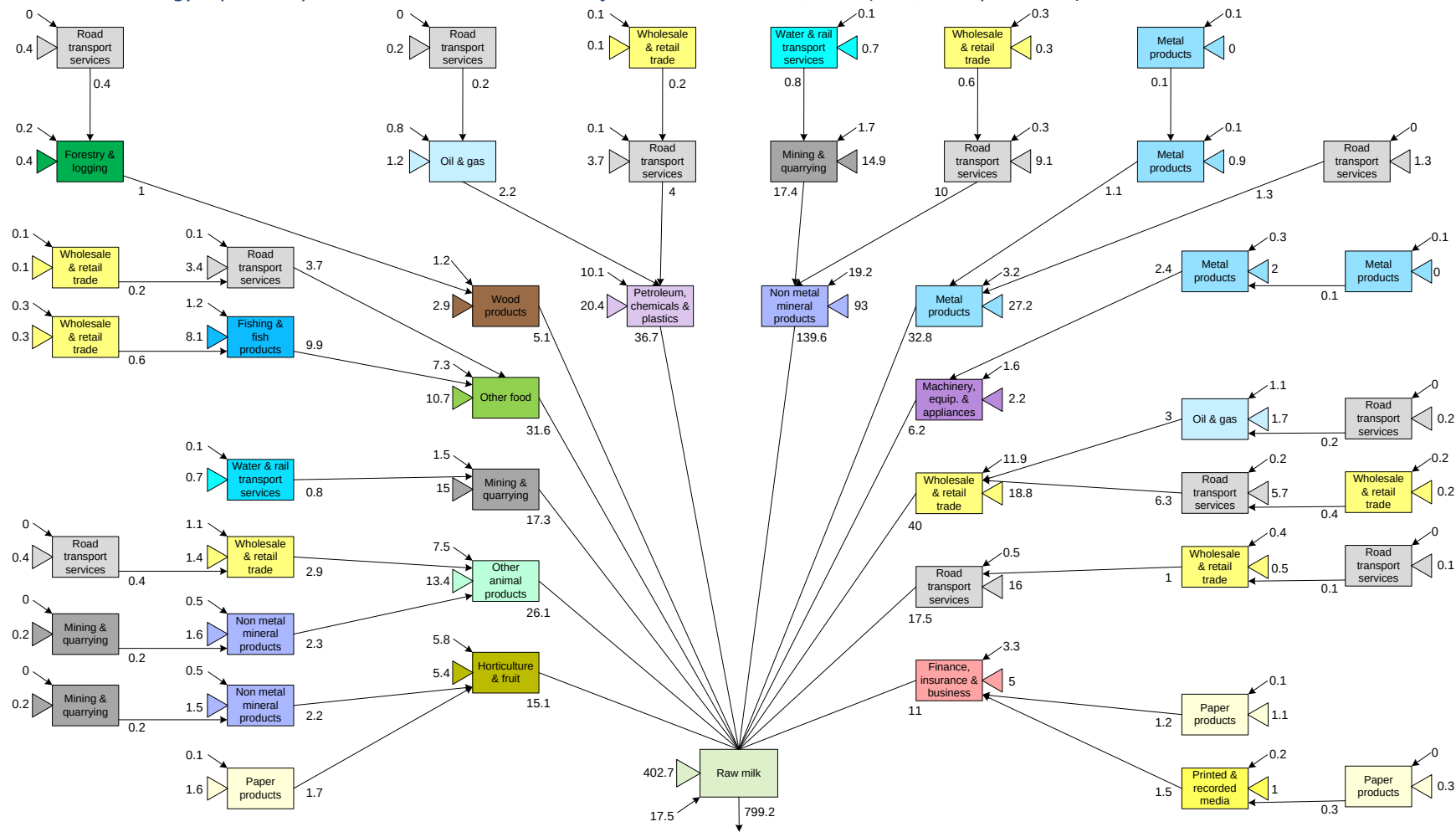


Figure 6.2 - Electricity Inputs Required to Produce One Tonne of Raw Milk Products, 2004 (MJ, Heat Equivalents)

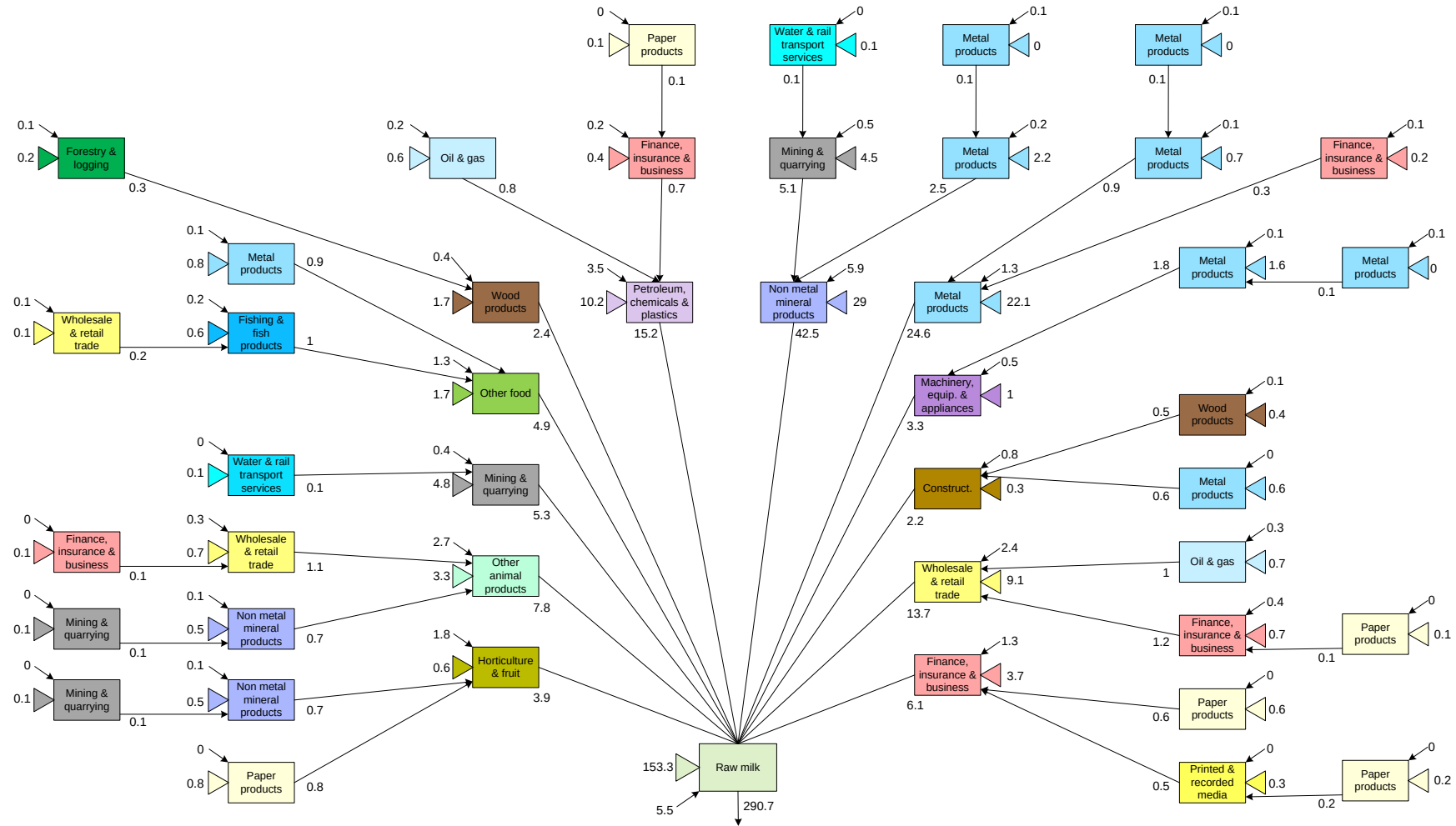


Figure 6.3 - Fossil Fuel Inputs Required to Produce One Tonne of Raw Milk Products, 2004 (MJ, Heat Equivalents)

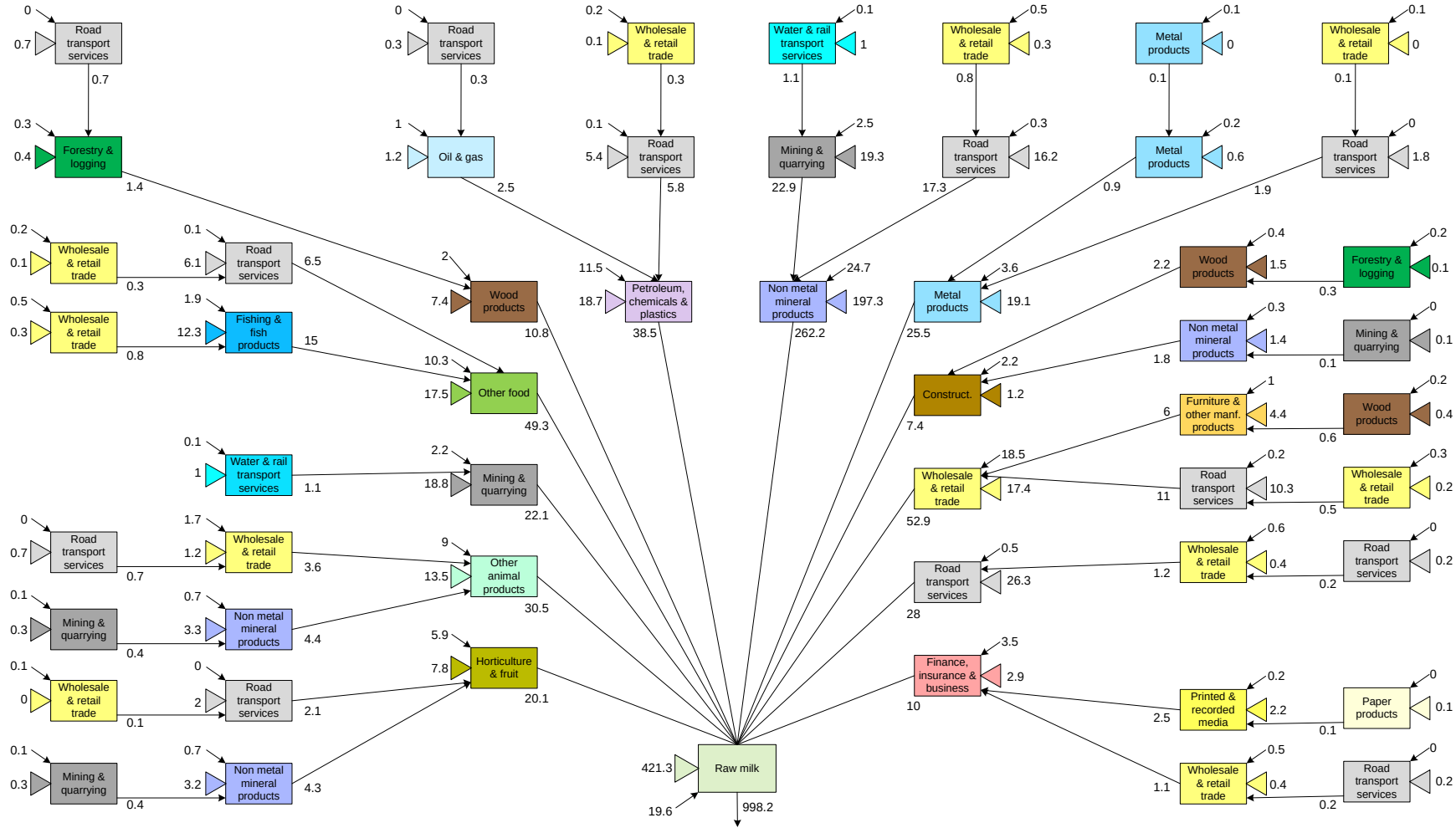


Figure 6.4 - Land Required to Produce One Tonne of Raw Milk Products, 2004 (m²)

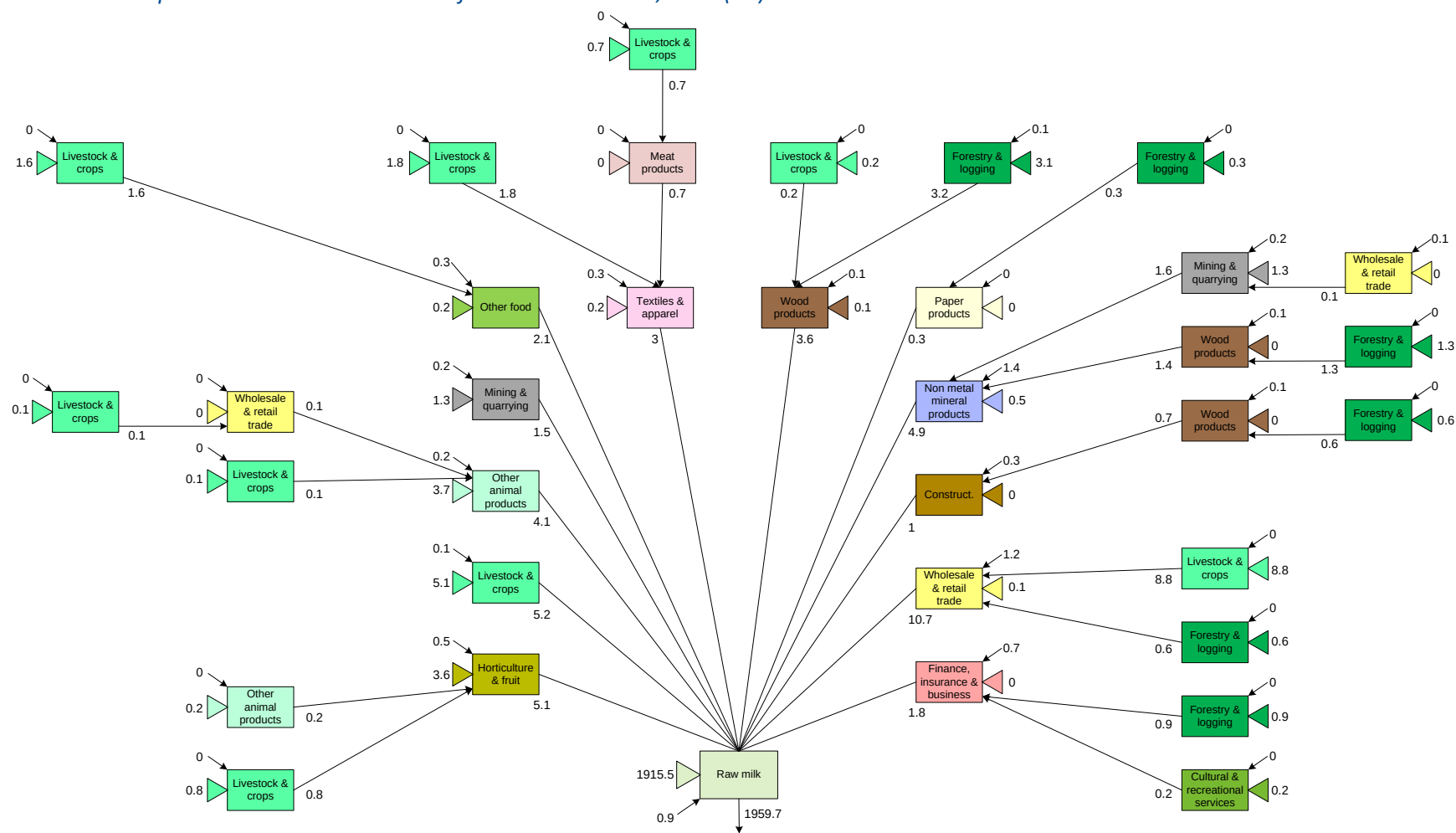


Figure 6.5 - Water Inputs Required to Produce One Tonne of Raw Milk Products, 2004 (Litres)

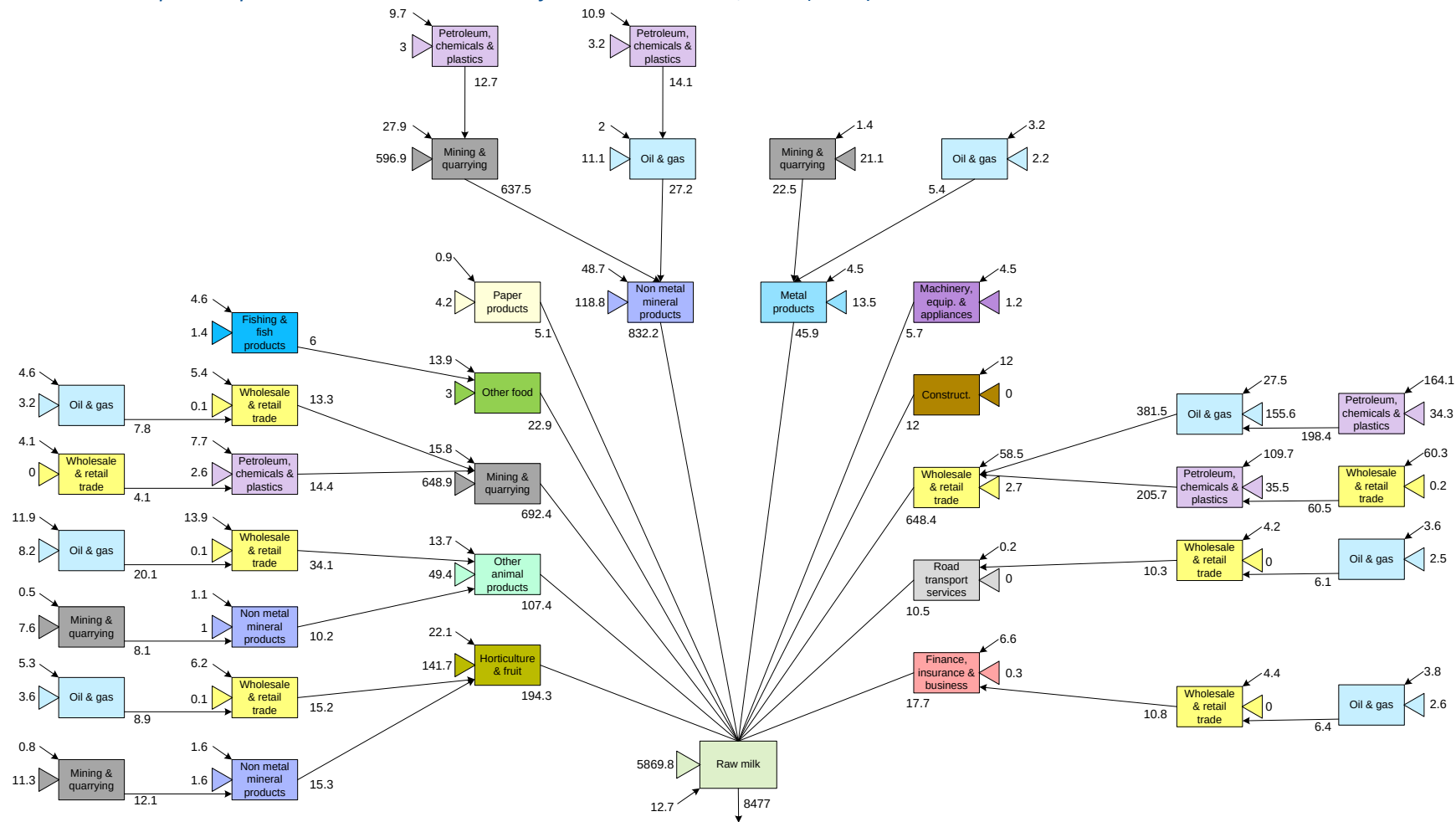


Figure 6.6 - Landfill Waste Generated in Producing One Tonne of Raw Milk Products, 2004 (grams)

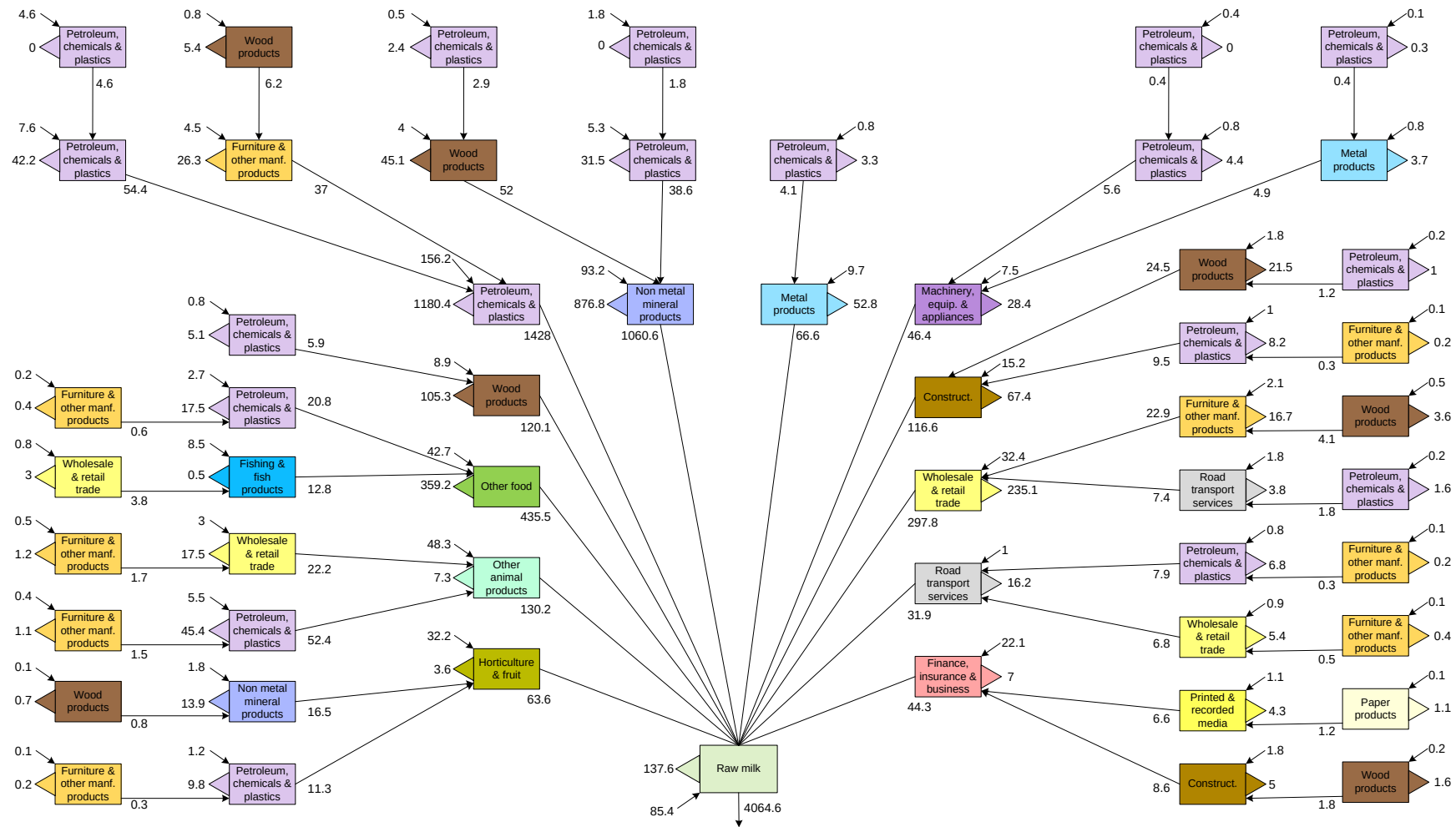


Figure 6.7 - Water Waste Generated in Producing One Tonne of Raw Milk Products, 2004 (Litres)

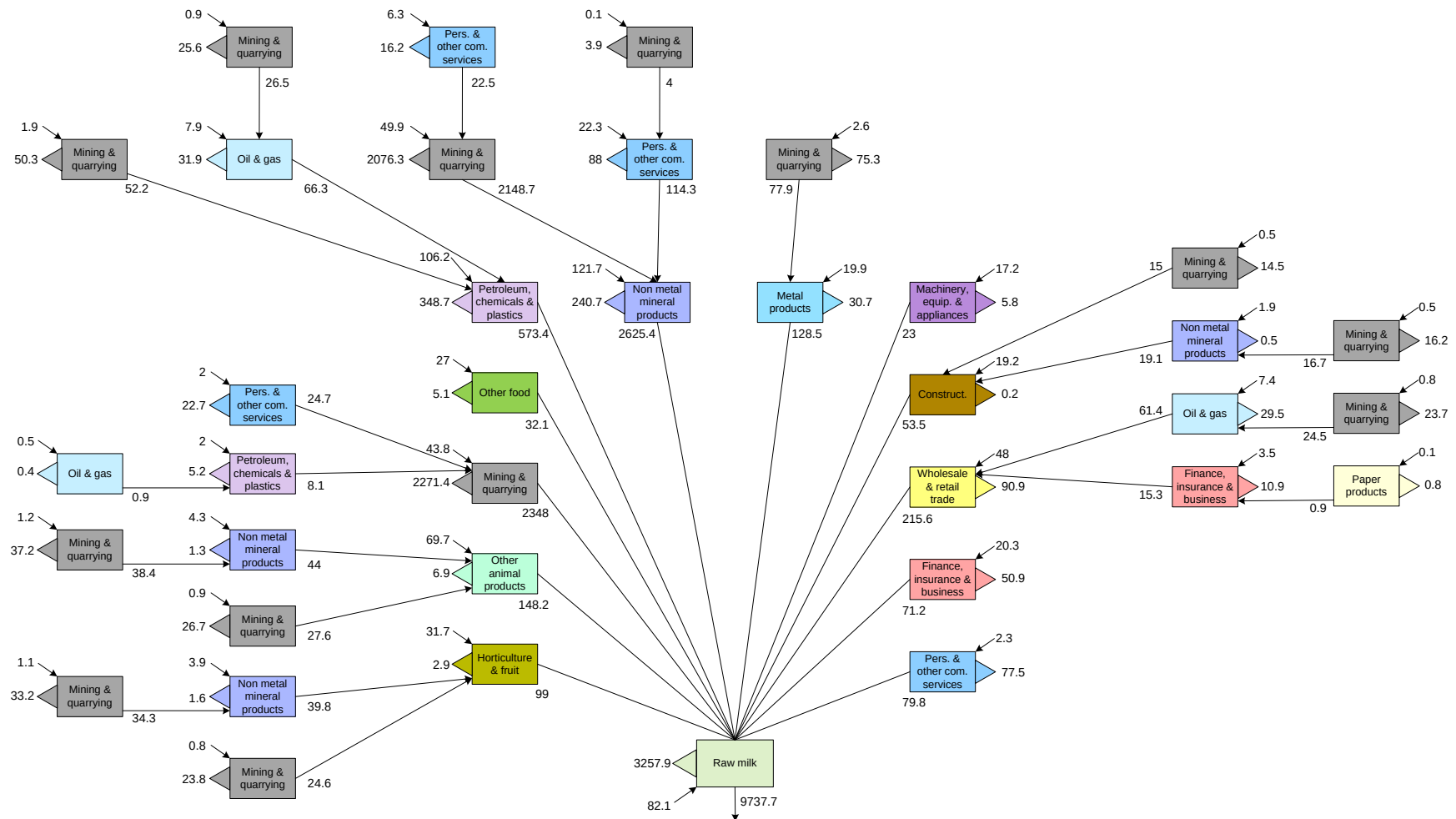


Figure 6.8 - Phosphorus Waste Generated in Producing One Tonne of Raw Milk Products, 2004 (Grams)

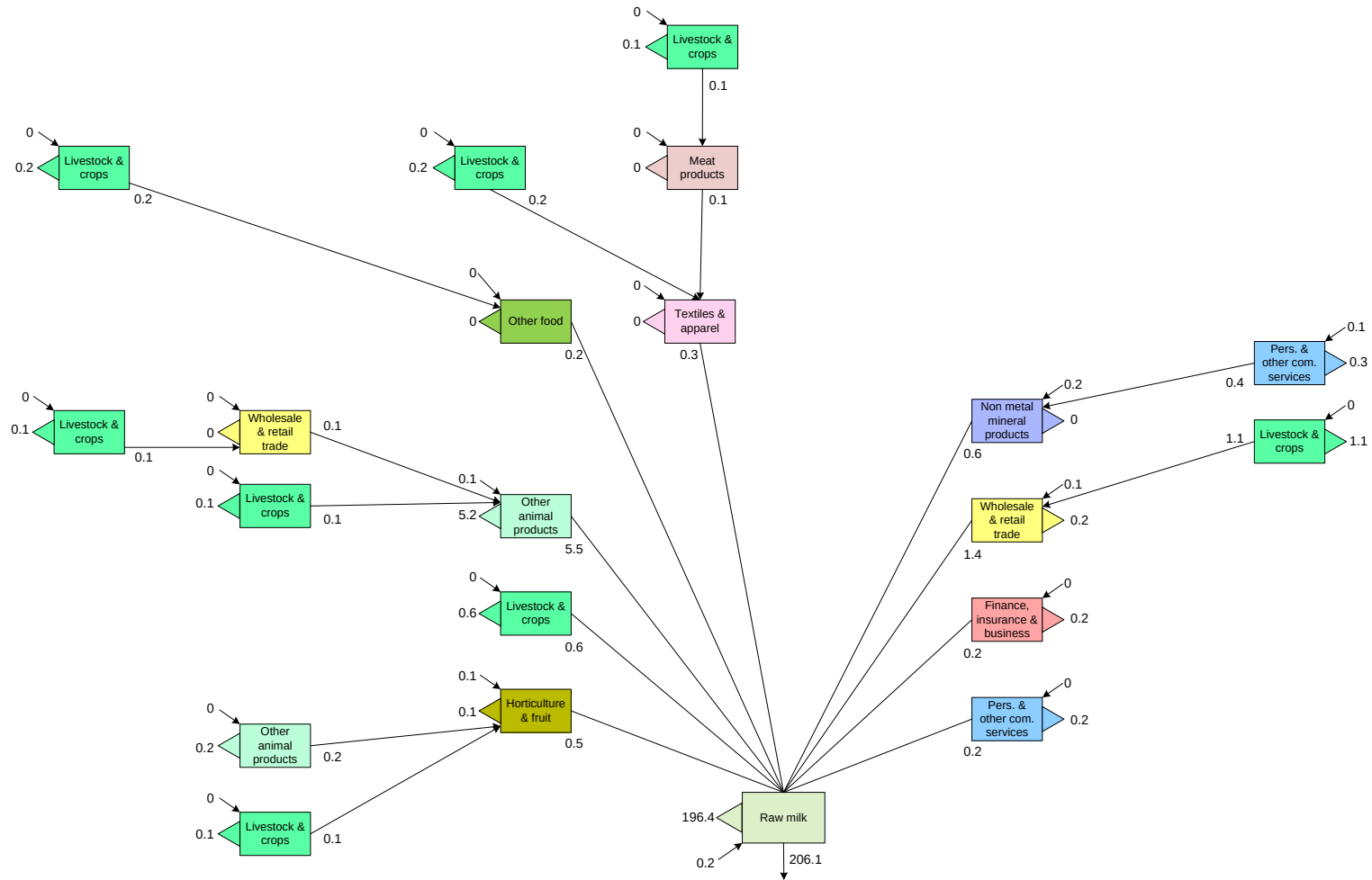
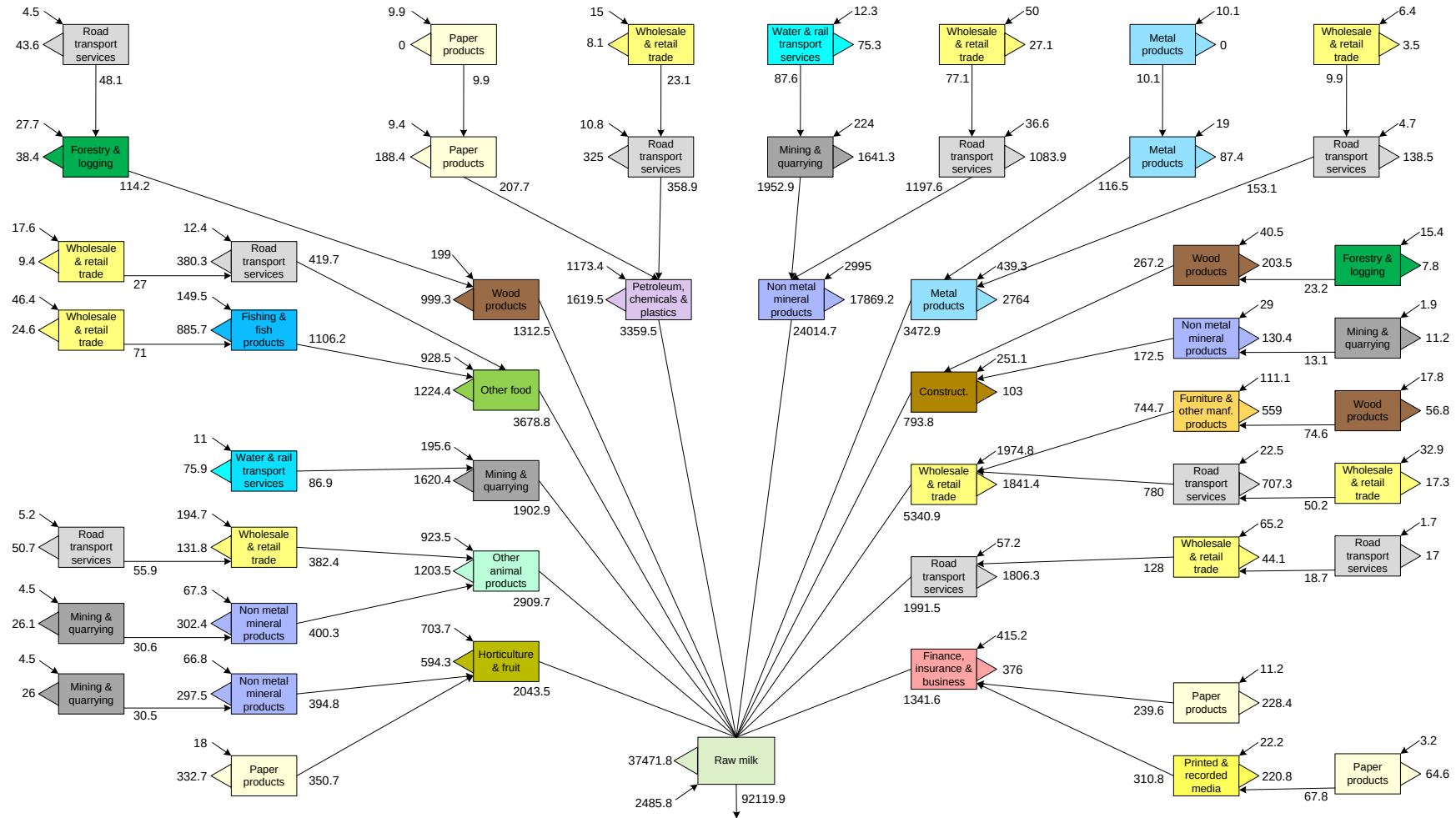


Figure 6.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Raw Milk Products, 2004 (Grams)



7. Forestry and Logging

Description

ANZSIC Codes covered:

- 0301 – Forestry
- 0302 – Logging

Main commodities supplied:

- Rough-sawn timber (4,215,000 cubic metres),
Roundwood (18,767 removals)¹⁰²

GDP 2016 = \$1.56 billion
Rank = 24th

Average annual growth rate
2006 to 2016 = 7.85%
Rank = 5th

Employment 2016 = 5,660
Rank = 30th

Economic Overview

Forestry is a well-established industry in New Zealand. Founded with European settlement in the 19th century, it is now an industry worth 1% of GDP.¹⁰³ Planted production forests cover about 7%, or 1.8 million hectares, of New Zealand's land area. Of this, about 6.3 million ha are indigenous forests and the remaining 1.7 million ha are planted production forests.¹⁰⁴ 90% of the planted production forests are radiata pine, a species which grows more than twice as fast in the NZ climate than when planted in its natural habitat in California.¹⁰⁵ The wood from radiata pine is not considered high-quality wood by international standards, but the fast maturity rate of 25-30 years means it out-produces most other plantation species, making economic turnover quite high.¹⁰⁶ Native forest logging on public land attracted opposition with protests and environmental groups becoming very active until it ended in 2000. Now logging of native forests only occurs on private land if it is shown to be sustainable.

The quantity of harvested forestry products from plantations in New Zealand exceeds the domestic demand, leaving the industry heavily export-oriented. Large plantations are concentrated close to export ports in anticipation for large proportions of total production to be exported to overseas markets. Due to the small size of the domestic market, it is prone to boom/bust cycles closely tied to the construction and wood and paper products industries. China, Australia, South Korea, and Japan make up the main export markets, with around 70% of the wood from the planted production forests being exported in a variety of forms.¹⁰⁷ On the global stage, the New Zealand forestry industry is a relatively small contributor in terms of production, accounting for 1% of global wood supply for industrial purposes.¹⁰⁸

¹⁰² Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. Auckland, New Zealand: David Bateman Ltd. (pp. 381)

¹⁰³ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from; <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

¹⁰⁴ Statistics New Zealand. (2005). *Forests and Forest Products*. Retrieved from

http://archive.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts/forests-and-forest-products-2005.aspx

¹⁰⁵ Ministry of Forestry. (1988). Report #4932

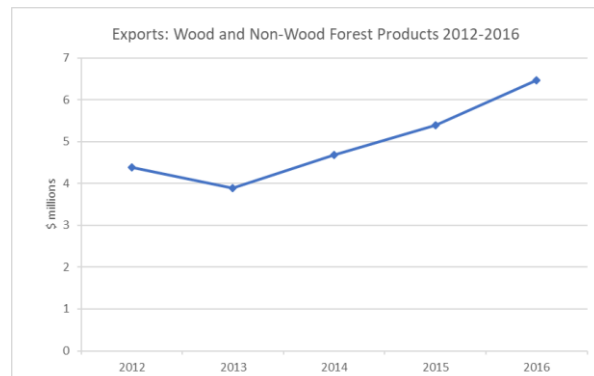
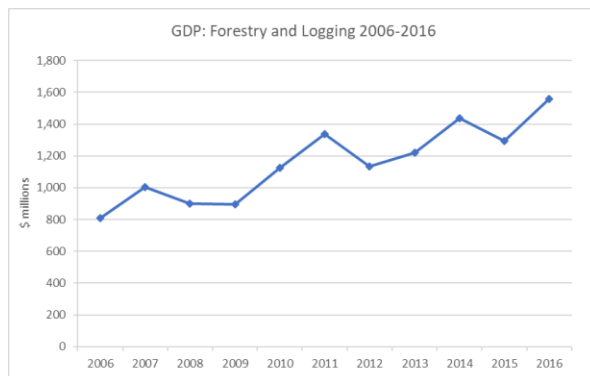
¹⁰⁶ Ibid

¹⁰⁷ Forest Owners Association. (2019). *Facts and Figures 2018/2019*. Wellington. Retrieved from

https://www.nzfoa.org.nz/images/Facts_and_Figures_2018-2019_Web.pdf

¹⁰⁸ NZ Ministry of Agriculture and Forestry. (n.d). *The Forestry Industry in New Zealand*. Retrieved 19/02/14 from; <http://www.mpi.govt.nz/forestry>

Sector Trends



Production

The forestry and logging sector, while relatively volatile, has shown a strong upward trend in production over the 10-year period, increasing from \$803 million in 2006 to \$1.56 billion in 2016. Effects from the GFC can be seen, with an 11.43% decrease from 2007 to 2008. Strong recovery followed the downturn from the GFC, while more volatility is seen from 2011 through to 2016 the overall growth continues. Some of this volatility can be explained by the industry's reliance on the construction industry and the paper and paper product manufacturing sector, with the latter experiencing a volatile decline in production from 2006 to 2016. The downturn seen in 2015 is likely due to a decline in forestry product prices as a response to the downturn in the Chinese housing market. The forestry and logging sector is likely to continue improvement in the future following the government's One Billion Trees programme, which aims to double the current planting rate to reach one billion trees planted by 2028.¹⁰⁹ Further government initiatives such as KiwiBuild are likely to fuel further growth in the construction sector and demand for timber.¹¹⁰

Exports

In total exports of wood and non-wood forest products is very low, peaking in 2016 at \$6.5 million following a steady upward trend from 2013. While this value appears low for an export-oriented industry, commodities that make up this sector are largely non-wood forest products such as vegetable saps and extracts, which rank lowly in terms of exports. Contributing \$6 million in exports in 2016. Logs and other wood products are included in wood product manufacturing, indicating the low value of exports in this sector despite the prominence forestry has in the New Zealand economy.

Additionally, international prices have a large influence on what happens in this sector. For example, higher prices for hardwoods have caused Korean and Japanese manufacturers to substitute hardwoods for New Zealand logs. Thus, the sector is subject to large price fluctuations as international supply and demand vary. As is often the case in New Zealand, the lack of scale together with higher wage rates than competing countries limits our ability to remain competitive. Furthermore, an appreciating New Zealand dollar has been hurting local producers, along with higher fuel, labour and shipping costs. Exporting raw products from the forestry and logging industry such as rough-sawn

¹⁰⁹ Te Uru Rākau. (2020, January 14). *One Billion Trees Programme*. Retrieved from <https://www.teururakau.govt.nz/funding-and-programmes/forestry/one-billion-trees-programme/>

¹¹⁰ McBeth, P. (2017, December 14). *KiwiBuild spearheads \$42b capital spending programme*. Retrieved February 5, 2020, from NBR: <https://www.nbr.co.nz/article/kiwibuild-spearheads-42-billion-capital-spending-programme-b-211193>

timber is a much less common and less profitable occurrence than exporting processed wood products from further down the manufacturing chain.¹¹¹

Life Cycle Assessment Diagrams

Energy (Figure 7.1, Figure 7.2, Figure 7.3)

Forestry and logging products were found to have a total energy intensity of 409.4 MJ_{OE} per tonne of product (0.409 MJ_{OE} per kg). Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand forestry and logging sector is 0.644 MJ_H/kg

It should be noted that the total energy intensity (409.4 MJ_{OE}/tonne) for forestry and logging products is the second-lowest, ranking 19th out of the 20 product producing sectors covered in this publication. Thus, it can be concluded that forestry and logging products have a relatively low energy intensity compared to other sectors products.

Direct energy use was 37% of the total energy intensity, measuring 150.3 MJ_{OE} per tonne of raw milk products. Direct energy uses would include fossil fuels for heavy machinery used in harvesting the trees and transportation of logs – the EECA in use database reports that a total of 450.76 TJ of energy was used in the forestry and logging sector in 2006/07. *Indirect energy* use made up the other half of total energy intensity at 63%, measuring 259.1 MJ_{OE} per tonne of raw milk product. The main indirect energy uses were from; (i) energy embodied in road transport services at 150.4 MJ_{OE}/tonne of product produced; (ii) energy embodied in non-metal mineral products at 25 MJ_{OE} /tonne of product produced; (iii) energy embodied in other petroleum chemicals & plastics at 14.8 MJ_{OE} /tonne of product produced.

Land (Figure 7.4)

Forestry and logging products have a total land intensity of 1,371.2 m² per tonne of product produced, ranking 10th out of the 20 product producing sectors covered in this publication.

Direct land use for the production of forestry and logging products is the majority of the total footprint at 98%, measuring 1,338.9 m² per tonne of product. Direct land use is the total land used for planting and harvesting the trees. *Indirect land use* makes up only 2% of all embodied land used to produce forestry and logging products, measuring 32.3 m² per tonne of product. *The major indirect land uses came from;* (i) *land embodied in livestock and crops at 7.6 m² per tonne of forestry and logging products;* (ii) *land embodied in wholesale and retail trade at 4 m² per tonne of forestry and logging products;* (iii) *land embodied in textiles and apparel products at 3.4 m² per tonne of forestry and logging products;* (iv) *land embodied in finance, insurance and business services at 3.3 m² per tonne of forestry and logging products.*

Water Inputs (Figure 7.5)

Forestry and logging products require 144.5 litres of water inputs per tonne of product produced. In comparison with the other product producing sectors covered in this publication, forestry and logging products require the least water inputs, ranking 20th out of 20.

¹¹¹ Forbes, S. (2019, May 15). *Sino demand for NZ forestry products highlights dilemma faced by timber processors*. Retrieved from Interest: <https://www.interest.co.nz/news/99701/sino-demand-nz-forestry-products-highlights-dilemma-faced%C2%A0timber-processors>

Direct water inputs only make up 1%, using 1.5 litres per tonne of product produced. *Indirect water inputs* make up the majority of total water use at 99%, using 143 litres per tonne of forestry and logging product. *The main indirect water inputs into forestry and logging products came from; (i) water inputs embodied in non-metal mineral products at 80.1 litres per tonne of product produced; (ii) water inputs embodied in wholesale and retail trade at 24.4 litres per tonne of product produced (iii) water inputs embodied in horticulture and fruit at 17.6 litres per tonne of product produced; (iv) water inputs embodied in metal products at 8.7 litres per tonne.*

Landfill Wastes (Figure 7.6)

Forestry and logging products were found to generate 1,140 grams (1.14 kg) of landfill waste per tonne of product. This landfill waste is relatively low compared to the other product producing sectors covered in this publication, ranking 19th out of 20.

Landfill waste directly generated by forestry and logging products was a mere 1% of total waste produced or 7.4 grams per tonne of product. This is likely because direct forestry and logging products waste is mostly organic and can thus be either left to decompose naturally or be burnt off. *Landfill waste indirectly generated* by forestry and logging products was the majority of total landfill waste produced at 99%, or 1,132.6 grams per tonne of product produced. *The main sources of indirect landfill waste for forestry and logging products came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 483.1 grams per tonne of product; (ii) landfill wastes embodied in road transport services at 238.2 grams per tonne of product; (iii) landfill wastes embodied in non-metal mineral products at 173.3 grams per tonne of product; (iv) landfill wastes embodied in wholesale and retail trade at 40.6 grams per tonne of product.*

Water Wastes (Figure 7.7)

Forestry and logging products were found to produce 1,132.9 litres of wastewater per tonne of product. The amount of wastewater produced by the forestry and logging products sector is the lowest when compared to other product producing sectors covered by this publication, ranking 20^h out of 20.

Wastewater directly generated by forestry and logging products was only 2% of total waste produced at 21.3 litres per tonne of product produced. *Wastewater indirectly generated* by forestry and logging products make up the majority of the total at 98%, or 1,111.6 litres per tonne of product produced. *The indirect wastewater from forestry and logging production is mostly made up of (i) wastewater embodied in non-metal mineral products at 424.4 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 210.5 litres per tonne of product produced; (iii) wastewater embodied in road transport services at 84.6 litres per tonne of product produced; (iv) wastewater embodied in metal products at 79.1 litres per tonne of product produced.*

Phosphorus Wastes (Figure 7.8)

Forestry and logging products were found to produce 17.3 grams of phosphorus waste per tonne of product produced. This is in a similar order of magnitude to reported phosphorus waste produced by various other products. *Phosphorus waste directly generated* by forestry and logging products made up the majority (84%) at 14.5 grams per tonne of product. On the other hand, *Phosphorus waste indirectly generated* by forestry and logging products made up only 16% of the total phosphorus waste produced at 3 grams per tonne of product.

Indirect phosphorus waste from the production of forestry and logging products was mostly made up of (i) phosphorus waste embodied in livestock and crops at 0.9 grams per tonne of product produced; (ii) phosphorus waste embodied in personal and other community services at 0.8 grams per tonne of

product produced; (iii) phosphorus waste embodied in textile and apparel at 0.3 grams per tonne of product produced.

Energy Greenhouse Gases (Figure 7.9)

In terms of CO₂ greenhouse gas emissions, forestry and logging products were found to have emitted 44,368.5 grams (44.36 kg) of energy-related CO₂ per tonne of product produced. This is relatively low among the other product producing sectors covered in this publication, ranking 19th out of 20. It can, therefore, be considered that forestry and logging products are a relatively low CO₂ producing sector.

Energy-related CO₂ directly generated by forestry and logging products was 31% of total waste produced at 13,595.1 grams per tonne of product produced. Energy-related CO₂ indirectly generated by forestry and logging products was 69% or 30,773.4 grams per tonne of product produced. The indirect energy-related CO₂ from the production of forestry and logging products was mostly made up of (i) energy-related CO₂ embodied in non-metal mineral products at 4,244 grams per tonne of product produced; (ii) energy-related CO₂ embodied in metal products at 2,251 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services products at 17,043.1 grams per tonne of product produced; (iv) energy-related CO₂ embodied in petroleum, chemicals and plastics at 1,306.6 grams per tonne of product produced.

Figure 7.1 - Total Energy Inputs Required to Produce One Tonne of Raw Milk Products, 2004 (MJ_E, Oil Equivalents)

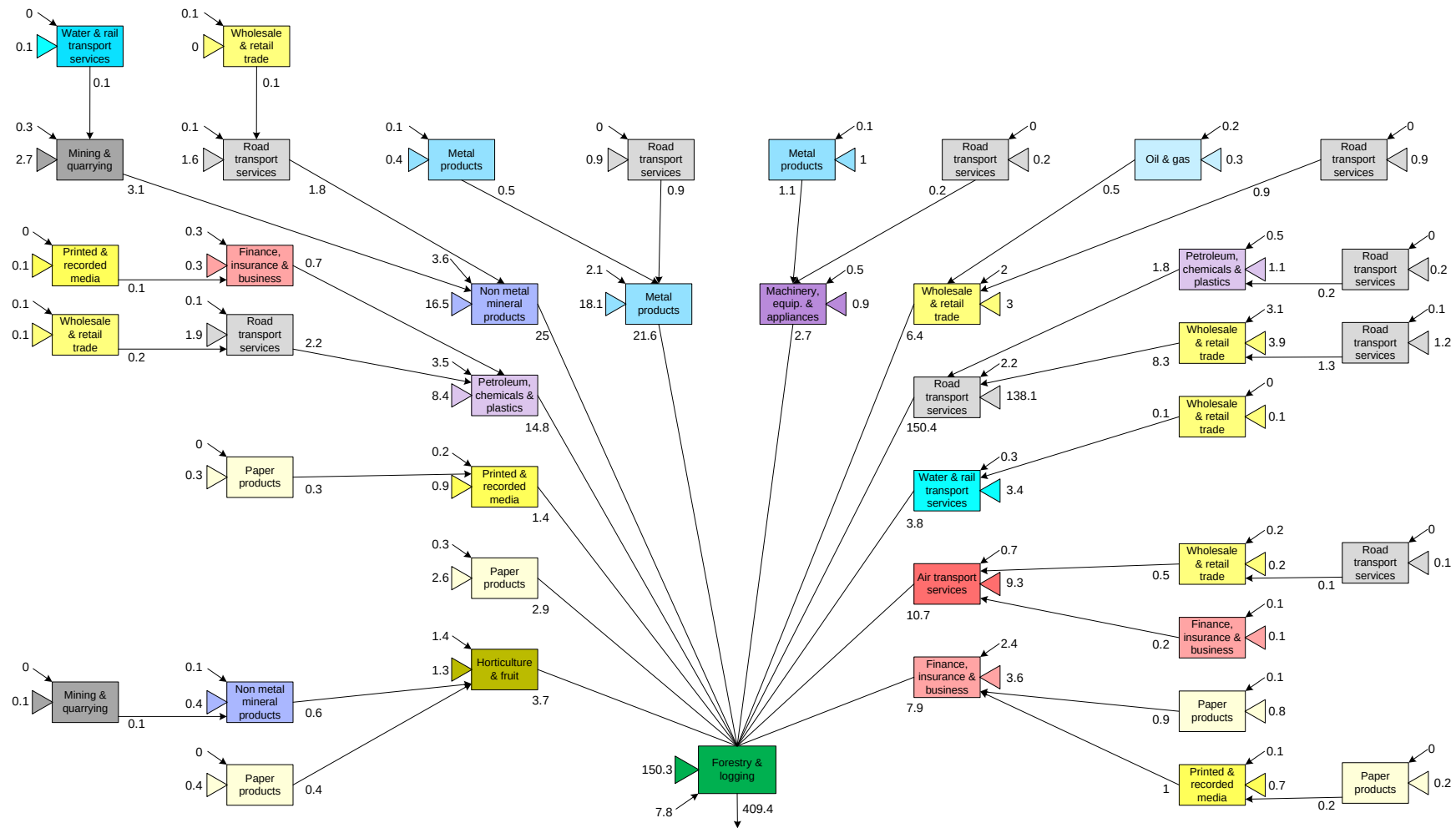


Figure 7.2 - Electricity Inputs Required to Produce One Tonne of Forestry and Logging Products, 2004 (MJ, Heat Equivalents)

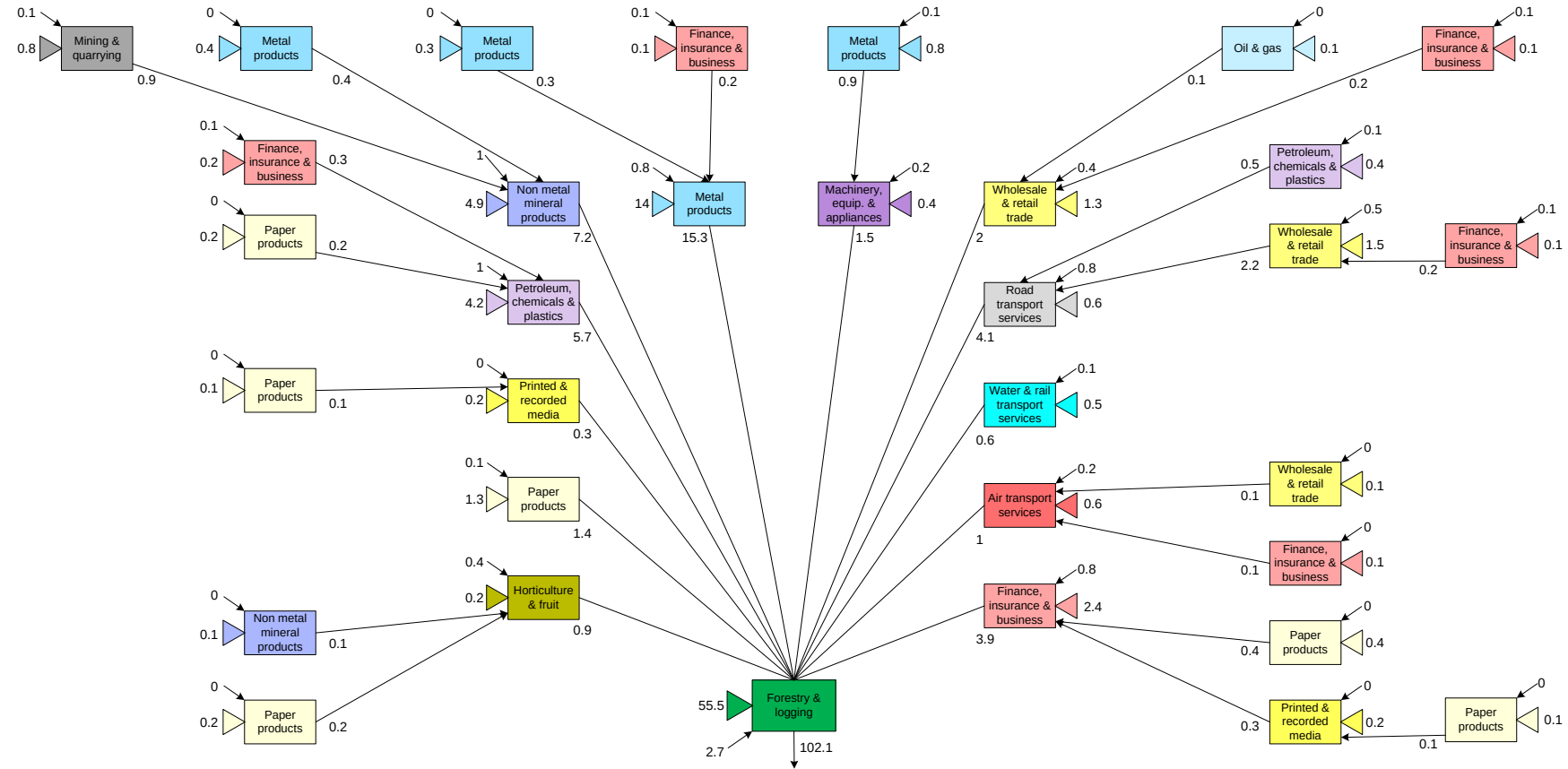


Figure 7.3 - Fossil Fuel Inputs Required to Produce One Tonne of Forestry and Logging Products, 2004 (MJ, Heat Equivalents)

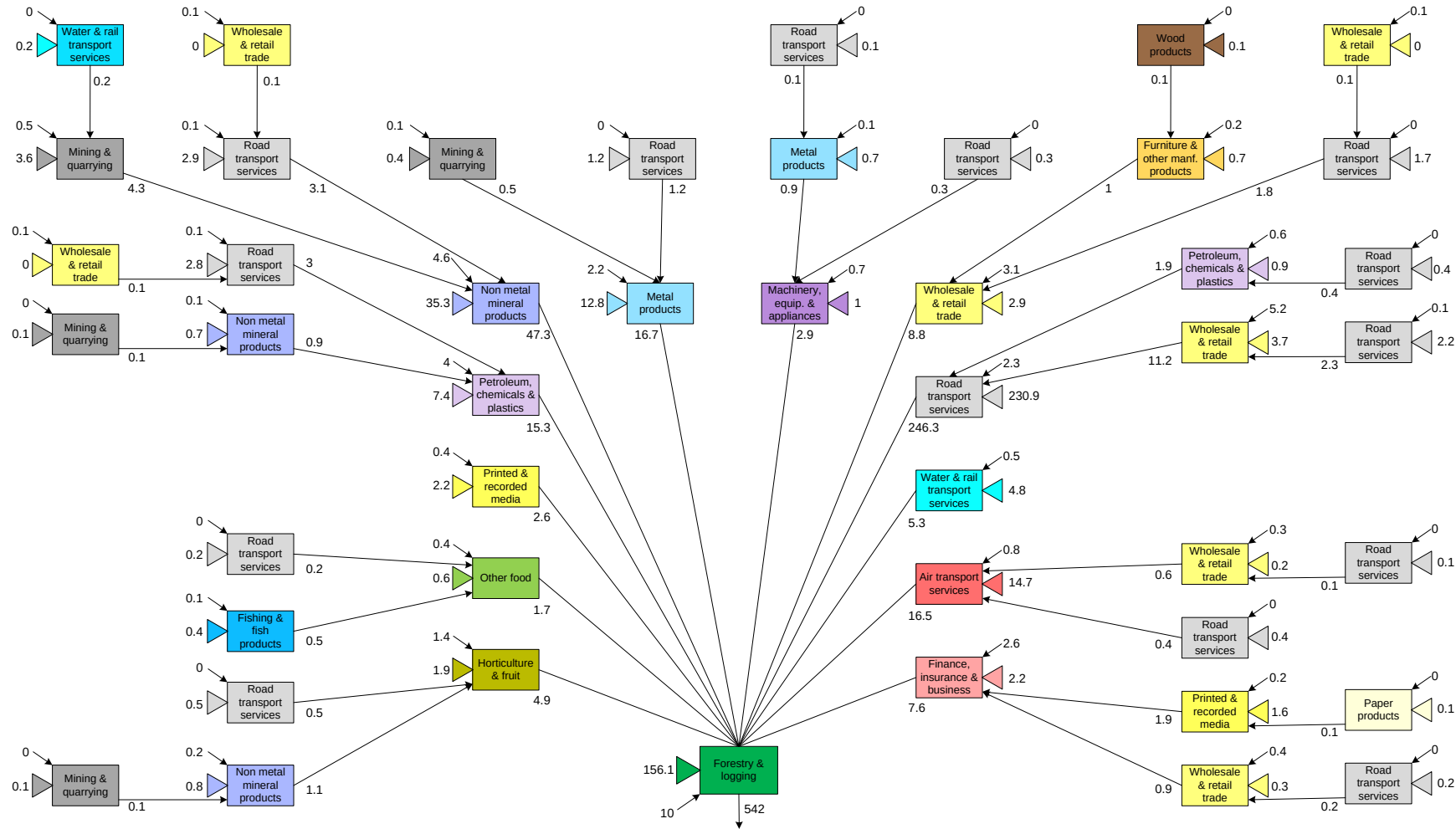


Figure 7.4 - Land Required to Produce One Tonne of Forestry and Logging Products, 2004 (m²)

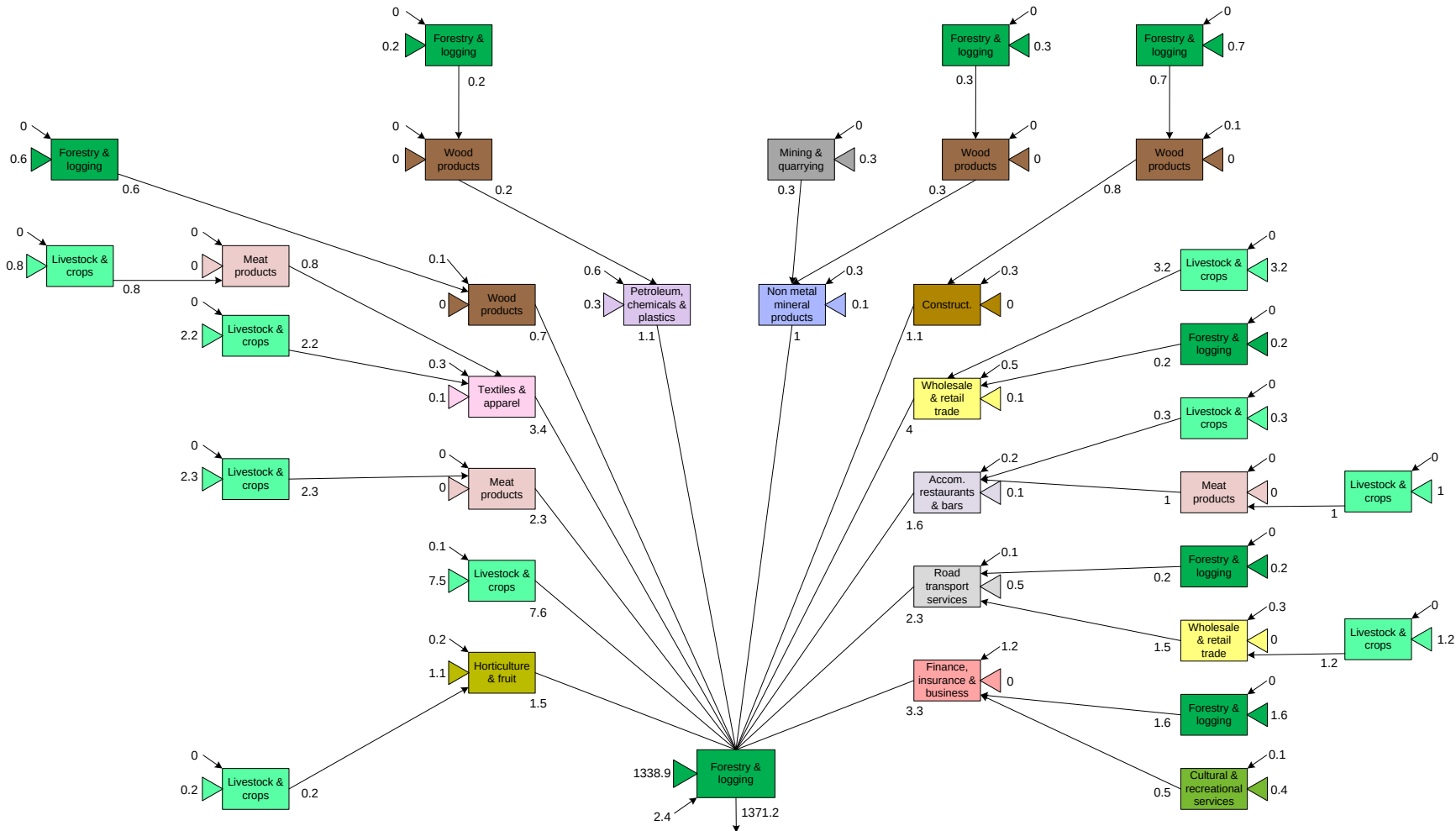


Figure 7.5 - Water Inputs Required to Produce One Tonne of Forestry and Logging Products, 2004 (Litres)

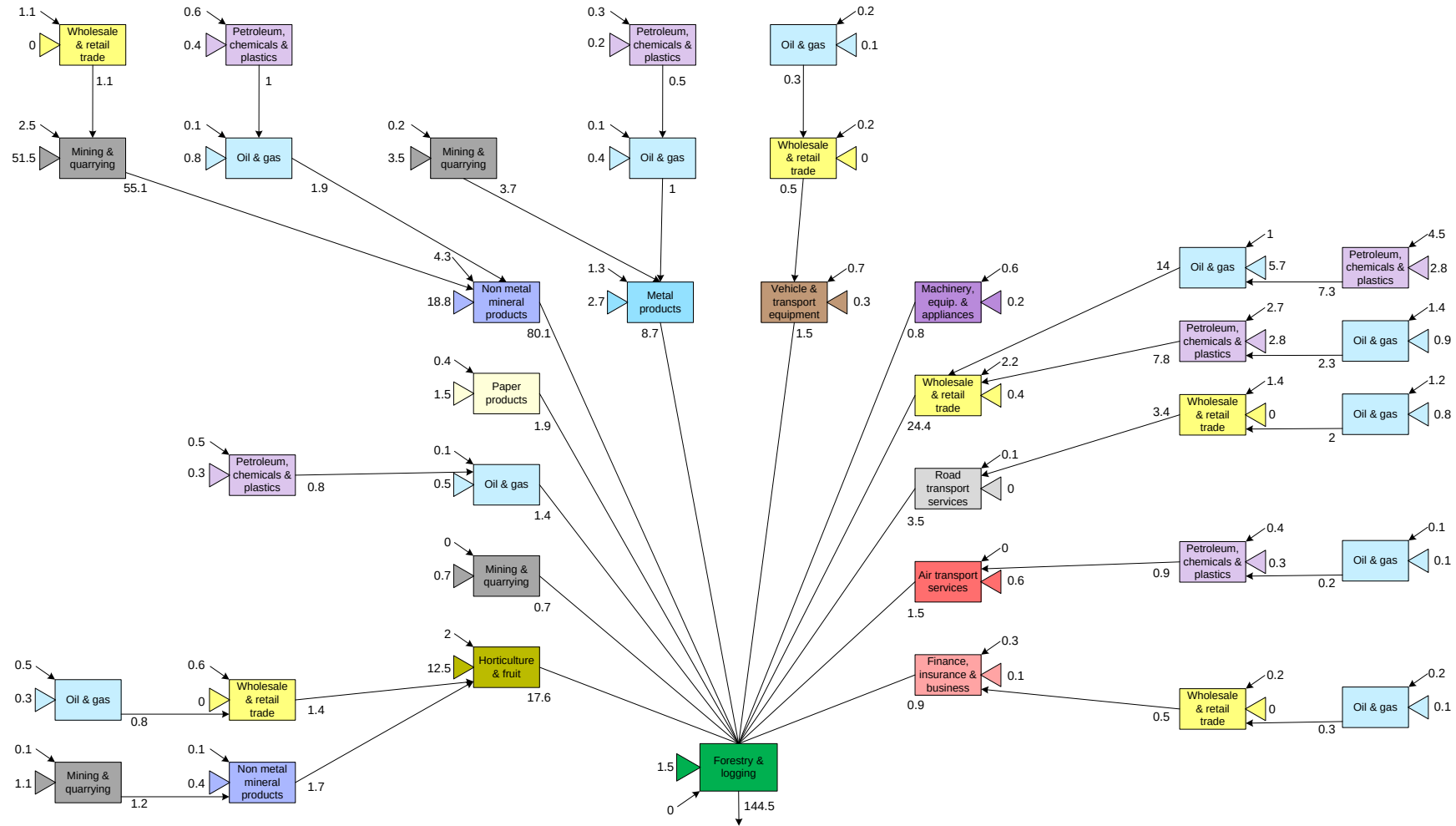


Figure 7.6 - Landfill Waste Generated in Producing One Tonne of Forestry and Logging Products, 2004 (Grams)

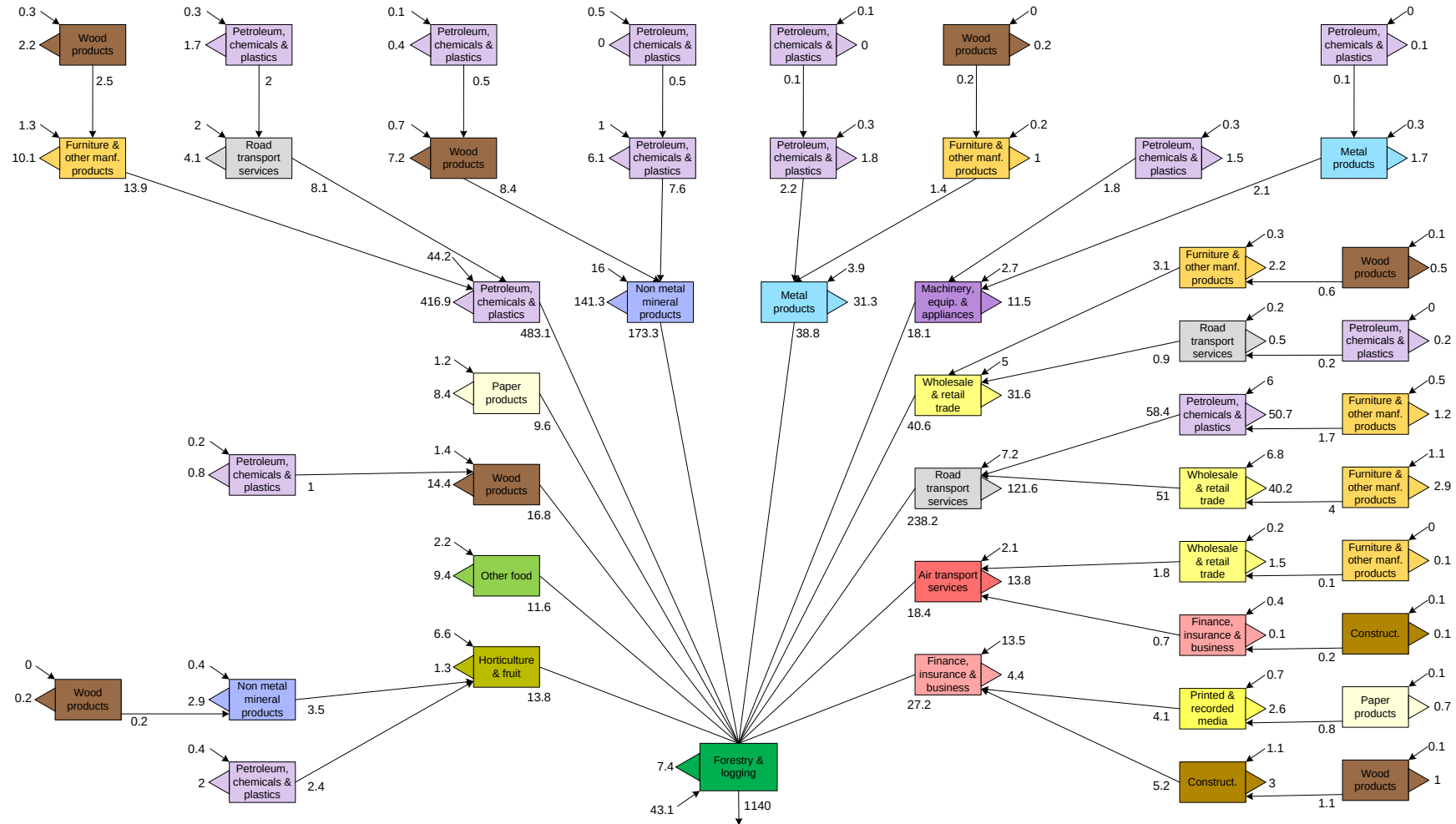


Figure 7.7 - Water Waste Generated in Producing One Tonne of Forestry and Logging Products, 2004 (Litres)



Figure 7.8 - Phosphorus Waste Generated in Producing One Tonne of Forestry and Logging Products, 2004 (Grams)

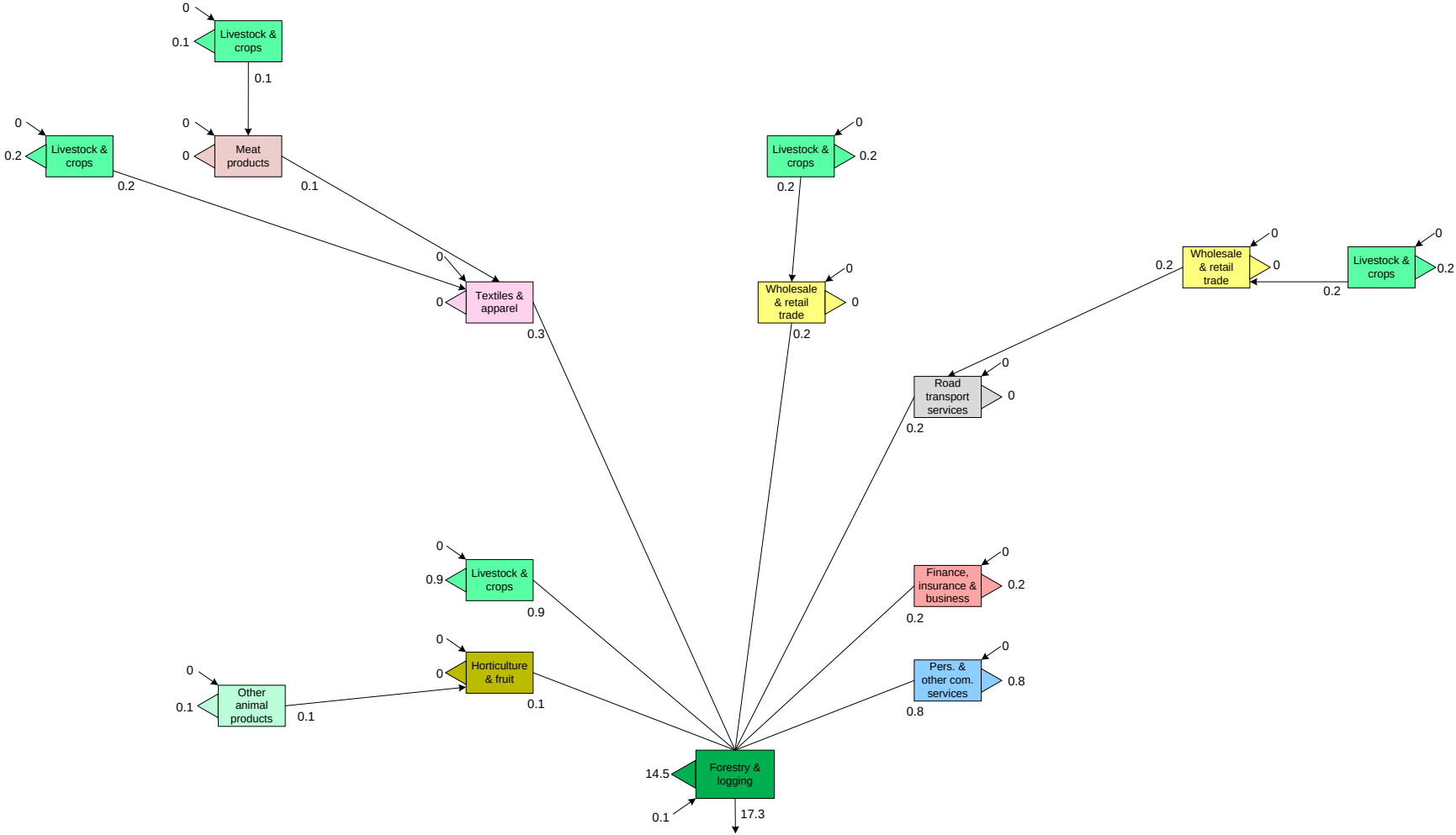


Figure 7.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Forestry and Logging Products, 2004 (Grams)



8. Mining and Quarrying

Description

ANZSIC Codes covered:

- 060 – Coal Mining
- 070 – Oil and Gas Exploration
- 080 – Metal Ore Mining (Gold, Silver, Nickel, Iron, Copper)
- 091 – Construction Material Mining (Gravel and Sand Quarrying)
- 099 – Other mining and quarrying
- 101 – Exploration (Petroleum and Mineral)
- 109 – Other Mining Support Services

GDP 2016 = \$2.378 billion
Rank = 21st

Average annual growth rate
2006 to 2016 = 6.06%
Rank = 9th

Employment 2016 = 4,434
Rank = 31st

Main commodities supplied:

- Tonnes (000) in 2006: Coal (5,767.91), Ironsand (2,146.5)
- Kilograms in 2006: Gold (10,300), Silver (27,220)
- Tonnes (million) in 2006: Limestone (179.2), Rock, sand, and gravel (39.5)
- Tonnes in 2006: Silica sand (58,824), pumice (305,659), decorative pebbles including scoria (131,074), perlite (3,552), bentonite (3,028), building and dimension stone (22,880), and dolomite (1,626)¹¹²

Economic Overview

Coal is New Zealand's most abundant fossil fuel, with the total in-ground resource being estimated at more than 15 billion tonnes.¹¹³ Of this, 8.6 million tonnes are judged to be economically recoverable,¹¹⁴ located mostly in the South Island. NZ Coal & Carbon, Birchfield Coal Mines and BT Mining are the major producers, with the latter operating two large opencast mines; Rotowaro in the Waikato and Stockton on the West Coast, which accounts for 65% of national production.¹¹⁵ Otago/Southland coals mainly supply local industrial and domestic markets, while most of the output from the West Coast is exported. Coal supplied from the Waikato is used mainly for domestic steel production by NZ Steel.¹¹⁶ In 2016, the main end use of coal in NZ was in the production of dairy productions, which accounted for 59.16% of total energy delivered by coal production, this follows a large usage of coal from the Huntly Power Station in the Waikato. Usage of coal in electricity production has been scaled back in

¹¹² Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. Auckland, New Zealand: David Bateman Ltd. (pp.399-402).

¹¹³ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

¹¹⁴ Sherwood, A., and Phillips, J. (2012). *Coal and coal mining - Coal resources* Te Ara - the Encyclopaedia of New Zealand. Retrieved from <http://www.TeAra.govt.nz/en/coal-and-coal-mining/2>

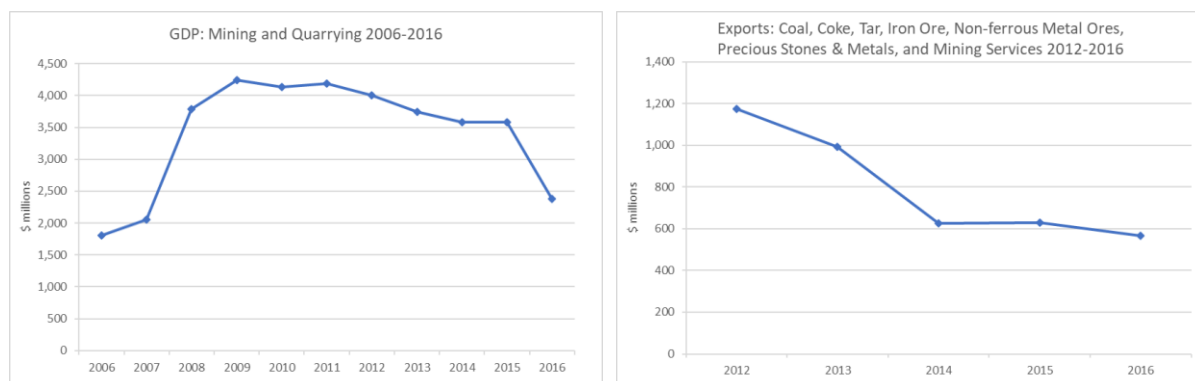
¹¹⁵ Let's Talk About Coal. (n.d.). *Coal in NZ*. Retrieved from <https://www.letstalkaboutcoal.co.nz/coal-in-nz/>

¹¹⁶ Ministry of Business, Innovation and Employment. (2019). *Coal Statistics*. Retrieved from <https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/coal-statistics/>

recent years with the intention to completely remove coal by 2030, due to environmental concerns.¹¹⁷ Japan and India are the largest export markets for New Zealand coal. Anyone wanting to prospect, explore or mine the Government's coal resources must obtain a permit from New Zealand Petroleum & Minerals under the Crown Minerals Act 1991.¹¹⁸

New Zealand has a wide variety of minerals, and while it is best known for its gold production¹¹⁹ (10,045 kg in 2018),¹²⁰ the country also produces silver, ironsands, limestone, clay, dolomite, pumice, and salt along with other minerals. Ironsand is exported in large volumes from the Taharoa mine, with 2.3 million tonnes being exported in 2013, with this expected to increase further in years to come.¹²¹ Volumes of gold and silver exported in New Zealand make up a small proportion of the international market and thus are very sensitive to fluctuations in world demand. The other main exports in this sector are halloysite clay, limestone, sulphur and pumice. Most output of industrial minerals is for domestic use because the distances to overseas markets limited most exports to the high-value commodities or products with unique applications or specifications.

Sector Trends



Production

The mining and quarrying industry experienced a large growth of 45.9% from 2007 to 2008 during the GFC, this may be explained by a significant jump in the contract price for coal between Japan, the leading importer of coal, and global coal producers.¹²² Since then, production levels in the mining and quarrying sector have declined slowly, with an overall decrease of 5.8% from 2008 through to 2015. This may be explained by the introduction of the Emissions Trading Scheme which commenced in 2008, which impacted the profitability of coal-based industries as they are now required to cover their carbon emissions.¹²³ A large downturn is evident most recently, with a fall in production from \$3.12 billion to \$2.53 billion. International commodity prices will continue to have a substantial effect on

¹¹⁷ Frykberg, E. (2018, 2 14). *Genesis Energy to phase out Huntly coal use*. Retrieved from RNZ: <https://www.rnz.co.nz/news/national/350390/genesis-energy-to-phase-out-huntly-coal-use>

¹¹⁸ Ministry of Economic Development. (2013). *New Zealand Petroleum and Mineral Permits*. Retrieved from <http://www.nzpam.govt.nz/cms/coal/permits>

¹¹⁹ Encyclopaedia of the Nations. (2010). *New Zealand-Mining*. Retrieved from; <http://www.nationsencyclopedia.com/Asia-and-Oceania/New-Zealand-MINING.html>

¹²⁰ New Zealand Petroleum & Minerals. (2019, November 20). *2018 Mining Production Statistics*. Retrieved from Annual Minerals Industry Statistics: <https://www.nzpam.govt.nz/our-industry/nz-minerals/minerals-data/industry-statistics/>

¹²¹ Smellie, P. (2018, 7 11). *NZ Steel boosts BlueScope with extra ironsand exports*. Retrieved from NBR: <https://www.nbr.co.nz/article/nz-steel-boosts-bluescope-extra-ironsand-exports-bd-161446>

¹²² Denne, T., Bond-Smith, S., & Hennessy, W. (2009). *Coal Prices in New Zealand Markets*. Auckland: Covec Ltd. Retrieved from <https://www.mbie.govt.nz/assets/b22df3463e/coal-price-report.pdf>

¹²³ Ministry for the Environment. (2018). *A Guide to the New Zealand Emissions Trading Scheme*. Retrieved from <https://www.mfe.govt.nz/publications/climate-change/guide-new-zealand-emissions-trading-scheme>

coal, gold and silver production and investment expenditure. Domestic consumption of coal is likely to decrease in the future, due to the scaling back of coal use at the Huntly Power Station following environmental concerns.¹²⁴ This may in turn, either decrease overall production, or the additional surpluses will be exported.

Exports

Exports in the mining and quarrying sector decline significantly from \$1.18 billion in 2012 to \$626 million in 2014. Following this drop, exports begin to stagnate at around the \$600 million level. This drop in the value of exports can be explained by the steady decline of exported bituminous coal and iron ore. The decline in exports can be further explained by the decreasing price of coal throughout this period. Additionally, the substitution away from coal as a primary source of energy supply, in favour of cleaner, more environmentally friendly sources, is likely to slow international demand for the product in the future. However, coal demand remains steady through parts of Asia.¹²⁵ In 2016, additional shipping capacity was introduced to the ironsands industry, with expectations of increasing exports to almost 10 million tonnes. While this has yet to be seen in the graph above, it would be likely that exports in this sector increase.¹²⁶

Life Cycle Assessment Diagrams

Energy (Figure 8.1, Figure 8.2, Figure 8.3)

Mining and quarrying products were found to have a total energy intensity of 280.1 MJ_{OE} per tonne of product (0.280 MJ_{OE}/kg). Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand mining and quarrying sector is 0.445 MJ_H/kg. It should be noted that the total energy intensity for mining and quarrying products is the lowest energy-consuming sector, ranking 20th out of the 20 product producing sectors covered in this publication.

Direct energy use was the majority at 83% of the total energy intensity, measuring 231.9 MJ_{OE} per tonne of mining and quarrying products. Most of this direct energy use would come from fuel used in mining and quarrying machinery, and trucks for transportation – the EECA in use database reports that a total of 1,900.410 TJ of energy was used in the mining and quarrying sector in 2006/07. *Indirect energy use* made up the remaining total energy intensity at 17%, measuring 48.2 MJ_E per tonne of mining and quarrying product.

The main indirect energy uses were from; (i) energy embodied in water and rail transport services at 13.1 MJ_{OE} per tonne of product produced; (ii) energy embodied in wholesale and retail trade at 5 MJ_{OE} per tonne of product produced; (iii) energy embodied in non-metal mineral products and petroleum, chemicals and plastics, both at 4.3 MJ_{OE} per tonne of product produced.

Land (Figure 8.4)

Mining and quarrying products have a total land intensity of 30.5 m² per tonne of product produced. This figure is very low in comparison to the other product producing sectors covered in this

¹²⁴ Frykberg, E. (2018, 2 14). *Genesis Energy to phase out Huntly coal use*. Retrieved from RNZ:

<https://www.rnz.co.nz/news/national/350390/genesis-energy-to-phase-out-huntly-coal-use>

¹²⁵ IEA. (2018). *Coal 2018*. Paris: IEA. Retrieved February 5, 2020, from <https://www.iea.org/reports/coal-2018>

¹²⁶ BusinessDesk. (2013, December 30). *Iron sand exports could soar after shipping expansion*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11179421

publication, ranking 20th out of 20 indicating that the mining and quarrying is not a land-intensive sector.

Direct land use for the production of mining and quarrying products is 85%, measuring 25.9 m² per tonne of product produced. *Direct land use* is the total land used for excavating the mines and quarries themselves to extract the products. *Indirect land use* only makes up only 4.6 m² of total land use per tonne of product. *The major indirect land uses came from; (i) land embodied in wholesale and retail trade at 1.6 m² per tonne of product produced; (ii) land embodied in water and rail transport services and livestock and crop products both at 0.5 m² per tonne of product produced.*

Water Inputs (Figure 8.5)

Mining and quarrying products require 10,640.9 litres of water inputs per tonne of product produced, ranking 14th out of the 20 product producing sectors covered in this publication. *Direct water inputs* make up the majority of total water inputs at 93%, using 9,934.7 litres per tonne of mining and quarrying product produced. *Indirect water inputs* make up only 7% of total water inputs, using 706.2 litres per tonne of fishing product produced.

The main indirect water inputs into mining and quarrying products came from; (i) water inputs embodied in wholesale and retail trade at 227.3 litres per tonne of product produced; (ii) water inputs embodied in petroleum, chemicals and plastics at 191 litres per tonne of product produced (iii) water inputs embodied in fishing and fish products at 39.1 litres per tonne of product produced; (iv) water inputs embodied in oil and gas at 38.5 litres per tonne.

Landfill Wastes (Figure 8.6)

Mining and quarrying products were found to generate 344.4 grams (0.344 kg) of landfill waste per tonne of product. It should be noted that the landfill waste generated in producing mining and quarrying products the lowest-ranked sector at 20th out of the 20 product producing sectors covered in this publication. It is by far the lowest-ranked sector in the publication, only producing around a third of the waste of forestry and logging products which is ranked 19th out of 20.

Landfill waste directly generated by mining and quarrying products was only 10% of total waste produced or 33.3 grams per tonne of product. Landfill waste indirectly generated by mining and quarrying products was the majority of total landfill waste produced at 90%, or 311.1 grams per tonne of product produced. *The main sources of indirect landfill waste for mining and quarrying products came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 160.8 grams per tonne of product; (ii) landfill wastes embodied in wholesale and retail trade at 34.9 grams per tonne of product; (iii) landfill wastes embodied in non-metal mineral products at 28.8 grams per tonne of product; (iv) landfill wastes embodied in construction services at 26 grams per tonne of product.*

Water Wastes (Figure 8.7)

Mining and quarrying products were found to produce 35,276.1 litres of wastewater per tonne of product produced. The amount of wastewater produced by the mining and quarrying sector is ranked 12th highest out of the 20 product producing sectors covered by this publication. The amount of wastewater produced by this sector is similar in order of magnitude to reported wastewater produced by various mining and quarrying products: *Wastewater directly generated* by mining and quarrying products was 96% of total wastewater produced at 33,955.7 litres per tonne of product produced. *Wastewater indirectly generated* by mining and quarrying products makes up only 4% or 1,320.4 litres per tonne of product produced. *The indirect wastewater from mining and quarrying production is mostly made up of (i) wastewater embodied in personal and other community services at 368.7 litres*

per tonne of product produced; (ii) wastewater embodied non-metal mineral products at 146.8 litres per tonne of product produced; (iii) wastewater embodied in petroleum, chemicals and plastics at 142.7 litres per tonne of product produced; (iv) wastewater embodied in mining and quarrying at 97.1 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 8.8)

In terms of CO₂ greenhouse gas emissions, mining and quarrying products emitted 31,241.2 grams (3.12 kg) of energy-related CO₂ per tonne of product produced. This sector is the lowest emitter of energy-related CO₂ per tonne among the other product producing sectors covered in this publication, ranking 20th out of 20. The EECA in use database reports that a total of 1,900.41 TJ of energy was used in the mining and quarrying sector in 2006/07.

Energy-related CO₂ directly generated mining and quarrying was 81% of the total CO₂ emitted at 25,309.8 grams per tonne of product produced. Energy-related CO₂ indirectly generated by mining and quarrying products was 19% or 427.3 grams of the total CO₂ emitted per tonne of product produced. The indirect energy-related CO₂ from the production of mining and quarrying products was mostly made up of (i) energy-related CO₂ embodied in water and rail transport services at 1,422.2 grams per tonne of product produced; (ii) energy-related CO₂ embodied in non-metal mineral products at 733.7 grams per tonne of product produced; (iii) energy-related CO₂ embodied in wholesale and retail trade at 679.9 grams per tonne of product produced; (iv) energy-related CO₂ embodied in metal products at 424.7 grams per tonne of product produced.

Figure 8.1 - Total Energy Inputs Required to Produce One Tonne of Mining and Quarrying Products, 2004 (MJ_E, Oil Equivalents)

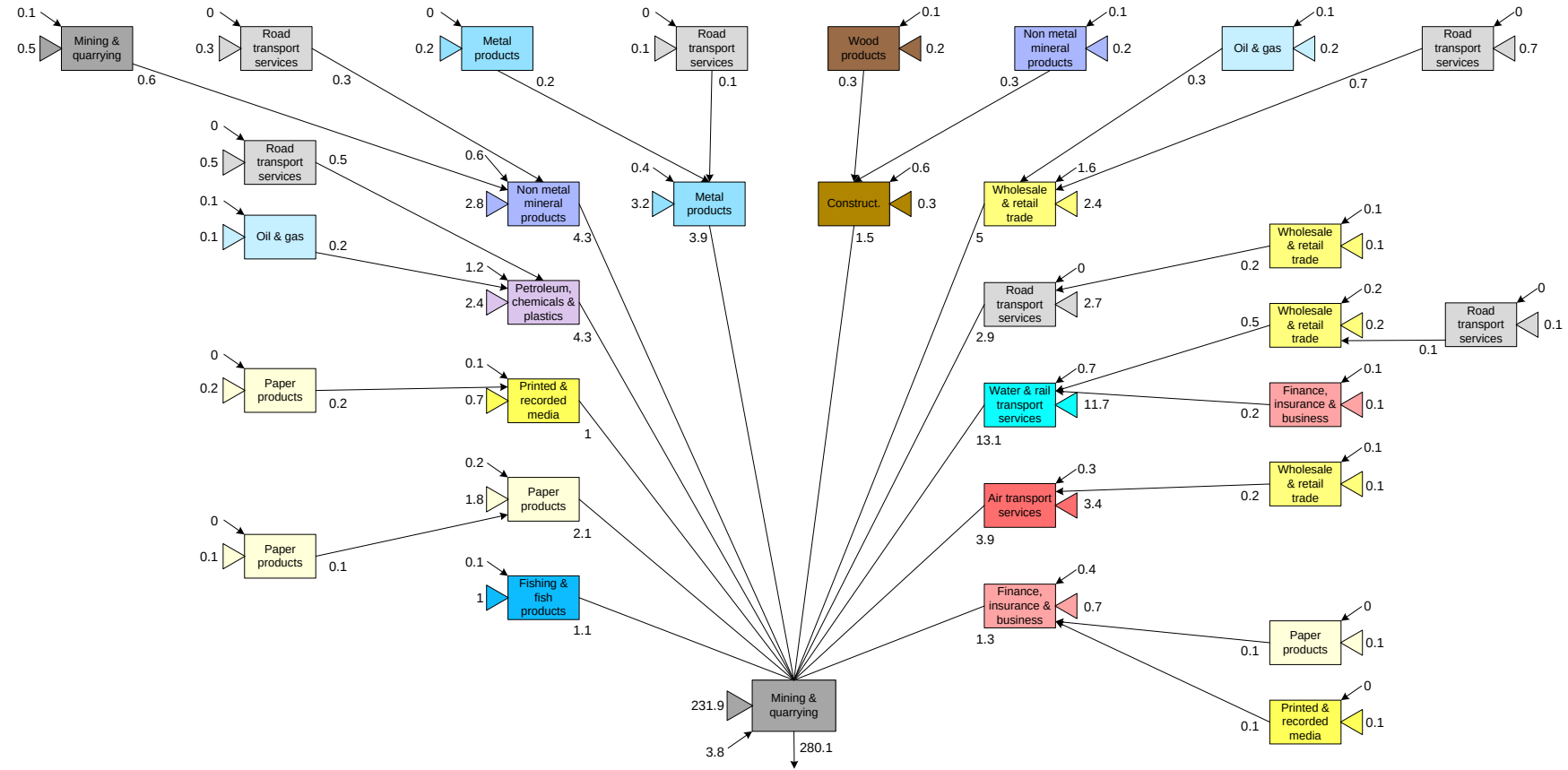


Figure 8.2 - Electricity Inputs Required to Produce One Tonne of Mining and Quarrying Products, 2004 (MJ, Heat Equivalents)

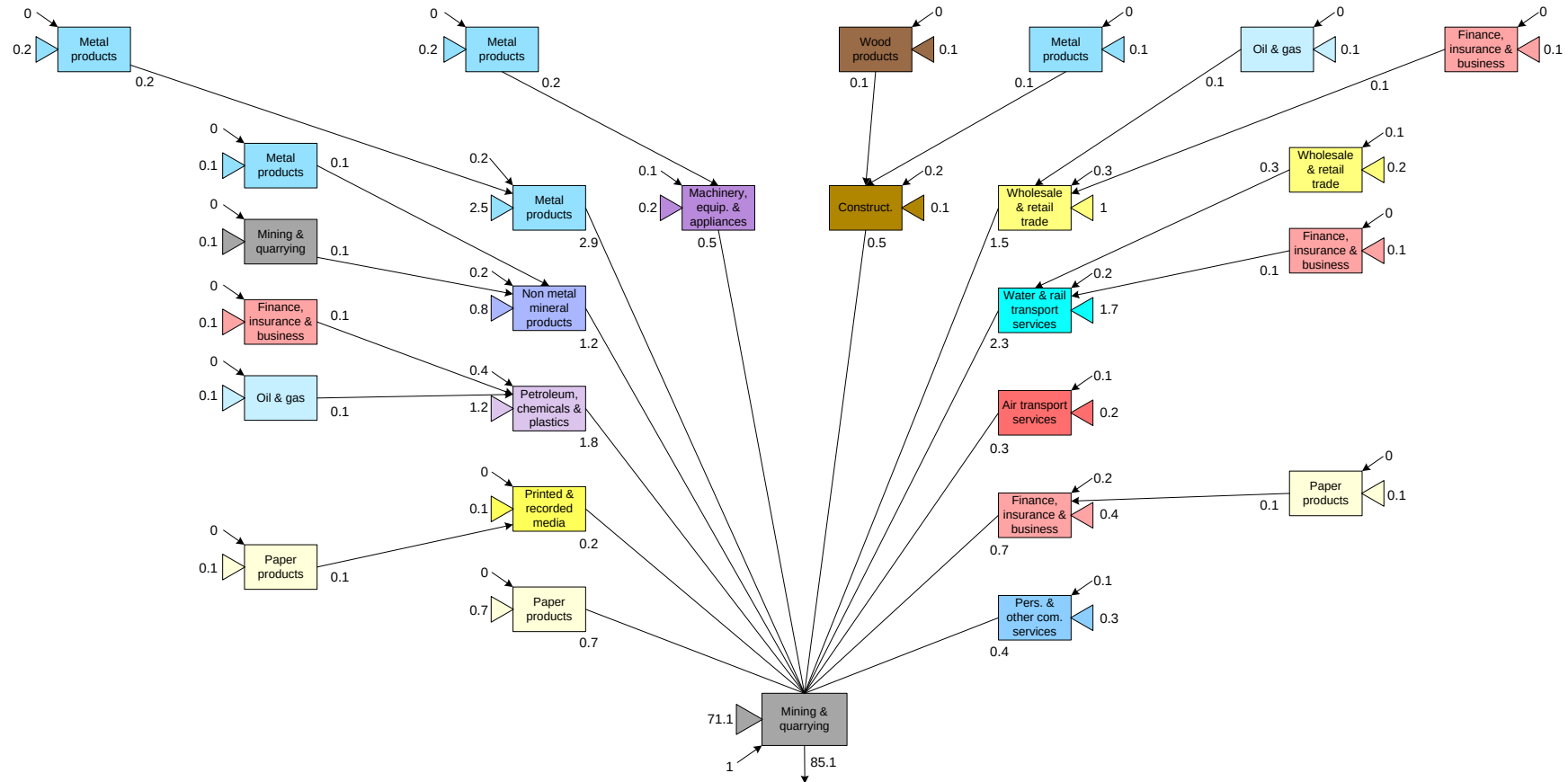


Figure 8.3 - Fossil Fuel Inputs Required to Produce One Tonne of Mining and Quarrying Products, 2004 (MJ, Heat Equivalents)

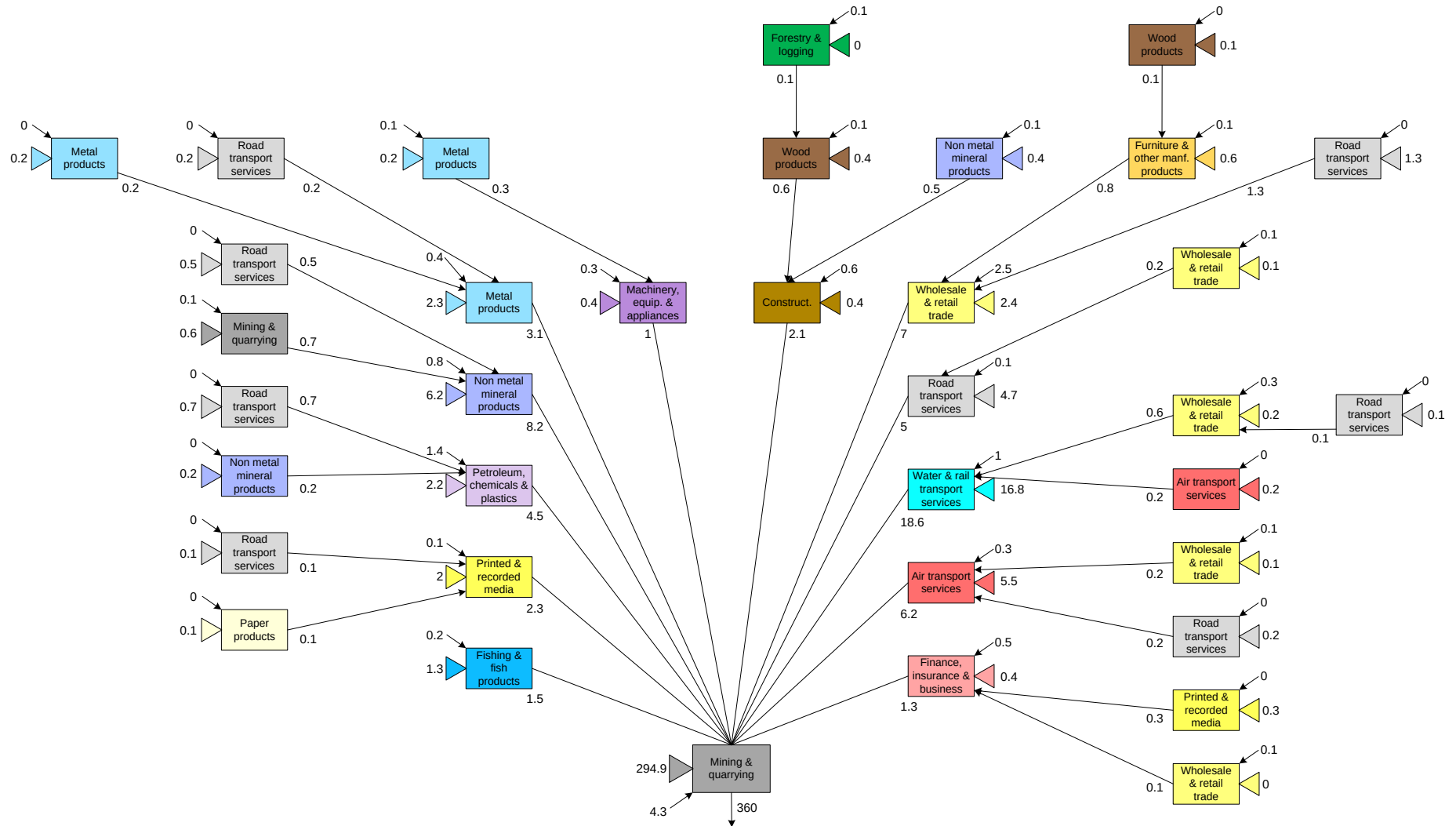


Figure 8.4 - Land Required to Produce One Tonne of Mining and Quarrying Products, 2004 (m²)

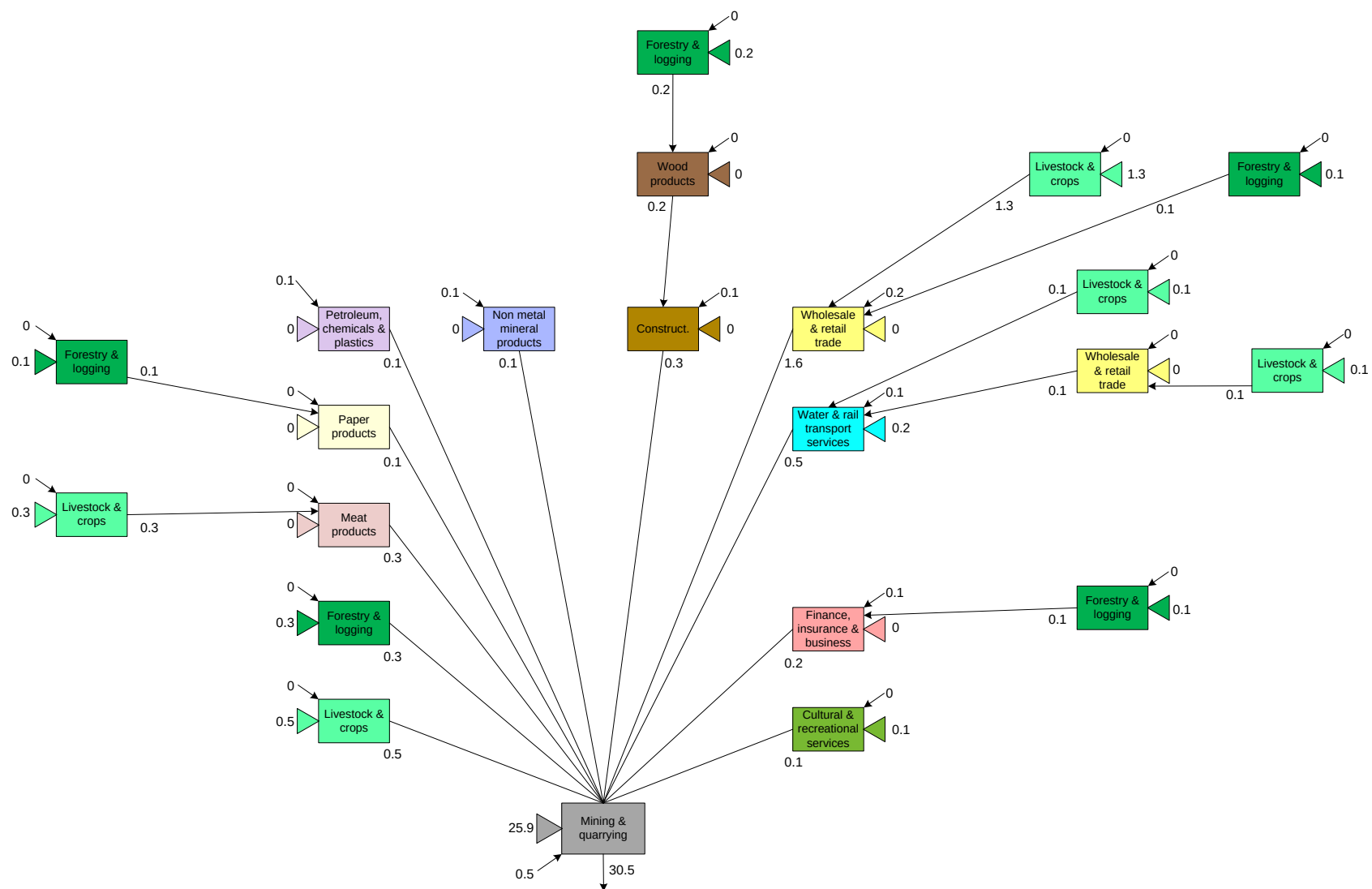


Figure 8.5 - Water Inputs Required to Produce One Tonne of Mining and Quarrying Products, 2004 (Litres)

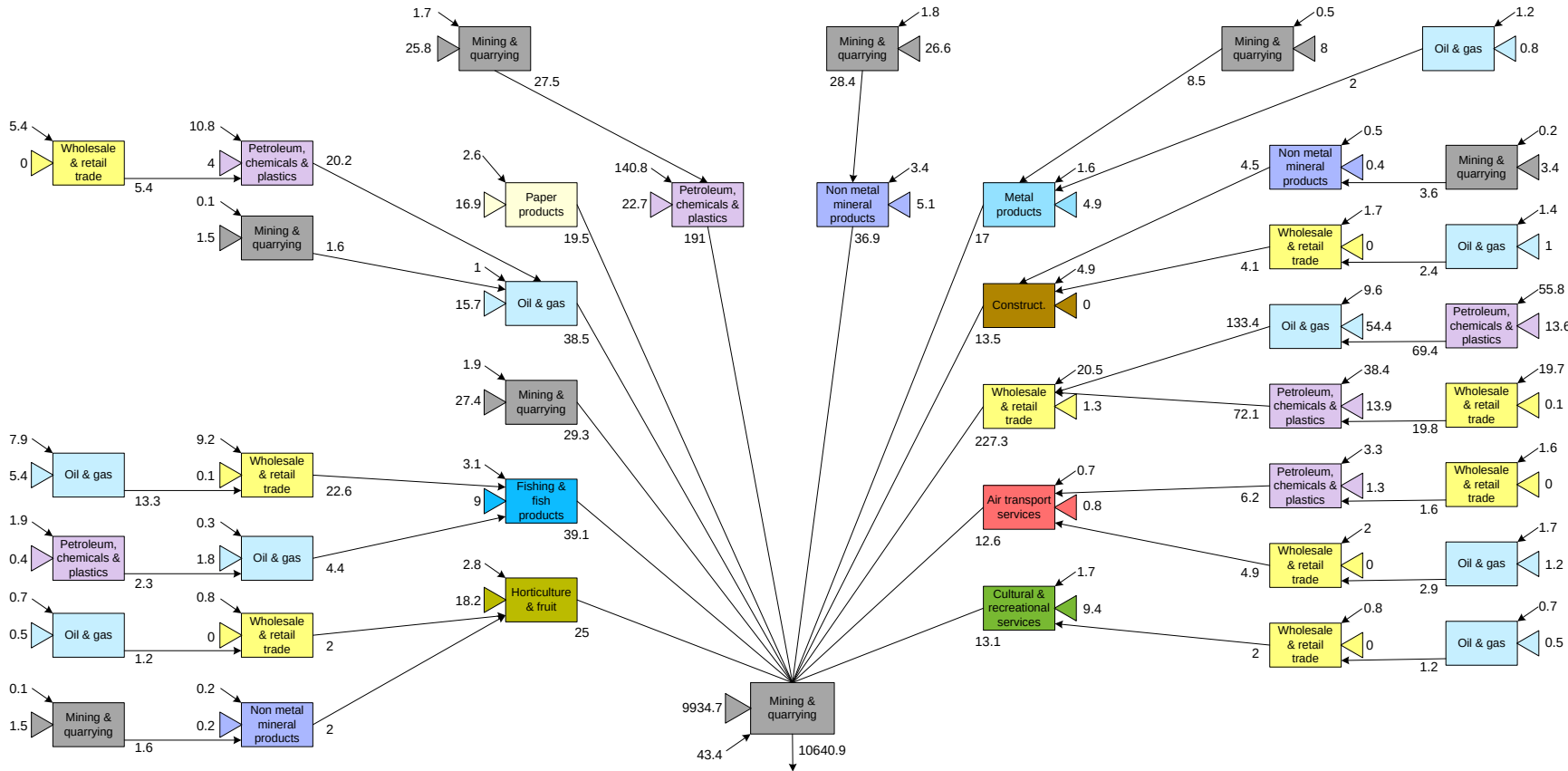


Figure 8.6 - Landfill Waste Generated in Producing One Tonne of Mining and Quarrying Products, 2004 (Grams)

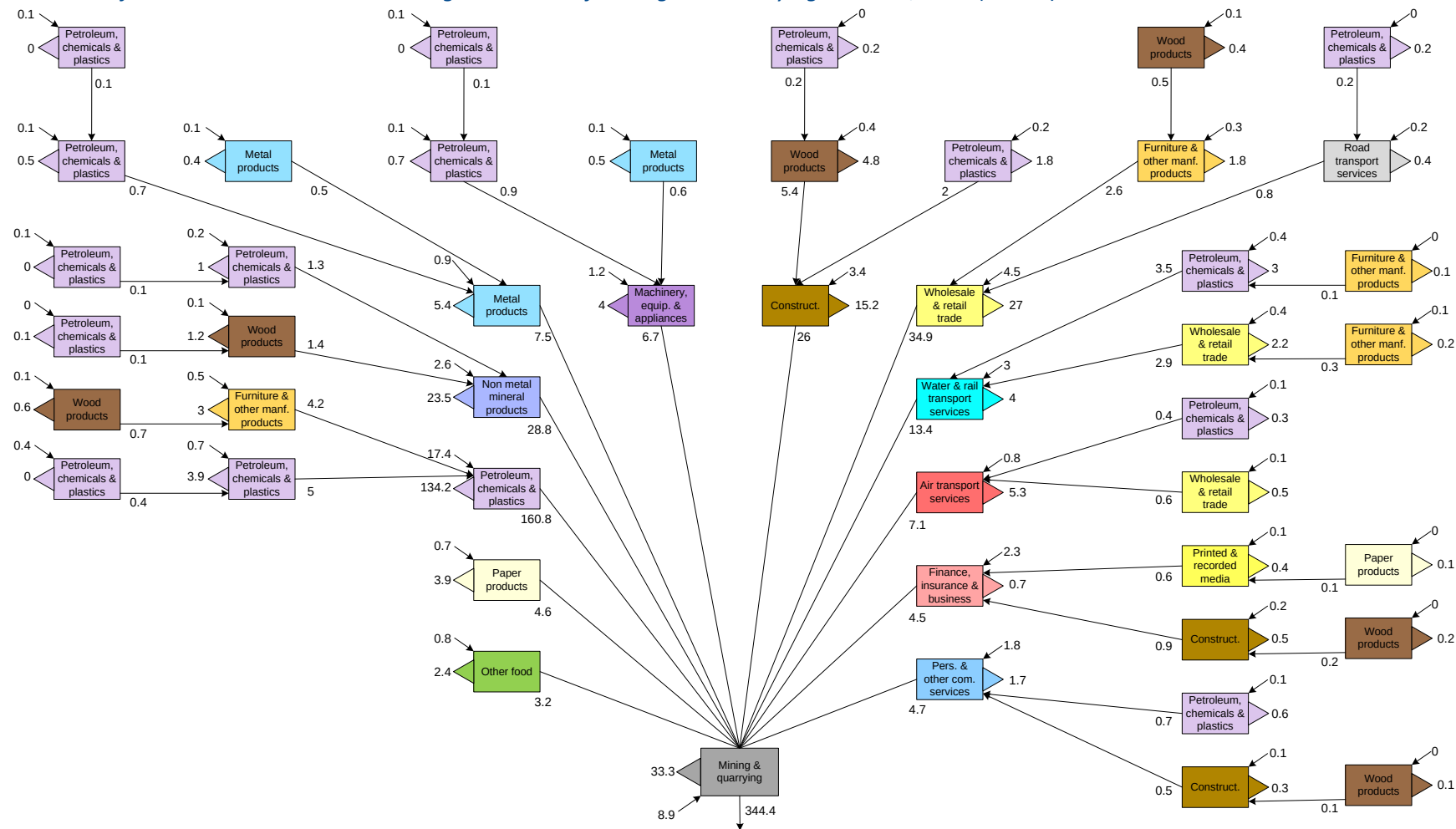
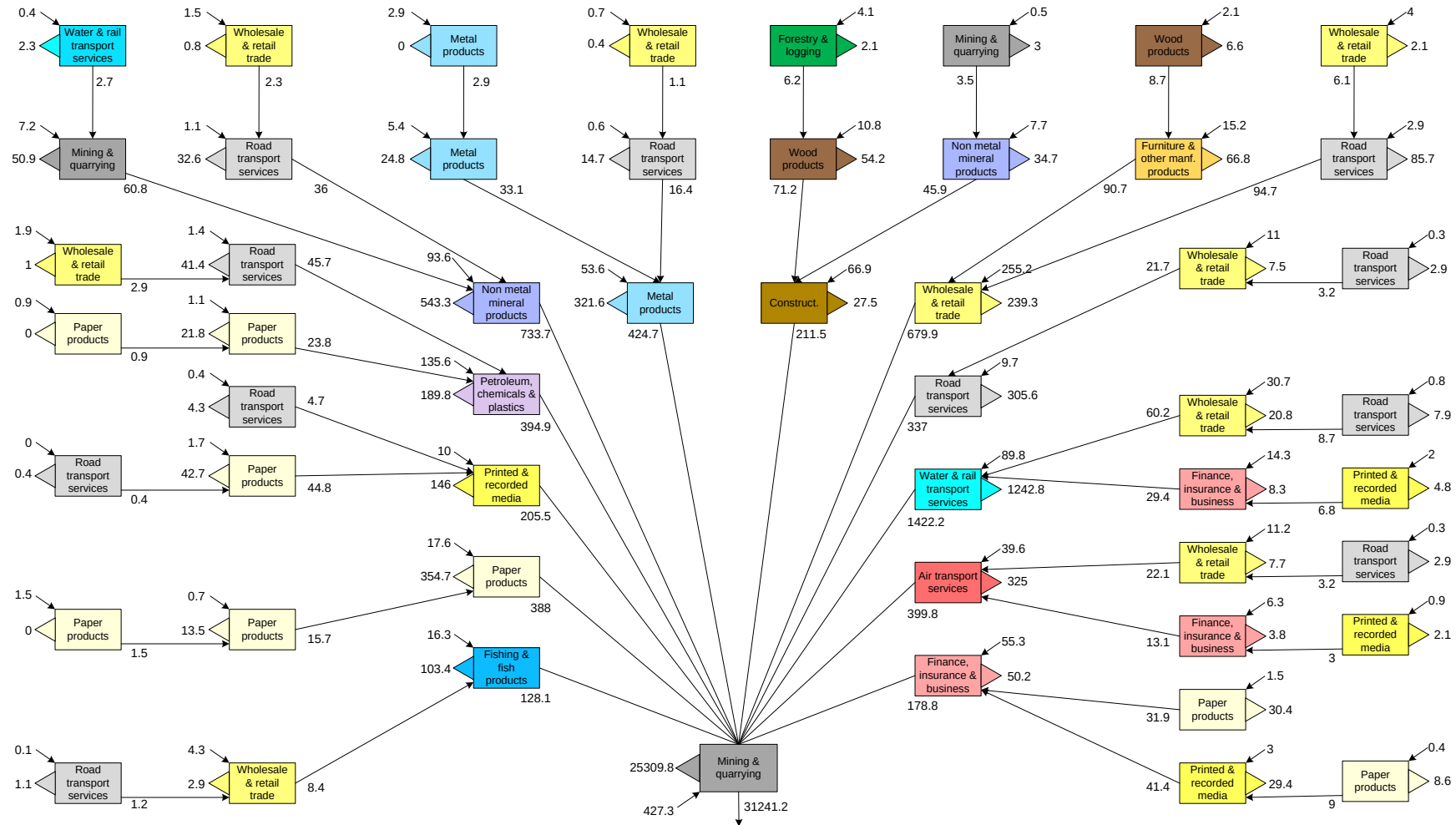


Figure 8.7 - Water Waste Generated in Producing One Tonne of Mining and Quarrying Products, 2004 (Litres)



Figure 8.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Mining and Quarrying Products, 2004 (Grams)



9. Meat and Meat Product Manufacturing

Description

ANZSIC Codes covered:

- 1111 – Meat Processing (including slaughtering & packing)
- 1112 – Poultry Processing (including slaughtering & packing)
- 1113 – Cured Meat and Smallgood Manufacturing

Main commodities supplied (Tonnes in 2006):

- Beef (620,000), mutton (104,000), and lamb (438,000)
- Pig meat (51,000) and poultry (155,000)
- Deer (39,000) and veal (23,000)¹²⁷

GDP 2016 = \$1.698 billion

Rank = 23rd

Average annual growth
rate 2006 to 2016 = 2.77%

Rank = 23rd

Employment 2016 = 30,441

Rank = 18th

Economic Overview

While a relatively small contributor to New Zealand's GDP, contributing \$1.698 billion, ranking 23rd overall. Meat products are New Zealand's second-largest export income earner after dairy produce, accounting for 13.9% of total merchandise export values in 2015, made up largely of beef and sheepmeat.¹²⁸

The country is a major player on the world market, accounting for 8% of global export beef trade, and 55% of global lamb and mutton world export trade, with exports going to more than 100 countries. New Zealand's major sheepmeat markets are the EU, North America, and the Middle East. In 2018, lamb exports contributed to 45.4% of New Zealand's total meat exports.¹²⁹ Being an export-driven industry, 92% of lamb, 82% of beef, and 95% of venison produced in New Zealand are exported.¹³⁰

Although world meat production has increased, demand coming from developing countries has increased more than supply and resulted in high prices over the past few years.¹³¹ The meat products industry is highly dependent on international meat prices and market access.

¹²⁷ Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. Auckland, New Zealand: David Bateman Ltd. (pp.361).

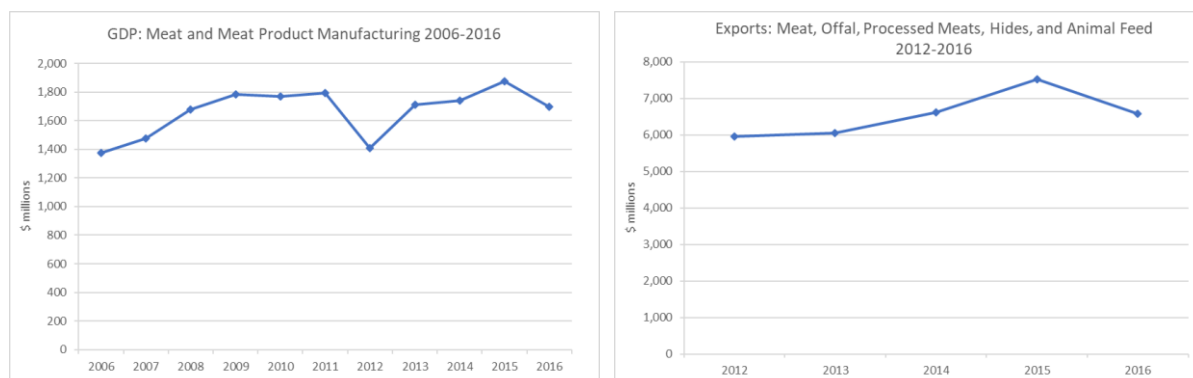
¹²⁸ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from; <https://treasury.govt.nz/sites/default/files/2010-04/nzeo-16.pdf>

¹²⁹ Statistics New Zealand. (2018, June 27). *Lamb exports set new record*. Retrieved February 5, 2020, from Stats NZ: <https://www.stats.govt.nz/news/lamb-exports-set-new-record>

¹³⁰ Meat Industry Association. (2009). *Meat In Focus*. Wellington: MIA. Retrieved February 5, 2020, from <https://www.mia.co.nz/assets/MIA-Publications/Meat-in-focus.pdf>

¹³¹ Brester, G., Department of Agricultural Economics, Montana State University. (2012). *International Lamb Profile, Agricultural Marketing Resource Centre*. Retrieved from http://www.agmrc.org/commodities_products/livestock/lamb/international-lamb-profile/

Sector Trends



Production

Over the time period between 2006 and 2011, production in the meat and meat product manufacturing sector increased 30.3% from \$1.38 billion in 2006 and then levelled out at around \$1.8 billion. This period of stagnant growth suggests that demand over this period was relatively constant. In 2012, production fell 21.3% to \$1.4 billion, this is likely the result of the 2012-2013 drought throughout New Zealand, which was also felt by the livestock and crop farming sector. However, the sector recovered strongly and grew 33% over the following three years, where production levels peaked in 2015 at \$1.88 billion.

Exports

New Zealand and Australia are the world's leaders in lamb exports and account for nearly 90% of the global export quantity. Like the upward trend in production observed between 2012 and 2015, the value of the meat and meat product manufacturing sector's exports rose, growing at an average annual rate of 8.8% and peaking at \$7.56 billion in 2015. In more recent times, just as production appears to be declining, the value of the sector's exports is also downward trending, as value fell to \$6.57 billion in 2016. This may be meat and meat product manufacturing returning to historic levels, following high levels of production and exports in 2015 as a result of strong US demand for New Zealand beef exports as well as increase commodity prices.

Life Cycle Assessment Diagrams

Energy (Figure 9.1, Figure 9.2, Figure 9.3)

Meat products were found to have a total energy intensity of 9,302.9 MJ_{OE} per tonne of product (9.3 MJ_E/kg). This total energy intensity ranks the meat products sector 8th highest out of the 20 product producing sectors covered in this publication.

Direct energy use was only 29% of the total energy intensity, measuring 2,670 MJ_{OE} per tonne of meat product. Direct energy uses would include electricity to operate machinery, lighting, and refrigeration, and fossil fuels for transportation – the EECA in use database reports that a total of 6,655.417 TJ of energy was used in the slaughterhouse and meat processing sector in 2006/07. *Indirect energy use* made up 71% of the total energy intensity, measuring 6,632.9 MJ_{OE} per tonne of meat product.

The main indirect energy uses for the production of meat products were from; (i) energy embodied livestock and crops at 3,388.9 MJ_{OE} per tonne of product produced; (ii) energy embodied road transport services at 1,291.5 MJ_{OE} per tonne of product produced; (iii) energy embodied in other animal products at 543.3 MJ_{OE} per tonne of product produced; (iv) energy embodied in metal products at 305.3 MJ_E per tonne of product produced.

The total energy intensity measured in conventional units is 15.88 MJ_H/kg for the meat and meat product manufacturing sector. This compares with the total energy intensity reported by McChesney, Sharp and Hayward (1982) for dressed beef meat of 13.8 MJ_H/kg New Zealand. Similarly, Slessor and Wallace reported a total energy intensity of 11.0 MJ_H/kg for European Union countries.

Land (Figure 9.4)

Meat products have a total land intensity of 74,998.5 m² per tonne of product produced. Meat products have the largest land intensity out of the 20 product producing sectors covered by this publication. *Direct land use* for the production of meat products was minuscule at only 0.2% of the total land intensity, measuring 176.5 m² per tonne of product produced. *Indirect land use* makes up the majority of total land use at 99.8% measuring 74,822 m² per tonne of product.

The major indirect land uses in the production of meat products came from; (i) land embodied in livestock and crops at 73,383.9 m² per tonne of product produced; (ii) land embodied meat products at 273 m² per tonne of product produced; (iii) land embodied in forestry and logging at 268.2 m² per tonne of product produced; (iv) land embodied in finance, insurance & business at 155.9 m² per tonne of product produced.

Water Inputs (Figure 9.5)

Meat products require 74,998.5 litres of water inputs per tonne of product produced, ranking the sector the 2nd highest consumer of water out of the 20 product producing sectors covered in this publication. This is in a similar magnitude to reported amounts of water inputs for various reported meat products such as Australian red meat between 18-540 litres per kg of product,¹³² the Australian average being 209 litres per kg of product.¹³³

Direct water inputs make up 56%, using 46,891.1 litres per tonne of meat product produced. While *indirect water inputs* make up 44%, using 37,544.8 litres per tonne of meat product produced. *The main indirect water inputs into meat products came from; (i) water inputs embodied in livestock and crops at 19,433 litres per tonne of product produced; (ii) water inputs embodied in plastics, chemicals and petroleum at 6,195 litres per tonne of product produced; (iii) water inputs embodied in oil and gas at 4,072.1 litres per tonne of product produced (iv) water inputs embodied in other animal products at 2,363 litres per tonne of product produced.*

Landfill Wastes (Figure 9.6)

Meat products were found to generate 61,635.6 grams (61.6 kg) of landfill waste per tonne of product. The landfill waste generated by this sector in producing meat products is ranked 8th out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by meat products was 56.5% of total waste produced or 34,819.7 grams per tonne of product. And so, landfill waste *indirectly generated* by meat products was 43.5%

¹³² Peters, G.M., Wiedemann, S.G., Rowley, H.V., Tucker, R.W. (2010). Accounting for Water Use in Australian Red Meat Production. *International Journal of Life Cycle Assessment*, 15(3), 311-320.

¹³³ Foran, B., Lenzen, M., Dey, C. (2005). *Balancing Act – A triple bottom line analysis of the Australian economy*. CSIRO, Canberra.

or 182,816.1 grams per tonne of product produced. *The main sources of indirect landfill waste in the production of meat products came from; (i) landfill wastes embodied in livestock and crops at 15,074.3 grams per tonne of product; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 3,401.7 grams per tonne of product; (iii) landfill wastes embodied in other animal products at 2,274.1 grams per tonne of product; (iv) landfill wastes embodied in road transport services at 1,928.4 grams per tonne of product.*

Water Wastes (Figure 9.7)

Meat products were found to produce 109,126.1 litres of wastewater per tonne of product produced. The meat products sector is the 5th highest producer of water wastes when compared to other 20 product producing sectors covered by this publication.

Wastewater directly generated by meat products was 44.5% of total water waste produced at 48,570.2 litres per tonne of product produced. Direct wastewater could be attributed to the wastewater produced from washing down machinery at the factories. Wastewater indirectly generated by meat products make up 55.5% or 60,555.9 litres per tonne of product produced. The indirect wastewater from meat product production is mostly made up of (i) wastewater embodied in livestock and crops at 35,064.1 litres per tonne of product produced; (ii) wastewater embodied in personal and other community services at 9,122.3 litres per tonne of product produced; (iii) wastewater embodied in mining and quarrying at 3,495.6 litres per tonne of product produced; (iv) wastewater embodied in oil and gas at 2,214.2 litres per tonne of product produced.

Phosphorus Wastes (Figure 9.8)

Meat products were found to produce 9,506.2 grams (9.5 kg) of phosphorus waste per tonne of product produced. *Phosphorus waste directly generated by meat products was tiny at only 2.7% of total phosphorus wastes at 258.5 grams per tonne of product produced. On the other hand, phosphorus waste indirectly generated by meat products made up the majority at 97.3% of the total phosphorus waste produced at 9,247.7 grams per tonne of product. Indirect phosphorus waste from the production of meat products was mostly made up of (i) phosphorus waste embodied in livestock and crops at 8,932.4 grams per tonne of product produced; (ii) phosphorus waste embodied in other animal products at 154.6 grams per tonne of product produced; (iii) phosphorus waste embodied in personal and other community services at 47.7 grams per tonne of product produced; (iv) phosphorus waste embodied in meat products at 34.5 grams per tonne of product produced.*

Energy Greenhouse Gases (Figure 9.9)

In terms of CO₂ greenhouse gas emissions, meat products emitted 1,129,426.3 grams (1,129.4 kg) of energy-related CO₂ per tonne of product produced. This sector is the 8th highest emitter of energy-related CO₂ per tonne among the 20 product producing sectors covered in this publication. This amount of energy-related CO₂ is within the range of reported energy-related CO₂ produced by various other products in the meat products sector such as New Zealand Lamb at 563.2 kg of energy-related

CO₂ per tonne of product produced;¹³⁴ New Zealand pig meat at 3,500 kg of energy-related CO₂ per tonne of product produced.^{135, 136}

Energy-related CO₂ directly generated meat products was 30.2% of the total CO₂ emitted at 340,935.3 grams per tonne of product produced. This direct energy into the meat products sector is likely from running of machines to process the meat, and electricity for refrigeration of the meat. Energy-related CO₂ indirectly generated by the production of meat products was 69.8% or 788,491 grams. The indirect energy-related CO₂ from the production of meat products was mostly made up of (i) energy-related CO₂ embodied in livestock and crop products at 414,429.1 grams per tonne of product produced; (ii) energy-related CO₂ embodied in road transport services at 145,290 grams per tonne of product produced; (iii) energy-related CO₂ embodied in other animal products at 59,159.8 grams per tonne of product produced; (iv) energy-related CO₂ embodied in metal products at 31,700.8 grams per tonne of product produced.

¹³⁴ Saunders, C., Barber, A., Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry (Research Report No.285)*. Christchurch, New Zealand: Lincoln University.

¹³⁵ Ministry of Primary Industries. (n.d). *Agriculture in the New Zealand Emissions Trading Scheme: Emissions factors (agriculture)*. Retrieved 17th December 2013, from <http://www.mpi.govt.nz/Portals/0/Documents/agriculture/agri-ets/agents-emissions-factors.pdf>

¹³⁶ Caution needs to be displayed in interpreting these data, as both direct and indirect energy-related CO₂ emissions, are only a relatively small proportion (10-20%) of the total carbon footprint of producing meat products. Accordingly, the Meat Industry Association reports that the "cradle to grave" carbon footprint of New Zealand sheep meat is on average 14.73 kilogram of CO₂ equivalents per kilogram of product for sheep meat and 21.94 kilogram of CO₂ equivalents per kilogram of product for beef – as sheep and cattle are ruminant livestock they have high emissions of methane, which are not taken into account in the data presented in this publication . Data retrieved from: <https://beeflambnz.com/knowledge-hub/PDF/factsheet-and-faqs-carbon-footprint-new-zealand-sheepmeat-and-beef.pdf>

Figure 9.1 - Total Energy Inputs Required to Produce One Tonne of Meat Products, 2004 (MJ_E, Oil Equivalents)

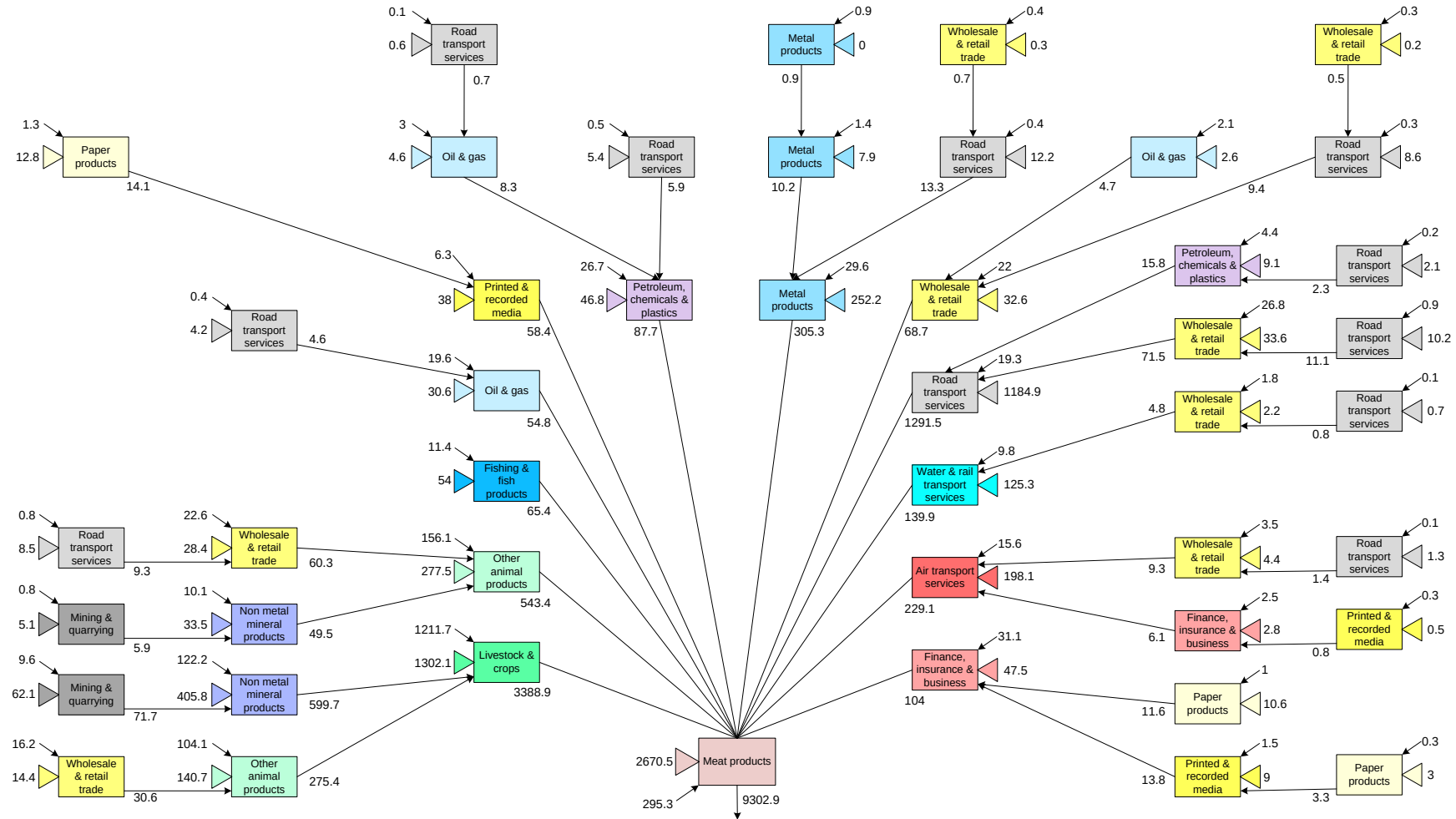


Figure 9.2 - Electricity Inputs Required to Produce One Tonne of Meat Products, 2004 (MJ, Heat Equivalents)

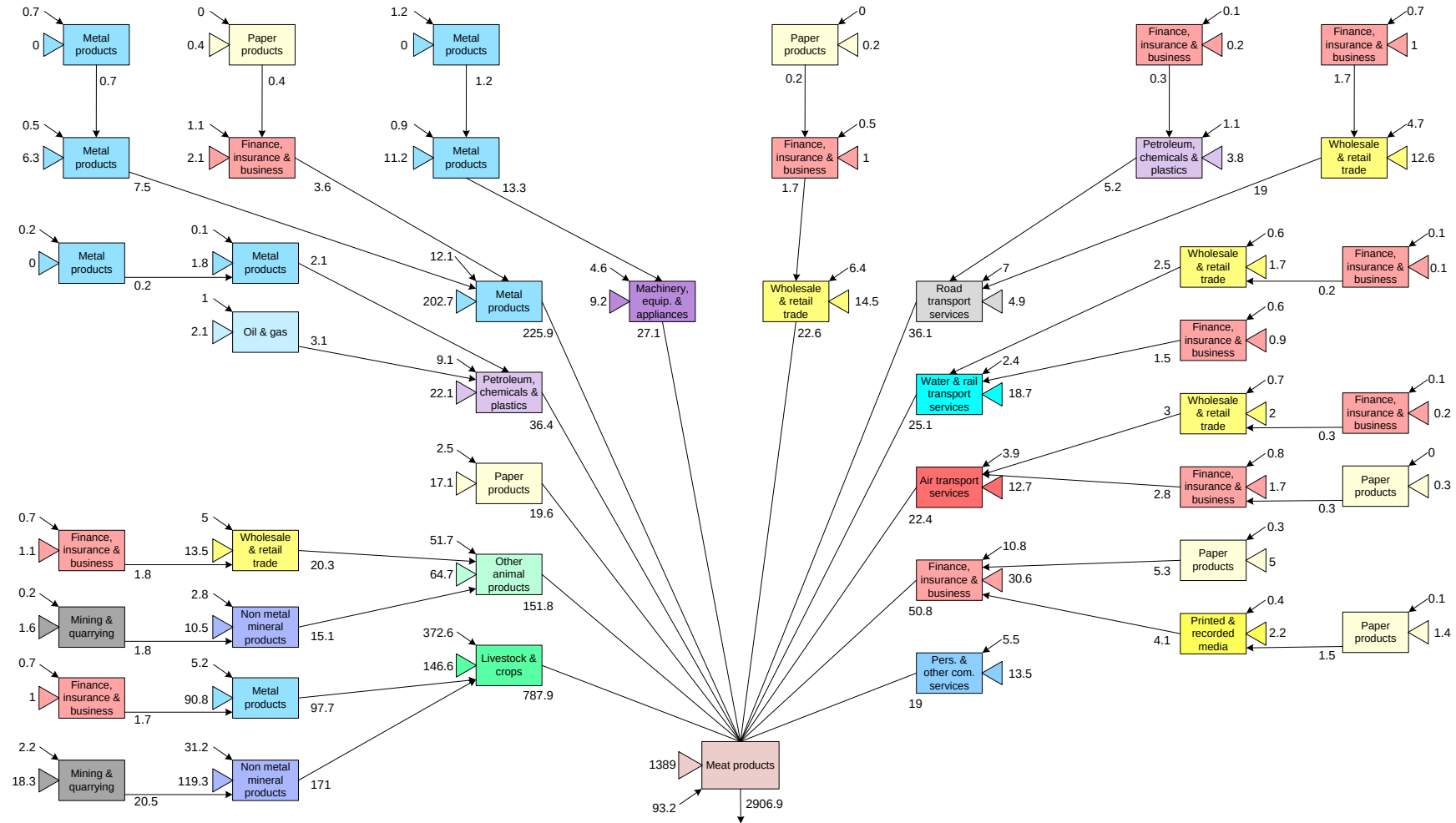


Figure 9.3 - Fossil Fuel Inputs Required to Produce One Tonne of Meat Products, 2004 (MJ, Heat Equivalents)

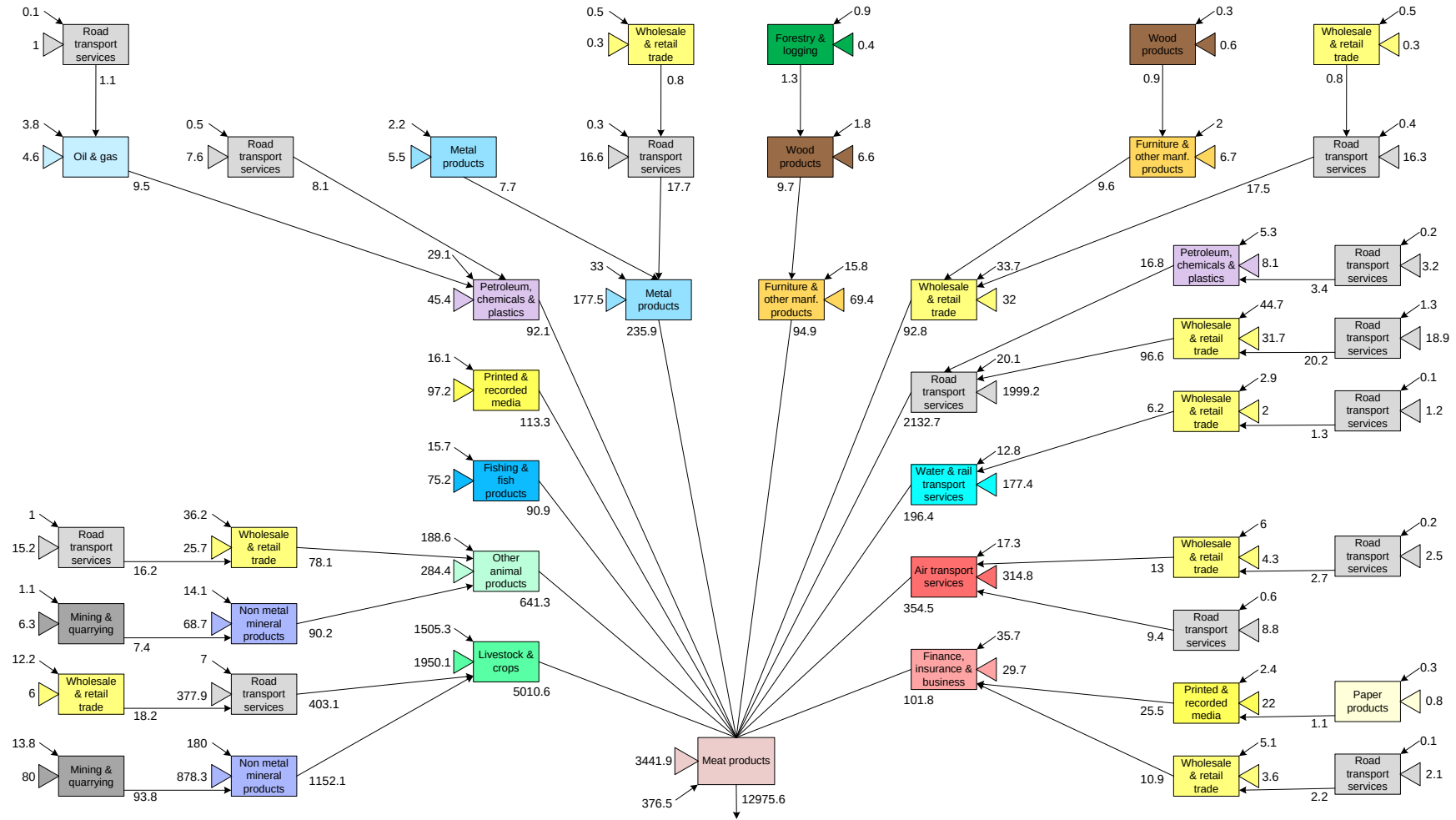


Figure 9.4 - Land (m²) Required to Produce One Tonne of Meat Products, 2003-04

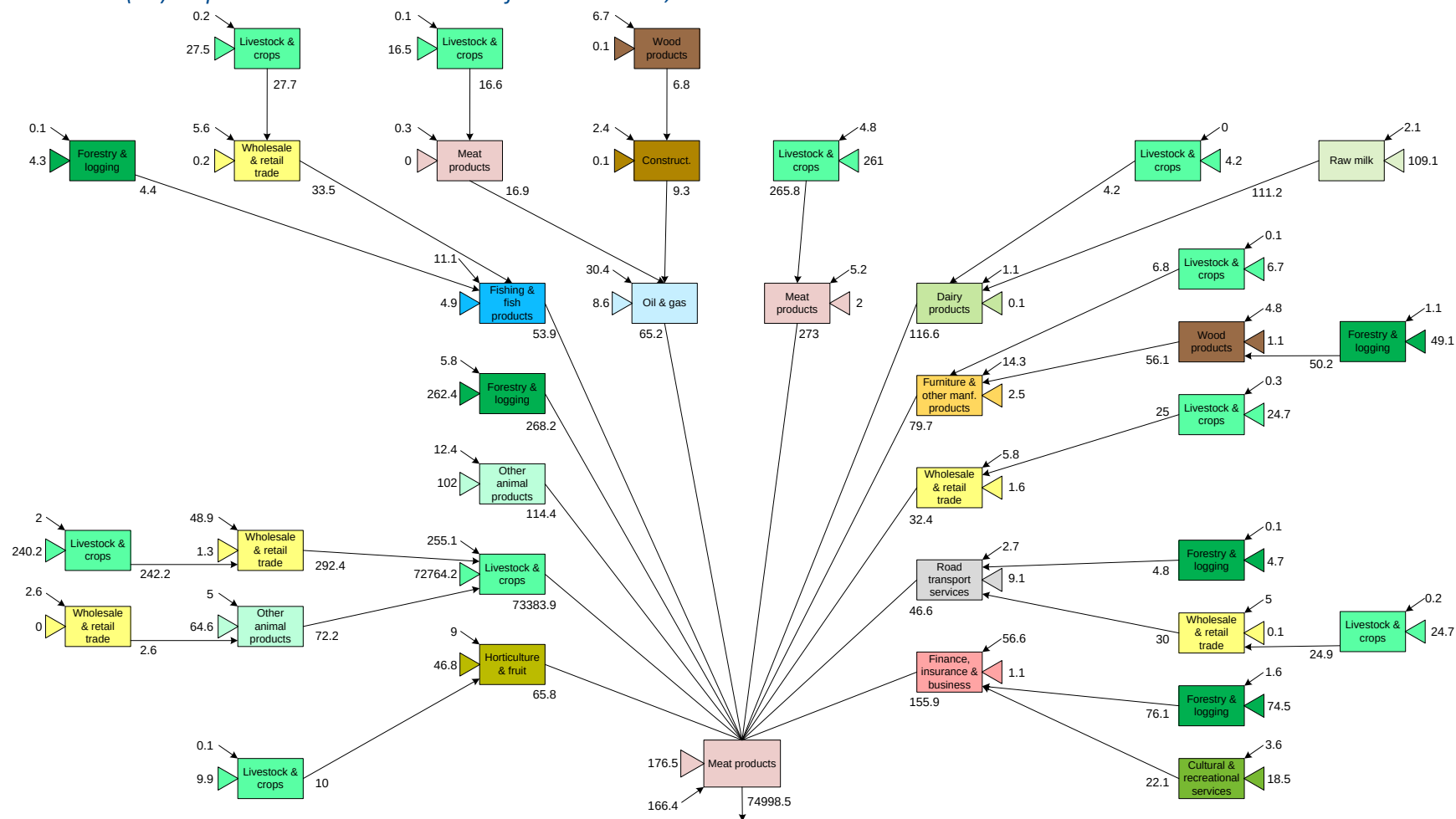


Figure 9.5 - Water Inputs Required to Produce One Tonne of Meat Products, 2004 (Litres)

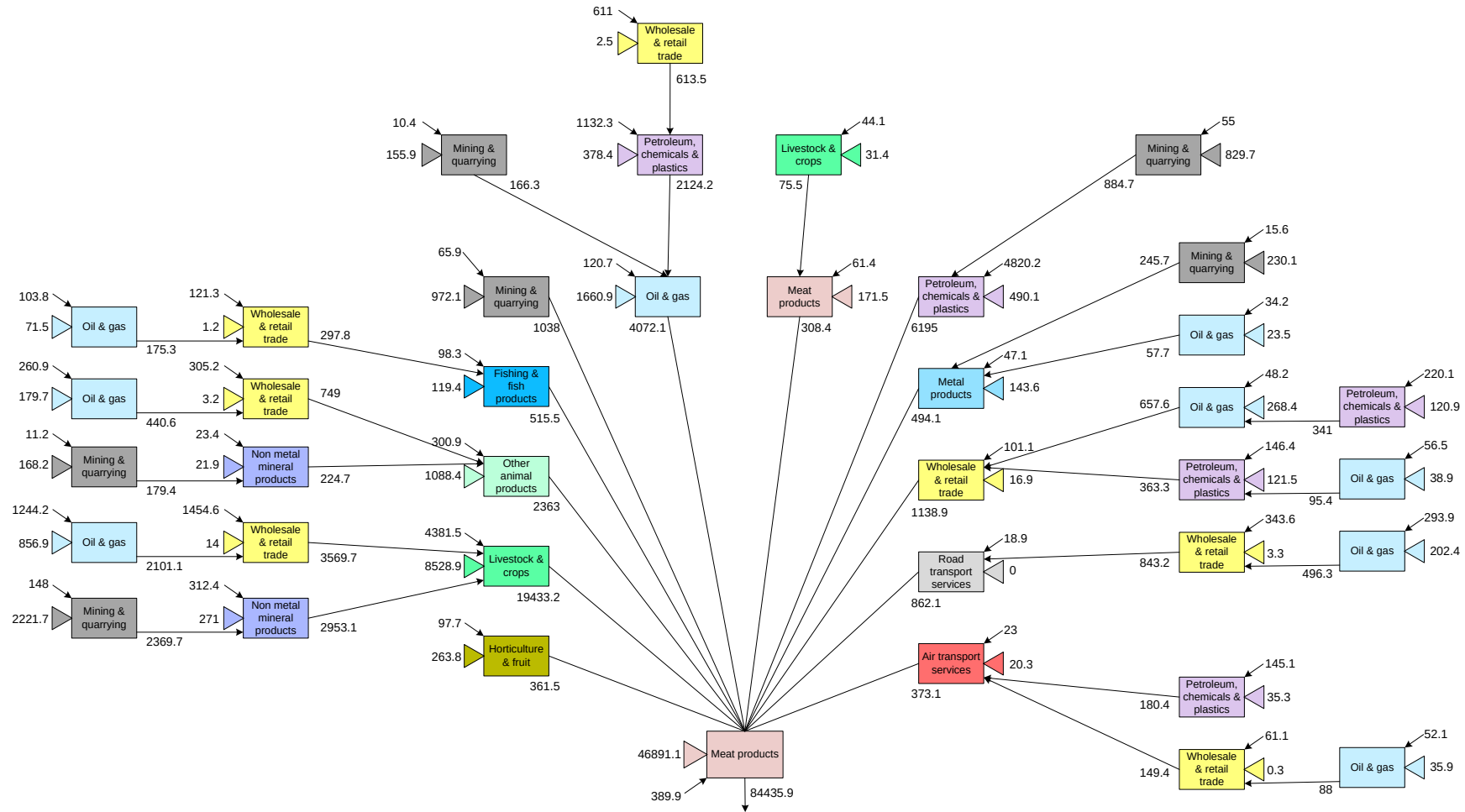


Figure 9.6 - Landfill Waste Generated in Producing One Tonne of Meat Products, 2004 (Grams)

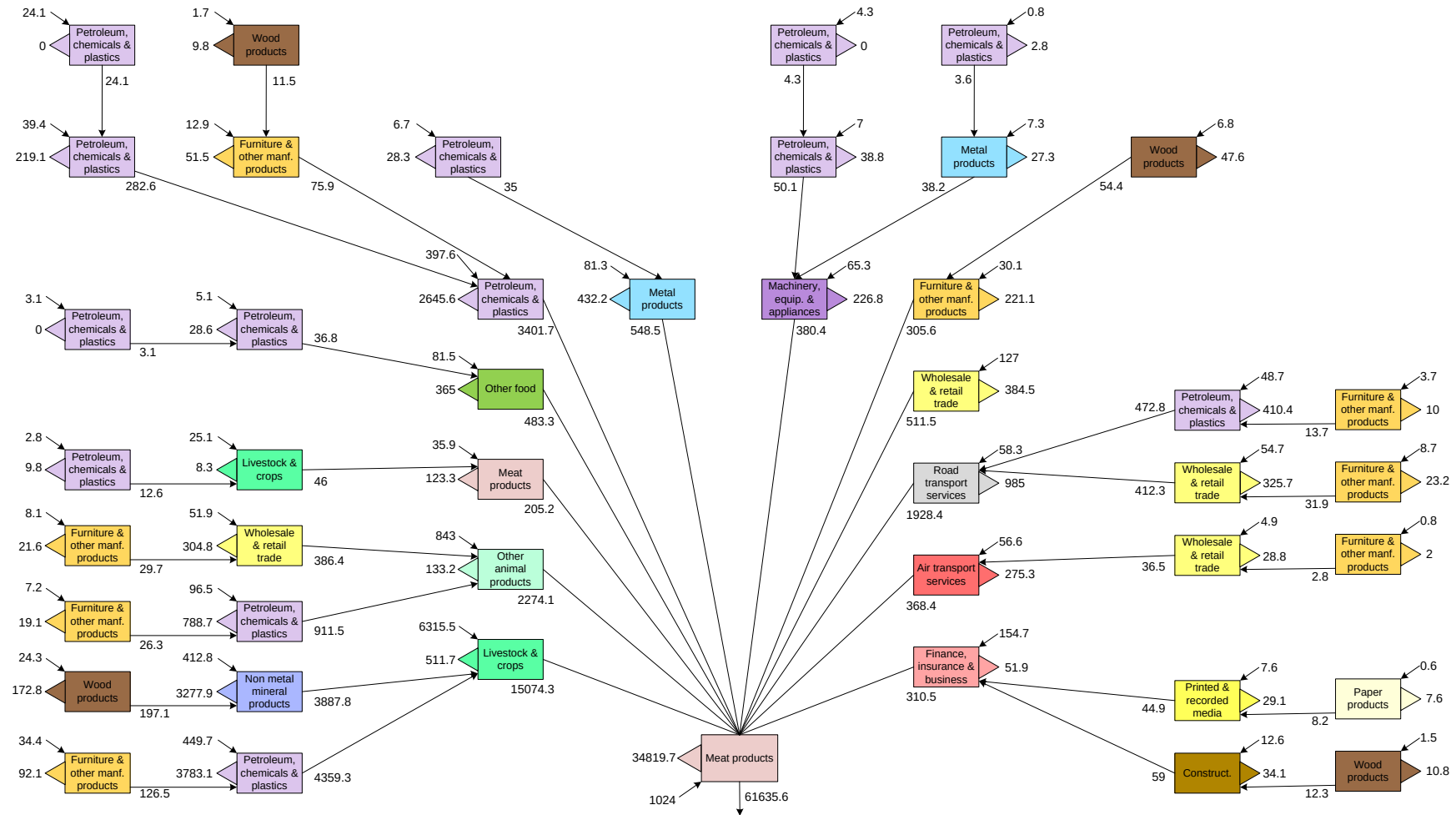


Figure 9.7 - Water Waste Generated in Producing One Tonne of Meat Products, 2004 (Litres)



Figure 9.8 - Phosphorus Waste Generated in Producing One Tonne of Meat Products, 2004 (Grams)

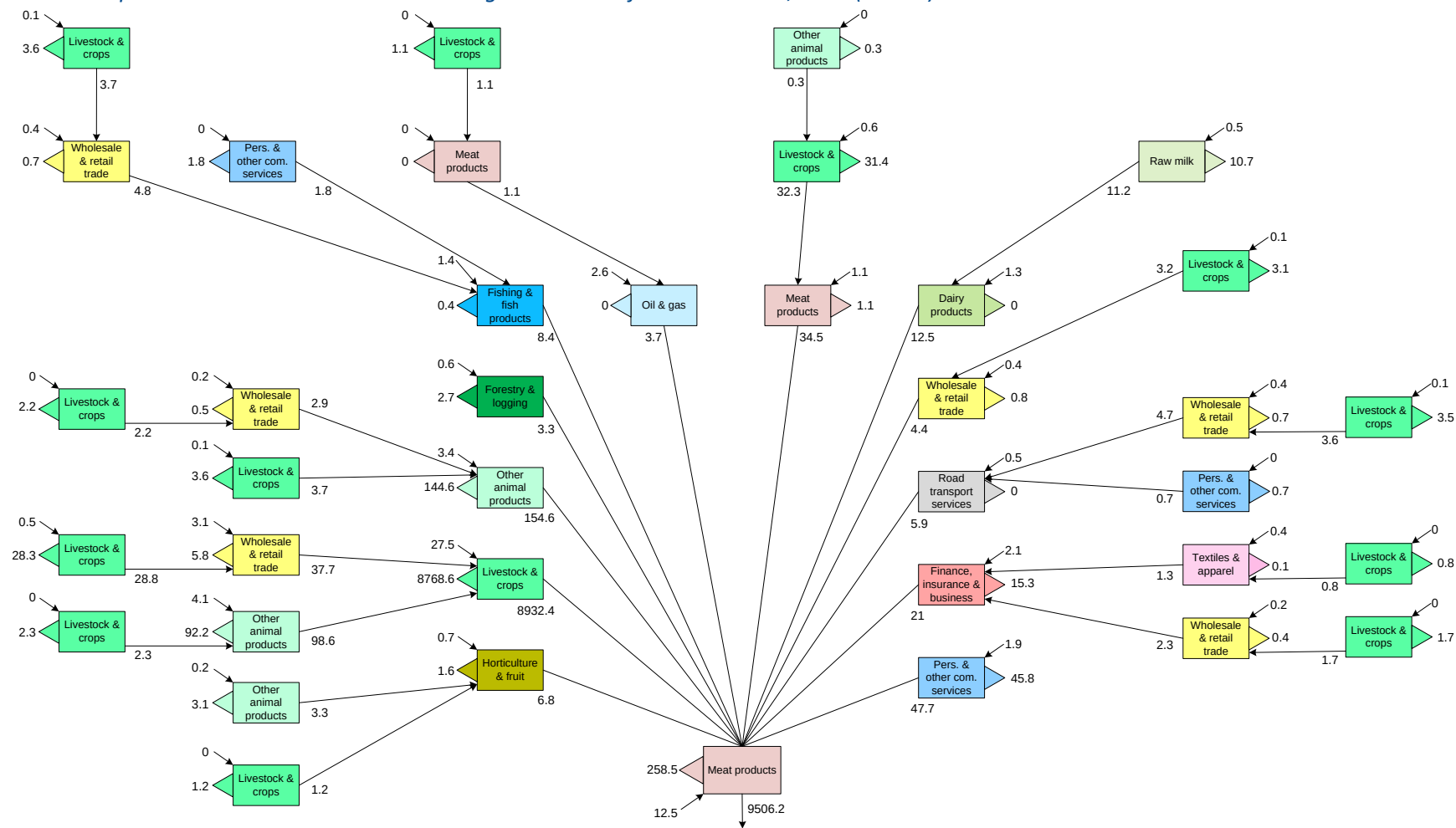
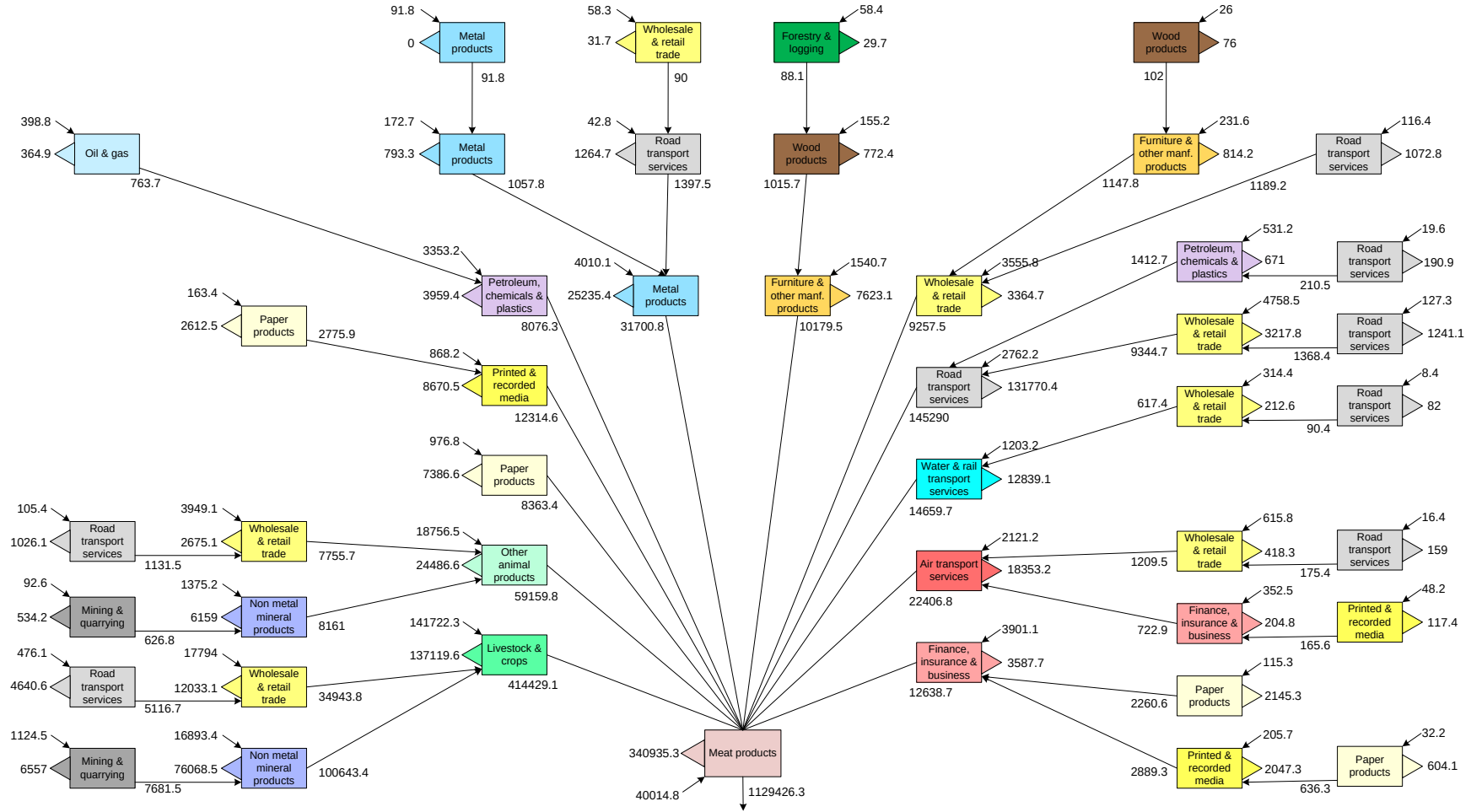


Figure 9.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Meat Products, 2004 (Grams)



10. Dairy Product Manufacturing

Description

ANZSIC Code covered:

- 1131 – Milk and Cream Processing
- 1132 – Ice Cream Manufacturing
- 1133 – Cheese and Other Dairy Product Manufacturing (butter, milk fat)

Main commodities supplied:

- Milk (21,217 million litres in 2018/19)¹³⁷
- Cheese (estimated 380,000 tonnes in 2018)¹³⁸
- Butter (estimated 530,000 tonnes in 2018)¹³⁹

GDP 2016 = \$4.162 billion

Rank = 13th

Average annual growth rate

2006 to 2016 = 39.31%

Rank = 1st

Employment 2016 = 12,820

Rank = 23rd

Economic Overview

Dairy products, at \$11.82 billion, made up 28.3% of the value of New Zealand's total merchandise exports in 2016. Except for milk and other dairy products used for local consumption, the dairy industry is primarily geared towards overseas markets. The three leading cooperative dairy companies Fonterra, Westland Milk, and Tatua helped process nearly 21 billion litres of milk containing nearly 2 million tonnes of milk solids over the 2017/2018 season.¹⁴⁰ More than 90% of this production is exported, and the balance is consumed by the domestic market.¹⁴¹ The major dairy exporters are the EU, New Zealand, Australia and, to a lesser degree, the US and Canada. NZ is the 8th largest milk producer internationally and this milk is manufactured into more than 1,000 ingredient products, including milk and whey proteins, milk powders, cream products, cheese and cheese ingredients and organics for the international food industry.¹⁴²

New Zealand controls around 25% of total world dairy export market¹⁴³ and is a leading producer of bulk commodities like casein and milk powders, contributing about 30.8% and 23.5% of world trade respectively in 2015. New Zealand is the largest butter exporter outside

¹³⁷ LIC. (2019). *2018-2019 New Zealand Dairy Statistics*. Retrieved February 10, 2020, from Dairy Statistics: <https://www.lic.co.nz/about/dairy-statistics/>

¹³⁸ USDA Foreign Agricultural Service. (2018). *New Zealand Annual Dairy and Milk Supply Report 2018*. USDA Foreign Agricultural Service. Retrieved February 10, 2020, from https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Dairy%20and%20Products%20Annual_Wellington_New%20Zealand_10-16-2018.pdf

¹³⁹ Ibid.

¹⁴⁰ Dairy NZ. (2019). *QuickStats about dairying*. Retrieved from <https://www.dairynz.co.nz/media/5791052/quickstats-about-dairying-new-zealand-2019.pdf>

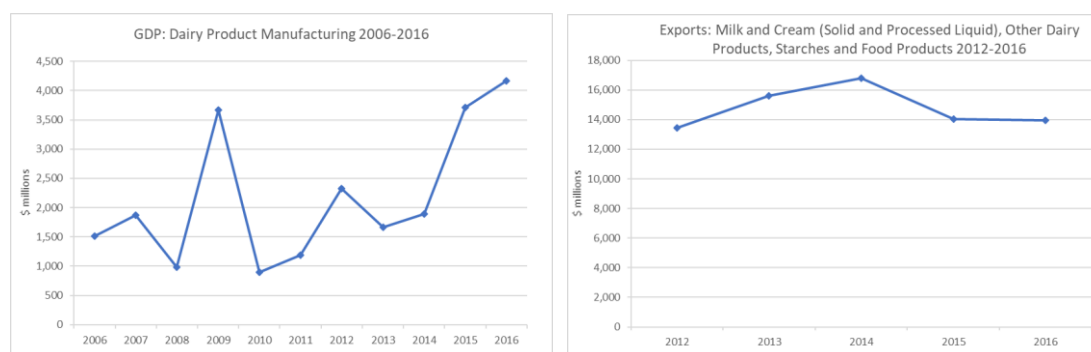
¹⁴¹ Dairy Companies Association of New Zealand. (n.d.). *About the NZ Dairy Industry*. Retrieved from <https://www.dcanz.com/about-the-nz-dairy-industry/>

¹⁴² Ibid.

¹⁴³ Food and Agriculture Organization of the United Nations. (2019). *Dairy Market Review*. Rome. Retrieved from <http://www.fao.org/3/ca3879en/ca3879en.pdf>

of Europe,¹⁴⁴ accounting for about 24.4% of all traded butter.¹⁴⁵ The export market is diversified with exports going to 141 countries, the major markets being China, Australia, the United States, the United Arab Emirates, and Japan.¹⁴⁶ The international market for dairy products is characterised by its small size relative to total world milk production, with less than 10% of production entering international trade, meaning the market is especially vulnerable to shifts in climatic, commercial and political forces. Marginal production changes by major producers can trigger major shifts in supplies of, thus prices for, dairy products on the international market.¹⁴⁷

Sector Trends



Production

Similar to the dairy cattle farming sector, growth in production of the dairy product manufacturing sector was highly volatile between 2006 and 2016. Overall, production has been on a generally upward trajectory and is, on average, the fastest growing sector at 39.3%. However, this is primarily due to the highly variable growth observed over the 10-year period. That is, between 2006 and 2013, there was no period of continued growth or continued decline in production. Rather, production either rose or fell relative to the previous year. In 2008, production fell 47.2% to \$987 million, then steeply rose by 271.2% to \$3.66 billion in 2009, then fell once again by 75.4% to \$900 million in 2010. Such volatility can be attributed to the volatility in commodity prices and exchange rates. However, following another peak-trough episode between 2011 and 2013, as a direct result of the 2012-2013 drought throughout New Zealand, production continued to rise, reaching its highest peak at \$4.16 billion in 2016.

Exports

There was strong growth in the dairy product sector between 2012 and 2014, with the value of exports peaking at \$16.78 billion in 2014, this was likely driven by foreign demand, particularly from China, resulting in high commodity prices. In the following year, the export value dropped to \$14.05 billion around about the level it continued to remain at. The decline seen in the value of exports for the dairy product sector reflects the decrease in dairy prices,

¹⁴⁴ Coriolis. (2017). *The Investor's Guide to the New Zealand Dairy Industry 2017*. Auckland: Ministry of Business, Innovation and Employment. Retrieved from <https://www.mbie.govt.nz/assets/ebd383c353/investors-guide-to-the-new-zealand-dairy-industry-2017.pdf>

¹⁴⁵ New Zealand Dairy Statistics. (2010). *IDF World Dairy Summit*. Retrieved from <http://wds2010.com/dairystats.html>

¹⁴⁶ Dairy Companies Association of New Zealand. (n.d.). *About the NZ Dairy Industry*. Retrieved from <https://www.dcanz.com/about-the-nz-dairy-industry/>

¹⁴⁷ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 368-9).

which declined 50% following their peak in 2014. The performance of the dairy cattle farming sector is highly important to the profitability of the dairy product manufacturing sector as a whole, as domestic demand accounts for only a small proportion of total production, thus it is largely export-oriented. Additionally, this makes both sectors highly volatile, as the New Zealand dairy sector as a whole, is a price taker and are highly reliant on the world price and foreign demand.

Despite a slowdown in China's growth rate, the country's switch to industrialisation and urbanisation, matched with rapidly growing incomes and increased dependence on consumption will mean foreign demand for agricultural commodities that New Zealand produces is likely to grow.¹⁴⁸

Life Cycle Assessment Diagrams

Energy (Figure 10.1, Figure 10.2, Figure 10.3)

Dairy products were found to have a total energy intensity of 6,259.2 MJ_{OE} per tonne of product (6.2 MJ_{OE}/kg) or 11,908 MJ_H per tonne of product (11.908 MJ_H/kg). The dairy products sector ranks 10th highest for total energy intensity out of the 20 product producing sectors covered in this publication. This is in a similar order of magnitude to reported energy intensities for dairy products such as New Zealand Dairy Products at 22,912 MJ_H per tonne of product,¹⁴⁹ Swedish milk (1.5% fat) at 5,000 MJ_H per tonne of product, Swedish yoghurt at 11,000 MJ_H per tonne of product, Southern European cheese at 65,000 MJ_H per tonne of product, Swedish milk powder at 58,000 MJ_H per tonne of product.¹⁵⁰ Similar direct energy intensities were recorded for dairy manufacturing products in New Zealand for the year 1979/1980, although it needs to be borne in mind that in most cases these direct energy intensities would need to be approximated doubled to take account of the indirect energy inputs outlined by Figure 11.1: Pasteurised Milk (1.22 MJ_H/kg) Cheese (5.24 MJ_H/kg), Butter (4.72 MJ_H/kg), Caesin (27.21 MJ_H/kg), and Spray Dried Milk (119.49 MJ_H/kg).¹⁵¹

Direct energy use was 49% of the total energy intensity, measuring 3,072.6 MJ_E per tonne of dairy product. Direct energy uses would include electricity to operate machinery such as dairy processing equipment, lighting, and refrigeration, and fossil fuels for transportation – the EECA in use database reports that a total of 11,346.886 TJ of energy was used in the dairy products sector in 2006/07. *Indirect energy* use made up 51% of the total energy intensity, measuring 3,186.6 MJ_E per tonne of dairy product.

The main indirect energy uses for dairy products were from; (i) energy embodied in raw milk at 2,293.5 MJ_{OE}/tonne of product produced; (ii) energy embodied metal products at 228.7 MJ_{OE}/tonne of product produced; (iii) energy embodied in road transport services at 206.8 MJ_{OE}/tonne of product produced; (iv) energy embodied in finance, business and insurance at 80.1 MJ_{OE}/tonne of product produced.

¹⁴⁸ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

¹⁴⁹ Saunders, C., Barber, A., Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry (Research Report No.285)*. Christchurch, New Zealand: Lincoln University.

¹⁵⁰ Carlsson-Kanyama, A., Ekstrom, M.P., Shanahan, H. (2002). Food and Lifecycle Energy Inputs: Consequences of diet and ways to increase efficiency. *Ecological Economics*, 44(203), 293-307.

¹⁵¹ Miller, E. J. 1984. Energy Use in the Dairy Processing Industry. *Energy in Agriculture* 307-312 3:

Land (Figure 10.4)

Dairy products have a total land intensity of 6,894.6 m² per tonne of product produced. Dairy products have the 4th largest land intensity out of the 20 product producing sectors covered by this publication. *Direct land use* for the production of dairy products was minuscule at only 0.8% of the total land intensity, measuring 5.4 m² per tonne of product produced. *Indirect land use* makes up the majority of total land use at 99.92% measuring 6,889.2 m² per tonne of product. The major indirect land uses came from; (i) land embodied in raw milk at 6,519.4 m² per tonne of product produced; (ii) land embodied in livestock and crops at 298.9 m² per tonne of product produced; (iii) land embodied in wholesale and retail trade at 26.6 m² per tonne of product produced; (iv) land embodied in finance, insurance & business at 16 m² per tonne of product produced.

Water Inputs (Figure 10.5)

Dairy products use 6,259.2 litres of water inputs per tonne of product produced, ranking the sector the 17th highest consumer of water out of the 20 product producing sectors covered in this publication. A study by Ledgard and Zonderland-Thomassen (2012),¹⁵² found that the total blue water footprint for rain-fed Waikato Dairy farm was only 0.1% of the total footprint, resulting in 945 litres per tonne of fat-and protein corrected milk (FPCM). Whereas the blue-water footprint of an irrigated Canterbury dairy farm was 23% of the total water footprint resulting in 249,320 litres per tonne of FPCM.

Direct water inputs make up 49.1%, using 3,072.6 litres per tonne of dairy product produced. While *indirect water inputs* make up 50.9%, using 3,186.6 litres per tonne of dairy product produced.

Indirect water inputs into dairy products came mainly from; (i) water inputs embodied in raw milk at 2,293.5 litres per tonne of product produced; (ii) water inputs embodied in metal products at 228.7 litres per tonne of product produced; (iii) water inputs embodied in road transport services at 206.8 litres per tonne of product produced (iv) water inputs embodied in finance, insurance and business at 80.1 litres per tonne of product produced.

Landfill Wastes (Figure 10.6)

Dairy products were found to generate 49,302.9 grams (49 kg) of landfill waste per tonne of product produced. The landfill waste generated by the dairy product sector is ranked 10th out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by dairy products made up the majority at 72% of total waste produced or 35,290 grams per tonne of product. While landfill waste *indirectly generated* by dairy products was 28% or 14,012.9 grams per tonne of product produced.

The main sources of indirect landfill waste generated in the production of dairy products came from; (i) landfill wastes embodied in raw milk at 8,930.4 grams per tonne of product; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 2,288.5 grams per tonne of product;

¹⁵² Ledgard, S. F., Zonderland-Thomassen, M., Liewfering, M., McLaren, S. (). Role of Life Cycle Assessment in Agriculture for Realising Market Opportunities and Enhancing on-farm Efficiency. In: *Advanced nutrient management: Gains from the past – goals for the future*. (Eds. Currie L D, Christensen C L). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 25, Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 11p.

(iii) landfill wastes embodied in wholesale and retail trade at 576.2 grams per tonne of product; (iv) landfill wastes embodied in metal products at 449.2 grams per tonne of product.

Water Wastes (Figure 10.7)

Dairy products were found to produce 75,336.8 litres of wastewater per tonne of product produced. The dairy products sector is the 8th highest producer of water wastes when compared to other 20 product producing sectors covered by this publication.

Wastewater directly generated by dairy products was 39% of total water waste produced at 29,450.9 litres per tonne of product produced. Wastewater indirectly generated from the production of dairy products made up 61% of total water wastes or 29,450.9 litres per tonne of product produced.

The indirect wastewater from dairy product production is mostly made up of (i) wastewater embodied in raw milk at 27,694.9 litres per tonne of product produced; (ii) wastewater embodied in personal and other community services at 10,179.5 litres per tonne of product produced; (iii) wastewater embodied in mining and quarrying at 4,033.5 litres per tonne of product produced; (iv) wastewater embodied in petroleum, chemicals and plastics at 890.9 litres per tonne of product produced.

Phosphorus Wastes (Figure 10.8)

Dairy products were found to produce 774.8 grams (0.77 kg) of phosphorus waste per tonne of product produced. Total phosphorus waste was made up entirely of indirect sources, as no phosphorous wastes were produced from the production of dairy products directly.

Indirect sources of phosphorus waste from the production of dairy products were mostly made up of (i) phosphorus waste embodied in raw milk at 687.1 grams per tonne of product produced; (ii) phosphorus waste embodied in personal and community services at 43.3 grams per tonne of product produced; (iii) phosphorus waste embodied in livestock and crops at 36.4 grams per tonne of product produced.

Energy Greenhouse Gases (Figure 10.9)

In terms of CO₂ greenhouse gas emissions, dairy products emitted 848,350.9 grams (848 kg) of energy-related CO₂ per tonne of product produced. This sector is the 10th highest emitter of energy-related CO₂ per tonne among the 20 product producing sectors covered in this publication. This amount is similar Saunders et al.'s (2005) value for New Zealand dairy products at 1,297.6 kg of energy-related CO₂ per tonne of product produced.¹⁵³

Energy-related CO₂ directly generated dairy products was 59% of the total CO₂ emitted at 489,596.5 grams per tonne of product produced. Energy-related CO₂ indirectly generated by the production of meat products was 42% or 358,754.4 grams. The indirect energy-related CO₂ from the production of dairy products was mostly made up of (i) energy-related CO₂ embodied in raw milk at 255,023.9 grams per tonne of product produced; (ii) energy-related CO₂ embodied in metal products at 24,155.3 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services at 23,959.1 grams per tonne of

¹⁵³ Saunders, C., Barber, A., Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry (Research Report No.285)*. Christchurch, New Zealand: Lincoln University

product produced; (iv) energy-related CO₂ embodied in wholesale and retail trade at 10,661.5 grams per tonne of product produced.

Figure 10.3 - Fossil Fuel Inputs Required to Produce One Tonne of Dairy Products, 2004 (MJ, Heat Equivalents)

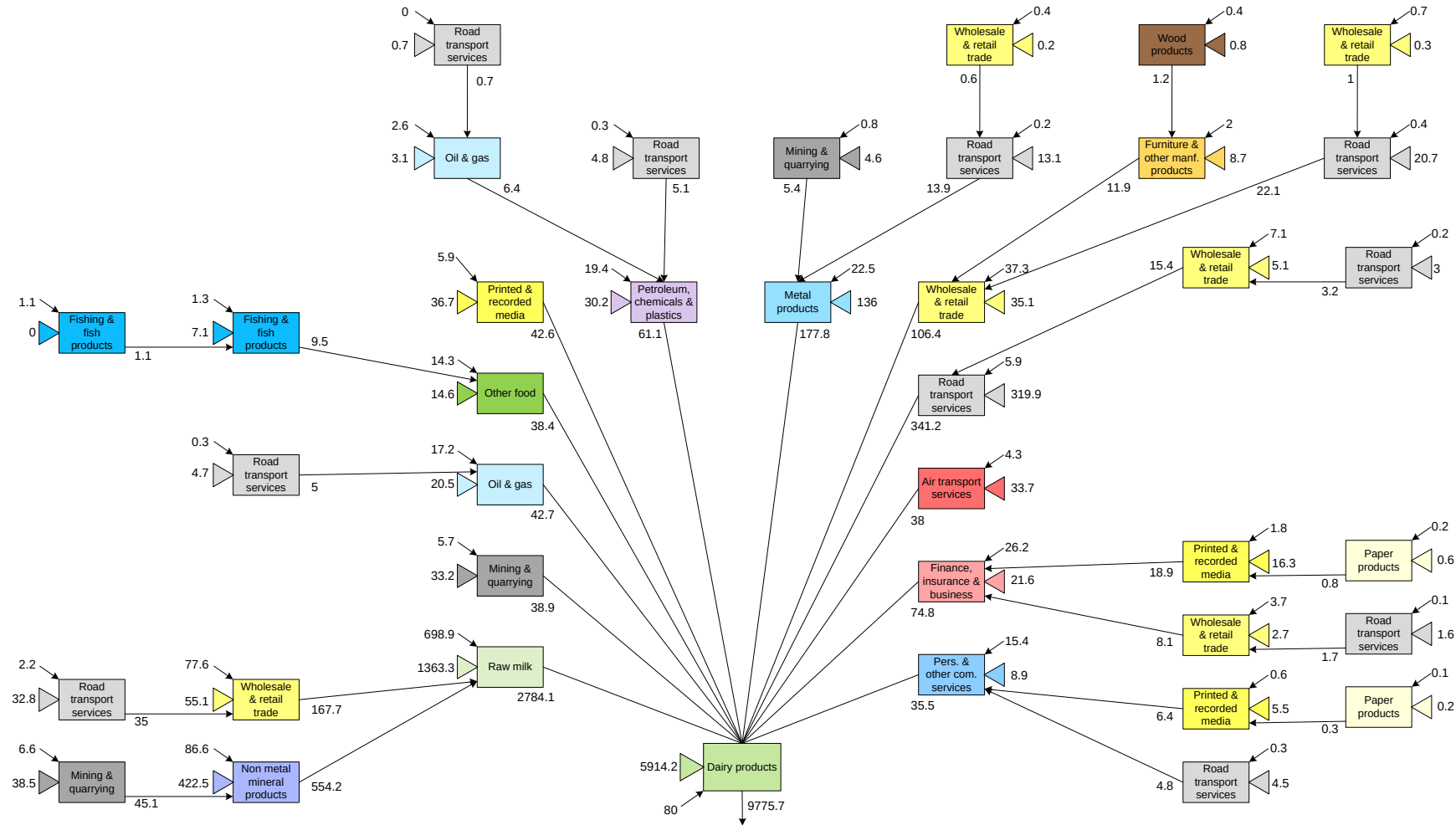


Figure 10.4 - Land Required to Produce One Tonne of Dairy Products, 2004(m²)

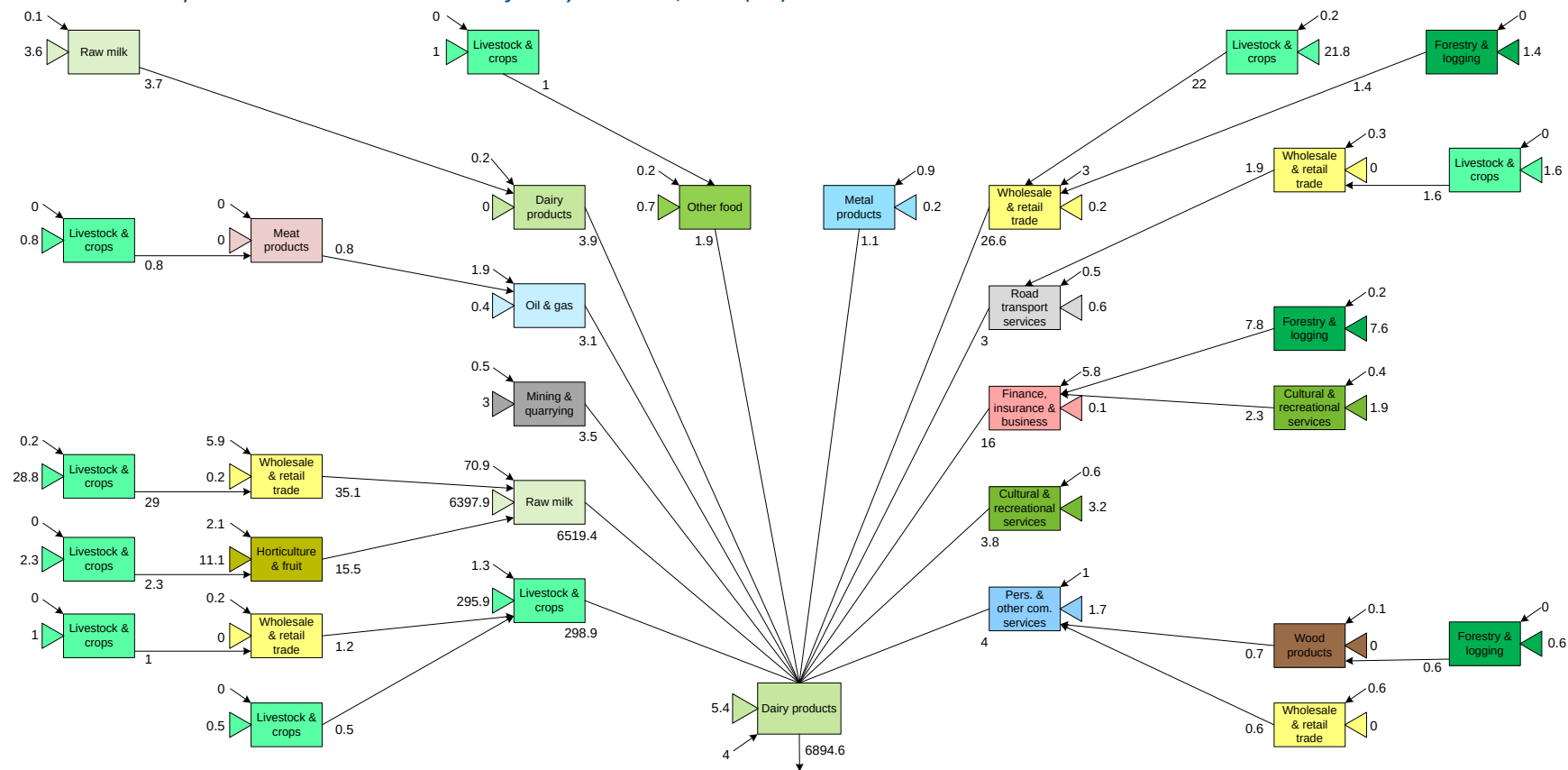


Figure 10.5 - Total Water Inputs Required to Produce One Tonne of Dairy Products, 2004 (Litres)

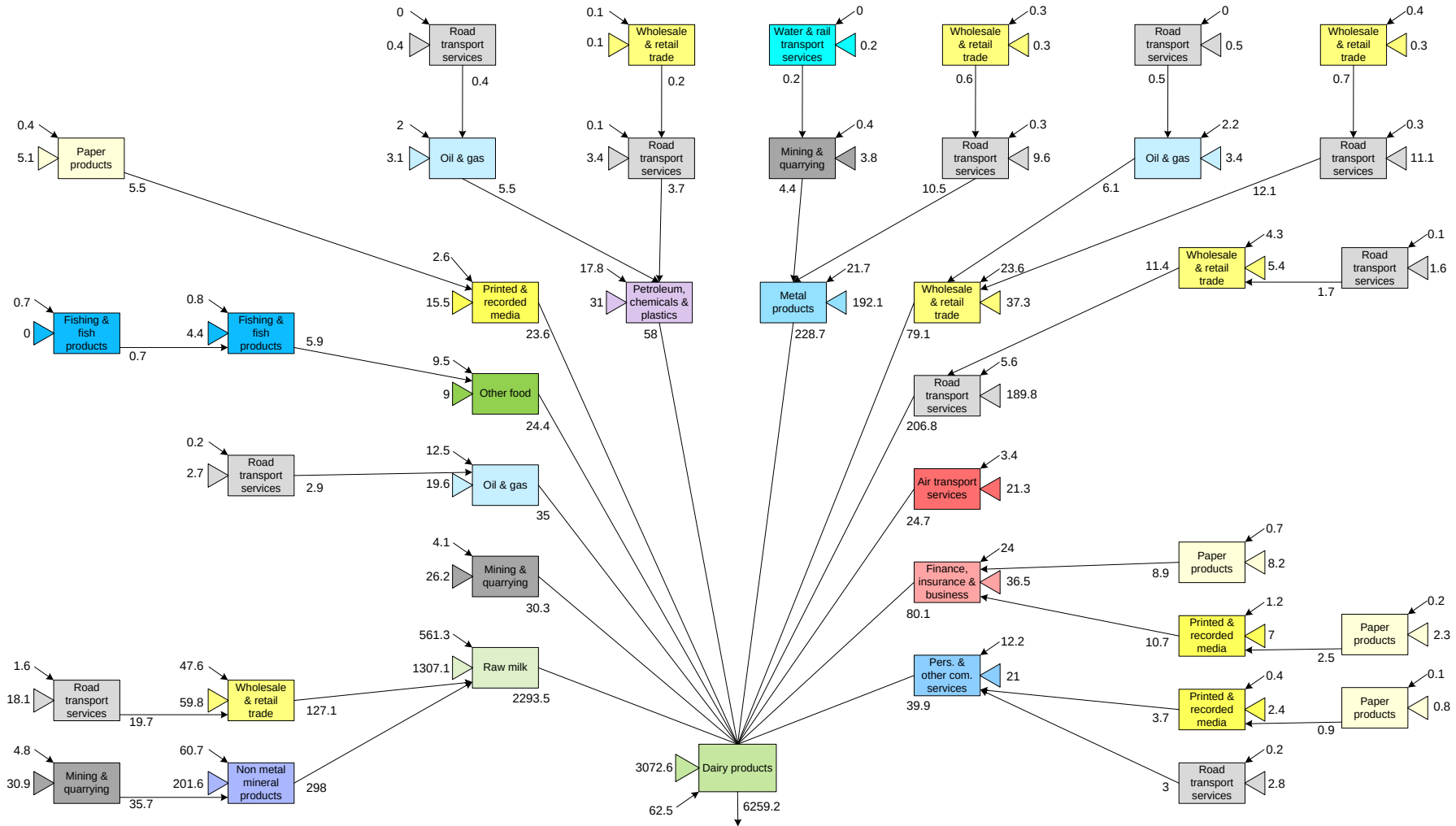


Figure 10.6 - Landfill Waste Generated in Producing One Tonne of Dairy Products, 2004 (Grams)

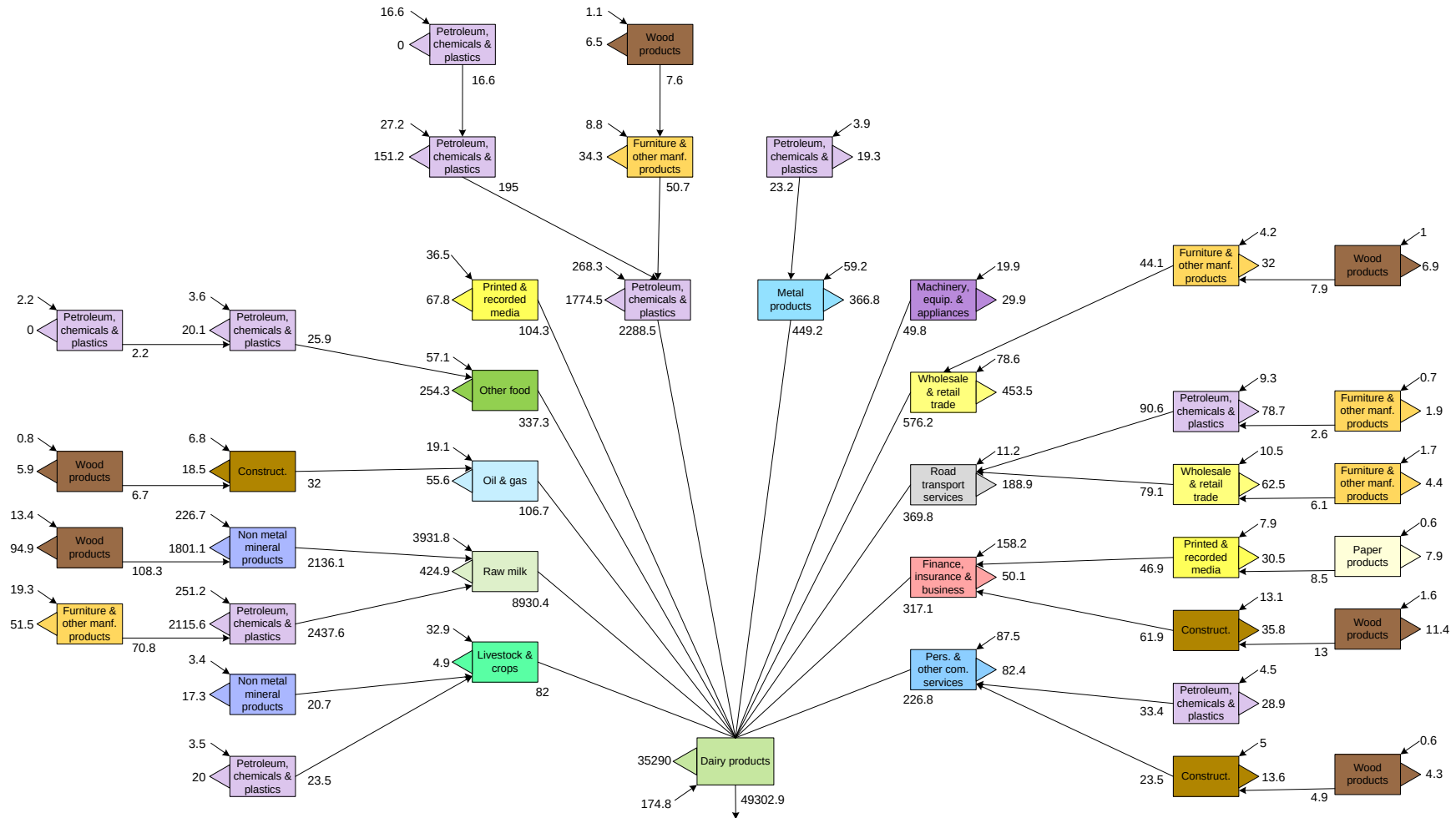


Figure 10.7 - Water Waste Generated in Producing One Tonne of Dairy Products, 2004 (Litres)

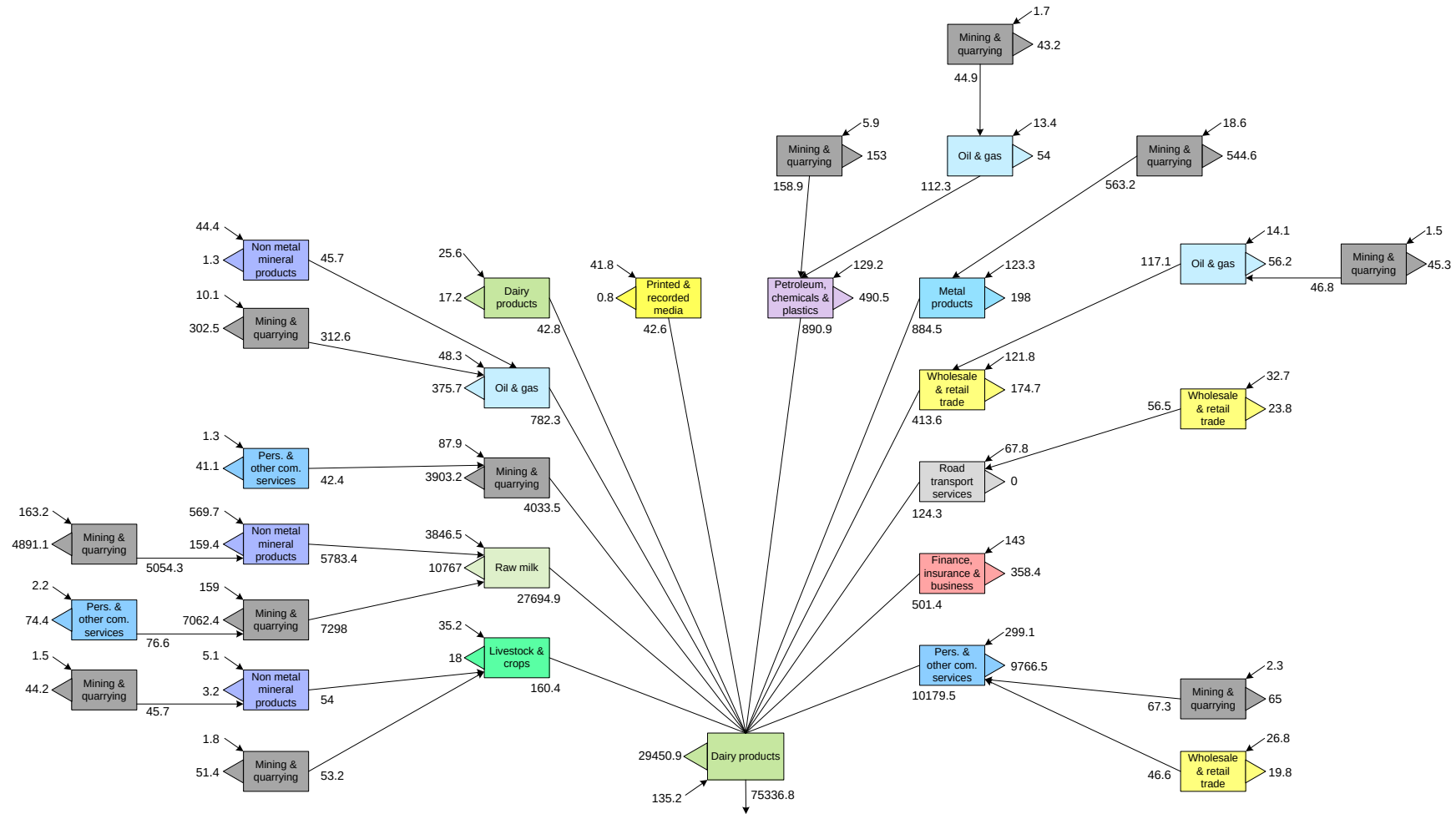


Figure 10.8 - Phosphorus Waste Generated in Producing One Tonne of Dairy Products, 2004 (Grams)

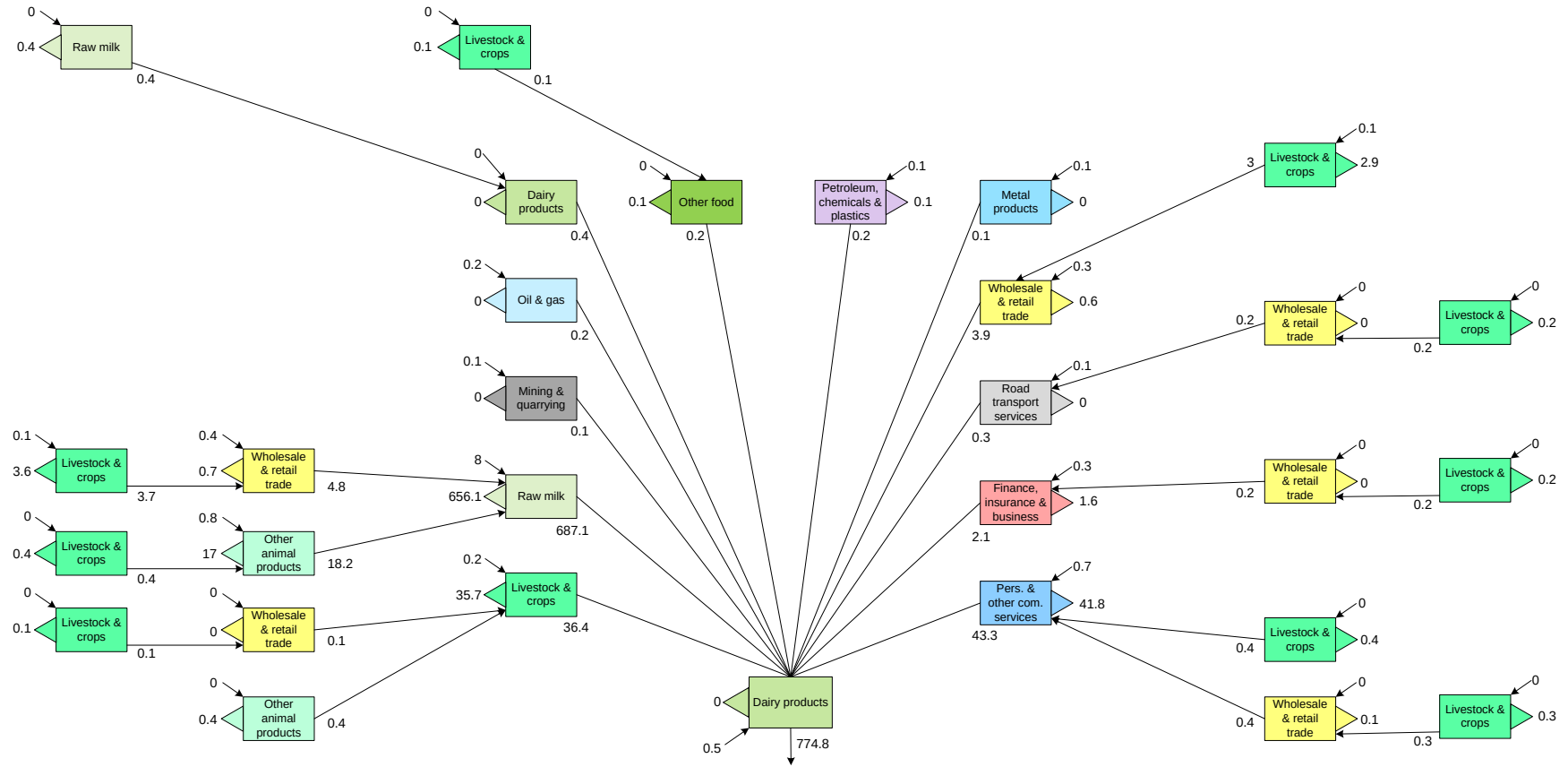
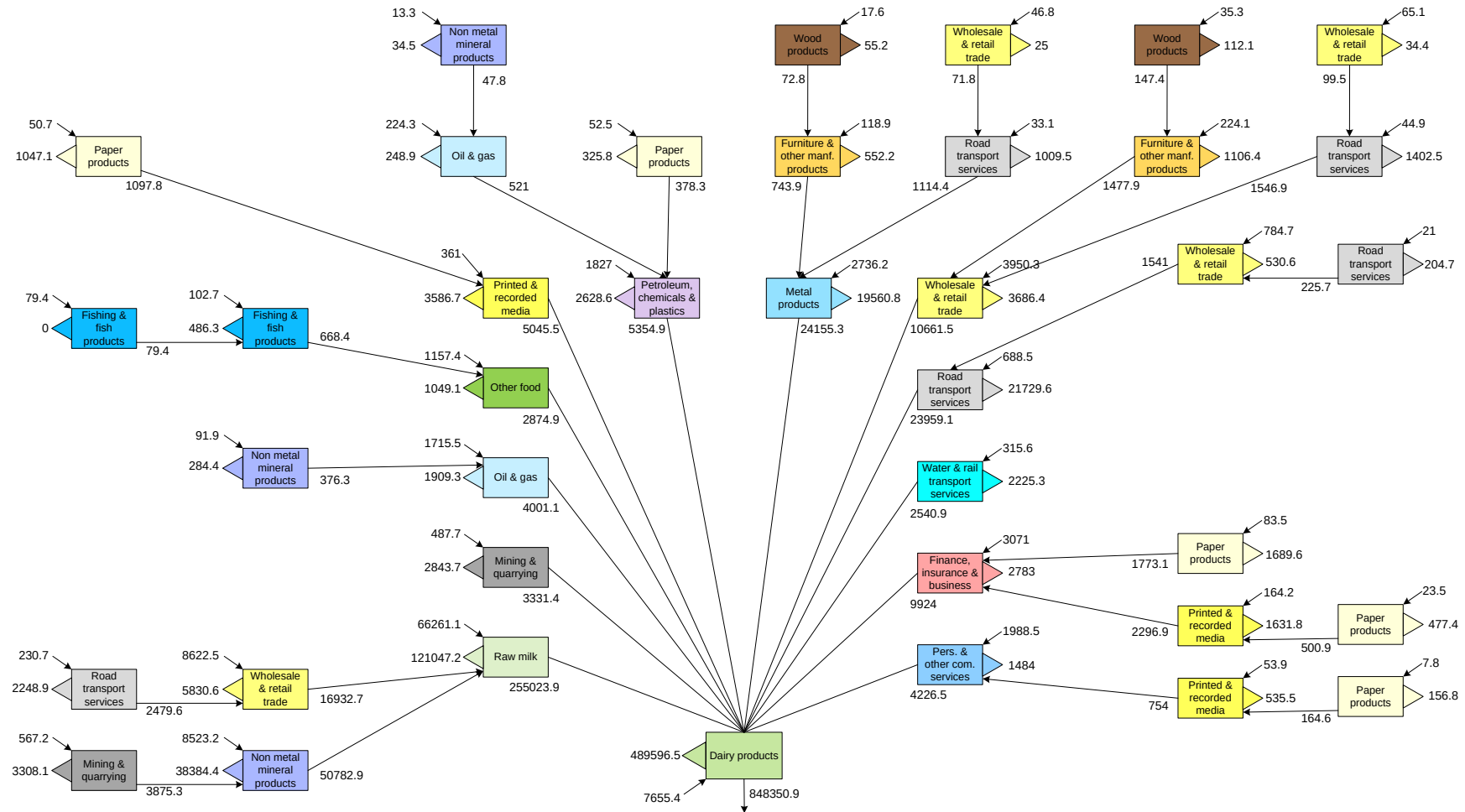


Figure 10.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Dairy Products, 20004 (Grams)



11. Beverage, Malt and Tobacco Manufacturing

Description

ANZSIC Codes covered:

- 1211 – Soft Drink, Cordial and Syrup Manufacturing
- 1212 – Beer Manufacturing
- 1213 – Spirit Manufacturing
- 1214 – Wine and Other Alcoholic Beverage Manufacturing
- 1220 – Cigarette and Tobacco Product Manufacturing

GDP 2016 = \$2.537 billion

Rank = 19th

Average annual growth rate

2006 to 2016 = -0.01%

Rank = 30th

Employment 2016 = 7,359

Rank = 29th

Main commodities supplied (2005):

- Wine (102 million litres),¹⁵⁴ beer (350 million litres), and spirits
- Non-alcoholic drinks including fruit juices, soft drinks, bottled water, teas, and energy drinks
- Tobacco

Economic Overview

New Zealand has an international reputation for quality wines, not to mention an ingrained pub-loving culture leading to a historically large domestic demand for beer. The wine industry is the fastest-growing market within this sector; in 1996, the wine industry was worth \$60.3 million per year in exports, however by 2018 exports had grown to reach \$1.7 billion, following 23 consecutive years of export growth. The United States, which imported 30.29% of NZ exports in 2018, is New Zealand's major export market with the other major importers being Australia, the United Kingdom, and Canada.¹⁵⁵ Environmental factors play a large part in the wine industry in New Zealand, with fertile soil and long sunshine hours in Marlborough, Hawkes Bay and Gisborne contributing to the country's success as a leading producer of white wine.

Brewing is part of a billion-dollar alcoholic beverages business in New Zealand, with breweries Lion Nathan Ltd and DB Group sharing 90% of the market. However, since 1980 there has been a downward trend in absolute and per capita consumption, mainly due to a change in tastes towards other beverages such as wine and spirits. Recently, while there has been a decline in the domestic consumption of lower-strength beer, the rise in popularity of craft beers in New Zealand has maintained the performance of this industry.¹⁵⁶ Beverages are 100% value-added export products; the beverage/tobacco industry adds 35% of all value-added in the food, beverage and tobacco manufacturing industry, partly reflecting the inclusion of indirect taxes that are collected at the time of production.¹⁵⁷ The quantity of tobacco exported from New Zealand is small and has been declining

¹⁵⁴ Statistics New Zealand. (2006). New Zealand Official Yearbook 2006. Auckland, New Zealand: David Bateman Ltd. (pp. 375).

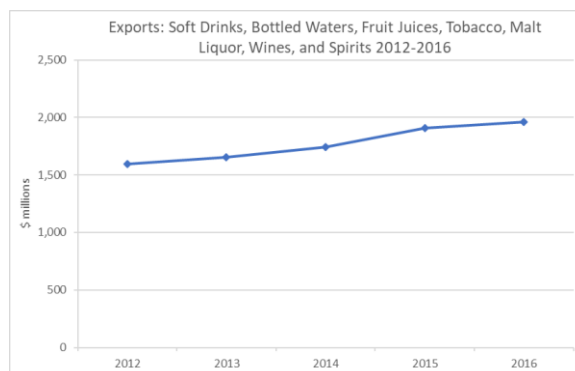
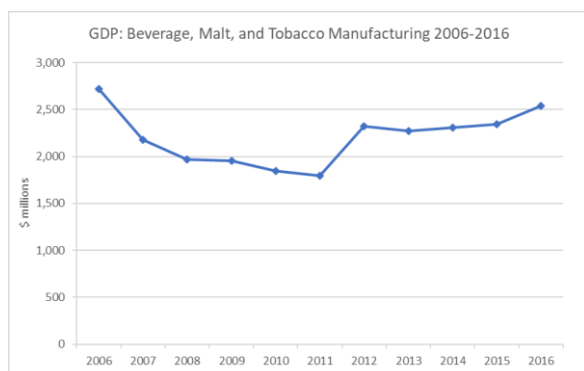
¹⁵⁵ New Zealand Wine. (2019). *Key Performance Indicators*. Retrieved from <https://www.nzwine.com/media/12236/nzwine-kpis-feb-2019.jpg>

¹⁵⁶ Statistics New Zealand. (2019, February 26). *More high-strength beer available in 2018*. Retrieved from <https://www.stats.govt.nz/news/more-high-strength-beer-available-in-2018>

¹⁵⁷ NZ Trade and Enterprise and Massey University. (2003). *The Level of Added-Value in New Zealand's Food and Beverage Exports*. Retrieved from <http://www.foodnavigator-asia.com/Markets/Value-added-food-and-beverage-exports-from-NZ-on-the-rise>

at a quite rapid pace over the last ten years. On the other hand, New Zealand's international reputation for pure 'glacier' water has led to an emerging bottled water industry that is expected to grow at a fast pace.^{158 159}

Sector Trends



Production

Growth in production in the beverage, malt, and tobacco manufacturing sector started strong in 2006 at \$2.72 billion. However, production followed a downward trend from the high experienced in 2006 through to 2011, where production reached a low of \$1.8 billion, some of this prolonged decline is likely explained by the GFC, as individuals switch away from consuming luxuries such as wine or spirits. A sudden increase in production is seen the following year, bouncing back up by 29.31%, to \$2.33 billion. Following this, the sector has experienced modest growth, reaching \$2.54 billion in 2016. Research and development in the sector has kept New Zealand competitive in the wine industry, with government-funded projects implemented to train workers and keep pace with technology. Automation of many of the jobs previously performed by workers, such as processing and packaging products, has led to a more efficient means of production. These productivity increases have been the driving force behind the steady growth illustrated in the graph. Continued government investment as part of the Ministry for Primary Industries; Primary Growth Partnership programmes,¹⁶⁰ is likely to continue enhancing productivity in the New Zealand beverage industry. As with many primary industries, environmental factors will have significant impacts on the production levels of this sector. Recently, red wine varieties have recorded significant production increases under good conditions, boding well for future production.¹⁶¹

Exports

Growth in the value of exports followed a steady upward trend in production in this sector, increasing 22.91% from \$1.6 billion in 2012 to \$1.96 billion in 2016. This sector's steady improvement in the value of their exports appears to be driven by increasing quantities of exported wines. Given New Zealand's reputation as a high-quality wine producer, foreign demand for New Zealand's wines, primarily in the

¹⁵⁸ Newhart, B. (2018, November 28). *Bottled water dominates 2018: Sparkling and value-added options surge*. Retrieved from Beveragedaily.com: <https://www.beveragedaily.com/Article/2018/11/28/Bottled-water-dominates-2018-sparkling-and-value-added-options-surge>

¹⁵⁹ NZ Beverage Council. (n.d.). *New Zealand's Bottled Water Industry*. Retrieved from <https://www.nzbeveragecouncil.org.nz/assets/PDFs/9ee61a0436/An-Overview-of-Water-Bottling-in-New-Zealand.pdf>

¹⁶⁰ Ministry for Primary Industries. (2019, December 23). *Current PGP Programmes*. Retrieved February 5, 2020, from <https://www.mpi.govt.nz/funding-and-programmes/sustainable-food-and-fibre-futures/primary-growth-partnership/current-gpg-programmes/>

¹⁶¹ New Zealand Winegrowers Inc. (2018). *Annual Report 2018*. Auckland: New Zealand Wine. Retrieved from <https://www.nzwine.com/media/9567/nzw-annual-report-2018.pdf>

United States, and the United Kingdom, continues to grow. The future outlook for this sector continues to look promising, with productive vineyard are expected to continue to grow, despite the Marlborough region nearing capacity.¹⁶² While 70% of the wine produced in NZ is exported, only 10% of beer in NZ is exported.¹⁶³ Most growth seen in this sector is therefore largely driven by wine exports.

Life Cycle Assessment Diagrams

Energy (Figure 11.1, Figure 11.2, Figure 11.3)

Beverage and tobacco products were found to have a total energy intensity of 3,446.6 MJ_{OE} per tonne of product (3.4 MJ_{OE}/kg). The beverage and tobacco products sector rank 12th highest for total energy intensity out of the 20 product producing sectors covered in this publication.

Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand “Beverage¹⁶⁴, Malt and Tobacco manufacturing” sector is 5,572 MJ_H/tonne. This is in a similar order of magnitude to reported energy intensities for other dairy products such as Swedish soft drinks at 5,900 MJ per tonne of product, Southern European wine at 12,000 MJ per tonne of product, central European bottled water at 2,000 per tonne of product, Swedish beer at 12,000 MJ per tonne of product.¹⁶⁵

Direct energy use was only 15% of the total energy intensity, measuring 518.5 MJ_{OE} per tonne of beverage and tobacco product. *Indirect energy use* made up the majority at 85% of the total energy intensity, measuring 2,928.1 MJ_{OE} per tonne of beverage and tobacco product. *The main indirect energy uses for beverage and tobacco products were from; (i) energy embodied in metal products at 1,223.3 MJ_{OE} per tonne of product produced; (ii) energy embodied in paper products at 271.2 MJ_{OE} per tonne of product produced; (iii) energy embodied in horticulture and fruit at 232.2 MJ_{OE} per tonne of product produced; (iv) energy embodied in road transport services 221.3 MJ_{OE} per tonne of product produced.*

Land (Figure 11.4)

Beverage and tobacco products have a total land intensity of 1,097.8 m² per tonne of product produced. Beverage and tobacco products have the 13th largest land intensity out of the 20 product producing sectors covered by this publication.

Direct land use for the production of beverage and tobacco products was minuscule at only 0.8% of the total land intensity, measuring 9.1 m² per tonne of product produced. *Indirect land use* makes up the majority of total land use at 99.92% measuring 1,088.7 m² per tonne of product produced. *The major indirect land uses came from; (i) land embodied in livestock and crops at 823.4 m² per tonne of product produced; (ii) land embodied in horticulture and fruit at 95.9 m² per tonne of product produced; (iii) land embodied in wholesale and retail trade at 34.4 m² per tonne of product produced; (iv) land embodied in textile and apparel at 26 m² per tonne of product produced.*

¹⁶² New Zealand Winegrowers Inc. (2019). *Annual Report 2019*. Auckland: New Zealand Wine. Retrieved from <https://www.nzwine.com/en/media/statistics/annual-report>

¹⁶³ Brewers Association of New Zealand. (2018). *2018 Brewing in New Zealand Report*.

¹⁶⁴ Almost all of the output from this sector is “beverages” rather than “malt” or “tobacco

¹⁶⁵ Carlsson-Kanyama, A., Ekstrom, M.P., Shanahan, H. (2002). Food and Lifecycle Energy Inputs: Consequences of diet and ways to increase efficiency. *Ecological Economics*, 44(203), 293-307.

Water Inputs (Figure 11.5)

Beverage and tobacco products use 12,026.7 litres of water inputs per tonne of product produced, ranking the sector the 13th highest consumer of water out of the 20 product producing sectors covered in this publication. Other reported amounts of water inputs for various reported beverage and tobacco products are much lower than the one found for New Zealand with the global average water footprint of Grape wines (sparkling) at 140,214 litres per tonne of product & Orange juice at 202,193 litres per tonne of product.¹⁶⁶ A possible reason for such a low figure found for water inputs in this sector is that the reported figures above are global averages, and suggest New Zealand beverage and tobacco products requires less blue water inputs due to geographical differences, relying more on green water inputs (rainwater) which are not taken into account in these figures.

Direct water inputs made up 24% of total water inputs, using 2,888 litres per tonne of beverage and tobacco product produced. While *indirect water inputs* made up 76% of total water inputs, using 9,138.7 litres per tonne of beverage and tobacco product produced. *Indirect water inputs into beverage and tobacco products came mainly from; (i) water inputs embodied in horticulture and fruit at 2,877 litres per tonne of product produced; (ii) water inputs embodied in metal products at 1,610.7 litres per tonne of product produced; (iii) water inputs embodied in wholesale and retail products at 1,605 litres per tonne of product produced (iv) water inputs embodied in non-metal mineral products at 1,030.5 litres per tonne of product produced.*

Landfill Wastes (Figure 11.6)

Beverage and tobacco products were found to generate 33,283.2 grams (33 kg) of landfill waste per tonne of product produced. The landfill waste generated by the beverage and tobacco product sector is ranked 13th out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by beverage and tobacco products was 58% of total waste produced or 19,293.9 grams per tonne of product produced. *Landfill waste indirectly generated* by beverage and tobacco products was 42% or 13,989.3 grams per tonne of product produced. *The main sources of indirect landfill waste for beverage and tobacco products came from; (i) landfill wastes embodied in other food products at 2,877.1 grams per tonne of product produced; (ii) landfill wastes embodied in metal products at 2,502.7 grams per tonne of product; (iii) landfill wastes embodied in petroleum, chemicals and plastics at 1,421.3 grams per tonne of product produced; (iv) landfill wastes embodied in non-metal mineral products at 1,395.4 grams per tonne of product.*

Water Wastes (Figure 11.7)

Beverage and tobacco products were found to produce 15,998.1 litres of water wastes per tonne of product produced. This makes the beverage and tobacco products sector is the 16th highest producer of water wastes out of the 20 product producing sectors covered by this publication.

Wastewater directly generated by beverage and tobacco products was only 3% of total water waste produced or 439.2 litres per tonne of product produced. *Wastewater indirectly generated* from the production of beverage and tobacco products made up resulting majority at 97% of total wastewater produced, or 15,558.9 litres per tonne of product produced. *The indirect wastewater from beverage and tobacco product production is mostly made up of (i) wastewater embodied metal products at 4,644.1 litres per tonne of product produced; (ii) wastewater embodied in non-metal mineral products at 3,313.8 litres per tonne of product produced; (iii) wastewater embodied in horticulture and fruit at*

¹⁶⁶ Mekonnen, M.M. and Hoekstra, A.Y. (2011). The green, blue and grey water footprint of crops and derived crop products, *Hydrology and Earth System Sciences*, 15(5): 1577-1600 McDonald.

1,479.5 litres per tonne of product produced; (iv) wastewater embodied in personal and other community service at 1,158.3 litres per tonne of product produced.

Phosphorus Wastes (Figure 11.8)

Beverage and tobacco products were found to produce 774.8 grams (0.77 kg) of phosphorus waste per tonne of product produced. Total phosphorus waste was made up mostly of indirect sources, with direct sources only making up 0.7% of total phosphorus waste, at 0.9 grams per tonne of beverage and tobacco products produced. The remaining 99.3% of phosphorous wastes or 133.5 grams per tonne of beverage and tobacco products produced *came from Indirect sources which were mostly made up of (i) phosphorus waste embodied in livestock and crops with 100.1 grams per tonne of product produced; (ii) phosphorus waste embodied in horticulture and fruit at 10 grams per tonne of product produced; (iii) phosphorus waste embodied in personal and other community services at 4.8 grams per tonne of product produced.*

Energy Greenhouse Gases (Figure 11.9)

In terms of CO₂ greenhouse gas emissions, beverage and tobacco products emitted 446,130.4 grams (446 kg) of energy-related CO₂ per tonne of product produced. This sector is the 12th highest emitter of energy-related CO₂ per tonne among the 20 product producing sectors covered in this publication.

Energy-related CO₂ directly generated beverage and tobacco products was 14% of the total CO₂ emitted at 61,227.7 grams per tonne of product produced. Energy-related CO₂ indirectly generated by the production of beverage and tobacco products was 86% or 384,902.7 grams. The indirect energy-related CO₂ from the production of beverage and tobacco products was mostly made up of; (i) energy embodied in metal products at 129,716.6 MJ_E per tonne of product produced; (ii) energy embodied in paper products at 54,265.1 MJ_E per tonne of product produced; (iii) energy embodied in horticulture and fruit at 31,419.7 MJ_E per tonne of product produced; (iv) energy embodied in non-metal mineral products at 31,396.4 MJ_E per tonne of product produced.

Integrate the economics and ecology integrating

Figure 11.1 - Total Energy Inputs Required to Produce One Tonne of Beverages and Tobacco Products, 2004 (MJ_E, Oil Equivalents)

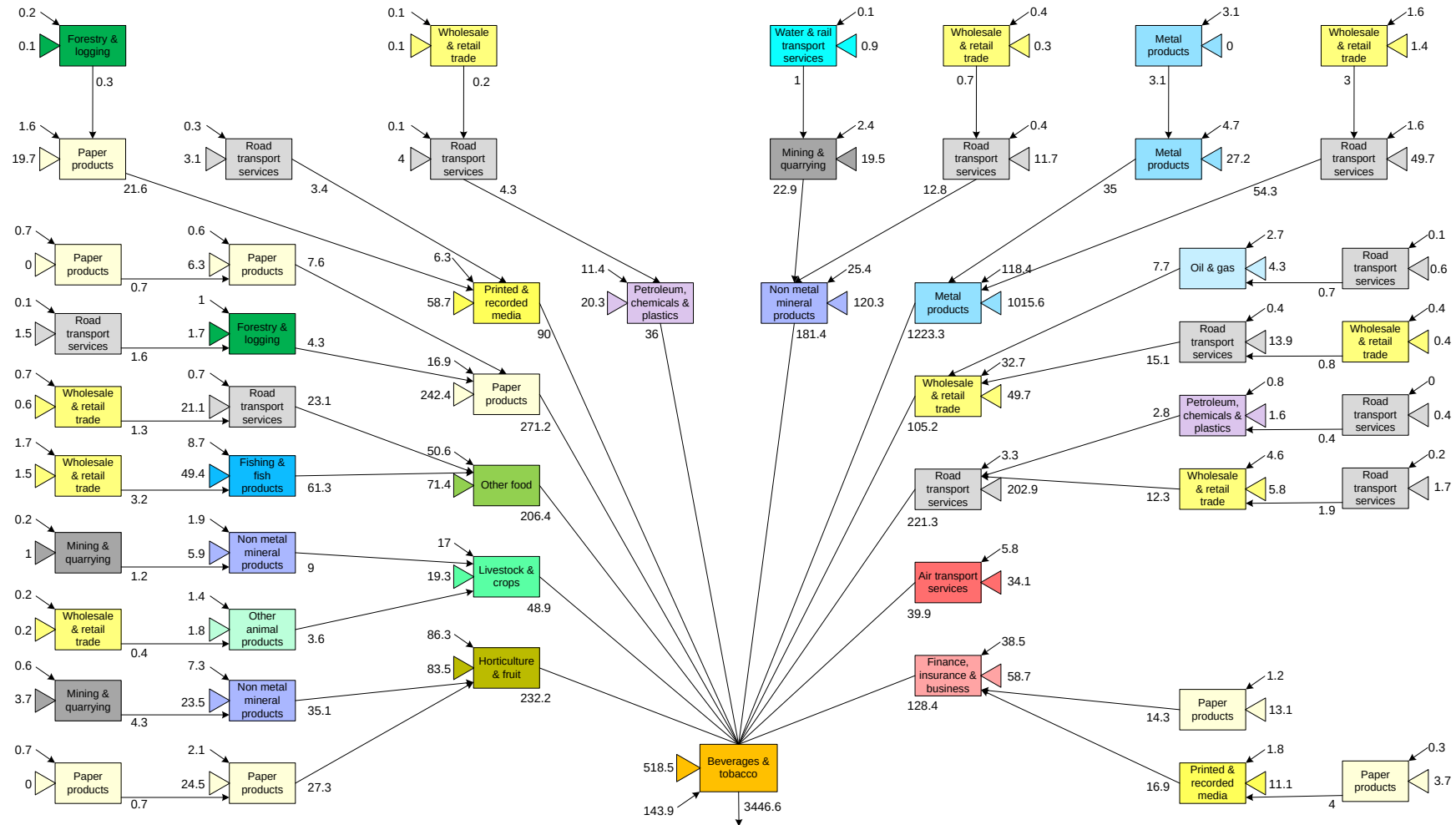


Figure 11.2 - Electricity Inputs Required to Produce One Tonne of Beverages and Tobacco Products, 2004 (MJ, Heat Equivalents)

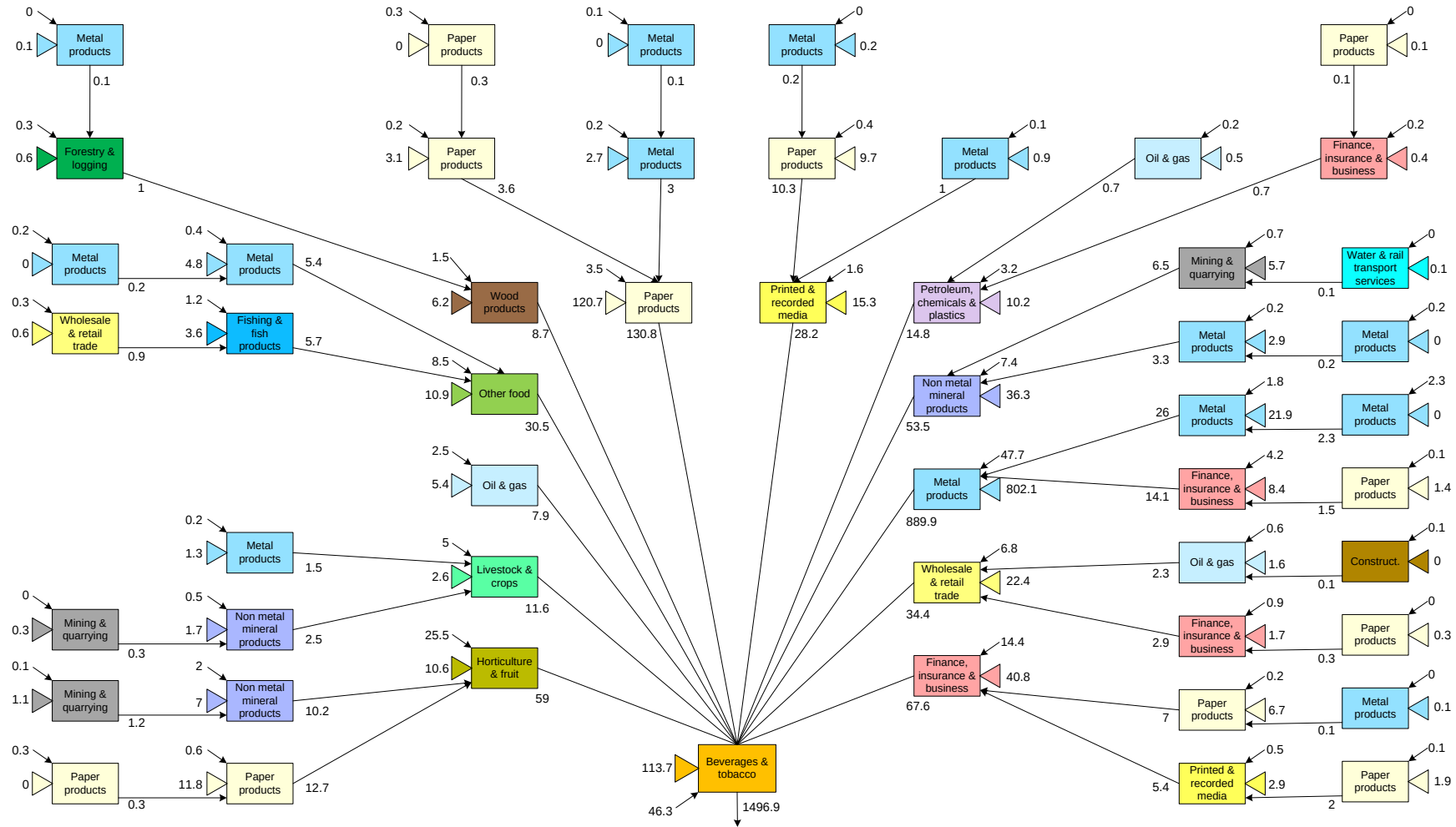


Figure 11.3 - Fossil Fuel Inputs Required to Produce One Tonne of Beverages and Tobacco Products, 2004 (MJ, Heat Equivalents)

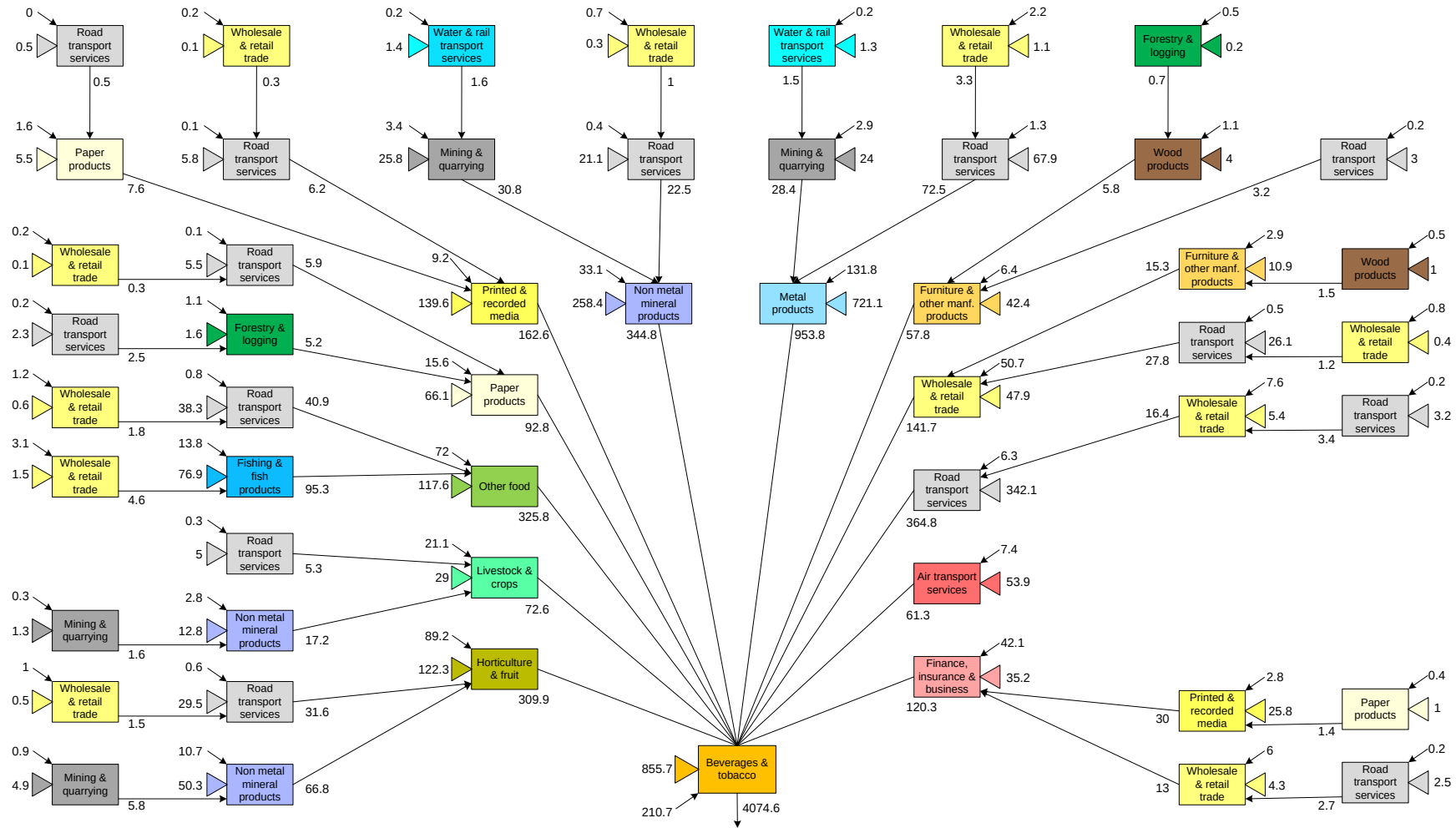


Figure 11.4 - Land Required to Produce One Tonne of Beverages and Tobacco Products, 2004 (m²)

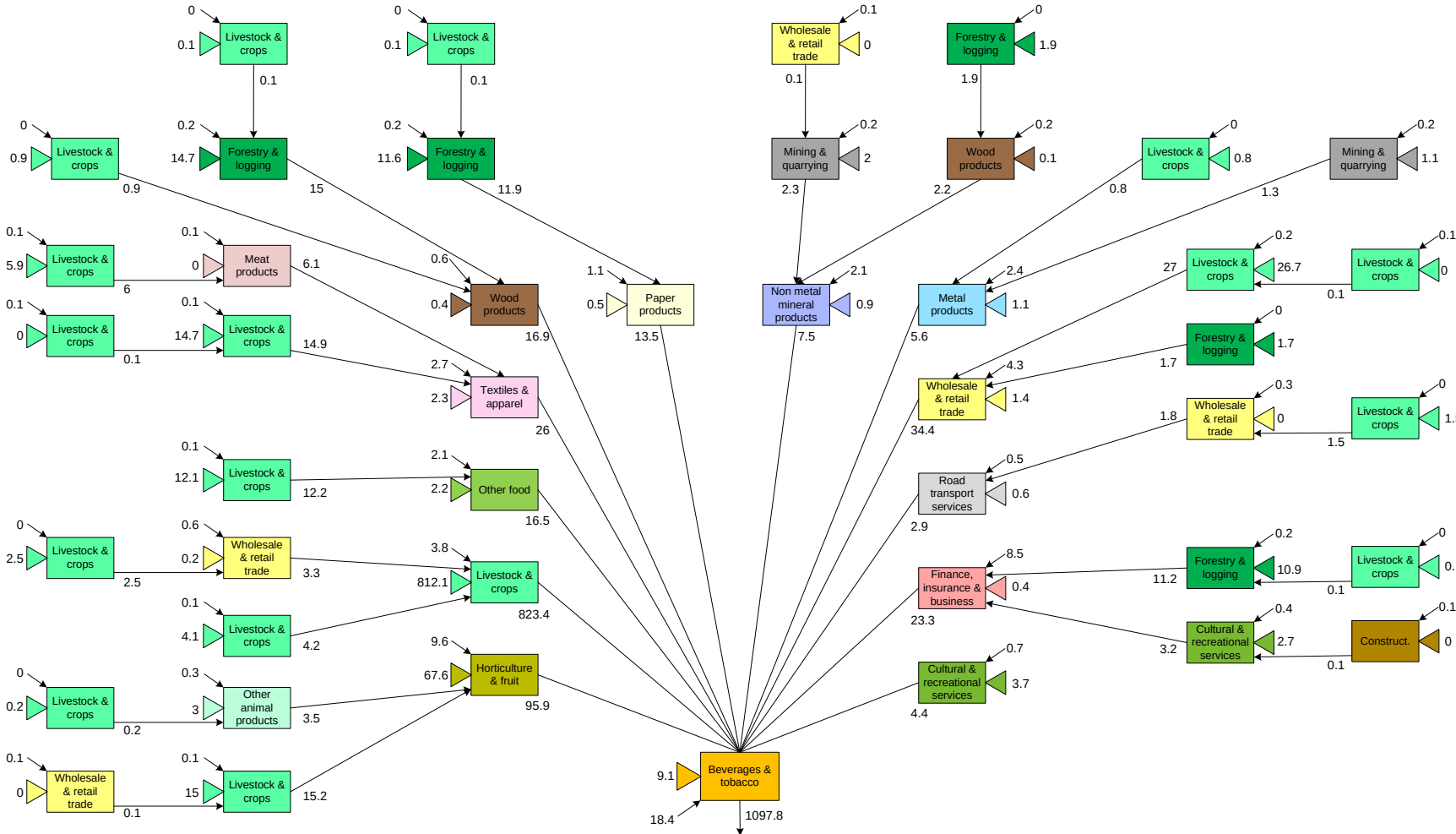


Figure 11.5 - Water Inputs Required to Produce One Tonne of Beverages and Tobacco Products, 2004 (Litres)

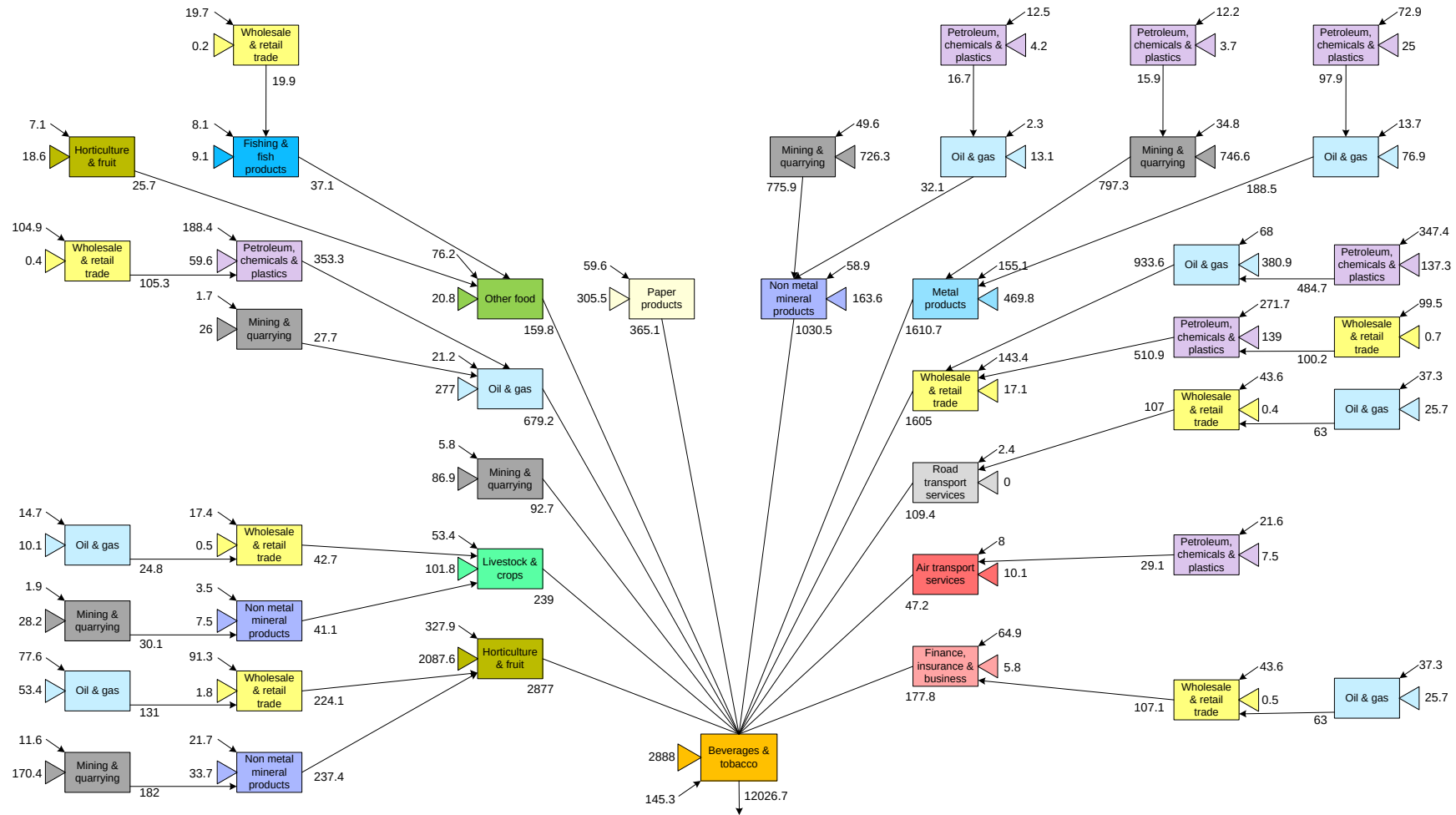


Figure 11.6 - Landfill Waste Generated in Producing One Tonne of Beverages and Tobacco Products, 2004 (Grams)

Figure 11.7 - Water Waste Generated in Producing One Tonne of Beverages and Tobacco Products, 2004 (Litres)

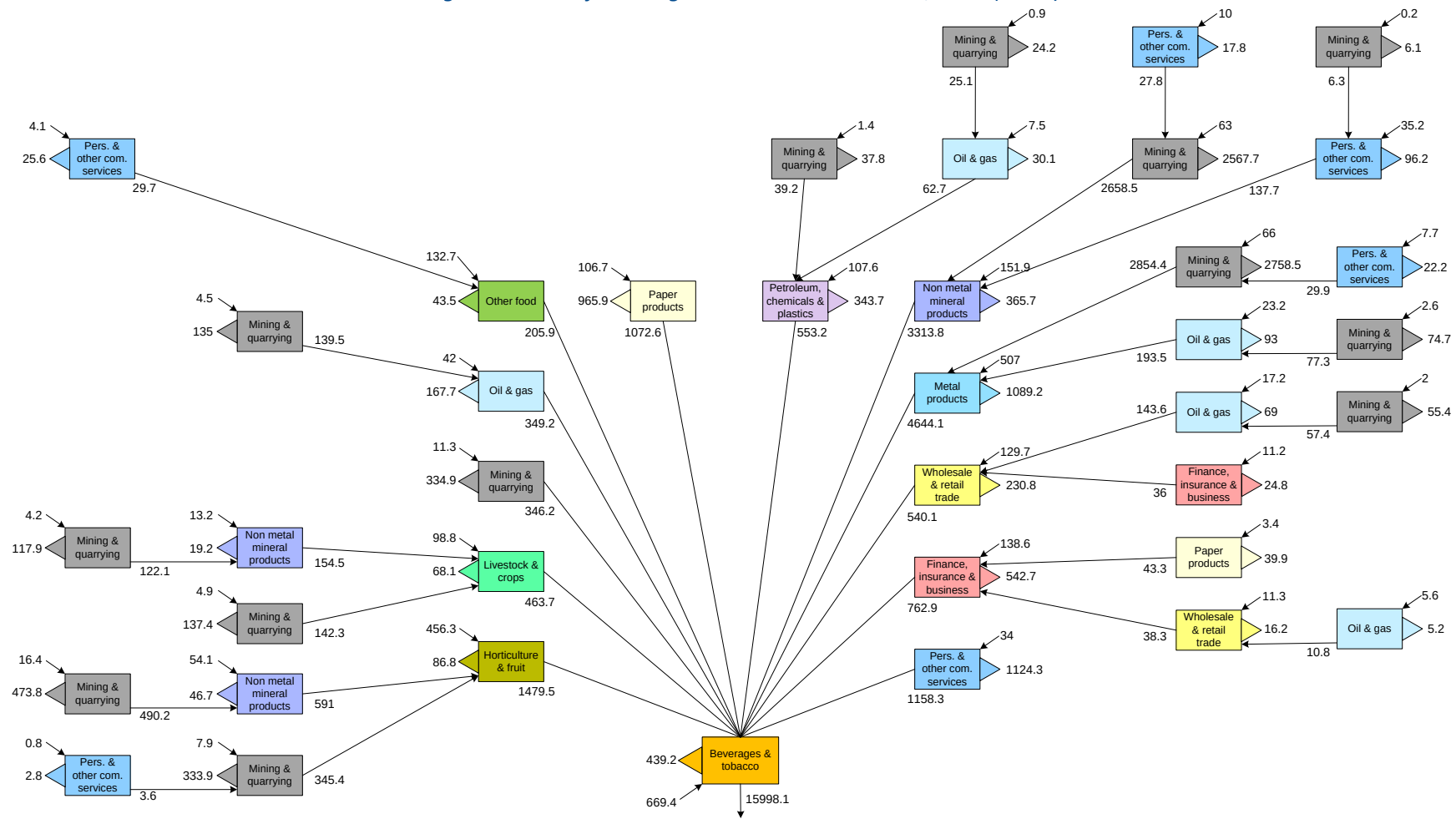


Figure 11.8 - Phosphorus Waste Generated in Producing One Tonne of Beverages and Tobacco Products, 2004 (Grams)

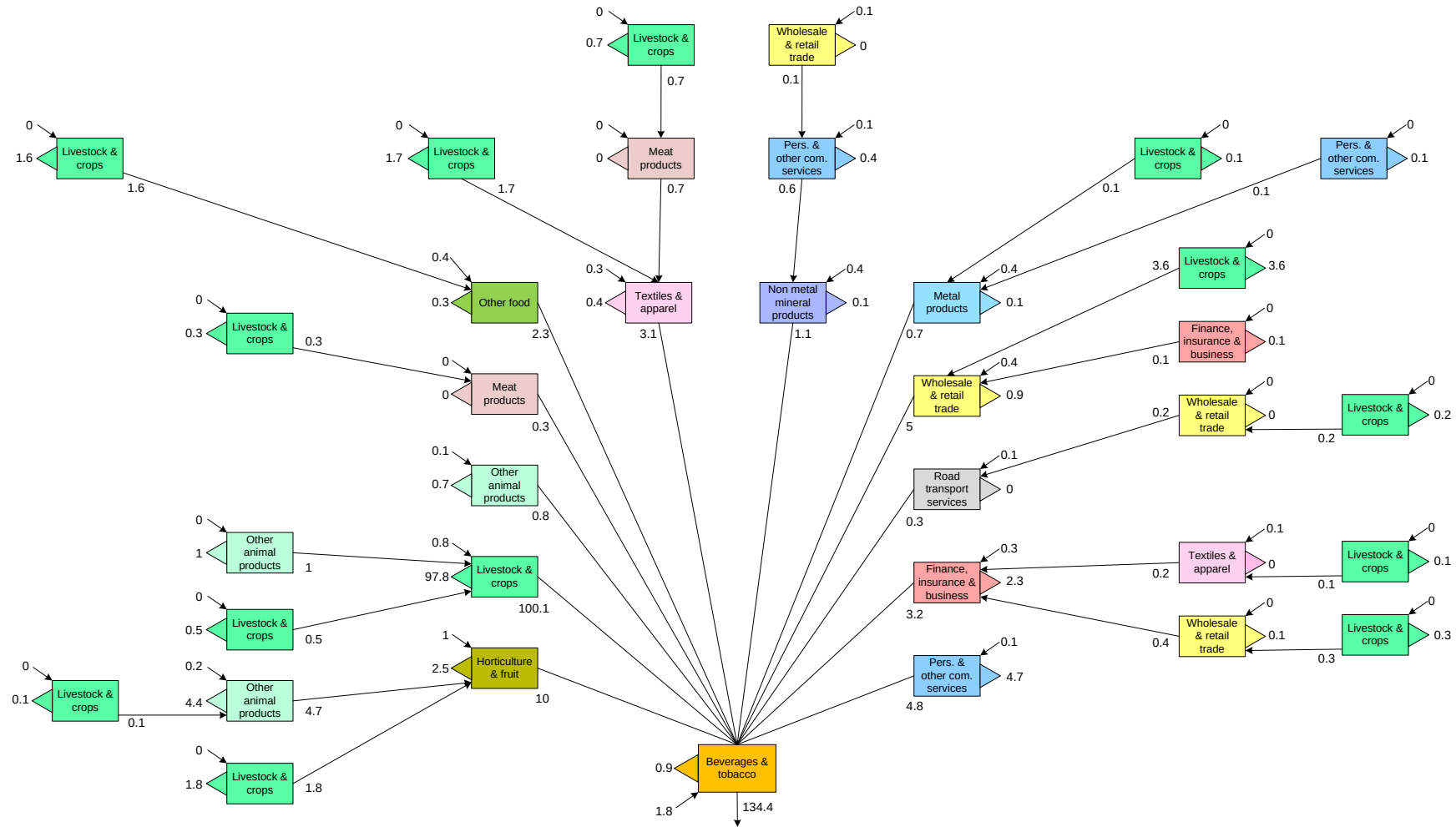
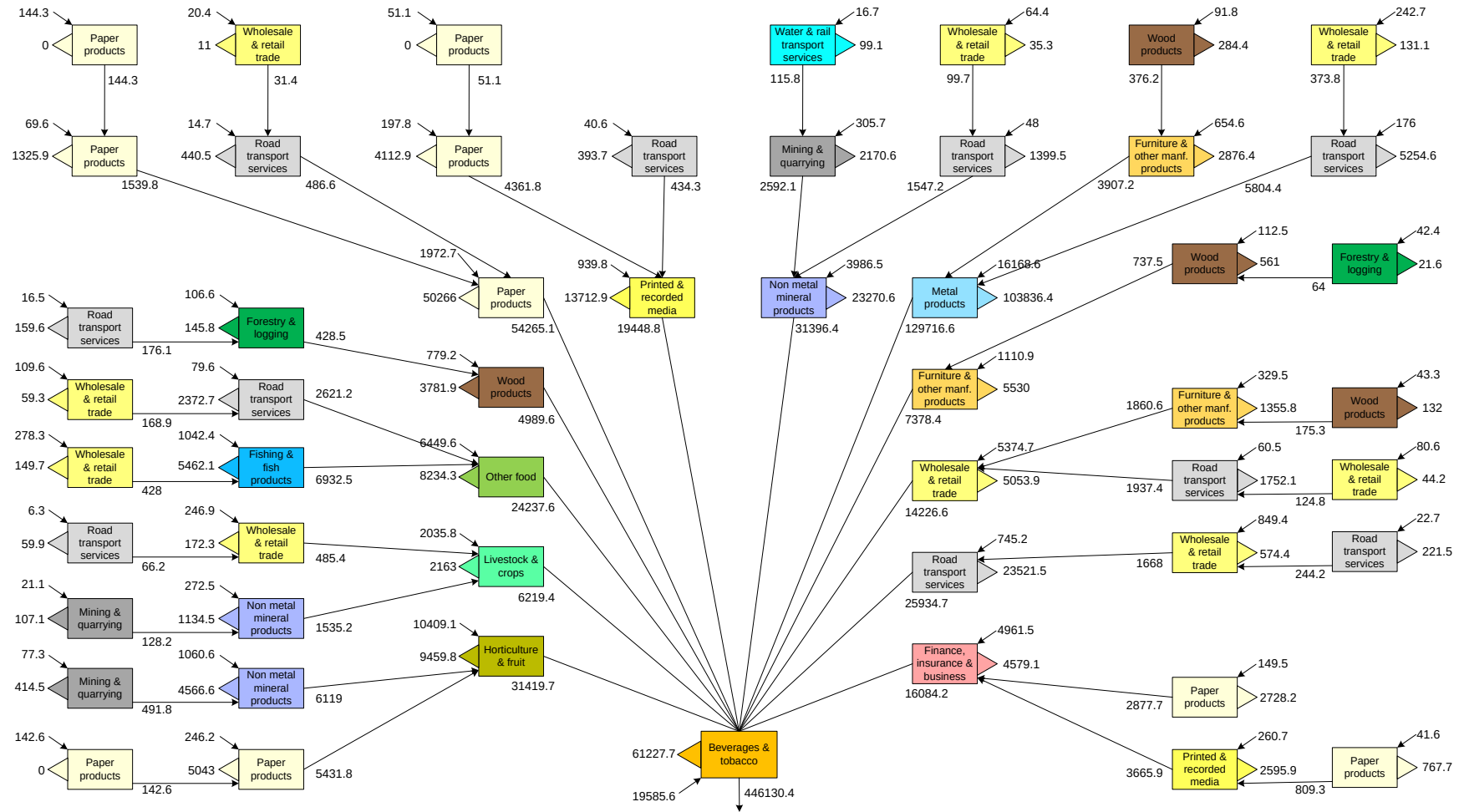


Figure 11.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Beverages and Tobacco Products, 2004 (Grams)



12. Textile and Apparel Manufacturing

Description

ANZSIC Codes covered:

- 131 – Textile Manufacturing (wool scouring, natural and synthetic textiles)
- 132 – Leather Tanning, Fur Dressing and Leather product manufacturing
- 133 – Textile Product Manufacturing (floor coverings, rope and twine etc)
- 134 – Knitted Product Manufacturing
- 135 – Clothing and Footwear Manufacturing

GDP 2016 = \$0.67 billion

Rank = 32nd

Average annual growth rate

2006 to 2016 = -1.19%

Rank = 33rd

Employment 2016 = 10,889

Rank = 25th

Main commodities supplied:

- Natural textiles, rugs, tanned skins and leather, footwear and clothing.

Economic Overview

The importance of the textile and apparel sector to the overall economy has been declining in recent years; in 2016, at \$0.67 billion, the sector made up about 2% of total manufacturing sector sales, ranking it among all manufacturing sectors.¹⁶⁷ The industry employs almost 11,000 people in more than 1,750 businesses. In 2006, Australia was the largest export market by value with 87% of garments headed across the Tasman (\$364.6 million), followed by the US (\$52.3 million), Hong Kong (\$14.4 million), the UK (\$14 million) and Fiji (\$8.2 million). Of the four sub-sectors, textiles were the largest industry exporter (\$192.3 million) followed by apparel (\$151.1 million), carpet (\$110 million) and footwear (\$46.5 million).¹⁶⁸

The textile industry is one of New Zealand's oldest manufacturing activities, the ready availability of wool and skins from livestock made the production of woollen goods, carpets and leather products logical industries to establish in New Zealand, and thus products made from wool fibre have historically been the largest commodity group in this sector.¹⁶⁹ However, because the dollar value of wool exports has been declining since the 1950s, there has been a decline in products made from wool and thus stagnant growth in production and exports.¹⁷⁰ The end-use for most of the wool yarn made in New Zealand is in the production of carpet, with 61% of New Zealand's wool production being used in either machine or handmade carpets.¹⁷¹ In 2018, wool carpet and rug exports amounted to \$104.3

¹⁶⁷ Reserve Bank of New Zealand. (2005). *Overview of the Manufacturing Sector. Bulletin*, 68(1). Retrieved from http://www.rbnz.govt.nz/research_and_publications/reserve_bank_bulletin/2005/2005mar68_1turner.pdf

¹⁶⁸ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 414).

¹⁶⁹ Fashion United. (2016). *New Zealand Fashion Statistics*. Retrieved from <https://fashionunited.nz/statistics/fashion-industry-statistics-newzealand/>

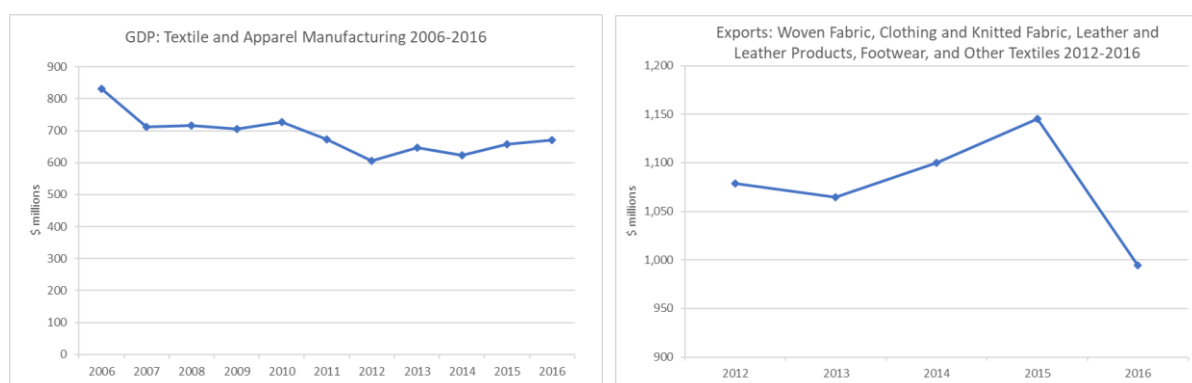
¹⁷⁰ Statistics New Zealand. (2012). *Off the sheep's back: a look at historical wool export prices and volumes*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/historical-wool-export-prices-volumes-2011.aspx

¹⁷¹ Nicol, A., & Saunders, C. (2008, November 24). *Meat and wool - Wool products and marketing*. Retrieved from Te Ara - the Encyclopedia of New Zealand: <https://teara.govt.nz/en/meat-and-wool/page-7>

million, with other final woollen products contributing an additional \$40.6 million.¹⁷² The main market for NZ wool is North Asia, including countries such as Hong Kong and China, but significant quantities are also exported to countries in the European Union and South Asia.¹⁷³

Additionally, the footwear subsector which previously enjoyed high levels of tariff and licencing protection has been hurt by the liberal reforms of 1984 which opened the NZ economy to free trade. The subsequent restructuring of the industry led to a decline of profitability; domestic production reduced from 7.7 million pairs in 1987 to 1.5 million pairs in 1998,¹⁷⁴ of which about 1 million were exported. Footwear manufacturers struggled to compete with overseas manufacturers who had lower labour costs, better technology which produces higher quality leather, and lower environmental standards to meet. Its share of the domestic market has dropped to around 2%; the balance of trade is now negative, with 19 million pairs of footwear imported annually, 84% from China.¹⁷⁵ As of 2008, more than 95% of footwear sold in New Zealand was imported, mainly from China.¹⁷⁶ Similar trends are seen in the clothing and apparel industry within New Zealand. The rise of fast fashion and mass manufacturing in overseas markets such as China has shifted New Zealand's production to smaller, high-end producers incorporating high-end textiles such as New Zealand merino wool.¹⁷⁷

Sector Trends



Production

Production in textiles and apparel manufacturing has experienced an overall downward trend from 2006 to 2016. Production decreased by 19.37%, from \$831 million to \$670 million over the 10-year period, reaching a low of \$606 million in 2012. A possible explanation for the decline seen in this sector is the shift in emphasis towards producing sheepmeat, rather than wool. Furthermore, levels of production in the fabric sector are highly dependent on world prices and competitiveness through the exchange rate. The rise in demand for high-quality wool such as merino wool provides some positive outlook for the sector.¹⁷⁸

¹⁷² Beef and Lamb New Zealand. (2019). *Compendium of Farm Facts*. Wellington. Retrieved from <https://beeflambnz.com/sites/default/files/data/files/Compendium%202019.pdf>

¹⁷³ Ibid.

¹⁷⁴ Statistics New Zealand. (2002). *New Zealand Official Yearbook 2002*. Auckland, New Zealand: David Bateman Ltd.

¹⁷⁵ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 414).

¹⁷⁶ Tolerton, J. (2010, March 11). *Clothing and footwear manufacturing - Footwear*. Retrieved from Te Ara - the Encyclopedia of New Zealand: <http://www.TeAra.govt.nz/en/clothing-and-footwear-manufacturing/page-4>

¹⁷⁷ Tolerton, J. (2010, March 11). *Clothing and footwear manufacturing - From mass market to niche market*. Retrieved from Te Ara - the Encyclopedia of New Zealand: <https://teara.govt.nz/en/clothing-and-footwear-manufacturing/page-3>

¹⁷⁸ Cook, A. (2017, March 6). *Wool export value drops 25% coming into 2017*. Retrieved from RNZ: <https://www.rnz.co.nz/news/business/325941/wool-export-value-drops-25-percent-coming-into-2017>

Exports

Growth in the value of exports in the textile and apparel manufacturing industry was generally seen, where the value of exports grew moderately from \$1.06 billion to \$1.15 billion from 2013 to 2015, an increase of 7.62%. Following this growth, the value of exports dropped considerably to \$995 million in 2016, a decrease of 13.16% from the previous year. Textile products from New Zealand such as wool tufted carpet have a strong international reputation - New Zealand's status as the world's fourth-largest producer of wool and provider of wool services has helped to maintain the modest performance of export growth. However, as mentioned previously, the diverging trends in the world price for wool and sheepmeat will have likely contributed to the levels of exports seen in this sector.¹⁷⁹ Additionally, the industry is continually facing high labour and transport costs, which further reduces the ability to remain competitive against apparel manufacturing giants such as China, the US and India. Products shipped overseas often face import tariffs and other measures that are in place to protect local manufacturers in many overseas countries, which further hurts domestic producers. With the introduction of more FTA's, these barriers are likely to ease.

Life Cycle Assessment Diagrams

Energy (Figure 12.1, Figure 12.2, Figure 12.3)

Textile and Apparel products were found to have a total energy intensity of 19,115.1 MJ_E per tonne of product (19 MJ_E/kg), ranking this sector 5th highest out of the 20 product producing sectors covered in this publication. The total energy intensity measured in conventional terms is 31,666 MJ_H/tonne. This is in a similar order of magnitude to reported energy intensities produced by various textile and apparel products such as average total energy use for dry Merino wool top at 24,915 MJ_H per tonne of product.¹⁸⁰

Direct energy use was 42% of the total energy intensity, measuring 8,118.6 MJ_{OE} per tonne of textile and apparel product produced. The EECA in use database reports that a total of 1,412.099 TJ of direct energy was used in the textile, apparel & leather goods sector in 2006/07. *Indirect energy use* was 58% of the total energy intensity, measuring 10,996.5 MJ_{OE} per tonne of textile and apparel product produced. The main *indirect energy uses* in the production of textile and apparel products came from; (i) *energy embodied in textile and apparel at 1,740.7 MJ_{OE} per tonne of product produced*; (ii) *energy embodied in road transport services at 1,497.7 MJ_{OE} per tonne of product produced*; (iii) *energy embodied in meat products at 1,215.8 MJ_{OE} per tonne of product produced*; (iv) *energy embodied in livestock and crops at 909.8 MJ_{OE} per tonne of product produced*.

Land (Figure 12.4)

Textile and apparel products have a total land intensity of 40,651.3 m² per tonne of product produced, ranking the sector 3rd highest in terms of land intensity out of the 20 product producing sectors covered in this publication.

Direct land use was minuscule at only 0.3% of the total land intensity at 118.4 m² per tonne of product produced. *While Indirect land use* makes up the majority of textile and apparel product's total land intensity at 99.7% measuring 49,460.7 m² per tonne of product produced. *The major indirect land uses in the production of textile and apparel products came from; (i) land embodied in livestock and crops*

¹⁷⁹ Statistics New Zealand. (2012). *Off the sheep's back: a look at historical wool export prices and volumes*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/historical-wool-export-prices-volumes-2011.aspx

¹⁸⁰ Barber, A., Pellow, G. (2006, March). *Life Cycle Assessment: New Zealand Merino Wool Total Energy Use and Carbon Dioxide Emissions*. The Agibusiness Group. Retrieved from <http://www.merinoinc.co.nz/Reports/LCA-NZMerinoWool.pdf>

at 23,095.3 m² per tonne of product produced; (ii) land embodied in meat products at 10,901.7 m² per tonne of product produced; (iv) land embodied in textile and apparel at 4,117.7 m² per tonne of product produced; (iv) land embodied in forestry and logging at 591.3 m² per tonne of product produced.

Water Inputs (Figure 12.5)

Textile and apparel products require 58,588.6 litres of water inputs per tonne of product produced, ranking the sector the 3rd highest consumer of water compared to the 20 product producing sectors covered in this publication. This is in a similar magnitude to reported amounts of water inputs for various textile and apparel products such as the textile industry of Bangladesh found to use 135 litres of blue water inputs per kg of fabric produced.¹⁸¹

Textile and apparel product's total water inputs are made up mostly of *indirect water inputs*. *Direct water inputs* only make up 16% of the total water inputs or 9,127.9 litres per tonne of textile and apparel products produced. *Indirect water inputs* make up the majority at 84% of the total water inputs, or 3,679 litres per tonne of textile and apparel product produced.

The main indirect water inputs into the production of textile and apparel products came from; (i) water inputs embodied in oil and gas at 14,793.2 litres per tonne of product produced; (ii) water inputs embodied in meat products at 11,464.9 litres per tonne of product produced; (iii) water inputs embodied in wholesale and retail at 6,388.4 litres per tonne of product produced; (iv) water inputs embodied in textile and apparel at 5,946.5 litres per tonne of product produced.

Landfill Wastes (Figure 12.6)

Textile and apparel products were found to generate 185,689.5 grams (185 kg) of landfill waste per tonne of product produced. This ranks the sector the 4th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by textile and apparel products was 56% of total waste produced or 103,618.2 grams per tonne of product produced. *Landfill waste indirectly generated* by textile and apparel products was 44% of the total waste produced or 82,071.3 grams per tonne of production. *The main sources of indirect landfill waste came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 29,674.3 grams per tonne of product produced; (ii) landfill wastes embodied in textile and apparel at 15,759 grams per tonne of product produced; (iii) landfill wastes embodied in meat products at 7,612.1 grams per tonne of product produced; (iv) landfill wastes embodied in livestock and crops at 4,814.5 grams per tonne of product produced.*

Water Wastes (Figure 12.7)

Textile and apparel products were found to produce 93,312.6 litres of wastewater per tonne of product produced. This ranks the sector as the 6th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication.

Wastewater directly generated by the production of textile and apparel products was only 10% of total waste produced at 9,757.4 litres per tonne of product produced. Wastewater indirectly generated made up the majority of the total at 90% of the total wastewater produced, or 83,555.2 litres per tonne of product produced. *The indirect wastewater from the production of textile and apparel products was mostly made up of (i) wastewater embodied in meat products at 14,349.4 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 11,459.6 litres*

¹⁸¹ Hossain, L., & Khan, M. S. (2017). Blue and Grey Water Footprint Assessment of Textile Industries of Bangladesh. *Fifth International Conference on Chemical Engineering*. Dhaka, Bangladesh.

per tonne of product produced; (iii) wastewater embodied in personal and other community services at 9,832.5 litres per tonne of product produced; (iv) wastewater embodied mining and quarrying at 9,154 litres per tonne of product produced.

Phosphorus Wastes (Figure 12.8)

Textile and apparel products were found to produce 5,121 grams (5.1 kg) of phosphorus waste per tonne of product produced. The total amount of phosphorus produced in the production of textile and apparel products came mostly from indirect sources. *Direct phosphorus wastes produced was only 4% of the total or 201.4 grams per tonne of product produced. While phosphorus waste produced indirectly made up 96% of the total at 4,919.6 grams per tonne of product produced. This indirect phosphorus waste was mostly made up of (i) phosphorus waste embodied in livestock and crops at 2,769.7 grams per tonne of product produced; (ii) phosphorus waste embodied in meat products at 1,392.5 grams per tonne of product produced; (iii) phosphorus waste embodied in textile and apparel products at 518.2 grams per tonne of product produced.*

Energy Greenhouse Gases (Figure 12.9)

In terms of CO₂ greenhouse gas emissions, textile and apparel products were found to emit 2,169,658.2 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of textile and apparel products are ranked the 5th highest out of the 20 product producing sectors covered in this publication. This is similar to reported CO₂ greenhouse gas emissions produced by various textile and apparel products such as New Zealand Merino wool top at 2,230,000 CO₂ per tonne of product produced.¹⁸²

Energy-related CO₂ directly generated by textile and apparel products was 37% of the total emissions produced or 810,969.7 grams per tonne of product produced. Energy-related CO₂ indirectly generated by textile and apparel products made up 63% of the total emissions produced or 323,591.1 grams per tonne of product produced.

This indirect energy-related CO₂ emissions were mostly made up of (i) energy-related CO₂ embodied in textile and apparel products at 193,300.7 grams per tonne of product produced; (ii) energy-related CO₂ embodied in road transport services at 162,521.6 grams per tonne of product produced; (iii) energy-related CO₂ embodied in meat products at 143,139.7 grams per tonne of product produced; (iv) energy-related CO₂ embodied in livestock and crops at 109,096.8 grams per tonne of product produced.

¹⁸² Barber, A., Pellow, G. (2006, March). *Life Cycle Assessment: New Zealand Merino Wool Total Energy Use and Carbon Dioxide Emissions*. The Agibusiness Group. Retrieved from <http://www.merinoinc.co.nz/Reports/LCA-NZMerinoWool.pdf>

Figure 12.1 - Total Energy Inputs Required to One Tonne of Produce Textile and Apparel Products, 2004 (MJ_E, Oil Equivalents)

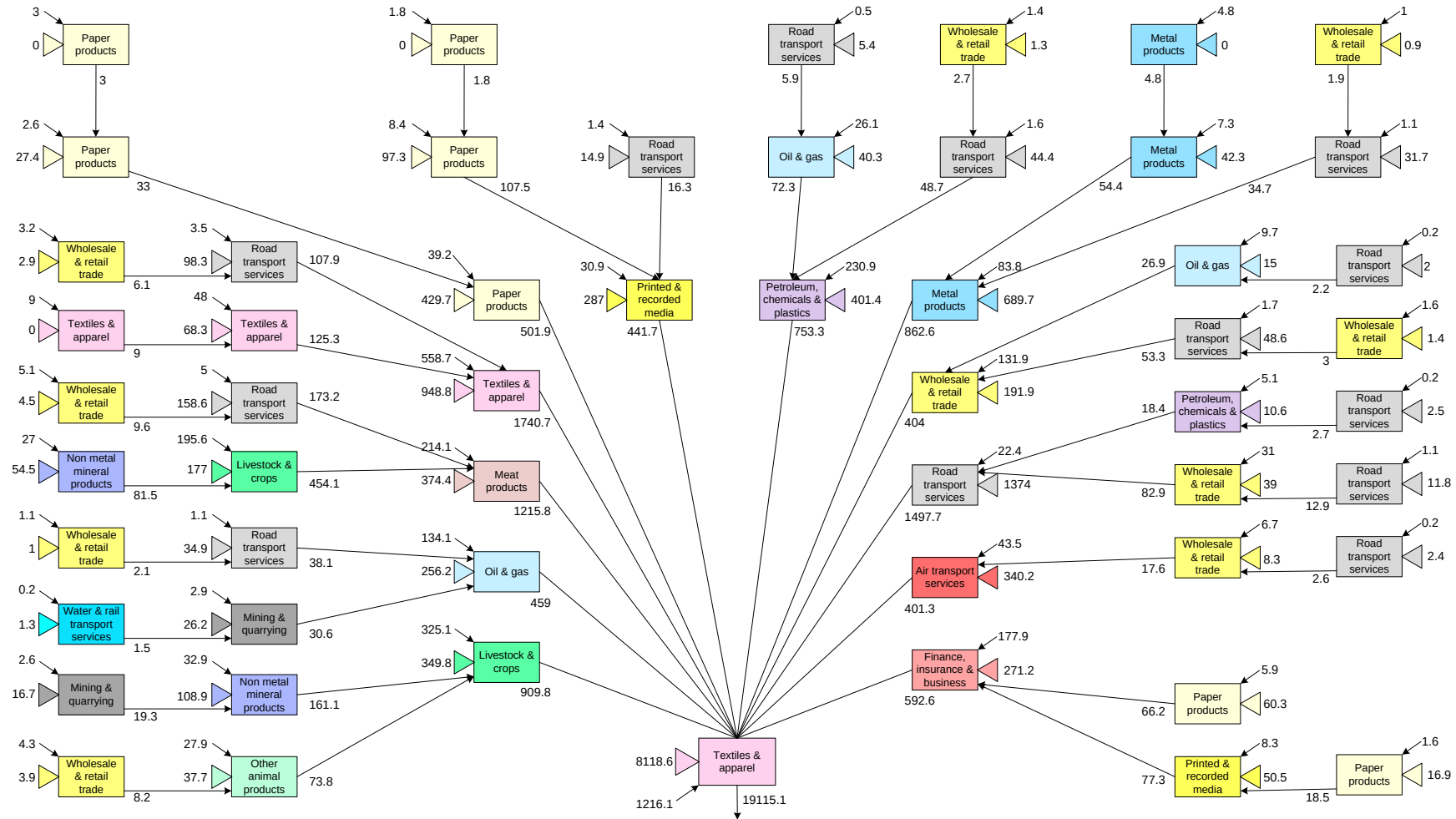


Figure 12.2 - Electricity Inputs Required to Produce One Tonne of Textile and Apparel Products, 2004 (MJ, Heat Equivalents)

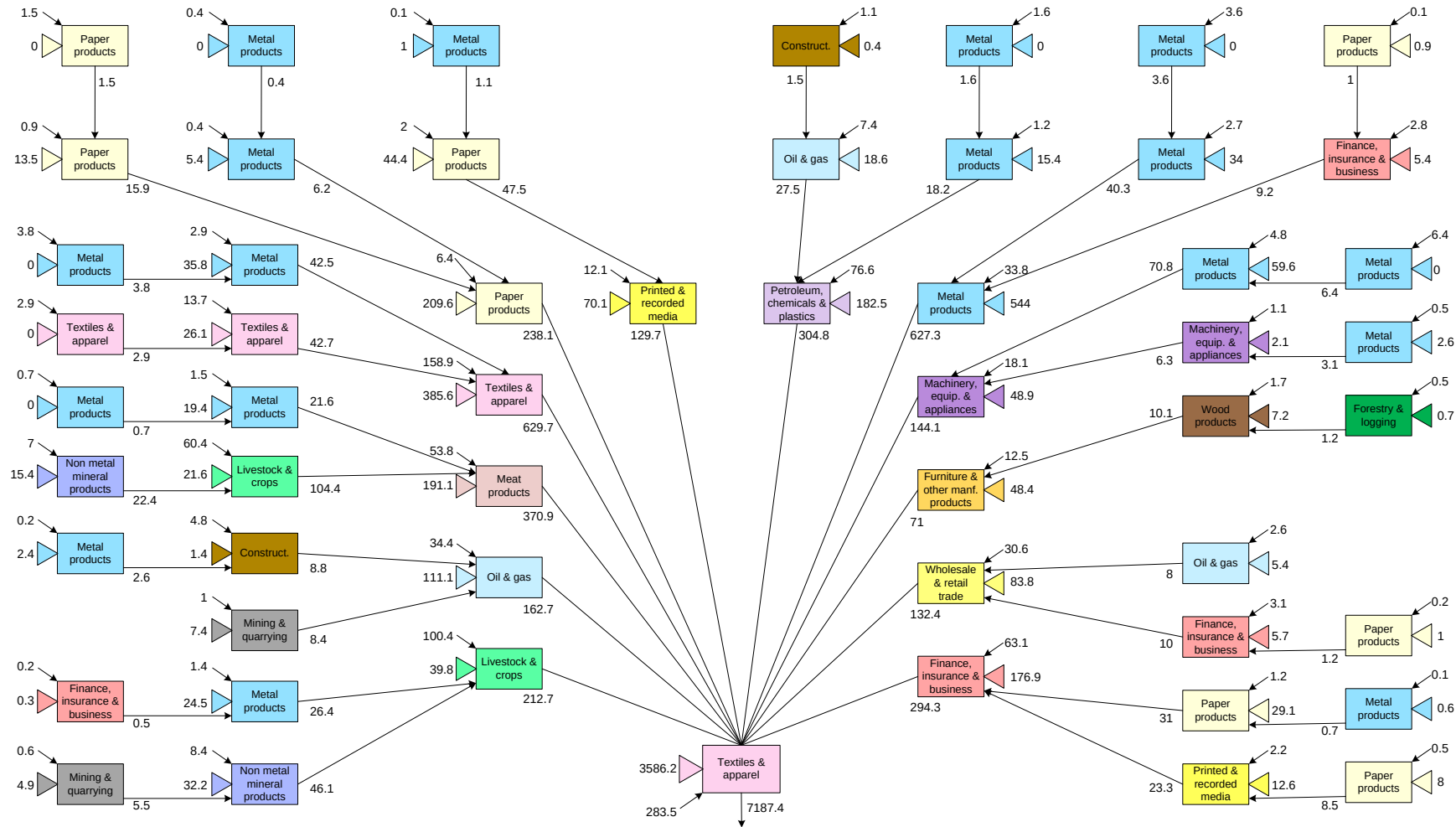


Figure 12.3 - Fossil Fuel Inputs Required to Produce One Tonne of Textile and Apparel Products, 2004 (MJ, Heat Equivalents)

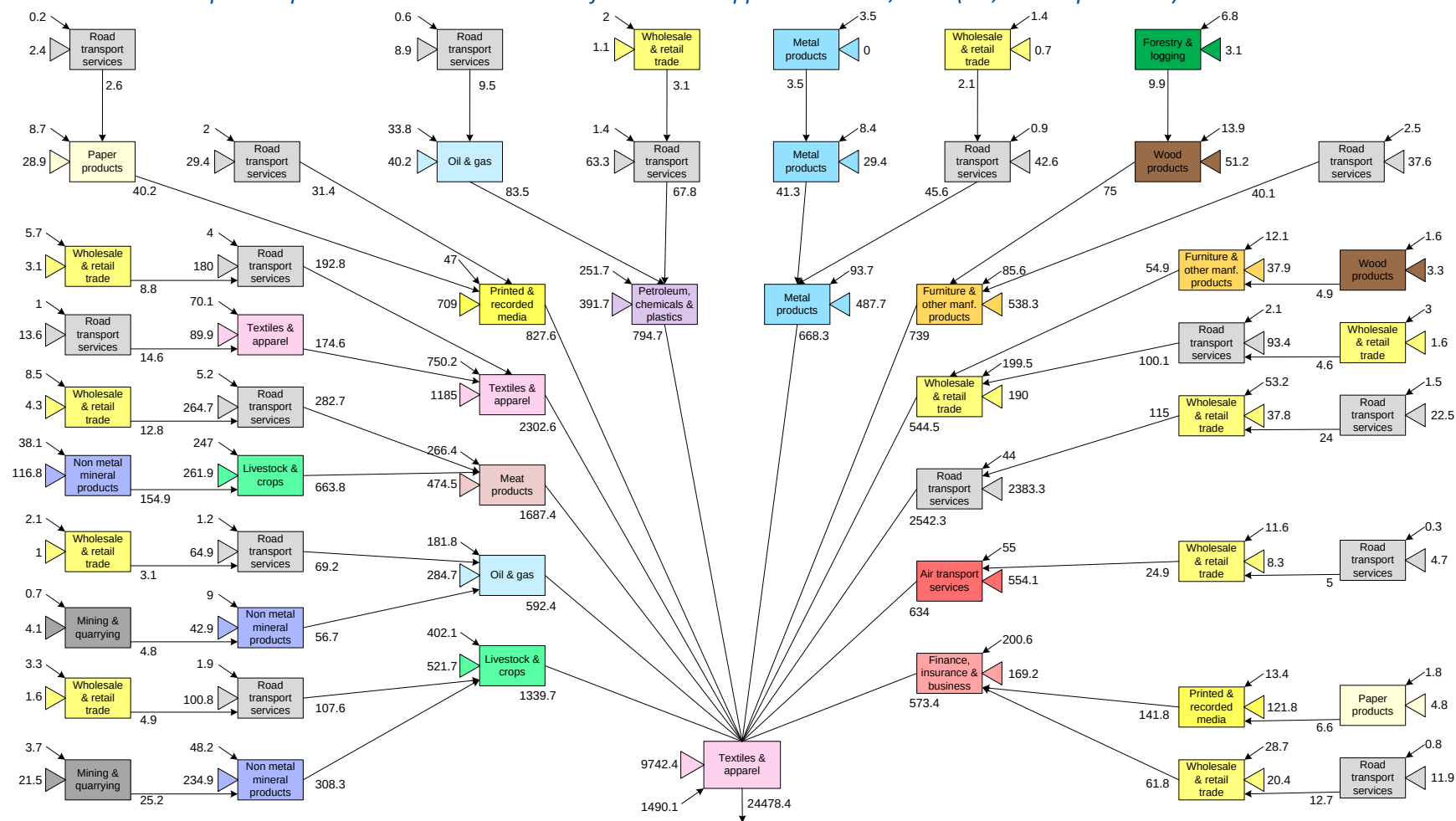


Figure 12.4 - Land Required to Produce One Tonne of Textiles and Apparel Products, 2004 (m²)

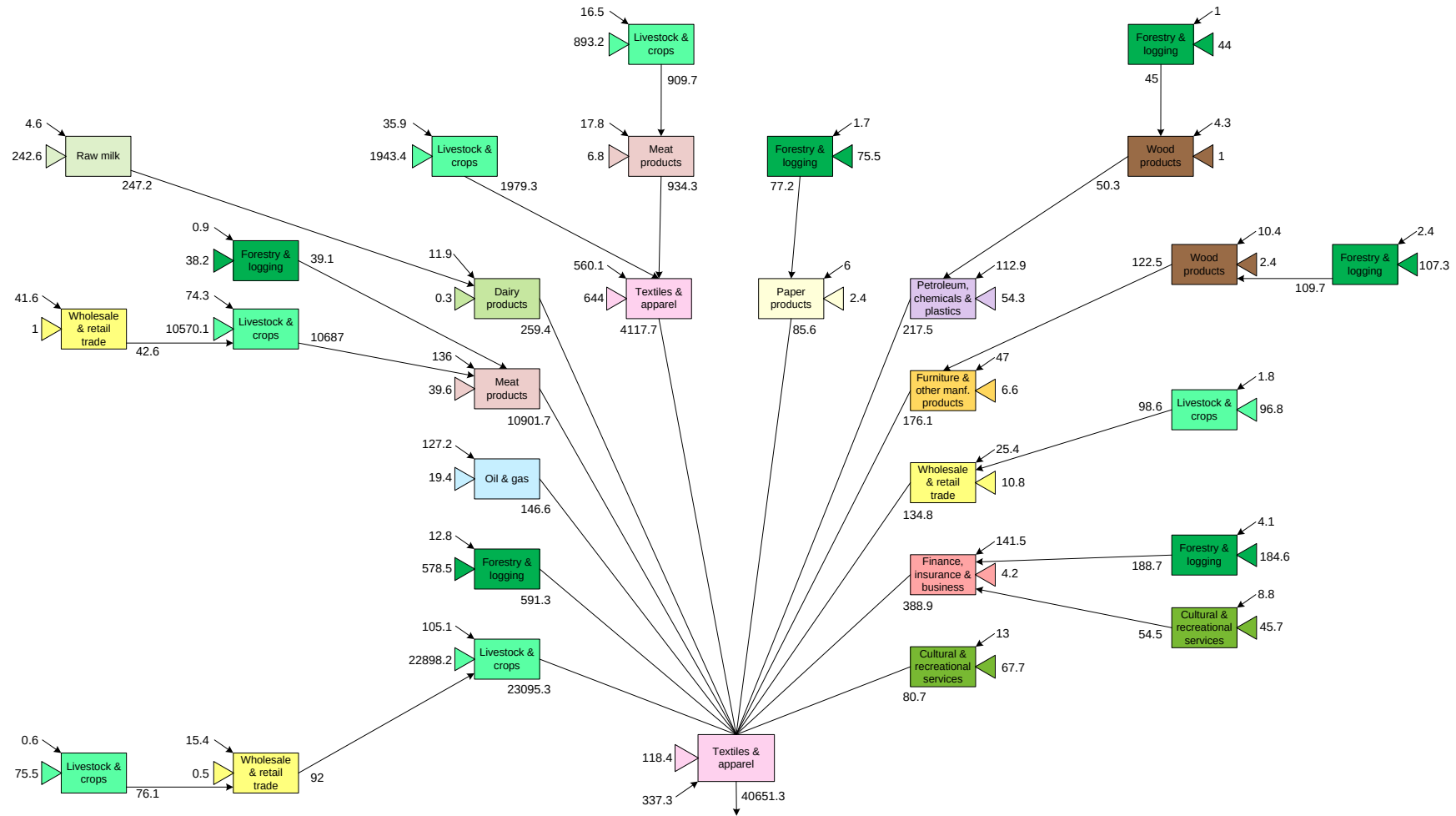


Figure 12.5 - Water Inputs Required to Produce One Tonne of Textiles and Apparel Products, 2004 (Litres)

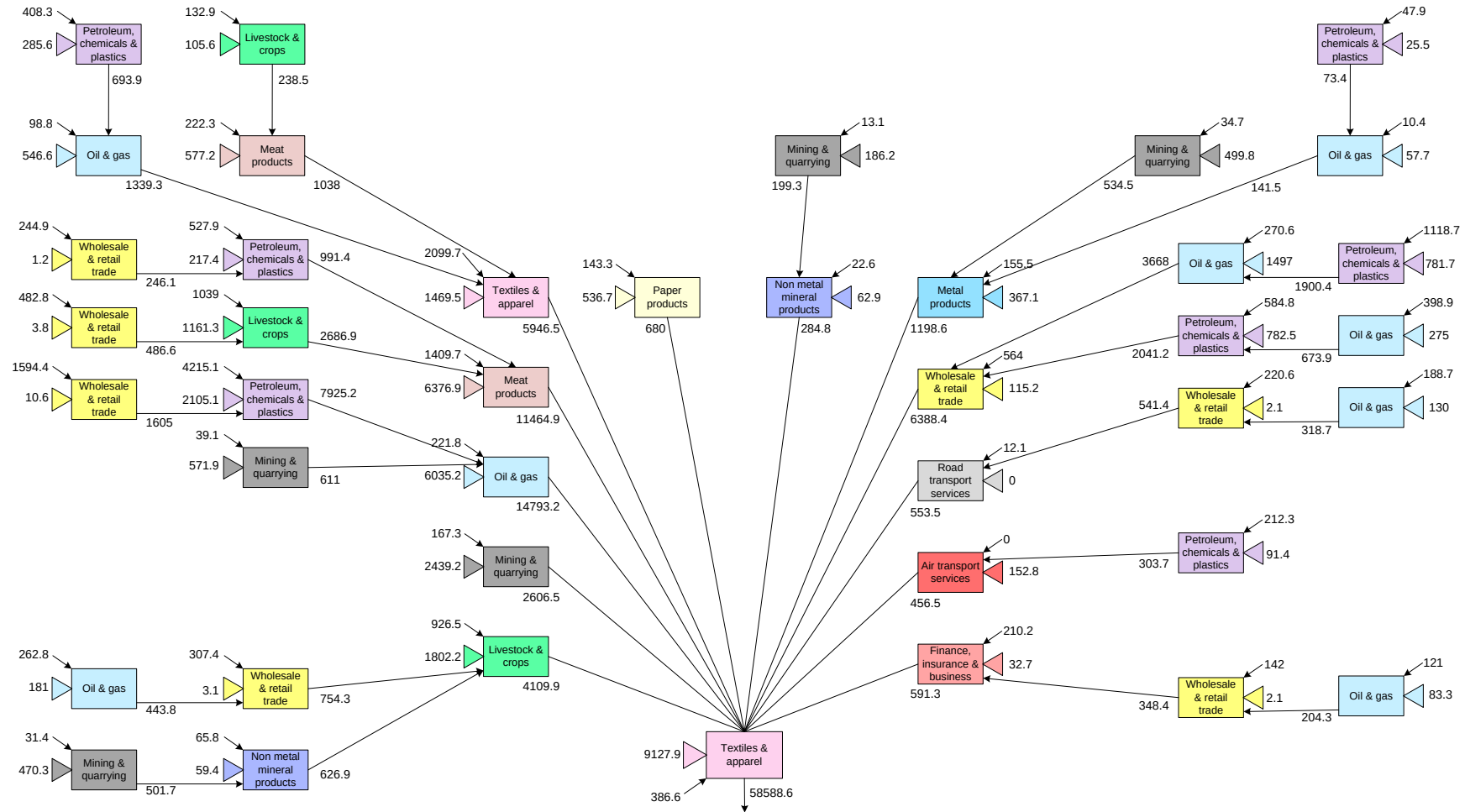


Figure 12.6 - Landfill Waste Generated in Producing One Tonne of Textiles and Apparel Products, 2004 (Grams)

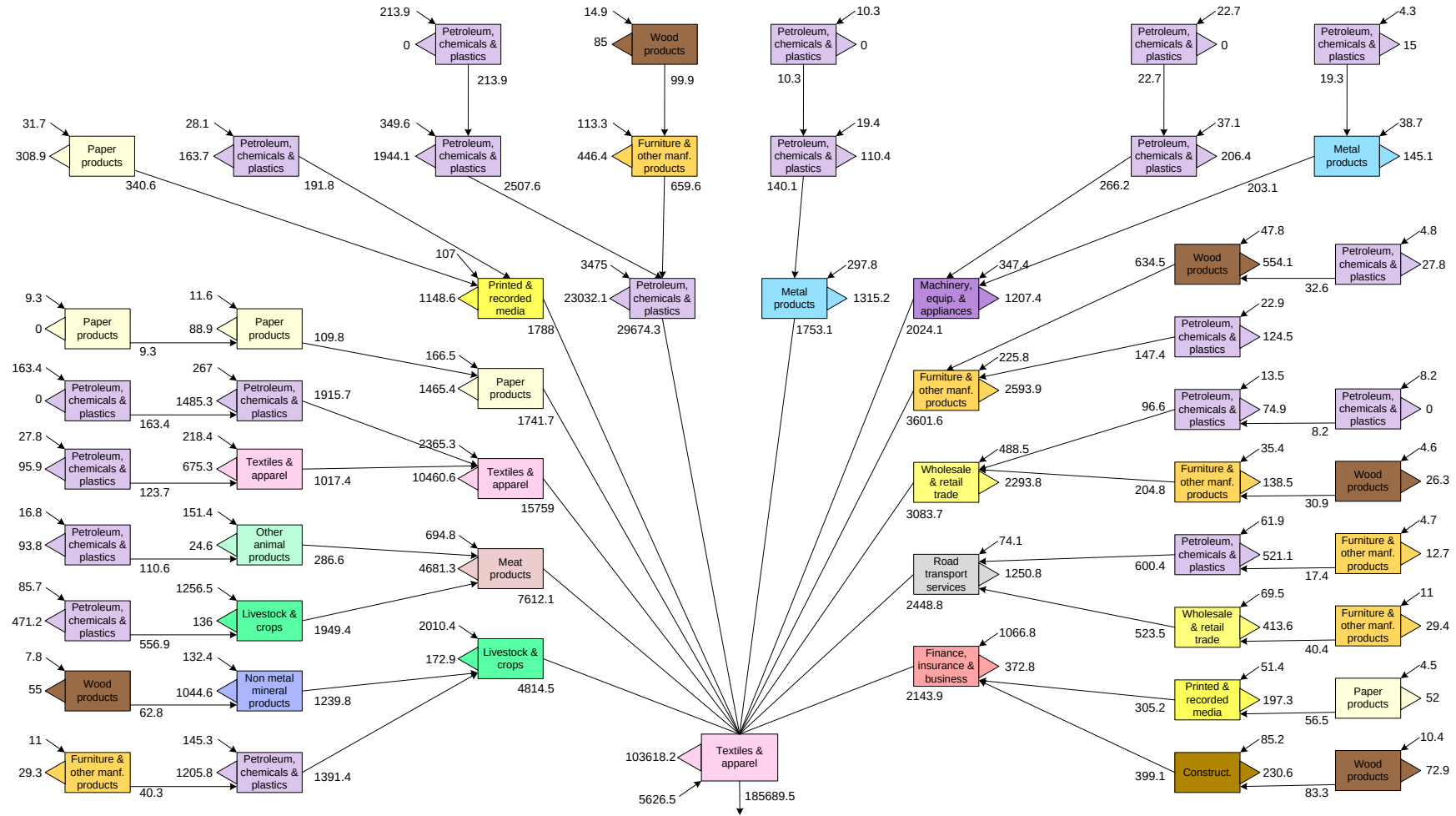


Figure 12.7 - Water Waste Generated in Producing One Tonne of Textiles and Apparel Products, 2004 (Litres)

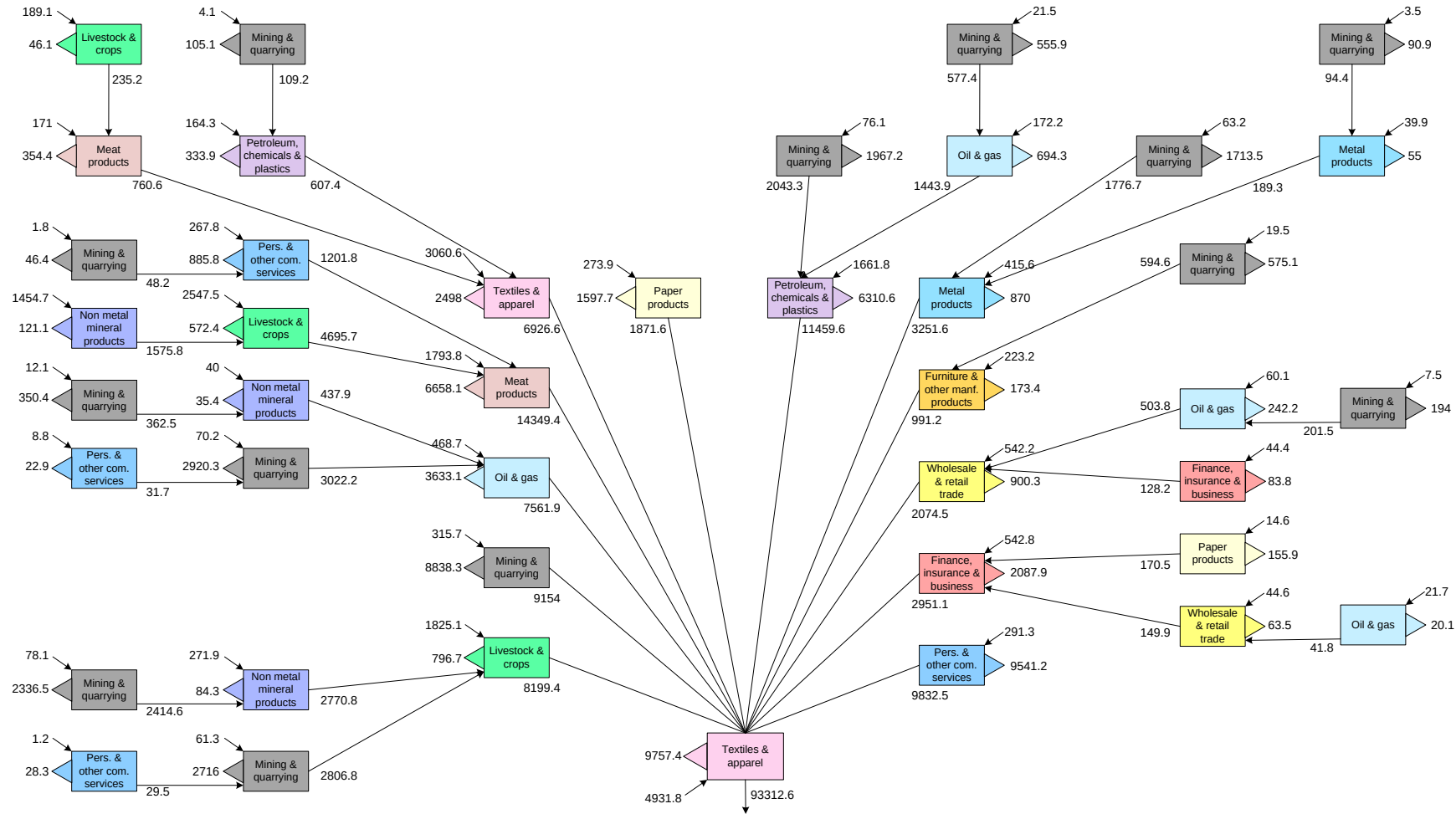


Figure 12.8 - Phosphorus Waste Generated in Producing One Tonne of Textiles and Apparel Products, 2004 (Grams)

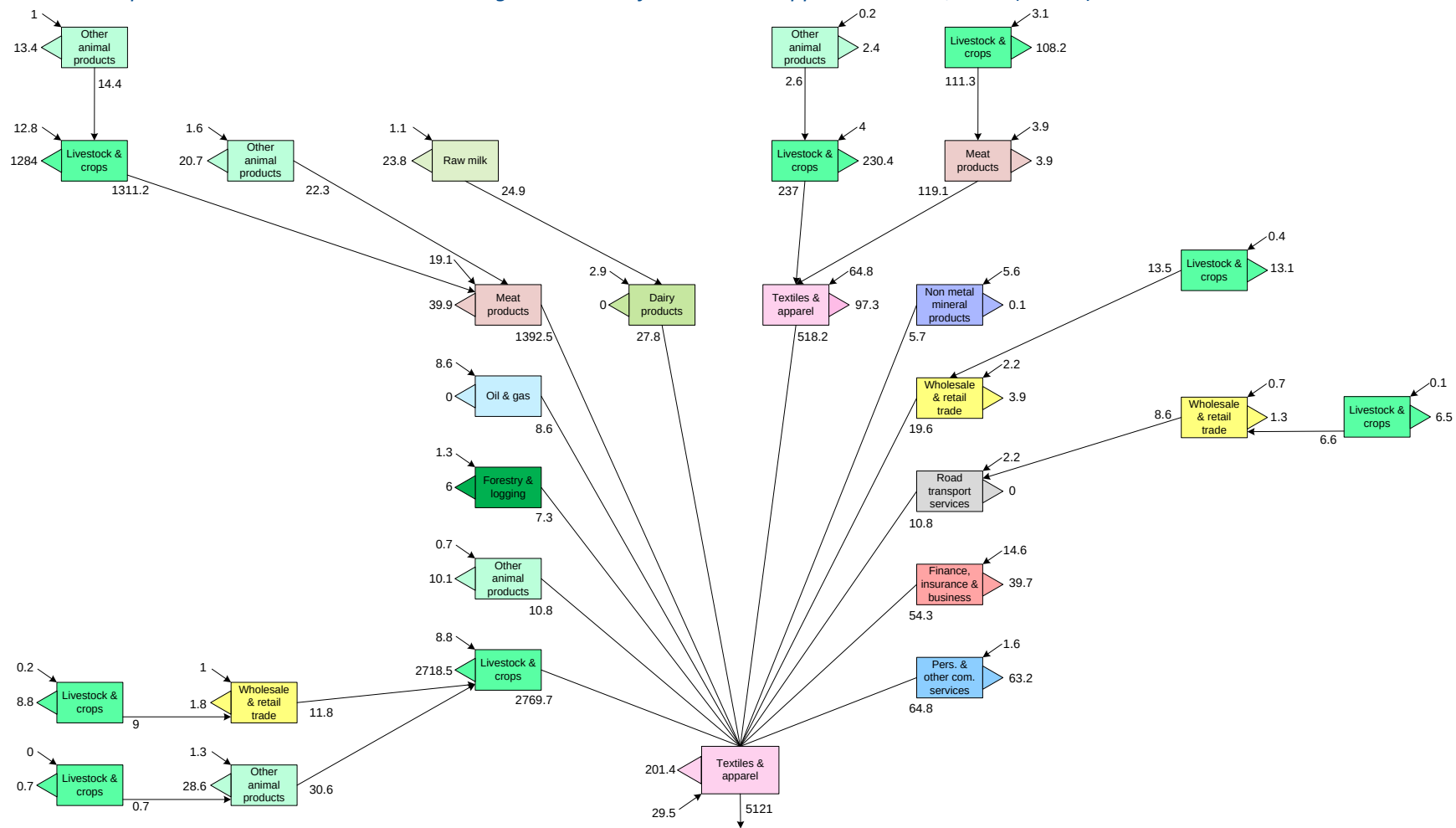
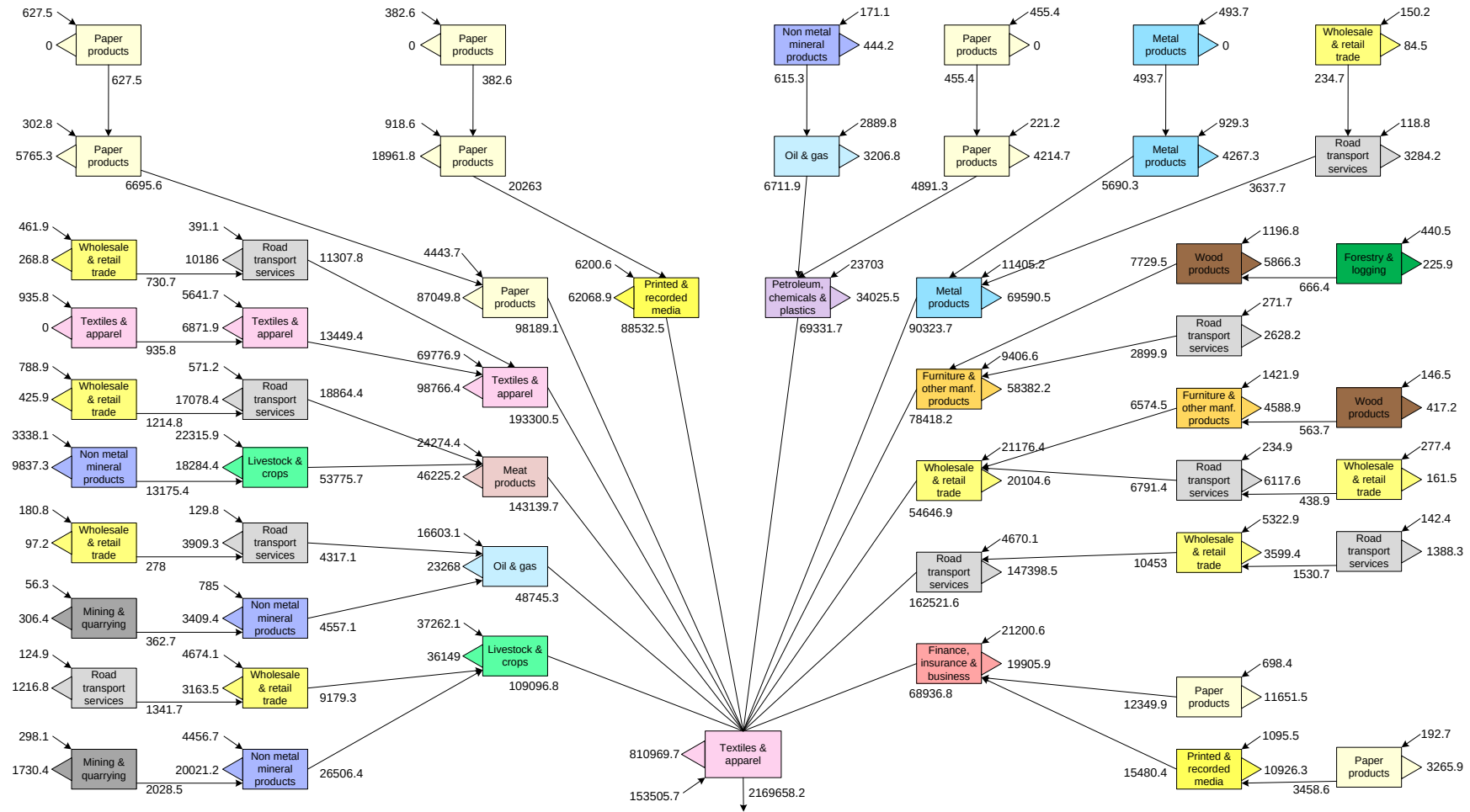


Figure 12.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Textiles and Apparel Products, 2004 (Grams)



13. Wood Product Manufacturing

Description

ANZSIC Codes covered:

- 141 – Log Sawmilling and Timber Dressing
- 149 – Other Wood Product Manufacturing (prefabricated building, veneer and plywood manufacturing)

Main commodities supplied:

- Wood chips and processed timber

GDP 2016 = \$1.406 billion

Rank = 25th

Average annual growth rate
2006 to 2016 = 1.12%

Rank = 28th

Employment 2016 = 14,972

Rank = 22nd

Economic Overview

New Zealand is a relatively small player in the international market for wood products; in 2004, it was the 17th largest exporter of wood panels and the 14th largest exporter of sawn wood.¹⁸³ In 2019, New Zealand supplied 1.1% of the world's total supply of industrial wood.¹⁸⁴ Key destinations for wood products are China, which imports 48% of total New Zealand forestry exports. This value is driven by log and pole exports which make up 82% of NZ exports to China, as of 2017.¹⁸⁵ The initial development of the wood products manufacturing industry was largely in sawmilling with the marketing emphasis on the building industry.¹⁸⁶ Radiata pine, which makes up 90% of all forestry plantings in New Zealand,¹⁸⁷ is commonly seen to have significant shortcomings in higher value end-uses compared with other species because its fast growth rate produces wood of a quality that is not suited to all building uses and so it is generally used as a 'carcass' material for veneering. However, a focus on providing technical information has changed this outlook, as marketing efforts to elevate radiata pine from a wood regarded in the Japanese market as suitable only for packaging influenced demand to an extent where it is now imported by Japan as a multi-purpose building timber.¹⁸⁸ Thus, as log quality improved, radiata pine was more increasingly used for value-added reprocessing, where specialist lumber factories turn sawn timber into products such as clear pine mouldings, panels, speciality packaging and wooden componentry.

Exports were initially a minor concern to a domestically focused industry, mainly a way of utilizing material surplus to domestic needs. However, the major structural reforms of the New Zealand economy in the mid-1980s resulted in the previously highly protected domestic market being opened to more international competition, investment and trade. Aggregated investment in wood-processing

¹⁸³ Food and Agriculture Organization of the United Nations, Rome. (2007). *State of the World's Forests*. Retrieved from <http://www.fao.org/docrep/009/a0773e/a0773e00.htm>

¹⁸⁴ Te Uru Rākau. (2020, January 13). *Forestry*. Retrieved from <https://www.mpi.govt.nz/news-and-forecasting/forestry/>

¹⁸⁵ Te Uru Rākau. (2020, January 13). *Wood Product Markets*. Retrieved from <https://www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/>

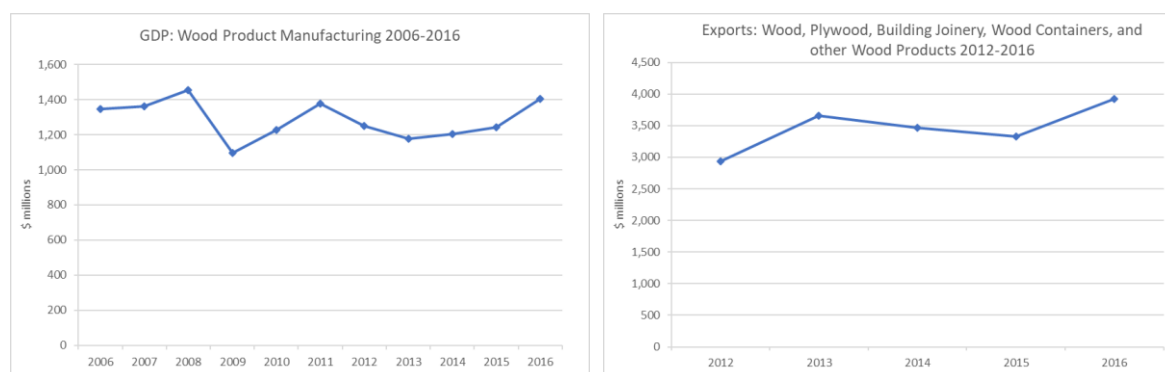
¹⁸⁶ Ministry of Forestry. (1988). Report #4932.

¹⁸⁷ Ministry for Primary Industries. (2016). *Wood Availability Forecasts - New Zealand 2014-2050*. Wellington. Retrieved from <https://www.teururakau.govt.nz/dmsdocument/14221-wood-availability-forecasts-new-zealand-2014-2050>

¹⁸⁸ Horgan, G.P. and Maplesden, F.M. (1995). *The role of marketing in developing exports of plantation-grown New Zealand radiata pine*. *Unasylva*. 183(46):29-36

facilities increased as a result with \$250 million invested in 1990 in wood processing facilities (sawmills, MDF and veneer plants, drying kilns), and a reasonable rate of investment continued through the 1990s.¹⁸⁹ Domestic demand for wood products is relatively small, not demanding of sophisticated or specialised products and prone to boom/bust cycles linked to construction, making the sector is highly export-oriented. With total sales at \$4.58 billion, this sector made up 6.7% of the manufacturing industry as a whole in 2004.¹⁹⁰ As of 2016, around 70% of the wood from planted production forests were being exported in a variety of forms.¹⁹¹

Sector Trends



Production

In total over the 10-year period from 2006 to 2016, the wood product manufacturing sector has remained fairly constant, starting and finishing the period with production close to \$1.4 billion. However, fluctuations throughout the period have been felt. Most notably from 2008 to 2009, as a result of the GFC, where production decreased 24.67%, from \$1.46 billion to \$1.1 billion. A strong couple of years recovery followed this, returning production to almost pre-GFC levels. Following this recovery, the sector's production decreased from 2011 to 2013 by 14.46% and has again since recovered to similar levels pre-GFC. Due to the close ties to the construction industry, factors influencing domestic demand include inflation, mortgage interest rates and disposable incomes, and changes in any of these areas will have a direct effect on new building rates and thus the demand for products in this sector. This is illustrated with the downturn seen in wood product manufacturing as a result of the GFC, where construction was forgone. Woodchips produced in New Zealand are largely consumed by the company Carter Holt Harvey, which is vertically integrated from forest to mills and accounts for a large proportion of domestic demand for products such as wood chips, sawn timber and packaging.

Exports

The value of exports in this sector has shown strong growth, both at the start and end of the 4-year period shown, with the value of exports increasing by 24.51% and 17.92%, respectively. Throughout the middle of the period, a slight decrease in the value of exports was seen, decreasing from \$3.65 billion to \$3.33 billion. A downturn in 2015 in the value of exports may be due to the drop of forestry product prices as a result of a weakening Chinese housing market. Low supply from other regions and economic stimulus measures in China in 2016 helped increase New Zealand's exports of wood

¹⁸⁹ Le Heron, R. and Pawson, E (Eds.). (1996). *Changing Places, New Zealand in the Nineties*. Auckland, New Zealand: Longman Paul.

¹⁹⁰ Reserve Bank of New Zealand. (2005). *Overview of the Manufacturing Sector, Bulletin, 68(1)*, 23-33.

¹⁹¹ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

products.¹⁹² High wages and distance to overseas markets provide additional barriers to growth in exports, as is the case in many manufacturing sectors in New Zealand.

Life Cycle Assessment Diagrams

Energy (Figure 13.1, Figure 13.2, Figure 13.3)

Wood products were found to have a total energy intensity of 2,008.2 MJ_E per tonne of product (2 MJ_E/kg). The total energy intensity measured in conventional terms for this sector is 4,975 MJ_H/tonne. It is difficult to compare this total energy intensity with literature values as the sector produces “sawmill logs” and “dressed timber” which will have a comparatively low energy intensity, compared with the more processed other products produced by the sector such as “plywood”, “veneer products” and “particleboard”. Reported levels of total energy intensity for various wood products are for example, UK general timber at 8,500 MJ_H per tonne of product, UK plywood at 15,000 MJ_H per tonne of product, and UK veneer particle board for furniture at 23,000 MJ_H per tonne of product.¹⁹³ Whereas total energy intensity for producing sawmill logs, is likely to be in the order of 1,000 to 2,000 MJ_H /tonne given that logs produced by the “Forestry and Logging” sector have a total energy intensity of 644 MJ_H/tonne.

Direct energy use into the production of wood products was 51% of the total energy intensity, measuring 1,033.1 MJ_{OE} per tonne product produced. The EECA in use database reports that a total of 16,737.020 TJ of energy was used in the wood processing and wood products sector in 2006/07. *Indirect energy use*, on the other hand, made up 49% of the total energy intensity, measuring 975.1 MJ_{EO} per tonne of wood product. *The main indirect energy into wood products came from; (i) energy embodied in forestry and logging at 392.2 MJ_{OE} per tonne of product produced; (ii) energy embodied in road transport services at 154.3 MJ_{OE} per tonne of product produced; (iii) energy embodied in metal products at 103.4 MJ_{OE} per tonne of product produced; (iv) energy embodied in petroleum, chemicals and plastics at 70.9 MJ_{OE} per tonne of product produced.*

Land (Figure 13.4)

Wood products have a total land intensity of 1,642 m² per tonne of product produced; ranking the sector the 8th largest out of the 20 product producing sectors covered by this publication. Direct land use for the production of wood products was minuscule at only 2% of the total land intensity, measuring 31.6 m² per tonne of product produced. Indirect land use makes up the majority of total land use at 98% measuring 1,610.4 m² per tonne of product produced. The major indirect land uses came from; (i) land embodied in forestry and logging at 1,145.9 m² per tonne of product produced; (ii) land embodied in livestock and crops at 86.8 m² per tonne of product produced; (iii) land embodied in wholesale and retail trade at 13.1 m² per tonne of product produced; (iv) land embodied in textile and apparel at 12.6 m² per tonne of product produced.

Water Inputs (Figure 13.5)

Wood products consumed 308.2 litres of water inputs per tonne of product produced. This sector ranks as the 19th highest consumer of water out of the 20 product producing sectors covered in this publication, indicating that this is not a water-intensive sector.

¹⁹² New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from; <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

¹⁹³ Hammond, G.P., Jones, C.I. (2008). Embodied Energy and Carbon in Construction Materials. *Proceedings of the Institution of Civil Engineers – Energy*, 161(2), 87-98.

Direct water inputs made up 4% of the total, using 11.9 litres per tonne of wood product produced. While *indirect water inputs* made up the majority of the total at 94%, using 296.3 litres per tonne of wood product produced. *Indirect water inputs into wood products came mainly from; (i) water inputs embodied in wholesale and retail trade at 113.4 litres per tonne of product produced; (ii) water inputs embodied in metal products at 59.1 litres per tonne of product produced; (iii) water inputs embodied in paper products at 57.3 litres per tonne of product produced; (iv) water inputs embodied in mining and quarrying at 14 litres per tonne of product produced.*

Landfill Wastes (Figure 13.6)

Wood products were found to generate 45,630.2 grams (45 kg) of landfill waste per tonne of product produced. The landfill waste generated by the wood product sector is ranked 11th highest out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by wood products was 84% of total waste produced or 38,543.1 grams per tonne of product produced. *Landfill waste indirectly generated by wood products was only 16% or 7,087.1 grams per tonne of product produced. The main sources of indirect landfill waste for wood products came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 3,087.6 grams per tonne of product produced; (ii) landfill wastes embodied in forestry and logging at 987.1 grams per tonne of product produced; (iii) landfill wastes embodied in furniture and other manufactured products at 587.6 grams per tonne of product produced; (iv) landfill wastes embodied in wood products at 326.5 grams per tonne of product.*

Water Wastes (Figure 13.7)

Wood products were found to produce 6,103.6 litres of water wastes per tonne of product produced. This makes the wood products sector is the 19th highest producer of water wastes out of the 20 product producing sectors covered by this publication.

Wastewater directly generated by wood products was only 11% of total water waste produced or 671.2 litres per tonne of product produced. *Wastewater indirectly generated* from the production of wood products made up resulting majority at 89% of total wastewater produced, or 5,432.4 litres per tonne of product produced. *The indirect wastewater from wood product production is mostly made up of (i) wastewater embodied in personal and other community services at 1,258.5 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 1,079.8 litres per tonne of product produced; (iii) wastewater embodied in forestry and logging at 858.5 litres per tonne of product produced; (iv) wastewater embodied in mining and quarrying at 779.5 litres per tonne of product produced.*

Phosphorus Wastes (Figure 13.8)

Wood products were found to produce 30.2 grams (0.03 kg) of phosphorus waste per tonne of product produced. Total phosphorus waste was made up mostly of indirect sources, with *direct sources* only making up 1.7% of total phosphorus waste, at 0.5 grams per tonne of wood product produced. The remaining 98.3% of phosphorous wastes or 29.7 grams per tonne of wood product produced *came from indirect sources which were mostly made up of (i) phosphorus waste embodied in forestry and logging at 18.5 grams per tonne of product produced; (ii) phosphorus waste embodied in personal and other community services at 5.3 grams per tonne of product produced; (iii) phosphorus waste embodied in livestock and crops at 1.7 grams per tonne of product produced.*

Energy Greenhouse Gases (Figure 13.9)

In terms of CO₂ greenhouse gas emissions, wood products emitted 496,970.9 grams (496 kg) of energy-related CO₂ per tonne of product produced. This sector ranks as the 11th highest emitter of energy-related CO₂ per tonne among the 20 product producing sectors covered in this publication. This amount is similar to reported energy-related CO₂ of various wood products such as UK general timber at 460,000 grams of energy-related CO₂ per tonne of product produced and UK hardwood at 860,000 grams of energy-related CO₂ per tonne of product produced.¹⁹⁴

Energy-related CO₂ directly generated wood products was 73% of the total CO₂ emitted at 362,347.8 grams per tonne of product produced. Energy-related CO₂ indirectly generated by the production of wood products was 27% or 134,623.1 grams. The indirect energy-related CO₂ from the production of wood products was mostly made up of; (i) energy embodied in forestry and logging at 41,456.9 MJ_E per tonne of product produced; (ii) energy embodied in road transport services at 21,362.4 MJ_E per tonne of product produced; (iii) energy embodied in paper products at 11,307.2 MJ_E per tonne of product produced; (iv) energy embodied in furniture and other manufactured products at 11,218.9 MJ_E per tonne of product produced.

¹⁹⁴ Hammond, G.P., Jones, C.I. (2008). Embodied Energy and Carbon in Construction Materials. *Proceedings of the Institution of Civil Engineers – Energy*, 161(2), 87-98.

Figure 13.1 - Total Energy Inputs Required to Produce One Tonne of Wood Products, 2004 (MJ_E, Oil Equivalents)

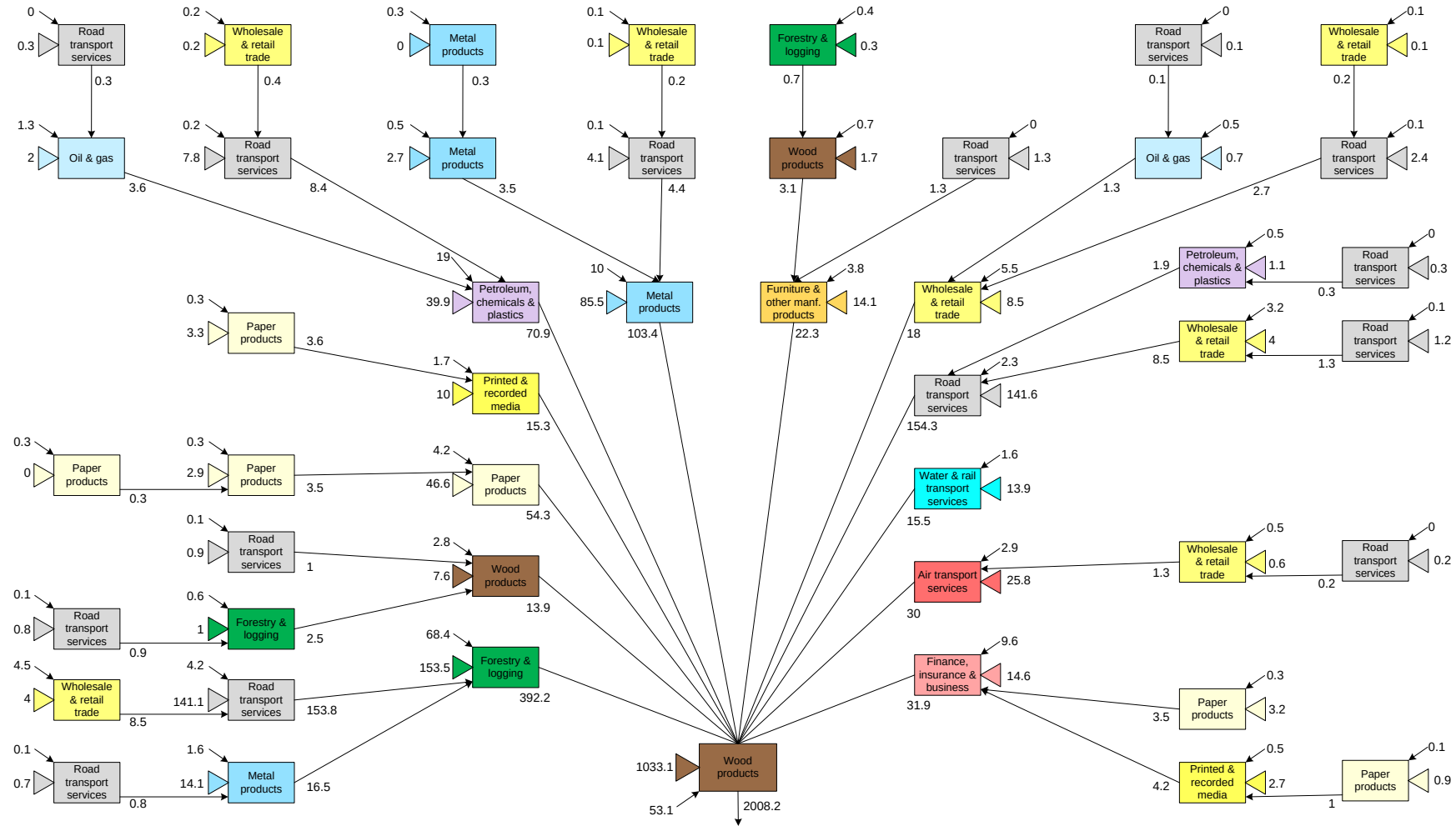


Figure 13.2 - Electricity Inputs Required to Produce One Tonne of Wood Products, 2004 (MJ, Heat Equivalents)

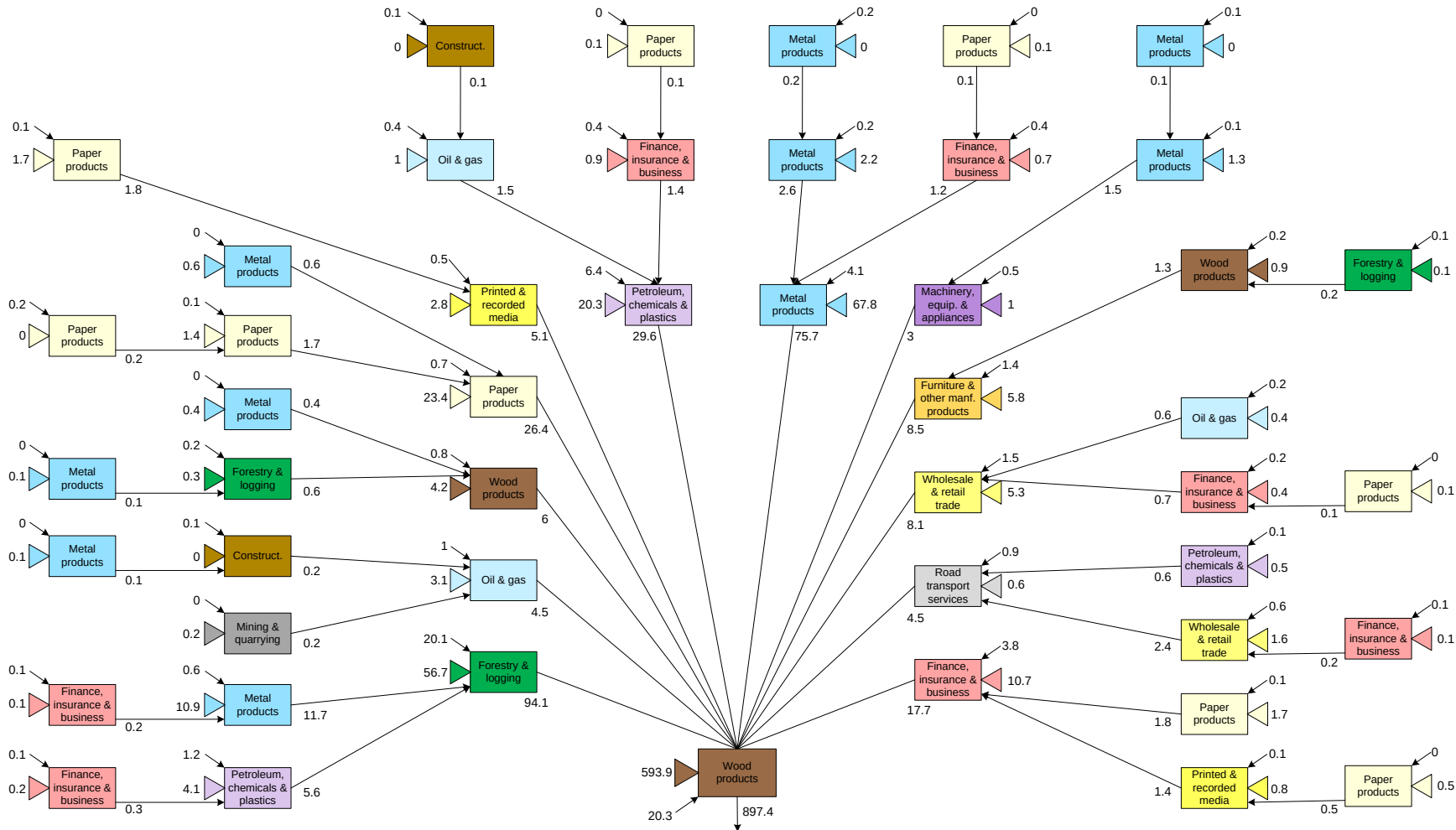


Figure 13.3 - Fossil Fuel Inputs Required to Produce One Tonne of Wood Products, 2004 (MJ, Heat Equivalents)

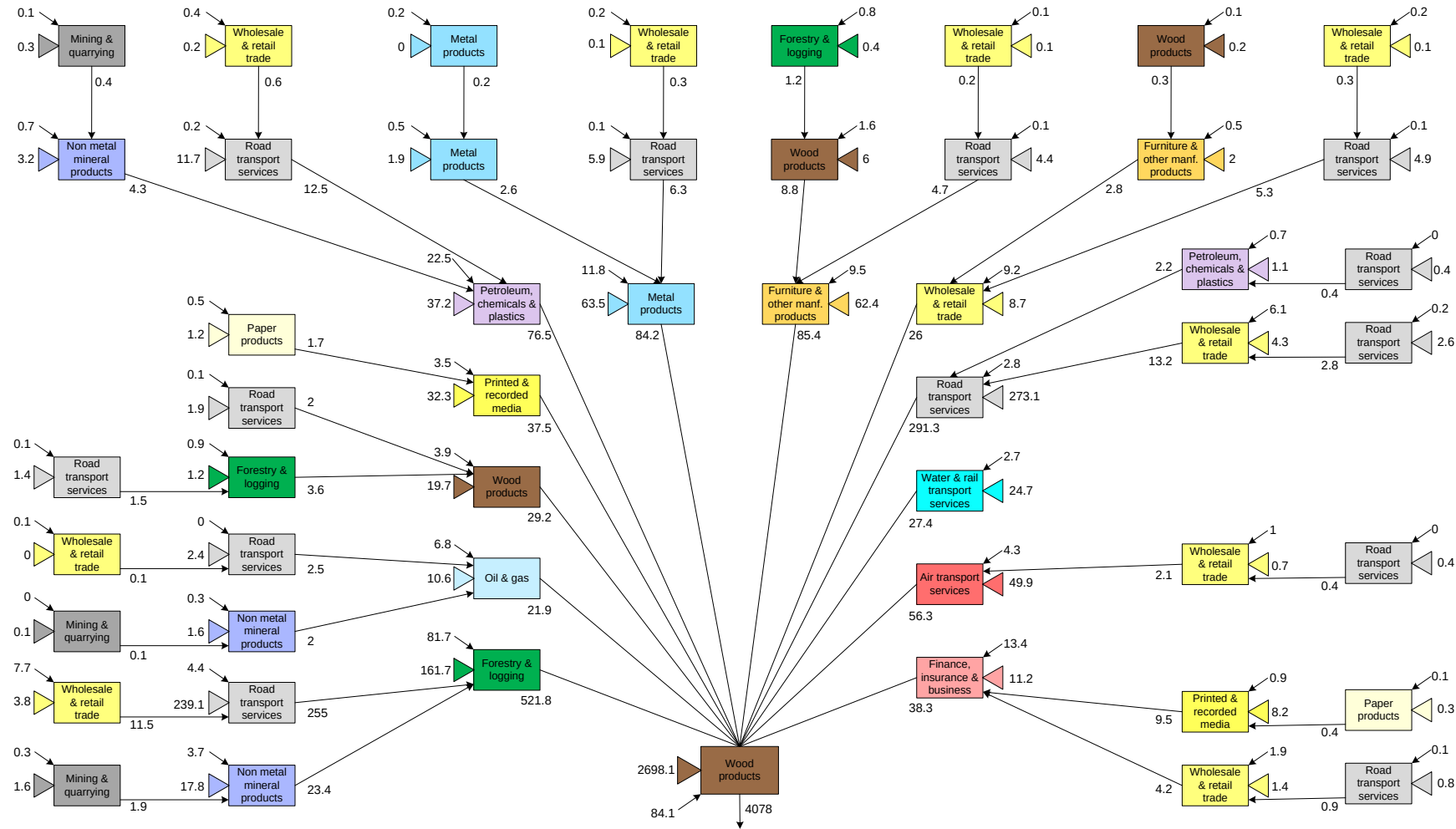


Figure 13.4 - Land Required to Produce One Tonne of Wood Products, 2004 (m²)

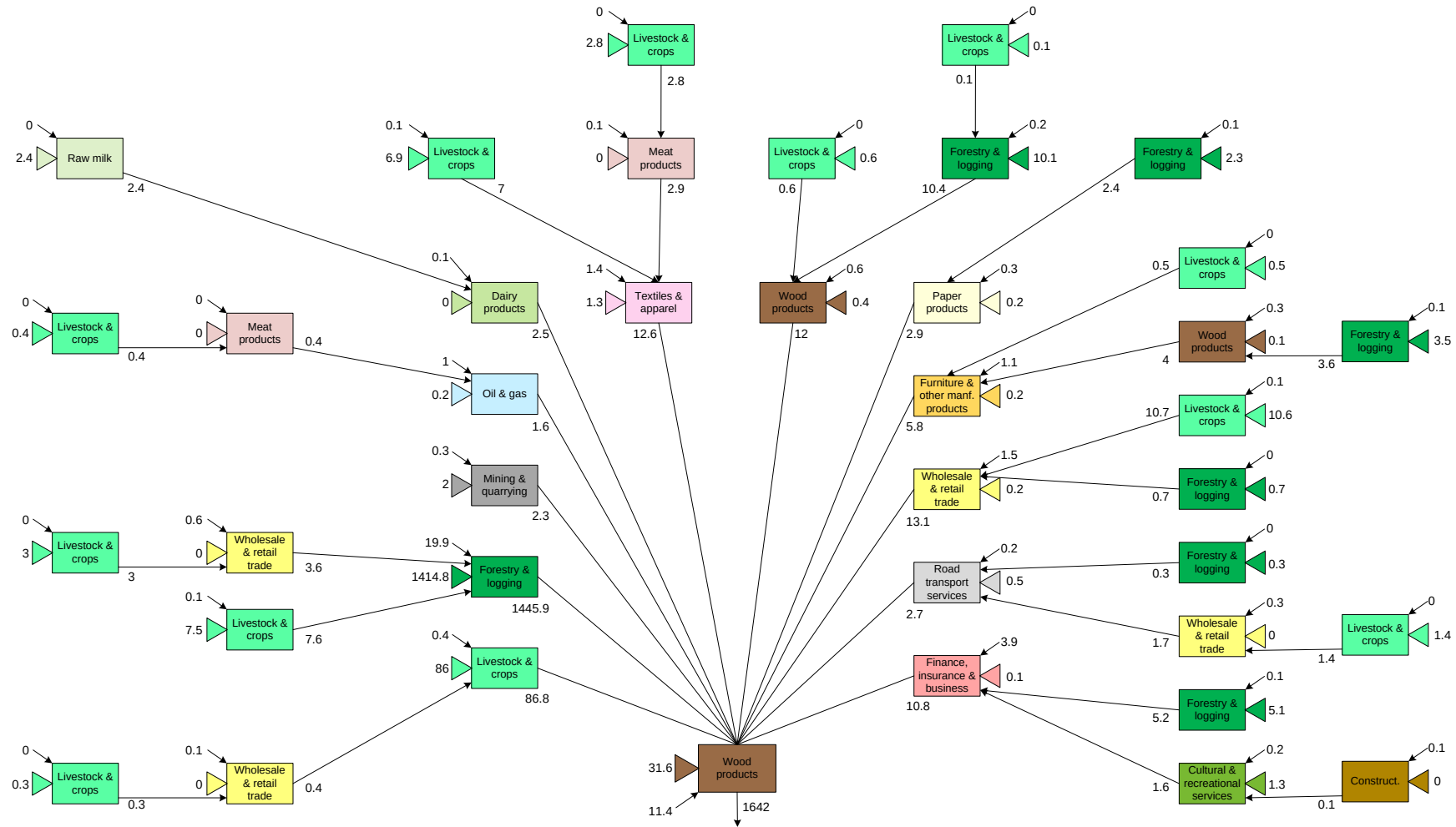


Figure 13.5 - Water Inputs Required to Produce One Tonne of Wood Products, 2004 (Litres)

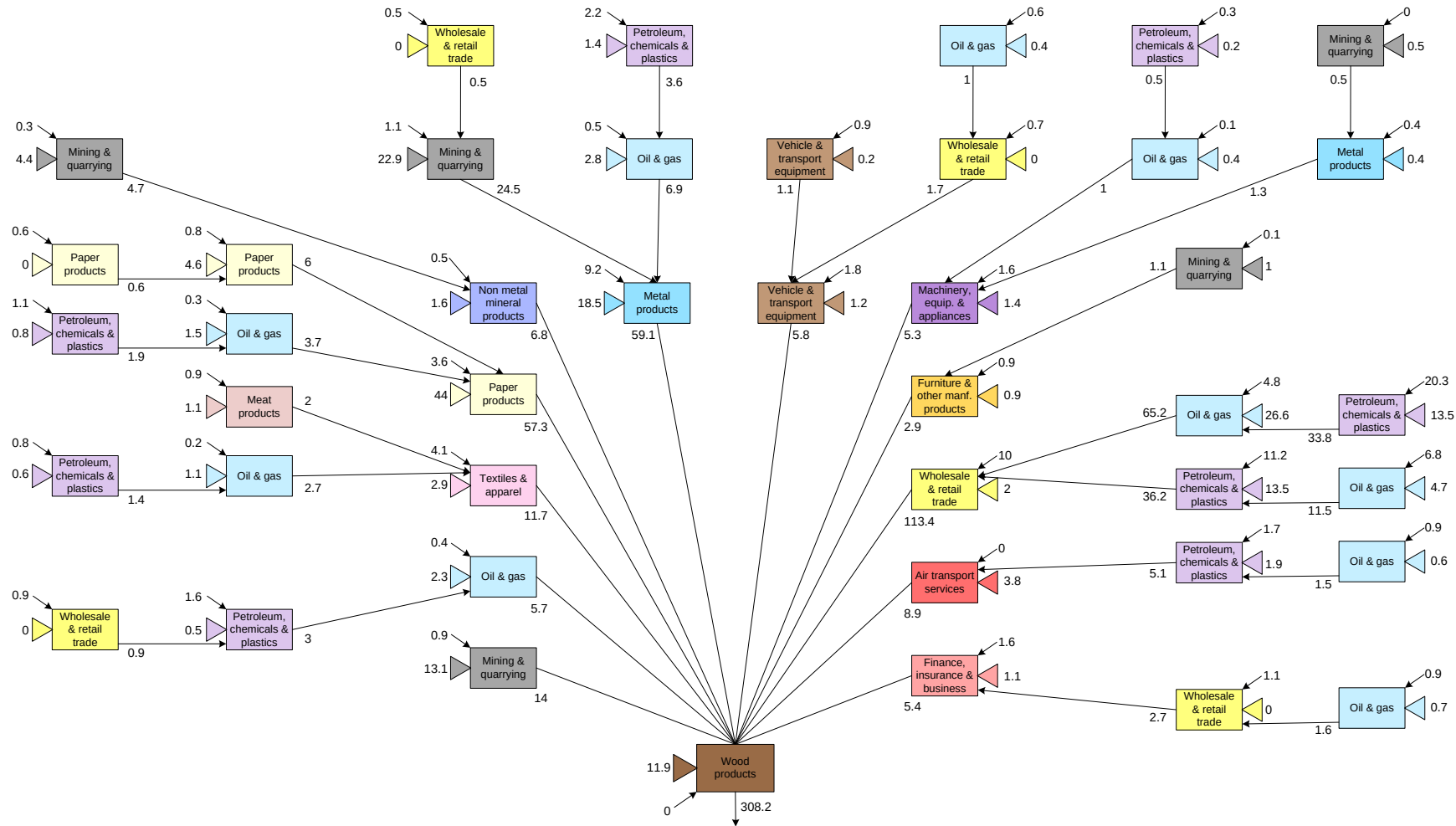


Figure 13.6 - Landfill Waste Generated in Producing One Tonne of Wood Products, 2004 (Grams)

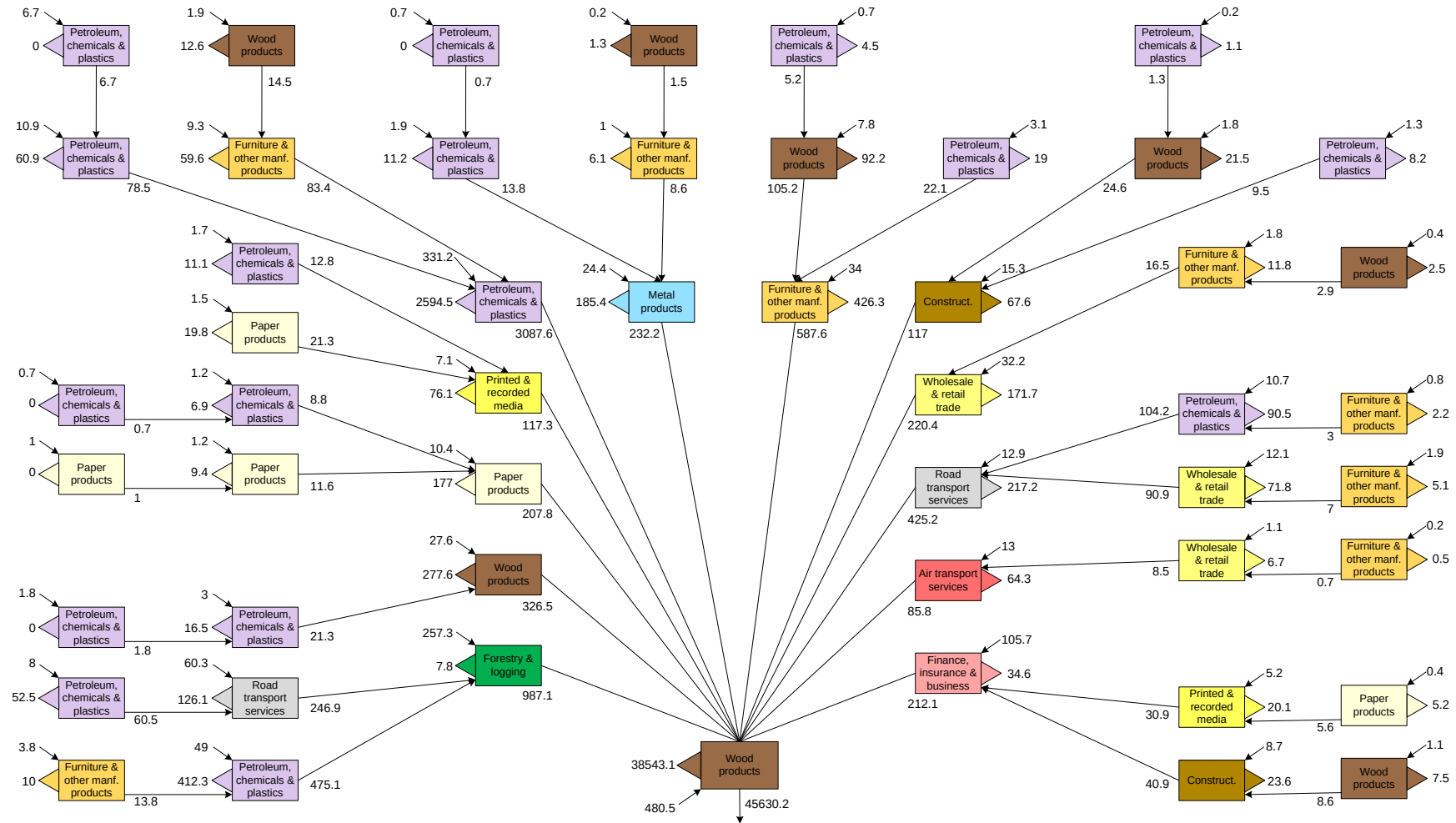


Figure 13.7 - Water Waste Generated in Producing One Tonne of Wood Products, 2004 (Litres)

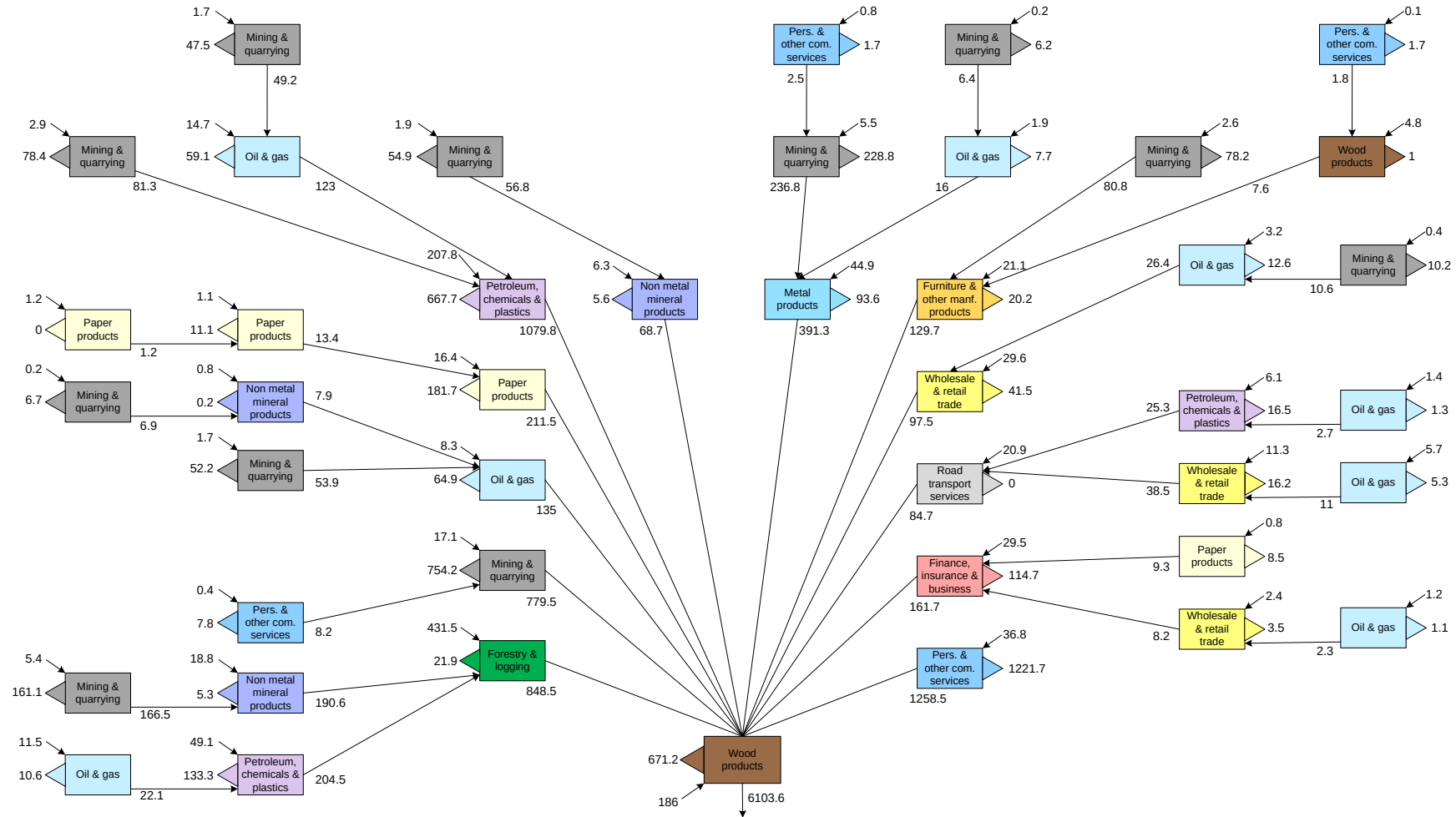


Figure 13.8 - Phosphorus Waste Generated in Producing One Tonne of Wood Products, 2004 (Grams)

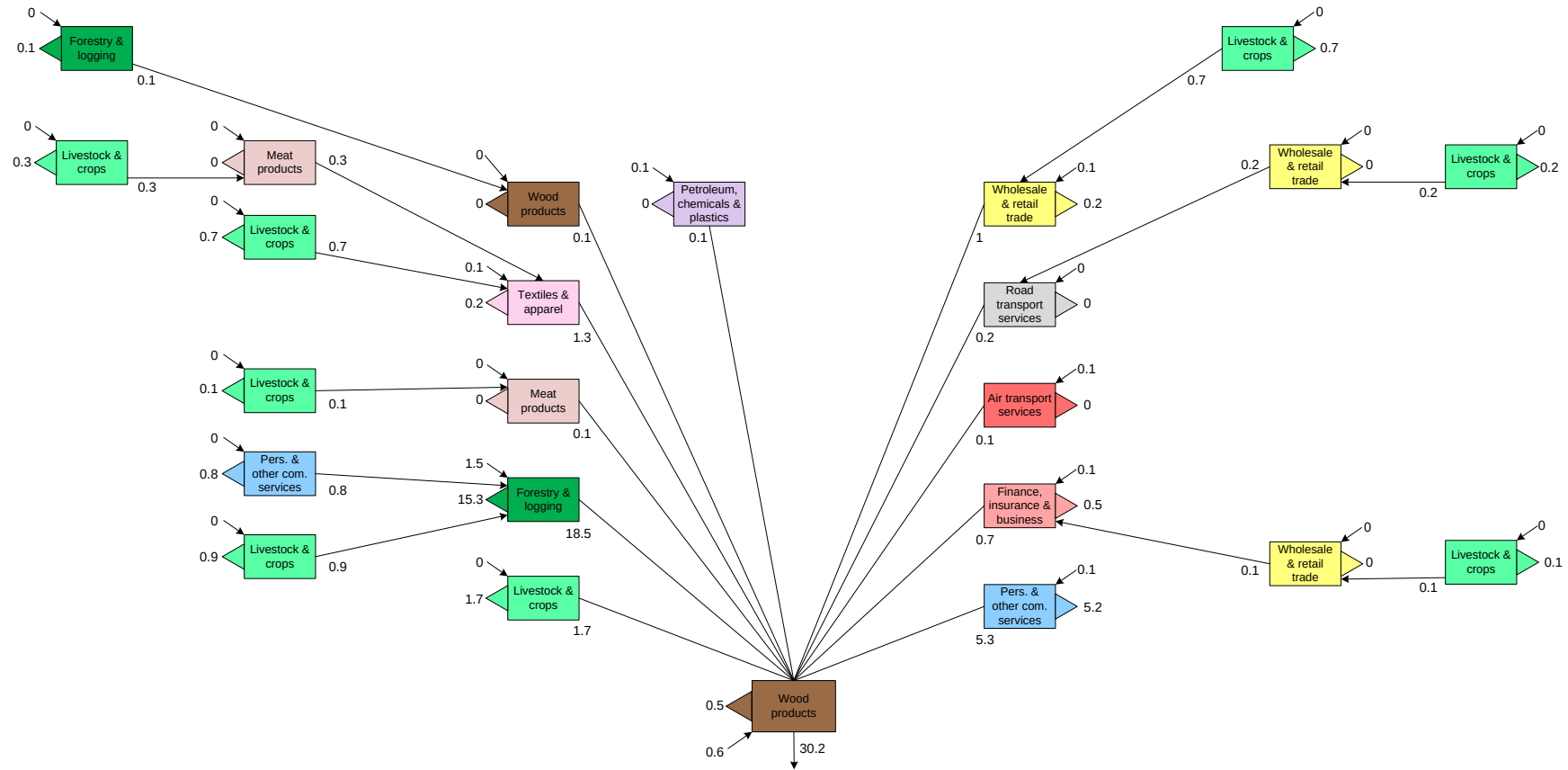
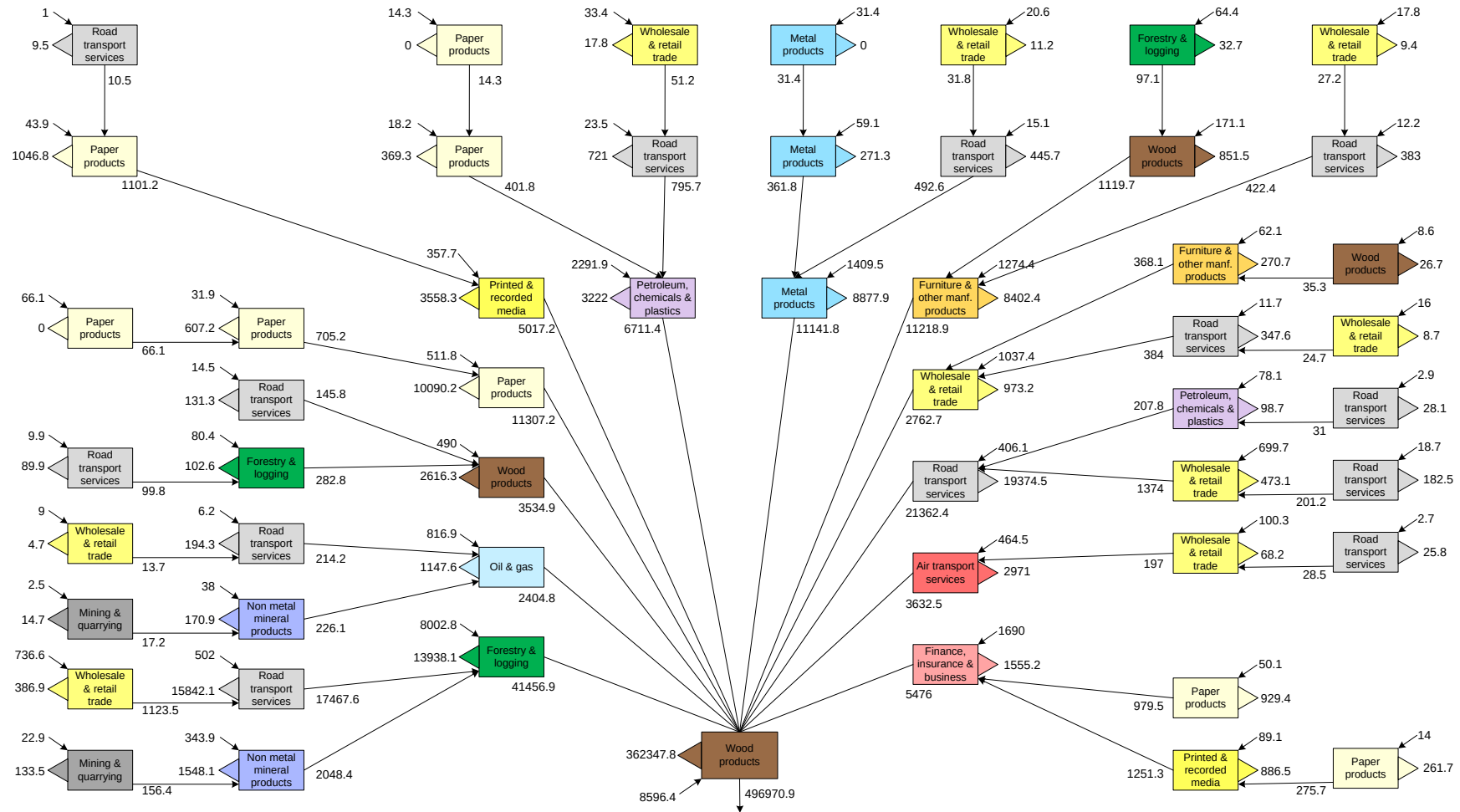


Figure 13.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Wood Products, 2004 (Grams)



14. Paper and Paper Product Manufacturing

Description

ANZSIC Codes covered:

- 151 – Pulp, paper and paperboard manufacturing
- 152 – Converted paper product manufacturing (paper bags, stationary)

Main commodity supplied:

- Paper products

GDP 2016 = \$0.699 billion
Rank = 30th

Average annual growth rate
2006 to 2016 = -1.53%
Rank = 32nd

Employment 2016 = 3,307
Rank = 33rd

Economic Overview

New Zealand is a minor player in the international market in the paper manufacturing sector, ranking 48th in the world in export volumes of paper with 0.2% of the world paper supply in 2019.¹⁹⁵ The key destination for paper products is Australia, where the bulk of wood pulp goes. The offcuts of the main tree species used in New Zealand (radiata pine) have a high fibre content well suited to the papermaking process which has helped to boost this industry. Large numbers of radiata pine were planted and fully mature before the papermaking industry was fully established, and the expansion of the industry led to a planting boom in the 1980s.¹⁹⁶ Fully integrated forestry operations like the Kinleith and Kawerau mills produce a range of pulp, paper and sawn timber which provide economies of scale. Most of the value created through the international exchange of forest-based products comes from value-added products: measured by the value of gross inter-regional trade, pulp and paper create more than ten times the value of wood raw materials.¹⁹⁷ In 2018, the wood and paper sector made up 1% of total manufacturing sector sales.¹⁹⁸

The paper and paper products industry in New Zealand was established as a result of state promotion of import substitution.¹⁹⁹ From 1985 onwards, the deregulated economy required productivity improvements and restructuring to facilitate competing in the global marketplace. In the early 1980's it took six worker hours at Kawerau to produce one tonne of paper compared with one worker hour in North America,²⁰⁰ and such realities led to the necessity of greater efficiency and productivity to improve the international competitiveness of the industry. New technology introduced into the pulp and paper industry in the 1980s was successful in doing just that, as subsequently domestic consumption of paper and paperboard as a percentage of total production declined in 2006, 72% of total production was exported compared to just 35% in 1989. In New Zealand in 1980, there were

¹⁹⁵ Workman, D. (2019, December 6). *Paper Exports by Country*. Retrieved from World's Top Exports: <http://www.worldstopexports.com/paper-exports-by-country/>

¹⁹⁶ Roche, Michael. (1990). *History of New Zealand Forestry*. Wellington: GP Print Ltd.

¹⁹⁷ Rytönen, A. (2003). *Market access of tropical timber*. Final report submitted to the International Tropical Timber Council, Porvoo, Finland.

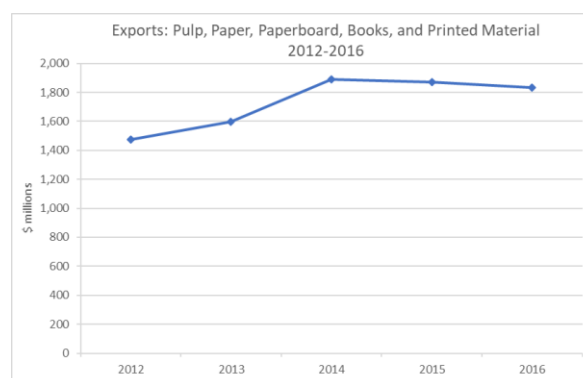
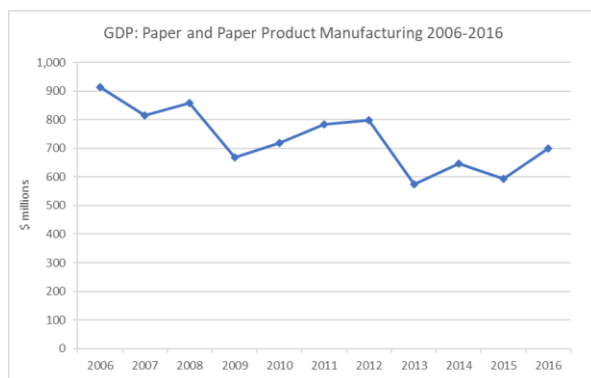
¹⁹⁸ Ministry of Business, Innovation and Employment. (2018). *Beyond Commodities: Manufacturing into the Future*. Wellington. Retrieved from <https://www.mbie.govt.nz/assets/f0f81b6194/new-zealand-manufacturing-sector-report-2018.pdf>

¹⁹⁹ Healy, B. (1982). *A Hundred Million Trees: The story of New Zealand Forest Products*. Auckland.

²⁰⁰ Roche, Michael. (1990). *History of New Zealand Forestry*. Wellington: GP Print Ltd.

seven plants in the pulp and paper/paperboard industry and the same number (although not the same plants) were in business in 2008,²⁰¹ illustrating that the large increases in volume were due to increases in productivity.

Sector Trends



Production

Growth in production in the paper and paper products sector has been rather volatile over the 10-year period between 2006 and 2016. Overall, there has been a general downward trend in the level of production, decreasing from \$915 million in 2006 to \$699 million in 2016. A large decrease in production as a result of the GFC, causing production to decrease by 22.14% between 2008 and 2009. A recovery period was seen following this downturn with 3 years of growth. However, production failed to reach pre-GFC levels. Subsequently, following this recovery the sector suffered another large downturn, with production decreasing 27.94%, from \$798 million to \$575 million. In the three years following the second downturn, the sector has experienced mixed growth. Domestic demand for goods and services in this sector stems mainly from the printing industry, publishing and recorded media manufacturing, wholesale trade and households, meaning the sector is highly reliant on conditions in these sectors of the economy. Declining demand for newspapers is likely to further slow paper production in New Zealand, as news consumption turns to digital platforms.²⁰² Additionally, any increase in log prices lifts the costs of raw materials for paper manufacturers and impacts on profitability.

Exports

From 2012 through to 2014, the paper and paper products sector experienced strong growth in the value of exports, increasing from \$1.47 billion to \$1.89 billion, an increase of 28.30%. Following this growth, the value of exports has remained rather stagnant with a slight decline over the final two years of the period. Although domestic producers have made many attempts to stay globally competitive, pulp and paper exports have become a diminishing percentage of export returns from forestry.

²⁰¹ Forest Industry Engineering Association. (2008).

²⁰² APNZ. (2012, September 12). *Paper mill confirms plans to halve production*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=10833117

Life Cycle Assessment Diagrams

Energy (Figure 14.1, Figure 14.2, Figure 14.3)

Paper products were found to have a total energy intensity of 9,681.9 MJ_{OE} per tonne of product (9.7 MJ_E/kg), ranking 7th highest out of the 20 product producing sectors covered in this publication. *Direct energy* use was 81% of the total energy intensity, measuring 7,832 MJ_H per tonne of paper product produced. *Indirect energy use* was only 19% of the total energy intensity, measuring 1,849.9 MJ_H per tonne of paper product produced.

The main indirect energy uses in the production of paper products came from; (i) energy embodied in paper products at 1,002.8 MJ_{OE} per tonne of product produced; (ii) energy embodied in metal products at 206.7 MJ_{OE} per tonne of product produced; (iii) energy embodied in forestry and logging 144.6 MJ_{OE} per tonne of product produced; (iv) energy embodied in road transport services at 85.6 MJ_{OE} per tonne of product produced.

Land (Figure 14.4)

Paper products have a total land intensity of 489.5 m² per tonne of product produced, ranking the sector 16th highest in terms of land intensity out of the 20 product producing sectors covered in this publication. *Direct land use* was minuscule at only 0.4% of the total land intensity at 1.9 m² per tonne of product produced. *Indirect land use* makes up the majority of the paper product's total land intensity at 99.6% measuring 487.6 m² per tonne of product produced.

The major indirect land uses for paper products come from; (i) land embodied in forestry and logging at 402.9 m² per tonne of product produced; (ii) land embodied in paper products at 50.3 m² per tonne of product produced; (iii) land embodied in textiles and apparel at 5.6 m² per tonne of product produced; (iv) land embodied in finance, insurance and business at 5.1 m² per tonne of product produced.

Water Inputs (Figure 14.5)

Paper products require 13,597.1 litres of water inputs per tonne of product produced, ranking the sector the 12th highest consumer of water compared to the 20 product producing sectors covered in this publication. *Direct water inputs* make up 75% of the total water inputs or 10,221.6 litres per tonne of paper product produced. *Indirect water inputs* make up 25% of the total water inputs or 3,375.5 litres per tonne of paper product produced.

The main indirect water inputs came from; (i) water inputs embodied in paper products at 1,506.8 litres per tonne of product produced; (ii) water inputs embodied in oil and gas at 892.7 litres per tonne of product produced; (iii) water inputs embodied in metal products at 281.4 litres per tonne of product produced; (iv) water inputs embodied in wholesale and retail trade at 211.4 litres per tonne of product produced.

Landfill Wastes (Figure 14.6)

Paper products were found to generate 37,044.5 grams (37 kg) of landfill waste per tonne of product produced. This ranks the sector the 12th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by paper products was 78% of total waste produced or 28,841.7 grams per tonne of product

produced. *Landfill waste indirectly generated* by paper products was 22% of the total waste produced or 8,202.8 grams per tonne of product produced.

The main sources of indirect landfill waste came from; (i) landfill wastes embodied in paper products at 3,646.3 grams per tonne of product produced; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 2,419.8 grams per tonne of product produced; (iii) landfill wastes embodied in metal products at 401.2 grams per tonne of product produced; (iv) landfill wastes embodied in forestry and logging at 327.7 grams per tonne of product produced.

Water Wastes (Figure 14.7)

Paper products were found to produce 39,009.6 litres of wastewater per tonne of product produced. This ranks the sector as the 11th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* by the production of paper products was 81% of the total waste produced at 31,411.3 litres per tonne of product produced. *Wastewater indirectly generated* by paper products made up only 19% of the total wastewater produced or 7,598.3 litres per tonne of product produced.

The indirect wastewater of textile and apparel products were mostly made up of (i) wastewater embodied in paper products at 3,977.3 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 951.5 litres per tonne of product produced; (iii) wastewater embodied in metal products at 781.7 litres per tonne of product produced; (iv) wastewater embodied mining and quarrying at 527.9 litres per tonne of product produced.

Phosphorus Wastes (Figure 14.8)

Paper products were found to produce 8.4 grams of phosphorus waste per tonne of product produced. The total amount of phosphorus produced in the production of textile and apparel products came entirely from indirect sources.

The main sources of this indirect phosphorus waste in the production of paper products came from; (i) phosphorus waste embodied in forestry and logging at 4.6 grams per tonne of product produced; (ii, iii) phosphorus waste embodied in finance business and insurance, as well as paper products, both at 0.7 grams per tonne of product produced; (iii) phosphorus waste embodied in textile and apparel products at 0.6 grams per tonne of product produced.

Energy Greenhouse Gases (Figure 14.9)

In terms of CO₂ greenhouse gas emissions, paper products were found to emit 1,919,182.9 grams of energy-related CO₂ per tonne of product produced (1.9kgCO₂/kg). Energy-related CO₂ emissions from the production of paper products are ranked the 6th highest out of the 20 product producing sectors covered in this publication. This is similar to reported *CO₂ greenhouse gas emissions* produced by various paper products: such as UK paperboard at 1.32kgCO₂/kg, and UK fine paper at 1.50kgCO₂/kg.²⁰³

Energy-related CO₂ directly generated by paper products was the majority of total emissions produced at 85%, or 1,621,959.6 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by paper products made up only 15% of the total emissions produced or 297,223.3 grams per tonne of product produced.

²⁰³ Hammond, G. P., & Jones, C. I. (n.d.). *Inventory of Carbon and Energy (ICE) (Version 1.6a)*. University of Bath, UK, Sustainable Energy Research Team, Department of Mechanical Engineering. Retrieved from <http://web.mit.edu/2.813/www/readings/ICE.pdf>

The indirect energy-related CO₂ emissions from the production of paper products was mostly made up of (i) energy-related CO₂ embodied in paper products at 200,488.8 grams per tonne of product produced; (ii) energy-related CO₂ embodied in metal products at 21,910.6 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services at 16,245.5 grams per tonne of product produced; (iv) energy-related CO₂ embodied in forestry and logging at 15,161.1 grams per tonne of product produced.

Figure 14.1 - Total Energy Inputs Required to Produce One Tonne of Paper Products, 2004 (MJ_E, Oil Equivalents)

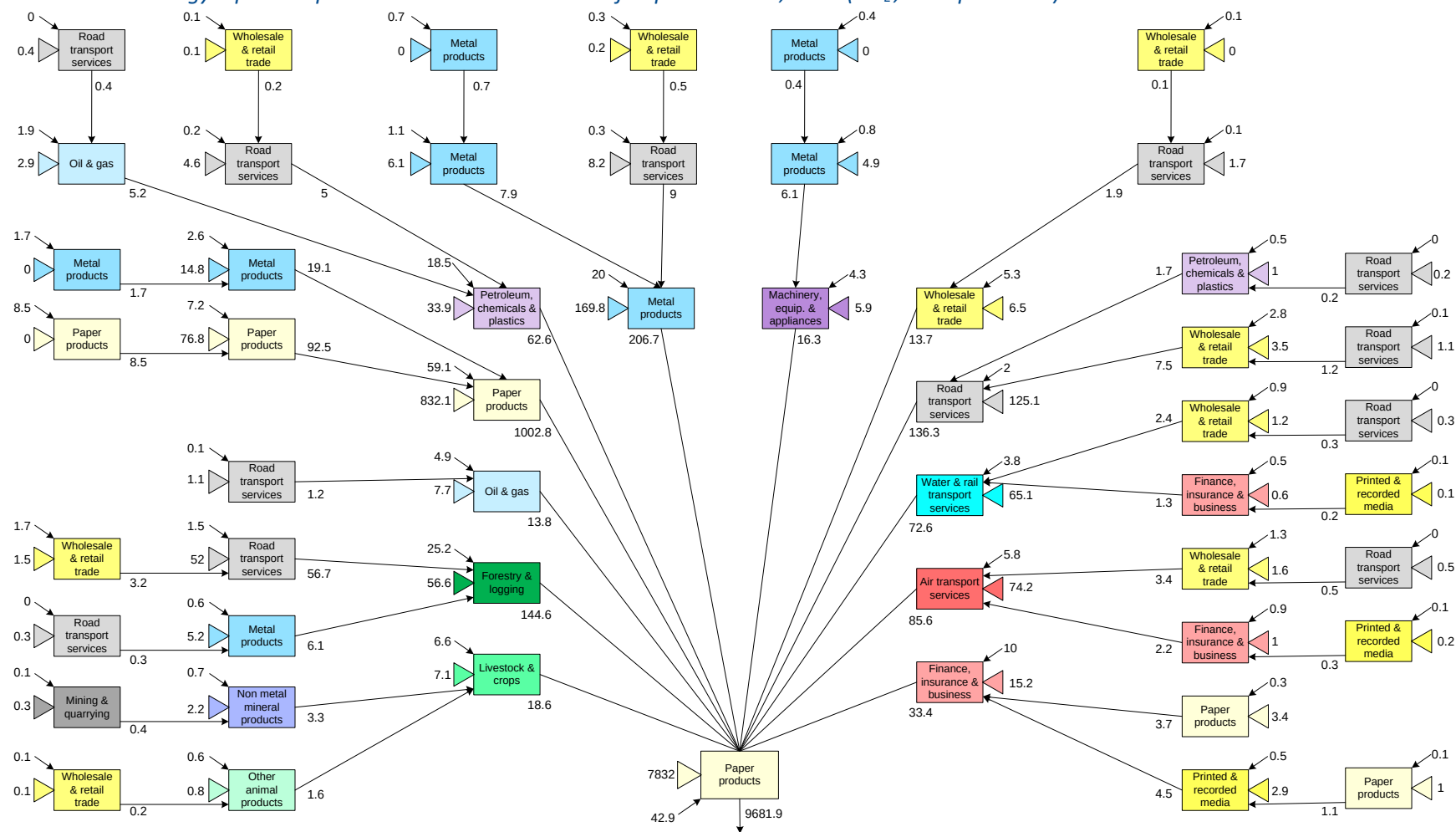


Figure 14.2 - Electricity Inputs Required to Produce One Tonne of Paper Products, 2004 (MJ, Heat Equivalents)

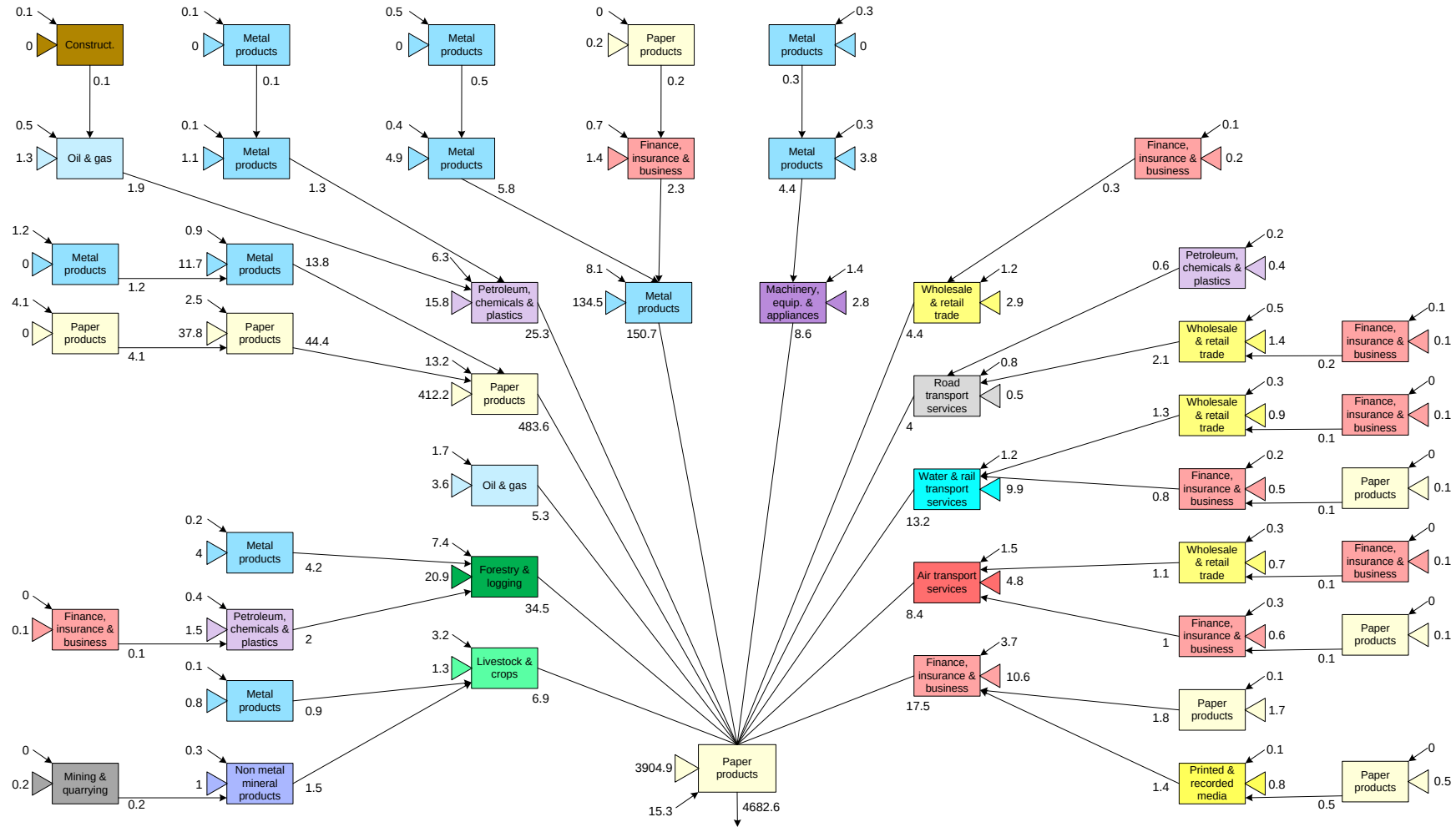


Figure 14.3 - Fossil Fuel Inputs Required to Produce One Tonne of Paper Products, 2004 (MJ, Heat Equivalents)

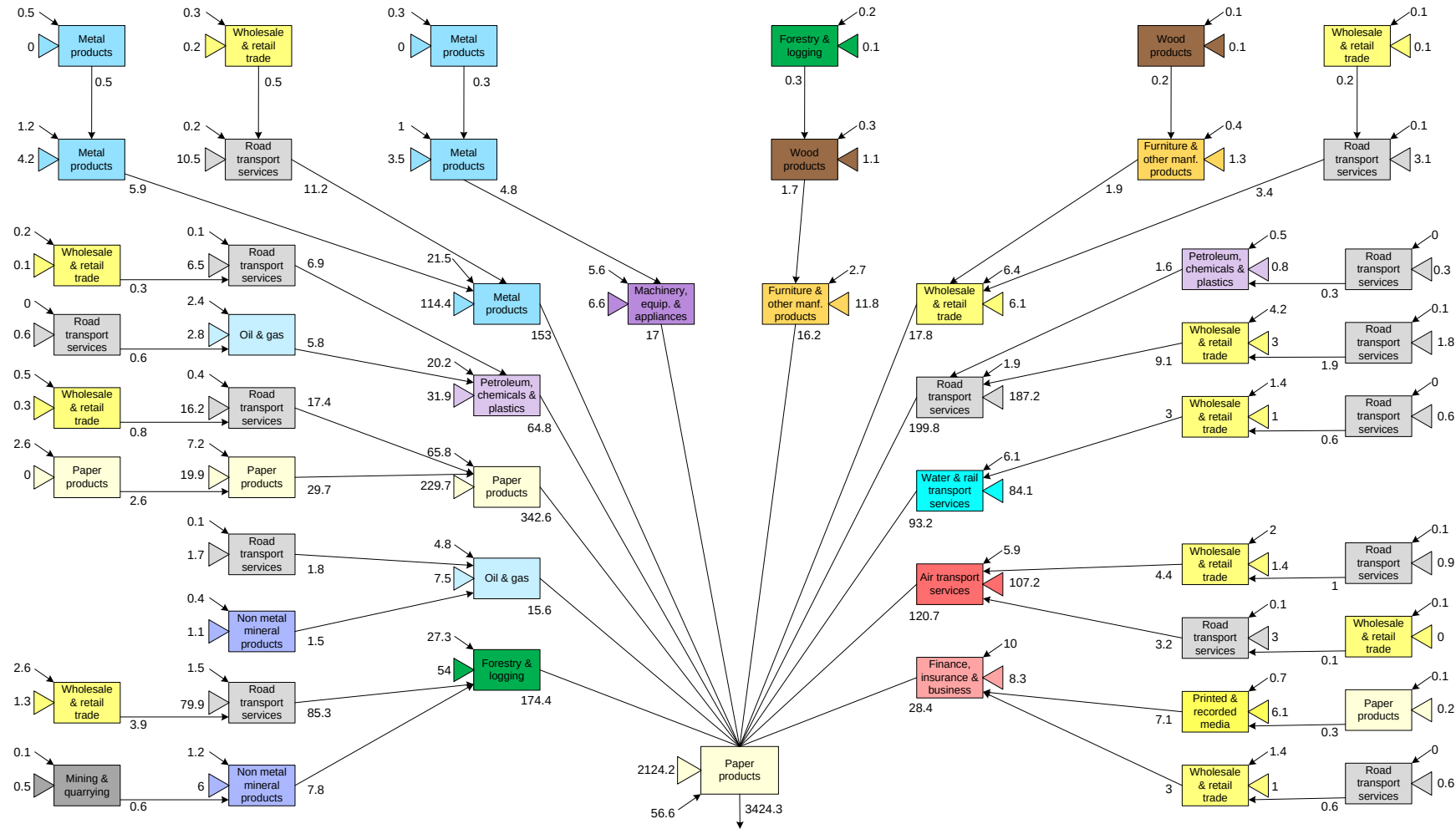


Figure 14.4 - Land Required to Produce One Tonne of Paper Products, 2004 (m²)

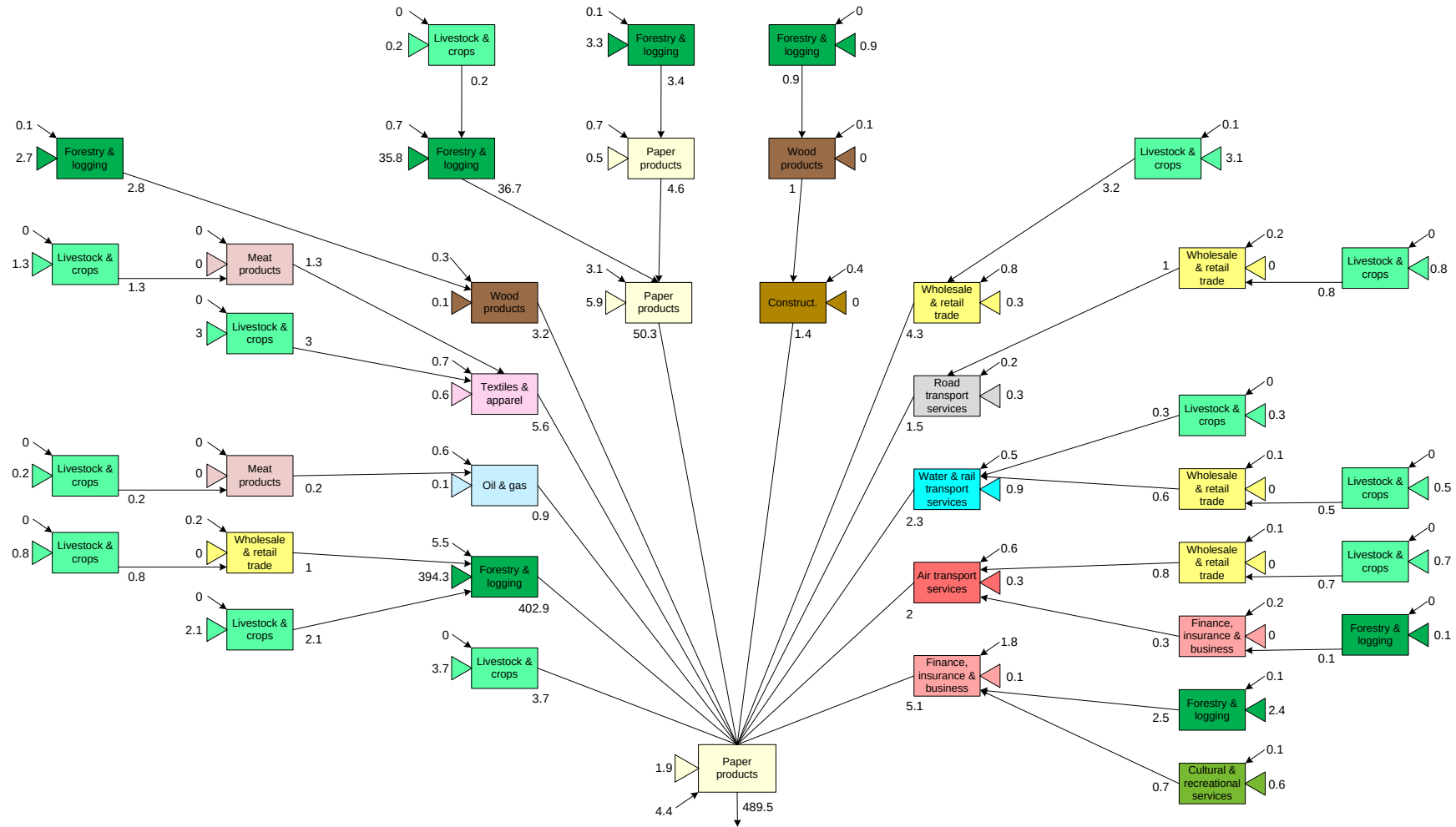


Figure 14.5 - Water Inputs Required to Produce One Tonne of Paper Products, 2004 (Litres)

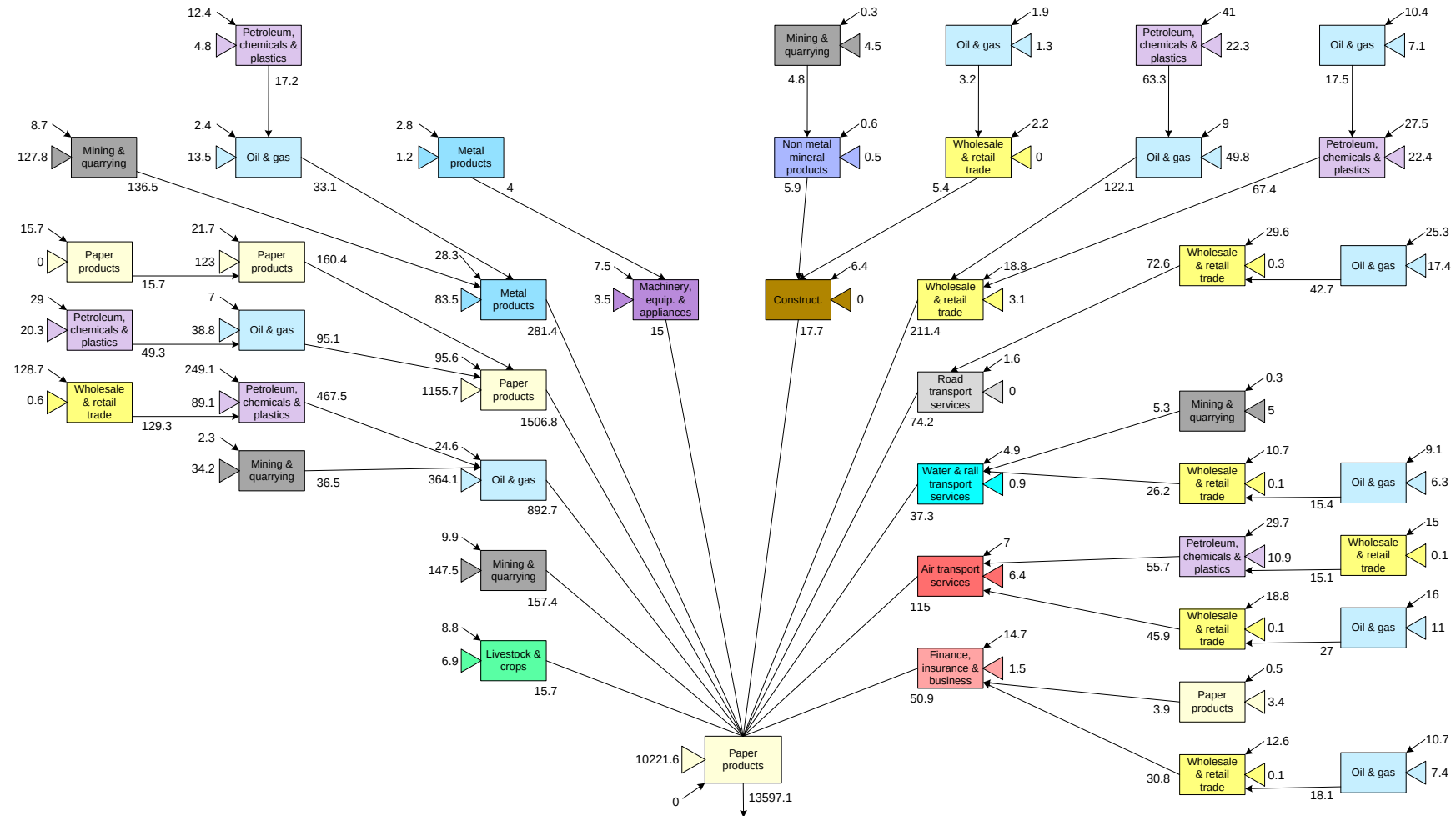


Figure 14.6 - Landfill Waste Generated in Producing One Tonne of Paper Products, 2004 (Grams)

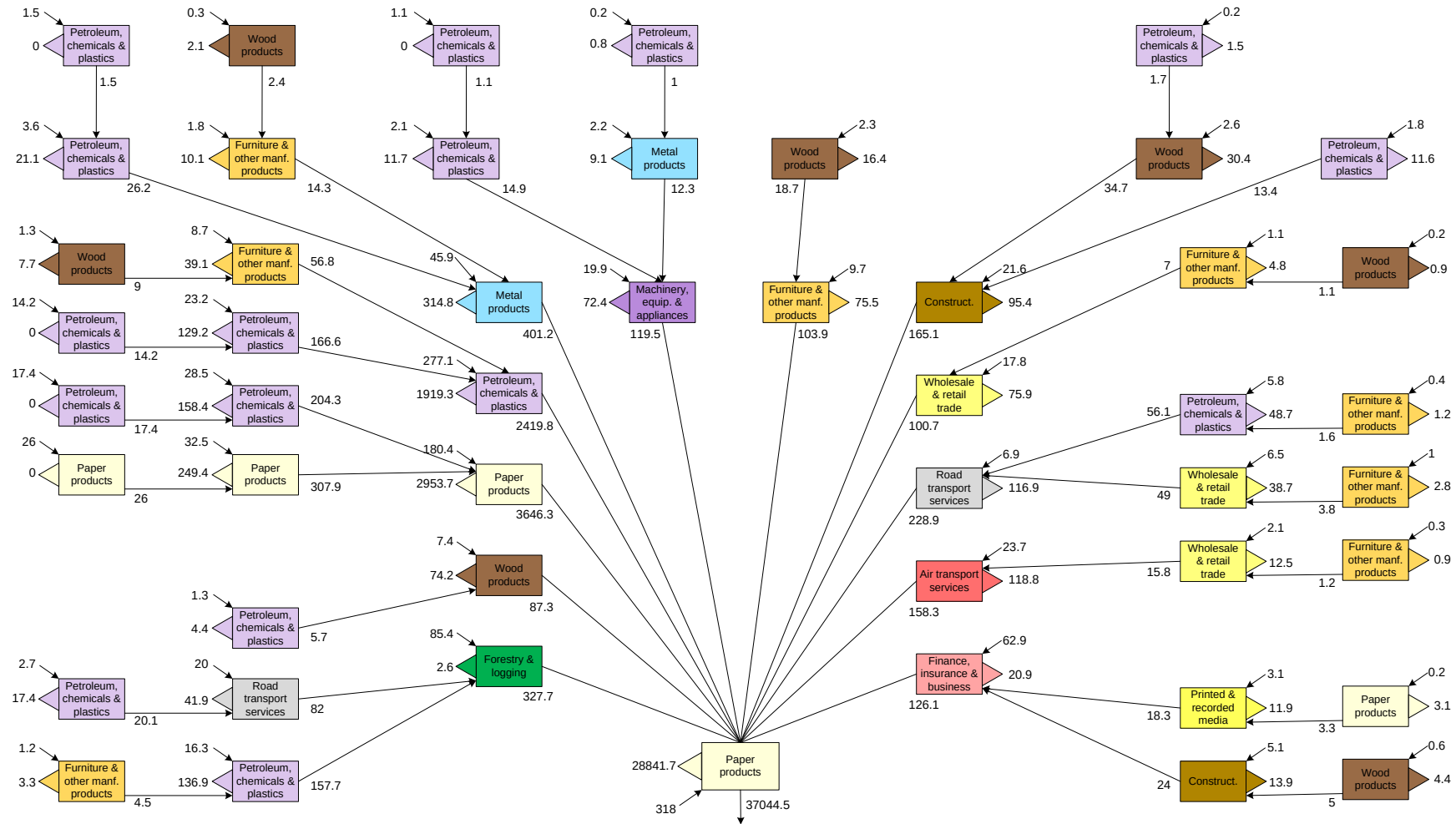


Figure 14.7 - Water Waste Generated in Producing One Tonne of Paper Products, 2004 (Litres)

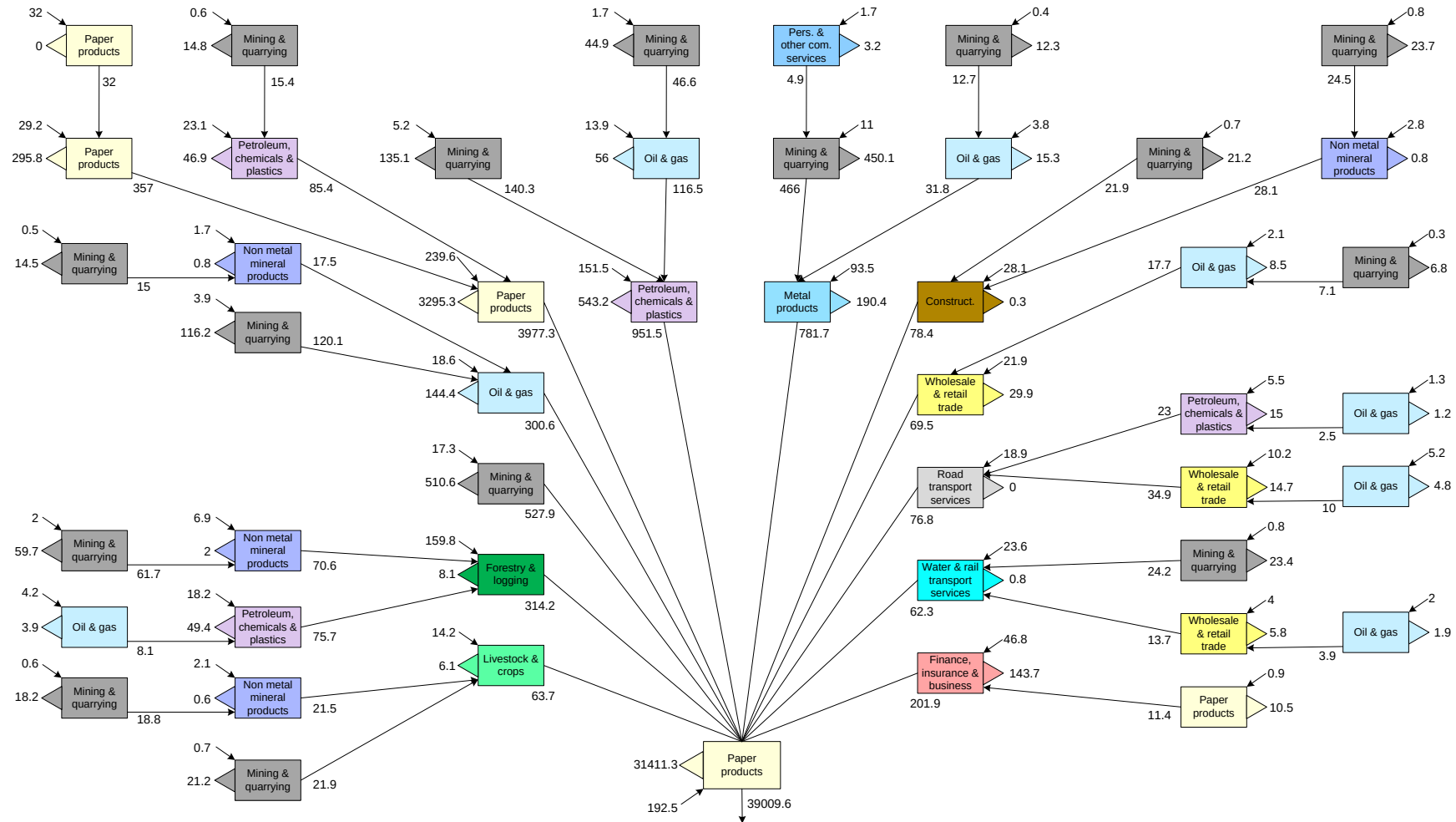


Figure 14.8 - Phosphorus Waste Generated in Producing One Tonne of Paper Products, 2004 (Grams)

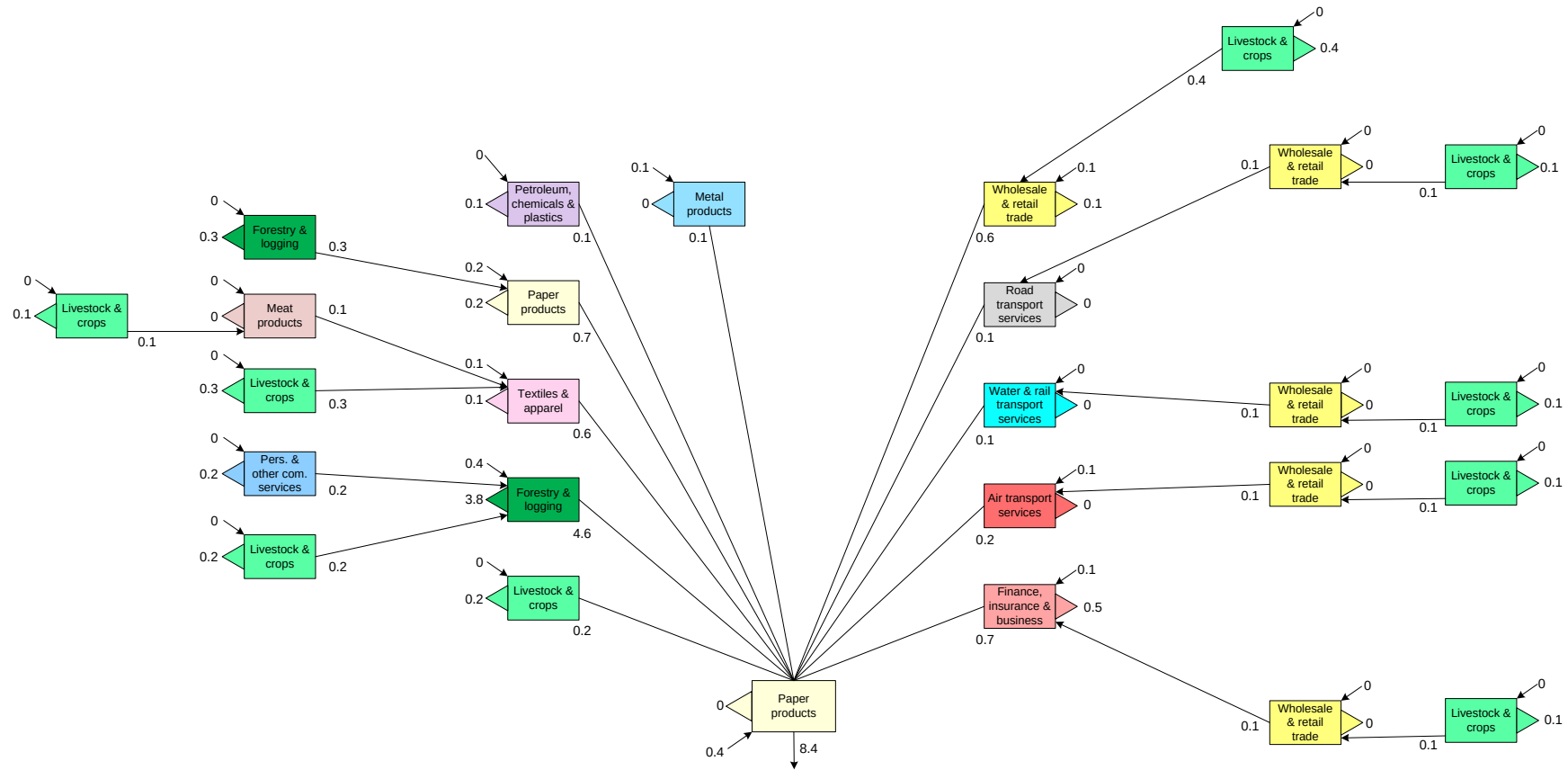
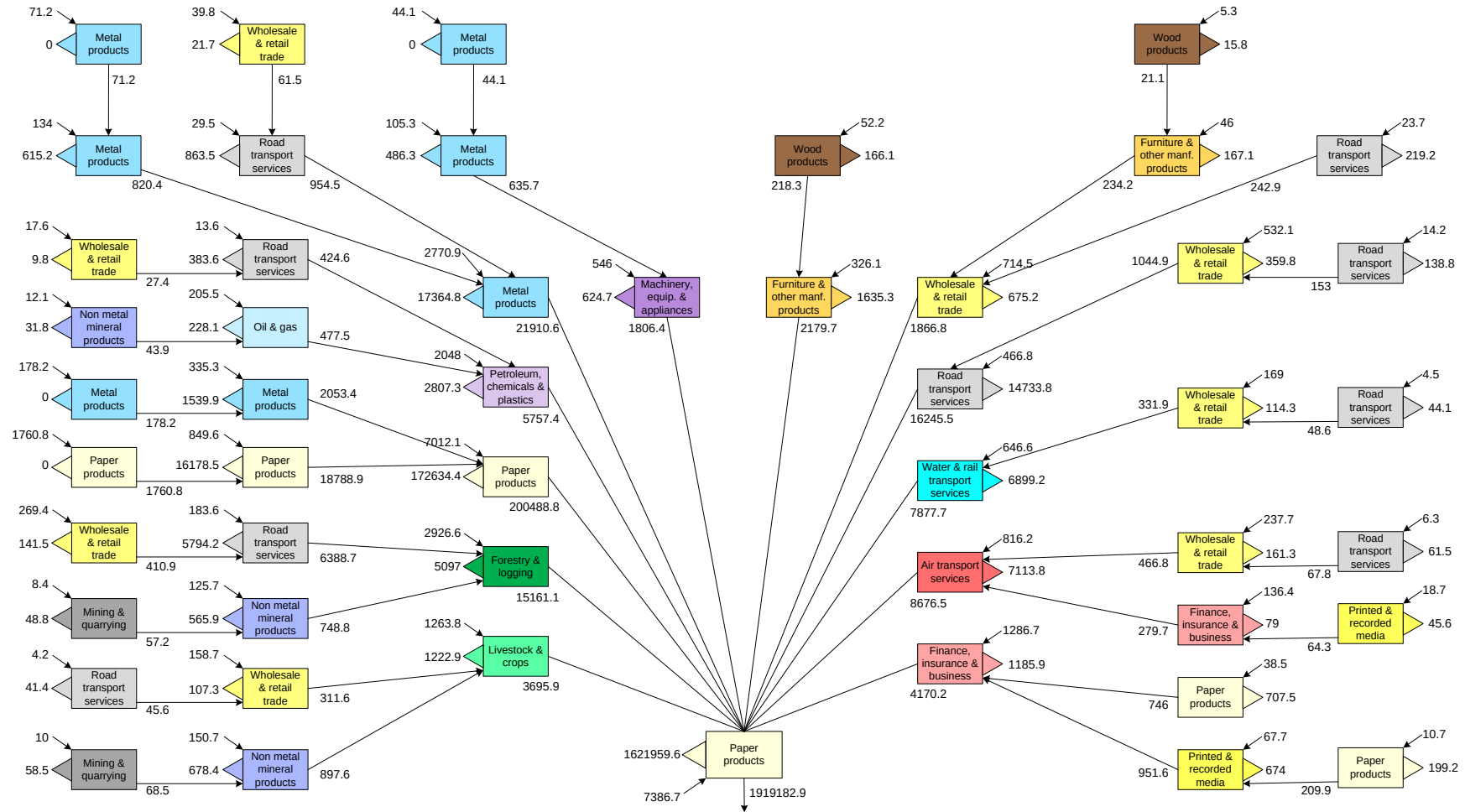


Figure 14.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Paper Products, 2004 (Grams)



15. Printing, Publishing and Recorded Media

Description

ANZSIC Codes covered:

- 161 – Printing and printing support services
- 162 – Reproduction of recorded media

Main commodities supplied:

- Printed and recorded media such as books, stationery, prepared printing plates, newspapers, and journals.

GDP 2016 = \$0.654 billion
Rank = 33rd

Average annual growth rate
2006 to 2016 = -2.29%
Rank = 34th

Employment 2016 = 8,935
Rank = 27th

Economic Overview

The printing, publishing and recorded media industry contributed a combined worth of \$0.654 billion dollars to New Zealand's GDP in 2016. Newspapers are worth more in economic sales than magazines, books and other (brochures, catalogues and cards) products combined. The four largest markets for exports are North America, Australia, Europe and the UK. The industry employed 19,881 full-time equivalent employees in 2007, with employees split more or less evenly between printing and publishing and only 150 involved in recorded media.²⁰⁴ Employment has declined to 8,935 in 2016, reflecting both global and domestic trends away from traditional media sources.²⁰⁵ There are 18 daily newspapers in New Zealand, four of which have a circulation of over 25,000.²⁰⁶ In 2004, New Zealanders spent \$613 million on books, magazines and newspapers, which was an increase of 10% since 2001.²⁰⁸ New Zealand has one of the freest printing presses in the world and is seeing as having the second-lowest level of corruption in the world.²⁰⁹

The printing and publishing industry is highly consolidated into a small number of large businesses. Within the book publishing industry, there are approximately 1,000 companies, however, the largest 5% of publishers (over half of whom are wholly overseas-owned companies) produced nearly 90% of total turnover. Almost all the country's newspaper and magazine publishing businesses are owned by only two wholly overseas-owned companies, APN and Fairfax. The nature of demand in this industry is changing, with more of a focus on New Zealand's growing digital multimedia industry which is gaining a significant international market. Companies such as the special effects giant Weta Digital offer products including animation, interactive entertainment, 3D data capture and display services. Related to this is a growing film and television industry, with multi-million dollar films such as the Lord of the Rings being filmed in New Zealand.

²⁰⁴ Careers New Zealand. (n.d). *Printing Industry Profile*. Retrieved 15/02/2013 from <http://www.careers.govt.nz/default.aspx?id0=104&id1=FD029BBD-CC00-48E0-A1E7-9E4F5C4283E5>

²⁰⁵ MacDonald, M. (2013, September 15). *Is this the end for NZ publishing?* Retrieved from Stuff: <http://www.stuff.co.nz/dominion-post/culture/9162076/is-this-the-end-for-NZ-publishing>

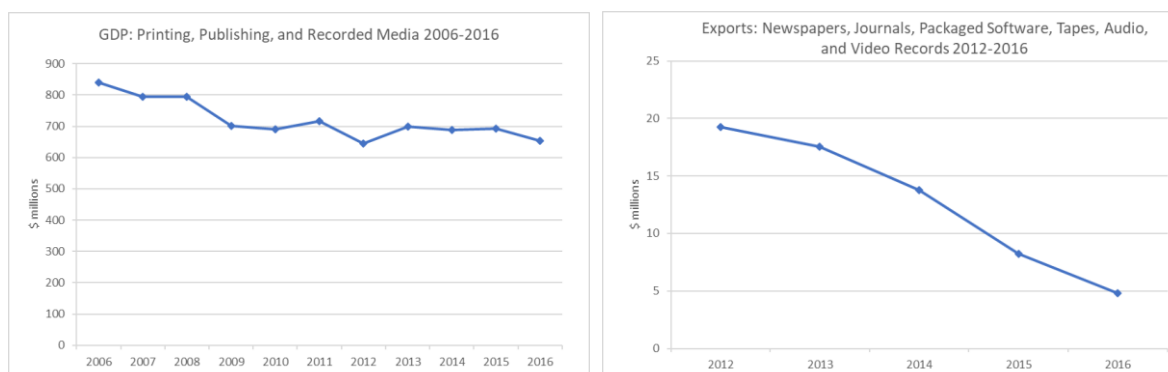
²⁰⁶ New Zealand Audit Bureau of Circulation Inc. (2019). *Newspaper Audit Result*. Retrieved from <http://newspaper.abc.org.nz/audit.html>

²⁰⁷ Myllylahti, M., & Baker, S. (2019). *New Zealand Media Ownership 2019*. Auckland: AUT research center for Journalism, Media and Democracy. Retrieved from https://www.aut.ac.nz/_data/assets/pdf_file/0010/329770/JMAD-2019-Report.pdf

²⁰⁸ Careers New Zealand. (n.d). *Printing Industry Profile*. Retrieved 15/02/2013 from <http://www.careers.govt.nz/default.aspx?id0=104&id1=FD029BBD-CC00-48E0-A1E7-9E4F5C4283E5>

²⁰⁹ Transparency International. (2011). *Corruption Perceptions Index*. Retrieved from <https://www.transparency.org/cpi2018>

Sector Trends



Production

Production in this sector has been steadily decreasing since 2006. Overall, production has decreased by 22.05%, from \$839 million to \$654 million, with positive growth seen in only two periods, the greatest of which is an increase in production of 8.70%. The decline seen reflects a substitution away from products supplied by this sector as technology and the internet exerted their influence, such as recorded media and newspapers.

Exports

The value of exports in this sector follows a similar, bleak trend to the level of production. Exports of products such as Journals, Packaged Software, and Video Records have steadily declined at an annual rate of 18.78% over the 4-year period from 2012 to 2016. This follows similar trends to what has been experienced in the production levels in the sector, with the substitution away from traditional printed media to internet-based sources.²¹⁰

Life Cycle Assessment Diagrams

Energy (Figure 15.1, Figure 15.2, Figure 15.3)

Printed and recorded media products were found to have a total energy intensity of 52,540.6 MJ_{OE} per tonne of product (52.5 MJ_{OE}/kg), ranking is the highest out of the 20 product producing sectors covered in this publication. The total energy intensity measured in conventional energy terms is 98,979 MJ_H/tonne.

Direct energy use was 53% of the total energy intensity, measuring 27,734.7 MJ_{OE} per tonne of product produced. While *indirect energy use* was 47% of the total energy intensity, measuring 24,805.9 MJ_{OE} per tonne of product produced. *The main indirect energy uses in the production of printed and recorded media products came from; (i) energy embodied in paper products at 18,997.8 MJ_{OE} per tonne of product produced; (ii) energy embodied in road transport services at 1,633.7 MJ_{OE} per tonne of product produced; (iii) energy embodied in metal products at 1,087.8 MJ_{OE} per tonne of product produced; (iv) energy embodied in petroleum, chemicals and plastic at 719.1 MJ_{OE} per tonne of product produced.*

²¹⁰ du Fresne, K. (2017, June 18). *New Zealand papers are in dangerous decline - here's what's at stake*. Retrieved from Noted: <https://www.noted.co.nz/money/money-business/new-zealand-papers-are-in-dangerous-decline-heres-whats-at-stake>

Land (Figure 15.4)

Printed and recorded media products have a total land intensity of 1,416.7 m² per tonne of product produced, ranking the sector 9th highest in terms of land intensity out of the 20 product producing sectors covered in this publication.

Direct land use was minuscule at only 5% of the total land intensity at 77.4 m² per tonne of product produced. *Indirect land use* makes up the majority of printed and recorded product's total land intensity at 95% measuring 1,339.3 m² per tonne of product produced. *The major indirect land uses for printed and recorded media products come from;* (i) *land embodied in paper products at 903.5 m² per tonne of product produced;* (ii) *land embodied in forestry and logging at 85.3 m² per tonne of product produced;* (iii) *land embodied in finance insurance and business at 76.4 m² per tonne of product produced;* (iv) *land embodied in wholesale and retail trade at 69.2 m² per tonne of product produced.*

Water Inputs (Figure 15.5)

Printed and recorded media products require 26,204.1 litres of water inputs per tonne of product produced, ranking the sector the 10th highest consumer of water compared to the 20 product producing sectors covered in this publication.

Direct water inputs made up a tiny 1.14% of the total water inputs, or 299.8 litres per tonne of printed and recorded media product produced. *Indirect water inputs* made up the majority of total water inputs at 99%, or 25,904.3 litres per tonne of printed and recorded media product produced.

The main indirect water inputs came from; (i) *water inputs embodied in paper products at 17,903.9 litres per tonne of product produced;* (ii) *water inputs embodied in oil and gas at 2,921.7 litres per tonne of product produced;* (iii) *water inputs embodied in wholesale and retail trade at 2,488.6 litres per tonne of product produced;* (iv) *water inputs embodied in metal products at 870 litres per tonne of product produced.*

Landfill Wastes (Figure 15.6)

Printed and recorded media products were found to generate 240,434.3 grams (240.4 kg) of landfill waste per tonne of product produced. This ranks the sector the 2nd highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication.

Landfill waste directly generated by printed and recorded media products was 53% of total waste produced or 127,684.4 grams per tonne of product produced. *Landfill waste indirectly generated* by printed and recorded media products was 47% of total waste produced or 112,749.9 grams per tonne of product produced.

The main sources of indirect landfill waste came from; (i) *landfill wastes embodied in paper products at 68,647.6 grams per tonne of product produced;* (ii) *landfill wastes embodied in petroleum, chemicals and plastics at 27,681.8 grams per tonne of product produced;* (iii) *landfill wastes embodied in road transport services at 2,896.3 grams per tonne of product produced;* (iv) *landfill wastes embodied in wholesale and retail trade at 2,221 grams per tonne of product produced.*

Water Wastes (Figure 15.7)

Printed and recorded media products were found to produce 118,925.2 litres of wastewater per tonne of product produced. This ranks the sector as the 4th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication.

Wastewater directly generated by the production of printed and recorded media products was tiny at only 1% of total waste produced, or 1,240.4 litres per tonne of product produced. *Wastewater indirectly generated* by printed and recorded media products made up the majority at 99% of the total wastewater produced, or 117,684.8 litres per tonne of product produced.

The indirect wastewater of printed and recorded media products was mostly made up of (i) wastewater embodied in paper products at 74,285.3 litres per tonne of product produced; (ii) wastewater embodied in personal and other community services at 18,788.6 litres per tonne of product produced; (iii) wastewater embodied in petroleum, chemicals and plastics at 10,496.3 litres per tonne of product produced; (iv) wastewater embodied metal products at 4,047.8 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 15.8)

In terms of CO₂ greenhouse gas emissions, printed and recorded media products were found to emit 11,041,923.9 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of printed and recorded media products are ranked the highest out of the 20 product producing sectors covered in this publication.

Energy-related CO₂ directly generated by printed and recorded media products was 58% of total emissions or 6,442,062.6 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by printed and recorded media products made up 42% of the total emissions produced or 4,599,861.3 grams per tonne of product produced.

The indirect energy-related CO₂ emissions from the production of printed and recorded media products was mostly made up of (i) energy-related CO₂ embodied in paper products at 3,796,385.9 grams per tonne of product produced; (ii) energy-related CO₂ embodied in road transport services at 208,362 grams per tonne of product produced; (iii) energy-related CO₂ embodied in metal products at 115,713.4 grams per tonne of product produced; (iv) energy-related CO₂ embodied in finance, insurance and business at 99,963.4 grams per tonne of product produced.

Figure 15.1 - Total Energy Inputs Required to Produce One Tonne of Printed and Recorded Media Products, 2004 (MJ_E, Oil Equivalents)

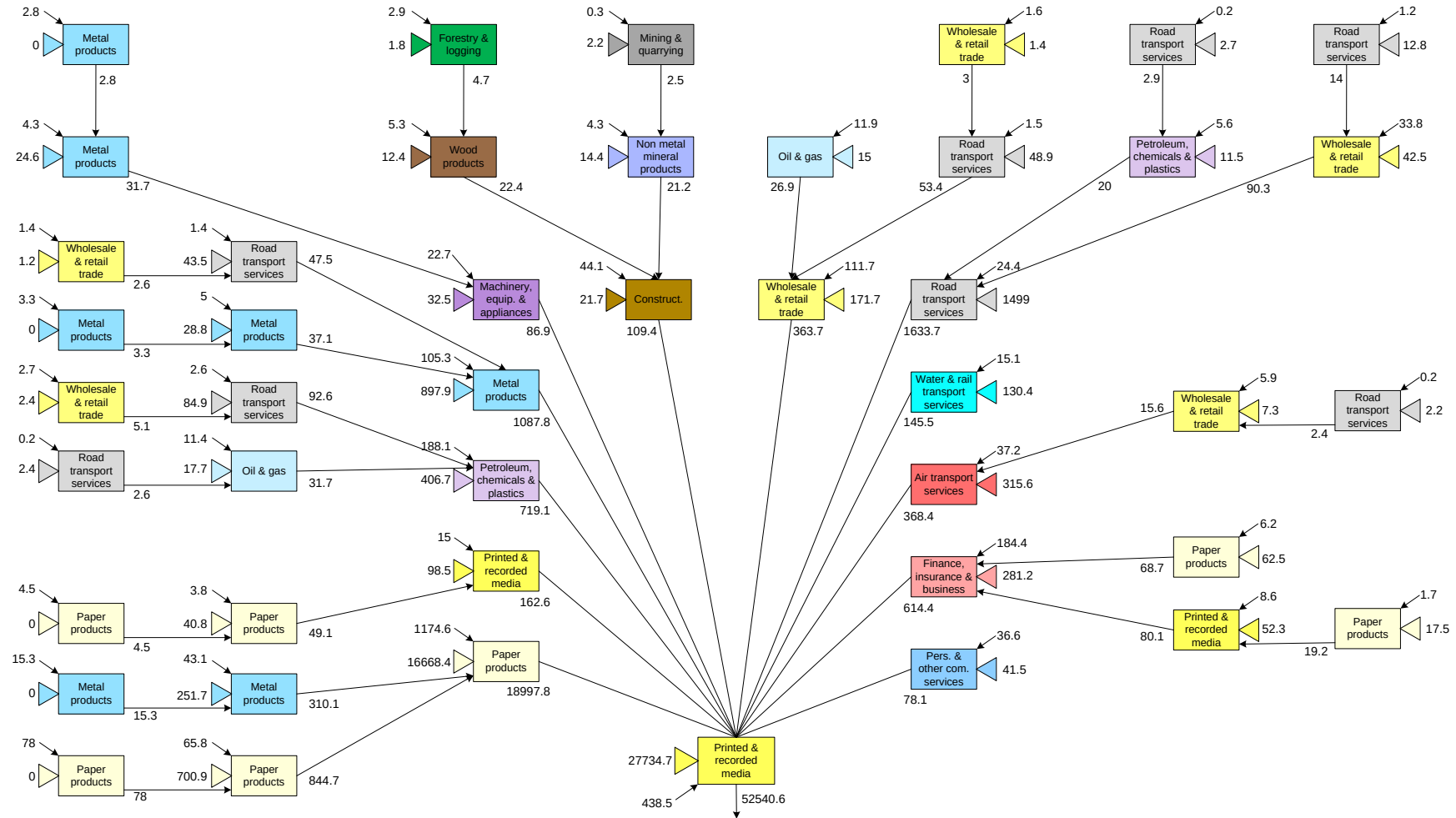


Figure 15.2 - Electricity Inputs Required to Produce One Tonne of Printed and Recorded Media Products, 2004 (MJ, Heat Equivalents)

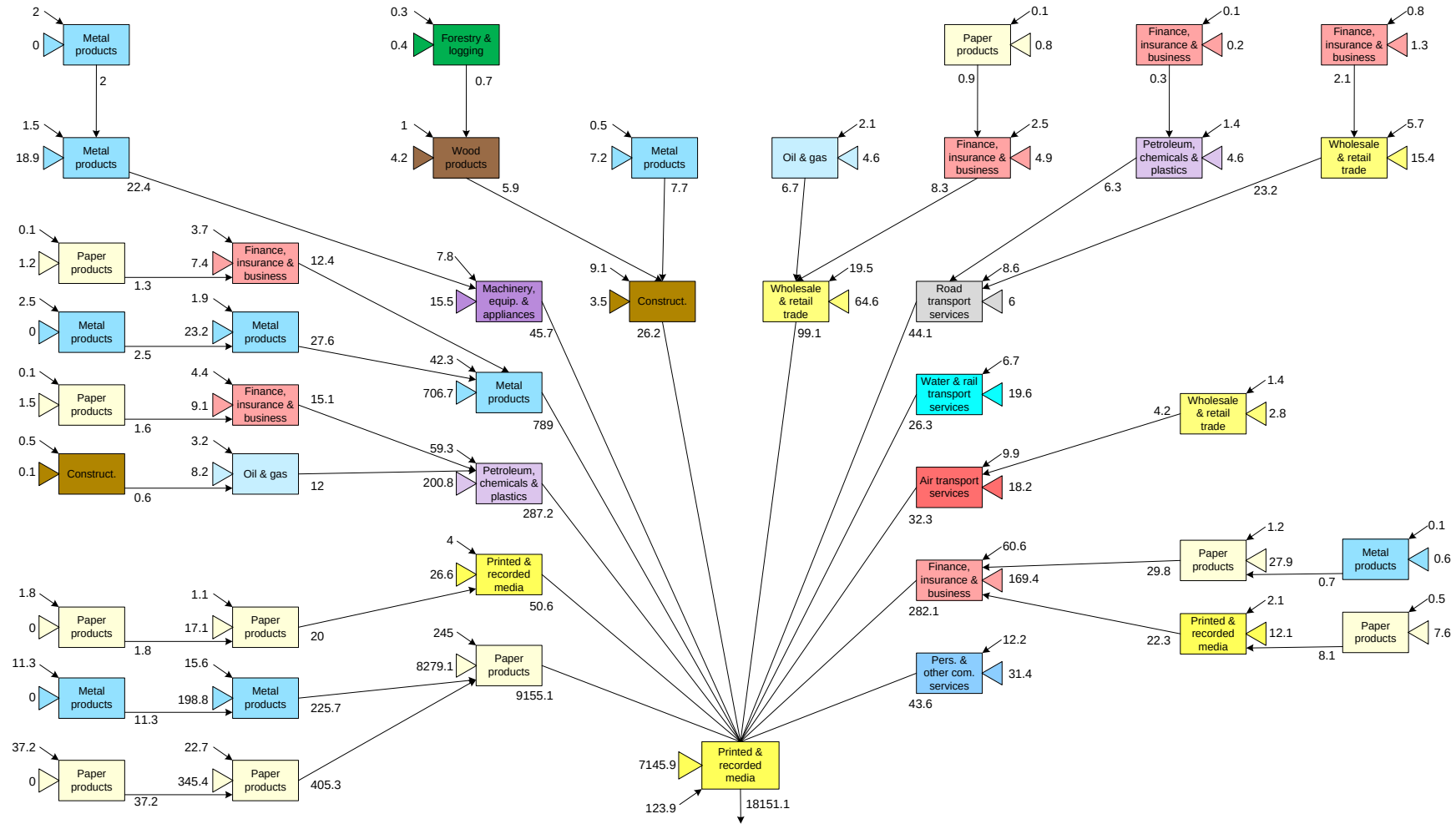


Figure 15.3 - Fossil Fuel Inputs Required to Produce One Tonne of Printed and Recorded Media Products, 2004 (MJ, Heat Equivalents)

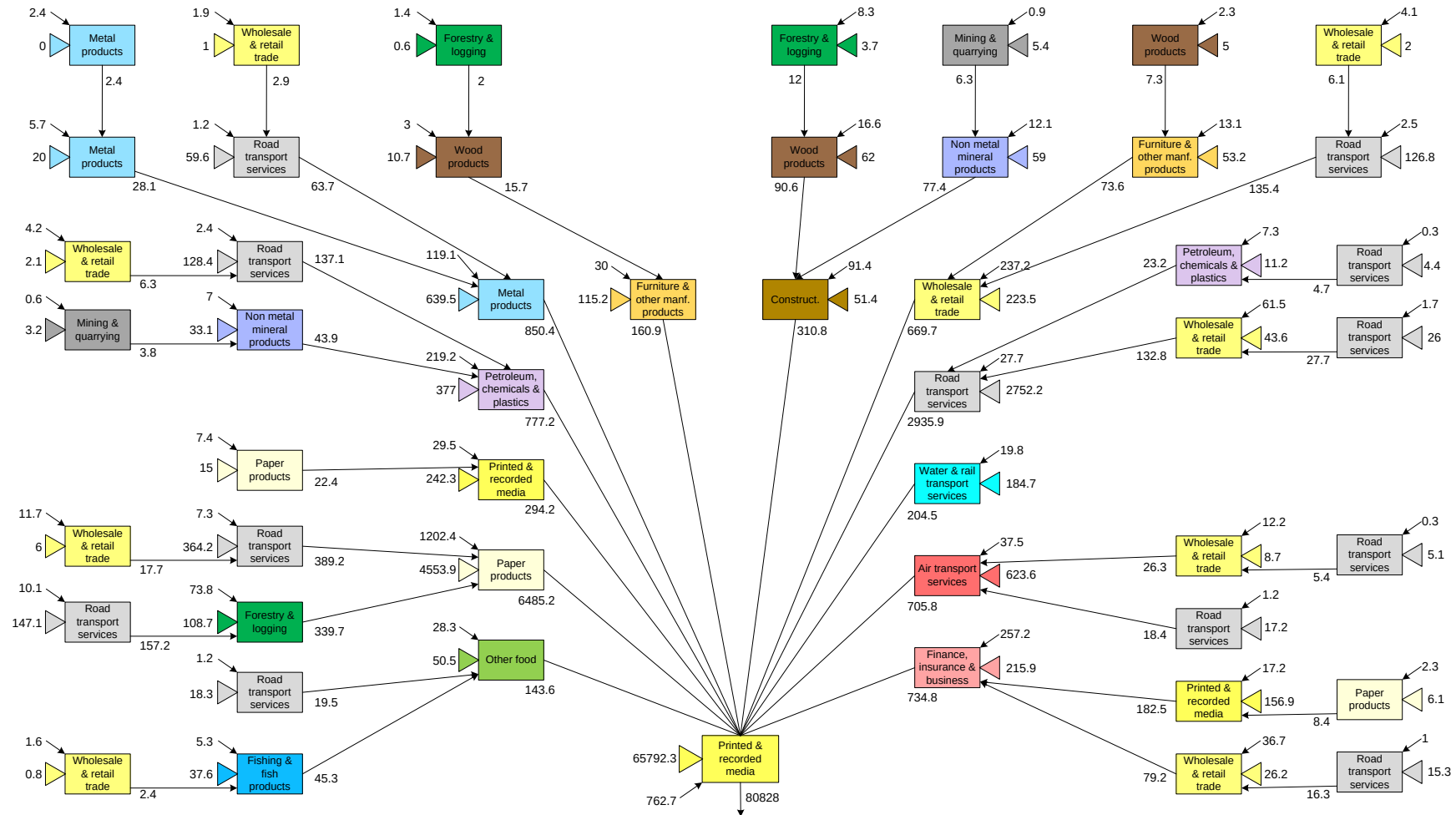


Figure 15.4 - Land Required to Produce One Tonne of Printed and Recorded Media Products, 2004 (m²)

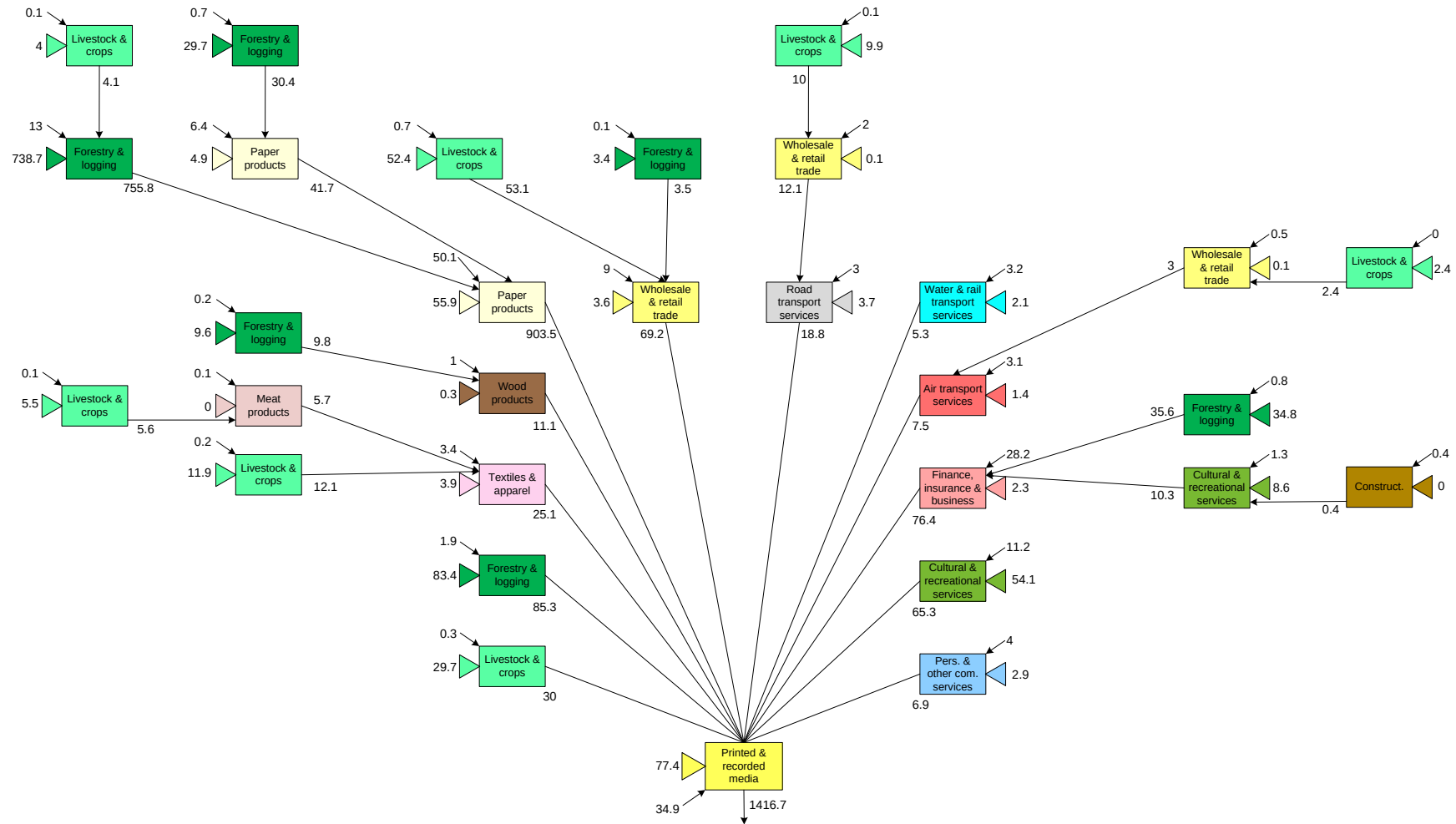


Figure 15.5 - Water Inputs Required to Produce One Tonne of Printed and Recorded Media Products, 2004 (Litres)

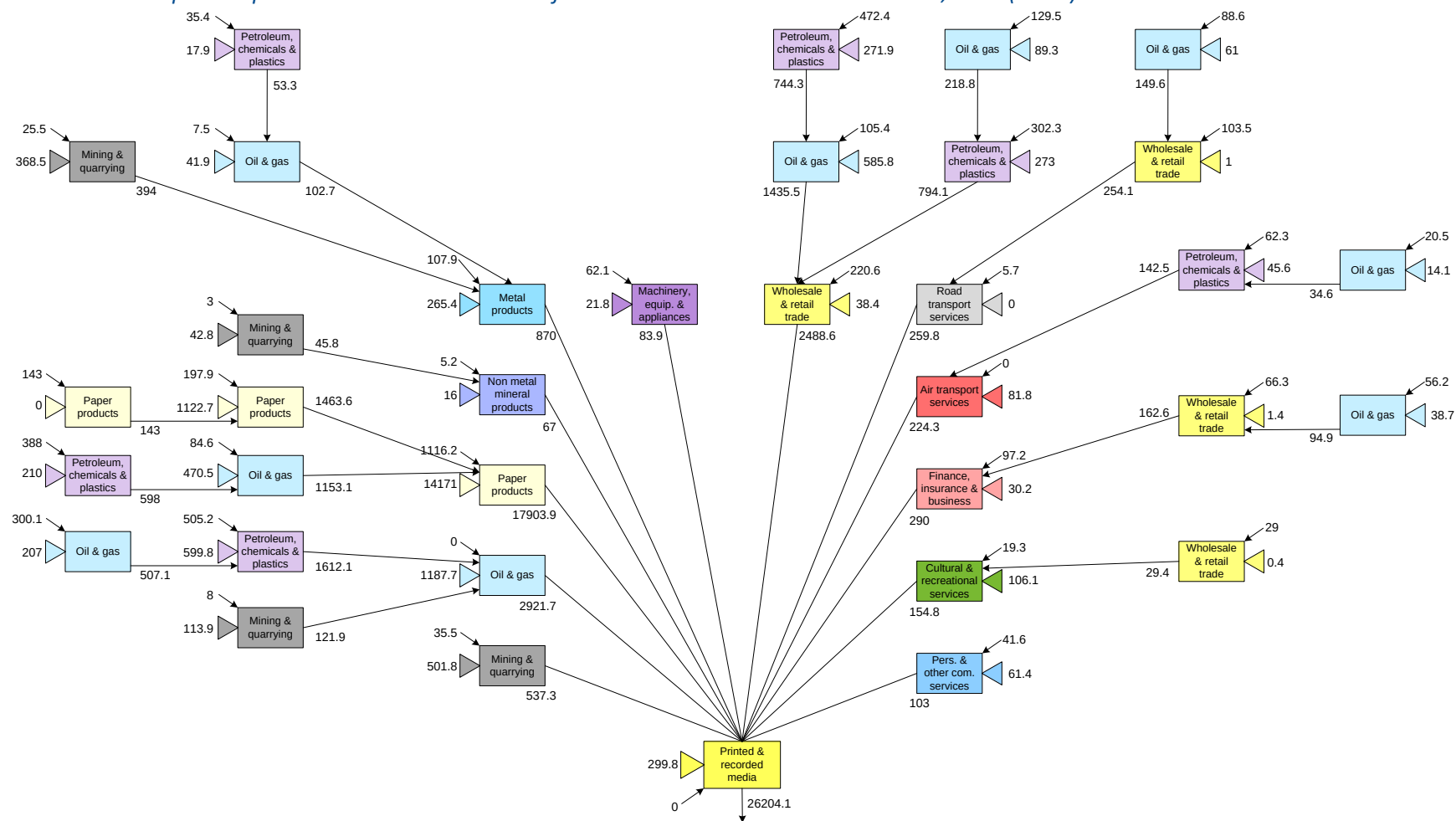


Figure 15.6 - Landfill Waste Generated in Producing One Tonne of Printed and Recorded Media Products, 2004 (Grams)

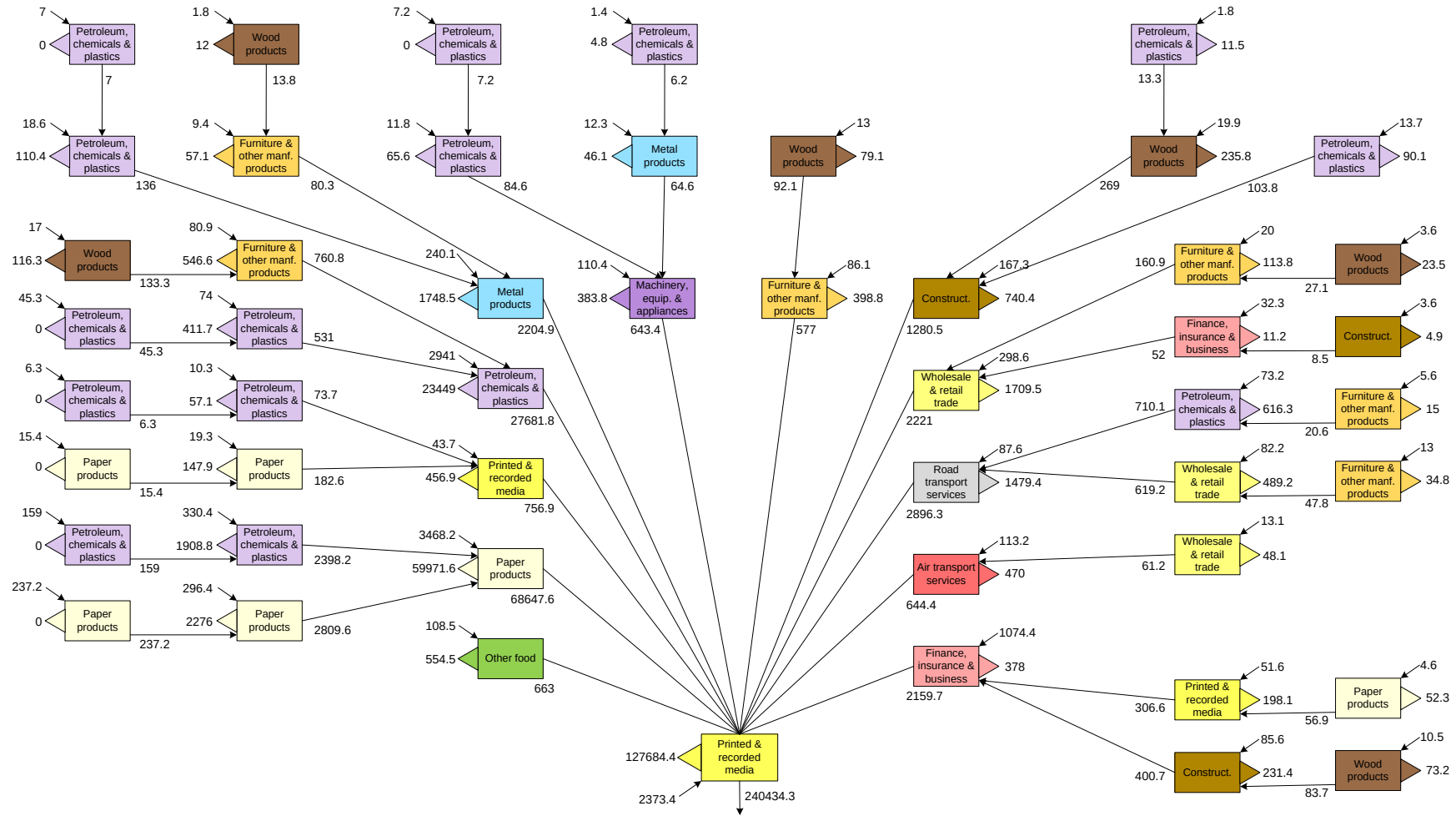


Figure 15.7 - Water Waste Generated in Producing One Tonne of Printed and Recorded Media Products, 2004 (Litres)

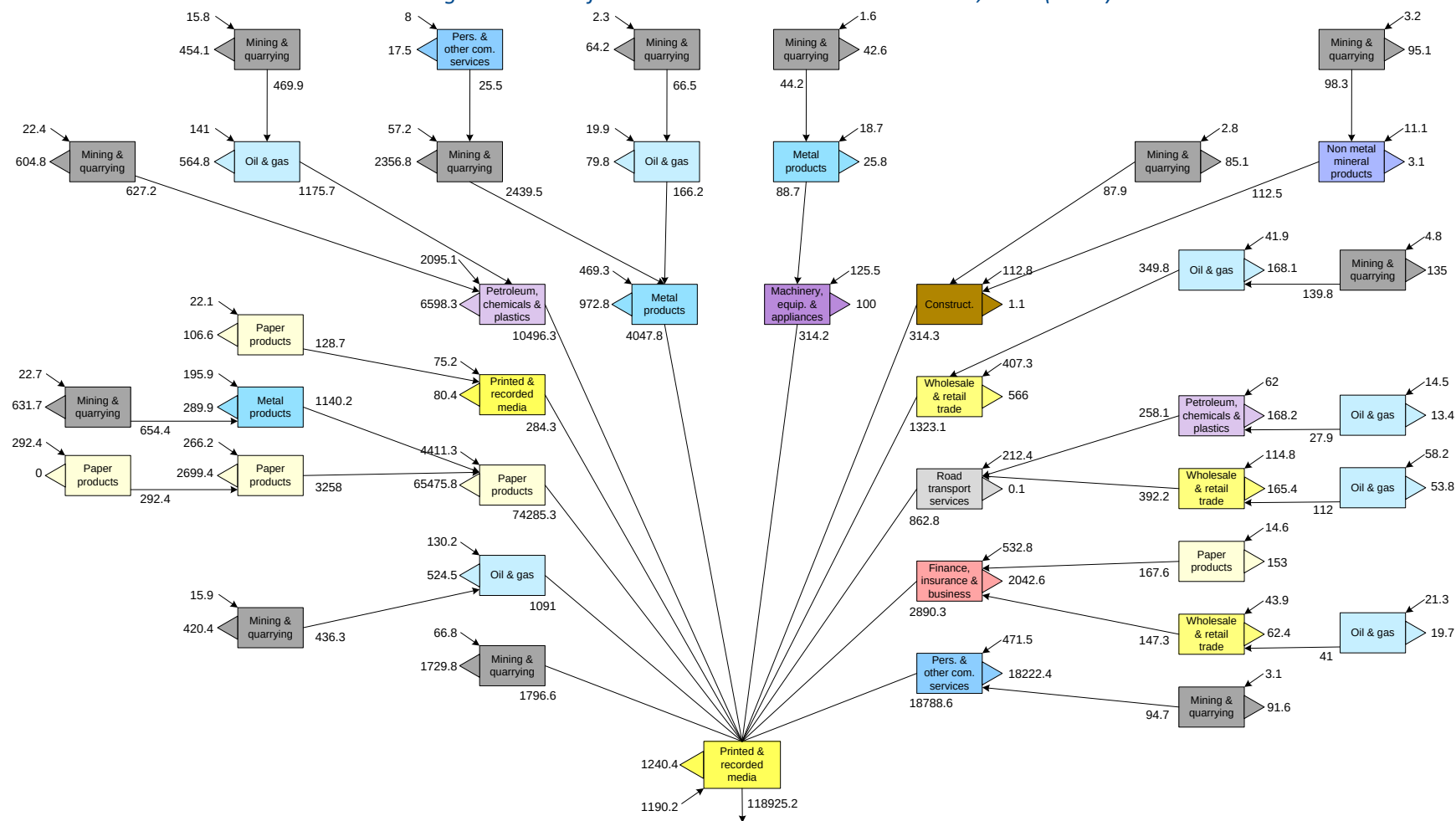
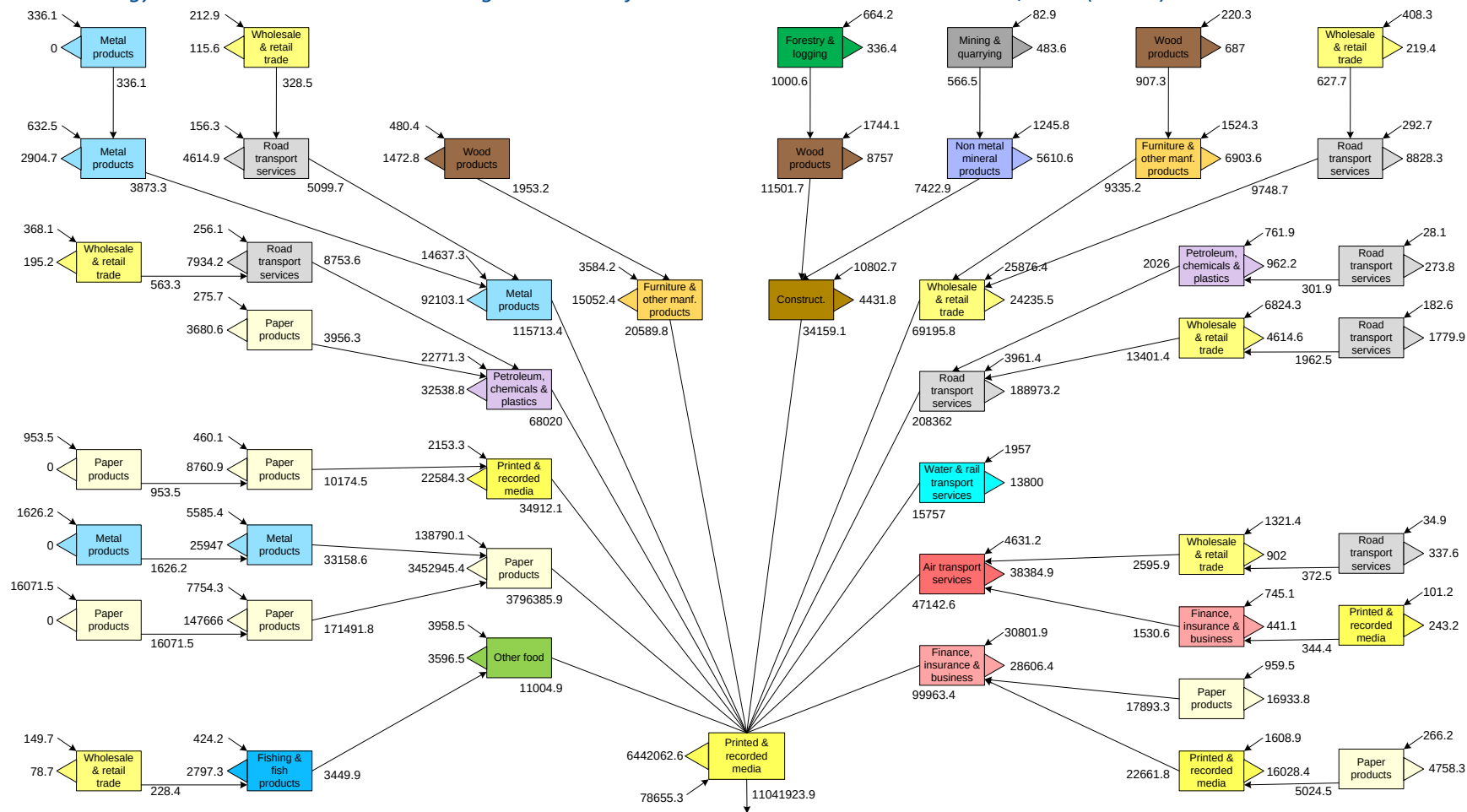


Figure 15.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Printed and Recorded Media Products, 2004 (Grams)



16. Petroleum, Plastic, Rubber and Industrial Chemical Manufacturing

Description

ANZSIC Codes covered :

- 170 – Petroleum and Coal Product manufacturing
- 181 – Basic Chemical Manufacturing (industrial gas, organic and inorganic chemical manufacturing)
- 182 – Basic Polymer Manufacturing (synthetic rubber and resin)
- 183 – Fertiliser and Pesticide Manufacturing
- 184 – Pharmaceutical and Medicinal Product Manufacturing
- 185 – Cleaning Compound and Toiletry Preparation Manufacturing
- 189 – Other Basic Chemical Product Manufacturing (photographic chemical, explosive)
- 191 – Polymer Product Manufacturing (plastics, tyres, paint)
- 192 – Natural Rubber Product

GDP 2016 = \$5.239 billion

Rank = 11th

Average annual growth rate
2006 to 2016 = 2.66%

Rank = 24th

Employment 2016 = 20,109

Rank = 21st

Main commodities supplied:

- Petroleum, rubber, chemicals, and plastics

Economic Overview

The plastics industry in New Zealand has an annual turnover of more than \$2 billion, employing greater than 9,000 people in more than 300 enterprises.²¹¹ Approximately 60% of production is used in the packaging industry and therefore is a significant supplier to the agriculture, horticulture, aquaculture, appliance manufacturing and the IT industries. More than 50% of production is exported, either directly or indirectly, and more than \$60 million is invested each year in research and development. The annual growth rate of the plastics industry has exceeded 7% in the mid-2000s, meaning it has been a significant contributor to the growth seen in this sector as a whole.²¹² Similarly, the rubber manufacturing sub-sector has been growing steadily, with domestic demand remaining strong and exports contributing to overall profits in this sector.

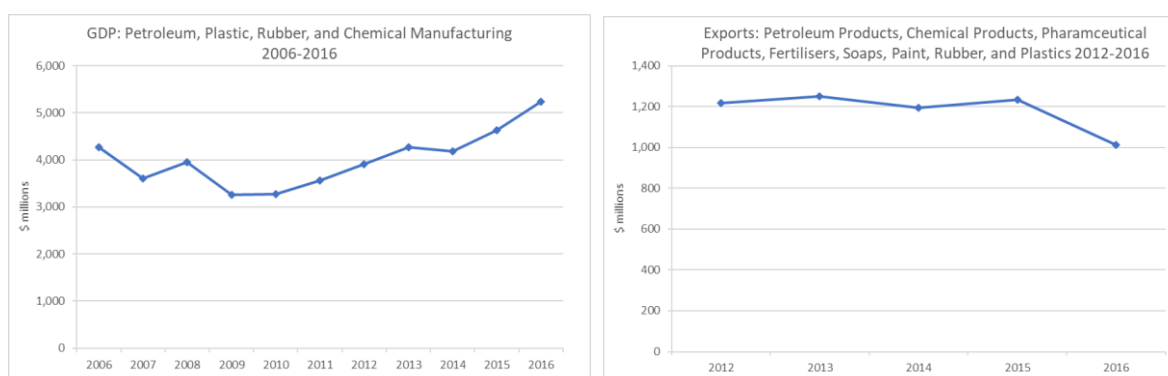
Petrochemical and other energy-based industries in New Zealand expanded significantly in the 1980s following discovery and exploitation of natural gas resources, crude and condensate. These natural resources enabled the establishment of a number of manufacturing industries and allowed import substitution. The discovery of gas fields led to a major investment by the government in synthetic fuels, industrial methanol and gasoline. In 1999, approximately 31% of gas extracted was used for this

²¹¹ Plastics NZ. (2014). *General Statistics*. Retrieved from <https://www.plastics.org.nz/doing-business-in-nz/new-zealand-industry/general-statistics>

²¹² Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 414)

purpose, chemical methanol used another 10% and ammonia urea used 3%.²¹³ Synthetic fuels could not compete with imported oil products, so this use has stopped. Currently, 42% of gas is used for petrochemicals, mostly by Methanex for chemical methanol and ammonia/urea production,²¹⁴ of which 95% is exported to the Asia Pacific region.²¹⁵ Methanol occupies a key position in the chemical industry, used mainly to make wood adhesives and plastics. About 20% of production goes into making dyes and plexiglass and 15% into solvents for paints and dyes. It is also used for polyester fibres, methyl cellulose and silicone compounds, and can be used to manufacture the antiknock petrol additive methyl tertiary butyl ether (MTBE).²¹⁶

Sector Trends



Production

Following a downturn in the level of production from 2006 to 2009, where a 23.41% decrease in production was felt. The petroleum, plastic, rubber and chemical manufacturing sector has recovered strongly with growth in production in all but one year since 2009 through to 2016 resulting in an increase of production of 60.46%, from \$3.27 billion to \$5.24 billion. In contrast to many other manufacturing sectors, this sector performed well immediately following the GFC, increasing by 9.34% in 2008.

Exports

Between 2012 and 2015, export value remained relatively constant, at around \$1.2 billion. However, there has been a substantial, 17.87%, decrease in the value of exports in the final year of the period. Taking the value of exports from \$1.23 billion down to \$1.01 billion. This downturn has been driven largely by three product groups; other petroleum products, other chemical products and man-made fibres, as well as soaps and perfumes. This follows a sharp downturn in the world price for crude oil.²¹⁷ Additionally, New Zealand exporters face large difficulty when attempting to compete internationally against countries such as China, India, and Brazil who have made large advancements in plastic and rubber manufacturing over these years.

²¹³ New Zealand Treasury. (2002). *New Zealand Economic and Financial Overview*. Retrieved from <http://www.treasury.govt.nz/economy/overview/archive/pdfs/nzeo-02.pdf>

²¹⁴ Gas Industry Company. (2019, May). *Gas industry - facts at a glance*. Retrieved from <https://gasindustry.co.nz/dmsdocument/6540>

²¹⁵ Methanex. (n.d.). *About Methanex in New Zealand*. Retrieved from <https://www.methanex.com/location/new-zealand/about-methanex-new-zealand>

²¹⁶ Anonymous. (n.d.). A History of Technological Innovation in New Zealand, Think Big Methanol Project. Retrieved 1/02/2013 from <http://www.techhistory.co.nz/ThinkBig/Methanol.htm>

²¹⁷ U.S. Energy Information Administration. (2017, January 4). *Crude oil prices increased in 2016, still below 2015 averages*. Retrieved from <https://www.eia.gov/todayinenergy/detail.php?id=29412>

Life Cycle Assessment Diagrams

Energy (Figure 16.1, Figure 16.2, Figure 16.3)

Petroleum, chemical and plastic products were found to have a total energy intensity of 2,845.8 MJ_{OE} per tonne of product (2.8 MJ_{OE}/kg), ranking the sector 13th highest out of the 20 product producing sectors covered in this publication.

Direct energy use was 35% of the total energy intensity, measuring 990.5 MJ_{OE} per tonne of petroleum, chemical and plastic product produced. The EECA in-use database reports that a total of 6,864.299 TJ of direct energy was used in the chemicals, related products, and plastics sector in 2006/07. *Indirect energy use* was 65% of the total energy intensity, measuring 1,855.3 MJ_{OE} per tonne of petroleum, chemical and plastic product produced. *The main indirect energy uses in the production of petroleum, chemical and plastic products came from; (i) energy embodied in oil and gas at 383.3 MJ_{OE} per tonne of product produced; (ii) energy embodied in road transport services at 253.4 MJ_{OE} per tonne of product produced; (iii) energy embodied in petroleum, chemicals and plastics at 196.4 MJ_{OE} per tonne of product produced; (iv) energy embodied in paper products at 163.5 MJ_{OE} per tonne of product produced.*

Land (Figure 16.4)

Petroleum, chemical and plastic products have a total land intensity of 230.1 m² per tonne of product, ranking the sector 17th highest out of the 20 product producing sectors covered in this publication. Direct land use was tiny at only 2% of the total land intensity at 4.5 m² per tonne of product produced. *Indirect land use* makes up the majority of petroleum, chemical and plastic product's total land intensity at 98% measuring 225.6 m² per tonne of product produced. *The major indirect land uses in the production of petroleum, chemical and plastic products come from; (i) land embodied in forestry and logging at 40.3 m² per tonne of product produced; (ii) land embodied in livestock and crops at 40.2 m² per tonne of product produced; (iii) land embodied in meat products at 32.1 m² per tonne of product produced; (iv) land embodied in oil and gas at 29.4 m² per tonne of product produced.*

Water Inputs (Figure 16.5)

Petroleum, chemical and plastic products require 44,759.9 litres of water inputs per tonne of product, ranking the sector the 5th highest consumer of water compared to the 20 product producing sectors covered in this publication. *Direct water inputs* make up only 6% of the total water inputs, or 2,847.1 litres per tonne of petroleum, chemical and plastic product produced. *Indirect water inputs* make up the remaining 94% of the total water inputs, or 41,912.8 litres per tonne of petroleum, chemical and plastic product produced. *The main indirect water inputs came from; (i) water inputs embodied in oil and gas at 22,515.1 litres per tonne of product produced; (ii) water inputs embodied in mining and quarrying at 6,536 litres per tonne of product produced; (iii) water inputs embodied in wholesale and retail trade at 5,844.5 litres per tonne of product produced; (iv) water inputs embodied in non-metal mineral products at 2,465.4 litres per tonne of product produced.*

Landfill Wastes (Figure 16.6)

Petroleum, chemical and plastic products were found to generate 79,281 grams (79 kg) of landfill waste per tonne of product. This ranks the sector the 6th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by petroleum, chemical and plastic products was 74% of total waste produced or 58,902.9 grams per tonne of product produced. *Landfill waste indirectly generated* by petroleum,

chemical and plastic products was 26% of total waste produced or 20,378.1 grams per tonne of product produced.

The main sources of indirect landfill waste came from; (i) landfill wastes embodied in petroleum, chemical and plastic products at 7,734.8 grams per tonne of product produced; (ii) landfill wastes embodied in furniture and other manufactured products at 2,010.4 grams per tonne of product produced; (iii) landfill wastes embodied in oil and gas at 1,616.8 grams per tonne of product produced; (iv) landfill wastes embodied in non-metal mineral products at 1,225.1 grams per tonne of product produced.

Water Wastes (Figure 16.7)

Petroleum, chemical and plastic products were found to produce 53,168.8 litres of wastewater per tonne of product. This ranks the sector as the 11th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* by the production of petroleum, chemical and plastic products was 32% of total water waste produced or 17,087 litres per tonne of product produced. Wastewater indirectly generated by petroleum, chemical and plastic products made up 68% of the total wastewater produced or 36,081.8 litres per tonne of product produced.

The indirect wastewater in the production of petroleum, chemical and plastic products was mostly made up of (i) wastewater embodied in mining and quarrying at 14,404.5 litres per tonne of product produced; (ii) wastewater embodied in oil and gas at 10,110.3 litres per tonne of product produced; (iii) wastewater embodied in petroleum, chemicals and plastics at 2,986.6 litres per tonne of product produced; (iv) wastewater embodied non-metal mineral products at 2,277.5 litres per tonne of product produced.

Phosphorus Wastes (Figure 16.8)

Petroleum, chemical and plastic products were found to produce 23.5 grams of phosphorus waste per tonne of product. Direct sources of phosphorus only made up 1% of the total wastes or 0.2 grams per tonne of product produced. The total amount of phosphorus produced in the production of petroleum, chemical and plastic products came almost entirely from indirect sources at 99% or 23.3 grams per tonne of product produced.

The main sources of this indirect phosphorus waste came from; (i) phosphorus waste embodied in livestock and crops at 6.2 grams per tonne of product produced; (ii) phosphorus waste embodied in meat products at 5.3 grams per tonne of product produced; (iii) phosphorus waste embodied in textile and apparel at 3.6 grams per tonne of product produced; (iv) phosphorus waste embodied in wholesale and retail trade at 2.4 grams per tonne of product produced.

Energy Greenhouse Gases (Figure 16.9)

In terms of CO₂ greenhouse gas emissions, petroleum, chemical and plastic products were found to emit 297,632.5 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of petroleum, chemical and plastic products are ranked the 16th highest out of the 20 product producing sectors covered in this publication.

Energy-related CO₂ directly generated by petroleum, chemical and plastic were 25% of total emissions or 75,360.8 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by petroleum, chemical and plastic products made up the majority at 75% of total emissions produced, or 222,271.7 grams per tonne of product. *The indirect energy-related CO₂ emissions from the*

production of paper products was mostly made up of (i) energy-related CO₂ embodied oil and gas at 42,527.7 grams per tonne of product produced; (ii) energy-related CO₂ embodied in paper products at 30,860.6 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services at 23,639.4 grams per tonne of product produced; (iv) energy-related CO₂ embodied in non-metal mineral products at 21,054.1 grams per tonne of product produced.

Figure 16.2 - Electricity Inputs Required to Produce One Tonne of Petroleum, Chemical and Plastic Products, 2003-04 (MJ, Heat Equivalents)

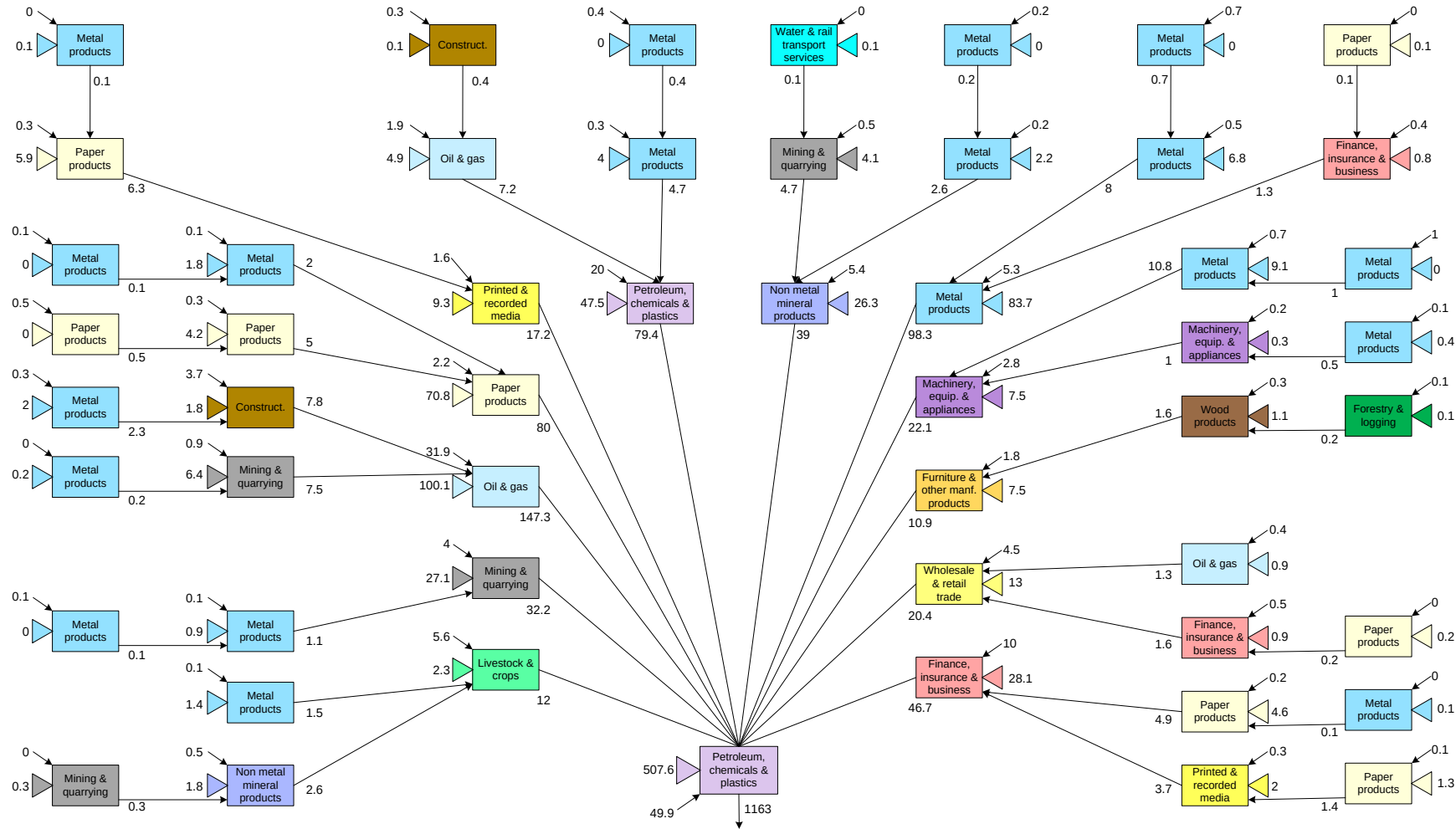


Figure 16.3 - Fossil Fuel Inputs Required to Produce One Tonne of Petroleum, Chemicals and Plastic Products, 2004 (MJ, Heat Equivalents)

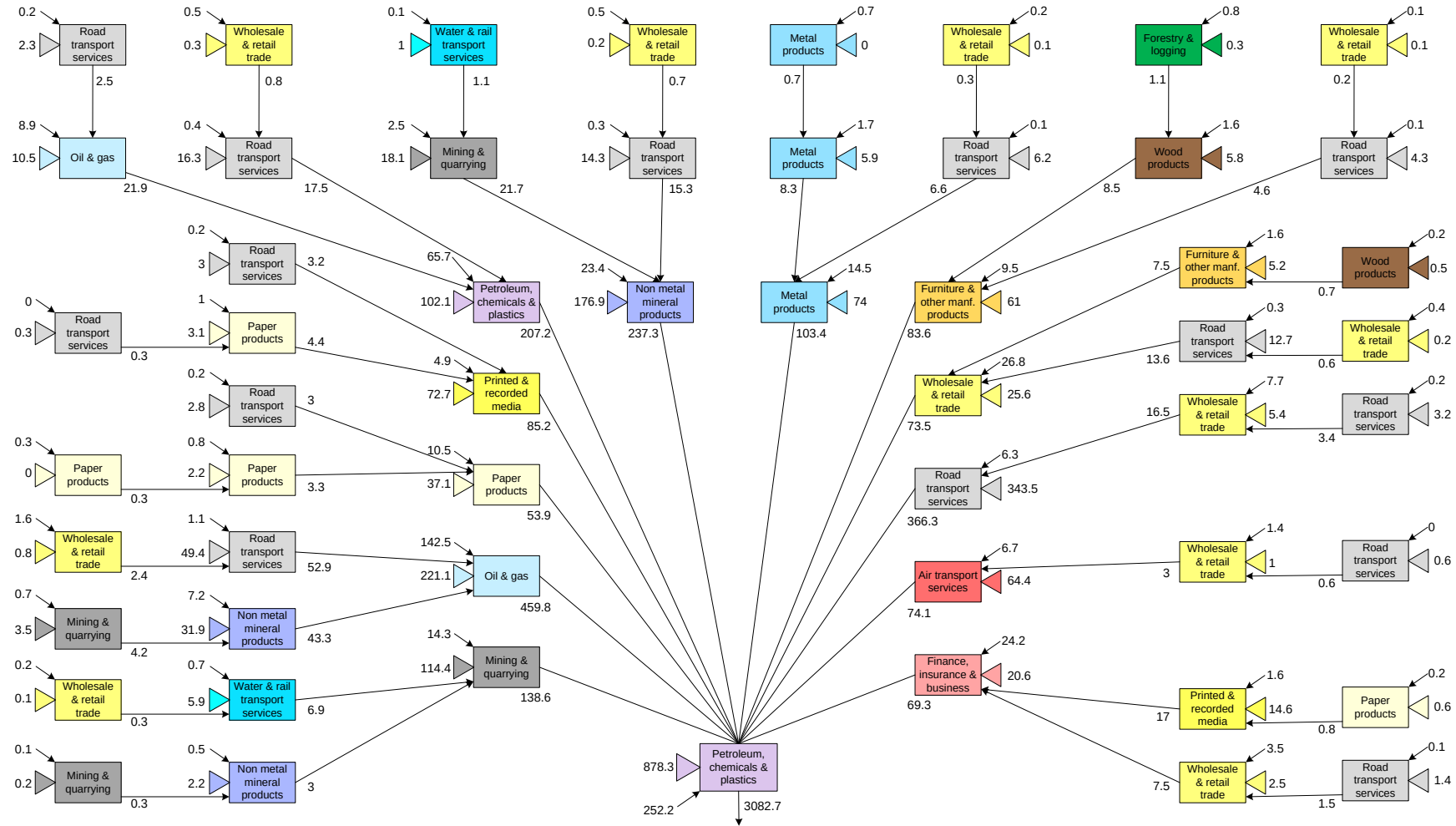


Figure 16.4 - Land Required to Produce One Tonne of Petroleum, Chemicals will and Plastics Products, 2004 (m²)

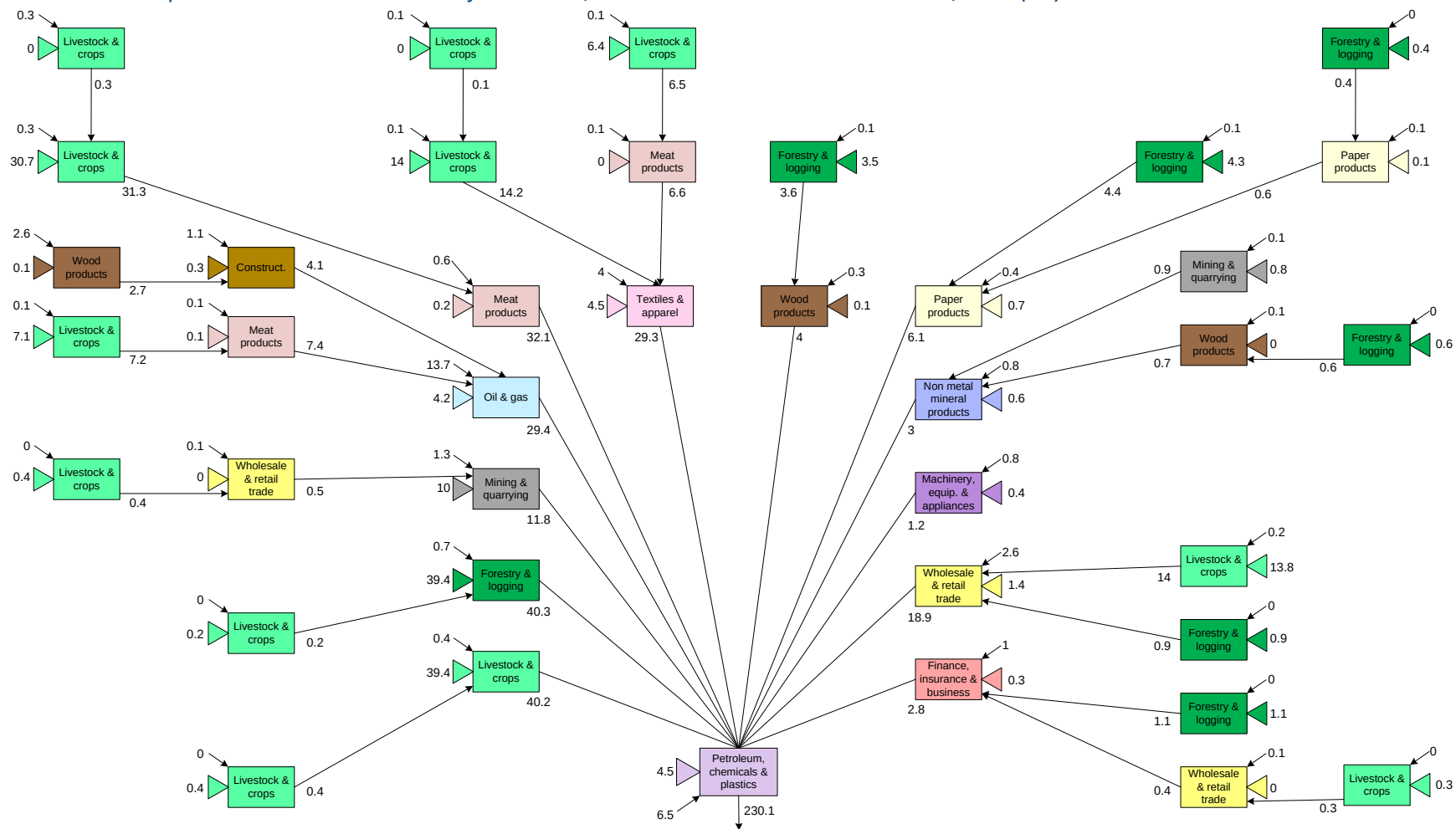


Figure 16.5 - Water Inputs Required to Produce One Tonne of Petroleum, Chemical and Plastic Products, 2004 (Litres)

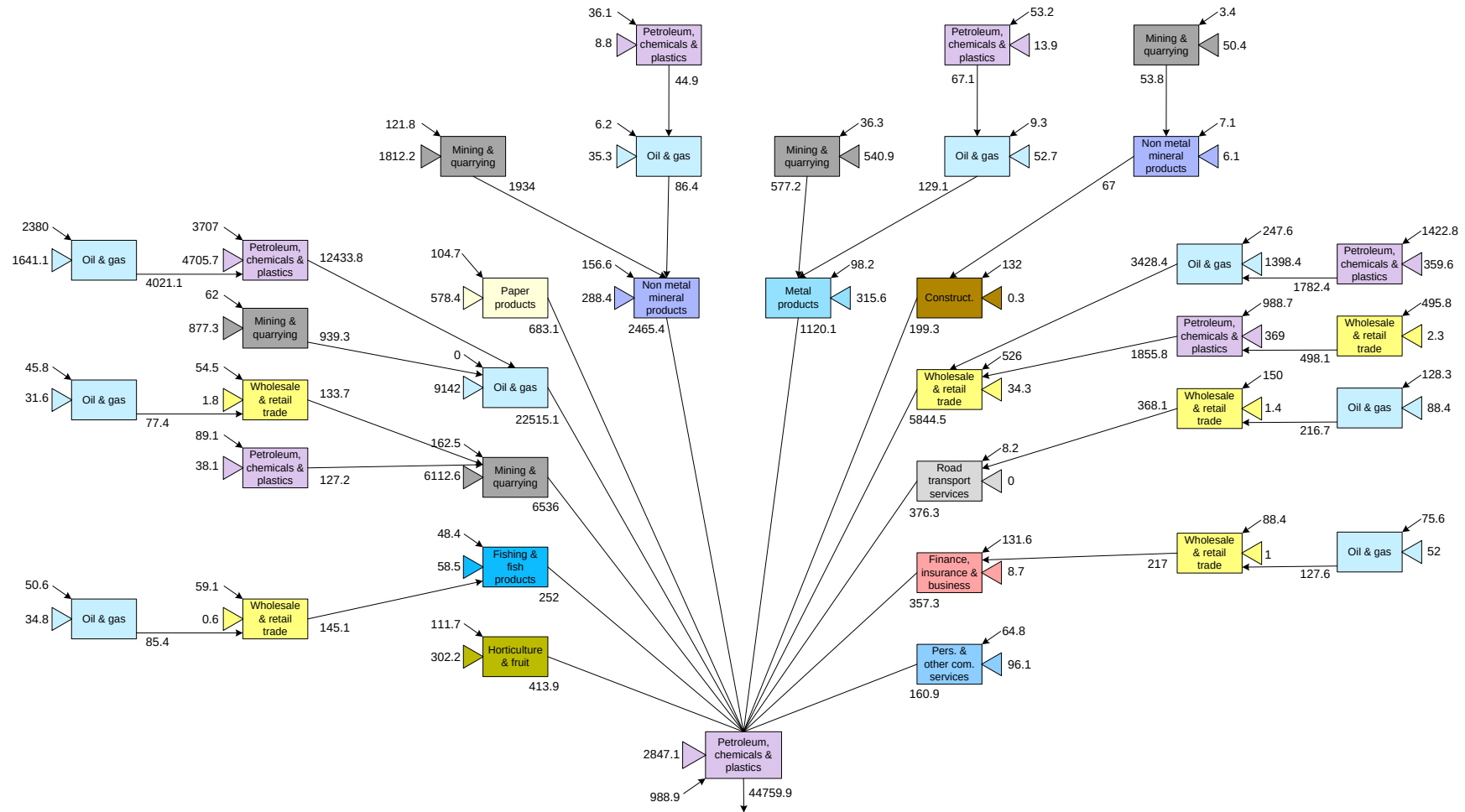


Figure 16.6 - Landfill Waste Generated in Producing One Tonne of Petroleum, Chemical and Plastic Products, 2004 (Grams)



Figure 16.7 - Water Waste Generated in Producing One Tonne of Petroleum, Chemical and Plastic Products, 2004 (Litres)

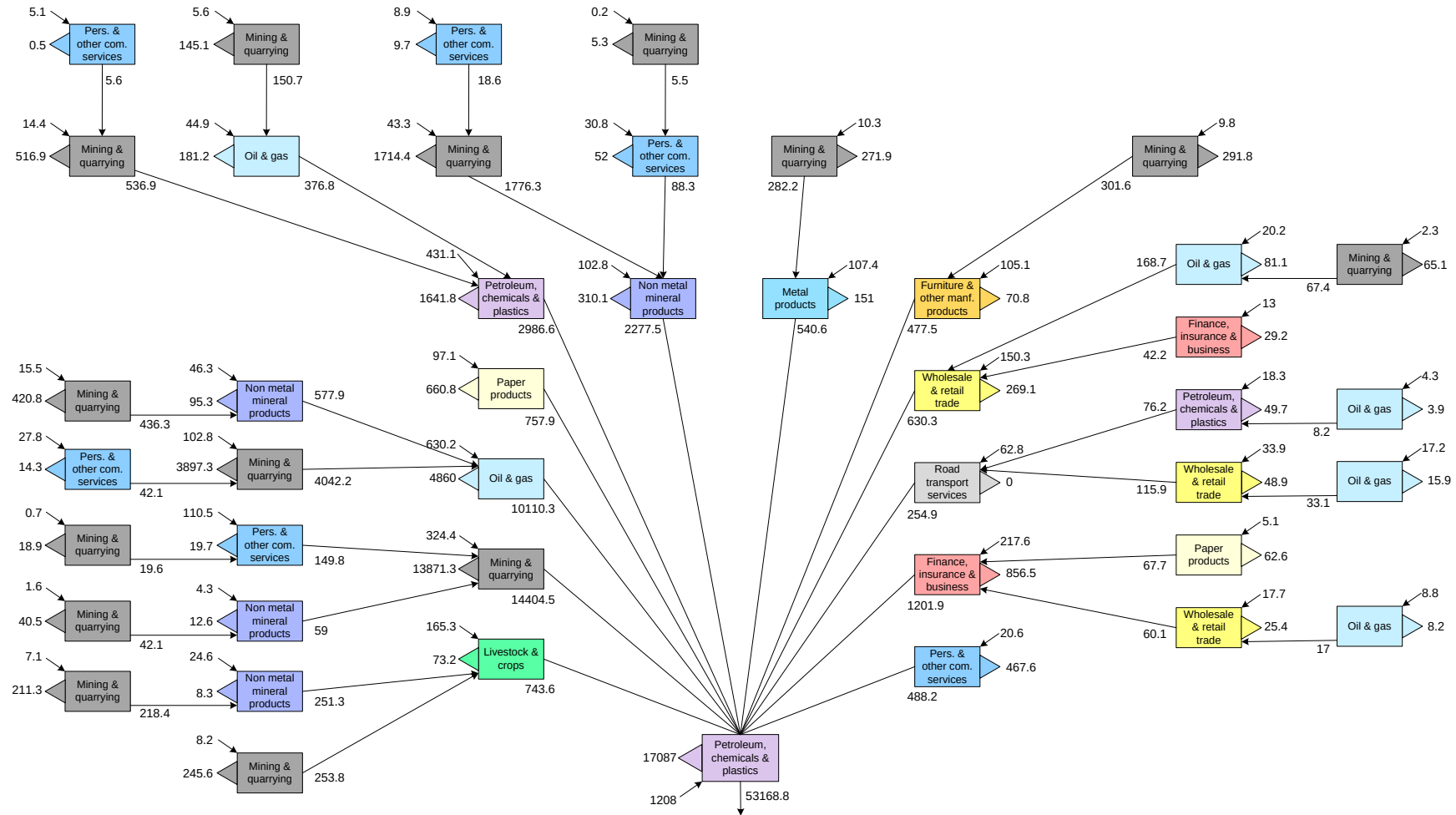


Figure 16.8 - Phosphorus Waste Generated in Producing One Tonne of Petroleum, Chemical and Plastic Products, 2004 (Grams)

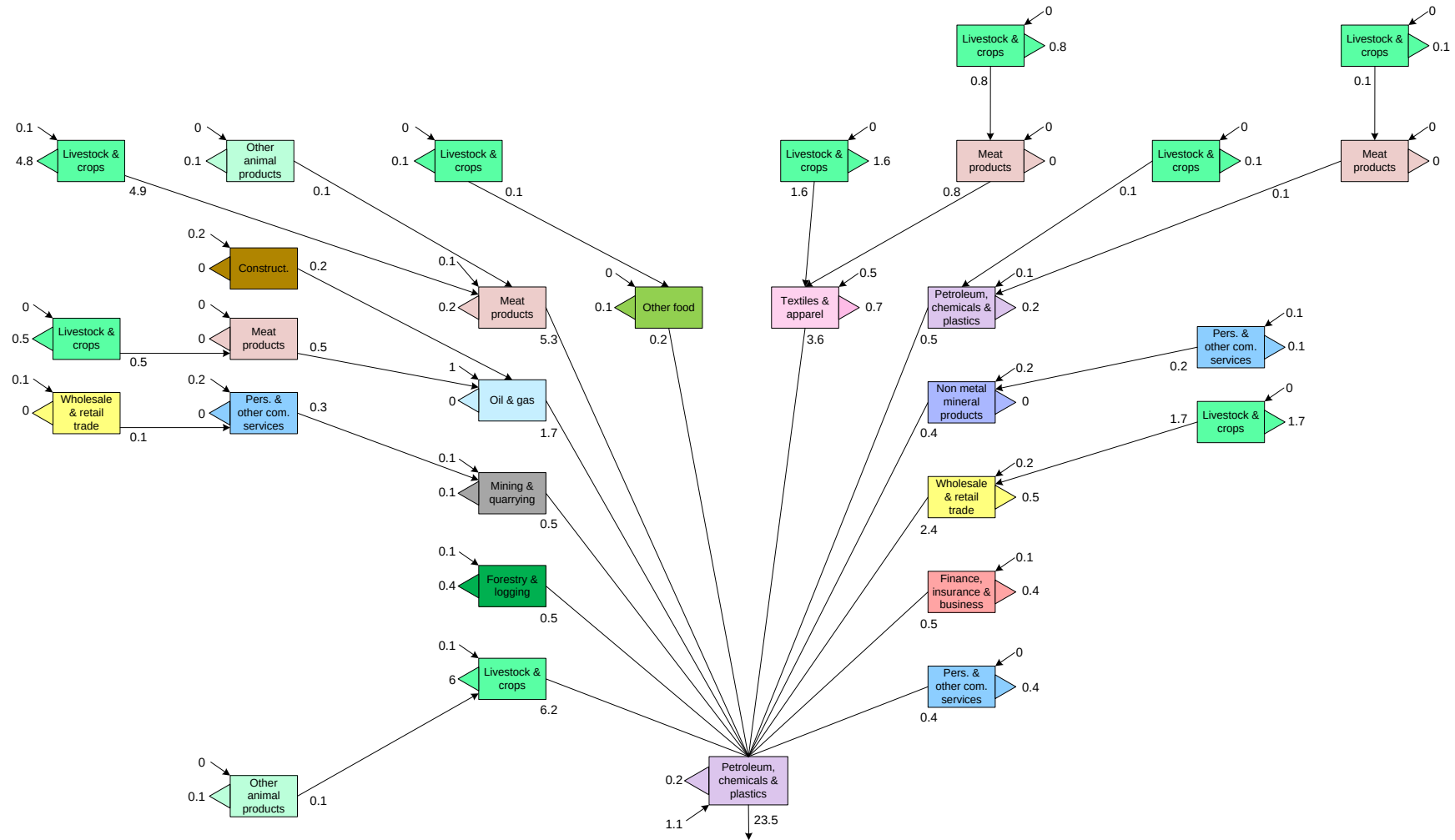
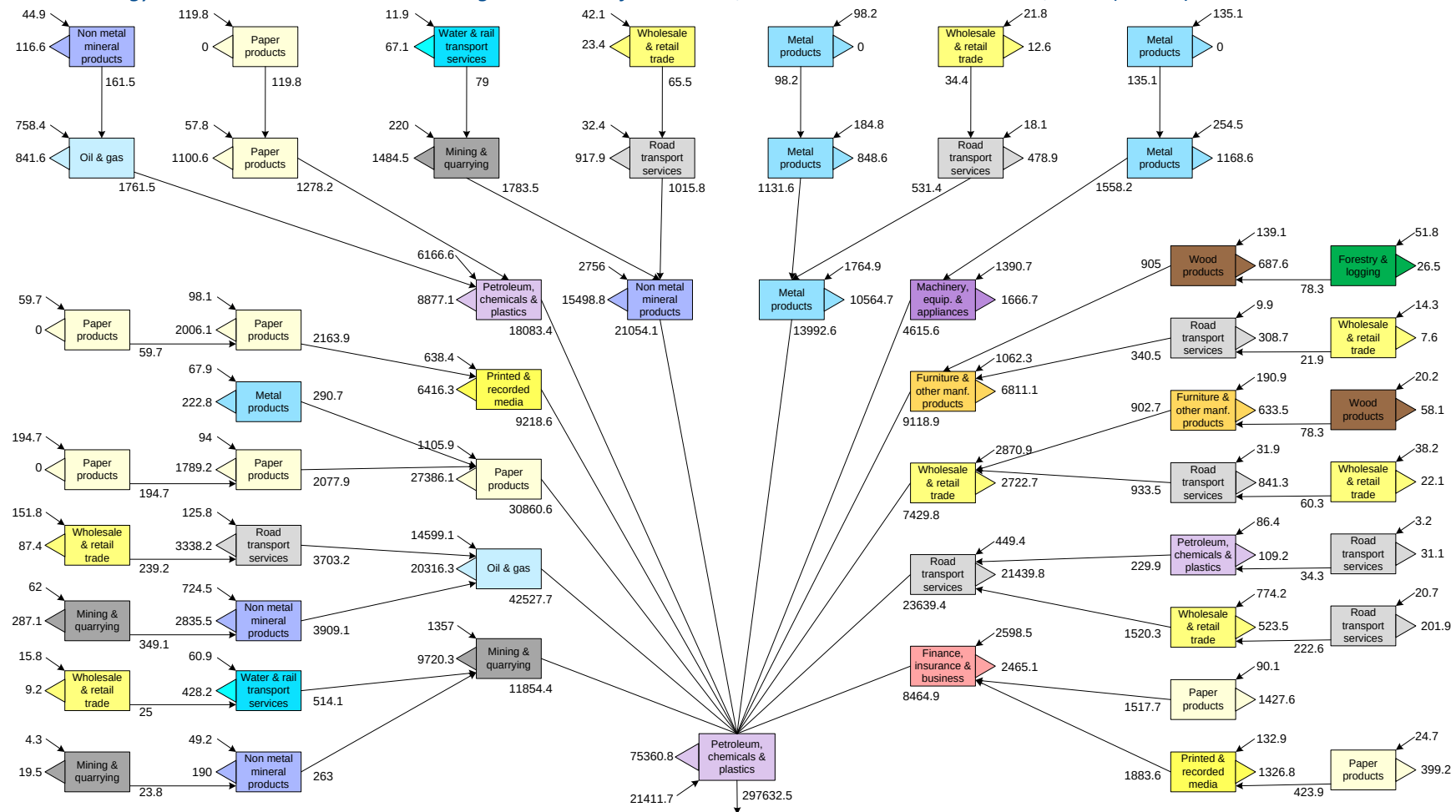


Figure 16.9 - Energy-Related CO₂ Emitted in Producing One Tonne of Petroleum, Chemical and Plastic Products, 2004 (Grams)



17. Non-Metallic Mineral Product Manufacturing

Description

ANZSIC Codes covered:

- 201 – Glass and Glass Product Manufacturing
- 202 – Ceramic Product Manufacturing (incl. clay brick, ceramic tile and pipe)
- 203 – Cement, Lime, Plaster and Concrete Product Manufacturing
- 209 – Other Non-Metallic Mineral Product Manufacturing (incl. abrasives and asbestos products)

GDP 2016 = \$1.113 billion
Rank = 29th

Average annual growth rate
2006 to 2016 = 1.85%
Rank = 26th

Employment 2016 = 8,687
Rank = 28th

Main commodities supplied:

- Ceramics, glass, cement, lime, and plaster

Economic Overview

The non-metallic mineral product manufacturing industry was the 29th largest sector in the economy in 2016 and accounted for 3.4% of total sales for the broader manufacturing sector in 2004.²¹⁸ The output of non-metallic minerals (aggregate, limestone and specialised high-value minerals) and their processed products such as cement have increased in line with economic and population growth.²¹⁹

The sector's products are used in a wide range of applications cement, bricks & roof tiles, wall & floor tiles, and some glass products used in the construction industry, through to consumer products like tableware and decorative goods.

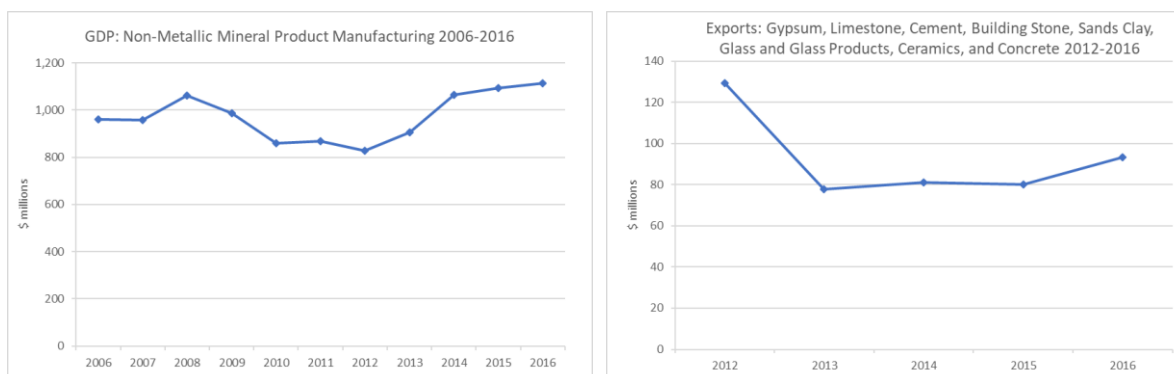
Domestic demand for products in this sector is closely tied to the construction industry, which has been increasing over time, driven in recent years by the Christchurch rebuild and KiwiBuild programmes. In 2016, this sector contributed \$1.113 billion to GDP and employed 8,687 people in New Zealand. Although, the non-metallic mineral product manufacturing sector is one of New Zealand's smaller exporting sectors, making up just 0.2% of New Zealand's exports. Products such as ceramic pottery and decorative glassware are exported in significant amounts to markets such as Australia (33%), the UK (15%) and the US (14.5%).²²⁰

²¹⁸ Turner, J. (Reserve Bank of New Zealand). (2005). Overview of the Manufacturing Sector. *Bulletin*, 68(1). Retrieved from http://www.minerals.co.nz/pdf/Natural_Resource_NZ_web.pdf

²¹⁹ Barker, R. (2008). *The Natural Resource Potential of New Zealand*. Retrieved from http://www.minerals.co.nz/pdf/Natural_Resource_NZ_web.pdf

²²⁰ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd.

Sector Trends



Production

Initially, the non-metallic mineral product manufacturing sector experienced some growth, with a 10.73% increase in production over the first two years. Following this, production began on a downward trend as a potential result of the GFC, decreasing from \$1.06 billion to \$827 million over a 4-year period. Recovery from this downturn was strong, particularly in the first two years, where an increase in production reached 17.44%, before petering out to the sector's peak of \$1.11 billion. The recovery of this industry has likely been spurred on by the Christchurch earthquake recovery, where lots of products included in this sector, such as cement and glass, are required in construction. Further residential construction taking place in Auckland is likely to continue the growth in production of this sector.

Exports

Noticeably, the period from 2012 to 2016 began with a large decrease in the value of exports from the non-metallic mineral product manufacturing sector. The value of exports dropped 39.92%, down from \$129 million to \$78 million. This was followed by a couple of years of constant export returns and a slight uptick in the final year of 16.36%. The downturn was driven by the poor performance of the product group; articles of concrete and stone while the uptick was partly driven by a recovery in this product group. This slow pattern of growth likely reflects the fact that the natural availability of non-metallic mineral products in New Zealand is limited compared to other countries, leading to a significant portion of the processed product used domestically, with only a small, and shrinking, portion exported. Additionally, the tough logistical task of exporting products such as bricks, cement and glassware usually offer natural protection for local producers.

Life Cycle Assessment Diagrams

Energy (Figure 17.1, Figure 17.2, Figure 17.3)

Non-metal mineral products were found to have a total energy intensity of 1,202.4 MJ_{OE} per tonne of product (1.2 MJ_{OE}/kg), ranking 17th highest out of the 20 product producing sectors covered in this publication. The total energy intensity measured in conventional terms is 2,565 MJ_H/tonne (2.565 MJ_H/kg). This compares reported energy intensities produced by various non-metal mineral products such as NZ concrete at 1,500 MJ_H per tonne of product, NZ glass at 15,900 MJ_H per tonne of product, NZ

clay bricks at 6,700 MJ_H per tonne of product, NZ ceramic tiles at 8,320 MJ_H per tonne of product;²²¹ UK asbestos at 7,400 MJ_H per tonne of product, UK lime at 5,300 MJ_H per tonne of product, and UK concrete products from 0.81 to 1.36 MJ_H per tonne of product.²²²

Direct energy use was 61% of the total energy intensity, measuring 735 MJ_{OE} per tonne of non-metal mineral product produced. *Indirect energy* use was 39% of the total energy intensity, measuring 467.4 MJ_{OE} per tonne of paper product produced. *The main indirect energy uses in the production of non-metal mineral products came from; (i) energy embodied in mining and quarrying at 178.3 MJ_{OE} per tonne of product produced; (ii) energy embodied in road transport services at 82.6 MJ_{OE} per tonne of product produced; (iii) energy embodied in metal products at 47.5 MJ_{OE} per tonne of product produced; (iv) energy embodied in paper products at 29.6 MJ_{OE} per tonne of product produced.*

Land (Figure 17.4)

Non-metal mineral products have a total land intensity of 55.5 m² per tonne of product produced, ranking the sector 19th highest out of the 20 product producing sectors covered in this publication. *Direct land use* was very small at only 4% of the total land intensity at 2.2 m² per tonne of product produced. *Indirect land use* makes up the majority of non-metal mineral product's total land intensity at 96% measuring 53.3 m² per tonne of product produced.

The major indirect land uses in the production of non-metal mineral products come from; (i) land embodied mining and quarrying at 19.6 m² per tonne of product produced; (ii) land embodied in wood products at 15.8 m² per tonne of product produced; (iii) land embodied in wholesale and retail trade at 4.6 m² per tonne of product produced; (iv) land embodied in livestock and crops at 3 m² per tonne of product produced.

Water Inputs (Figure 17.5)

Non-metal mineral products require 8,421.5 litres of water inputs per tonne of product produced, ranking the sector the 16th highest consumer of water compared to the 20 product producing sectors covered in this publication.

Direct water inputs make up only 7% of total water inputs, or 585.9 litres per tonne of non-metal mineral product produced. While *Indirect water inputs* make up the remaining 93% of the total water inputs or 7,835.6 litres per tonne of non-metal mineral product produced. *The main indirect water inputs to non-metal mineral products came from; (i) water inputs embodied in mining and quarrying at 7,043.6 litres per tonne of product produced; (ii) water inputs embodied in oil and gas at 239 litres per tonne of product produced; (iii) water inputs embodied in wholesale and retail trade at 225.9 litres per tonne of product produced; (iv) water inputs embodied in metal products at 66.7 litres per tonne of product produced.*

Landfill Wastes (Figure 17.6)

Non-metal mineral products were found to generate 9,024.2 grams (9 kg) of landfill waste per tonne of product produced. This ranks the sector the 17th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by non-metal mineral products was 78% of total waste produced or 7,045.2 grams

²²¹ BRANZ Ltd. (2007). Life Cycle Assessment: Material Use. Retrieved from <http://www.level.org.nz/material-use/life-cycle-assessment/>

²²² Hammond, G.P., Jones, C.I. (2008). Inventory of Carbon and Energy (ICE) (Version 1.6a). Sustainable Energy Research Team, Department of Mechanical Engineering, University of Bath, UK. Retrieved from <http://web.mit.edu/2.813/www/readings/ICE.pdf>

per tonne of product produced. *Landfill waste indirectly generated* by non-metal mineral products was 22% of total waste produced or 1,979 grams per tonne of product produced.

The main sources of indirect landfill waste in the production of non-metal mineral products came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 564.2 grams per tonne of product produced; (ii) landfill wastes embodied in wood products at 444.9 grams per tonne of product produced; (iii) landfill wastes embodied in mining and quarrying at 155.8 grams per tonne of product produced; (iv) landfill wastes embodied in road transport services at 152.6 grams per tonne of product produced.

Water Wastes (Figure 17.7)

Non-metal mineral products were found to produce 26,654.1 litres of water wastes per tonne of product produced. This ranks the sector as the 14th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* by the production of non-metal mineral products was a mere 2% of total waste produced at 546.9 litres per tonne of product produced. *While wastewater indirectly generated* by non-metal mineral products made up the majority at 98% of the total wastewater produced or 26,107.2 litres per tonne of product produced.

The indirect wastewater produced by non-metal mineral products was mostly made up of (i) wastewater embodied in mining and quarrying at 23,674.7 litres per tonne of product produced; (ii) wastewater embodied in personal and other community services at 1,000 litres per tonne of product produced; (iii) wastewater embodied in petroleum, chemicals and plastics at 243.5 litres per tonne of product produced; (iv) wastewater embodied in oil and gas at 205.6 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 17.8)

In terms of CO₂ greenhouse gas emissions, non-metal mineral products were found to emit 202,454 grams (202.45 kg) of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of non-metal mineral products are ranked the 17th highest out of the 20 product producing sectors covered in this publication. This is similar to reported CO₂ greenhouse gas emissions produced by various non-metal mineral products: UK general bricks at 60 kg of CO₂ per tonne of product produced, UK general cement at 226kg of CO₂ per tonne of product produced, UK general glass at 232kg of CO₂ per tonne of product produced (Hammond & Jones, 2008²²³).

Energy-related CO₂ directly generated by non-metal mineral products was the majority of total emissions produced at 70%, or 142,116.8 grams per tonne of product produced. Energy-related CO₂ indirectly generated by non-metal mineral products made up the remaining 30% of the total emissions produced or 60,337.2 grams per tonne of product produced.

The indirect energy-related CO₂ emissions from the production of non-metal mineral products was mostly made up of (i) energy-related CO₂ embodied in mining and quarrying at 19,697.4 grams per tonne of product produced; (ii) energy-related CO₂ embodied in road transport services at 9,829.1 grams per tonne of product produced; (iii) energy-related CO₂ embodied in paper products at 5,913.1 grams per tonne of product produced; (iv) energy-related CO₂ embodied in metal products at 5,034.2 grams per tonne of product produced.

²²³ Hammond, G.P., Jones, C.I. (2008). Embodied Energy and Carbon in Construction Materials. Proceedings of the Institution of Civil Engineers – Energy, 161 (2), 87-98.

Figure 17.1 - Total Energy Inputs Required to Produce One Tonne of Non-Metal Mineral Products, 2004 (MJ_E, Oil Equivalents)

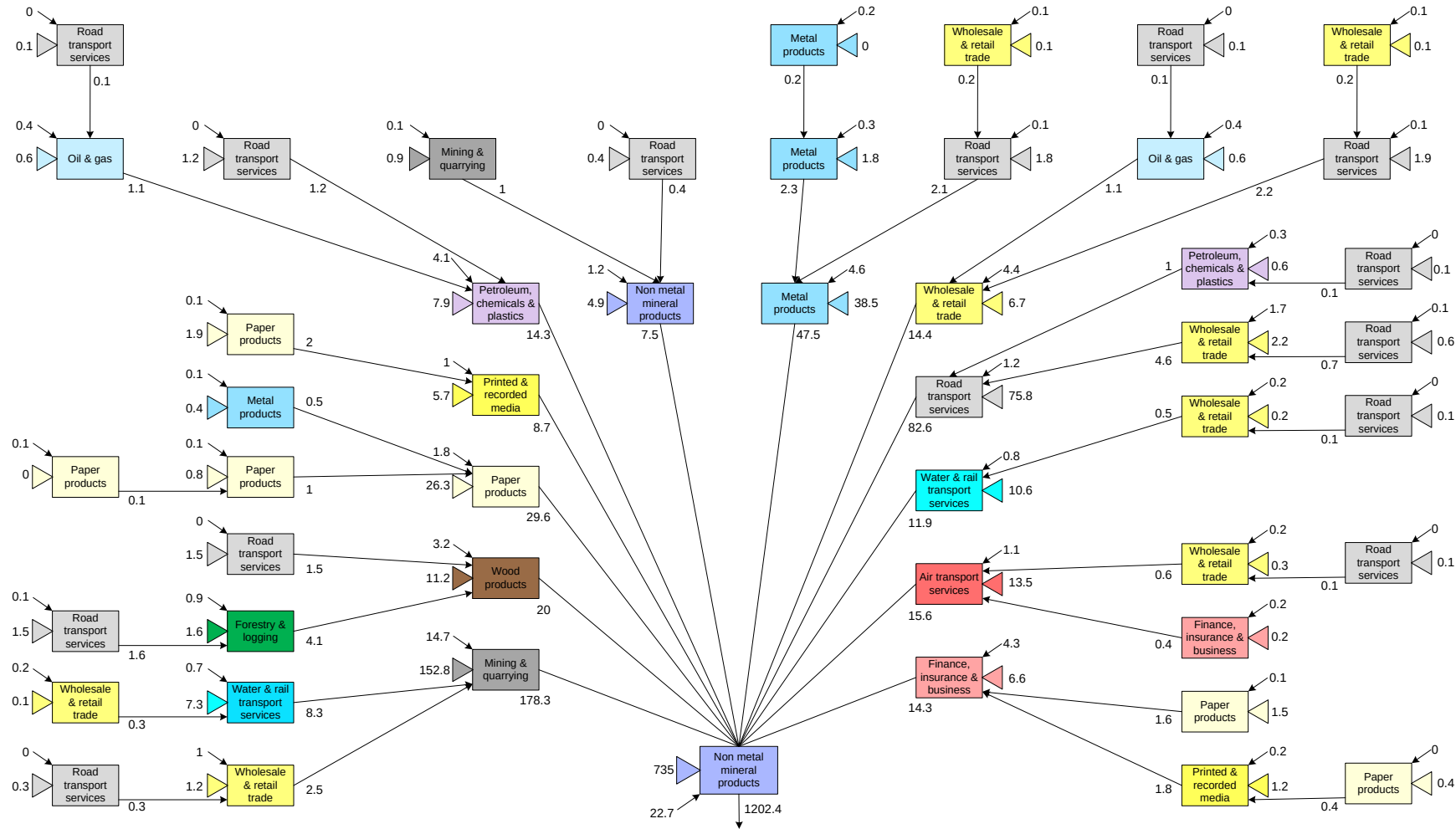


Figure 17.2 - Electricity Inputs Required to Produce One Tonne of Non-Metal Mineral Products, 2004 (MJ, Heat Equivalents)

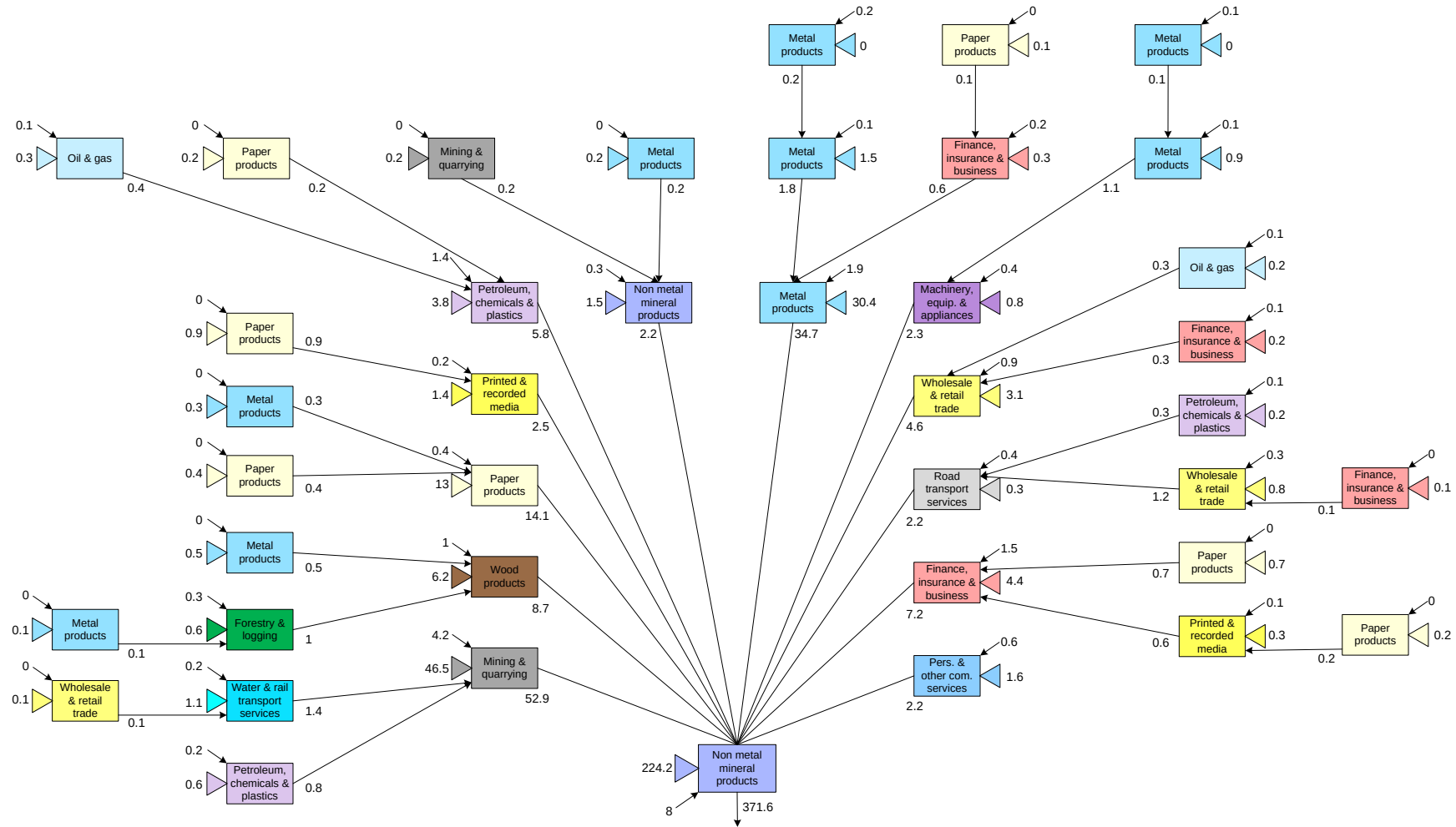


Figure 17.3 - Fossil Fuel Inputs Required to Produce One Tonne of Non-Metal Mineral Products, 2004 (MJ, Heat Equivalents)

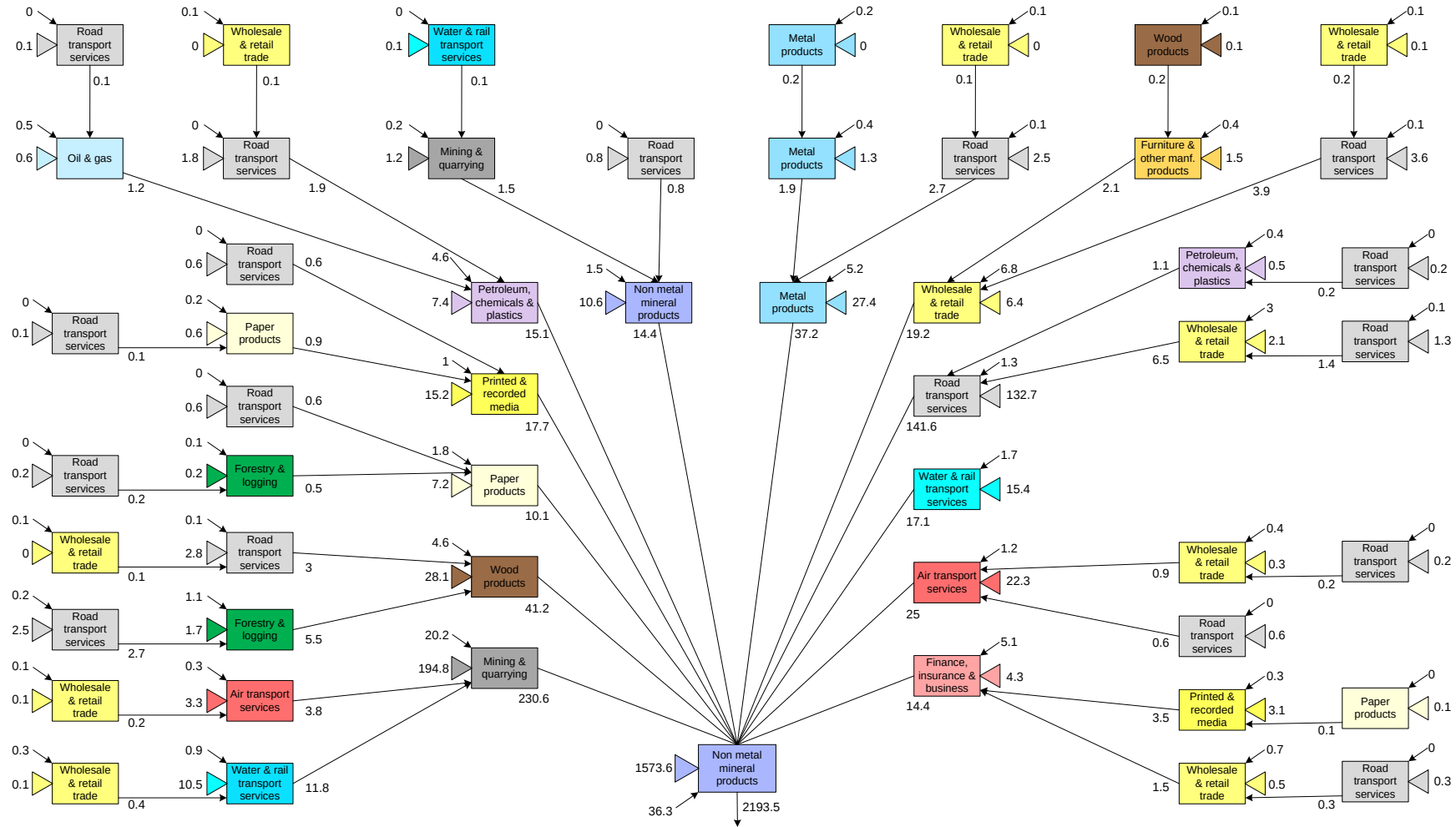


Figure 17.4 - Land Required to Produce One Tonne of Non-Metal Mineral Products, 2004 (m²)

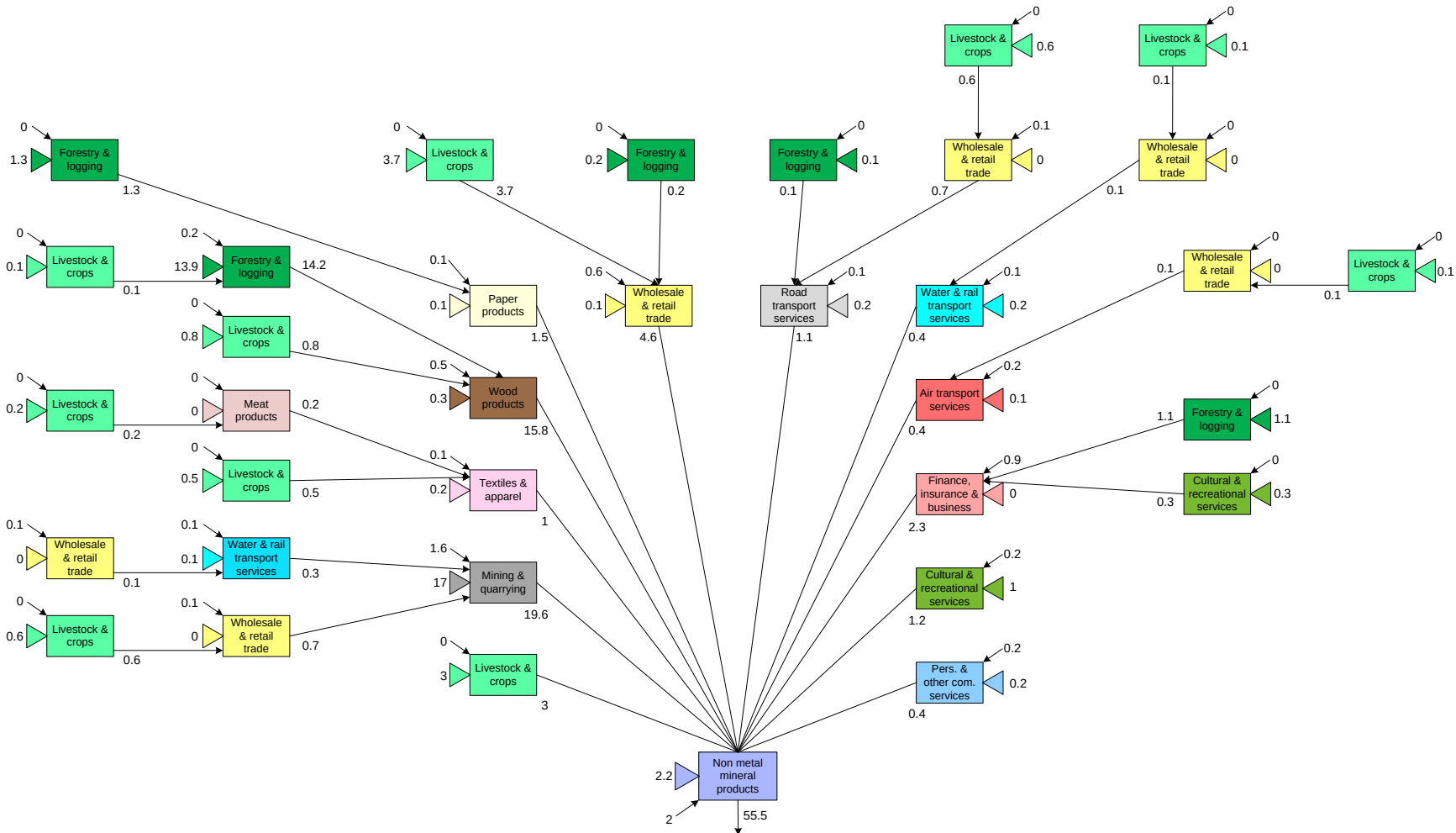


Figure 17.5 - Water Inputs Required to Produce One Tonne of Non-Metal Mineral Products, 2004 (Litres)

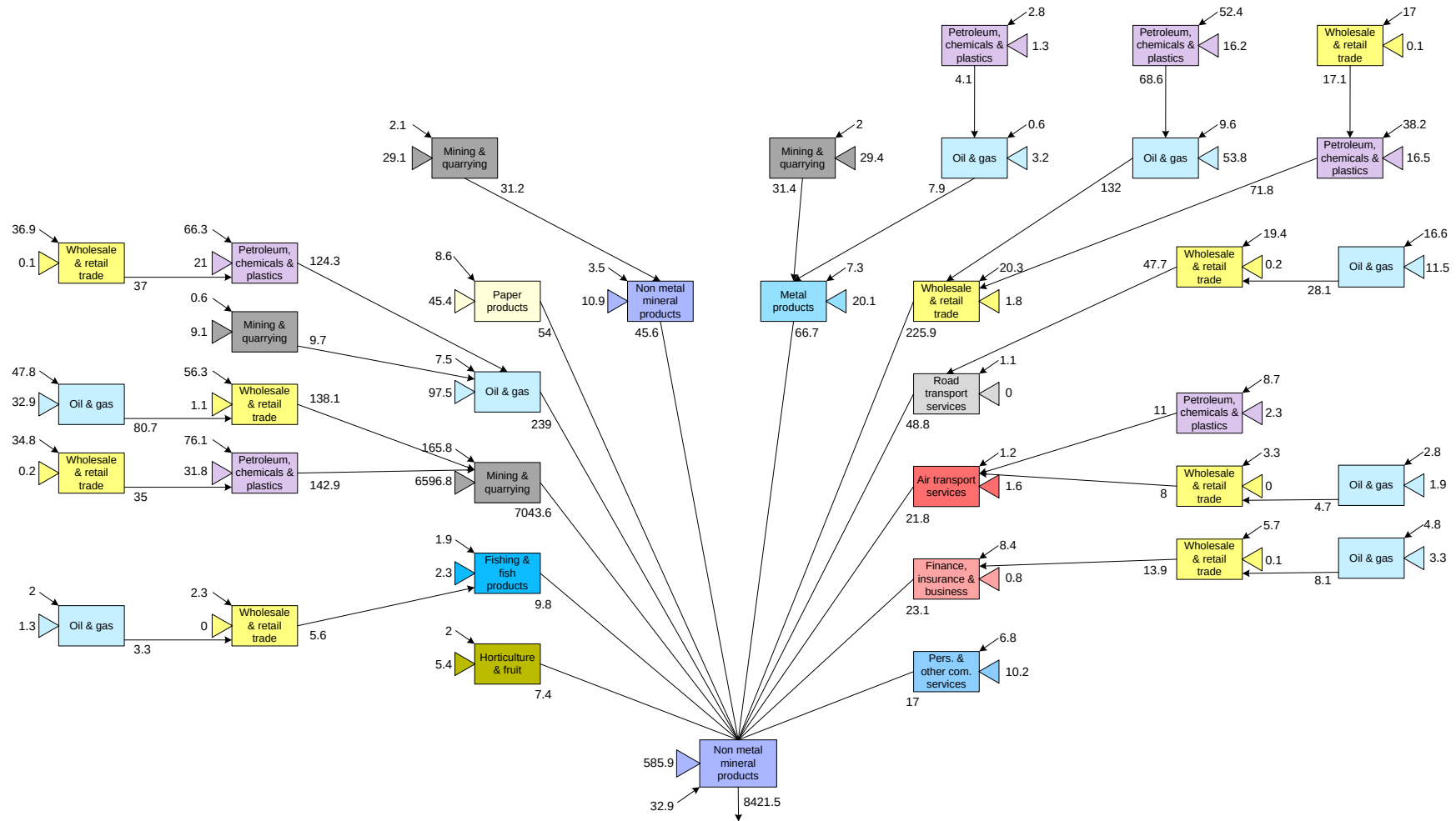


Figure 17.6 - Landfill Waste Generated in Producing One Tonne of Non-Metal Mineral Products, 2004 (Grams)

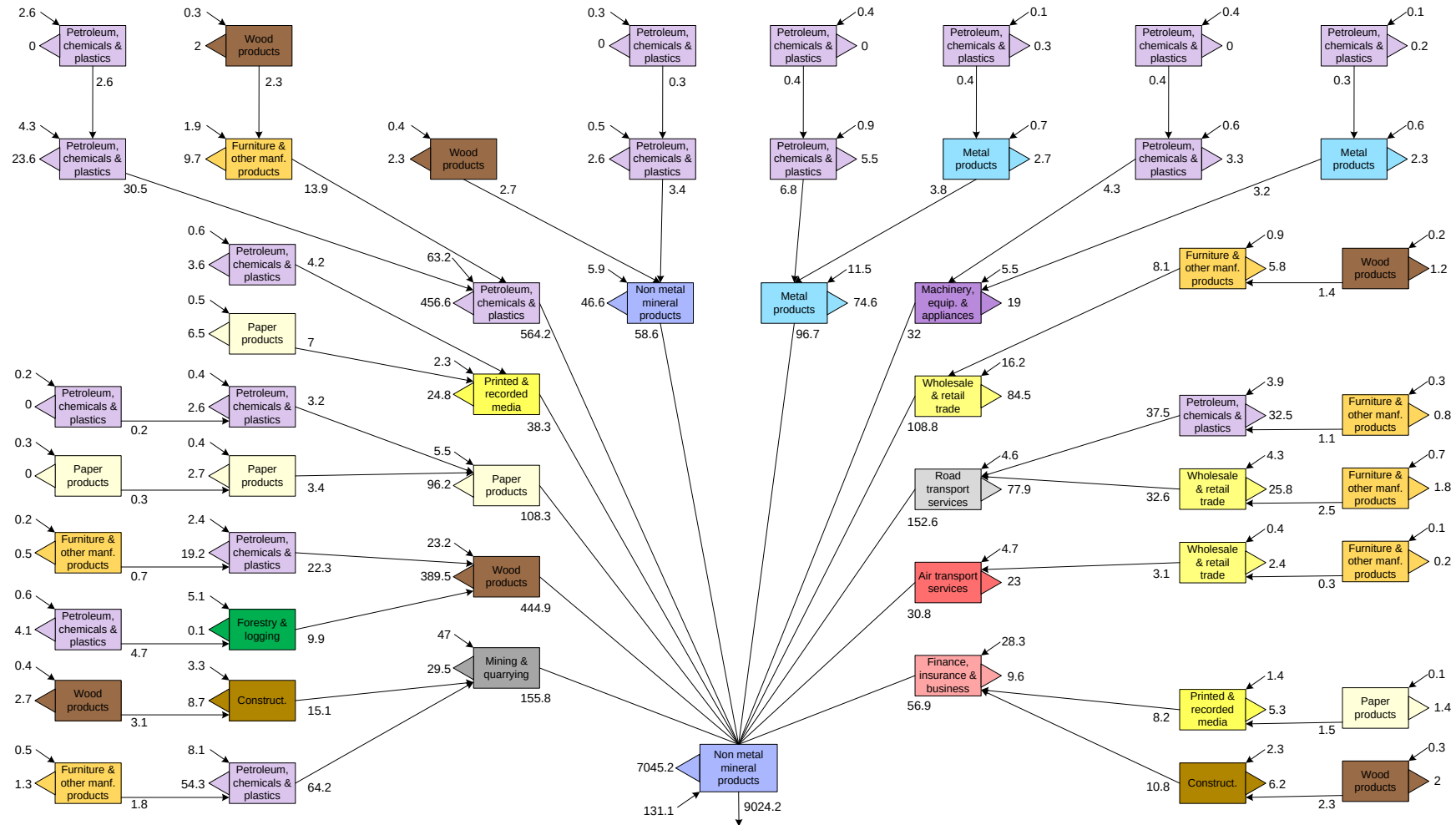


Figure 17.7 - Water Waste Generated in Producing One Tonne of Non-Metal Mineral Products, 2004 (Litres)

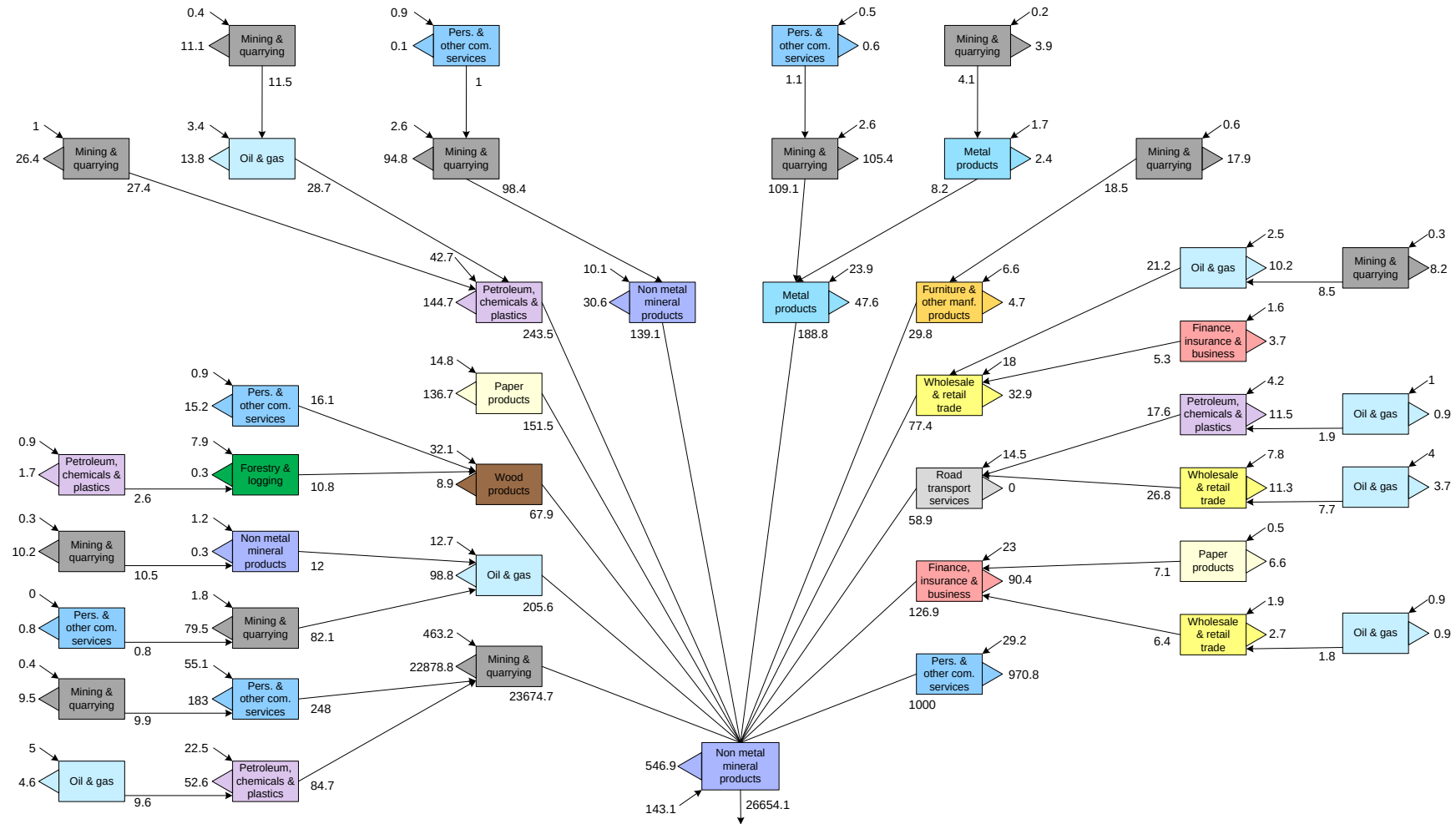
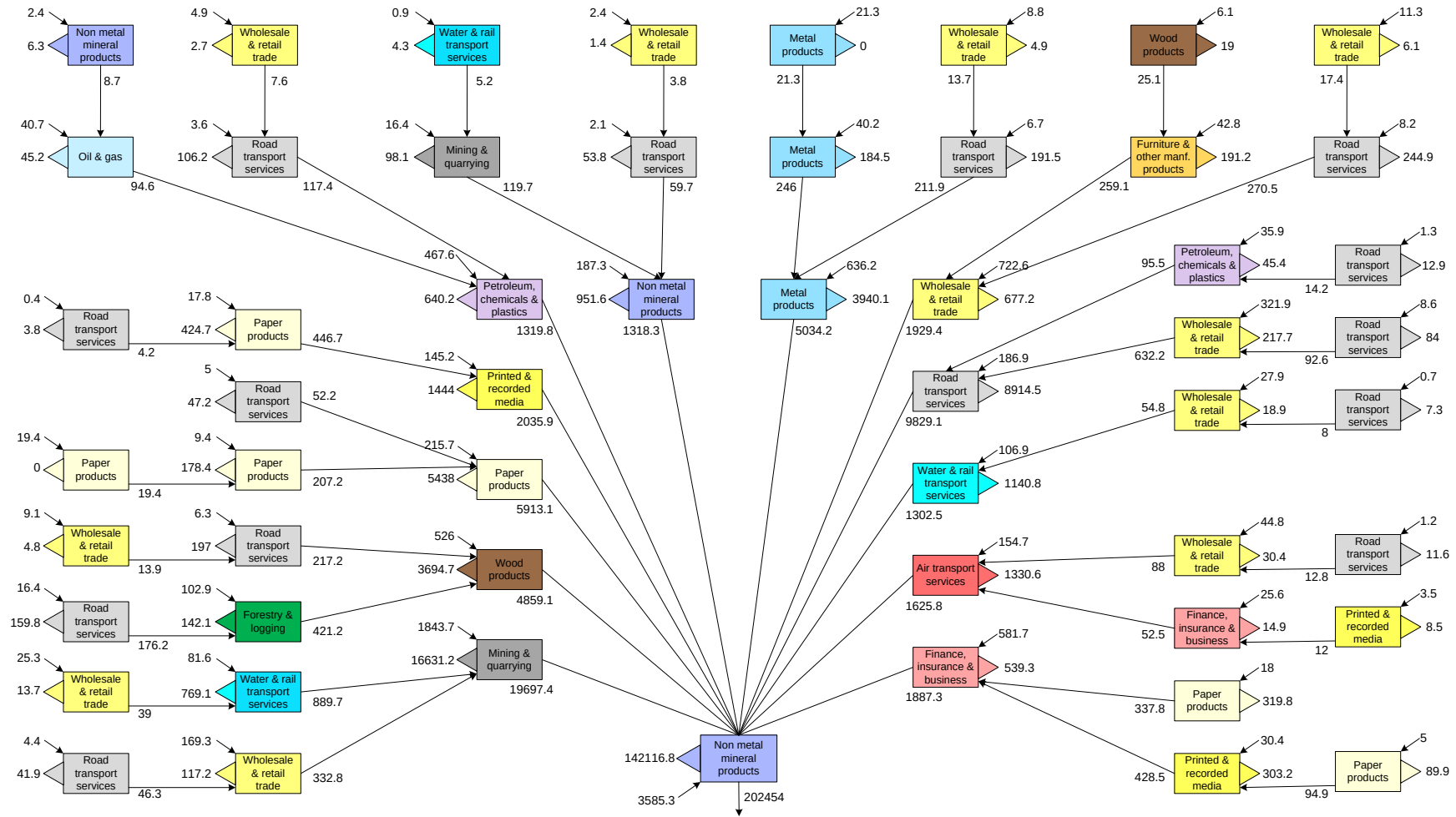


Figure 17.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Non-Metal Mineral Products, 2004 (Grams)



18. Basic, Structural and Fabricated Metal Manufacturing

Description

ANZSIC Codes covered:

- 211 – Basic Ferrous Metal Manufacturing (Iron smelting and steel manufacturing)
- 212 – Basic Ferrous Metal Product Manufacturing (Iron and steel casting, e.g. pipes and tubes)
- 213 – Basic Non-Ferrous Metal Manufacturing (incl. aluminium, copper, silver, lead and zinc smelting)
- 214 – Basic Non-Ferrous Metal Product Manufacturing (e.g. aluminium rolling, drawing, extruding)
- 221 – Iron and Steel Forging
- 222 – Structural Metal Product Manufacturing (incl. architectural aluminium product manufacturing and prefabricated metal product)
- 223 – Metal Container Manufacturing
- 224 – Sheet Metal Product Manufacturing
- 229 – Other Fabricated Metal Product Manufacturing (springs and wire, nuts bolts and screws)

GDP 2016 = \$2.753 billion

Rank = 18th

Average annual growth rate

2006 to 2016 = 0.27%

Rank = 29th

Employment 2016 = 29,311

Rank = 19th

Main commodities supplied:

- Aluminium (350,000 tonnes)
- Iron and steel (650,000 tonnes)²²⁴

Economic Overview

Abundant supplies of iron sand, coal, and limestone provided the necessary factor conditions for the establishment of metal manufacturing in New Zealand. The government was responsible for the establishment of both domestic steel manufacturing and aluminium smelting, as growth in the domestic economy in the 1950s and the demand for steel led to government research into utilising indigenous raw materials for a homegrown steel industry using technologies developed overseas. The construction of the giant Manapouri hydroelectricity scheme allowed the Tiwai Point factory in Southland to start producing in 1969, which is currently the only aluminium smelter in New Zealand. It is the single biggest user of power in the country, consuming 15% of the total power generated in New Zealand.²²⁵ Tiwai Point imports bauxite as a raw material from Australia, and most of the finished product from the smelter goes to Japan.²²⁶ This is by far the most significant export by value from this

²²⁴ Glenbrook Steel Site Operations, New Zealand Steel Limited (2011). Glenbrook Steel Site. Retrieved from <http://www.nzsteel.co.nz/about-new-zealand-steel/operations-/glenbrook-steel-site>

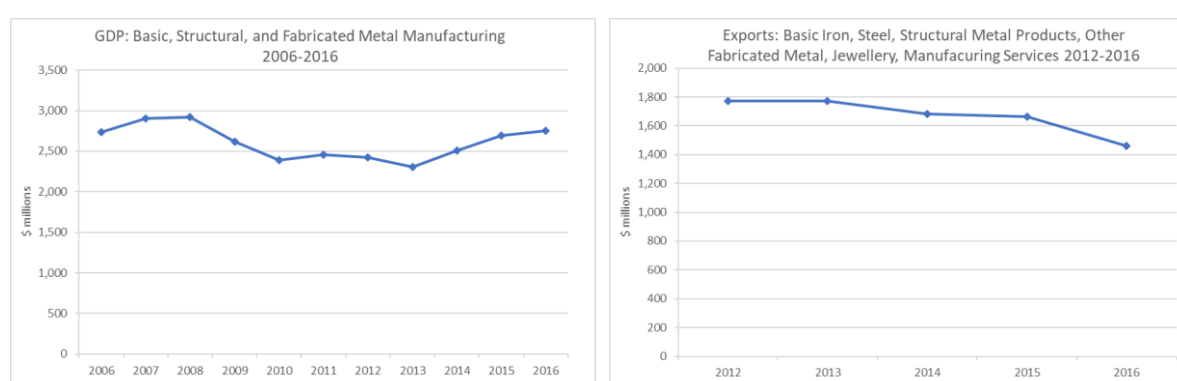
²²⁵ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

²²⁶ Weir, J. (2008, November 12). *Smelter output slashed*. *The Dominion Post*. Page C3.

sector, producing more than 2% of New Zealand's total export income.²²⁷ The smelter exports 90% of its production.²²⁸

New Zealand Steel Limited owns the Glenbrook Steel Mill in the North Island, which produces 90% of the country's steel requirements, with the remainder produced by Pacific Steel, a steel recycling facility. Around 715,000 tonnes of iron and steel are exported annually, and after the inclusion of aluminium exports, most of the remaining export trade in this sector is from scrap metal. Sheetmetal manufacturers specialise in the fabrication of stainless steel, aluminium, brass, copper and mild steel products. Most of the demand for these products comes from the domestic market, from sectors such as the food processing industry. The sheet metal industry is made up of many businesses that cater to a range of requirements, and many small companies produce for local niche markets.

Sector Trends



Production

Growth in this sector followed a general downward trend, similarly to other manufacturing sectors as a result of the GFC, from \$2.92 billion in 2008 down to \$2.30 billion in 2013, despite a small recovery and plateau from 2010 to 2012. In 2014, production began to recover and over the three-year period from 2013 to 2016. Production grew 19.50%, from \$2.30 billion to \$2.75 billion, a similar level of production that was seen pre-GFC in the sector. This follows a similar pattern to the non-metallic mineral product manufacturing sector, in that the strong growth seen from 2013 onwards is likely due to the increase in construction as a result of the Christchurch earthquake recovery and Auckland residential construction. As the Tiwai Point smelter is the major holder of market share in aluminium production, the performance of this company will have a direct impact on the performance of the metal manufacturing sector as a whole. Profitability will be at risk if cheap and clean alternative energy sources such as nuclear power become available in Australia, as well as being hurt by increases in wholesale power prices, due to the large quantity of electricity used by the plant. Illuminating this fact, the smelter has had to cut back on production in recent years and has threatened closure as a result of high New Zealand wholesale power prices.²²⁹

Exports

²²⁷ Devlin, C., & McCarthy, P. (2015, August 3). *Tiwai Smelter deal signed between Meridian Energy and NZAS*. Retrieved from Stuff: <https://www.stuff.co.nz/business/industries/70763839/tiwai-smelter-deal-signed-between-meridian-energy-and-nzas>

²²⁸ Brett Kelly, S. (2019, November 1). *The Detail: The Tiwai Point aluminium smelter bluff*. Retrieved from Stuff: <https://www.stuff.co.nz/national/the-detail/117070250/the-detail-the-tiwai-point-aluminium-smelter-bluff>

²²⁹ Harding, E. (2019, October 30). *Rio Tinto 'not bluffing' about threat to shut Tiwai Point smelter*. Retrieved from Stuff: <https://www.stuff.co.nz/business/industries/116995107/nzas-closure-team-coming-south>

Growth in the value of exports followed a general downward trend from 2012 through to 2016, decreasing on average 4.39% per year, taking the value of exports down from a high of \$1.78 billion in 2012 to \$1.46 billion in 2016. Noticeably, the decrease in the value of exports was the largest in the final year where it decreased 12.13%. The decline in value is most likely due to falling international commodity prices during this time.

Life Cycle Assessment Diagrams

Energy (Figure 18.1, Figure 18.2, Figure 18.3)

Metal products were found to have a total energy intensity of 12,064.9 MJ_{OE} per tonne of product (12 MJ_E/kg), ranking 6th highest out of the 20 product producing sectors covered in this publication. The total energy intensity measured in conventional terms is 18,242 MJ_H per tonne. This total energy intensity seems to be much lower than other reported energy intensities produced by various metal products such as NZ virgin aluminium at 194,000 MJ_H per tonne;²³⁰ NZ copper at 191,000 MJ_H per tonne, NZ stainless steel at 50,400 MJ_H per tonne;²³¹ UK iron (general) at 25,000 MJ_H per tonne MJ_E per tonne, UK lead (general) at MJ_H per tonne.²³² However, there is a lack of New Zealand 'total energy intensity' data for fabricated metal products and for metal products from recycled sources both of which are likely to have lower total energy intensities.

Direct energy use was 70% of the total energy intensity, measuring 8,454.5 MJ_{OE} per tonne of product produced. While *indirect energy use* was 30% of the total energy intensity, measuring 3,610.4 MJ_{OE} per tonne of product produced. The EECA in-use database reports that a total of 2,481.592 TJ of energy was used in the fabricated metal products, machinery and equipment sector in 2006/07.

The main indirect energy uses in the production of metal products came from; (i) energy embodied in metal products at 1,904.8 MJ_{OE} per tonne of product produced; (ii) energy embodied in road transport services at 472 MJ_{OE} per tonne of product produced; (iii) energy embodied in mining and quarrying at 205.6 MJ_{OE} per tonne of product produced; (iv) energy embodied in finance insurance and business services at 158.9 MJ_{OE} per tonne of product produced.

Land (Figure 18.4)

Metal products had a total land intensity of 140.3 m² per tonne of product produced, ranking the sector 18th highest in terms of land intensity out of the 20 product producing sectors covered in this publication. *Direct land use* was minuscule at only 3% of the total land intensity at 3.8 m² per tonne of product produced. *Indirect land use* made up the majority of the metal product's total land intensity at 97%, measuring 136.5 m² per tonne of product produced.

The major indirect land uses for metal products come from; (i) land embodied in livestock and crops at 29 m² per tonne of product produced; (ii) land embodied in textile and apparel at 26.2 m² per tonne of product produced; (iii) land embodied in metal products at 17.6 m² per tonne of product produced; (iv) land embodied in mining and quarrying at 14.2 m² per tonne of product produced.

²³⁰ BRANZ Ltd. (2007). Life Cycle Assessment: Material Use. Retrieved from <http://www.level.org.nz/material-use/life-cycle-assessment/>

²³¹ Alcorn, A., W

ood, P. (1998). *New Zealand Building Materials Embodied Energy Coefficients Database (volume II- coefficients)*. Wellington: Centre for Building Performance Research, Victoria University of Wellington.

²³² Hammond, G.P., Jones, C.I. (2008). Inventory of Carbon and Energy (ICE) (Version 1.6a). Sustainable Energy Research Team, Department of Mechanical Engineering, University of Bath, UK. Retrieved from <http://web.mit.edu/2.813/www/readings/ICE.pdf>

Water Inputs (Figure 18.5)

Metal products require 29,844.8 litres of water inputs per tonne of product produced, ranking the sector the 8th highest consumer of water compared to the 20 product producing sectors covered in this publication. *Direct water inputs* made up only 12% of the total water inputs or 3,720.8 litres per tonne of metal product produced. *While indirect water inputs* made up the majority of total water inputs at 88% or 26,124 litres per tonne of metal product produced.

The main indirect water inputs came from; (i) water inputs embodied in metal products at 15,036.7 litres per tonne of product produced; (ii) water inputs embodied in mining and quarrying at 7,520.2 litres per tonne of product produced; (iii) water inputs embodied in oil and gas at 2,171.5 litres per tonne of product produced; (iv) water inputs embodied wholesale and retail trade at 615.3 litres per tonne of product produced.

Landfill Wastes (Figure 18.6)

Metal products were found to generate 27,374 grams (27.4 kg) of landfill waste per tonne of product produced. This ranks the sector the 14th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by metal products was 62% of total waste produced or 17,048.1 grams per tonne of product produced. *Landfill waste indirectly generated* by metal products was 38% of the total waste produced or 10,325.9 grams per tonne of product produced.

The main sources of indirect landfill waste in the production of metal products came from; (i) landfill wastes embodied in metal products at 3,349.5 grams per tonne of product produced; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 3,085.7 grams per tonne of product produced; (iii) landfill wastes embodied furniture and other manufactured products at 959.6 grams per tonne of product produced; (iv) landfill wastes embodied in road transport services at 501.2 grams per tonne of product produced.

Water Wastes (Figure 18.7)

Metal products were found to produce 89,545 litres of wastewater per tonne of product produced. This ranks the sector as the 7th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication.

Wastewater directly generated in the production of metal products was only 9% of total water wastes or 7,777.2 litres per tonne of product produced. While wastewater indirectly generated by metal products made up the majority at 91% of the total water wastes or 81,767.8 litres per tonne of product produced. *The indirect wastewater of metal products was mostly made up of (i) wastewater embodied in metal products at 48,824.3 litres per tonne of product produced; (ii) wastewater embodied in mining and quarrying at 26,126.1 litres per tonne of product produced; (iii) wastewater embodied in oil and gas at 1,875.3 litres per tonne of product produced; (iv) wastewater embodied petroleum, chemicals, and plastics at 1,220.4 litres per tonne of product produced.*

Energy Greenhouse Gases (Figure 18.8)

In terms of CO₂ greenhouse gas emissions, metal products were found to emit 1,288,620.1 grams (1,288.6 kg) of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of metal products are ranked the 7th highest out of the 20 product producing sectors covered in this publication. *Energy-related CO₂ directly generated* by metal products was 67% of total

emissions or 864,098 grams per tonne of product produced. Energy-related CO₂ indirectly generated made up 33% of the total emissions produced, or 424,522.1 grams per tonne of product produced.

The indirect energy-related CO₂ emissions from the production of metal products was mostly made up of (i) energy-related CO₂ embodied in metal products at 202,153.1 grams per tonne of product produced; (ii) energy-related CO₂ embodied in road transport services at 50,677.8 grams per tonne of product produced; (iii) energy-related CO₂ embodied in furniture and other manufactured products at 36,005.3 grams per tonne of product produced; (iv) energy-related CO₂ embodied in mining and quarrying at 22,192.2 grams per tonne of product produced.

Figure 18.1 - Total Energy Inputs Required to Produce One Tonne of Metal Products, 2004 (MJ_E, Oil Equivalents)

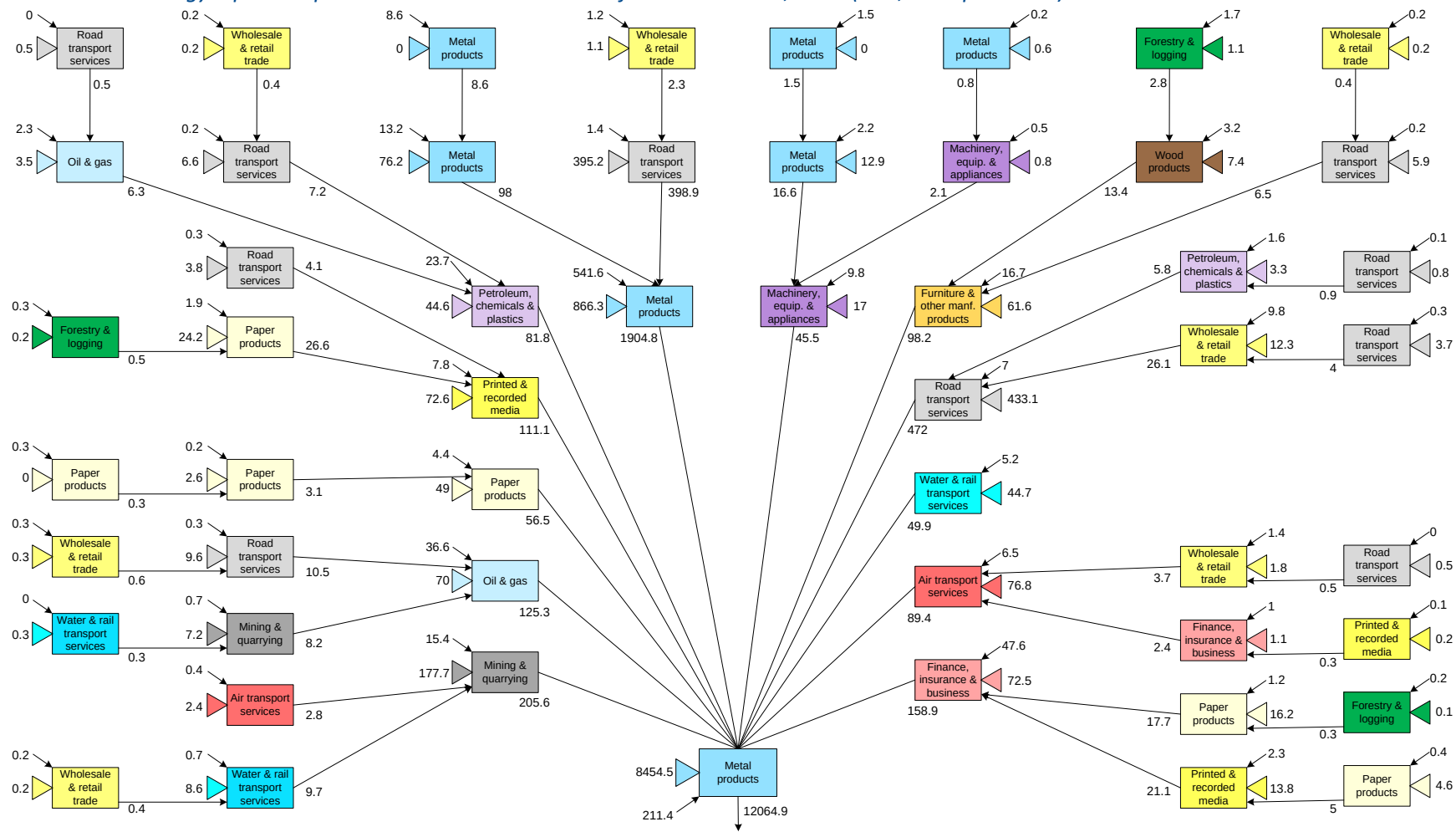


Figure 18.2 - Electricity Inputs Required to Produce One Tonne of Metal Products, 2004 (MJ, Heat Equivalents)

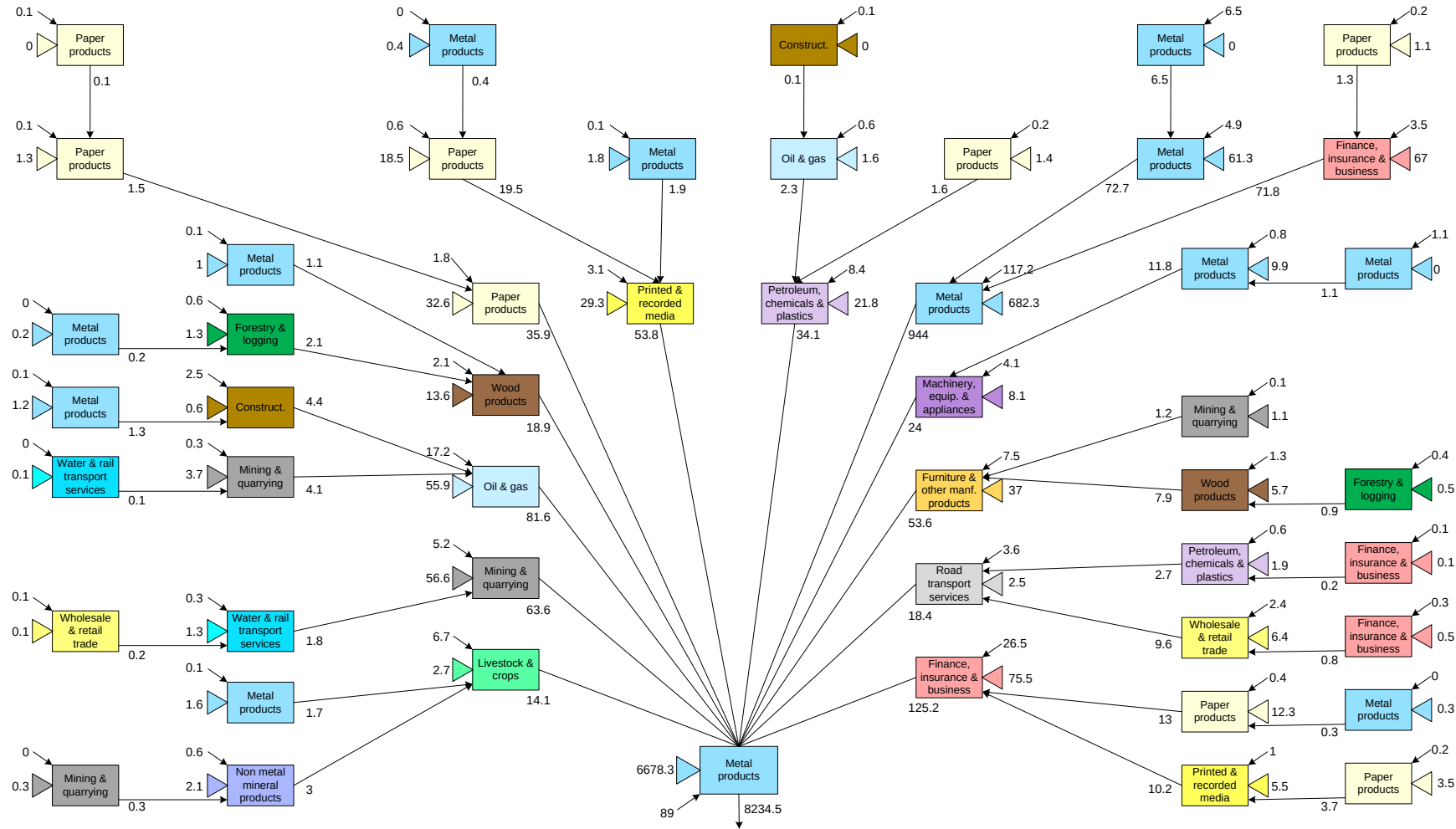


Figure 18.3 - Fossil Fuel Inputs Required to Produce One Tonne of Metal Products, 2004 (MJ, Heat Equivalents)

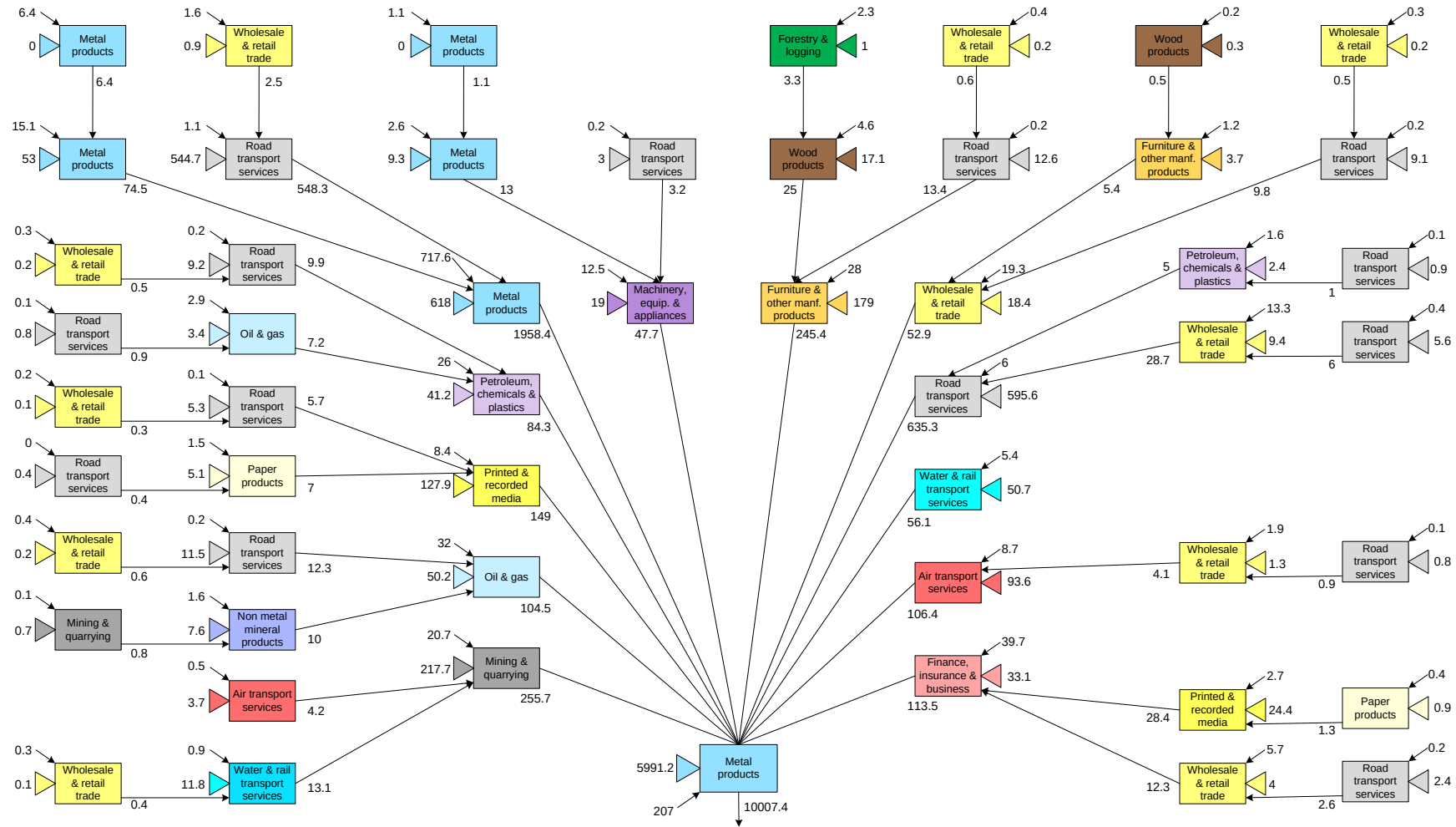


Figure 18.4 - Land Required to Produce One Tonne of Metal Products, 2004 (m²)

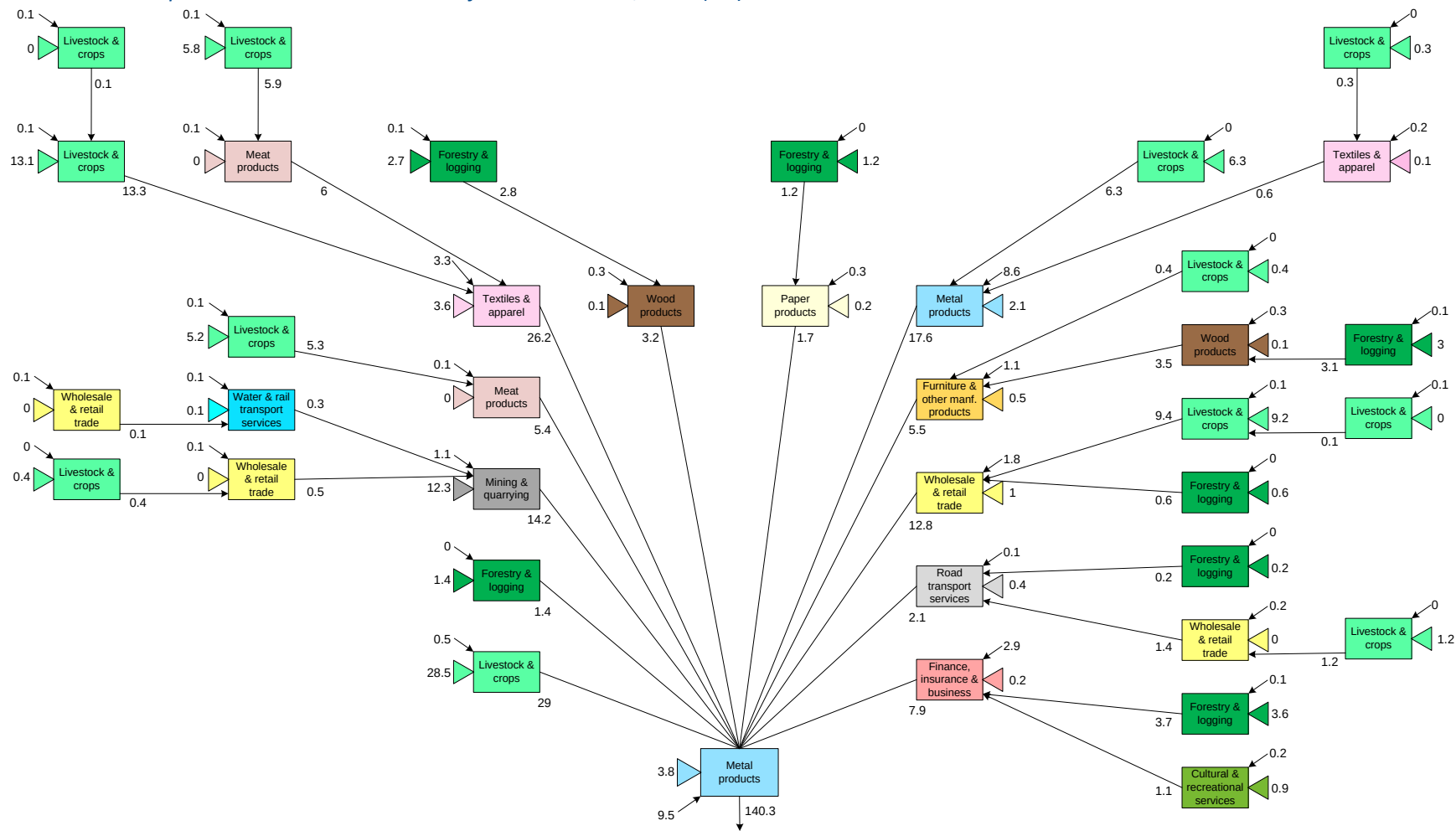


Figure 18.5 - Water Inputs Required to Produce One Tonne of Metal Products, 2004 (Litres)

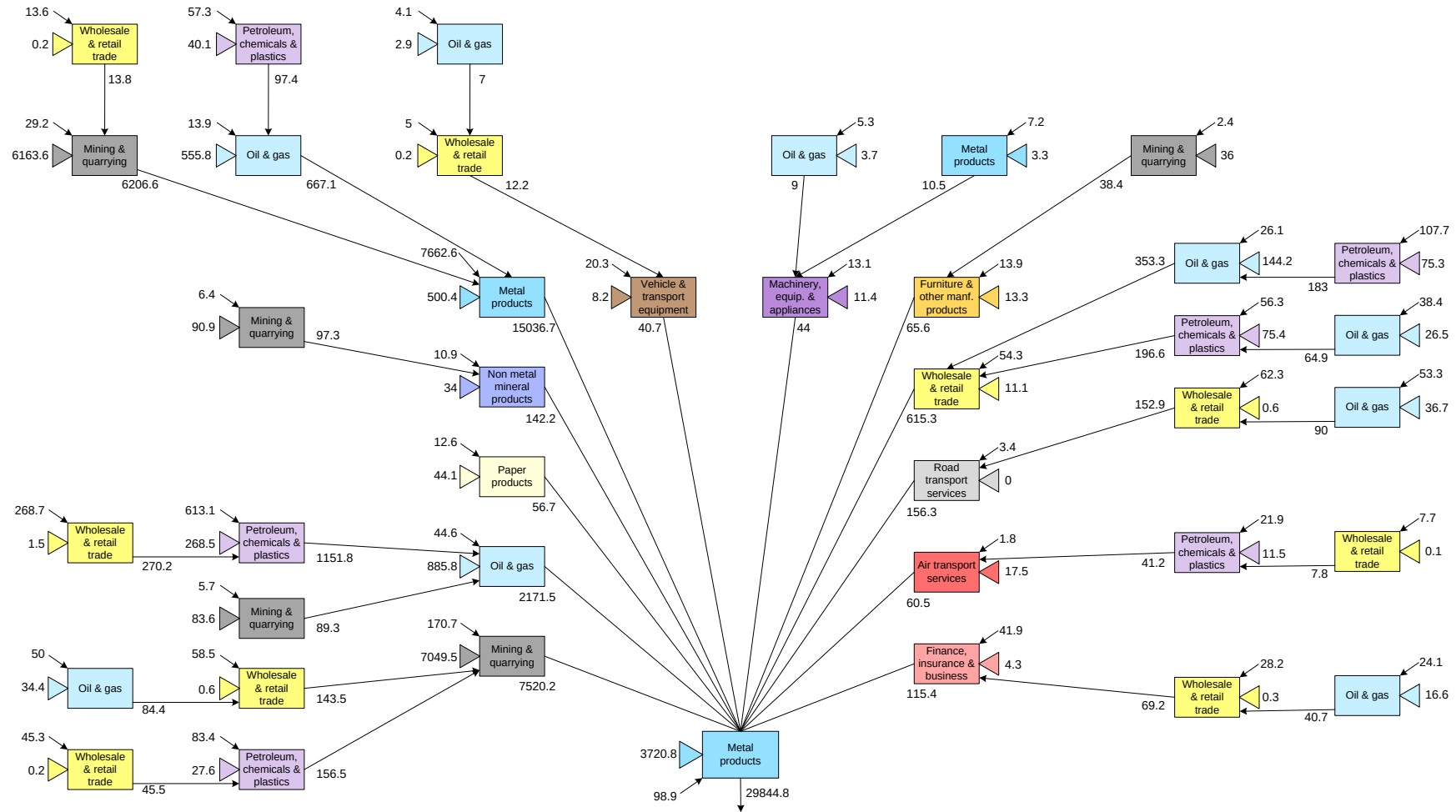


Figure 18.6 - Landfill Waste Generated in Producing One Tonne of Metal Products, 2004 (Grams)

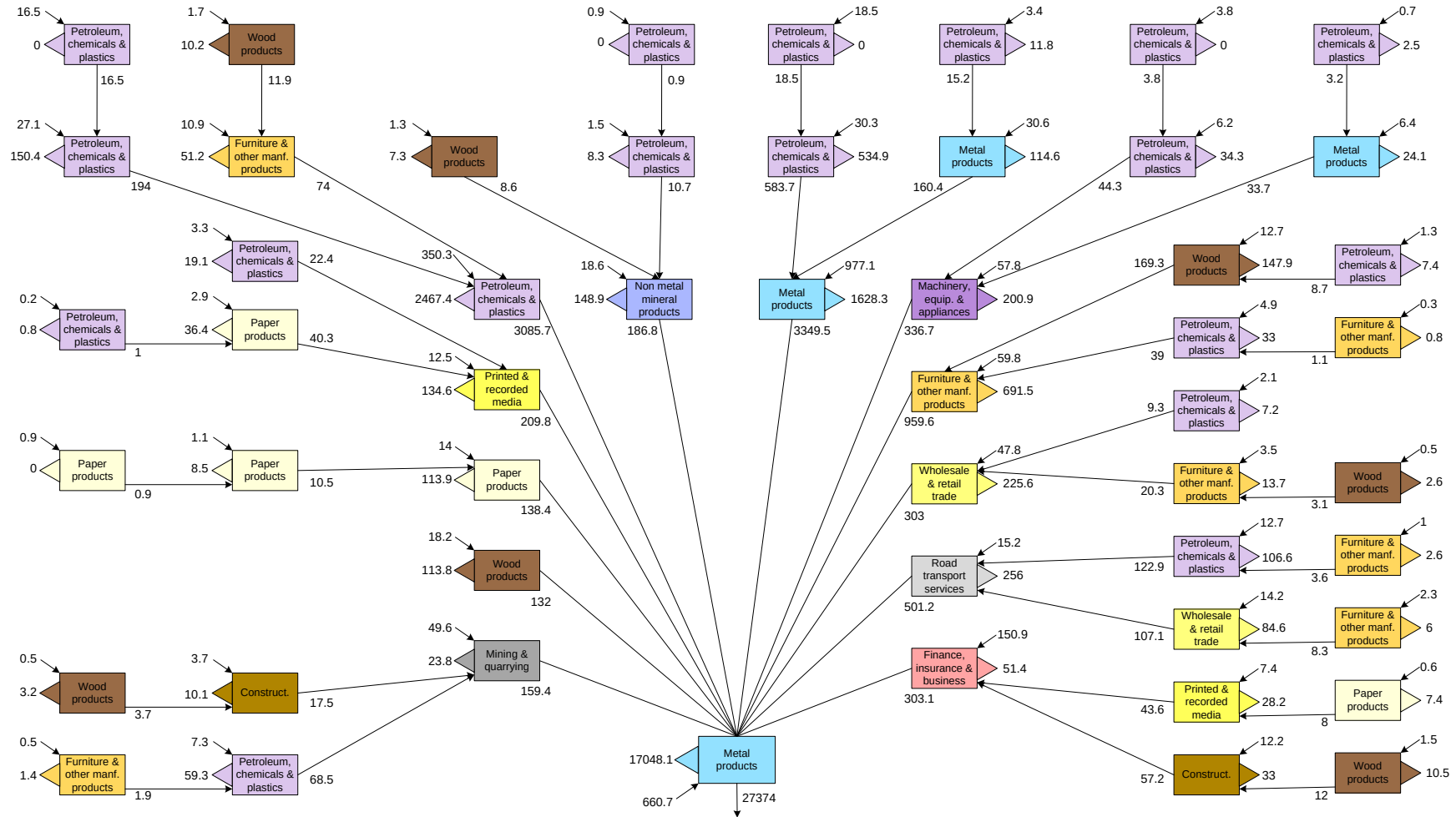


Figure 18.7 - Water Waste Generated in Producing One Tonne of Metal Products, 2004 (Litres)

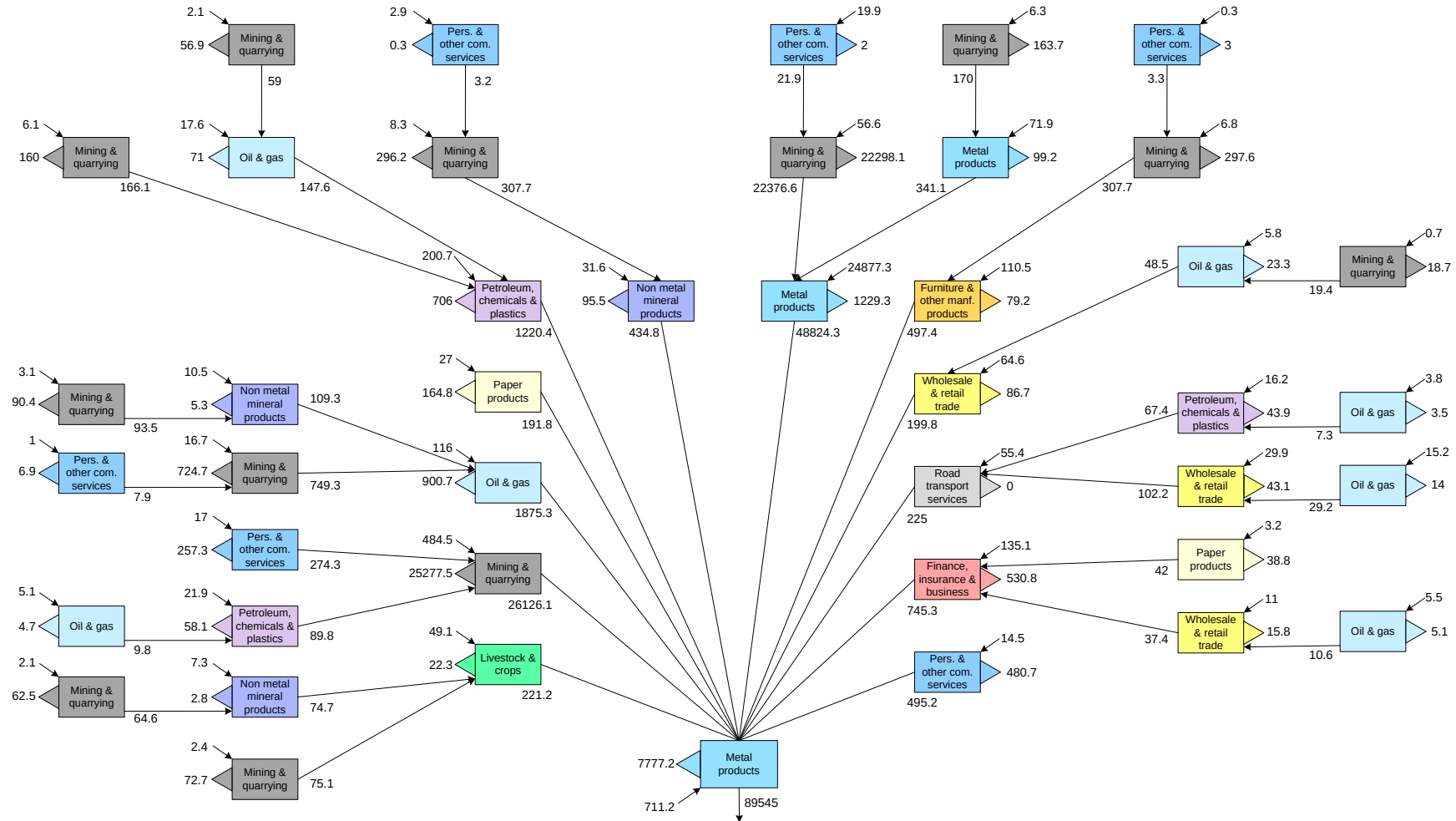
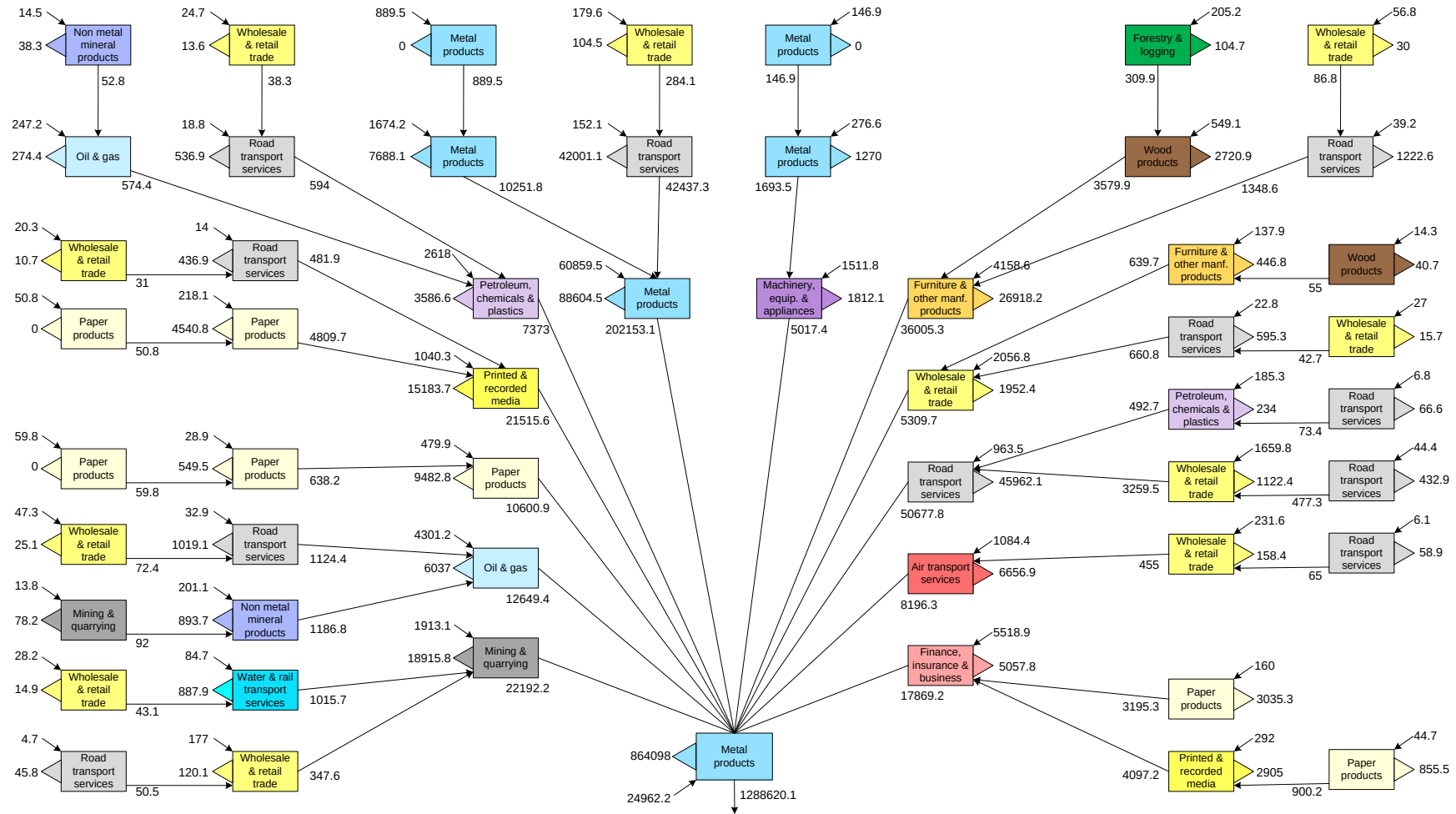


Figure 18.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Metal Products, 2004 (Grams)



19. Transport Equipment Manufacturing

Description

ANZSIC Codes covered:

- 231 – Motor Vehicle and Motor Vehicle Part Manufacturing
- 239 – Other Transport Equipment Manufacturing (boatbuilding and repair services, aircraft, bicycles etc)

Main commodities supplied:

- Engines, motor vehicles and parts, coachwork, ships, pleasure and sporting boats, aircraft, and parts

GDP 2016 = \$1.118 billion

Rank = 28th

Average annual growth rate

2006 to 2016 = 2.19%

Rank = 25th

Employment 2016 = 12,585

Rank = 24th

Economic Overview

The transport equipment manufacturing sector is a subset of the larger manufacturing sector, extending from motor vehicle part manufacturing to aviation parts and boatbuilding, representing 3.7% of the manufacturing sectors contribution to New Zealand's GDP. Owing to the specialised and luxury niche markets in this sector, a significant portion of these sales are exported. In 2016, exports were worth \$205 million, with goods from this sector are reaching over 100 countries, most notably the USA, Australia, Japan and South Africa. The conditions that render this sector competitive vary significantly depending on which form of transport is considered. Within the motor vehicle industry, New Zealand manufacturers have specialised in exporting to international niche markets with commodities like alloy wheels, pick-up truck liners, roof rack systems, electric fuel pumps, engine parts, cylinder heads, automotive glass and specialised seating for buses and racing cars.

Boating is a highly popular recreational activity in New Zealand and over the past 15 years has been developing a marine industry that's now rated among the best in the world;²³³ hence the marine manufacturing portion of this sector is large. In 2005, marine industry manufacturing exports were worth \$535 million,²³⁴ and there were over 1,000 marine companies in operation in 2008, the Auckland region comprised of 93% of New Zealand's superyacht exports, totalling \$486.7 million.²³⁵ Of the 13,094 people employed by the transport equipment sector in 2007, over 10,000 of these were from the marine manufacturing industry, including between 600-650 apprentice boat builders; the most in the world,²³⁶ illustrating that the sector has an advantage characterised by highly skilled labour and innovation. Additionally, the aviation industry in New Zealand has a reputation for quality which is helping smaller, specialised aviation providers to build new markets overseas.²³⁷

²³³ Sutton, J. (2003). *Speech to New Zealand Marine Industry Conference*. Retrieved from <http://www.beehive.govt.nz/node/16484>

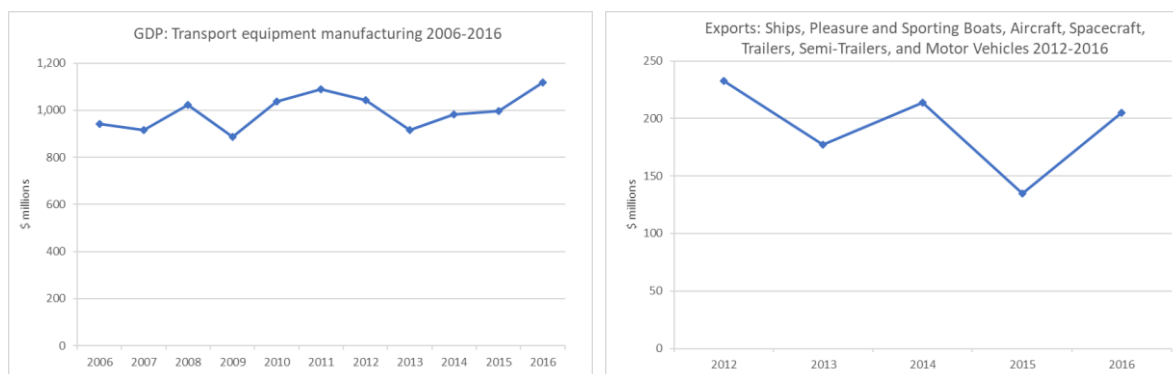
²³⁴ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. pp. 414.

²³⁵ Knowledge Auckland. (2008). *Industry Snapshot for the Auckland Region - The Marine Sector*. Auckland. Retrieved from http://knowledgeauckland.org.nz/assets/publications/Industry_snapshot_for_the_Auckland_region_The_marine_sector.pdf

²³⁶ Beech, J. (2009). Marine Industry Exports tipped to double in next decade. *The Otago Daily Times*. Retrieved from <http://www.odt.co.nz/your-town/queenstown/52687/marine-industry-exports-tipped-double-next-decade>

²³⁷ Pacific Aerospace. (n.d.). *New Zealand Aviation*. Retrieved from <https://www.aerospace.co.nz/company/new-zealand-aviation>

Sector Trends



Production

Production in the transport equipment manufacturing sector has been volatile over from 2006 through to 2016. In 2008, following the GFC, the sector increased production before a decrease a year later took the sector to the lowest level of production of \$887 million. Following the downturn, the sector recovered for a couple of years before beginning another downturn. Recovery from the second downturn remained strong, increasing 22.19%, from \$915 million in 2013 through to \$1.11 billion in 2016. New Zealand attracts a sizeable portion of the maintenance and re-fitting work for the worlds super-yachts, largely due to the competitive advantage of the country's geographical location for sailors. Following a joint venture started in 2013, between Auckland Tourism Events and Economic Development, New Zealand Trade and Enterprise, and NZ Marine dubbed the Destination New Zealand Superyacht Attraction Initiative, growth in this sector is likely to continue.²³⁸

Exports

Similarly, the value of exports in this sector followed a volatile pattern. In total, the value of exports declined 11.94%, from \$232 million to \$205 million over the 4-year timeframe. A key component in the transport equipment manufacturing sector in NZ is the specialisation into niche markets such as maintenance and re-fitting work for the world super-yachts. Due to the luxury nature of these markets, production in this sector is largely export-focused, given there is not a significantly sophisticated domestic demand.

Life Cycle Assessment Diagrams

Energy (Figure 19.1, Figure 19.2, Figure 19.3)

Vehicle and transport equipment was found to have a total energy intensity of 7,339.1 MJ_{OE} per tonne of product (7.3 MJ_{OE}/kg)²³⁹, ranking 9th highest out of the 20 product producing sectors covered in this publication. *Direct energy* use was 15% of the total energy intensity, measuring 1,066.4 MJ_{OE} per tonne of produced. *Indirect energy use* was 85% of the total energy intensity, measuring 6,272.7 MJ_{OE} per tonne of vehicle and transport equipment produced.

²³⁸ NZ Marine. (n.d.). *Destination New Zealand*. Retrieved from <https://www.nzmarine.com/destination-nz/>

²³⁹ Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand transport equipment manufacturing sector is 12.42 MJ_H/kg.

The main indirect energy uses in the production of vehicle and transport equipment came from; (i) energy embodied in metal products at 1,892.8 MJ_{OE} per tonne of product produced; (ii) energy embodied in vehicle and transport equipment at 973.7 MJ_E per tonne of product produced; (iii) energy embodied in non-metal mineral products at 656.8 MJ_E per tonne of product produced; (iv) energy embodied in machinery, equipment and appliances at 570.7 MJ_E per tonne of product produced.

Land (Figure 19.4)

Vehicle and transport equipment has a total land intensity of 1,117.2 m² per tonne of product produced, ranking the sector 12th highest out of the 20 product producing sectors covered in this publication. *Direct land use* was minuscule at only 1% of the total land intensity at 15.8 m² per tonne of product produced. *Indirect land use* makes up the majority of vehicle and transport equipment's total land intensity at 99% measuring 1101.4 m² per tonne of product produced.

The major indirect land uses in the production of vehicle and transport equipment come from; (i) land embodied textiles and apparels at 320.1 m² per tonne of product produced; (ii) land embodied in wholesale and retail trade at 228.7 m² per tonne of product produced; (iii) land embodied in livestock and crops at 168.3 m² per tonne of product produced; (iv) land embodied in vehicle and transport equipment at 139.1 m² per tonne of product produced.

Water Inputs (Figure 19.5)

Vehicle and transport equipment require 30,805.6 litres of water inputs per tonne of product produced, ranking the sector the 7th highest consumer of water compared to the 20 product producing sectors covered in this publication.

Direct water inputs make up just 0.5% of total water inputs or 142.1 litres per tonne of vehicle and transport equipment produced. *While indirect water inputs* make up the remaining 99.5% of the total water inputs or 30,663.5 litres per tonne of vehicle and transport equipment produced.

The main indirect water inputs came from; (i) water inputs embodied in wholesale and retail trade at 11,396.8 litres per tonne of product produced (ii) water inputs embodied in vehicle and transport equipment at 7,108.2 litres per tonne of product produced; (iii) water inputs embodied in non-metal mineral products at 4,193.8 litres per tonne of product produced; (iv) water inputs embodied in metal products at 2,998.3 litres per tonne of product produced.

Landfill Wastes (Figure 19.6)

Vehicle and transport equipment were found to generate 72,261.4 grams (72 kg) of landfill waste per tonne of product produced. This ranks the sector the 7th highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by vehicle and transport equipment was 28% of the total waste produced or 20,219 grams per tonne of product produced. *Landfill waste indirectly generated* by vehicle and transport equipment was 72% of the total waste produced or 52,042.4 grams per tonne of product produced.

The main sources of indirect landfill waste in the production of vehicle and transport equipment came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 14,619 grams per tonne of product produced; (ii) landfill wastes embodied in vehicle and transport equipment at 10,364.2 grams per tonne of product produced; (iii) landfill wastes embodied in non-metal mineral products at 5,018.2 grams per tonne of product produced; (iv) landfill wastes embodied in wholesale and retail trade at 4,283 grams per tonne of product produced.

Water Wastes (Figure 19.7)

Vehicle and transport equipment were found to produce 50,170.5 litres of water wastes per tonne of product produced. This ranks the sector as the 10th highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* by the production of vehicle and transport equipment was a mere 3% of total waste produced at 1,336.2 litres per tonne of product produced. *While wastewater indirectly generated* by vehicle and transport equipment made up the majority at 97% of the total wastewater produced, or 48,834.3 litres per tonne of product produced.

The indirect wastewater of vehicle and transport equipment was mostly made up of (i) wastewater embodied in non-metal mineral products at 12,159.3 litres per tonne of product produced; (ii) wastewater embodied in metal products at 7,395.3 litres per tonne of product produced; (iii) wastewater embodied in vehicle and transport equipment at 6,148.9 litres per tonne of product produced; (iv) wastewater embodied in petroleum, chemicals and plastics at 5,663.1 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 19.8)

In terms of CO₂ greenhouse gas emissions, vehicle and transport equipment products were found to emit 960,013.4 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of vehicle and transport equipment are ranked the 9th highest out of the 20 product producing sectors covered in this publication. *Energy-related CO₂ emissions directly generated* by vehicle and transport equipment was 13% of total emissions or 122,829.7 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by the vehicle and transport equipment sector made up the majority at 87.2% of total emissions, or 837,183.7 grams per tonne of product produced.

The indirect energy-related CO₂ emissions from the production of vehicle and transport equipment was mostly made up of (i) energy-related CO₂ embodied in metal products at 203,866.9 grams per tonne of product produced; (ii) energy-related CO₂ embodied in vehicle and transport equipment at 128,372.7 grams per tonne of product produced; (iii) energy-related CO₂ embodied in non-metal mineral products at 114,648.1 grams per tonne of product produced; (iv) energy-related CO₂ embodied in machinery, equipment and appliances at 63,015.7 grams per tonne of product produced.

[illegible]

Figure 19.2 - Electricity Inputs Required to Produce One Tonne of Vehicle and Transport Equipment Products, 2004 (MJ, Heat Equivalents)

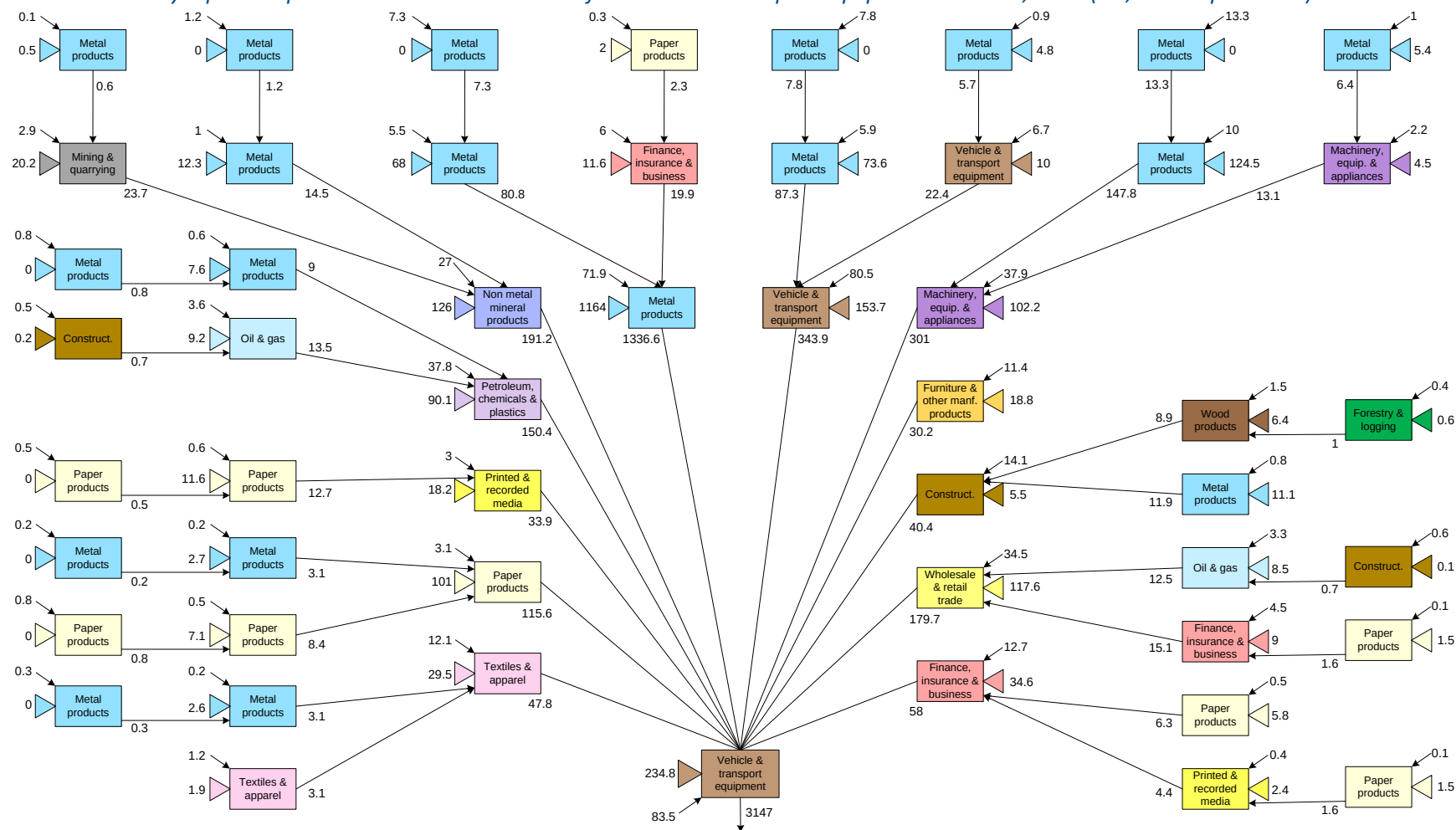


Figure 19.3 - Fossil Fuel Inputs Required to Produce One Tonne of Vehicle and Transport Equipment Products, 2004 (MJ, Heat Equivalents)

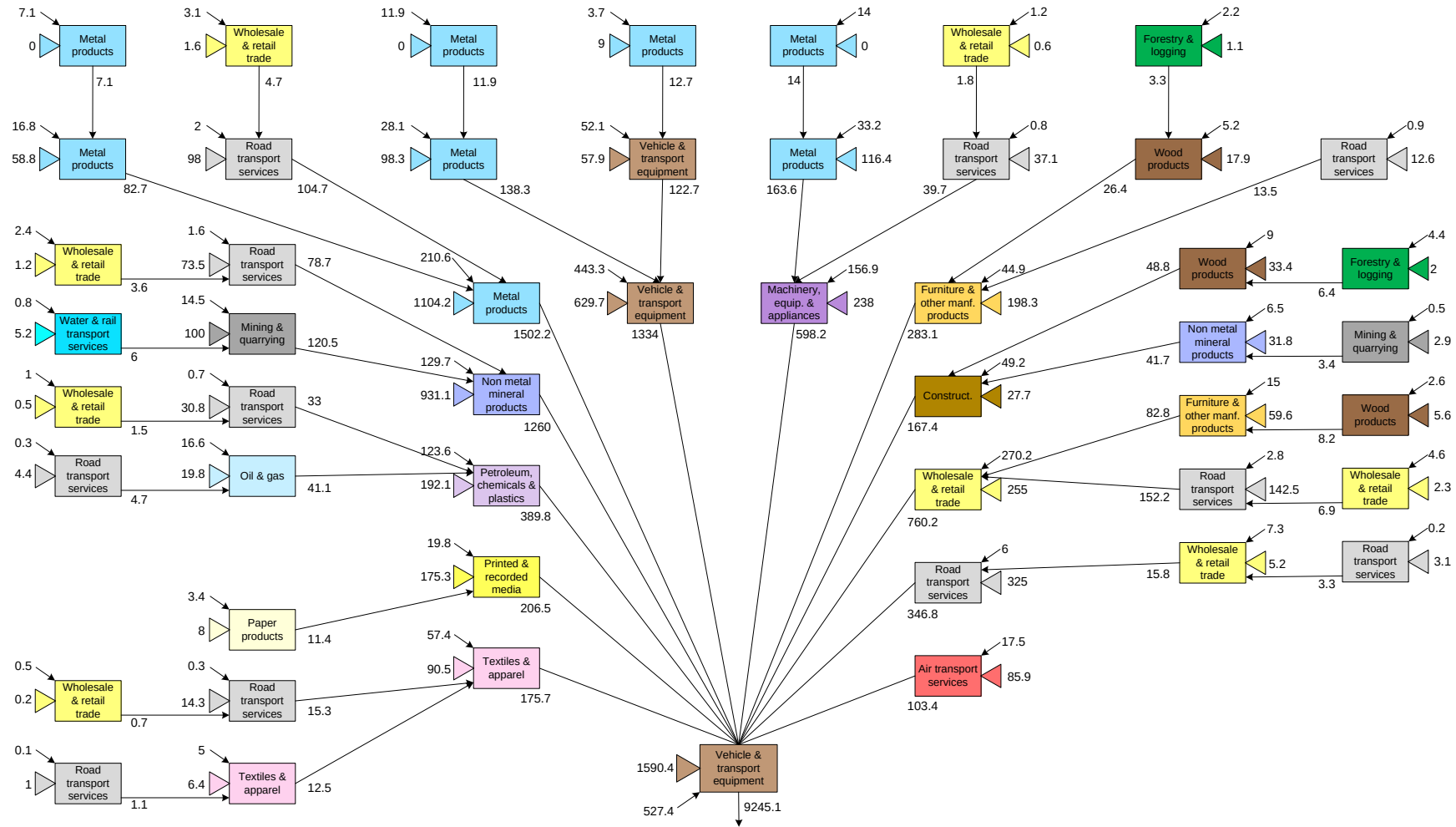


Figure 19.4 - Land (m²) Required to Produce One Tonne of Vehicle and Transport Equipment Products, 2004

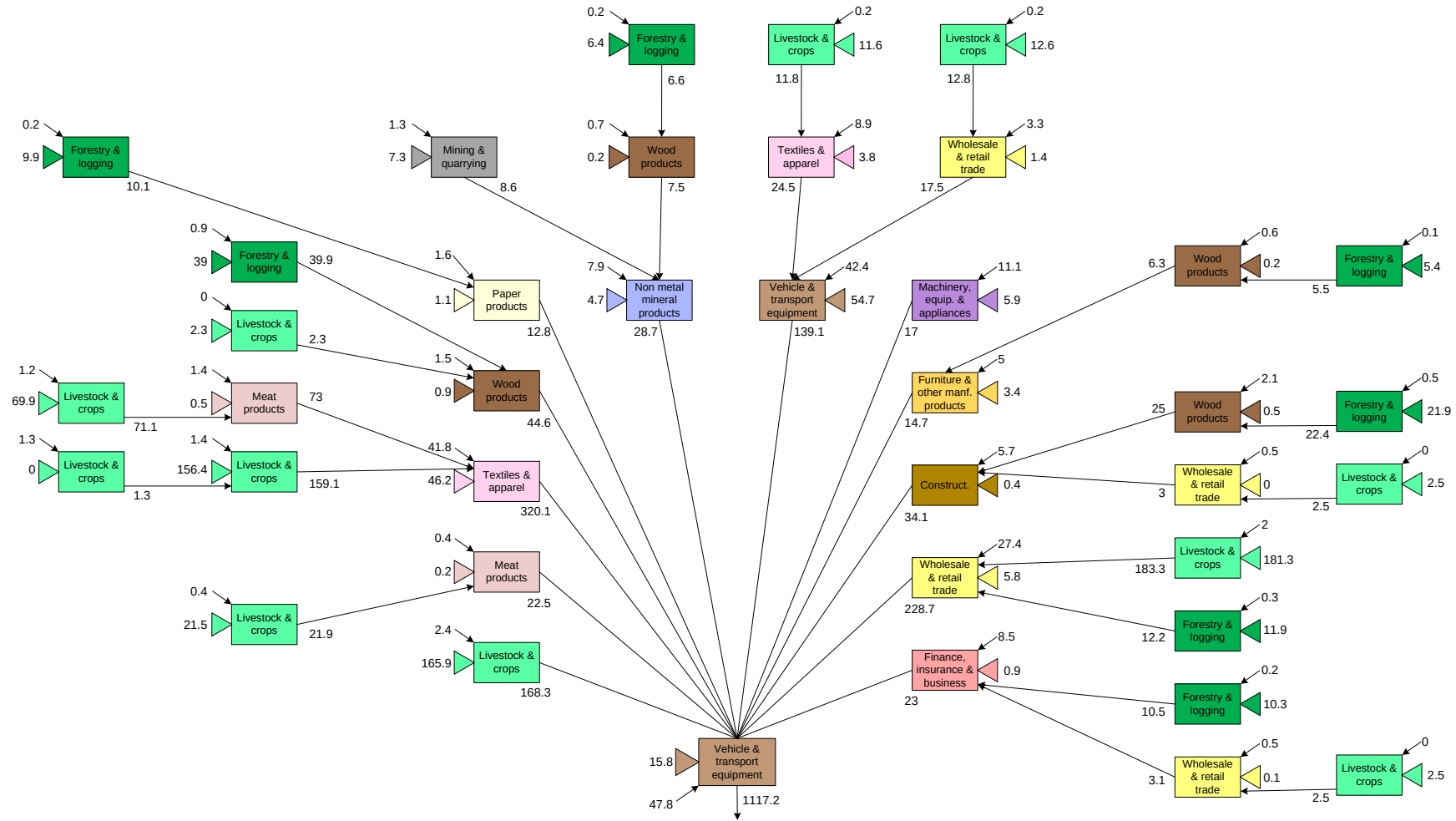


Figure 19.5 - Water Inputs Required to Produce One Tonne of Vehicle and Transport Equipment Products, 2004 (Litres)

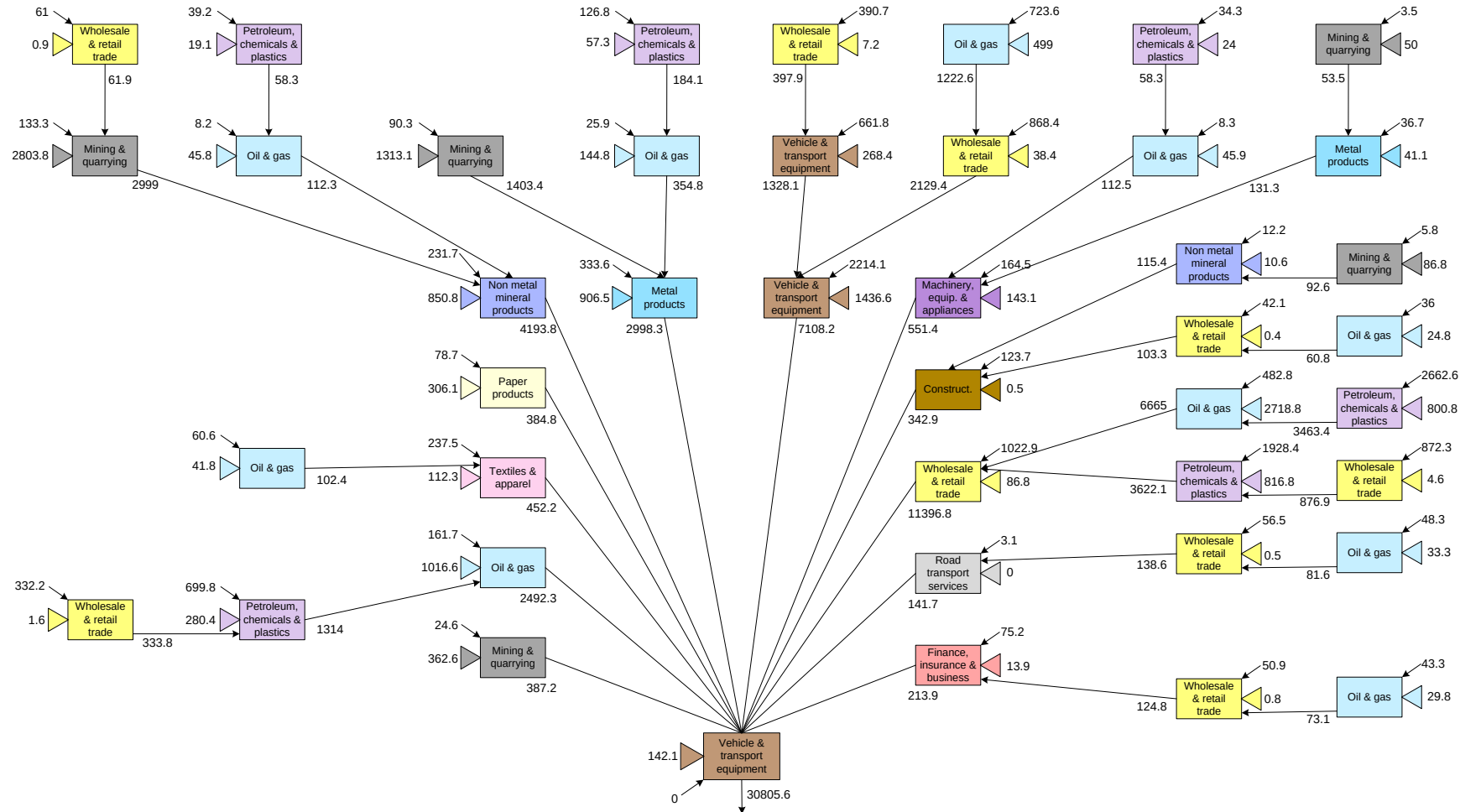


Figure 19.6 - Landfill Waste Generated in Producing One Tonne of Vehicle and Transport Equipment Products, 2004 (Grams)

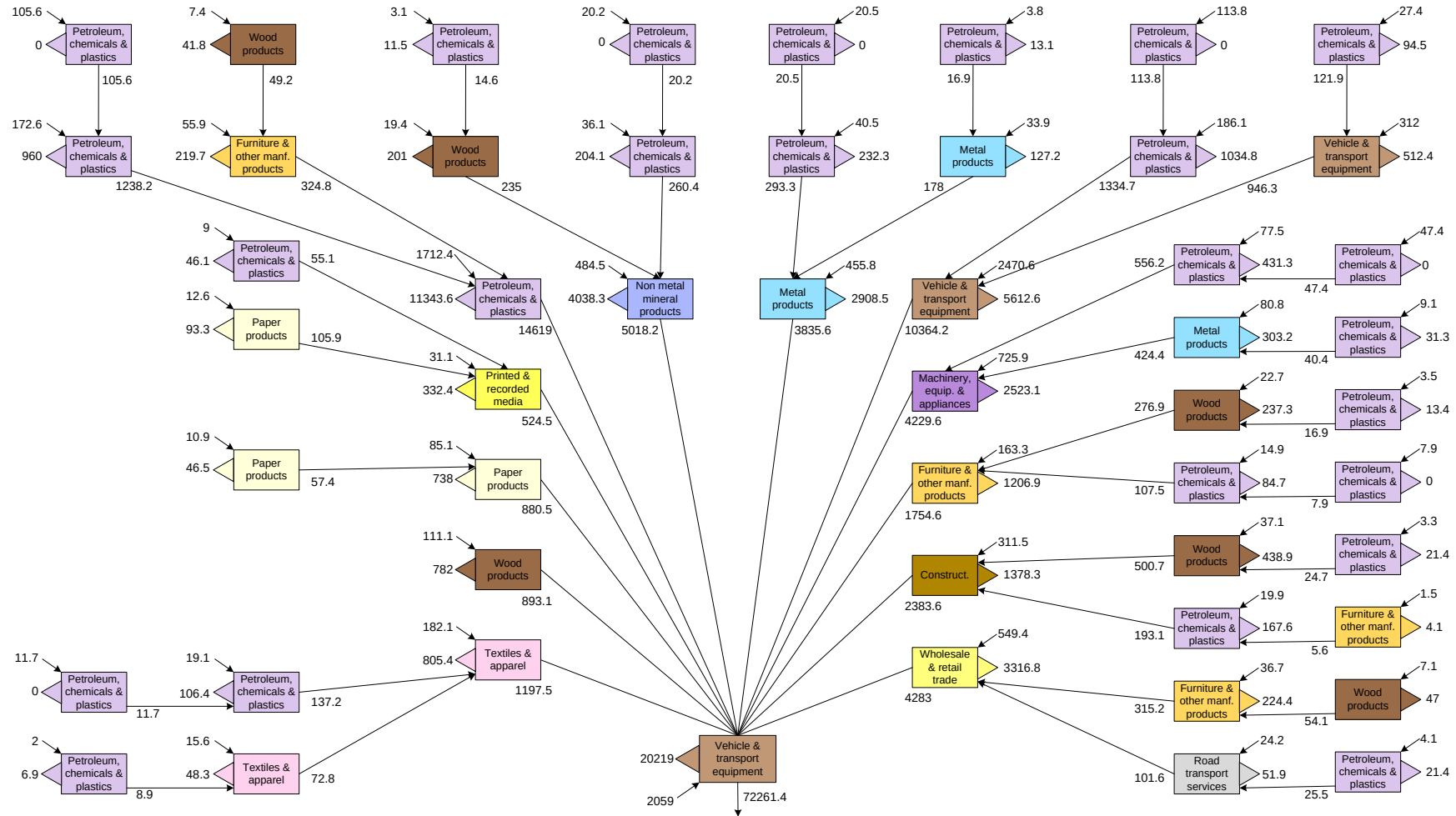
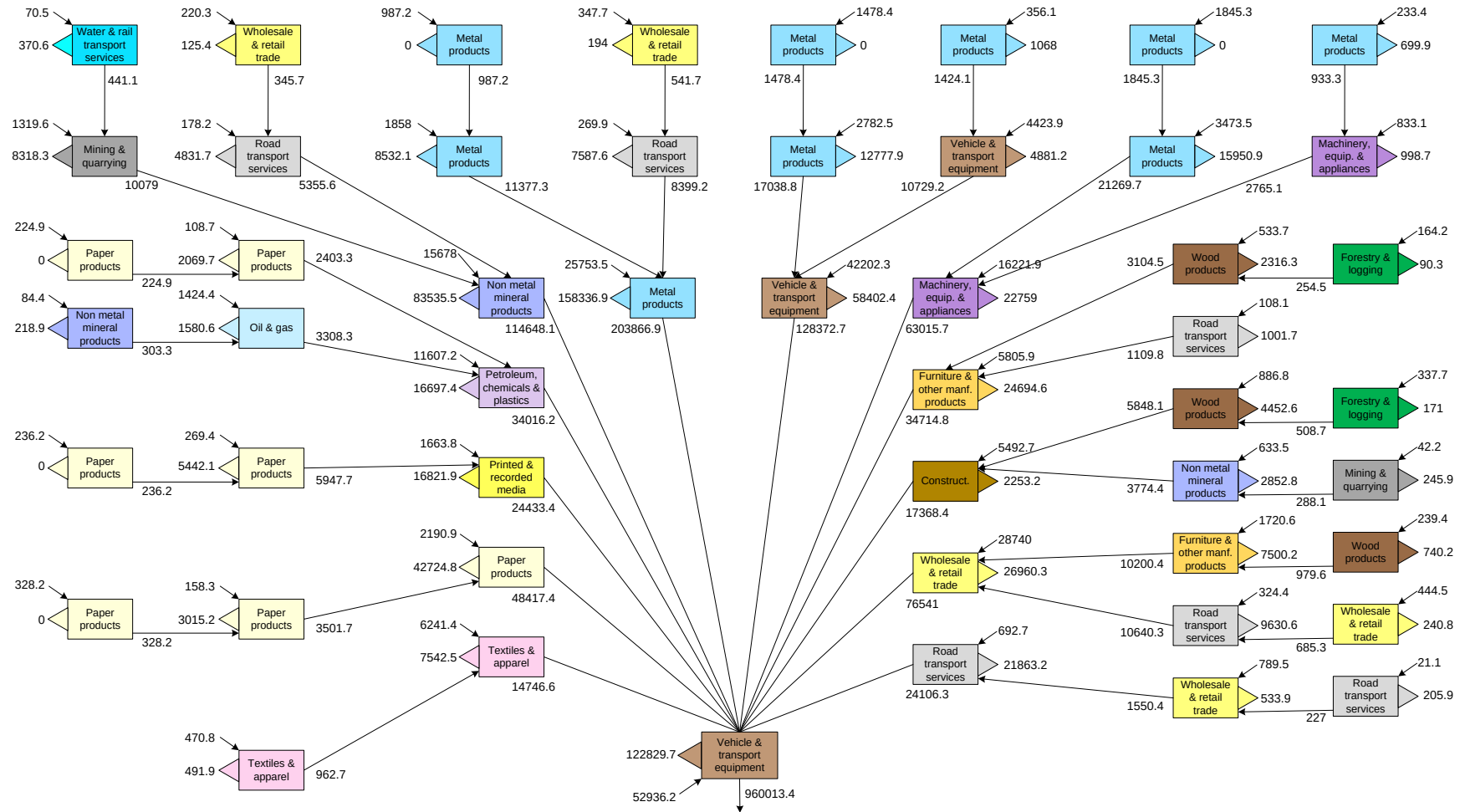


Figure 19.7 - Water Waste Generated in Producing One Tonne of Vehicle and Transport Equipment Products, 2004 (Litres)



Figure 19.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Vehicle and Transport Equipment Products, 2004 (Grams)



20. Machinery and Other Equipment Manufacturing

Description

ANZSIC Codes covered:

- 241– Professional and Scientific Equipment Manufacturing
- 242 – Computer and Electronic Equipment Manufacturing
- 243 – Electrical Equipment Manufacturing
- 244 – Domestic Appliance Manufacturing
- 245 – Pump, Compressor, Heating, and Ventilation Equipment Manufacturing
- 246 – Specialised Machinery and Equipment Manufacturing
- 249 – Other Machinery and Equipment Manufacturing

GDP 2016 = \$5.007 billion
Rank = 12th

Average annual growth rate
2006 to 2016 = 3.51%
Rank = 21st

Employment 2016 = 30,539
Rank = 17th

Economic Overview

The machinery and equipment manufacturing sector is a significant contributor to growth in the economy, being the second largest subset within manufacturing, contributing just over 16% to the manufacturing sector's total GDP in 2016.²⁴⁰

Total exports volumes within the sector are large and varied, with the most significant export subsector being electrical goods, which exports almost all its production. Demand for products in this sector is closely tied to the domestic and Australian construction cycle.²⁴¹ In total, the sector ranks 8th out of the 14 manufacturing sectors studied here in terms of exports. Largely due to the significant costs associated with exporting large machinery.

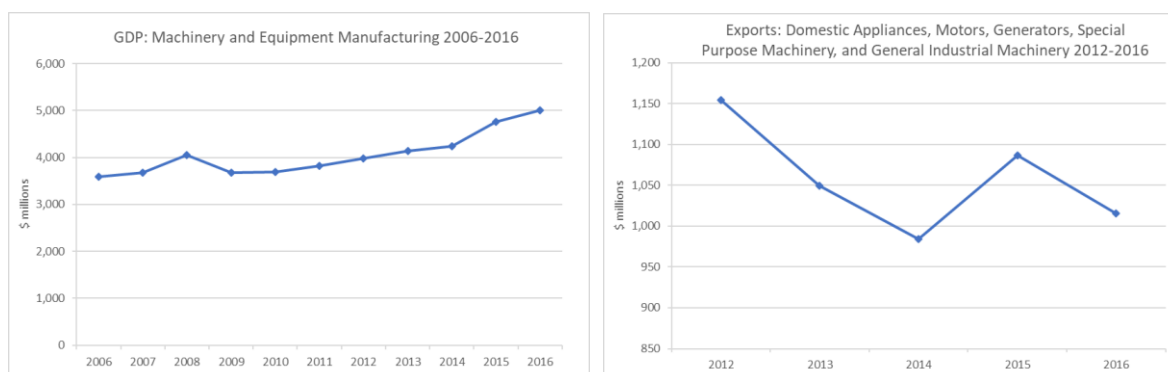
In 2016, there were 30,539 employees employed across this sector, who need to be well trained and able to work with increasingly sophisticated machinery as many stages of the production chain become automated. Although the industry is growing, it is restricted by a limited number of adequately trained staff, with the electrical industry expressing a desire for more graduates trained in electrical engineering.²⁴²

²⁴⁰ Ministry of Business, Innovation and Employment. (2018). *Beyond Commodities: Manufacturing into the Future*. Wellington. Retrieved from <https://www.mbie.govt.nz/assets/f0f81b6194/new-zealand-manufacturing-sector-report-2018.pdf>

²⁴¹ Turner, J (Reserve Bank of New Zealand). (2005). Overview of the Manufacturing Sector. *Bulletin*, 68(1). Retrieved from http://www.minerals.co.nz/pdf/Natural_Resource_NZ_web.pdf

²⁴² Earle, D. (2009). *Advanced trade, technical and professional qualifications – Trends in supply*. Retrieved from http://www.educationcounts.govt.nz/_data/assets/pdf_file/0005/47723/Report-3-supply-of-graduates-formatted-v2.pdf

Sector Trends



Production

Growth in the machinery and equipment manufacturing sector has been considerably constant. Overall, production has grown from \$3.60 billion in 2006 to \$5.01 billion in 2016. Interestingly, production increased in 2008, during the GFC, but declined the following year to levels similar to what was produced pre-GFC. More recently, there has been a larger increase in the levels of production, as production increased by 12.01% from 2014 to 2015, compared to the annual average growth rate of 3.92%. The strong performance of this sector can be attributed to the steady demand for the products, stemming largely from the agricultural, forestry and construction industries which were all performing well over this time.

Exports

The value of exports begins on a downward trend over the first two years, decreasing from \$1.15 billion down in 2012 down to \$984 billion in 2014. A year of recovery is then experienced, increasing the value of exports by 10.44%, before the downward trend continues. In 2015, Australian building approvals reached a peak, having increased since 2011,²⁴³ this may be a possible explanation in the boom of export sales made in 2015, as illustrated above by the graph. Overall, demand for products in this industry is relatively inelastic, that is, products are not particularly responsive to price or exchange rate fluctuations. This is due to equipment such as food processing equipment, computer equipment and office equipment being valued as necessities, leading to a reliably high level of demand.

Life Cycle Assessment Diagrams

Energy (Figure 20.1, Figure 20.2, Figure 20.3)

Machinery, equipment and appliance products were found to have a total energy intensity of 28,773.8 MJ_E per tonne of product (28.7 MJ_{OE}/kg), ranking 3rd highest out of the 20 product producing sectors covered in this publication. *Direct energy* use was 23% of the total energy intensity, measuring 6,502

²⁴³ Property Observer. (2017, February 26). *New home building approvals in longest and largest cycle in Australia's history*. Retrieved February 7, 2020, from <https://www.propertyobserver.com.au/finding/residential-investment/65844-new-home-building-approvals-in-longest-and-largest-cycle-in-australia-s-history.html>

MJ_{OE} per tonne of product produced. While *indirect energy use* was 77% of the total energy intensity, measuring 22,271.8 MJ_{OE} per tonne of product produced.

The main indirect energy uses in the production of machinery, equipment and appliance products came from; (i) energy embodied in metal products 12,953.3 MJ_{OE} per tonne of product produced; (ii) energy embodied in machinery, equipment and appliances at 1,601.4 MJ_{OE} per tonne of product produced; (iii) energy embodied in road transport services at 1,562.8 MJ_{OE} per tonne of product produced; (iv) energy embodied petroleum, chemicals and plastics at 867.4 MJ_{OE} per tonne of product produced.

Land (Figure 20.4)

Machinery, equipment and appliance products have a total land intensity of 1,225.1 m² per tonne of product produced, ranking the sector 11th highest in terms of land intensity out of the 20 product producing sectors covered in this publication. *Direct land use* was small at only 5% of the total land intensity at 58.8 m² per tonne of product produced. *Indirect land use* makes up the majority of machinery, equipment and appliances' total land intensity at 95% measuring 1166.3 m² per tonne of product produced.

The major indirect land uses in the production of machinery, equipment and appliances products came from; (i) land embodied in livestock and crops at 228.6 m² per tonne of product produced; (ii) land embodied in textile and apparel at 178.7 m² per tonne of product produced; (iii) land embodied in forestry and logging at 154.9 m² per tonne of product produced; (iv) land embodied in wholesale and retail trade at 125.4 m² per tonne of product produced.

Water Inputs (Figure 20.5)

Machinery, equipment and appliances products require 40,538.8 litres of water inputs per tonne of product produced, ranking the sector the 6th highest consumer of water compared to the 20 product producing sectors covered in this publication. *Direct water inputs* made up a minuscule 2% of the total water inputs, or 970.2 litres per tonne of machinery, equipment and appliances produced. *While indirect water inputs* made up the majority of total water inputs at 98%, or 39,568.6 litres per tonne of machinery, equipment and appliances produced.

The main indirect water inputs came from; (i) water inputs embodied in metal products at 12,201.4 litres per tonne of product produced; (ii) water inputs embodied in oil and gas at 10,901.4 litres per tonne of product produced; (iii) water inputs embodied in wholesale and retail trade at 5,519.2 litres per tonne of product produced; (iv) water inputs embodied non-metal mineral products at 3,310.4 litres per tonne of product produced.

Landfill Wastes (Figure 20.6)

Machinery, equipment and appliances products were found to generate 211,216.1 grams (21.2 kg) of landfill waste per tonne of product produced. This ranks the sector the 3rd highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste is almost evenly split 50/50 between direct and indirect source, with directly sources producing 106,414.4 grams of landfill waste per tonne of product produced, and indirect sources producing 104,801.7 grams of landfill waste per tonne of product produced.*

The main sources of indirect landfill waste came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 34,160.5 grams per tonne of product produced; (ii) landfill wastes embodied metal products at 26,062.1 grams per tonne of product produced; (iii) landfill wastes embodied in

machinery, equipment and appliances at 11,868 grams per tonne of product produced; (iv) landfill wastes embodied in non-metal mineral products at 5,579.1 grams per tonne of product produced.

Water Wastes (Figure 20.7)

Machinery, equipment and appliance products were found to produce 125,410 litres of water wastes per tonne of product produced. This ranks the sector as the 3rd highest producer of water wastes per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* in the production of machinery, equipment and appliance products was only 7% of total water wastes or 8,599.7 litres per tonne of product produced. *While wastewater indirectly generated* in the production of machinery, equipment and appliance products made up the majority at 93%, or 116,810.3 litres per tonne of product produced.

These indirect water wastes generated in the production of machinery, equipment and appliance products are mostly made up of (i) wastewater embodied in metal products at 48,394.6 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 13,070.9 litres per tonne of product produced; (iii) wastewater embodied in non-metal mineral products at 13,070.7 litres per tonne of product produced; (iv) wastewater embodied mining and quarrying at 12,944.2 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 20.8)

In terms of CO₂ greenhouse gas emissions, machinery, equipment and appliance products were found to emit 322,7115 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of machinery, equipment and appliance products are ranked the 4th highest out of the 20 product producing sectors covered in this publication.

Energy-related CO₂ directly generated by machinery, equipment and appliance products was 20% of total emissions or 652,681.3 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by machinery, equipment and appliance products made up 80% of the total emissions produced or 2,574,433.7 grams per tonne of product produced.

This indirect energy-related CO₂ emissions from the production of machinery, equipment and appliance products was mostly made up of (i) energy-related CO₂ embodied in no-metal mineral products at 1,360,193.8 grams per tonne of product produced; (ii) energy-related CO₂ embodied in machinery, equipment and appliances at 176,845.8 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services at 173,321.3 grams per tonne of product produced; (iv) energy-related CO₂ embodied in non-metal mineral products at 130,011.9 grams per tonne of product produced.

Figure 20.1 - Total Energy Inputs Required to Produce One Tonne of Machinery, Equipment and Appliances Products, 2004 (MJ_E, Oil Equivalents)

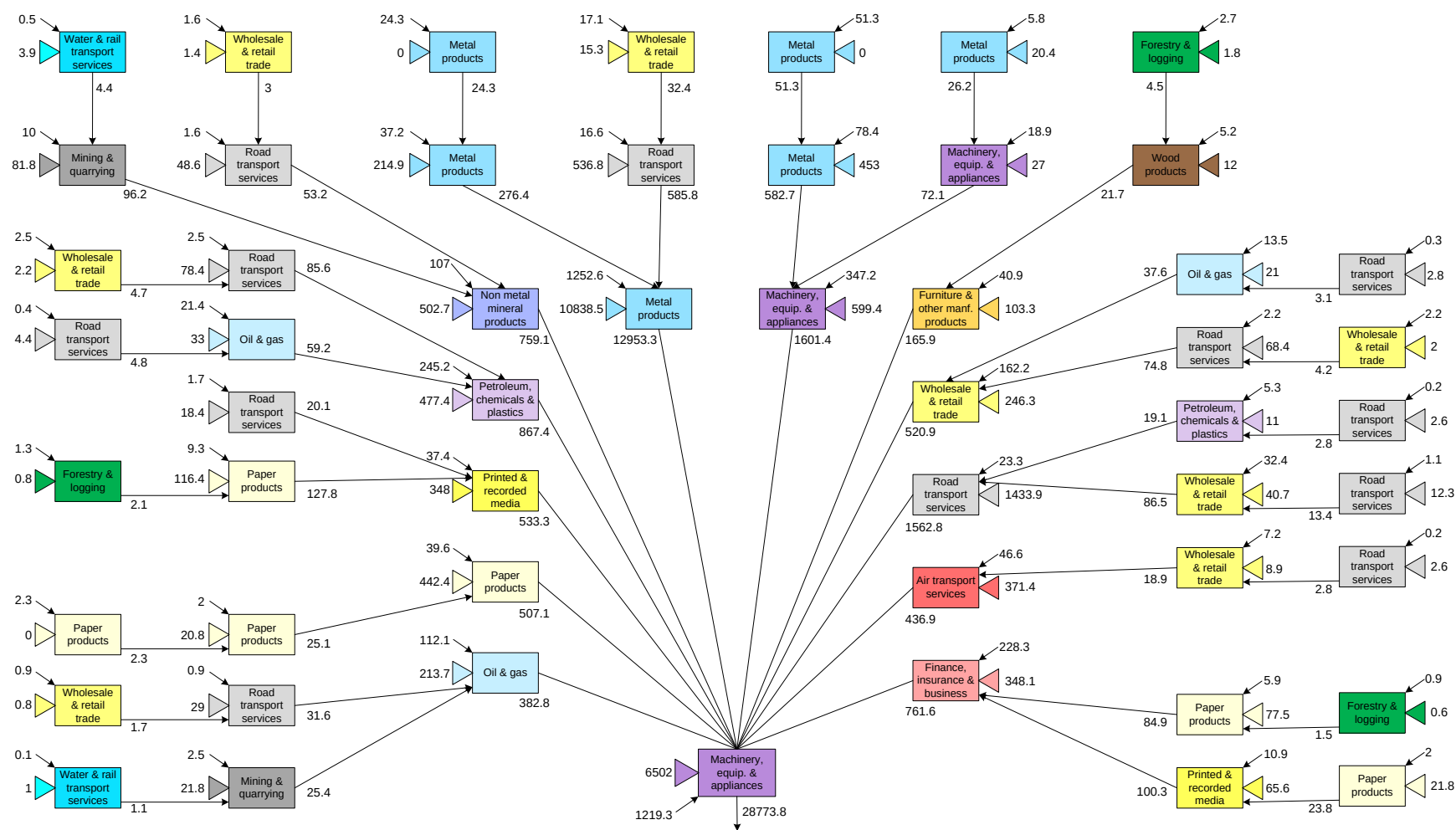


Figure 20.2 - Electricity Inputs Required to Produce One Tonne of Machinery, Equipment and Appliances Products, 2004 (MJ, Heat Equivalents)

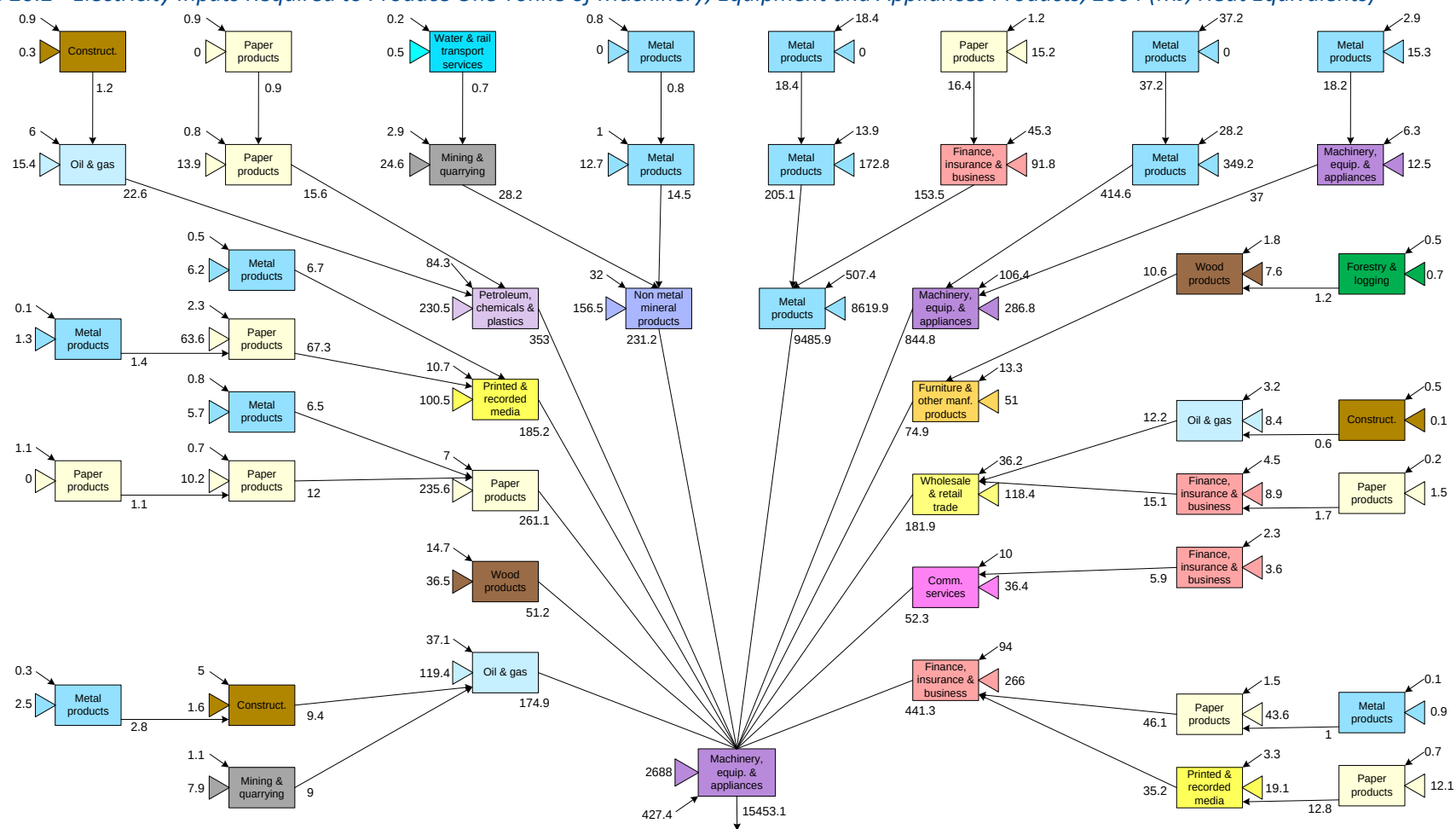


Figure 20.3 - Fossil Fuel Inputs Required to Produce One Tonne of Machinery, Equipment and Appliances Products, 2004 (MJ, Heat Equivalents)

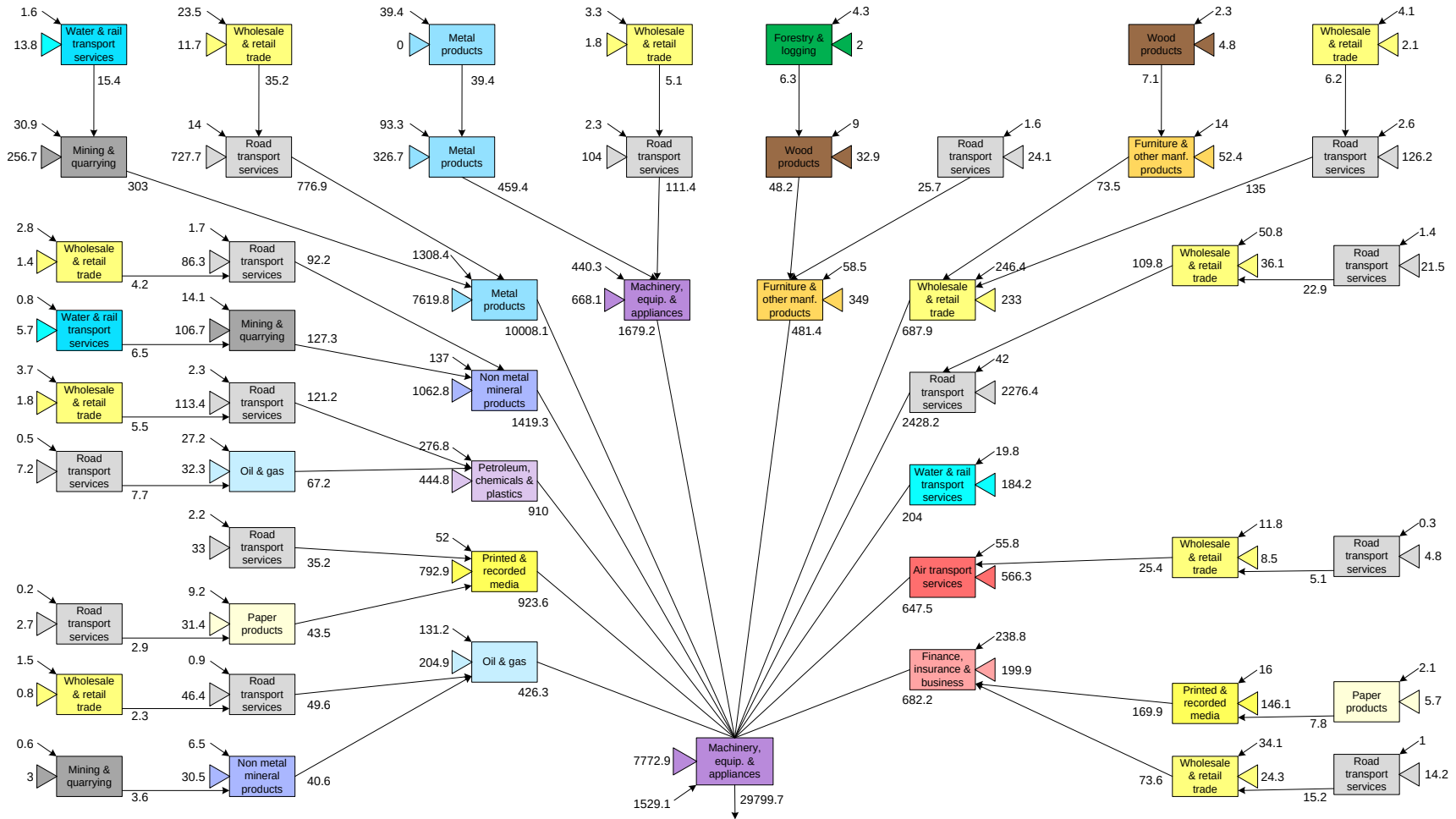


Figure 20.4 - Land Required to Produce One Tonne of Machinery, Equipment and Appliances Products, 2003-04 (m²)

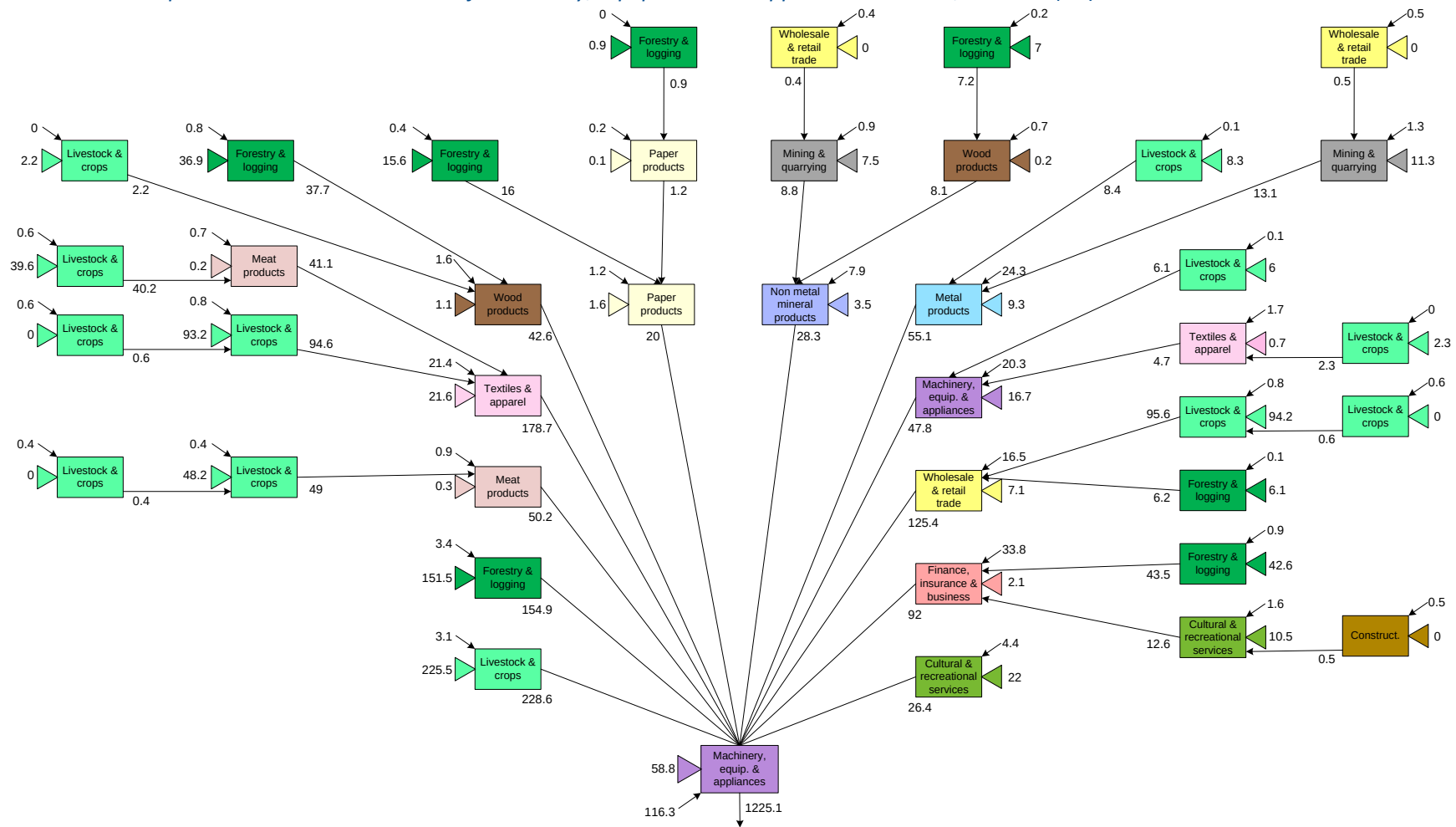


Figure 20.5 - Water Inputs Required to Produce One Tonne of Machinery, Equipment and Appliance Products, 2004 (Litres)

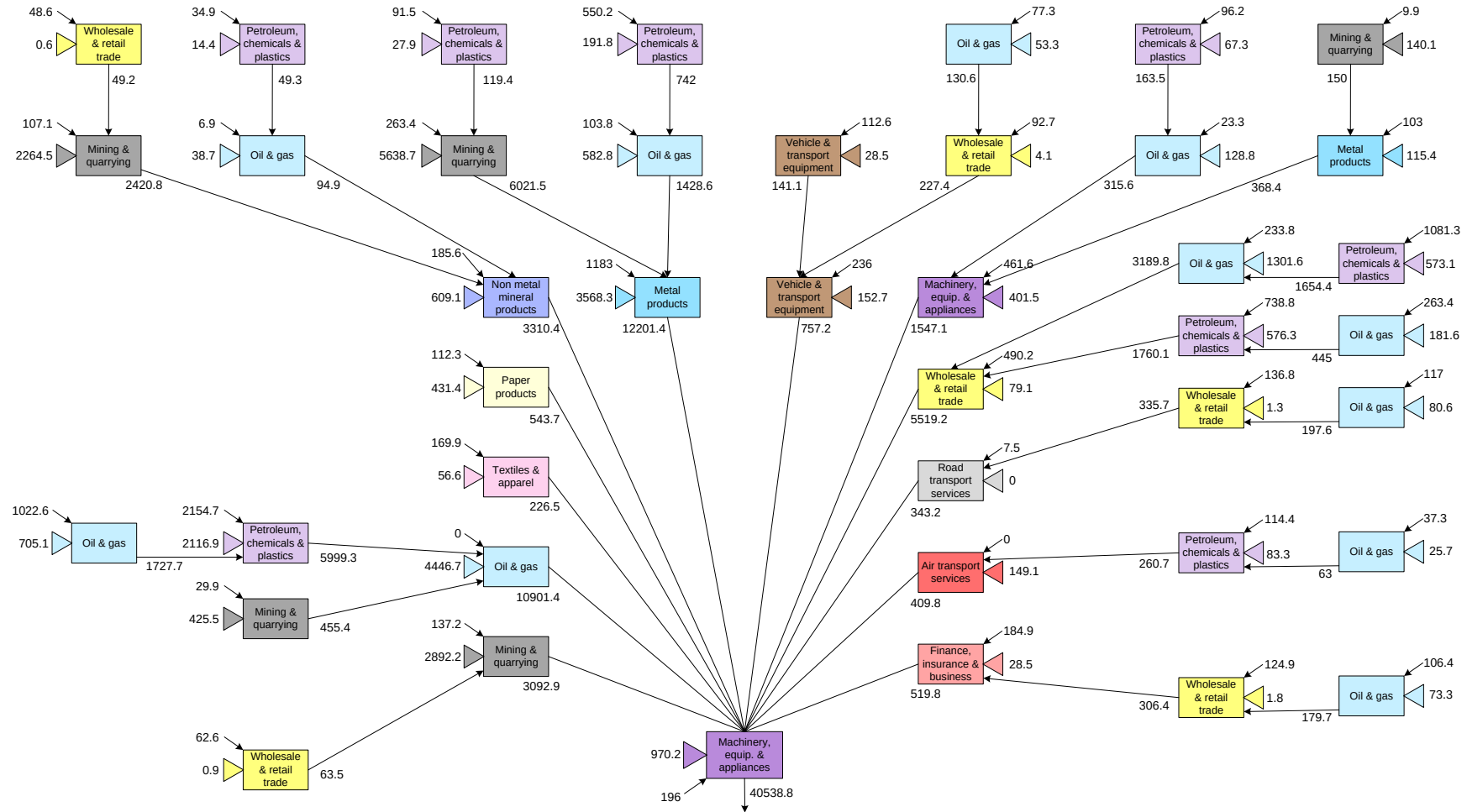


Figure 20.6 - Landfill Waste Generated in Producing One Tonne of Machinery, Equipment and Appliance Products, 2004 (Grams)



Figure 20.7 - Water Waste Generated in Producing One Tonne of Machinery, Equipment and Appliance Products, 2004 (Litres)

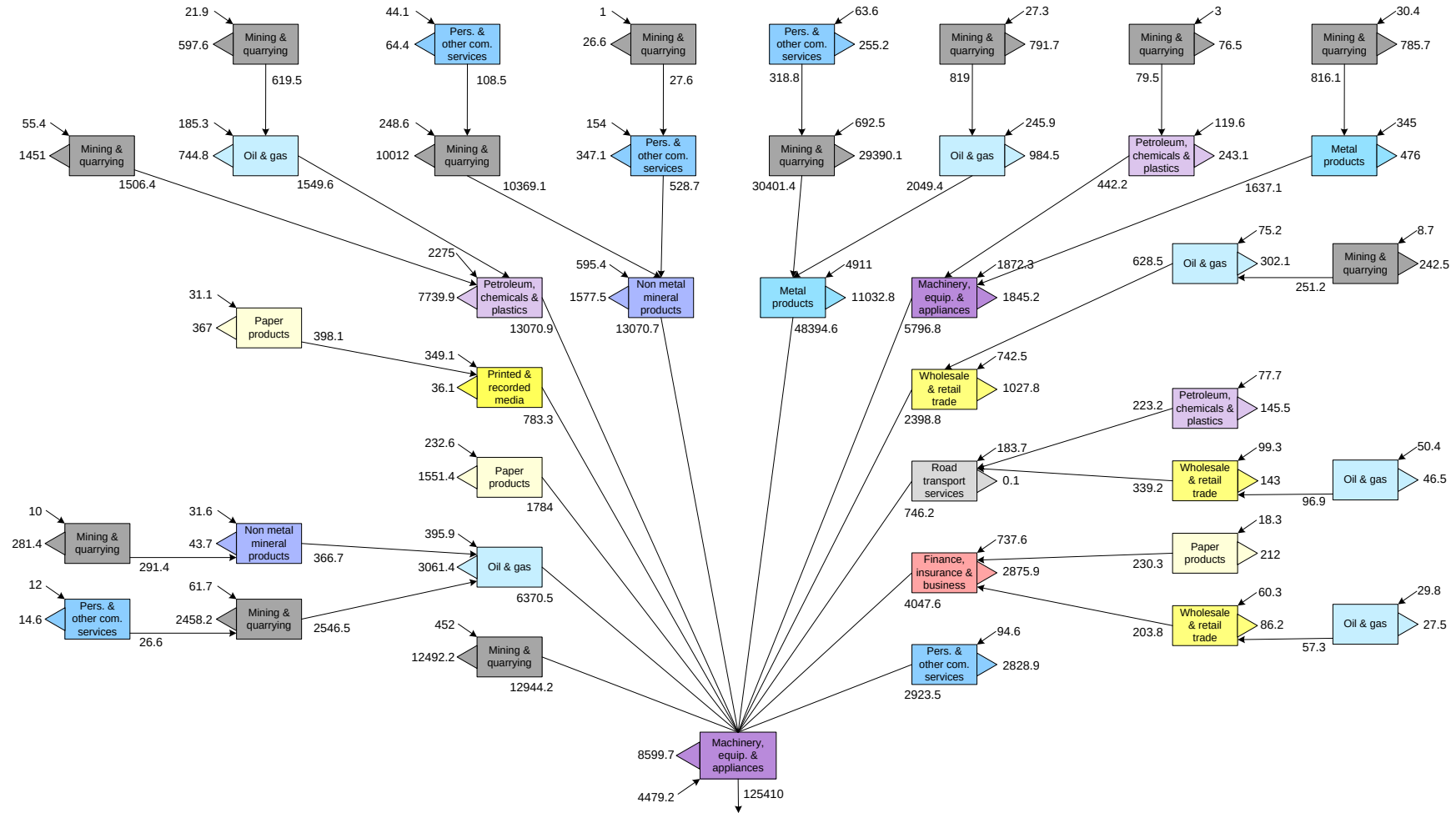
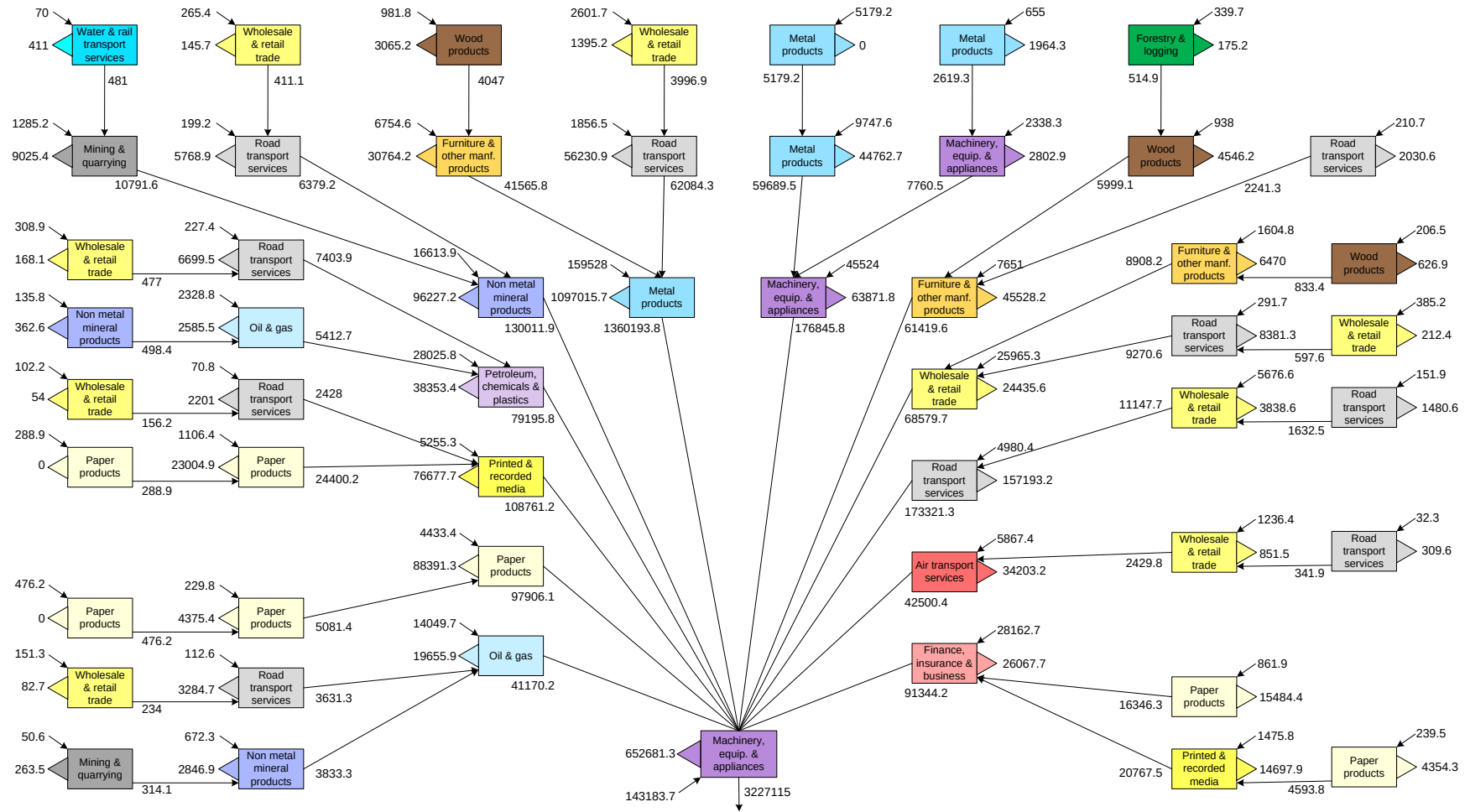


Figure 20.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Machinery, Equipment and Appliance Products, 2004 (Grams)



21. Furniture and Other Manufacturing

Description

ANZSIC Codes covered:

- 2511 – Wooden Furniture and Upholstered Seat Manufacturing
- 2512 – Metal Furniture Manufacturing
- 2513 – Mattress Manufacturing
- 2519 – Other Furniture Manufacturing
- 2591 – Jewellery and Silverware Manufacturing
- 2592 – Toy, Sporting and Recreational Product Manufacturing
- 2599 – Other Manufacturing

GDP 2016 = \$0.671 billion
Rank = 31st

Average annual growth rate
2006 to 2016 = -0.15%
Rank = 31st

Employment 2016 = 9,950
Rank = 26th

Main commodities supplied:

- Furniture, mattresses, and prefabricated buildings
- Jewellery, musical instruments, sports goods and games, and toys

Economic Overview

The furniture and other manufacturing sector has a very wide scope and includes furniture, mattresses, and other things from jewellery and toys to sporting and musical instruments. This sector was the third-lowest contributor to the overall manufacturing sector in 2016, worth just over 2% of total manufacturing sector sales.²⁴⁴ Ranked low at 31st among other sectors in the economy in terms of GDP contribution, it has been showing stagnant growth from 2006 to 2016 with an average annual growth rate of -0.15%. The sector is characterised by a low level of technology used in production, with production processes such as furniture and jewellery production utilising less than 1% of revenues in research and development.²⁴⁵

Australia is the dominant market for furniture exports, accounting for 63% of total exports, with China taking approximately 5%. Other significant trading partners for products in this sector include the United States as well as the Asia/Pacific region.²⁴⁶

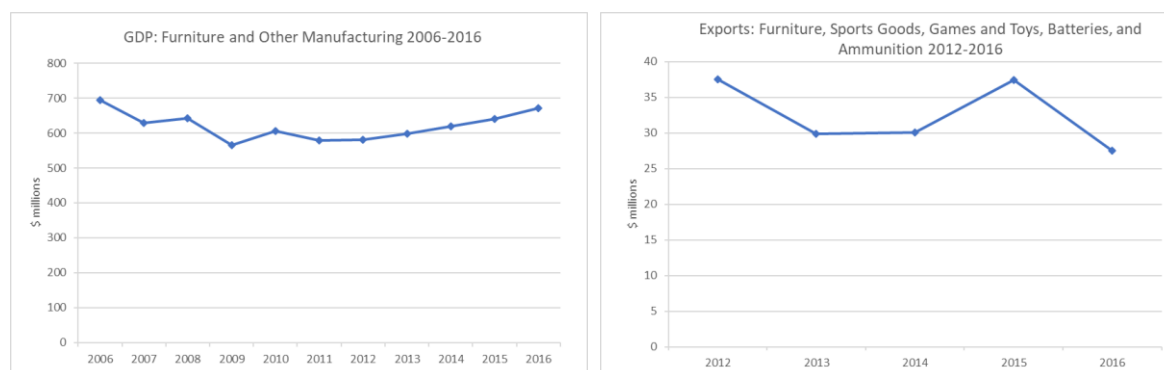
This sector is highly reliant on raw materials supplied by the forestry and logging sector, with radiata pine providing a sturdy and lower cost wood for outdoor furniture and prefabricated buildings, and indigenous woods providing more upmarket high quality indoor wooden furniture. The domestic market accounts for the majority of production, with exports representing 45% of this sector.

²⁴⁴ Reserve Bank of New Zealand. (2005). Overview of the Manufacturing Sector. *Bulletin*, 68(1), 23-33.

²⁴⁵ Ministry of Business, Innovation and Employment. (2018). *Beyond Commodities: Manufacturing into the Future*. Wellington. Retrieved from <https://www.mbie.govt.nz/assets/f0f81b6194/new-zealand-manufacturing-sector-report-2018.pdf>

²⁴⁶ FCANZ. (2016, February 15). *Furniture Exports*. Retrieved from <https://fcanz.net.nz/furniture-exports-2/>

Sector Trends



Production

Early on production took a slightly volatile, yet, downwards trend. Decreasing from an initial \$694 million in 2006 to \$578 million in 2011, with a noticeable drop in 2009, as a result of decreased construction and consumer spending due to the GFC. Following this downturn, the sector has improved slowly at an average yearly growth rate of 3.22%. This recovery is likely to have been spurred by rapid growth in housing construction over this time, both in the Christchurch rebuild following destructive earthquakes and Auckland residential construction, leading to a parallel growth in the furniture industry as people purchase furnishings and other articles for their new homes. With construction planned into the future with the KiwiBuild programme, this growth is likely to continue.

Exports

Initially, the value of exports declined over the first year by 20.26%, decreasing from \$38 million to \$30 million. The sector then recovered to similar levels in 2015 before decreasing further to a low of \$28 million. A downturn in the Chinese housing market, as seen with other forestry dominated sectors, is likely to have contributed to the decline in exports seen in 2016, with decreased demand for New Zealand furniture products in China.

Life Cycle Assessment Diagrams

Energy (Figure 21.1, Figure 21.2, Figure 21.3)

Furniture and other manufactured products were found to have a total energy intensity of 20,305.1 MJ_{OE} per tonne of product (20.3 MJ_E/kg)²⁴⁷, ranking 4th highest out of the 20 product producing sectors covered in this publication. *Direct energy* use was 47% of the total energy intensity, measuring 9,614.7 MJ_{OE} per tonne of product produced. While *indirect energy use* was 53% of the total energy intensity, measuring 10,690.4 MJ_{OE} per tonne of product produced.

The main indirect energy uses in the production of furniture and other manufactured products came from; (i) energy embodied in wood products at 2,323.5 MJ_{OE} per tonne of product produced; (ii) energy

²⁴⁷ Measured in conventional energy terms the total energy intensity derived in this study for the New Zealand "Furniture and Other Manufacturing" sector is 63.31 MJ_H/kg.

embodied in metal products at 1,626 MJ_{OE} per tonne of product produced; (iii) energy embodied in paper products at 1,229 MJ_{OE} per tonne of product produced; (iv) energy embodied in road transport services at 1,019.4 MJ_{OE} per tonne of product produced.

Land (Figure 21.4)

Furniture and other manufactured products have a total land intensity of 4,456.1 m² per tonne of product produced, ranking the sector 5th largest in terms of land intensity out of the 20 product producing sectors covered in this publication. *Direct land use* was small at only 2% of the total land intensity at 95.2 m² per tonne of product produced. *Indirect land use* makes up the majority of furniture and other manufactured product's total land intensity at 98% measuring 4,360.9 m² per tonne of product produced.

The major indirect land uses for furniture and other manufactured products come from; (i) land embodied in wood products at 2,324.7 m² per tonne of product produced; (ii) land embodied in textile and apparel products at 770.6 m² per tonne of product produced (iii) land embodied in livestock and crops at 336.3 m² per tonne of product produced; (iv) land embodied in meat products at 257.8 m² per tonne of product produced.

Water Inputs (Figure 21.5)

Furniture and other manufactured products require 56,619.6 litres of water inputs per tonne of product produced, ranking the sector the 4th highest consumer of water compared to the 20 product producing sectors covered in this publication. *Direct water inputs* made up only 7% of the total water inputs or 3,699.6 litres per tonne of furniture and other manufactured product produced. *While indirect water inputs* made up the majority of total water inputs at 93% or 52,920 litres per tonne of product produced.

The main indirect water inputs in the production of furniture and other manufactured products came from; (i) water inputs embodied in oil and gas at 21,338 litres per tonne of product produced; (ii) water inputs embodied in mining and quarrying at 21,040.1 litres per tonne of product produced; (iii) water inputs embodied in metal products at 2,272 litres per tonne of product produced; (iv) water inputs embodied 2,110.7 litres per tonne of product produced.

Landfill Wastes (Figure 21.6)

Furniture and other manufactured products were found to generate 365,430.2 grams (365.4 kg) of landfill waste per tonne of product produced. This ranks the sector the highest producer of landfill waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Landfill waste directly generated* by furniture and other manufactured products was 63% of total waste produced or 231,924.7 grams per tonne of product produced. *Landfill waste indirectly generated* by furniture and other manufactured products was 37% of total waste produced or 133,505.5 grams per tonne of product produced.

The main sources of indirect landfill waste in the production of furniture and other manufactured products came from; (i) landfill wastes embodied in wood products at 62,283.9 grams per tonne of product produced; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 28,313.1 grams per tonne of product produced; (iii) landfill wastes embodied in furniture and other manufactured products at 10,057.3 grams per tonne of product produced; (iv) landfill wastes embodied in livestock and crops at 5,804 grams per tonne of product produced.

Water Wastes (Figure 21.7)

Furniture and other manufactured products were found to produce 155,463.3 litres of wastewater per tonne of product produced. This ranks the sector as the highest producer of water waste per tonne of product produced out of the 20 product producing sectors covered in this publication. *Wastewater directly generated* in the production of furniture and other manufactured products was only 9% of total water wastes or 14,303.9 litres per tonne of product produced. *While wastewater indirectly generated* by furniture and other manufactured products made up the majority at 91% of the total water wastes or 141,159.4 litres per tonne of product produced.

The indirect wastewater from the production of furniture and other manufactured products was mostly made up of (i) wastewater embodied in mining and quarrying at 87,331.7 litres per tonne of product produced; (ii) wastewater embodied in petroleum, chemicals and plastics at 10,432.1 litres per tonne of product produced; (iii) wastewater embodied in oil and gas at 7,168.8 litres per tonne of product produced; (iv) wastewater embodied in wood products at 6,670.2 litres per tonne of product produced.

Energy Greenhouse Gases (Figure 21.8)

In terms of CO₂ greenhouse gas emissions, furniture and other manufactured products were found to emit 6,943,839.9 grams of energy-related CO₂ per tonne of product produced. Energy-related CO₂ emissions from the production of furniture and other manufactured products are ranked second highest out of the 20 product producing sectors covered in this publication.

Energy-related CO₂ directly generated by furniture and other manufactured products made up 66% of total emissions or 4,596,693.6 grams per tonne of product produced. *Energy-related CO₂ indirectly generated* by furniture and other manufactured products made up 34% of the total emissions produced or 2,347,146.3 grams per tonne of product produced.

The indirect energy-related CO₂ emissions from the production of furniture and other manufactured products was mostly made up of (i) energy-related CO₂ embodied in wood products at 666,216.5 grams per tonne of product produced; (ii) energy-related CO₂ embodied in paper products at 280,964 grams per tonne of product produced; (iii) energy-related CO₂ embodied in road transport services at 232,665.5 grams per tonne of product produced; (iv) energy-related CO₂ embodied in metal products at 202,803.3 grams per tonne of product produced.

Figure 21.1 - Total Energy Inputs Required to Produce One Tonne of Furniture and Other Manufactured Products, 2004 (MJ_E, Oil Equivalents)

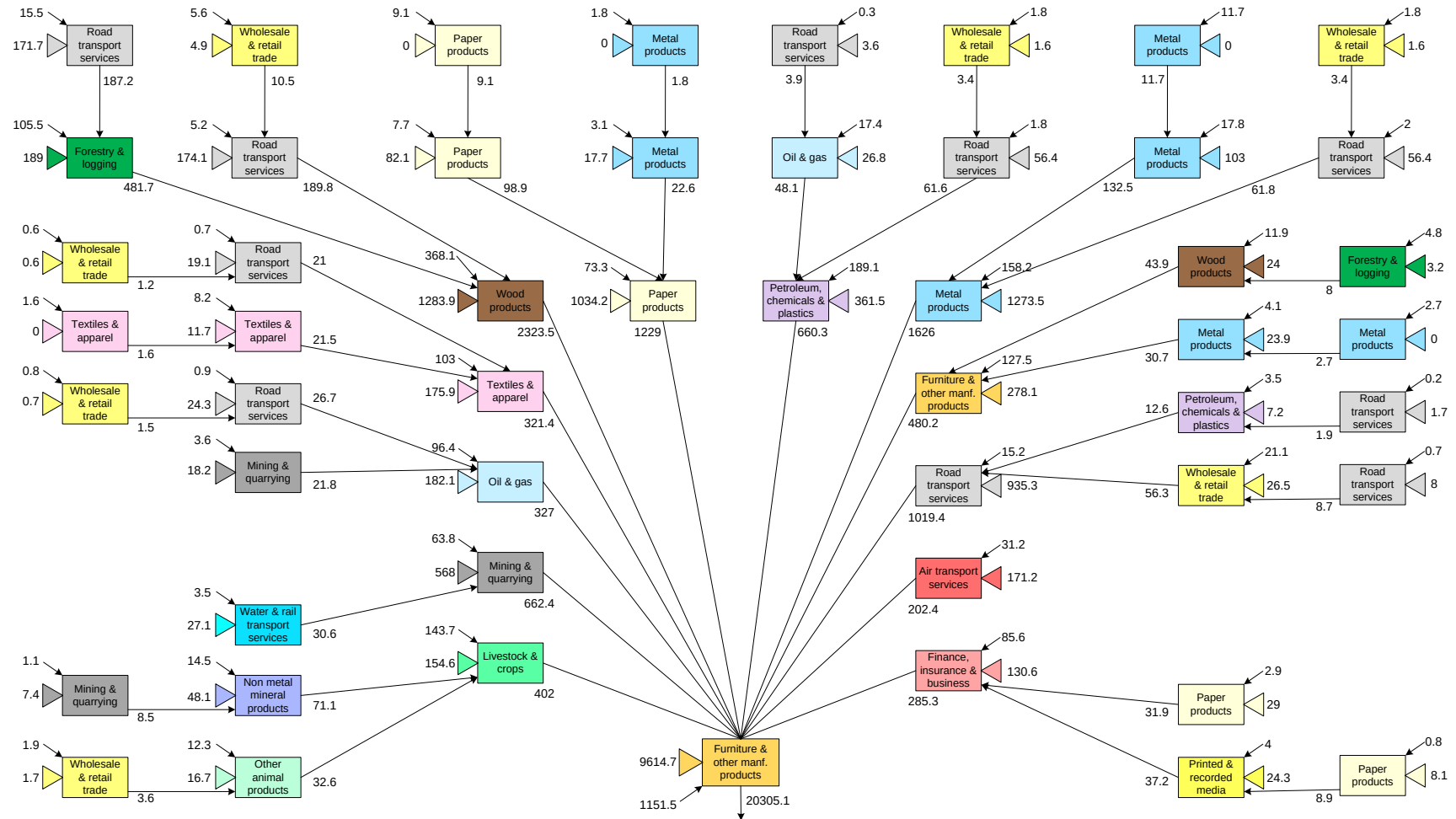


Figure 21.2 - Electricity Inputs Required to Produce One Tonne of Furniture and Other Manufactured Products, 2004 (MJ, Heat Equivalents)

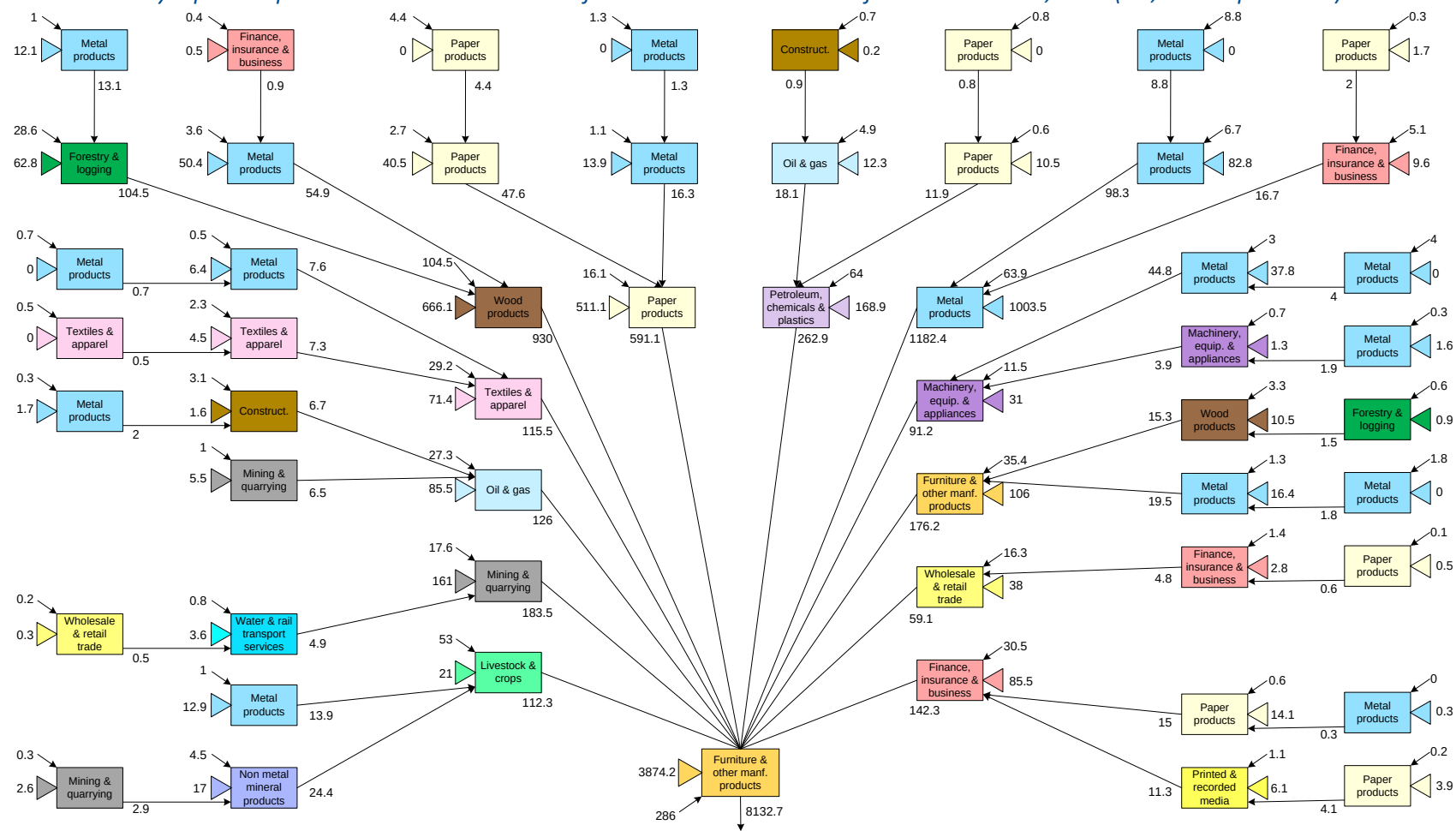


Figure 21.3 - Fossil Fuel Inputs Required to Produce One Tonne of Furniture and Other Manufactured Products, 2004 (MJ, Heat Equivalents)

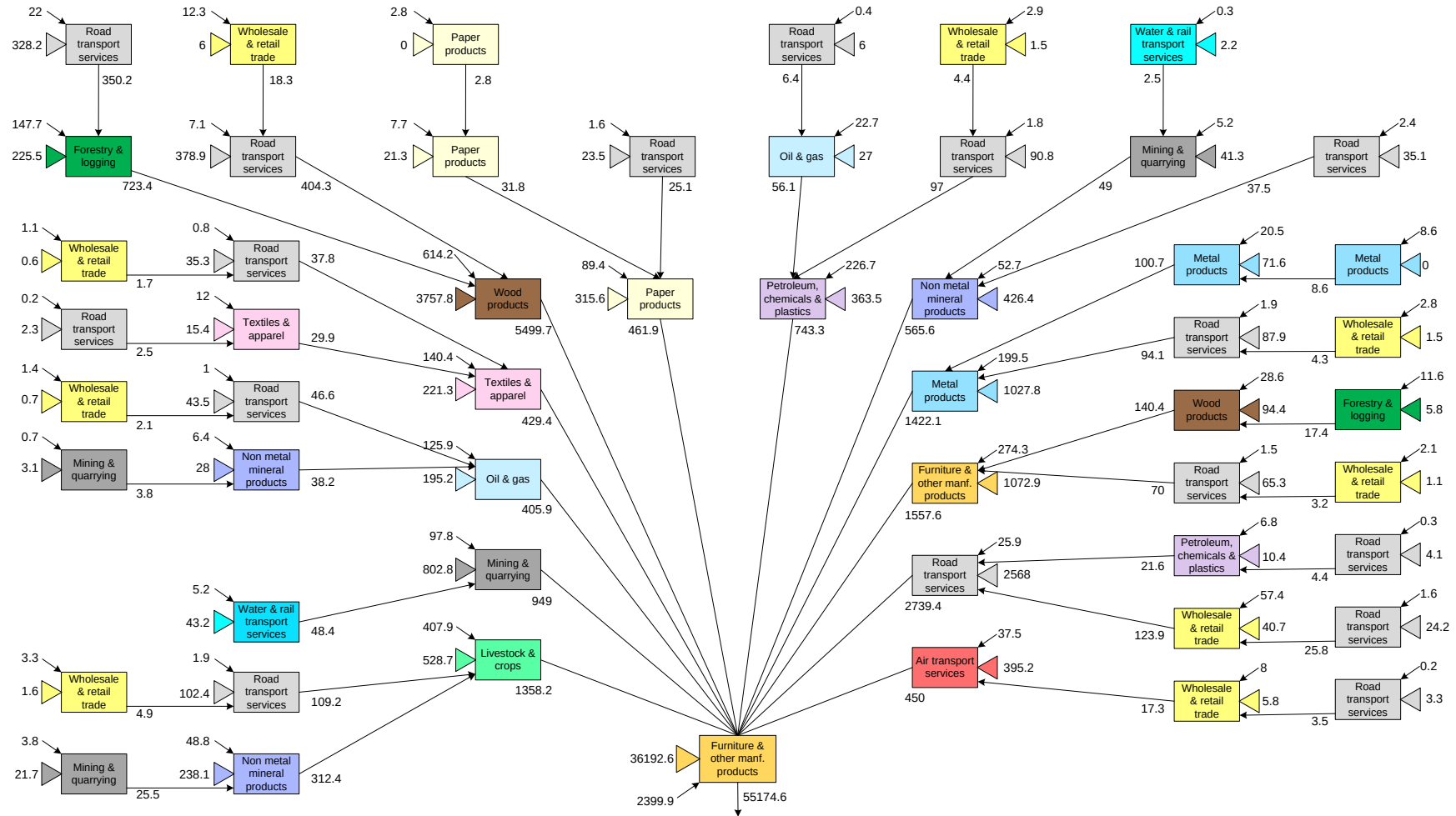


Figure 21.4 - Land (m^2) Required to Produce One Tonne of Furniture and Other Manufactured Products, 2004 (m^2)

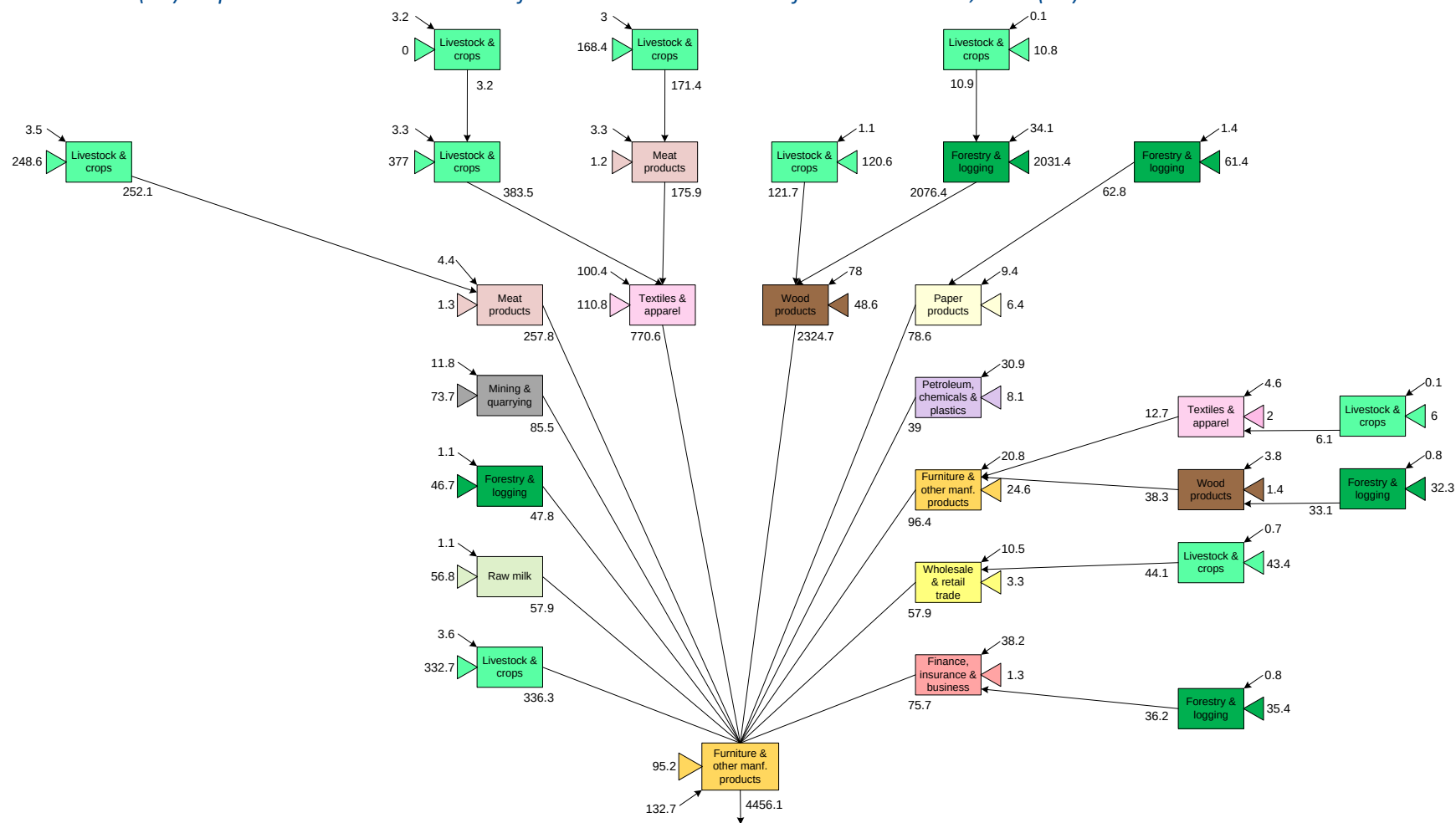


Figure 21.5 - Water Inputs Required to Produce One Tonne of Furniture and Other Manufactured Products, 2004 (Litres)

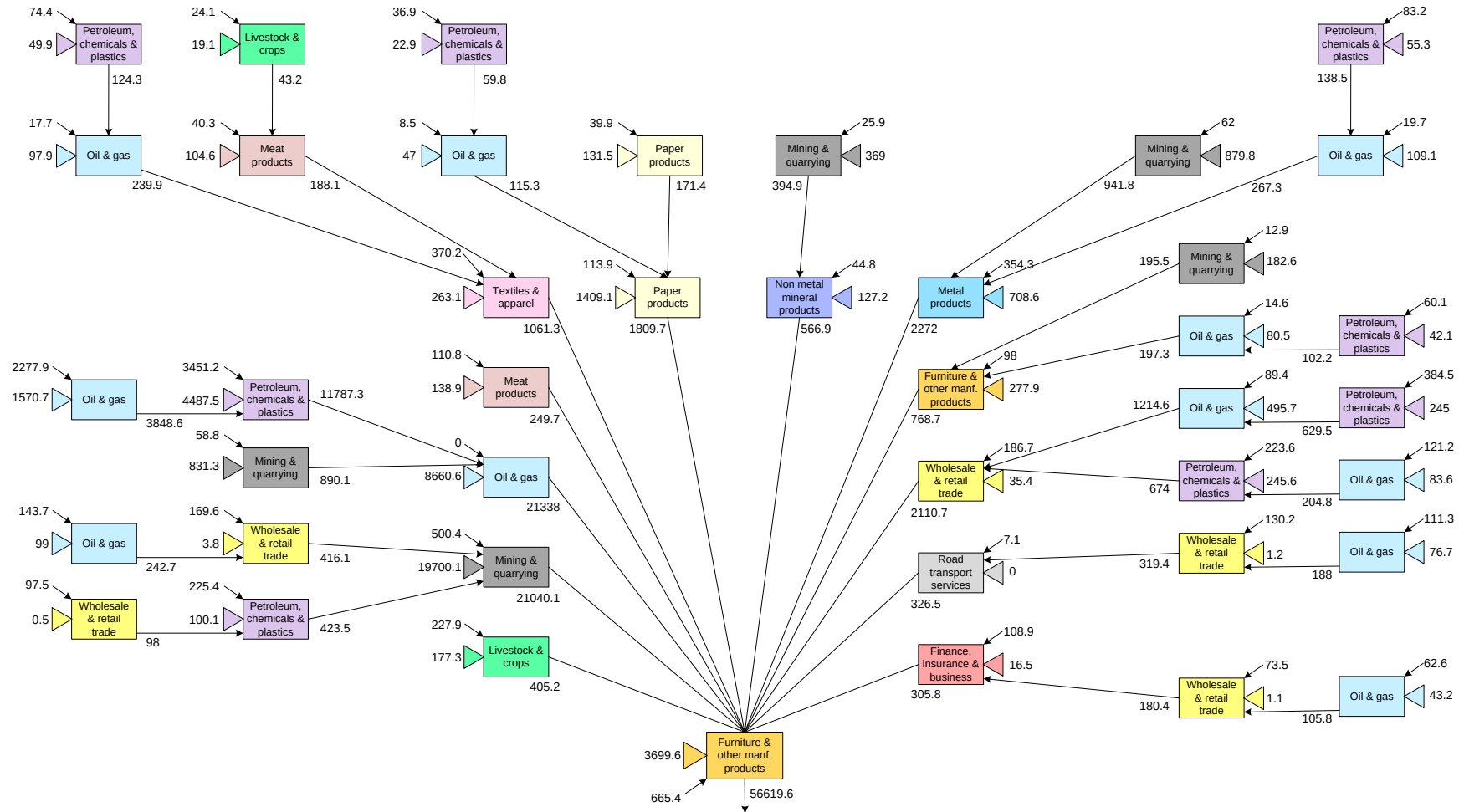


Figure 21.6 - Landfill Waste Generated in Producing One Tonne of Furniture and Other Manufactured Products, 2004 (Grams)

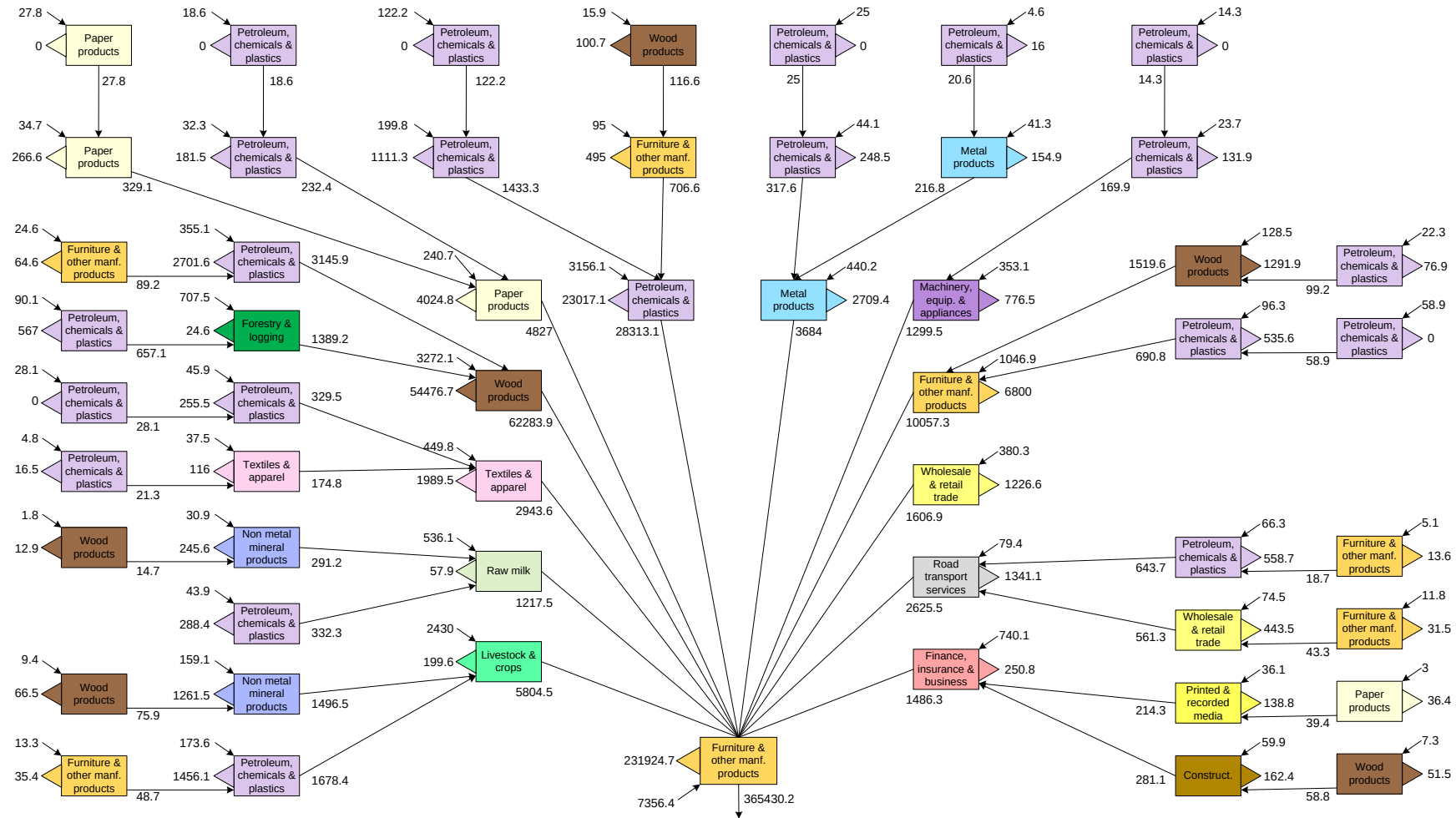


Figure 23.7 - Water Waste Generated in Producing One Tonne of Furniture and Other Manufactured Products, 2004 (Litres)

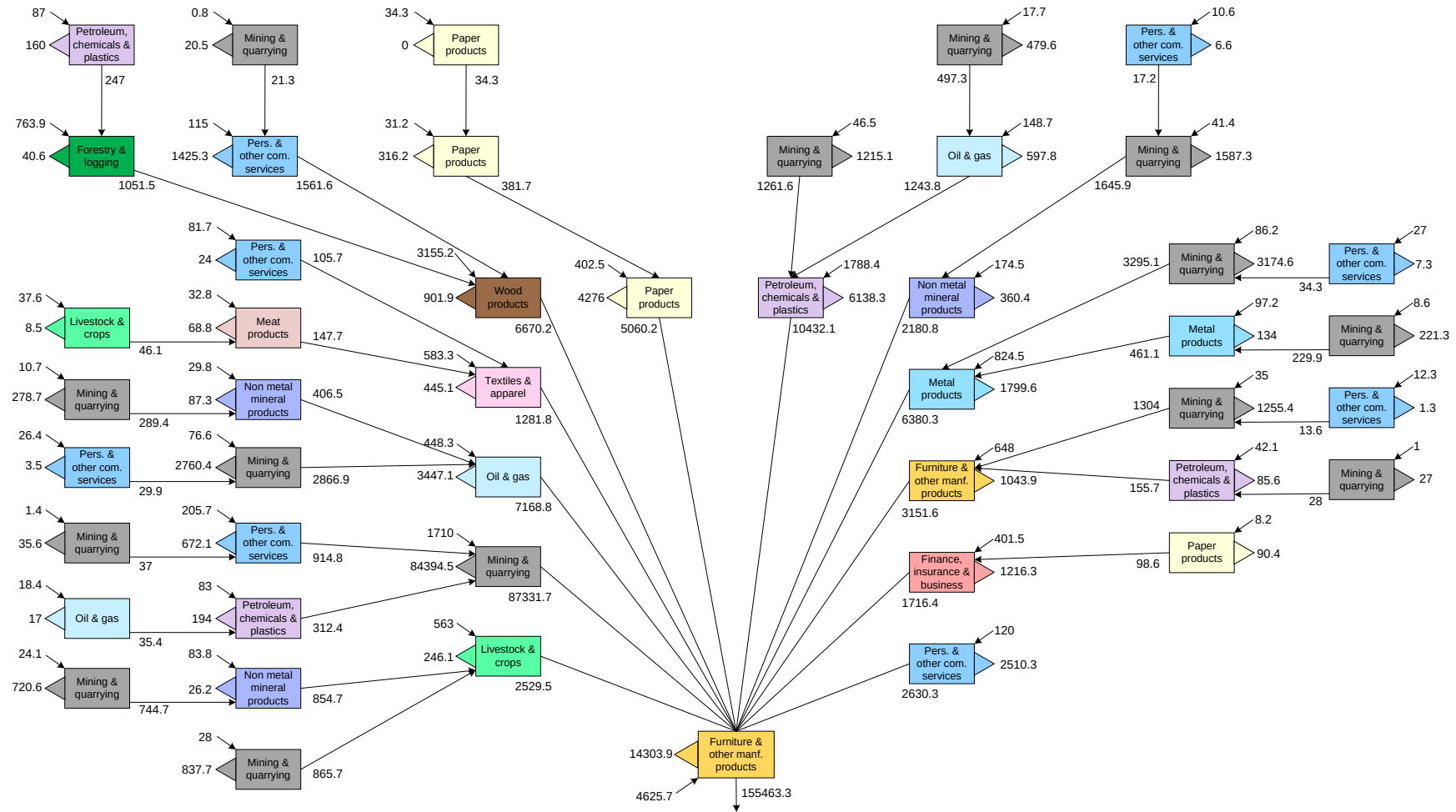
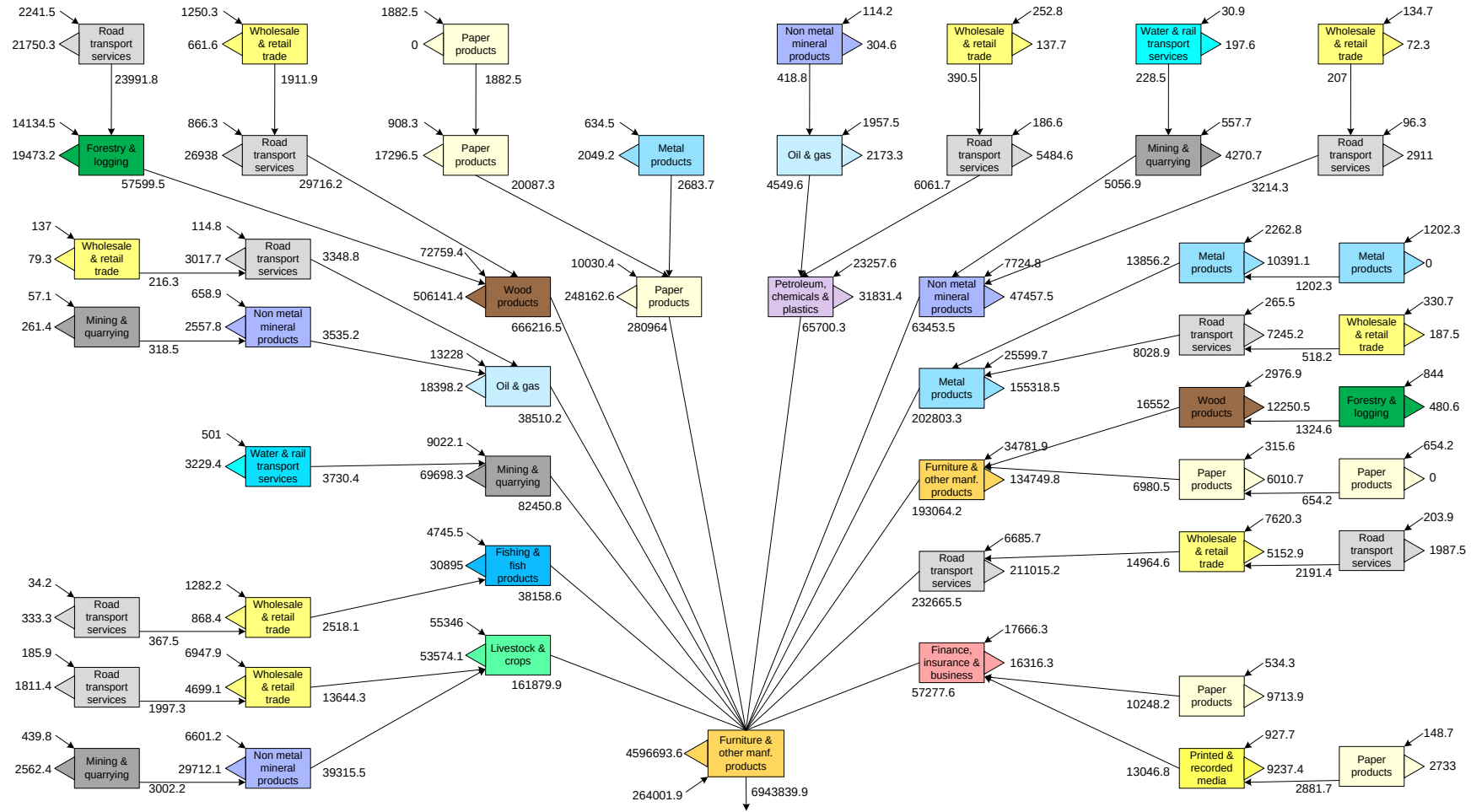


Figure 21.8 - Energy-Related CO₂ Emitted in Producing One Tonne of Furniture and Other Manufactured Products, 2004 (Grams)



22. Construction Services

Description

ANZSIC Codes covered:

- 301 – Residential Building Construction
- 302 – Non-Residential Building Construction
- 310 – Heavy and Civil Engineering Construction
- 321 – Land Development and Site Preparation Services
- 322 – Building Structure Services
- 323 – Building Installation Services
- 324 – Building Completion Services
- 329 – Other Construction Services

GDP 2016 = \$15.267 billion
Rank = 3rd

Average annual growth rate
2006 to 2016 = 5.89%
Rank = 10th

Employment 2016 = 207,023
Rank = 4th

Main commodities supplied:

- Building construction, civil engineering, pre-erection work, other installation work, plumbing, electrical installation work, fencing, and land improvements

Economic Overview

The construction sector is fundamental in New Zealand, it is the third-largest contributor to GDP in the New Zealand economy,²⁴⁸ estimated to have contributed \$15.267 billion to the New Zealand economy in 2016.

The construction sector accounts for 1 in 12 jobs in New Zealand employing over 157,000 full-time equivalents (FTEs), of which 86.7% are male in 2011.²⁴⁹ Employment in the sector has grown over the next five years, reaching 207,023 FTEs in 2016. The construction sector is characterised largely by small businesses which are spread out throughout New Zealand, generally in proportion with the general population.²⁵⁰ The sector is also characterised by low productivity levels compared to other industries such as mining due to its labour-intensive nature.

The construction sector is involved with the construction, alteration and repair of buildings and infrastructure such as houses, commercial buildings, roads and pavements, bridges, and dams. The sector primarily uses products produced in the forestry sector such as wood, and in the manufacturing sector such as machinery, and other equipment.

²⁴⁸ PricewaterhouseCoopers. (2011). *Valuing the role of Construction in the New Zealand Economy: A Report to the Construction Strategy Group*. Auckland: New Zealand.

²⁴⁹ Department of Labour. (2011). *Construction Sector Action Plan 2010-2013*. Retrieved from <http://www.dol.govt.nz/whss/sector-plans/construction/action-plan.pdf>

²⁵⁰ PricewaterhouseCoopers. (2011). *Valuing the role of Construction in the New Zealand Economy: A Report to the Construction Strategy Group*. Auckland: New Zealand: Author.

The construction sector is closely connected with economic cycles and so any economic changes within the economy such as changes in interest rates, business and consumer confidence, employment, house prices, and migration impacts are easily felt.²⁵¹

Sector Trends



In 2016, the construction industry was recorded as the 3rd largest sector by production (valued in GDP terms). Between 2006 and 2016, production in this sector steadily increased by 75.3% from \$8.7 billion to \$15.27 billion. While the trend has been upward overall, growth in the construction industry rose more rapidly at the onset of the GFC, rising 23% to \$10.7 billion in 2008. In 2009, however, production dipped slightly by 2.77% to \$10.4 billion where it largely remained for the next three years, growing annually by 0.45% on average. Indeed, the GFC is the most plausible explanation for the rather sluggish growth in production. In fact, production in the construction industry has fluctuated in a similar fashion historically, following other disruptive events including other financial crises (1997 Asian financial crisis) and state economic initiatives, notably the 'Think Big' programmes in the 1980s.²⁵² Since 2012, growth in production appears to have accelerated and will continue to do so in the near future, with annual production rising by 8.84%, on average, between 2012 and 2016. The size and importance of this sector means that it affects a wide range of other sectors throughout the economy. In recent years, the Christchurch rebuild following the 2011 earthquake, as well as KiwiBuild, has driven the accelerated growth from 2012 onwards. With KiwiBuild scheduled to continue through to 2028, this growth is likely to continue.

Life Cycle Assessment Diagrams

Energy (Figure 22.1, Figure 22.2, Figure 22.3)

Construction services were found to consume a total energy intensity of 1,864.2 MJ_{OE} per \$1,000 worth of output. The construction sector ranks as having the 6th highest total energy intensity out of the 14 service and construction sectors covered in this publication.

Direct energy use for construction services was only 17% of the total energy intensity, measuring 316.2 MJ_{OE} per \$1,000 worth of output. Direct energy uses would include electricity to operate machinery such as electric saws, as well as electricity for lighting and fossil fuels for transportation – the EECA in use database reports that a total of 1,716.289 TJ of energy was used in the construction sector in

²⁵¹ Statistics New Zealand. (2009). *A Statistical Overview of the Construction Industry from 2000 to 2008*. Christchurch, New Zealand: Author.

²⁵² Hembry, O. (2011, January 30). *In the shadow of Think Big*. Retrieved February 5, 2020, from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=10703096

2006/07. *Indirect energy use* made up 83% of the total energy intensity, measuring 1,548 MJ_{OE} per \$1,000 worth of output.

The main indirect energy uses in construction services came from; (i) energy embodied in metal products at 384.9 MJ_{OE} per \$1,000 of output; (ii) energy embodied non-metal mineral products at 350.1 MJ_{OE} per \$1,000 of output; (iii) energy embodied in wood products at 337.7 MJ_{OE} per \$1,000 of output; (iv) energy embodied in wholesale and retail trade at 120.9 MJ_{OE} per \$1,000 of output.

Land (Figure 22.4)

Construction services have a total land intensity of 408.4 m² per \$1,000 of services supplied. Construction services have the 4th largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for construction services was minuscule at only 1% of the total land intensity, measuring 4.4 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 99% measuring 404 m² per \$1,000 of services supplied.

The major indirect land uses came from; (i) land embodied in wood products at 290.6 m² per \$1,000 of services supplied; (ii) land embodied in wholesale and retail trade at 40 m² per \$1,000 of services supplied; (iii) land embodied in textile and apparel at 30.1 m² per \$1,000 of services supplied; (iv) land embodied in finance, insurance & business at 7.4 m² per \$1,000 of services supplied.

Water Inputs (Figure 22.5)

Construction services use a total of 4,516.4 litres of water inputs per \$1,000 of services supplied, ranking the sector the 6th highest consumer of water out of the 14 service sectors covered by this publication. *Direct water inputs* make up a tiny 0.02%, using only 5.3 litres per \$1,000 of construction services supplied. While *indirect water inputs* make up the majority at 99.8%, using 4,511.1 litres per \$1,000 of construction services supplied.

Indirect water inputs into construction services came mainly from; (i) water inputs embodied in non-metal mineral products at 1,468.2 litres per \$1,000 of services supplied; (ii) water inputs embodied in wholesale and retail trade at 1,390.7 litres per \$1,000 of services supplied; (iii) water inputs embodied in mining and quarrying at 927.7 litres per \$1,000 of services supplied; (iv) water inputs embodied in metal products at 412.6 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 22.6)

Construction services were found to generate 38,761.4 grams (38.7 kg) per \$1,000 of services supplied. *Landfill waste directly generated* by the construction services sector is 55% of total waste produced or 21,143.1 grams per \$1,000 of construction services supplied. While landfill waste *indirectly generated* by construction services was 45% or 17,618.3 grams per \$1,000 of construction services supplied.

The main sources of indirect landfill waste for construction services came from; (i) landfill wastes embodied in wood products at 7,951.6 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 3,745.9 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in non-metal mineral products at 2,695.6 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in wholesale and retail trade at 938.2 grams per \$1,000 of services supplied.

Water Wastes (Figure 22.7)

Construction services were found to produce a total of 17,768.2 litres of wastewater per \$1,000 of services supplied, ranking the sector 2nd highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* by construction services was minimal at only 0.03% of total water waste produced, at 54.4 litres per \$1,000 of services supplied. *Wastewater indirectly generated* from construction services make up the majority 99.7% or 17,713.8 litres per \$1,000 of services supplied.

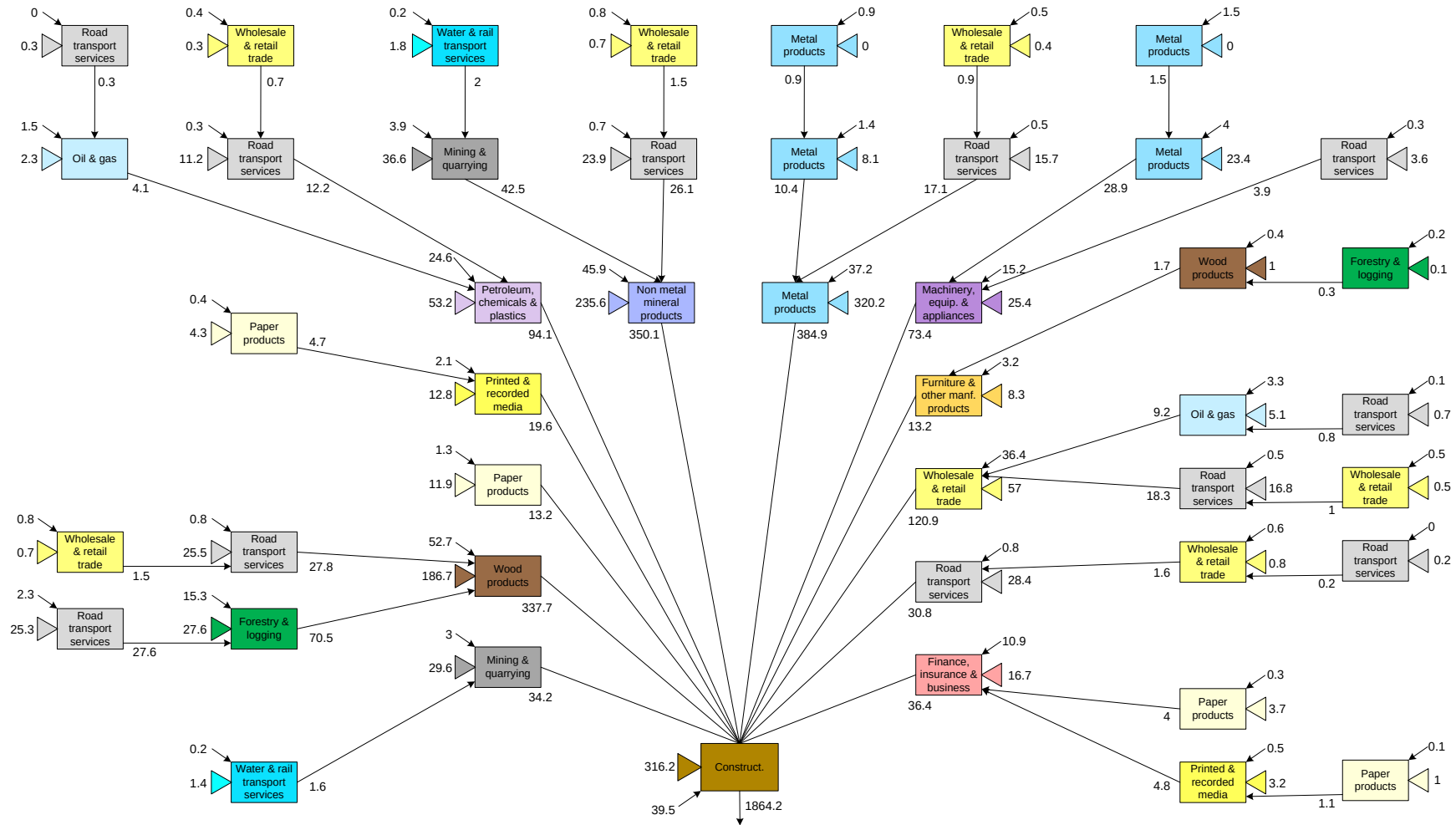
The indirect wastewater generated from construction services is mostly made up of (i) wastewater embodied in non-metal mineral products at 6,398.2 litres per \$1,000 of services supplied; (ii) wastewater embodied in mining and quarrying at 4,512.4 litres per \$1,000 of services supplied; (iii) wastewater embodied in personal and other community services at 1,475.5 litres per \$1,000 of services supplied; (iv) wastewater embodied in metal products at 1,472.4 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 22.8)

In terms of CO₂ greenhouse gas emissions, construction services emit a total of 281,352 grams (281 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the 6th highest emitter of energy-related CO₂ per tonne among the 14 service and construction sectors covered in this publication. *Energy-related CO₂ directly generated* by construction services was only 11% of the total CO₂ emitted at 32,020.5 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by construction services makes up the remaining 89% or 249,331.5 grams.

The indirect energy-related CO₂ from construction services was mostly made up of (i) energy-related CO₂ embodied in wood products at 86,039.9 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in non-metal mineral products at 60,628.9 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in metal products at 40,889.5 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in wholesale and retail trade at 16,376.7 grams per \$1,000 of services supplied.

Figure 22.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Construction Services, 2004 (MJ_E, Oil Equivalents)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,590 (\$ = Year of 2019)

Figure 22.2 - Electricity Inputs Required to Produce \$1,000 Worth of Construction Services, 2004 (MJ, Heat Equivalents)

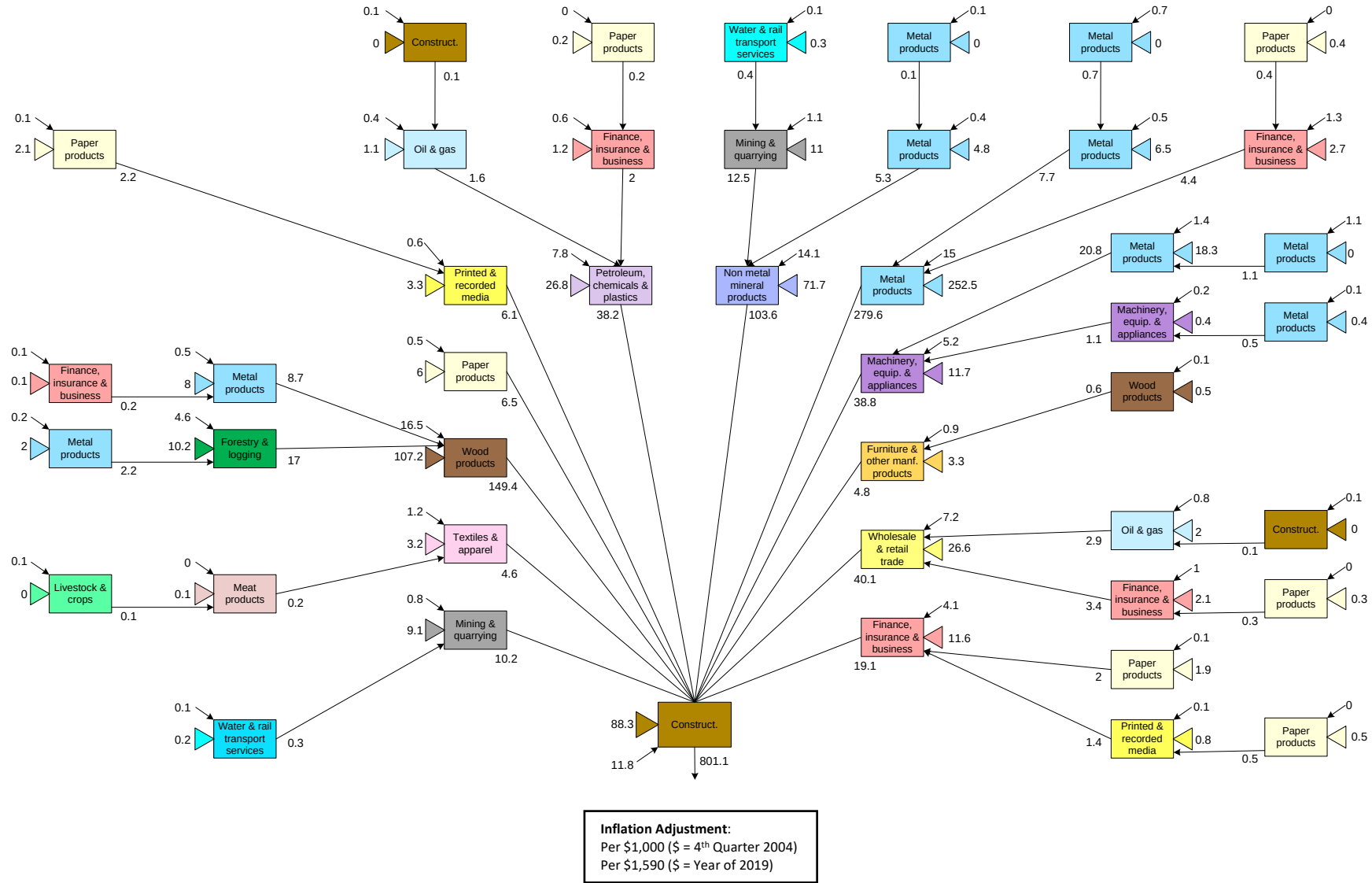
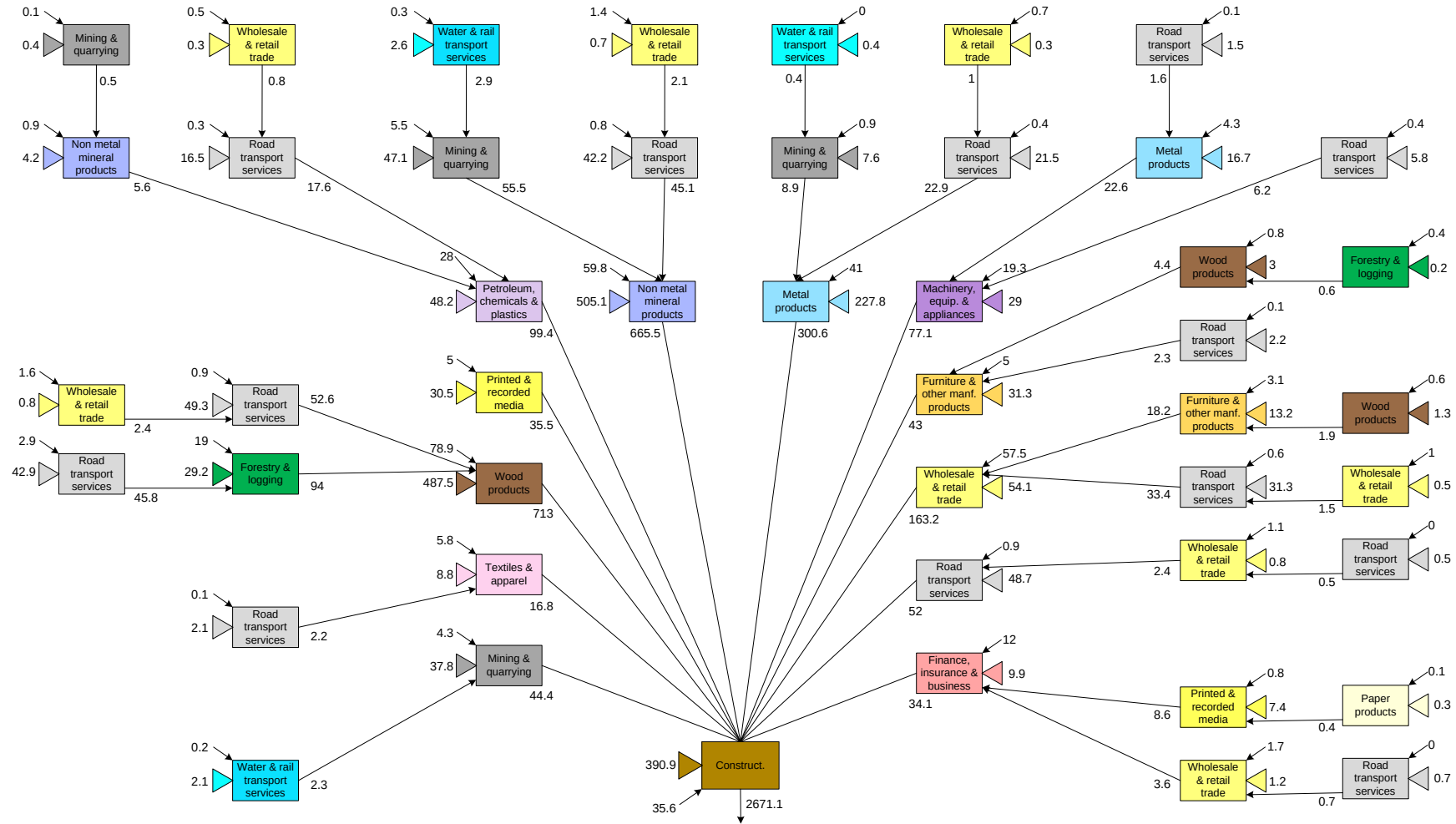
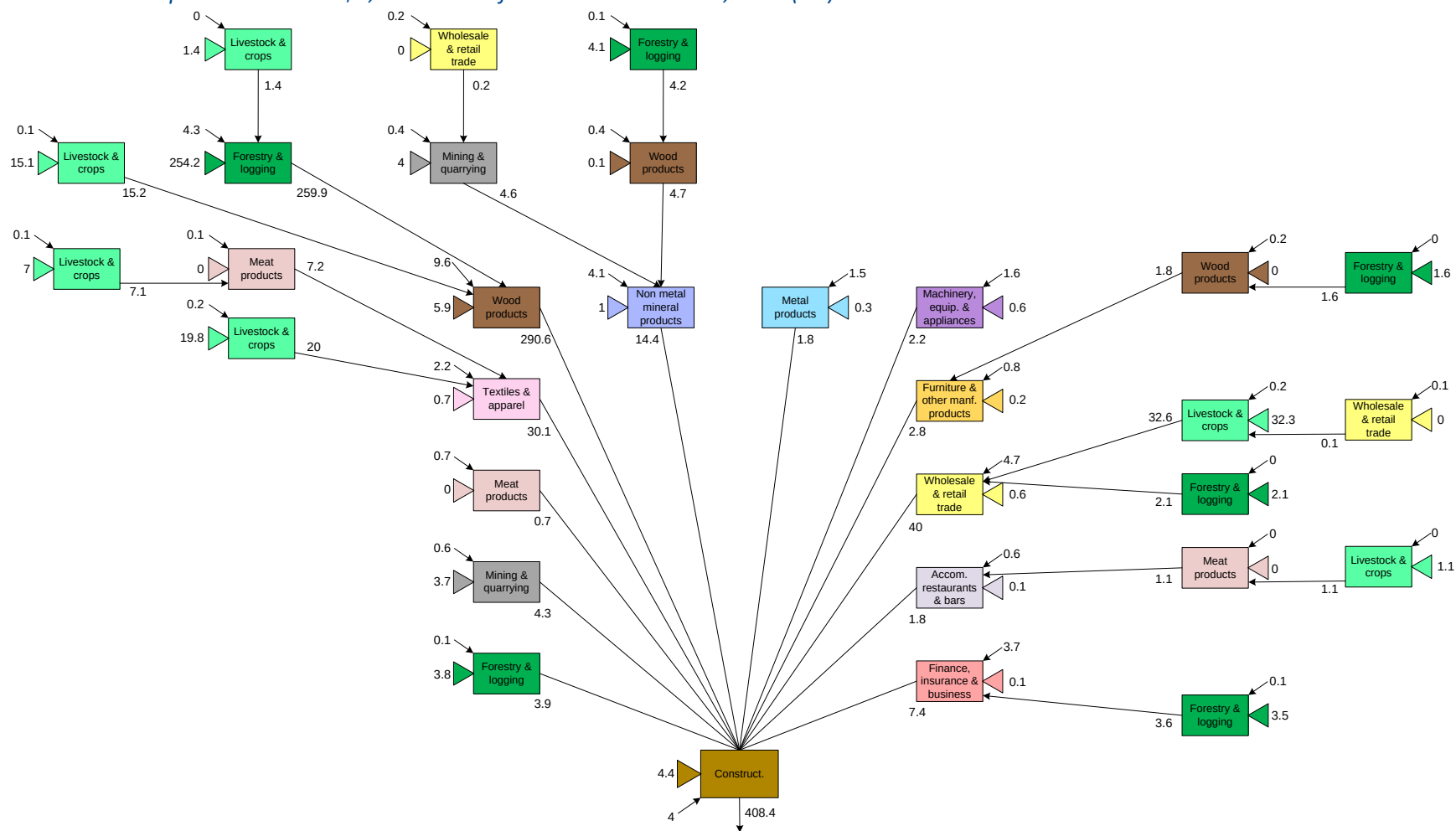


Figure 22.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Construction Services, 2004 (MJ, Heat Equivalents)



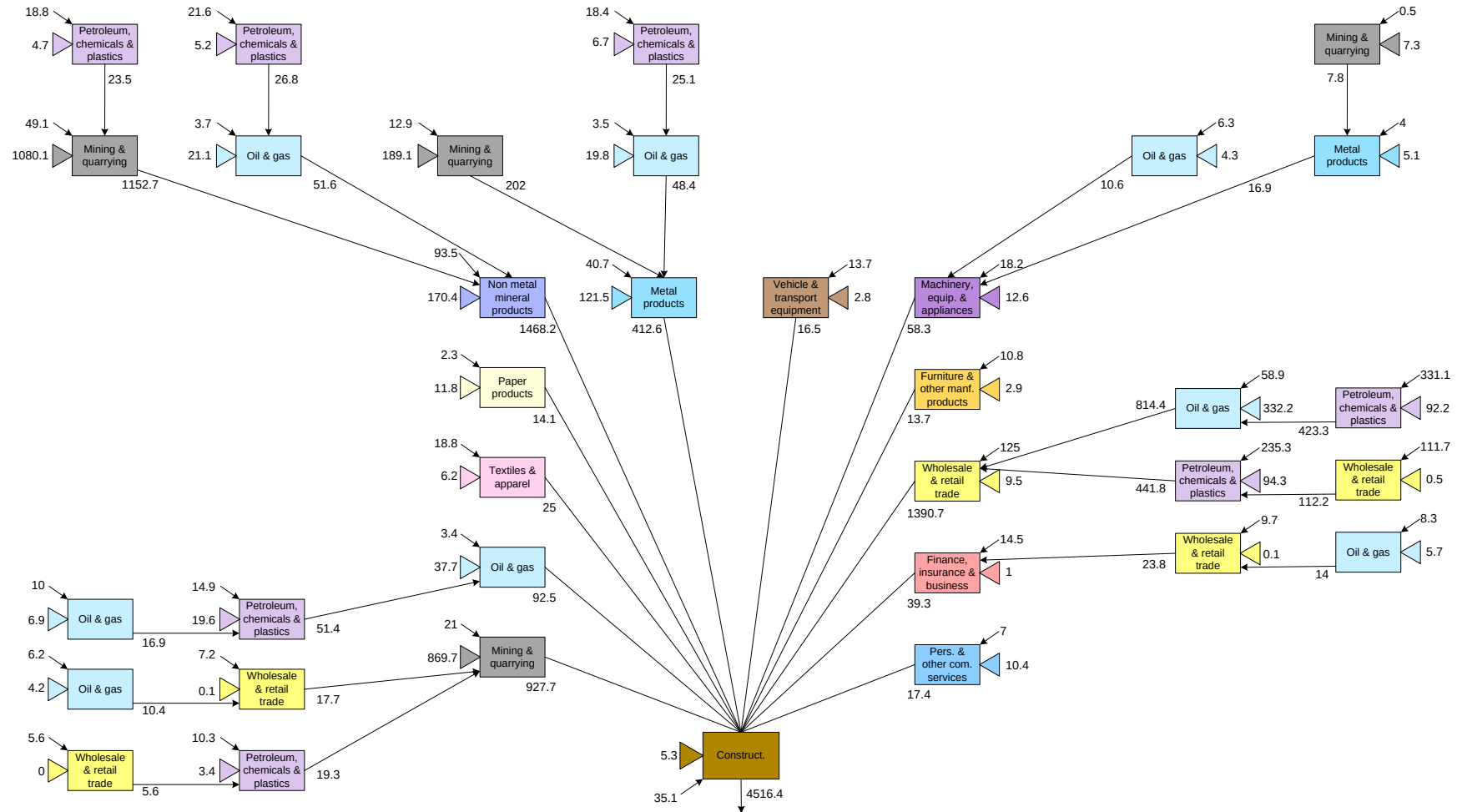
Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,590 (\$ = Year of 2019)

Figure 22.4 - Land Required to Produce \$1,000 Worth of Construction Services, 2004 (m²)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,590 (\$ = Year of 2019)

Figure 22.5 - Water Inputs Required to Produce \$1,000 Worth of Construction Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,590 (\$ = Year of 2019)

Figure 22.6 - Landfill Waste Generated in Producing \$1,000 Worth of Construction Services, 2004 (Grams)

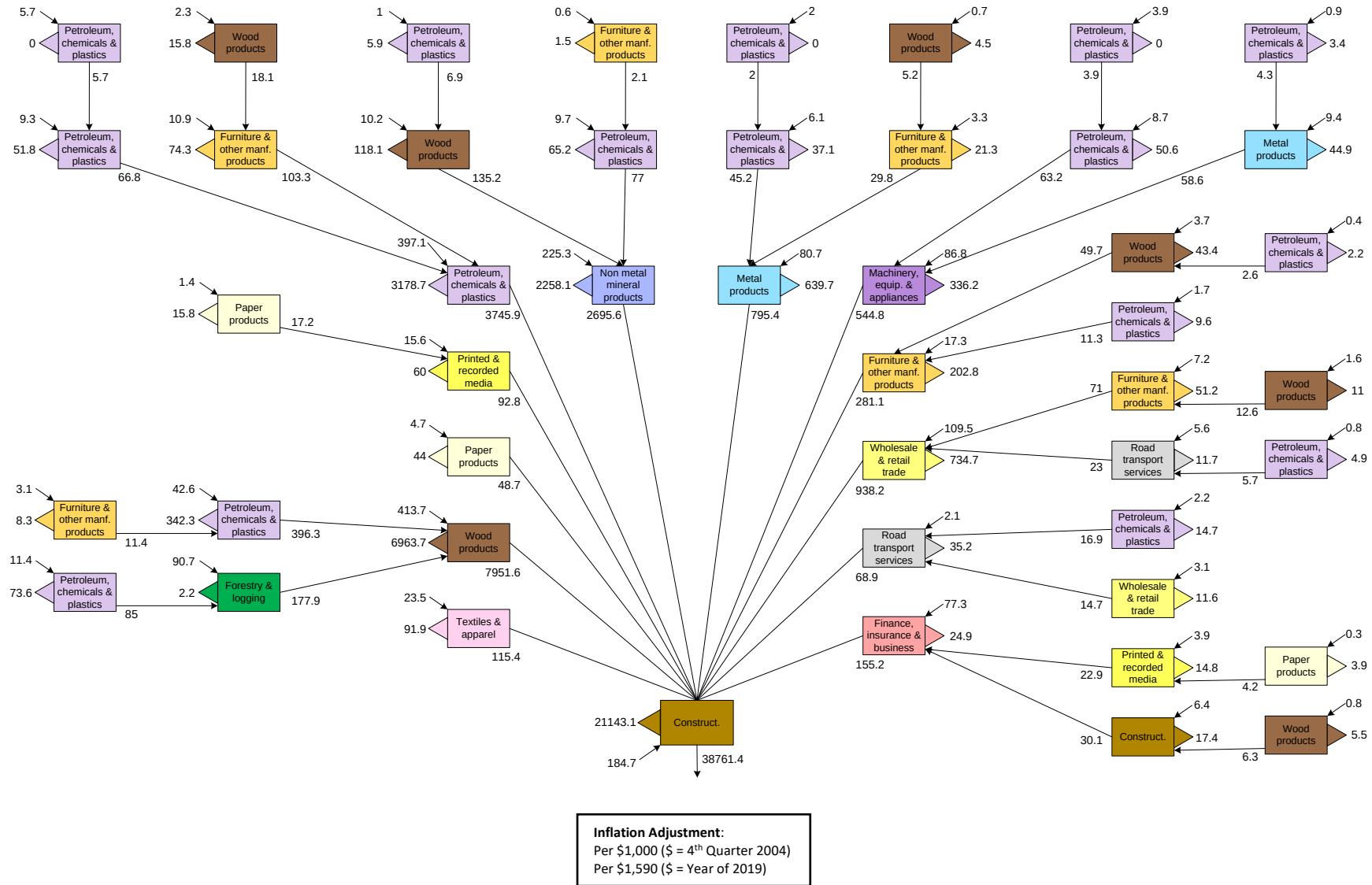
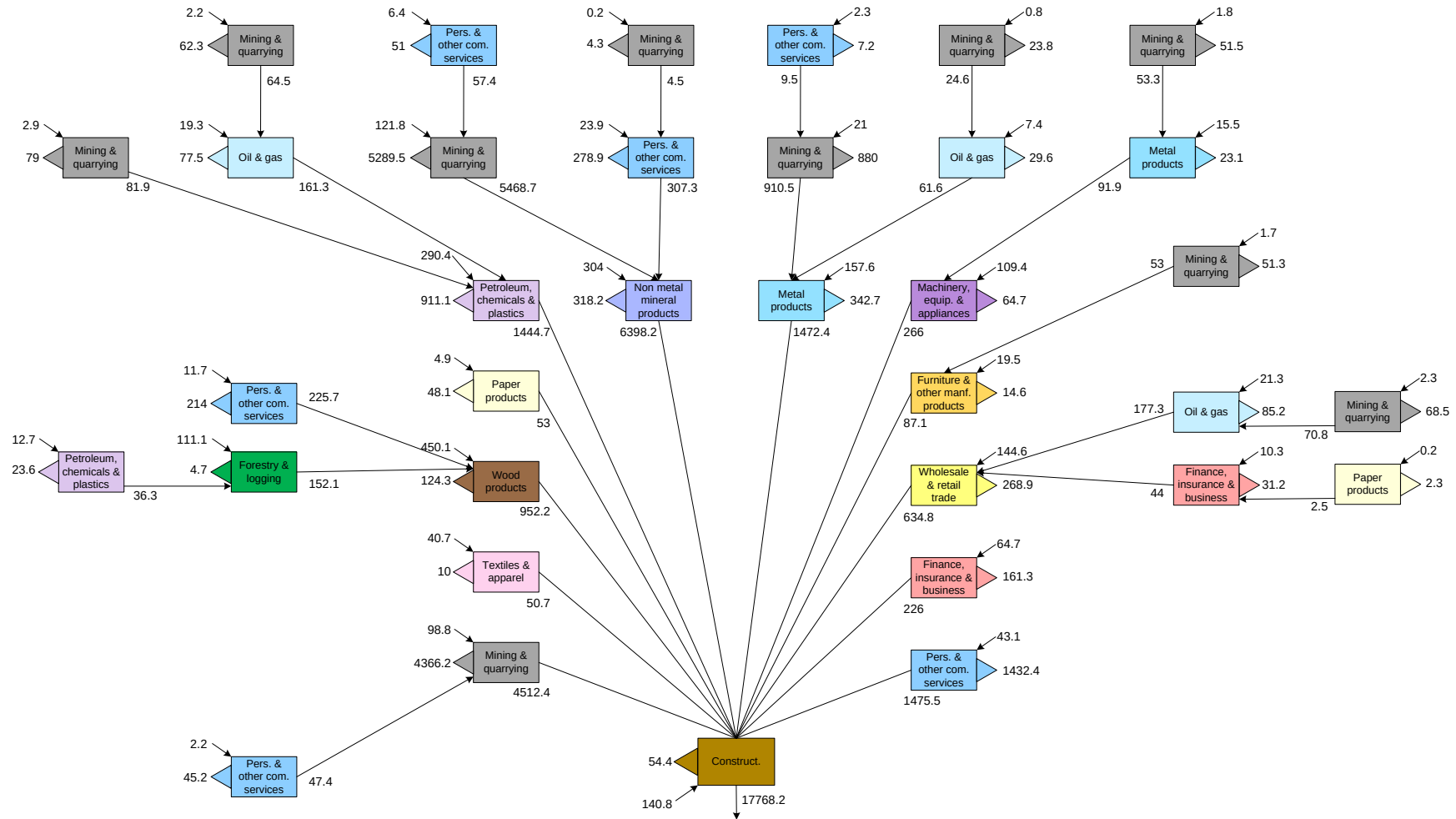
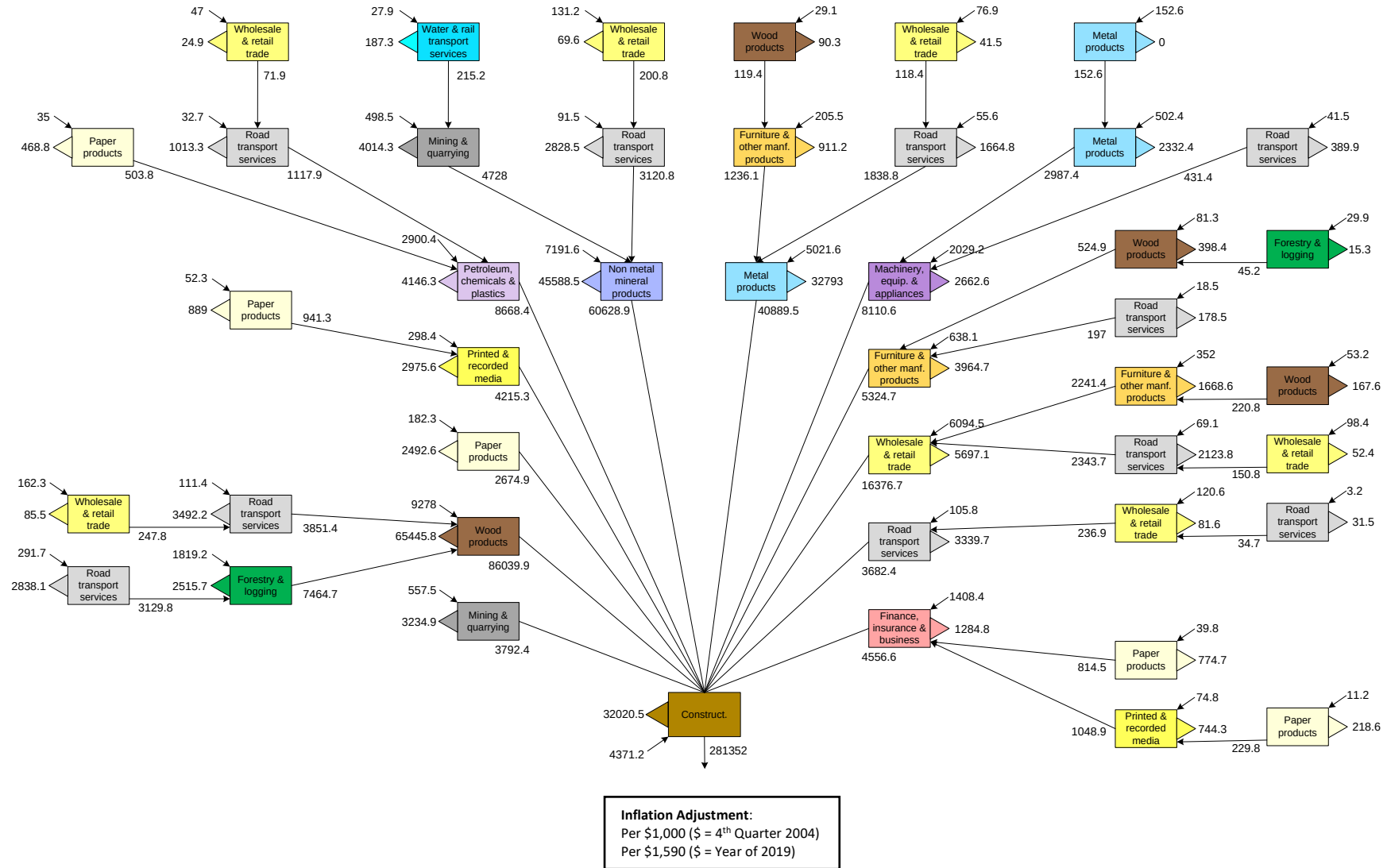


Figure 22.7 - Water Waste Generated in Producing \$1,000 Worth of Construction Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,590 (\$ = Year of 2019)

Figure 22.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Construction Services, 2004 (Grams)



23. Wholesale and Retail Trade

Description

Wholesale ANZSIC Codes covered:

- 331 – Agricultural Product Wholesaling
- 332 – Mineral, Metal and Chemical Wholesaling
- 333 – Timber and Hardware Goods Wholesaling
- 341 – Specialised Industrial Machinery and Equipment Wholesaling
- 349 – Other Machinery and Equipment Wholesaling
- 350 – Motor Vehicle and Motor Vehicle Parts Wholesaling
- 360 – Grocery, Liquor and Tobacco Product Wholesaling
- 371 – Textile, Clothing and Footwear Wholesaling
- 372 – Pharmaceutical and Toiletry Goods Wholesaling
- 373 – Furniture, Floor Covering and Other Goods Wholesaling
- 380 – Commission-Based Wholesaling

GDP 2016 = \$22.136 billion

Rank = 2nd

Average annual growth rate

2006 to 2016 = 4.04%

Rank = 18th

Employment 2016 = 339,026

Rank = 2nd

Retail ANZSIC Codes covered:

- 391 – Motor Vehicle Retailing
- 392 – Motor Vehicle Parts and Tyre Retailing
- 400 – Fuel Retailing
- 411 – Supermarket and Grocery Stores
- 412 – Specialised Food Retailing
- 421 – Furniture, Floor Coverings, Housewares and Textile Goods Retailing
- 422 – Electrical and Electronic Goods Retailing
- 423 – Hardware, Building and Garden Supplies Retailing
- 424 – Recreational Goods Retailing
- 425 – Clothing, Footwear, and Personal Accessory Retailing
- 426 – Department Stores
- 427 – Pharmaceutical and Other Store-Based Retailing
- 431 – Non-Store Retailing
- 432 – Retail Commission-Based Buying and/or Selling

Main commodities supplied:

- Wholesale and retail trade and repair services to machinery and equipment.

Economic Overview

The retail sector is associated with shops that offer goods and services and is an important part of the New Zealand economy, as it acts as a channel for a large component of household consumption and

spending by international visitors.²⁵³ While the wholesale industry involves buying, selling, storing and distributing goods for businesses and shops.

The wholesale & retail trade industry has seen many changes in recent years which have led to increased efficiency and productivity in the sector. These changes have been driven by technological and market developments such as online shopping, computerized stocktaking, electronic tracking of stock worldwide, handheld scanners that record barcodes and computers that print freight notes and packing slips.²⁵⁴

The wholesale and retail sector production has been increasing since 1987 at an average annual rate of 4.29% p.a, with the annual growth rate from 2006 through to 2016 remaining at a similar level. This sustained growth could be from a range of factors including increased demand for wholesale and retail goods from an increasing resident population and increasing tourism numbers. Increased number of imports because of the high New Zealand dollar, as well as exports increasing due to factors such as increased demand for dairy products, meat, and wood from China – one of New Zealand's main trading partners²⁵⁵ and New Zealand's participation in free trade agreements around the world.²⁵⁶

Both the wholesale and retail trade sectors are a significant part of the New Zealand economy, contributing \$22.136 billion in GDP, the second-highest contributing sector. Since both the wholesale and retail sectors are closely aligned with the health of the economy, the industry's exposure to rapidly changing economic conditions is reflected in the nature of the industry.²⁵⁷

In 2016, almost 350,000 people worked in the sector, combining to form the second-largest employer in the New Zealand economy, employing nearly 20% of the national labour force.

Sector Trends



Production

Overall, wholesale and retail trade has been steadily increasing between 2006 and 2016 to increase by around 48.2% during this period. In 2016, this sector was recorded as the 2nd largest in terms of its contribution to GDP at \$22.14 billion and employed the 2nd highest number of people at 339,026

²⁵³ Kite, H. (2005). Overview of the New Zealand Retail Sector. Reserve Bank of New Zealand: Bulletin, 68(2), 32-41.

²⁵⁴ The University of Auckland. (n.d). Retail. Retrieved 16/11/2012, from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-retail>

²⁵⁵ Careers NZ. (n.d). Logistics, Trade and Warehousing – About this industry. Retrieved 16/11/2012, from <http://www.careers.govt.nz/default.aspx?id0=10104&id1=1569CD93-F7B2-4962-9050-23755CBE2CD4>

²⁵⁶ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

²⁵⁷ Department of Labour. (2009). Employment Skills Snapshot – Wholesale trade: Overview July 2009. Retrieved from <http://www.dol.govt.nz/services/lmi/tools/skillsinsight/snapshots/wholesale-trade/skillsinsight-snapshot-wholesale-trade.pdf>

employees, closely following the finance, insurance, property and business services sector in both categories. During this 10-year time period, growth in production has been relatively stable, however, it has been growing more rapidly in recent years. Between 2008 and 2016, the average growth rate was 2.3% p.a., which rose to 6% p.a. between 2013 and 2016, as illustrated in the graph above by the relatively steeper incline of the trend.

Life Cycle Assessment Diagrams

Energy (Figure 23.1, Figure 23.2, Figure 23.3)

Wholesale and retail trade services were found to consume a total energy intensity of 1,864.2 MJ_E per \$1,000 worth of output. The wholesale and retail trade services sector ranks as having the 5th highest total energy intensity out of the 14 service sectors covered in this publication. *Direct energy* use for wholesale and retail services was 43% of the total energy intensity, measuring 1,111.4 MJ_{OE} per \$1,000 worth of output. Direct energy uses would include electricity for lighting, heating and air-conditioning, as well as fossil fuels for transportation. *Indirect energy* use made up the remaining total at 57%, measuring 1,456.1 MJ_{OE} per \$1,000 worth of output.

The main indirect energy uses in wholesale and retail services came from; (i) energy embodied in road transport services at 46,777 MJ_{OE} per \$1,000 of output; (ii) energy embodied water and rail transport services at 4,675.9 MJ_{OE} per \$1,000 of output; (iii) energy embodied in furniture and other manufactured products at 45,284.3 MJ_{OE} per \$1,000 of output; (iv) energy embodied in printed and recorded media at 32,451.1 MJ_{OE} per \$1,000 of output.

Land (Figure 23.4)

Wholesale and retail trade services have a total land intensity of 848.1 m² per \$1,000 of services supplied. Wholesale and retail trade services have the 3rd largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for wholesale and retail trade services was minuscule at only 0.4% of the total land intensity, measuring only 3.5 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 99.6% measuring 844.6 m² per \$1,000 of services supplied.

The major indirect land uses came from; (i) land embodied in livestock and crops at 671.1 m² per \$1,000 of services supplied; (ii) land embodied in forestry and logging at 43.3 m² per \$1,000 of services supplied; (iii) land embodied in finance, insurance and business at 21.4 m² per \$1,000 of services supplied; (iv) land embodied in dairy products at 19.4 m² per \$1,000 of services supplied.

Water Inputs (Figure 23.5)

Wholesale and retail trade services use a total of 37,880.2 litres of water inputs per \$1,000 of services supplied, ranking the sector the highest consumer of water out of the 14 service sectors covered by this publication. *Direct water inputs* made up a minimal 0.04%, using 145.5 litres per \$1,000 of wholesale and retail trade services supplied. While *indirect water inputs* make up the majority at 99.6%, using 37,734.7 litres per \$1,000 of wholesale and retail trade services supplied.

Indirect water inputs into wholesale and retail trade services came mainly from; (i) water inputs embodied in oil and gas at 22,063.4 litres per \$1,000 of services supplied; (ii) water inputs embodied in petroleum, chemicals and plastics at 11,442.2 litres per \$1,000 of services supplied; (iii) water inputs embodied in wholesale and retail trade at 589.7 litres per \$1,000 of services supplied; (iv) water inputs embodied in livestock and crops at 542.7 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 23.6)

Wholesale and retail trade services were found to generate a total of 19,724.8 grams (19.7 kg) per \$1,000 of services supplied. *Landfill waste directly generated* by the wholesale and retail trade services sector is 72% of total waste produced or 14,232.2 grams per \$1,000 of services supplied. While *landfill waste indirectly generated* by wholesale and retail trade services was 28% or 5,492.6 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for construction services came from; (i) landfill wastes embodied in furniture and other manufactured products at 1,423.9 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 672.2 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in finance, insurance and business at 466.4 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in road transport services at 451.8 grams per \$1,000 of services supplied.

Water Wastes (Figure 23.7)

Wholesale and retail trade services were found to produce a total of 13,257.3 litres of wastewater per \$1,000 of services supplied, ranking the sector 4th highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* by wholesale and retail trade services was 39% of total water waste produced, at 5,112.7 litres per \$1,000 of services supplied. *Wastewater indirectly generated* by wholesale and retail trade services make up the remaining 61% or 8,144.6 litres per \$1,000 of services supplied.

The indirect wastewater generated by wholesale and retail trade services is mostly made up of (i) wastewater embodied in oil and gas at 3,493.7 litres per \$1,000 of services supplied; (ii) wastewater embodied in finance, insurance and business at 889.4 litres per \$1,000 of services supplied; (iii) wastewater embodied in mining and quarrying at 718.9 litres per \$1,000 of services supplied; (iv) wastewater embodied in furniture and other manufactured products at 582.2 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 23.8)

In terms of CO₂ greenhouse gas emissions, wholesale and retail trade services emit a total of 347,926.4 grams (347.9 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the 3rd highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. *Energy-related CO₂ directly generated* by wholesale and retail trade services was 32% of the total CO₂ emitted at 10,998.8 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by wholesale and retail trade services makes up the remaining 68% or 237,937.6 grams.

The indirect energy-related CO₂ from wholesale and retail trade services was mostly made up of (i) energy-related CO₂ embodied in road transport services at 46,777 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in furniture and other manufactured products at 45,284.3 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in printed and recorded media at 32,451.1 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in oil and gas at 23,302.8 grams per \$1,000 of services supplied.

Figure 23.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (MJ_E, Oil Equivalents)

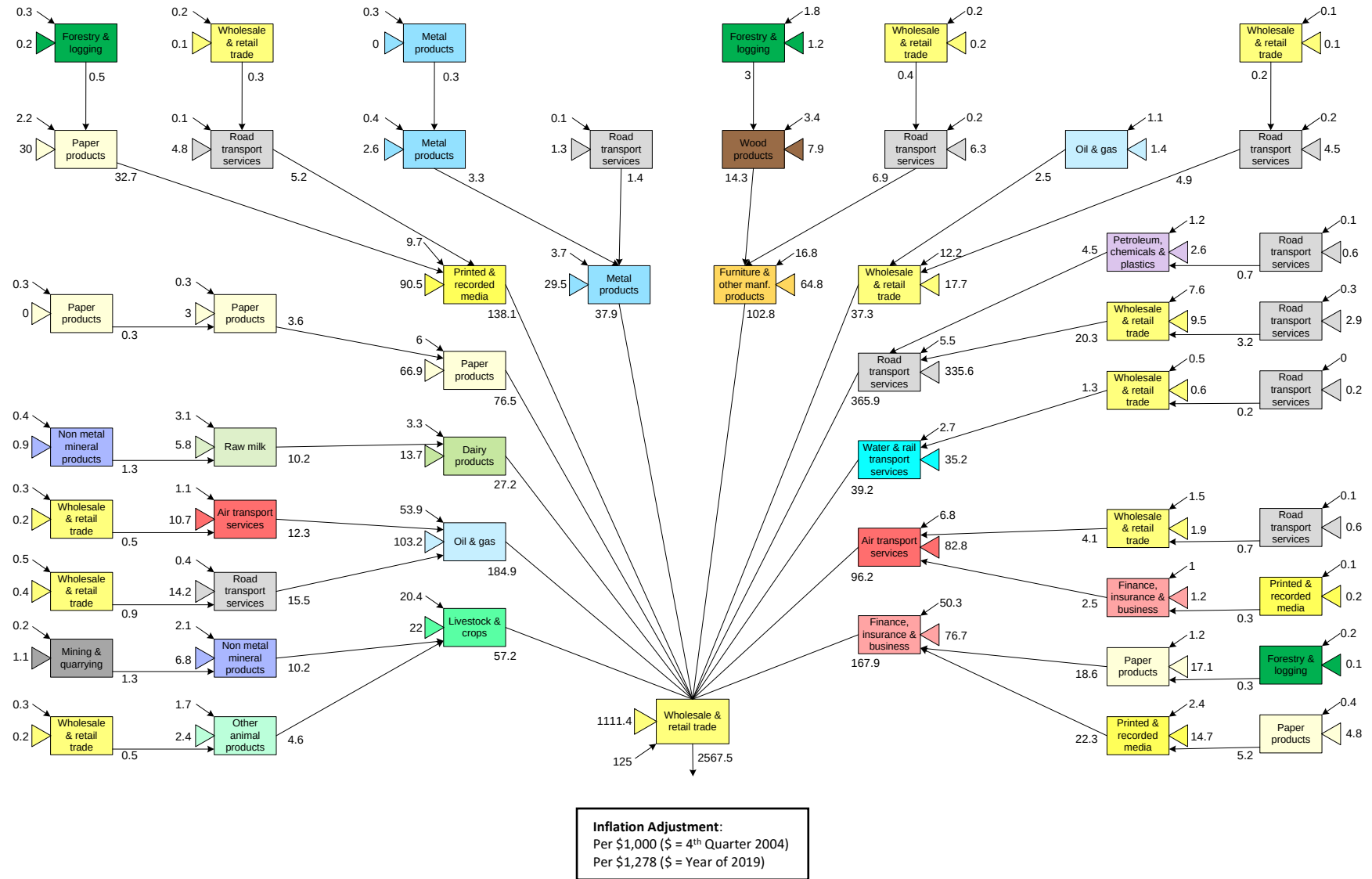


Figure 23.2 - Electricity Inputs Required to Produce \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (MJ, Heat Equivalents)

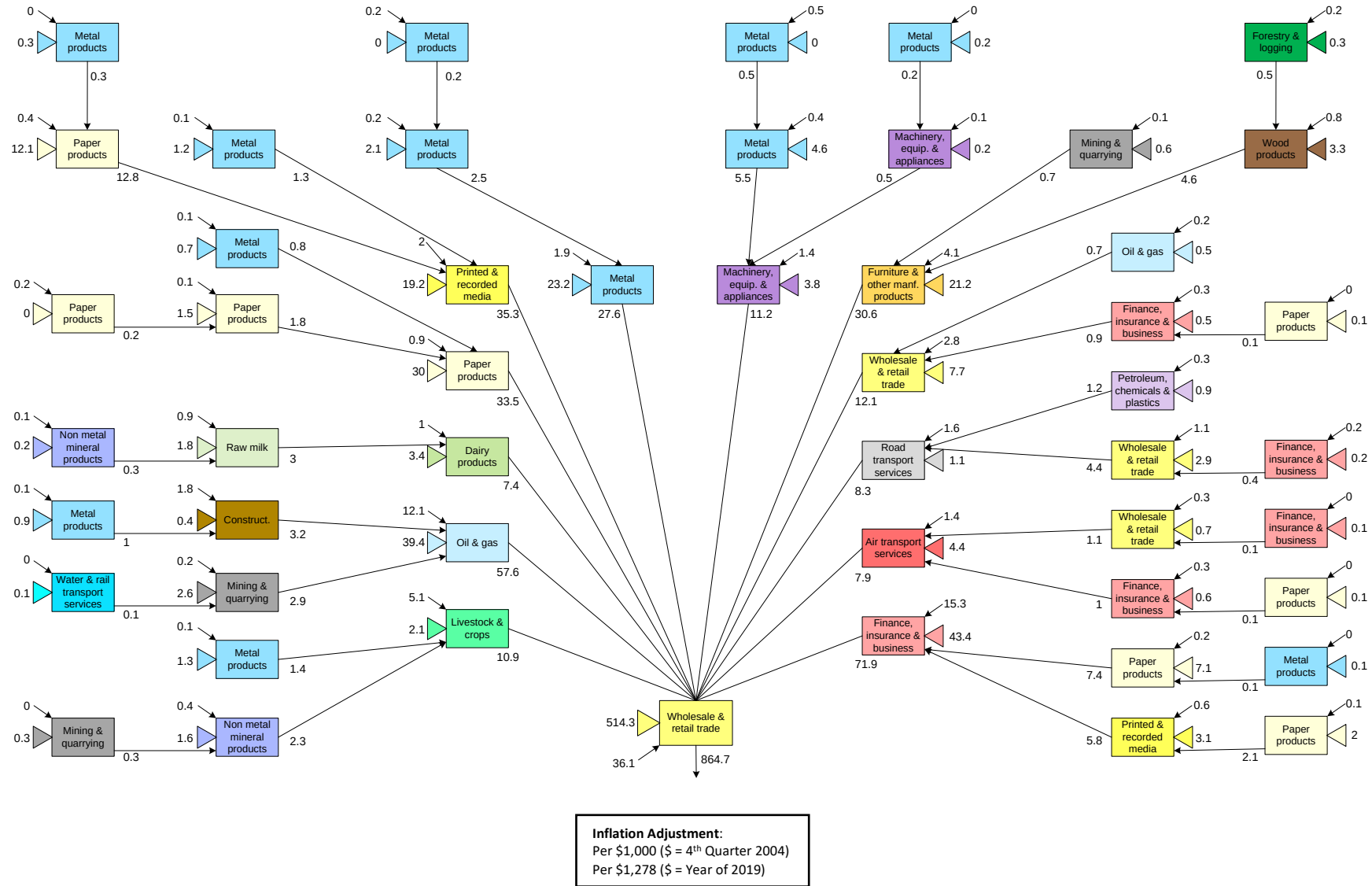
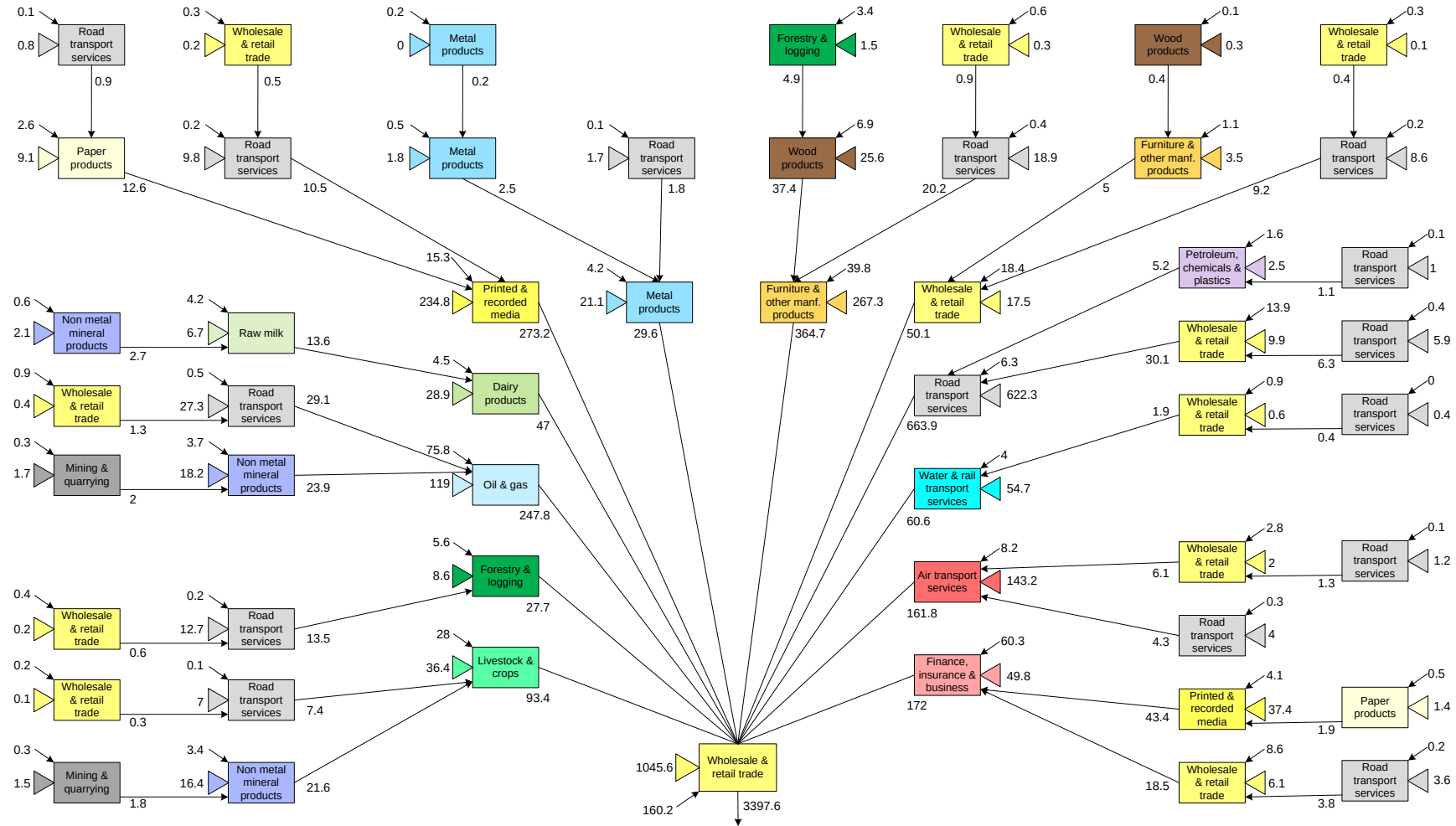


Figure 23.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,278 (\$ = Year of 2019)

Figure 23.4 - Land Required to Produce \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (m²)

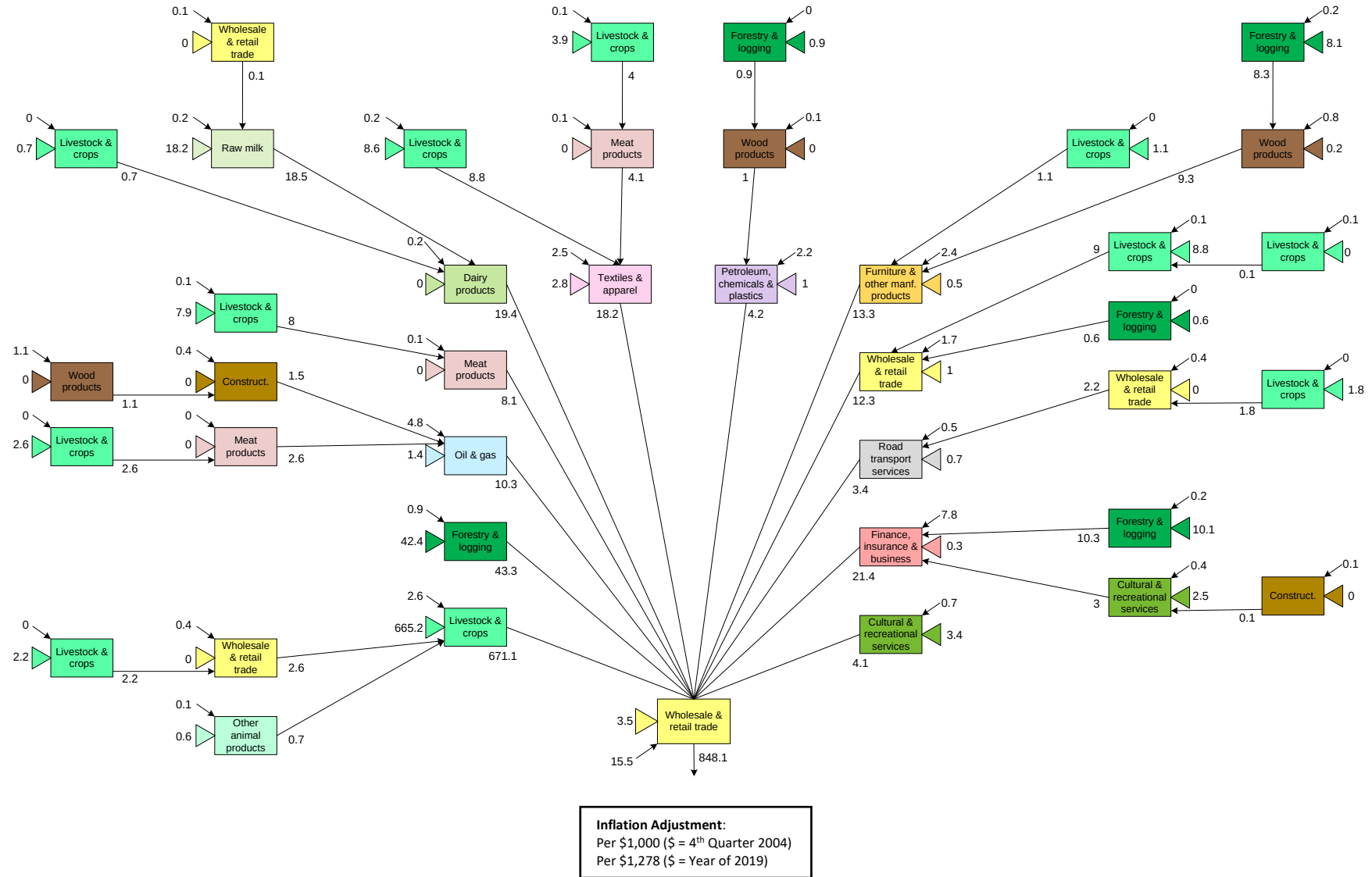


Figure 23.5 - Water Inputs Required to Produce \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (Litres)

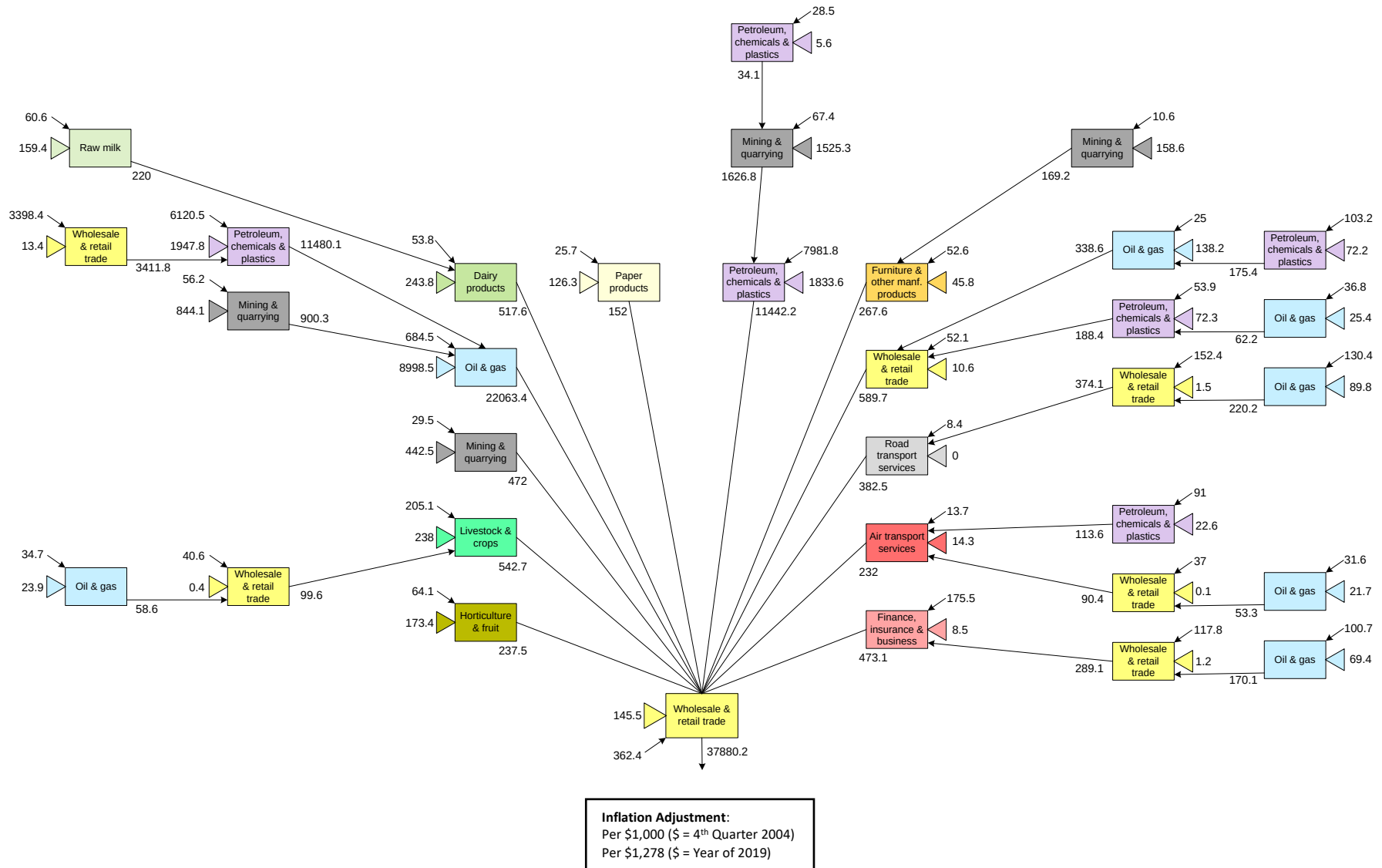


Figure 23.6 - Landfill Waste Generated in Producing \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (Grams)

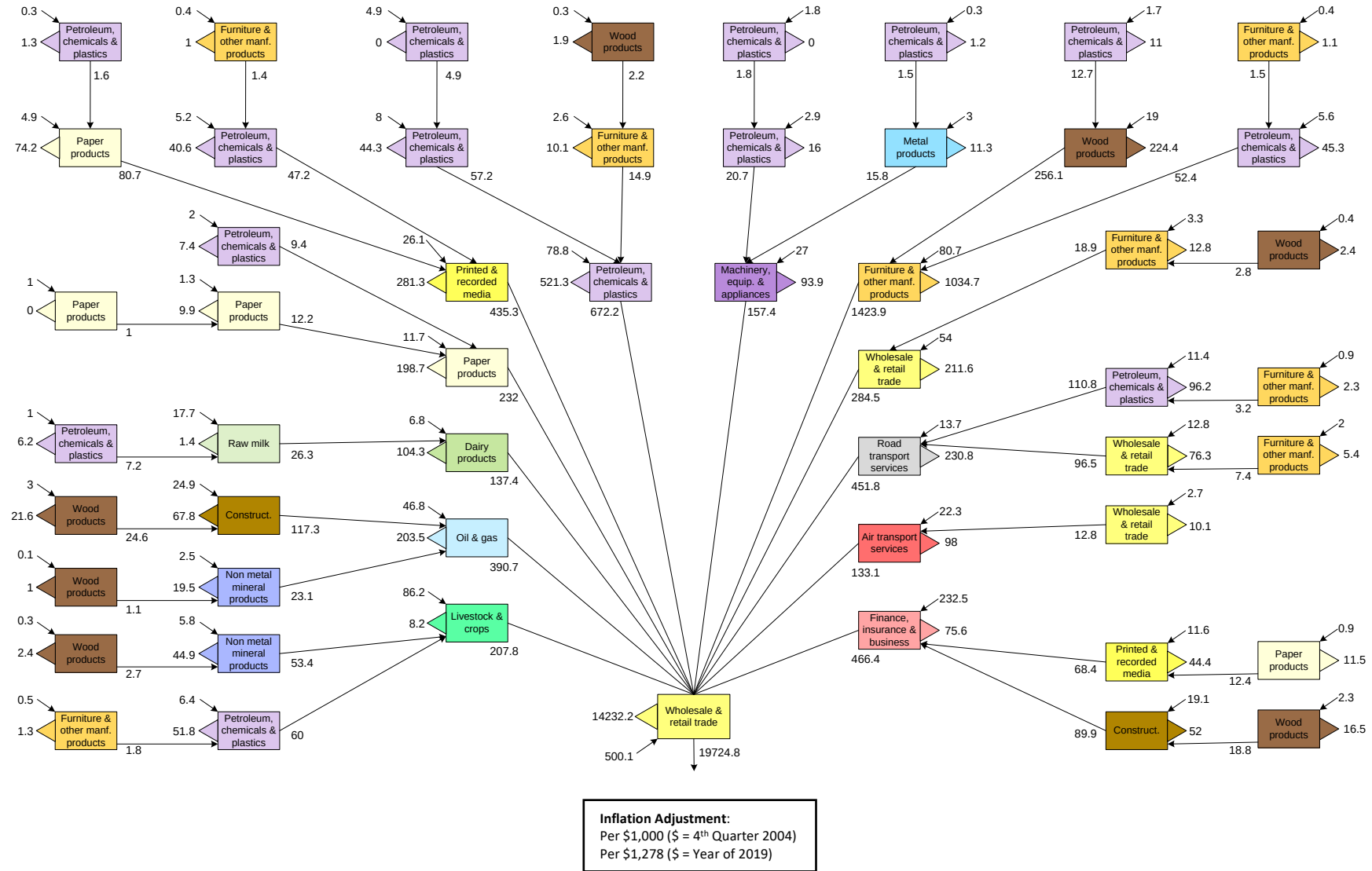


Figure 23.7 - Water Waste Generated in Producing \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (Litres)

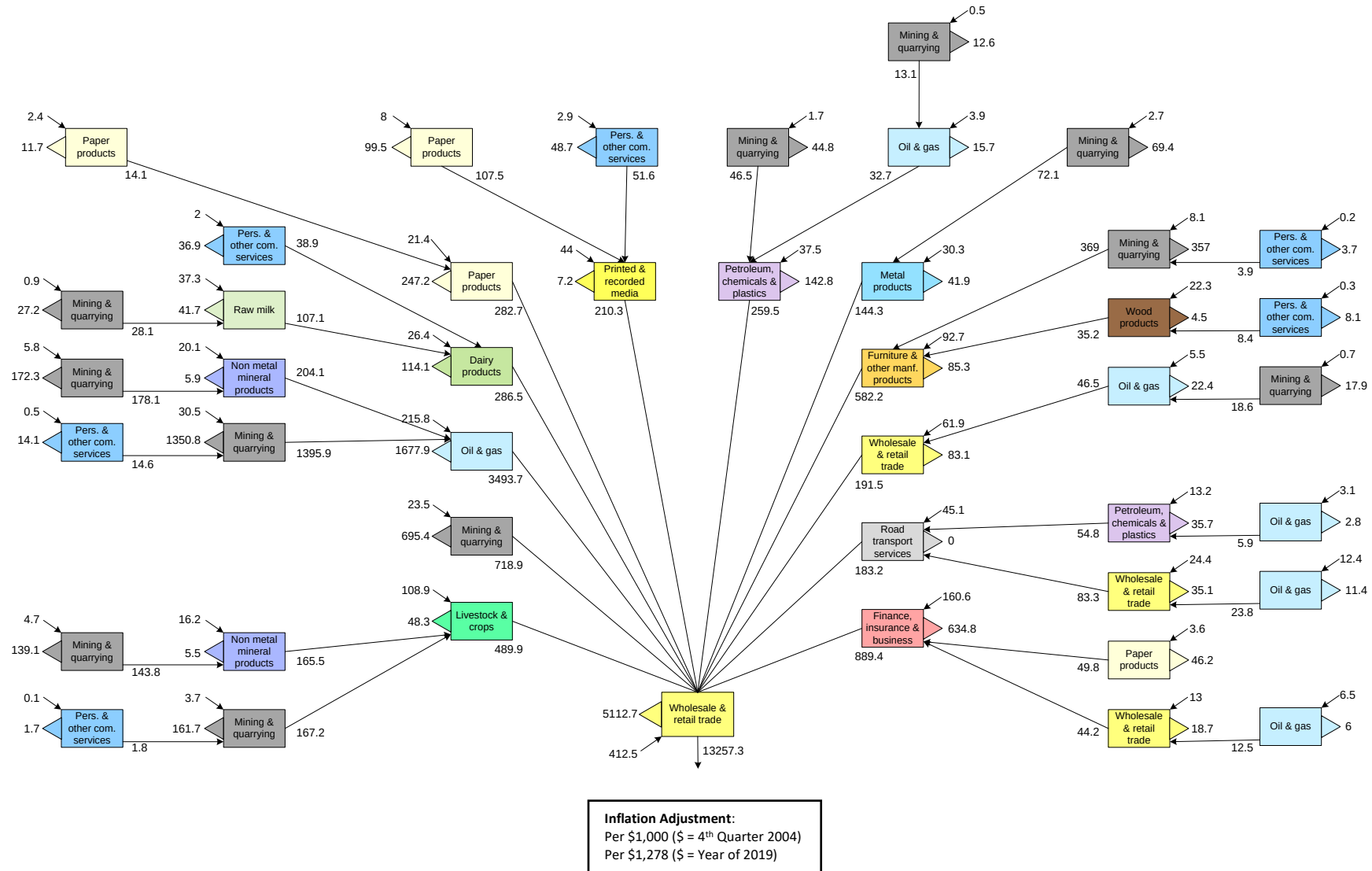
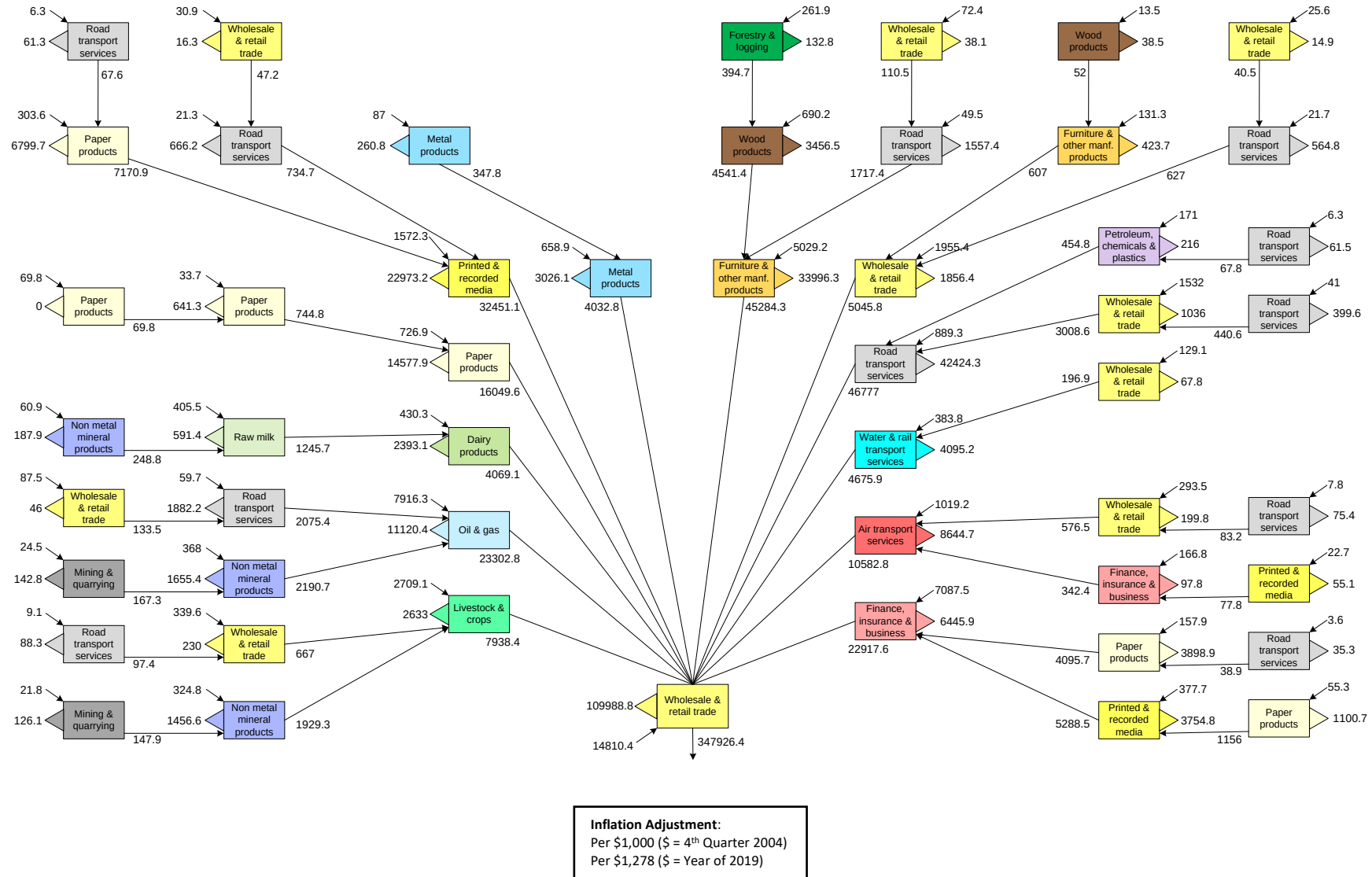


Figure 23.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Wholesale and Retail Trade Services, 2004 (Grams)



24. Accommodation, Restaurants and Bars

Description

ANZSIC Codes covered:

- 4400 – Accommodation
- 4511 – Cafes and Restaurants
- 4512 – Takeaway Food Services
- 4513 – Catering Services
- 4520 – Pubs, Taverns and Bars
- 4530 – Clubs (Hospitality)

GDP 2016 = \$5.264 billion
Rank = 10th

Average annual growth rate
2006 to 2016 = 5.19%
Rank = 13th

Employment 2016 = 164,819
Rank = 6th

Main commodities supplied:

- Accommodation, meal services, takeaways, and beverage services.

Economic Overview

Any analysis of the accommodation, restaurants and bars sector must highlight the importance of tourism as a whole to the New Zealand economy, and the fact that a large contribution of growth in this sector stems from foreigners visiting the country. Nearly 3.4 million overseas visitors arrived in New Zealand in 2018, an increase of 3.25% on the previous year. Australia, the UK, the US, Japan, Korea, China and Germany represented 75% of these visitors.²⁵⁸ In terms of accommodation, 35% of travellers stayed in hotels, motels, motor inns or apartments; 22% with family and friends; and 8% in a rented flat or house.²⁵⁹ It is a sector highly affected by seasonality with some businesses relying entirely on the peak tourist season in summer.

Eating and drinking places are mostly small businesses, with seven out of ten employing no more than eight people,²⁶⁰ and many family owned. Restaurant Association president Mike Egan said some restaurants had struggled, but the sector had seen consecutive growth, as although trade may have slowed recently, “Restaurants are a reasonably low-cost sort of luxury and they’re an important part of people’s lives”. There has been a changing attitude towards eating out over the last 20 years, with more people incorporating dining at restaurants with family and friends as part of their social lives. The total volume of alcoholic beverages available for consumption in 2018 was 482 million litres.²⁶¹ This sector also employs many people, ranking 6th in the economy at 164,819 people in 2016.

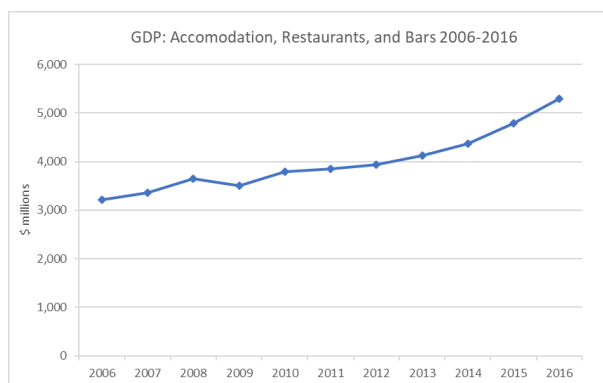
²⁵⁸ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 268)

²⁵⁹ Statistics New Zealand. (2018). *International Visitor Survey*. Retrieved from <http://nzdotstat.stats.govt.nz/wbos/Index.aspx>

²⁶⁰ Restaurant Association of New Zealand. (2006). *Restaurant Industry Forecast: Executive Summary*. Retrieved from restaurantnz.co.nz

²⁶¹ Statistics New Zealand. (2019, February 26). *Alcohol available for consumption: Year ended December 2018*. Retrieved from <https://www.stats.govt.nz/information-releases/alcohol-available-for-consumption-year-ended-december-2018>

Sector Trends



Production in this sector has been steadily expanding since 2006, with an increase of 64.6% from \$3.22 billion in 2006 to \$5.29 billion in 2016. The performance of this sector can largely be attributed to New Zealand's reputation as a popular tourist destination, as well as to a large increase in the number of people eating meals outside the home. In 2009, like many tradeable and non-tradeable sectors, this sector was negatively hit by the GFC, with production dipping slightly by 4%. In such unpredictable financial times, it is likely that people were more conservative with their expenses and thus emphasised holidaying or eating out as a luxury. This sector however recovered rather impressively as production rose to pre-GFC levels and continued to rise thereafter. In fact, the pace of growth appears to have accelerated, growing annually at 8.7% on average between 2013 and 2016.

Life Cycle Assessment Diagrams

Energy (Figure 24.1, Figure 24.2, Figure 24.3)

Accommodation, restaurant and bar services were found to consume a total energy intensity of 3,044.3 MJ_{OE} per \$1,000 worth of output, ranking the sector as the 3rd highest total energy intensity out of the 14 service sectors covered in this publication. *Direct energy* use for accommodation, restaurant and bar services was 57% of the total energy intensity, measuring 1,737.8 MJ_{OE} per \$1,000 worth of output. Direct energy uses would include electricity for lighting, heating, air-conditioning, cooking and refrigeration as well as fossil fuels for transportation. *Indirect energy use* made up the remaining total at 43%, measuring 1,306.5 MJ_{OE} per \$1,000 worth of output.

The main indirect energy uses in accommodation, restaurant and bar services came from; (i) energy embodied in beverages and tobacco at 197 MJ_{OE} per \$1,000 of output; (ii) energy embodied in other food at 191.1 MJ_{OE} per \$1,000 of output; (iii) energy embodied in meat products at 125.4 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in metal products at 104.4 MJ_{OE} per \$1,000 of output.

Land (Figure 24.4)

Accommodation, restaurant and bar services have a total land intensity of 1,692 m² per \$1,000 of services supplied. The accommodation, restaurant and bar service sector has the largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for accommodation, restaurant and bar services was only 4% of the total land intensity, measuring only 59.8 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 96% measuring 1,632.2 m² per \$1,000 of accommodation, restaurant and bar services supplied.

The major indirect land uses came from; (i) land embodied in meat products at 1,036.1 m² per \$1,000 of services supplied; (ii) land embodied in livestock and crops at 321.4 m² per \$1,000 of services supplied; (iii) land embodied in dairy products at 110.2 m² per \$1,000 of services supplied; (iv) land embodied in beverages and tobacco at 42.3 m² per \$1,000 of services supplied.

Water Inputs (Figure 24.5)

Accommodation, restaurant and bar services use a total of 5,979 litres of water inputs per \$1,000 of services supplied, ranking the sector the 4th highest consumer of water out of the 14 service sectors covered by this publication. *Direct water inputs* make up just 17%, using 1,000.6 litres per \$1,000 of accommodation, restaurant and bar services supplied. While *indirect water inputs* make up the majority at 83%, using 4,978.4 litres per \$1,000 of accommodation, restaurant and bar services supplied.

Indirect water inputs into accommodation, restaurant and bar services came mainly from; (i) water inputs embodied in meat products at 1,063.2 litres per \$1,000 of services supplied; (ii) water inputs embodied in dairy products at 889.4 litres per \$1,000 of services supplied; (iii) water inputs embodied in horticulture and fruit at 638.7 litres per \$1,000 of services supplied; (iv) water inputs embodied in beverages and tobacco at 625.3 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 24.6)

Accommodation, restaurant and bar services were found to generate a total of 36,084.4 grams (36 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the accommodation, restaurant and bar service sector is 69% of total waste produced or 24,925.1 grams per \$1,000 of services supplied. While *landfill waste indirectly generated* was 31% or 11,159.3 grams per \$1,000 of accommodation, restaurant and bar services supplied.

The main sources of indirect landfill waste for accommodation, restaurant and bar services came from; (i) landfill wastes embodied in other food at 2,678.5 grams per \$1,000 of services supplied; (ii) landfill wastes embodied beverages and tobacco at 2,186.9 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in petroleum, chemicals and plastics at 1,087.2 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in furniture and other manufactured products at 957.5 grams per \$1,000 of services supplied.

Water Wastes (Figure 24.7)

Accommodation, restaurant and bar services were found to produce a total of 7,520.9 litres of wastewater per \$1,000 of services supplied, ranking the sector 7th highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* by accommodation, restaurant and bar services was 15% of total water waste produced, at 1,153.6 litres per \$1,000 of services supplied. *Wastewater indirectly generated* by accommodation, restaurant and bar services made up the remaining 85%, or 8,144.6 litres per \$1,000 of services supplied.

The indirect wastewater generated by wholesale and retail trade services is mostly made up of (i) wastewater embodied in meat products at 1,471.4 litres per \$1,000 of services supplied; (ii) wastewater embodied in dairy products at 1,158.6 litres per \$1,000 of services supplied; (iii) wastewater embodied in beverages and tobacco at 845.8 litres per \$1,000 of services supplied; (iv) wastewater embodied in metal products at 390.2 litres per \$1,000 of services supplied.

Phosphorus Wastes (Figure 24.8)

Accommodation, restaurant and bar services were found to produce 213.3 grams (0.2 kg) of phosphorus waste per \$1,000 of services supplied. Total phosphorus waste was made up mostly of *indirect sources*, with *direct sources* only making up 3.4% of total phosphorus waste, at 7.3 grams per \$1,000 of services supplied. *The remaining 96.6% of phosphorous wastes, or 206 grams per \$1,000 of accommodation, restaurant and bar services supplied came from Indirect sources which were mostly made up of (i) phosphorus waste embodied in meat products at 134.9 grams per \$1,000 of services supplied; (ii) phosphorus waste embodied in livestock and crops at 39.3 grams per \$1,000 of services supplied; (iii) phosphorus waste embodied in dairy products at 12.6 grams per \$1,000 of services supplied.*

Energy Greenhouse Gases (Figure 24.9)

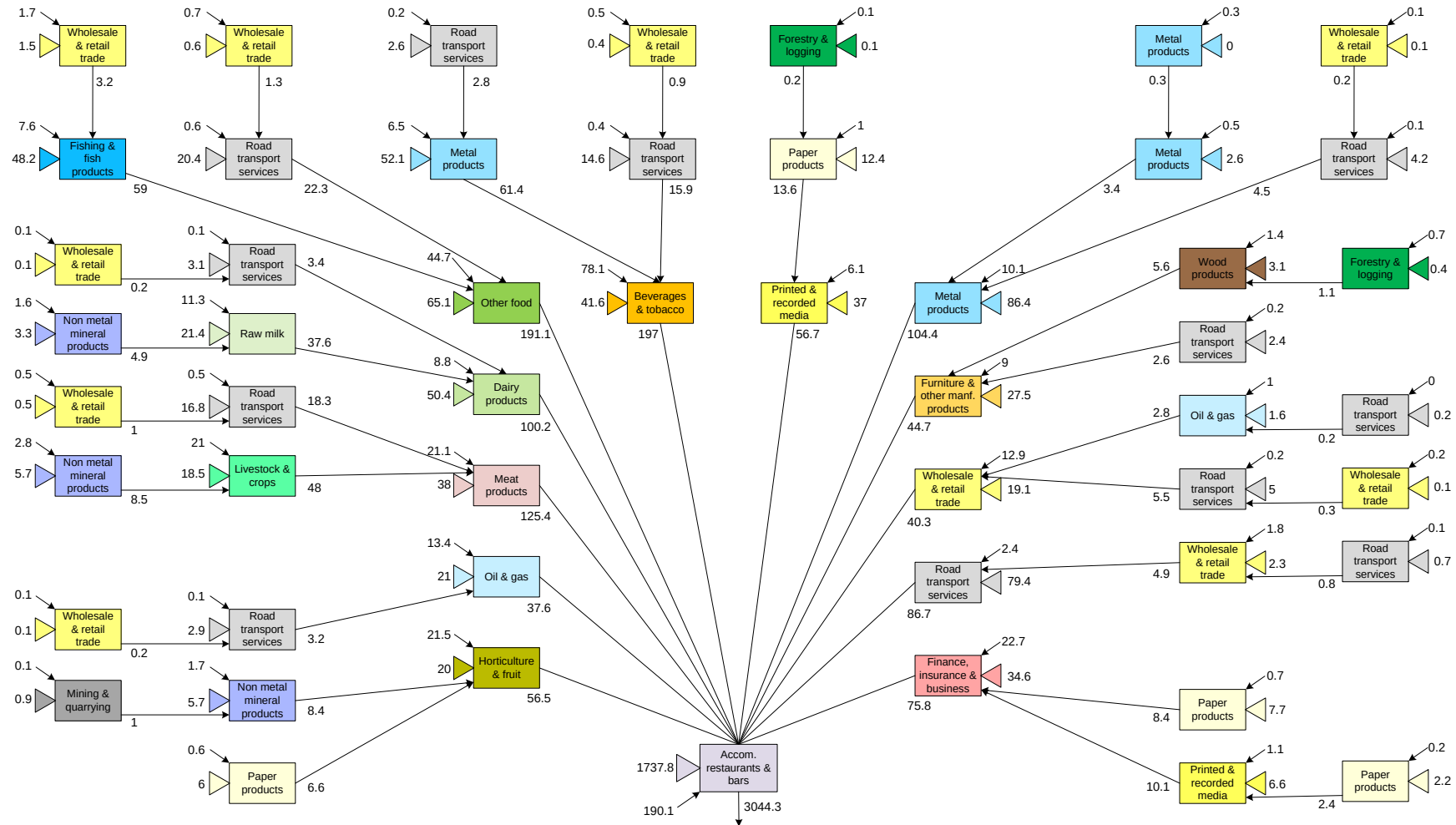
In terms of CO₂ greenhouse gas emissions, accommodation, restaurant and bar services emit a total of 295,387.6 grams (295.3 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the 5th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. This total energy figure for construction services is similar to a previous estimate of 273 kg MJ_E per \$1,000 worth of services supplied.²⁶²

Energy-related CO₂ directly generated by accommodation, restaurant and bar services was 43% of the total CO₂ emitted at 126,958.3 grams per \$1,000 of services supplied. Energy-related CO₂ indirectly generated by accommodation, restaurant and bar services make up the remaining 57% or 168,429.3 grams.

The indirect energy-related CO₂ from accommodation, restaurant and bar services was mostly made up of (i) energy-related CO₂ embodied in beverages and tobacco at 25,488.5 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied other food at 22,409.6 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in furniture and other manufactured products at 15,893 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in meat products at 15,237.5 grams per \$1,000 of services supplied.

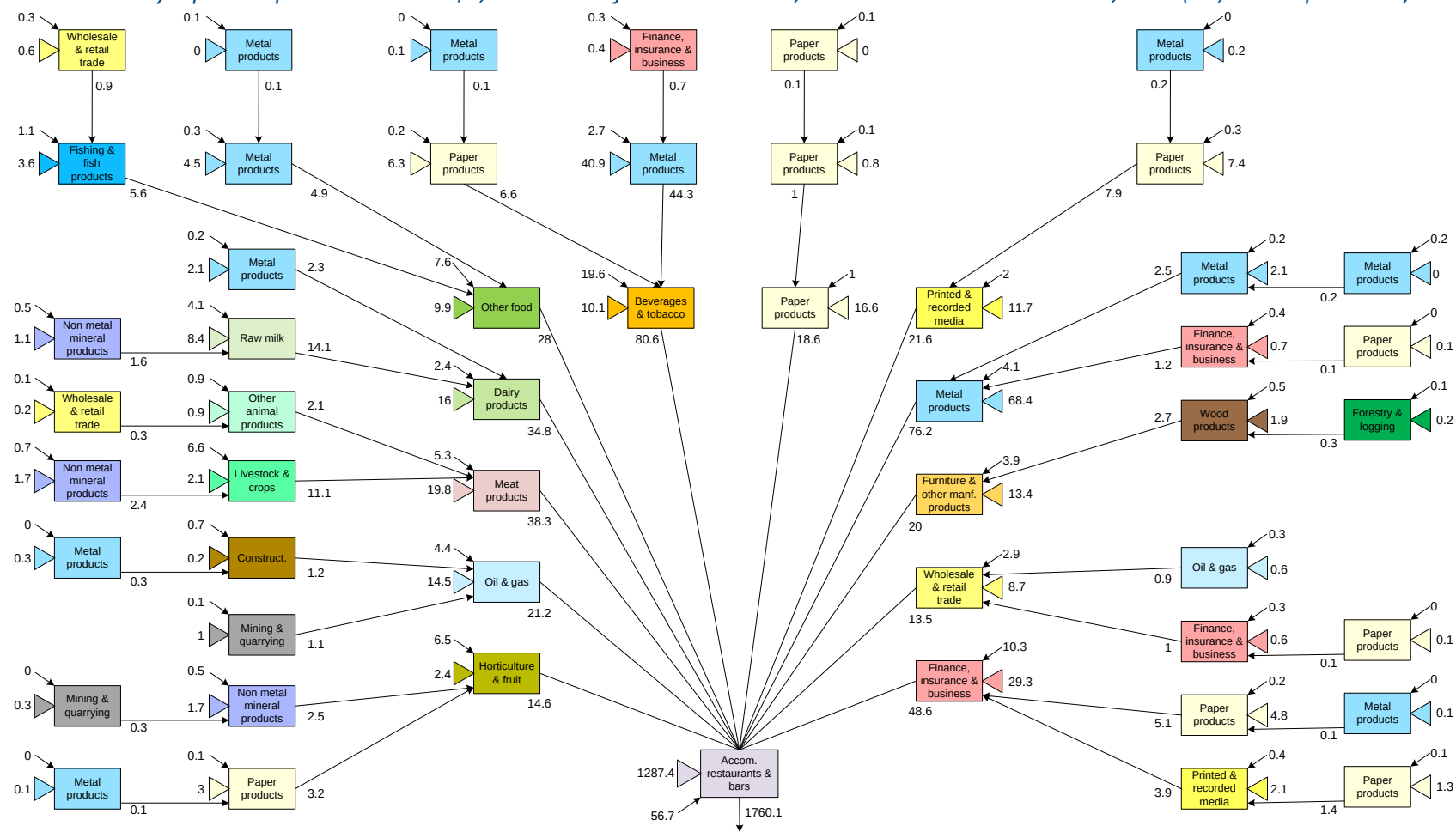
²⁶² Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

Figure 24.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (MJ_E, Oil Equivalents)



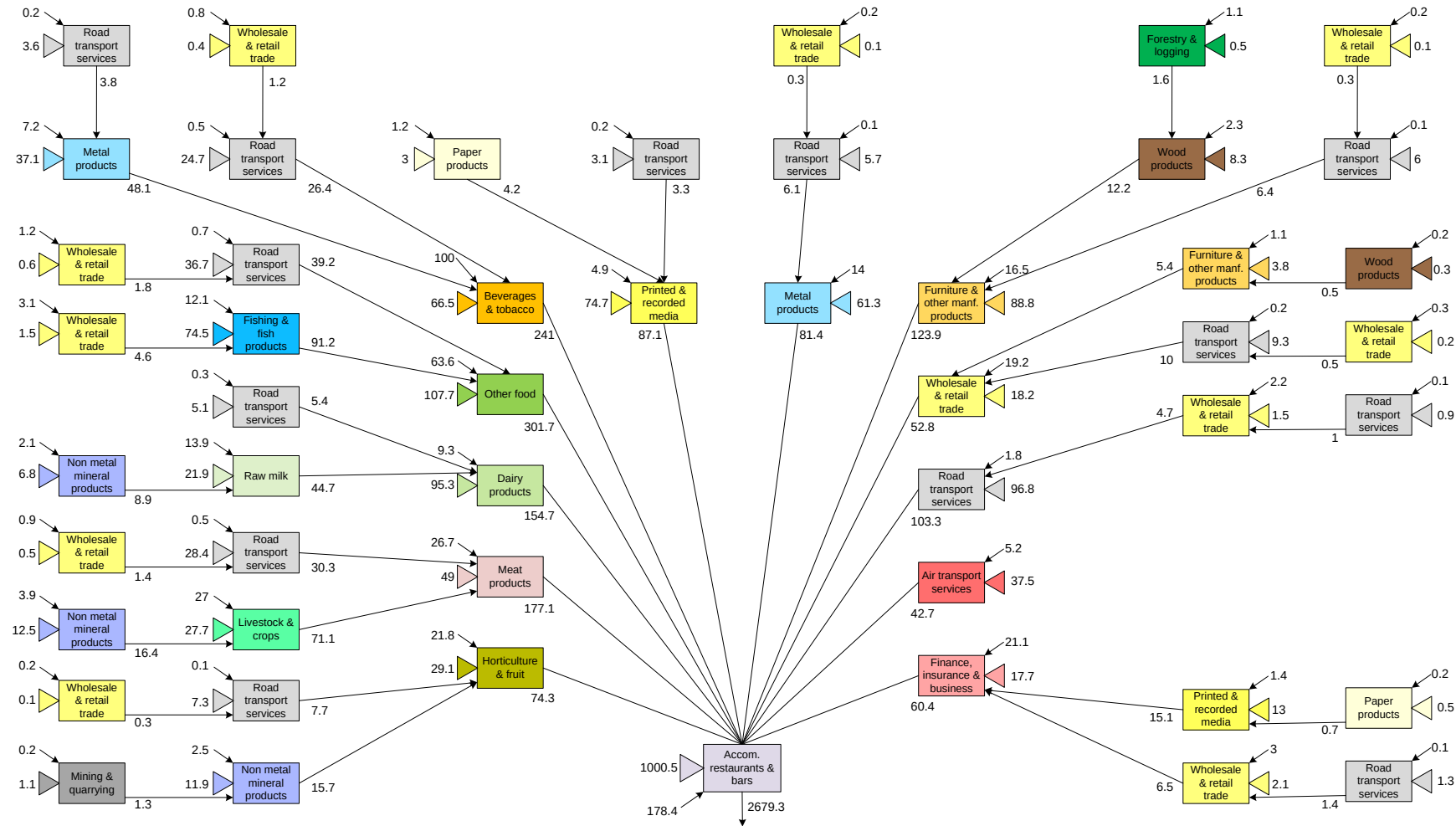
Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,333 (\$ = Year of 2019)

Figure 24.2 - Electricity Inputs Required to Produce \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,333 (\$ = Year of 2019)

Figure 24.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,333 (\$ = Year of 2019)

Figure 24.4 - Land Required to Produce \$1,000 Worth of Accommodation Restaurants and Bars Services, 2004 (m²)

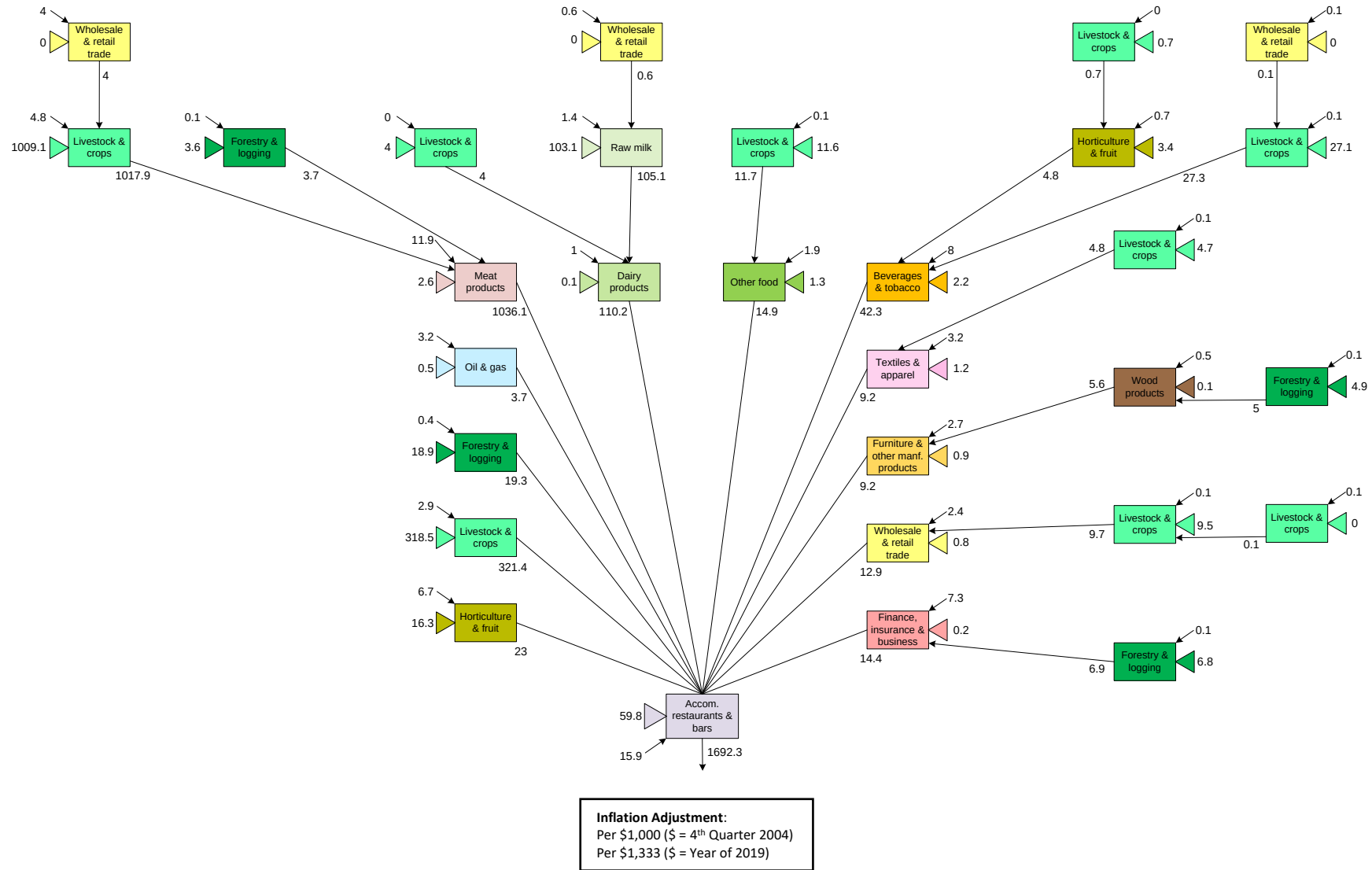
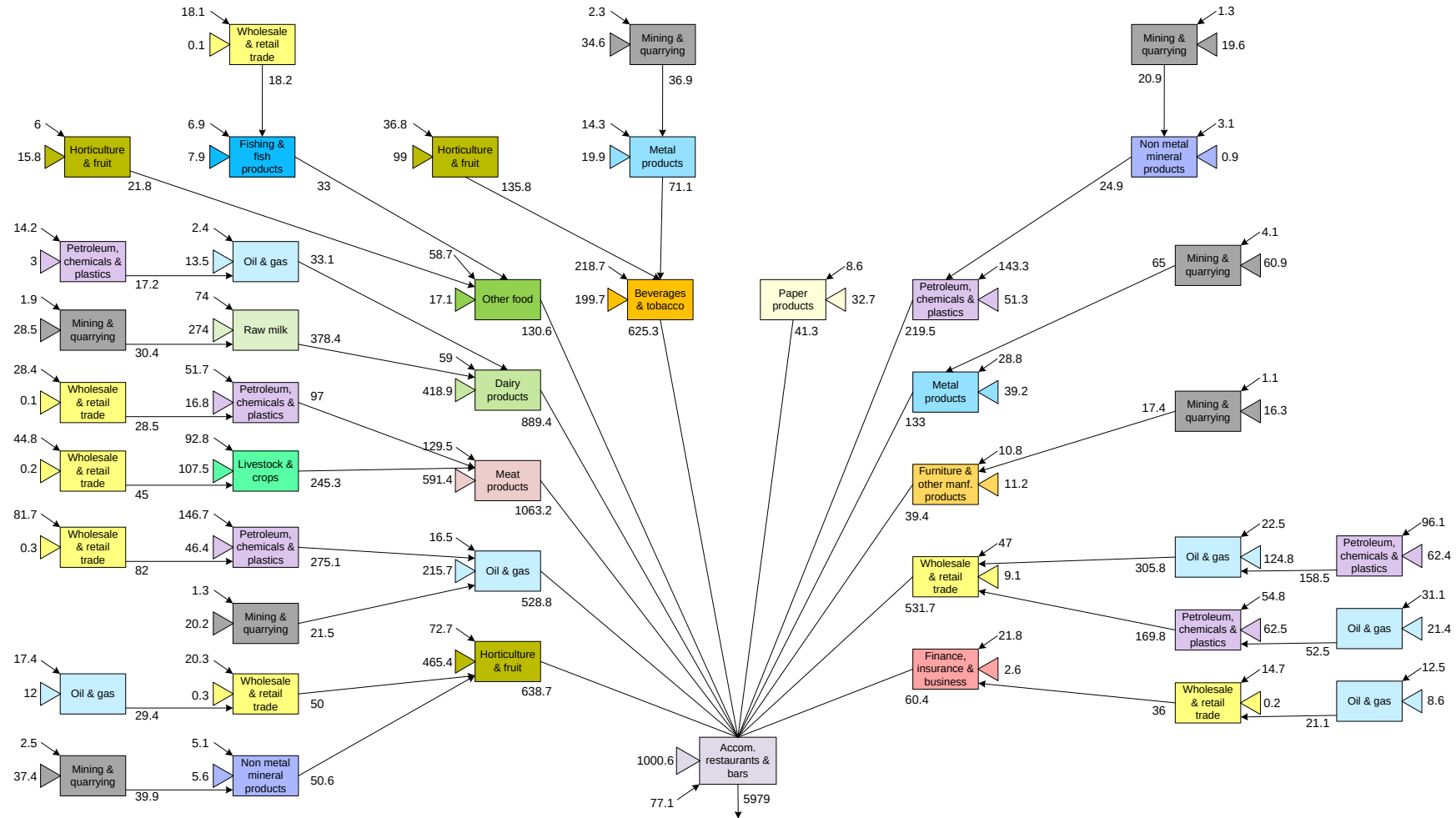
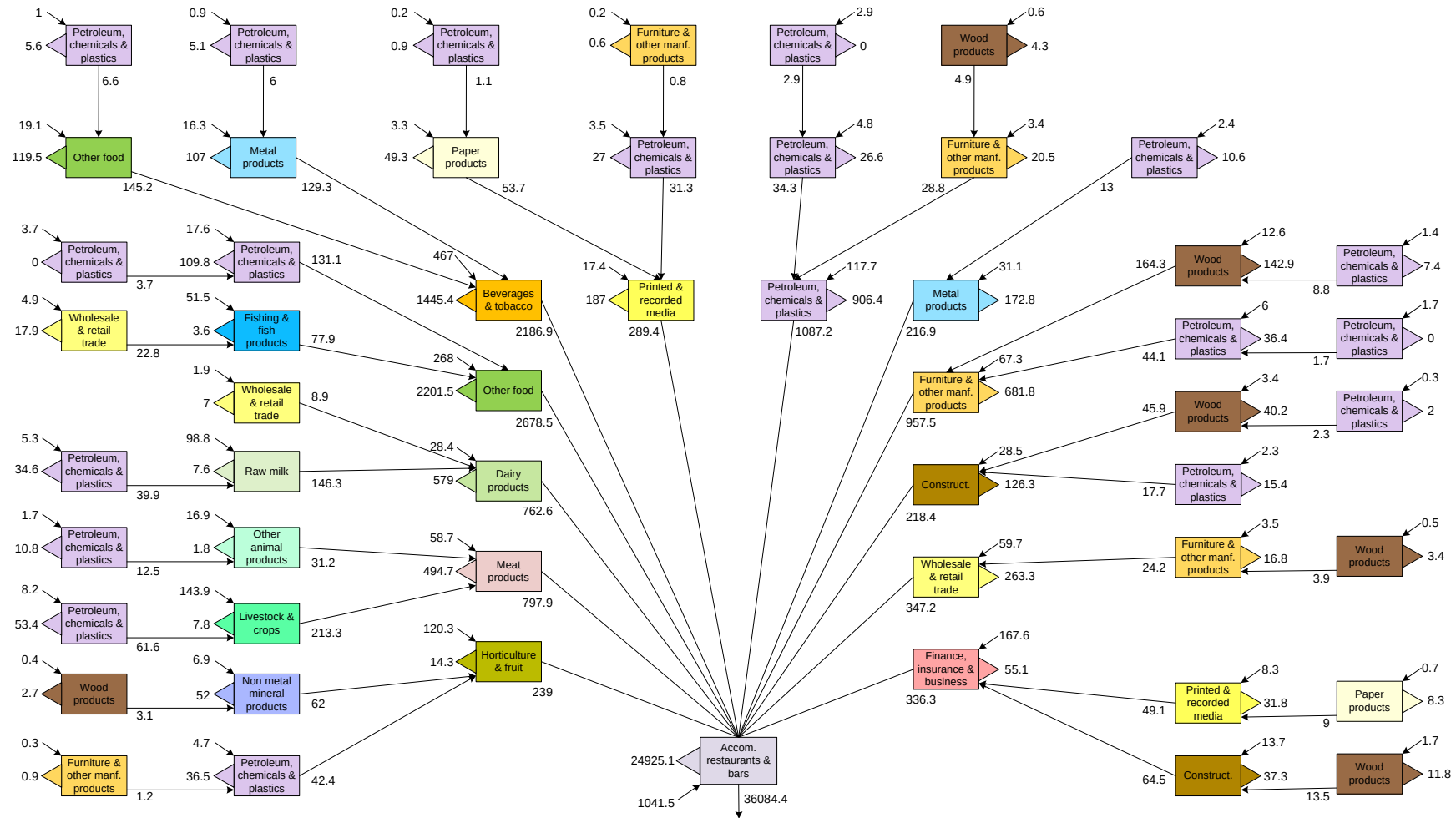


Figure 24.5 - Water Inputs Required to Produce \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (Litres)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,333 (\$ = Year of 2019)

Figure 24.6 - Landfill Waste Generated in Producing \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (Grams)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,333 (\$ = Year of 2019)

Figure 24.7 - Water Waste Generated in Producing \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (Litres)

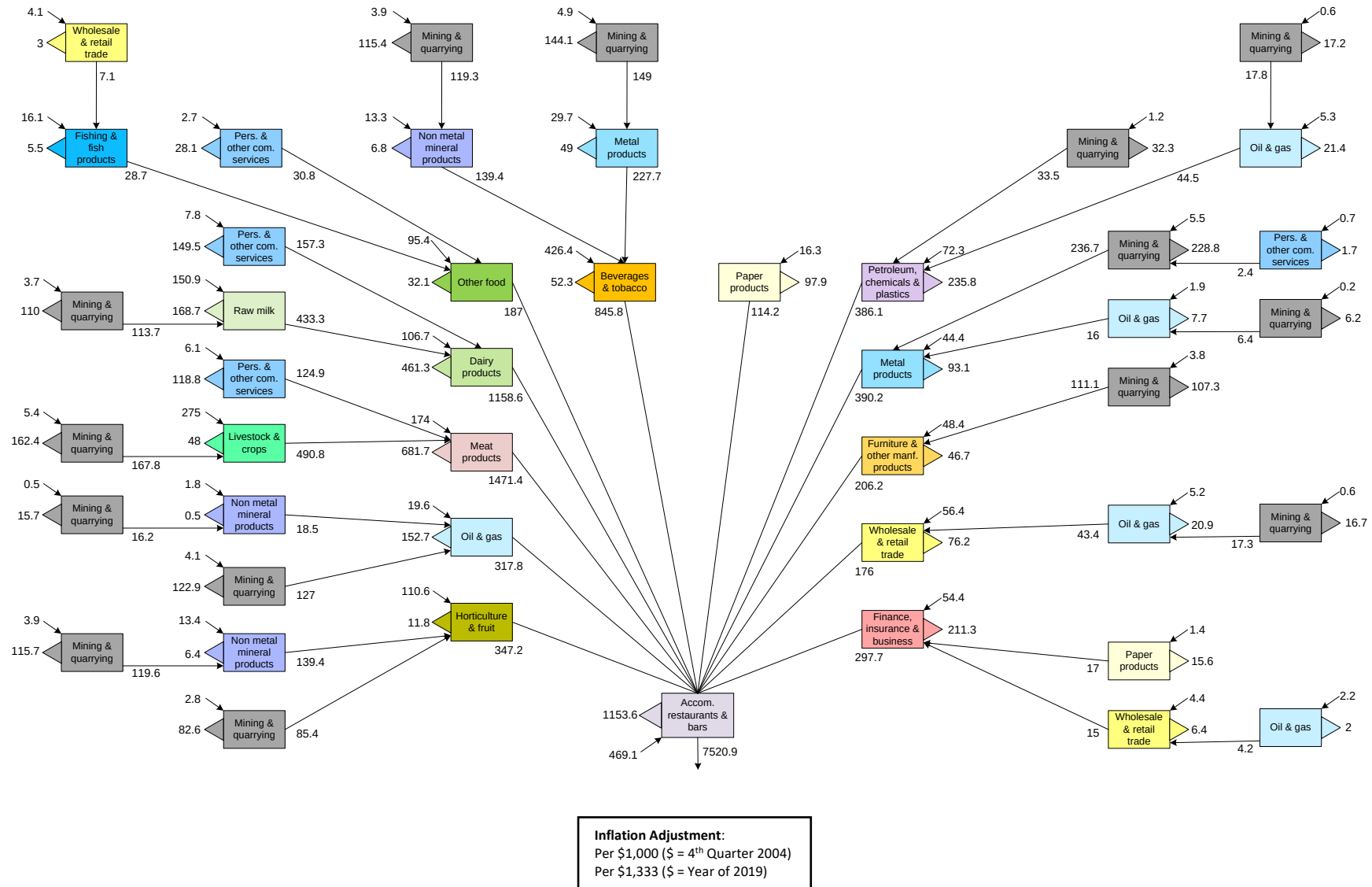


Figure 24.8 - Phosphorus Waste Generated in Producing \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (Grams)

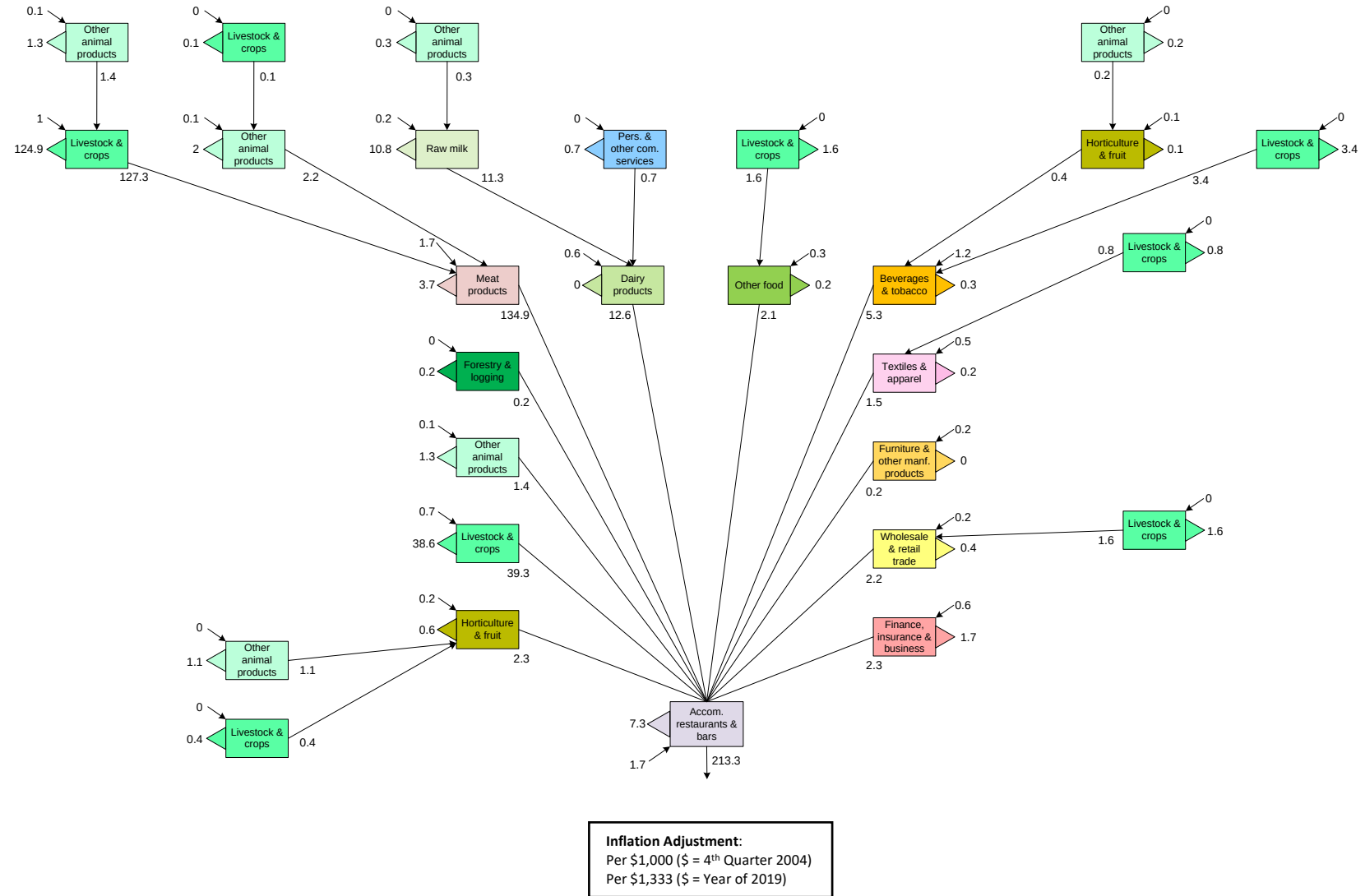
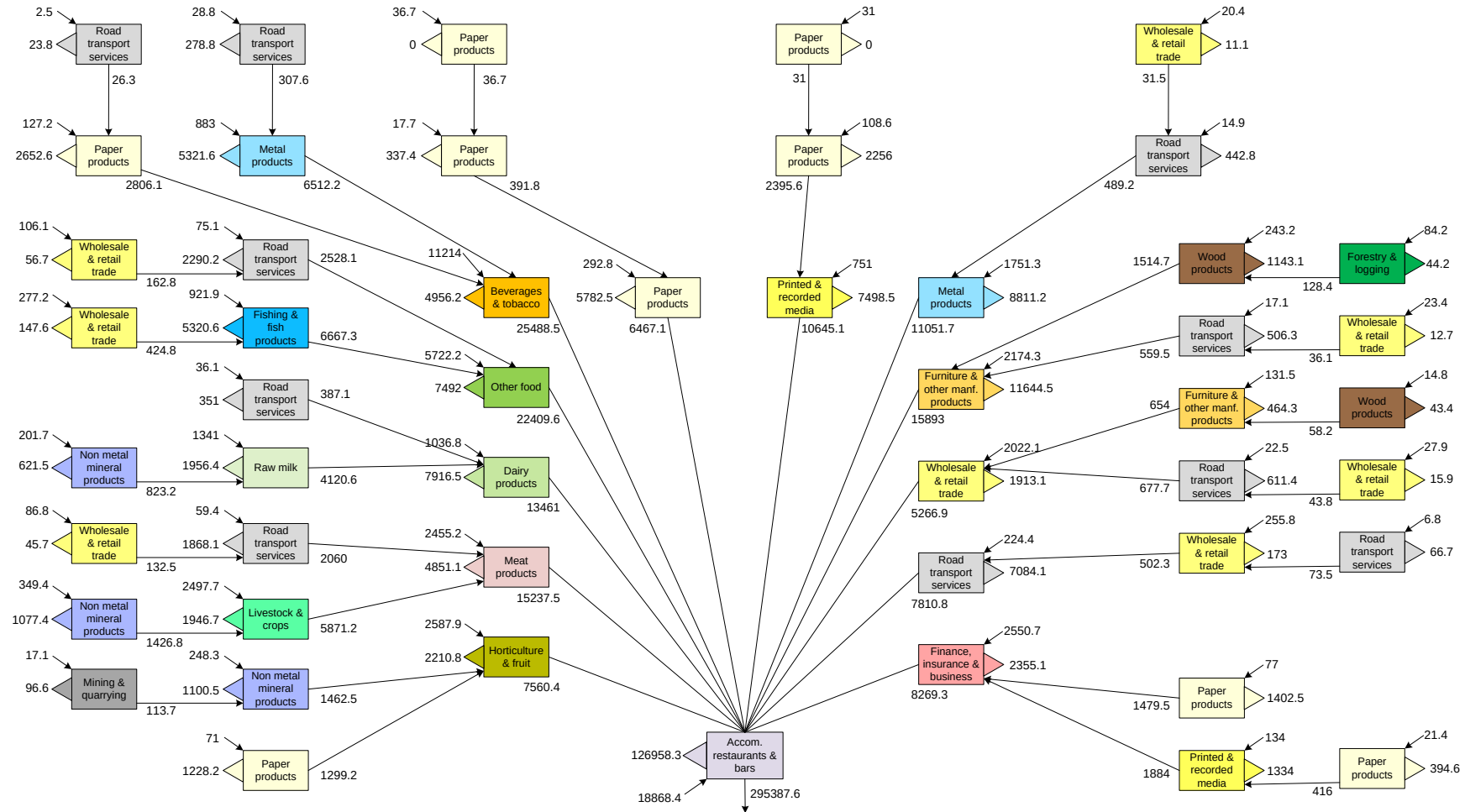


Figure 24.9 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Accommodation, Restaurants and Bars Services, 2004 (Grams)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,333 (\$ = Year of 2019)

25. Road Transport

Description

ANZSIC Codes covered:

- 4610 – Road Freight Transport
- 4621 – Inter-Urban and Rural Bus Transport
- 4622 – Urban Bus Transport (including Tramway)
- 4623 – Taxi and Other Road Passenger Transport

Main commodities supplied:

- Road transport including bus, tram, taxi, and other road transport services

GDP 2016 = \$3.897 billion

Rank = 14th

Average annual growth rate

2006 to 2016 = 3.54%

Rank= 20th

Employment 2016 = 46,072

Rank = 11th

Economic Overview

New Zealand is a long thin country with a scattered population that travel readily. A comprehensive 10,855 km of state highways link people, goods, and business to ports and airports.²⁶³ For the size of the population, the country has made a high capital investment in transport infrastructure, particularly roads. Many communities and businesses in New Zealand are reliant on road transport. Road transport is an important component of the economy with over 90% of all freight by volume going by road and 75% of tonnes-kms movement by road.²⁶⁴

Passenger transport provided by bus and coach operators in New Zealand transfer over 153 million passengers annually, in 1,900 school buses, 2,000 city buses, and 2,000 tour and charter coaches.²⁶⁵ An increase in the number of tourists visiting New Zealand over the years is one of the main reasons for the increasing popularity of coach travel.

In NZ, road transport is the standard option for moving freight as most domestic freight travels less than 100 kilometres and it is more cost-efficient over short distances.²⁶⁶ Road transport has the added advantage over rail transport of going to where the customer is and requiring less handling which reduces the risk of breakage and pilfering. Road transport is also best suited for goods, such as, livestock, fruit and vegetables, refrigerated and dangerous goods that require delivery by the quickest, most direct route. In terms of actual commodities, the three biggest transported within New Zealand are other manufactured and retail goods and general freight at 96.7 million tonnes (99% by road), logs

²⁶³ Ministry of Transport. (2019, June 6). *Transport Outlook*. Retrieved from <https://www.transport.govt.nz/mot-resources/transport-outlook/>

²⁶⁴ Ministry of Transport. (2019). *National Freight Demand Study 2017/2018*. Retrieved from <https://www.transport.govt.nz/assets/Import/Uploads/Research/Documents/NFDS3-Final-Report-Oct2019-Rev1.pdf>

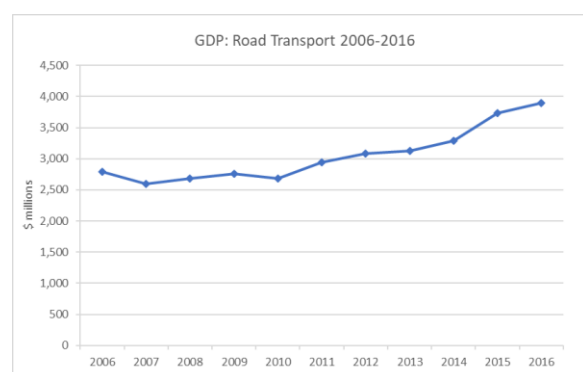
²⁶⁵ Bus and Coach Association. (n.d). *New Zealand Industry Facts*. Retrieved 16/11/2012, from <http://www.busandcoach.co.nz/about/bca/nz-industry-facts.html>

²⁶⁶ National Road Carriers. (n.d). *Industry Facts*. Retrieved 16/11/2012, from http://www.transport.org.nz/Section?Action=View&Section_id=45

and timber at 46.5 million tonnes, (94% by road) and aggregate at 40.5 million tonnes, (96% by road).²⁶⁷

The globalisation of business has increased the demand for an efficient road transport industry. Not having to incur the real cost (i.e. including externalities) has allowed the industry to grow, as costs until recent oil prices increases have been static. New Zealand's higher profile as a tourism destination has increased the demand for rental cars, campervans, and bus travel.²⁶⁸

Sector Trends



Overall, production in this sector has been rising over time. Between 2006 and 2016, production grew 39.7% from \$2.79 billion to \$4 billion. While the trajectory has been upward, for the most part, the sector experienced a period of stagnant growth early on during this time period. Between 2007 and 2010, production levels dropped to \$2.68 billion, where it largely remained, with minor fluctuations above and below this mark. This is most likely due to the economic downturn caused by the GFC. Since then, growth in production not only recovered to pre-GFC levels but in fact increased in momentum. Most notably, production grew 13.6% over the course of one year, from \$3.23 billion in 2014 to \$3.73 billion in 2015.

Life Cycle Assessment Diagrams

Energy (Figure 25.1, Figure 25.2, Figure 25.3)

Road transport services were found to consume a total energy intensity of 7,745.3 MJ_{OE} per \$1,000 worth of services supplied. The road transport services sector has the highest total energy intensity out of the 14 service sectors covered in this publication. It can, therefore, be considered that road transport services are an energy-intensive service sector, largely due to its large consumption of fossil fuels.

Direct energy use for road transport services was 91% of the total energy intensity, measuring 7,055.6 MJ_E per \$1,000 worth of services supplied. Direct energy uses come mostly from fossil fuels. *Indirect energy use* made up the remaining total at 9%, measuring 689.7 MJ_E per \$1,000 worth of services supplied.

²⁶⁷ Ministry of Transport. (2019). *National Freight Demand Study 2017/2018*. Retrieved from <https://www.transport.govt.nz/assets/Import/Uploads/Research/Documents/NFDS3-Final-Report-Oct2019-Rev1.pdf>

²⁶⁸ Statistics New Zealand. (2018). *International Visitor Survey*. Retrieved from <http://nzdotstat.stats.govt.nz/wbos/Index.aspx>

The main indirect energy uses in road transport services came from; (i) energy embodied wholesale and retail trade at 433.9 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in petroleum, chemicals and plastics at 116.3 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in finance, insurance and business at 37.4 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in paper products at 27.5 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 25.4)

Road transport services have a total land intensity of 113.8 m² per \$1,000 of services supplied. The road transport services sector has the 10th largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for road transport services was 18% of the total land intensity, measuring just 21 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 82% measuring 92.8 m² per \$1,000 of road transport services supplied.

The major indirect land uses came from; (i) land embodied in wholesale and retail trade at 72.6 m² per \$1,000 of services supplied; (ii) land embodied in forestry and logging at 11.1 m² per \$1,000 of services supplied; (iii) land embodied in finance, insurance and business at 3.7 m² per \$1,000 of services supplied; (iv) land embodied in textile and apparel at 2.5 m² per \$1,000 of services supplied.

Water Inputs (Figure 25.5)

Road transport services use a total of 4,608.7 litres of water inputs per \$1,000 of services supplied, ranking the sector the 5th highest consumer of water out of the 14 service sectors covered by this publication. *Water inputs* to road transport services are made up entirely of indirect sources.

These indirect water inputs came mainly from; (i) water inputs embodied in wholesale and retail trade at 4,442 litres per \$1,000 of services supplied; (ii) water inputs embodied in finance, insurance and business services at 38 litres per \$1,000 of services supplied; (iii) water inputs embodied in paper products at 28.6 litres per \$1,000 of services supplied; (iv) water inputs embodied in vehicle and transport equipment at 28.5 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 25.6)

Road transport services were found to generate a total of 15,532.5 grams (15.5 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the road transport service sector is 48% of total waste produced or 7,390.8 grams per \$1,000 of services supplied. While landfill waste *indirectly generated* was 52% or 8,141.7 grams per \$1,000 of road transport services supplied.

The main sources of indirect landfill waste for road transport services came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 4,409.8 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in wholesale and retail trade at 3,158.6 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in finance, insurance and business services at 148.4 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in paper products at 96 grams per \$1,000 of services supplied.

Water Wastes (Figure 25.7)

Road transport services were found to produce a total of 4,972.6 litres of wastewater per \$1,000 of services supplied, ranking the sector 9th highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* road transport services was a minuscule 0.02% of total water waste produced, at 0.6 litres per \$1,000 of services supplied

Wastewater indirectly generated by road transport services made up the remaining 99.98%, or 4,972 litres per \$1,000 of services supplied.

The indirect wastewater generated by wholesale and retail trade services is mostly made up of (i) wastewater embodied in wholesale and retail trade at 2,078.6 litres per \$1,000 of services supplied; (ii) wastewater embodied in petroleum, chemicals and plastics at 1,671.4 litres per \$1,000 of services supplied; (iii) wastewater embodied in personal and other community services at 699.3 litres per \$1,000 of services supplied; (iv) wastewater embodied in finance, insurance and business at 213 litres per \$1,000 of services supplied.

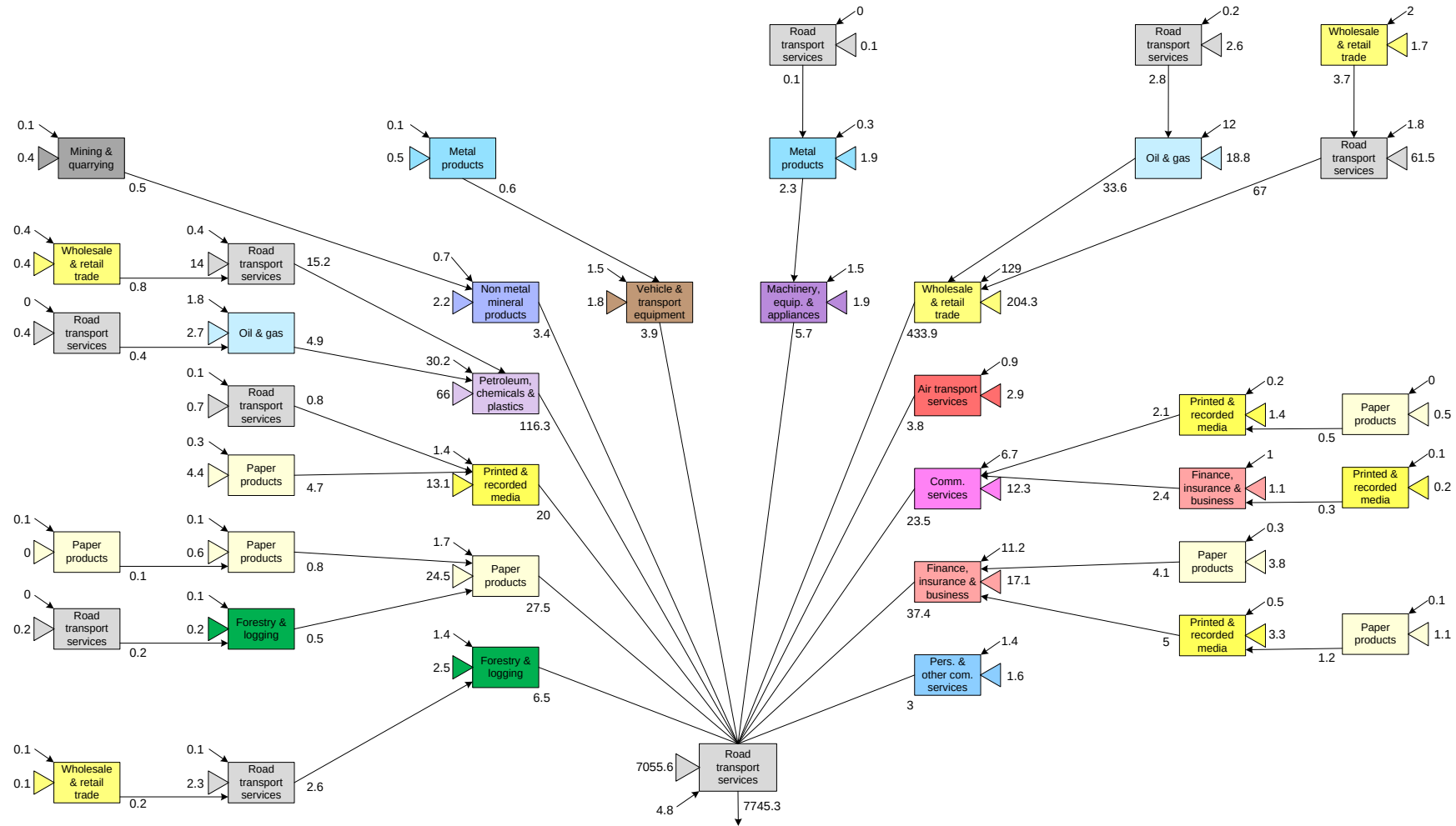
Energy Greenhouse Gases (Figure 25.8)

In terms of CO₂ greenhouse gas emissions, road transport services emitted a total of 901,240 grams (901.2 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the highest emitter of energy-related CO₂ per tonne among the 14 service, construction and transport sectors covered in this publication.

Energy-related CO₂ directly generated by road transport services was 90% of the total CO₂ emitted at 811,149.9 grams per \$1,000 of services supplied. Energy-related CO₂ indirectly generated by road transport services make up the remaining 10% or 90,090.1 grams.

The indirect energy-related CO₂ from road transport services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 58,683.2 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in petroleum, chemicals and plastics at 10,711.7 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in paper products at 5,459.9 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in finance, insurance and business at 4,665.5 grams per \$1,000 of services supplied.

Figure 25.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Road Transport Services, 2004 (MJ_E, Oil Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,569 (\$ = Year of 2019)

Figure 25.2 - Electricity Inputs Required to Produce \$1,000 Worth of Road Transport Services, 2004 (MJ, Heat Equivalents)

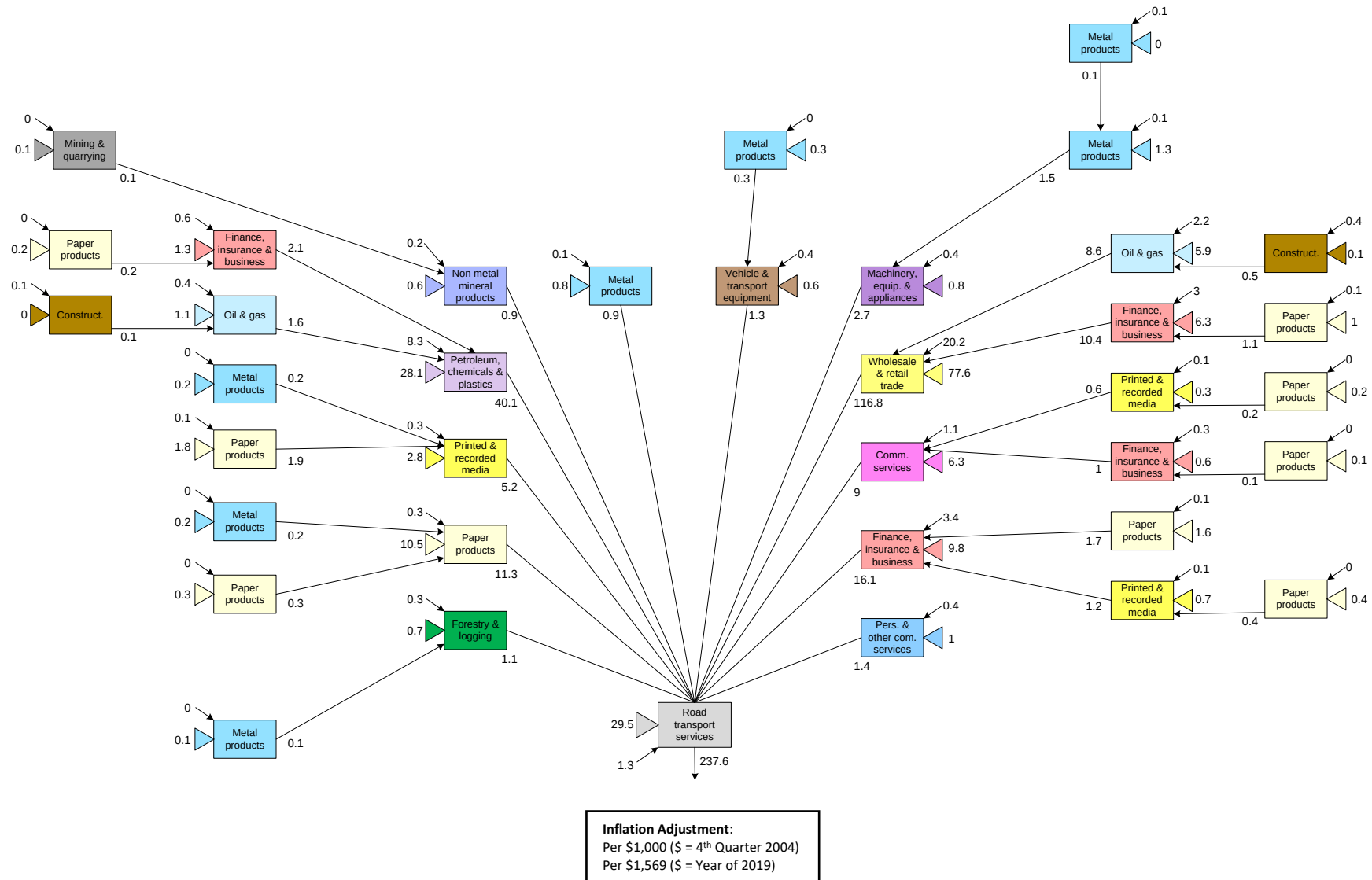
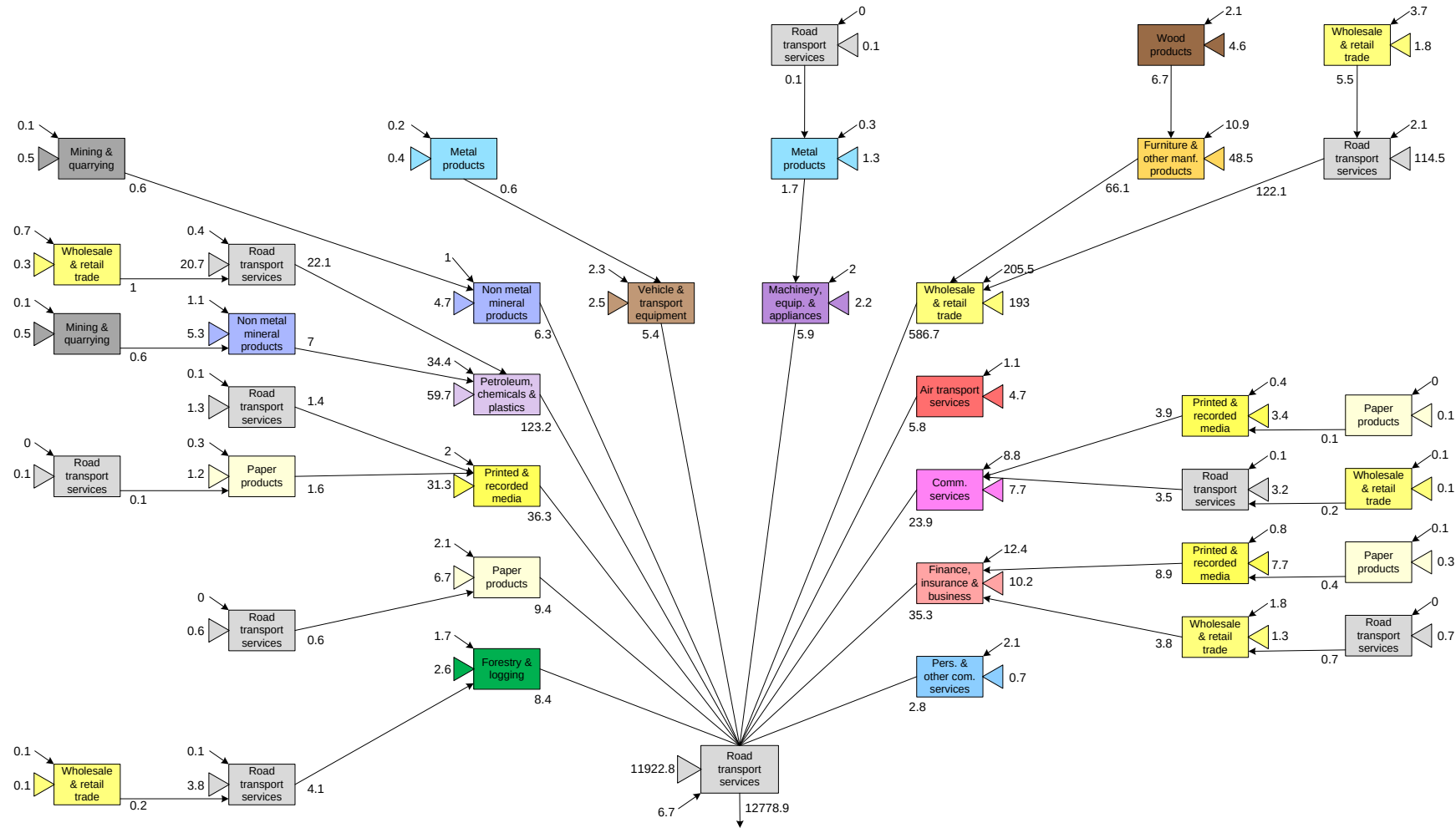


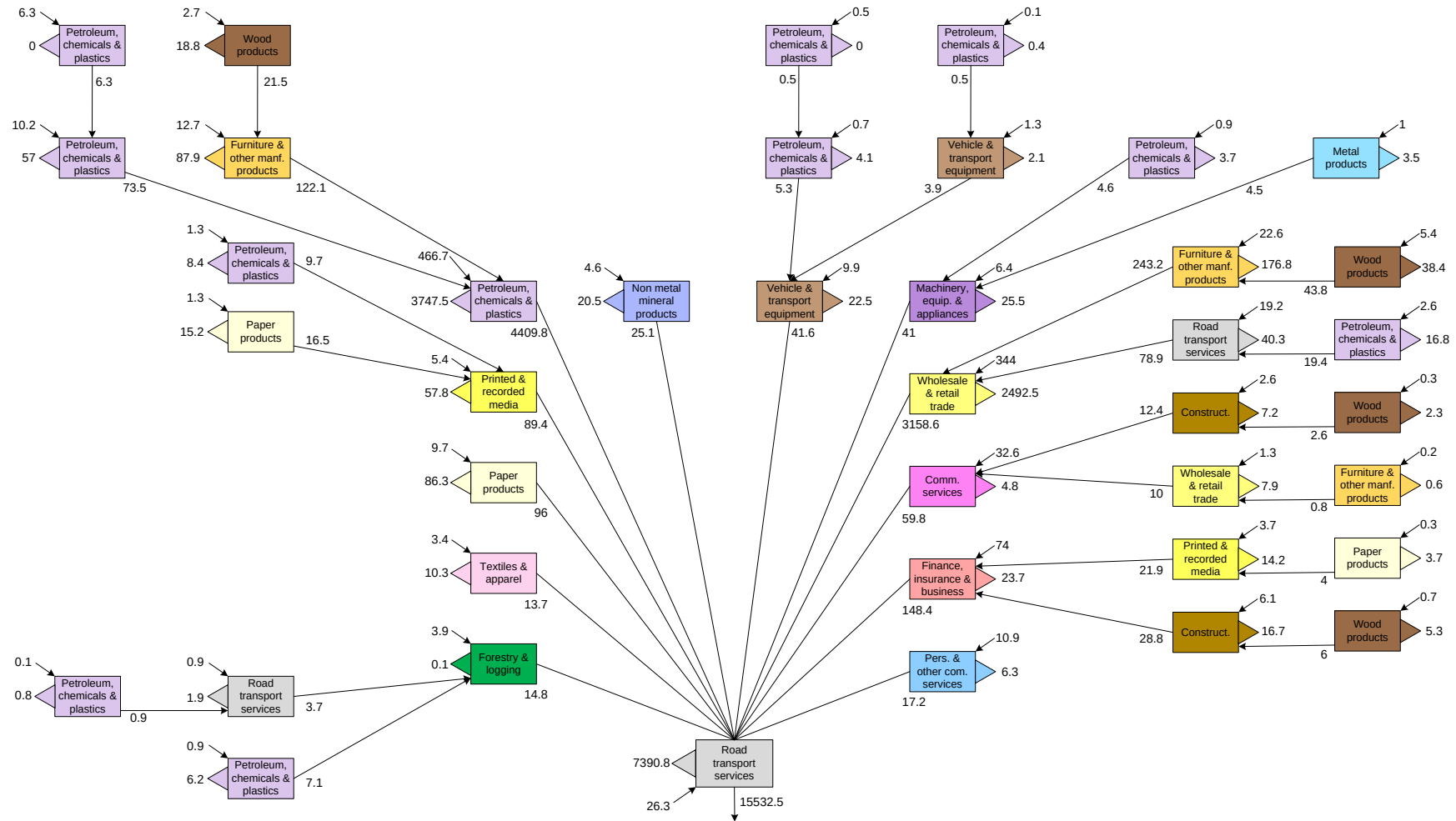
Figure 25.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Road Transport Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Figure 25.5 - Landfill Waste Generated in Producing \$1,000 Worth of Road Transport Services, 2004 (Grams)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Figure 25.6 - Water Inputs Required to Produce \$1,000 Worth of Road Transport Services, 2004 (Litres)

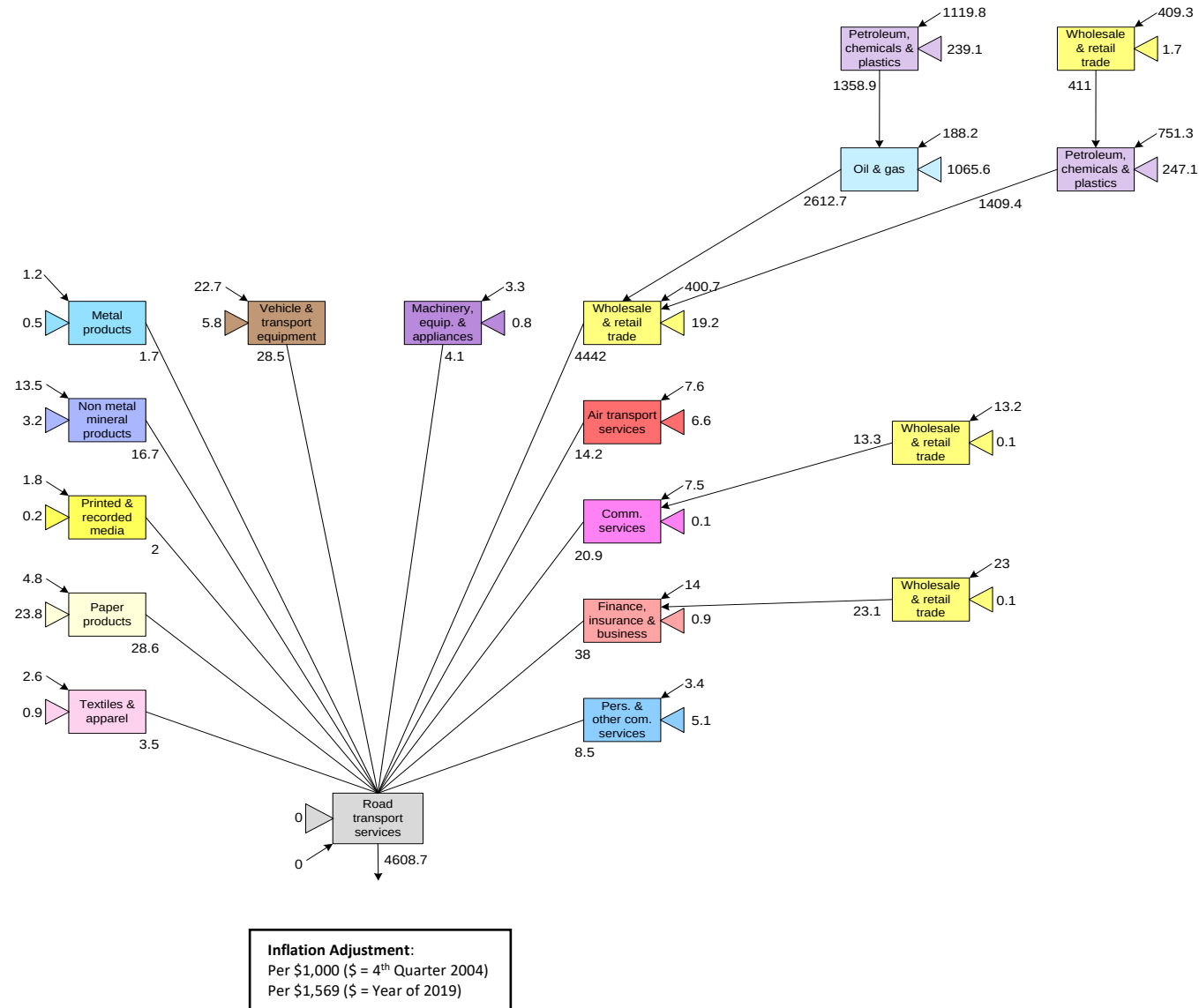
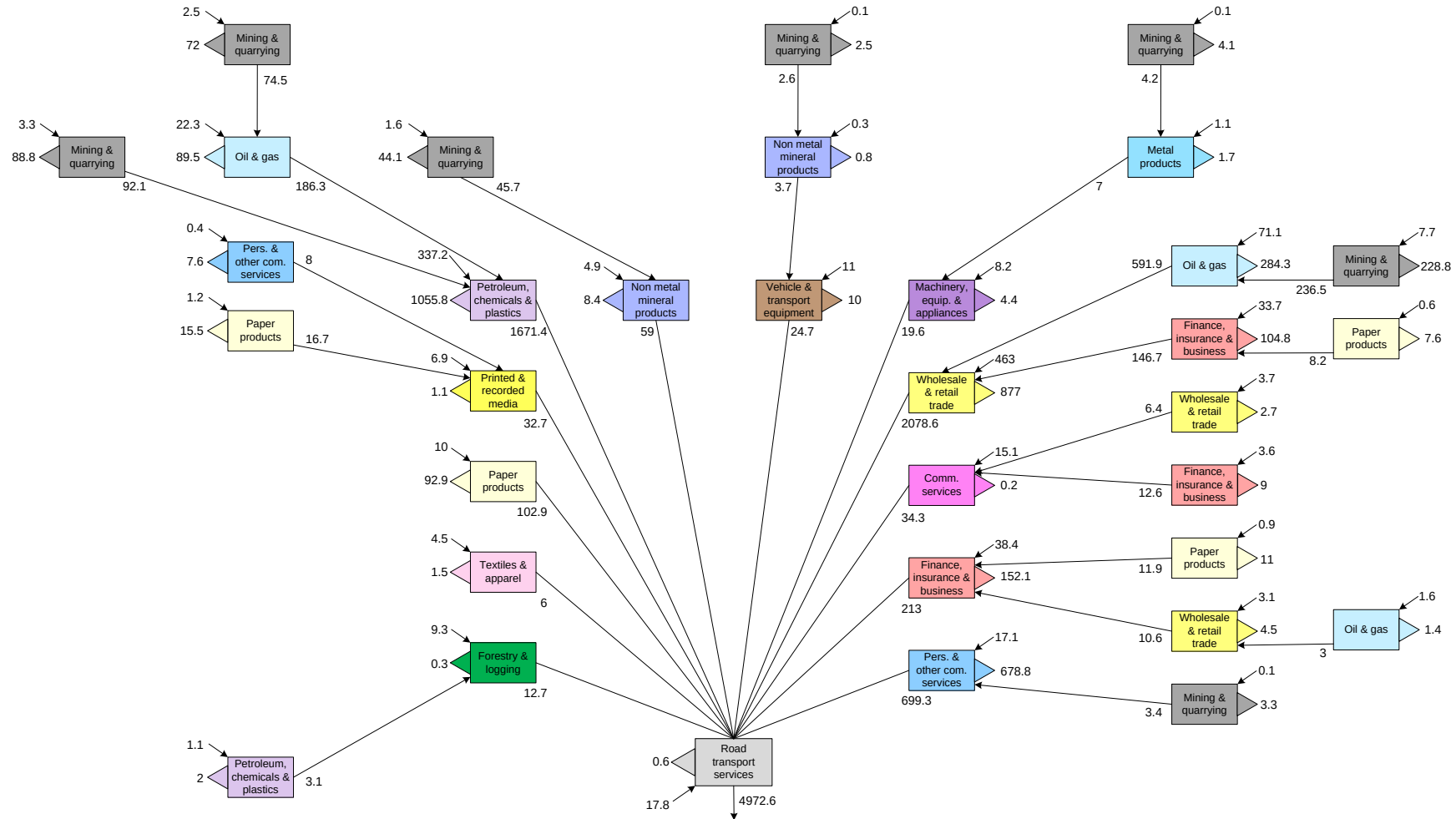
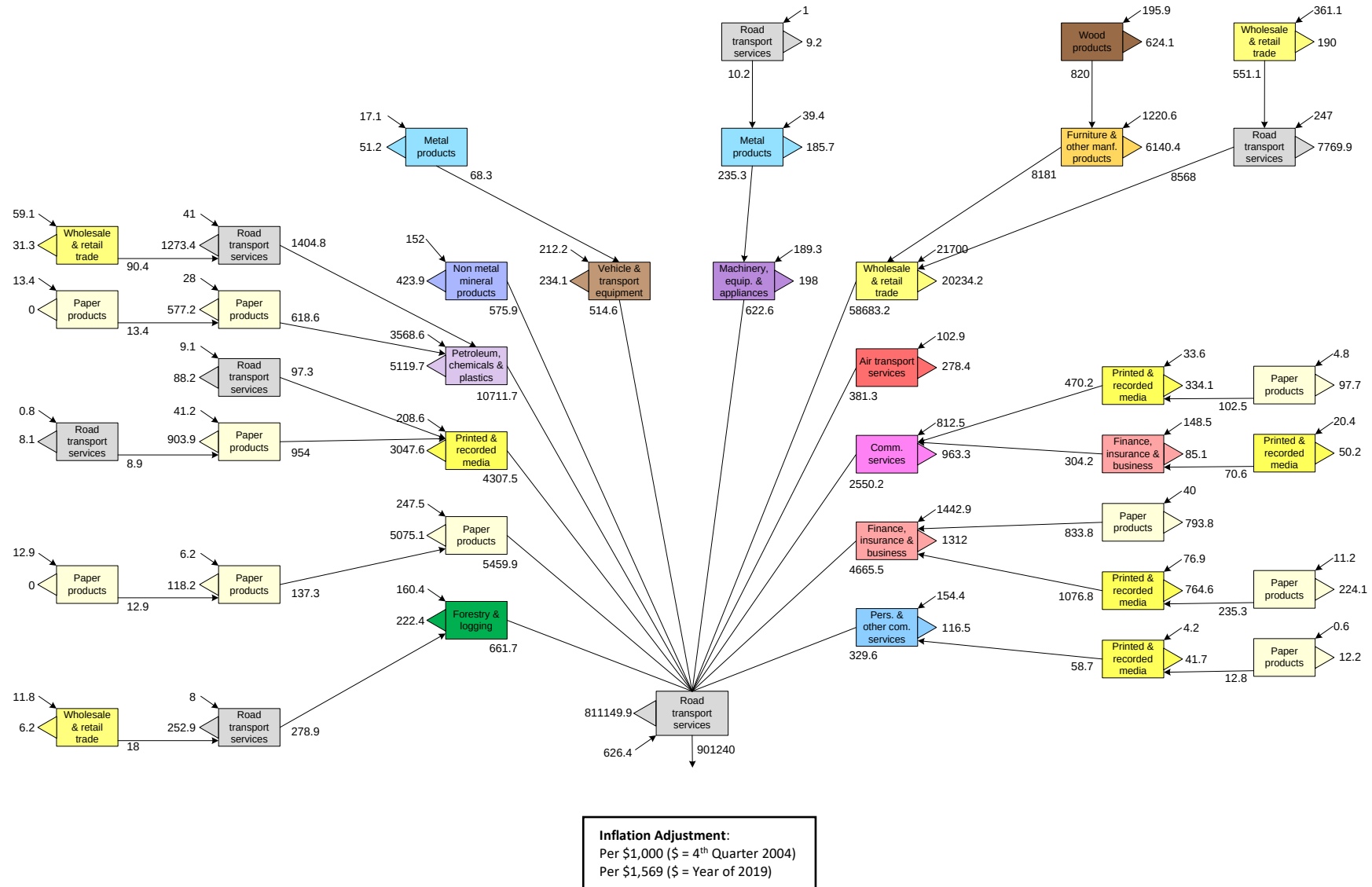


Figure 25.7 - Water Waste Generated in Producing \$1,000 Worth of Road Transport Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Figure 25.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Road Transport Services, 2004 (Grams)



26. Water and Rail Transport

Description

ANZSIC Codes covered:

- 4710 – Rail Freight Transport
- 4720 – Rail Passenger Transport
- 4810 – Water Freight Transport
- 4820 – Water Passenger Transport
- 5211 – Stevedoring (e.g. Ship loading/unloading)
- 5212 – Port and Water Transport Terminal Operations
- 5219 – Other Water Transport Support Services

GDP 2016 = \$1.276 billion
Rank = 26th

Average annual growth rate
2006 to 2016 = 9.52%
Rank = 3rd

Employment 2016 = 0
Rank = 34th

Main commodities supplied:

- Water and rail transport and port operations

Economic Overview

Both the water and rail transport sectors are important for the movement of freight and passengers in New Zealand.

New Zealand has a comprehensive rail network that covers around 4000 kms with links to ports and airports.²⁶⁹ The rail system connects all major population centres and includes inter-island roll-on, roll-off rail ferries. Although, almost half of freight tonnage carried by rail is centred in the “Golden Triangle” between Auckland, Waikato, and the Bay of Plenty.²⁷⁰ Prior to the 1983 Transport Amendment Act, most long-distance freight in New Zealand was moved by rail due to restrictions on the distance goods could be moved by road.²⁷¹

Long-distance rail passenger travel is now less popular, with services impacted by competition from cheap airfares. In contrast, demand for commuting services has increased as petrol prices and parking costs have escalated which has required an upgrade of passenger networks in Wellington and Auckland.²⁷²

New Zealand relies on shipping for the bulk of its international trade of goods. Ninety-nine percent of New Zealand’s total international trade is carried by sea, with around 30 global and regional shipping lines calling at NZ ports.²⁷³ Water transport within New Zealand is predominantly freight and passenger travel between the North Island and South Island and commuter ferries (mostly in Auckland). Improved wharf services have halved shipping turnaround times and New Zealand

²⁶⁹ Ministry of Transport. (2017). *New Zealand Transport Outlook: Current State*. Wellington: Ministry of Transport. Retrieved from <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Transport-Outlook/4897ce4d17/MoT-Transport-Outlook.pdf>

²⁷⁰ Ibid.

²⁷¹ New Zealand Treasury. (2012). *Economic and Financial Overview*. Retrieved from <http://www.treasury.govt.nz/economy/overview/2012/nzefto-12.pdf>

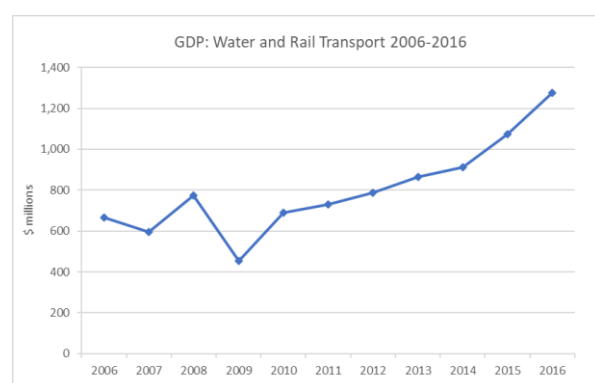
²⁷² Ministry of Transport. (2017). *New Zealand Transport Outlook: Current State*. Wellington: Ministry of Transport. Retrieved from <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Transport-Outlook/4897ce4d17/MoT-Transport-Outlook.pdf>

²⁷³ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from; <https://treasury.govt.nz/sites/default/files/2010-04/nzefto-16.pdf>

exporters have been able to negotiate lower freight rates as a result of port reforms.²⁷⁴ Reforms to the New Zealand port industry included corporatisation and privatisation, the introduction of new technology, changes in employment conditions and reduced manning levels. Furthermore, NZ's shipping policy seeks to ensure unrestricted access to the carrier of their choice for exporters and shippers. With the benefits of fair competition improving the competitiveness of this industry.²⁷⁵

The main purchases the water and rail transport sector makes in the New Zealand economy are from air transport, services to transport and storage. The largest consumers of the goods and services provided by the water and rail industry are wholesale trade and final consumption expenditure by households.²⁷⁶

Sector Trends



The water and rail transport sector initially felt strong impacts from the GFC. In 2009, production dropped 41.13%, from \$773 million down to \$455 million. However, the sector recovered well, growing production 180.32% from 2009 to 2016. In 2010, KiwiRail, a state-owned enterprise responsible for rail operations in New Zealand, released their 10-Year Turnaround Plan. In support of this, KiwiRail has received a large level of crown investment.²⁷⁷ Additionally, the government's Provincial Growth Fund and further large-scale investment such as the Auckland City Rail Link is likely to continue investment into this sector.

Life Cycle Assessment Diagrams

Energy (Figure 26.1, Figure 26.2, Figure 26.3)

Water and rail transport services were found to consume a total energy intensity of 5,011.9 MJ_{OE} per \$1,000 worth of services supplied. The water and rail transport service sector has the 2nd highest total energy intensity out of the 14 service sectors covered in this publication.

²⁷⁴ New Zealand Treasury. (1994). *New Zealand Economic and Financial Overview*. Wellington, New Zealand.

²⁷⁵ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from; <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

²⁷⁶ New Zealand Treasury. (1994). *New Zealand Economic and Financial Overview*. Wellington, New Zealand.

²⁷⁷ KiwiRail Group. (2011). *KiwiRail Group Turnaround Plan*. Wellington. Retrieved from <https://treasury.govt.nz/sites/default/files/2010-07/b10-cab-kgtf-14apr11.pdf>

Direct energy use for water and rail transport services was 84% of the total energy intensity, measuring 4,225.3 MJ_{OE} per \$1,000 worth of services supplied. *Indirect energy* use made up the remaining total at 16%, measuring 786.6 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses in water and rail transport services came from; (i) energy embodied in wholesale and retail trade at 208.4 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in water and rail transport services at 171 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in air transport services at 92.7 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in finance, insurance and business services at 89.6 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 26.4)

Water and rail transport services have a total land intensity of 216.5 m² per \$1,000 of services supplied. The road transport services sector has the 6th largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for water and rail transport services was 34% of the total land intensity, measuring 74 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 66% measuring 142.5 m² per \$1,000 of road transport services supplied.

The major indirect land uses for water and rail transport services came from; (i) land embodied in wholesale and retail trade at 72.2 m² per \$1,000 of services supplied; (ii) land embodied in livestock and crops at 22.1 m² per \$1,000 of services supplied; (iii) land embodied in finance, insurance and business services at 17.5 m² per \$1,000 of services supplied; (iv) land embodied in water and rail transport services at 6.9 m² per \$1,000 of services supplied.

Water Inputs (Figure 26.5)

Water and rail transport services use a total of 3,405.9 litres of water inputs per \$1,000 of services supplied, ranking the sector the 9th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to water and rail transport services were made up mostly of indirect sources, with *direct sources* only making up 2% or 61.7 litres per \$1,000 of services supplied, while *indirect sources* made up the remaining 98% or 3,344.2 litres per \$1,000 of services supplied.

These indirect water inputs came mostly from; (i) water inputs embodied in wholesale and retail trade at 2,500.9 litres per \$1,000 of services supplied; (ii) water inputs embodied in mining and quarrying at 354 litres per \$1,000 of services supplied; (iii) water inputs embodied in air transport services at 162.5 litres per \$1,000 of services supplied; (iv) water inputs embodied in water and rail transport services at 101.7 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 26.6)

Water and rail transport services were found to generate a total of 6,650.2 grams (6.6 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the water and rail transport service sector is 22% of total waste produced or 1,479.1 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 78% or 5,171.1 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for water and rail transport services came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 2,206.1 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in wholesale and retail trade at 1,437.4 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in finance, insurance and business services at 337.3 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in construction services at 201.8 grams per \$1,000 of services supplied.

Water Wastes (Figure 26.7)

Water and rail transport services were found to produce a total of 4,922.6 litres of wastewater per \$1,000 of services supplied, ranking the sector 10th highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* by water and rail transport services was only 1% of total water waste produced, at 49.6 litres per \$1,000 of services supplied. *Wastewater indirectly generated* by water and rail transport services made up the remaining 99%, or 4,873 litres per \$1,000 of services supplied.

The indirect wastewater generated by water and rail transport services is mostly made up of (i) wastewater embodied in mining and quarrying at 1,579.8 litres per \$1,000 of services supplied; (ii) wastewater embodied in wholesale and retail trade at 1,145.9 litres per \$1,000 of services supplied; (iii) wastewater embodied in petroleum, chemicals and plastics at 916.6 litres per \$1,000 of services supplied; (iv) wastewater embodied in finance, insurance and business services at 573.7 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 26.8)

In terms of CO₂ greenhouse gas emissions, water and rail transport services emitted a total of 544,631.2 grams (544.6 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the 2nd highest emitter of energy-related CO₂ per tonne among the 14 service, construction and transport sectors covered in this publication.

Energy-related CO₂ directly generated by water and rail transport services was 82% of the total CO₂ emitted at 447,652.6 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by water and rail transport services make up the remaining 18% or 96,978.6 grams.

The indirect energy-related CO₂ from water and rail transport services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 28,116.1 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in water and rail transport services at 18,549.4 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in finance, insurance and business at 11,219 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in air transport services at 9,349.5 grams per \$1,000 of services supplied.

Figure 26.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Water and Rail Transport Services, 2004 (MJ_E, Oil Equivalents)

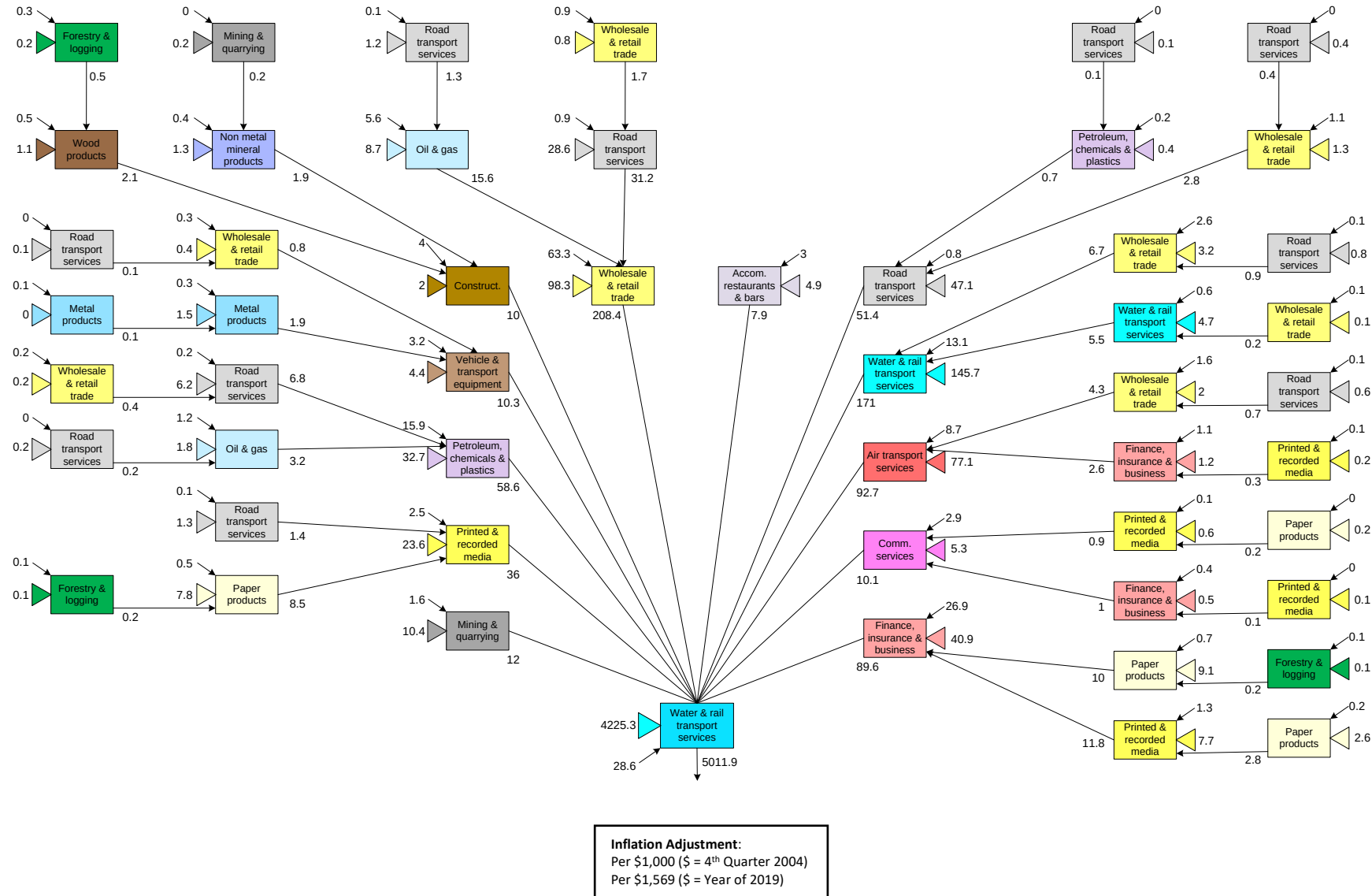
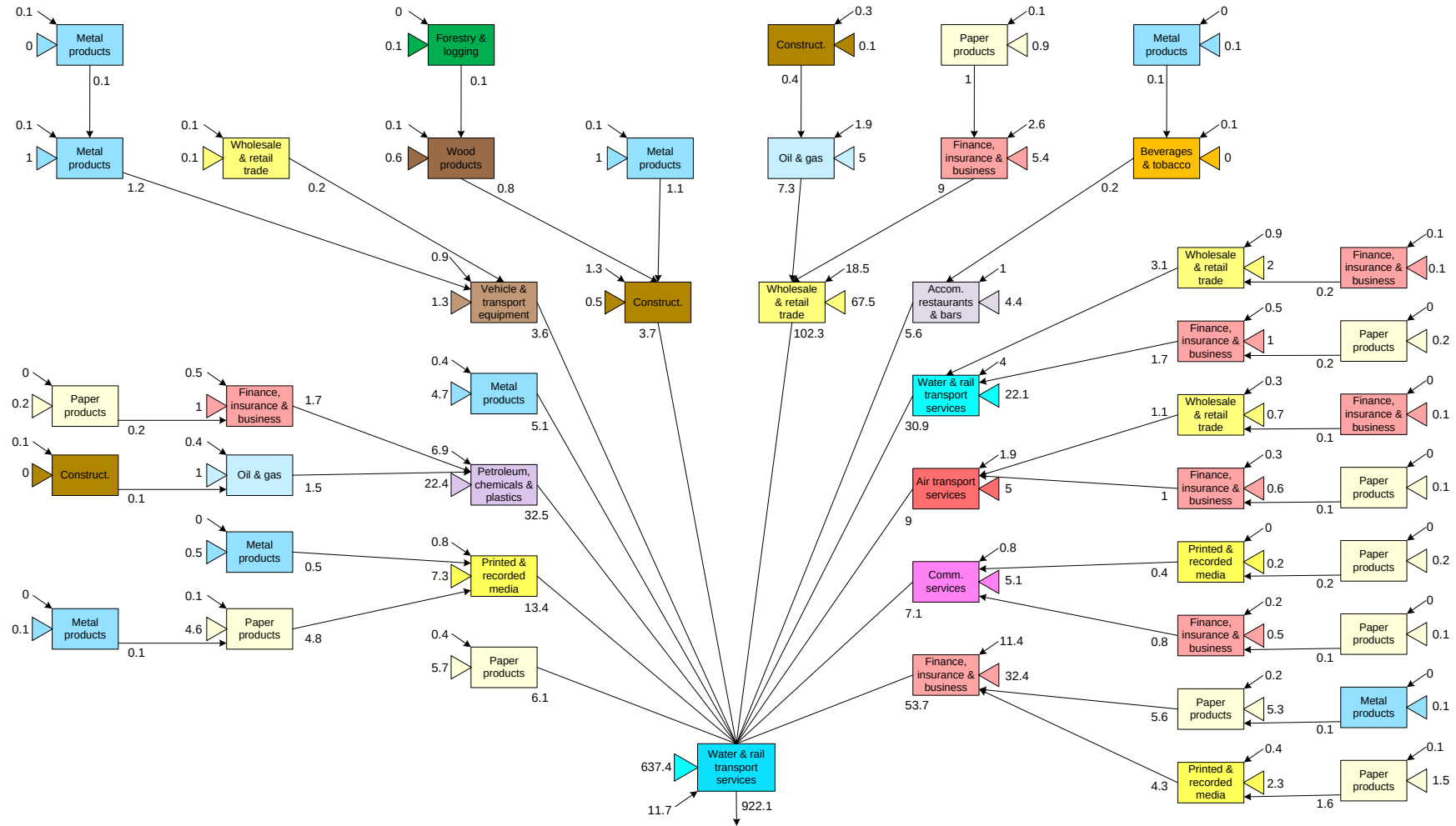


Figure 26.2 - Electricity Inputs Required to Produce \$1,000 Worth of Water and Rail Transport Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Figure 26.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Water and Rail Transport Services, 2004 (MJ, Heat Equivalents)

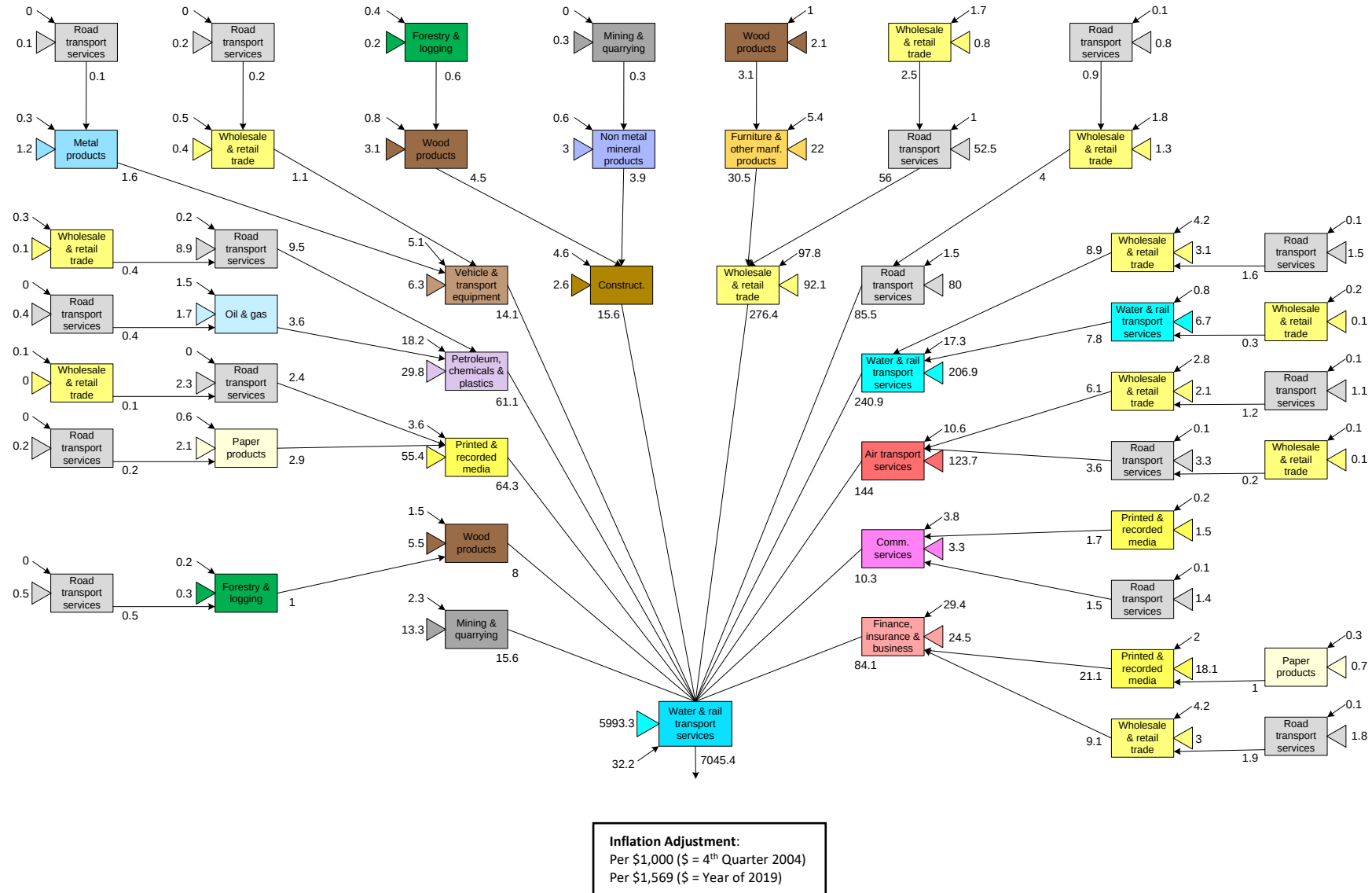
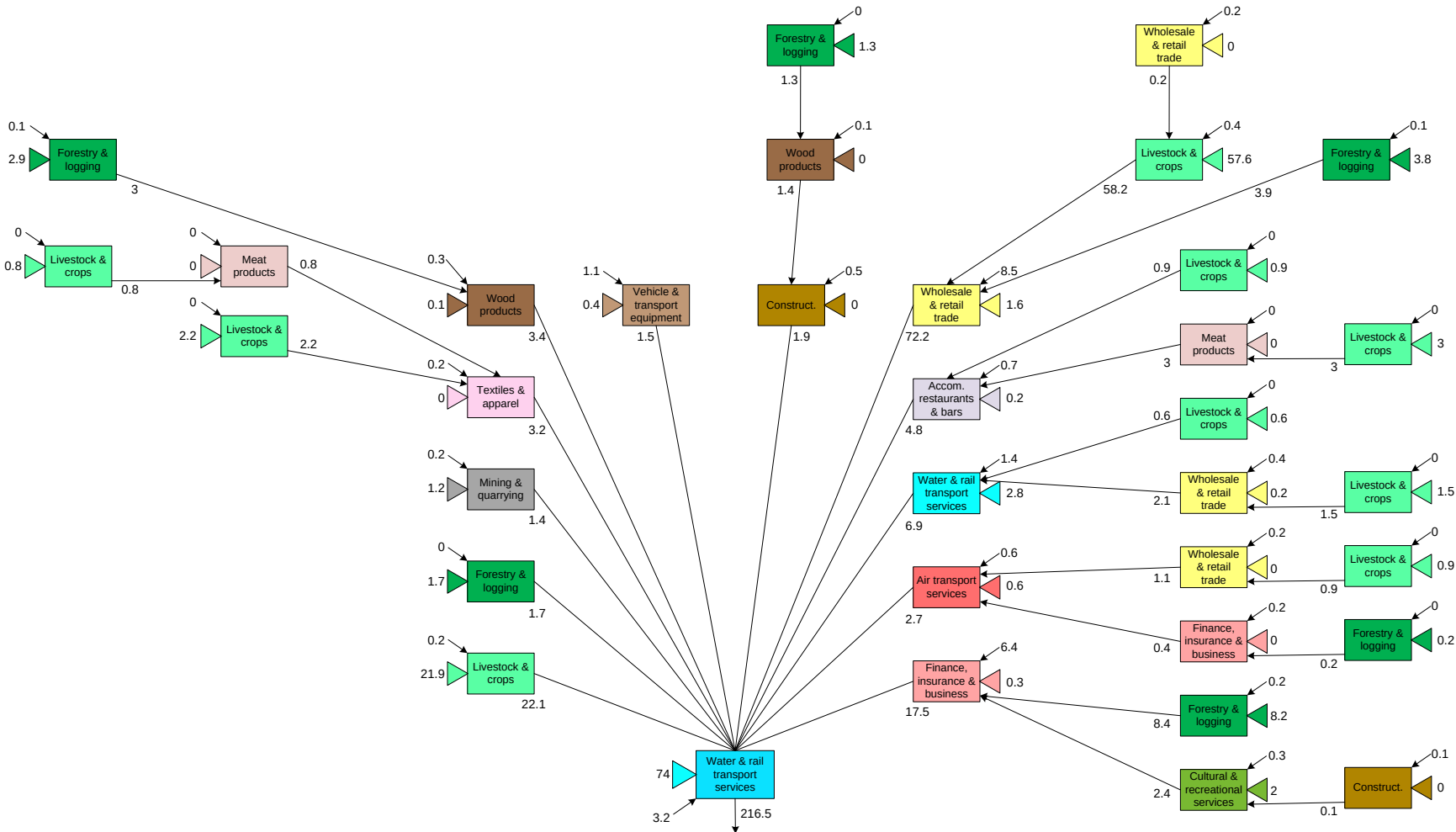
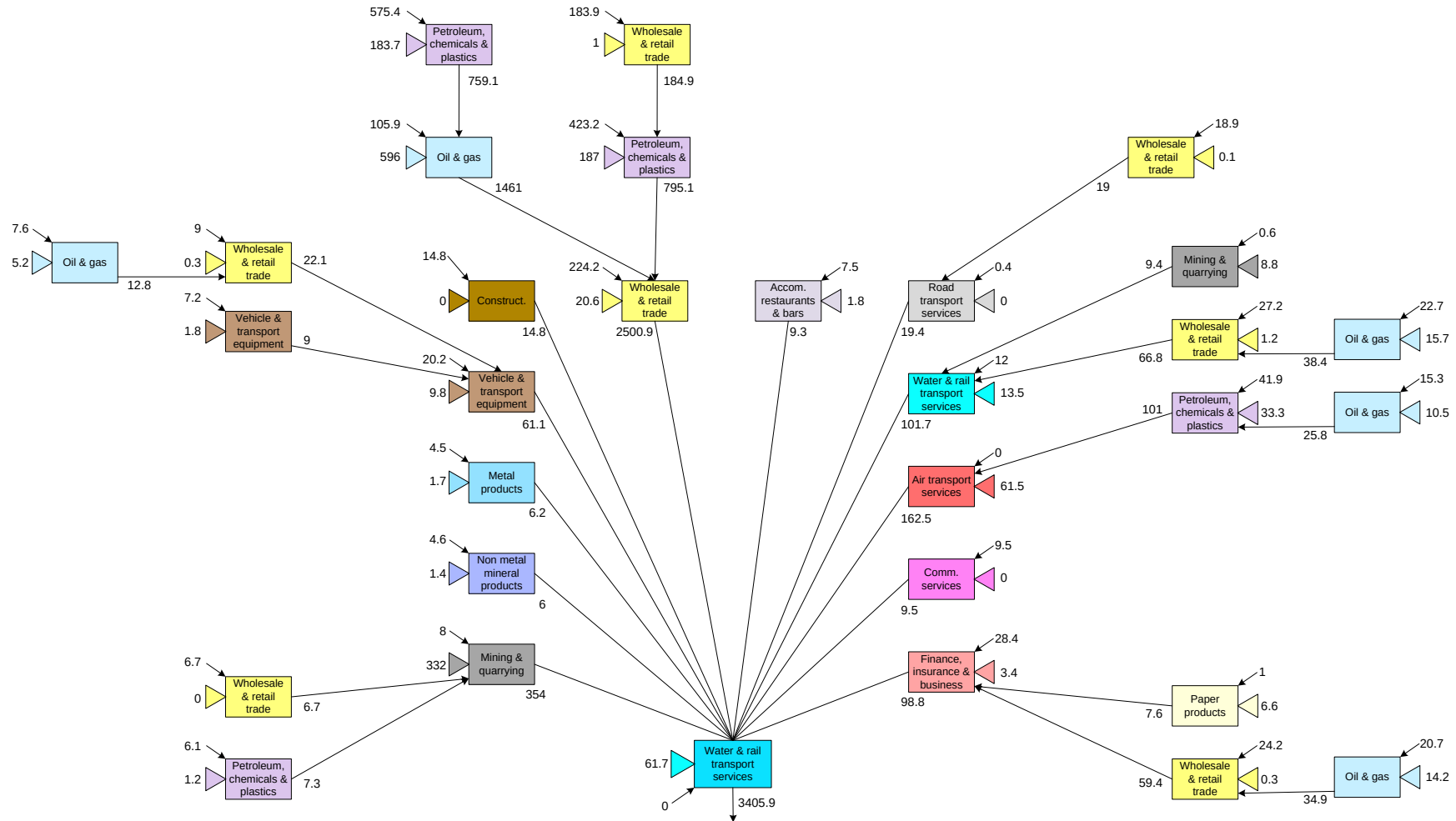


Figure 26.4 - Land Required to Produce \$1,000 Worth of Water and Rail Transport Services, 2004 (m²)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,569 (\$ = Year of 2019)

Figure 26.5 - Water Inputs Required to Produce \$1,000 Worth of Water and Rail Transport Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,569 (\$ = Year of 2019)

Figure 26.6 - Landfill Waste Generated in Producing \$1,000 Worth of Water and Rail Transport Services, 2004 (Grams)

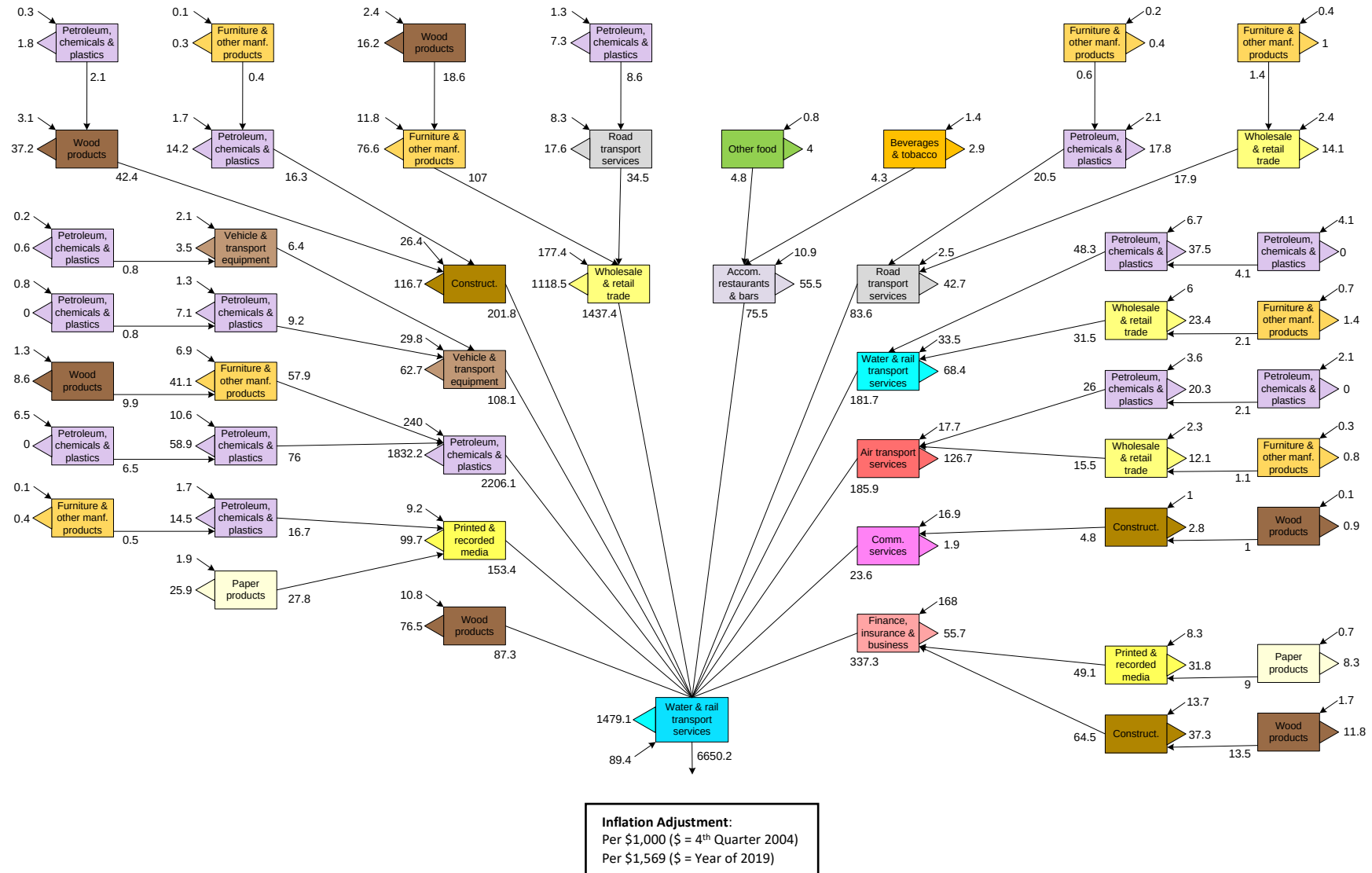


Figure 26.7 - Water Waste Generated in Producing \$1,000 Worth of Water and Rail Transport Services, 2004 (Litres)

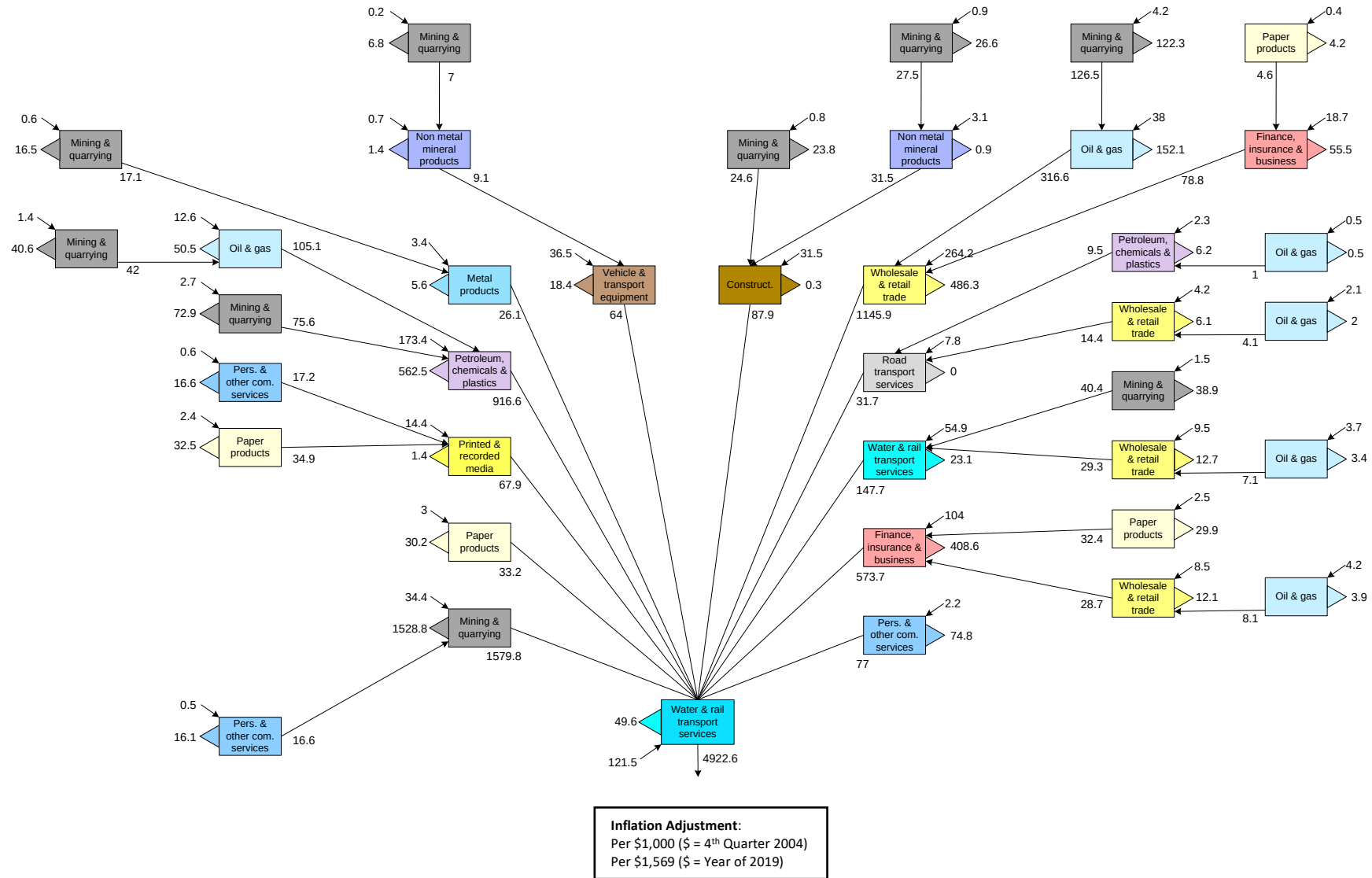
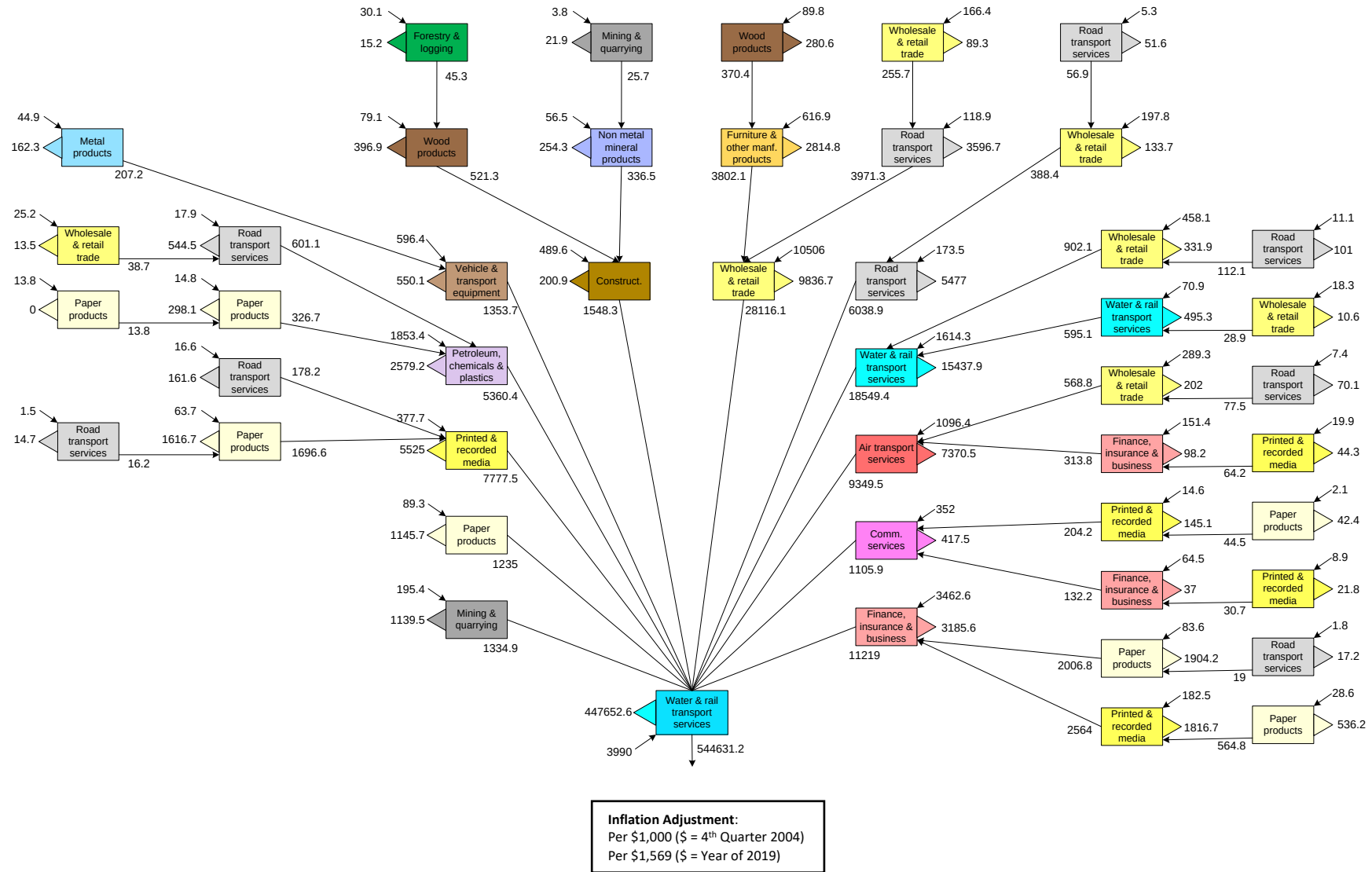


Figure 26.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Water and Rail Transport Services, 2004 (Grams)



27. Air Transport, Services to Transport and Storage

Description

ANZSIC Codes covered:

- 4900 – Air and Space Transport
- 5220 – Airport Operations and Other Air Transport Support Services
- 5291 – Customs Agency Services
- 5292 – Freight Forwarding Services
- 5299 – Other Transport Support Services
- 5301 – Grain Storage Services
- 5309 – Other Services

GDP 2016 = \$7.233 billion

Rank = 7th

Average annual growth rate

2006 to 2016 = 6.09%

Rank = 8th

Employment 2016 = 54,695

Rank = 9th

Main commodities supplied:

- Air transport, other transport, and storage services

Economic Overview

The majority of the air transport infrastructure in New Zealand was originally constructed and operated by government-owned monopolies. In 1983, the domestic airline industry was deregulated and in 1986 restrictions on foreign ownership of NZ airlines were lifted. The major airports were restructured as limited liability companies to allow the government to sell their interests in provincial and international airports.²⁷⁸

A major influence in this sector is Air New Zealand. The airline's international business is primarily tourism, so the scenic attractiveness of NZ is important for success and growth.²⁷⁹ New Zealand's main international airport is located near Auckland City where around 75% of international arrivals enter New Zealand.²⁸⁰ Other main international airports are located in Wellington and Christchurch, whilst Queenstown and Dunedin operate as secondary airports operating some trans-Tasman flights.²⁸¹

Despite being a private company Air New Zealand enjoys government support as having a national airline is seen as important. Currently, the Government retains a 53% ownership of Air New Zealand, which holds approximately 80% of the market share with the rest of the market share largely held by Jetstar, which operates flights down the main trunk.²⁸²

²⁷⁸ New Zealand Treasury. (2006). *Economic and Financial Overview 2006*. Retrieved from <http://www.treasury.govt.nz/economy/overview/archive/pdfs/nzeo-06.pdf>

²⁷⁹ Air New Zealand. (2008). *Annual Shareholder review: Making our Way*. Retrieved from <http://airnz.web1.interactiveinvestor.com.au/airnz0801/Annual%20Shareholder%20Review%202008/EN/body.aspx?z=2&p=-1&v=2&uid=#>

²⁸⁰ Auckland Airport. (2019, March). *Fast Facts*. Retrieved from <https://corporate.aucklandairport.co.nz/news/publications/fast-facts>

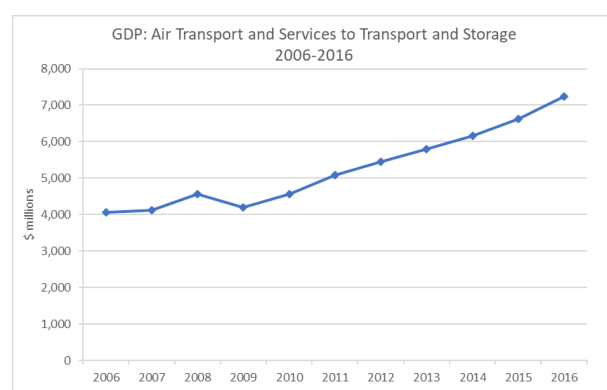
²⁸¹ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzeo-16.pdf>

²⁸² Ministry of Transport. (2017). *New Zealand Transport Outlook: Current State*. Wellington: Ministry of Transport. Retrieved from <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Transport-Outlook/4897ce4d17/MoT-Transport-Outlook.pdf>

NZ has one of the largest numbers of registered aircraft and licensed pilots per capita. Light aircraft including helicopters are used in agriculture (topdressing, spraying, planting) and commercial hunting and trapping operations.²⁸³ Light aircraft are also a major component of scheduled flights on provincial routes and NZ's tourism infrastructure – between locations, remote locations, flightseeing and heli-skiing.

The air transport, services to transport and storage sector is important for the New Zealand economy as it is the 7th largest in the economy producing \$7.233 billion in GDP in 2016. This sector purchases goods and services mainly from other transport equipment manufacturing, wholesale and retail trade, finance, insurance, property and business services. The largest consumers of the goods and services provided by the air transport, services to transport and storage sector are wholesale trade, road freight transport, households and exports. Petroleum refining will now be more significant as Air New Zealand is the country's largest single user of aviation fuel produced by the New Zealand refinery company.

Sector Trends



Overall, this sector's contribution to GDP has increased by 78.31% from \$4.06 billion in 2006 to \$7.23 billion in 2016. However, growth has not been continuous over this period. As the graph above indicates, between 2006 and 2008, the GDP generated by this sector appeared to be growing at an increasing rate, reaching a peak of \$4.56 billion. In 2009, this sector's GDP dropped 7.81% to 2007 levels at \$4.21 billion, mainly owing to the GFC. Interestingly, this slowdown and decline lasted for only one year. That is, not only did the sector recover to pre-GFC levels the following year, but GDP generated by this sector was increasing more rapidly at 8.1% p.a. on average between 2009 and 2016. Such rapid growth, however, is unlikely to be sustainable, and so, it is likely that the sector will reach another peak in the near future. It is interesting to note that had the GFC not occurred, and the 10.5% p.a. growth rate continued, the sector's contribution to national GDP in 2016 would have been considerably higher than the actual result (assuming all else remained the same).

Life Cycle Assessment Diagrams

Energy (Figure 27.1, Figure 27.2, Figure 27.3)

Air transport services were found to have a total energy intensity of 2,921.1 MJ_{OE} per \$1,000 worth of services supplied. The air transport service sector has the 4th highest total energy intensity out of the

²⁸³ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

14 service sectors covered in this publication. *Direct energy* use for air transport services was 73% of the total energy intensity, measuring 2,142.9 MJ_{OE} per \$1,000 worth of services supplied. *Indirect energy use* made up the remaining total at 27%, measuring 778.2 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses in air transport services came from; (i) energy embodied petroleum, chemicals and plastics at 199.2 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in wholesale and retail trade at 192.3 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in finance, insurance and business services at 101.3 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in air transport services at 85.9 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 27.4)

Air transport services have a total land intensity of 117.6 m² per \$1,000 of services supplied. The Air transport services sector has the 9th largest land intensity out of the 14 service sectors covered by this publication. *Direct land use* for air transport services was 10% of the total land intensity, measuring 11.4 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 90% measuring 106.2 m² per \$1,000 of air transport services supplied.

The major indirect land uses for air transport services came from; (i) land embodied in wholesale and retail trade at 60.9 m² per \$1,000 of services supplied; (ii) land embodied in finance, insurance and business services at 19 m² per \$1,000 of services supplied (iii) land embodied in accommodation, restaurants and bars at 10.1 m² per \$1,000 of services supplied; (iv) land embodied in livestock and crops at 4.6 m² per \$1,000 of services supplied.

Water Inputs (Figure 27.5)

Air transport services use a total of 3,955 litres of water inputs per \$1,000 of services supplied, ranking the sector the 8th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to air transport services were made up mostly of indirect sources, with *direct sources* only making up 0.5% or 18.4 litres per \$1,000 of services supplied, while *indirect sources* made up the remaining 99.5% or 3,936.6 litres per \$1,000 of services supplied.

These indirect water inputs into the air transport sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 3,074.1 litres per \$1,000 of services supplied; (ii) water inputs embodied in air transport services at 337 litres per \$1,000 of services supplied; (iii) water inputs embodied in finance, insurance and business at 163.4 litres per \$1,000 of services supplied; (iv) water inputs embodied in oil and gas at 132.8 litres per \$1,000 of services supplied.

Water Wastes (Figure 27.6)

Air transport services were found to produce a total of 4,190.7 litres of wastewater per \$1,000 of services supplied, ranking the sector 11th highest in the production of water wastes out of the 14 service sectors covered by this publication. *Wastewater directly generated* by air transport services was only 1% of total water waste produced, at 3.3 litres per \$1,000 of services supplied. *Wastewater indirectly generated* by air transport services made up the remaining 99%, or 4,187.4 litres per \$1,000 of services supplied.

The indirect wastewater generated by air transport services is mostly made up of (i) wastewater embodied in petroleum, chemicals and plastics at 2,991.6 litres per \$1,000 of services supplied; (ii) wastewater embodied in wholesale and retail trade at 550.2 litres per \$1,000 of services supplied; (iii) wastewater embodied in finance, insurance and business services at 283.7 litres per \$1,000 of services

supplied; (iv) wastewater embodied in mining and quarrying at 76.8 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 27.7)

In terms of CO₂ greenhouse gas emissions, air transport services emitted a total of 299,079.4 grams (299 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the 4th highest emitter of energy-related CO₂ per tonne among the 14 service, transport and construction sectors covered in this publication. The CO₂ greenhouse gas emissions by the air transport services sector are within range of a previous estimate of 341 kg per \$1,000 worth of services supplied.²⁸⁴

Energy-related CO₂ directly generated by air transport services was 68% of the total CO₂ emitted at 204,711.4 grams per \$1,000 of services supplied. Energy-related CO₂ indirectly generated by air transport services make up the remaining 32% or 94,368 grams. The indirect energy-related CO₂ from air transport services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 25,806.8 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in petroleum, chemicals and plastics at 18,323.3 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in finance, insurance and business at 12,593 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in air transport services at 8,659.4 grams per \$1,000 of services supplied.

²⁸⁴ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

Figure 27.1 - Total Energy Inputs Required to Produce \$1,000 worth of Air Transport Services, 2004 (MJ_E, Oil Equivalents)

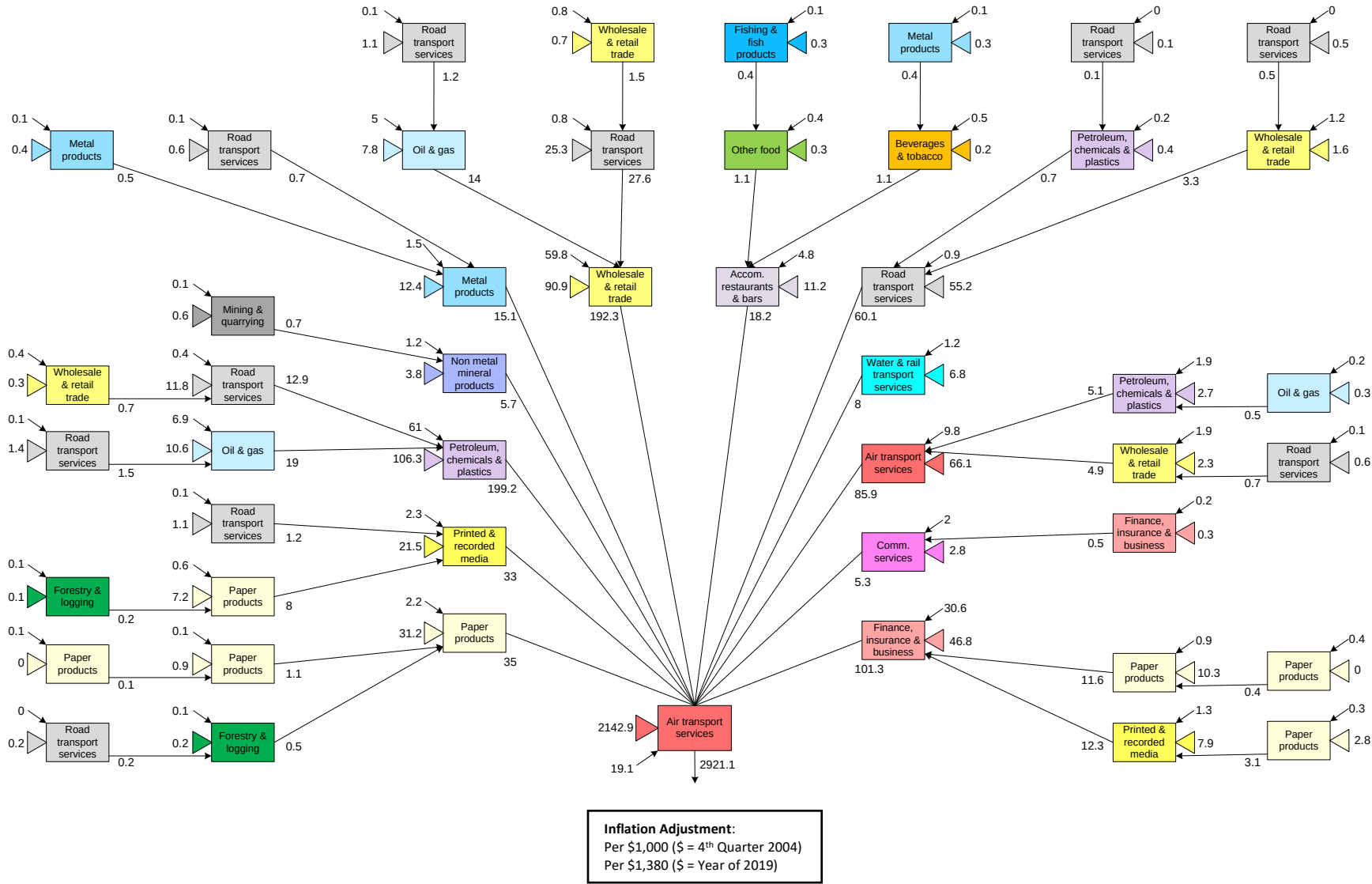
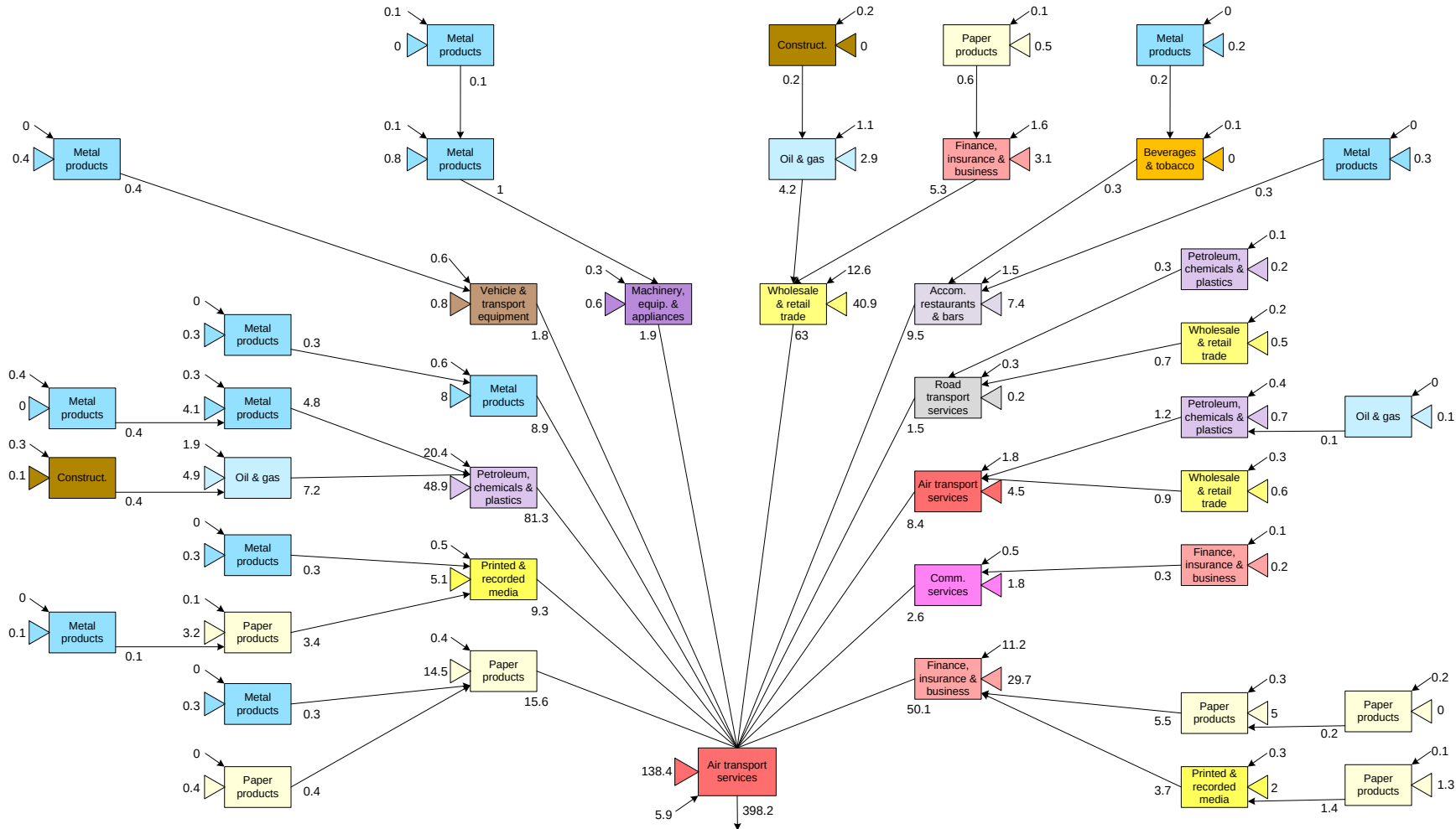


Figure 27.2 - Electricity Inputs Required to Produce \$1,000 Worth of Air Transport Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,380 (\$ = Year of 2019)

Figure 27.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Air Transport Services, 2004 (MJ, Heat Equivalents)

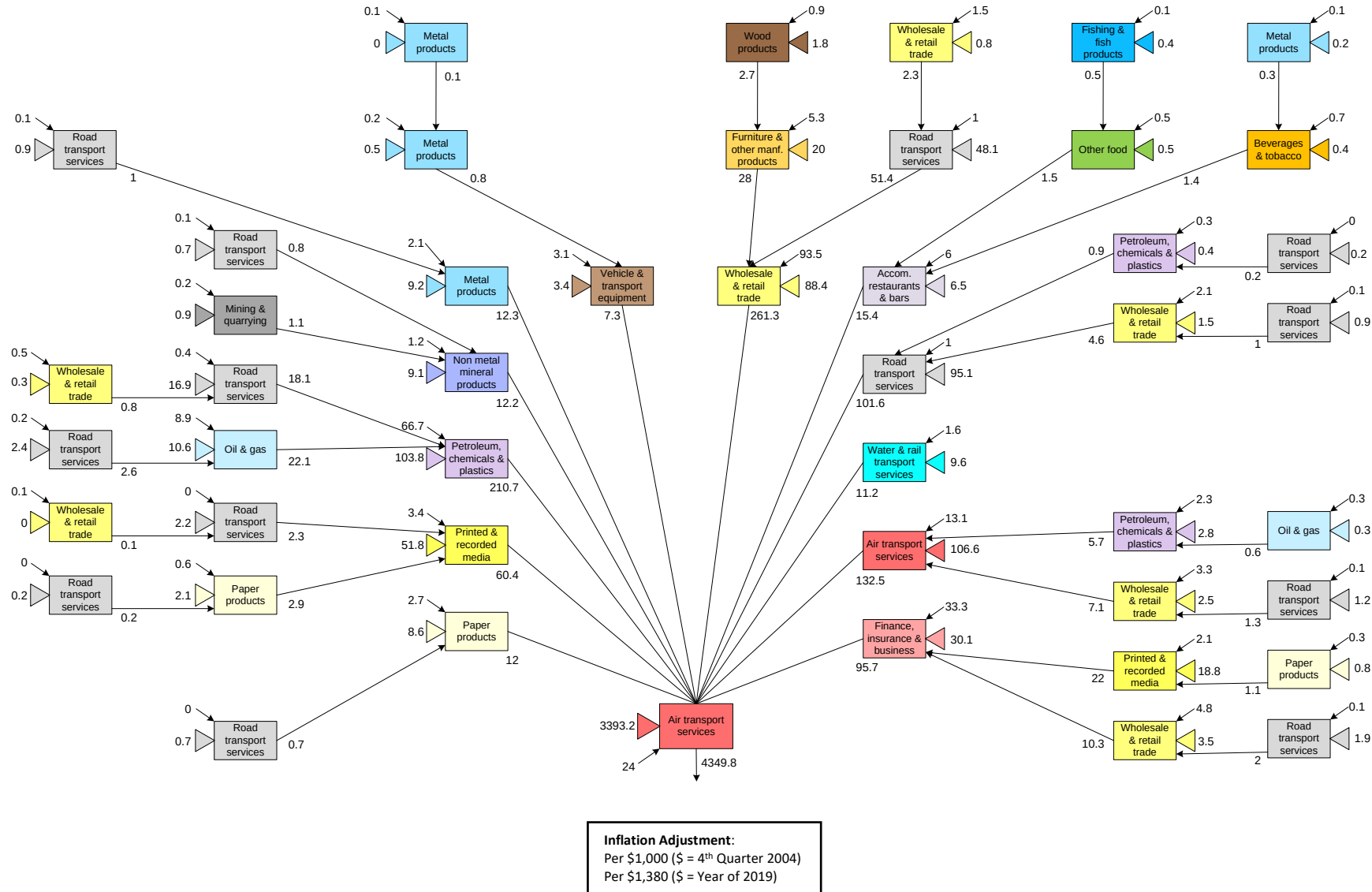


Figure 27.4 - Land Required to Produce \$1,000 Worth of Air Transport Services, 2004 (m²)

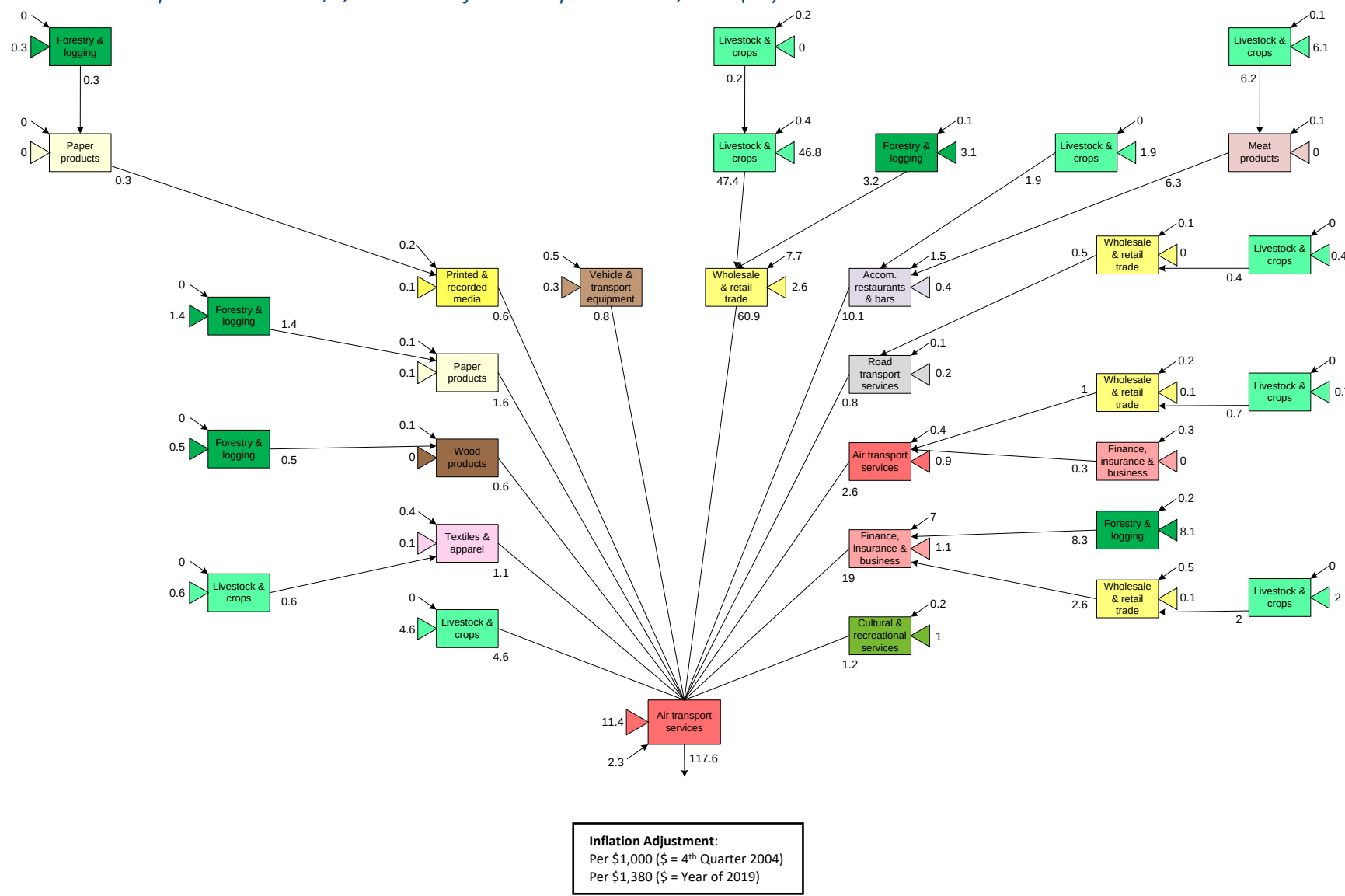


Figure 27.5 - Water Inputs Required to produce \$1,000 Worth of Air Transport Services, 2004 (Litres)

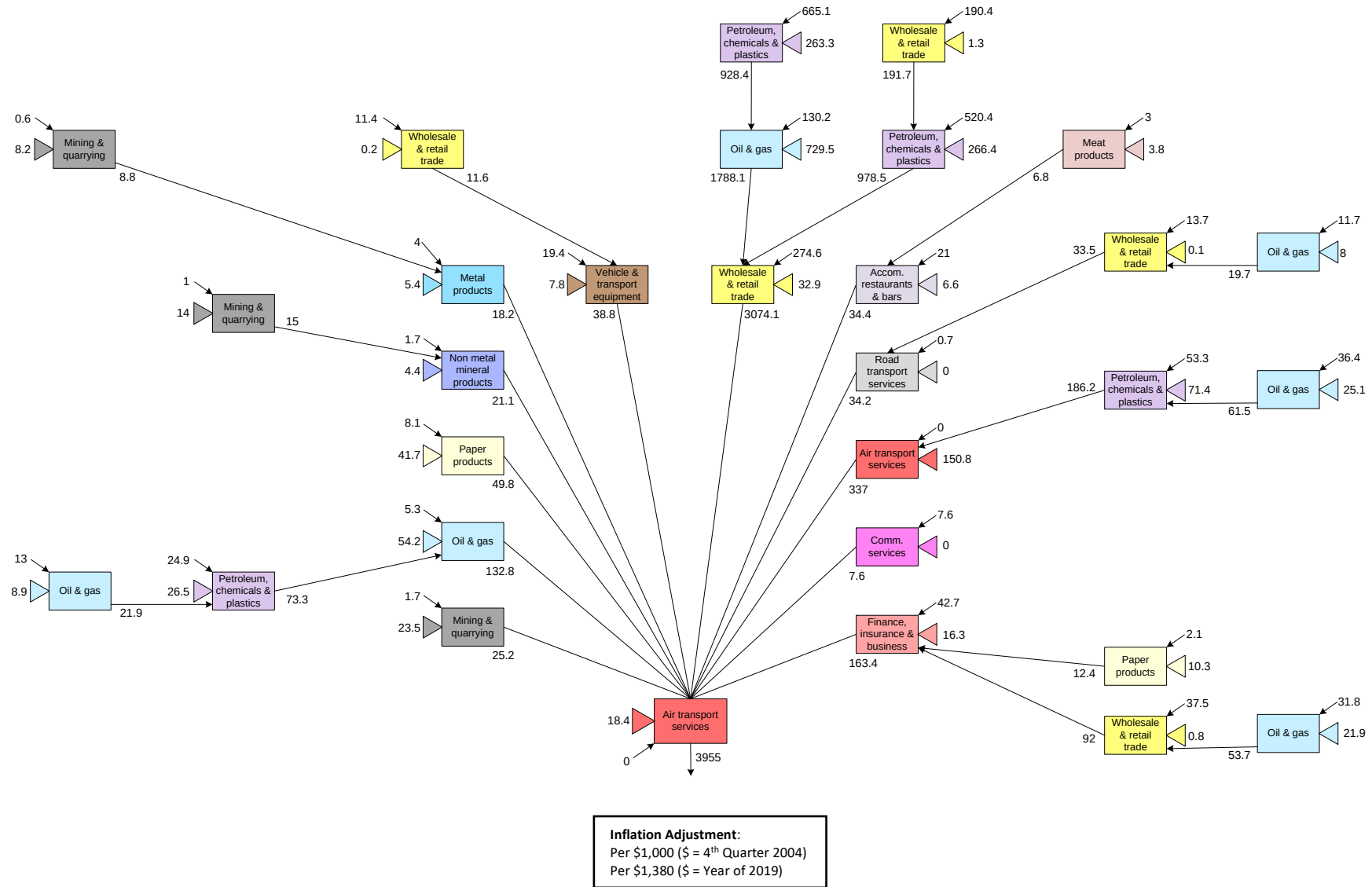


Figure 27.6 - Water Waste Generated in Producing \$1,000 Worth of Air Transport Services, 2004 (Litres)

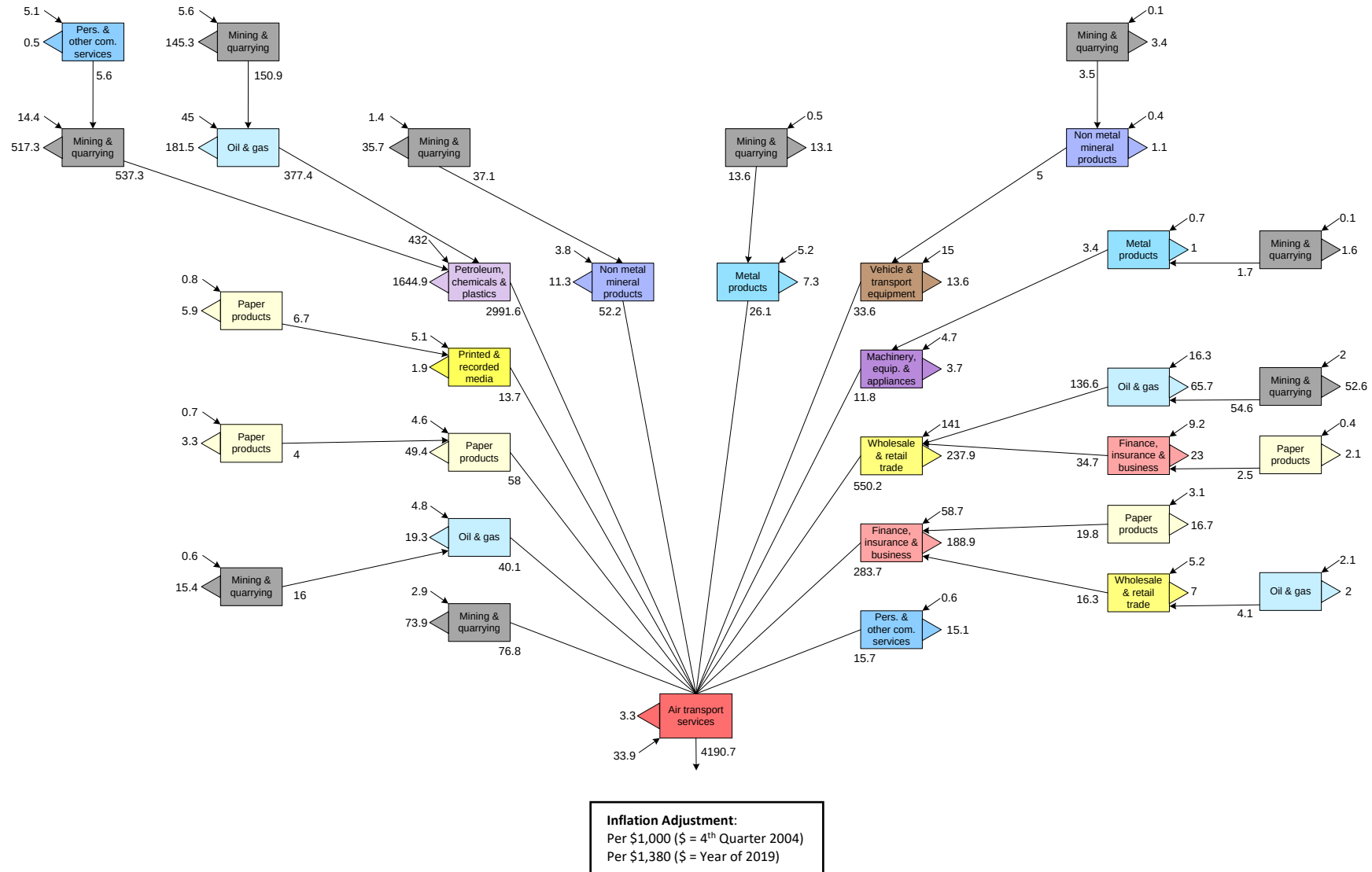
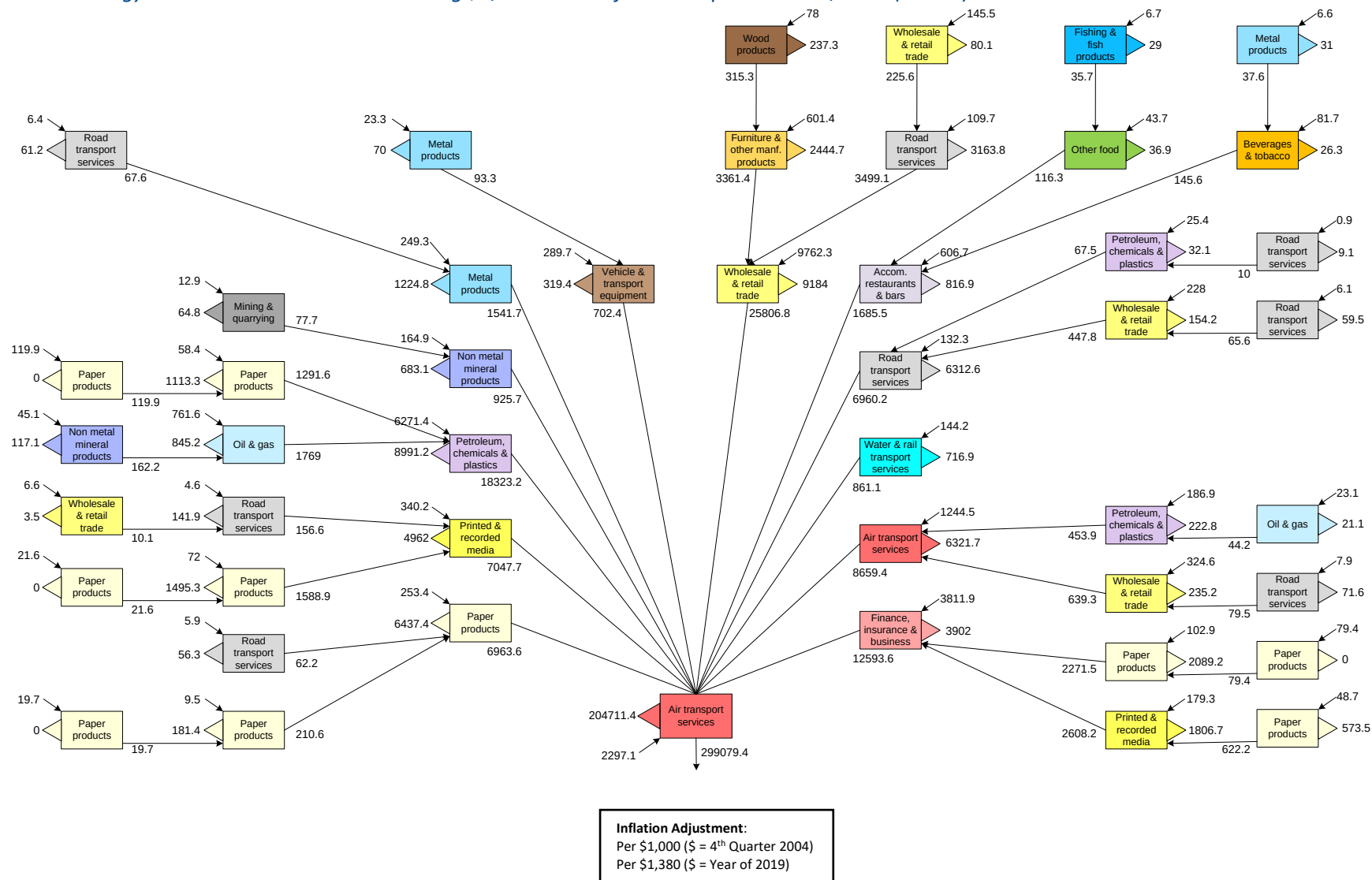


Figure 27.7 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Air Transport Services, 2004 (Grams)



28. Communication Services

Description

ANZSIC Codes covered:

- 5101 – Postal Services
- 5102 – Courier Pick-up and Delivery Services
- 5801 – Wired Telecommunications Network Operation
- 5802 – Other Telecommunications Network Operation
- 5809 – Other Telecommunications Services
- 5910 – Internet Service Providers and Web Search Portals
- 5921 – Data Processing and Web Hosting Services
- 5922 – Electronic Information Storage Services

GDP 2016 = \$6.766 billion
Rank = 8th

Average annual growth rate
2006 to 2016 = 1.23%
Rank = 27th

Employment 2016 = 45,215
Rank = 12th

Main commodities supplied:

- Postal, courier and telecommunication services, including postal and courier services, fixed-line rental, fixed-line international and domestic toll calls, mobile phone calls, and internet usage.

Economic Overview

Telecommunications play a critical role in many areas of New Zealand life. Most industry sectors rely on telecommunications in their day-to-day operations, whether using high-speed Internet connections or a simple telephone. Because of the diverse geography, New Zealanders have become experts in wireless communication and strong consumers of mobile data,²⁸⁵ which is often used to supply remote locations with telecommunication links.²⁸⁶ Furthermore, the Rural Broadband Initiative is aimed at improving broadband availability outside of major areas covered by the Ultra-Fast Broadband Initiative.²⁸⁷ In the 1990s and 2000s, digital telecommunication devices became widely available. Mobile telephones, the smallest and cheapest of the new devices, were rapidly taken up and became standard.²⁸⁸

Both the mobile and broadband markets are dominated by Vodafone NZ and Spark, with the two combining for 73% and 69% of the market share, respectively. Smaller players in each market such as 2degrees in the mobile market and Vocus Communications in the broadband market are also

²⁸⁵ Commerce Commission New Zealand. (2018). *Annual Telecommunications Monitoring Report: 2018 Key Facts*. Wellington. Retrieved from https://comcom.govt.nz/_data/assets/pdf_file/0016/111292/2018-Annual-Telecommunications-Monitoring-Report-18-December-2018.pdf

²⁸⁶ Careers NZ. (n.d). *Telecommunications – Jobs in the Industry*. Retrieved 21/11/2012, from <http://www.careers.govt.nz/default.aspx?id0=20104&id1=EE742A95-CC4D-4D35-9027-2B9F2B6D5128>

²⁸⁷ New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from: <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>

²⁸⁸ Wilson, A. C. (2010). *Telecommunications - Mobile phones*. Retrieved from <http://www.TeAra.govt.nz/en/telecommunications/7>

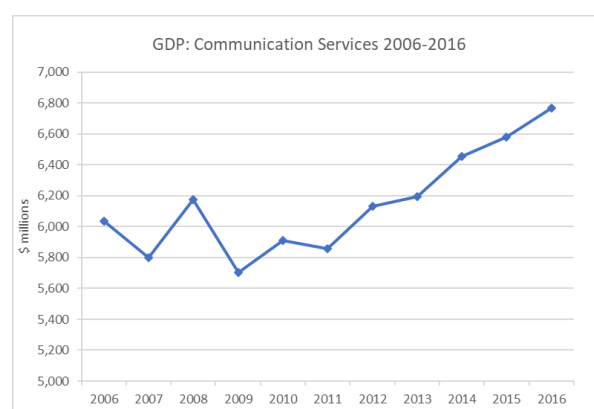
significant contributors, while the rest of the market share is made up of a number of smaller operators.²⁸⁹

However, the increase in production in telecommunications comes at the expense of postal services. Jobs in the postal service have generally declined in recent years, with email a more efficient substitute, though courier services have increased with online ordering becoming increasingly popular.²⁹⁰

Mail volume determines job numbers for people employed in the postal services industry. International trends show that mail volumes are flat or falling in most developed countries, particularly in New Zealand, where letter volume decline has been one of the highest.²⁹¹ This is partly due to the growth of electronic communication such as the internet and email.

An increase in revenues in the postal services industry has been driven by the increase in online shopping and the uptake of e-commerce within New Zealand.^{292 293} This is particularly evident through the increased popularity of Black Friday and Cyber Monday sales in New Zealand. Between 2014 and 2017, NZ Post's annual parcel volume increased by 21%, with a 50% increase seen in November due to Black Friday and Cyber Monday.²⁹⁴

Sector Trends



Similarly to other service sectors, the communications services sector was affected by the GFC, suffering a 7.63% decrease in production. Recovery from the GFC was strong growing 18.62%, from 2009 through to 2016. A small decrease is seen in 2011, this is likely as a result of the catastrophic 2011 Christchurch earthquake, causing immense destruction and disruption to New Zealand's second-largest city at the time. The introduction of 2 Degrees, a telecommunications provider, in 2009, added further competition to this sector and helped drive growth following the GFC. While letter volumes continue to decline, parcel volumes continue to rise. With the rise in online sales and

²⁸⁹ Consumer. (2019, February 15). *Mobile & internet provider satisfaction survey 2019*. Retrieved from <https://www.consumer.org.nz/articles/telco-providers>

²⁹⁰ NZ Post. (2018, August 24). *NZ Post annual results – impacted by continual letter decline*. Retrieved from <https://www.nzpost.co.nz/about-us/media-centre/media-release/nz-post-annual-results-impacted-by-continual-letter-decline>

²⁹¹ Flaws, B. (2019, March 6). *NZ Post hikes letter price as volumes plunge 60 million in a year*. Retrieved from Stuff: <https://www.stuff.co.nz/business/111064863/nz-post-hikes-letter-price-as-volumes-plunge-60-million-in-a-year>

²⁹² Stock, R. (2019, September 27). *NZ Post reports \$121 million loss due to declining letter volumes*. Retrieved from Stuff: <https://www.stuff.co.nz/business/116146097/nz-post-reports-121-million-loss-due-to-declining-letter-volumes>

²⁹³ Shaw, A. (2019, June 24). *New Zealand e-commerce figures hit new highs: Kiwis spent \$4.2 billion online last year*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=12243090

²⁹⁴ NZ Post. (2018, November 20). *NZ Post prepares for huge increase in volumes following Black Friday online sales*. Retrieved from <https://www.nzpost.co.nz/about-us/media-centre/media-release/nz-post-prepares-for-huge-increase-in-volumes-following-black-friday-online-sales>

ongoing investment in processing and delivery technology, revenues in the postal sector will be expected to increase.²⁹⁵ Additionally, the introduction of the 5G network, planned for December 2019 in New Zealand, will improve the efficiency and capability, both of the wider New Zealand economy and of this sector.²⁹⁶

Life Cycle Assessment Diagrams

Energy (Figure 28.1, Figure 28.2, Figure 28.3)

Communication services were found to have a total energy intensity of 560.3 MJ_E per \$1,000 worth of services supplied. The communication services sector is not very energy-intensive, ranking 11th highest out of the 14 service sectors covered in this publication.

Direct energy use for communication services was 38% of the total energy intensity, measuring 211.2 MJ_E per \$1,000 worth of services supplied. The EECA end-use database reports that 1,725.27 TJ of direct end-use energy was used for communication services in New Zealand during the year 2006/07. *Indirect energy* use made up the remaining total at 62%, measuring 349.1 MJ_E per \$1,000 worth of services supplied.

The main indirect energy uses in communication services came from; (i) energy embodied in machinery, equipment and appliances at 109.5 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in finance, insurance and business at 43.7 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in printed and recorded media at 41.1 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in road transport services 35.9 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 28.4)

Communication services have a total land intensity of just 25.7 m² per \$1,000 of services supplied, ranking the sector 13th out of the 14 service sectors covered by this publication. *Direct land use* for communication services was 9% of the total land intensity, measuring 2.3 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 91% measuring 23.4 m² per \$1,000 of communication services supplied.

The major indirect land uses for communication services came from; (i) land embodied in wholesale and retail trade at 7.3 m² per \$1,000 of services supplied; (ii) land embodied in finance, insurance and business services at 6.7 m² per \$1,000 of services supplied (iii) land embodied machinery, equipment and appliances at 3.3 m² per \$1,000 of services supplied; (iv) land embodied in construction at 1.8 m² per \$1,000 of services supplied.

Water Inputs (Figure 28.5)

Communication services use a total of 749.7 litres of water inputs per \$1,000 of services supplied, ranking the sector the 12th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to communication services are *made up entirely of indirect sources*.

These indirect water inputs into the communication services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 392.7 litres per \$1,000 of services supplied; (ii) water inputs

²⁹⁵ New Zealand Post Group. (2016). *Annual Report 2016*. Wellington. Retrieved from <https://www.nzpost.co.nz/sites/default/files/uploads/shared/annual%20reports/2016-nz-post-group-full-year-annual-report.pdf>

²⁹⁶ Griffin, P. (2019, December 10). *5G is live – now what?* Retrieved from Noted: <https://www.noted.co.nz/tech/tech-tech/5g-is-live-now-what>

embodied in machinery, equipment and appliances at 105.9 litres per \$1,000 of services supplied; (iii) water inputs embodied in finance, insurance and business services at 60.1 litres per \$1,000 of services supplied; (iv) water inputs embodied in oil and gas at 45.8 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 28.6)

Communication services were found to generate a total of 2,071.1 grams (2 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the communication services sector is just 4% of total waste produced or 80.2 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 96% or 1,990.9 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for communication services sector came from; (i) landfill wastes embodied in machinery, equipment and appliances at 811.7 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in construction at 227.6 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in wholesale and retail trade at 201.4 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in printed and recorded media at 179.1 grams per \$1,000 of services supplied.

Water Wastes (Figure 28.7)

Communication services were found to produce a total of 1,140.9 litres of wastewater per \$1,000 of services supplied, ranking the sector lowest at 14th out of the 14 service sectors covered by this publication in the production of water wastes. *Wastewater was entirely generated by indirect sources which were mostly made up of (i) wastewater embodied in machinery, equipment and appliances at 396.4 litres per \$1,000 of services supplied; (ii) wastewater embodied in finance, insurance and business services at 243.2 litres per \$1,000 of services supplied; (iii) wastewater embodied in wholesale and retail trade at 132 litres per \$1,000 of services supplied; (iv) wastewater embodied in construction at 95.6 litres per \$1,000 of services supplied.*

Energy Greenhouse Gases (Figure 28.8)

In terms of CO₂ greenhouse gas emissions, communication services emitted a total of 618,207 grams (618 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked lowly, the 13th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. This total CO₂ greenhouse gas emissions figure for communication services is much higher than a previous estimate of 100 kg per \$1,000 worth of services supplied.²⁹⁷

Energy-related CO₂ directly generated by communication services was just 3% of the total CO₂ emitted at 16,551.7 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by communication services makes up the remaining 97% or 601,655.3 grams.

The indirect energy-related CO₂ from communication services was mostly made up of (i) energy-related CO₂ embodied in machinery, equipment and appliances at 12,094.2 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in printed and recorded media at 8,829.9 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in finance, insurance and business services at 5,460.4 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in road transport services at 4,179.5 grams per \$1,000 of services supplied.

²⁹⁷ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

Figure 28.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Communication Services, 2004 (MJ_E, Oil Equivalents)

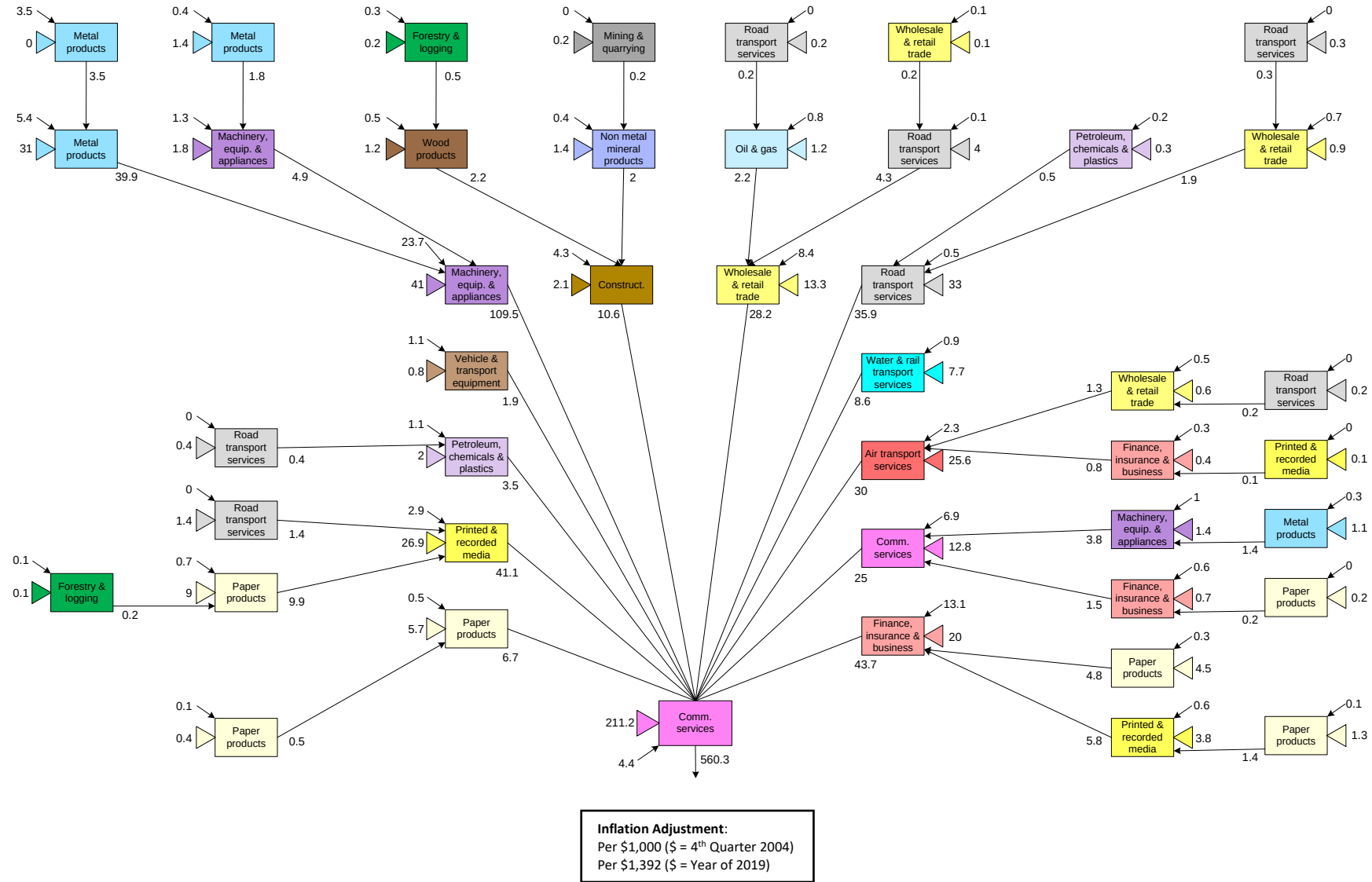
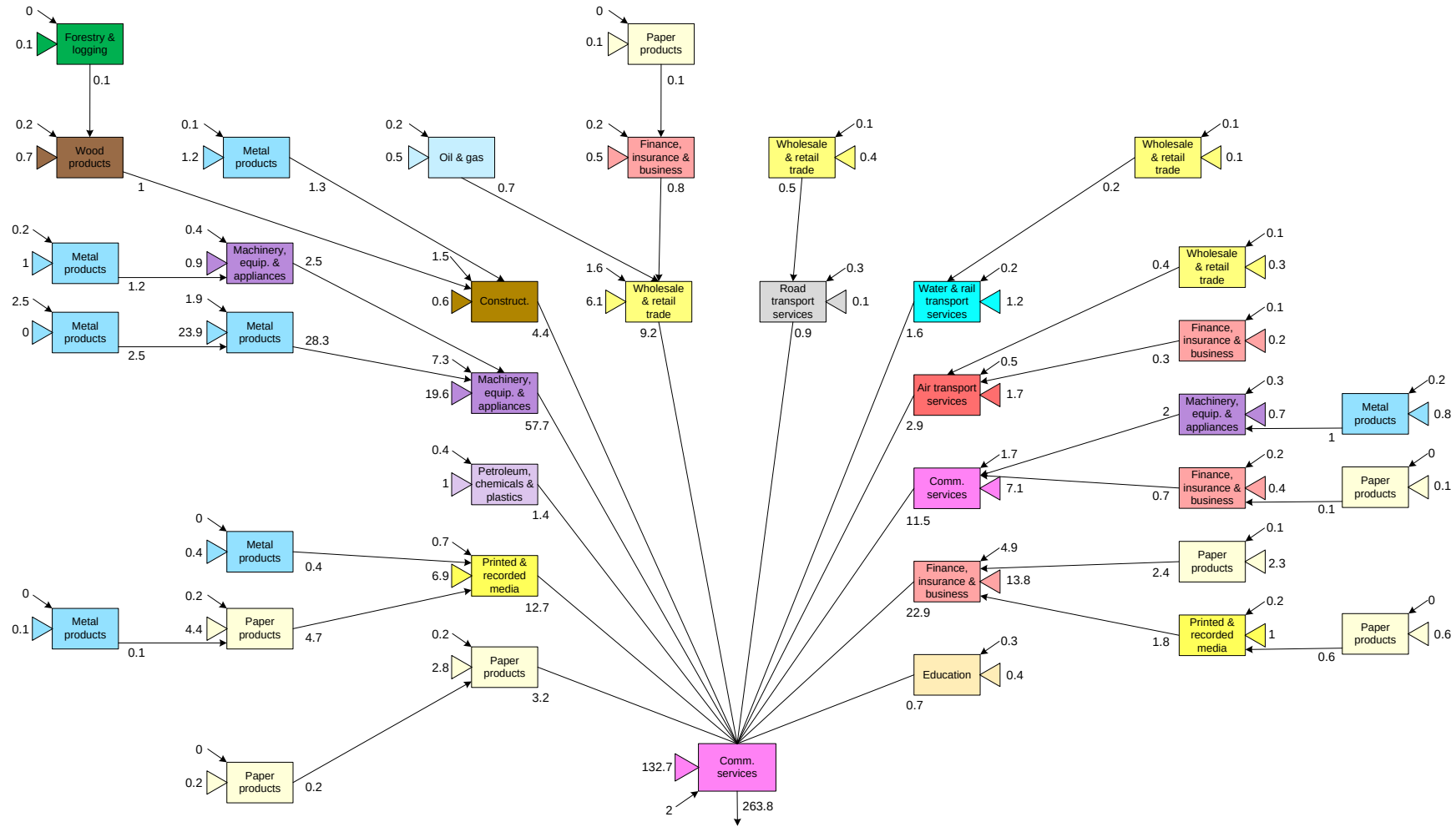


Figure 28.2 - Electricity Inputs Required to Produce \$1,000 Worth of Communication Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 28.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Communication Services, 2004 (MJ, Heat Equivalents)

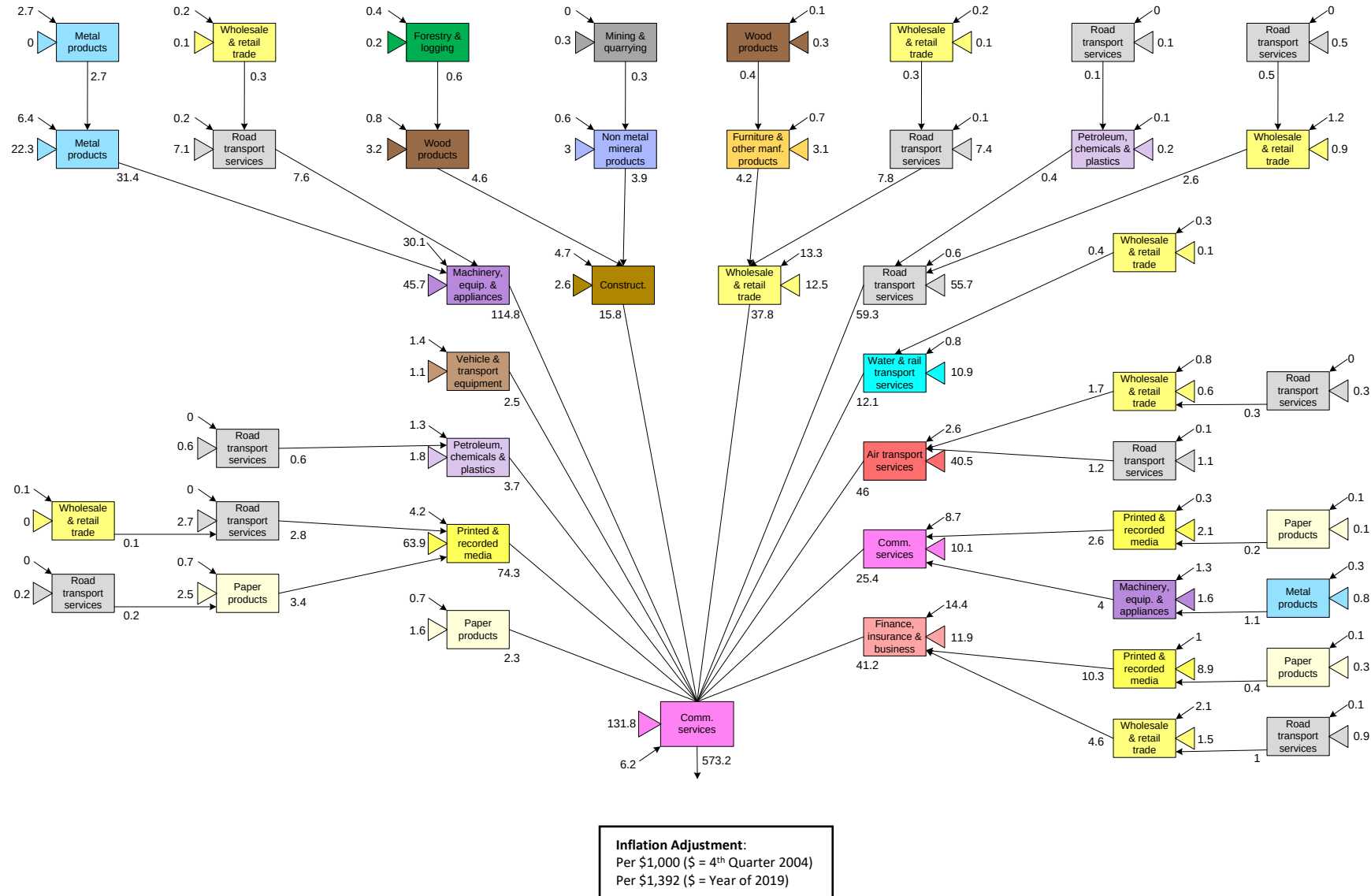


Figure 28.4 - Land Required to Produce \$1,000 Worth of Communication Services, 2004 (m²)

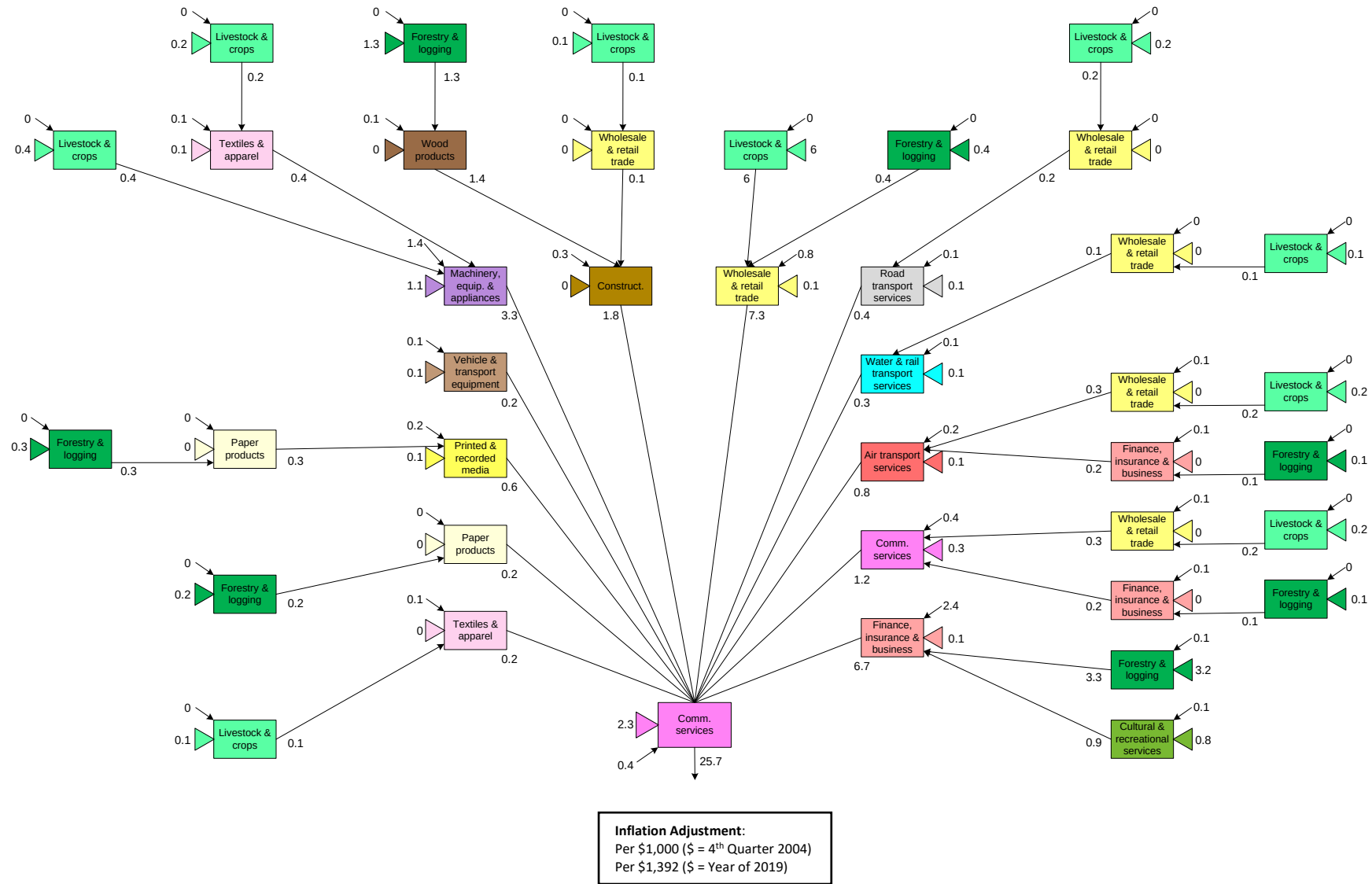


Figure 28.5 - Water Inputs Required to Produce \$1,000 Worth of Communication Services, 2004 (Litres)

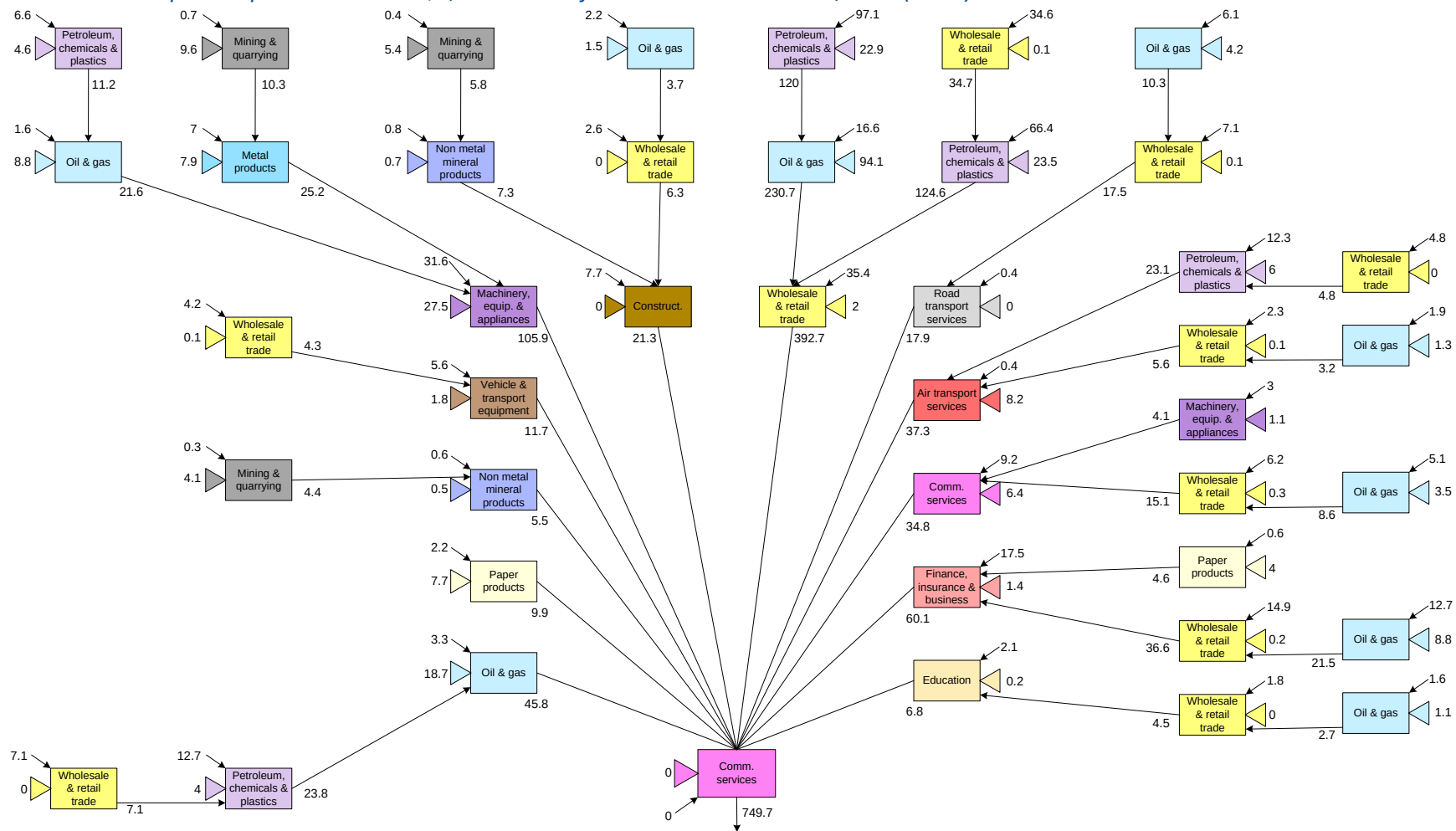
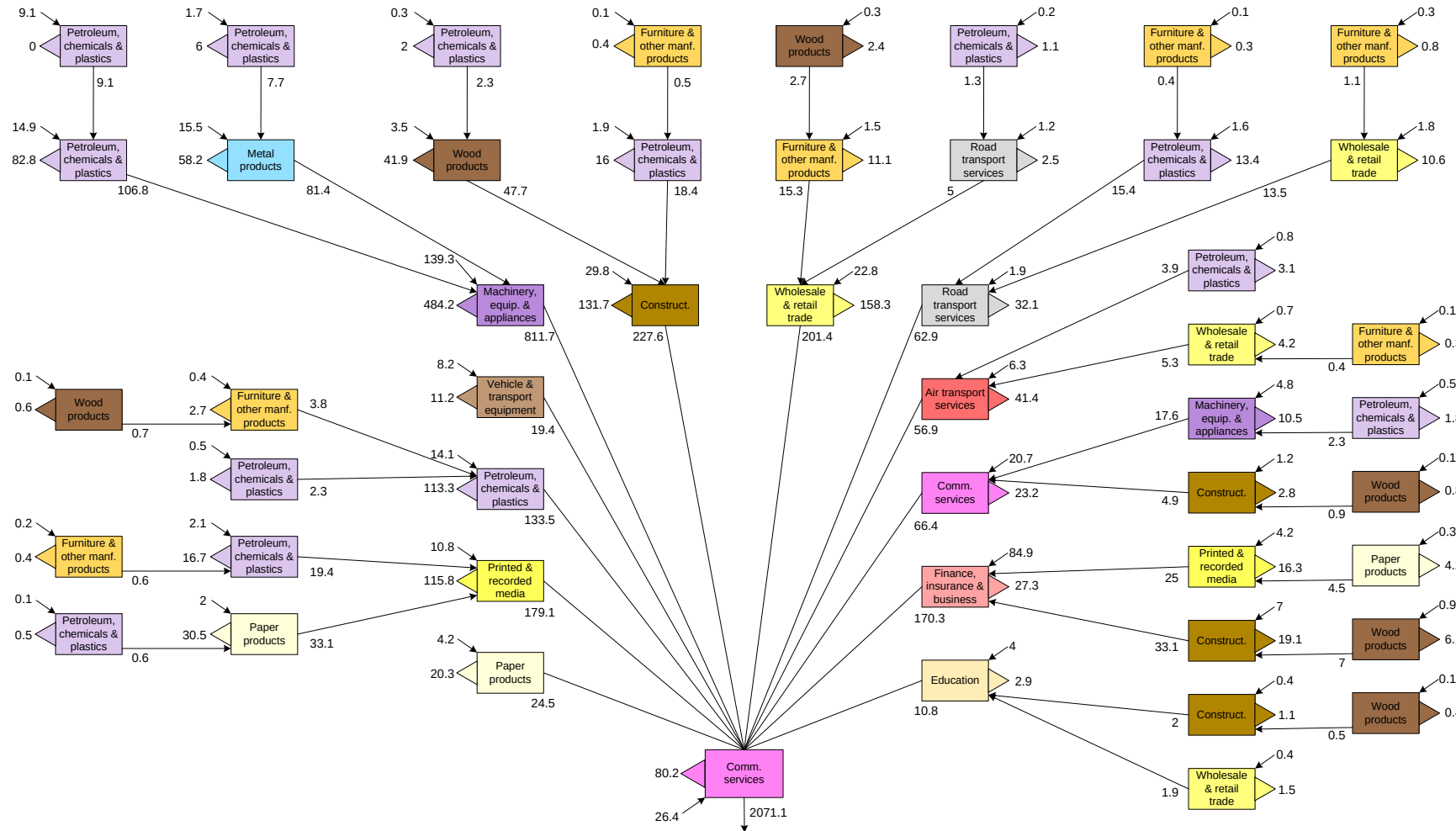


Figure 28.6 - Landfill Waste Generated in Producing \$1,000 Worth of Communication Services, 2004 (Grams)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 28.7 - Water Waste Generated in Producing \$1,000 Worth of Communication Services, 2004 (Litres)

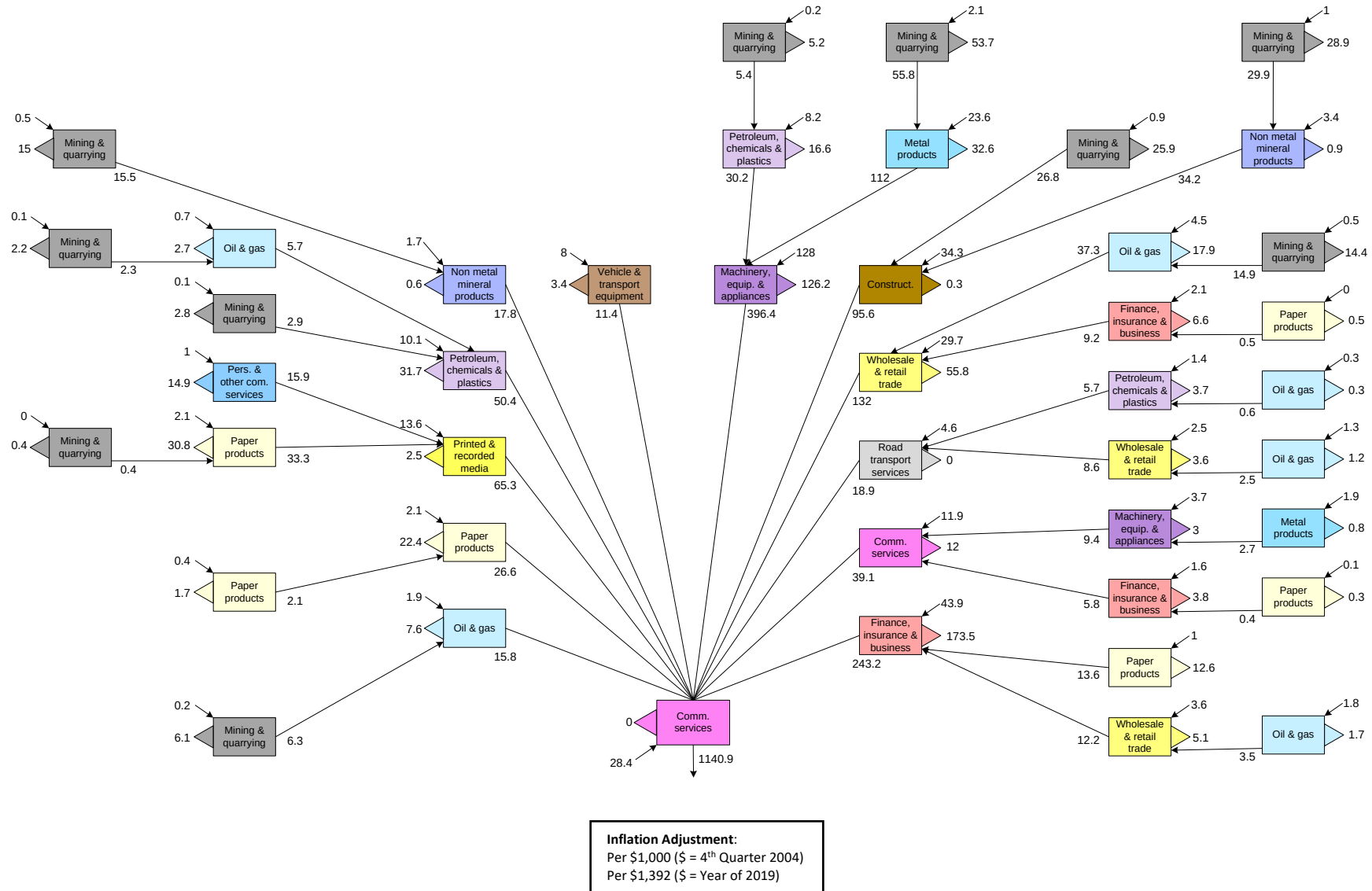
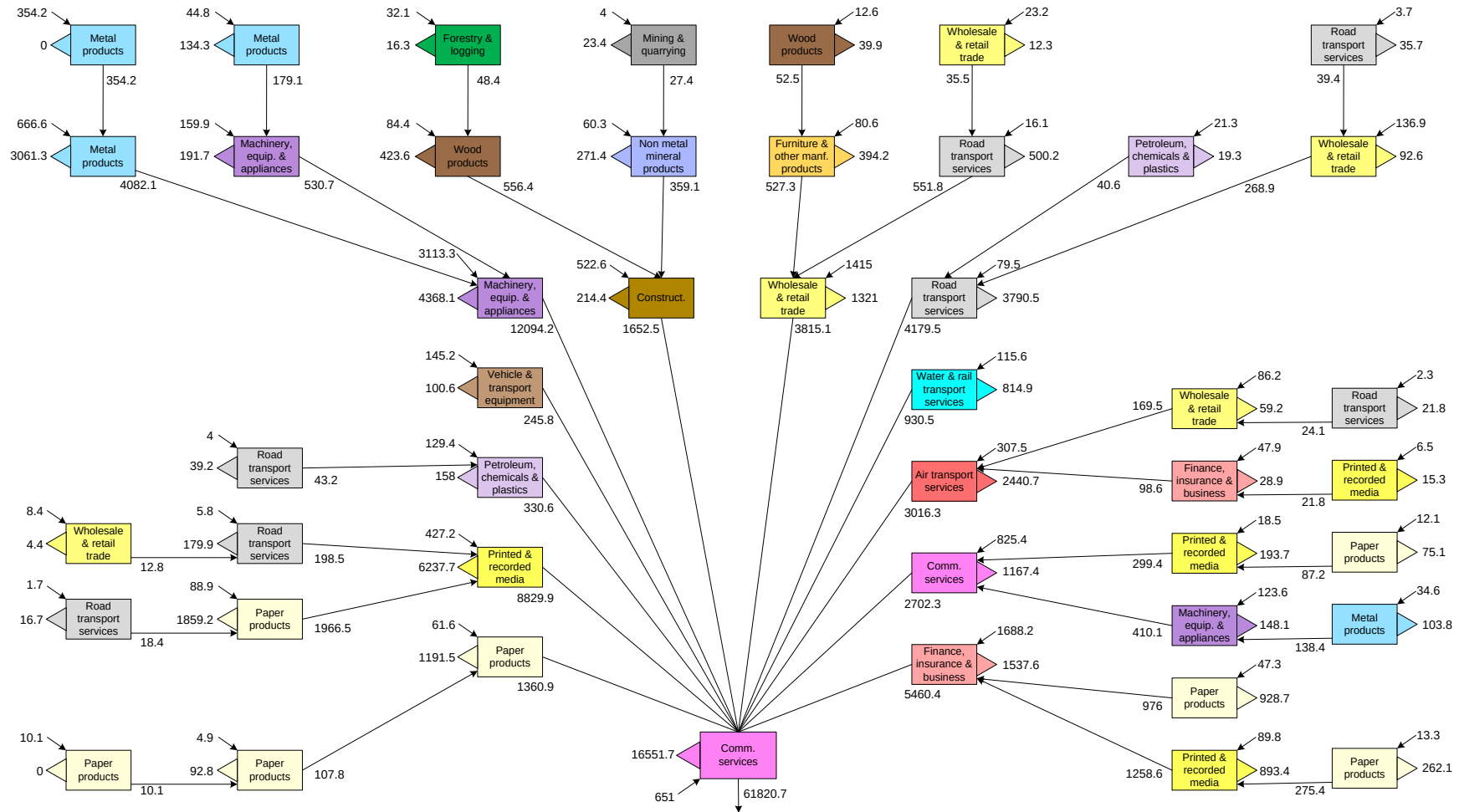


Figure 28.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Communication Services, 2004 (Grams)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

29. Finance, Insurance, Property and Business Services

Description

ANZSIC Codes covered:

- 621 – Central Banking
- 622 – Depository Financial Intermediation
- 623 – Non-Depository Financing
- 624 – Financial Asset Investing
- 631 – Life Insurance
- 632 – Health and General Insurance
- 633 – Superannuation Funds
- 641 – Auxiliary Finance and Investment Services
- 642 – Auxiliary Insurance Services
- 661 – Motor Vehicle and Transport Equipment Rental and Hiring
- 662 – Farm Animal and Bloodstock Leasing
- 663 – Other Goods and Equipment Rental and Hiring
- 664 – Non-Financial Intangible Assets (except Copyrights) Leasing
- 671 – Property Services
- 672 – Real Estate Service

GDP 2016 = \$57.399 billion
Rank = 1st

Average annual growth rate
2006 to 2016 = 5.75%
Rank= 11th

Employment 2016 = 457,585
Rank = 1st

Economic Overview

This sector encompasses a large range of finance, insurance, property and business services which are all crucial to New Zealand's overall economy. It was the largest sector in the economy in 2016, with a GDP of \$57.4 billion, and employed the highest amount of people in 2016, at 457,585. The finance industry contributed 4% to GDP in 2016, illustrating the importance of finance to both the sector and New Zealand's economy overall. It is closely related to the insurance industry and together with all other property and business services they make up the most profitable sector in the economy. The highly competitive nature of the industry has resulted in strategic alliances, particularly between life insurance companies and other financial organisations. For example, many insurance companies now sell their policies through organisations such as banks.

The insurance industry remained steady over the past 20 years. Statistics New Zealand recorded 33 life insurance enterprises in 2019, down from 39 in 2001, following a recent downturn since 2011.²⁹⁸ Some New Zealand insurance business is placed directly offshore. The ability to spread risk through international reinsurance markets has allowed domestic insurers to absorb large increases in business,²⁹⁹ but this also means that the premiums reinsurance companies charge insurance companies directly affect the premiums charged to NZ consumers. Many insurance firms have merged in the last decade and as a result, the main growth areas in insurance have been in customer service

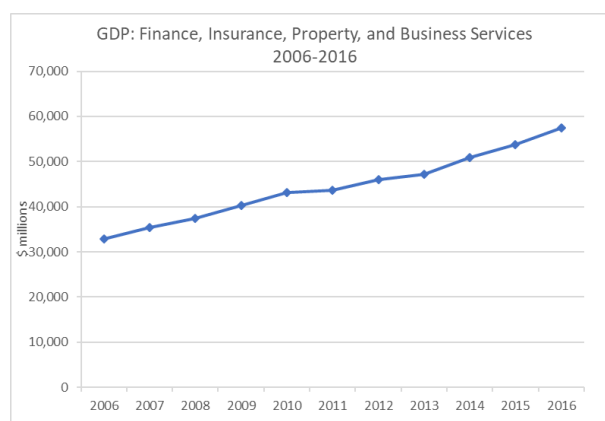
²⁹⁸ Figure.nz. (2019, October 25). *Enterprises in the life insurance industry in New Zealand*. Retrieved from Figure.nz: <https://figure.nz/chart/IW0xisEu03j4YW09-H4hIPzb94VRE4Ytx>

²⁹⁹ Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd. (pp. 457).

and call centre roles. Two crown entities, the Earthquake Commission (EQC) and Accident Compensation Corporation (ACC) provide all New Zealanders coverage against earthquake damage and accidents, and thus private insurance companies do not need to offer packages in these areas.

Most of the banks in New Zealand are internationally owned companies that operate globally. Of the 26 registered banks in New Zealand, only TSB, the Co-operative Bank, and the state-owned Kiwibank are New-Zealand owned. Competition to attract and retain clients has resulted in regular restructuring, mergers and take-overs within the finance and commercial banking industries as companies struggle to gain a share of the market.

Sector Trends



In 2016, the finance, insurance and business services sector was the largest sector in terms of contribution to GDP at \$57.4 billion. Between 2006 and 2016, production in this sector grew steadily, averaging at 5.74% over this time period. As illustrated in the graph above, the upward trend in production can be broken down into two stages. First, between 2006 and 2010, growth was noticeably linear and steep, with a relatively constant growth rate of 7%. The second phase of growth occurred between 2011 and 2015. While production was still increasing during this time, it was doing so at variable growth rates. For example, production grew 2.58% between 2012 and 2013, then 8% the following year. In more recent times, however, production appears to have increased in momentum, as the pace of growth returned to the 7% rate. The period of stagnation seen in 2011, is likely explained by the Christchurch earthquakes. Significant disruptions across many sectors were felt in one of New Zealand's major hubs.

Life Cycle Assessment Diagrams

Energy (Figure 29.1, Figure 29.2, Figure 29.3)

Finance, insurance and business services were found to have a total energy intensity of 655 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 9th highest in out of the 14 service sectors covered in this publication. The EECA end-use database reports that 5,179.37 TJ of direct energy was used for finance, insurance, real estate, and business services in New Zealand during the year 2006/07. Direct energy use makes up 36% of the total energy intensity in the supply of finance, insurance and business services, measuring 238.2 MJ_{OE} per \$1,000 worth of services supplied. Indirect energy use made up the remaining total at 64%, measuring 416.8 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses in finance, insurance and business services came from; (i) energy embodied in paper products at 96 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in printed and recorded media at 79.4 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in wholesale and retail trade at 60.9 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied metal products at 40.9 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 29.4)

Finance, insurance and business services have a total land intensity of just 120.6 m² per \$1,000 of services supplied, ranking the sector 8th highest out of the 14 service sectors covered by this publication. *Direct land use* for finance, insurance and business services was minuscule at just 0.5% of the total land intensity, measuring 0.6 m² per \$1,000 of services supplied. *Indirect land use* makes up the majority of total land use at 99.5% measuring 120 m² per \$1,000 of finance, insurance and business services supplied.

The major indirect land uses for finance, insurance and business services came from; (i) land embodied in forestry and logging at 49.6 m² per \$1,000 of services supplied; (ii) land embodied in wholesale and retail trade at 20.2 m² per \$1,000 of services supplied; (iii) land embodied in cultural and recreational services at 14.7 m² per \$1,000 of services supplied; (iv) land embodied in textile and apparels at 11.4 m² per \$1,000 of services supplied.

Water Inputs (Figure 29.5)

Finance, insurance and business services use a total of 1,329.6 litres of water inputs per \$1,000 of services supplied, ranking the sector the 11th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to finance, insurance and business services are made up mostly of indirect sources, with *direct sources* only contributing 1%, or 11.2 litres per \$1,000 of services supplied. *While indirect sources of water inputs* make up the remaining 99% of the total, at 1,318.4 litres per \$1,000 of services supplied.

These indirect water inputs into the finance, insurance and business services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 833.7 litres per \$1,000 of services supplied; (ii) water inputs embodied in paper products at 121 litres per \$1,000 of services supplied; (iii) water inputs embodied in oil and gas at 55.6 litres per \$1,000 of services supplied; (iv) water inputs embodied in cultural and recreational services at 50 litres per \$1,000 of services supplied

Landfill Wastes (Figure 29.6)

Finance, insurance and business services were found to generate a total of 2,993.1 grams (2.9 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the finance, insurance and business services sector is 11% of total waste produced or 337.6 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 89% or 2,655.5 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for finance, insurance and business services sector came from; (i) landfill wastes embodied in wholesale and retail trade at 462.9 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in construction services at 428.6 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in printed and recorded media at 367 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in petroleum, chemicals and plastics at 354 grams per \$1,000 of services supplied.

Water Wastes (Figure 29.7)

Finance, insurance and business services were found to produce a total of 3,843.5 litres of wastewater per \$1,000 of services supplied, ranking the sector the 12th highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated* by the finance, insurance and business services sector accounted for 60% of total water wastes or 2,287.5 litres per \$1,000 of services supplied. *Indirect sources of water wastes* accounted for the remaining 40% of total water wastes or 1,556 litres per \$1,000 of services supplied.

The main sources of indirect sources of water wastes were mostly made up of (i) wastewater embodied in paper products at 329.1 litres per \$1,000 of services supplied; (ii) wastewater embodied in wholesale and retail trade at 266.5 litres per \$1,000 of services supplied; (iii) wastewater embodied in construction services at 144.2 litres per \$1,000 of services supplied; (iv) wastewater embodied in non-metal mineral products at 134.9 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 29.8)

In terms of CO₂ greenhouse gas emissions, finance, insurance and business services emitted a total of 85,064.8 grams (85 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked as the 11th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. *Energy-related CO₂ directly generated* by finance, insurance and business services was 21% of the total CO₂ emitted at 18,136 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by finance, insurance and business services makes up the remaining 79% or 66,928.8 grams.

The indirect energy-related CO₂ from finance, insurance and business services was mostly made up of (i) energy-related CO₂ embodied in paper products at 19,284.5 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in printed and recorded media at 17,120.8 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in wholesale and retail trade at 8,276.2 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in metal products at 4,359.7 grams per \$1,000 of services supplied.

Inflation Rate

Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,492 (\$ = Year of 2019)

Figure 29.2 - Electricity Inputs Required to Produce \$1,000 Worth of Finance, Insurance and Business Services, 2004 (MJ, Heat Equivalents)

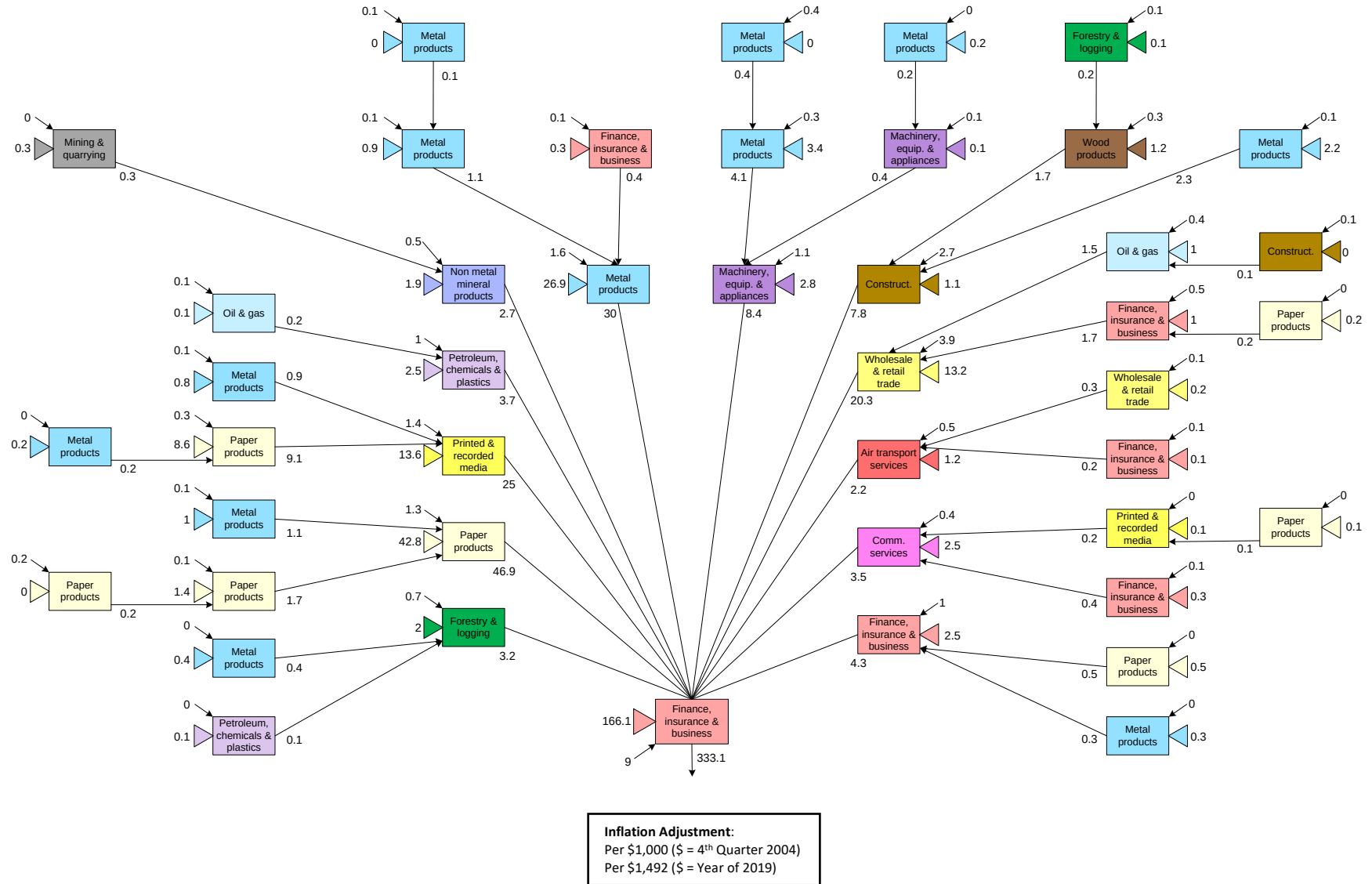


Figure 29.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Finance, Insurance and Business Services, 2003-04 (MJ, Heat Equivalents)

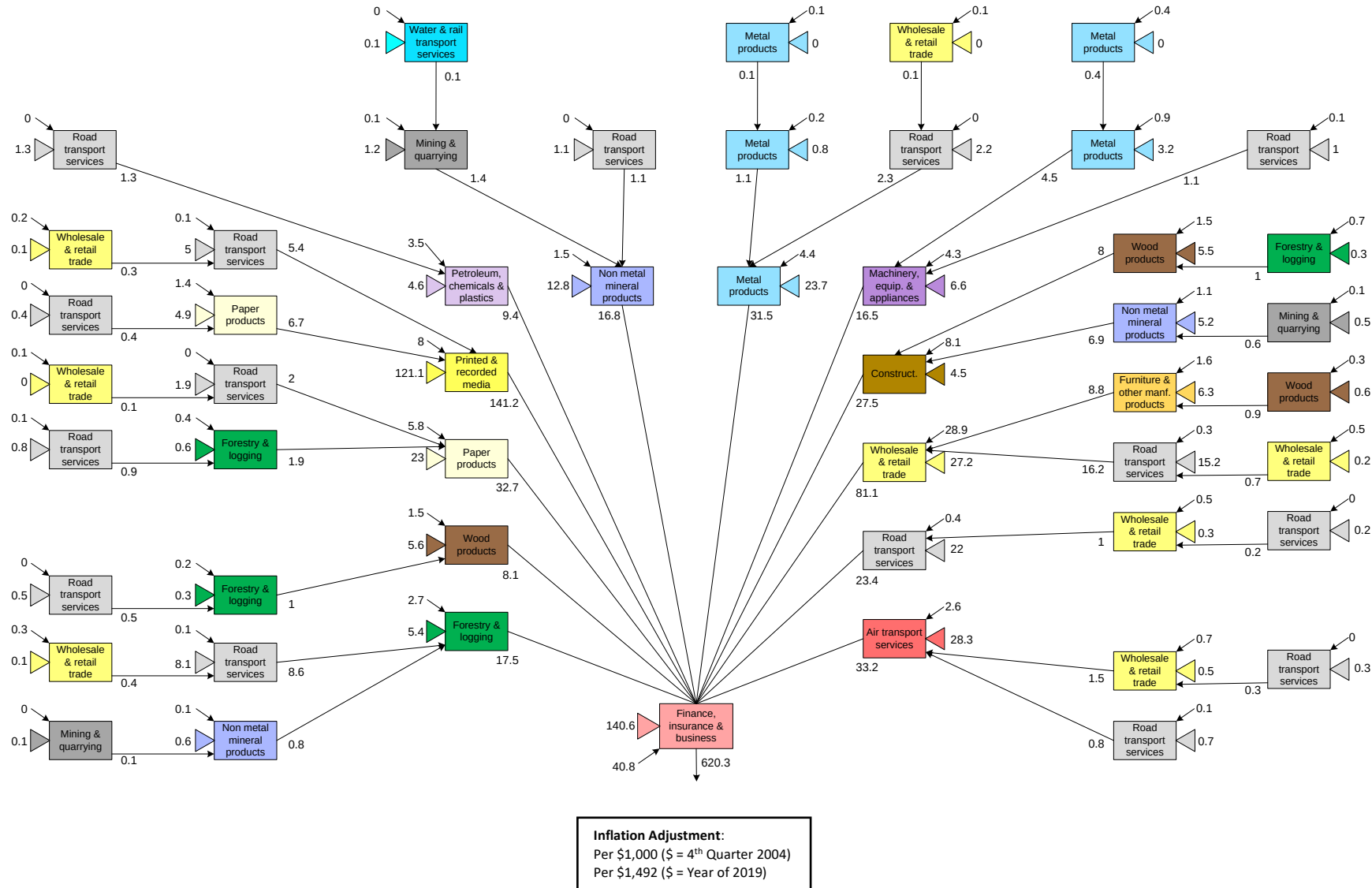


Figure 29.4 - Land Required to Produce \$1,000 Worth of Finance, Insurance and Business Services, 2004(m²)

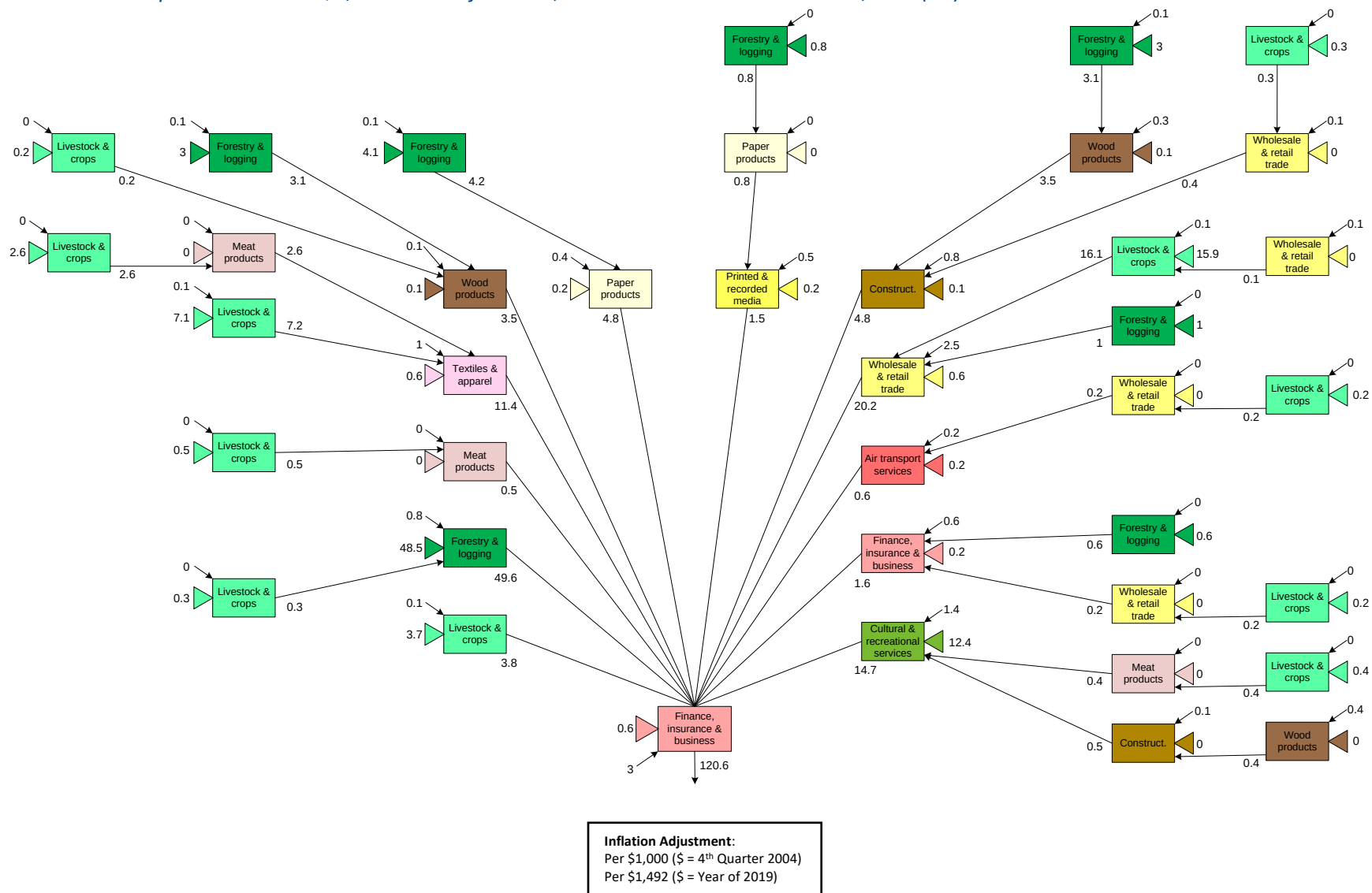


Figure 29.5 - Water Inputs Required to Produce \$1,000 Worth of Finance, Insurance and Business Services, 2004 (Litres)

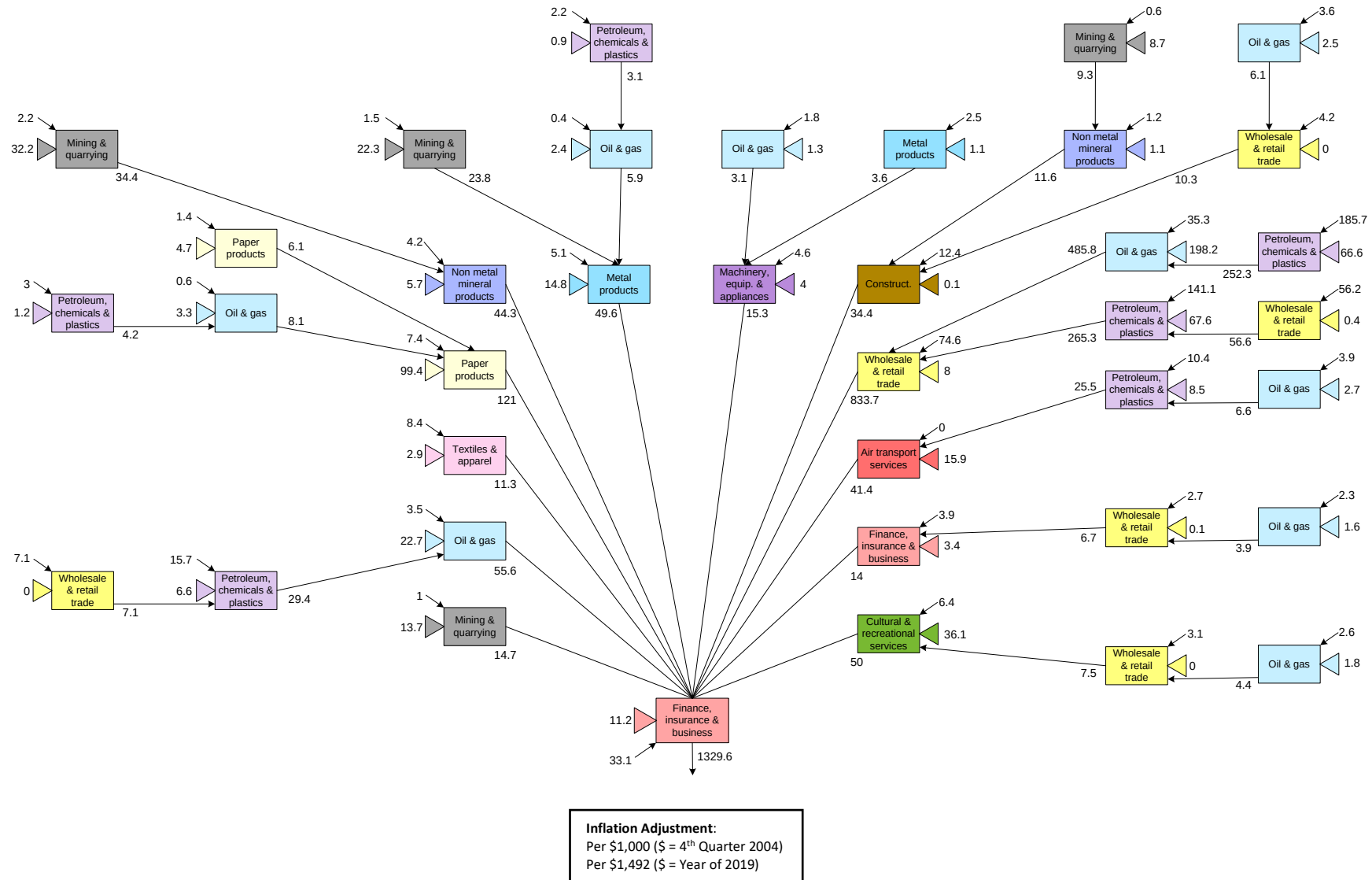


Figure 29.6 - Landfill Waste Generated in Producing \$1,000 Worth of Finance, Insurance and Business Services, 2004 (Grams)

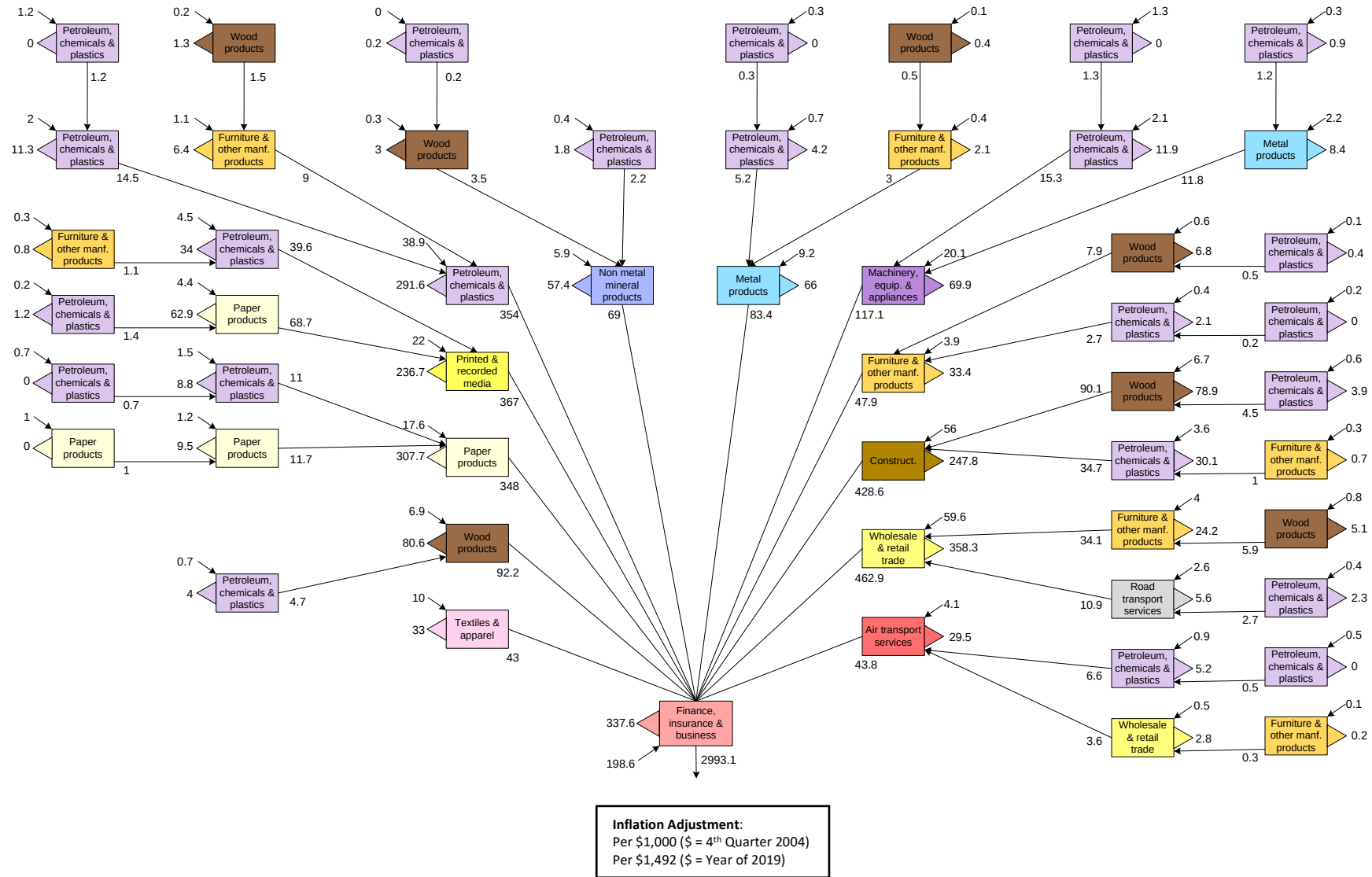


Figure 29.7 - Water Waste Generated in Producing \$1,000 Worth of Finance, Insurance and Business Services, 2004 (Litres)

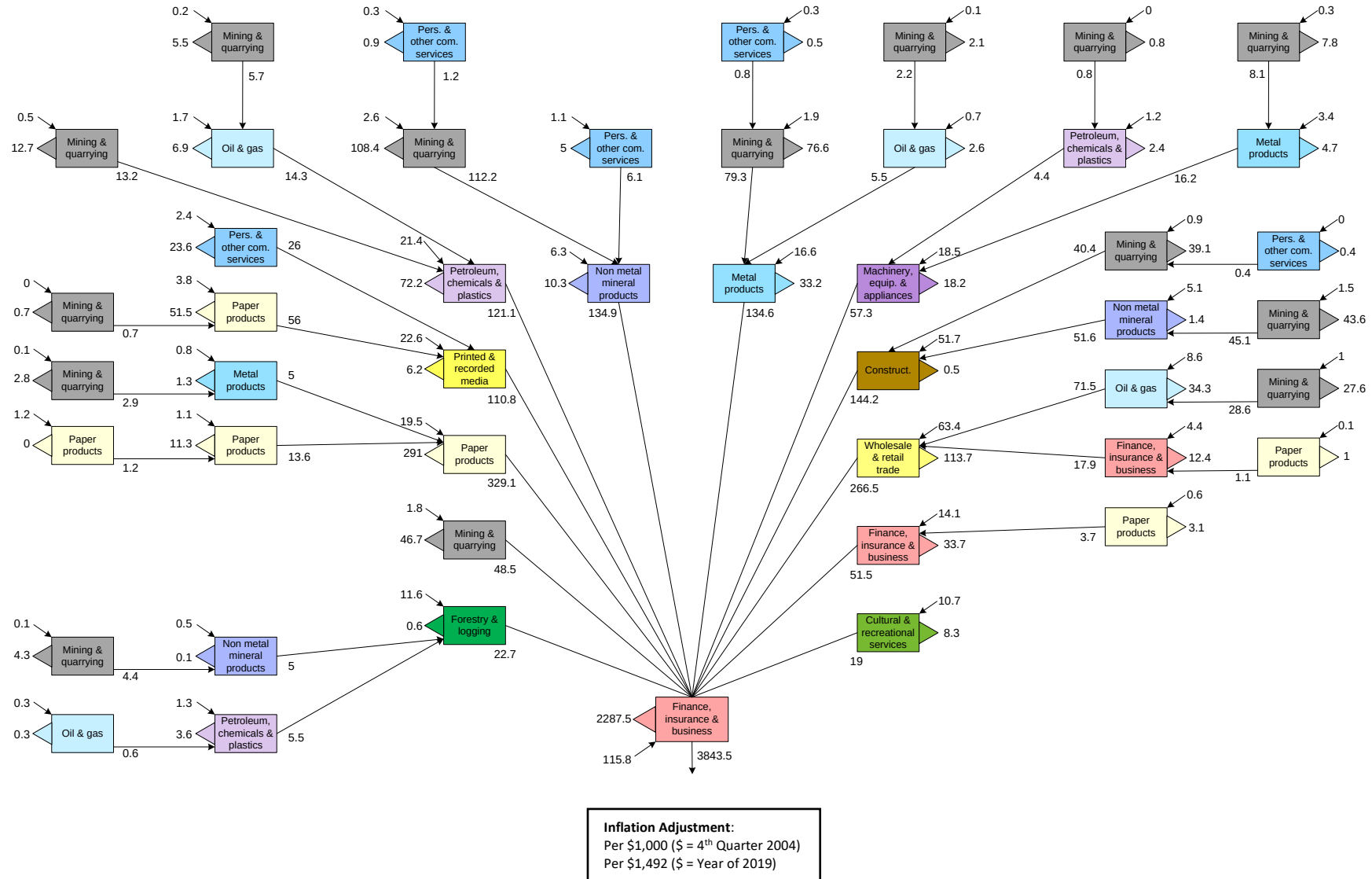
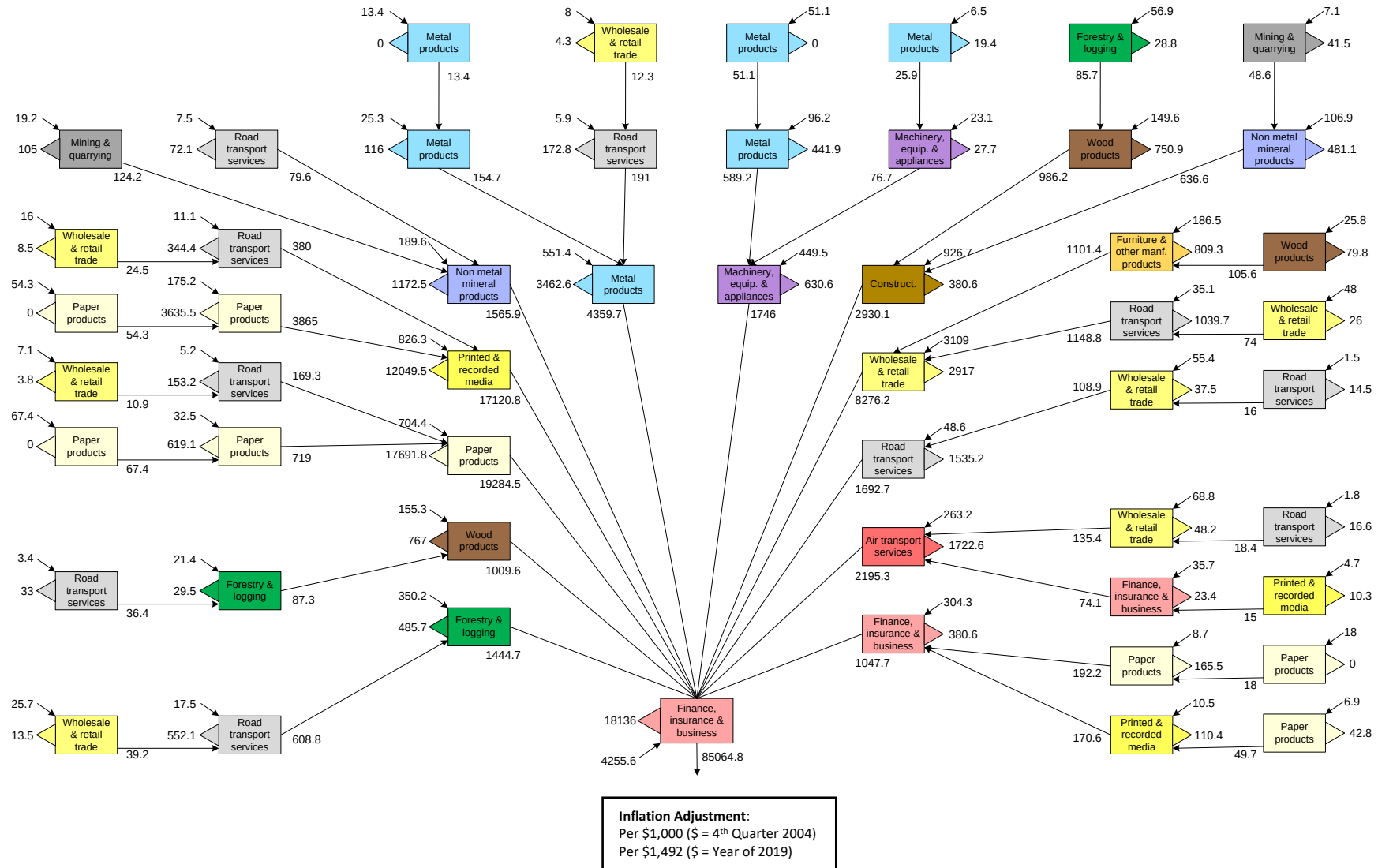


Figure 29.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Finance, Insurance and Business Services, 2004 (Grams)



30. Central Government Administration and Defence

Description

ANZSIC Codes covered:

- 7510 – Central Government Administration
- 7540 – Justice
- 7551 – Domestic Government Representation
- 7552 – Foreign Government Representation
- 7600 – Defence
- 7711 – Police Services
- 7712 – Investigation and Security Services
- 7713 – Fire Protection and Other Emergency Services
- 7714 – Correctional and Detention Services
- 7719 – Other Public Order and Safety Services
- 7720 – Regulatory Services

GDP 2016 = \$9.118 billion

Rank = 6th

Average annual growth rate

2006 to 2016 = 4.62%

Rank = 16th

Employment 2016 = 96,474

Rank = 7th

Main commodity supplied:

- Central government administration services, public order, safety, and defence

Economic Overview

New Zealand is a sovereign state with a democratic parliamentary government based on the Westminster system, and its constitutional history dates back to the signing of the Treaty of Waitangi in 1840. The role of government administration, or more broadly the state sector, is to implement central, state and local government policy decisions to deal with issues relevant to New Zealand and its people.³⁰⁰ It is responsible for drafting the laws and regulations that govern the whole of New Zealand.³⁰¹

Two government agencies oversee defence in New Zealand, the Ministry of Defence and the New Zealand Defence Force (NZDF). The Ministry is a civilian organisation that advises the Government about defence policy and funds the purchase of new equipment, while the NZDF runs the three branches of the defence force: NZ Army, Royal NZ Navy and Royal NZ Air Force. The government maintains the defence sector to defend the country's people and resources, assist with international peacekeeping, humanitarian missions, maintain security in the south pacific, as well as to help with disaster relief.³⁰² New Zealand has a strong history of contributing to international peacekeeping

³⁰⁰ The University of Auckland. (n.d). *Government*. Retrieved 23/11/2012, from <http://www.auckland.ac.nz/uoa/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-government>

³⁰¹ Mossman, E., Mayhew, P. (2007). *Central Government Aims and Local Government Responses: The Prostitution Reform Act 2003*. Retrieved from <http://www.justice.govt.nz/policy/commercial-property-and-regulatory/prostitution/prostitution-law-review-committee/publications/central-local-govt-responses/documents/report.pdf>

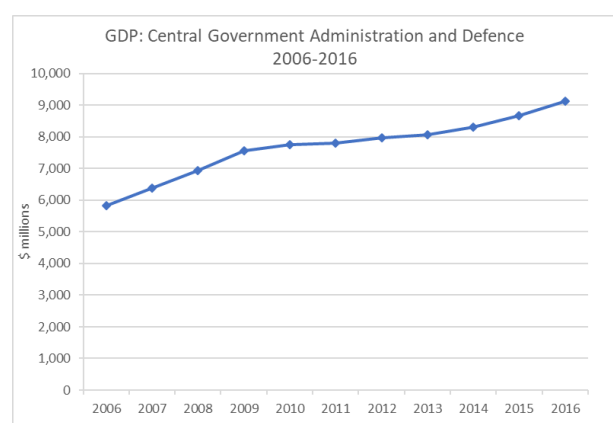
³⁰² The University of Auckland. (n.d). *Defence*. Retrieved 23/11/2012, from <http://www.auckland.ac.nz/uoa/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-defence>

missions to resolve conflict. The NZDF has served in many places around the world, most notably Afghanistan, Balkans, East Timor, and the Solomon Islands.³⁰³

The Ministry of Justice is the lead agency in the justice sector. The different branches of the justice sector collaborate to reduce crime and enhance public safety; and to provide access to justice by delivering modern, effective and affordable services.³⁰⁴

The government administration and defence industry are important employers in New Zealand, employing 96,474 (around 4% of New Zealand's total workforce) in 2016, making the sector the 7th biggest employer in that year. Employment in the government administration and defence industry has experienced strong growth over the last decade, consistent with other sectors throughout the economy.³⁰⁵ In 2016, this sector contributed \$9.118 billion to GDP, making it the 6th biggest sector in the economy.

Sector Trends



Between 2006 and 2016, the contribution of the central government and defence services sector to national GDP has maintained an upward trajectory, with a positive growth rate throughout this period. Overall, the sector's contribution rose 56.6% from \$5.83 billion in 2006 to \$9.12 billion in 2016. From the graph above, the sector's contribution can be disaggregated into three distinct phases of growth. First, between 2006 and 2009, the sector's GDP contribution grew by 9% p.a. on average, which is the fastest annual growth rate recorded over this 10-year period. In 2009, however, the sector's contribution was recorded at \$7.55 billion and grew by just 1.7% p.a. on average over the next four years, the second phase of growth, this phase covers the recovery period from the late 2008 GFC and 2011 Christchurch earthquakes. The final and current phase began in 2013 when the sector's contribution rose more rapidly, as the growth rate increased to 4.2% p.a. on average, this surge in growth coincides with the Christchurch rebuild. It is likely that this resurgence will continue in the near future until the sector reaches either a peak or turning point (i.e. an acceleration/deceleration in the growth rate).

³⁰³ Rolfe, J. (2012). *Armed Forces - Partnerships and international deployments*. Retrieved from <http://www.TeAra.govt.nz/en/armed-forces/4>

³⁰⁴ Ministry of Justice. (n.d). About the Justice Sector. Retrieved 26/11/2012, from <http://www.justice.govt.nz/justice-sector/about-the-justice-sector>

³⁰⁵ Department of Labour. (2009). *Employment and Skills Snapshot – Government Administration and Defence*. Retrieved from <http://www.dol.govt.nz/services/LMI/tools/skillsinsight/snapshots/government/government.pdf>

Life Cycle Assessment Diagrams

Energy (Figure 30.1, Figure 30.2, Figure 30.3)

Central government administration and defence services were found to have a total energy intensity of 1,803 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 7th highest out of the 14 service sectors covered in this publication. This represents 2,867 MJ_H per \$1,000 worth of services, when measured in conventional energy units. This total energy figure for central government administration and defence services is within range of a previous estimate of 2,026 MJ_H per \$1,000 worth of services supplied.³⁰⁶

Direct energy use for central government administration and defence services was 45% of the total energy intensity, measuring 807.5 MJ_{OE} per \$1,000 worth of services supplied. The EECA end-use database reports that 1,195.278 TJ of direct energy was used for central government administration services, and 1,301.560 TJ of direct energy was used for defence services in New Zealand during the year 2006/07. *Indirect energy* use made up the remaining total at 55%, measuring 995.5 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses in central government administration and defence services came from; (i) energy embodied in wholesale and retail trade at 206.2 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in finance, insurance and business services at 161.2 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in printed and recorded media at 91.5 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in construction services at 89.1 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 30.4)

Central government administration and defence services have a total land intensity of just 349.7 m² per \$1,000 of services supplied, ranking the sector 5th highest out of the 14 service sectors covered by this publication. *Direct land use* for central government administration and defence services was 35% of the total land intensity, measuring 121.4 m² per \$1,000 of services supplied. *Indirect land use* makes up the remaining total land use at 65% measuring 228.3 m² per \$1,000 of central government administration and defence services supplied.

The major indirect land uses for central government administration and defence services came from; (i) land embodied in wholesale and retail trade at 76.8 m² per \$1,000 of services supplied; (ii) land embodied in finance, insurance and business services at 34.9 m² per \$1,000 of services supplied; (iii) land embodied in accommodation, restaurants and bars at 26.6 m² per \$1,000 of services supplied; (iv) land embodied in construction services at 22.3 m² per \$1,000 of services supplied.

Water Inputs (Figure 30.5)

Central government administration and defence services use a total of 4,251.9 litres of water inputs per \$1,000 of services supplied, ranking the sector the 6th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to central government administration and defence services are made up mostly of indirect sources, with *direct sources* only contributing 4% or

³⁰⁶ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

189.2 litres per \$1,000 of services supplied. *While indirect sources of water inputs make up the remaining 96% of the total, at 4,062.7 litres per \$1,000 of services supplied.*

These indirect water inputs into the central government administration and defence services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 2,502.3 litres per \$1,000 of services supplied; (ii) water inputs embodied in oil and gas at 491.7 litres per \$1,000 of services supplied; (iii) water inputs embodied in mining and quarrying at 203.6 litres per \$1,000 of services supplied; (iv) water inputs embodied in finance, insurance and business services at 193.1 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 30.6)

Central government administration and defence services were found to generate a total of 10,033.1 grams (10 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated by the Central government administration and defence services sector is 24% of total waste produced or 2,412.3 grams per \$1,000 of services supplied. While landfill waste indirectly generated was 76% or 7,620.8 grams per \$1,000 of services supplied.*

The main sources of indirect landfill waste for central government administration and defence services sector came from; (i) landfill wastes embodied in construction services at 1,742.9 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in petroleum, chemicals and plastics at 1,498.2 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in wholesale and retail trade at 1,352.4 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in finance, insurance and business at 549.8 grams per \$1,000 of services supplied.

Water Wastes (Figure 30.7)

Central government administration and defence services were found to produce a total of 9,103.7 litres of wastewater per \$1,000 of services supplied, ranking the sector the 5th highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated by the central government administration and defence services sector accounted for just 4% of total water wastes or 408.5 litres per \$1,000 of services supplied. Indirect sources of water wastes accounted for the remaining 96% of total water wastes or 8,695.2 litres per \$1,000 of services supplied.*

The main sources of indirect sources of water wastes were mostly made up of (i) wastewater embodied in personal and other community services at 3,705 litres per \$1,000 of services supplied; (ii) wastewater embodied in wholesale and retail trade at 900 litres per \$1,000 of services supplied; (iii) wastewater embodied in finance, insurance and business services at 818.1 litres per \$1,000 of services supplied; (iv) wastewater embodied in construction services at 747.6 litres per \$1,000 of services supplied.

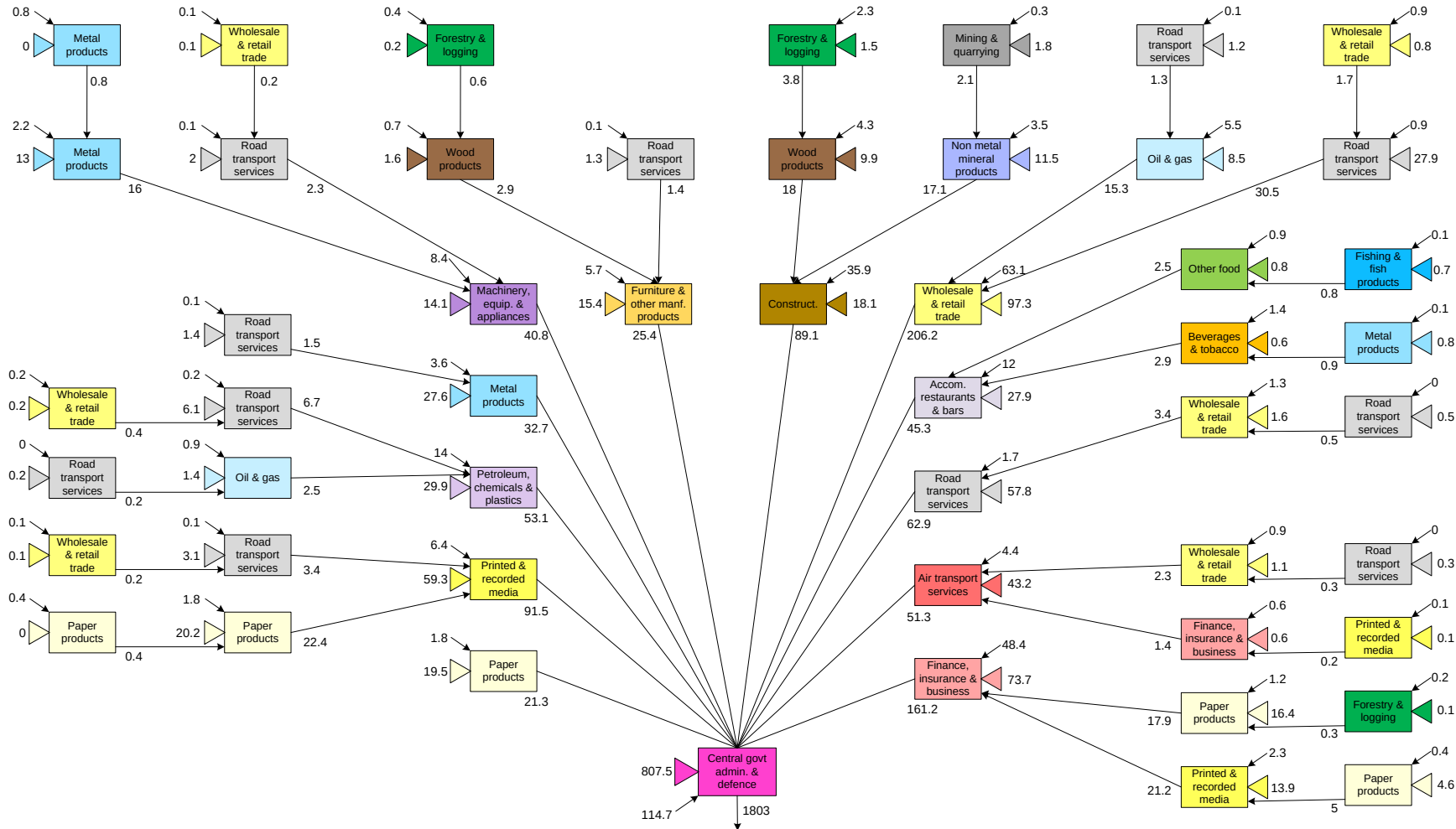
Energy Greenhouse Gases (Figure 30.8)

In terms of CO₂ greenhouse gas emissions, central government administration and defence services emitted a total of 208,520.1 grams (208.5 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked the 7th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. This figure of CO₂ greenhouse gas emissions for the central government administration and defence services sector is within range of a previous estimate of 154 kg per \$1,000 worth of services supplied.³⁰⁷

³⁰⁷ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological

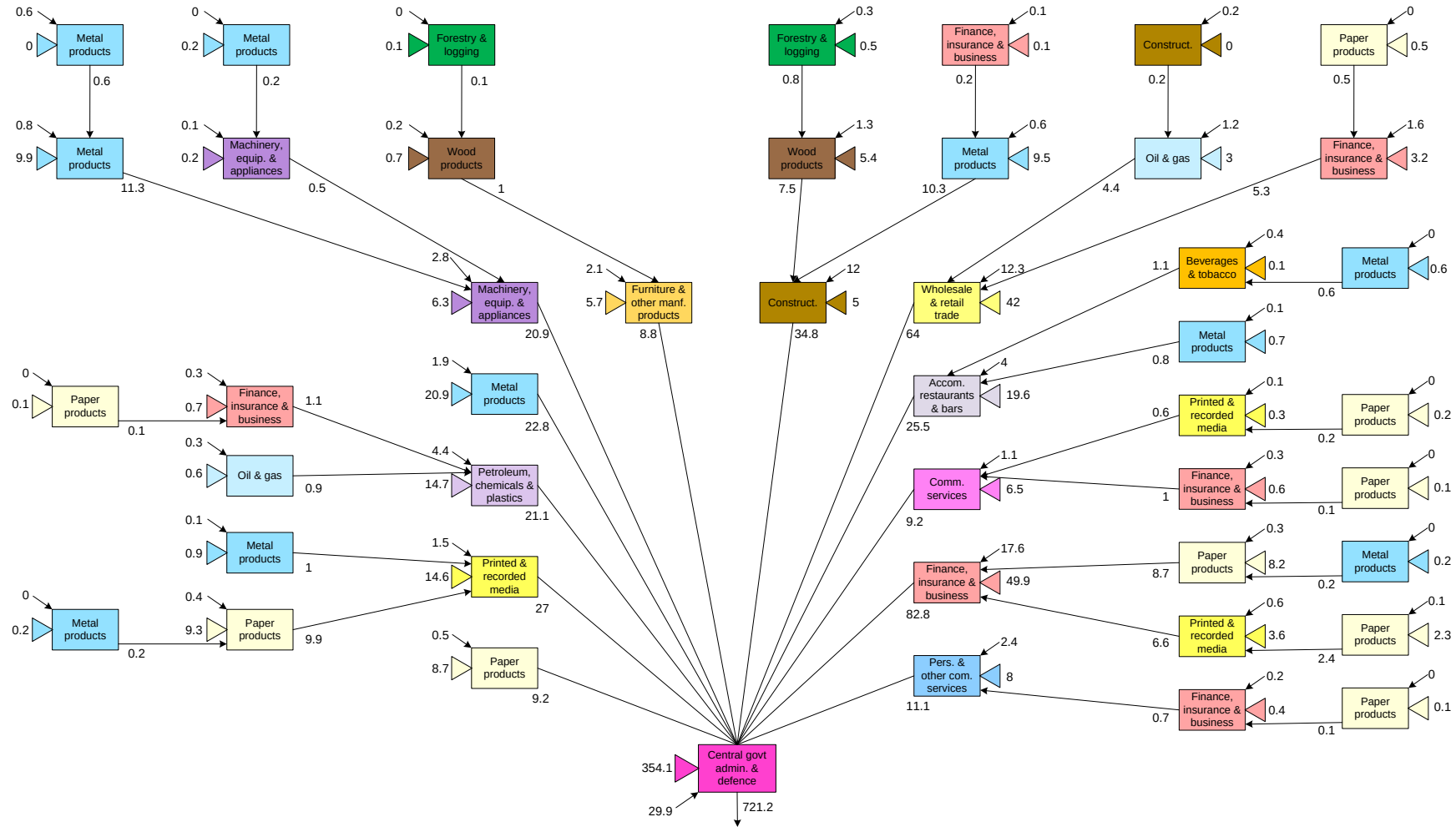
Energy-related CO₂ directly generated by central government administration and defence was 38% of the total CO₂ emitted at 79,020 grams per \$1,000 of services supplied. Energy-related CO₂ indirectly generated by central government administration and defence services makes up the remaining 62% or 129,500.1 grams. The indirect energy-related CO₂ from central government administration and defence services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 25,943 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in finance, insurance and business services at 18,853.1 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in printed and recorded media at 18,124.9 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in construction services at 12,867.4 grams per \$1,000 of services supplied.

Figure 30.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Central Government Administration and Defence Services, 2004 (MJ_E, Oil Equivalents)



Inflation Adjustment: Per \$1,000 (\$ = 4th Quarter 2004) Per \$1,392 (\$ = Year of 2019)

Figure 30.2 - Electricity Inputs Required to Produce \$1,000 Worth of Central Government Administration and Defence Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 30.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Central Government Administration and Defence Services, 2004 (MJ, Heat Equivalents)

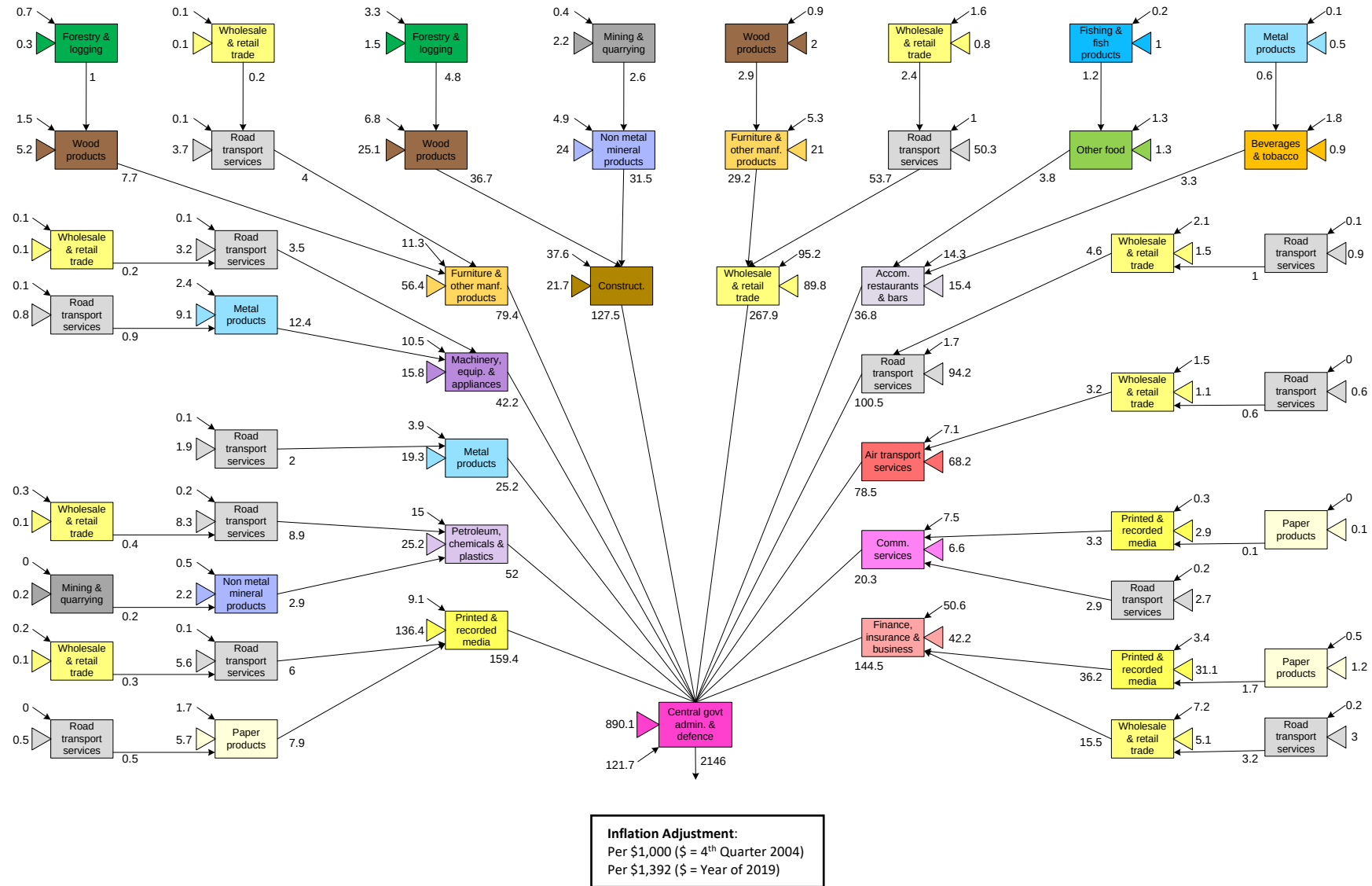
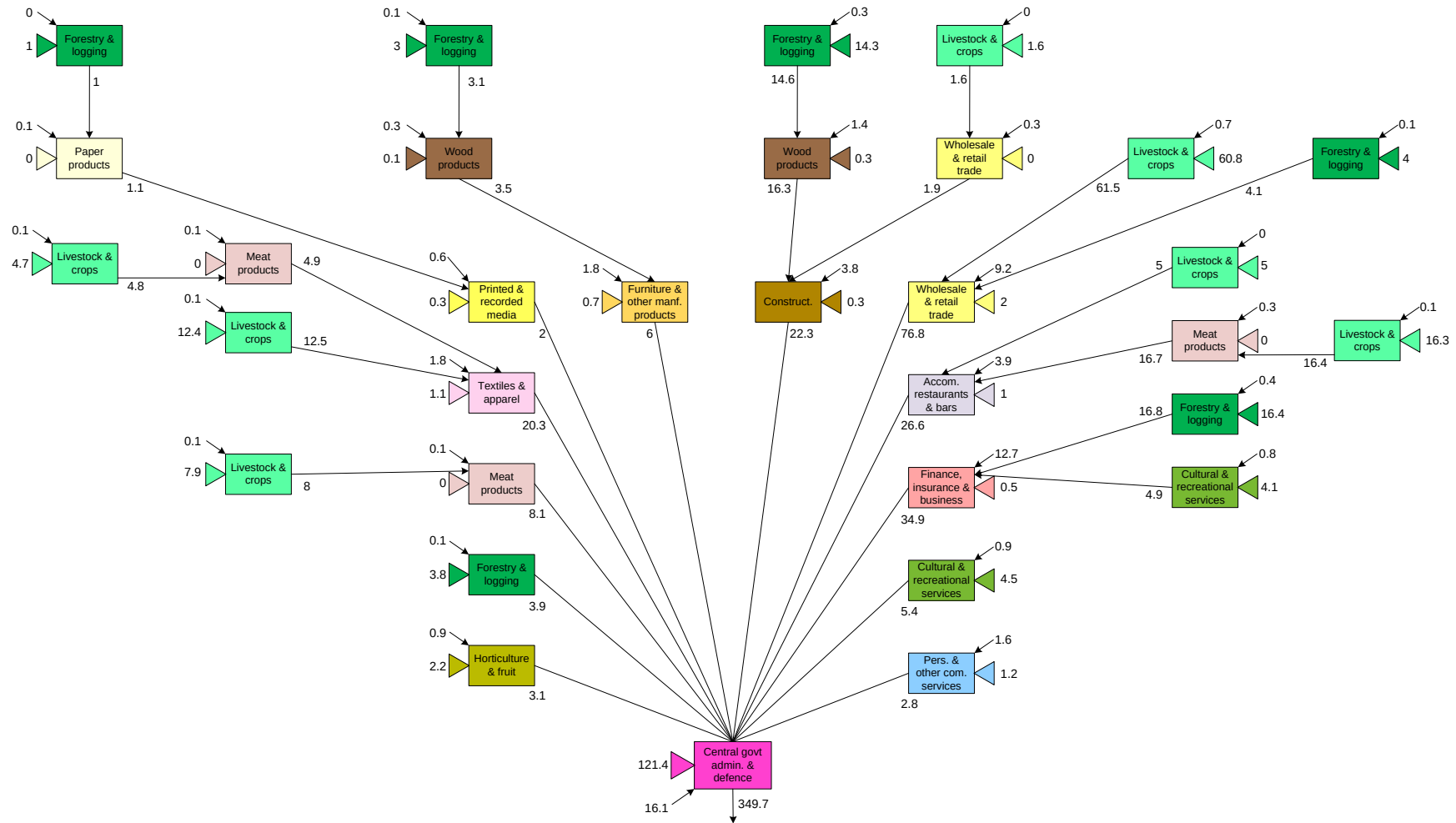


Figure 30.4 - Land Required to Produce \$1,000 Worth of Central Government Administration and Defence Services, 2004 (m2)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 30.5 - Water Inputs Required to Produce \$1,000 Worth of Central Government Administration and Defence Services, 2004 (Litres)

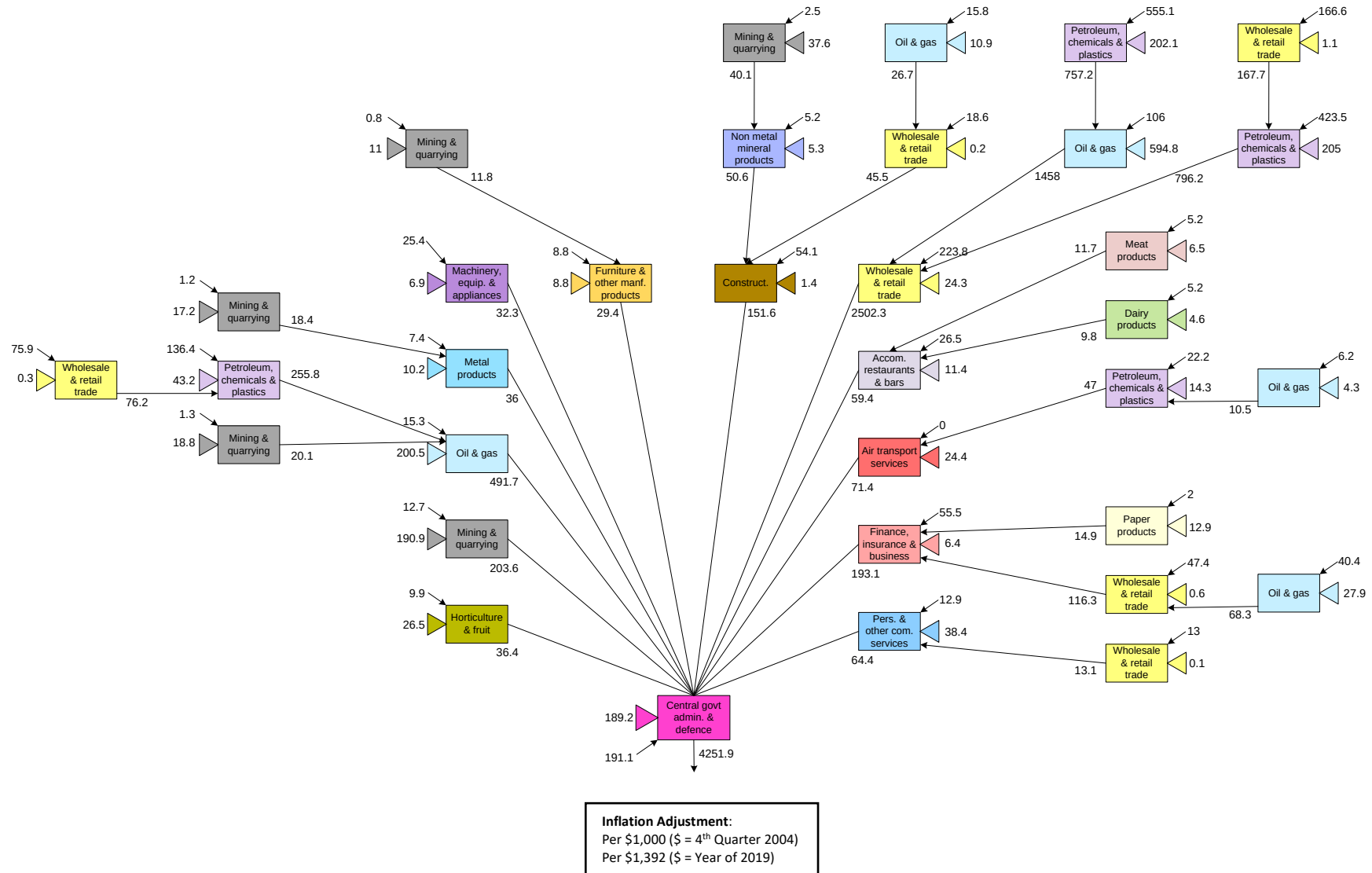
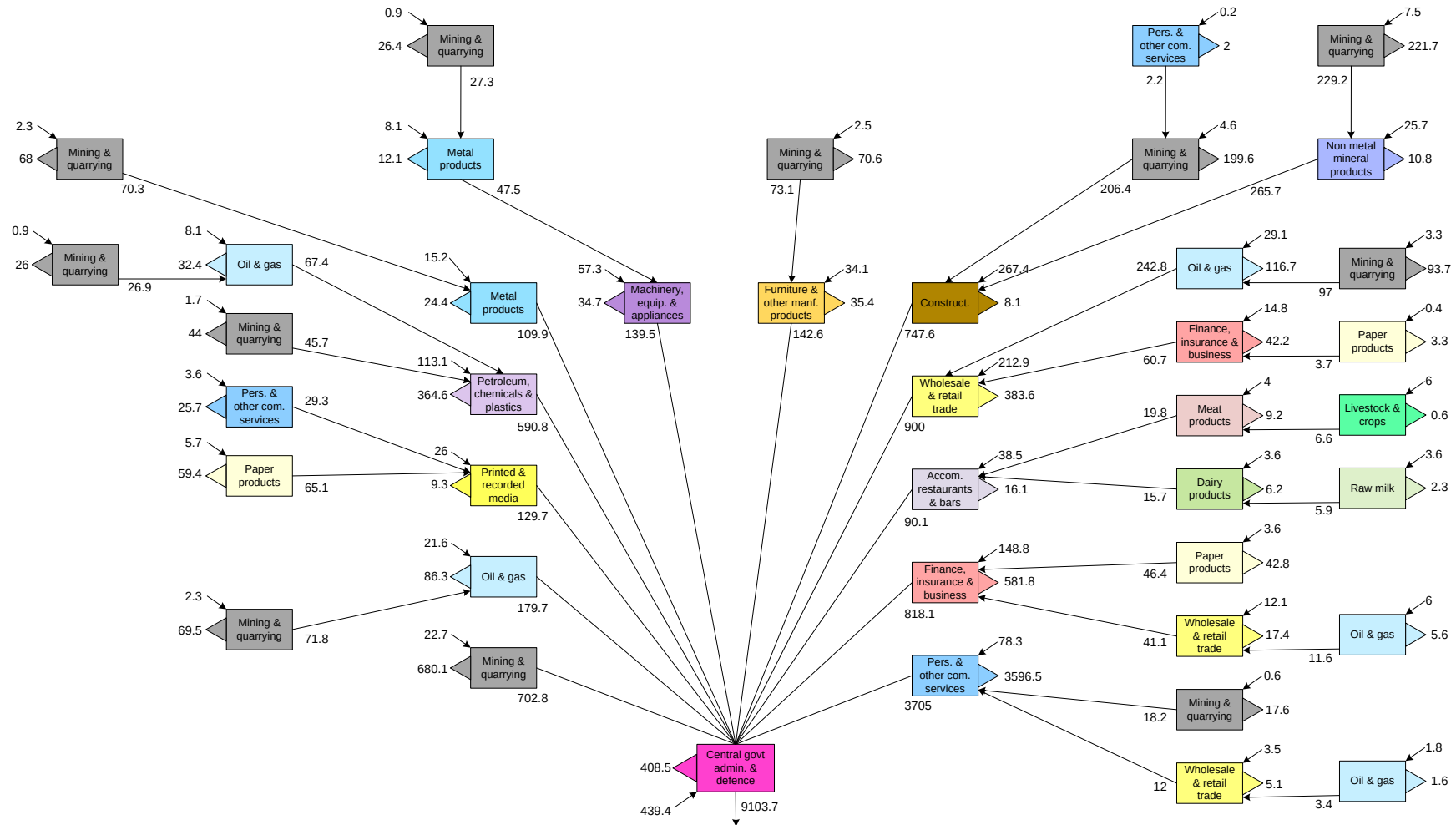


Figure 30.6 - Landfill Waste Generated in Producing \$1,000 Worth of Central Government Administration and Defence Services, 2004 (Grams)



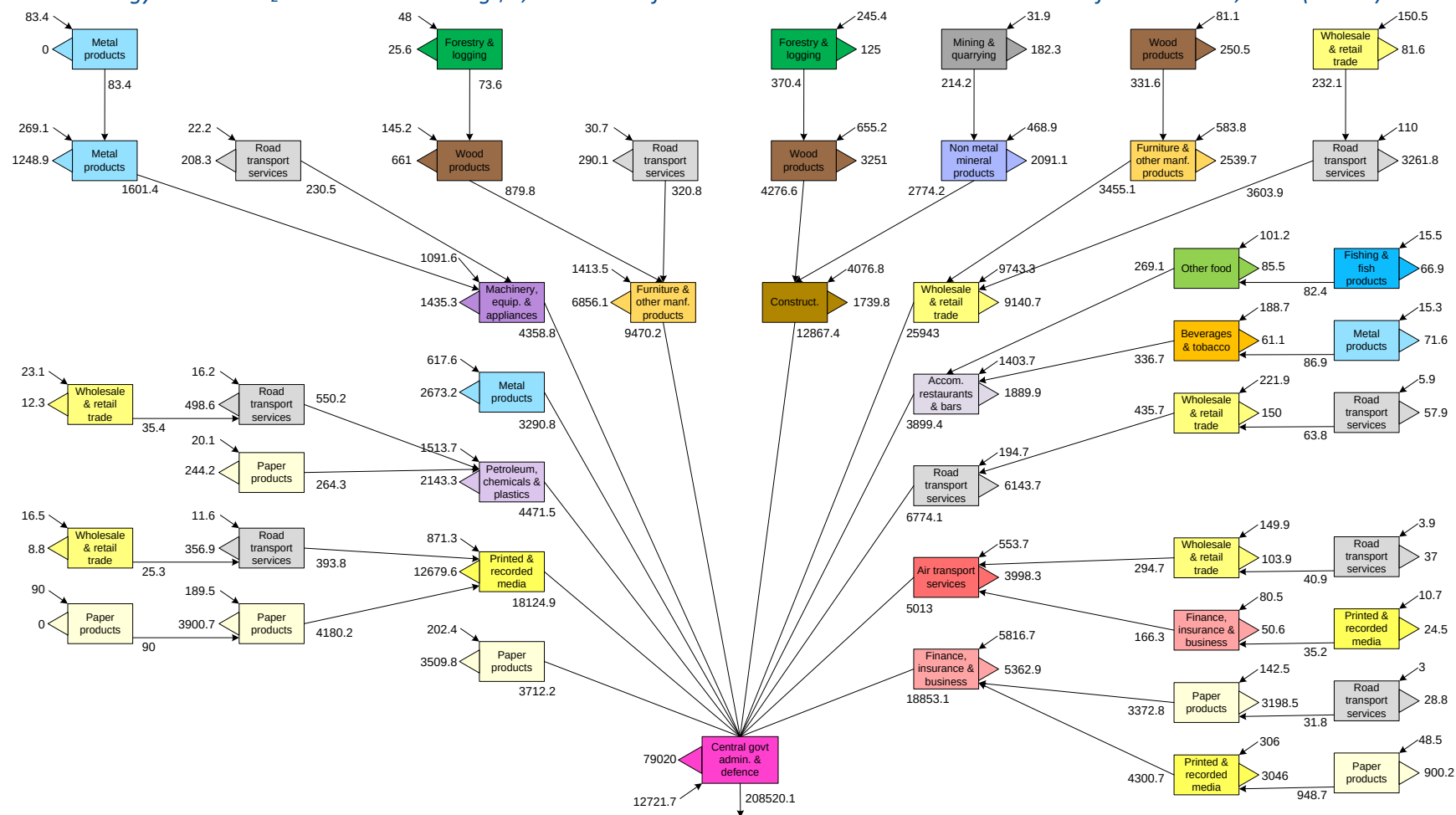
Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 30.7 - Water Waste Generated in Producing \$1,000 Worth of Central Government Administration and Defence Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 30.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Central Government Administration and Defence Services, 2004 (Grams)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

31. Local Government Administration Services

Description

ANZSIC Codes covered:

- 7530 – Local government administration services and civil defence

Main commodity supplied:

- Councils are required to make decisions and set directions for promoting the social, cultural, environmental and economic well-being of their communities. They therefore administer and provide for resource management, biosecurity control, river management and flood mitigation, land transport planning and contracting, civil defence, community wellbeing and development, environmental health and safety, infrastructure, and recreation and culture. Their brief is to provide adequate, equitable and appropriate services for the community, and ensure efficient and effective management of such service provision.³⁰⁸

GDP 2016 = \$1.203 billion

Rank = 27th

Average annual growth rate

2006 to 2016 = 7.68%

Rank = 6th

Employment 2016 = 23,518

Rank = 20th

Economic Overview

New Zealand's government is split into central and local government, with local government further split into two tiers; comprising 67 local territorial authorities and 11 regional authorities (five unitary authorities share the functions of both of these tiers).^{309 310 311}

New Zealand's local government's combined total income for the year ending June 2018 was \$9.9 billion. Local government has \$144.1 billion in assets and \$20.5 billion in total liabilities. New Zealand's 78 local authorities spent \$10.3 billion in 2018 to deliver the services needed by local communities. Of this expenditure, \$4.0 billion was spent on goods and services, \$2.3 billion was spent on employee costs, \$2.1 billion was depreciation, and the rest was associated with interest and grants. Of the expenditure spent on goods and services, the majority at 28% was spent on roading and transport collectively, followed by 18% of operating expenditure spent on governance and council support services.³¹²

In 2018, local government funding came from several different sources including rates (55%), regulatory fees and fuel tax (6%), investments (6%), grants and subsidies from central government

³⁰⁸Local Government New Zealand. (2012). *Local Government Sector*. Retrieved from <http://www.lgnz.co.nz/lg-sector/>

³⁰⁹ Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. North Shore City, Auckland: David Bateman Ltd.

³¹⁰ Statistics New Zealand. (2015, December 10). *Territorial Authority*. Retrieved from Stats NZ: <http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/territorial-authority/definition.aspx>

³¹¹ Local Councils. (n.d.). *Council Profiles by Type*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_url/Profiles-Councils-by-Type-Index

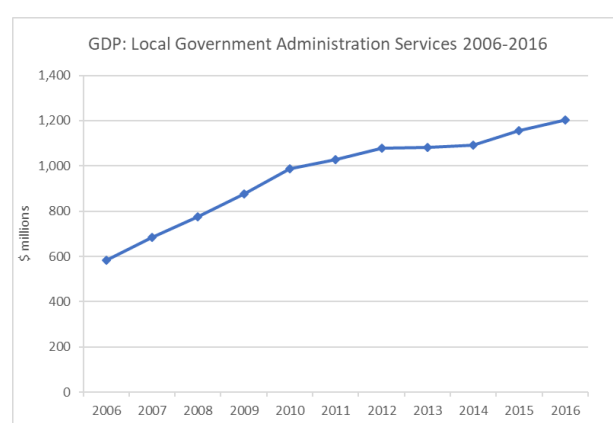
³¹² Local Councils. (2018). *Operating Expenditure*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_URL/Profiles-Local-Government-Statistical-Overview-Operating-Expenditure?OpenDocument

(11%), and other sources (15%).³¹³ Ultimately the rates, fees and charges placed on a community will vary across local government entities, and depend on political will, the state of infrastructure in the area, the expectation of services put on a council, and its geographical location. Recently, the government has created a targeted fund to assist poorer communities with infrastructure needs or research needs for example,³¹⁴ as well as a Rates Rebate Scheme.³¹⁵

There were 23,518 people employed in the local government sector in New Zealand in 2016, over a huge range of roles and professions.³¹⁶ The concern is that owing to the diverse range of goods and services offered by local government, it cannot afford to retain staff with significant expertise in every area. This sees a move to generally qualified staff, with out-sourcing to professional consultancies as and when a more specific service is required.

Local government expenditure on infrastructure needs to be considered as supportive of all industries operating at both the local and national scale. Together with the central government, local government expenditure on infrastructure is essential to economic growth in the regions and nationally. As testament by the high relative expenditure on roading and transport, this is one area where local government investment is clearly linked to the economic growth of all industries.³¹⁷

Sector Trends



From the graph above, it is clear that the contribution of the local government administration services sector to national GDP continued to rise, increasing 106.7% from \$582 million in 2006 to \$1.2 billion in 2016. While the general trajectory over time has been upward, the pace of growth has varied considerably. Growth in the sector's GDP contribution was the fastest between 2006 and 2010 at 14.1% p.a. on average, rising to \$1.03 billion. Indeed, this period of relatively rapid growth is a large reason for the massive increase in the sector's contribution over the 10-year period. Over the next year (2010-11), however, the growth rate had dropped to 4.1%, and growth in the sector's contribution slowed to 2.6% p.a. on average the following the three years. In more recent times, it seems that growth has increased in momentum, growing 5% p.a. on average between 2014 and 2016.

³¹³ Local Councils. (2018). *Operating Revenue*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_URL/Profiles-Local-Government-Statistical-Overview-Operating-Revenue

³¹⁴ Grow Regions. (n.d.). *The Provincial Growth Fund*. Retrieved from <https://www.growregions.govt.nz/about-us/the-provincial-growth-fund/>

³¹⁵ Local Government New Zealand. (2007, October). *Funding Local Government*. Retrieved from <http://www.lgnz.co.nz/lg-sector/Local-government-funding.html>

³¹⁶ Local Government Online. (2006, April 10). *New Zealand Local Government Employees not Seeking a 'Job for Life'*. Retrieved from <http://www.free-press-release.com/news/200604/1144709339.html>

³¹⁷ Local Government New Zealand. (2008, November 3). *Local Infrastructure Key to Economic Pricing*. Retrieved from http://www.lgnz.co.nz/news/media_releases/pr1225677926.pdf

Life Cycle Assessment Diagrams

Energy (Figure 31.1, Figure 31.2, Figure 31.3)

Local government administration services were found to have a total energy intensity of 1,241 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 13th highest out of the 14 service sectors covered in this publication. This represents 1,941 MJ_H per \$000 when measured in conventional energy terms. This total energy figure for local government administration services is similar to a previous estimate of 1,630 MJ_H per \$1,000 worth of services supplied.³¹⁸

Direct energy use for local government administration services was 51% of the total energy intensity, measuring 633.6 MJ_{OE} per \$1,000 worth of services supplied. *Indirect energy* use made up the remaining total at 49%, measuring 607.3 MJ_{OE} per \$1,000 worth of services supplied.

The main *indirect energy* uses in local government administration services came from; (i) energy embodied in construction at 326.8 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in wholesale and retail trade at 90.6 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in finance, insurance and business services at 83.5 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in personal and other community services at 42 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 31.4)

Local government administration services have a total land intensity of just 44.1 m² per \$1,000 of services supplied, ranking the sector 12th highest out of the 14 service sectors covered by this publication. *Direct land use* for local government administration services was just 1% of the total land intensity, measuring 0.3 m² per \$1,000 of services supplied. *Indirect land use* makes up the remaining total land use at 99% measuring 43.8 m² per \$1,000 of local government administration services supplied. The major *indirect land* uses for local government administration services came from; (i) land embodied in construction services at 21.5 m² per \$1,000 of services supplied; (ii) land embodied in wholesale and retail trade at 10.9 m² per \$1,000 of services supplied; (iii) land embodied in finance, insurance and business services at 4.8 m² per \$1,000 of services supplied; (iv) land embodied in textile and apparel at 2.7 m² per \$1,000 of services supplied.

Water Inputs (Figure 31.5)

Local government administration services use a total of 2,699.1 litres of water inputs per \$1,000 of services supplied, ranking the sector the 10th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to local government administration services are made up mostly of indirect sources, with *direct sources* only contributing 0.5% or 12.7 litres per \$1,000 of services supplied. While *indirect sources of water inputs* make up the remaining 99.5% of the total, at 2,686.4 litres per \$1,000 of services supplied.

These indirect water inputs into the local government administration and defence services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 1,230.1 litres per \$1,000 of services supplied; (ii) water inputs embodied in construction services at 630 litres per \$1,000 of services supplied; (iii) water inputs embodied in oil and gas at 506.1 litres per \$1,000 of services supplied; (iv)

³¹⁸ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

water inputs embodied in personal and other community services at 154.7 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 31.6)

Local government administration services were found to generate a total of 10,655.9 grams (10.6 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by local government administration services is 11% of total waste produced or 1,149.4 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 89% or 9,506.5 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste from local government administration services sector came from; (i) landfill wastes embodied in construction services at 7,467.1 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in wholesale and retail trade at 688.7 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in finance, insurance and business services at 345.7 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in petroleum, chemicals and plastics at 340.5 grams per \$1,000 of services supplied.

Water Wastes (Figure 31.7)

Local government administration services were found to produce a total of 15,315.9 litres of wastewater per \$1,000 of services supplied, ranking the sector the 3rd highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated* by the local government administration services sector accounted for just 0.2% of total water wastes or 19.6 litres per \$1,000 of services supplied. *Indirect sources of water wastes* accounted for the remaining 99.8% of total water wastes or 15,296.3 litres per \$1,000 of services supplied.

The main sources of indirect sources of water wastes were mostly made up of (i) wastewater embodied in personal and other community services at 10,566.3 litres per \$1,000 of services supplied; (ii) wastewater embodied in construction services at 3,255 litres per \$1,000 of services supplied; (iii) wastewater embodied in finance, insurance and business services at 514.9 litres per \$1,000 of services supplied; (iv) wastewater embodied in wholesale and retail trade at 468.3 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 31.8)

In terms of CO₂ greenhouse gas emissions, local government administration services emitted a total of 140,738.8 grams (140.7 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked the 9th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. This figure of CO₂ greenhouse gas emissions for the local government administration services sector is much the same as another reported figure of 144 kg per \$1,000 worth of services supplied.³¹⁹

Energy-related CO₂ directly generated by local government administration services was 37% of the total CO₂ emitted, at 52,212.5 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* makes up the remaining 63% or 88,526.3 grams.

³¹⁹ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

The indirect energy-related CO₂ from local government administration services was mostly made up of (i) energy-related CO₂ embodied in construction services at 50,878.5 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in wholesale and retail trade at 12,314.1 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in finance, insurance and business services at 10,448.4 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in personal and other community services at 4,501.1 grams per \$1,000 of services supplied.

Figure 31.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Local Government Administration Services, 2004 (MJ_E, Oil Equivalents)

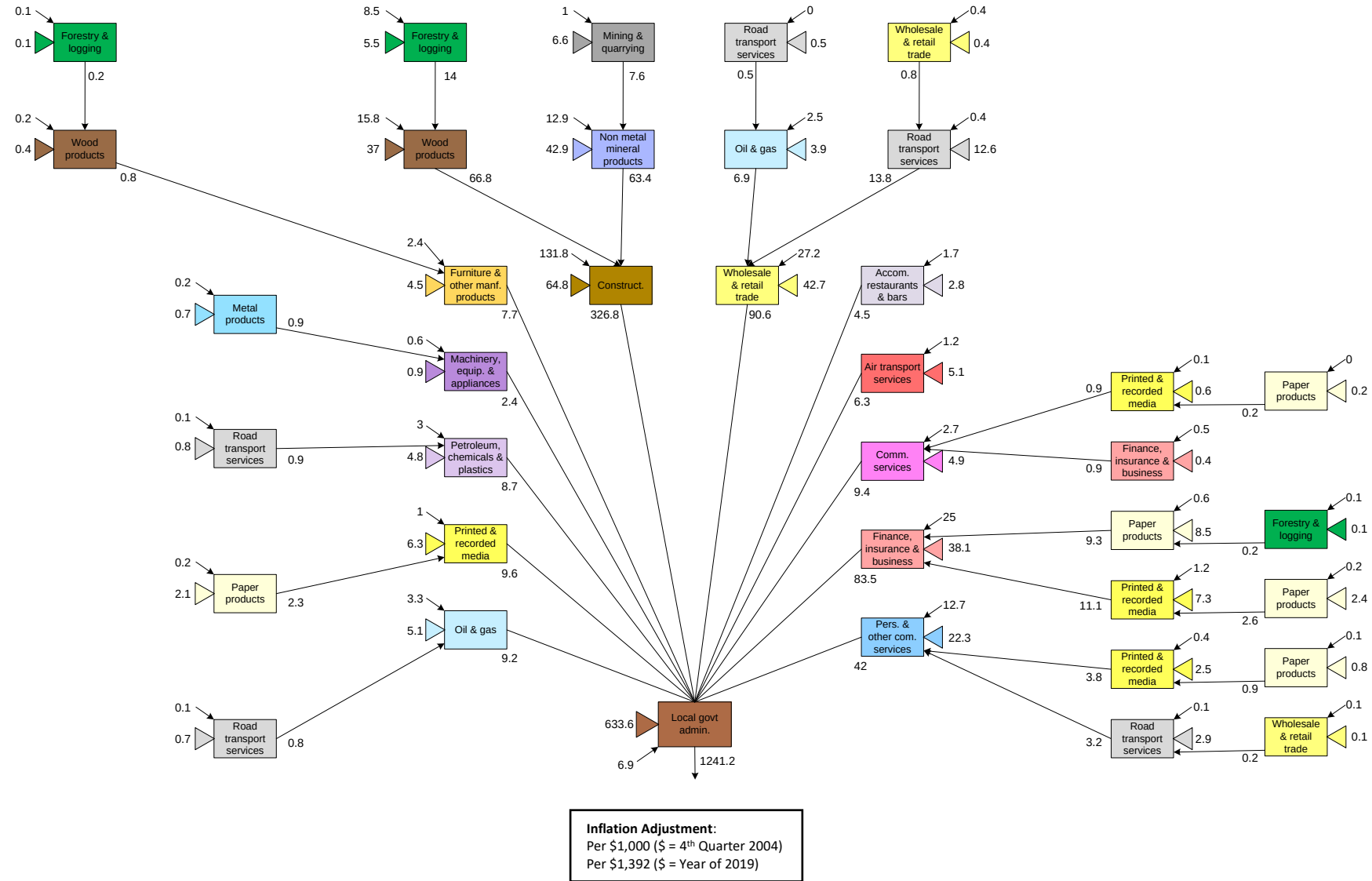


Figure 31.2 - Electricity Inputs Required to Produce \$1,000 Worth of Local Government Administration Services, 2004 (MJ, Heat Equivalents)

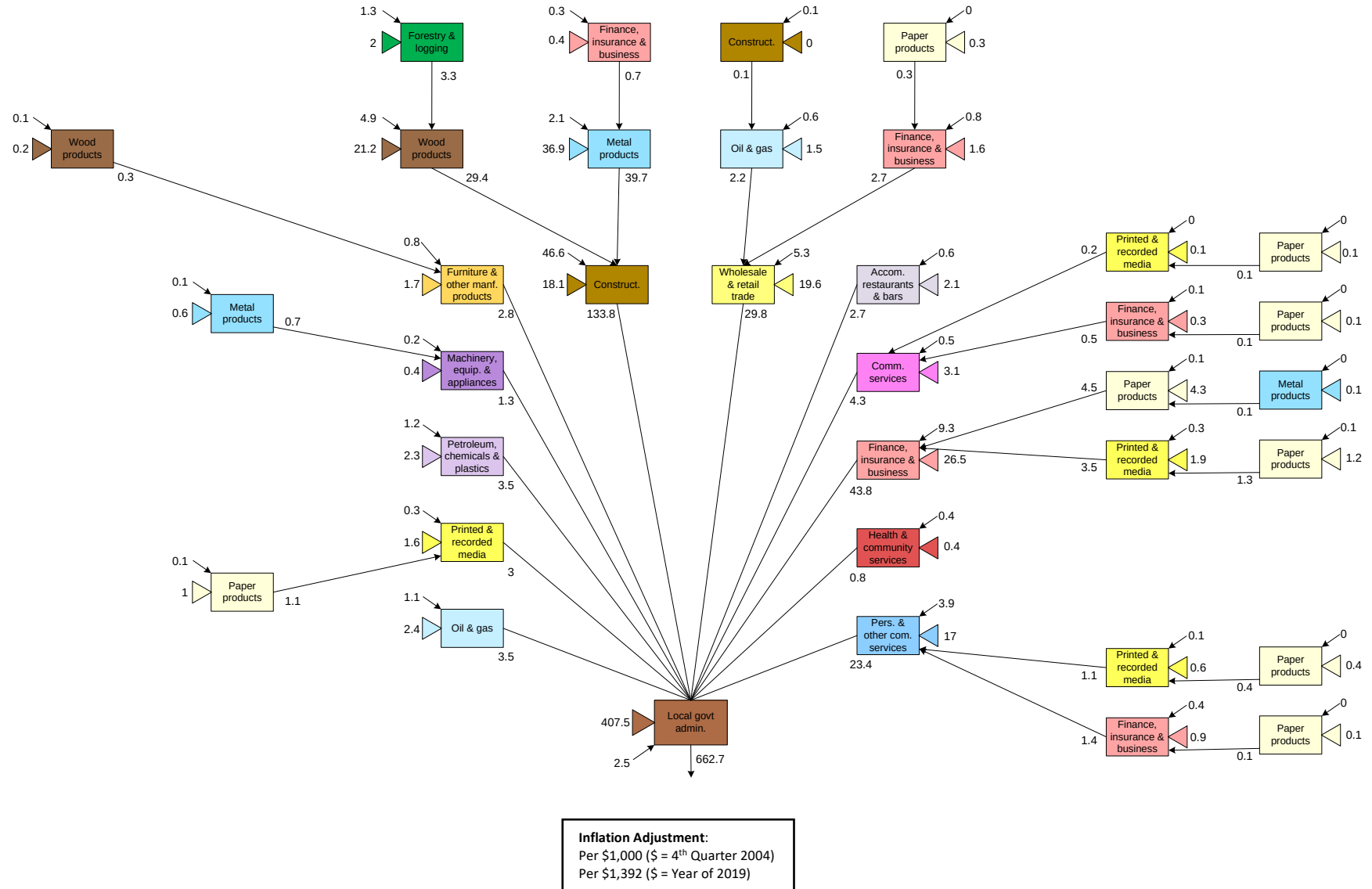


Figure 31.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Local Government Administration Services, 2004 (MJ, Heat Equivalents)

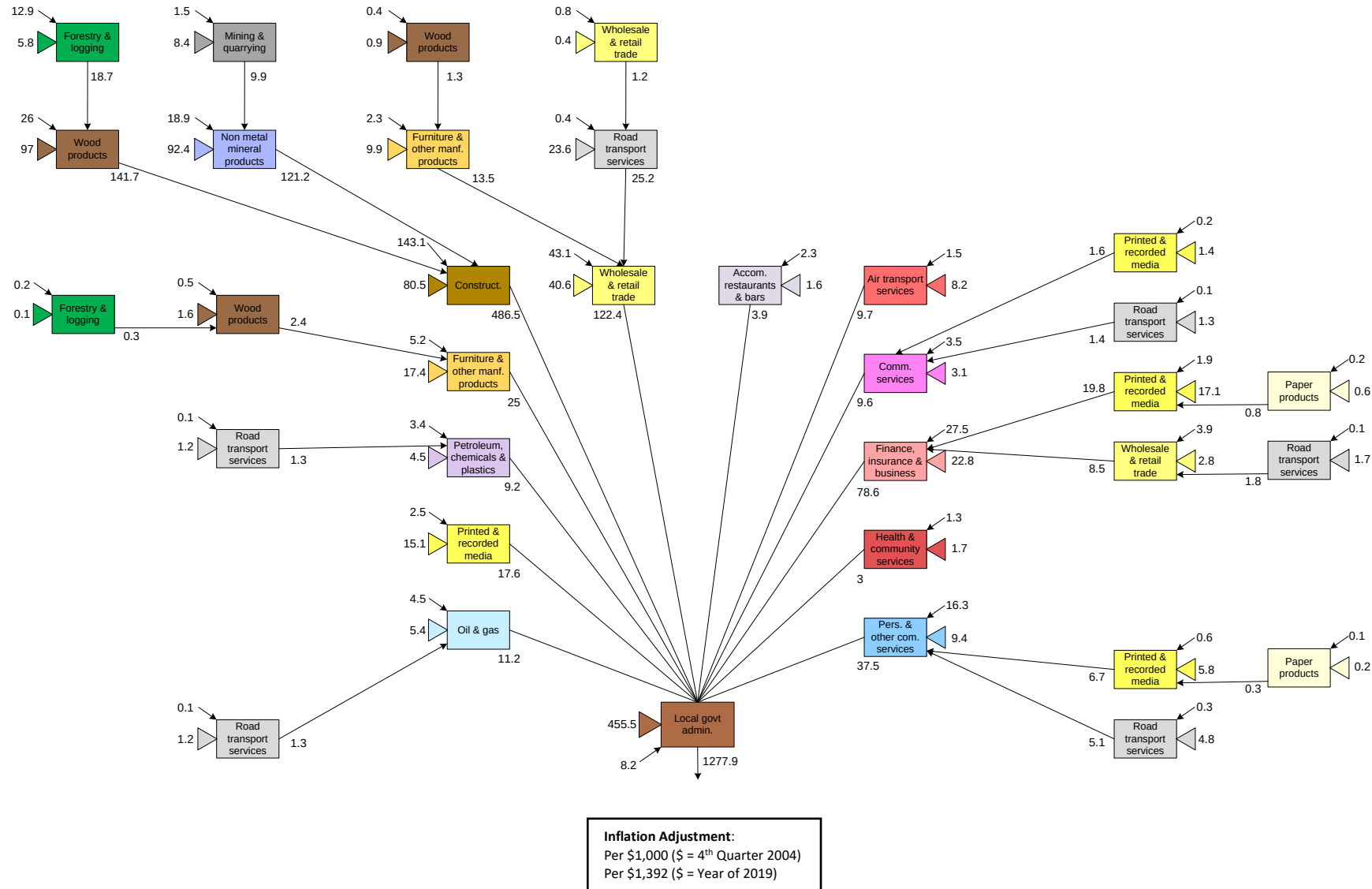


Figure 31.4 - Land Required to Produce \$1,000 Worth of Local Government Administration Services, 2004 (m²)

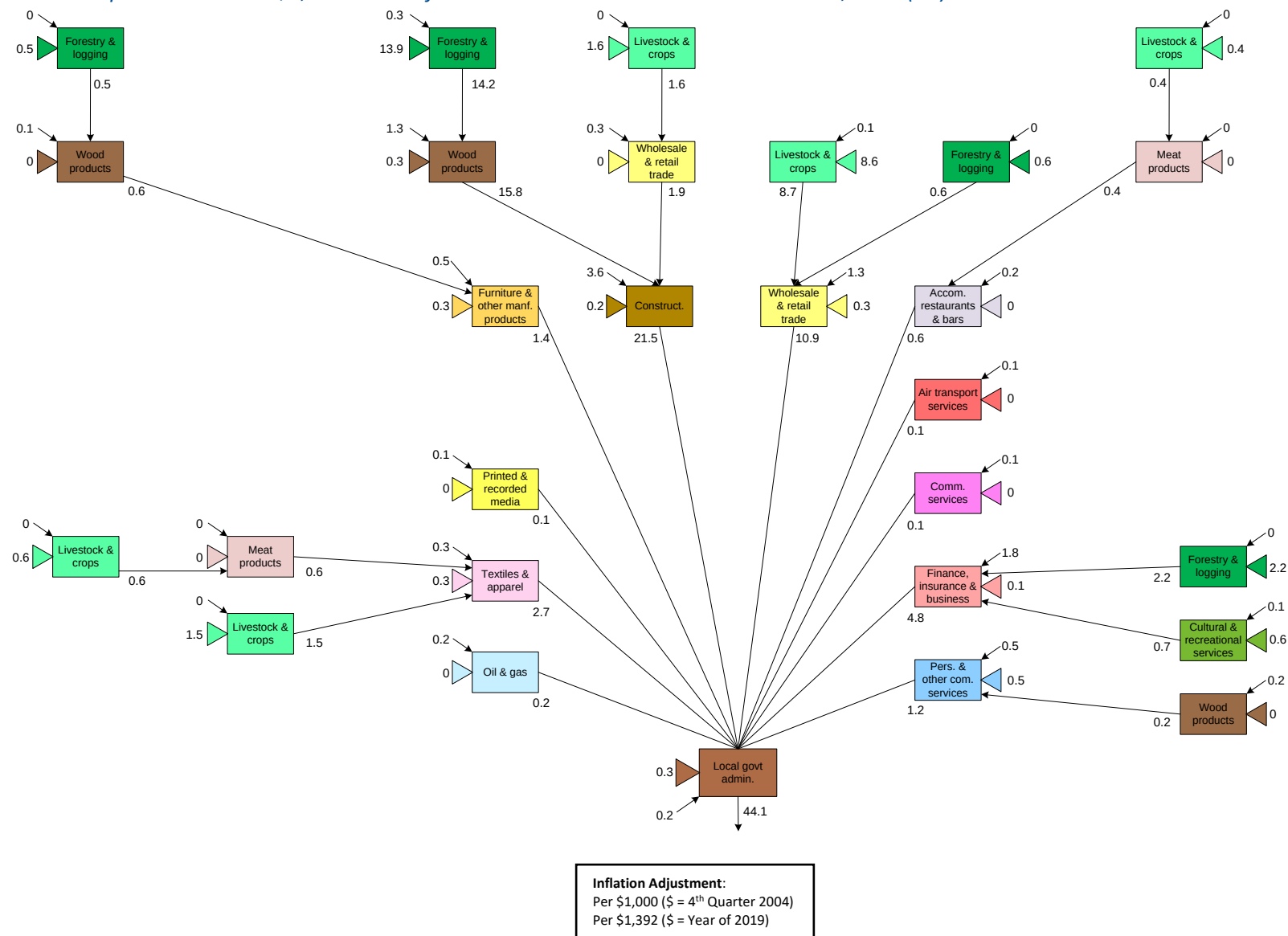
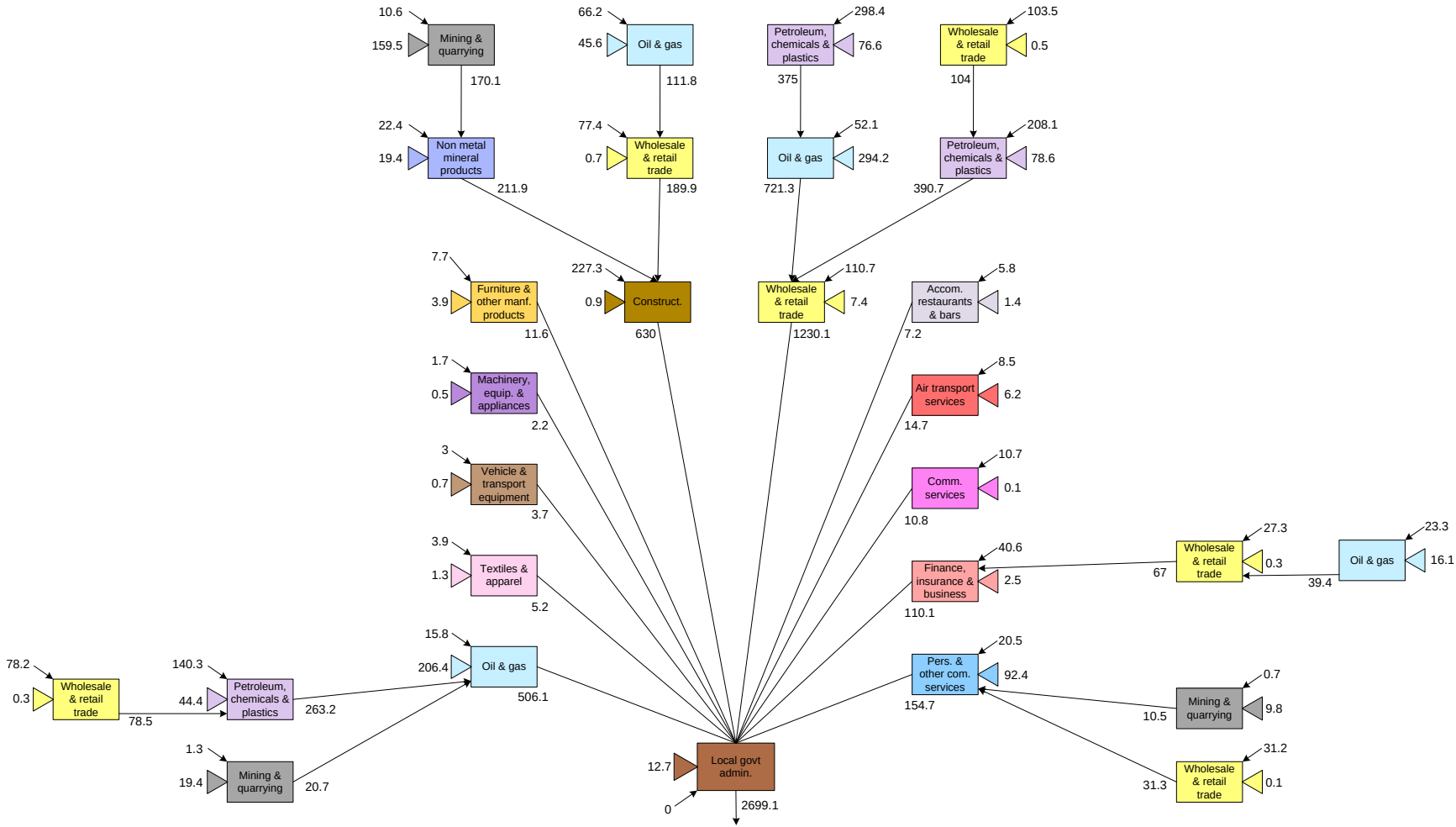


Figure 31.5 - Water Inputs Required to Produce \$1,000 Worth of Local Government Administration Services, 2004 (Litres)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 31.6 - Landfill Waste Generated in Producing \$1,000 Worth of Local Government Administration Services, 2004 (Grams)

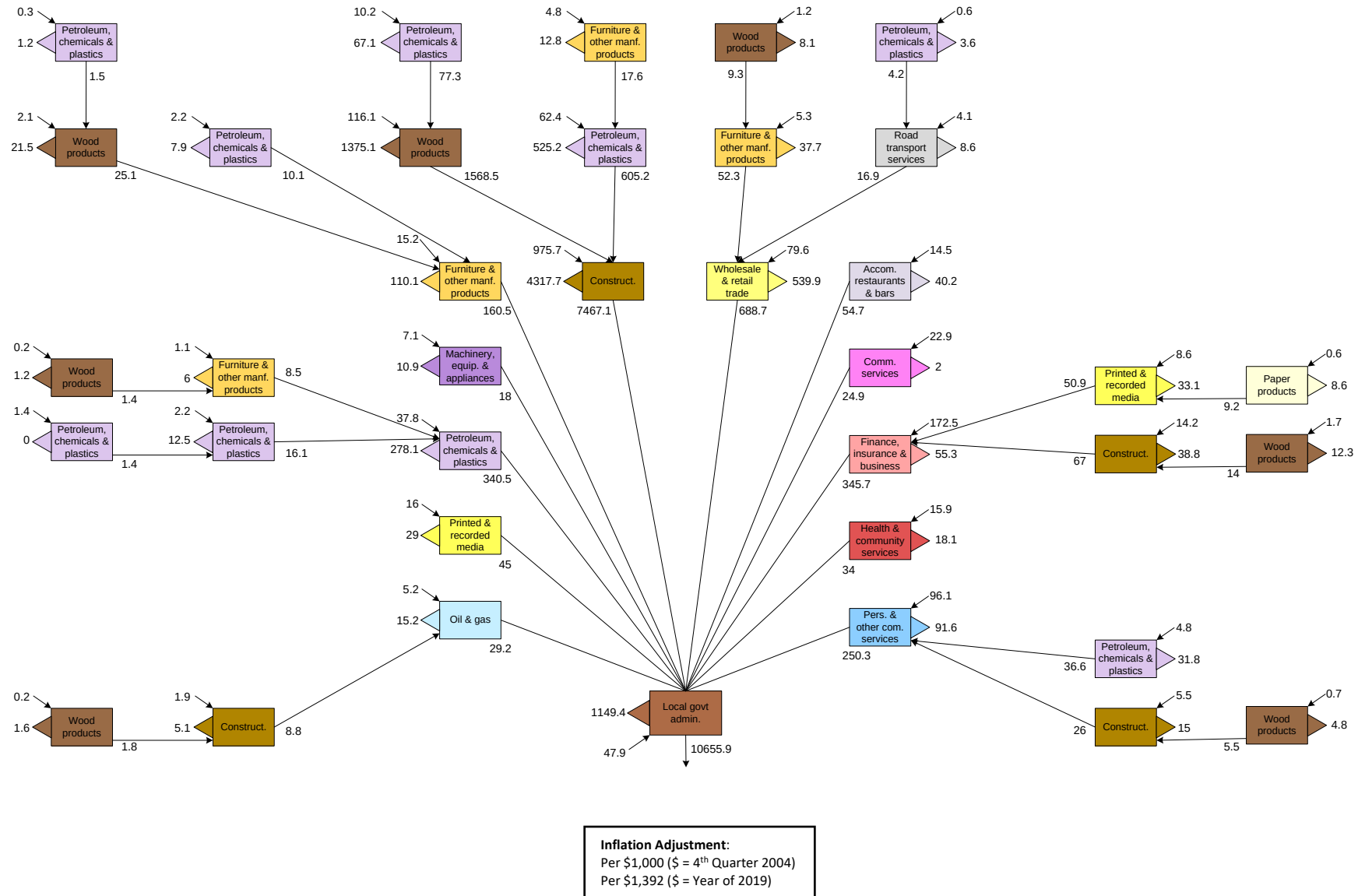


Figure 31.7 - Water Waste Generated in Producing \$1,000 Worth of Local Government Administration Services, 2004 (Litres)

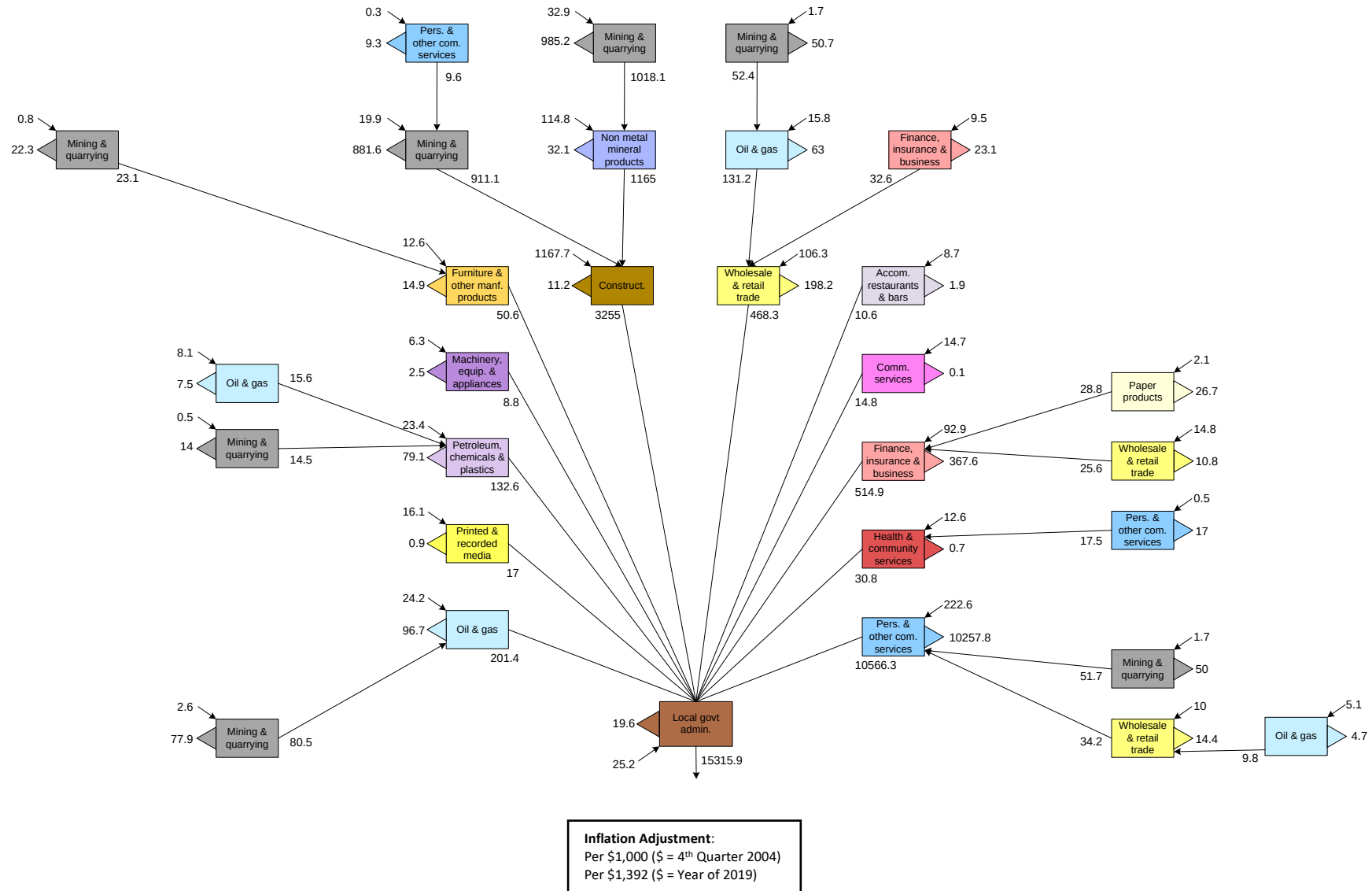
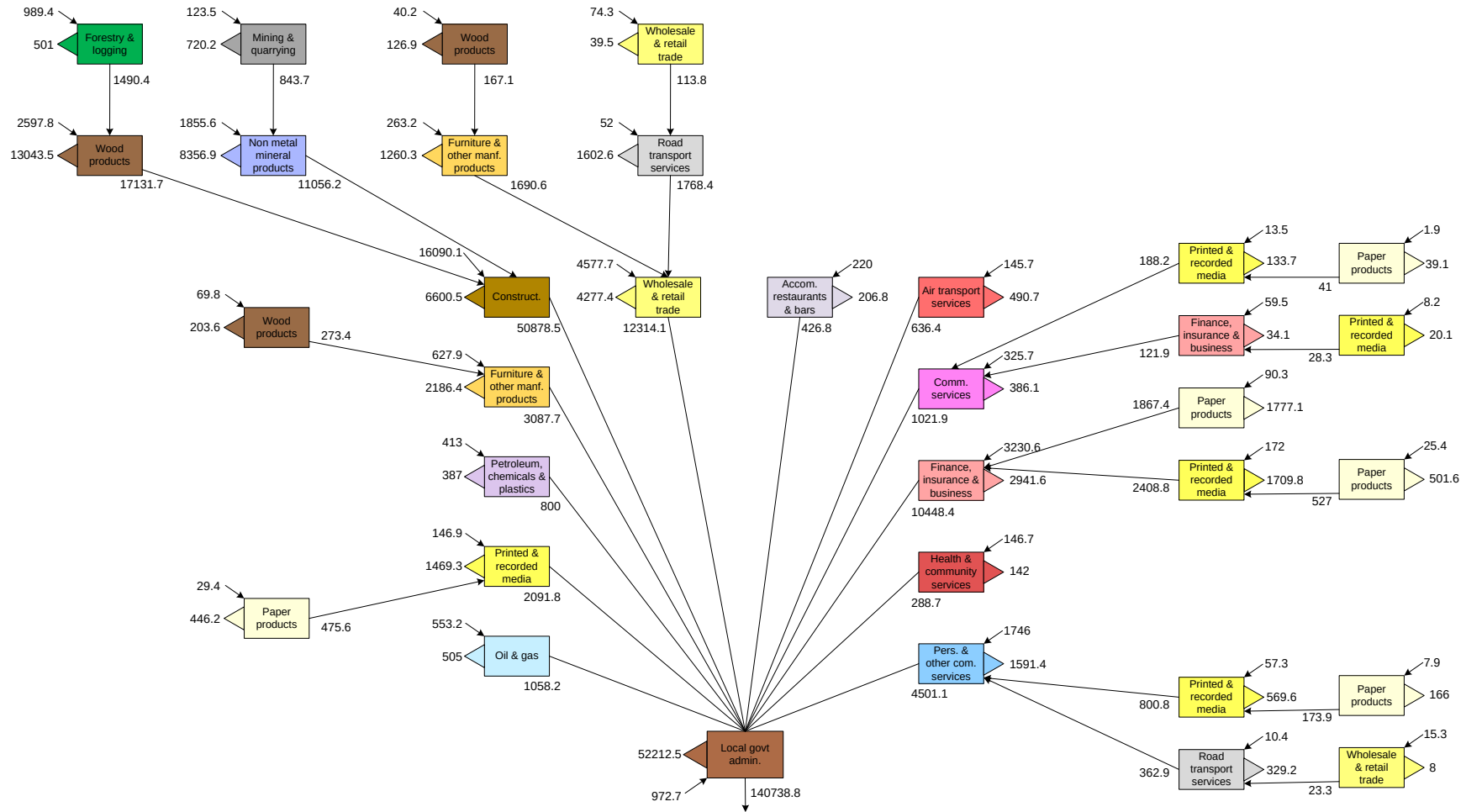


Figure 31.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Local Government Administration Services, 2003-04 (Grams)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

32. Education and Training Services

Description

ANZSIC Codes covered:

- 8010 – Preschool Education
- 8021 – Primary Education
- 8022 – Secondary Education
- 8023 – Combined Primary and Secondary Education
- 8024 – Special School Education
- 8031 – Higher Education (e.g. University)
- 8032 – Technical and Vocational Education and Training
- 8102 – Further Education
- 8211 – Sport and Physical Recreation Instruction
- 8212 – Arts Education
- 8219 – Other Adult, Community and Other Education
- 8220 – Educational Support Services

GDP 2016 = \$11.431 billion

Rank = 5th

Average annual growth rate

2006 to 2016 = 5.19%

Rank = 14th

Employment 2016 = 181,802

Rank = 5th

Main commodity supplied:

- Education

Economic Overview

Education is important to New Zealand's long-term economic and fiscal outlook, both as a major area of government expenditure, and for the significant role skills and research can play as a driver of long-term productivity growth.³²⁰ The education sector is a significant employer in the New Zealand economy, employing around 181,802 people as of 2016. Workers in this sector are highly qualified with both primary and secondary school teachers requiring at least a bachelor's degree to teach within New Zealand.^{321 322}

Primary and secondary level education in New Zealand is primarily funded from government sources, with the rest funded privately.³²³ Free primary and secondary education is a right for all New Zealand citizens and permanent residents and is compulsory for students between the ages of 6 and 16 (15 with parental and school permission).³²⁴ Expenditure on education is an investment that boosts productivity, facilitates economic growth, reduces inequality among social groups and contributes to the personal and social development of individuals.³²⁵ School funding is set to be based on an Equity

³²⁰New Zealand Treasury. (2009). *Challenges and Choices: New Zealand's Long-term Fiscal Statement*. Retrieved from <http://www.treasury.govt.nz/government/longterm/fiscalposition/2009/lfts-09.pdf>

³²¹Careers NZ. (n.d.). *Primary School Teacher*. Retrieved from <https://www.careers.govt.nz/jobs-database/education-and-social-sciences/education/primary-school-teacher/>

³²²Careers NZ. (n.d.). *Secondary School Teacher*. Retrieved from <https://www.careers.govt.nz/jobs-database/education-and-social-sciences/education/secondary-school-teacher/>

³²³Ibid

³²⁴Ministry of Education New Zealand. (2008). *The New Zealand Education System: An overview*. Wellington, New Zealand: Author.

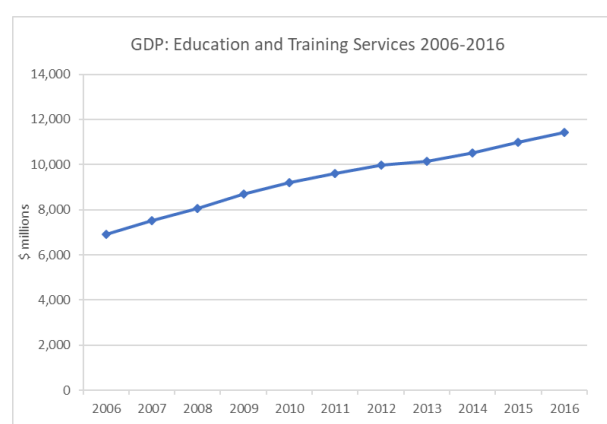
³²⁵Strategy and System Performance Group (Ministry of Education). (2009). *Indicators Live: Education at a Glance 2009, Results for New Zealand*. Retrieved from <http://www.educationcounts.govt.nz/publications/schooling/56219/2>

Index in either 2021 or 2022,³²⁶ replacing the decile funding system, first introduced in 1995.³²⁷ The switch comes with the aim of providing increased education resourcing to New Zealand's most disadvantaged students.³²⁸

Although most Māori students are in mainstream (English medium) education, there is increasing numbers of enrolling in Kaupapa Māori (Māori medium) education in all three levels of education. The government currently has a range of initiatives to improve Māori education outcomes and the preservation of Te Reo as an obligation of the Government under the Treaty of Waitangi.³²⁹

Government policy throughout the 1990s was based on raising participation and increasing the equity of access, especially at the tertiary level. Between 1991 and 2005, the proportion of adults with a bachelors' degree or higher qualification rose from 8% to almost 20% (418,000 people).³³⁰ In 2017, this rose further to 26% of New Zealanders holding a bachelor's degree or higher.³³¹ New Zealand's tertiary education system is funded through both student fees and government subsidies.³³² Students enrolled in tertiary education can usually access student loans and allowances through the government to assist with fees and living costs.³³³ In 2018, the government introduced a fees-free tertiary education and training policy to improve educational attainment in New Zealand.³³⁴

Sector Trends



The New Zealand education sector's contribution to national GDP has been steadily rising from 2006 to 2016, with an average annual growth rate of 5.2%. This increase could be due to the increasing population, with more people going through the education system in New Zealand. While growth in the sector's contribution has never declined, and indeed the general trajectory has been up over the 10-year period considered, it has been increasing at a decreasing rate as illustrated above by a rather

³²⁶ Education Central. (2019, September 24). *Goodbye deciles, hello Equity Index*. Retrieved from <https://educationcentral.co.nz/goodbye-deciles-hello-equity-index/>

³²⁷ Education and Science Committee. (2003, December). *Inquiry into decile funding in New Zealand State and integrated schools*. Retrieved from https://www.parliament.nz/resource/en-nz/47DBSCH_SCR2635_1/a0d737616dee49badb33dd37823f97891af572dc

³²⁸ Education Central. (2019, September 24). *Goodbye deciles, hello Equity Index*. Retrieved from <https://educationcentral.co.nz/goodbye-deciles-hello-equity-index/>

³²⁹ Education Information and Analysis Group (Ministry of Education). (2009). *Ngā Haeata Mātauranga - The Annual Report on Māori Education, 2007/08*. Retrieved from <http://www.educationcounts.govt.nz/publications/series/5851/35307/5>

³³⁰ Mahoney, P. (2003). *Tertiary Education Funding – Overview of Recent Reform*. Wellington, New Zealand: Parliamentary Library.

³³¹ Education Counts. (2018, December). *Educational attainment in the adult population*. Retrieved from https://www.educationcounts.govt.nz/statistics/indicators/main/education-and-learning-outcomes/educational_attainment_in_the_adult_population

³³² Universities New Zealand. (n.d.). *How NZ universities are funded*. Retrieved from <https://www.universitiesnz.ac.nz/about-university-sector/how-nz-universities-are-funded>

³³³ StudyLink. (n.d.). *Student Loan*. Retrieved from <https://www.studylink.govt.nz/products/a-z-products/student-loan/index.html>

³³⁴ Education NZ. (2017, December 4). *Details of fees free tertiary education and training for 2018 announced*. Retrieved from <https://www.education.govt.nz/news/details-of-fees-free-tertiary-education-and-training-for-2018-announced/>

sloped trendline. The annual growth rate declined from 9.7% between 2006 and 2007 to 1.7% between 2012 and 2013. In more recent times, however, there appears to be a resurgence in the sector's GDP contribution, with a rise in the annual growth rate to an average of 4% between 2014 and 2016. In 2016, GDP generated in the education sector reached a peak of \$11.43 billion.

Life Cycle Assessment Diagrams

Energy (Figure 32.1, Figure 32.2, Figure 32.3)

Education services were found to have a total energy intensity of 627.3 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 10th highest out of the 14 service sectors covered in this publication.

Direct energy use for education services was 39% of the total energy intensity, measuring 242.4 MJ_{OE} per \$1,000 worth of services supplied. *The EECA in-use database reports that the NZ total direct energy consumed in the education services sector in the year 2006/07 was 3,575.605 TJ (made up of 2,165.537 TJ for pre-school, primary and secondary education, and 1,410.068 TJ for tertiary education).*

Indirect energy use made up the remaining total at 61%, measuring 384.9 MJ_{OE} per \$1,000 worth of services supplied. The main indirect energy uses for education services came from; (i) energy embodied in wholesale and retail trade at 131.5 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in printed and recorded media at 41.5 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in finance, insurance and business services at 29.1 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in construction services at 27.8 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 32.4)

Education services have a total land intensity of just 53.9 m² per \$1,000 of services supplied, ranking the sector 11th highest out of the 14 service sectors covered by this publication. *Direct land use* for education services was 9% of the total land intensity, measuring 5.1 m² per \$1,000 of services supplied. *Indirect land use* makes up the remaining total land use at 91% measuring 48.8 m² per \$1,000 of education services supplied.

The major indirect land uses for education services came from; (i) land embodied in wholesale and retail trade at 27.1 m² per \$1,000 of services supplied; (ii) land embodied in accommodation, restaurants and bars at 4.9 m² per \$1,000 of services supplied; (iii) land embodied in textiles and apparel at 4.8 m² per \$1,000 of services supplied; (iv) land embodied in furniture and other manufactured products at 2.9 m² per \$1,000 of services supplied.

Water Inputs (Figure 32.5)

Education services use a total of 4,077.8 litres of water inputs per \$1,000 of services supplied, ranking the sector the 7th highest consumer of water out of the 14 service sectors covered by this publication. *Water inputs* to education services are made up mostly of indirect sources, with *direct sources* only contributing 3% or 110.8 litres per \$1,000 of services supplied. *While indirect water inputs make up the remaining 97% or 3,967 litres per \$1,000 of education services supplied.*

These indirect water inputs into the education services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 2,922.4 litres per \$1,000 of services supplied; (ii) water inputs embodied in mining and quarrying at 438.3 litres per \$1,000 of services supplied; (iii) water inputs

embodied in construction services at 106 litres per \$1,000 of services supplied; (iv) water inputs embodied in finance, insurance and business services at 75.7 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 32.6)

Education services were found to generate a total of 1,241.1 grams (1.2 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the education services sector is 23% of total waste produced or 1,303.8 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 77% or 4,417.9 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for the education services sector came from; (i) landfill wastes embodied in wholesale and retail trade at 1,241.1 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in construction services at 880.9 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in furniture and other manufactured products at 581.7 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in petroleum, chemicals and plastics at 424.3 grams per \$1,000 of services supplied.

Water Wastes (Figure 32.7)

Education services were found to produce a total of 5,702.4 litres of wastewater per \$1,000 of services supplied, ranking the sector the 8th highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated by the education services sector* accounted for just 0.4% of total water wastes or 21.8 litres per \$1,000 of services supplied. *Indirect sources* of water wastes accounted for the remaining 99.6% of total water wastes or 5,680.6 litres per \$1,000 of services supplied.

The main indirect sources of water wastes were mostly made up of (i) wastewater embodied in mining and quarrying at 1,247.5 litres per \$1,000 of services supplied; (ii) wastewater embodied in personal and other community services at 2,031.6 litres per \$1,000 of services supplied; (iii) wastewater embodied in wholesale and retail trade at 858.4 litres per \$1,000 of services supplied; (iv) wastewater embodied in construction services 396.1 litres per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 32.8)

In terms of CO₂ greenhouse gas emissions, education services emitted a total of 106,106.5 grams (106.1 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked the 10th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication. This figure of CO₂ greenhouse gas emissions for the central government administration and defence services sector is within range of a previously reported estimate of 87 kg of CO₂ emissions per \$1,000 worth of education services supplied.³³⁵

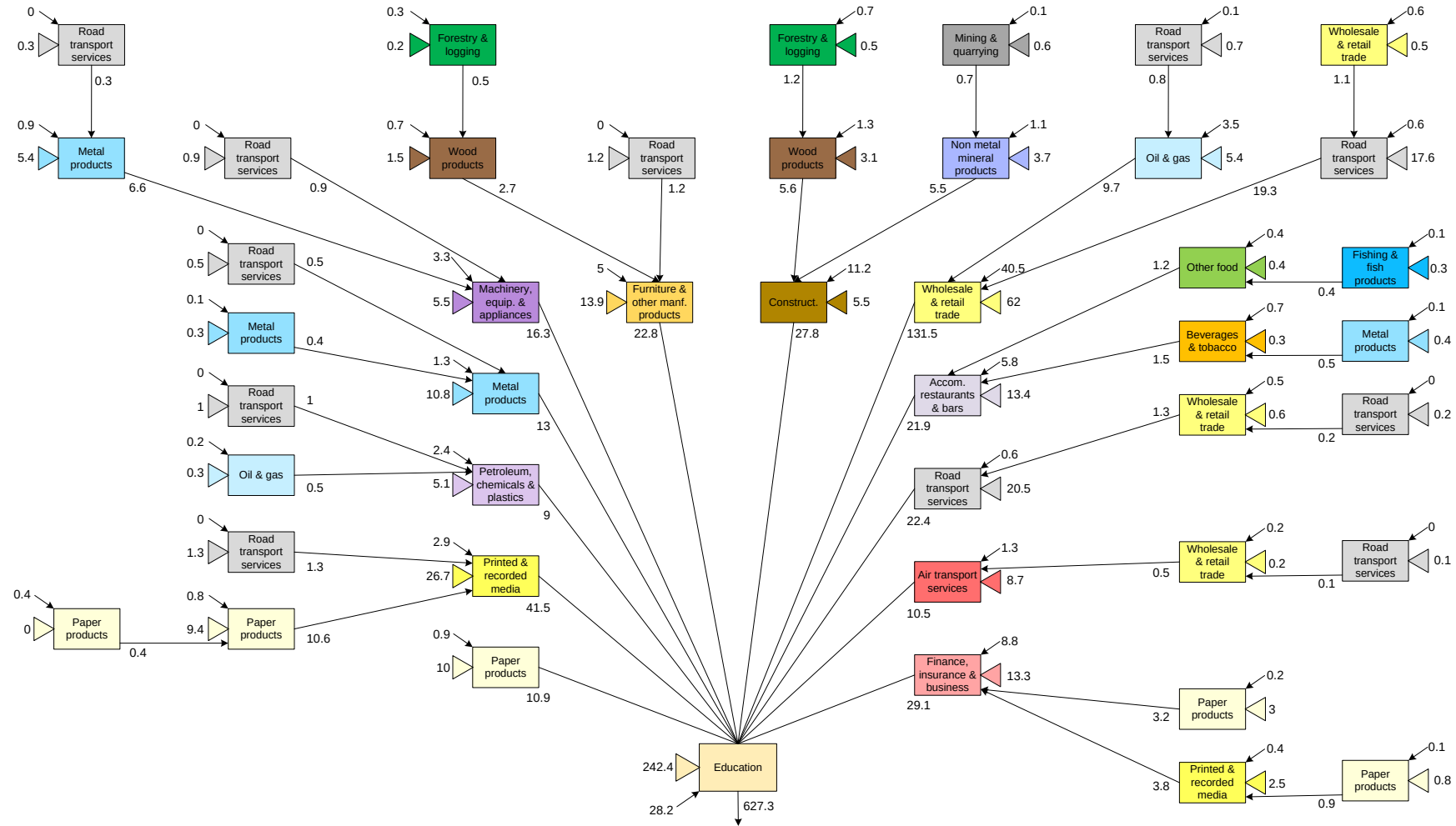
Energy-related CO₂ directly generated by education services was 33% of the total CO₂ emitted at 35,439.8 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by central education services makes up the remaining 67% or 70,666.7 grams.

The indirect energy-related CO₂ from education services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 20,732.3 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in printed and recorded media at 10,598.9 grams per \$1,000 of services

³³⁵ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

supplied; (iii) energy-related CO₂ embodied in furniture and other manufactured products at 10,568.3 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in finance, insurance and business services at 4,574.6 grams per \$1,000 of services supplied.

Figure 32.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Education Services, 2004(MJ_E, Oil Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 32.2 - Electricity Inputs Required to Produce \$1,000 Worth of Education Services, 2004 (MJ, Heat Equivalents)

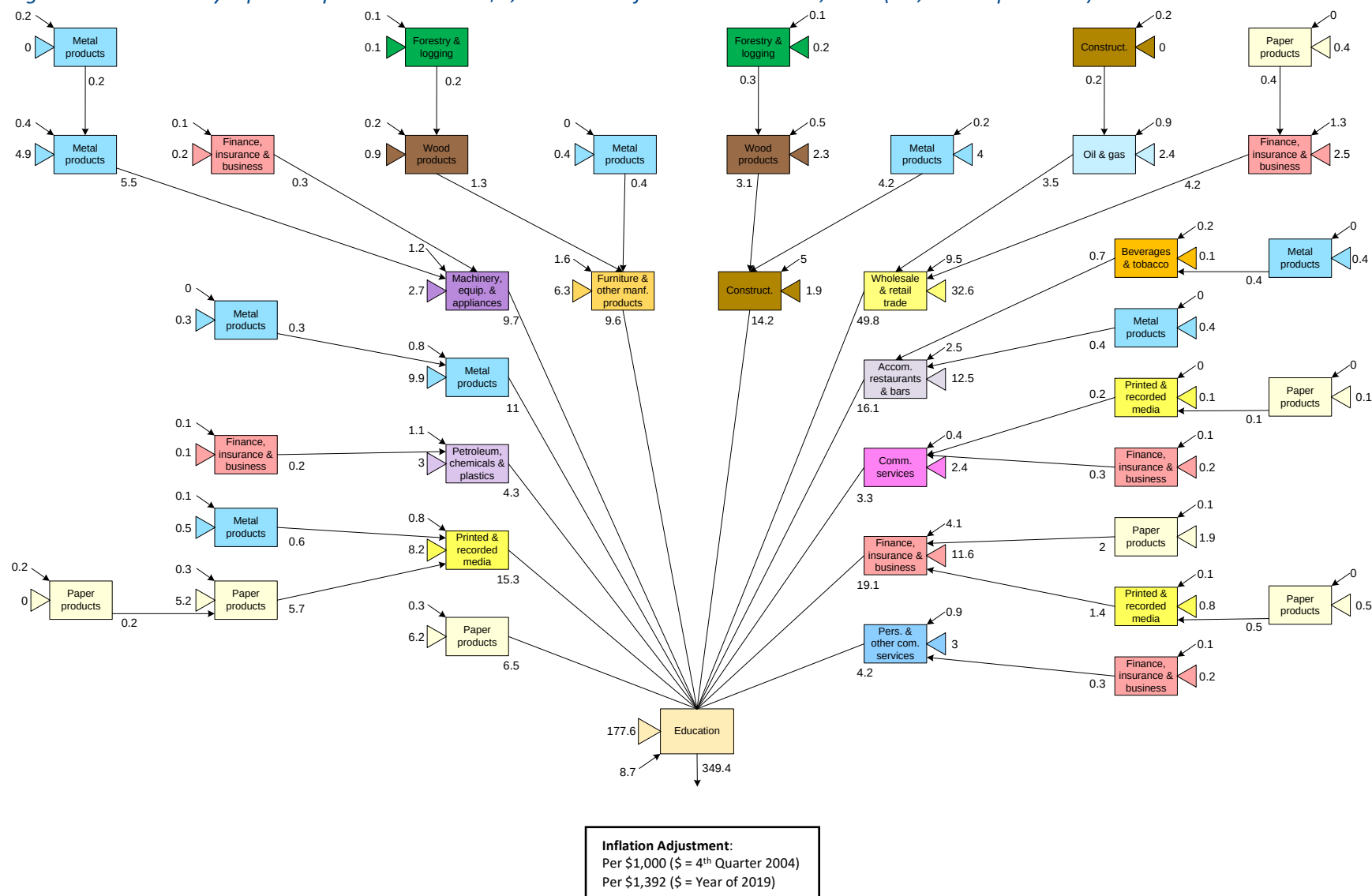


Figure 32.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Education Services, 2004 (MJ, Heat Equivalents)

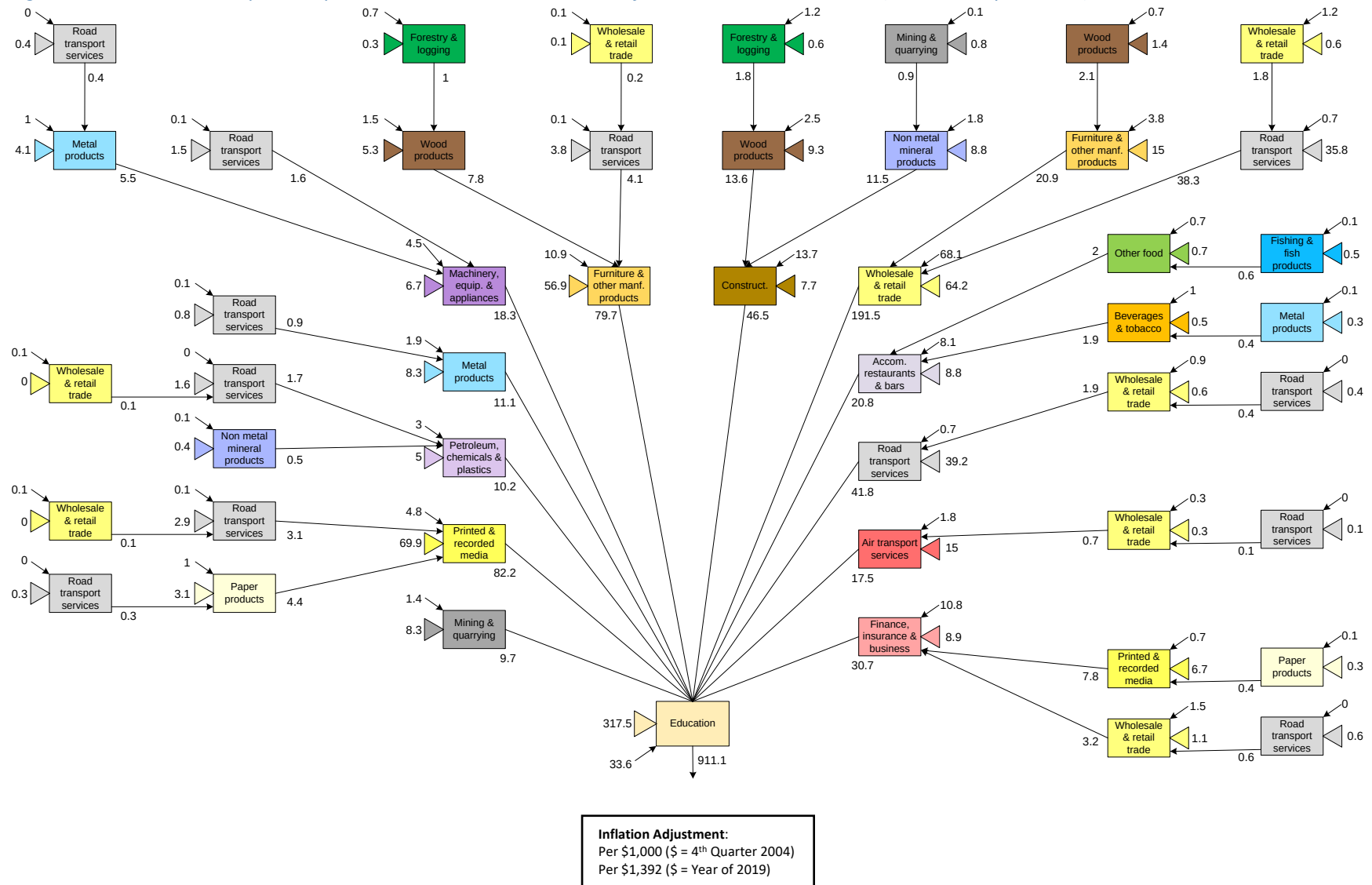


Figure 32.4 - Land Required to Produce \$1,000 Worth of Education Services, 2004 (m²)

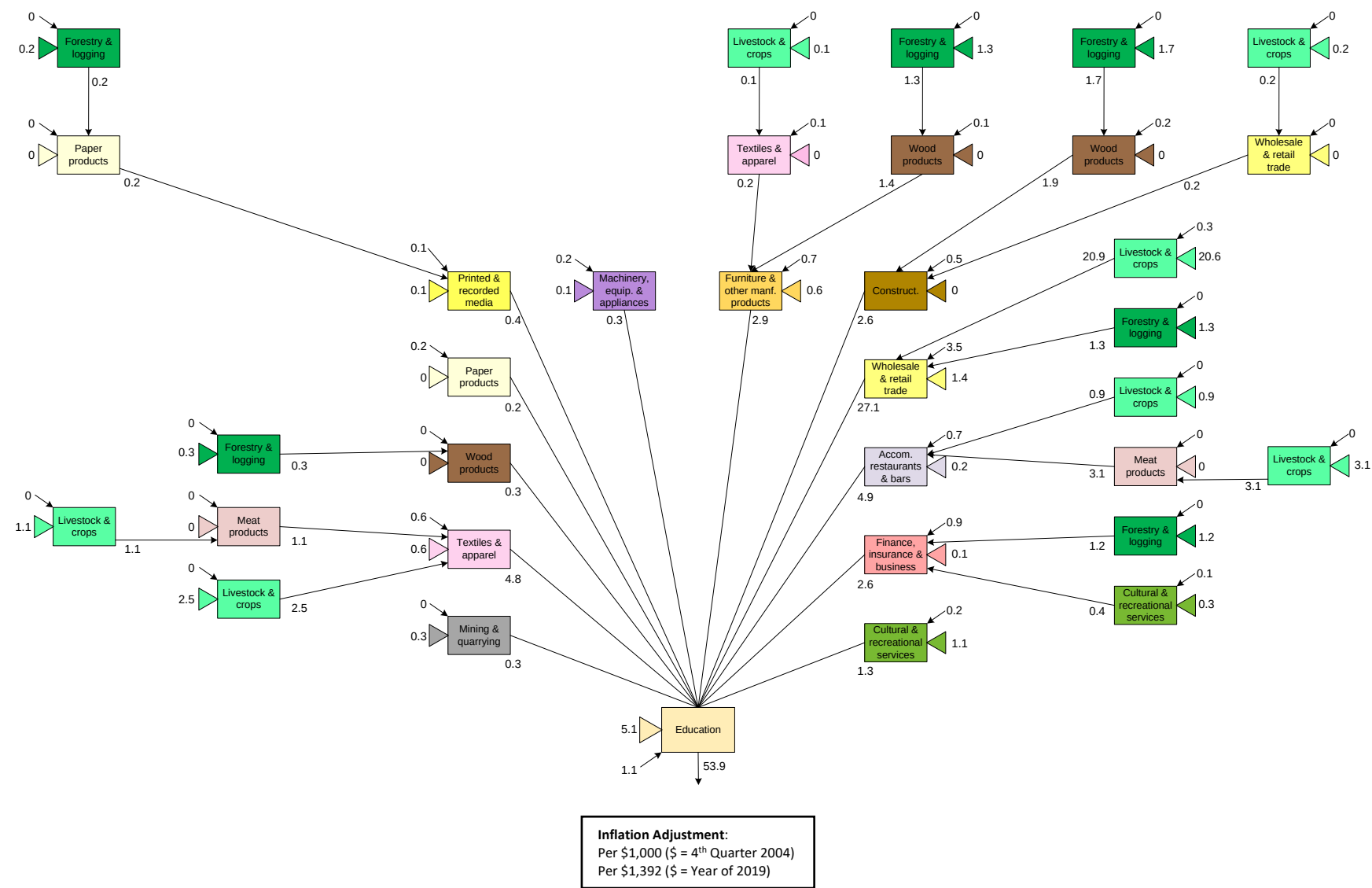


Figure 32.5 - Water Inputs Required to Produce \$1,000 Worth of Education Services, 2004 (Litres)

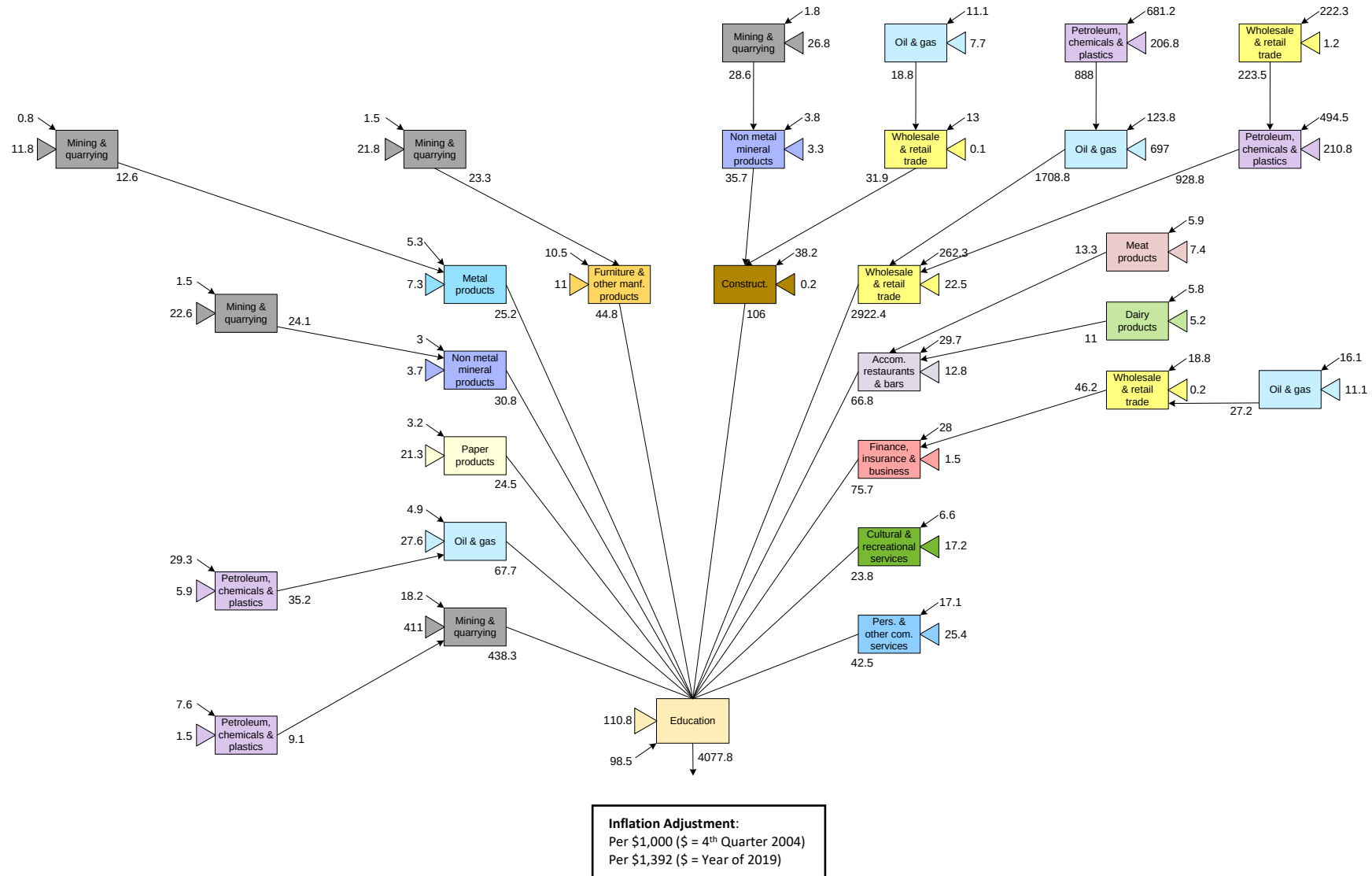
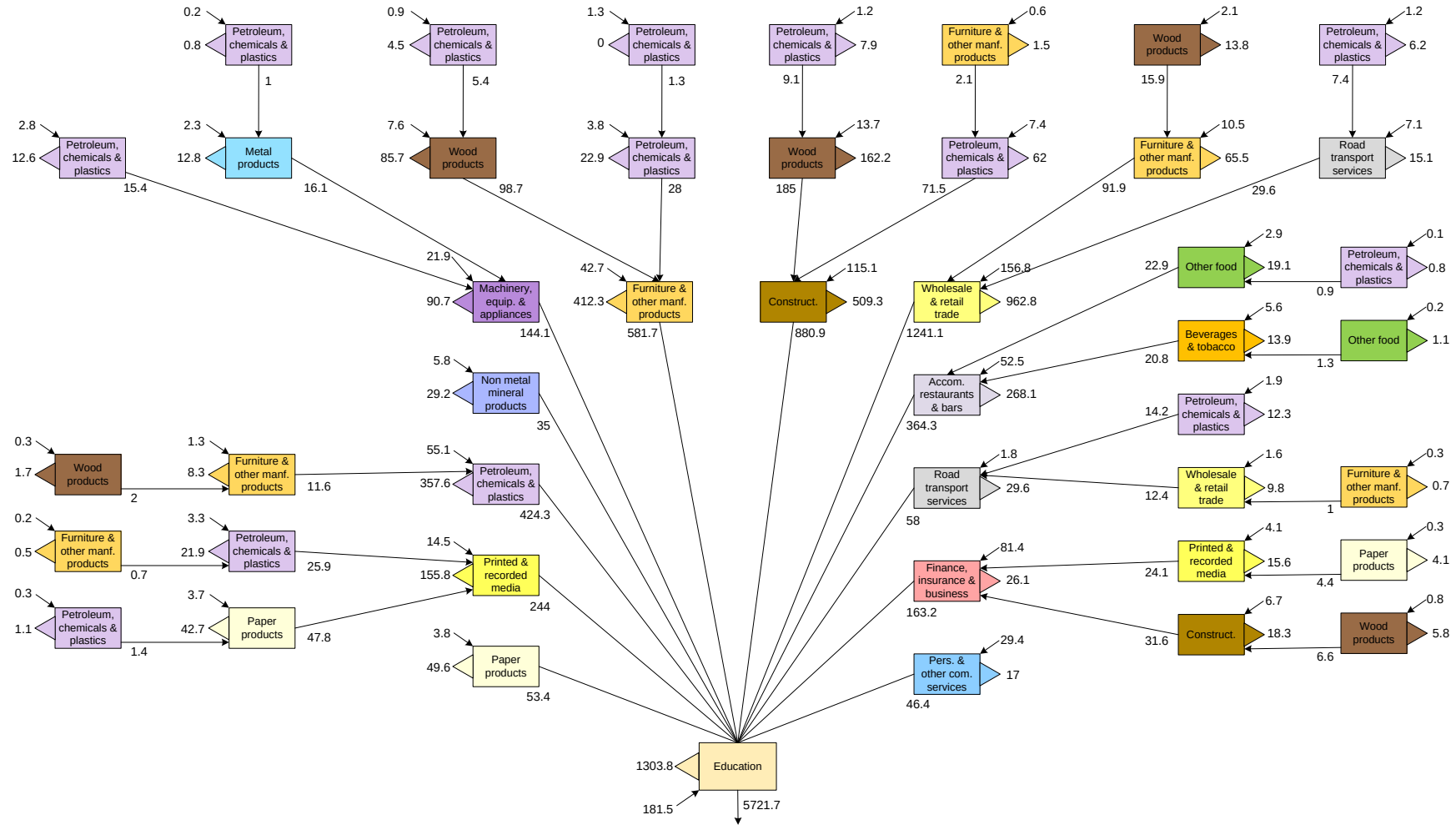
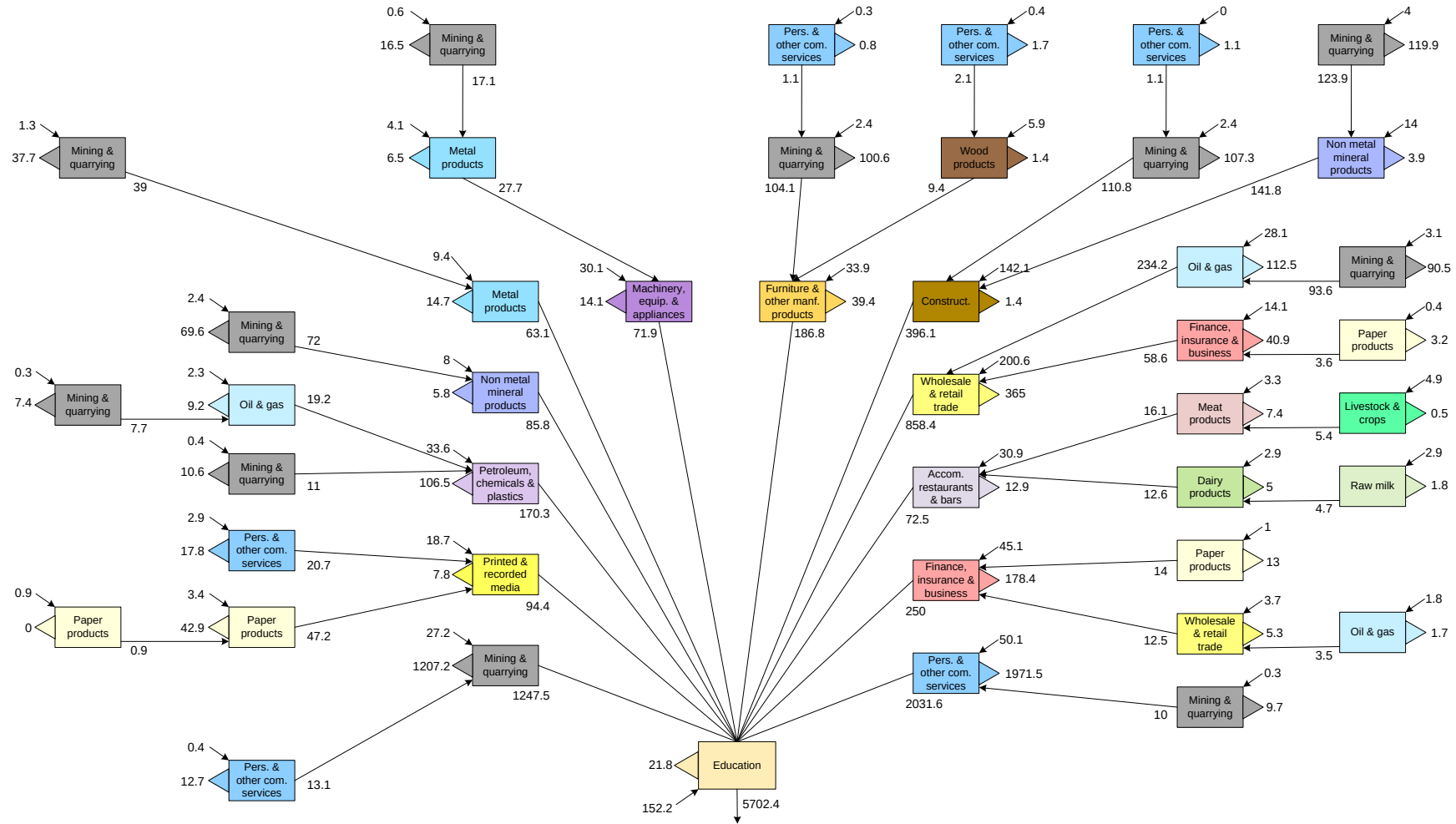


Figure 32.6 - Landfill Waste Generated in Producing \$1,000 Worth of Education Services, 2004 (Grams)



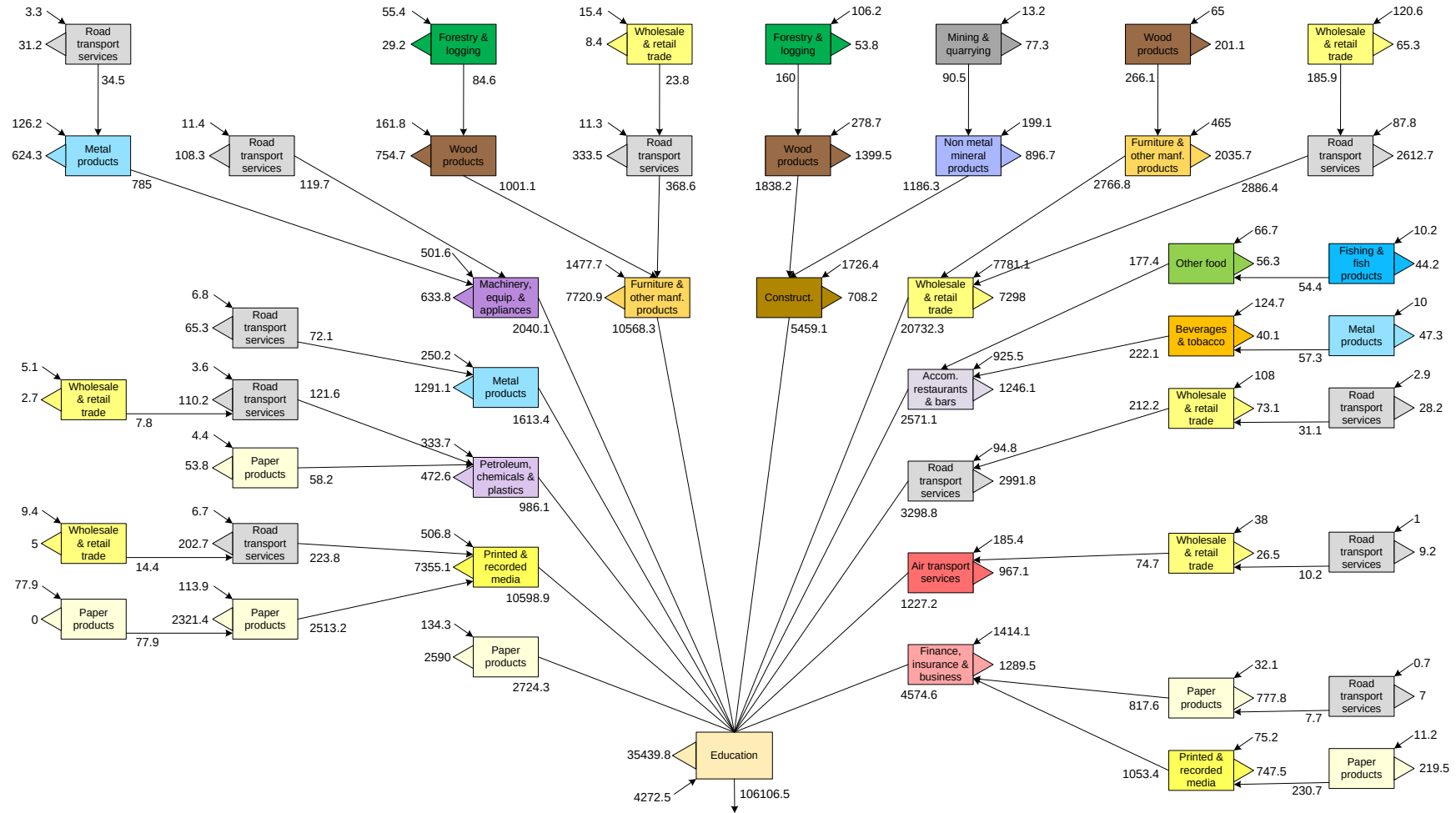
Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 32.7 - Water Waste Generated in Producing \$1,000 Worth of Education Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 32.8 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Education Services, 2004 (Grams)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

33. Health and Community Services

Description

ANZSIC Codes covered:

- 840 – Hospitals
- 851 – Medical Services
- 852 – Pathology and Diagnostic Imaging Services
- 853 – Allied Health Services
- 859 – Other Health Care Services
- 860 – Residential Care Services
- 871 – Child Care Services
- 879 – Other Social Assistance Services

GDP 2016 = \$15.151 billion

Rank = 4th

Average annual growth rate

2006 to 2016 = 5.69%

Rank = 12th

Employment 2016 = 241,080

Rank = 3rd

Main commodities supplied:

- Hospital and nursing care; Medical, dental and other health services; Vet services; Accommodation for the aged; Other social services; and Childcare services.

Economic Overview

The New Zealand healthcare system has undergone significant restructuring over the past three decades.³³⁶ From the early 20th century where it was essentially a fully public system, to a mixed public-private system for delivering healthcare created by reforms that introduced market and health insurance elements in the last three decades.³³⁷ Currently, around 79% of healthcare is publicly funded, while private healthcare provides 21% of all healthcare services.³³⁸

In the public healthcare system, essential services such as emergency care, essential surgery, and hospital care are provided free for all New Zealand residents, and those living here on a work visa valid for two years or longer.³³⁹

The Health and Community Services sector is a significant employer in New Zealand, with around 241,080 FTE employees in 2016. The overwhelming majority of employees within the health and community services industry are female, accounting for over four-fifths (82.5%) of total industry employment.³⁴⁰ Over the past twenty years, the number of women returning

³³⁶ Sheridan, N.F., Kenealy, T.W., Connolly, M.J., Mahony, F., Barber, P.A., ...Moffitt, A. (2011). Health Equity in the New Zealand Health Care System: A national survey. *Equity Health*, 10(45). Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3216847/>

³³⁷ Bandaranayake, D. (1994). Public Health and the Reforms: The New Zealand experience. *Health Policy*, 19(1-2), 127-141.

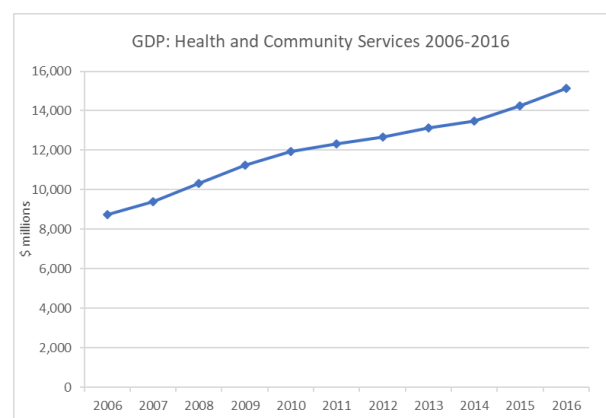
³³⁸ Medical Technology Association of New Zealand. (n.d). Overview. Retrieved 20/11/2012, from <http://mtanz.org.nz/NZ-Market-The-NZ-Healthcare-Market/Overview-6374.htm>

³³⁹ New Zealand Government. (n.d.). *Getting publicly funded health services*. Retrieved 5/02/2020, from <https://www.govt.nz/browse/health/public-health-services/getting-publicly-funded-health-services/>

³⁴⁰ Ministry of Business, Innovation and Employment. (2009). *Employment and Skills Snapshot – Health and Community Services*. Retrieved from <http://www.dol.govt.nz/services/Imi/tools/skillsinsight/snapshots/health/index.asp>

back to the workforce has dramatically increased, increasing the demand for childcare services.³⁴¹

Sector Trends



Overall, this sector's contribution to GDP has been rapidly increasing over the years, growing 73.5% from \$8.73 billion in 2006 to \$15.15 billion in 2016. Spending on healthcare and community services in New Zealand has generally increased over the years, as has employment in the sector. In 2016, the sector was the 3rd largest in terms of employment, with 241,080 employees. Historically, the main drivers of spending on related services have been New Zealand's growing and ageing population, increased rates of obesity and associated diseases, as well as increased range and cost of new services, technologies and medicines.

Life Cycle Assessment Diagrams

Energy (Figure 33.1, Figure 33.2, Figure 33.3)

Health and community services were found to have a total energy intensity of 520.9 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 12th highest out of the 14 service sectors covered in this publication.

Direct energy use for health and community services was 43% of the total energy intensity, measuring 225.8 MJ_E per \$1,000 worth of services supplied. *Indirect energy* use made up the remaining total at 57%, measuring 295.1 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses for health and community services came from; (i) energy embodied in petroleum, chemicals and plastics at 70.2 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in Finance, insurance and business services at 49.7 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in wholesale and retail trade at 38.6 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in printed and recorded media at 24.1 MJ_{OE} per \$1,000 of services supplied.

³⁴¹Callister, P., Didham, R. (2010). *Workforce Composition: Men's work, women's work*. Retrieved from <http://www.TeAra.govt.nz/en/workforce-composition/4>

Land (Figure 33.4)

Health and community services have a total land intensity of just 14.8 m² per \$1,000 of services supplied. This ranks the sector last out of the 14 service sectors covered by this publication, indicating a small total land intensity. *Direct land use* for health and community services was 6% of the total land intensity, measuring 0.9 m² per \$1,000 of services supplied. *Indirect land use* makes up the remaining total land use at 94% measuring 13.9 m² per \$1,000 of services supplied.

The major indirect land uses for health and community services came from; (i) land embodied in wholesale and retail trade at 5.1 m² per \$1,000 of services supplied; (ii) land embodied in finance, insurance and business services at 2.1 m² per \$1,000 of services supplied; (iii) land embodied in textiles and apparel at 1.6 m² per \$1,000 of services supplied; (iv) land embodied in meat products at 1.4 m² per \$1,000 of services supplied.

Water Inputs (Figure 33.5)

Health and community services use a total of 218 litres of water inputs per \$1,000 of services supplied, ranking the sector the 13th highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to health and community services are made up mostly of indirect sources, with *direct sources* only contributing 1% or 2.8 litres per \$1,000 of services supplied. *While indirect sources of water inputs* make up the remaining 99% or 215.2 litres per \$1,000 of services supplied.

These indirect water inputs into the health and community services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 155.9 litres per \$1,000 of services supplied; (ii) water inputs embodied in machinery, equipment and appliances at 14.6 litres per \$1,000 of services supplied; (iii) water inputs embodied in horticulture and fruit at 13.5 litres per \$1,000 of services supplied; (iv) water inputs embodied in mining and quarrying at 6.8 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 33.6)

Health and community services were found to generate a total of 9,360.8 grams (9.3 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the health and community services sector is 44% of total waste produced or 4,111.6 grams per \$1,000 of services supplied. While landfill waste *indirectly generated* was 56% or 5,249.2 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for the health and community services sector came from; (i) landfill wastes embodied in petroleum, chemicals and plastics at 3,268.2 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in construction services at 411 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in wholesale and retail trade at 378 grams per \$1,000 of services supplied; (iv) landfill wastes embodied in finance, insurance and business services at 279.5 grams per \$1,000 of services supplied.

Water Wastes (Figure 33.7)

Health and community services were found to produce a total of 7,570.7 litres of wastewater per \$1,000 of services supplied, ranking the sector the 6th highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated* by the health and community services sector accounted for just 2% of total water wastes or 148.9

litres per \$1,000 of services supplied. *Indirect sources* of water wastes accounted for the remaining 98% of total water wastes or 7,421.8 litres per \$1,000 of services supplied.

The main indirect sources of water wastes were mostly made up of (i) wastewater embodied in personal and other community services at 3,920.9 litres per \$1,000 of services supplied; (ii) wastewater embodied in petroleum, chemicals and plastics at 1,255.9 litres per \$1,000 of services supplied; (iii) wastewater embodied in mining and quarrying at 980.1 litres per \$1,000 of services supplied; (iv) wastewater embodied in wholesale and retail trade at 251.8 litres per \$1,000 of services supplied.

Phosphorus Wastes (Figure 33.8)

Health and community services were found to produce 22.1 grams (0.02 kg) of phosphorus waste per \$1,000 of services supplied. Total phosphorus waste was made up mostly of indirect sources, with direct sources only making up 2.7% of total phosphorus waste, at 0.6 grams per \$1,000 of services supplied. The remaining 97.3% of phosphorous wastes or 21.5 grams per \$1,000 of health and community services supplied came from indirect sources which were mostly made up of (i) phosphorus waste embodied in personal and other community services at 15.1 grams per \$1,000 of services supplied; (ii) phosphorus waste embodied in wholesale and retail trade at 2.1 grams per \$1,000 of services supplied; (iii) phosphorus waste embodied in finance, insurance and business services at 1.6 grams per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 33.9)

In terms of CO₂ greenhouse gas emissions, health and community services emitted a total of 72,880.4 grams (72.8 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked the 12th highest emitter of energy-related CO₂ per tonne among the 14 service sectors covered in this publication.

Energy-related CO₂ directly generated by health and community services was 44% of the total CO₂ emitted at 31,997.5 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* makes up the remaining 56% or 40,882.9 grams per \$1,000 of services supplied.

The indirect energy-related CO₂ from health and community services was mostly made up of (i) energy-related CO₂ embodied in petroleum, chemicals and plastics at 6,737.3 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in finance, insurance and business services at 6,681.8 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in wholesale and retail trade at 5,560.4 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in paper products at 2,547.6 grams per \$1,000 of services supplied.

Figure 33.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Health and Community Services, 2004 (MJ_E, Oil Equivalents)

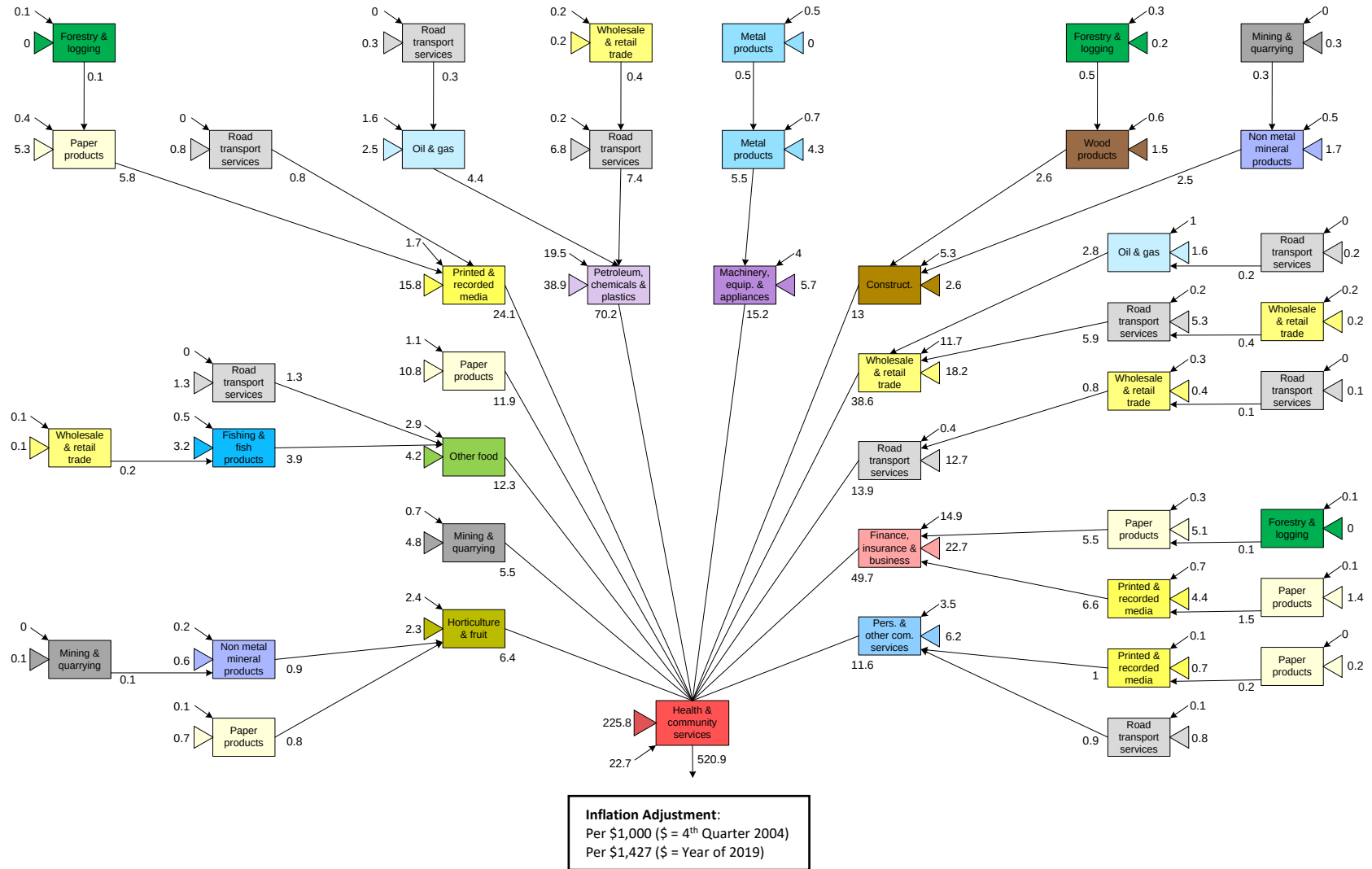
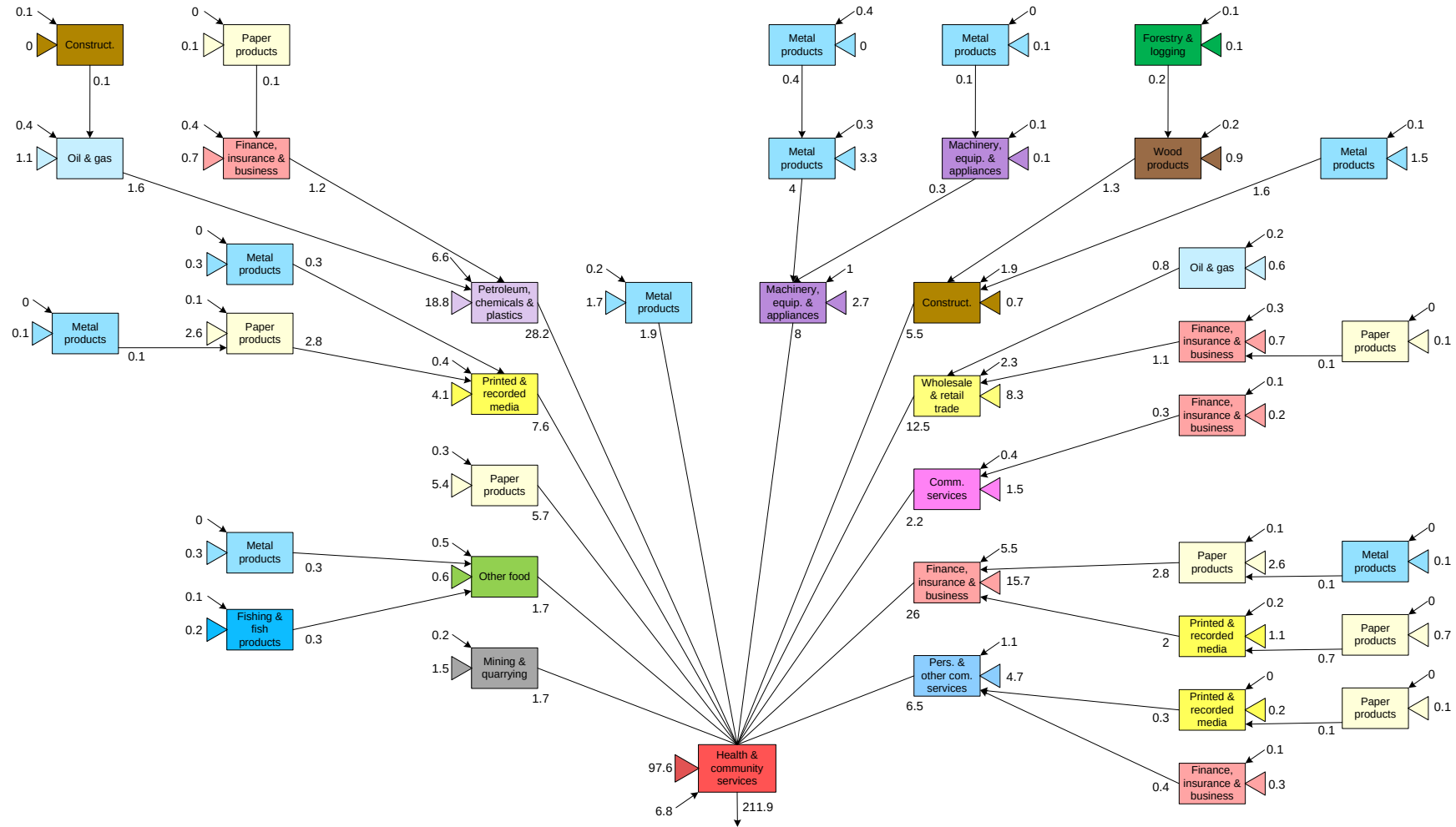


Figure 33.2 - Electricity Inputs Required to Produce \$1,000 Worth of Health and Community Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,427 (\$ = Year of 2019)

Figure 33.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Health and Community Services, 2004 (MJ, Heat Equivalents)

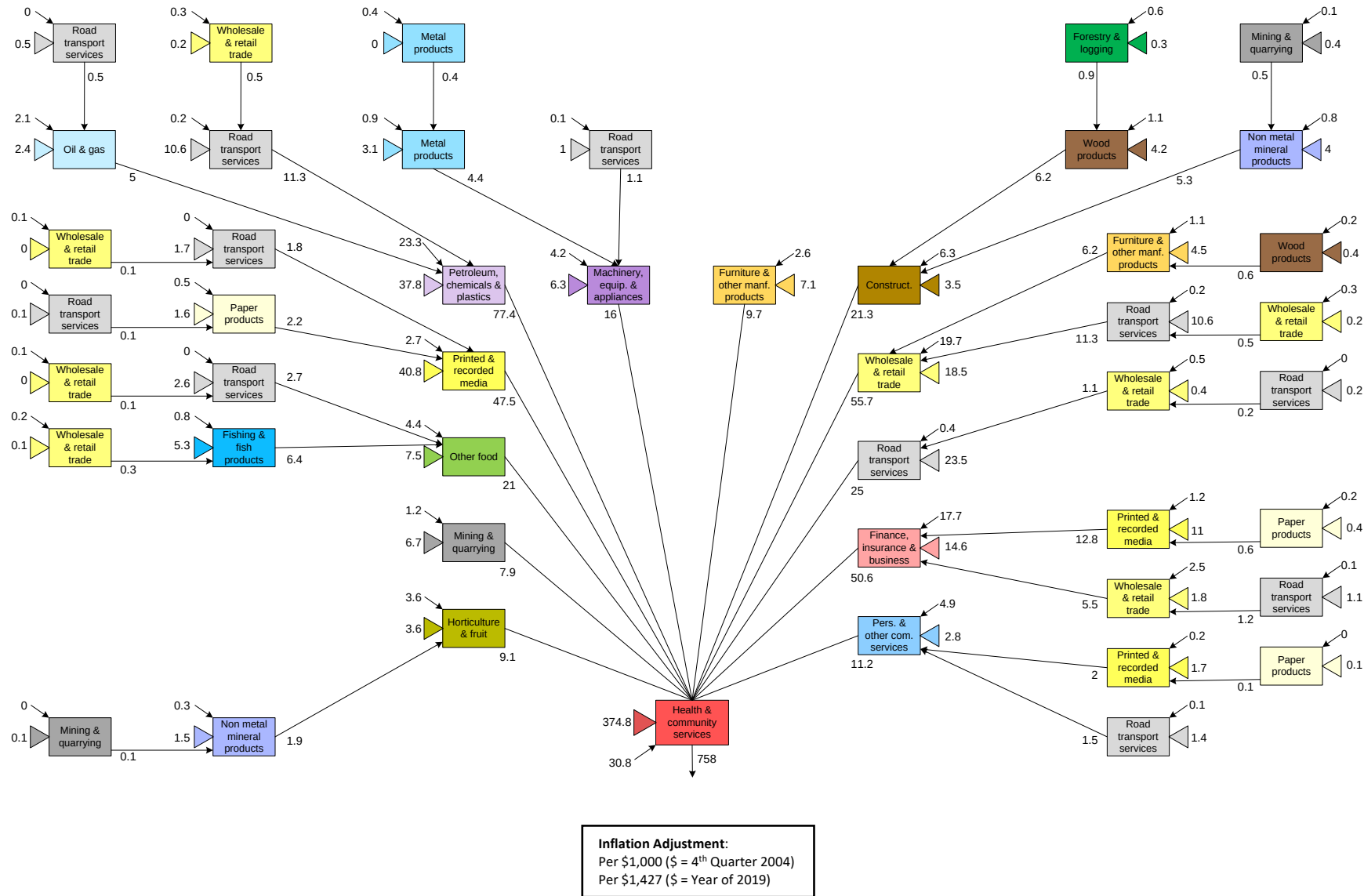
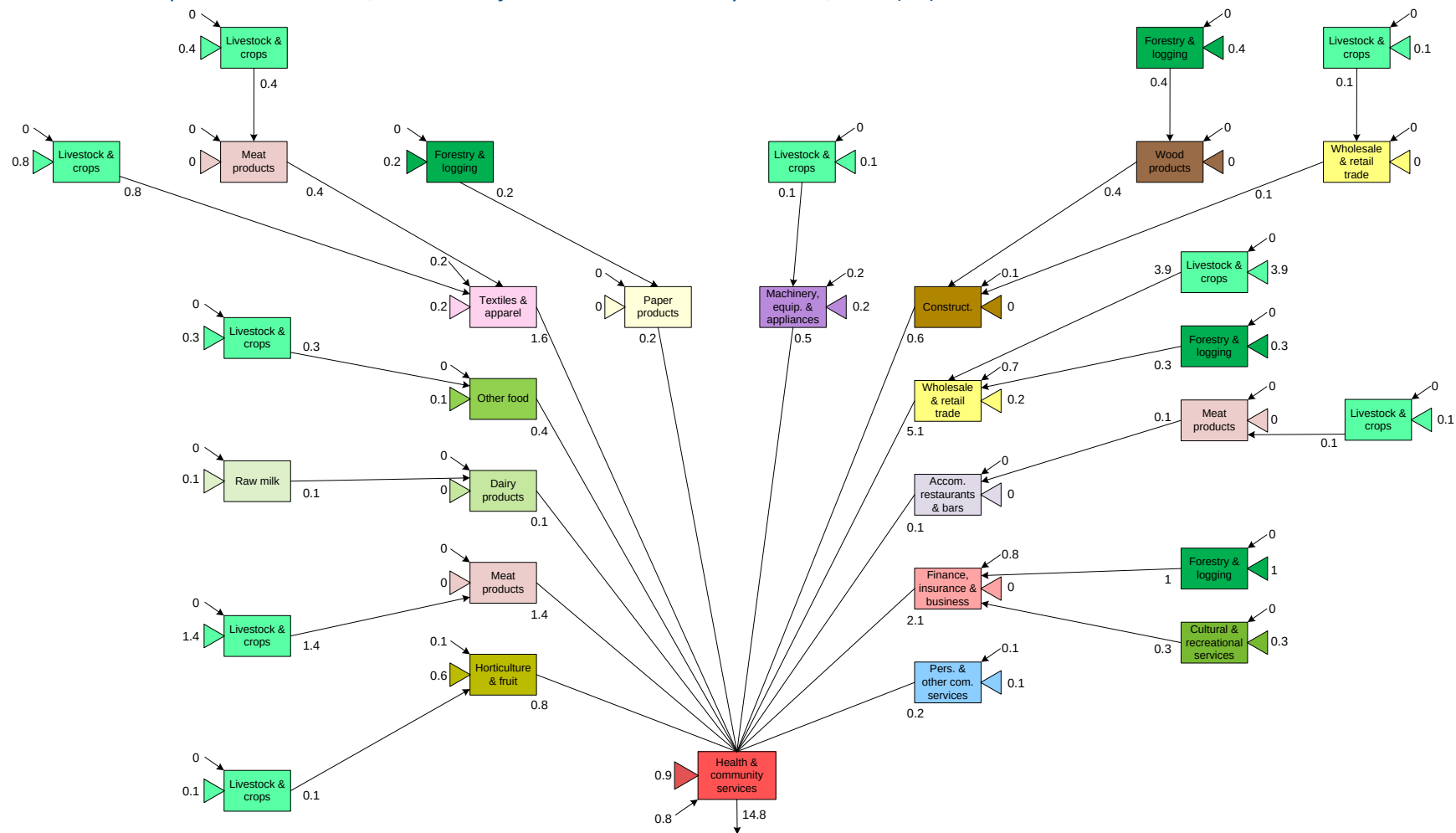
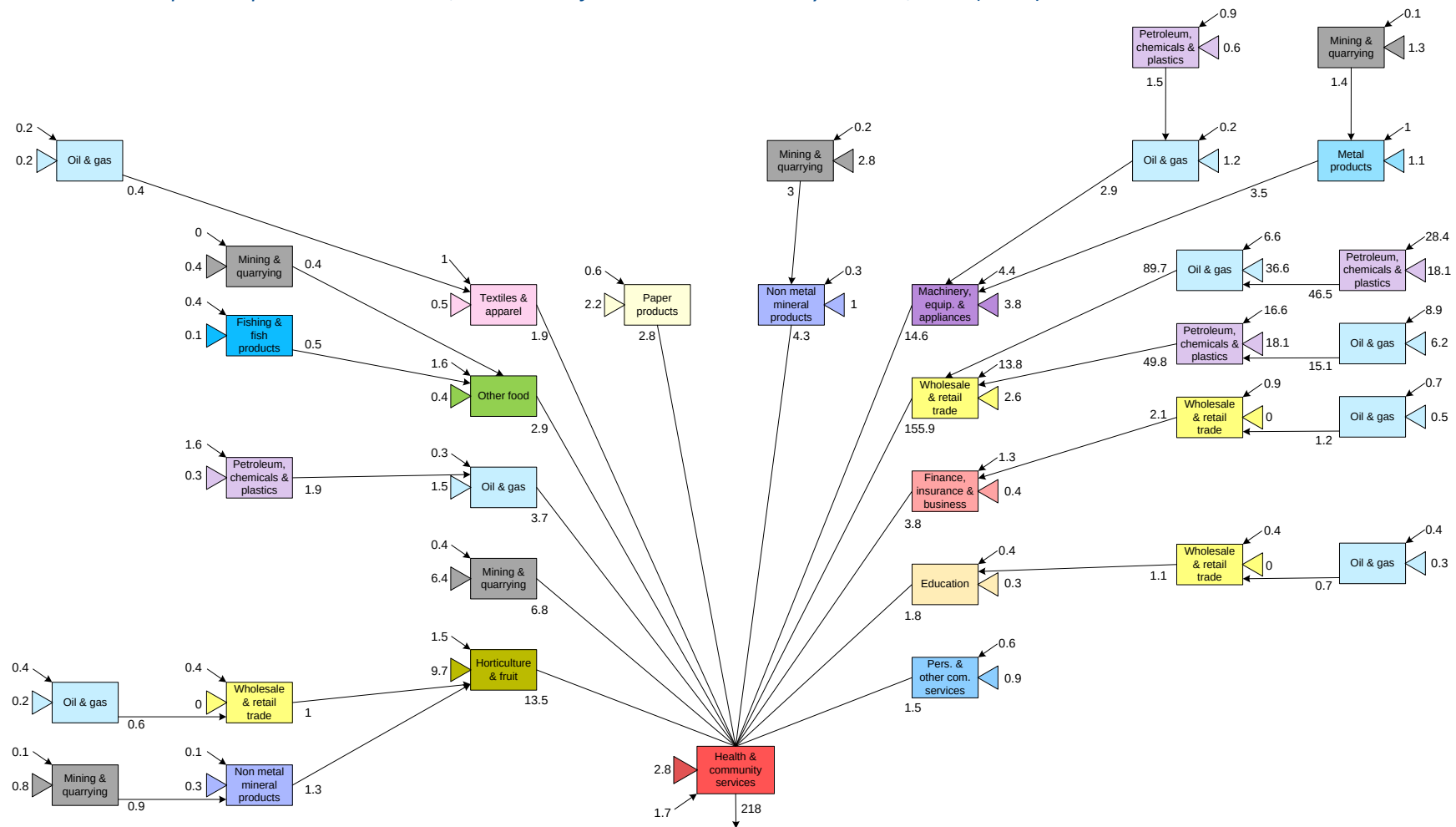


Figure 33.4 - Land Required to Produce \$1,000 Worth of Health and Community Services, 2004 (m²)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,427 (\$ = Year of 2019)

Figure 33.5 - Water Inputs Required to Produce \$1,000 Worth of Health and Community Services, 2004 (Litres)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,427 (\$ = Year of 2019)

Figure 33.6 - Landfill Waste Generated in Producing \$1,000 Worth of Health and Community Services, 2004 (Grams)

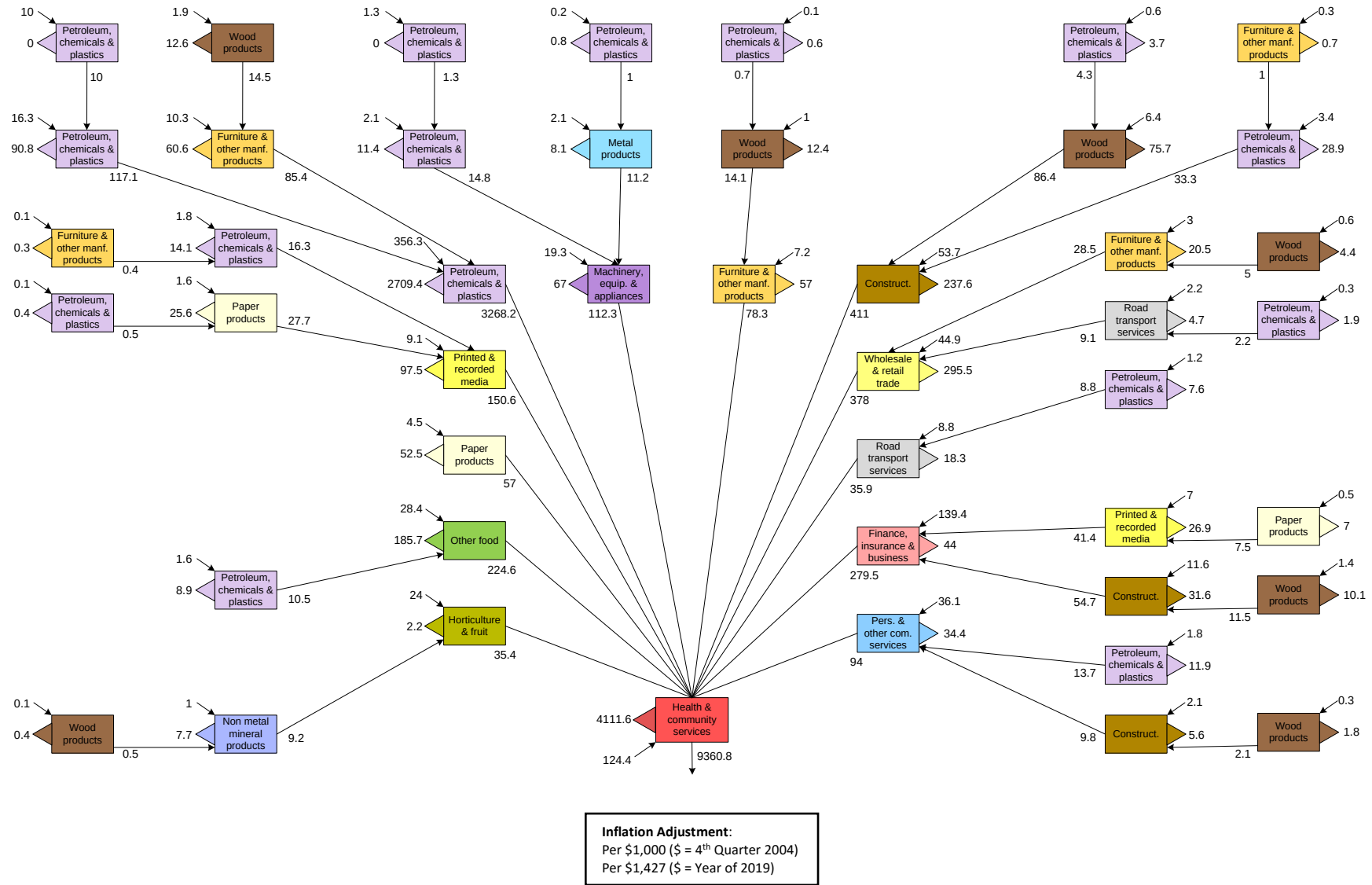


Figure 33.7 - Water Waste Generated in Producing \$1,000 Worth of Health and Community Services, 2004 (Litres)

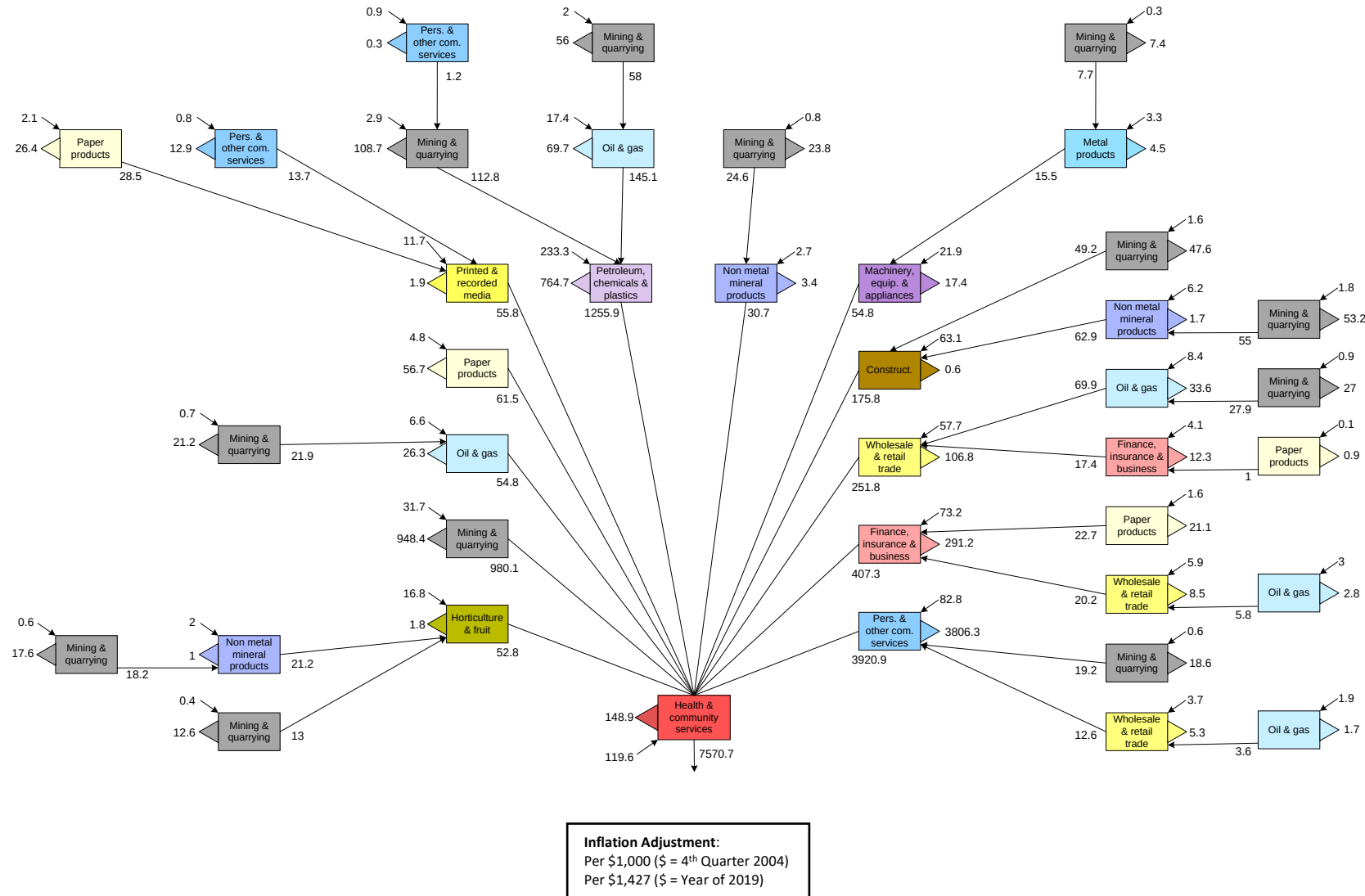


Figure 33.8 - Phosphorus Waste Generated in Producing \$1,000 Worth of Health and Community Services, 2004 (Grams)

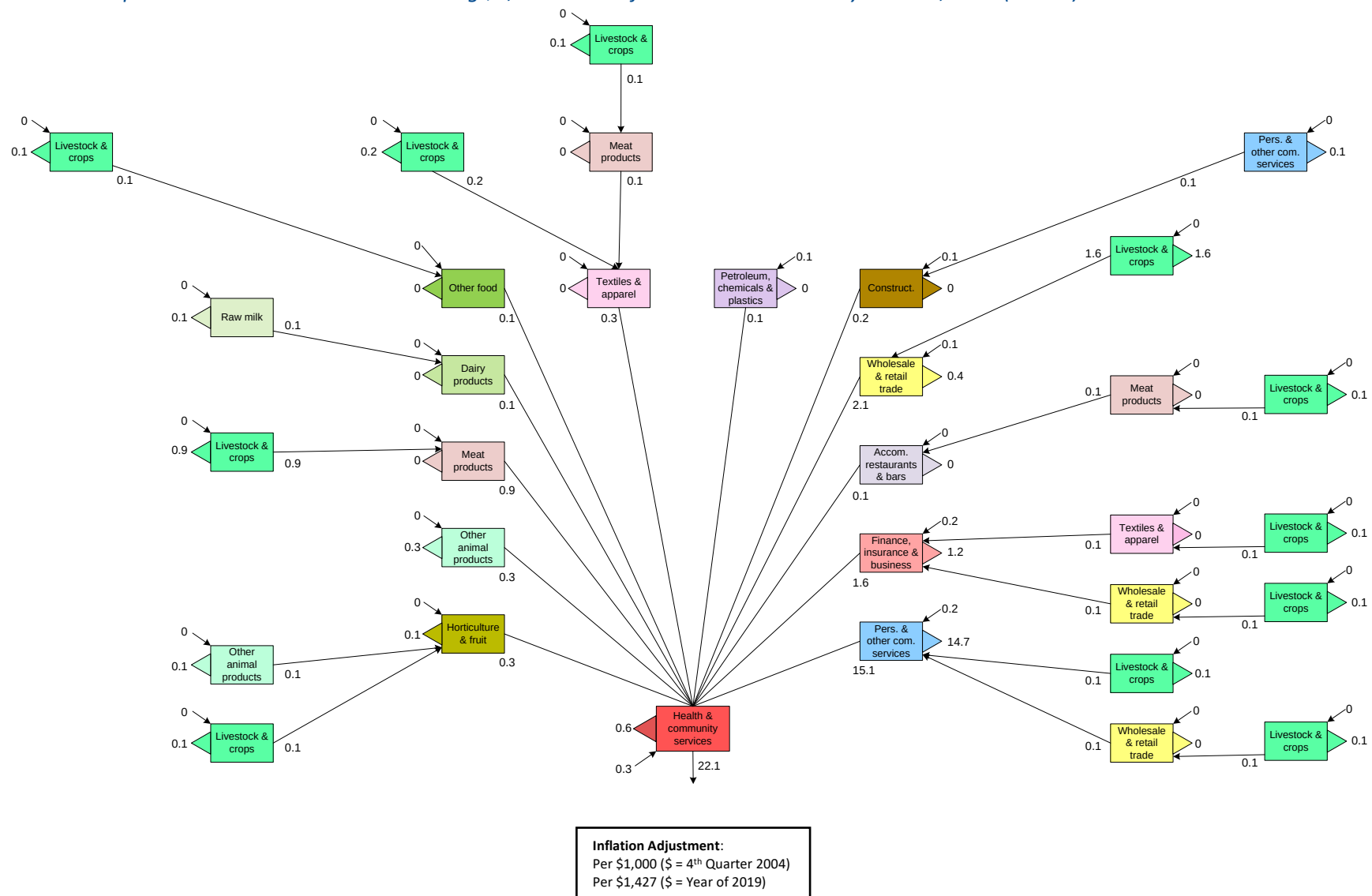
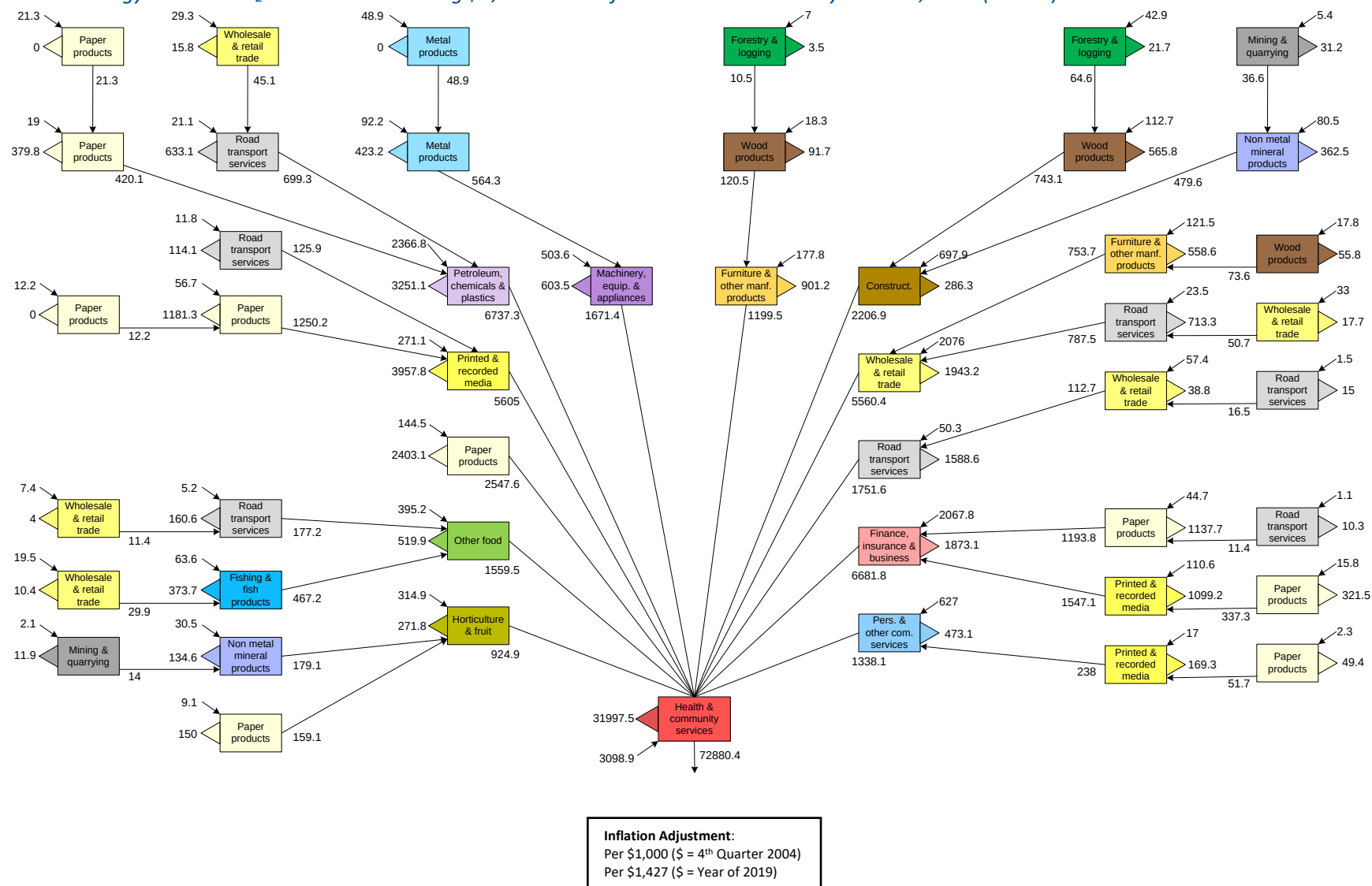


Figure 33.9 - Energy-Related CO₂ Emitted in Producing \$1,000 worth of Health and Community Services, 2004 (Grams)



34. Cultural and Recreational Services

Description

ANZSIC Codes covered:

- 891 – Museum Operation
- 892 – Parks and Gardens Operations
- 900 – Creative and Performing Arts Activities
- 911 – Sports and Physical Recreation Activities
- 912 – Horse and Dog Racing Activities
- 913 – Amusement and Other Recreation Services
- 920 – Gambling Activities
- 561 – Radio Broadcasting
- 562 – Television Broadcasting
- 601 – Libraries and Archives

GDP 2016 = \$3.572 billion

Rank = 15th

Average annual growth rate

2006 to 2016 = 3.95%

Rank = 19th

Employment 2007 = 46,992

Rank = 10th

Main commodities supplied:

- Motion picture, radio, TV services, news agency services, libraries, museums, art, and sport and recreation services

Economic Overview

New Zealand's cultural sector encompasses a broad range of cultural and creative industries and activities such as film, music, broadcasting, design and digital technologies; as well as our built heritage, libraries, literature, museums and galleries, performing and visual arts.

The cultural sector is central to New Zealand's economic activity, our wellbeing and quality of life as almost three-quarters of New Zealanders see culture and cultural activities as very, extremely or critically important to national identity, ranking above sport or the economy.³⁴² In 2013, roughly 14,600 people were employed in arts-related industries, increasing from 13,100 in 2006. While the sector generated \$3.572 billion to the New Zealand economy in 2016, the arts sector involves a considerable amount of non-market activity, activities done which do not include any financial transactions.³⁴³

The recreational sector also plays a major part in the lives of most New Zealanders. Sports especially play an important part because of the positive impact it has on the nation's health and well-being, conservatively estimated, physical inactivity cost New Zealand's healthcare system over \$200 million

³⁴² Ministry for Culture and Heritage. (2012). *Cultural Sector Overviews*. Retrieved from <http://www.mch.govt.nz/what-we-do/cultural-sector-overviews>

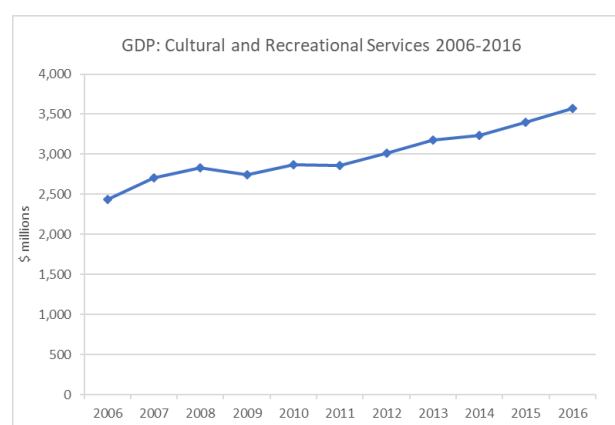
³⁴³ Stroombergen, A. (2015). *Working Paper: An economic profile of the arts in New Zealand*. Wellington: Ministry for Culture and Heritage. Retrieved from [https://mch.govt.nz/files/Economic%20profile%20arts%202015%20\(D-0590039\).PDF](https://mch.govt.nz/files/Economic%20profile%20arts%202015%20(D-0590039).PDF)

in 2013.³⁴⁴ Sport also provides a sense of community, improving community involvement whilst reducing perceived instances of antisocial behaviour within a community.³⁴⁵

New Zealand's gambling and racing industry has grown rapidly in the last 20 years and is now a major contributor to the country's economy and local communities. Gambling expenditure illustrates this trend, with over a twelvefold increase in expenditure from \$191 million in 1985 to \$2.383 billion in 2018.³⁴⁶ Under the Gambling Act 2003, all profits from playing Lotto, New Zealand's national lottery, are used to benefit New Zealand communities.³⁴⁷ Net profits are paid to the New Zealand Lottery Grants Board for distribution to the community to fund recreation, arts, community projects and sports. Since its creation, NZ Lotteries has contributed more than \$2.7 billion to the Lottery Grants Board.³⁴⁸

For many New Zealanders, home is still where they like to spend their leisure hours, for example watching television, videos and DVDs, and listening to music. New Zealand is developing quite a reputation in the film and television production industry and has been described by the American Film Institute as "one of the wonders of the world... an unparalleled success story".³⁴⁹ The success is mainly attributed to New Zealand's spectacular landscape, talented filmmakers, and being leaders in technology and innovation, such as the multi-award winning Weta Digital.³⁵⁰

Sector Trends



Between 2006 and 2016, this sector grew steadily by 4% p.a. on average from \$2.44 billion to \$3.57 billion. In terms of size and pace of growth, the sector ranked close to the middle at 15th and 19th place respectively, in 2016. While the pace of growth remained relatively constant during this time, the sector experienced a period of relatively slower growth between 2008 and 2011. Following the GFC, households would likely have cut back on their spending whereby purchases of necessities were prioritised over luxury commodities and recreational services. Due to this shift in preferences and

³⁴⁴ Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., & Pratt, M. (2016). *The economic burden of physical inactivity: a global analysis of major non-communicable diseases*. The Lancet. doi:[https://doi.org/10.1016/S0140-6736\(16\)30383-X](https://doi.org/10.1016/S0140-6736(16)30383-X)

³⁴⁵ Sport NZ. (2017). *The Value of Sport*. Wellington. Retrieved from <https://sportnz.org.nz/assets/Uploads/The-Value-of-Sport-Main-Report.pdf>

³⁴⁶ The Department of Internal Affairs. (2008). *Gambling Expenditure Statistics 1984-2008*. Wellington. Retrieved from [https://www.dia.govt.nz/Pubforms.nsf/URL/Expendstats08.pdf/\\$file/Expendstats08.pdf](https://www.dia.govt.nz/Pubforms.nsf/URL/Expendstats08.pdf/$file/Expendstats08.pdf)

³⁴⁷ Community Matters. (n.d.). *Lottery Grants Board*. Retrieved February 5, 2020, from <https://www.communitymatters.govt.nz/lottery-grants-board/>

³⁴⁸ NZ Lotteries. (2010). *Statement of Intent: For the Financial years ending 30 June 2011-2013*. Retrieved from www.comu.govt.nz/resources/pdfs/nzlc/nzlc-sci-10.pdf

³⁴⁹ New Zealand Tourism. (2014, December 3). *Background: New Zealand's screen industry*. Retrieved February 5, 2020, from 100% Pure New Zealand: <https://media.newzealand.com/en/story-ideas/background-new-zealands-screen-industry/>

³⁵⁰ Ibid.

behaviour, the sector's contribution remained largely at \$2.68 billion during this period, with marginal fluctuations above and below this level.

Life Cycle Assessment Diagrams

Energy (Figure 34.1, Figure 34.2, Figure 34.3)

Cultural and recreation services were found to have a total energy intensity of 341.9 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 13th highest out of the 14 service sectors covered in this publication.

Direct energy use for cultural and recreation services was 21% of the total energy intensity, measuring 72.8 MJ_{OE} per \$1,000 worth of services supplied. *Indirect energy* use made up the remaining total at 79%, measuring 269.1 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses for cultural and recreation services came from; (i) energy embodied in wholesale and retail trade at 70.3 MJ_{OE} per \$1,000 of services supplied; (ii) energy embodied in finance, insurance and business services at 43 MJ_{OE} per \$1,000 of services supplied; (iii) energy embodied in machinery, equipment and appliances at 32.2 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in air transport services at 20.5 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 34.4)

Cultural and recreation services have a total land intensity of 1,279.1 m² per \$1,000 of services supplied, ranking the sector second highest out of the 14 service sectors covered by this publication. Direct land use for cultural and recreation services was 80% of the total land intensity, measuring 1,024 m² per \$1,000 of services supplied. Indirect land use makes up the remaining total land use at 20% measuring 255.1 m² per \$1,000 of cultural and recreation services supplied.

The major indirect land uses for cultural and recreation services came from; (i) land embodied in wholesale and retail trade at 48.8 m² per \$1,000 of services supplied; (ii) land embodied in construction services at 47.8 m² per \$1,000 of services supplied; (iii) land embodied in meat products at 37.2 m² per \$1,000 of services supplied; (iv) land embodied in livestock and crops at 27.5 m² per \$1,000 of services supplied.

Water Inputs (Figure 34.5)

Cultural and recreation services use a total of 6,300 litres of water inputs per \$1,000 of services supplied, ranking the sector the 2nd highest consumer of water out of the 14 service sectors covered by this publication. Water inputs to cultural and recreation services are made up mostly of indirect sources, with *direct sources* only contributing 60% or 3,793.2 litres per \$1,000 of services supplied. *While indirect water inputs* make up the remaining 40% or 2,506.8 litres per \$1,000 of cultural and recreation services supplied.

These indirect water inputs into the cultural and recreation services sector came mostly from; (i) water inputs embodied in wholesale and retail trade at 1,614.4 litres per \$1,000 of services supplied; (ii) water inputs embodied in construction services at 141 litres per \$1,000 of services supplied; (iii) water inputs embodied in finance, insurance and business services at 132.3 litres per \$1,000 of services supplied; (iv) water inputs embodied in cultural and recreational services at 92.3 litres per \$1,000 of services supplied.

Landfill Wastes (Figure 34.6)

Cultural and recreation services were found to generate a total of 3,413.6 grams (3.4 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the cultural and recreation services sector is 28% of total waste produced or 943.5 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 72% or 2,470.1 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for the cultural and recreation services came from; (i) landfill wastes embodied in wholesale and retail trade at 580.8 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in construction services at 463.2 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in Machinery, equipment and appliances at 239.5 grams per \$1,000 of services supplied; (iv) landfill wastes embodied finance, insurance and business services at 209.7 grams per \$1,000 of services supplied.

Water Wastes (Figure 34.7)

Cultural and recreation services were found to produce a total of 2,762.7 litres of wastewater per \$1,000 of services supplied, ranking the sector the 13th highest producer of water wastes out of the 14 service sectors covered by this publication. *Water wastes directly generated by the* cultural and recreation services sector accounted for 32% of total water wastes or 891.4 litres per \$1,000 of services supplied. *Indirect sources* of water wastes accounted for the remaining 68% of total water wastes or 1,871.3 litres per \$1,000 of services supplied.

The main indirect sources of water wastes were mostly made up of (i) wastewater embodied in wholesale and retail trade at 433.5 litres per \$1,000 of services supplied; (ii) wastewater embodied in finance, insurance and business services at 375.6 litres per \$1,000 of services supplied; (iii) wastewater embodied in construction services at 250.4 litres per \$1,000 of services supplied; (iv) wastewater embodied in personal and other community services at 157.6 litres per \$1,000 of services supplied.

Phosphorus Wastes (Figure 34.8)

Cultural and recreation services were found to produce 12.4 grams (0.01 kg) of phosphorus waste per \$1,000 of services supplied. Total phosphorus waste was made up mostly of indirect sources, with direct sources only making up 2% of total phosphorus waste, at 0.2 grams per \$1,000 of services supplied. The remaining 98% of phosphorous wastes or 21.5 grams per \$1,000 of cultural and recreation services supplied came from indirect sources which were mostly made up of (i) phosphorus waste embodied in wholesale and retail trade at 3.6 grams per \$1,000 of services supplied; (ii) phosphorus waste embodied in other animal products at 2.4 grams per \$1,000 of services supplied; (iii) phosphorus waste embodied in textile and apparels at 1.7 grams per \$1,000 of services supplied.

Energy Greenhouse Gases (Figure 34.9)

In terms of CO₂ greenhouse gas emissions, cultural and recreation services emitted a total of 31,832.7 grams (31.8 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is the lowest-ranked among the 14 service sectors covered in this publication, indicating that the sector emits comparatively low levels of energy-related CO₂ per \$1,000 of services supplied.

Energy-related CO₂ directly generated by cultural and recreation services was 8% of the total CO₂ emitted at 2,439.5 grams per \$1,000 of services supplied. *Energy-related CO₂ indirectly generated* by cultural and recreation services makes up the remaining 92% or 29,393.2 grams per \$1,000 of services supplied.

The indirect energy-related CO₂ from cultural and recreation services was mostly made up of (i) energy-related CO₂ embodied in wholesale and retail trade at 8,293.4 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in finance, insurance and business services at 3,920.2 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in machinery, equipment and appliances at 3,562.1 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in printed and recorded media at 3,253.4 grams per \$1,000 of services supplied.

Figure 34.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Cultural and Recreational Services, 2004 (MJ_E, Oil Equivalents)

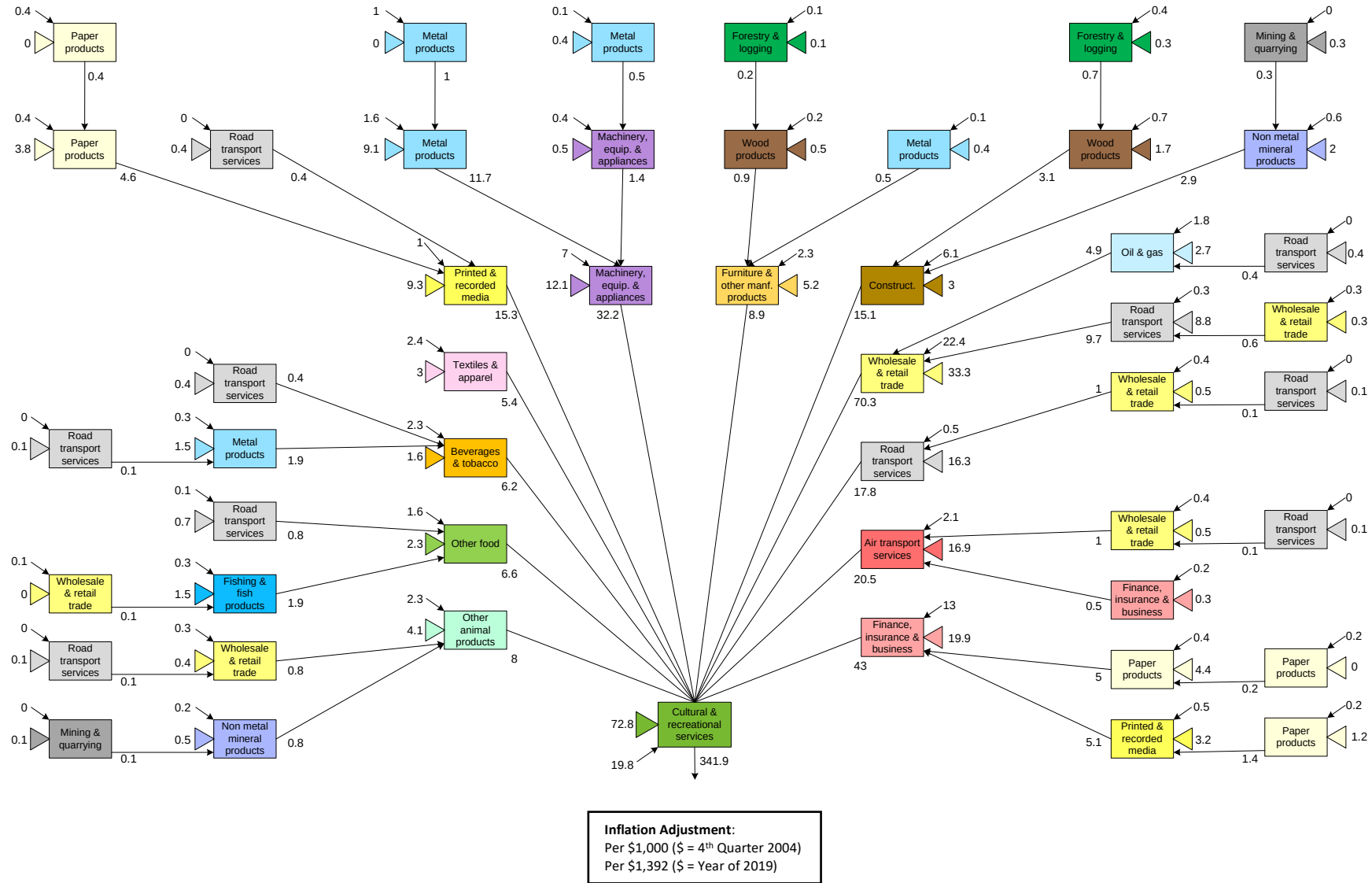
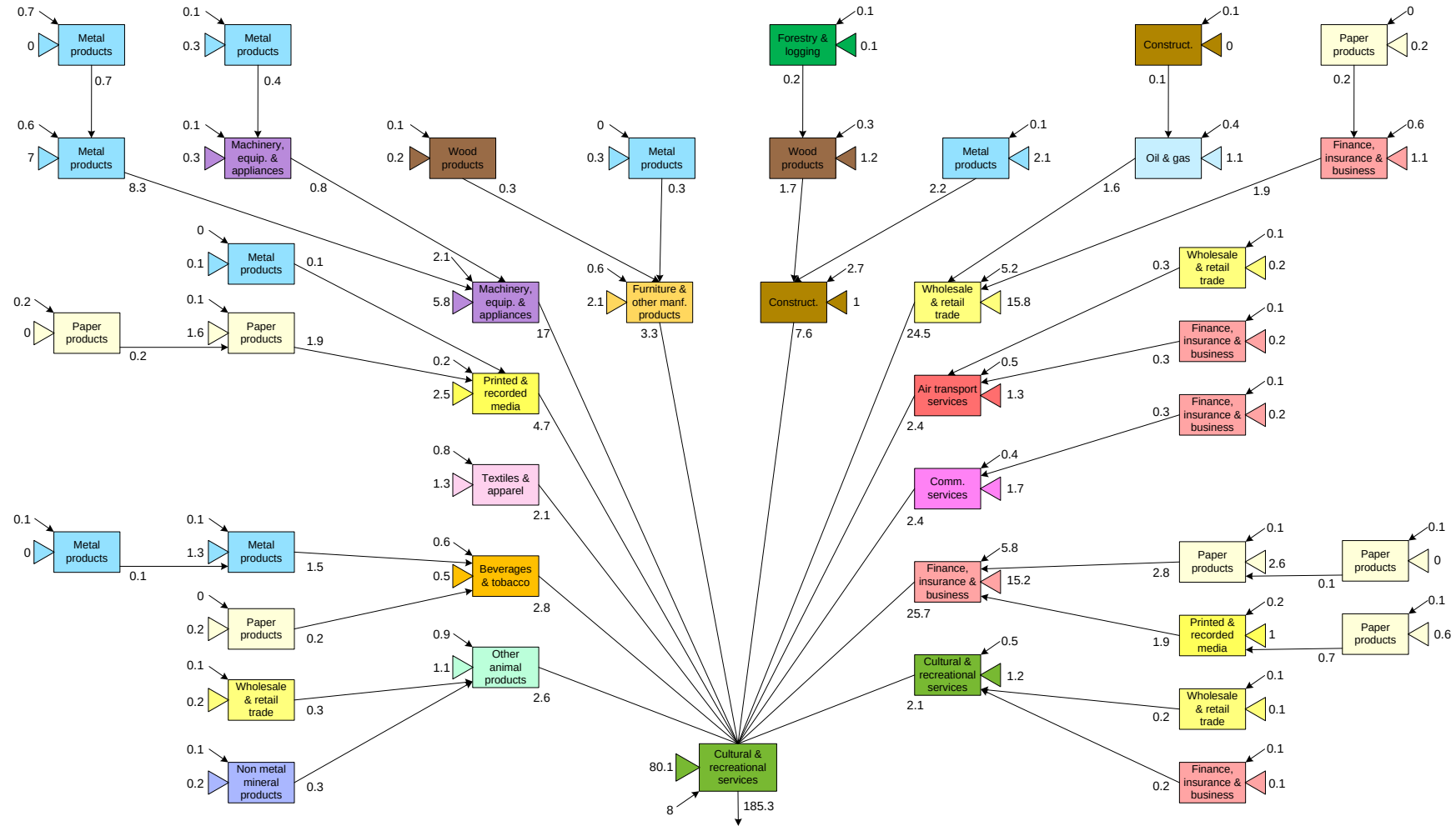


Figure 34.2 - Electricity Inputs Required to Produce \$1,000 Worth of Cultural and Recreational Services, 2004 (MJ, Heat Equivalents)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 34.3 - Fossil Fuel Inputs Required to Produce \$1,000 Worth of Cultural and Recreational Services, 2004 (MJ, Heat Equivalents)

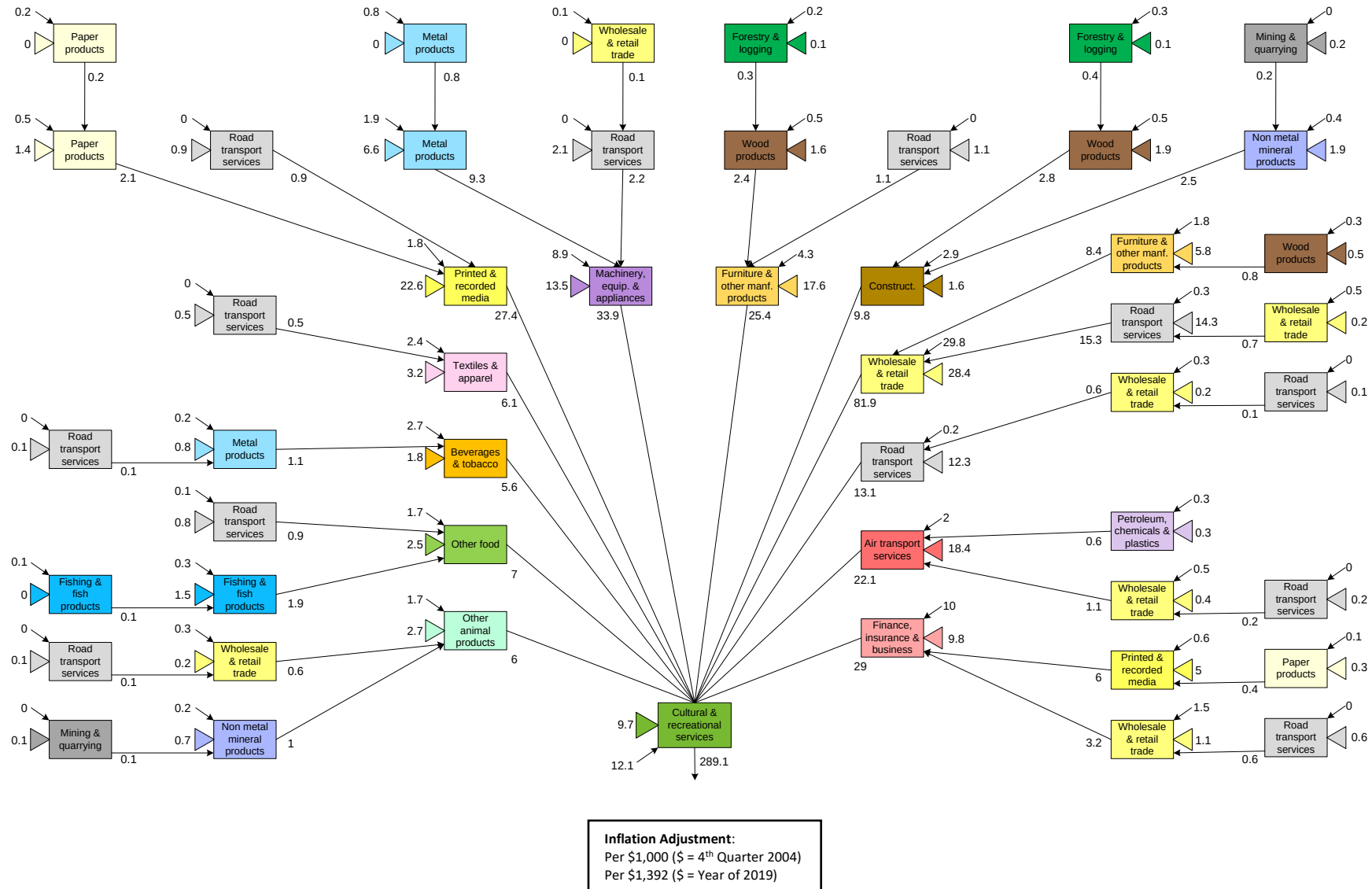


Figure 34.4 - Land Required to Produce \$1,000 Worth of Cultural and Recreational Services, 2004 (m²)

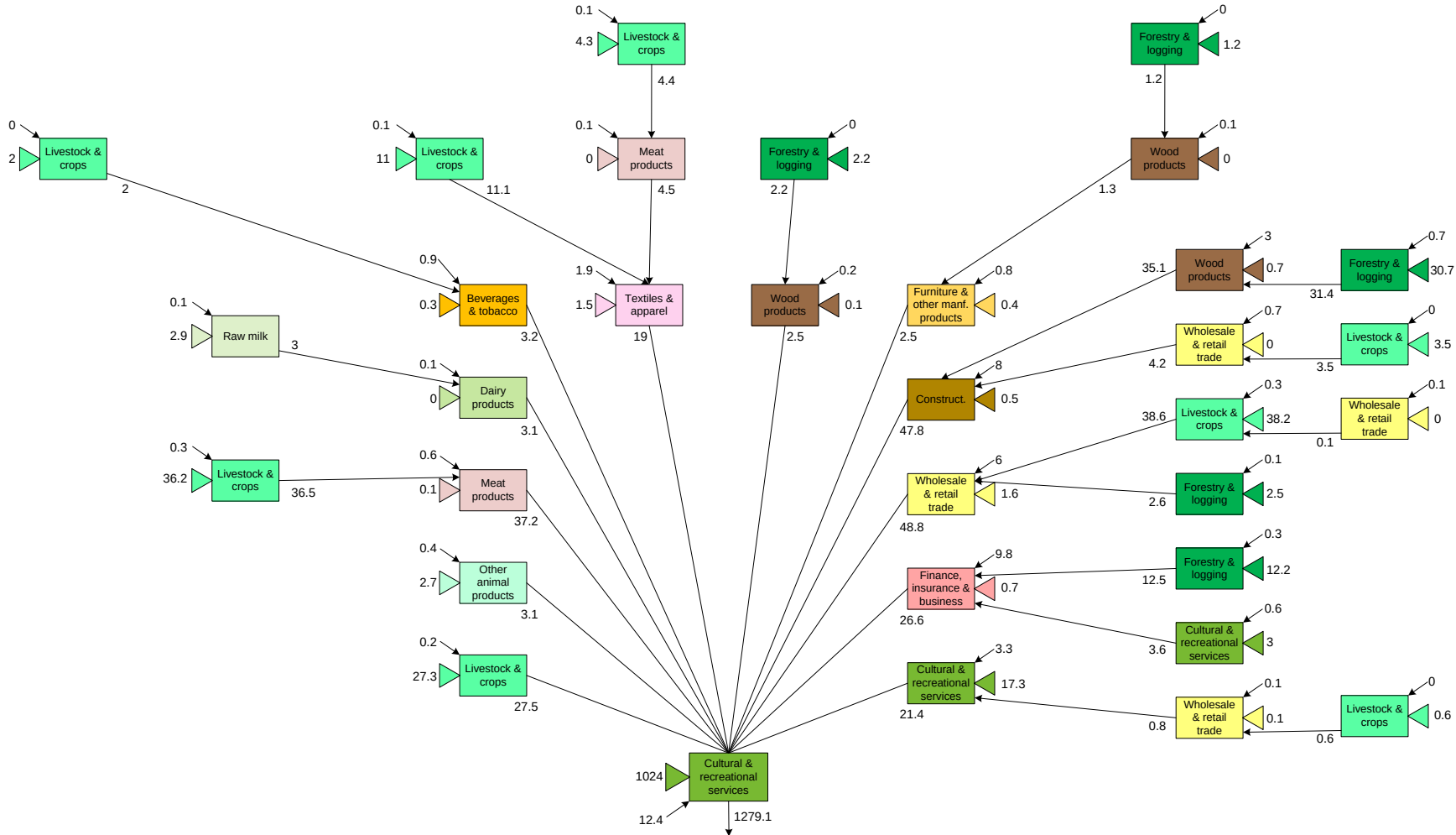
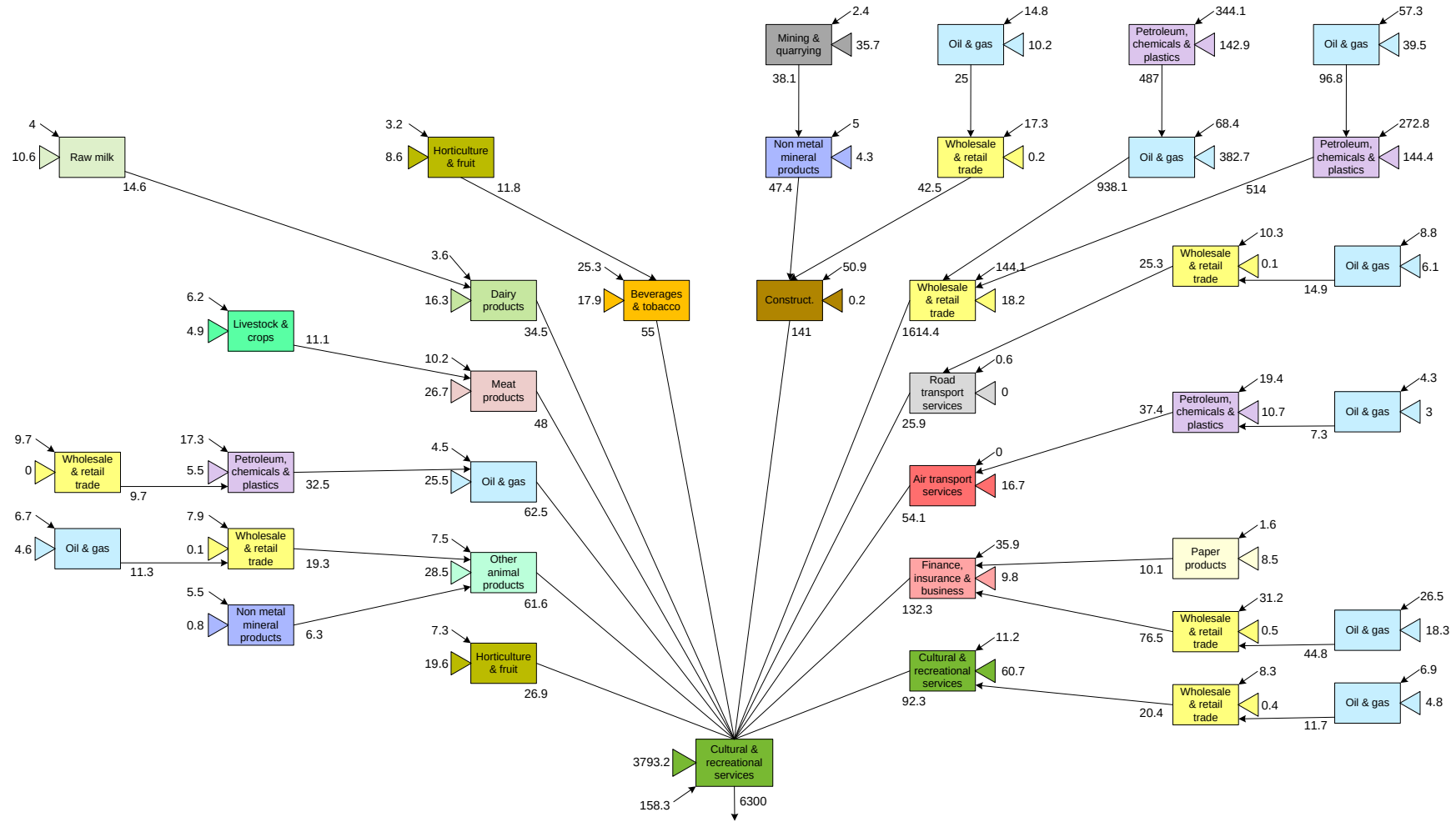


Figure 34.5 - Water Inputs Required to Produce \$1,000 Worth of Cultural and Recreational Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 34.6 - Landfill Waste Generated in Producing \$1,000 Worth of Cultural and Recreational Services, 2004 (Grams)



Inflation Adjustment:
Per \$1,000 (\$ = 4th Quarter 2004)
Per \$1,392 (\$ = Year of 2019)

Figure 34.7 - Water Waste Generated in Producing \$1,000 Worth of Cultural and Recreational Services, 2004 (Litres)

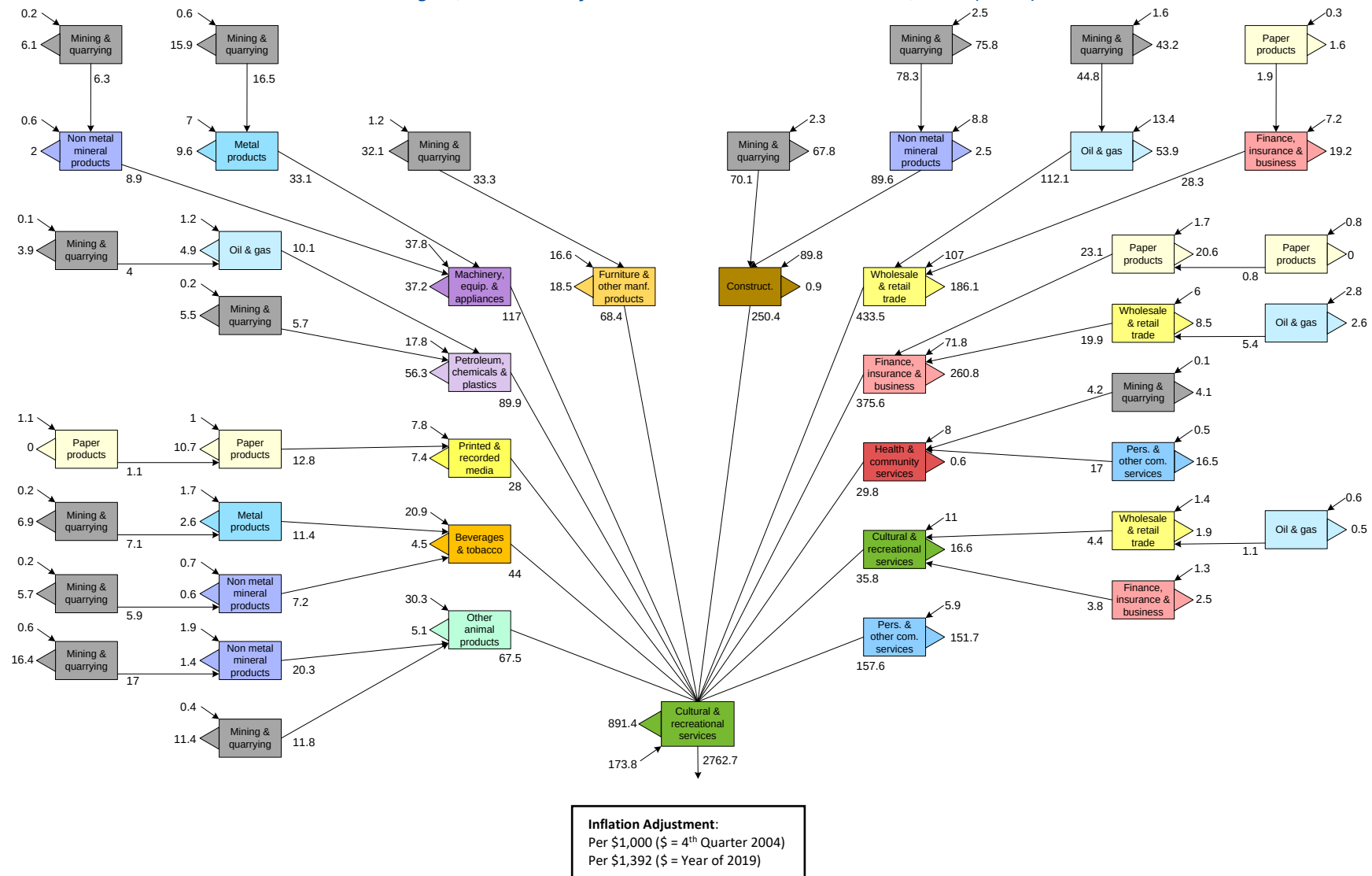


Figure 34.8 - Phosphorus Waste Generated in Producing \$1,000 Worth of Cultural and Recreational Services, 2004 (Grams)

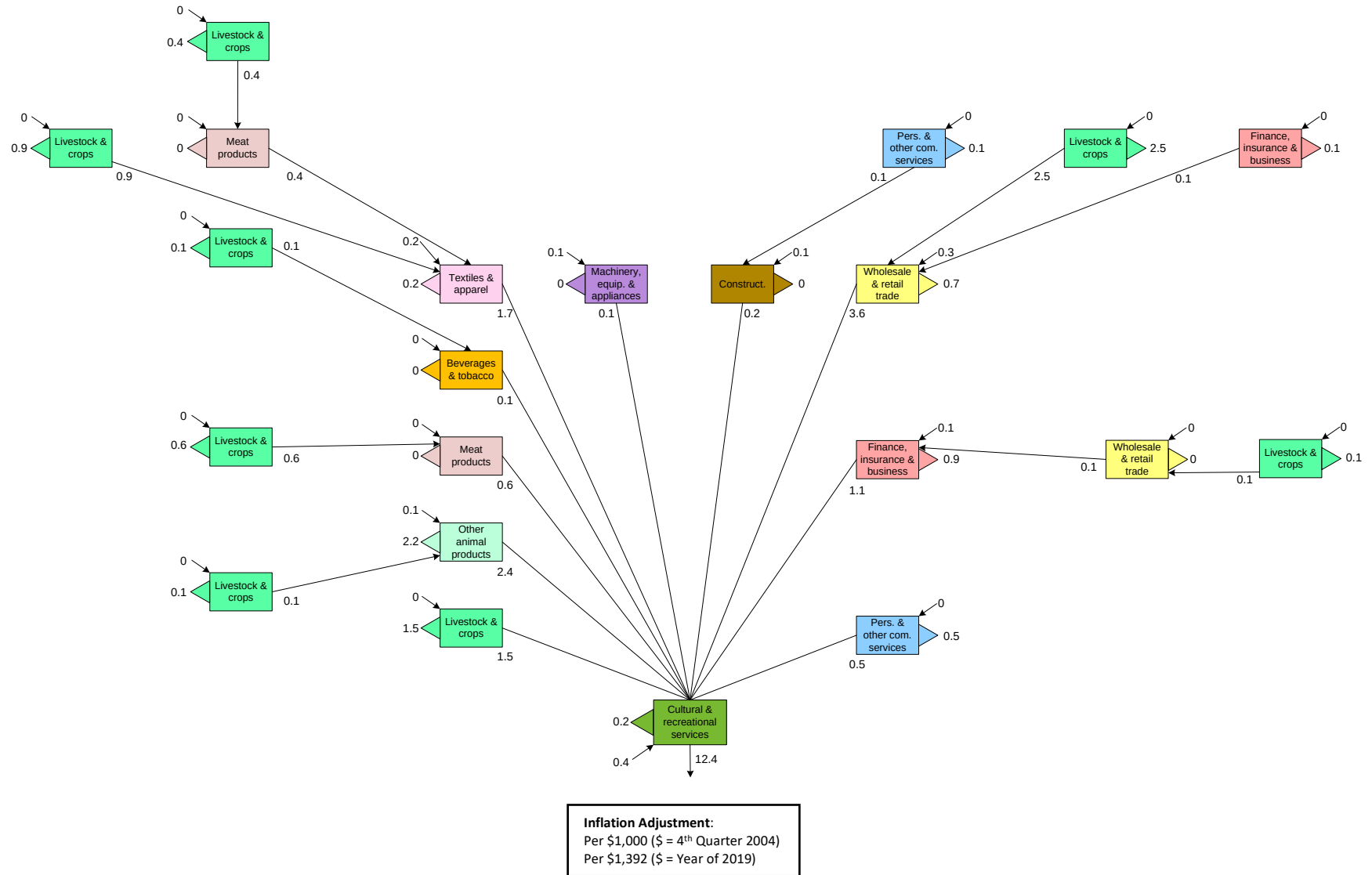
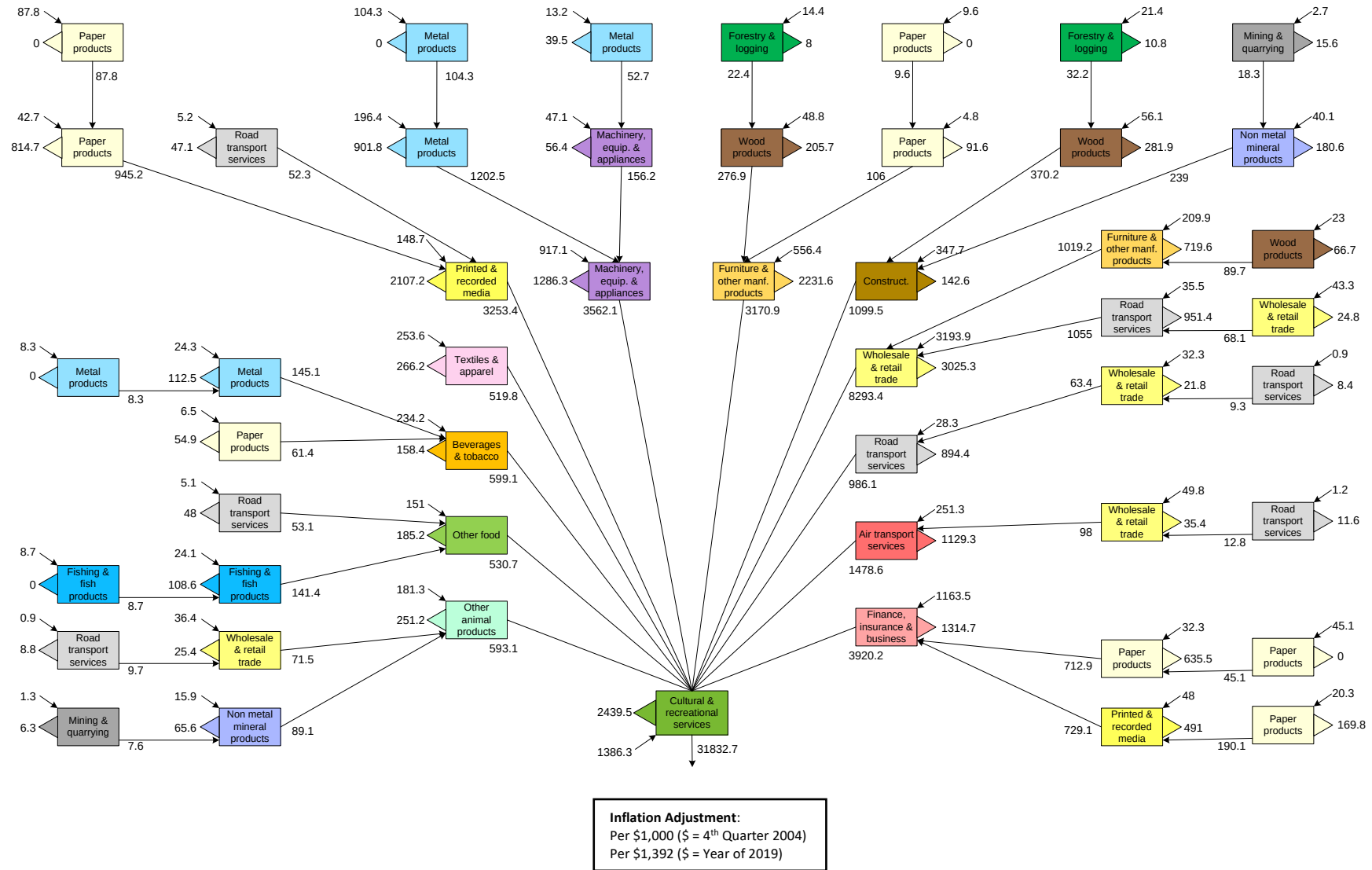


Figure 34.9 - Energy-Related CO₂ Emitted in Producing \$1,000 Worth of Cultural and Recreational Services, 2004 (Grams)



35. Personal and Other Community Services

Description

ANZSIC Codes covered:

- 941 – Automotive Repair and Maintenance
- 942 – Machinery and Equipment Repair and Maintenance
- 949 – Other Repair and Maintenance
- 951 – Personal Care Service
- 952 – Funeral, Crematorium and Cemetery Services
- 953 – Other Personal Services
- 954 – Religious Services
- 955 – Civic, Professional, and Other Interest Group Services
- 960 – Private Household Employing Staff and Undifferentiated Goods-and-Services Producing Activities of Households for Own Use

GDP 2016 = \$6.551 billion
Rank = 9th

Average annual growth
rate 2006 to 2016 = 4.72%
Rank = 15th

Employment 2016 = 91,735
Rank = 8th

Economic Overview

The personal and other community services sector is a relatively large sector contributing \$6.551 billion to New Zealand's economy and employing 91,735 people in 2016, making it the 9th largest sector and 8th largest by employment. The sector includes a wide variety of activities from furniture hiring to hairdressing services to religious services to gardening and lawn mowing services. Work in the personal and community services sector is often labour-intensive and can require specialized skills.

The sector plays a vital role in supporting the community, as a result, many of the services provided by the personal and community services sector are people-oriented. It is also not surprising that the jobs in this industry are distributed in the same way as the population of New Zealand.

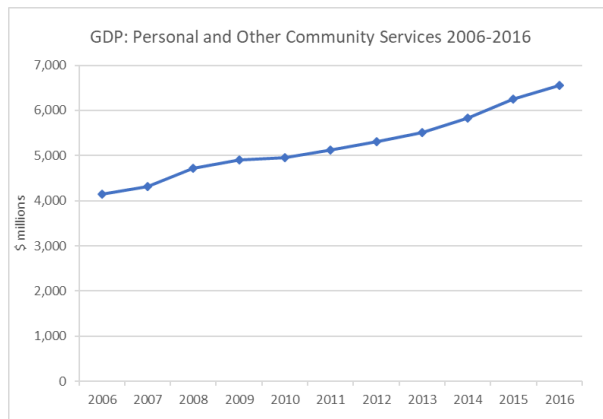
Due to the wide range of industries that compose this sector, it is highly susceptible to a wide range of outside influences. For example, aggregation in the insurance sector may have large flow-on effects on automotive and equipment repairers.³⁵¹ A shift in education preferences may also have large impacts on specialized parts of the sector such as hairdressing. An increasing trend in New Zealander's identifying with "No Religion" will also likely influence the sector, with religious services making up a proportion of the sector.^{352 353}

³⁵¹ Knight, K. (2017, August 6). *Changing Times for the Car Accident Repair Industry in New Zealand*. Retrieved February 5, 2020, from Crash Management: <https://crashmanagement.nz/changing-times-car-accident-repair-industry-new-zealand/>

³⁵² Statistics New Zealand. (2019, December 16). *Statistical area 1 dataset for 2018 Census*. Retrieved from Stats NZ: <https://www.stats.govt.nz/information-releases/statistical-area-1-dataset-for-2018-census>

³⁵³ Statistics New Zealand. (2019, October 3). *Losing our religion*. Retrieved from Stats NZ: <https://www.stats.govt.nz/news/losing-our-religion>

Sector Trends



Population growth increases in disposable household income, and the trend of consumers spending greater amounts over the years on their personal appearance have contributed to the steady growth of this sector over time. Between 2006 and 2016, the sector's contribution to GDP increased by 58.3% from \$4.14 billion to \$6.55 billion. The annual growth rate has been relatively constant at around 4.7% over the 10 years considered. However, the growth rate deviated from this average on two occasions, as illustrated by the slightly jagged series above. First, the sector grew more rapidly by 9.98% between 2007 and 2008, then from 2009 to 2010, the growth rate fell to 1.33%, a period in which the sector would have been recovering from the economic disruption caused by the GFC.

Life Cycle Assessment Diagrams

Energy (Figure 35.1, Figure 35.2, Figure 35.3)

Personal and other community services were found to have a total energy intensity of 1,406.8 MJ_{OE} per \$1,000 worth of services supplied, ranking the sector 8th highest out of the 14 service sectors covered in this publication. This represents 2,095 MJ_H per \$000 of services when measured in conventional energy units. This is a similar to the previously reported figure for total energy intensity for the personal and community services sector at 1,825 MJ_H per \$1,000 worth of services supplied.³⁵⁴

Direct energy use for the personal and other community services sector was 47% of the total energy intensity, measuring 667.8 MJ_{OE} per \$1,000 worth of services supplied. *Indirect energy use* made up the remaining total at 53%, measuring 739 MJ_{OE} per \$1,000 worth of services supplied.

The main indirect energy uses for personal and other community services came from; (i) *energy embodied in printed and recorded media at 133.3 MJ_{OE} per \$1,000 of services supplied*; (ii) *energy embodied in wholesale and retail trade at 110.9 MJ_{OE} per \$1,000 of services supplied*; (iii) *energy*

³⁵⁴ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

embodied in road transport services at 94.8 MJ_{OE} per \$1,000 of services supplied; (iv) energy embodied in finance, insurance and business services at 91.1 MJ_{OE} per \$1,000 of services supplied.

Land (Figure 35.4)

Personal and other community services have a total land intensity of 153.1 m² per \$1,000 of services supplied, ranking the sector 7th highest out of the 14 service sectors covered by this publication. *Direct land use* for personal and other community services was 34% of the total land intensity, measuring 52.8 m² per \$1,000 of services supplied. *Indirect land use* makes up the remaining total land use at 66% measuring 100.3 m² per \$1,000 of personal and other community services supplied.

The major indirect land uses for personal and other community services came from; (i) *land embodied in wholesale and retail trade at 31.2 m² per \$1,000 of services supplied; (ii) land embodied in wood products at 31.1 m² per \$1,000 of services supplied; (iii) land embodied in finance, insurance and business services at 14.1 m² per \$1,000 of services supplied; (iv) land embodied in construction services at 6.6 m² per \$1,000 of services supplied.*

Water Inputs (Figure 35.5)

Personal and other community services use a total of 6,259.8 litres of water inputs per \$1,000 of services supplied, ranking the sector the 3rd highest consumer of water out of the 14 service sectors covered by this publication. Direct sources of water inputs to the personal and other community services sector was 53% of the total or 3,289.1 litres per \$1,000 of services supplied. While indirect water inputs make up the remaining 47% or 2,970.7 litres per \$1,000 of personal and other community services supplied.

These indirect water inputs into the cultural and recreation services sector came mostly from; (i) *water inputs embodied in wholesale and retail trade at 1,710.5 litres per \$1,000 of services supplied; (ii) water inputs embodied in mining and quarrying at 372.3 litres per \$1,000 of services supplied; (iii) water inputs embodied in non-metal mineral products at 204.7 litres per \$1,000 of services supplied; (iv) water inputs embodied in finance, insurance and business services at 127.9 litres per \$1,000 of services supplied.*

Landfill Wastes (Figure 35.6)

Personal and other community services were found to generate a total of 9,016.2 grams (9 kg) of landfill waste per \$1,000 of services supplied. *Landfill waste directly generated* by the personal and other community services sector is 30.5% of total waste produced or 2,749.5 grams per \$1,000 of services supplied. *While landfill waste indirectly generated* was 69.5% or 6,266.7 grams per \$1,000 of services supplied.

The main sources of indirect landfill waste for the personal and other community services sector came from; (i) *landfill wastes embodied in petroleum, chemicals and plastics at 1,527.6 grams per \$1,000 of services supplied; (ii) landfill wastes embodied in wood products at 971.4 grams per \$1,000 of services supplied; (iii) landfill wastes embodied in wholesale and retail trade at 836.5 grams per \$1,000 of*

services supplied; (iv) landfill wastes embodied construction services 779.3 grams per \$1,000 of services supplied.

Water Wastes (Figure 35.7)

Personal and other community services were found to produce a total of 316,120.5 litres of wastewater per \$1,000 of services supplied, ranking the sector the highest producer of water wastes out of the 14 service sectors covered by this publication. This high direct water waste of 316,120.5 litres water disposed of by sewerage treatment works which is included in this sector.

Water wastes directly generated by the personal and other community services sector accounted for the majority of total water wastes at 97% or 305,880.5 litres per \$1,000 of services supplied. Indirect sources of water wastes accounted for the remaining 3% of total water wastes or 10,240 litres per \$1,000 of services supplied.

The main indirect sources of water wastes from the personal and other community services sector were mostly made up of *(i) wastewater embodied in mining and quarrying at 1,546.2 litres per \$1,000 of services supplied; (ii) wastewater embodied in wholesale and retail trade at 1,210.1 litres per \$1,000 of services supplied; (iii) wastewater embodied in non-metal mineral products at 1,066.4 litres per \$1,000 of services supplied; (iv) wastewater embodied in construction services at 927.8 litres per \$1,000 of services supplied.*

Phosphorus Wastes (Figure 35.8)

Personal and other community services were found to produce 1,347.4 grams (1.3 kg) of phosphorus waste per \$1,000 of services supplied. Total phosphorus waste was made up mostly of direct sources, making up 96% of total phosphorus waste, at 1,294.6 grams per \$1,000 of services supplied. *The remaining 4% of phosphorous wastes or 52.8 grams per \$1,000 of personal and other community services supplied came from indirect sources which were mostly made up of (i) phosphorus waste embodied in personal and other community services at 18.4 grams per \$1,000 of services supplied; (ii) phosphorus waste embodied in wholesale and retail trade at 11.3 grams per \$1,000 of services supplied; (iii) phosphorus waste embodied in livestock and crops at 7.8 grams per \$1,000 of services supplied.*

Energy Greenhouse Gases (Figure 35.9)

In terms of CO₂ greenhouse gas emissions, personal and other community services emitted a total of 156,446.2 grams (156.4 kg) of energy-related CO₂ per \$1,000 of services supplied. This sector is ranked 8th highest in the production of CO₂ greenhouse gas emissions per \$1,000 of services supplied among the 14 service sectors covered in this publication. *This amount of CO₂ greenhouse gas emissions is in a similar to a previously reported figure of 166 kg of energy-related CO₂ per \$1,000 of services supplied.*³⁵⁵

³⁵⁵ Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. (pp. 294-312). 2005 Australia New Zealand Society for Ecological Economics Conference, http://www.anzsee.org/anzsee2005papers/Andrew_EF_Primary_industries.pdf, December 11-13, Massey University, Palmerston North, NZ. Massey University, Palmerston North, NZ: NZCEE.

Energy-related CO₂ directly generated by personal and other community services was 30% of the total CO₂ emitted at 47,350.3 grams per \$1,000 of services supplied. Energy-related CO₂ indirectly generated by personal and other community services makes up the remaining 70% or 109,095.9 grams per \$1,000 of services supplied.

The indirect energy-related CO₂ from personal and other community services was mostly made up of (i) energy-related CO₂ embodied in printed and recorded media at 28,077 grams per \$1,000 of services supplied; (ii) energy-related CO₂ embodied in wholesale and retail trade at 14,777.8 grams per \$1,000 of services supplied; (iii) energy-related CO₂ embodied in finance, insurance and business services at 11,162.8 grams per \$1,000 of services supplied; (iv) energy-related CO₂ embodied in road transport services at 10,801.6 grams per \$1,000 of services supplied.

Figure 35.1 - Total Energy Inputs Required to Produce \$1,000 Worth of Personal and Other Community Services, 2004 (MJ_E, Oil Equivalents)

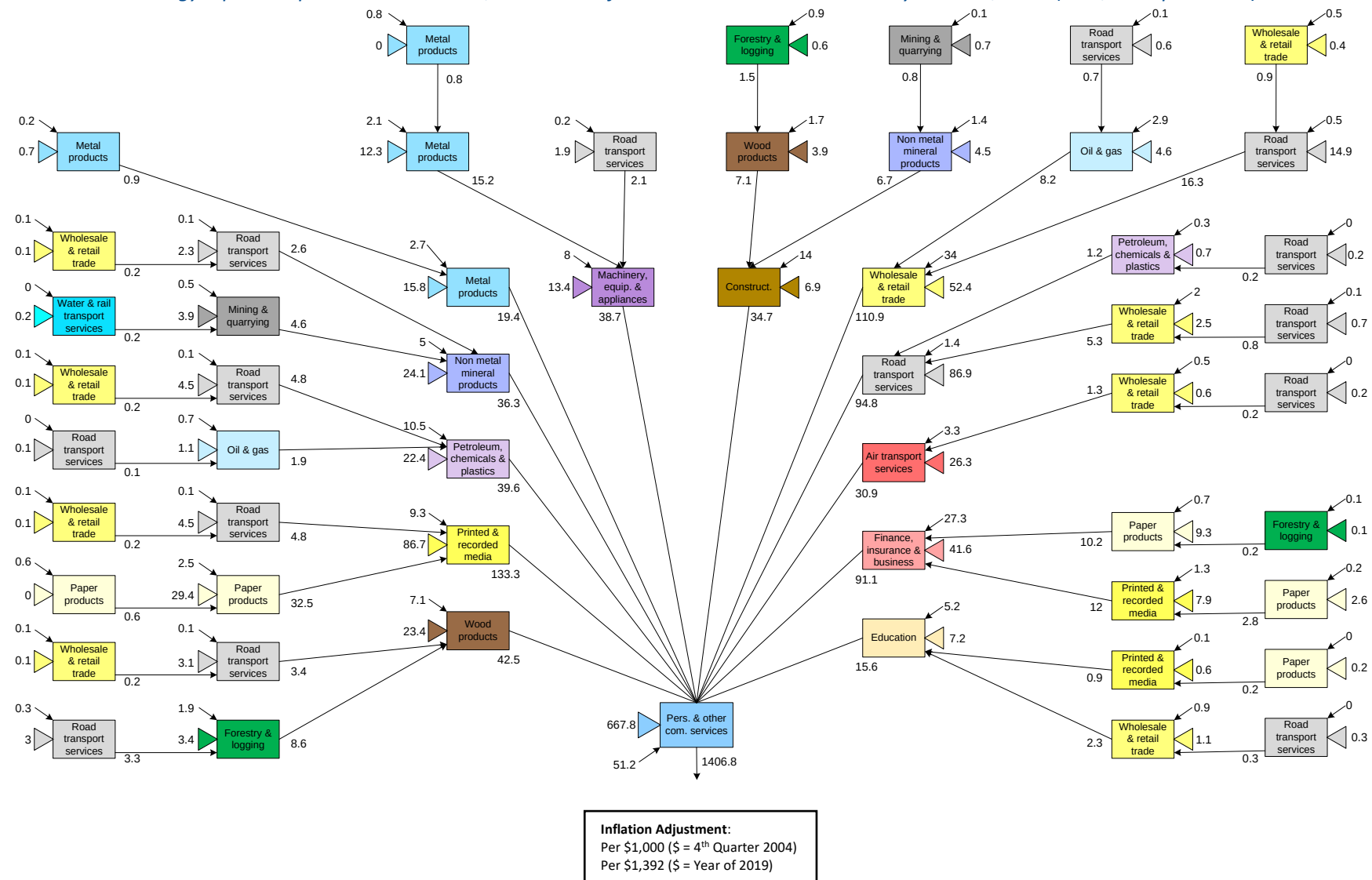


Figure 35.2 - Electricity Inputs Required to Produce \$1,000 Worth of Personal and Other Community Services, 2004 (MJ, Heat Equivalents)

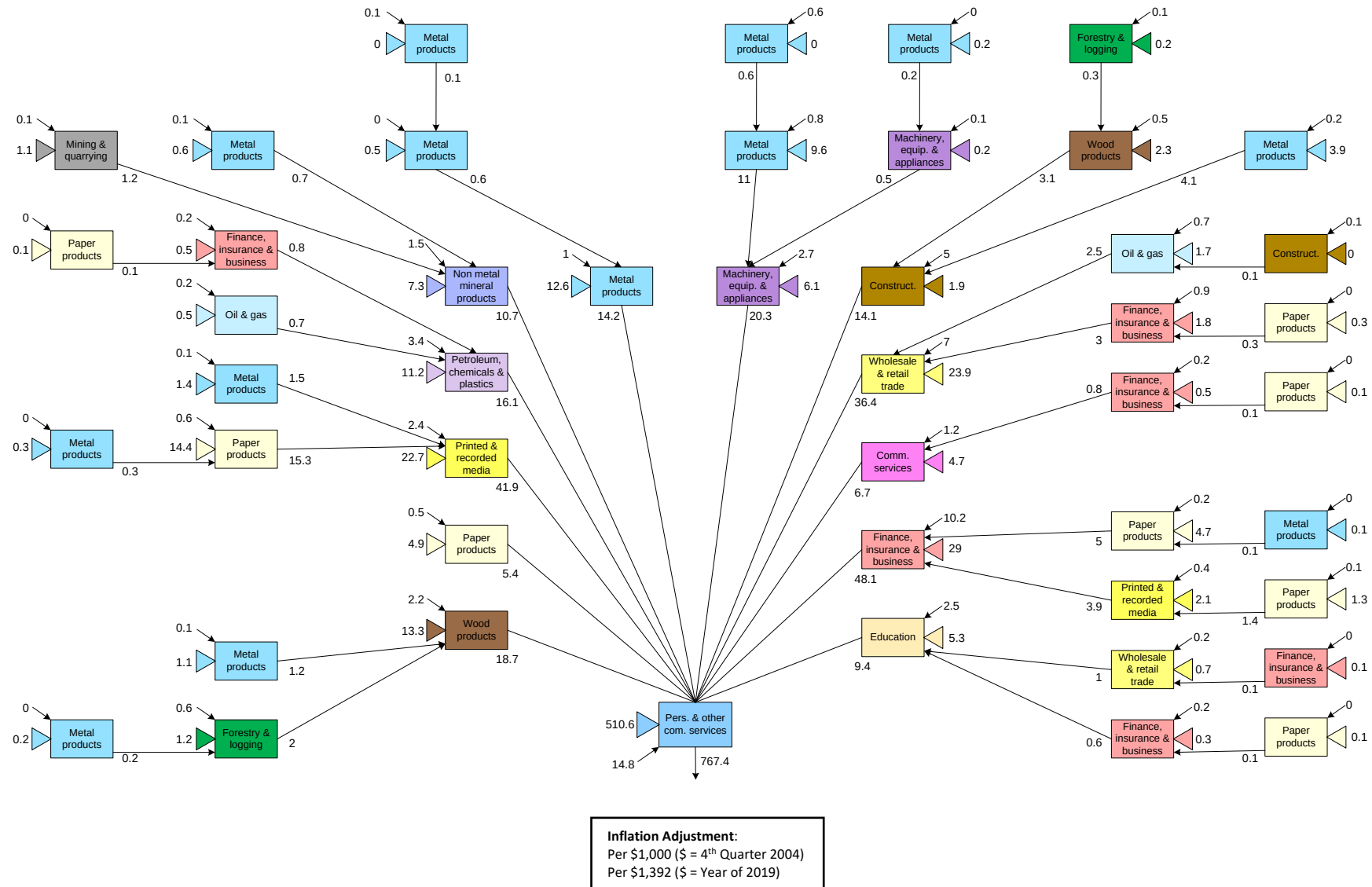


Figure 35.4 - Land (m²) Required to Produce \$1,000 Worth of Personal and Other Community Services, 2004

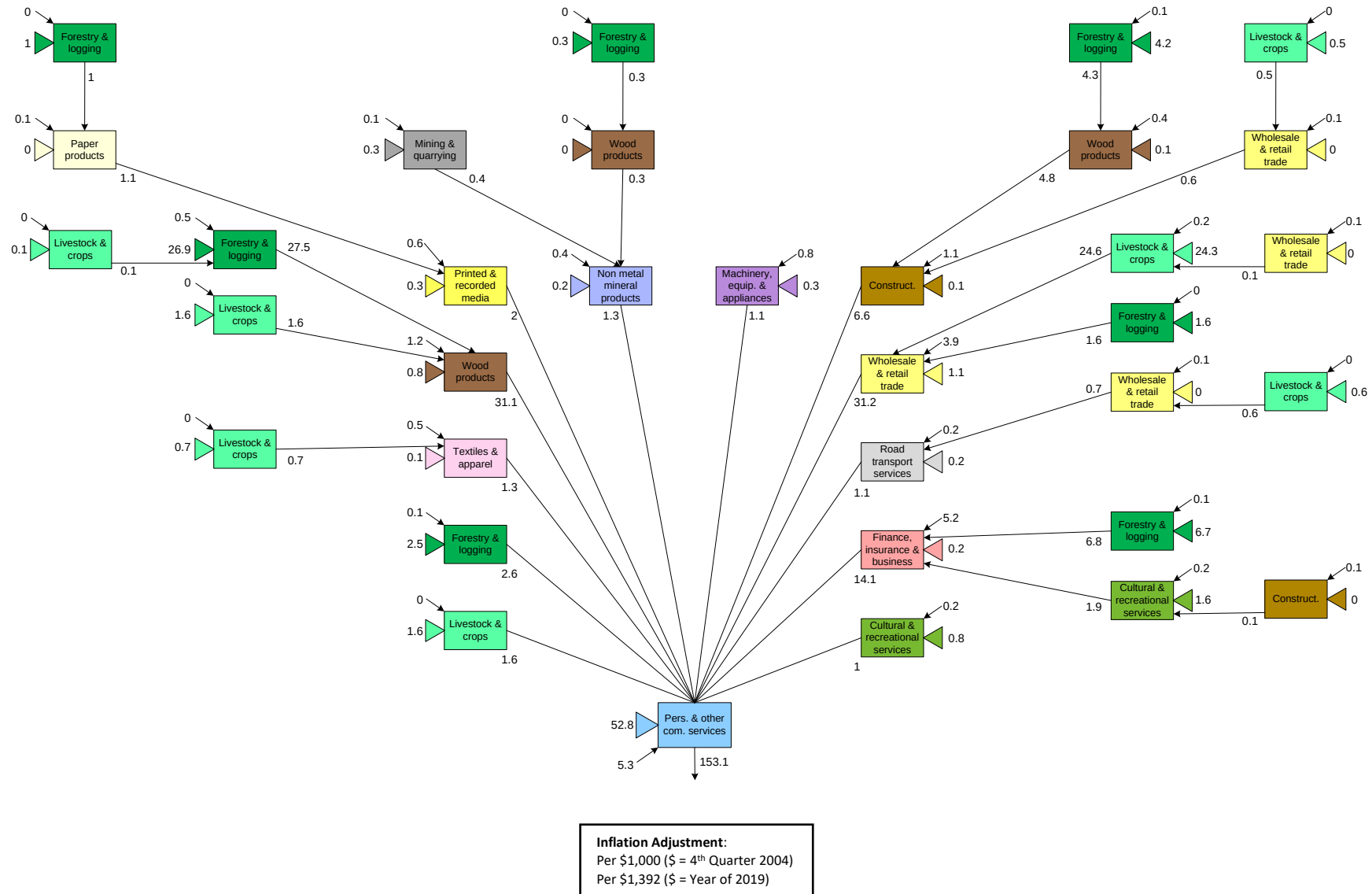


Figure 35.5 - Water Inputs Required to Produce \$1,000 Worth of Personal and Other Community Services, 2004 (Litres)

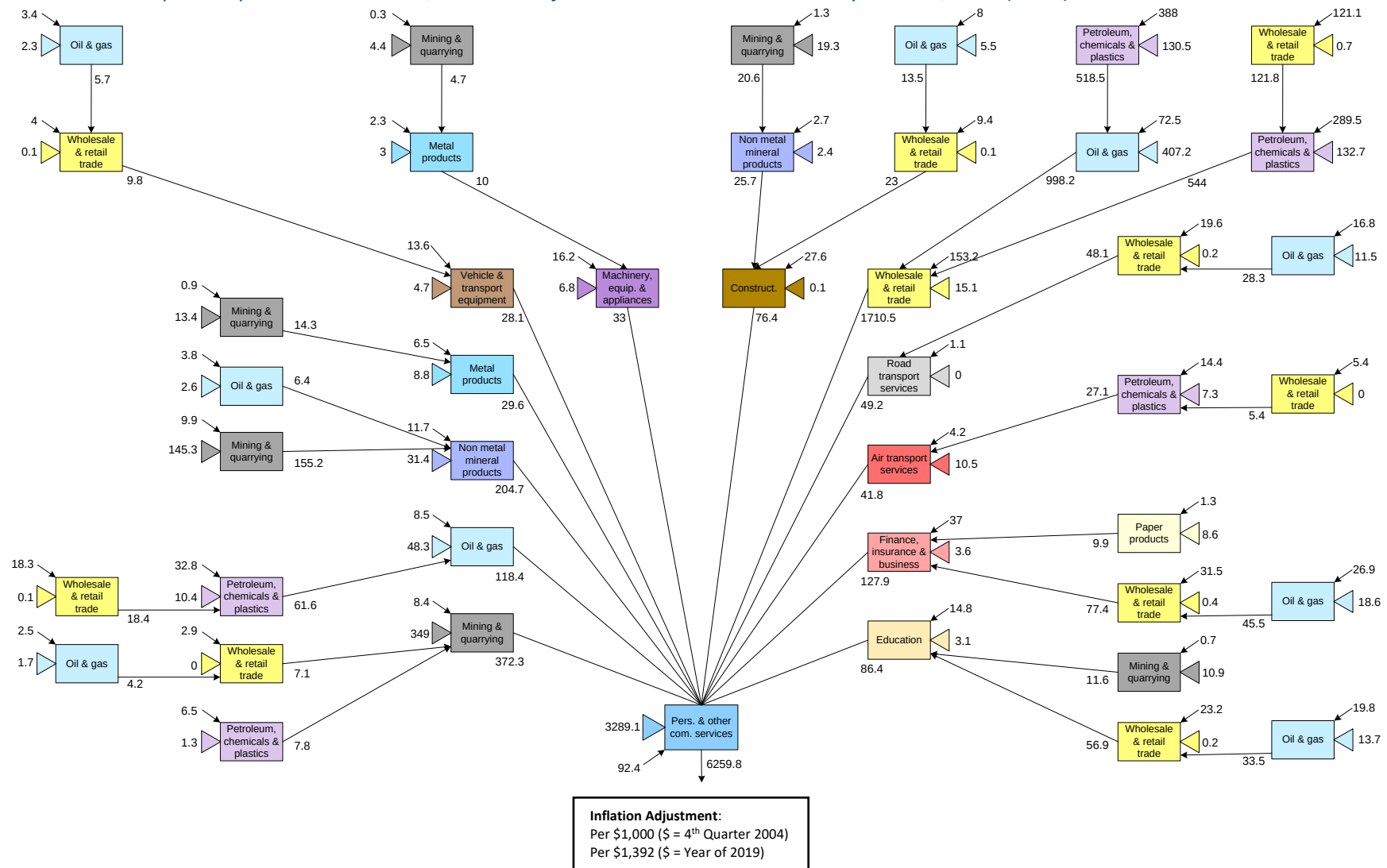


Figure 35.6 - Landfill Waste Generated in Producing \$1,000 Worth of Personal and Other Community Services, 2004 (Grams)

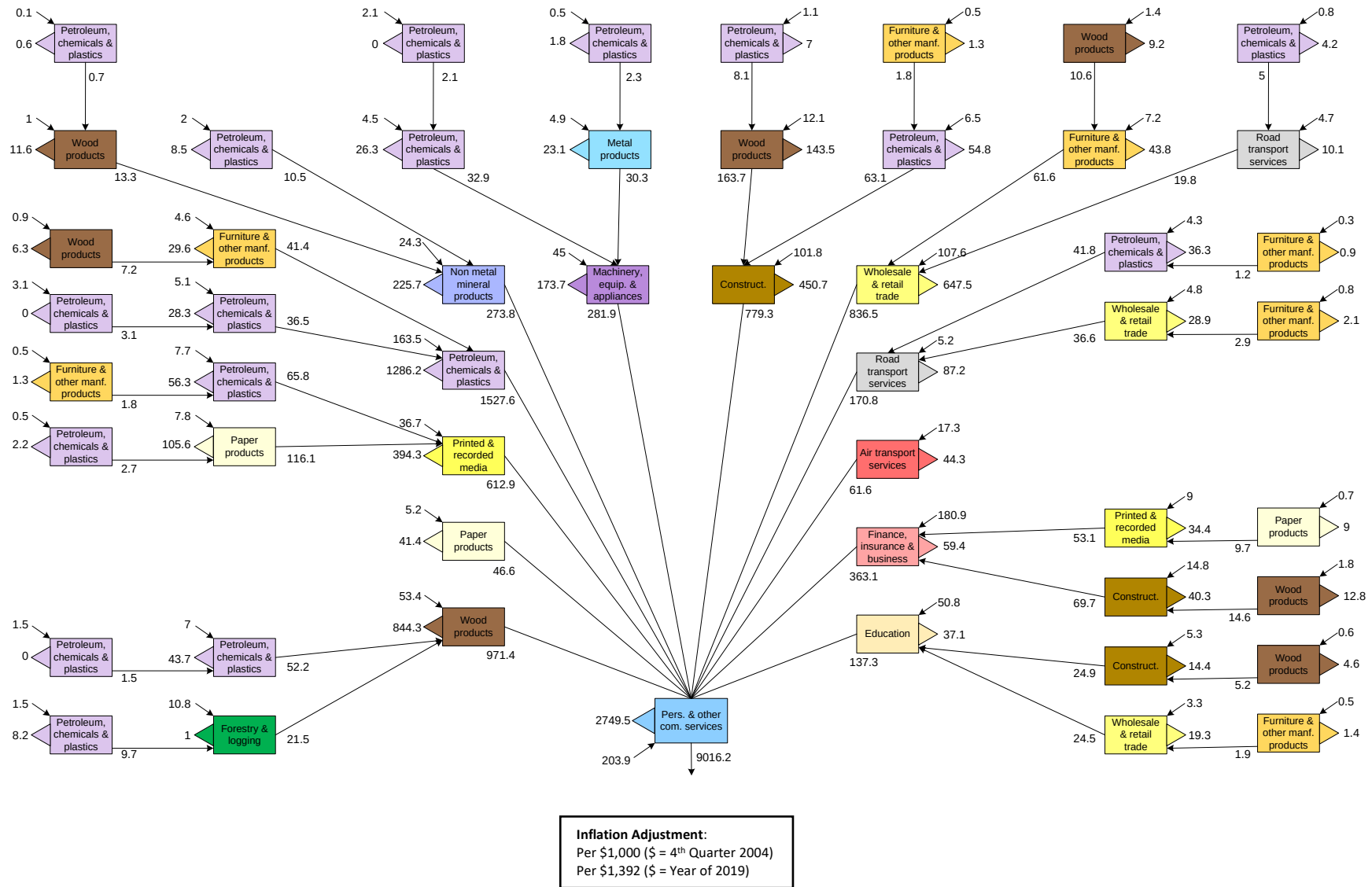
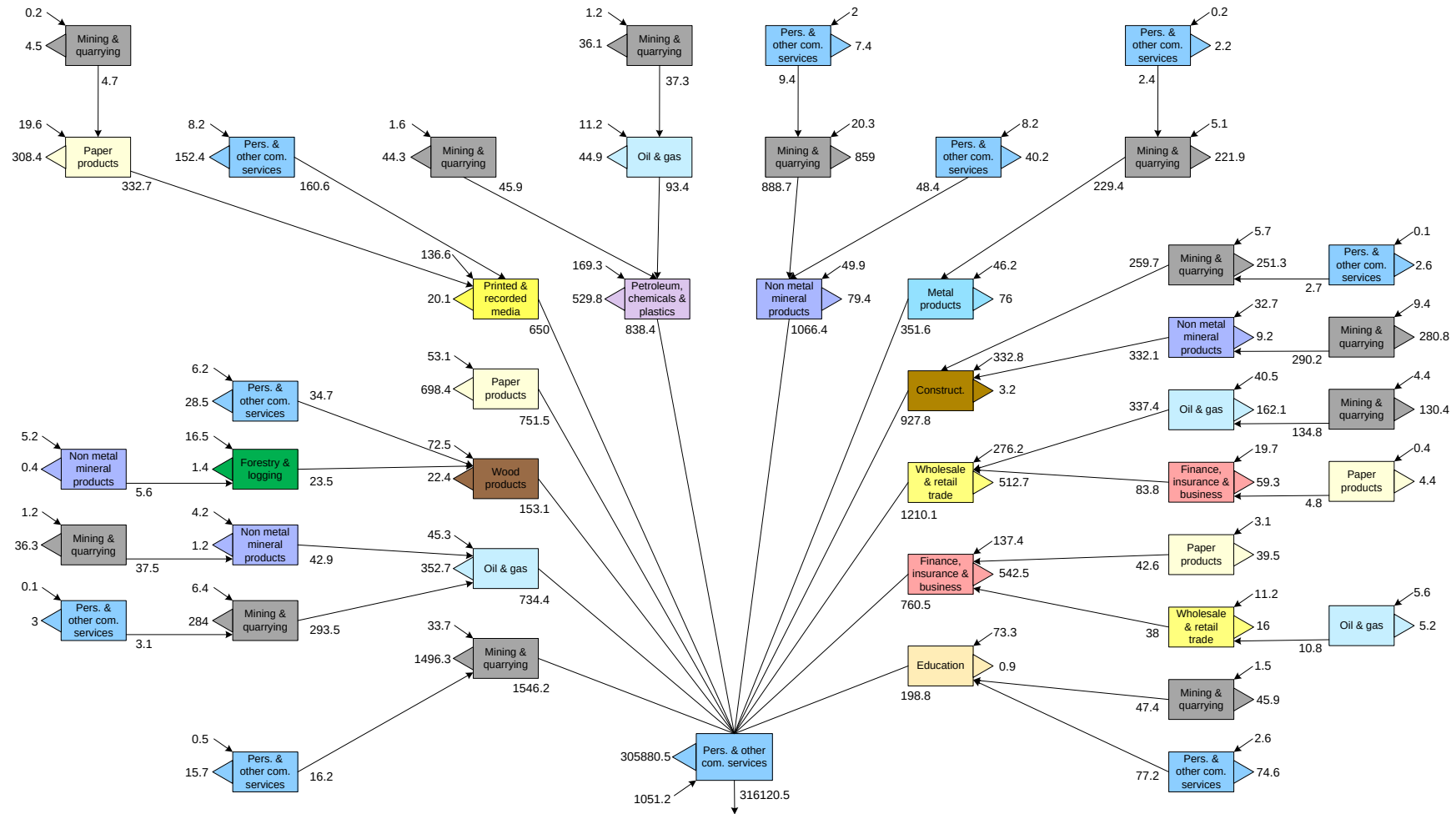


Figure 35.7 - Water Waste Generated in Producing \$1,000 Worth of Personal and Other Community Services, 2004 (Litres)



Inflation Adjustment:
 Per \$1,000 (\$ = 4th Quarter 2004)
 Per \$1,392 (\$ = Year of 2019)

Figure 35.8 - Phosphorus Waste Generated in Producing \$1,000 Worth of Personal and Other Community Services, 2004 (Grams)

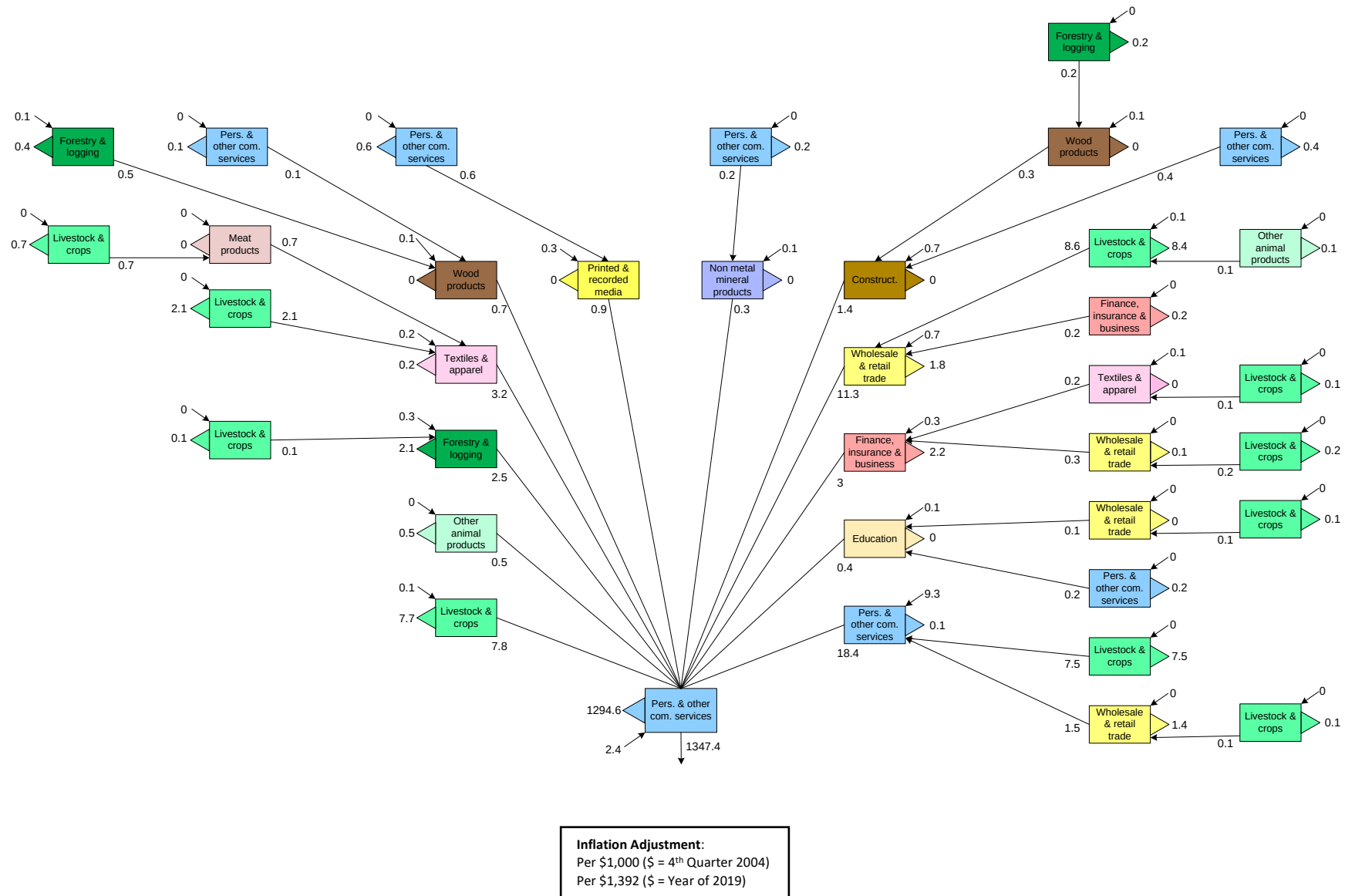
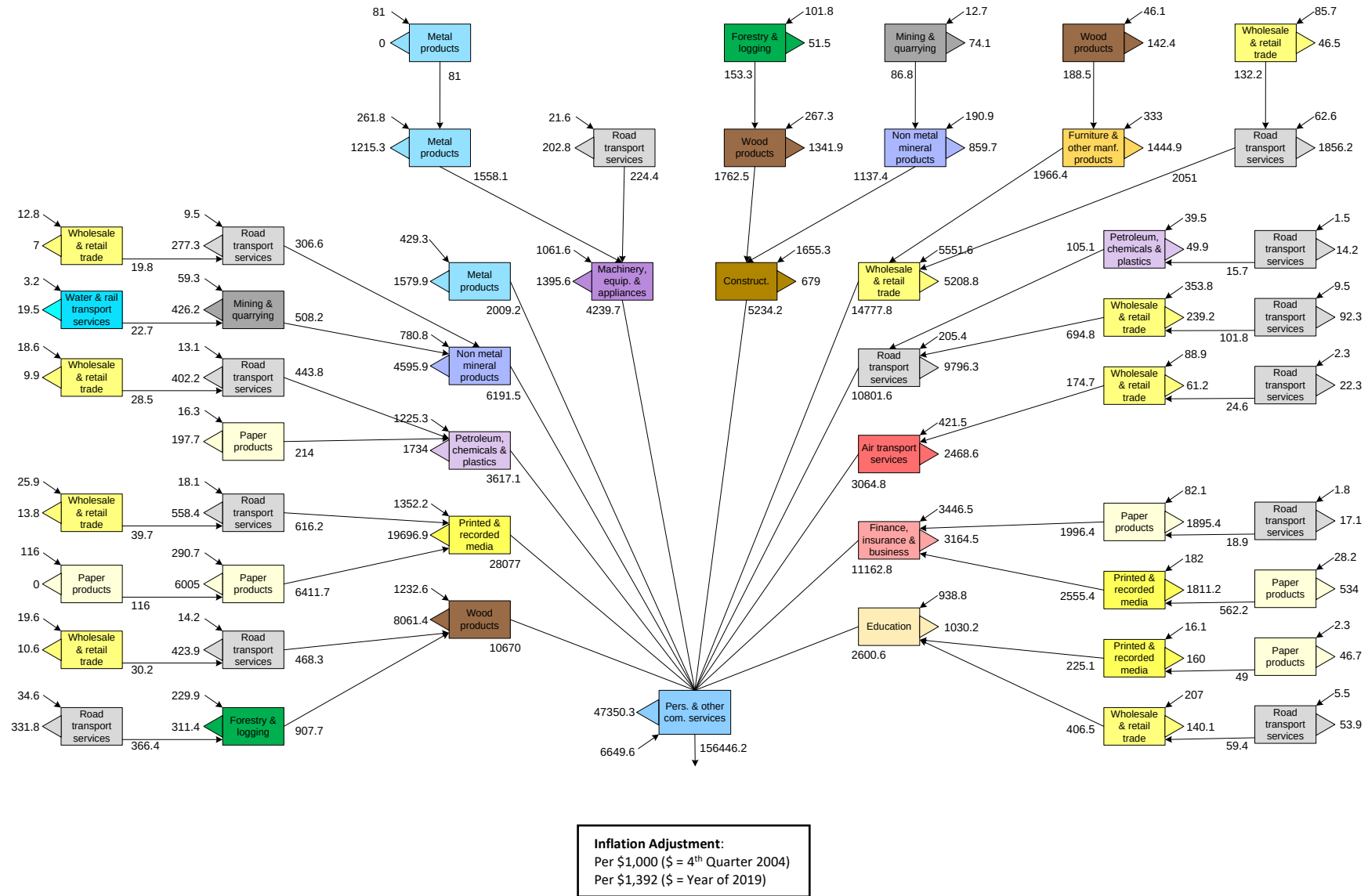


Figure 35.9 - Energy-Related CO₂ Emitted in Producing \$1,000 worth of Personal and Other Community Services, 2004 (Grams)



36. Ecosystem Services

Ecosystem services is one of the fastest growing academic literatures. Based on the bibliographic analysis using the Web of Science, Gangahagedara et al. (2021)³⁵⁶ found that the number of publications and citations have both grown exponentially since 2000. Even before 2000 there were important publications by Daily (1997)³⁵⁷ who perhaps for the first time provided a wider audience with an understanding of ecosystem services concept, while Costanza et al. (1997)³⁵⁸ undertook the first comprehensive valuation of global ecosystem services which attracted worldwide attention from academia and the media. Before these landmark publications, de Groot (1987)³⁵⁹ was the first to lay down the foundations for the modern analysis of ecosystem services.

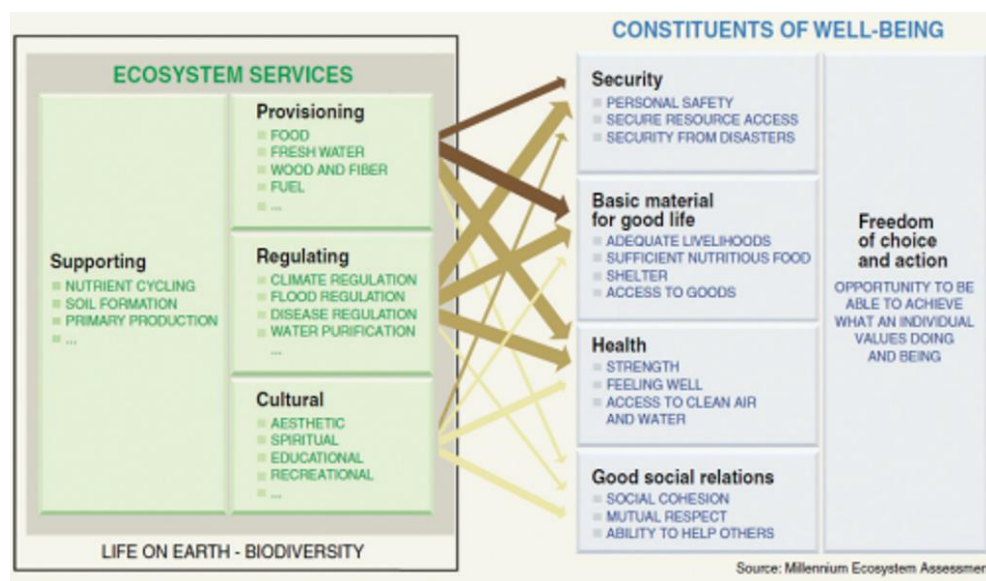


Figure 36.1 Millennium Ecosystem Assessment Framework

It would be reasonable to assume that the concept of ecosystem services actually applies to “ecosystems”. But that said, as Nahlik et al. (2012)³⁶⁰ points out this is not necessarily the case, as it tends to be used as a catchall phrase to cover any benefits (to humans) from nature or the environment. For example, Boyd and Spencer (2007)³⁶¹ define ecosystem services as the “components of nature, directly enjoyed, consumed or used to yield human well-being” and similarly de Groot et al.

³⁵⁶ Gangahagedara, R., Subasinghe, S., Lankathilake, M., Athukorala, W., Gamage, I., 2021. Ecosystem Services Research Trends: A Bibliometric Analysis from 2000–2020. *Ecologies* 2(4): 366 - 379

³⁵⁷ Daily, G.C. 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington D.C. United States.

³⁵⁸ Costanza, R., d'Arge, R., deGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The Value of the World's Ecosystem Services and Natural Capital. *Nature* 387 (6630): 253–260

³⁵⁹ de Groot, R.S. 1987. Environmental Functions as a Unifying Concept for Ecology and Economics. *The Environmentalist* 7:2 105-109

³⁶⁰ Nahlik, A.M., Kentula, M.E., Fennessy, S., Landers, D.H. 2012. Where is the Consensus? A Proposed Foundation for Moving Ecosystem Service Concepts into Practice. *Ecological Economics* 77: 27-35

³⁶¹ Boyd, J., Spencer, S. 2007. What Are Ecosystem Services? The Need for Standardised Environmental Accounting Units. *Ecological Economics* 2-3 615-626

(2002)³⁶² defines ecosystem services as “the capacity of natural processes and components to provide goods and services that satisfy human needs directly and indirectly”.

Many authors such as Liqueste et al. (2013)³⁶³ in developing classification systems only include ecosystem services that directly impact on human well-being, and exclude any candidate ecosystem services that do not directly contribute to human well-being. For example, ‘primary production’ (photosynthesis) may be excluded because it doesn’t directly contribute to human well-being. The Millennium Ecosystem Assessment framework³⁶⁴ overcomes this problem by defining ‘supporting services’ such as nutrient cycling or primary production that ‘support’ other services which directly contribute to human well-being. As can be seen by Figure 36.1, the Millennium Ecosystem Assessment (2005)³⁶⁵ framework explicitly shows how ‘supporting ecosystem services’ contribute to: (1) ‘regulating services’ (services that maintain an environment suitable for human habitation), (2) ‘provisioning services’ (supply of ecosystem goods such as food, raw material and fresh water) (3) ‘cultural services’ (nonmaterial services such as recreation, tourism, scientific knowledge and aesthetics).

LCA Diagrams

Illustrative examples of the LCA diagrams that depict direct and indirect inputs of ecosystem services into sectors and the production of commodities are outlined by Figures 36.1 to 36.11. The ecosystem services inputs covered are: climate regulation, disturbance regulation, erosion control and waste treatment. These ecosystem services were required for the production of the following commodities: meat products, dairy products, other food products, textile and apparel products, wood products. In all cases, the measurement units are: ‘ecosystem services inputs (\$1,000) required’ per ‘tonne product produced’.

In the LCA diagrams, those sectors (e.g. ‘livestock and crops’ and ‘forestry and logging’) that have the largest land inputs, also have the largest inputs of ecosystem services measured in terms of \$1,000 per tonne produced. This is because the ecosystem services are calculated from the different categories of land covered by each sector, using the method and data outlined by Patterson and Cole (2013)³⁶⁶ which has recently been updated by Patterson (2023)³⁶⁷. In almost all other cases, ecosystem services input from other sectors, is relatively small because these sectors cover only small land areas.

³⁶² de Groot, R., Wilson, M., Boumans, R. 2002. A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services, *Ecological Economics* 41: 393-408

³⁶³ Liqueste, C Piroddi, C., Drakou, E.G. Gurney, L., Stelios Katsanevakis, S., Aymen Charef, A., Benis Egoh, B. 2013. Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. *PLOS One* 8:7 e67737

³⁶⁴ One of the advantages of the MEA ecosystem services framework is that if properly used, it avoids the problem of double counting ‘supporting’ ecosystem services which is an often-cited problem encountered in ecosystem services research. That is, as is shown by Patterson and Cole (2013) demonstrate when aggregating ecosystem services, ‘supporting services’ should not be double counted.

³⁶⁵ Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington DC. , United States: Patterson, M.G. and Cole, A.O. 2013. ‘Total Economic Value’ of New Zealand’s Land-Based Ecosystems and their Services. In, Ecosystem Services in New Zealand: Conditions and Trends. Dymond, J.R. (Editor) pp 496-510. Manaaki Whenua Press, Lincoln, New Zealand.

³⁶⁶ Patterson, M.G. and Cole, A.O. 2013. ‘Total Economic Value’ of New Zealand’s Land-Based Ecosystems and their Services. In, Ecosystem Services in New Zealand: Conditions and Trends. Dymond, J.R. (Editor) pp 496-510. Manaaki Whenua Press, Lincoln, New Zealand.

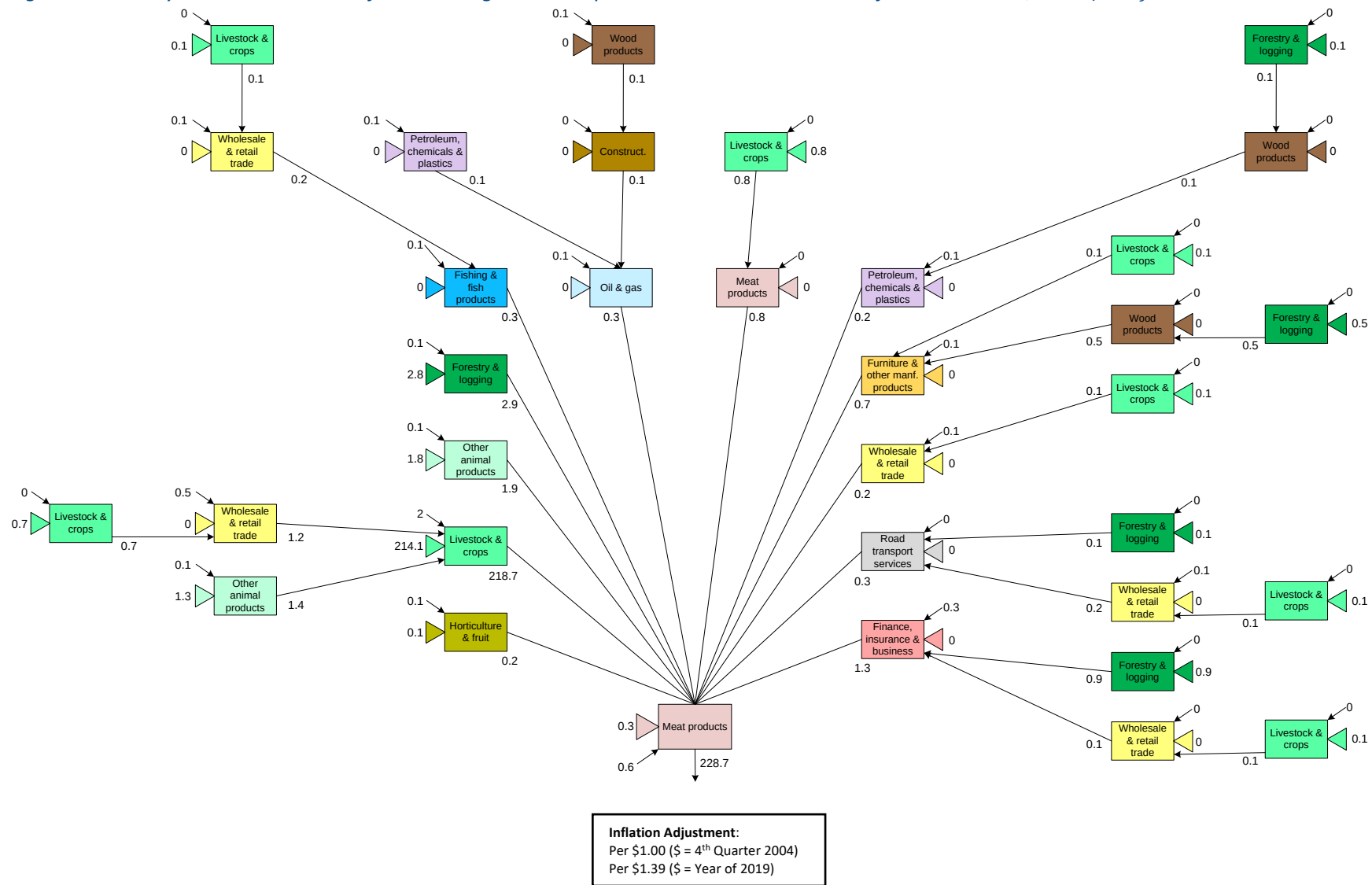
³⁶⁷ Patterson, M.G. 2023. The State-of-the-Art and Prospects: Economic Valuation of Ecosystem Services in Environmental Impact Assessment. *Impact Connector* pp1-13, 15:11 <https://www.nzaia.org.nz/patterson.html> (Refer to Table 1 for the land use category data, \$/ha)

Table 36.1 Definitions, Examples and Classification of Ecosystem Services

Ecosystem Services	Definition	Examples	Ecosystem Service Classification
Gas regulation	Regulation of atmospheric chemical composition	CO ₂ /O ₂ balance, O ₃ for UV protection, and SO _x levels	Regulating
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	Greenhouse gas regulation, DMS production affecting cloud formation	Regulating
Disturbance regulation	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations	Storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure	Regulating
Water provisioning	Regulation of hydrological flows	Provisioning of water for agricultural, industrial processes or transportation	Provisioning
Water storage and retention	Storage and retention of water	Storage of water by watersheds, reservoirs, and aquifers	Supporting
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of loss of soil by wind, runoff or other removal processes. Storage of silt in lakes and wetlands	Supporting
Soil formation	Soil formation processes	Weathering of rock and the accumulation of organic material	Supporting
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	N, P and other element or nutrient cycles	Supporting
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Processing dairy cow urine, faeces and fertiliser run-off	Regulating
Pollination	Movement of floral gametes	Pollinators for the reproduction of plant populations	Supporting
Biological control	Trophic-dynamic regulations of populations	Keystone predator control of prey species, reduction of herbivory by top predators	Regulating
Refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory species, regional habitats for locally harvested species or overwintering grounds	Supporting
Food production	That portion of primary production extractable as food	Production of animals, fish, fruit and vegetables for human consumption	Provisioning
Raw materials	That portion of primary production extractable as raw materials	The production of timber, fibres (e.g. wool) or fodder	Provisioning
Genetic resources	Sources of unique biological materials and products	Medicine, genes for resistance to plant pathogens and crop pests	Provisioning
Primary Production	Synthesis of organic compounds CO ₂ mainly from the atmosphere via the process of photosynthesis which 'captures' solar energy as the primary source of energy in the ecosystem.	Growth of grass in the dairy pasture agro-ecosystem. Growth of harakeke (flax) in the wetlands ecosystem	Supporting
Recreation	Providing opportunities for recreational activities	Tourism (visitors to wetlands), birdwatching, fishing and other recreational pursuits	Cultural
Other Cultural	Aesthetic, artistic, educational, spiritual and/or scientific values of ecosystems	Iwi/hapū cultural values associated with the wetlands	Cultural

Note: Adapted from Costanza et al. (1997), with some changes to names of ecosystem services, adding primary production and the classification column.

Figure 36.1 Ecosystem Service Value of Climate Regulation Required to Produce One Tonne of Meat Products, 2004 (\$₂₀₀₄)



452

Figure 36.3 Ecosystem Service Value of Climate Regulation Required to Produce One Tonne of Wood Products, 2004 (\$₂₀₀₄)

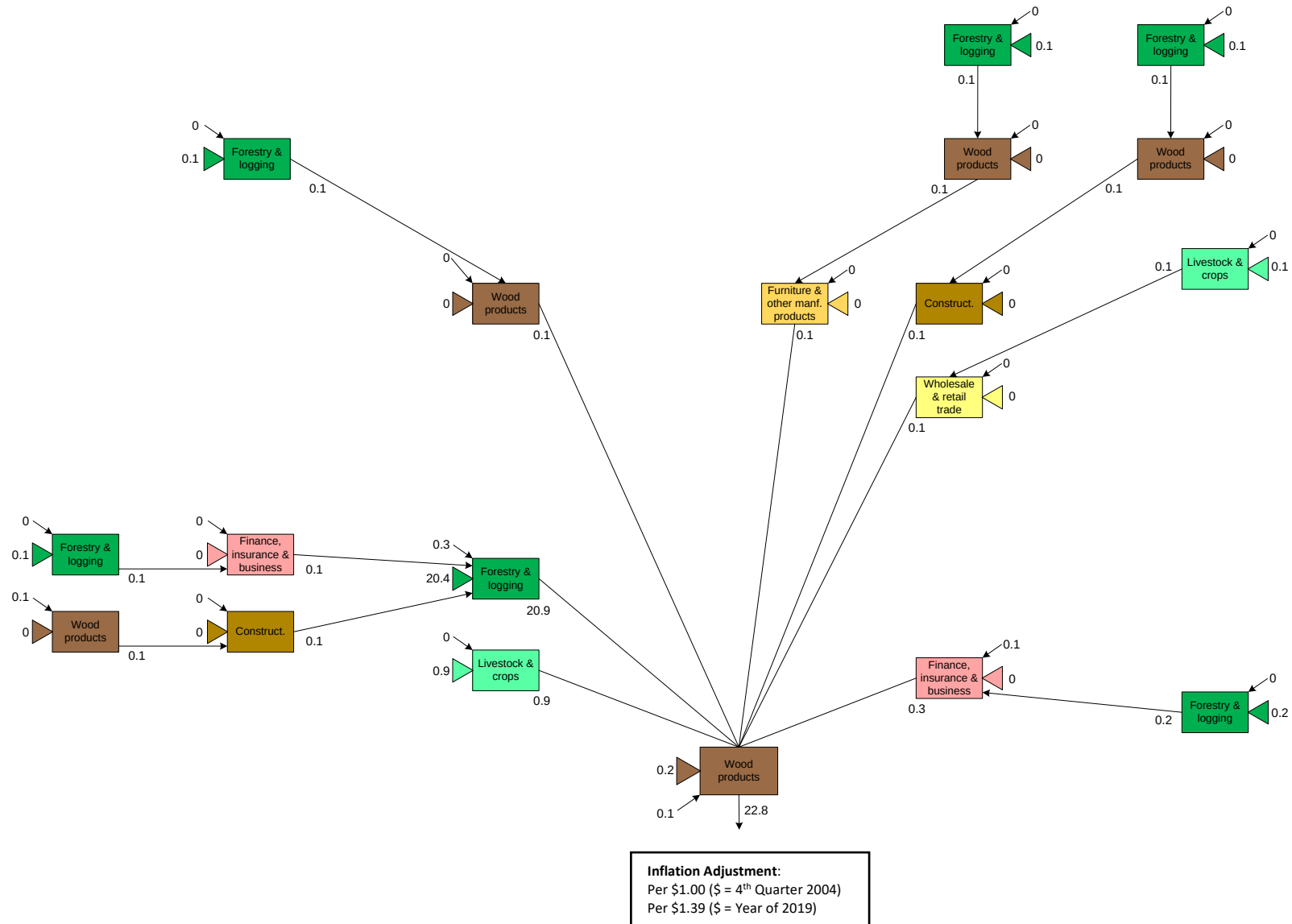


Figure 36.4 Ecosystem Service Value of Disturbance Regulation Required to Produce One Tonne of Textiles and Apparel Products, 2004 (\$₂₀₀₄)

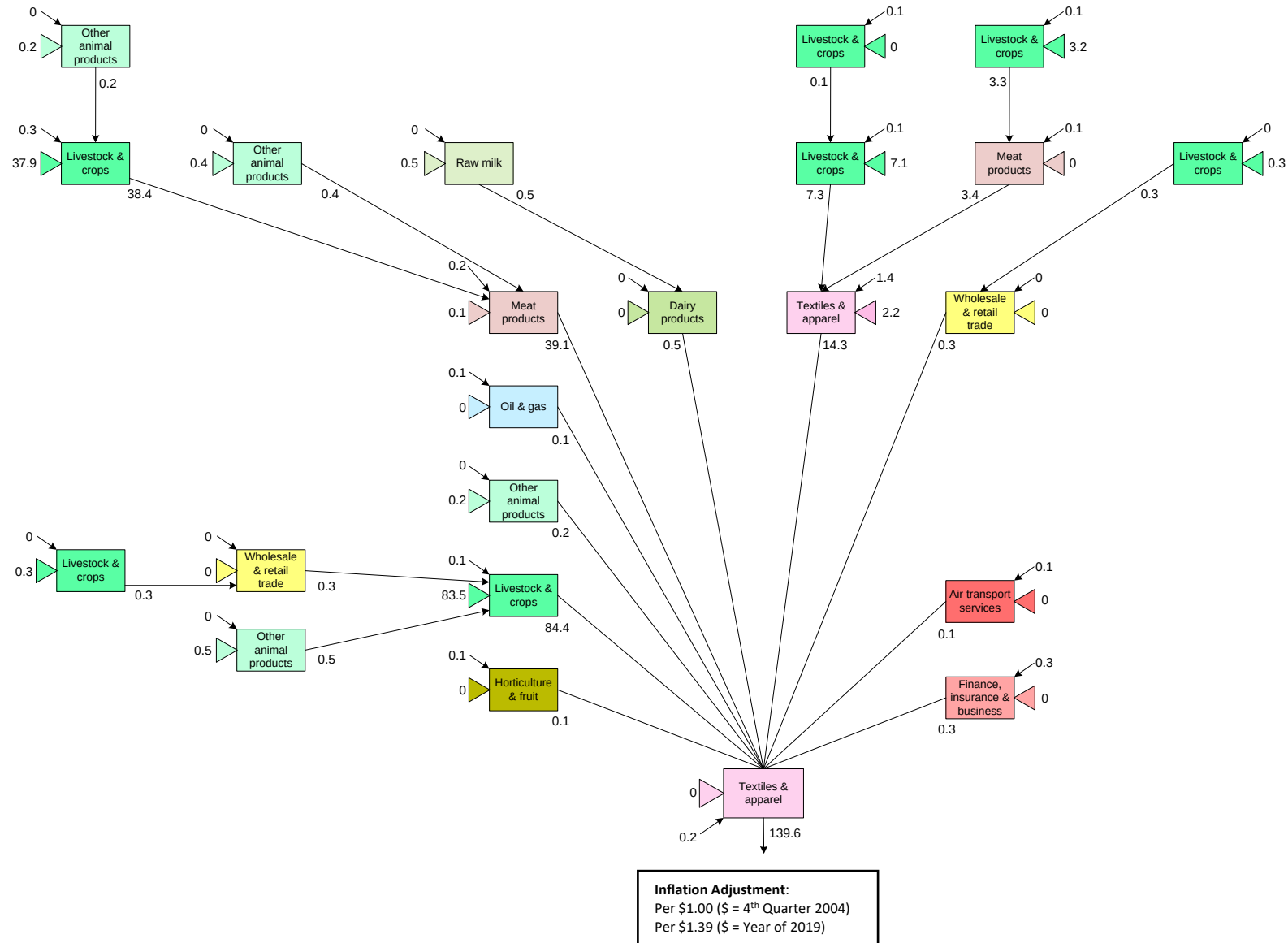


Figure 36.5 Ecosystem Service Value of Erosion Control Required to Produce One Tonne of Meat Products, 2004 (\$₂₀₀₄)

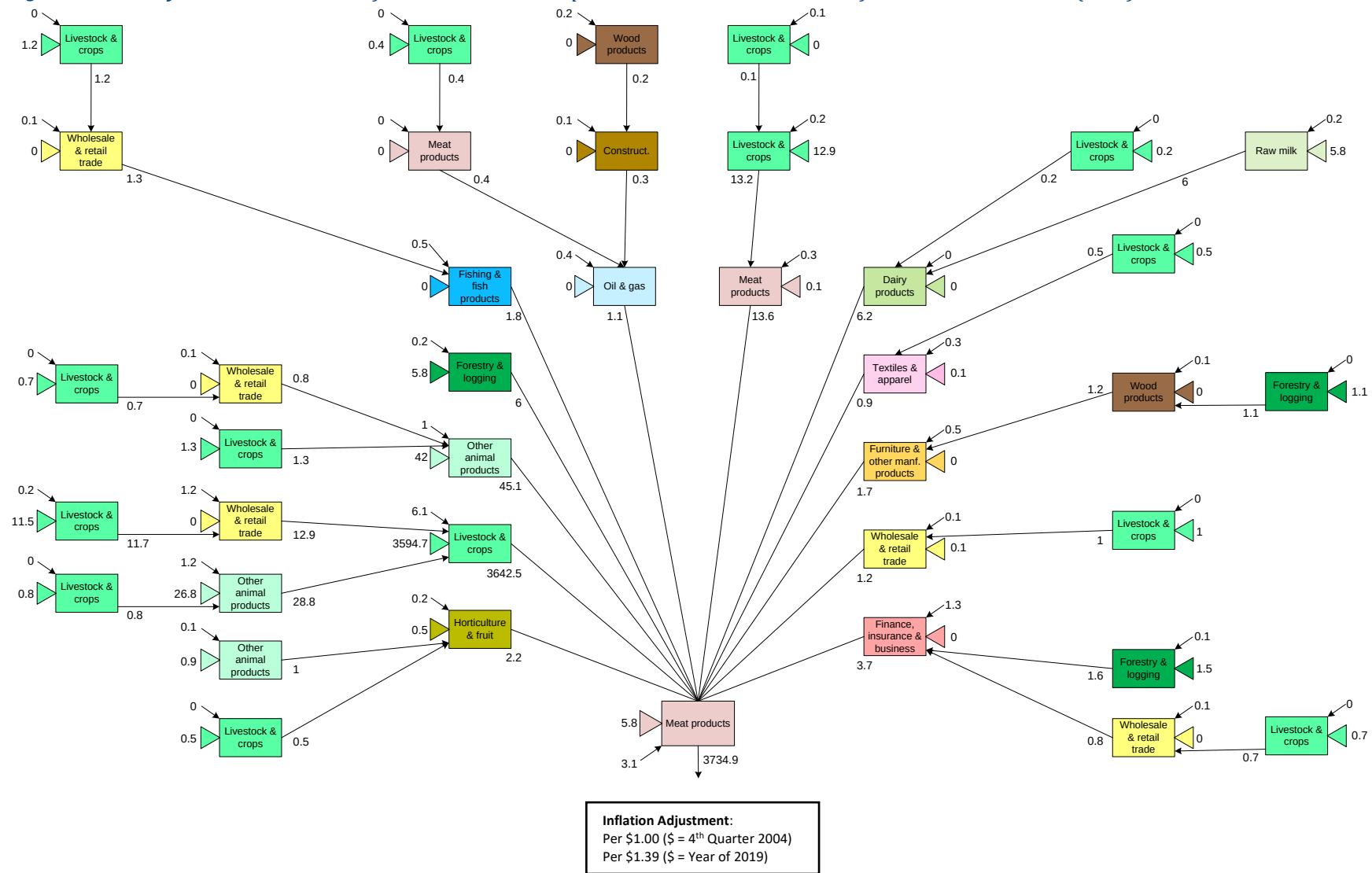


Figure 36.6 Ecosystem Service Value of Erosion Control Required to Produce One Tonne of Dairy Products, 2004 (\$₂₀₀₄)

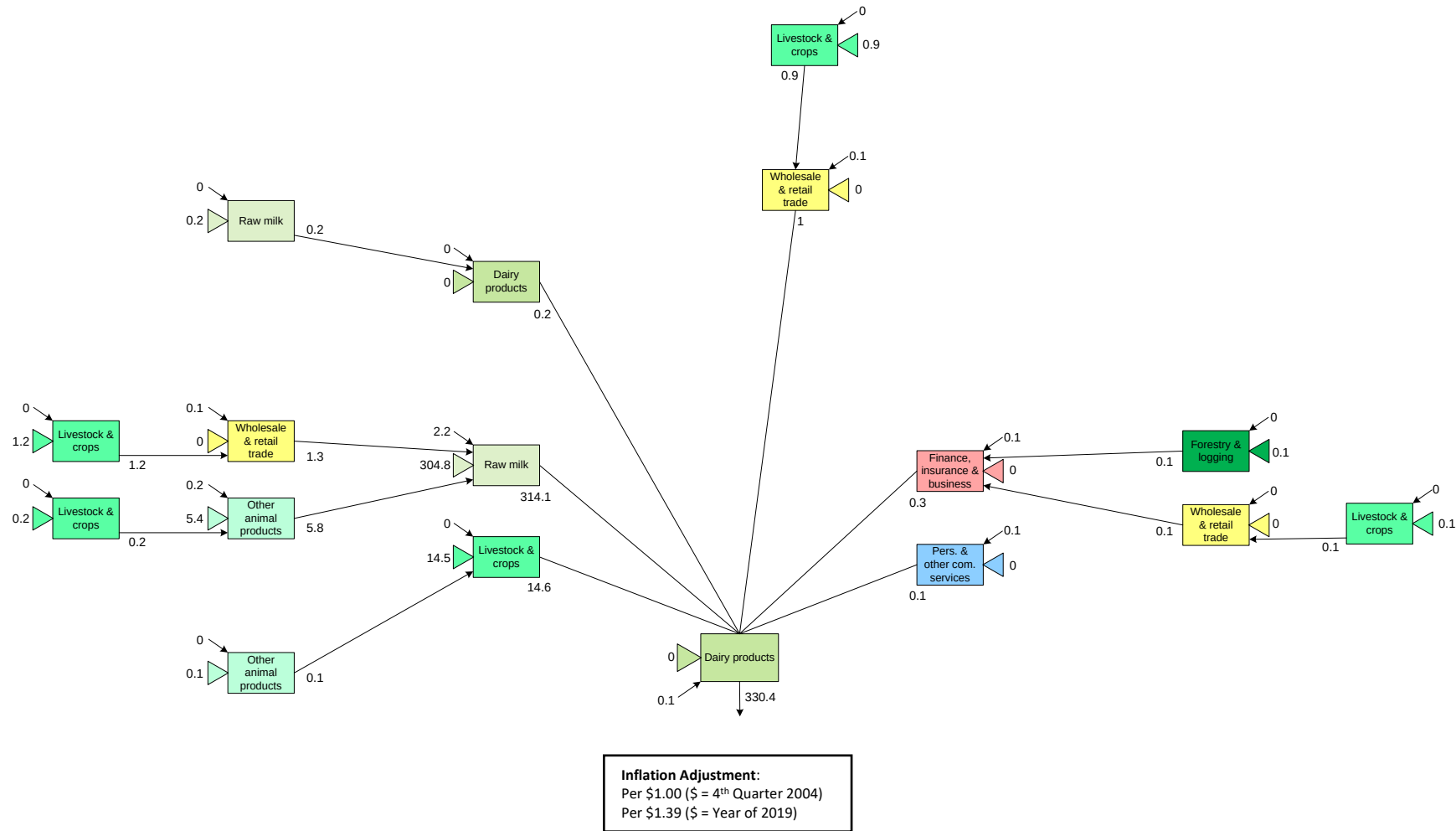


Figure 36.7 Ecosystem Service Value of Erosion Control Required to Produce One Tonne of Other Food Products, 2004 (\$₂₀₀₄)

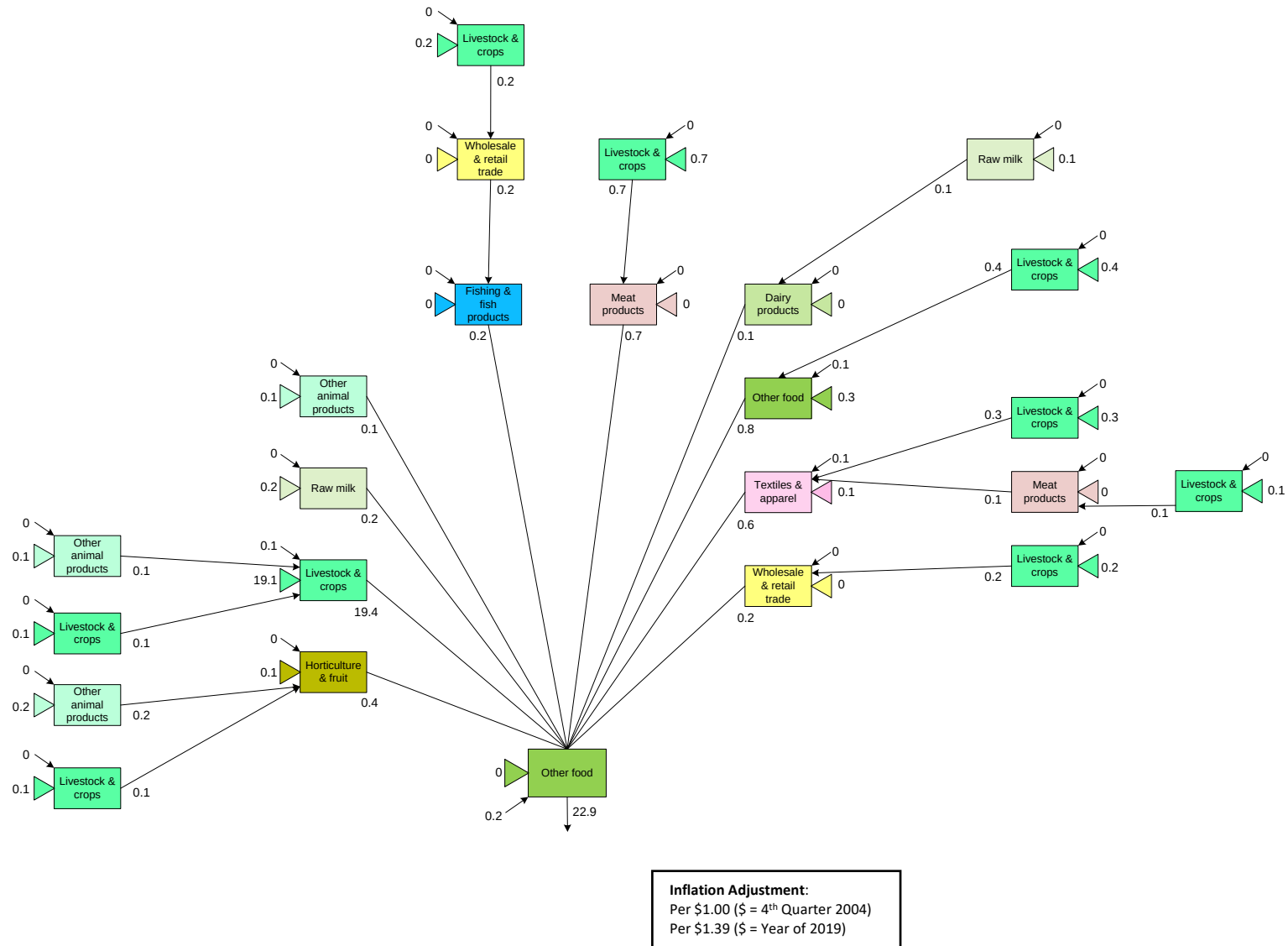


Figure 36.8 Ecosystem Service Value of Erosion Control Required to Produce One Tonne of Textiles and Apparel Products, 2004 (\$₂₀₀₄)

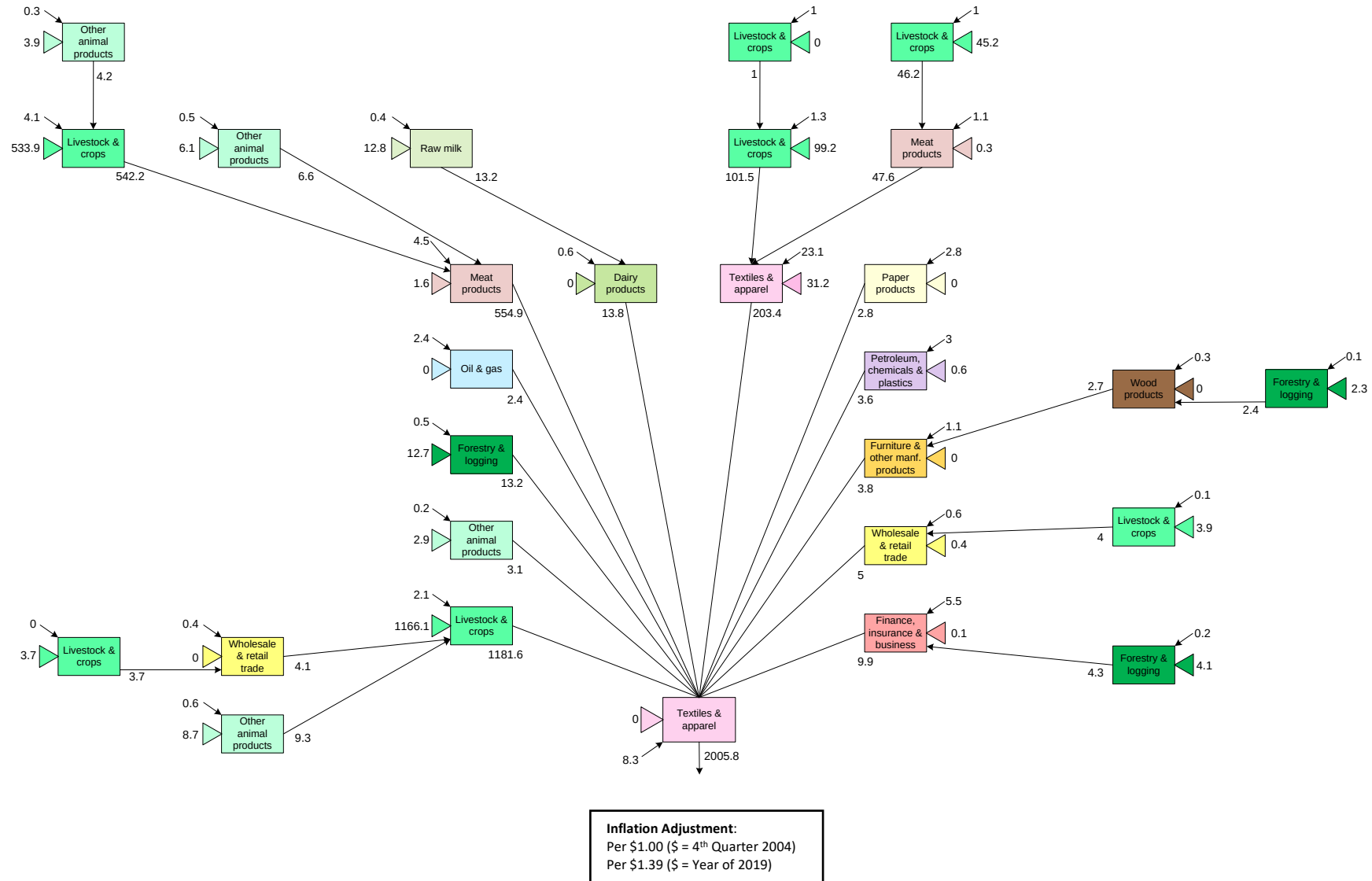


Figure 36.9 Ecosystem Service Value of Erosion Control Required to Produce One Tonne of Wood Products, 2004 (\$₂₀₀₄)

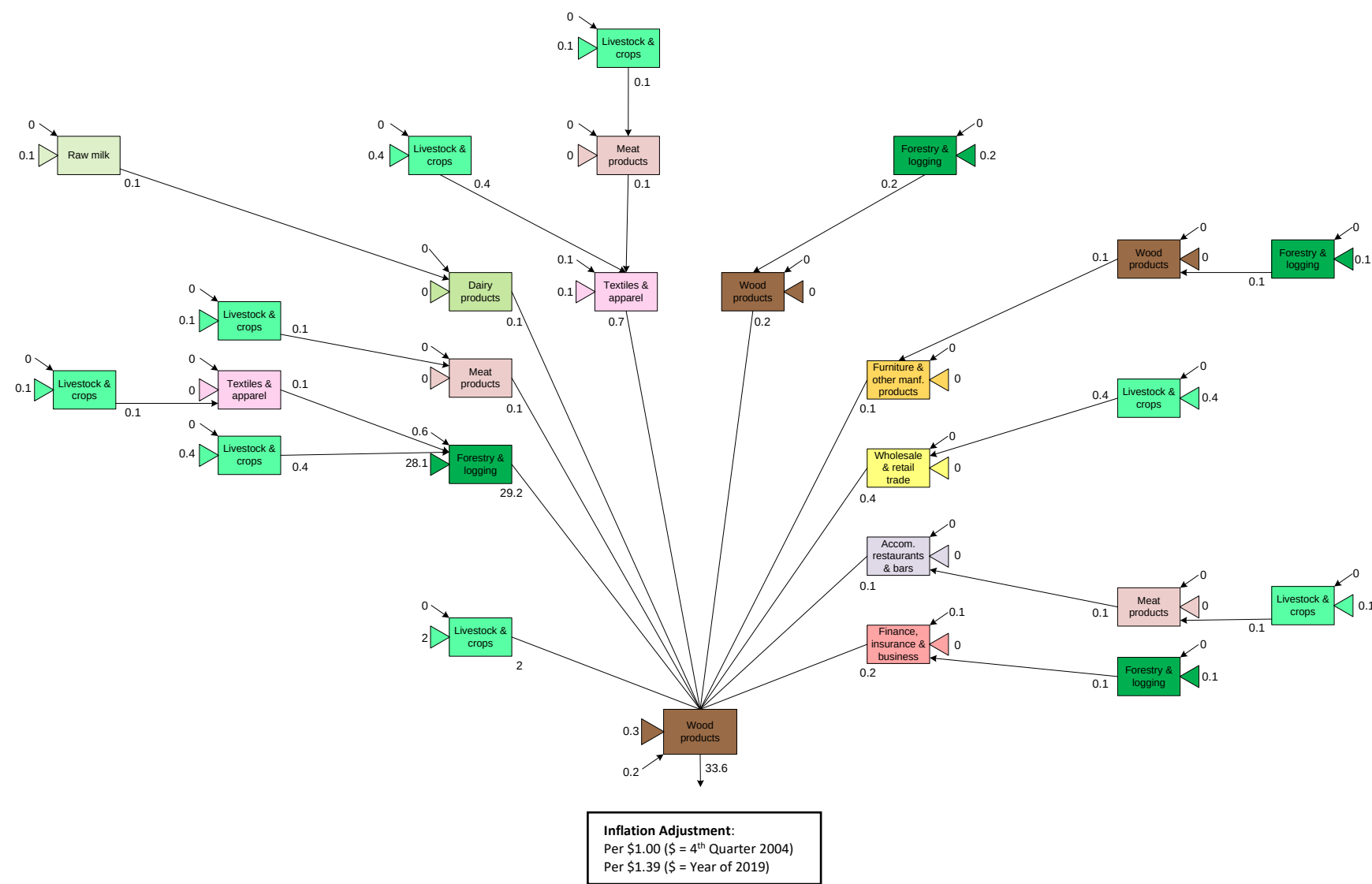


Figure 36.10 Ecosystem Service Value of Waste Treatment Required to Produce One Tonne of Meat Products, 2004 (\$₂₀₀₄)

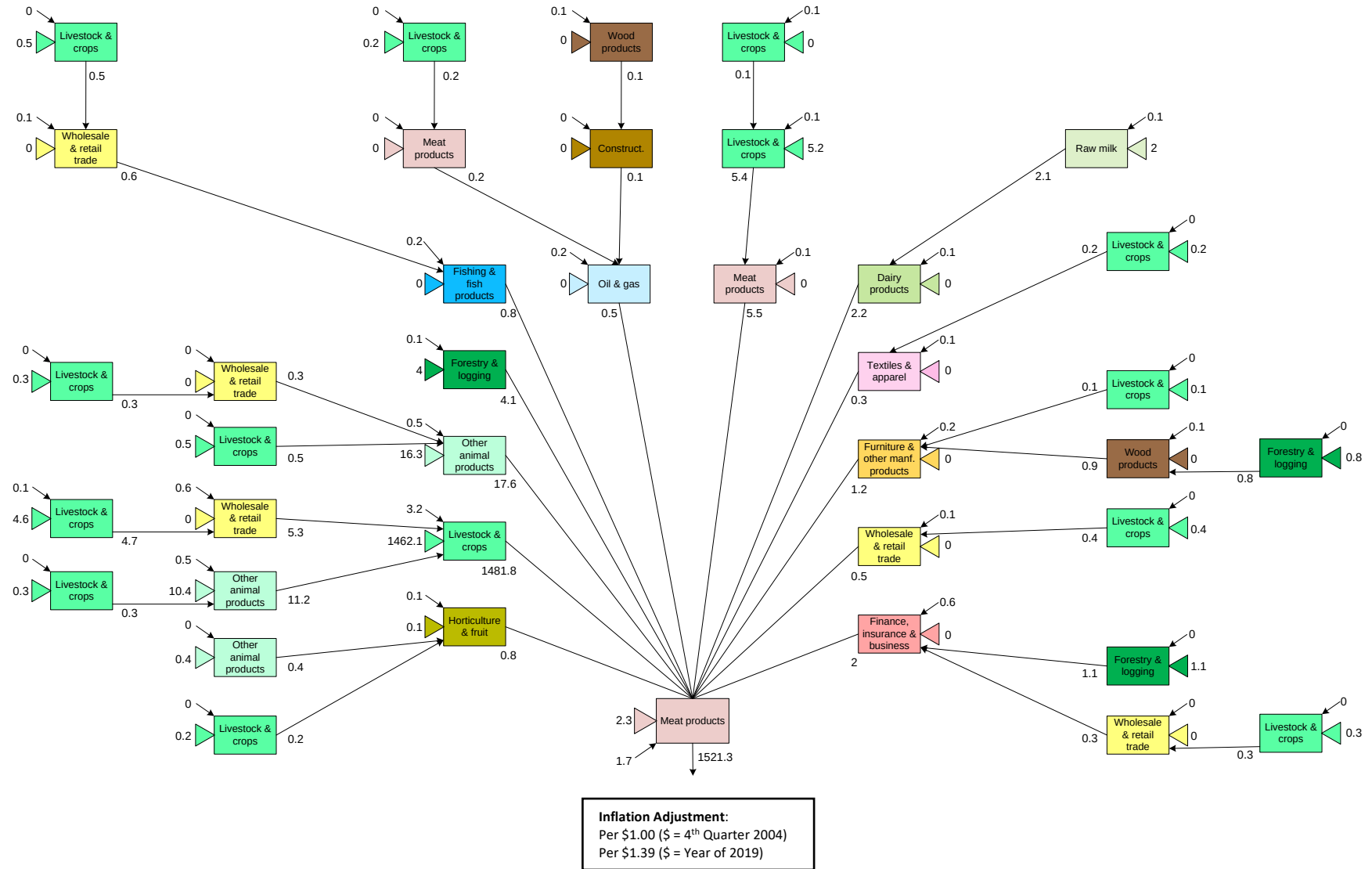
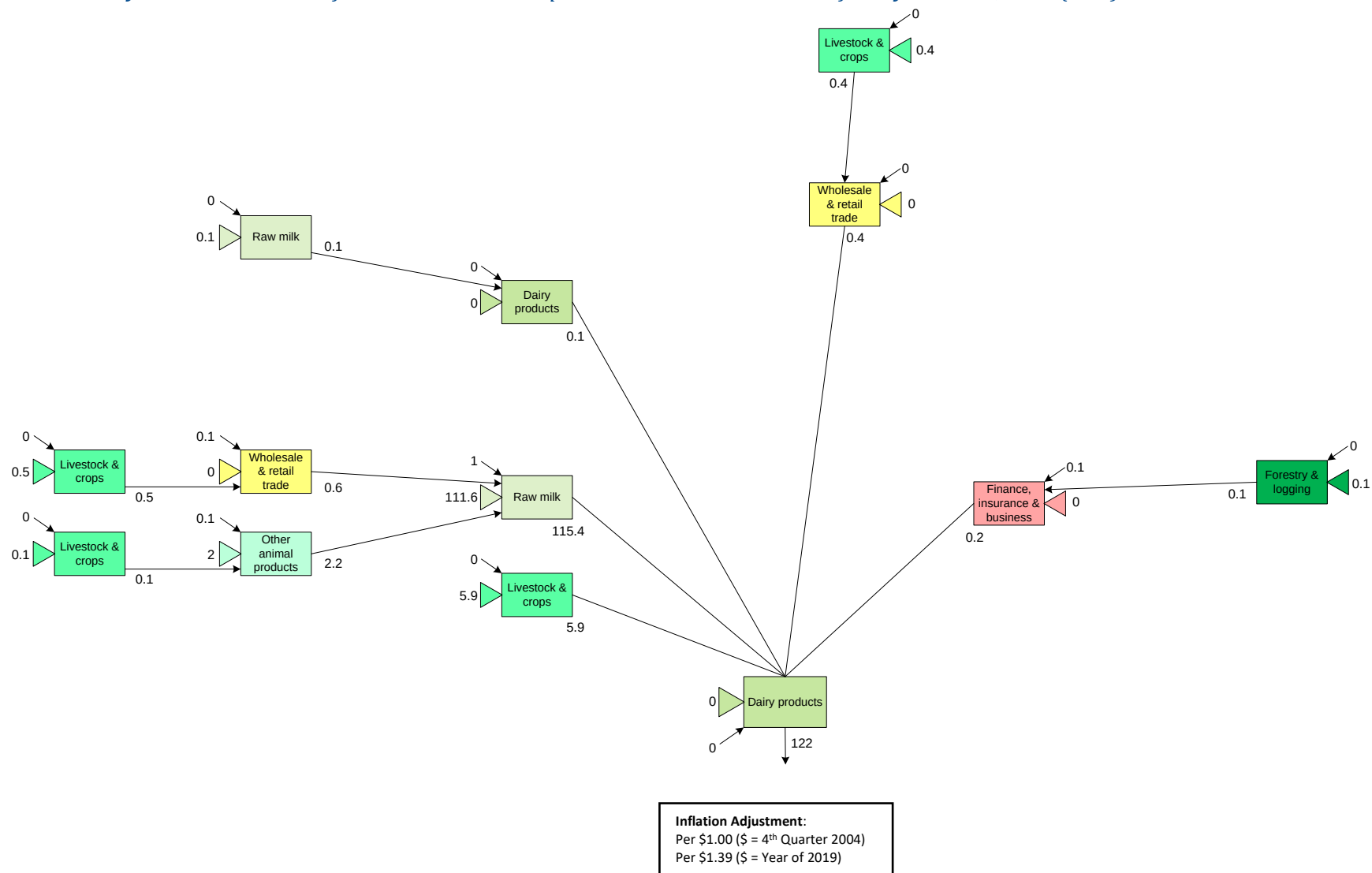


Figure 36.11 Ecosystem Service Value of Waste Treatment Required to Produce One Tonne of Dairy Products, 2004 (\$₂₀₀₄)



37. Bibliography

- Agriquality New Zealand. (2004). *Regional agricultural land use by farm type, as taken from Agribase*. Wellington: Agriquality New Zealand.
- Air New Zealand. (2008). *Annual Shareholder Review: Making our Way*. Retrieved from <http://airnz.web1.interactiveinvestor.com.au/airnz0801/Annual%20Shareholder%20Review%202008/EN/body.aspx?z=2&p=-1&v=2&uid=#>
- Air New Zealand. (n.d). *Help Air New Zealand Help the Environment*. Retrieved from <http://www.airnewzealand.co.nz/environment-information>
- Alcorn, A., & Wood, P. (1998). *New Zealand Building Materials Embodied Energy Coefficients Database (volume II - coefficients)*. Wellington: Centre for Building Performance Research, Victoria University of Wellington.
- Allan, N., Yin, Y., & Scheepbouwer, E. (2008). A Study into the Cyclical Performance of the New Zealand Construction Industry. *Journal for Emerging Issues in the Construction Industry*, 1-16.
- Andrew, R., Forgie, V. E., Nielsen, P., Hodgson, C., Reid, T., & McDonald, G. (2005). Ecological footprint plus: Calculating the total environmental impacts of New Zealand's food and fibre industries. *2005 Australia New Zealand Society for Ecological Economics Conference* (pp. 294-312). Palmerston North, NZ: NZCEE.
- Anonymous. (2002, September 21). *Scenes of Struggle for Emerging Film Industry*. Retrieved from The New Zealand Herald: http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=2848459
- Anonymous. (2009, September 1). *40 Years of Internet History*. Retrieved from Newshub: <http://www.newshub.co.nz/40-years-of-internet-history/tabid/412/articleID/119125/Default.aspx>
- Anonymous. (n.d). *History of Technological Innovation in New Zealand*. Retrieved from Think Big Methanol Project: <http://www.techhistory.co.nz/ThinkBig/Methanol.htm>
- APNZ. (2012, September 12). *Paper mill confirms plans to halve production*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=10833117
- Aquaculture New Zealand. (2012). *A sector overview with key facts, statistics and trends*. Retrieved from <https://www.aquaculture.org.nz/wp-content/uploads/2012/05/NZ-Aquaculture-Facts-2012.pdf>
- Aquaculture New Zealand. (2013). *National Aquaculture Strategy and Five-year Action Plan*. <http://www.aquaculture.govt.nz/strategy.php>.

- Auckland Airport. (2019, March). *Fast Facts*. Retrieved from <https://corporate.aucklandairport.co.nz/news/publications/fast-facts>
- Australian Bureau of Statistics. (1993). *Australian and New Zealand Standard Industrial Classification (ANZSIC): 952 other personal services*. Retrieved from <http://www.abs.gov.au/ausstats/abs@.nsf/0/E04702E43F6C60D3CA25697E0018FCCD?open=document>
- Bandaranayake, D. (1994). Public Health and the Reforms: The New Zealand experience. *Health Policy*, 19(1-2), 127-141.
- Barber, A. (2004). *Severn Case Study Farms: Total Energy and Carbon for New Zealand Arable and Outdoor Vegetable Production*. AgriLINK New Zealand Ltd.
- Barber, A., & Pellow, G. (2006). *Life Cycle Assessment: New Zealand Merino Industry, Merino wool total energy use and carbon dioxide emissions*. Pukekohe, Auckland: The Agribusiness Group. Retrieved from <http://www.merinoinc.co.nz/Reports/LCA-NZMerinoWool.pdf>
- Barber, A., Pellow, G., & Barber, M. (2011). *Carbon Footprint of New Zealand Arable Production - Wheat, Maize Silage, Maize Grain, and Ryegrass Seed*. Retrieved from <http://www.fedfarm.org.nz/Files/2011-MPIGrainCarbon.pdf>
- Barker, R. (2008). *The Natural Resource Potential of New Zealand*. Retrieved from http://www.minerals.co.nz/pdf/Natural_Resource_NZ_web.pdf
- Beech, J. (2009). *Marine Industry Exports tipped to double in next decade*. Retrieved from The Otago Daily Times. : <http://www.odt.co.nz/your-town/queenstown/52687/marine-industry-exports-tipped-double-next-decade>
- Beef and Lamb New Zealand. (2019). *Compendium of Farm Facts*. Wellington. Retrieved from <https://beeflambnz.com/sites/default/files/data/files/Compendium%202019.pdf>
- Beehive. (2015, November 25). *NZ food and beverage sector adding value to volume*. Retrieved from <https://www.beehive.govt.nz/release/nz-food-and-beverage-sector-adding-value-volume>
- Bevilacqua, M., Braglia, M., Carmignani, G., & Zammori, F. (2007). Life Cycle Assessment of Pasta Production in Italy. *Journal of Food Quality*, 932-953. doi:10.1111/j.1745-4557.2007.00170.x
- Bilec, M., Ries, R., Matthews, H. S., & Sharrard, A. L. (2006). Example of a Hybrid Life-Cycle Assessment of Construction Processes. *Journal of Infrastructure Systems*, 12(4). doi:10.1061/(ASCE)1076-0342(2006)12:4(207)
- BRANZ Ltd. (2007). *Life Cycle Assessment: Material Use*. Retrieved from <http://www.level.org.nz/material-use/life-cycle-assessment/>
- Brester, G., Economics, D. o., & University, M. S. (2012). *International Lamb Profile*. Retrieved from Agricultural Marketing Resource Centre: http://www.agmrc.org/commodities__products/livestock/lamb/international-lamb-profile/

- Brettkelly, S. (2019, November 1). *The Detail: The Tiwai Point aluminium smelter bluff*. Retrieved from Stuff: <https://www.stuff.co.nz/national/the-detail/117070250/the-detail-the-tiwai-point-aluminium-smelter-bluff>
- Brewers Association of New Zealand. (2018). *2018 Brewing in New Zealand Report*. Retrieved from <https://www.brewers.org.nz/2018-brewing-in-nz-report>
- Bryant, J., Teasdale, A., Tobias, M., Cheung, J., & McHugh, M. (2004). *Population Aging and Government Health Expenditures in New Zealand, 1951-2051*. Working Paper 04/14, New Zealand Treasury. Retrieved from New Zealand Treasury: <http://www.treasury.govt.nz/publications/research-policy/wp/2004/04-14/twp04-14.pdf>
- Burtini, G. (2009, January 2). *History of Economics Recessions: Dot-Com bubble burst*. Retrieved from <http://politonomist.com/history-of-economic-recessions-00273/6/>
- Bus and Coach Association. (n.d). *New Zealand Industry Facts*. Retrieved 11 16, 2012, from <http://www.busandcoach.co.nz/about/bca/nz-industry-facts.html>
- BusinessDesk. (2013, December 30). *Iron sand exports could soar after shipping expansion*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11179421
- Callister, P., & Didham, R. (2010). *Workforce Composition: Men's work, women's work*. Retrieved from <http://www.TeAra.govt.nz/en/workforce-composition/4>
- Careers NZ. (n.d). *Hair, Beauty and Personal Services – About this Industry*. Retrieved from <http://www.careers.govt.nz/default.aspx?id0=10104&id1=BFC9A692-5831-4F7B-B8CC-72C22BE53387>
- Careers NZ. (n.d). *Logistics, Trade and Warehousing – About this industry*. Retrieved from <http://www.careers.govt.nz/default.aspx?id0=10104&id1=1569CD93-F7B2-4962-9050-23755CBE2CD4>
- Careers NZ. (n.d). *Printing Industry Profile*. Retrieved from <http://www.careers.govt.nz/default.aspx?id0=104&id1=FD029BBD-CC00-48E0-A1E7-9E4F5C4283E5>
- Careers NZ. (n.d). *Seafood and Aquaculture- About this Industry* . Retrieved from <http://www.careers.govt.nz/default.aspx?id0=10104&id1=99F7D046-6D34-4261-99F4-198F7146994C>
- Careers NZ. (n.d). *Telecommunications – Jobs in the Industry* . Retrieved from <http://www.careers.govt.nz/default.aspx?id0=20104&id1=EE742A95-CC4D-4D35-9027-2B9F2B6D5128>
- Careers NZ. (n.d). *Water Transport – About this Industry*. Retrieved from <http://www.careers.govt.nz/default.aspx?id0=10104&id1=AE49DD7C-F4D8-47F4-8139-BB8E364D4A58>

- Careers NZ. (n.d.). *Primary School Teacher*. Retrieved from <https://www.careers.govt.nz/jobs-database/education-and-social-sciences/education/primary-school-teacher/>
- Careers NZ. (n.d.). *Secondary School Teacher*. Retrieved from <https://www.careers.govt.nz/jobs-database/education-and-social-sciences/education/secondary-school-teacher/>
- Carlsson-Kanyama, A., Ekstrom, M. P., & Shanahan, H. (2002). Food and Lifecycle Energy Inputs: Consequences of diet and ways to increase efficiency. *Ecological Economics*, 44(203), 293-307.
- Carnegie Mellon University Green Design Institute. (2020). *Economic Input-Output Life Cycle Assessment*. Retrieved February 7, 2020, from <http://www.eiolca.net/>
- Chalikias, K., Kyriakopolous, G., & Kolovos, K. (2009). Environmental sustainability and financial feasibility evaluation of woodfuel biomass used for a potential replacement of conventional space heating sources. *Operational Research*, 10(1), 57-69.
- Commerce Commission New Zealand. (2003, June 23). *Telecommunications Act: Commerce Commission releases draft RSO cost calculation*. Retrieved from <http://www.comcom.govt.nz/telecommunications-media-releases/detail/2003/telecommunicationsa13>
- Commerce Commission New Zealand. (2018). *Annual Telecommunications Monitoring Report: 2018 Key Facts*. Wellington. Retrieved from https://comcom.govt.nz/__data/assets/pdf_file/0016/111292/2018-Annual-Telecommunications-Monitoring-Report-18-December-2018.pdf
- Community Gambling Association. (2009, October 14). *Communities and Funding Continue to Suffer from Decline in Revenue*. Retrieved from <http://www.cga.org.nz/files/news-detail.asp?NewsID=181>
- Community Matters. (n.d.). *Lottery Grants Board*. Retrieved February 5, 2020, from <https://www.communitymatters.govt.nz/lottery-grants-board/>
- Consumer. (2019, February 15). *Mobile & internet provider satisfaction survey 2019*. Retrieved from <https://www.consumer.org.nz/articles/telco-providers>
- Cook, A. (2017, March 6). *Wool export value drops 25% coming into 2017*. Retrieved from RNZ: <https://www.rnz.co.nz/news/business/325941/wool-export-value-drops-25-percent-coming-into-2017>
- Coriolis. (2015). *The Investor's Guide to the New Zealand Food and Beverage Industry*. Wellington: Ministry for Business, Innovation and Employment. Retrieved from <https://www.mbie.govt.nz/assets/aaefdb3085/investors-guide-nz-food-beverage-industry.pdf>
- Coriolis. (2017). *The Investor's Guide to the New Zealand Dairy Industry 2017*. Auckland: Ministry of Business, Innovation and Employment. Retrieved from

<https://www.mbie.govt.nz/assets/ebd383c353/investors-guide-to-the-new-zealand-dairy-industry-2017.pdf>

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., . . . van den Belt, M. (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature*, 387, 253-260. doi:10.1038/387253a0

Crawford, R. H. (2014). Post-occupancy life cycle energy assessment of a residential building in Australia. *Architectural Science Review*, 57(2), 114-124. doi:10.1080/00038628.2013.819556

Dairy Companies Association of New Zealand. (n.d.). *About the NZ Dairy Industry*. Retrieved from <http://www.dcanz.com/about-the-nz-dairy-industry/>

Dairy NZ. (2019). *QuickStats about dairying*. Retrieved from <https://www.dairynz.co.nz/media/5791052/quickstats-about-dairying-new-zealand-2019.pdf>

Denne, T., Bond-Smith, S., & Hennessy, W. (2009). *Coal Prices in New Zealand Markets*. Auckland: Covec Ltd. Retrieved from <https://www.mbie.govt.nz/assets/b22df3463e/coal-price-report.pdf>

Department of Labour. (2005). Construction Industry: Workforce trends. *Work Insight*, 5, 32-34.

Department of Labour. (2009). *Employment and Skills Snapshot – Government Administration and Defence*. Retrieved from <http://www.dol.govt.nz/services/LMI/tools/skillsinsight/snapshots/government/government.pdf>

Department of Labour. (2009). *Employment Skills Snapshot – Wholesale trade: Overview July 2009*. Retrieved from <http://www.dol.govt.nz/services/lmi/tools/skillsinsight/snapshots/wholesaletrade/skillsinsight-snapshot-wholesale-trade.pdf>

Department of Labour. (2011). *Construction Sector Action Plan 2010-2013*. Retrieved from <http://www.dol.govt.nz/whss/sector-plans/construction/action-plan.pdf>

Department of the Prime Minister and Cabinet. (2008). *Final Report of the House Prices Unit: House Price Increases and Housing in New Zealand*. Retrieved from <http://www.dpmc.govt.nz/sites/all/files/publications/hpr.pdf>

Devlin, C., & McCarthy, P. (2015, August 3). *Tiwai Smelter deal signed between Meridian Energy and NZAS*. Retrieved from Stuff: <https://www.stuff.co.nz/business/industries/70763839/tiwai-smelter-deal-signed-between-meridian-energy-and-nzas>

Ding, D., Lawson, K. D., Kolbe-Alexander, T. L., Finkelstein, E. A., Katzmarzyk, P. T., van Mechelen, W., & Pratt, M. (2016). *The economic burden of physical inactivity: a global analysis of major non-communicable diseases*. The Lancet. doi:[https://doi.org/10.1016/S0140-6736\(16\)30383-X](https://doi.org/10.1016/S0140-6736(16)30383-X)

- du Fresne, K. (2017, June 18). *New Zealand papers are in dangerous decline - here's what's at stake*. Retrieved from Noted: <https://www.noted.co.nz/money/money-business/new-zealand-papers-are-in-dangerous-decline-heres-whats-at-stake>
- Earle, D. (2009). *Advanced trade, technical and professional qualifications – Trends in supply*. Retrieved from http://www.educationcounts.govt.nz/__data/assets/pdf_file/0005/47723/Report-3-supply-of-graduates-formatted-v2.pdf
- Education and Science Committee. (2003, December). *Inquiry into decile funding in New Zealand State and integrated schools*. Retrieved from https://www.parliament.nz/resource/en-nz/47DBSCH_SCR2635_1/a0d737616dee49badb33dd37823f97891af572dc
- Education Central. (2019, September 24). *Goodbye deciles, hello Equity Index*. Retrieved from <https://educationcentral.co.nz/goodbye-deciles-hello-equity-index/>
- Education Counts. (2018, December). *Educational attainment in the adult population*. Retrieved from https://www.educationcounts.govt.nz/statistics/indicators/main/education-and-learning-outcomes/educational_attainment_in_the_adult_population
- Education Information and Analysis Group (Ministry of Education). (2009). *Ngā Haeata Mātauranga - The Annual Report on Māori Education, 2007/08*. Retrieved from <http://www.educationcounts.govt.nz/publications/series/5851/35307/5>
- Education NZ. (2017, December 4). *Details of fees free tertiary education and training for 2018 announced*. Retrieved from <https://www.education.govt.nz/news/details-of-fees-free-tertiary-education-and-training-for-2018-announced/>
- Encyclopaedia of the Nations. (2010). *New Zealand-Mining*. Retrieved from <http://www.nationsencyclopedia.com/Asia-and-Oceania/New-Zealand-MINING.html>
- Energy Efficiency Conservation Authority (EECA). (2004). *Energy End-Use Database 2001-02*. Wellington: Energy Efficiency Conservation Authority.
- Engler, R. (2009). *Future Demand for Tertiary Education in New Zealand; 2009 to 2025 and beyond*. Retrieved from http://www.educationcounts.govt.nz/__data/assets/pdf_file/0007/46681/Tertiary-demand-FINAL-Updated.pdf
- Environment Guide. (2017). *EEZ*. Retrieved from <http://www.environmentguide.org.nz/eez/>
- Fashion United. (2016). *New Zealand Fashion Statistics*. Retrieved from <https://fashionunited.nz/statistics/fashion-industry-statistics-newzealand/>
- FCANZ. (2016, February 15). *Furniture Exports*. Retrieved from <https://fcanz.net.nz/furniture-exports-2/>
- Figure.nz. (2019, October 25). *Enterprises in the life insurance industry in New Zealand*. Retrieved from Figure.nz: <https://figure.nz/chart/IW0xisEu03j4YW09-H4hIPzb94VRE4Ytx>

- Film New Zealand. (n.d). *Introducing New Zealand: Film Industry History*. Retrieved from <http://www.filmnz.com/introducing-nz/film-industry-history.html>
- Film Wellington. (n.d). *Weta Workshop*. Retrieved from <http://www.filmwellington.com/page/industry-directory-profile.aspx?p=Weta+Workshop>
- Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., . . . Suh, S. (2009). Recent developments in Life Cycle Assessment. *Journal of Environmental Management*, 91(1), 1-21. doi:10.1016/j.jenvman.2009.06.018
- Flaws, B. (2019, March 6). *NZ Post hikes letter price as volumes plunge 60 million in a year*. Retrieved from Stuff: <https://www.stuff.co.nz/business/111064863/nz-post-hikes-letter-price-as-volumes-plunge-60-million-in-a-year>
- Food and Agriculture Organization of the United Nations. (2007). *State of the World's Forest International Convention*. Rome. Retrieved from <http://www.fao.org/docrep/009/a0773e/a0773e00.htm>
- Food and Agriculture Organization of the United Nations. (2019). *Dairy Market Review*. Rome. Retrieved from <http://www.fao.org/3/ca3879en/ca3879en.pdf>
- Foran, B., Lenzen, M., & Dey, C. (2005). *Balancing Act – A triple bottom line analysis of the Australian economy*. Canberra: CSIRO.
- Forbes, S. (2019, May 15). *Sino demand for NZ forestry products highlights dilemma faced by timber processors*. Retrieved from Interest: <https://www.interest.co.nz/news/99701/sino-demand-nz-forestry-products-highlights-dilemma-faced%C2%A0-timber-processors>
- Forest Owners Association. (2019). *Facts and Figures 2018/2019*. Wellington. Retrieved from https://www.nzfoa.org.nz/images/Facts_and_Figures_2018-2019_Web.pdf
- Fox, A. (2005, August 29). *TradeMe Clients Bolster NZ Post Parcel Volumes*. Retrieved from The New Zealand Herald: http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=10342863
- Friday Offcuts. (2008, June 27). *Friday Offcuts*. Retrieved from http://www.fridayoffcuts.com/dsp_newsletter.cfm?id=277
- Frykberg, E. (2018, 2 14). *Genesis Energy to phase out Huntly coal use*. Retrieved from RNZ: <https://www.rnz.co.nz/news/national/350390/genesis-energy-to-phase-out-huntly-coal-use>
- Gas Industry Company. (2019, May). *Gas industry - facts at a glance*. Retrieved from <https://gasindustry.co.nz/dmsdocument/6540>
- Glenbrook Steel Site Operations, New Zealand Steel Limited. (2011). *Glenbrook Steel Site*. Retrieved from <http://www.nzsteel.co.nz/about-new-zealand-steel/operations-/glenbrook-steel-site>
- Goucher, L., Bruce, R., Cameron, D. D., Koh, S. L., & Horton, P. (2017). The environmental impact of fertilizer embodied in a wheat-to-bread supply chain. *Nature Plants*, 3(17012). doi:10.1038/nplants.2017.12

- Griffin, P. (2019, December 10). *5G is live – now what?* Retrieved from Noted: <https://www.noted.co.nz/tech/tech-tech/5g-is-live-now-what>
- Grow Regions. (n.d.). *The Provincial Growth Fund*. Retrieved from <https://www.growregions.govt.nz/about-us/the-provincial-growth-fund/>
- Guignard, C., Verones, F., Loerincik, Y., & Joillet, O. (2009). Environmental / Ecological Impact of the Dairy Sector. *Bulletin of the International Dairy Federation*, 436. Retrieved from <http://www.ukidf.org/documents/Bulletin436.pdf>
- Hall, P., & Jack, M. (2008). *Bioenergy Options for New Zealand: Pathways Analysis*. Rotorua, New Zealand: Scion Energy Group.
- Hammond, G. P., & Jones, C. I. (2008). Embodied Energy and Carbon in Construction Materials. *Proceedings of the Institution of Civil Engineers - Energy*, 161(2), 87-98.
- Hammond, G. P., & Jones, C. I. (n.d.). *Inventory of Carbon and Energy (ICE) (Version 1.6a)*. University of Bath, UK, Sustainable Energy Research Team, Department of Mechanical Engineering. Retrieved from <http://web.mit.edu/2.813/www/readings/ICE.pdf>
- Harding, E. (2019, October 30). *Rio Tinto 'not bluffing' about threat to shut Tiwai Point smelter*. Retrieved from Stuff: <https://www.stuff.co.nz/business/industries/116995107/nzas-closure-team-coming-south>
- Hargreaves, D. (2019, October 22). *Fonterra gives new milk price range for the season of \$6.55-\$7.55 per kilogram of milk solids; says it has been achieving 'good prices' for its milk so far*. Retrieved February 5, 2020, from Interest: <https://www.interest.co.nz/rural-news/102236/fonterra-gives-new-milk-price-range-season-655-755-kilogram-milk-solids-says-it>
- Healy, B. (1982). *A Hundred Million Trees: The story of New Zealand Forest Products*. Auckland.
- Hembry, O. (2011, January 30). *In the shadow of Think Big*. Retrieved February 5, 2020, from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=10703096
- Hendrickson, C., Horvath, A., Joshi, S., & Lave, L. (1998). Economic Input-Output Models for Environmental Life-Cycle Assessment. *Environmental Science & Technology*, 32(7), 184A-191A. doi:DOI: 10.1021/es983471i
- Hendrickson, C., Lave, L. B., Matthews, H. S., Horvath, A., Joshi, S., McMichael, F. C., . . . Bergerson, J. A. (2006). *Environmental Life Cycle Assessment of Goods and Services: An Input-Output Approach*.
- Horgan, G. P., & Maplesden, F. M. (1995). The role of marketing in developing exports of plantation-grown New Zealand radiata pine. *Unasylva*, 183(46), 29-36.
- Horticulture New Zealand. (2018). *A Food Story: Annual Report 2018*. Wellington. Retrieved February 5, 2020, from <https://www.hortnz.co.nz/assets/Annual-Report/HortNZ-Annual-Report-2018.pdf>

- Horticulture New Zealand. (2018). *Fresh Facts*. Auckland: The New Zealand Institute for Plant and Food Research Ltd.
- Horticulture New Zealand. (2019). *Our Food Future*. Wellington.
- Hossain, L., & Khan, M. S. (2017). Blue and Grey Water Footprint Assessment of Textile Industries of Bangladesh. *Fifth International Conference on Chemical Engineering*. Dhaka, Bangladesh.
- IEA. (2018). *Coal 2018*. Paris: IEA. Retrieved February 5, 2020, from <https://www.iea.org/reports/coal-2018>
- Infometrics Limited. (2012). *Labour Market and Economic Profile: New Zealand*. Retrieved from <http://www.infometrics.co.nz/products-services/regional/New-ZealandRevisedJun2012.pdf>
- Infometrics, NZ Trade and Enterprise & Nimmo-Bell and Company Ltd. (2003). *Economic Evaluation of the Food Processing Sector: A Strategic Review for New Zealand Trade and Enterprise*. Retrieved from <http://www.infometrics.co.nz/reports/food-processing-review.pdf>
- ISO. (2007). *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework*. Geneva, Switzerland: ISO. Retrieved February 7, 2020, from <https://www.iso.org/standard/37456.html>
- Jensen, A. A., Christiansen, K., Elkington, J., Hoffman, L., Møller, B. T., Schmidt, A., & van Dijk, F. (1998). *Life cycle assessment (LCA) - a guide to approaches, experiences and information sources*. Copenhagen, Denmark: European Environment Agency. Retrieved from https://www.researchgate.net/publication/299446257_Life_cycle_assessment_LCA_-_a_guide_to_approaches_experiences_and_information_sources
- Joshi, S. (1999). Product Environmental Life-Cycle Assessment Using Input-Output Techniques. *Journal of Industrial Ecology*, 3(2-3), 95-120. doi:10.1162/108819899569449
- Kite, H. (2005). Overview of the New Zealand Retail Sector. *Bulletin*, 68(2), 32-41.
- KiwiRail Group. (2011). *KiwiRail Group Turnaround Plan*. Wellington. Retrieved from <https://treasury.govt.nz/sites/default/files/2010-07/b10-cab-kgtf-14apr11.pdf>
- Knight, K. (2017, August 6). *Changing Times for the Car Accident Repair Industry in New Zealand*. Retrieved February 5, 2020, from Crash Management: <https://crashmanagement.nz/changing-times-car-accident-repair-industry-new-zealand/>
- Knowledge Auckland. (2008). *Industry Snapshot for the Auckland Region - The Marine Sector*. Auckland. Retrieved from http://knowledgeauckland.org.nz/assets/publications/Industry_snapshot_for_the_Auckland_region_The_marine_sector.pdf
- Lave, L. B., Cobas-Flores, E., Hendrickson, C., & McMichael, F. C. (1995). Using input-output analysis to estimate economy-wide discharges. *Environmental Science and Technology*, 29(9), 420A-426A. doi:10.1021/es00009a748

- Le Heron, R., & Pawson, E. (1996). *Changing Places, New Zealand in the Nineties*. Auckland, New Zealand: Longman Paul.
- Ledgard, S. F., Zonderland-Thomassen, M., Lieffering, M., & McLaren, S. (2012). Role of Life Cycle Assessment in Agriculture for Realising Market Opportunities and Enhancing on-farm Efficiency. In L. D. Currie, & C. L. Christensen (Eds.), *Advanced Nutrient Management: Gains from the Past - Goals from the Future* (Vol. Occasional Report No. 25 Fertilizer and Lime Research Centre, p. 11). Palmerston North, New Zealand: Massey University. Retrieved from <http://flrc.massey.ac.nz/publications.html>
- Lenzen, M., & Crawford, R. (2009). The Path Exchange Method for Hybrid LCA. *Environmental Science & Technology*, 43(21), 8251-8256. doi:10.1021/es902090z
- Lesschen, J. P., van den Berg, M., Westhoek, H. J., Witzke, H. P., & Oenema, O. (2011). Greenhouse Gas Emission Profiles of European Livestock Sectors. *Animal Feed Science and Technology*, 166-167, 16-28.
- Let's Talk About Coal. (n.d.). *Coal in NZ*. Retrieved from <https://www.letstalkaboutcoal.co.nz/coal-in-nz/>
- LIC. (2019). *2018-2019 New Zealand Dairy Statistics*. Retrieved February 10, 2020, from Dairy Statistics: <https://www.lic.co.nz/about/dairy-statistics/>
- Liddell, C. (2002, March 28). *New Zealand Herald*. Retrieved from Page C1.
- Local Councils. (2018). *Operating Expenditure*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_URL/Profiles-Local-Government-Statistical-Overview-Operating-Expenditure
- Local Councils. (2018). *Operating Revenue*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_URL/Profiles-Local-Government-Statistical-Overview-Operating-Revenue
- Local Councils. (n.d.). *Council Profiles by Type*. Retrieved from http://www.localcouncils.govt.nz/lqip.nsf/wpg_url/Profiles-Councils-by-Type-Index
- MacDonald, M. (2013, September 15). *Is this the end for NZ publishing?* Retrieved from Stuff: <http://www.stuff.co.nz/dominion-post/culture/9162076/Is-this-the-end-for-NZ-publishing>
- Macfie, R. (2006). *Sharechat Article*. Retrieved from Rotten Apples.
- Mahoney, P. (2003). *Tertiary Education Funding – Overview of Recent Reform*. Wellington: New Zealand: Parliamentary Library.
- Maritime New Zealand. (n.d.). *Marine Dumping*. Retrieved February 10, 2020, from <https://www.maritimenz.govt.nz/commercial/environment/marine-dumping.asp>
- McBeth, P. (2017, December 14). *KiwiBuild spearheads \$42b capital spending programme*. Retrieved February 5, 2020, from NBR: <https://www.nbr.co.nz/article/kiwibuild-spearheads-42-billion-capital-spending-programme-b-211193>

- McDonald, G. (2005). *Integrating economics and ecology : a systems approach to sustainability in the Auckland region*. Palmerston North: Massey University. Retrieved from <http://hdl.handle.net/10179/1776>
- McDonald, G., & Patterson, M. (2006). Development of a New Zealand Physical Input-Output Table. *Intermediate Input–Output Meetings on Sustainability, Trade & Productivity*. Sendai, Japan.
- McLaughlin, M. (2003). *Tertiary Education Policy in New Zealand (Fulbright Report)*. Retrieved from http://www.fulbright.org.nz/wp-content/uploads/2011/12/axford2002_mclaughlin.pdf
- McPhail, T. L. (2002). *New Zealand Media Industry Profile*. Retrieved from <http://www.pressreference.com/Ma-No/New-Zealand.html>
- Meat Industry Association. (2009). *Meat In Focus*. Wellington: MIA. Retrieved February 5, 2020, from <https://www.mia.co.nz/assets/MIA-Publications/Meat-in-focus.pdf>
- Medical Technology Association of New Zealand. (n.d). *Overview*. Retrieved from <http://mtanz.org.nz/NZ-Market-The-NZ-Healthcare-Market/Overview-6374.htm>
- Mekonnen, M. M., & Hoekstra, A. Y. (2011). The green, blue and grey water footprint of crops and derived crop products. *Hydrology and Earth System Sciences*, 15(5), 1577-1600.
- Methanex. (n.d.). *About Methanex in New Zealand*. Retrieved from <https://www.methanex.com/location/new-zealand/about-methanex-new-zealand>
- Ministry for Culture and Heritage. (2012). *Cultural Sector Overviews*. Retrieved from <http://www.mch.govt.nz/what-we-do/cultural-sector-overviews>
- Ministry for Primary Industries. (2016). *Wood Availability Forecasts - New Zealand 2014-2050*. Wellington. Retrieved from <https://www.teururakau.govt.nz/dmsdocument/14221-wood-availability-forecasts-new-zealand-2014-2050>
- Ministry for Primary Industries. (2019, December 23). *Current PGP Programmes*. Retrieved February 5, 2020, from <https://www.mpi.govt.nz/funding-and-programmes/sustainable-food-and-fibre-futures/primary-growth-partnership/current-pgp-programmes/>
- Ministry for Primary Industries. (2020). *Review of livestock exports*. Retrieved from <https://www.mpi.govt.nz/news-and-resources/consultations/review-of-livestock-exports/>
- Ministry for Primary Industries. (n.d). *Agriculture in the New Zealand Emissions Trading Scheme: Emissions factors (agriculture)*. Retrieved from <http://www.mpi.govt.nz/Portals/0/Documents/agriculture/agri-ets/agets-emissions-factors.pdf>
- Ministry for Primary Industries. (n.d). *The New Zealand Fishing Industry*. Retrieved from <http://www.fish.govt.nz/en-nz/Commercial/About+the+Fishing+Industry/default.htm>
- Ministry for the Environment. (2007). *Transport*. Retrieved from www.mfe.govt.nz/publications/ser/enz07-dec07/chapter-4.pdf

- Ministry for the Environment. (2018). *A Guide to the New Zealand Emissions Trading Scheme*. Retrieved from <https://www.mfe.govt.nz/publications/climate-change/guide-new-zealand-emissions-trading-scheme>
- Ministry for the Environment. (2019). *Environment Aotearoa 2019 Summary*. Wellington, New Zealand: Ministry for the Environment. Retrieved February 8, 2020, from <https://www.mfe.govt.nz/environment-aotearoa-2019-summary>
- Ministry for the Environment. (n.d). *Influences on Vehicle Kilometres Travelled (VKT)*. Retrieved from <http://www.mfe.govt.nz/environmental-reporting/transport/vehicle-km-travelled/total-vkt/factors-increase-vkt.html>
- Ministry of Agriculture and Forestry. (2006). *2004 National Exotic Forest Description*. Wellington: Ministry of Agriculture and Forestry.
- Ministry of Agriculture and Forestry. (2007). *Situation Outlook for New Zealand Agriculture and Forestry*. Retrieved from <http://maxa.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/archive/sonzaf-2007.pdf>
- Ministry of Agriculture and Forestry. (n.d). *Forestry Statistics Section*. Policy Innovation & Research Group.
- Ministry of Business, Innovation and Employment. (2009). *Employment and Skills Snapshot – Health and Community Services*. Retrieved from <http://www.dol.govt.nz/services/lmi/tools/skillsinsight/snapshots/health/index.asp>
- Ministry of Business, Innovation and Employment. (2009). *Identifying the Resilience of the New Zealand Workforce in a Recession* . Retrieved from http://www.dol.govt.nz/services/LMI/workforce2020/resilience-to-recession/resilience-to-recession_04.asp
- Ministry of Business, Innovation and Employment. (2011). *Likely Areas of Growth in Employment Opportunities: Quarterly Report* . Retrieved from <http://www.dol.govt.nz/publications/research/growth-employment-opportunities/growth-employment-opportunities.pdf>
- Ministry of Business, Innovation and Employment. (2018). *Beyond Commodities: Manufacturing into the Future*. Wellington. Retrieved from <https://www.mbie.govt.nz/assets/f0f81b6194/new-zealand-manufacturing-sector-report-2018.pdf>
- Ministry of Business, Innovation and Employment. (2019). *Coal Statistics*. Retrieved from <https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/coal-statistics/>
- Ministry of Economic Development. (2011). *Energy Data File*. Retrieved from <http://www.med.govt.nz/sectors-industries/energy/energy-modelling/data/oil>
- Ministry of Economic Development. (2013). *New Zealand Petroleum and Mineral Permits*. Retrieved from <http://www.nzpam.govt.nz/cms/coal/permits>

- Ministry of Education. (2008). *The New Zealand Education System: An overview*. Wellington, New Zealand.
- Ministry of Forestry. (1988). *Report #4932*.
- Ministry of Health. (2006). *Health Workforce Development: An Overview*. Wellington, New Zealand.
- Ministry of Justice. (n.d). *About the Justice Sector*. Retrieved from <http://www.justice.govt.nz/justice-sector/about-the-justice-sector>
- Ministry of Social Development. (1994). *What does Employment Change have in store for the Unemployed in the 1990s?* Retrieved from <http://www.msd.govt.nz/documents/about-msd-and-our-work/publications-resources/journals-and-magazines/social-policy-journal/spj03/spj3-employment-change.doc>
- Ministry of Tourism. (2008). *New Zealand Aviation Overview: Flights, Passengers and related statistics*. Retrieved from www.treasury.govt.nz/economy/overview/2010/nzefto-10-3.pdf
- Ministry of Transport. (2011). *Connecting New Zealand: A summary of the government's policy direction for transport* . Retrieved from http://www.transport.govt.nz/ourwork/KeyStrategiesandPlans/Documents/Connecting%20NZ_online_version_9_September.pdf
- Ministry of Transport. (2012). *The Total Current Freight Task – National Freight Demands Survey*. Retrieved from <http://www.transport.govt.nz/research/TheTotalCurrentFreightTask/>
- Ministry of Transport. (2017). *New Zealand Transport Outlook: Current State*. Wellington: Ministry of Transport. Retrieved from <https://www.transport.govt.nz/assets/Uploads/Research/Documents/Transport-Outlook/4897ce4d17/MoT-Transport-Outlook.pdf>
- Ministry of Transport. (2019). *National Freight Demand Study 2017/2018*. Retrieved from <https://www.transport.govt.nz/assets/Import/Uploads/Research/Documents/NFDS3-Final-Report-Oct2019-Rev1.pdf>
- Ministry of Transport. (2019, June 6). *Transport Outlook*. Retrieved from <https://www.transport.govt.nz/mot-resources/transport-outlook/>
- Ministry of Transport. (n.d). *Infrastructure and Investment: Infrastructure size*. Retrieved from <http://www.transport.govt.nz/ourwork/TMIF/Pages/II001.aspx>
- Moriguchi, Y., Kondo, Y., & Shimizu, H. (1993). Analyzing the life cycle impact of cars: The case of CO₂. *Industry and Environment*, 16(1-2), 42-45.
- Mossman, E., & Mayhew, P. (2007). *Central Government Aims and Local Government Responses: The Prostitution Reform Act 2003*. Retrieved from <http://www.justice.govt.nz/policy/commercial-property-and-regulatory/prostitution/prostitution-law-review-committee/publications/central-local-govt>

- Myllylahti, M., & Baker, S. (2019). *New Zealand Media Ownership 2019*. Auckland: AUT research center for Journalism, Media and Democracy. Retrieved from https://www.aut.ac.nz/__data/assets/pdf_file/0010/329770/JMAD-2019-Report.pdf
- National Road Carriers. (n.d). *Industry Facts* . Retrieved from http://www.transport.org.nz/Section?Action=View&Section_id=45
- New York State Department of Environmental Conservation. (2007). *DEC Reports: Progress since Marks Dairy Spill [Press Release]*. Retrieved from <http://archive.today/KLm9i>
- New Zealand Audit Bureau of Circulation Inc. (2019). *Newspaper Audit Result*. Retrieved from <http://newspaper.abc.org.nz/audit.html>
- New Zealand Dairy Statistics. (2010). *IDF World Dairy Summit* . Retrieved from <http://wds2010.com/dairystats.html>
- New Zealand Food and Innovation Network. (n.d). . Retrieved from <http://www.foodinnovationnetwork.co.nz/>
- New Zealand Government. (n.d.). *Getting publicly funded health services*. Retrieved from <https://www.govt.nz/browse/health/public-health-services/getting-publicly-funded-health-services/>
- New Zealand Immigration. (n.d). *Hospital and Practices across the Country are Looking for Doctors, Nurses, and Other Healthcare Specialists*. Retrieved from <http://www.newzealandnow.govt.nz/working-in-nz/great-career-opportunities/healthcare>
- New Zealand Marine Industry. (n.d). *New Zealand Boat Building CPC Programme*. Retrieved from <http://www.nzmarine.com/Boating+in+NZ/New+Zealand+Boat+Building+Standard+CPC+Programme.html>
- New Zealand Petroleum & Minerals. (2019, November 20). *2018 Mining Production Statistics*. Retrieved from Annual Minerals Industry Statistics: <https://www.nzpam.govt.nz/our-industry/nz-minerals/minerals-data/industry-statistics/>
- New Zealand Post. (2006). *History of New Zealand Post*. Retrieved from <http://www.nzpost.co.nz/about-us/who-we-are/history-of-new-zealand-post>
- New Zealand Post Group. (2016). *Annual Report 2016*. Wellington. Retrieved from <https://www.nzpost.co.nz/sites/default/files/uploads/shared/annual%20reports/2016-nz-post-group-full-year-annual-report.pdf>
- New Zealand Public Service Administration. (2007). *Strong Public Services make a Strong New Zealand*. Retrieved from www.psa.org.nz/election/PSReport.pdf
- New Zealand Tourism. (2014, December 3). *Background: New Zealand's screen industry*. Retrieved February 5, 2020, from 100% Pure New Zealand: <https://media.newzealand.com/en/story-ideas/background-new-zealands-screen-industry/>

- New Zealand Trade and Enterprise. (2008, August). *Boat Manufacturing and Marine Industry in New Zealand*. Retrieved from <http://www.docstoc.com/docs/39997121/Boat-manufacturing-and-marine-industry-profile>
- New Zealand Trade and Enterprise. (2009). *New Zealand Seafood Industry Profile*. Retrieved from <https://www.nzte.govt.nz/en/buy/our-sectors/food-and-beverage/seafood/>
- New Zealand Trade and Enterprise. (n.d). *Food and Beverage Industry Summary*. Retrieved from <http://www.nzte.govt.nz/access-international-networks/explore-opportunities-in-growth-industries/growth-industries/pages/food-and-beverage.aspx>
- New Zealand Treasury. (1994). *New Zealand Economic and Financial Overview*. Wellington, New Zealand.
- New Zealand Treasury. (2002). *New Zealand Economic and Financial Overview*. Retrieved from <http://www.treasury.govt.nz/economy/overview/archive/pdfs/nzefo-02.pdf>
- New Zealand Treasury. (2006). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from <http://www.treasury.govt.nz/economy/overview/archive/pdfs/nzefo-06.pdf>
- New Zealand Treasury. (2007). *New Zealand Economic and Financial Overview*. Wellington, New Zealand.
- New Zealand Treasury. (2009). *Challenges and Choices: New Zealand's Long-term Fiscal Statement*. Retrieved from <http://www.treasury.govt.nz/government/longterm/fiscalposition/2009/ltfs-09.pdf>
- New Zealand Treasury. (2010). *New Zealand Economic and Financial Overview*. Wellington, New Zealand.
- New Zealand Treasury. (2010). *Taking on the West Island: How does New Zealand's labour productivity stack up?* Wellington, New Zealand. Retrieved from <http://www.treasury.govt.nz/publications/research-policy/tprp/10-01/tprp10-01.pdf>
- New Zealand Treasury. (2012). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from <http://www.treasury.govt.nz/economy/overview/2012/nzefo-12.pdf>
- New Zealand Treasury. (2016). *New Zealand Economic and Financial Overview*. Wellington, New Zealand. Retrieved from <https://treasury.govt.nz/sites/default/files/2010-04/nzefo-16.pdf>
- New Zealand Wine. (2019). *Key Performance Indicators*. Retrieved from <https://www.nzwine.com/media/12236/nzwine-kpis-feb-2019.jpg>
- New Zealand Winegrowers Inc. (2018). *Annual Report 2018*. Auckland: New Zealand Wine. Retrieved from <https://www.nzwine.com/media/9567/nzw-annual-report-2018.pdf>
- New Zealand Winegrowers Inc. (2019). *Annual Report 2019*. Auckland: New Zealand Wine. Retrieved from <https://www.nzwine.com/en/media/statistics/annual-report>

- Newhart, B. (2018, November 28). *Bottled water dominates 2018: Sparkling and value-added options surge*. Retrieved from Beveragedaily.com:
<https://www.beveragedaily.com/Article/2018/11/28/Bottled-water-dominates-2018-sparkling-and-value-added-options-surge>
- Nichols, L. (2012, February 4). *Beloved Wellington Shop Battling to Survive*. Retrieved from The Dominion Post: <http://www.stuff.co.nz/dominion-post/news/6365838/Beloved-Wellington-shop-battling-to-survive>
- Nicol, A., & Saunders, C. (2008, November 24). *Meat and wool - Wool products and marketing*. Retrieved from Te Ara - the Encyclopedia of New Zealand:
<http://www.TeAra.govt.nz/en/meat-and-wool/page-7>
- NIWA. (2013). *The 2012-13 drought: an assessment and historical perspective*. Wellington: Ministry for Primary Industries.
- NZ Beverage Council. (n.d.). *New Zealand's Bottled Water Industry*. Retrieved from
<https://www.nzbeveragecouncil.org.nz/assets/PDFs/9ee61a0436/An-Overview-of-Water-Bottling-in-New-Zealand.pdf>
- NZ Lotteries. (2010). *Statement of Intent: For the Financial years ending 30 June 2011-2013*. Retrieved from www.comu.govt.nz/resources/pdfs/nzlc/nzlc-sci-10.pdf
- NZ Marine. (n.d.). *Destination New Zealand*. Retrieved from
<https://www.nzmarine.com/destination-nz/>
- NZ Ministry of Agriculture and Forestry. (2007). *Situation and outlook for New Zealand agriculture and forestry*. Retrieved from <http://maxa.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/archive/sonzaf-2007.pdf>
- NZ Ministry of Agriculture and Forestry. (n.d.). *The Forestry Industry in New Zealand*. Retrieved from <http://www.mpi.govt.nz/forestry>
- NZ Post. (2018, August 24). *NZ Post annual results – impacted by continual letter decline*. Retrieved from <https://www.nzpost.co.nz/about-us/media-centre/media-release/nz-post-annual-results-impacted-by-continual-letter-decline>
- NZ Post. (2018, November 20). *NZ Post prepares for huge increase in volumes following Black Friday online sales*. Retrieved from <https://www.nzpost.co.nz/about-us/media-centre/media-release/nz-post-prepares-for-huge-increase-in-volumes-following-black-friday-online-sales>
- NZ Trade and Enterprise and Massey University. (2003). *The Level of Added-Value in New Zealand's Food and Beverage Exports*. Retrieved from <http://www.foodnavigator-asia.com/Markets/Value-added-food-and-beverage-exports-from-NZ-on-the-rise>
- OFX. (n.d.). *Historical Exchange Rates*. Retrieved from <https://www.ofx.com/en-nz/forex-news/historical-exchange-rates/yearly-average-rates/>

- Pacific Aerospace. (n.d.). *New Zealand Aviation*. Retrieved from <https://www.aerospace.co.nz/company/new-zealand-aviation>
- Pairotti, M. B., Cerutti, A. K., Martini, F., Vesce, E., Padovan, D., & Beltramo, R. (2015). Energy consumption and GHG emission of the Mediterranean diet: a systemic assessment using a hybrid LCA-IO method. *Journal of Cleaner Production*, 103, 507-516. doi:10.1016/j.jclepro.2013.12.082
- Patterson, M. G., McDonald, G. W., & Smith, N. J. (2011). Ecosystem Service Appropriation in the Auckland Region Economy: An Input–Output Analysis. *Regional Studies*, 45(3), 333-350. doi:10.1080/00343400903241451
- Perreau, K. (2007). Wanting to Get Up and Go: Challenges and Opportunities for Transport Energy Policy in New Zealand. *International Association for Energy Economics Conference*. Wellington, New Zealand.
- Peters, G. M., Wiedemann, S. G., Rowley, H. V., & Tucker, R. W. (2010). Accounting for Water Use in Australian Red Meat Production. *International Journal of Life Cycle Assessment*, 15(3), 311-320.
- Plastics NZ. (2014). *General Statistics*. Retrieved from <https://www.plastics.org.nz/doing-business-in-nz/new-zealand-industry/general-statistics>
- PricewaterhouseCoopers. (2011). *Valuing the role of Construction in the New Zealand Economy: A Report to the Construction Strategy Group*. Auckland, New Zealand.
- Property Observer. (2017, February 26). *New home building approvals in longest and largest cycle in Australia's history*. Retrieved February 7, 2020, from <https://www.propertyobserver.com.au/finding/residential-investment/65844-new-home-building-approvals-in-longest-and-largest-cycle-in-australia-s-history.html>
- Quotable Value New Zealand. (2004). *Regional Land Use Estimates by Land Use Code*. Auckland: Quotable Value New Zealand.
- Rae, S. (2019). *Now 5.6 sheep for each NZer*. Retrieved from Otago Daily Times: <https://www.odt.co.nz/rural-life/red-meat/now-56-sheep-each-nzer>
- Recchia, L., Cappelli, A., Cini, E., & Pegna, F. G. (2019). Environmental Sustainability of Pasta Production Chains: An Integrated Approach for Comparing Local and Global Chains. *Resources*, 8(56). doi:10.3390/resources8010056
- Reserve Bank of New Zealand. (2005). Overview of the Manufacturing Sector. *Bulletin*, 68(1). Retrieved from http://www.rbnz.govt.nz/research_and_publications/reserve_bank_bulletin/2005/2005mar68_1turner.pdf
- Restaurant Association of New Zealand. (2006). *Restaurant Industry Forecast: Executive Summary*. Retrieved from <http://www.restaurantnz.co.nz>

- Richard Paling Consulting. (2008). *National Freight Demands Survey*. Retrieved from <http://www.transport.govt.nz/research/Documents/FreightStudyComplete.pdf>
- Ridoutt, B. G., Williams, S. R., Baud, S., Fraval, S., & Marks, N. (2010). Short communication: The water footprint of dairy products: Case study involving skim milk powder. *Journal of Dairy Science*, 93(11), 5114-5117. doi:10.3168/jds.2010-3546
- Roche, M. (1990). *History of New Zealand Forestry*. Wellington: GP Print Ltd.
- Rolfe, J. (2012). *Armed Forces - Partnerships and international deployments*. Retrieved from <http://www.TeAra.govt.nz/en/armed-forces/4>
- Ross, K. (2005, October 31). *One-Tenth of the World's Population Shopping Online*. Retrieved from http://nz.nielsen.com/news/Shopping_Online.shtml
- Ross-Thomas, E. (2008, June 2). *Global Airline Losses Possible in 2008: Industry Group*. Retrieved from http://www.enn.com/top_stories/article/37238
- Ruini, L., Marino, M., Pignatelli, S., Laio, F., & Ridolfi, L. (2013). Water Footprint of a Large-Sized Food Company: The Case of Barilla Pasta Production. *Water Resources and Industry*, 1-2, 7-24. doi:10.1016/j.wri.2013.04.002
- Rytkönen, A. (2003). *Market access of tropical timber*. Porvoo, Finland.: International Tropical Timber Council.
- Sanford Limited. (2014). *Sustainable Seafood*. Retrieved from <http://www.sanford.co.nz/sanfordfisheries/sustainability/en/sustainable-seafood.cfm>
- Saunders, C., & Barber, A. (2008). A Carbon footprints, life cycle analysis, food miles: Global trade trends and market issues. *Political Science*, 60(1), 73-88.
- Saunders, C., Barber, A., & Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions Performance of New Zealand's Agriculture Industry (Research Report No.285)*. Christchurch, New Zealand: Lincoln University.
- Scientific Application International Corporation. (2006). *Life Cycle Assessment: Principles and Practice*. Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRML&dirEntryId=155087
- Scott, B. M. (2011, November). *Survival Strategies of Services Subcontracting Firms in an Economic Downturn (A Report for Industry Project CONS 7819)*. Waitakere, New Zealand.: Unitec, Department of Construction.
- Seafood Industry Council. (2011). *New Zealand Emissions Trading System Review*. Retrieved from <http://www.climatechange.govt.nz/emissions-trading-scheme/ets-review-2011/consultation/submission065.pdf>
- Seafood New Zealand. (2018). *Key Facts*. Retrieved from <https://www.seafoodnewzealand.org.nz/industry/key-facts/>

- Seafood New Zealand. (2019). *Export Information*. Retrieved from <https://www.seafoodnewzealand.org.nz/publications/export-information/>
- Shaw, A. (2019, June 24). *New Zealand e-commerce figures hit new highs: Kiwis spent \$4.2 billion online last year*. Retrieved from NZ Herald: https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=12243090
- Sheridan, N. F., Kenealy, T. W., Connolly, M. J., Mahony, F., Barber, P. A., & Moffitt, A. (2011). Health Equity in the New Zealand Health Care System: A national survey. *Equity Health*, 10(45). Retrieved from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC32168>
- Sherwood, A., & Phillips, J. (2012). *Coal and coal mining - Coal resources Te Ara – the Encyclopaedia of New Zealand*. Retrieved from <http://www.TeAra.govt.nz/en/coal-and-coal-mining/2>
- Smellie, P. (2018, 7 11). *NZ Steel boosts BlueScope with extra ironsand exports*. Retrieved from NBR: <https://www.nbr.co.nz/article/nz-steel-boosts-bluescope-extra-ironsand-exports-bd-161446>
- Socolow, R., & Thomas, V. (1997). The Industrial Ecology of Lead and Electric Vehicles. *Journal of Industrial Ecology*, 1(1), 13-36. doi:<https://doi.org/10.1162/jiec.1997.1.1.13>
- Sport NZ. (2017). *The Value of Sport*. Wellington. Retrieved from <https://sportnz.org.nz/assets/Uploads/The-Value-of-Sport-Main-Report.pdf>
- Statistics New Zealand. (1994). *New Zealand Official Yearbook 1994*. Auckland, New Zealand.
- Statistics New Zealand. (2000). *New Zealand Official Yearbook 2000*. Auckland, New Zealand: David Bateman Ltd.
- Statistics New Zealand. (2001). *Harmonised System Statistics 2001*. Wellington: Statistics New Zealand.
- Statistics New Zealand. (2002). *New Zealand Official Yearbook 2002*. Auckland, New Zealand: David Bateman Ltd.
- Statistics New Zealand. (2005). *Demographic Trends 2005*. Retrieved from <http://www.stats.govt.nz/~media/Statistics/browse-categories/population/estimates-projections/demographic-trends/2005/full-report.pdf>
- Statistics New Zealand. (2005). *Forests and Forest Products*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/environment/environmental-economic-accounts/forests-and-forest-products-2005.aspx
- Statistics New Zealand. (2006). *New Zealand Official Yearbook 2006*. Auckland, New Zealand: David Bateman Ltd.
- Statistics New Zealand. (2007). *Agricultural Productions Census*.
- Statistics New Zealand. (2007). *How Petrol Prices have tracked since the 1980s*. Retrieved from http://www.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/how-petrol-prices-have-tracked-since-1980s.aspx

- Statistics New Zealand. (2008). *New Zealand Official Yearbook 2008*. Auckland, New Zealand: David Bateman Ltd.
- Statistics New Zealand. (2009). *A Statistical Overview of the Construction Industry from 2000 to 2008*. Christchurch, New Zealand.
- Statistics New Zealand. (2009). *National Population Projections: 2009 (base) – 2061*. Retrieved from http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationProjections_HOTP09base-61.aspx
- Statistics New Zealand. (2012). *2012 Agricultural Census Tables*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/2012-agricultural-census-tables/land-use.aspx#
- Statistics New Zealand. (2012). *Off the sheep's back: a look at historical wool export prices and volumes*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/historical-wool-export-prices-volumes-2011.aspx
- Statistics New Zealand. (2012). *Wool at a Glance*. Retrieved from http://archive.stats.govt.nz/browse_for_stats/economic_indicators/prices_indexes/wool-at-a-glance-2011-infographic.aspx
- Statistics New Zealand. (2013, May 13). *Agricultural Production Statistics: June 2013 (final)*. Retrieved from http://www.stats.govt.nz/~media/Statistics/Browse%20for%20stats/AgriculturalProduction_final/HOTPJun12final/AgriculturalProduction_finalJun12
- Statistics New Zealand. (2015, December 10). *Territorial Authority*. Retrieved from Stats NZ: <http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/territorial-authority/definition.aspx>
- Statistics New Zealand. (2018). *International Visitor Survey*. Retrieved from <http://nzdotstat.stats.govt.nz/wbos/Index.aspx>
- Statistics New Zealand. (2018, June 27). *Lamb exports set new record*. Retrieved February 5, 2020, from Stats NZ: <https://www.stats.govt.nz/news/lamb-exports-set-new-record>
- Statistics New Zealand. (2019, February 26). *Alcohol available for consumption: Year ended December 2018*. Retrieved from <https://www.stats.govt.nz/information-releases/alcohol-available-for-consumption-year-ended-december-2018>
- Statistics New Zealand. (2019, October 3). *Losing our religion*. Retrieved from Stats NZ: <https://www.stats.govt.nz/news/losing-our-religion>
- Statistics New Zealand. (2019, February 26). *More high-strength beer available in 2018*. Retrieved from <https://www.stats.govt.nz/news/more-high-strength-beer-available-in-2018>

- Statistics New Zealand. (2019, December 16). *Statistical area 1 dataset for 2018 Census*. Retrieved from Stats NZ: <https://www.stats.govt.nz/information-releases/statistical-area-1-dataset-for-2018-census>
- Stock, R. (2019, September 27). *NZ Post reports \$121 million loss due to declining letter volumes*. Retrieved from Stuff: <https://www.stuff.co.nz/business/116146097/nz-post-reports-121-million-loss-due-to-declining-letter-volumes>
- Stone, R. (1961). *Input-Output and National Accounts*. Paris: Organization for European Economic Cooperation.
- Stone, R. (1966). *Mathematics in the social sciences, and other essays*. Cambridge, Massachusetts: M.I.T. Press.
- Strategy and System Performance Group. (2009). *Indicators Live: Education at a Glance 2009, Results for New Zealand*. Retrieved from Ministry of Education: <http://www.educationcounts.govt.nz/publications/schooling/56219/2>
- Stringleman, H., & Scrimgeour, F. (n.d). *Dairying and dairy products - Dairy cattle breeds*. Retrieved 2 15, 2013, from Te Ara, the Encyclopaedia of New Zealand.: <http://www.TeAra.govt.nz/en/dairying-and-dairy-products/6>
- Stroombergen, A. (2015). *Working Paper: An economic profile of the arts in New Zealand*. Wellington: Ministry for Culture and Heritage. Retrieved from [https://mch.govt.nz/files/Economic%20profile%20arts%202015%20\(D-0590039\).PDF](https://mch.govt.nz/files/Economic%20profile%20arts%202015%20(D-0590039).PDF)
- StudyLink. (n.d.). *Student Loan*. Retrieved from <https://www.studylink.govt.nz/products/a-z-products/student-loan/index.html>
- Suh, S., & Hupples, G. (2005). Methods for Life Cycle Inventory of a product. *Journal of Cleaner Production*, 13(7), 687-697. doi:10.1016/j.jclepro.2003.04.001
- Suttie, E. (2011). *Learning Legacy: Lessons learned from the London 2012 Games construction project*. Retrieved from <http://learninglegacy.independent.gov.uk/documents/pdfs/sustainability/425009-188-timber-aw.pdf>
- Sutton, J. (2003). *Speech to New Zealand Marine Industry Conference*. Retrieved from <http://www.beehive.govt.nz/node/16484>
- Taunton, E. (2019, 10 17). *Live cattle exports climb despite continued calls for a halt to trade*. Retrieved from <https://www.stuff.co.nz/business/farming/116653286/live-cattle-exports-climb-despite-continued-calls-for-a-halt-to-trade>
- Te Ara - The Encyclopedia of New Zealand. (2010). *Story: Department Stores and Shopping Malls: Decline and survival*. Retrieved from <http://www.teara.govt.nz/en/department-stores-and-shopping-malls/3>
- Te Ara, The Encyclopaedia of New Zealand. (n.d). *Grain production, 1905–2005*.

- Te Uru Rākau. (2020, January 13). *Forestry*. Retrieved from <https://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/forestry/>
- Te Uru Rākau. (2020, January 14). *One Billion Trees Programme*. Retrieved from <https://www.teururakau.govt.nz/funding-and-programmes/forestry/one-billion-trees-programme/>
- Te Uru Rākau. (2020, January 13). *Wood Product Markets*. Retrieved from <https://www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/>
- Tectra Ltd. (2004). *NZ Wool Market Info Stats Handbook*. Wellington.
- Terralink. (2004). *Land Coverage Database (LCDBII)*. Wellington: Terralink.
- The Department of Internal Affairs. (2008). *Gambling Expenditure Statistics 1984-2008*. Wellington. Retrieved from [https://www.dia.govt.nz/Pubforms.nsf/URL/Expendstats08.pdf/\\$file/Expendstats08.pdf](https://www.dia.govt.nz/Pubforms.nsf/URL/Expendstats08.pdf/$file/Expendstats08.pdf)
- The New Zealand Institute for Plant and Food Research Ltd. (2010). *The New Zealand Institute for Plant and Food Research Ltd*. Retrieved from <http://www.plantandfood.co.nz/page/our-research/breeding-genomics/key-crops/>
- The University of Auckland. (n.d). *Defence*. Retrieved from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-defence>
- The University of Auckland. (n.d). *Education*. Retrieved from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-education>
- The University of Auckland. (n.d). *Government*. Retrieved from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-government>
- The University of Auckland. (n.d). *Health* . Retrieved from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-health>
- The University of Auckland. (n.d). *Retail* . Retrieved from <http://www.auckland.ac.nz/ua/home/for/current-students/cs-career-planning/cs-industry-profiles/cs-ip-retail>
- The World Bank. (n.d). *Public Spending on Education, total (% of GDP)*. Retrieved from <http://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS?page=4>
- Timmins, J. (2009). *Seasonal Employment Patterns in the Horticultural Industry*. Wellington: Statistics New Zealand. Retrieved February 5, 2020, from http://archive.stats.govt.nz/browse_for_stats/income-and-

work/employment_and_unemployment/LEED-reports/seasonal-employment-patterns-in-the-horticultural-industry.aspx

Tolerton, J. (2010, March 11). *Clothing and footwear manufacturing - Footwear*. Retrieved from Te Ara - the Encyclopedia of New Zealand: <http://www.TeAra.govt.nz/en/clothing-and-footwear-manufacturing/page-4>

Tolerton, J. (2010, March 11). *Clothing and footwear manufacturing - From mass market to niche market*. Retrieved from Te Ara - the Encyclopedia of New Zealand: <http://www.TeAra.govt.nz/en/clothing-and-footwear-manufacturing/page-3>

Tourism Research New Zealand. (2008). *Data Analysis Forecasts*.

Transparency International. (2018). *Corruption Perceptions Index*. Retrieved from <https://www.transparency.org/cpi2018>

Turner, J. (2005). Overview of the Manufacturing Sector. *Bulletin*, 68(1). Retrieved from http://www.minerals.co.nz/pdf/Natural_Resource_NZ_web.pdf

U.S. Energy Information Administration. (2017, January 4). *Crude oil prices increased in 2016, still below 2015 averages*. Retrieved from <https://www.eia.gov/todayinenergy/detail.php?id=29412>

U.S. Geological Survey Fact Sheet. (2004). *New Zealand Coal Resources, no. 3089*. Retrieved from <http://pubs.usgs.gov/fs/2004/3089/fs2004-3089.html>

United Nations. (1999). *Handbook of Input-Output Table Compilation and Analysis. Handbook of National Accounting: Studies in Methods. Series F, No. 74*. New York: United Nations.

United Nations. (2003). *Integrated Environmental and Economic Accounting*.

Universities New Zealand. (n.d.). *How NZ universities are funded*. Retrieved from <https://www.universitiesnz.ac.nz/about-university-sector/how-nz-universities-are-funded>

USDA Foreign Agricultural Service. (2010). *GAIN Report NZ 1014: Report on State of Kiwifruit Sector in New Zealand*.

USDA Foreign Agricultural Service. (2018). *New Zealand Annual Dairy and Milk Supply Report 2018*. USDA Foreign Agricultural Service. Retrieved February 10, 2020, from https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Dairy%20and%20Products%20Annual_Wellington_New%20Zealand_10-16-2018.pdf

Victor, P. A. (1972). Input-Output Analysis of Economic and Environmental Interactions. *Economics of Pollution*, 55-72. doi:10.1007/978-1-349-01531-3_4

Von Lanthen, K. (2004). *The Long Term Funding of New Zealand Healthcare*. Retrieved from <http://www.healthfunds.org.nz/Publications.asp#Funding>

Weir, J. (2008, November 12). Smelter output slashed. *The Dominion Post*, p. Page C3.

- Welch, D. (2006, April 29). The Disarming of New Zealand. *New Zealand Listener*. Retrieved from <http://www.listener.co.nz/commentary/the-disarming-of-new-zealand/>
- Williams, J., Stokes, F., Dixon, H., & Hurren, K. (2017). *The economic contribution of commercial fishing to the New Zealand economy*. Wellington: Business and Economic Research Limited. Retrieved from https://www.seafood.co.nz/fileadmin/Media/BERL_report/BERL_Report_August_2017.pdf
- Wilson, A. C. (2010). *Telecommunications - Mobile phones*. Retrieved from <http://www.TeAra.govt.nz/en/telecommunications/7>
- Work and Income New Zealand. (n.d). *Help with Childcare costs* . Retrieved from <http://www.workandincome.govt.nz/individuals/forms-and-brochures/help-with-childcare-costs.html#EarlyChildhoodEducation20HoursECE4>
- Workman, D. (2019, December 6). *Paper Exports by Country*. Retrieved from World's Top Exports: <http://www.worldstopexports.com/paper-exports-by-country/>
- Works Consultancy Services Ltd. (1996). *Transit New Zealand National Traffic Database. Contents and Operation of Database*. Wellington: Transit New Zealand.
- World Bank Group. (2014). *Turn Down the Heat : Confronting the New Climate Normal*. Washington, DC: World Bank. Retrieved from <https://openknowledge.worldbank.org/handle/10986/20595>
- Zespri Group. (2018). *Boldly Moving Forward: Annual Review 2017/18*. Tauranga: Zespri Group.