Greenhouse gas emission consequences of New Zealand's urban sprawl

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I wish to thank the Kellogg Programme Investing Partners for their continued support.

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1. Executive Summary

Land use change from agriculture to urban is occurring at record rates. Stats NZ (2021) report that record numbers of stand-alone houses are being built. Emissions from the building sector increased 77% in the decade to 2017 (Stats NZ, 2019).

In contrast, pastoral farming land area is decreasing, and the emissions profile of the industry is flat to declining (Ministry for the Environment, 2021).

Legislation and numerous reports reference agriculture as New Zealand's largest Greenhouse Gas (GHG) emitter and as the main industry targeted for emissions reduction to meet New Zealand's GHG obligations under the United Nations Paris Agreement of 2015. The housing sector has significantly less reference within the same documents.

If agriculture is recommended to decrease land area and therefore emissions to help achieve New Zealand's obligations (New Zealand Productivity Commission, 2018), why is that same agricultural land then allowed to be subdivided and turned into housing which emits potentially more emissions?

This is the context of the data sought for this study's hypothesis: There isn't a carbon footprint reason for land use change from primary to urban residential.

The results of the data analysis from a literature review suggest that the emissions from land use change to one hectare of urban subdivision are significantly higher than if the land had stayed as one ha of primary land use.

Seven interviews with industry leaders were undertaken for discussion surrounding the hypothesis. They were thematically analysed showing the agriculture sector having concerns about the way its emissions are reported and the availability of tools to decrease emissions. This limits the industries potential to do what it does well, producing some of the lowest carbon footprint nutritional products in the world, for its growing population.

The housing sector has potential to improve its industry unity to lift its GHG reporting performance. Several solutions are available to reduce housing's carbon footprint and minimise the use of agricultural land. They are too slowly being taken up for the sector to meet its emissions reductions targets.

Reporting gases on their separate warming potentials would clarify the impact of pastoral farming on the overall emissions. Reporting of land use change emissions associated with subdivisions, and emissions per dwelling should be undertaken. Resource consent applications for land use change should consider the associated GHG consequences. More research could be undertaken to express the emissions of the civil infrastructure surrounding houses. Paths to strategically meet our GHG reduction obligations can then be more clearly identified, and decisions made to ultimately improve the planet's overall goal – reducing global warming.

2. Acknowledgements

Firstly, I would like to acknowledge the hard work of The New Zealand Rural Leadership Trust. Chris Parsons, Scott Champion, Patrick Aldwell, Lisa Rogers, and Annie Chant – you provided an engaging thought-provoking course and are great ambassadors for the Rural Leaders Trust's objectives.

To the people interviewed, thank you for your contribution and support of this project. Your opinions, ideas and passion for your industry was rewarding to capture. I wish you all the best to lead your sectors forward in the field of sustainability, land use, and emissions.

I would like to thank my friends and family for providing encouragement to complete this course. To my wife Christiane, thank you for your support and patience.

I would like to thank Kellogg Cohort 46. Your friendship, wisdom, critical eye, and support throughout the programme has made for learnings and some great memories.

3. Introduction

> "Land is central to our identity as people of Aotearoa New Zealand, It is our tūrangawaewae, our place to stand" (Ministry for the Environment, 2021, p. 5)

Who in New Zealand can't identify with this statement?

Images of the New Zealand Wars, immigrants steaming the world half over in the pursuit of clear title, the kiwi backyard barbeque, the public give-a-little campaign to buy a beach in Abel Tasman. Land is tied into a country's identity.

Today the land themes abound in mainstream literature. Urban: a 'housing crisis' is a term used by both the National and Labour parties (Parker & Woods, 2021), contextualised by people's aspirations of home ownership. Rural: a generational success story of primary industry growth and productivity likely to contribute 50 billion dollars to New Zealand's economy in 2022 (Rowarth, 2021).

We now find ourselves at a crossroads about our strategy with land use. Land use is defined as the human use of land (US EPA, 2021) corresponding to its socio-economic description (EEA, 2022). This is seen in New Zealand, where our land is constantly being developed to meet the economic, environmental, political, and social needs and wants of its people.

Examples of these are climate change and a growing population, which are only going to make future choices more difficult. These population growth claims for New Zealand were produced in 2003 (Ministry of Social Development, 2003, p 7):

> The resident population may not reach five million in the next 50 years. It may never do so. The New Zealand population is projected to grow to 4.4 million by 2021, to 4.6 million by 2051 and to fall back slightly to 4.2 million by 2101.

The reality is that New Zealand's population reached 5 million in 2020 (Stats NZ, 2020).

Current ambitions to meet the Paris Agreement targets have seen New Zealand agree to reduce net greenhouse emissions to 50 percent below gross 2005 levels by 2030 (New Zealand Government, 2021). This output is in response New Zealand's Climate Change Response (Zero Carbon) Bill which is a legally binding commitment to living within 1.5 degrees of preindustrial levels (Ministry for the Environment, 2019). Agriculture is specifically itemised as our biggest contributor and challenge to overcome, with reference to agriculture, land, or methane on every page of the first submission regarding the Paris Agreement. In contrast, only a single line reference to building is noted as a strategy being worked on, the Building Transformation Plan. Whilst the scope of NZ's contribution is stated as 'economy wide', building and construction are not mentioned in the list of sectors considered (New Zealand Government, 2021).

This research report will focus the greenhouse gas (GHG) emission profiles of primary versus changing to urban residential land use in the context of a desirable outcome for gross emissions in respect to national and global targets. It will then analyse the understanding and opinions of specialists in relation to land use change from primary to urban land.

The hypothesis for this report states; there isn't a carbon footprint reason for land use change from primary to urban residential.

Undertaking to produce comparative data, the outcome of this report may show a conflicting story with the ambition of the current strategy to meet New Zealand's commitments to international climate change agreements.

4. Aims and Objectives

The objectives of this project are to:

- Provide data that supports land use change to minimise increases in GHGs to align with climate change objectives: Specifically, the study will undertake a data comparison of the GHG emission profiles of land use change to one hectare of residential subdivision from one ha of primary industry farm systems.
- Develop understanding of these land use emission perceptions, anomalies, and misalignments with current goals.
- Provide insight on the future of GHG emissions, perceptions, and strategies in respect to this land use change.

5. Methodology

To achieve the objectives of this project it was completed in two main parts. Firstly, as a literature review resulting in numerical findings, and secondly, as a discussion of thematic analysis results of industry leader interviews.

5.1 Literature Review

A literature review was undertaken about land use change and its drivers as a report context. The key report data was sourced for the GHG emissions of the comparison topics. Data was available from Life Cycle Analysis (LCA) studies and backed up by data from research farm trials and New Zealand agricultural inventory methodologies (government approved GHG calculation methodologies).

The farming life cycle analysis studies used a mixture of farm gate to farm gate, and, cradle to farm gate boundaries. Cradle refers to from resource extraction and farm gate refers to an input or product crossing entering or leaving the farm boundary. Refer to the emissions included inside the box in Figure 1 below.

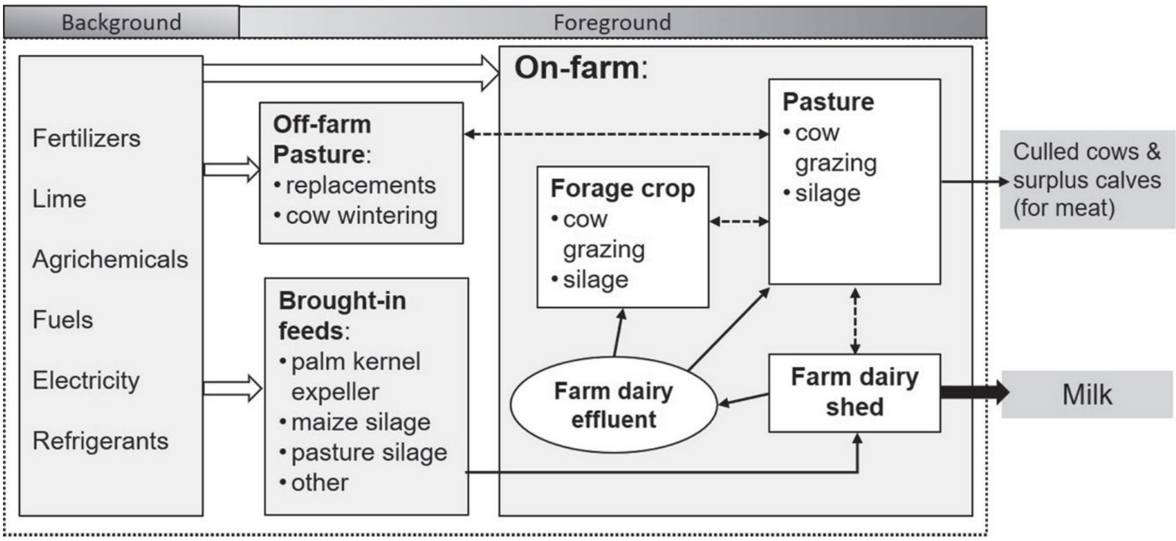

Figure 1 *Cradle to Farm Gate emissions included in LCA methodology for dairy farms*

Note: The emissions included are shown above inside the box labelled Background and Foreground.
From "Temporal, spatial, and management variability in the carbon footprint of New Zealand milk", by Ledgard, S., Falconer, S., Abercrombie, R., Philip, G., Hill, J. (2020). *J. Dairy Sci*. 103:1031–1046. (https://doi.org/10.3168/jds.2019-17182).

The housing life cycle analysis study data used cradle to cradle boundaries. Refer to stages A1 to C4 in Figure 2.

BUILDING LIFE CYCLE													
Production stage			Construction process stage		Use stage				End-of-life stage				Benefit and loads beyond the system boundary
A1	A2	A3	A4	A5	B2	B4	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Maintenance	Replacement	Operational energy use	Operational water use	Deconstruction / demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential

Figure 2 *Cradle to End of Life emissions included in LCA methodology for housing*

Note: The emissions included are shown above inside the boxes labelled A1 to C4.
From "A Comparative Study on the Life Cycle Assessment of New Zealand Residential Buildings.", by Dani, A., Roy, K., Masood, R,. Fang, Z., Lim, J. (2022). *Buildings* 2022, *12*(1), 50;
(**https://www.mdpi.com/2075-5309/12/1/50).**

5.2 Findings and discussion

The data sourced from literature (Shepherd et al. (2016), Reisinger et al. (2017), Ledgard et al,. (2020)) was brought into a comparison metric of carbon dioxide equivalent (CO_2e) emissions from one ha of land. A conversion calculation was required to turn houses emissions into a subdivision's emissions. This was reviewed by authors of life cycle analysis studies.

Seven semi-structured interviews of industry specialists from across the sectors were undertaken. Five people from industry funded bodies and two from government funded or run bodies were represented. They were chosen for their authoritative knowledge of land use and policy relating to New Zealand's greenhouse gas emissions, or methodologies to measure and compare emissions. This was firstly to understand insights about the data that are critical to the analysis: what is missing, and how reliable is it? What consideration should be given to the data adaptation to be able to compare between the two sectors?

Interviewees were then asked for perceptions of the industries in relation to their emissions and the work being undertaken to minimise effects. Future insights about upcoming change in their sector emissions that should be considered were collected. Participants were questioned for their understanding and viewpoints on the direction of industry travel against the hypothesis result.

The seven interviews undertaken were analysed using a thematic analysis approach. This research approach provided depth to otherwise quantitative analysis of the comparative emissions. The goal of the thematic analysis was to identify themes, or patterns in the data that are important or interesting, and to use these themes to address the research or say something about the issues (Maguire, M., Delahunt, B., 2017). Because the themes were the most important summary of the interviews, names have been kept anonymous. The interview questions can be found in the appendices.

5.3 Limitations of this research

Data for this project was derived from available New Zealand scientific papers in each sector. Some data was sourced from overseas studies to check its alignment with local research. No physical measurement of emissions was undertaken.

The data outcomes are provided as a guide for comparison, evaluation, and discussion in this report only.

6. Literature Review

6.1 Current Land Use and Population Trends in New Zealand

Currently the population of New Zealand is over five million people. It is now projected to reach 6.8 million by 2073. Approximately half of our land is used for agriculture. 40% is grassland, 8% forestry, 2% cropping and horticulture, while housing makes up 1% (Ministry for the Environment, 2021).

Land use classes 1 to 3 are called highly productive land and are particularly good for food production. This represents 15% of all land. Consultation is ongoing for its protection via the proposed National Policy Statement for Highly Productive Land (Ministry for Primary Industries, 2022). This land class became more divided between 2002 and 2019, especially through residential development of land sized between two to eight hectares. The area of highly productive land that was unavailable for agriculture (due to housing) increased by 54 percent during this period, from 69,920 hectares in 2002 to 107,444 hectares in 2019 (Ministry for the Environment, 2021).

The total area of land used for agriculture and horticulture has been decreasing since 2002, with an overall reduction of 1,878,409 hectares (14%) between 2002 and 2019, and a reduction of 207,747 hectares (2%) between 2017 and 2019 (Ministry for the Environment, 2021).

Between 1996 and 2018 (22 years):

- Just over 83 percent (25,248 hectares) of the landcover converted to urban area was from pastoral farming land use.
- Nearly nine percent (2,602 hectares) of the landcover converted to urban area was from cropping or horticulture. This amounted to 30 percent of the horticultural land converted during this period. (Ministry for the Environment, 2021).

Consents issued for new dwellings in 2021 were the most on record. In September 2021, 50% of these were for standalone houses, the remainder being townhouses, apartments, and retirement village units. The graph in figure 3 below, clearly shows a continuing trend of building standalone houses, those which dominate the need for greenfield subdivision sites (Stats NZ, 2021).

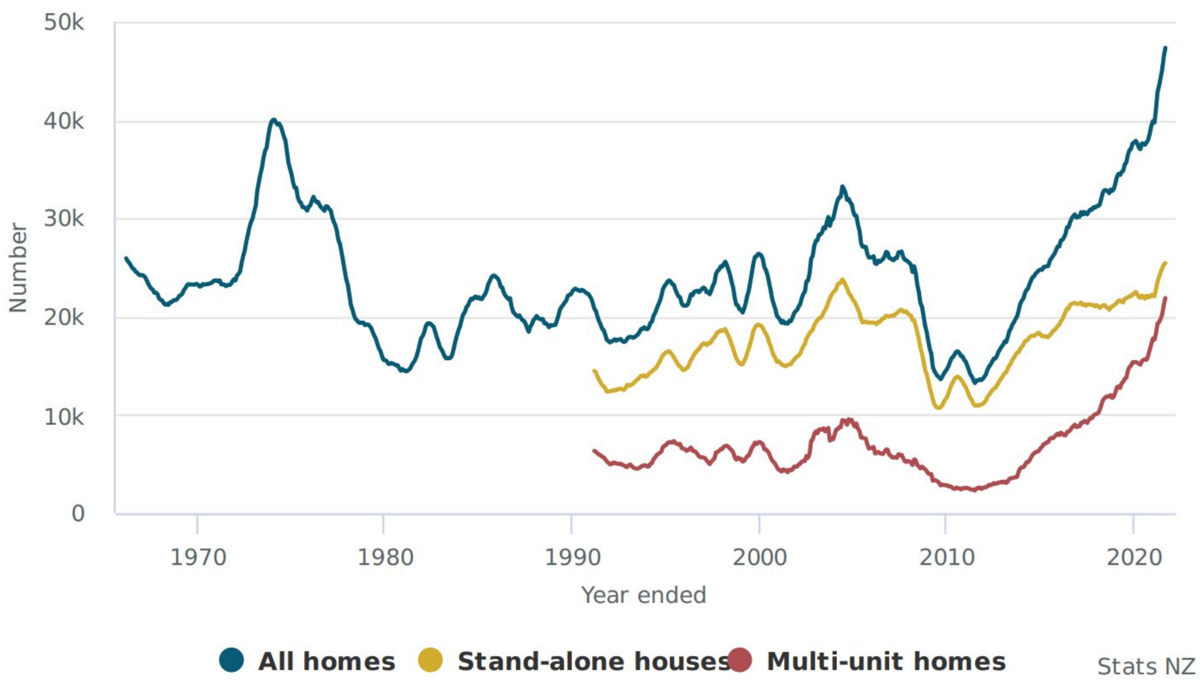

Figure 3: *Record stand alone house building consents in 2021*

Note: The middle line represents standalone house consents. From Stats NZ, 2021.(https://www.stats.govt.nz/news/annual-number-of-new-homes-consented-rises-25-percent)

6.2 Historical concepts driving land use change

According to Thorrold (2010), what is important is that land use change whilst seeming topical, or significant at present, is constant and always occurring. What is unique in New Zealand's sense, is that the country is highly reliant on land based primary production for our economy. Change has been regionally specific as new opportunities to use land, sunshine, and water attract the attention of investment.

Other factors which drive land use consideration are slope and soil type (Thorrold, 2010). Typically horticulture and arable have used the highest quality land followed by pasture (Kerr, 2009).

Witten et al (2011) summarises that the issues around New Zealand urban sprawl are those faced by more developed nations a century ago. The abundance of greenfield space and a history of immigration of people drawn here by its open spaces along with aspirations of working on the land.

> The notion of New Zealand as a rural paradise offering space has been a driving force of suburban development throughout our period of urbanisation, our towns and cities characterized by sprawling patterns that reflect reliance on the private motor car (Department of Internal Affairs, 2008).

In fact, the private motor car as referenced by Department of Internal Affairs (2008) agrees with Xu et al., (2021) who attribute periods of unchecked urban sprawl in Auckland as a direct response to population growth facilitated by improved transportation.

6.3 Comparative Emissions Profiles – Primary Industries

Emissions in the New Zealand rural sector are represented with studies of data across all sectors of the primary industry.

Shepherd et al. (2016) estimated the impact of four primary production systems: sheep and beef, dairy, cropping, and forestry. Modelling was undertaken on OVERSEER® (a New Zealand farm system emissions modelling program) of the farm systems and the results are shown in figure 4 below.

Sector	N and P loss (kg/ha)		GHG	Contribution (%)			Area
	N	P	(kg CO_2-e/ha)	CH_4	N_2O	CO_2	(M ha)
Sheep & Beef	11-31	0.2-5.3	1288-7431 [4861][1]	34-81	15-65	1-5	7.7
Median	***16***	***1.0***	***4734***	***57***	***41***	***2***	
Dairy	36-61	0.5-2.3	9427-18459	46-69	17-47	7-15	1.5
Median	***44***	***1.1***	***11769***	***66***	***22***	***12***	
Cropping	14-240	0.1-2.5	1326-15000 [5980][2]	0-14[3]	17-87	13-83	0.5
Median	***32***	***0.4***	***3696***	***0***	***40***	***51***	
Forestry[4]	0.5-6	0.2	(27000)-(48000)				1.5

Figure 4: Summary of GHG emissions for a variety of farm types

Note: Primary GHG Emissions shown in the middle GHG column.

From "An assessment of climate mitigation co-benefits arising from the Freshwater Reforms" by Shepard, M., Mackay, A., Monaghan, R., Vibart, R., Devantier, B., Wakelin, S., Payn, T., Müller, K., Lucci, G., Clothier, B., Hock, B., Harrison, D. *Ministry for Primary Industries,* p 64. *(*https://www.mpi.govt.nz/dmsdocument/16849-an-assessment-of-climate-mitigation-co-benefits-arising-from-the-freshwater-reforms)

Dairy farming shows the highest GHG gas emissions relative to the other farm types, with a median value of 11769 $kgCO_2e/ha/yr$. It can also be noted that forestry sequesters carbon from the atmosphere, therefore is a carbon sink rather than emitter (figure 4).

Reisinger et al. (2017) further considered horticultural systems including kiwifruit, wine grapes, apples, and arable. Modelling was also undertaken using OVERSEER® with the results being shown in figure 5 below.

Crop System	Average Total Greenhouse Gas Emissions (TGE) T $CO_{2\text{-}e}$ ha^{-1}	IPCC Biological Greenhouse Gas Emissions (BGE) T $CO_{2\text{-}e}$ ha^{-1}	Average Percentage of TGE as BGE %
Kiwifruit	5.5	1.03	19
Wine grapes	3.0	0.17	6
Apples	5.0	0.71	14
Arable [1]	2.4	0.95	40

Figure 5: Further Summary of GHG emissions from different land uses

Note: Table showing values for primary emissions in the lefthand column.

From "On-farm options to reduce agricultural GHG emissions in New Zealand" by Reisinger, A., Clark, H., Journeaux, P., Clark, D., Lambert, G. *New Zealand Agricultural Greenhouse Gas Research Centre*, p 59. (https://ourlandandwater.nz/wp-content/uploads/2019/03/BERG-Current-mitigaiton-potential-FINAL.pdf)

Agricultural emissions have increased 17% since 1990, the global emissions baseline year. 90% of agricultural emissions are from dairy, beef, sheep, and deer (Stats NZ, 2021).

A report placing New Zealand as one of the most efficient milk producer in the world was published in 2021 (Mazzetto et al,. 2021). Data was taken from Ledgard et al,. (2020) which measured the 'cradle to farm gate' life cycle emissions of dairy resulting in a figure of 13.3 T CO_2e/ha. This figure covers GHG emissions including young stock reared off farm, cows wintered off farm, and production and transport of bought in feeds, as displayed in figure 1 (pg 7).

Comparing the GHG emissions values in figures 4 and 5 and those of the report by Ledgard et al,. (2020), it can be seen that the range of agricultural emissions is from 2.4 to 13.3 T CO_2e /ha/year.

6.4 Comparative Emissions Profiles – Urban Residential

The Building Research Association of New Zealand (BRANZ) funded a report in 2021 into the carbon footprints of New Zealand buildings (Bullen et al. 2021). Emissions profiles from a life cycle analysis study taken from the report give the carbon footprint of a standalone New Zealand house, of average floor area, to be 233.1 T CO_2e over a 90-year service life (2.59 T CO_2e/year/house). The average residential standalone dwelling size at the time of this report was 198m^2. Four houses deemed of typical current construction materials were analysed for the results.

Dani et al., (2022) published a report calculating the whole of life emissions on a typical low density timber framed Auckland New Zealand house. The 104m^2 houses were two storied. The results were 13.72 kg CO_2e/m^2/year (1.43 T CO_2e/year/house). The house area was notably smaller than the BRANZ average value. The houses also had a 90-year service life. 58% of the emissions were considered 'operational', meaning they come from normal operation of the house (for example, heating, water, and power). The study also modelled a steel frame house of the same size. Its overall emissions were 12.3% higher than the timber version. Further investigation into alternative construction materials was outside the scope of this report.

Australian researchers Carre et al., (2011) modelled a life cycle analysis on a typical home, which happens to be almost identical to BRANZ's New Zealand case study house. Both 3-bedroom, standalone, internal double garage, similar cladding materials and near identical floor areas. Both studies are accredited life cycle analyses, include operational, maintenance, and end of life emissions. Two differences are the heating and cooling energy requirements for operation of the home, as well as the service life of the Australian version being 50 years. Further investigation extended the service life to 75 years, resulting in approximately 10% reduction of CO2 emissions per year (Carre et al., 2011).

The GHG emissions ranged from about 1.2T CO_2e / year/house in warmer cities to 2.6T CO_2e /year/house in Melbourne (the climate most like New Zealand in the study). The extra operational energy requirement being the difference.

Building's emissions are commonly calculated over the whole structure and then reported per building area, m^2. For comparison with agriculture on a hectare basis, further literature noted below enabled a conversion. The conversion formula is found in the discussion section of this report.

The number of houses in a hectare of land is regulated by local government planning laws. Tauranga City Council, for example, states the need for a target average of 15 dwellings per hectare, based on a minimum lot size of 350m2 (Tauranga City, 2021). Comparatively, Auckland minimum lot size in single home zones is 600m2 (Auckland Council, 2022). A larger lot size led to a lower possible house yield of 10 per hectare. This data can be utilised to calculate the GHG emissions per hectare, based on the emissions per dwelling.

In a typical subdivision there are many houses, but there is also significant civil infrastructure such as roads, wastewater pipes, footpaths, and core services. Little specific emissions data could be found for this infrastructure in New Zealand subdivisions. A Finnish study of a medium density 54ha development, states 10% of the total development emissions could be apportioned to the supporting infrastructure (Säynäjoki et al., 2011).

Buildings make up 40% of global energy related CO_2 emissions (NZGBC, 2017). New Zealand's built environment is responsible for 20 percent of the countries carbon footprint Vickers et al., (2018). Emissions from the construction industry have increased 66% in the decade from 2007 to 2017 (Stats NZ, 2019).

6.5 Land use strategies to combat GHG emissions

The independent crown entity, The New Zealand Productivity Commission, advised how New Zealand can best make the transition to a low emission economy. The commission relies on increased afforestation (an additional 90,000ha) to combat increased emissions of a higher than forecast population (NZ Productivity Commission, p. 97, 2018).

A disclaimer is provided that the effect of growing population will be modest if per head emissions fall dramatically. The fall required for this is from currently 15T CO_2e per person per year, to 4 T CO_2e per person for this to have effect (NZ Productivity Commission, p. 107, 2018). That is a significant 73% reduction per person.

Agriculture is noted as the one of the three main areas to reduce GHG emissions, the others being expansion of forestry and the reduction of fossil fuel uses (NZ Productivity Commission, p. 103, 2018). A graph showing the contributions to emissions is shown in figure 6 below, note that building or construction is not mentioned.

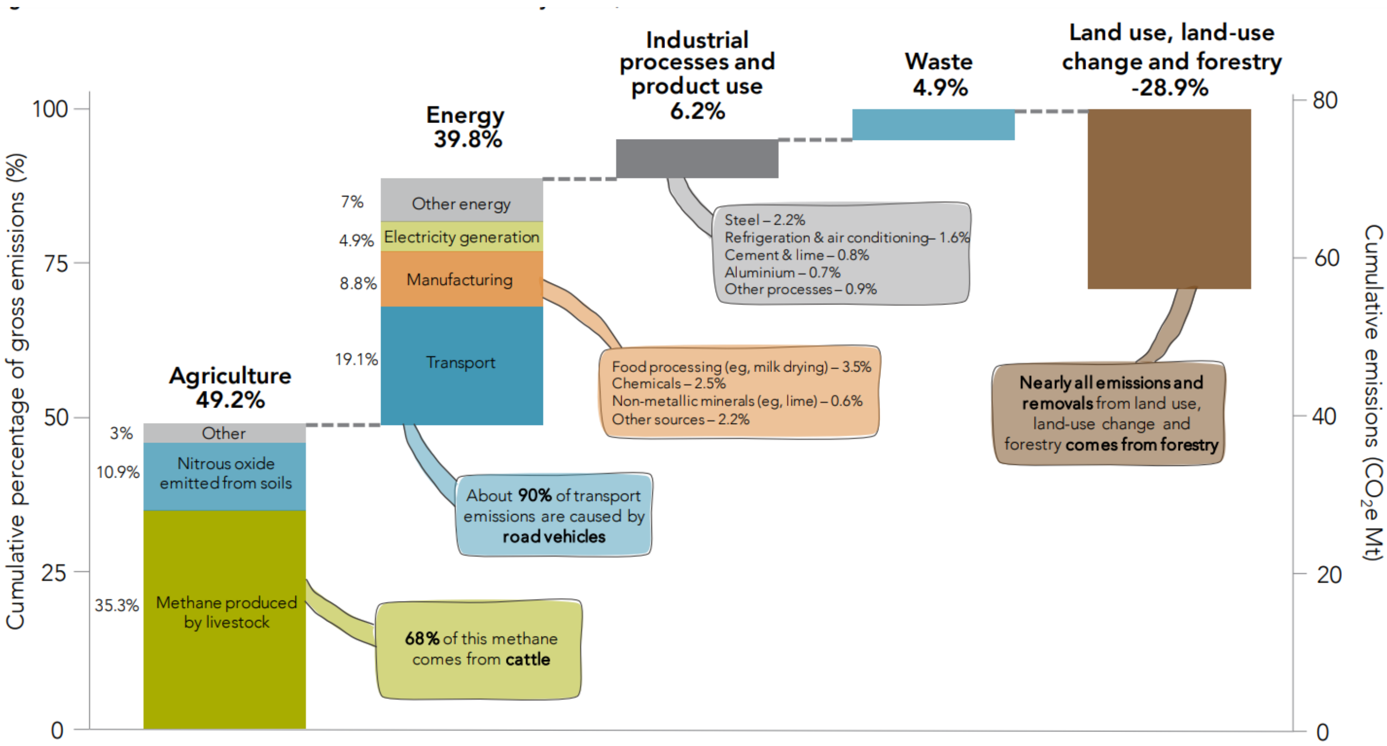

Figure 6: New Zealand's GHG emissions and removals in 2018

Note: The graph highlights agriculture by its scale and has no reference to building or housing.

From: *New Zealand Productivity Commission. (2018).* Low-emissions economy: Final report. (https://www.productivity.govt.nz/assets/Documents/lowemissions/4e01d69a83/Productivity-Commission_Low-emissions-economy_Final-Report_FINAL_2.pdf)

7. Findings: Which has higher emissions, primary industries or urban subdivisions?

The comparison data supports the hypothesis of the project (figure 7).

It is likely that development of primary industry land into residential land use will increase the emissions profile therefore moving New Zealand further away from its climate change obligations.

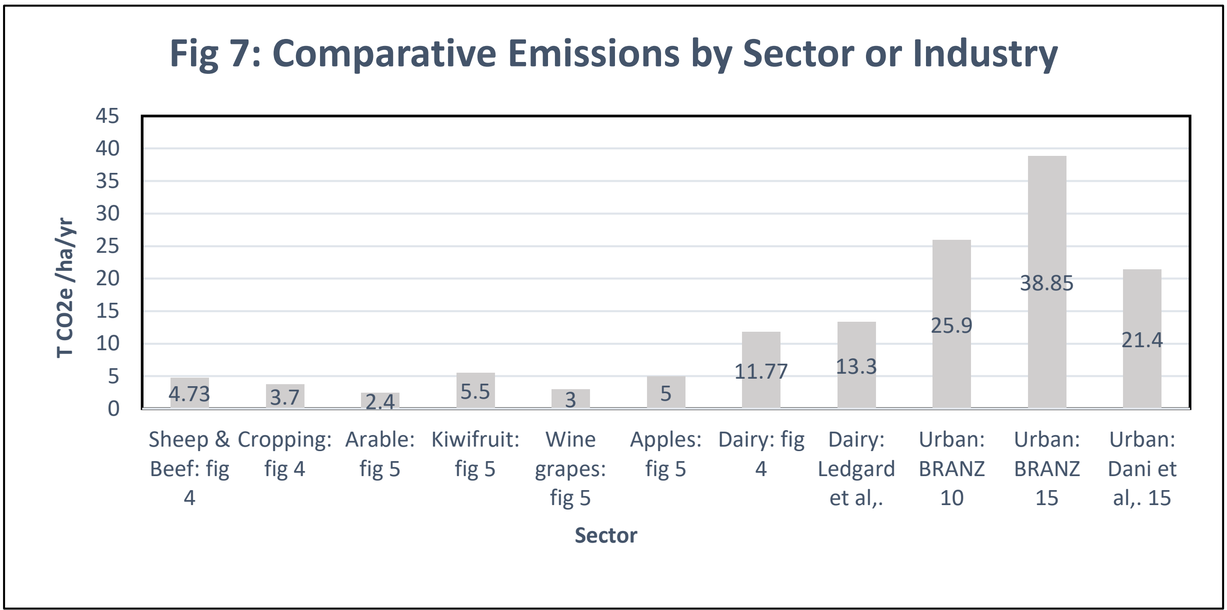

Figure 7: Summarising the data from the literature review in a comparison format

Note: comparative emissions (created by author)

Converting the land to urban residential standalone housing, the annual CO_2e emissions are higher. From dairy, Ledgard et al,. (2020) to urban, Dani et al,. (2022) is a 60% increase.

The following figures 8 & 9 show how the housing data was converted:

Dani et al., Study GHG Profile of Residential Standalone NZ House		13.72	kg CO2e/m2/yr	
multiply by floor area 104m2	x	104		
Equals GHG emission per year per House	=	1426.9	kg CO2e/yr	
multiply by Nett Yield of houses per ha	x	15		*ref:*
Equals GHG emission per year per Ha, for 15 houses	=	21.4	T CO2/ha/yr	*Dani et al. 15*

Figure 8: Dani et al., (2022) Conversion of per m^2 to per ha

Note: shows conversion of data from per house/m2 to per ha/year (created by author)

BRANZ Study GHG Profile of Residential Standalone NZ House		233.1	T CO2	
divided by 90 yr calculated service life	÷	90		
Equals GHG emission per year per House	=	2.59	T CO2	*1
**1 matches figure from Australian study (Carre et al., 2011).*				
multiply by Nett Yield of houses per ha	x	10		*ref:*
Equals GHG emission per year per Ha, for 10 houses	=	25.9	T CO2/ha/yr	*BRANZ 10*
or				
multiply by Nett Yield of houses per ha	x	15		*ref:*
Equals GHG emission per year per Ha, for 15 houses	=	38.85	T CO2/ha/yr	*BRANZ 15*

Figure 9: BRANZ Conversion of per house to per ha

Note: shows conversion of data from per house over 90 years, to per ha/year (created by author)

8. Discussion: Thematic Analysis of Interviews

The themes analysed from the interviews can be summarised in the table below (table 10). The report then follows on to discuss these themes.

Table 10: Thematic Analysis Theme Flowchart

STEP 1 →	STEP 2 →	STEP 3
Raw coding of interview transcripts	Streamlined description	Refined section topic heading
accurate data small data set → omissions	Accuracy / omissions /validity →	How accurate is the data
poor/low uptake wrong way → picked on / misunderstanding	Picked on / singled out / wrong way →	What do people think about what is going on
next steps / future requirements trends →	Trends / what needs to happen next →	Whats happening and what needs to happen
unintended consequences complexity →	Unintended consequences / complexity →	Complexity around strategy realignment to be consistent with goals

Note: shows thematic analysis themes from interviews undertaken (created by author)

8.1 How accurate is the data considered for this type of comparison?

Factors affecting the data comparison are discussed in this section. For example, there are omissions of road and service infrastructure for houses and the conversion of methane from farming to carbon dioxide equivalent using an often discussed formula.

Specialists for this project from both the rural and urban sector agreed that the emissions data was of an accuracy and completeness enabling robust comparison.

The methodology tools (for example life cycle analysis) require some decisions about what is included or excluded from the model. Calculating the emissions of a subdivision require far more elements than just the houses. However, for simplicity, emissions from the infrastructure, services, and green space were excluded from the calculations in this report. On evaluation, this is likely to have had little effect on the conclusion. The housing alone component of emissions is significantly higher than the comparative dairy farming value.

The omitted emissions include the driveways, footpaths, kerbs, and streets that the houses sit beside. Streets are built for cars. Cars are built for people. There are considerable 'butterfly effect' emissions of building more houses. The associated infrastructure, transport, and life emissions quickly add to the emissions total of just the houses alone.

The yield of houses per hectare was chosen from guidelines within city zone rules and satellite imagery. Figures on the conservative side of yield were considered however statistical confirmation study of actual yields would increase the accuracy.

The emissions profiles of housing and agriculture are different. Housing emissions have an upfront construction and embodied (built in the materials) carbon footprint and then following that, an operational (living use and maintenance) and end of life (demolishment and disposal) footprint. Data from interviewees and studies suggests approximately 14% of the total footprint is embodied (Dani et al,. 2022). Although most emissions occur across the operational life span of the house, the way the house is constructed and what of has a significant effect on the quantum of these operational emissions. The numbers shown in the charts (figures 8&9) are averaged effectively over every year of the 90-year service life. In reality, embodied and upfront emissions occur at the start of the process. Comparatively the agriculture emissions are largely operational year on year, ongoing numbers. Further analysis into the time function of the housing emissions profile were outside the scope of this report.

8.1.1 Different gases: CH_4 and N_2O vs CO_2

When asked about the current reporting of greenhouse gases, interviewees repeated themes of a preference for split gas reporting and concern about the GWP conversion factor for short lived gases. This is explained below.

> 'If New Zealand's GHGs were reported by warming potential, agriculture would only sit at around 20% of total GHG emissions' - interviewee

Methane and Nitrous Oxide are the major output gases of the farming system. This study, and for example The Ministry of the Environment reporting to the government, use numbers in carbon dioxide equivalent (CO_2e) figures. They are currently converted to CO_2e using the 'GWP100' formula. Using the GWP100 metric can be viewed to overstate the warming effect of methane and over a longer time frame. Much advocacy from the primary sector has been occurring including reporting on a split gas approach in which each gas is named separately, and their individual warming potentials are reported. Agriculture being labelled as the largest source of warming in New Zealand has a lot at play based on any terms of conversion used.

It is well understood for example that dairy cow numbers in New Zealand are stable to decreasing (Stats NZ, 2021). Because the concentration of methane in the atmosphere is no longer increasing, the updated conversion metric, GWP* (called GWP star), is well suited to this emission profile:

> Recently, a group of researchers proposed a new methodology (GWP*) to account for the surface temperature effects of gases with different lifetimes. Because it accurately reflects the surface warming of a time-series of gases, GWP* gives a stronger warming effect than GWP100 when CH_4 emissions are rising, and a smaller effect with CH_4 emissions are stable or falling. This reflects the actual physical effects on surface temperatures, whereas GWP100 does not. – (Mazzetto et al., 2021. p. 13)

On comparison, the figures for standalone New Zealand housing are different, mostly CO_2 emissions. Whilst this report attempts to compare the profiles on a CO_2e unit basis, it should be remembered the gases are different, their warming potentials are different, therefore the results will change as the conversion protocols change in the future.

8.1.2 Industry Concerns about progress, fairness, and being singled out

Interviewees were asked about possible omissions and errors that affect them from current models used:

- Sequestration inclusions for small lot size tree plantings and shelterbelts are not allowed to be included in current emission calculations as they fall under minimum area size of 1ha. The effect of carbon fixing of these on farm is currently under study by industry bodies.
- Smaller farms, for example some using less than 40T of synthetic nitrogen per year, are likely to be omitted from reporting emissions (He Waka Eke Noa, 2022). As a result, alternative forms of nitrogen are being sought (Stuff, 2021). If this continues the emissions from these farms may need to be reconsidered for inclusion.
- The OVERSEER software is regarded with mixed review (Environment Canterbury Regional Council, 2022) however provides data that is representative for this study. Rather than discussing the accuracy of the model, an interviewee stated the biggest issue with farmer based emissions calculations was data entry. Examples included a significant driver of emissions being the maintenance feed requirement of the animal.

Farmers commonly overstating there liveweight values are a large concern as it correlates to increased GHG emission. Another example given was the replacement rate of dairy herds falling victim to the notion of ‘Swedish Rounding’. Where a user may choose 20% or 25% as a best estimate, when in fact the rate is somewhere in between. Also, when choosing the percentage, there is no hard definition of the denominator total cow numbers. These lead to inaccuracies in emissions calculated for replacement animals & their grazing.

8.2 What do interviewees think about the current direction of strategy and policy

8.2.1 Unique profile based on fundamental food production

In New Zealand themes of food marketing away from animal proteins can be seen, because of negative environmental and animal welfare connotations. The dairy sector has been vulnerable with smear campaigns such as ‘dirty dairying’. In contrast to the market sentiment, in the interviewee’s opinions, food production capability or food security shouldn’t be treated equally with the likes of transport and energy emissions. This is because food production is a fundamental need and will continue to be, to meet the growing population of the world. Interviewees reference that this is recognized by the United Nations Paris Agreement on Climate Change (United Nations, 2015). The specific reference to protecting food production is inclusive of plant or animal-based food types. The interviewees were asked about the growth of urban sprawl and the outcome of it being a potentially higher GHG emitter than agriculture. The theme of responses was that there is also currently a fundamental value, be it social, or basic human right to housing, meaning it’s not receiving the same terms of negative exposure as agriculture.

It was discussed that critical thought should be put into the concept of locking land into one way land use change because of the Emissions Trading Scheme (ETS). Areas planted in trees which by regulation can no longer be converted back up the intensity scale may one day be needed for feeding a growing population. This correlates with the United Nations reference to protecting food production land, and interviewees desires to recognise different treatments for it.

The feeling is that the primary sector has been singled out, and predictably so, because it is New Zealand’s highest GHG emitter. Consideration needs to be given to this position when evaluated from different viewpoints. One is as above, that its not entirely fair given these emissions are for food production. Secondly, New Zealand has a unique emissions profile in the world. The proportion of the GHG emissions that are long lived gases are only ~45 percent. This is unique in the world, for example Australia’s emissions profile is ~60% CO_2 (Timperley, 2019) and China’s over 80% (CSIS, 2022). Due to this there is a consensus among those interviewed to support the use of unique split gas reporting or an alternative conversion metric (for example, GWP*). The result of this is that it may level the playing field across industries and even the pressure from media between industries like agriculture and housing.

8.2.2 Tool availability and 'green' concern

The primary industry can somewhat feel left high and dry by the shortage of available emission reduction tools. Interviewees gave the examples of the transport industry. With their electric vehicle pathway and hydrogen technology available, both are socially accepted. They have tools available now.

Conversely, farmers with animals must deal with the fact it is the only biological cycle included for consideration by the International Panel for Climate Change. It is far more complex and completely different to carbon dioxide. The technologies available are limited to reduce emissions and maintain profitability. Tools such as low methane ryegrass, vaccines, or feed additives are not available currently.

New Zealand has maintained an imagery of being 'clean & green'. This was led by marketing claims around year 2000 (Ministry for the Environment, 2001). Interviewees noted this was a very successful imagery that is now defining perception of what tools we should, and shouldn't, consider to be using to reduce our emissions profile. Gene editing being one, nuclear energy being another. Is the country 'clean & green' if it won't use these technologies that reduce the world's climate change?

Further concern regards the recognition of alternative tools in approved models. Interviewees cited some fertiliser alternatives that provide nitrogen with less losses however these aren't yet modelled and recognised in tools such as OVERSEER®.

Based on these points, agriculture specialists interviewed recommend aligning emission cuts timing more with funding and availability of solutions. Conversely building specialists were concerned at the slow uptake of available proposals and industry recommendations by central government.

8.2.3 Tax and Trading mechanisms

The tax charged on emissions is charged differently for each sector. Agriculture through He Waka Eke Noa has a preferred option to charge the tax on emissions at the point of production, the farm gate. This focuses the individual producer on their effect. Other consumables, for example petrol, have a carbon tax put on them at point of sale to the end user. If the tax is paid at the end user, these considerations should be noted: there is increased administration to pass the tax back through the supply chain to the creator of the emission, and there is a normality of passing the price of the tax straight on to the consumer. This is a price setter market. This is played out frequently when the taxes on fuel change – the price at pump is immediately adjusted and the producer is buffered from cost implication. This has a consequence of potentially slowing the GHG mitigation urgency. Food produced by agriculture are commonly sold in a price taker commodity market, whereas builders sell houses as the price setter. Farmers may have to absorb carbon tax whereas house builders could pass them on.

The units traded in the Emissions Trading Scheme are reflective of the quantity of emissions the government has allowed in its carbon budget for that period. This is a decreasing number as the emissions quantity cap is bought down over time (the sinking lid analogy). A sinking lid of tradable units is forecast to see a near term rise in the price of the unit due to the supply and demand principle. Planting trees can gain credits, therefore we are seeing incentivised forestry planting on a return-on-investment basis. This is reducing pastoral land which is the targeted land use change aligning with GHG reduction strategy. Urbanization is not directly affected, with the afforestation becoming more like a carbon offset for a growing urban emissions source. Different industries are affected differently, having a flow on affect to land use change.

8.3 What's happening looking forwards

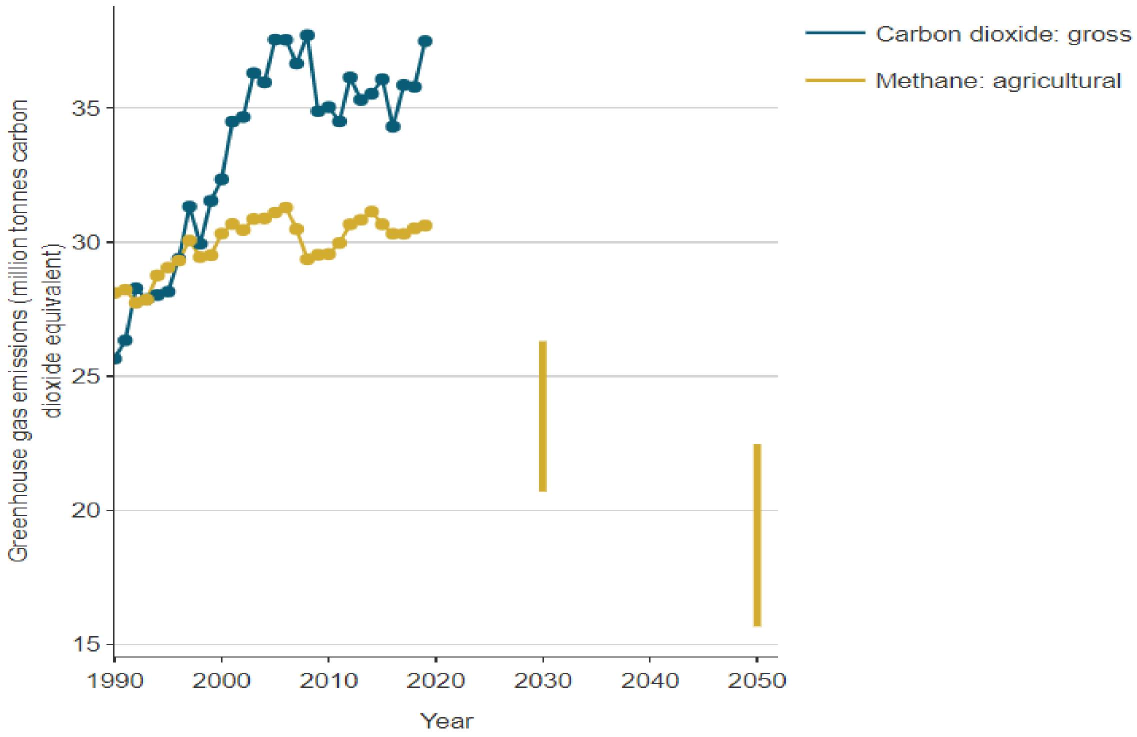

Figure 11: GHG emissions trajectories

Note: the increase in emissions is more significant for carbon dioxide than methane. *From: Stats NZ (2021).* (https://www.stats.govt.nz/indicators/new-zealands-greenhouse-gas-emissions)

8.3.1 Pastoral land use decreasing while horticulture static

Methane and carbon dioxide emissions (excluding sequestration) could be on different trajectories moving forwards (figure 11, above). This ties into the points below that interviewees focused on.

Urban expansion has continued every year from 1996 to today. Contrast this with number of beef cattle and sheep which were higher in the 2000’s and a dairy herd declining in numbers since 2014. Since 1996, there is estimated to be a 5% decrease in pastoral land due to change into trees or high value horticulture. Assuming a portion of this is dairy farmland, the emissions profile from the food and fibre sector will be decreasing (Stats NZ, 2021).

The interviewees also agree there will be a dairy land creep out to other uses, but primarily for economic reasons: Staffing, regulation, aging population of owners or key management, and diversification of strategy (Māori agribusiness, for example).

Another driver for such land use change referred to in interviews was changing climate. Struggle with the droughts (Northland or Hauraki farmers), or alternatively flooding. Perhaps even a genuine desire to reduce potential future climate risk by diversifying incomes.

Land use change in horticulture is approximately static. Some farms are being lost to urban sprawl whilst some land is being converted to horticulture. Noted by an interviewee, they went on to describe the need for local consumption of fresh vegetables. They are difficult to export and transport, share highly productive soils besides urban areas, hence usually are produced close to the point of consumption. Due to urban sprawl they are moving further afield. The Hutt Valley used to produce vegetables for Wellington city. That production was pushed out by urban sprawl to the vicinity of Levin. An unintended consequence of opening the new Transmission Gully motorway is that urbanisation is now threatening horticultural production around Levin.

8.3.2 Opportunity provided by industry certification and reporting on GHG’s

With climate change, climates in other countries may become more unsuitable for food production. This was spoken out about as our golden opportunity to increase our role as a provider for the world. Our challenge is to show this is done in an efficient way: within freshwater, biodiversity, and other environmental limits. This was viewed as the role for He Waka Eke Noa and other industry good programs, preparing us for future opportunities. Primary industry levy bodies are rising to the global provider opportunity. Certification programs discussed include:

- in horticulture: Good Agricultural Practise (GAP)
- in dairy (for example Lead with Pride, Cooperative Difference, the Miraka Way)
- in sheep and beef (carbon neutral 2050)

At individual business level, reporting differs. The aim is for every dairy farm in New Zealand to know their GHG number by 2022. An understanding of change levers is being built up so that when tax starts in 2025, most farmers will have ideas about making reductions in their emissions.

8.3.3 Urban footprint growing but with options for improvement and reporting uptake

The building sector doesn't yet have the same reporting requirements. The state housing provider, Kainga Ora, acknowledges new builds emit five times the carbon permitted to meet 2050 targets. They will expand emissions reporting to include that of the homes they build although when is not specified (Kainga Ora, 2021).

A low reporting uptake was of concern to interviewees. The Construction Sector Environment Roadmap for Action backs up their feedback that the industry is also fragmented and focused more on low cost. The sector used an expert advisory group that noted factors slowing adoption of environmental practices being 'limited collaboration and trust across the construction value chain' and 'a cost focused and growth led mindset'. The sector aims to start reporting environmental impacts for the whole value chain by 2024 (Construction Sector Accord, 2021).

In the study by Bullen et al,. (2021) it was concluded that newly built dwellings exceed their required carbon emissions targets by a factor of between 6.7 to 10.9 times. At this current rate of building these houses, the full carbon budget allocation from now until 2050, will be used up in only three years. In response, interviewees state the need for far quicker uptake of industry recommendations into legislation. They also noted factors working against uptake from the industry such as high demand for more entry level houses. Price being king, carbon reduction features are cut from the budget.

An interviewee stated that a list of six rules of thumb were created to reduce emissions in new houses:

- increase insulation
- remove floor coverings
- more compact forms (for example less junctions or wings to a building)
- smaller window to wall ratio
- better distribution of windows
- reduce house size

These changes require no new technology, little cost change, and are claimed to cut emissions by approximately one third in Auckland and up to half in Queenstown.

8.3.4 Significant urban growth projects underway

While pastoral land use decreases in area, the growth of urban sprawl area is represented in these latest projects:

- In May this year residents of Lincoln were informed that a 1700 lot 186 hectare subdivision, doubling the urban area, was recommended for approval (Stuff, 2022).

- Auckland Council has in May 2022, approved 'Patumahoe', a 22 hectare rezoning of highly productive Pukekohe horticultural soils to residential and urban use (Auckland Council, 2022).
- The Hamilton City Council has for ten years been planning the development of over 700ha of land called 'Peacocke', to house over 20,000 people. The stated aim of the development is to create a 'sustainable community' (Hamilton City Council, 2021).

Currently the process for the above plan change residential projects involves formally submitting on many areas of assessment. For Patumahoe this included:

- cultural
- urban design
- landscape and visual design
- traffic impact
- infrastructure
- earthworks and sediment
- geotechnical
- land use capability
- land productivity
- economic impact
- stormwater
- archaeological
- catchment management

Mentioned in interview was the notable omission of any required GHG emissions reporting.

8.4 Complexity around strategy realignment to be consistent with goals

8.4.1 Urban Intensification might not be a straightforward winner

The Urban Development Act (2020) allows intensive development within urban boundaries. This is a clear strategy for taking the pressure off primary industry productive land by reducing urban sprawl. The changes in the act are substantial. For example, any residential section in earmarked cities can now be developed into units of three stories (Urban Development Act, 2020). This building form is gaining popularity, however from interviews it was concluded that issues such as the leaky building claims in the 2000's have formed some societal stigma against higher density housing.

One must consider that while building smaller homes means each one has a smaller GHG footprint, more of them are built on an area of land. There is some cancelling out effect.

The results are shown in the box, right.

MDH footprint

If you applied similar methodology to the standalone house, using BRANZ data for a Medium Density House (MDH):

135 tCO_2e emitted per MDH,

times 15 MDH's per ha = 2025 tCO_2e

2025 tCO_2e divided by 90 year life

= **22.5 tCO_2e/ha emitted per year**

This result is similar in emission to the standalone calculations. Intensification does reduce land use change and emissions from transport, however further consideration of emissions from intensity of urban development is outside the scope of this study. One can say that the scale of low-density housing is still predominant. The literature reviewed in section 6 stated, nearly 30,000 ha of land was converted from farming to urban since 1996, and stand-alone new houses made up over half of all building consents in 2021.

8.4.2 Pollution Leakage can swamp national improvements

New Zealand sets national targets to meet its international climate change obligations. However, by this very method, it creates the opportunity for the notion of GHG leakage. This unintended consequence means that by trying to be world leading, New Zealand will reduce emissions and it is argued, also productivity. If overseas nations take up that production demand, likely doing it with a higher emissions profile due to a fossil fuel energy source or a more intensive livestock feeding systems, it will create a worser outcome for the planet. A common theme amongst those interviewed was strategising to reduce land use and productivity in pastoral farming would create pollution leakage overseas. They believed this isn't reported on well by New Zealand media.

8.4.3 Perception of agriculture's emissions and opportunity look at this differently

Discussion on how to reposition perceptions of industries led to themes of focusing on what we do well. Problems referred to involve implementing strategy with short term political focus.

The uniqueness of New Zealand's emissions profile could be reported differently. The current coverage of agriculture's high emissions and building's minority role could change by using different conversion factors for methane and bringing in the notion of the proportion of emissions associated with consumption changes a reader's perceptions. The left pie graph shows all the agricultural and building emissions *produced* whilst the right pie graph shows the emission associated with what is *consumed* here (figure 12, below).

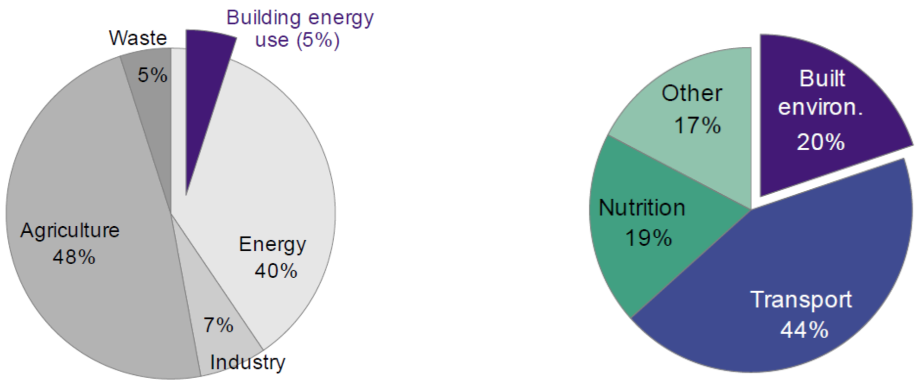

Figure 12: Traditional reporting of *production* based emissions profile (left) vs alternative national *consumption* based emissions profile (right)

Note: the transition of sectors when changing where the emissions are measured is significant.
From: Vickers, J., Fisher, B. (2018). *The Carbon Footprint of New Zealand's built environment: hotspot or not?* Thinkstep Ltd. (https://www.nzgbc.org.nz/Attachment?Action=Download&Attachment_id=2635)

The charts when considered in tandem demonstrate opportunities for farming and building. They show the significant reduction of consumption agriculture related emissions because of those associated with what we export overseas. New Zealand leads as the most efficient milk producer in the world therefore positive sentiment could be attached to that emission export.

The built environment becomes more significant, largely in line with the rest of worlds building contribution (Vickers et al,. 2018). Therefore, more notice is taken of its impact. Discussion presented options that are right in front of the building sector to decarbonise:

- Plentiful low carbon materials available: timber piles (versus concrete slab), timber cladding (versus steel, cement, or synthetic), timber framing (versus steel or concrete), timber suspended floors and beams (versus steel and concrete).

- High renewable energy availability: power supply, space heating, and hot water heating.
- Efficient supply chain: trees and power generation close to end use locations.

A positive side effect of lower carbon footprint homes are they are generally healthier, drier and easier to heat. Another positive is that timber's raw form, trees, sequesters carbon prior to harvest.

8.4.4 Splitting out urban sprawl emissions will benefit strategic thinking

Statistics NZ data of New Zealand's GHG emissions report in net and gross. Gross being after consideration of a sector called land use change. It is noted that this is the only land use sector where carbon dioxide is removed from the atmosphere, through biomass and sequestration. If every hectare of land urbanised is increasing our gross emissions total, splitting out the urbanisation effect in the land use sector and reporting on it specifically could create better discussions about strategies going forwards.

8.4.5 Global Population Growth and its tricky side effects

A growing world population has more people needing more resources: more to eat, and more houses to live in. This potential land use collision is an ethical conundrum. When questioned about this, interviewees were supportive of the opportunity to supply dairy, meat, fruit, and vegetables for this national and global demand. This was because of New Zealand's low emissions profile per unit of product. It makes sense considering the Paris Agreement to do this in the most efficient way. An agreed condition of this social licence to supply globally was improving key indicators such as in tourism marketability, water quality, soil degradation, and animal welfare. Viewed perhaps with a socialist lens, doing more to help supply healthy nutrition to many people is a fundamental belief.

When asked about the conflict of producing more food and also more houses, there was a theme of commonality. Focusing on higher density living minimises conflict with land use, so industries can coexist. New Zealand has fantastic resources to become world leading in decarbonising the construction and operation of the built environment. This gives the sector the ability to reduce its emissions and establish goodwill with respects to climate change goals.

Ultimately population growth fuels emissions growth and was referred to by interviewees as the 'monkey in the room', so to speak. In democratically elected societies, elections cycles of three to four years are common. They commented election success can occur by convincing voters what is in it for the person short term, rather than what is best for the planet long term. Politicians can tend to avoid taboo subjects that alienate key voting blocks such as urban constituents. Possible examples of these can include population, making building costs more expensive, and increasing taxes with the Emissions Trading Scheme.

9. Conclusions

This research suggests that:

- Emissions from agricultural land use are significantly less than those from urban residential standalone housing.

- Land use change away from pastoral agriculture is being promoted to reduce GHG emissions, but land use change to urban residential purposes is not being discouraged even though it has much higher GHG emissions.

- Significant literature and political legislation make numerous references to agriculture and its effect on GHG emissions, but the same legislation doesn't reference housing.

- Land use change to urban use is increasing at record rates. Record number of stand-alone houses are being built in subdivisions on what was agricultural land. Pastoral farming continues to decrease in area.

- More housing is openly promoted across the political spectrum. From this report's perspective, it takes New Zealand further away from its GHG commitments than if the land had stayed in farming. The effect of housings emissions are largely unreported in figures.

- There are international frameworks for protecting food production, potential for stopping urban sprawl with higher intensity housing, and technology currently available to reduce the carbon footprint of houses. All the above are being taken up slowly even though they are critical to a low emissions future and meeting climate goals.

- The perception of agriculture as New Zealand's number one emissions problem is a poor platform for the primary industry in the issues it is facing. These include pollution leakage, appeal for split gas acceptance, limited mitigation availability, short cycle democratic political processes, and permanent land use change away from the sector. This is risking low emission future food production for the world and threatening the social licence to farm here.

10. Recommendations

- Acknowledge split gas reporting. A current example is as per recommended by submission of He Waka Eke Noa proposals - Ministry for Primary Industries.

- Split out urban land use change emissions in land use change, in reporting – Ministry for the Environment.

- Urge GHG reporting requirements per build in the housing sector – Minister for Building and Construction through the Ministry for Business, Innovation and Employment.

- Require GHG reporting on project specific versus national targets in submissions for land use change – Resource consent legislation overseen by the Ministry for the Environment.

- Fund and promote research into housing related infrastructure emissions data that can be comparatively measured – Universities within New Zealand.

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12. Appendices:

Personal Interviews and interview questions

Name: Paul Melville
Title: Principal Advisor, Water & Environment Strategy; Federated Farmers of New Zealand
Method of communication: Online Meeting
Date of Interview: 6/5/22

Name: Nick Tait
Title: Lead Advisor – Solutions and Development; DairyNZ
Method of communication: Online Meeting
Date of Interview: 11/5/22

Name: Pierre Beukes
Title: Senior Scientist; DairyNZ
Method of communication: Online Meeting
Date of Interview: 6/5/22

Name: Dr David Dowdell
Title: Principal Scientist – Sustainability; BRANZ
Method of communication: Online Meeting
Date of Interview: 13/5/22

Name: Dr Stewart Ledgard
Title: Scientist; AgResearch, New Zealand
Method of communication: Online Meeting
Date of Interview: 3/6/22

Name: Kok Hong Wan
Title: Land Policy Analyst; Ministry of Primary Industries, New Zealand
Method of communication: Online Meeting
Date of Interview: 31/5/22

Name: Michelle Sands
Title: Strategy and Policy Manager; Horticulture New Zealand
Method of communication: Online Meeting
Date of Interview: 11/5/22

Written transcripts held by author.

Interview Discussion Questions - options chosen based on field of expertise of subject

A) How accurate are the GHG equivalent numbers that your industry is using now to represent its emissions?

B) What are significant emissions that are left out of the figures commonly used when considering the full life cycle of the emissions created by a farm/orchard/house/subdivision?

C) As an industry, what are your opinions on where dairy/horticulture/housing sits in its understanding of its emissions compared to other industries in NZ?

Why?

D) Do you think ruminants, be it sheep, beef cattle or dairy, are singled out for a leading role in NZ's GHG production?

Do you think this is fair?

Why/why not?

E) Can you provide data on the change in land use of dairy/ horticulture/housing in the recent past? I.e. in last 0 to 10years?

How does this affect the industries contribution to GHG emission and the outlook going forwards?

F) As a knowledgeable person in GHGs related to NZ dairy farming/horticulture/housing development, what are your opinions/questions about change of land use strategy that NZ is taking to meet our climate change obligations?

G) Do you think the policy output of NZ is reflective of using scientific reason to create the best drivers for the dairy/horticulture/housing industry to help meet NZs climate change goals?

Why/why not?

H) The World has an increasing demand for our primary products yet New Zealand policy is focused on reducing our intensive farming production. I.e. We are the most efficient producers of milk in the world so it could be argued we should produce more. In your opinion, Is the government strategy dealing with the contrasting challenge the right way? For example, by reducing our output?

Or Housing specific H):

We have heard about for years how Govt and Council are going to need to build more homes. Building homes creates GHGs. In the context of trying to reduce our GHG emissions to meet climate change objectives, how does your industry deal with this contrasting challenge?