# Auckland Council

## Potential policy options to reduce greenhouse gas emissions

## Technical report

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# Glossary

| | |
|---|---|
| ANZSIC | Australian and New Zealand Standard Industrial Classification |
| ASD | Adjustable speed drives |
| BaU | Business as usual |
| CBD | Central business district |
| CHP | Combined heat and power |
| C&I | Commercial and Industrial Waste |
| CO2e | Carbon dioxide equivalent |
| CST | Concentrating solar thermal |
| EECA | Energy efficiency and conservation authority |
| EPC | Energy Purchasing Contracts |
| EPRI | Electric Power Research Institute |
| ETS | Emissions trading scheme |
| EV | Electric Vehicle |
| FCC | Freight Consolidation Centres |
| GBCA | Green Building Council Australia |
| GDP | Gross domestic product |
| GHG | Greenhouse gas |
| GIS | Geographical Information Systems |
| GJ | Gigajoule |
| GRP | Gross regional product |
| HVAC | heating, ventilation, and air conditioning |
| ICE | Internal Combustion Engine |
| ICLEI CCP | International Council for Local Environmental Initiatives - Cities for Climate Protection |
| $ktCO_2e$ | Kilotons of carbon dioxide emissions |
| kW | Kilowatt |
| $kW_e$ | Kilowatt (electrical) |
| LCZ | Low Greenhouse gas zones |
| LEED | Leadership in Energy and Environmental Design (Building rating system, USA) |
| MRF | Materials Recovery Facility |
| MSW | Municipal Solid Waste |
| MW | Megawatt |
| $MW_e$ | Megawatt (electrical) |
| mWh | Megawatt hour |
| $MW_{th}$ | Megawatt (thermal) |
| NABERS | National Australian Built Environment Rating System |
| nBaU | Naive business as usual |

| | |
|---|---|
| NPV | Net present value |
| NZGBC | New Zealand Green Building Council |
| PHEV | Plug-in Hybrid electric vehicle |
| Ppm | Parts per million |
| Precinct | Area of land containing multiple sites (usually mixed use) which can be grouped together based on single ownership or precinct wide governance arrangements |
| PV | Photovoltaic |
| RLTS | Regional Land Transport Strategy |
| SDT | Self-determination theory |
| S.T.A.R.T. | Short Term Actions to Reorganize Transport of Goods |
| $tCO_2e$ | Tonnes of carbon dioxide equivalent |
| TJ | Terajoule |
| VIBAT | Visioning and backcasting for transport |

# Executive Summary

The newly formed Auckland Council is establishing the first ever strategic spatial plan for Auckland region. The plan will be a vehicle for delivering the Council's vision of Auckland becoming "The most liveable city in the world". The plan is underpinned by a comprehensive visionary framework and a suite of strategic targets, including the Council's target of a 40% reduction in Auckland's GHG emissions by 2031 based on 1990 levels.

Council commissioned Arup to develop a strategy for achieving the GHG emissions reduction target. It is intended that the strategy will inform development of the strategic spatial plan. The strategy is informed by baseline modelling of the sectoral and spatial distribution of GHG emissions in Auckland, and draws inspiration from GHG reduction initiatives implemented in other global cities. It demonstrates that Auckland can meet the nominated target and that doing so is likely to deliver significant benefits in terms of the economy and in liveability.

## Baseline Modelling

The baseline modelling and projections suggest that the Council's target equates to a requirement for Auckland to reduce its emissions to a total of 5,256 kt$CO_2$e per annum by 2031 as shown in Figure 1 below. This represents an annual emission target of 2.8t$CO_2$e per capita or 53.7t$CO_2$e per $M Gross Regional Product (GRP). Achieving this level of emissions would establish Auckland as a global leader in emission reduction

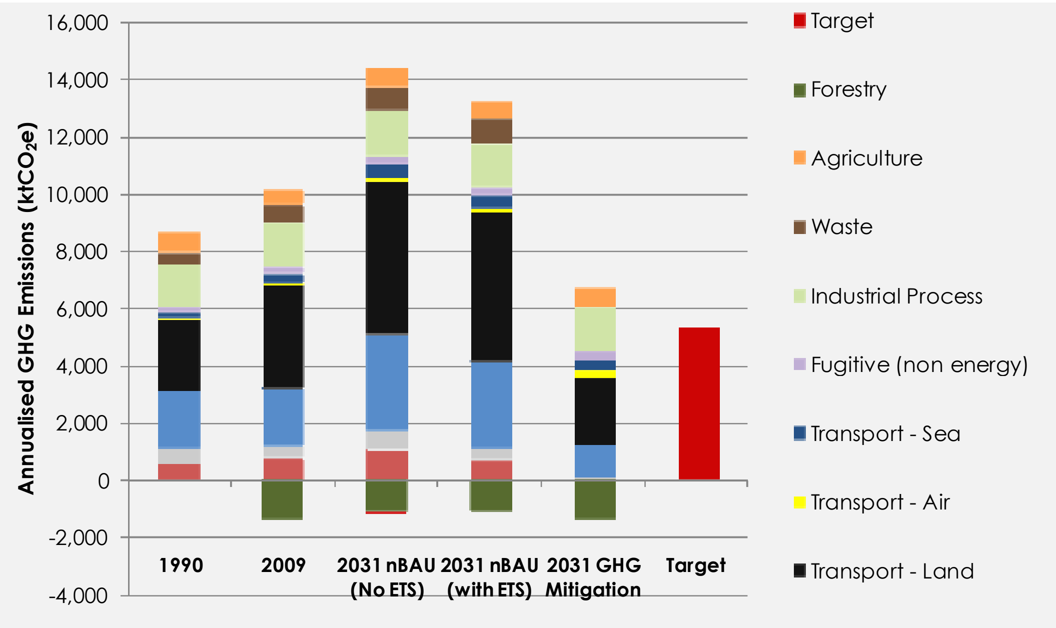


Figure 1 The Council's 2031 Target

## Strategic Policy Options

This report proposes the following strategic directions for Auckland to leapfrog other international cities and establish itself as one of the world's leading cities in terms of GHG emissions reduction.

### Energy Supply

- Ensuring that new energy generation to accommodate Auckland's growth is provided by renewable resources.
- Maximising the potential for distributed electricity generation from building integrated and other small scale renewable generation.
- Adopting a precinct approach to optimise renewable energy generation and take advantage of otherwise marginal or undevelopable land.
- Establishing thermal networks in dense regional centres to capitalise on potential solar thermal and geothermal resources and industrial waste heat.
- Capturing the regional biomass resource for energy generation including agricultural, vegetable crop and forestry residues, municipal waste and sewage.

### Energy efficient buildings and industrial processes

- Establishing world's leading practice standards for energy efficient building design and operation across all sectors.
- Undertaking a targeted retrofit programme for commercial and residential buildings.
- Harnessing industry knowledge through the creation of industry cluster groups to implement programmes of energy efficiency upgrades across the manufacturing and industrial sectors.
- Ensuring that new manufacturing and industrial developments are required to adopt best available technology and best environmental practice and report upon performance.

### Transport and Urban Form

- Maximising the potential of travel demand management, active transport and public transport infrastructure to reduce private vehicle dependency.
- Reducing Auckland's dependency on imported transport fuel through the uptake of biofuels and electric vehicle technologies.
- Establishing quality compact growth to reduce the need for and distance of private vehicle trips.

### GHG sinks

- Utilising marginal riparian land management opportunities to generate GHG sinks.
- Investigating the potential of the marine environment to sequester GHG emissions.
- Investigating the potential of biochar to sequester GHG emissions.

## Abatement Potential

The GHG strategy indicates that the combined effect of these policy options has the potential to reduce Auckland's emissions by approximately **38.0%** based on 1990 levels by 2031. This outcome excludes measures to support behaviour change as well as other measures within the agricultural, industrial process and air travel sectors and other carbon sinks which could contribute to further reductions. It is not possible to quantify these potential gains within the scope of this study. However Arup believe that, taking into account these other potential measures, Council's target of 40% reduction in GHG emissions is achievable and should be retained by Council as an aspirational target.

The potential abatement modelled for this study is illustrated in the wedge diagram shown in Figure 2 below which indicates the contribution of the different policy sectors to the overall target. The upper level in the chart is the 2031nBaU projections without ETS and forestry (refer Figure 1), and the coloured wedges demonstrate the contribution of each proposed group of initiatives in reducing this level towards the target.

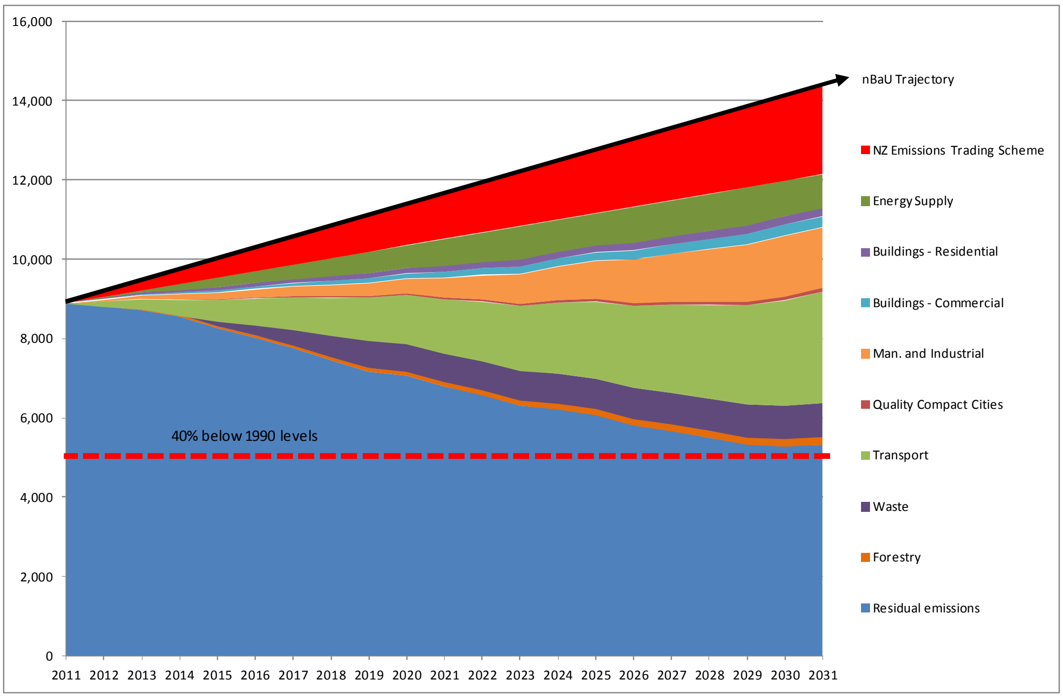


Figure 2 Wedge diagram of potential GHG abatement to 2031

## Cost of Initiatives

The strategy provides a high level estimate of the capital costs, operating costs and potential energy savings for each initiative over the period from 2011 to 2031. These are shown in Table 1 as both nominal cost and present value. The total capital costs are estimated as $39.4 billion (nominal cost) and $20.7 billion (present value), whilst the lifetime energy savings accrued result in an estimated present value of $57.9 billion. For most of the initiatives the ongoing savings outweigh the capital costs such that there is likely to be a significant overall positive cost benefit to Auckland from this investment.

Table 1 Estimated Nominal Value, Present Value and Net Present Value

| Sector | Nominal Value ($Billion) | | | Present Value (2011 $Billion) | | | Net Present Value (2011 $Bn) |
|---|---|---|---|---|---|---|---|
| | Capital Cost | Operating Cost | Energy Savings | Capital Cost | Operating Cost | Energy Savings | |
| Government | $19.1 | $3.9 | $0.2 | $10.1 | $1.3 | $0.1 | -$11.3 |
| Community | $15.1 | $1.0 | $185.8 | $7.7 | $0.4 | $34.5 | $26.4 |
| Business | $5.2 | $9.6 | $124.9 | $2.9 | $2.1 | $23.3 | $18.3 |
| **TOTAL** | **$39.4** | **$14.5** | **$310.9** | **$20.7** | **$3.8** | **$57.9** | **$33.3** |

In the above analysis, Present Value represents the value in 2011 dollars of future expenditure (capital and operating) associated with the proposed initiatives. Present Value is also applied to projected savings in fuel and energy expenditure. Net Present Value is the aggregate value of these costs and savings in 2011 dollars. Noting that Net Present Value includes the energy and fuel savings only and specifically excludes other operational or productivity cost benefits that may be accrued. These values have been calculated using generally accepted economic tools for determining the present, or discounted, value of money.

The $39.4 billion ($20.7bn PV) represents the total capital spending that would be required in order for the initiatives to proceed. It is important to note that this amount is not fully additional to Business as Usual expenditure. In many cases the cost of the initiatives will overlap with required and/or planned spend, such as expenditure on transport infrastructure and building upgrades. However it was beyond the scope of this study to quantify the gap between Business as Usual expenditure and the proposed initiatives.

The assessment indicates a potential benefit in the order of $33bn (net present value) from the investment, This benefit is achieved via estimated savings in fuel and energy costs of  $310.9 billion in nominal costs over the life of the investment and $57.9bn in 2011 dollars (present value). These represent an ongoing saving to government, businesses and residents, which will have direct economic benefit for the city and region.

Assumptions about who will pay the capital costs and who will benefit from savings are also included in Table 1. This preliminary assignment suggests a significant mismatch between who pays and who benefits, with the majority of the capital costs assigned to government whilst the majority of savings are realised by the community and business. In practice there is potential to shift some of the cost to the private sector, such as through direct capital investment or longer term value uplift mechanisms, and to recoup investment through user pays arrangements. Again it was beyond the scope of this study to prepare detailed business cases for each option.

In addition to GHG abatement, the majority of the options also yield significant co-benefits, particularly in terms of health and productivity. These are identified in this study but have not been quantified in terms of economic benefit. The experience of other global cities has been that these co-benefits can contribute significantly to the overall business case, in terms of economic and social benefit.

It is recommended that Auckland Council undertake feasibility studies or preliminary business cases for the various initiatives to:

- Quantify the order of cost above Business as Usual funding requirements;
- Determine funding models that align cost with beneficiary;
- Quantify the value of co-benefits; and
- Explore the relative cost or benefit of different program options and delivery models.

In many cases these feasibility studies would be required anyway to explore the feasibility of Business as Usual infrastructure proposals, such as the Transport Plan.

## Cost of Abatement

The cost of abatement curve (Figure 3) represents the relative value of each proposed initiative in terms GHG reduction and is determined as the net present value of the initiative divided by the discounted lifetime GHG abatement.

The net present value of each initiative is determined as the present value of the capital and operational costs minus the present value of energy savings. Initiatives which fall below the horizontal axis have the least cost of abatement and provide a positive return on investment (or a net present value greater than zero).

The width of the bar represents the GHG abatement potential of each initiative and the area of each bar the total net present value of the abatement.

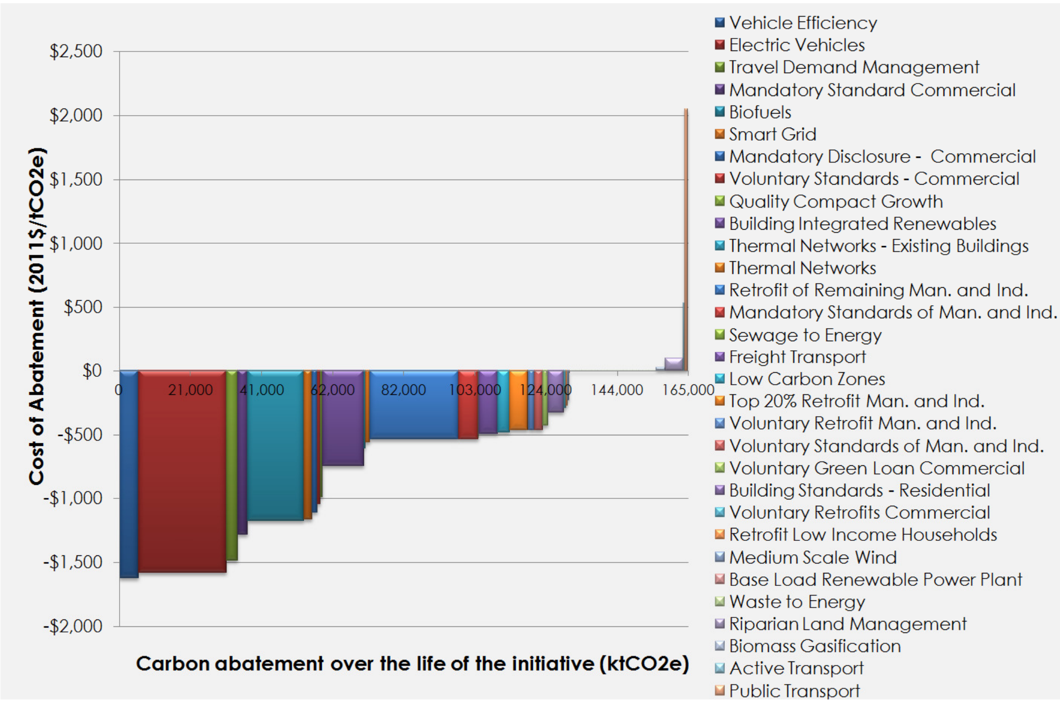


Figure 3 Cost of Abatement Curve

Figure 3 therefore provides a visual indication of the relative cost benefit of each initiative in terms of GHG reduction. The chart indicates that the three individual initiatives likely to deliver the largest benefit in terms of emissions reduction are retrofit of manufacturing and industrial buildings, electric vehicles and bio-fuels. All three of these options sit in the cost-positive sector of the chart.

Figure 3 depicts a high cost of abatement for public transport and active transport initiatives. This is to be expected and does not imply that public transport has a negative cost benefit. It merely indicates that the energy savings from public transport do not by themselves payback the significant capital costs. As with all initiatives, the only financial benefits included within the cost of abatement curve are benefits associated with fuel and electricity savings.

However, it is widely accepted that there are a range of wider benefits associated with public transport and active transport that would contribute to its business case including productivity benefits through travel time savings, reduced road congestion and improved health and air quality. Indeed, it is standard practice in New Zealand and elsewhere for transport infrastructure to undergo detailed cost benefit analysis as part of feasibility studies including consideration of wider economic benefits. Such a study was beyond the scope of this report.

## Conclusion

This study found that it is possible for Auckland to achieve a proposed target of a 40% reduction in GHG emissions by 2031 relative to 1990 levels. This outcome would position Auckland as a world leader in terms of emissions per capita. The report describes a suite of initiatives that together could achieve a 38% reduction with the remaining 2% estimated to be possible via efforts not quantified in the study, including behaviour change and gains in the agricultural, industrial process and air travel sectors.

The high level financial analysis undertaken for the study identified that in the long term the initiatives would deliver a substantial cost benefit for Auckland just considering the potential savings in energy and fuel. This does not include consideration of wider benefits to the community, environment and economy that are likely to flow from the initiatives. The study therefore demonstrates an imperative for Auckland to secure its long term future through investment in strategies that reduce GHG emissions and energy costs. Without this investment the combined impact of carbon pricing and energy costs are likely to see Auckland Council's goals to secure economic prosperity and create the world's most liveable city remain unrealised.

# 1 Introduction

## 1.1 Background

The newly formed Auckland Council is establishing the first ever strategic spatial plan for Auckland, New Zealand's gateway city to the world. The Auckland (Spatial) Plan will be underpinned by the Council's vision for Auckland as "The most liveable city in the world". The Council has also recognised the connection between a city's liveability and commitment to environmental performance by the city's leaders and community. Accordingly, the Council proposed a target of a 40% reduction in Auckland's greenhouse gas (GHG) emissions by 2031 based on 1990 levels.

**Auckland's GHG Emissions Reduction Target**

Arup estimates that the Council's GHG emissions reduction target requires that by 2031 Auckland will reduce its emissions to a total of 5,256 kt$CO_2$e by 2031 as shown in Figure 1. This represents an emission target of 2.8t$CO_2$e per capita or 53.7t$CO_2$e per $M Gross Regional Product (GRP) and would establish Auckland as a world leading city in terms of GHG emissions reduction.

This is a bold and courageous target and will establish Auckland as a world's leading city in terms of emissions per capita and GRP. This report sets out initiatives that would allow the target to be achieved; assuming consideration of GHG mitigation opportunities is incorporated in all policy areas and decision making processes.

Many governments at all levels across the world are setting GHG emissions reduction targets. For the most part, these are either short term pragmatic targets requiring little innovation or step change, or long term ambitious targets with no clear pathway for implementation. Cities are struggling to bridge the gap between what is considered to be achievable within current political and policy frameworks and the level of mitigation required to prevent dangerous levels of climate change. In this context, Auckland is uniquely positioned to leapfrog the world's leading cities in terms of greenhouse gas reductions where it can capitalise on:

- The opportunity under the Auckland Plan to develop policy frameworks which actively promote low GHG growth and development across all areas of policy;
- Its natural advantages including a large renewable resource base;
- Relatively abundant and affordable land available for transport and energy infrastructure which supports low GHG growth and development;
- Relatively low per capita household energy consumption;
- Institutional capacity and commitment to mitigation across central and local governments; and
- Strong connection to and cultural understanding of the value of a healthy environment.

This report outlines the transformations which will be required for Auckland to achieve the Council's GHG emissions reduction target. Although they represent an ambitious transformational program, the returns will be significant in terms of providing for an Auckland which:

- Is more resilient to a GHG price and corresponding increase in energy prices;
- Is more resilient to physical and economic impacts on the energy supply chain;
- Fosters a clean and healthy environment; and
- Is proud and unified.

The Auckland described in this report represents a City transformed in terms of the way people live and work, the way in which industry operates and the way Government prioritises investment. Notwithstanding this challenge, this report demonstrates that the Council's target is not only achievable but will provide a return on investment to the Auckland economy as a whole and transform Auckland to an ultimately more liveable city.



## 1.2 Scope and objective

The objective of this report is to describe the extent and type of transformation required across all sectors of Auckland's economy to achieve the Council's proposed GHG emissions reduction target of 40% by 2031 based on 1990 levels. The report firstly establishes the extent of the challenge by providing an understanding of the current GHG emissions baseline in terms of spatial and sectoral distribution. The report then identifies a suite of comprehensive GHG abatement policy options which can meet the target. The options are based on a review of world's leading practice and the applicability to Auckland's asset base in terms of natural, institutional, social and financial capital.

For each option the report describes:

- The extent to which the initiative can be implemented based on what is considered reasonably achievable by 2031;
- The corresponding level of abatement over the period to 2031;
- The costs and savings to government (both central government and Auckland Council), industry and the community;
- Other potential environmental, social economic and cultural co-benefits;
- Potential implementation measures including funding tools and financial instruments; and
- The level of intervention required by Auckland Council under various implementation measures.

## 1.3 Assumptions and limitations

### 1.3.1 GHG emissions baseline, back-casting and projections

In order to set the GHG emissions reduction target, Arup has relied upon previous estimates of baseline, back-casted and projected emissions prepared by other consultants[1,2]. While Arup has undertaken peer review of these estimates (see Appendix A), the project timeframe has not allowed these estimates to be refined and the recommendations within this report are therefore subject to the assumptions and methodologies adopted unless specifically noted otherwise.

Further, there are a range of potential scenarios which result in different projections of GHG emissions. Some of these scenarios have been investigated by previous consultants. Additional scenario analysis did not form part of the scope for this project.

For the purposes of this report a naive business as usual (nBaU) projection has been developed which projects current consumption patterns in accordance with a combination of published population growth GRP growth scenarios. In reality Auckland's GHG emissions are unlikely track according to nBaU and will undershoot or overshoot depending on a number of factors, including real population change and changes in consumption patterns and lifestyle choices. This will affect Auckland's ability to meet the target, as will the implementation strategies selected to deliver any one of the recommended measures.

Notwithstanding these variables, the strategic options presented within this report will transition Auckland to a low carbon future. In Arup's view further scenario analysis at this point would not represent value for money. Resources are better directed to implementing the measures, achieving supportive behaviour change, and monitoring progress towards the target. If the BAU changes significantly such that the target is not being achieved, Council can then consider additional measures that may be required.

### 1.3.2 Spatial and sectoral distribution

Arup has undertaken further analysis of the baseline emissions to understand the sectoral and spatial distribution. The purpose of this analysis is to identify the relative benefit of initiatives that target different emission categories. This process requires the use of proxy parameters in order to distribute emissions and algorithms which link the proxy parameter to energy consumption or emissions generation. The accuracy of this distribution is largely dependent on the quality of data available and should therefore be considered indicative only of the extent of distribution. This approach is considered fit for purpose in developing a broad baseline understanding of where and why Auckland generates emissions.

Further details on the methodologies adopted for each sector are provided in Section 3, Appendix B, Appendix C and Appendix D.

### 1.3.3 GHG abatement policy options

For each of the policy options, potential GHG abatement and associated cost and cost distributions have been estimated based on publicly available data. The methodology for the cost of abatement model is presented in Appendix E and summarised in Section 4.4 below.

[1] Maunsell AECOM (2008), *ARC GHG Future: Stage 1a - Baseline Data Review*, Auckland Regional Council, 15 July 2008

[2] URS (2011), GHG Now - Regional GHG Inventory Projections, Auckland Regional Council, 1 March 2011

In order to estimate the level of GHG abatement achievable under each policy option, it was necessary to make assumptions about particular technology types, costs and efficiencies. Technologies were selected on the basis of likely suitability for the purposes of GHG modelling only. They do not represent professional recommendations on the most appropriate technical solutions for Auckland. Alternative technology solutions should be investigated, and it is noted these may deliver slightly different outcomes in terms of actual GHG reduction (both up and down).

Further, the distribution of costs and savings between industry government and the community were assigned based on a relatively crude model which assumed that industry will only invest in any one initiative where a commercial return can be achieved, with Government responsible for the additional subsidy. In reality there are many more complex mechanisms for public private partnerships which may shift more of the capital cost burden from government to industry and/or enable government to recoup costs over time.

The assumptions should therefore not be considered as recommendations of particular technologies or financial mechanisms. Moreover, the policy options are intended to encourage industry technological and financial innovation so that the targets may be reached in the manner that is most effective and beneficial in the context of Auckland's economy.

# 2 Strategic context

## 2.1 GHG abatement and strategic spatial planning

There is a growing understanding of the relationship between spatial planning, urban form and GHG emissions. Leading global cities are demonstrating that land use and transport decisions can directly impact on GHG emissions through:

- Promoting urban form and housing typologies which reduce energy consumption;
- Integrating public transport and active transport infrastructure with quality compact growth;
- Optimising land use and roof space to generate renewable energy;
- Providing diversity of employment options close to residential areas and public transport access to reduce commuting time and transport related emissions; and
- Ensuring communities are connected and everyday needs provided for to reduce transport related emissions.

The figures below show some of this story. In the comparison of ecological footprints there is a twenty-fold variance in the 'footprint' of mobility and of housing between different cities (<0.1ha for mobility in Santiago, Beijing and Tokyo compared with 2 global hectares in Houston). This variance in the impact of mobility can be directly attributed to density, as shown in the second figure. Similarly the footprint variance for housing can be attributed to size of houses and energy consumption within the dwelling. These matters are all influenced by spatial planning.

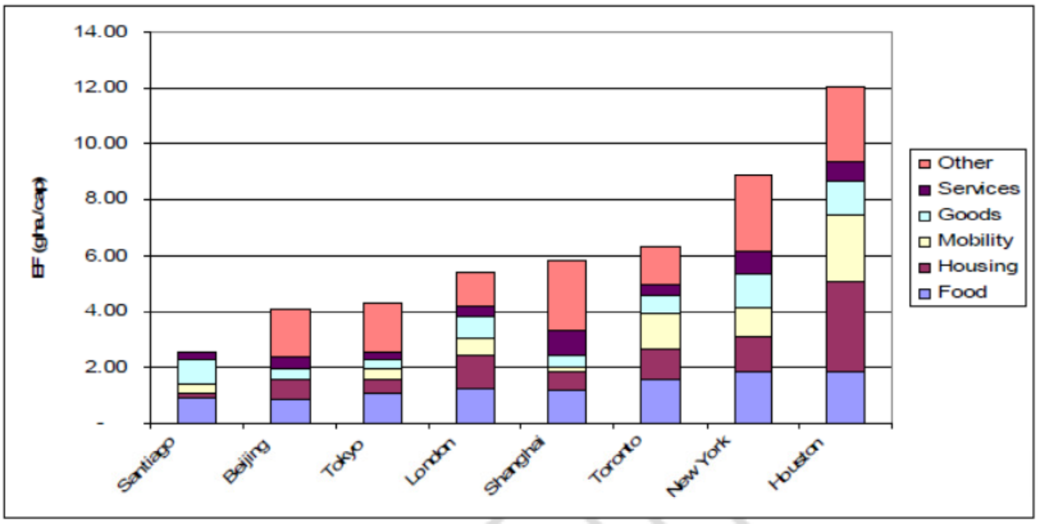


Figure 4 Ecological footprint of selected cities (Head, 2007)

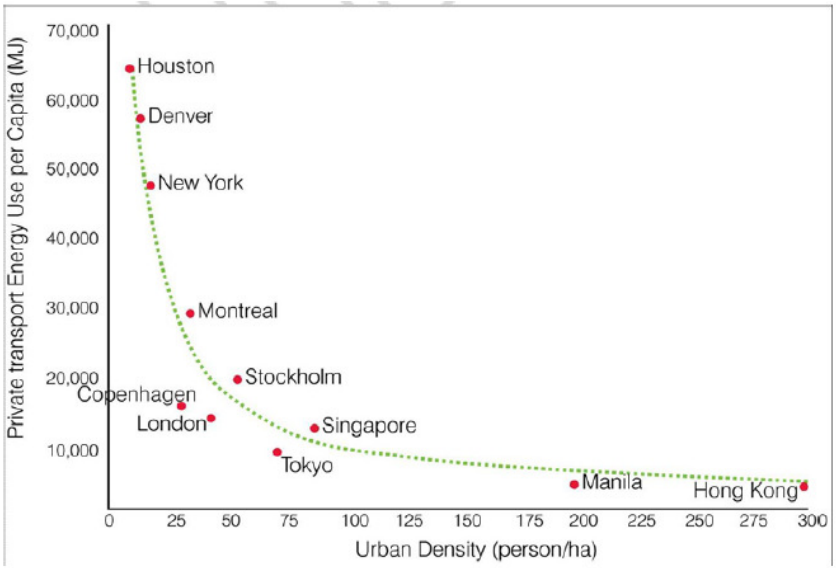


Figure 5 Relationship between private transport energy and density (after Newman and Kenworthy, 1999)

Leading global cities are demonstrating that land use and transport decisions can directly impact on GHG emissions. For example, a 30-year strategy by Vancouver to reduce private vehicle use through mode shifts, constraining road capacity and changing residential density has positioned that city at the leading edge of emission reduction per capita. The balance has changed from 60% of trips to the CBD being made by car in 1992 to over 60% now made by public or active transport. Significant reductions in private vehicle use have also been realised in London through the congestion changes, improvements in public transport services and steady increases in density.

Other cities have focused their planning effort on energy supplies. Land based strategies such as decentralising supply and locating power production closer to users are changing the energy and GHG profiles of European cities. The city of Freiburg has implemented significant urban changes to change building efficiency, energy supply for building and transport such that more 50% of the cities energy needs are now met locally from renewable sources.

In all of the above examples, these changes have been underpinned by a strong strategic framework.

## 2.2 Auckland Plan

The Auckland Council was established on 1st November 2010 and quickly embarked on a visionary and ambitious program to develop a new strategic spatial plan for the whole city by the end of 2011, in accordance with its statutory obligations. Council recognises the Auckland Plan as a once in a generation opportunity to transform the city, and its vision for this transformation is that Auckland become the most liveable city in the world. This vision forms part of a strategic framework for the plan which also includes values, principles, strategic directions and goals. This framework is illustrated at Figure 6.

The legislative framework for the plan establishes a scope that extends beyond the mandate and budgets of Council and creates a framework for collaboration with national government and other stakeholders. The plan is required to address:

- Long-term social, economic, environmental and cultural objectives for Auckland and its communities;
- The role of Auckland in New Zealand;
- Existing and future land use pattern (residential, business, rural production and industrial use);
- Existing and future location of critical infrastructure such as transport, water supply, wastewater and stormwater, other network utilities, open space and cultural and social infrastructure;
- Identification of nationally and regionally significant ecological areas that should be protected from development;
- Recreation and open space areas;
- Environmental constraints on development (such as unstable land);
- Landscapes, areas of heritage, and natural features;
- How Auckland might develop, including the sequencing of growth and provision of infrastructure; and
- Policies, priorities, programmes, and land allocations to implement the strategic direction and indicate how resources will be provided to enable that to happen.

| AUCKLAND'S VISION | | | | | |
|---|---|---|---|---|---|
| THE WORLD'S MOST LIVEABLE CITY - TE PAI ME TE WHAI RAWA O TĀMAKI | | | | | |
| OUTCOMES: WHAT THE VISION MEANS IN 2040 | | | | | |
| A FAIR, SAFE AND HEALTHY AUCKLAND | A GREEN AUCKLAND | AN AUCKLAND OF PROSPERITY AND OPPORTUNITY | A WELL CONNECTED AND ACCESSIBLE AUCKLAND | A BEAUTIFUL AUCKLAND THAT IS LOVED BY ITS PEOPLE | A CULTURALLY RICH AND CREATIVE AUCKLAND |
| PRINCIPLES: WE WILL WORK BY TO ACHIEVE THE OUTCOMES | | | | | |
| WORK TOGETHER | VALUE TE AO MĀORI | BE SUSTAINABLE | ACT FAIRLY | MAKE THE BEST USE OF EVERY DOLLAR SPENT | CHECK PROGRESS AND ADAPT TO IMPROVE |
| TRANSFORMATIONAL SHIFTS: TO ACHIEVE THE VISION | | | | | |
| DRAMATICALLY ACCELERATE THE PROSPECTS OF AUCKLAND'S CHILDREN AND YOUNG PEOPLE | SUBSTANTIALLY RAISE LIVING STANDARDS FOR ALL AUCKLANDERS AND FOCUS ON THOSE MOST IN NEED | STRONGLY COMMIT TO ENVIRONMENTAL ACTION AND GREEN GROWTH | MOVE TO OUTSTANDING PUBLIC TRANSPORT WITHIN ONE NETWORK | RADICALLY IMPROVE THE QUALITY OF URBAN LIVING | SUBSTANTIALLY RAISE LIVING STANDARDS FOR ALL AUCKLANDERS AND FOCUS ON THOSE MOST IN NEED |

Figure 6 Strategic framework for Auckland Plan

The Council has also recognised the connection between a city's liveability and commitment to environmental performance by the city's leaders and community. Accordingly, the Council proposed a target of a 40% reduction in Auckland's GHG emissions by 2031. This will require GHG mitigation opportunities to be considered across all of policy including via both spatial and non spatial responses. Council recognises the important link between spatial planning and

GHG reduction and hence the GHG reduction strategy is integral to the development of the Plan.

The Auckland Plan will inform development of the 2012/22 Long Term Plan and a number of other inter-related projects and programmes, including the Regional Land and Transport Strategy and Local Board Plans. Hence the ambitious program, which is driven by the need to quickly set a clear spatial policy that enables a consistent and integrated approach across other activities.

## 2.3 Comparison with other national and global targets

### 2.3.1 Global targets

National governments have recognised the need to set global emission reduction targets to prevent 'dangerous' levels of climate change. Through the United Nations Framework on Climate Change Convention (UNICCO) and Kyoto Protocol, and backed by the scientific evidence collated by the International Panel on Climate Change (IPCC), nations have pledged a number of national emission reduction targets.

At the Conference of the Parties (COP) to the UNFCCC at its fifteenth session in Copenhagen in November 2009, there was broad international agreement under the Copenhagen Accord to limit global temperature increase to less than 2ºC. This temperature threshold is frequently referred to in the scientific literature as representing the limit beyond which 'dangerous' climate change may occur. Stabilisation at 450ppm CO2e leaves a 50 per cent chance of limiting global average warming to around 2ºC above pre-industrial levels.

The Conference of the Parties (COP), at its sixteenth session in Cancun, recognised the need to strengthen the long-term global goal on the basis of the best available scientific knowledge and the emissions reductions recommended by the IPCC Fourth Assessment Report. The COP urged developed countries to increase the ambition of their targets, with a view to reducing the aggregate global anthropogenic emissions to achieve a global goal of 80% below 1990 levels by mid-century.

The Cancun COP further requested that countries reassert their pledges, clarifying the assumptions underpinning the targets including the use of carbon credits from the market-based mechanisms and land use, land-use change and forestry (LULUCF) activities, and options and ways to increase their level of ambition.

At present, 89 countries have pledged action representing 80% of global emissions and over 90% of the global economy (World Resource Institute, 2011; IMF, 2010). A selection of these targets is presented in Table 2 below.

Table 2 National 2020 targets

| Country or region | 2020 Target |
|---|---|
| Australia | 5% reduction relative to 2000 unconditional.<br>Up to 15% reduction if there is a global agreement that falls short of securing stabilisation of greenhouse gases at 450 ppm carbon dioxide equivalent and under which major developing economies commit to substantially restrain emissions and advanced economies take on commitments comparable to Australia's.<br>25% reduction if the world agrees to an ambitious global deal capable of stabilising levels of greenhouse gases in the atmosphere at 450 ppm carbon dioxide equivalent or lower. |
| Canada | 17% reduction relative to 2005; to be aligned with the final economy-wide emissions target of the United States in enacted legislation. |
| European Union | 20% reduction relative to 1990; 30% reduction as part of a global and comprehensive agreement, provided that:<br>• Other developed countries commit themselves to comparable emissions reductions;<br>• Developing countries contribute adequately according to their responsibilities and respective capabilities. |
| Japan | 25% reduction relative to 1990, premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets. |
| New Zealand | 10% to 20% reduction relative to 1990, conditional on a comprehensive global agreement to limit the temperature increase to less than 2°C, with effective rules for land use, land-use change and forestry regulation, recourse to a broad and efficient international carbon market, and advanced and major emitting developing countries taking comparable action commensurate with their respective capabilities. |
| Norway | Target of 30–40% emission reduction relative to 1990.<br>The 30% target is unconditional based on a political agreement on Norwegian climate policy made in Parliament in 2007. Norway will move to a target of 40% as part of a global and comprehensive agreement for the period beyond 2012 whereby major emitting Parties agree on emission reductions in line with the objective of a maximum 2°C global temperature rise. Under the same conditions Norway presented the target of becoming carbon neutral by 2030. |
| Russia | 15% to 25% reduction relative to 1990, conditional on appropriate accounting of the potential of Russia's forestry sector, and legally binding obligations by all major emitters. |
| United States | Reduction in the range of 17% relative to 2005, in conformity with anticipated US energy and climate legislation, recognising that the final target will be reported to the UN Framework Convention Secretariat in light of enacted legislation. |

Despite this coverage, there is widespread acknowledgement that the Cancun 2020 pledges leave an "emissions gap" such that deeper cuts will be required in order to achieve stabilisation of 450ppm $CO_2e$. The World Resources Institute analysis suggests that existing pledges by developed countries, when added together, represent a 12% to 19% reduction of emissions below 1990 levels by 2020 depending on the assumptions made about the details of the pledges. But they still fall far short of the range of emission reductions (25% to 40% by 2020) that the IPCC note would be necessary for stabilizing concentrations of $CO_2e$ at 450 ppm, a level associated with a 26% to 78% risk of overshooting a 2ºC goal[3].

Based on the current pledges, emission reductions between 2020 and 2050 would need to be increase significantly, with emissions dropping roughly 2.5% annually to reach a goal of 80% below 1990 levels by mid-century[3].

## 2.4 New Zealand national targets

The New Zealand 2020 pledged target is between 10% to 20% reduction below 1990 levels. New Zealand has also set a longer term 2050 target of a 50% reduction below 1990 levels. This is in line with the majority of other developed countries long term targets including Australia, Canada and the EU, but falls short of the globally required 80% reduction on 1990 levels recommended by the IPCC.

New Zealand has a unique emissions profile in that the majority of emissions are from agriculture and a relatively low proportion of emissions are derived from stationary energy due to the widespread use of hydro power generation. In this sense, there is less "low hanging fruit" in terms of energy efficiency which in many countries represents the lowest cost of abatement options. The New Zealand level is therefore considered aggressive as it comes at higher cost per unit GDP than many other countries' pledges including Australia.

In setting the target the New Zealand Government considered a number of approaches in setting its target (See box below).



[3] Levin, K., Bradley, R., *Comparability of Annex I Emission Reduction Pledges: WRI Working Paper*, World Resources Institute, Washington DC, February 2010. http://www.wri.org/publication/comparability-of-annexi-emission-reduction-pledges

**APPROACHES TO EMISSION REDUCTION TARGET SETTING**

**Equal cost approach**

The equal cost approach is based on the cost of meeting a target as a percentage of GDP. It has the advantage that each country carries the same burden for reaching an emissions reduction goal. Richer nations have higher absolute costs than poorer nations. Disadvantages of the approach are that the BAU projections are based on a number of assumptions about the future state of economies and that efforts to reduce emissions in the past are not acknowledged.

**GDP per capita**

The GDP per capita approach reflects the capability to pay for emissions reductions. An advantage of the approach is that countries with higher per capita income pay more. A disadvantage of the approach is that it could potentially penalise richer but more carbon efficient countries (i.e. does not recognise any decoupling of economic growth from environmental harm).

**Contraction and convergence**

The contraction and convergence (or emissions per capita approach) reflects the premise that all people should have equal rights to use the atmosphere. Countries, in the long-term, are given the same target on a per capita basis. Its advantages are that it encourages participation of all countries (and therefore create a global carbon market, as countries with lower than average GHG per capita would be able to sell credits), and more accurately reflects responsibility for emissions reductions than the approaches described above. A disadvantage is that it ignores several important national circumstances such as availability of renewable resources, climatic differences and consumption patterns.

**Past emissions**

The past emissions approach reflects historic responsibility for climate change. An advantage of the approach is that it is based on "polluter pays" principle so countries pay for what they have emitted in the past. A disadvantage of the approach is that it removes focus from current and future emissions.

The New Zealand "equal cost" target equates to an emissions reduction target of between 15% above 1990 levels and 10% below 1990 levels depending on the level of global ambition ultimately agreed to. However, the pledged target of between 10% - 20% below 1990 levels moderates the equal cost approach to take into account foreign affairs and environmental considerations. It also reflects New Zealand's high emissions per capita and the expectations in the negotiations for enhanced action on mitigation[4]. The primary mechanism for achieving both the long term and short term targets is through the NZ Emissions Trading Scheme (ETS).

The Figure 7 below presents the relative emission intensity of various countries in terms of emissions per capita (vertical axis) and emissions per GDP (size of dot point). The horizontal axis shows the relative economic performance of each country with the least developed countries to the far left.

[4] Ministry for the Environment (2009), New Zealand's 2020 Target – further analysis and options, MfE Ref No: 09-B-01825, http://www.mfe.govt.nz/issues/climate/emissions-target-2020/09-b-01825.html

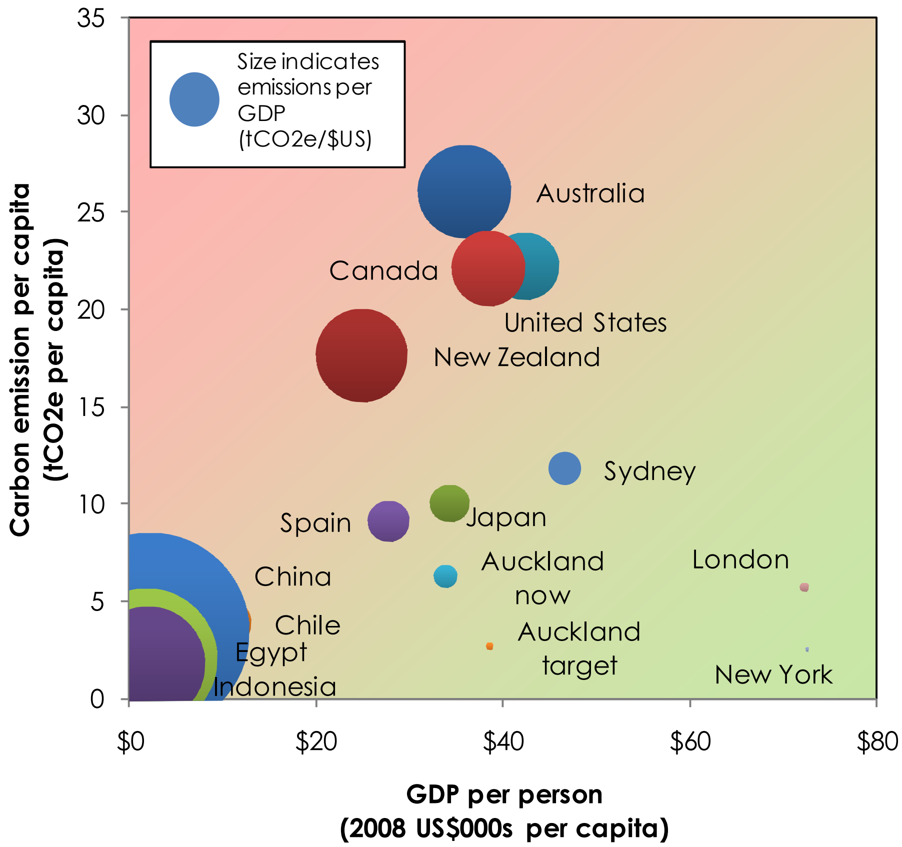


Figure 7 Relationship between emission intensity and economic performance of selected countries and cities

The figure shows that the least developed countries have relatively low emissions per capita, but high emissions per unit of economic output, due to the dependence of these economies on emission intensive industries including manufacturing and agriculture. New Zealand's emission intensity per unit of economic output is relatively high in global terms due to reliance on the emission intensive agricultural sector. Comparatively it is just less than Australia's rating.

The Auckland emission intensity in terms of both per capita and GRP is much less than New Zealand as a whole due to its reduced reliance on manufacturing, industrial and agriculture when compared to the rest of the country and increased reliance on service industries. This is typical of most global cities.

### 2.4.1 Other Global Cities

While many national governments grapple with the reconciliation of these targets, local governments across the world have set about investigating and implementing mitigation targets of their own. Cities in particular have joined forces through programmes such as the ICLEI CCP and the C40 Clinton Climate Initiative to identify effective technological and policy options to reduce GHG emissions.

In this context, it is generally at the city level where targets are first reconciled against actions required on the ground.

Auckland's GHG reduction target will place Auckland slightly ahead of New Zealand and amongst a small group of global leading cities. The table below summarises other targets to demonstrate the order of Auckland's ambition.

Table 3 Comparison of Auckland, New Zealand and international city targets

| City/Nation | Target |
|---|---|
| Auckland | 40% below 1990 levels by 2031 |
| New Zealand | Between 10% and 20% below 1990 levels by 2020<br>50% below 1990 levels by 2050 |
| Sydney | 70% below 2006 levels by 2030 |
| Vancouver | 80% below 1990 levels by 2050 (33% by 2020) |
| Rotterdam | 50% below 1990 levels by 2025 |
| Oslo | 50% below 1990 levels by 2030 |
| London | 34% below 1990 levels by 2020 and 80% by 2050 |

If it is assumed that emissions will abate uniformly across New Zealand, then Auckland will be required to achieve further reductions beyond 2031 to reach a 50% reduction by 2050 and fall in line with the national long term target. The remaining abatement will require further cuts in per capita emissions as Auckland continues to grow to 2051. The remaining abatement will likely require innovation beyond what can be recognised at this point in time and potentially come at a higher cost as the "quick wins" at lowest cost of abatement will have already been realised. In this context, the 2031 target will position Auckland to recognise this abatement and play its fair share in meeting the national target.

## 2.5 Auckland Target in the context of an ETS

The objective of the New Zealand Government's ETS is to incentivise abatement across the economy at least cost. In this respect, there is a risk that the Auckland target may drive perverse outcomes if policies incentivise abatement that would otherwise not be least cost. Notwithstanding, the Auckland target and underpinning policy options have an important role to play in:

- Identifying the extent of abatement that would likely be achieved by the ETS without any additional policy intervention by Auckland Council;
- Identifying the residual exposure to a carbon price;
- Ensuring Auckland businesses and residents are not exposed to high fuel and utility prices as emissions targets are ramped up in future years; and
- Branding Auckland as globally competitive clean and green city.

The objective of the target in this sense is to ensure that there are sufficient opportunities for Auckland businesses and residents to choose low carbon alternatives without affecting quality of life, business viability or productivity.

Key to this is the identification of policy options which are complementary to the ETS. These include:

- Addressing market failures that are not expected to be adequately addressed by the ETS or impinges on its effectiveness in driving emissions reductions (e.g. research and development failures, infrastructure provision, split incentives, information failures and excess market power);

- Addressing barriers that may prevent the take up of otherwise cost effective abatement measures;
- Identifying sectors of the economy where price signals may not be as significant a driver of decision making (including land use planning); and
- Policy options which have a high cost of abatement but include substantial co-benefits may also be considered complementary.

## 2.6 Co-benefits

The focus of this analysis has been to identify GHG strategies that will deliver the Council's target for Auckland. On the whole the strategies have been selected solely on the basis of their direct GHG abatement potential and/or indirect potential (e.g. by fostering behavioural change).

However many of the strategies also have the potential to deliver other beneficial outcomes for the City. These are called co-benefits. By the same token, some strategies may have negative (or adverse) impacts. Co-benefits and adverse impacts could be caused by the strategy itself, or may arise from particular technology or implementation options selected to deliver the strategy.

Identifying and understanding the potential co-benefits provides an opportunity to leverage maximum value from that benefit; and identifying and understanding potential adverse impacts enables Council to plan out or mitigate that impact. Consideration of co-benefits and adverse impacts should also form part of Council's overall cost-benefit analyses of options, and may inform prioritisation of strategies. It is recommended that a risk management process is undertaken for each potential adverse impact as part of further analysis of options.

Section 5 to Section 14 of this report provides a description of each of the proposed GHG abatement strategies. This description includes a brief summary of substantial co-benefits and potential adverse impacts for each option. A more detailed assessment is included at Appendix E. This assessment is complemented by a framework that proposes benchmarks or measures for each co-benefit which can inform Council's assessment and could be used in the future to measure outcomes.

# 3 Baseline and projections

## 3.1 Methodology

The baseline and projections of GHG emissions have been determined from previous studies undertaken as part of the former Auckland Regional Council's GHG Now and GHG Futures projects. These projects quantified the community emissions across each of the former local government areas which formed Auckland Regional Council. The inventories quantified emissions in accordance with the reporting sectors defined by the Kyoto Protocol, namely:

- Energy Generation – Stationary;
- Energy Generation – Transport;
- Fugitive Emissions;
- Industrial Process Emissions;
- Land Use, Land Use Change and Forestry;
- Agriculture;
- Waste.

Emissions associated with the power consumed in Auckland were also included, regardless of where that electricity was generated (and so where the emissions physically occurred).

### 3.1.1 1990 Baseline Methodology

Backcasting of current emissions to 1990 was undertaken as part of the GHG Now study prepared by Maunsell AECOM in 2009. The backcasting methodology adopted for energy related emissions was based on observed trends in fuel consumption between 2001 and 2006 for the residential, commercial and industrial sector and transport which have been recorded by the Ministry for Economic Development since 2001. The agricultural sector emissions were assumed to have remained constant over this period. Emissions associated with waste were assigned to Auckland based on the waste generated within the community which was assumed have increased in line with population trends.

These trends were then extrapolated back from 2001 to 1990 to provide the 1990 emissions baseline.

### 3.1.2 2009 Baseline Methodology

A GHG baseline for 2009 was prepared by URS as part of the GHG Futures project. The URS baseline adopted the same Kyoto sectors as the Maunsell AECOM study, but was based on metered data for the Auckland region including:

- Electricity consumption data provided by Vector;
- Natural gas consumption data provided by Vector; and
- Diesel and petrol consumption data sourced from fuel sales data.

The URS baseline is considered to represent an accurate baseline in terms of total emissions due to the representativeness of the primary source of data. However the metered and measured data was not able to be broken down into sector type and therefore less is known about the contribution of individual sectors of the economy to the overall baseline.

There is however a great deal of data available from EECA End Use Data base and the Economic Futures Study which enabled further breakdown of this data based on the relative energy intensity and activity of each section within Auckland. As a result Arup was able to provide estimations of the spatial and sectoral distribution of the 2009 emissions baseline. The detailed methodology underpinning this distribution is presented in Appendix A.

### 3.1.3 Projections to 2031 Methodology

A number of scenarios were adopted by URS to identify potential GHG futures and determine sensitivities to various parameters including population growth, economic growth, carbon price, oil price and fuel consumption. Arup has undertaken a review of these projections. The outcomes of this review are included in Appendix A.

Projections for the transport sector have also been developed by Auckland University as part of the VIBAT project[5]. These projections are based on increases in vehicle kilometres travelled. These have not been reviewed by Arup and it is not known whether these differ to the projections adopted in this report.

For the purposes of this report, Arup has used a combination of the URS population growth and the URS economic growth scenarios to develop a "naive Business as Usual" (nBaU) approach.

The nBaU assumes that:

- Emissions for private transport and the residential sector increase according to population growth;
- Emissions for the commercial, manufacturing and industrial sectors and freight transport increase according to growth in Gross Regional Product (GRP); and
- Energy use per capita and per unit GRP remains constant.

In addition, the nBaU assumes that the emission intensity of the national grid decreases as the NZ Emissions Trading Scheme drives an increase in renewable energy power plants (based on MED projections). This abatement is attributed to the NZ ETS wherever applicable in the results presented in subsequent sections.

In reality Auckland's GHG emissions are unlikely to track according to nBaU and will undershoot or overshoot depending on a number of factors. This would be the case with any projection, due to the rapidly changing nature of the energy sector and variables in population and economic growth. Whilst variance from the nBaU could affect Auckland's ability to meet the target the strategic options recommended within the GHG strategy will transition Auckland to a low carbon future and may be scaled up (or down) should future monitoring reveal that the emissions are digressing from the ultimate target.

[5] http://www.vibat.org

## 3.2 Baseline Estimates

### 3.2.1 1990 Baseline GHG Inventory

The 1990 Auckland GHG baseline is estimated to be a total of **8,760kt$CO_2$e** with a breakdown as presented in Figure 8 below. Land use change and forestry sinks are assumed to be zero in 1990 for consistency with national inventory protocols.

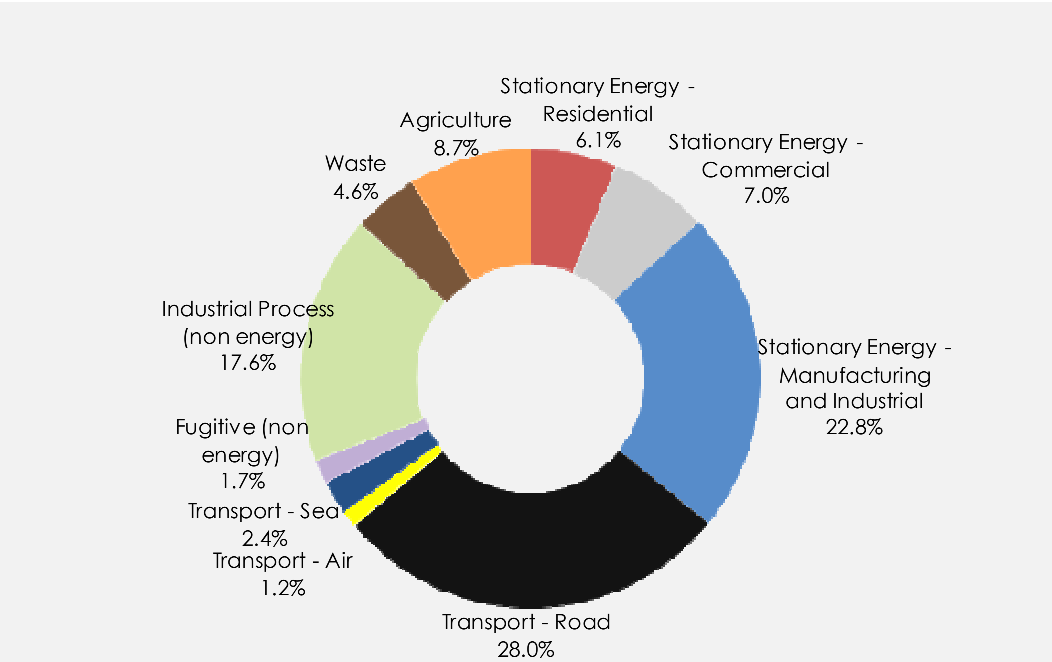


Figure 8 1990 GHG Emissions Baseline

### 3.2.2 2009 Baseline GHG Inventory

Auckland's total GHG emissions in 2009 excluding forestry were estimated to be **10,237kt$CO_2$e** which represents a 17% increase on 1990 levels.

However, consistent with Kyoto Protocol accounting rules, GHG sequestration associated with forestry on land which prior to 1990 was not associated with forestation is able to be subtracted from the emissions total as a GHG sink. This results in a net 2009 GHG emissions baseline of **8,890kt$CO_2$e**, representing a net 1.5% increase on 1990 levels.

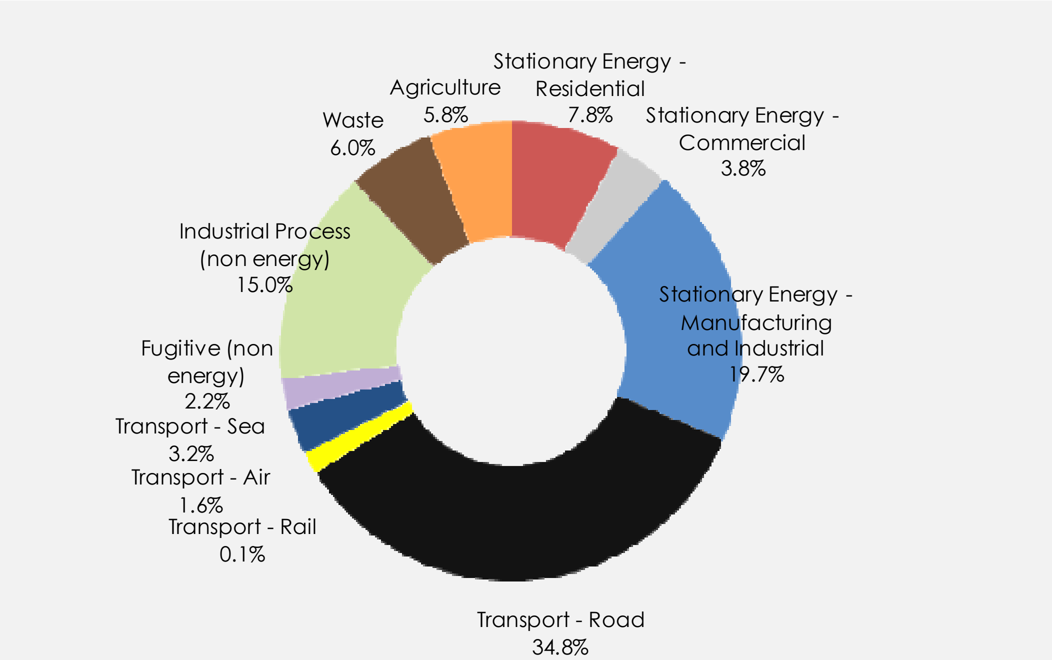


Figure 9 GHG Emissions Baseline 2009

### 3.2.3 2009 Stationary Energy Use by Residential Sector

The 2009 baseline for residential sector emissions was able to be further analysed using a "bottom up" residential model which estimates emissions by dwelling type, dwelling size, occupancy rates, tenure type and income level. This then allowed the 2009 baseline to be distributed spatially amongst the 21 local boards depending on the prevalence of dwelling parameters within each board. The dwelling parameters for each board were obtained from 2006 census and should therefore be considered indicative only of the 2009 distribution. Significant demographic shifts or concentration of residential development which may have occurred during this time is not able to be reflected in the model. The detailed methodology for the residential model is included in Appendix A.

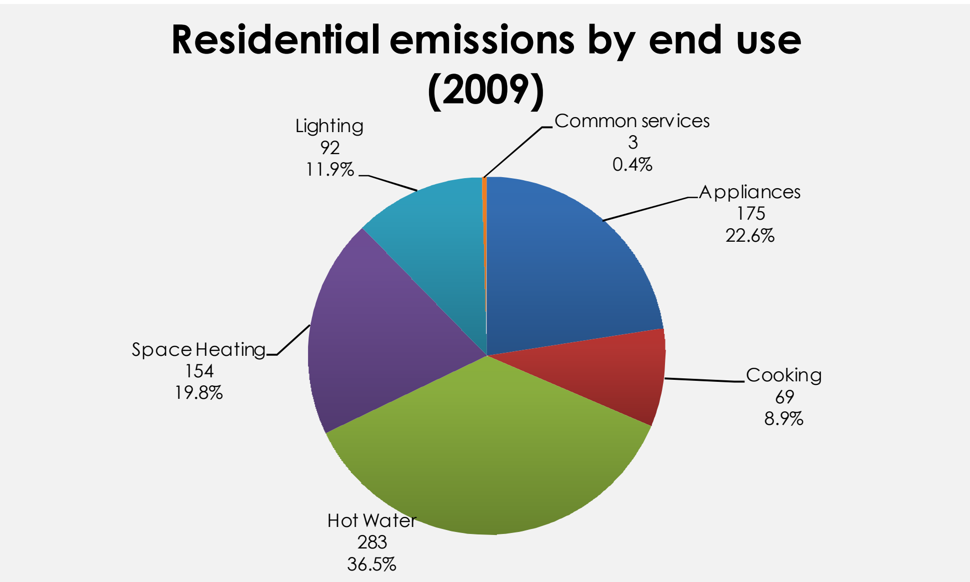


Figure 10 Residential Emissions by End Use (2009)

The residential model shows that emissions within the residential sector are mostly due to hot water heating, space heating and appliance use with significant gains to be made through energy efficiency upgrades targeting this sector.

The residential model is also able to differentiate between dwelling types in terms of separate houses and apartments or attached dwellings. The results of the model for dwelling type are shown in Figure 11 and Figure 12 below.

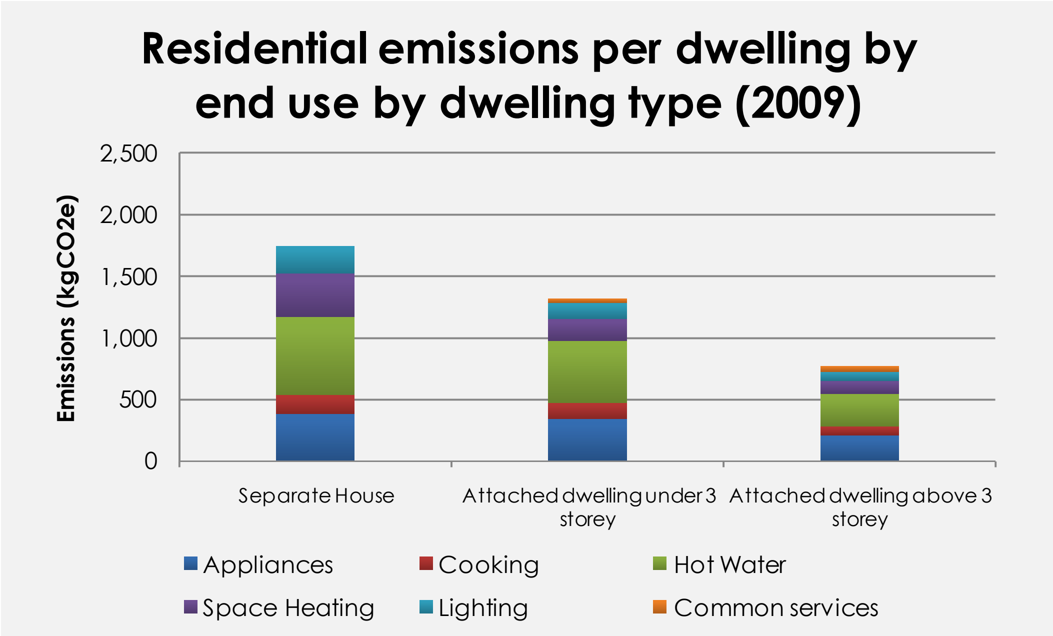


Figure 11 Residential emissions per dwelling by end use by dwelling type (2009)

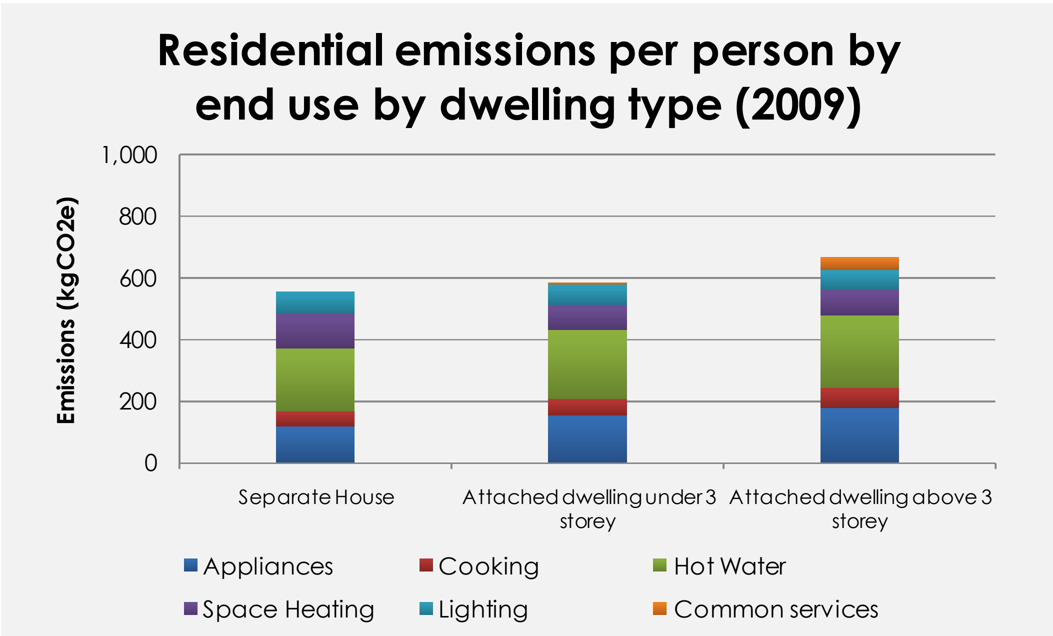


Figure 12 Residential emissions per person by end use dwelling type (2009)

These results show that on a per dwelling basis, smaller attached dwellings outperform larger attached dwellings. However, on a per person basis, these results are reversed showing only a small difference between dwelling types. It should be noted however, that this is not an argument against density and that the results represent existing buildings only. These results are more indicative of historical trends in Auckland of over occupancy of large dwellings and relatively poor performance and under occupancy of existing apartment style buildings.

There is therefore an argument towards quality compact growth which encourages energy efficient high performance attached and/or small lot dwellings over large detached dwellings. The quality compact growth model also favours in-fill development and development adjacent to existing activity centres over greenfield fringe development which tends to increases transport related emissions.

Using the distribution of dwellings types and occupancy rates throughout Auckland, Arup was also able to estimate the spatial distribution of residential emissions by local board as shown in Figure 13 and Figure 14.

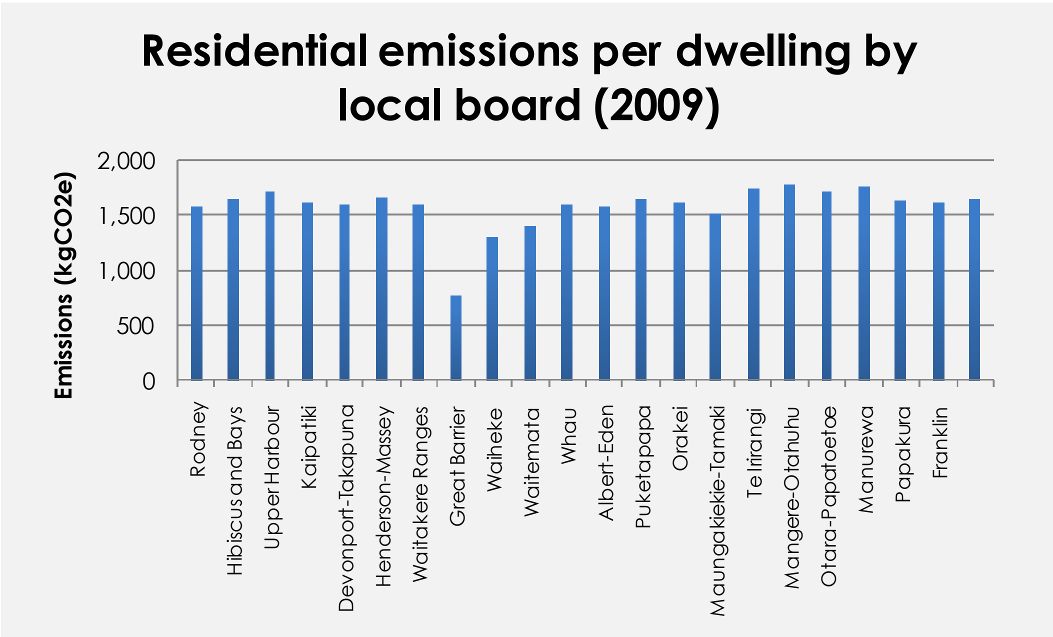


Figure 13 Residential emissions per dwelling by local board (2009)

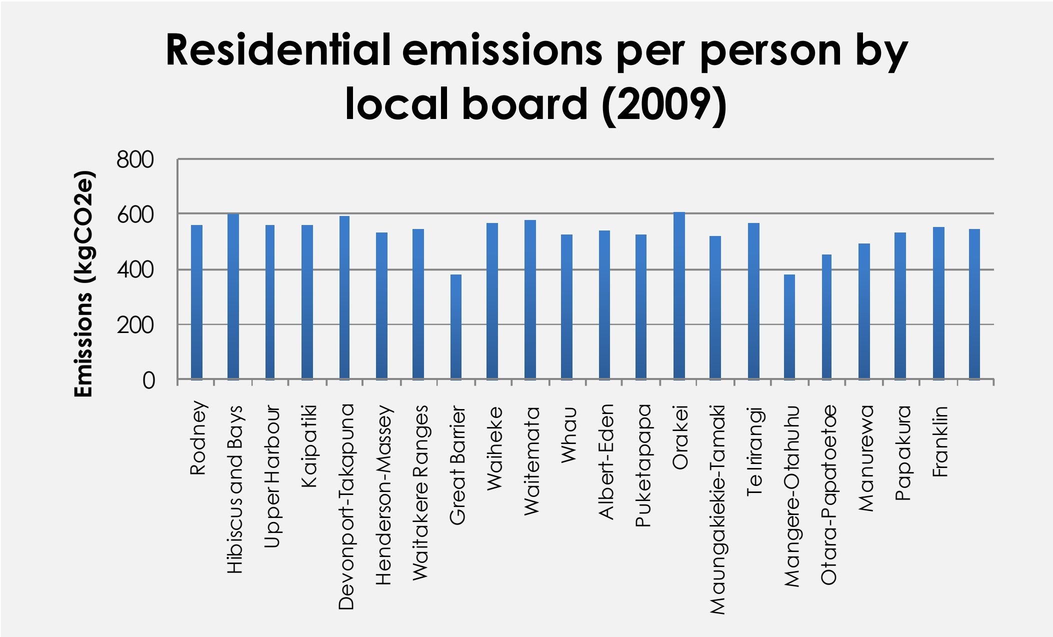


Figure 14 Residential emissions per person by local board (2009)

These figures indicate reasonably consistent results across the Auckland region. Although the residential model takes into account a range of parameters including income and tenure, the results are most sensitive to occupancy rates and size of dwellings. Therefore the areas which tend to have high occupancy levels perform better on a per person basis, but worse on a per dwelling basis.

### 3.2.4 Stationary energy - commercial sector

The 2009 baseline for the commercial sector emissions was also analysed on a sectoral and spatial basis. The commercial sector is represented by a wide range of sectors including education, health, retail as well as standard office based service industries. The majority of the energy consumed within the commercial sector is in building services and lighting. The commercial sector energy intensity is therefore relatively homogenous between each sub-sector with the discrepancies between industries largely as a result of the equipment requirements within the building fabric. The detailed methodology for the commercial model is presented in Appendix B. The relative breakdown between the commercial subsectors is presented in Figure 15 below.

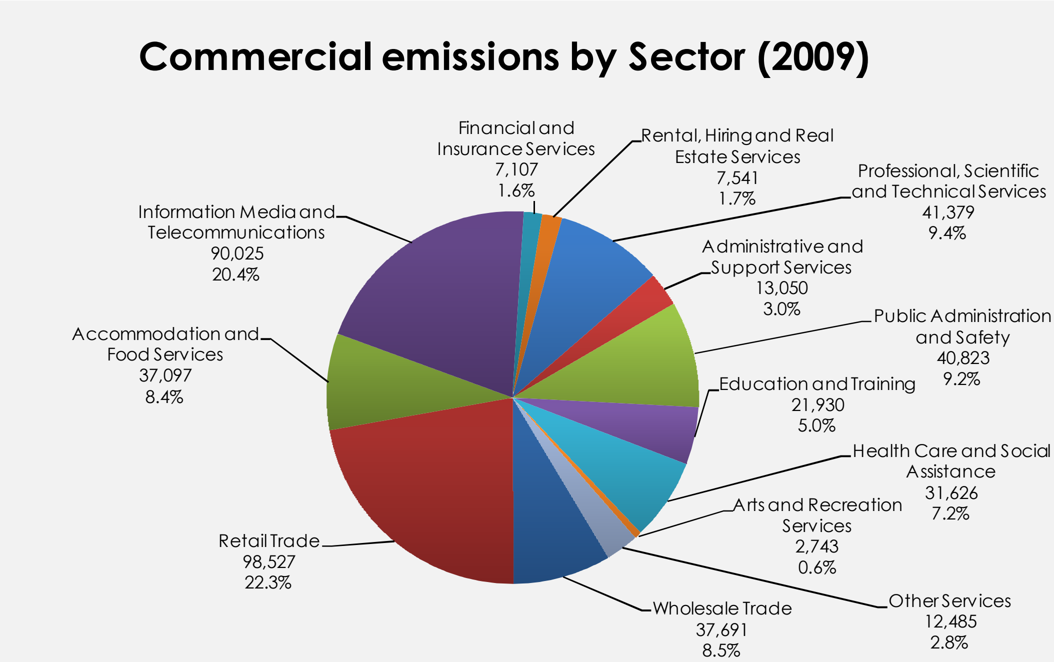


Figure 15 Commercial emissions by sector (2009)

These results in effect describe the relative size of the different commercial subsectors but do not give a good representation of the intensity or location of each subsector.

Commercial sector emissions were also distributed by local board area based on the relative employment concentration of each subsector. The results of this analysis are presented in Figure 16 in terms of absolute emissions and emission intensity (per employee) in Figure 17 below.

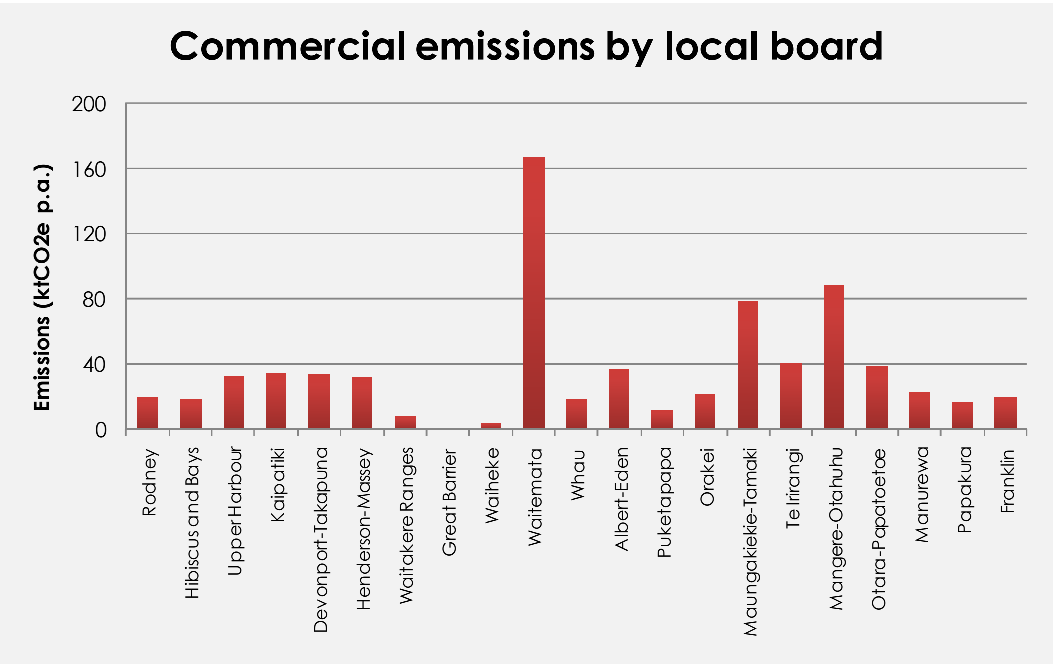


Figure 16 Commercial emissions by local board

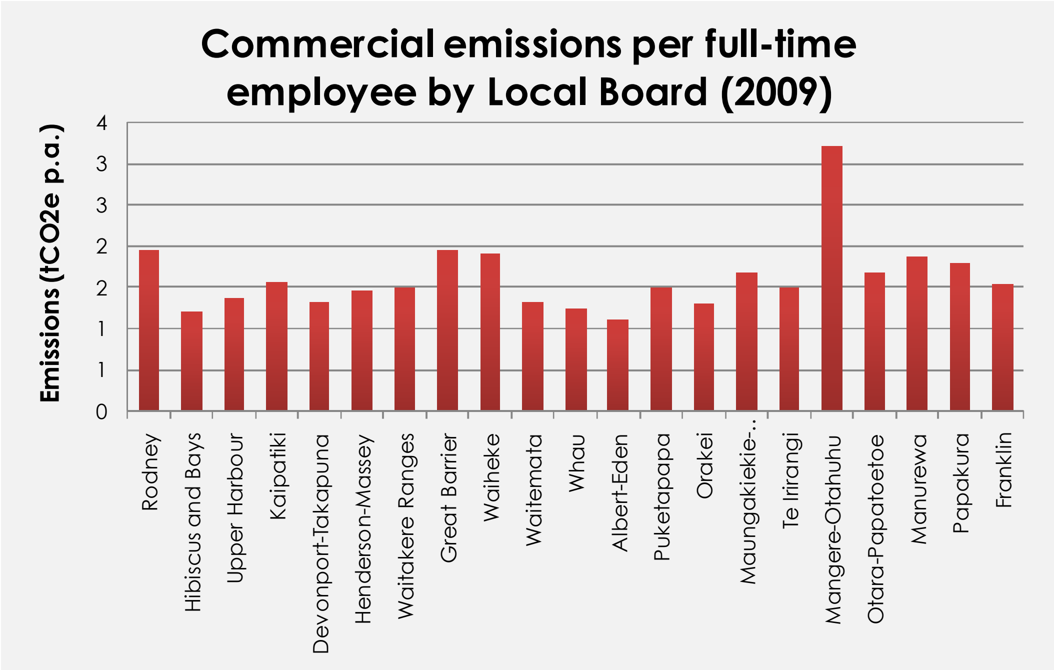


Figure 17 Commercial emissions per full-time employee by Local Board (2009)

Not surprisingly these results show that commercial emissions are concentrated in the commercial centres of Waitemata, Maungakiekie-Tarraki and Mangere-Otahuhu. On a per employee basis commercial sector emissions are greatest in Mangere-Otahuhu due to the higher emission intensity of the commercial subsectors in this region.

### 3.2.5 Stationary energy - manufacturing and industrial

The manufacturing and industrial sector was similarly distributed to represent the different energy intensities and location of industry types. The manufacturing and industrial sector covers an even wider group of industries with many varying processes which are generally more energy intensive than the commercial sector. Therefore there is a larger discrepancy between subsector types. The detailed methodology for analysis of the manufacturing and industrial model is based on energy consumption data by industry collated by EECA within their energy end use database. The detailed methodology is presented in Appendix B.

The relative breakdown between the manufacturing and industrial subsectors is presented in Figure 18 below.

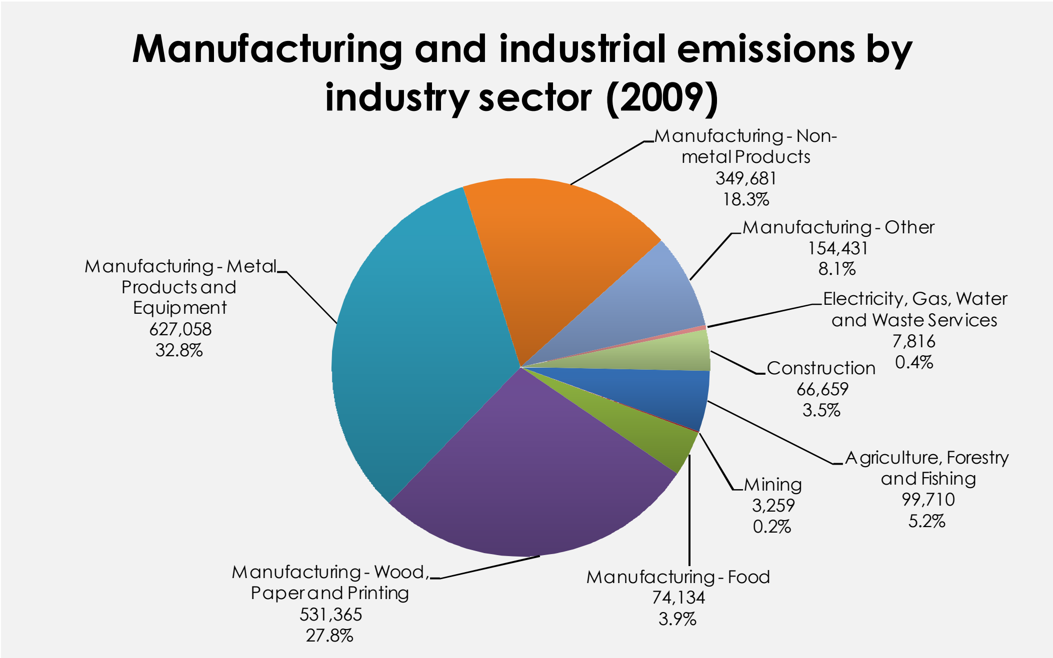


Figure 18 Manufacturing and industrial emissions by industry sector (2009)

These results show that two sectors - 'metal product' and 'wood, paper and printing'- constitute the majority of the manufacturing sector emissions. Emissions associated with the supply of essential services (water, gas, electricity and waste) are relatively low in comparison to the other industries.

Manufacturing sector emissions were also distributed by local board area based on the relative employment concentration of each subsector. The results of this analysis are presented in Figure 19 in terms of absolute emissions and emission intensity (per employee) in Figure 20 below.

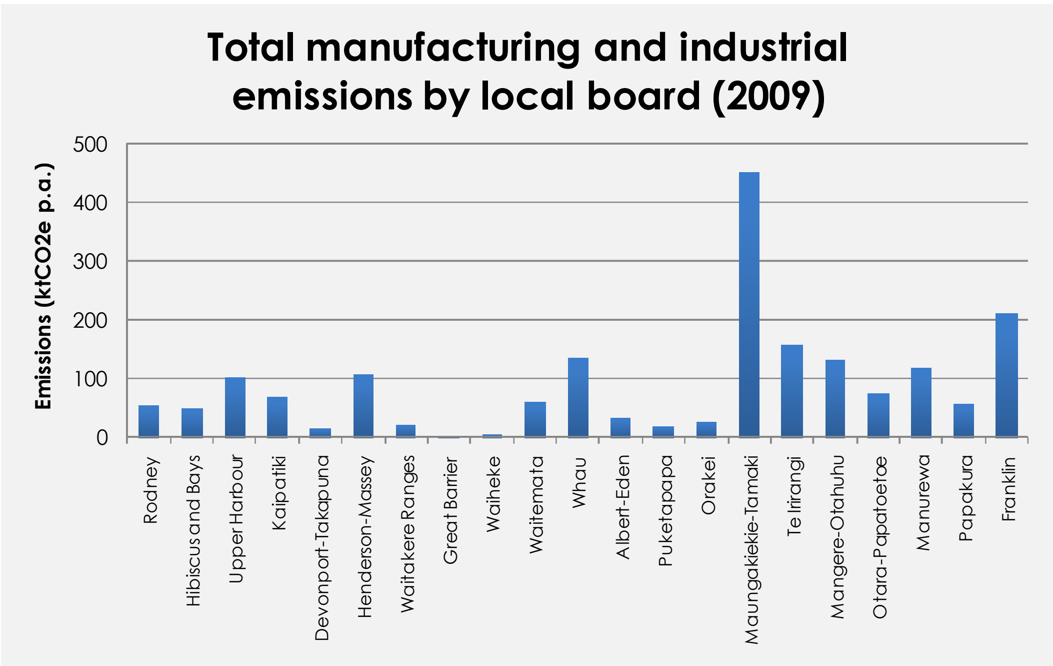


Figure 19 Total manufacturing and industrial emissions by local board (2009)

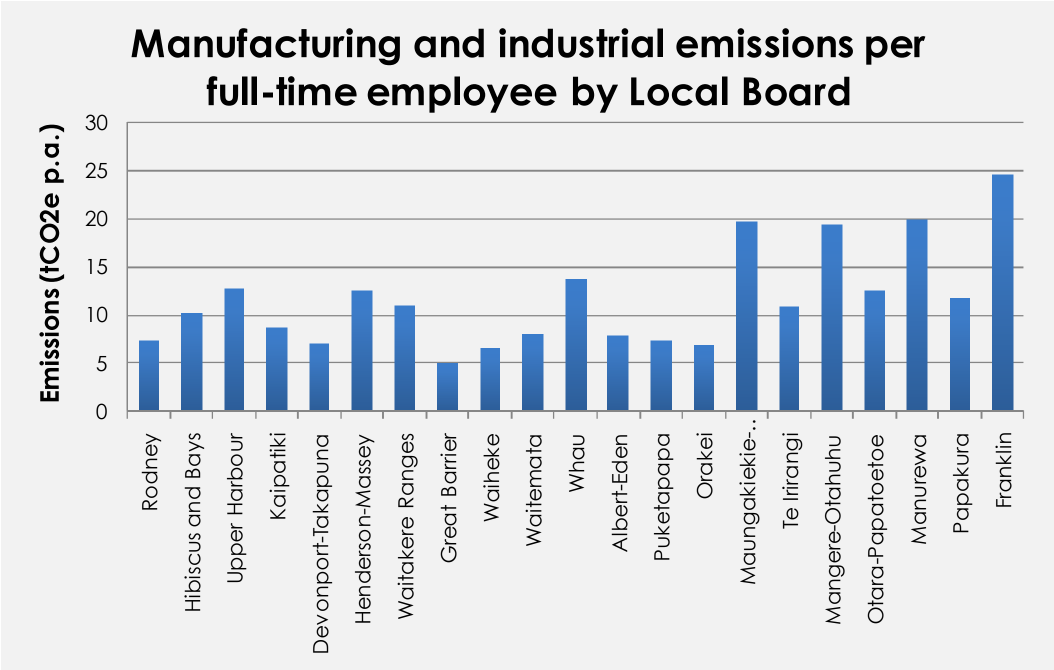


Figure 20 Manufacturing and industrial emissions per full-time employee by Local Board

These results show the largest absolute emissions in Maungakiekie-Tamaki and Franklin to the south, with lower total emissions in the northern areas. Franklin area shows the highest emission intensity due to the prevalence of the heaviest industry in this area.

### 3.2.6 Transport

GHG emissions associated with the transport sector were determined by URS using petrol and diesel sales data for all fuel purchased within Auckland. In reality, not all of this fuel will be consumed on Auckland's roads. For example, fuel purchased by Auckland's inter-regional freight will be mostly consumed outside of the region. Similarly some travel on Auckland's roads may be fuelled by petrol and diesel purchased outside Auckland.

For the purposes of this report, it is estimated that approximately 63% of freight fuel is consumed outside of Auckland's road based on estimates of VKTs travelled on Auckland's roads and the energy intensity of freight vehicles. It is further assumed that all fuel purchased in Auckland for use in private vehicles, commercial vehicles and bus is consumed on Auckland's road network.

In addition some of this fuel use is associated with non-transport uses including construction plant and equipment, agricultural plant and equipment and diesel generators. Arup estimates that approximately 6% of petrol and diesel emissions are associated with non-transport use based on data from EECA's energy end use data base. These emissions have been reapportioned to stationary energy sectors above.

The remainder of the transport emissions are separated into heavy freight, commercial vehicles, rail and private transport using EECA End Use Database allocations. Air and sea transport emissions have been taken directly from the URS projections representing trips made by Auckland residents only (rather than all trips made to and/or from Auckland.

The distribution of transport emissions by sector is presented in Figure 21 below.

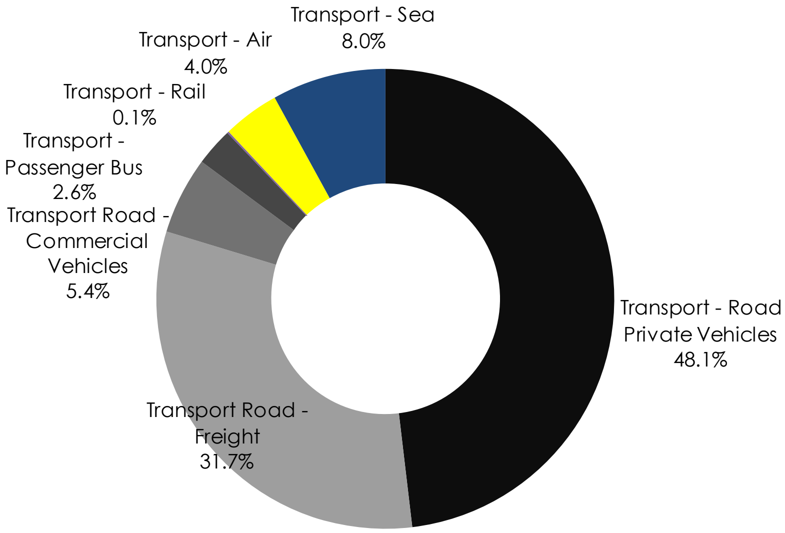


Figure 21 Transport emissions by sector

Road based transport emissions, including both freight and private travel constitute the largest sector of emissions. These emissions include emissions associated with fuel purchased within Auckland but potentially consumed outside of Auckland's road network.

Private transport GHG emissions were able to be spatially distributed using Auckland Council's 2006 ATM3 model which assigns home based travel to either the residence or place of interest (such as work, school or shopping). The 2009 emissions associated with private trips were allocated to local board by Arup using the 2006 ASTM3 distribution under two methods.

- The first method assigned all trips to the place of residence. This representation helps to understand which communities travel the most.
- The second method assigns all trips to the place of interest. This method helps to understand common destinations and is dominated by commercial centres[6].

Further detail around the distribution methodology is available in section 10. The transport emissions distributed spatially by this methodology are presented in Figure 22 below.



[6] Both these methodologies are in contrast to the VIBAT model currently being developed by Auckland University which spatially assigns emissions based on 'end of pipe' location. This methodology provides an indication of the most heavily trafficked roads but does not provide detail relating to trip types and in particular which areas are responsible for the generation of the most trips.

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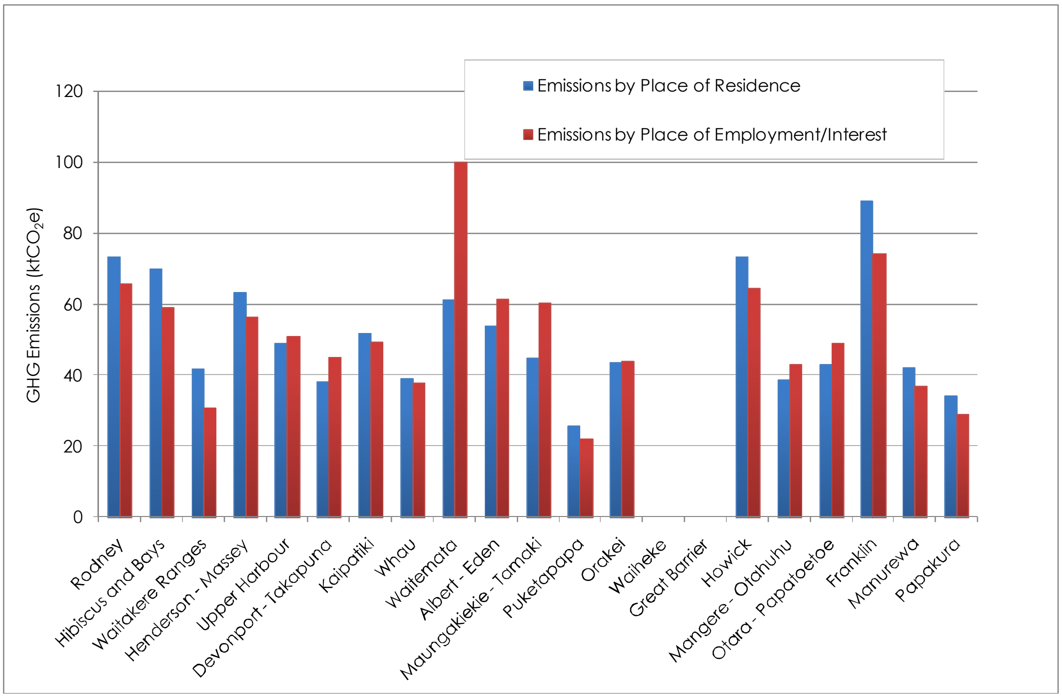


Figure 22 Total vehicle emissions by local board (2009)

The difference between the red and blue columns compares the emissions associated with trips made *by* a community to the trips made *to* a community. In theory a self sufficient community which is able to support its own employment and service needs will have a lower level of emissions associated with place of residence. In contrast a residential area with few job options and services will have a higher level of emissions by residence. Centres such as CBD and the airport which attract trips and have fewer residential options will have higher emission by place of interest (red). This provides further evidence in support of quality compact growth models.

Figure 23 and Figure 24 below indicate the emission intensity of these trips.

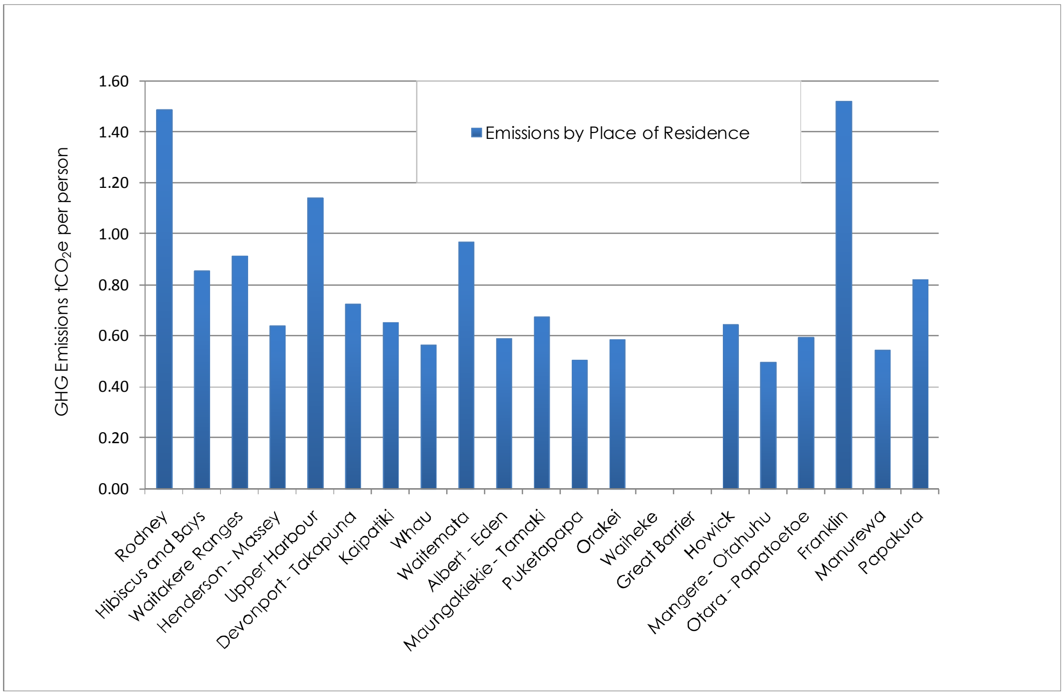


Figure 23 Vehicle emissions by place of residence per resident by local board (2009)

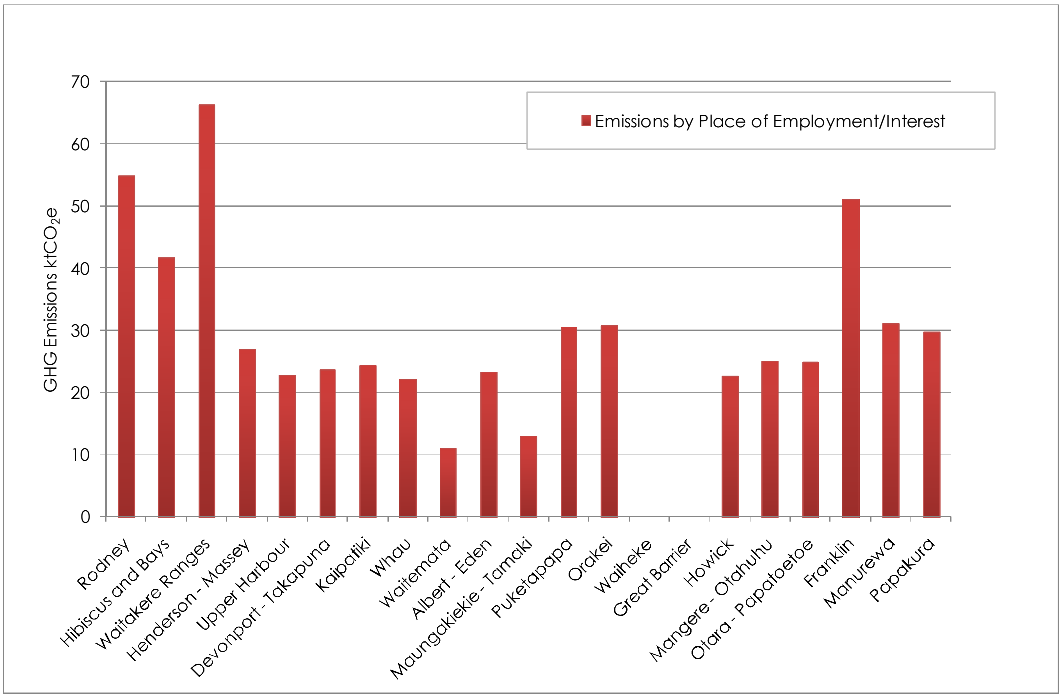


Figure 24 Vehicle emissions by place of interest per employee by local board (2009)

The per person or employee results indicate the relative distance travelled to and from each community or the extent to which private vehicle is the predominant mode of transport. This provides an explanation as to why the fringe areas give rise to higher transport emissions per person than the inner suburbs where trips are shorter and more often made by active transport or public transport modes. Trips made to the city as a place of interest appear to have relatively low emission intensity, while trips made by the City's residents appear to have relatively high emission intensity.

## 3.3 2031 Projections GHG Inventory

The total emissions for the nBaU in 2031 is projected to be 13,283 kt$CO_2$e excluding forestry. This represents a 52% increase on 1990 levels and 30% increase on 2009 levels.

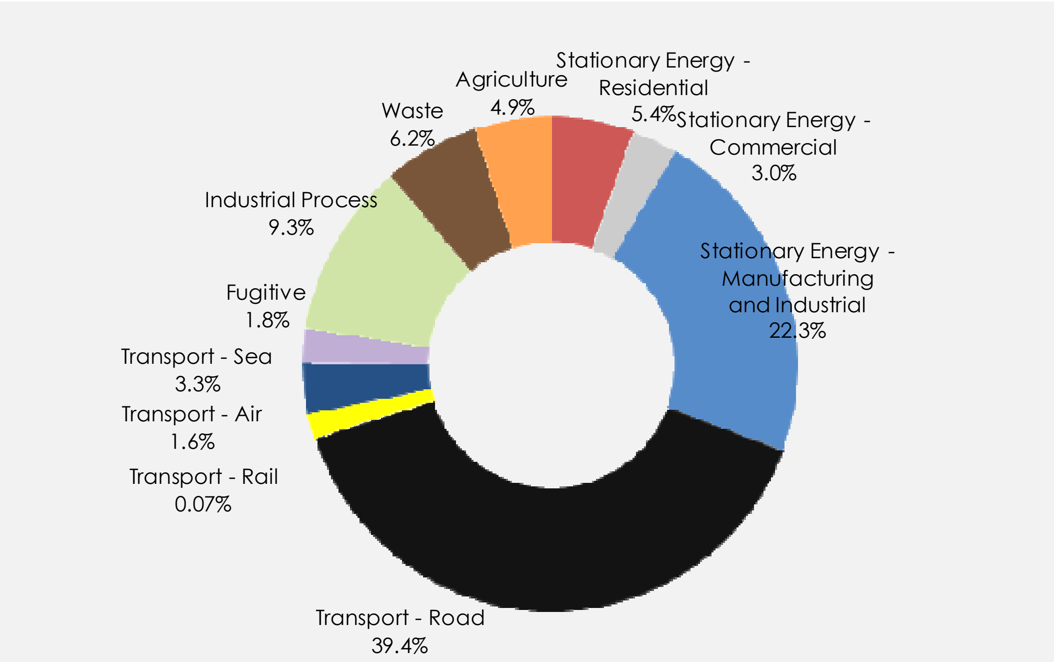


Figure 25 GHG Emissions Baseline 2031 nBaU

When GHG sequestration associated with forestry[7] is subtracted from the emissions total as a GHG sink, this results in a net 2031 nBaU projection of **12,172kt$CO_2$e**, representing a net 39% increase on 1990 levels and 37% on 2009 levels. The BAU analysis above represents a no GHG price scenario, ie without greening of the grid as a result of the ETS. The potential impact of the ETS on BAU is shown at Figure 27 and Figure 28.

The 2031 projection was further broken down into new and existing facilites in order to understand the relatve portion of emissions in 2031 that can be attributed to growth or existing facilities. This breakdown is presented in Figure 25 below, and informs later analysis of the savings and reductions achieved from various initiatives.

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[7] As described previously, forestry which has been established since 1990 can be counted as a GHG sink in accordance with the Kyoto Protocol accounting rules and NZ Emissions Trading Scheme rules for accounting of forestry credits.

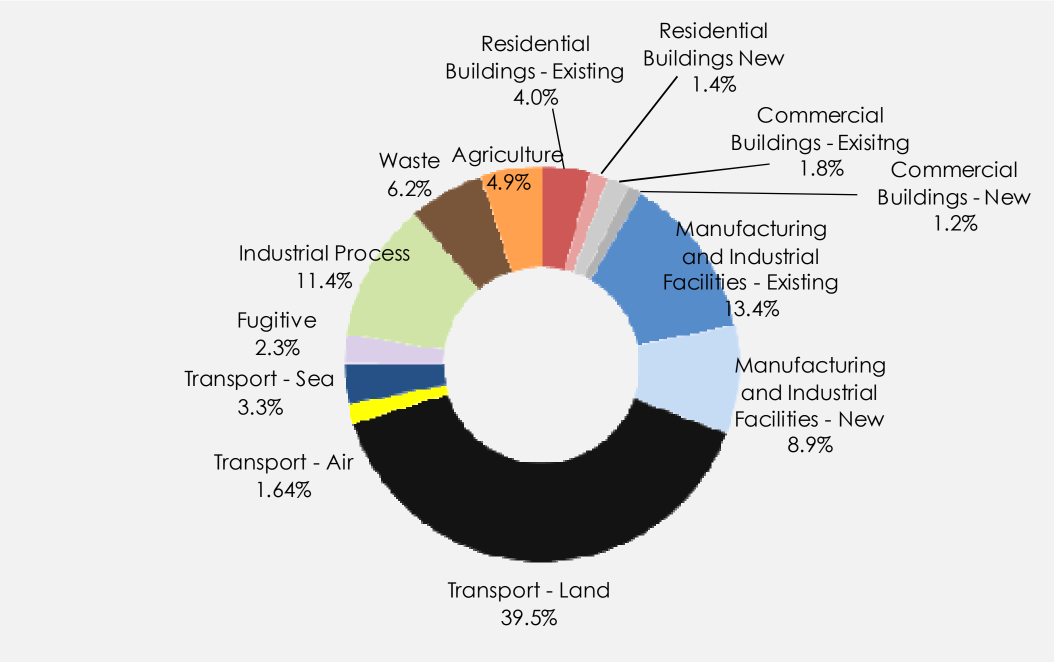


Figure 26 GHG Emissions Baseline 2031 nBaU (Existing and New)

The nBaU represents just one scenario of potential growth in emissions to 2031. There are a number of factors which could profoundly impact this.

One potential BAU future, independent of any intervention by Auckland Council, would see a reduced growth in emissions as a result of energy efficiency and a shift towards renewable energy across the wider New Zealand grid. There are a number of factors which may contribute to this including GHG price, fuel price and associated technological innovations. For the purposes of this strategy Arup has estimated the emission reductions which are projected to occur as a result of a wider “greening of the grid” under the NZ Emissions Trading Scheme. This is included as mitigation measure and is not considered within the nBaU described above which represents a no GHG price scenario.

Another potential BAU future would see a larger rise in emissions driven by growth in per capita energy consumption. Despite recent policy interventions and technological innovations to reduce energy use in developed countries across the world, there has been an exponential growth in per capita energy consumption across the majority of the western world. This has been largely driven by increasing prosperity which translates into bigger homes, extended use of heating and cooling systems in buildings, increasing use of energy intensive appliances per person and increased personal travel.

This trend is not as profound in Auckland which has experienced reasonably consistent energy per capita values over the last five years. Auckland may therefore be uniquely placed to avoid the phenomenon of growth in energy consumption and leapfrog other cities across the world in terms of GHG emissions per capita. However increasing prosperity in Auckland could drive an increase in per capita energy consumption if the community is not engaged in understanding the impacts of energy consumption and if the investment has not been made in infrastructure to support lower energy and lower emission lifestyles and businesses.

## 3.4 Target

The Council's proposed target is to achieve a 40% reduction on 1990 levels by 2031. This equates to a maximum of 5,256kt$CO_2$e annually by 2031. This represents a:

- 49% reduction on 2009 levels (excluding forestry),
- 61% reduction on nBaU (including the impact of the ETS on the electricity sector) and
- 64% reduction on nBaU (excluding the impact of the ETS on the electricity sector).

These results are presented Figure 27 and Figure 28 below.

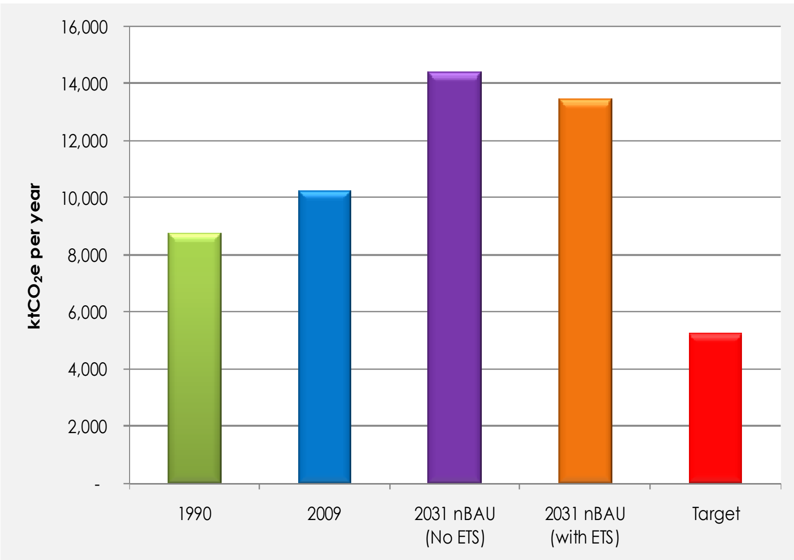


Figure 27 Baseline, projections and target (excluding forestry)

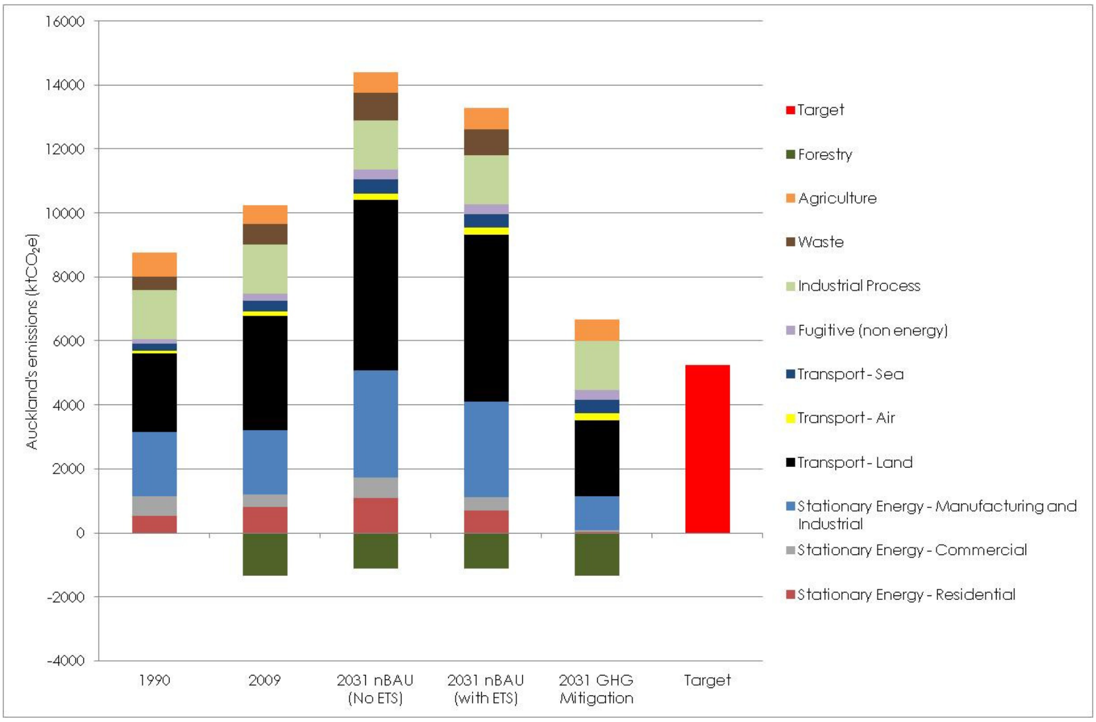


Figure 28 Baseline, projections and target by sector

# 4 Methodology

The following section outlines the process used to identify and model options to reduce Auckland's existing GHG emissions as well as to provide for low GHG growth.

## 4.1 Identification of options

Options were identified by consideration of the major emissions sectors and matching these against potential abatement strategies.

Policy options for abatement have been identified from:

- World's Leading Practice Review;
- Previous studies prepared for Auckland Council including GHG Now, GHG Futures and Renewable Energy Study; and
- Additional options from Arup's knowledge and experience.

Options were categorised under the following:

- Energy supply – options that reduce the GHG intensity or energy efficiency of delivered energy from the power plant to the consumer;
- Buildings – Residential – Options that reduce the energy demand within residential buildings;
- Buildings – Commercial – Options that reduce the energy demand within commercial buildings;
- Manufacturing and Industrial facilities – Options that reduce the energy demand within manufacturing and industrial facilities;
- Transport – Options that reduce the GHG intensity, energy efficiency and need for travel within the Auckland region;
- Waste – Options that reduce the GHG intensity of the disposal of waste;
- Behaviour change – Options which establish an imperative for prioritisation of low GHG, energy efficient outcomes via everyday decision-making;
- Industrial Process Emissions – Options which address the industrial process emissions from Glenbrook Steel Mill;
- Other: Other sectors including agriculture, air and sea travel and fugitive emissions which represent relatively small contributions to Auckland's overall emissions. Options have been suggested for these sectors but not quantified.

## 4.2 Mitigation hierarchy

In determining the extent of abatement available from each policy option, Arup has applied a mitigation hierarchy.

1. Avoid – Activities which generate GHG emissions are avoided altogether (e.g. avoid unnecessary travel by co-locating essential services within residential areas, avoid development of emission intensive industry sector by attracting green business);

2. Reduce – Emission intensity of activities are reduced by either reducing the extent of the activity (e.g. reducing travel distances) or reducing the energy intensity of the activity (shifting to less emission intensive forms of travel, energy efficiency);
3. Replace – Replace emission intensive fuel sources with alternatives (e.g. electric vehicles, biofuels, renewable energy); and
4. Offset/Sequester – Sequester emissions which have already been generated (forestry, marine and soil sinks).

This approach ensures that there is no double counting of abatement for each policy option.

### 4.2.1 Stationary Energy Mitigation Hierarchy

For stationary energy, the hierarchy implied the following staged approach to emissions abatement

1. Subtract abatement associated with industry shifts or change in urban form from nBaU;
2. Subtract abatement associated with energy efficiency; and
3. Subtract abatement associated with renewable energy.

This approach also ensured that renewable energy was not generated in excess of any particular building's or precinct's needs to which it was applied.

### 4.2.2 Transport Energy Mitigation Hierarchy

Similarly, for transport fuels, the hierarchy implied the following staged approach to emissions abatement

1. Subtract abatement associated with trip avoidance and trip length reduction from nBaU;
2. Subtract abatement associated with modal shift;
3. Subtract abatement associated with improved vehicle efficiencies;
4. Subtract abatement associated with fuel switching to electric vehicles and biofuels;
5. Subtract abatement associated with renewable energy supplying electric vehicles.

This approach ensured that renewable energy and biofuels were not assumed to be sourced in excess of Auckland's needs.

For emission reductions on Auckland transport network, estimates of reductions in vehicle kilometres travelled (VKTs) were determined from modelling of policy packages using Auckland Council's ASTM3 package. Further details are provided in Appendix F.

### 4.2.3 Waste mitigation hierarchy

For waste, emissions reductions were assumed to occur as a result of the application of the waste hierarchy. That is:

1. Avoid;
2. Reduce;
3. Reuse;
4. Recycle;
5. Energy recovery;
6. Disposal.

It was assumed that only the non recyclable organic component of the waste is available for any waste to energy initiative.

## 4.3 World's leading practice review

The long list of options includes policy options selected by other cities around the globe. The list of cities used for comparison was drawn from cities that were considered to be 'reasonably comparable' to Auckland. The selection was based on similarities of the cities in terms of:

- City geographic size;
- City Population;
- Climate conditions;
- Economy;
- Governance model;
- Land use mix and urban form;
- Industrial activity;
- Car dependency;
- Mix of generation technologies within the existing stationary energy supply.

This allowed the development of realistic measures which are applicable to the Auckland context in more than one way and potentially yield liveability co-benefits.

Arup has largely drawn from medium-sized cities that are the economic powerhouse of their region yet do not compare on a global scale to the likes of New York, Tokyo or Shanghai.

Our list of selected cities therefore comprises the following:

- Sydney (land use/ urban form, car dependency);
- Adelaide (land use/urban form, geographical size);
- Brisbane (governance model);
- Melbourne (climate);

- Oslo (car dependency);
- Helsinki (population size);
- Rotterdam (industrial activity);
- Vancouver (energy mix);
- London (governance model).

The review of the initiatives and plans proposed and implemented by these cities also provides insights into the transformational potential of some of these measures compared to others.

Not all of the measures listed in the world's leading practice review sections have been fully implemented but in many cases cost estimates and expected abatement potential are documented and so provided valuable information for this study.

Throughout this section, a short review of the world's leading practice will be supplied for each of the sectors for which options have been developed.

## 4.4 Assessment of options

Each policy option was assessed to determine:

- The extent of GHG abatement over the lifetime of the option and the annualised 2031 abatement;
- The capital costs and whether these costs were likely to be borne by government (either central or local), industry or the community;
- The lifecycle costs and benefits to government, industry and the community; and
- The associated co-benefits.

In order to undertake this assessment, high level assumptions were required in terms of:

- The extent of size of each options;
- The effectiveness or efficiency of each option;
- The timeline for implementation;
- The extent to which industry could co-contribute to capital and ongoing costs.

These assumptions were based on publicly available data and the experience of other cities and are specific to each policy option as outlined in the following sections.

## 4.5 Level of Council intervention

For each option, the level of Council intervention will depend on the implementation mechanism. Many of the options will be in part facilitated by the national Government's Emissions Trading Scheme (ETS). This has been taken into account within the Strategy in the following two ways.

Firstly, it has been assumed that the ETS represents a policy option in itself which will have the effect of reducing the emission intensity of grid electricity consumed in Auckland through the development of renewable energy power plants outside of Auckland. The reduction in emission intensity of grid electricity contributes to the total emissions reduction in Auckland and Auckland Council therefore has an advocacy role to ensure that the ETS continues to be an effective mechanism in facilitating low GHG energy generation.

Secondly, it has been assumed that industry will invest in options only where a commercial return is possible. The GHG price under the ETS will improve the business case for industry investment in renewable energy and energy efficiency. This has been incorporated in the consideration of the level of industry investment within each relevant policy option. Without the ETS the cost burden of these options would shift towards Government.

Despite the far reaching effect of the ETS, there is strong rationale for additional intervention by Council to ensure that:

- Market failures which may prevent the GHG price signal from achieving lowest cost abatement do not exist including information barriers and split incentives;
- Planning decisions made at council level do not “lock in” GHG intensity;
- Auckland community and businesses have a range of options available to actively choose to reduce GHG emissions rather than incur a GHG price; and
- Auckland does not incur a disproportionate share of the cost of abatement for all of New Zealand.

For each option, Arup has identified a range of potential implementation mechanisms and the corresponding appropriate level of council intervention reflecting the Auckland Council value chain.

For many of the options there are a range of potential implementation mechanisms which will require further investigation, negotiation with central government and with industry to determine the appropriate level of Council intervention

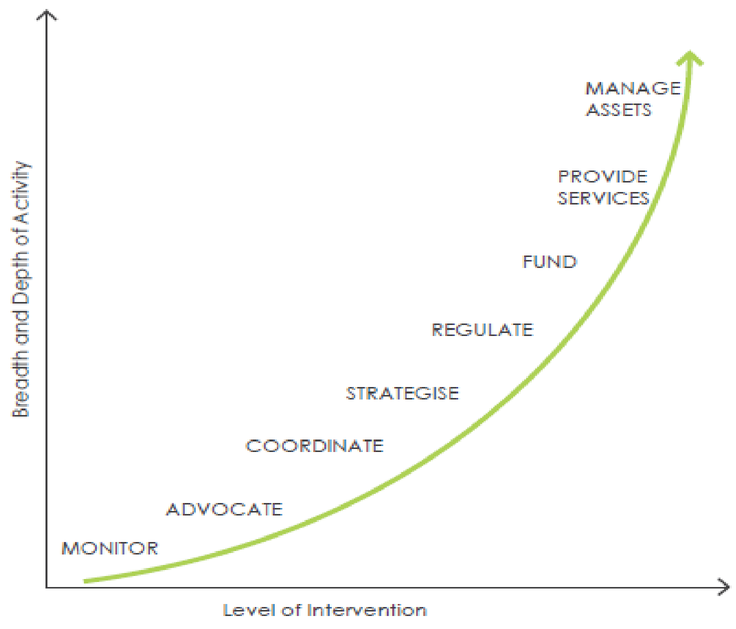


Figure 29 Auckland Council Value Chain

## 4.6 Co-benefits

In addition to delivering GHG reduction many of the initiatives may deliver other benefits for Council, residents and businesses. Or initiatives may have adverse impacts that need to be mitigated. The potential co-benefits/adverse impacts for each option are presented at Appendix G and key benefits are described throughout Sections 5 to 12. A methodology for future assessment is also provided at Appendix G. This can provide Council with a measurement framework for monitoring the non-carbon benefits and impacts of initiatives.

A quadruple bottom line framework has been used to categorise the co-benefits or adverse impacts. These are described below.

### Economic

| | |
|---|---|
| **Cost of living:** | Initiatives that will reduce or increase household costs (including power, water, gas, food and travel) through a change to the unit cost and/ or change in rate of consumption of the service. |
| **Cost of doing business:** | Initiatives that could reduce or increase the costs of doing business, as set out above for cost of living and including the cost of freight and raw materials and any proposed increase in emissions and waste charging. |
| **Employment:** | Initiatives that have the potential to change supply and demand in the employment sector, resulting in job, labour or skills shortages. This could impact the capacity of industry to meet demand for a program if there are insufficient workers with the required skills. |
| **Productivity:** | Initiatives that may benefit or hamper overall productivity through changes in labour force, transport networks, supply of resources, regulation or other factors contributing to productivity. |
| **Energy security:** | Initiatives that are likely to increase or decrease dependency on imported fuel sources and/or vulnerability to network disruptions |

### Environmental

Note: GHG reduction and resultant mitigation of climate change effects is an overall benefit. This assessment considers specific direct environmental benefits/impacts from individual initiatives, other than the GHG benefit.

| | |
|---|---|
| **Local air quality:** | Initiatives that will improve or detract from local air quality, particularly as it relates to the health of people and the environment. |

| | |
|---|---|
| **Water quality:** | Initiatives that have the potential to improve or lessen water quality in natural waterways and harbours, including measures of flow as well as quality indicators. |
| **Bio-diversity:** | Initiatives that may directly contribute to an increase in, protection of, or decline in bio-diversity by impacting on habitat, connectivity and/or migratory paths of fauna. |
| **Waste to landfill:** | Initiatives that will reduce or increase the quantity and toxicity of waste being disposed to landfill, with consideration of the impact on land use and surrounding environment rather than GHG benefit. |
| **GHG emissions beyond Auckland:** | Initiatives that may directly reduce or increase GHG emissions beyond Auckland, for example by sourcing a GHG intensive process from another location, or by supplying surplus green energy to another community. |

## Social

| | |
|---|---|
| **Health and wellbeing:** | Initiatives that have the potential to foster safe, healthier, more active lifestyles and therefore improve the overall health and well-being of the community. Or, conversely, initiatives that may exacerbate personal safety, lifestyle related health issues or introduce new health threats to the community. |
| **Household affordability:** | Initiatives that could impact the cost of housing, particularly the availability of affordable housing in affordable locations for low income households. |
| **Social equity and access to resources** | Initiatives that can contribute to greater social equity and equitable access to resources, thereby improving social cohesion. Or initiatives that have the potential to be socially divisive by creating greater socio-economic inequality or shortages in resources, jobs, housing or transport infrastructure. |
| **Social capital and community resilience:** | Initiatives that may enhance or detract from existing social systems, networks and capital and therefore affect the capacity of the community to respond to and recover from disasters or significant events. This may include the resilience of buildings, infrastructure and supply networks, as well as social systems. |

### Cultural

| | |
|---|---|
| **Pride and connection between people and place:** | Initiatives that have the potential to build a sense of community pride, reinforce Maori pride in Auckland and create new community events, symbols and narratives. |
| **Sites of significance:** | Initiatives that may reinforce or detract from the geo-physical identity of Auckland, including key cultural sites, landmarks and vistas, and character. |
| **Local knowledge:** | The extent to which initiatives use and develop local resources, organisations and knowledge. |
| **Community representation and leadership:** | Initiatives that provide opportunities for community leaders, community sectors and/or cultural groups to demonstrate leadership within their community or the broader Auckland community. |

## 4.7 Metric based indicators

The assessment of each policy option also provides metric based indicators which will allow Council to track progress towards the overall GHG target. The metrics represent proxy data for GHG emissions abatement within any given sector and specify medium term targets (2020) and long term targets (2031). The majority of the metrics are either already available to Council through existing monitoring programmes (e.g. census data, transport model outputs, economic data and utility data) or could be easily obtained from stakeholders or implementation of Council's own monitoring programme.

# 5 Policy options – Energy supply

## 5.1 World's leading practice

In terms of energy supply options, Arup reviewed proposed and implemented options in Adelaide, Brisbane, Melbourne and London. These options address renewable energy sources and mechanisms to incentivise distributed energy generation throughout cities as a way of reducing the GHG-intensity of the electricity grid.

Under the heading of 'Climate Change', the London Plan makes metropolitan-wide policy recommendations for the production of sustainable energy, consisting primarily in distributed energy production throughout London's boroughs. The policy provides the mandatory requirement for a 20% reduction in GHG emissions by new developments, unless it can be demonstrated that onsite distributed and renewable energy generating infrastructure cannot be retrofitted onto the site. This policy is complemented by a renewable energy masterplan which identifies sites across all boroughs that are suitable for wind turbines, the establishment of a large wind turbine scheme for the metropolitan region. London has therefore established a spatial and metropolitan wide plan to green the energy supply. This is very similar to the approach taken by South East Queensland, where renewable energy production potential is being mapped regionally.

London is also piloting 10 Low GHG Zones, a community approach to reducing $CO_2$ emissions. These 10 zones are both part of a larger strategy to reduce short term emissions and also serve as demonstration schemes to replicate elsewhere in the city and achieve 60% GHG emissions reduction by 2025, as per the Mayor of London's targets.

In Adelaide, all new development that provides embedded and distributed renewable energy (wind and solar) and smart grid/green grid technology is a deemed compliant development.  This policy ties the provision of distributed energy generation infrastructure to the planning controls, making development easier for development schemes that are able to take pressure off centralised, GHG-intensive grids.

Melbourne has opted for a combination of renewable energies and combined heat and power (CHP) and combined cycle cooling as a strategy for reducing the GHG intensity of the energy supply to the city.

Auckland, as the largest urban centre in New Zealand, will be benefitting from the positive impacts of national level policies that will deliver on national GHG emissions. It is important to discuss some of these policies in detail in this report, as they set the context for local government actions, especially in the space of energy supply.

The national emissions trading scheme is the main lever that can be utilised at a local level to place GHG-intensive energy supply at a competitive disadvantage in relation to renewable energy supply. This has transpired in the promotion of renewables to direct consumers of energy, such as businesses and households. EECA has established a consumer information program, Energywise, which promotes and provides information on micro-generation and distributed generation.

Transpower's report "Transmission Tomorrow" strongly indicates that although not planned at the moment, the wind energy potential of areas around Auckland will come to considerably reshape the North Island's electricity grid, which will positively impact on the consumer choice for renewables in the Auckland metropolitan area.

From the distribution perspective, Vector Limited has established a new standard for distributed generation to be fed back into the larger distribution network, making it possible for individuals and companies to feed back into the grid and reducing the reliance of generation plants.

## 5.2 Option E1 – Large scale renewable baseload power plant

### 5.2.1 Description

The policy option is to encourage the establishment of a $10MW_e$ base-load renewable electricity generator within Auckland. This is considered indicative only as a policy option which would enable new demand within the region to be supplied by renewable sources. The actual technology or size would be dictated by the market and largely affected by the carbon price[8]. Such a technology is not likely to be viable until towards the latter stages of the target period.

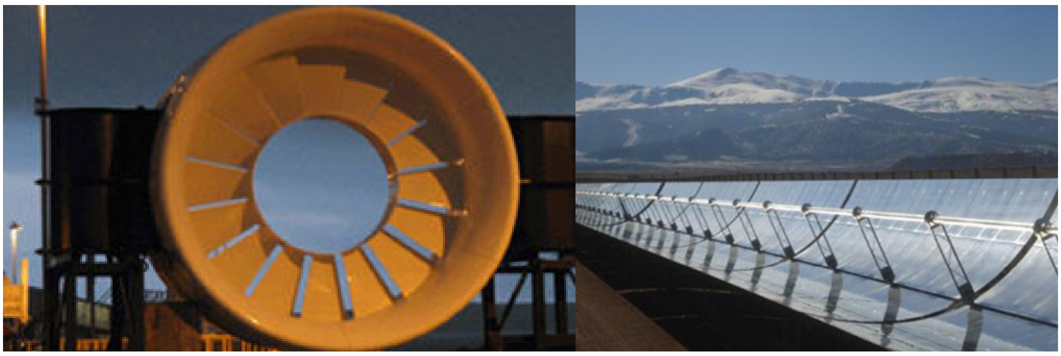

Figure 30 Examples of potential baseload renewable energy power plants (tidal turbines and concentrating solar thermal)

The scale of the generator is likely to be smaller than a typical utility generator, so capital costs are likely to be higher and it is likely to need financial support if implemented earlier. The financial support would be cost effective where it will help to increase energy security and avoid the need to augment transmission infrastructure.

For the purposes of this study the costs, generating performance, and land requirements are based on a Concentrating Solar Thermal (CST) power station with molten salt storage. CST was selected for the following reasons:

- CST will not take resources away from other options (e.g. biomass from biofuels) if placed in a suitable location; and

[8] Note that the Auckland Energy Strategy undertakes further analysis of potential options and suggests that tidal and/or wind are the most viable technologies and that larger scale is possible.

- CST is capable of baseload generation with the use of thermal storage and expected to reduce in costs significantly as more plants are built around the world.

Arup notes that tidal current turbines could also be considered as a near baseload technology as they are highly predictable and there is potential for their commercialisation within the Auckland Region. However the technology is still very much at the demonstration stage[9] but is unlikely to have a significantly different cost of abatement to CST.

The power station would ideally be located in or near to an industrial area with a high demand for low to medium heat in order that the plant can export waste heat.

The solar resource in Auckland cannot be considered significant by international standards, but compared to other regions in New Zealand it has one of the highest annual solar irradiances[10].



### 5.2.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 126TJ of electricity and 68TJ of natural gas.

The abatement potential is estimated to be an average of 5.9 kt$CO_2$e in 2031 and 196 kt$CO_2$e over the lifetime of the initiative.

### 5.2.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | Increased employment in energy generation sector. Solar thermal technology relies on a range of conventional manufacturing industries that are present within Auckland (e.g. steel fabrication). |
| Energy security: | Decreased dependency on imported fuels and transmission network. |
| Local air quality: | Potential to displace local air emissions from fossil fuel intensive alternative generation options. |
| Pride and connection between people and place: | Potential to build a sense of community pride through adoption of iconic new technology. |

9 The 200MW plant at Kaipara Harbour proposed by Crest Energy would be one of the world's first commercial scale installations.

10 Sinclair Knight Merz, 2007, *Renewable Energy Assessment: Auckland Region*, Energy Efficiency and Conservation Authority

A disbenefit that may require mitigation is the potential for increased cost of generation which would impact on energy costs for residents and businesses.

### 5.2.4 Implementation options

For the purposes of this study it has been assumed that the government will provide a performance based operational subsidy to a power station developer. The size of this grant has been assumed to be enough to ensure a commercial return to the power station. This subsidy could also be in the form of a capital grant; however this option has drawbacks in terms of upfront costs.

Performance based subsidies like feed-in tariffs and green certificates have been an important factor in the growth of the solar and renewable energy industries in Europe and the United States[11]. These kinds of subsidies from Government are often preferred as they isolate public funds from project risks by paying the subsidy for the energy generated.

Other assistance that could encourage private investment in a baseload power station include identifying suitable sites and using land use planning and development controls to facilitate planning of the power station.

Auckland Council is unlikely to invest in utility scale generation or to provide subsidies for developers. Further, as technologies develop and the impact of GHG taxes are felt, renewable baseload power stations will become more commercially viable in their own right. To fast track this, and to attract such developers to the Auckland region, Council could adopt planning mechanisms to ease the approvals process. Direct funding in the form of capital assistance or operational incentive would more likely come from national government. Auckland Council could have a role in advocating for this.

Table 4 Option E1 - Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Planning assistance | | ☑ | ☑ | ☑ | | | | |
| Operational incentive | ☑ | ☑ | | | | | | |
| Capital grant | | ☑ | | | | | | |

### 5.2.5 Costs

Arup estimates the capital costs associated with a $10MW_e$ CST power station with 15 hours storage to be NZ$96.6m[12]. Operational costs were based on US$70/kW

[11] M Ringal, 2005, *Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates*, Renewable Energy Vol 31 Issue 1

[12] The costs of the CST have been based on the costs estimated by the Sydney Advisory Model software developed by the National Renewable Energy Laboratory (United States). It was assumed that by 2020 the costs for the solar troughs and molten salt storage would be half that of today.

for mirror cleaning and mechanical systems maintenance or around NZ$800k per annum.

Arup estimates that Council would need to provide an upfront subsidy of around 45% of capital costs or alternatively an operational subsidy equivalent to $80/MWh of electricity sent out or $2.8m per annum.

## 5.3 Option E2 – Medium scale wind

There are likely to be large scale wind farms built within the Auckland region regardless of Council's actions given the good wind resource available in some areas (e.g. Kaipara South Head). These remote wind farms are likely to require additional transmission infrastructure and will effectively be feeding the entire New Zealand electricity grid. Arup considers that these developments should not be counted towards Auckland's targets as they are likely to occur from market forces in the electricity generation sector, primarily from the NZ Emissions Trading Scheme.

This policy is therefore to encourage the construction of medium scale wind farms across Auckland. The medium scale wind farms are proposed in areas with less than optimum conditions[13] 25% capacity factor assumed) and are likely to be a small number of <1MW turbines, rather than several dozen multi MW turbines. The medium scale wind farms are also likely to be in more highly populated areas so that they can reduce transmission losses and avoid large infrastructure, meaning that planning issues and community consultation become more important.

Planning and auxiliary infrastructure costs are likely to be more expensive on a total capacity basis. Assistance from government is critical for implementation, although not necessarily in the form of financial incentives.

These types of wind farms are not likely to be developed until the opportunities for large scale wind farms are significantly reduced. Arup has assumed that this will not occur until after 2020.

### 5.3.1 Potential GHG abatement

The GHG abatement potential of this option is based on generating 788 TJ of electricity per annum.

The abatement potential is estimated to be 15 $ktCO_2e$ in 2031 and 652$ktCO_2e$ over the lifetime of the initiative.

[13] A wind farm operating in optimal conditions in New Zealand would be expected to have a capacity factor of between 35% and 40%. Arup has assumed the medium scale wind farms have a 25% capacity factor assumed

### 5.3.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | Increased employment in energy generation sector in terms of maintenance and operations. |
| Energy security: | Decreased dependency on imported fuels and transmission network. |
| Local air quality: | Potential to displace local air emissions from fossil fuel intensive alternative generation options. |
| Pride and connection between people and place: | Highly visible symbol of Auckland's movement towards becoming an eco-city. |

A disbenefit that may require mitigation is the potential for increased cost of generation which would impact on energy costs for residents and businesses.

### 5.3.3 Implementation options

Although there may be some need for financial incentives, the majority of action required by Council is advocacy and regulation.

Wind turbines in suburban and urban areas are likely to require more consultation with the public during the planning process and site selection is likely to be more complicated as there are some constraints that need to be considered in more detail than with large scale wind farms (e.g. noise, flick effect, development controls for nearby buildings, distance to distribution sub stations).

Council could aid the planning process by developing site selection frameworks and community consultation guidelines. By standardising these approaches the approvals process would be streamlined.

Table 5 Option E2 - Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Planning assistance | | ☑ | | | | | | |
| Site identification | | | ☑ | ☑ | ☑ | | | |

Not Council Policy

### 5.3.4 Costs

The costs associated with the medium scale wind farms are based on a general assumption that development costs will be roughly 50% higher than large scale wind farms. Arup estimates this cost to be around $4.5/W or $448m to install 100MW of capacity.

Operational costs are also likely to be higher, as there are fewer turbines to spread costs. Arup has assumed that operational maintenance will cost the wind farm operators roughly $6.7m per annum.

Arup has assumed that the revenue to the wind farm operator reflects the avoided transmission infrastructure.

## 5.4 Option E3 – Thermal networks in redevelopment precincts

### 5.4.1 Description

This option is based on the distribution of decentralised generation of heat and hot water in a nominal four precincts with sufficiently high density and thermal demand.  A pipe network would distribute heated water that has drawn directly from enhanced geothermal wells[14] within Auckland. The thermal network would provide space heating and cooling and hot water for commercial development and heat for industrial processes requiring low grade heat.

The study assumes that there are four thermal networks in different regional centres supplied by direct use geothermal wells. There is potential for these networks to be fuelled from other sources including by solar thermal, biomass CHP and industrial waste heat.

The design of thermal networks is a significant exercise and so Arup has had to make numerous high level assumptions in order to estimate costs and potential savings[15].

[14] Although there are some hydrothermal wells active within he Auckland region, Arup has assumed that the wells drilled for the thermal networks are deep enough to supply water temperatures of around 90ºC.

[15] Assumptions include: Each thermal network  has a main pipe 4km  in length(8km flow and return); there is one business every 10m of main pipe who would be suitable for connection; the average pressure drop in the main pipe is 200pa/m; the pipe diameter is 500mm; the hot water flow rate is 2m/s; the temperature differential between flow and return pipes is 20ºC; the annual capacity factor for the thermal networks is 60%; the redevelopment areas retain 30% of the existing building stock who do not connect to the system (their connection is another initiative see

### 5.4.2 Potential GHG Abatement

The GHG abatement potential of this option is based on offsetting 357 TJ of electricity and 665 TJ of natural gas per annum.

The abatement potential is estimated to be 42.1 ktCO2e in 2031 and 1,254.1 kt$CO_2$e over the lifetime of the initiative.

### 5.4.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | As the cost of conventional heat escalates with the price of natural gas, electricity and coal, the thermal network will remain relatively consistent in terms of costs, offering highly affordable low grade heat to businesses. The internal plant and equipment requires significantly less maintenance than conventional heat generation. |
| Energy security: | The heat sources used for this option are all local, reducing Auckland's reliance on fuel imports. |
| Local air quality: | There will be significant savings in natural gas and coal consumption as a result of this option, both of which impact on air quality. |
| Endurance: | Thermal networks are a highly enduring solution. |
| Local Knowledge | Development of localised networks captures and builds local knowledge, systems and leadership |

### 5.4.4 Implementation options

There are many different method of implementing thermal networks. For the purposes of this study, Arup has assumed a simple model whereby Government (either Council and/or Central Government) build the infrastructure (pipes and pump houses) and business builds the power generation, building connections and heat exchangers.

Arup has also treated business as through it were one entity, however in reality it is certain that there will be a large range of entities involved. These entities include:

- Heat generators;

Section 5.4). Arup estimates that based on the assumptions above each network would be capable of delivering 18$MW_{th}$ of energy.

- Thermal network operators;
- Heat retailers;
- Heat consumers.

Government is likely to play a number of roles across within each of these entities. Most importantly Government is needed to create the business case and regulatory framework for the thermal networks to be built and to operate within Auckland.

Table 6 Option E3 - Role of council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Planning assistance and site selection | | ☑ | ☑ | ☑ | ☑ | | | |
| Infrastructure provision | | | | | ☑ | ☑ | ☑ | |

### 5.4.5 Costs

The costs associated with a thermal network can be broken down into the heat generation, the pipe network and the building level plant required.

Costs for the heat generation have been based on an enhanced geothermal well deeper than 3200m. Arup has estimated that this cost could be as much as $82m per network or $329m overall. This cost could be significantly reduced if the depth of well and number of wells can be reduced, reflecting a higher ground temperature in some areas of Auckland.

The pipe network costs have been based on insulated polyethylene pipes estimated at around $5,400 per metre of main pipe network (flow and return). This would mean each network would cost around $22m or $88m overall. The pumps required to drive the thermal network have been estimated to cost $1m per network or $4m overall.

As this option deals with the new buildings in redevelopment precincts only, it have been assumed that the heat exchangers, pumps and other ancillary equipment would be required with a conventional system and therefore should not be counted as part of this option. The cost of connection of the building to the main pipe has been included though and has been estimated at $20k per building, $5.8m per network or $23m overall.

As stated earlier it has been assumed that Government pays for the pipes and pumps, while business pays for the generation and the individual building connection. The price paid for heat is assumed to be the equivalent of the electricity and gas consumption it is offsetting.

## 5.5 Option E4 – Thermal networks for existing buildings

### 5.5.1 Description

This policy option involves encouraging existing buildings to connect to the proposed thermal network in option E3. Connecting to the network will have direct cost impacts on building owners as base building plant will need to be replaced or upgraded. These costs may need financial incentives from government as they may be more expensive in capital terms than conventional heat sources.

However, as the heat is likely to be cheaper over the lifecycle than using an electric or gas boiler there is potential that with the right advocacy and education campaigns by Council that the existing buildings will connect without the need for Government funding.

### 5.5.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 153 TJ of electricity and 285 TJ of natural gas per annum.

The abatement potential is estimated to be 18.0 kt$CO_2$e in 2031 and 525 kt$CO_2$e over the lifetime of the initiative.

### 5.5.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | As the cost of conventional heat escalates with the price of natural gas, electricity and coal, the thermal network will remain relatively consistent in terms of costs, offering highly affordable low grade heat to businesses. The internal plant and equipment requires significantly less maintenance than conventional heat generation. |
| Energy security: | The heat sources used for this option are all local, reducing Auckland's reliance on fuel imports. |
| Local air quality: | There will be significant savings in natural gas and coal consumption as a result of this option, both of which impact on air quality. |
| Endurance: | Thermal networks are a highly enduring solution. |
| Local Knowledge | Development of localised networks captures and builds local knowledge, systems and leadership |

### 5.5.4 Implementation options

As the infrastructure and organisational structure for the thermal network are built, existing buildings will become more confident about connecting to the thermal network.

Auckland Council's role is likely to be limited to education of existing building owners about the benefits of connecting to the system, and to regulate the pricing involved with new connections to the network.

Table 7 Option E4 – Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Encouraging building owners | | ☑ | ☑ | | ☑ | | | |

### 5.5.5 Costs

The costs associated with the connection of existing buildings are based on having to replace boilers and ancillary equipment with heat exchangers. This cost has been assumed to be $105/kW of heat exchanger, the pipe cost is assumed to be double that of new buildings.

Arup estimates the total cost of connection to be roughly $46k per building or $5.6m per network or $22.2m overall. This cost is assumed to be paid for by businesses.

## 5.6 Option E5 – Building integrated renewables

### 5.6.1 Description

As the price of energy rises and the cost of renewable energy generation technology decreases over time, individual building owners will be attracted to invest in building integrated renewables.

This policy option is to encourage this investment and remove barriers which prevent tenants and/or dwelling owners from taking similar action. There may also be a case for mandated removal of more GHG intensive options like conventional electric and gas hot water systems for replacement with renewable options.

For the purposes of this study the building integrated renewable technologies are assumed to be solar PV and solar hot water as the likely most cost effective options. In reality, a range of technologies may be adopted.

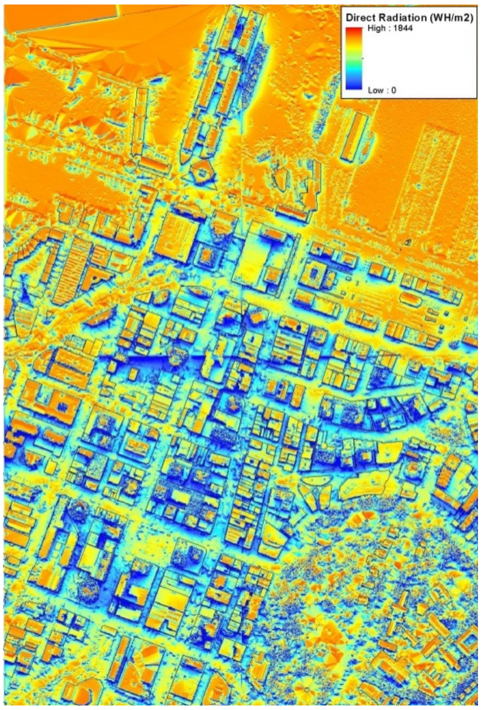


Figure 31 Solar Resource Mapping

**Solar Resource Mapping**

Arup has analysed Auckland for access to solar irradiance using GIS based software. This dataset has been created using a range of different datasets provided by council and allows users to identify sites suitable for building integrated and utility scale solar energy infrastructure.

An example output of the analysis is shown in the figure to the left. The blue colour indicates areas that receive minimal direct solar irradiance throughout the year, while the orange areas indicate that they are close to being unshaded.

While the detail of the analysis varies over the Auckland Council area, the dataset covers over 6,000km$^2$ and over 600,000 buildings and shows that the solar resource available to Auckland is considerable. For more information see Appendix H.

### 5.6.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 15,752 TJ of electricity and 3,797 TJ of natural gas per annum.[16]

The abatement potential is estimated to 456.1 kt$CO_2$e in 2031 and 11,928.6 kt$CO_2$e over the lifetime of the initiative.

### 5.6.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living / cost of doing business: | Although this option will require significant investment it will reduce the recurrent cost of living to households and costs of doing business significantly. |
| Employment: | Installation of building integrated renewable energy technology will require a significant workforce (10 full time employees per MW installed)[17] |

[16] It should be noted that these figures are highly likely to change in the final version of the Auckland GHG Strategy based on the finalised solar modelling.

[17] ACIL Tasman, 2009, *Employment in the Renewable Generation Sector: Job Opportunities in the Geothermal, Solar, Ocean and wind power sectors,* prepared for the Australian Geothermal Energy Association

| | |
|---|---|
| Local Knowledge: | This initiative will build on and enhance local skills and businesses in relation to solar PV technology. |
| Pride and connection between people and place: | Building integrated renewables are a powerful symbol for individual action on climate change, which will reinforce the community's awareness and pride in each other's actions. |

A potential disbenefit that may require mitigation is an increased cost of housing; whilst this can be offset by lower energy costs it may create a barrier for housing for lower income households.

### 5.6.4 Implementation

There are several roles for Council in the implementation of building integrated renewable technology across the region. These include:

- Protecting existing access to solar resource;
- Educating the community around the benefits of these technologies and the grants available from Central Government;
- Organising "mass" installations where multiple properties are serviced at once; and
- Providing accreditation to preferred suppliers for the community to ensure the quality of work.

Table 8 Option E5 – Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Encouraging building owners | | ☑ | | | | | | |
| Protecting access to solar resource | | | | ☑ | | | | |
| Organising mass installations | | | ☑ | | | | | |
| Accrediting suppliers | | | | | ☑ | | | |

### 5.6.5 Costs

Arup has based this option on the wide held belief that building integrated renewable energy technologies will reduce significantly in cost over the next decade[18]. The costs Arup used are based on a significant reduction in PV module, inverter and evacuated tube collectors over the next decade.

[18] IT Power Australia et al, 2009, *Assessment of the Future Costs and Performance of Solar Photovoltaic Technologies in New Zealand*, New Zealand Ministry of Economic Development

Arup assumed that the total installed cost to households and businesses was \$3,300/kW for solar PV and \$1,250/$m^2$ for evacuated tube based solar hot water systems.

For the purposes of this study it has been assumed that 60% of households install building integrated renewable energy technologies, or 264,100 dwellings. Arup estimates that the total capital cost to install the technology will be \$10,810m.

## 5.7 Option E6 – Low carbon precincts

### 5.7.1 Description

Low carbon precincts are a land use planning policy option whereby a target is set for each new development precinct for onsite renewable energy generation. Each precinct would evaluate the most cost effective and fit for purpose solution. This may include use of otherwise undevelopable land such as contaminated sites, floodplains and land along transport corridors to minimise the cost of generation.

The idea is that all new development will incorporate enough renewable energy generation so as to meet a set proportion of the likely annual energy consumption associated with the development. For the purposes of this study that proportion is assumed to be 20%. This equates to the typical heating requirements (e.g. space heating and hot water) for commercial buildings.

Where a household or business does not have access to a renewable energy resource within their own property boundaries, they could contribute financially to the establishment of a community owned distributed renewable energy generator.

For the purposes of this study the projections for energy demand growth have been used to estimate the requirement for renewable energy for new build. These amounts are a 3,700TJ for residential, 3,280TJ for commercial buildings and 13,367TJ for industrial buildings of additional energy taking into account the reduction from energy efficiency options across these building types.

### 5.7.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 1,768 TJ of electricity and 2,262 TJ of natural gas per annum.

The abatement potential is estimated to be 145.3 kt$CO_2$e in 2031 and 3,611.1 kt$CO_2$e over the lifetime of the initiative.

### 5.7.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | A minimum target for new development will give some assurances to renewable energy and zero-carbon technology businesses that there will be a continuing supply of work into the future. |
| Energy security: | By generating energy in a distributed way the need for network infrastructure upgrades and energy imports will be reduced |
| Social capital and community resilience / community leadership: | A low carbon precinct is likely to generate/enhance significant social capital and networks that will improve community resilience.<br>The precincts can also engage and foster local leaders. |
| Pride and connection between people and place: | The initiative can create a strong sense of local identity and pride centred around localised energy systems. |

A potential disbenefit is an increased cost of housing that may exclude some residents from the precinct without appropriate mitigation measures.

### 5.7.4 Implementation

The measures Arup has identified to ensure the implementation of low carbon precincts range from development controls to facilitating collective investment. The measures include:

- Establishing Auckland specific benchmarks for energy consumption in new development (e.g. kWh/m2 for the type of building being developed);
- Establishing a renewable energy target that could be mandated without significant impacts on the overall cost of development;
- Incorporating a renewable energy target within development controls;
- Identify an appropriate mechanism to allow developments that are unable to meet their low GHG obligations, these could include:
  - A fund that collects and invests contributions from the developments;
  - A tradable certificate that can be bought from developments that are generating more than their low GHG obligation.

Table 9 Option E6 – Role of Council

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Establishing benchmarks and target | ☑ | ☑ | | ☑ | | | | |
| Incorporate targets in development controls | | | | | ☑ | | | |
| Identify funding mechanisms | | | ☑ | | ☑ | | ☑ | |

### 5.7.5 Costs

For the purposes of costing the initiative it is assumed that residential and commercial buildings achieve the target with solar hot water. Industrial buildings are assumed to achieve the target through biomass boilers.

Arup estimates that the cost of meeting a 20% renewable energy target would be around $614m over the years between 2015 and 2031.

## 5.8 Option E7 – Biomass cogeneration in the wood processing industry

### 5.8.1 Description

Saw mills are significant consumers of heat for processing of timber. The harvesting of timber and the wood processors themselves produce significant quantities of waste wood that can be used as fuel. This measure is to encourage the wood processing industry to develop biomass cogeneration systems so that they use the waste biomass available and produce enough electricity and heat to become as self sufficient as possible.

Although the wood and wood processing industry already uses large amounts of wood fuel, the industry still uses a large amount of natural gas and electricity for process heat[19]. The existing systems are most likely boilers used solely for process heat whose secondary purpose is to

[19] According to the EECA end use database the Wood processing and Wood products industry used 4,647TJ of wood as fuel in 2009. Despite this the database also estimates that the industry also used 1,173TJ of natural gas and 264 TJ of electricity was used for process heat.

dispose of the waste timber[20]. There is therefore a great opportunity to upgrade these systems to more efficient boilers that generate both heat and electricity.

The majority of the waste wood that would enable this measure is wood harvesting residue, which is not currently collected at any significant level. Auckland Council has a role to encourage the collection and use of this biomass beyond the roles currently played by EECA and SCION in providing information to the wood processing industry.

### 5.8.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 516 TJ of electricity and 1516 TJ of natural gas per annum.

The abatement potential is estimated to be 82.7 kt$CO_2$e in 2031 and 2,688.9 kt$CO_2$e over the lifetime of the initiative.

### 5.8.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | The wide scale harvest of forest residues could lower the cost of wood fuel for the wider business community |
| Energy security: | The biomass cogeneration will use local fuel supply and support the electricity distribution system |
| Waste to landfill | The initiative has the potential to reduce green waste to landfill |

### 5.8.4 Implementation options

Arup analysis indicates that the financial benefit to the wood processing industry is marginal; however the greenhouse gas benefits and the benefits to energy security are substantial. Therefore it is possible that Auckland may need to provide financial assistance to encourage the industry to adopt cogeneration across the board.

However, the capital costs used by Arup are on the conservative end of a possible range and so for the purposes of this study it has been assumed that the industry takes action without financial support from Council.

At present only some harvest residues are collected (less than 10% according to Hall et al, 2008). Without access to this additional fuel it is unlikely that any wood processing facilities will invest in the fuel conversion technology. Council may have a role in creating partnerships between individual wood processors and timber harvesters.



[20] P. Hall and J. Gifford, 2008, *Bioenergy Options for New Zealand: Situation Analysis: Biomass Resources and Conversion Technologies*, SCION, Energy Group

At some point in the future it may be necessary for Council to regulate a target for the wood processing industry so that industry is obliged to invest in the conversion technologies.

Table 10 Role of council in Option E7 – Biomass cogeneration in the wood processing industry

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Encouraging wood processing industry | | ☑ | ☑ | | ☑ | | | |
| Encourage forestry industry to collect waste | | ☑ | | | | ☑ | | |

### 5.8.5 Costs

For the purposes of this study the costs have been based on Hall et al, 2008 study which estimated that a $7.5MW_e$ biomass cogeneration system would cost $34m with a boiler efficiency of 60% and a turbine efficiency of 27%. Arup has assumed an annual operating cost of $\$50/kW_e$.

In order to meet the process heat demand of the wood processing industry Arup estimates that there would need to be a total capacity of $80MW_e$ of biomass cogeneration installed within Auckland. This would equate to around $363m in capital costs.

## 5.9 Option E8 - Smart grids

### 5.9.1 Description

This policy option aims to accelerate enhancements to Auckland's electric power delivery systems in order to achieve a fully functioning 'Smart Grid'.

*The term 'Smart Grid' refers to a modernisation of the electricity delivery system so that it monitors, protects, and automatically optimises the operation of its interconnected elements – from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations, and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices. The Smart Grid will be characterised by a two-way flow of electricity and information to create an automated, widely distributed energy delivery network.*

(EPRI, 2011, p2-1)

The benefits of Smart Grids are widely acknowledged, and internationally recognised as necessary to meet the needs of the future electricity market and facilitate increased use of renewable energy sources. The US Electric Power

Research Institute (EPRI) categorise the benefits of smart grids into five types (EPRI, 2011):

- Increased power reliability and power quality - through automated monitoring, control and mitigation and correction of problems.
- Safety and cyber security benefits – through continuous monitoring to detect unsafe or insecure situations.
- Increased energy efficiency – providing reduced total energy use, reduced peak demand, reduced energy losses, and the ability to induce end-users to reduce electricity use.
- Environmental and conservation benefits –reducing GHG and other pollutant generation through increased efficiency, support of renewable energy sources, and facilitation of other energy efficient technologies such as electric vehicles.
- Direct financial/ economic benefits – through reduced operations costs, customer access to energy information and pricing choice, and acceleration of the introduction of new technologies.

Despite the advances in smart grid technologies, and numerous trials of individual Smart Grid components (most notably domestic smart meters), there is relatively limited information available on the costs of implementing Smart Grids on a large scale. In their 2011 technical report, EPRI have developed a preliminary estimate of the investment requirements and the resultant benefits of a fully functioning Smart Grid for the US.

For the purposes of this study, costs of implementing a fully functioning Smart Grid for Auckland have been assumed from the EPRI (2011) study, and scaled down based on energy consumption and population considerations. Various international studies and pilot projects have indicated that Smart Grids can make a major contribution to GHG emissions reductions, potentially reducing primary energy consumption by up to 10-15% (European Commission, 2011). A conservative 10% reduction has been assumed for the purposes of this study.

As further Smart Grid trials are implemented and more detailed investigations are undertaken, the estimated costs and benefits of implementing a fully functioning Smart Grid in Auckland can be refined. It is noted that that Orion New Zealand Ltd is currently in the process of rolling out an advanced Smart Grid system in its electricity distribution system in central Canterbury covering Christchurch City, high country, Banks Peninsula and surrounding farming communities. This project will provide valuable information and lessons for future Smart Grid implementation in Auckland.

### 5.9.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 4,674 TJ of electricity per annum.

The abatement potential is estimated to be 86.5 kt$CO_2$e in 2031 and 2,283.8 kt$CO_2$e over the lifetime of the initiative.

### 5.9.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | Increased consumer information and awareness of electricity use and costs will encourage reduction of electricity consumption, and reduce costs to all consumers. Availability of information will also increase electricity pricing choices for consumers, ultimately reducing electricity costs. |
| Cost of doing business: | Similar to the point above, commercial electricity consumers will also be able to reduce energy costs through reduced consumption and increased electricity pricing choices. |
| Employment: | Smart Grids will provide opportunities for entrepreneurs to accelerate new technology introduction into the generation, distribution, storage, and coordination of energy (EPRI, 2011), and facilitate the advancement of dependant industries such as the electric vehicle industry which will rely on smart grids to balance charging consumption. |
| Energy security: | Smart Grids will provide a more reliable power supply with fewer and briefer outages, “cleaner” power, and self healing power systems, through the use of digital information, automated control, and autonomous systems (EPRI, 2011). |

A potential disbenefit is that smart grid technology and smart meters can increase the cost of housing.

### 5.9.4 Implementation options

The large scale implementation of Smart Grids, in Auckland or anywhere, will need to be market driven. The key market drivers for Smart Grids include (European Commission, 2011):

- Electricity Network Operators: As the key beneficiaries network operators will likely be the main investors in Smart Grids. Natural drivers for investment include enhancing network efficiency, improving overall system operation through better demand response, and cost savings including remote operation of meters, lower reading costs, avoiding investment in peak generation, etc.
- Community and Business: The key driver for the community and business is having access to consumption information to allow reduce electricity consumption and cost.
- Energy Suppliers and Service Companies: Smart Grids will allow the large-scale integration of renewables within networks while maintaining the overall reliability of the system.

To encourage investment in Smart Grids, a suitable regulatory framework needs to be established that encourage cost savings or revenue gain, particularly for network operators, which are not linked to additional electricity sales but rather increased efficiency and decreased peak infrastructure investment needs (European Commission, 2011). The regulatory framework needs to provide incentives for each component of the market to contribute toward the development of the Smart Grid.

Table 11 Option E8 – Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Encourage network operators | | ☑ | | ☑ | ☑ | | | |
| Encourage business and the wider community | | ☑ | | | | | | |

### 5.9.5 Costs

The net investment necessary to implement a fully functioning Smart Grid in Auckland over the 20 year planning horizon is estimated to be in the order of NZ $2,341m. This investment is likely to be largely provided by electricity network operators.

## 5.10 Metric based indicators

The above energy supply options provide for a largely renewable based supply of both electrical and thermal energy. Therefore the implementation of these options could be measured in terms of the percentage of energy supplied by renewable sources within Auckland.

If all policy options are implemented as proposed it is estimated that by 2020 17% of Auckland's energy would be supplied by renewables generated within Auckland, and 48% by 2031.

| **Metric** | **2009 (baseline)** | **2020** | **2031** |
|---|---|---|---|
| % Energy Supplied by Renewables Generated within Auckland | 0% | 17% | 48% |
| % Properties with Smart Grid Access | 0% | 50% | 100% |

The energy supply options would also contribute to reduced greenhouse intensity for the metric based indicators for residential, commercial and manufacturing and industrial facilities as proposed in Section 6, Section 7 and Section 8 as well as for any electrification of the transport network.

# 6 Policy options: Residential

## 6.1 World's leading practice

Several cities in the world have developed initiatives to improve the energy efficiency and thermal performance of both existing and residential buildings. Bringing significant change to existing residential dwellings is a challenge that requires a thorough understanding of construction standards and practices in a given locality, well as the skills and trade available in that area.

As a starting point, the City of Melbourne has designed an audit program on 12,000 households to determine where and how most energy savings can be made. The sample is determined by housing typology and period of construction, in order to offer a representative cross section of Melbourne's existing building stock. The targeted areas for energy savings are: space heating, water heating, common areas in multi-residential developments as well as lighting.

In South East Queensland, the government's Solar Hot Water Program offered rebates on the purchase of a solar hot water systems under certain eligibility requirements. The program, using a demand-side behaviour change incentive, has resulted in the installation of over 200 000 solar hot water systems in the Brisbane metro area over the past 3 years. At full capacity, the program is projected to reduce the household electricity bills of participants by approximately 25 per cent and decrease emissions from household electricity use by up to 30 per cent.

The opportunities of integrating energy efficiencies, renewable energy sources, and distributed generation are much greater in new residential buildings that are being designed and constructed with a low GHG future in mind. Vancouver has been leading the way towards creating new residential building stock that by design and by legislation is much less-GHG intensive than existing buildings. Vancouver is taking a city-wide approach, whereby all new applications for construction that occurs as a result of rezoning required at least LEED Gold registration, thus ensuring more stringent approval process, at no extra cost to council.

The Sydney 2036 Metropolitan Strategy released in early 2011 proposes the establishment of precinct-wide initiatives that would result in district-wide strategic solutions for the reduction of GHG emissions that result from residential building, amongst other types of building. The innovation in this initiative is the focus on the precinct-wide, therefore multi-stakeholder, approach required to make significant economies of scale through universal adoption of a particular measure throughout the whole precinct, or the provision of district-wide shared green infrastructure such as smart grids or distributed energy generation.

The national Energywise initiative provides funding for insulation and clean, efficient heating and for the accreditation of providers. In conjunction with this program, Auckland Council has established the Auckland Sustainable Homes assessment program, which provides advice to home owners about how they can improve the energy efficiency of their homes and the funding streams available to assist them.

Section H1 of the New Zealand Building Code makes energy efficiency provisions for residential buildings however these are not stringent enough to achieve the high GHG emission reduction targeted by Auckland Council. Section H1 provides guidelines for insulation and draught-proofing but does not include any passive design solutions or requirements that would enhance the building's performance. The standards also focus significantly on thermal performance and less so on other efficiency aspects such as daylighting. Having said that, the mechanisms are in place to enforce more stringent, and therefore effective, building codes in the future.

## 6.2 Option R1 - Standards for new residential buildings

Improving the energy efficiency standards for new residential buildings includes: thermal performance of the building envelope; access to natural daylight and winter solar benefit; and, lighting power densities. The measure applies to new build residential development based on meeting best practice standards.

The standards are likely to include requirements for insulation, glazing, orientation, draught sealing, lighting (lamp and luminaire) selection, hot water system and space heating system.

The standards would begin as voluntary for new building and renovation like the NZGBC green homes rating tools, then to mandatory disclosure at the point of sale and finally to mandatory standards through the a mechanism like the New Zealand Building Code.

Section H1 Energy Efficiency of the New Zealand Building Code contains requirements for insulation and glazing for residential buildings. This measure will require advocacy and engagement from Council to make these regulations stronger and more comprehensive.

### 6.2.1 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 3210 TJ of electricity, 1582 TJ of natural gas and 576TJ of LPG per annum.

The abatement potential is estimated to be 194.0 kt$CO_2$e in 2031 and 4,517.4 kt$CO_2$e over the lifetime of the initiative.

### 6.2.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

Cost of living: Increasing the thermal and energy performance standards for new homes will have significant impacts on utility costs to households.

Local air quality: By increasing thermal performance and prescribing the types of heating systems used, local air quality will be improved, particularly by eliminating the use of wood burning heaters

| | |
|---|---|
| Health and wellbeing: | Under-heating of homes will be reduced by increasing thermal performance standards. This will decrease health impacts associated with exposure to sub 16ºC temperatures. |
| Social equity: | Improved housing standards can contribute to improved living standards and lower cost of living for all residents, reducing vulnerability and disparity. |

A potential disbenefit is that this initiative will add to the capital cost of housing. Innovative mechanisms are possible that offset these costs against future savings

### 6.2.3 Implementation options

For the purposes of this study, it is assumed that the Auckland Council shall implement this option with a focus on gradual uptake using the following commissioning stages:

1. A voluntary standard will occur initially in 2011.
2. A mandatory disclosure policy requiring commercial buildings to report on building energy performance beginning in 2015.
3. A mandatory standard to be adopted for all new buildings from 2020 onwards.

A mandatory disclosure policy will require new building owners to disclose the energy usage (either as a report or as a rating) of the building to potential tenants or buyers. The policy is designed to provide further information to the market, encouraging building owners to invest in energy efficient buildings to attract and secure tenants.

Table 12 Role of council in Option R1 - Standards for new residential buildings

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Voluntary standard | ☑ | ☑ | | ☑ | | | | |
| Mandatory disclosure at the point of sale | ☑ | | ☑ | | ☑ | | | |
| Mandatory standard | ☑ | | ☑ | | ☑ | | | |

### 6.2.4 Costs

Arup estimates that the implementation of higher standards in residential buildings could cost $2,769m to households and $646m to Central Government. These subsidies are based on the assumption that the cost of increased insulation, heating and lighting systems will be 80% of retrofit costs in Section 6.3.

## 6.3 Option R2 – Residential retrofit

Energy efficient retrofits of existing buildings occupied by households in the bottom quintile in terms of combined income. The option focuses on providing:

- Insulating wrap of hot-water pipes and hot water units;
- Installing additional thermal insulation into ceilings and walls and under floors;
- Draught stopping; and
- Heat pump for space heating.

This policy takes advantage of the existing subsidies offered by EECA under the Warm up New Zealand program and assumes savings.

The additional insulation is assumed to save 20% of space heating energy demand, the hot water insulation is assumed to save 10% of hot water energy consumption and the heat pump is assumed to have a Co-efficient of Performance (COP) of 3.

For the purposes of this study it has been assumed that the program is funded through an Energy Performance Contract (EPC) type arrangement. In this arrangement institutional investors would fund the upfront works with the households paying back the investor through the savings on their utility bills. Support from Council will be required to ensure that this pay back is sufficient to provide a commercial return for the investor.

### 6.3.1 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 265 TJ of electricity and 93 TJ of natural gas per annum.

The abatement potential is estimated to be 15.6 ktCO2e in 2031 and 512.3 ktCO2e over the lifetime of the initiative.

### 6.3.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | Increasing the thermal and energy performance standards for new homes will have significant impacts on utility costs to households. |
| Employment: | This scale of retrofit will require additional workforce in the construction industry. |
| Local air quality: | By increasing thermal performance and prescribing the types of heating systems used, local air quality will be improved, particularly by eliminating the use of wood burning heaters. |

| | |
|---|---|
| Health and wellbeing: | Under-heating of homes will be reduced by increasing thermal performance standards. This will decrease health impacts associated with exposure to sub-16ºC temperatures. |
| Social equity: | Improved housing standards can contribute to improved living standards and lower cost of living for all residents, reducing vulnerability and disparity. It will target the section of the community most at risk of fuel poverty. |

A potential disbenefit is that low income households may be excluded from this initiative due to the capital cost. This is discussed below.

### 6.3.3 Implementation options

Retrofitting the dwellings of low income households will require external finance, whether through direct subsidy or low interest loans, in order for the scheme to be affordable to a large number of households.

For the purposes of this study the implementation of the retrofit program is assumed to be funded by institutional investors through an Energy Performance Contract with the individual households. In this implementation method the low income households do not have to pay the upfront costs for the retrofit, increasing the likelihood of greater uptake. Instead the households pay back the retrofit in instalments over time with the savings they have made on energy costs.

Arup analysis indicates that the energy savings to households will not be enough to payback the upfront investment in a commercially attractive timeframe. Therefore the scheme may need to be partially funded by Government in order to engage institutional investors. This funding would be beyond the upfront funding already available through EECA's Warm up New Zealand programme. This additional contribution from Auckland Council could come in the form of additional up front grants or through a regular subsidy of the EPC payments which has been assumed for the purposes of this study.

Table 13 Role of council in Option R2 – Residential retrofit

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Encouraging institutional investment | | ☑ | ☑ | | | ☑ | | |
| Encouraging households | ☑ | ☑ | ☑ | | | | | |

### 6.3.4 Costs

The costs assumed for the residential retrofits are based on those suggested by EECA[21]. These costs are estimated to be $7,800 per household. The Warm up New Zealand program will provide at least 30% of the cost of insulation (60% if the household includes a Community Services Card holder) and $500 towards a clean heating system. This leaves roughly $5,800 per household. Arup estimates the total cost of this initiative to be $227m to households and $74m to Central Government.

## 6.4 Metric based indicators

The above options will reduce both the energy intensity and greenhouse intensity of the residential sector. Therefore the implementation of these options could be measured in terms of grid electricity and mains gas supplied to the residential sector on a per capita basis which should be readily available from utility suppliers.

Table 14 Metric based indicators – Residential sector

| Metric | 2009 (baseline) | 2020 | 2031 |
|---|---|---|---|
| Energy Consumption by Residential Sector (electricity and natural gas) per capita (per annum) | 3.21 GJ/capita (per annum) | 2.07GJ/capita (per annum) | 1.40GJ/capita (per annum) |

This metric will also be affected by the extent to which households reduce their reliance on grid supplied energy from the implementation of distributed generation including solar hot water and solar PV. The metric targets above assume that distributed generation is adopted as prescribed in Section 5.



[21] http://www.energywise.govt.nz/funding-available/insulation-and-clean-heating accessed on 31/05/2011

# 7 Policy options: Commercial

The commercial sector of Auckland contributed around 690 thousand tonnes of GHG emissions in 2009. Within the commercial sector consisting of trades and services, the use of buildings contributes to a large portion of these commercial emissions. Generally, buildings require the use of energy for lighting, heating, cooling and refrigeration. Improving the efficiencies of buildings in regards to this energy use can potentially reduce baseline emissions into 2031.

The following describes the potential initiatives and GHG benefits associated with improving building energy use in the commercial sector, particularly for:

- Retrofitting of existing buildings; and
- New buildings construction.



## 7.1 World's leading practice

In many markets such as Australia and the United States, the commercial property sector is driven by innovation and high standards of environmental and energy efficiency. High quality new build or successful retrofits of existing buildings drive market value and are seen as a worth-while investment in a competitive market.

In the United States, the LEED certification program is driving change in the commercial property sector through their range of certification program. In the UK, the BREEAM rating delivers similar outcomes in commercial property for new builds.

Equivalents to LEED exist in Australia and New Zealand and have been reshaping both the new build and retrofits markets. Green Star rating is attributed on the basis of whether the building is built and performing to the energy efficiency and passive design standards specified in the design. In Melbourne, a city with a comparable climate to Auckland, a few best practice examples of buildings built to high Green Star standards have set the benchmark in new build energy efficiency and environmental performance such as CH2 Building (Melbourne City Council) and the Pixel Building in Melbourne.

On a larger scale and in the retrofit market, Melbourne has developed the 1200 Buildings funding program which ties a critical mass of the city's commercial building owners and operators to energy efficiency and environmental performance targets in exchange for financing help. The program's website highlights the program's relevance and potential overall impact on the city's GHG emissions as commercial buildings are responsible for half of the city's emissions.[22]

Other ratings schemes such as NABERS in Australia, set energy savings targets for buildings and requires the mandatory disclosure of energy performance to maintain NABERS ratings. In Oslo, an additional energy certification for property

[22] From http://www.melbourne.vic.gov.au/1200buildings/Pages/Home.aspx accessed on 09/06/2011.

transactions is being proposed as a way to quantify the long-term value of energy efficient design and environmental performance of buildings.[23]

In terms of what is already being done in Auckland, New Zealand's Green Building Council has adopted a Green Star rating program similar to the Australian equivalent which will contribute to the recognition and value of energy efficiency and environmental performance in commercial buildings in Auckland.

KEMA has developed a guide to New Zealand's Energy Efficiency Potential commissioned by the Electricity Commission in Wellington which outlines various options for increasing base building energy efficiency for a variety of uses within the residential, commercial and industrial sectors. The study establishes a baseline of current energy efficiency per use and proposes voluntary initiatives across lighting, HVAC and insulation.

In addition, the NZ standard for energy efficiency NZS 4243 sets minimal performance standards for building thermal envelope and lighting efficiency.

## 7.2 Option C1 – Standards for new commercial buildings

The policy option is to develop a standard (initially voluntary, then mandatory) for new commercial buildings to include more stringent energy efficiency standards. This includes the development of policies which promote or request higher energy efficiency standards for new commercial buildings. Generally, these standards should focus on the areas of greatest energy use – the thermal envelope, lighting and HVAC.

For the purposes of this study the costs, generating performance, and technical requirements are based on a number of best-practice reports[24]. These standards will include the design for:

- Lower lighting power density limits (for varying purposes);
- Energy efficient lighting through occupancy sensors, programmable lighting control systems (continuous dimming), and energy efficient lights and ballasts; and
- Energy efficient base-building HVAC systems through high efficiency motors, optimization of controls, building management systems, and variable speed drives for pumps and drives.

This option presents an opportunity in regards to energy efficiency, as the current standards for energy efficiency in new buildings provide minimum energy efficiency requirements for lighting power density limits (for varying purposes) and thermal envelope requirement (R-value) for roofs, insulated walls and windows.

There are currently no requirements for energy efficient appliances to be installed in new buildings.



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[23] Department of Environmental Affairs and Transportation, *Reducing Greenhouse Gas Emissions and Improving Air Quality in Oslo*, 2006.

[24] New Zealand Green Building Council's (2009) *GreenStar Office*, Property Council of Australia, Arup (2009) *Existing Buildings – Survival Strategies*, KEMA (2007) *New Zealand Electric Energy-Efficiency Potential Study*

### 7.2.1 Potential GHG abatement

The GHG abatement potential of this option is based on saving 1856TJ of electricity, 688TJ of natural gas and 954TJ of diesel.

The abatement potential is estimated to 184.1 kt$CO_2$e in 2031 and 5,136.7 kt$CO_2$e over the lifetime of the initiative.

### 7.2.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | Energy efficient initiatives will directly reducing the cost of energy for businesses. Green buildings have been shown to have more far-reaching benefits for business including reduced productivity. |
| Endurance: | Embedding energy efficiency measures and technologies in new building stock creates an enduring energy solution. |
| Pride and connection between people and place: | High quality commercial buildings have the potential to instil a sense of community pride in Auckland, leading to recognition throughout the country or even internationally. |
| Local knowledge: | This initiative will utilise and enhance local design skills. |

### 7.2.3 Implementation options

For the purposes of this study, it is assumed that the Auckland Council shall implement this option with a focus on gradual uptake using the following commissioning stages:

1. A voluntary standard will occur initially in 2011.
2. A mandatory disclosure policy requiring commercial buildings to report on building energy performance beginning in 2015.
3. A mandatory standard to be adopted for all new buildings from 2020 onwards.

A mandatory disclosure policy will require new building owners to disclose the energy usage (either as a report or as a rating) of the building to potential tenants or buyers. The policy is designed to provide further information to the market, encouraging building owners to invest in energy efficient buildings to attract and secure tenants.

A ‘green loan’ financing model will be used to encourage the uptake of a more energy efficient building. ‘Green loans’ involve the lending of money to a building owner for investment into energy reductions and thus, cost savings. The financial savings from energy reductions are used to pay off the loan. Additionally, government grants and financial incentives incentivise building owners to provide initial investment in energy efficient building design and improve financial paybacks.

Table 15 Option C1 - Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Voluntary standard | ☑ | ☑ | ☑ | | ☑ | | | |
| Mandatory disclosure policy | ☑ | ☑ | ☑ | | ☑ | | | |
| Mandatory standard | ☑ | ☑ | ☑ | | ☑ | | | |
| 'Green loans' | | ☑ | | ☑ | | | | |
| Efficient building design grants | ☑ | | | | | ☑ | | |

### 7.2.4 Costs

Arup estimates the capital costs for undertaking this option, comprising of the costs to design and construct new buildings with more efficient lighting and HVAC systems are:

- Activities from a voluntary new building standard[25], $47.0m over nine years starting from 2011;
- Activities from a mandatory disclosure policy[26], $52.2m over six years starting from 2015; and
- Activities from a mandatory standard[27], $174.0m over ten years starting from 2021.

These costs are primarily carried by building owners and supported by the funding mechanisms as described previously.

## 7.3 Option C2 - Commercial retrofit

Auckland contains a large number of existing buildings, with approximately 15.9 millions square meters of net lettable area. Considering this large amount of old

[25] Assumes a 30% uptake of energy efficient new building design and construction.
[26] Assumes a 50% uptake of energy efficient new building design and construction.
[27] Assumes a 100% uptake of energy efficient new building design and construction.

buildings, a policy to improve and enhance these existing buildings in regard to energy efficiency has great potential in decreasing GHG emissions.

For the purposes of this study the costs, generating performance, and technical requirements are based on a number of best-practice reports[28]. As per Option C1, retrofitting will include the design for:

- Installation of energy-efficient lighting and ballasts;
- Installation of occupancy sensors and programmable lighting control systems (continuous dimming) for lighting;
- Upgrade of base building heating, ventilation and cooling (HVAC) systems, through high efficiency motors, optimization of controls, building management systems, and variable speed drives for pumps and drives; and
- Upgrade of refrigeration systems through high-efficiency fan motors, improved controls, efficient compressors, and variable speed drives.

This option presents an opportunity in regards to energy efficiency, as current and previous standards have minimum energy efficiency requirements for lighting power density limits (for varying purposes) and thermal envelope requirement (R-value) for roofs, insulated walls and windows.

There are currently no requirements for energy efficient appliances to be installed in buildings.

### 7.3.1 Potential GHG abatement

The GHG abatement potential of this option is based on saving 832 TJ of electricity, 309TJ of natural gas and 428 TJ of diesel.

The abatement potential is estimated to be 82.6 kt$CO_2$e in 2031 and 2,229.9 kt$CO_2$e over the lifetime of the initiative.

### 7.3.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | Energy efficient initiatives will directly reducing the cost of energy for businesses. |
| Employment: | Retrofitting existing buildings would stimulate building activity, increasing employment. |
| Endurance: | Retrofitting existing buildings realises the inherent value of existing infrastructure and future-proofs it, creating an enduring energy solution. |

[28] New Zealand Green Building Council's (2009) *GreenStar Office*, Property Council of Australia, Arup (2009) *Existing Buildings – Survival Strategies*, KEMA (2007) *New Zealand Electric Energy-Efficiency Potential Study*

| | |
|---|---|
| Pride and connection between people and place: | High quality commercial buildings have the potential to instil a sense of community pride in Auckland, leading to recognition throughout the country or even internationally. |
| Local knowledge: | This initiative will utilise and enhance local design skills. |

### 7.3.3 Implementation options

For the purposes of this study, it is assumed that the Auckland Council shall implement this option with a focus on gradual uptake using the following commissioning stages:

1. A mandatory new building standard and voluntary Green Loans, backed by financial institutions or the government and repaid through energy cost savings, beginning in 2012.
2. Increased uptake of voluntary Green Loans due to increased financial benefit from factors such as increased energy prices, beginning in 2020 and retrofitting all buildings.

The option shall be implemented by the council through a voluntary retrofit program and linked to a future mandatory code for new buildings.

A 'green loan' financing model will be used to encourage the uptake of a more energy efficient building. 'Green loans' involve the lending of money to a building owner for investment into energy reductions and thus, cost savings. The financial savings from energy reductions are used to pay off the loan.

Low-interest loans are to be funded by the Council, requiring a payback from energy cost savings within an agreed period of time. These loans shall be provided for specific building owners who require more financial assistance. Building owners will be required to apply for such loans.

Additionally, government grants and financial incentives incentivise building owners to provide initial investment in energy efficient building retrofit appliances.

Table 16 Option C1 - Role of Council

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Mandatory building standard | ☑ | ☑ | ☑ | | ☑ | | | |
| 'Green loans' | | ☑ | | ☑ | | | | |
| Council-funded 'Green loans' | | ☑ | | ☑ | | ☑ | ☑ | |
| Retrofitting grants | ☑ | | | | | ☑ | | |

### 7.3.4 Costs

Arup estimates the capital costs for undertaking this option, comprising of the costs to retrofit existing buildings with more efficient lighting, HVAC and refrigeration systems are:

- Activities from the introduction of voluntary green loans[29], $201.1m over nine years starting from 2011; and
- Activities from increased uptake of voluntary green loans[30], $603.5m over six years starting from 2015.

These costs are primarily carried by building owners and supported by the funding mechanisms as described previously.

Arup estimate that the Council will need to support 25% of voluntary green loans required from 2011, for eligible entities[31] such as; public care institutions, public hospitals, public schools and colleges, and special districts (local boards).

## 7.4 Metric based indicators

The above options will reduce both the energy intensity and greenhouse intensity of the commercial sector. Therefore the implementation of these options could be measured in terms of grid electricity and mains gas supplied to the commercial sector on a per employee or per unit GRP basis. Grid electricity and main gas utility data for the commercial sector should be readily available from utility suppliers.

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[29] Assumes a 25% uptake of energy efficient new building design and construction.

[30] Assumes a 100% uptake of energy efficient new building design and construction.

[31] California Energy Commission (2011) *Energy Efficiency Financing*, retrieved from http://www.energy.ca.gov/efficiency/financing/index.html on the 2nd of June 2011.

Table 17 Metric based indicators – Commercial sector

| Metric | 2009 (baseline) | 2020 | 2031 |
|---|---|---|---|
| Energy Consumption by Commercial Sector (electricity and natural gas) per unit GRP (per annum) | 0.76 TJ/$M GRP (per annum | 0.69TJ/$M GRP (per annum) | 0.65TJ/$M GRP (per annum) |

This metric will also be affected by the extent to which commercial properties reduced their reliance on grid supplied energy from the implementation of distributed generation including solar hot water and solar PV. The metric targets above assume that distributed generation is adopted as prescribed in Section 5.

# 8 Policy options: Manufacturing and Industrial

The manufacturing sector of Auckland contributed around 1.96 million tonnes of GHG emissions in 2009. Within the manufacturing sector consisting of agriculture, mining, manufacturing, core services and construction, the use of buildings and main plant equipment contributes to a large portion of these emissions.

Generally, buildings require the use of energy for lighting, heating, cooling and refrigeration in plant equipment. Improving the efficiencies of buildings in regards to this energy use can potentially reduce baseline emissions into 2031.

The following describes the potential initiatives and GHG benefits associated with improving building energy use in the manufacturing sector, focused in two main areas:

- Retrofitting of existing facilities and plant equipment; and
- New facilities and main plants construction.

## 8.1 World's leading practice

Examples of manufacturing and industry-led cities with a strong environmental agenda are hard to come by for obvious reasons: for one, the agenda of reducing emissions seems to stand in direct opposition with the city's economic engine, demanding restructuring of supply chains, affecting site decisions, and commanding significant investment in capital. In addition, the cost of design, delivery and implementation of low GHG solutions for the manufacturing and industrial sector, places products and exports at a competitive disadvantage with competing cities, who are either not obliged or willing to consider low GHG solutions in the immediate term.

In spite of its heavily industrial profile and its oil-based economy, Rotterdam is making substantial efforts to green its port facilities through various strategies but also to invest in research in the low GHG future of the industrial sector. Rotterdam is pursuing an ambitious GHG emissions reduction through energy savings in industrial process, developing models for the exchange of energy streams, clustering and co-siting in the working port area of the city.

The industrial ecology model has far-reaching potential but also far-reaching implications in terms of land-use and siting decisions for industrial and manufacturing premises. If an industrial symbiosis approach is adopted as a way of avoiding energy waste and sharing inputs, it also means that sites need to be clusters and encompass complimentary processes, where the outputs of one process can be an input into another. This requires an open waste disclosure policy by participants as well. Industrial clustering spatial strategies is a lever available to Council to develop a more consolidated and symbiotic approach to high emissions sectors such as industry and manufacturing.

Beyond this, there are few examples of truly innovative council-based measures that are able to deliver on significant savings and efficiencies that are not the remit of the individual operators, such as investment in energy efficient equipment for which standards are being developed in Australia and New Zealand.[32]

## 8.2 Option I1 – Standards for new manufacturing and industrial buildings

### 8.2.1 Description

The policy option is to develop a standard (initially voluntary, then mandatory) for manufacturing and industrial buildings and facilities to include more stringent energy efficiency standards. It should be noted that the manufacturing and industrial sector covers a broad range of processes, equipment and manufacturing techniques and a standard to cover all of these, will be exhaustive. Instead, the policy will focus on buildings and spaces for common areas related to manufacturing and industrial facilities, based on a number of best-practice reports[33]. These standards will include the design for:

- Efficient lighting;
- Efficient base processes equipment, i.e. pumps, fans, HVAC; and
- Efficient compressed air equipment.

This option presents an opportunity in regards to energy efficiency, as there are currently no requirements for energy efficient appliances to be installed in new manufacturing and industrial buildings or facilities.

### 8.2.2 Potential GHG abatement

The GHG abatement potential of this option is based on saving 882 TJ of electricity, 1180 TJ of natural gas, 1733 TJ of coal and 491 TJ of diesel.

The abatement potential is estimated to be 303.4 kt$CO_2$e in 2031 and 8,137.9 kt$CO_2$e over the lifetime of the initiative.

### 8.2.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | Energy efficient initiatives will directly reducing the cost of energy for manufacturing/industrial businesses. |
| GHG emissions beyond Auckland: | Energy reduction from manufacturing processes reduces the emissions from products exported from Auckland to countries across the world. |

[32] http://www.energyrating.gov.au/library/pubs/201009-indust-equip.pdf accessed 09/06/2011

[33] Ernest Orlando Lawrence Berkeley National Laboratory (2008) *Energy Efficiency Improvement and Cost Saving Opportunities for the Petrochemical Industry, An ENERGY STAR® Guide for Energy and Plant Managers*, U.S. Environmental Protection Agency, accessible at http://ies.lbl.gov/energystar also for *Vehicle Assembly Industry, Cement Making, Glass Industry.*

| | |
|---|---|
| Endurance: | Embedding energy efficiency measures and technologies in new manufacturing and industrial buildings creates an enduring energy solution. |
| Local knowledge: | This initiative will utilise and enhance local design skills. |

### 8.2.4 Implementation options

For the purposes of this study, it is assumed that the Auckland Council shall implement this option with a focus on gradual uptake using the following commissioning stages:

1. A voluntary standard will occur initially in 2011.
2. A mandatory standard to be adopted for all new facilities from 2021 onwards.

A 'green loan' financing model will be used to encourage the uptake of a more energy efficient building. 'Green loans' involve the lending of money to a building owner for investment into energy reductions and thus, cost savings. The financial savings from energy reductions are used to pay off the loan.

Additionally, government grants and financial incentives incentivise building owners to provide initial investment in energy efficient building design and improve financial paybacks.

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Voluntary standard | ☑ | ☑ | ☑ | | ☑ | | | |
| Mandatory standard | ☑ | ☑ | ☑ | | ☑ | | | |
| 'Green loans' | | ☑ | | ☑ | | | | |
| Efficient building design grants | ☑ | | | | | ☑ | | |

### 8.2.5 Costs

Arup estimates the capital costs for undertaking this option, comprising of the costs to design and construct the common spaces of new facilities in manufacturing and industrial sectors with more efficient lighting, base processes and compressed air equipment are:

- Activities from the introduction of voluntary standards[34], $27.3m over nine years starting from 2011; and
- Activities from mandatory standards35, $60.7m over six years starting from 2021.

These costs are primarily carried by building owners and supported by the funding mechanisms as described previously.

## 8.3 Option I2 - Manufacturing and industrial retrofit

Currently, the manufacturing and industrial sector in Auckland demands around 25,000 TJ of energy per year. A large part of this energy demand is contributed by existing manufacturing and industrial buildings or facilities. Considering this, a program for existing facility retrofit for energy efficiency has a great potential in decreasing GHG emissions.

For the purposes of this study the costs, generating performance, and technical requirements are based on a number of best-practice reports[36]. Retrofitting will include the design for:

- Lower lighting power density limits (for varying purposes);
- Installation of energy-efficient lighting and ballasts and lighting control systems;
- Upgrade of compressed air process systems, fans and pumps through controls upgrades, system optimization, motor replacements, installation of adjustable speed drives (ASD) and efficient transformers; and
- Upgrade of base building (HVAC) systems, through high efficiency motors, optimization of controls, building management systems, and programmable thermostats.

There are currently no requirements for energy efficient appliances to be installed in facilities.

### 8.3.1 Potential GHG abatement

The GHG abatement potential of this option is based on saving 3569 TJ of electricity, 4772 TJ of natural gas, 7012 TJ of coal and 1985 TJ of diesel.

The abatement potential is estimated to be 1,227.1 kt$CO_2$e in 2031 and 32,814.0 kt$CO_2$e over the lifetime of the initiative.

### 8.3.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.



[34] Assumes a 50% uptake of energy efficient new building design and construction.
[35] Assumes a 100% uptake of energy efficient new building design and construction.
[36] KEMA (2007) *New Zealand Electric Energy-Efficiency Potential Study*

| | |
|---|---|
| Cost of doing business: | Energy efficient initiatives will directly reducing the cost of energy for manufacturing/industrial businesses. |
| GHG emissions beyond Auckland: | Energy reduction from manufacturing processes reduces the emissions from products exported from Auckland to countries across the world. |
| Endurance | Retrofitting existing plant and buildings realises the inherent value of existing infrastructure and future proofs it, creating an enduring energy solution |
| Local knowledge | This initiative will utilise and enhance local design skills. |

### 8.3.3 Implementation options

For the purposes of this study, it is assumed that the Auckland Council shall implement a retrofit program containing voluntary measures. The program will use the following commissioning stages:

1. Mandatory participation of building audits program for top 20% energy consumers from 2012.
2. Voluntary participation of building audits program between 2012 and 2021.
3. Full retrofit of all existing manufacturing and industrial facilities between 2021 and 2032.

The government shall provide energy efficiency auditors to identify potential initiatives to reduce energy and costs in manufacturing facilities.

In regards to funding mechanisms, Energy Purchasing Contracts (EPC) shall be implemented to provide an attractive financial model for facility owners, requiring a lender to engage the program and help reduce the financial risk for the owner and their initial capital investment.

Initiatives can be additionally funded by ‘green loans’ and government grants to incentivise building owners to provide initial investment in energy efficient building retrofit appliances.

Table 18 Option I1 - Role of Council

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Mandatory building standard | ☑ | ☑ | ☑ | | ☑ | | | |
| Energy Purchasing | ☑ | ☑ | | ☑ | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Contracts (EPC) | | | | | | | | |
| 'Green loans' | | ☑ | | ☑ | | | | |
| Retrofitting grants | ☑ | | | | | ☑ | | |

### 8.3.4 Costs

Arup estimates the capital costs for undertaking this option, comprising of the costs to retrofit existing industrial and manufacturing facilities with more efficient lighting and base processes are:

- Mandatory building audits for the top 20% energy consumers[37], $49.3m over nine years starting from 2011;
- Voluntary building audits[38], $16.4m over nine years starting from 2011; and
- Full retrofit of all remaining existing facilities[39], $262.8m over 10 years starting from 2021.

These costs are primarily carried by building owners and supported by the funding mechanisms as described previously.

## 8.4 Metric based indicators

The above options will reduce both the energy intensity and greenhouse intensity of the manufacturing and industrial sector. Therefore the implementation of these options could be measured in terms of grid electricity and mains gas supplied to the manufacturing and industrial sector on per employee or per unit GRP basis. Grid electricity and mains gas utility data for the manufacturing and industrial sector should be readily available from utility suppliers.

Table 19 Metric based indicators – Commercial sector

| **Metric** | **2009 (baseline)** | **2020** | **2031** |
|---|---|---|---|
| Energy Consumption by the Manufacturing and Industrial Sector (electricity and natural gas) per unit GRP (per annum) | 1.69TJ/$M GRP (per annum) | 1.32TJ/$M GRP (per annum) | 0.8TJ/$M GRP (per annum) |

This metric will also be affected by the extent to which manufacturing and industrial properties reduced their reliance on grid supplied energy from the implementation of distributed generation including solar hot water and solar PV. The metric targets above assume that distributed generation is adopted as prescribed in Section 5.



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[37] Assumes a 75% uptake of retrofits as a result of audits.
[38] Assumes a 50% uptake of retrofits as a result of audits.
[39] Assumes a 100% uptake of retrofits as a result of audits.

# 9 Quality compact growth

## 9.1 World's leading practice

The Auckland Plan Discussion Document points to a transitional approach to a "Quality Compact Auckland" in order to achieve a high-value utilisation of Auckland's urban space. Approaches to quality compact growth differ from city to city, but all require a detailed integration of land use planning and infrastructure planning to optimise on catchment areas of public transport infrastructure to develop precincts that benefits from real transportation options and rely less on car-based transportation.

Whereas Portland, Oregon is the obvious case study for a city actively pursuing better land use and transportation integration in new and existing developments, Arup has looked at the long standing spatial policy that has come to characterise Vancouver, British Columbia as world's leading practice.

From the early 1970s, Vancouver has taken an approach to urban growth and infrastructure investment that aimed at consolidating a dense, vibrant centre with a high level of urban amenity instead of encouraging suburban patterns of development. This approach was developed through an early shift away from car-based infrastructure, and an active densification policy in the "downtown' part of the city reflected in planning regulations and land use plans.

More recently (2008), the City of Vancouver has released the Vancouver Ecodensity Charter, building on that past investment in densification to guide future design of dense land use that will contribute to environmental sustainability, affordability and liveability. This Eco-density charter places environmental sustainability above all other priorities in all city-building decisions. This has translated into city-building measures that yield the highest benefits in terms of GHG footprint improvements and environmental gains such as development around fixed transit, walkable shopping, employment and amenity areas, district energy and heating sources.

Building a more compact quality city also requires some metropolitan-level planning, following the example of Oslo, Norway, with the consolidation of existing centres into a polycentric regional growth strategy and zoning plans that encourage development and construction near main public transit and cycling infrastructure.

In Adelaide, the Adelaide 30-year plan has developed Transit Corridor Planning zones which are designated to protect transit corridors for the development of housing and associated amenity in order to contain Adelaide's net dwelling growth within 800m of major transit corridors.

The Auckland Plan Discussion Paper outlines the premise of a polycentric spatial strategy which identifies possible areas for densification or growth around existing town centres but does not outline any land use requirement or zoning policy that might encourage or incentivise these outcomes.

# 9.2 Option Q1 – Quality compact growth

## 9.2.1 Description

Quality compact growth provides for future residential growth within the existing urban fabric whilst at the same time providing diverse living choices including culturally relevant housing typologies and distinctive environments that add value to local context and identity. Quality compact growth provides for reduced transport related GHG emissions as a direct result of improved public transport options and access to services. Reductions in stationary energy related GHG emissions in homes are less affected by growth patterns due to the relatively constant emission intensity per capita of different housing typologies.

Auckland Council is currently undergoing an evaluation of four different long term spatial urban form scenarios to enable the testing and evaluation of various growth parameters for Auckland's future growth. The scenarios are being evaluated against a range of parameters including GHG emissions. The analysis within Appendix H presents the results of the GHG analysis.

The conceptual basis for the scenarios can be shown in the following diagram which displays the location of the scenarios in a quadrant – the two axes being the level of growth assumed to be in high density typologies (density), and the amount of land assumed to be required beyond the existing urban footprint (expansion).

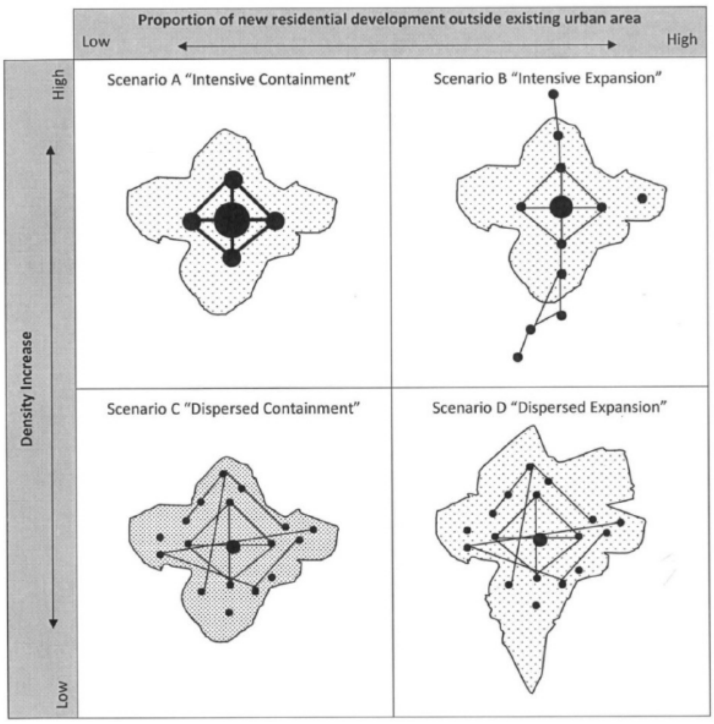


Figure 32 Four land-use scenarios by new residential development and density increase

**Scenario A – Intensive Containment**

Scenario A considers the growth of Auckland to be concentrated in a number of networks of centres, corridors and future urban areas with high-density residential growth occurring in the CBD and its fringes, with a majority of residents being within sub-regional and town centres. Growth within land corridors are limited, with no new capacity for rural, coastal and satellite areas. Retail and office-based business occur in the CBD and its fringes, with an increase in employment in sub-regional and town centres.  The transport network change includes broad improvements across the network with an emphasis is placed on public transport, walking and cycling and behaviour change programs. The construction of additional road capacity is limited.

**Scenario B – Intensive Expansion**

Scenario B considers the growth of Auckland to be concentrated within existing urban areas, particularly in centres and corridors with high-density residential occurring mainly in the CBD and its fringes (as per Scenario A). However, a majority of residential growth is focussed at key growth centres. Increased capacity for residential growth is provided for infill suburban areas (with high amenity), coastal and rural towns, beyond current scheduled greenfield sites and satellites. Rural and countryside living is reduced. Retail and office-based business occur in the CBD and its fringes but a majority of employment growth is focussed at key growth centres. The Rapid Transit Network and Quality Transit Networks are extended to provide high capacity services to support centres, corridors, coastal areas, ridgelines, urban fringes and rural settlements. Coastal areas are also supported by an extended ferry network. New expansion areas are supported by further road networks and public transport services. Growth areas are supported by increased transit orientated development, walking and cycling infrastructure.

**Scenario C – Dispersed Containment**

Scenario C considers low density growth of Auckland occur in existing urban areas, as well as dispersing the growth across a number of centres and corridors. Low density residential growth occurs in a number of small growth centres, as well as increased capacities in larger centres. Residential growth is largely dispersed in these areas. Some high-density residential growth occurs in the CBD and its fringes. Existing capacity occurs for future urban areas, coastal and rural towns, and satellite areas. A moderate increase in retail and office-based business occurs in the CBD and its fringes. Greater employment growth occurs in within the existing urban footprint and is widely dispersed.

The transport system supports a wide dispersion of growth in a large number of centres and urban areas. The system considers a greater distribution of goods and services. Public transport bus services are extended and have high frequencies across towns. Extensive arterial and local road network improvements are made for high levels of traffic for new areas.

**Scenario D – Dispersed Expansion**

Scenario D considers a dispersion of low-density growth in existing urban areas and across many centres and corridors. Extensive residential growth occurs in a number of coastal and rural towns, especially those with high amenity. Extensive growth also occurs in greenfield land all across Auckland, beyond the current scheduled. High-density residential growth occurs in the CBD and its fringes, but less than all other scenarios. The scenario also accounts for existing capacity for existing town centres, suburban infill, and future urban areas. Additionally, no growth occurs within corridors. An increase of retail and office-based business occurs in the CBD and its fringes. Additional business centres are provided at existing centres to provide for more employment. Extensive business development occurs in greenfield land all across Auckland, beyond the current scheduled. Expansion of public transport bus services occurs for new expansion areas, supported by increased park and ride facilities. Ferry network is expanded to support growth in coastal areas. New regional freight routes are required. Road infrastructure is increased to support new areas in the south and north of Auckland.

All scenarios include the combined impact of both land use change and transport network changes.

### 9.2.2 Potential GHG abatement

The analysis included in Appendix I shows GHG abatement potential of this option. This includes abatement from transport network changes which vary depending on the scenario. The abatement is therefore representative of the combined impact of land use planning and transport measures.

These results indicate that:

- Scenario A shows a reduction 2.6% in total GHG emissions compared to nBaU
- Scenario B shows a reduction 2.5% in total GHG emissions compared to nBaU
- Scenario C shows a reduction 3.0% in total GHG emissions compared to nBaU
- Scenario D shows an increase of 1.3% in total GHG emissions compared to nBaU

The abatement potential for option D is estimated to be 255 ktCO2e in 2031. Further analysis undertaken by Auckland Council indicates that of this approximately 25 kt$CO_2$e is associated with change in land use planning not including differences in the transport infrastructure.

The actual abatement from Quality Compact Growth could increase where densities facilitate further mitigation options such as thermal networks or low GHG zones.

### 9.2.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | Auckland residents in more compact areas, serviced by public and active transport, will have reduced living expenses. |
| Cost of business: | Compact urban growth can reduce the costs of transport and land for businesses. |
| Productivity: | Reduced travel time for staff and goods will increase productivity. |

| | |
|---|---|
| Local air quality: | Overall there will be fewer emissions to air across Auckland due to reduced transport journeys. |
| Social co-benefits: | A quality compact urban form is likely to deliver all five social co-benefits through improved population health, more affordable housing options, improved access to resources, opportunities to build community and social capital and development of enduring infrastructure. |
| Sites of significance and visual impact: | A quality compact urban growth model protects significant cultural, environmental and agricultural lands from the pressures of urban growth. |

Quality Compact Growth is projected to deliver more co-benefits than any other initiative described in this report.

### 9.2.4 Implementation

The role of Auckland Council in delivering Quality Compact Growth is significant. In order to ensure that the savings estimated in this study are realised a number of implementation measures could be appropriate. These include:

- Strengthening this strategic direction within the Auckland plan;
- Following through with this type of growth into development control plans across the Council area;
- Ensuring that each of the areas designated for compact growth is mixed use and has a level of self-sufficiency in terms of services;
- Ensuring that the property market is able to remain profitable with this sort of development, which often has very different cost structures and business cases to traditional separate house green field style development; and
- Invest in the public spaces and active transport infrastructure (e.g. cycleways) that will enable more uptake of active transport.

Table 20 Role of Council in Quality Compact Growth

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Strengthen Auckland Plan | | | ☑ | ☑ | | | | |
| Development Control Plans | | | | | ☑ | | | |
| Mixed use / self sufficiency | ☑ | | ☑ | ☑ | | | | |
| Property market support | ☑ | | | | ☑ | | | |
| Active transport investment | | | ☑ | ☑ | | ☑ | ☑ | ☑ |

### 9.2.5 Costs

The costs associated with Quality Compact Growth are uncertain as they relate to a change in the type of development rather than development itself. For the purposes of this report the costs are assumed to be indirect (i.e. $0).

# 10 Transport

## 10.1 World's leading practice

The analysis of the data for this technical report has revealed that most GHG emissions in Auckland are related to transport and within that, most of the transport-related emissions are due to car-based private transportation. Therefore, the goal of reducing GHG emissions in Auckland will be tied to the shift of transport modes.

As an example of the most dramatic behaviour change, London's Congestion Charge has yielded the most inspiring results in the area of road pricing. However, the congestion pricing scheme was not implemented alone, it was implemented in consort with a substantial increase in public transport capacity (mainly buses) and extensive capital works to London's underground system. Transport for London now reports increased levels of congestion at the moment, largely due to the road, gas and water mains improvements necessary for the 2012 Olympic Games.

Oslo has also adopted a road pricing as a mechanism to implement a "polluter pays" principle, in addition to sustainable mobility options such as cycling facilities and a fleet of 4,000 electric vehicles.[40] In terms of freight, Oslo is using smart logistics and centralised freight transport databases to plan freight-based trips more efficiently and reduce the waste of fuel.

Vancouver has invested significantly in fully segregated bike lanes, and has continued to develop a transportation management plan which seeks to manage private transportation demand to the Downtown and the rest of the metropolitan area. This includes a transportation demand management toolbox which includes comprehensive parking management, usage-based parking management and road pricing. The City of Vancouver predicts that by 2021, 44% of incoming people into the Downtown area will be doing so through public transit and 14% will walk or cycle.

Vancouver is also pushing towards an expansion of electric vehicle infrastructure with a requirement of 20% of all parking spaces in new residential and commercial development to have electric plug-in outlets.

In the UK, freight consolidation is a new approach to freight transport which aims to maximise the loads carried by individual vehicles, reducing the number of partially loaded vehicles on the roads. When achieved, freight consolidation can minimise the number of deliveries to a particular site, which can simplify deliveries for freight customers. Within the S.T.A.R.T[41] network of cities, Bristol is offering incentives to consolidate 5-10 major freight fleets through a package of support, technical guidance and training tools.



[40] http://www.sustainable-mobility.org/news/news-feed/is-oslo-the-capital-of-electric-mobility.html accessed 09/06/2011

[41] Short Term Actions to Reorganize Transport of Goods (S.T.A.R.T) <http://www.start-project.org/bristol.html> accessed 09/06/2011

In Auckland, some initiatives are aiming at the reduction of GHG emissions through transport such as subsidies to biodiesel, and EECA is providing incentives for petrol stations stock blends.[42]

For Auckland, the Regional Land Transport Strategy 2010 -2040 indicates a clear shift away from investment in roads and other car-based infrastructure into public transport improvement. The emphasis is on improving the quality of the existing system, electrifying the rail system and developing an integrated ticketing system for all modes of public transit in Auckland.

## 10.2 2031 Baseline Transport Sector Scenario

The nBaU scenario assumes that distance travelled on Auckland's road network increases according to population growth for private travel and according to GRP growth for commercial and freight travel. This is unrealistic as there will be a point where the available road and public transport infrastructure cannot meet the increasing demand. This will encourage a natural shift away from private vehicles to public transport modes such as rail, bus and ferry.

Therefore it is necessary to consider a 'do something' scenario which represents the expected transport outcomes based on the planned investment in new transport infrastructure, behavioural change programs and the reduced capacity of the Auckland road network.

The expected GHG abatement potential of the 'do something' scenario, with respect to 2031 nBaU, is based on saving 203 TJ of LPG, 2,476 TJ of petrol and 1,370 TJ of diesel per annum. The abatement potential is estimated to be 129.6 kt$CO_2$e in 2031. This represents the abatement which is expected to occur anyway. The following options represent additional measures on top of the 'do something'.

## 10.3 Option T1 – Travel demand management

### 10.3.1 Description

Travel demand management seeks to influence travel choices away from private vehicle use and towards active transport and public transport. Travel demand management may also seek to reduce the need for or length of trips or increase vehicle occupancy where private vehicle use is still required. Policy options include 'pull' measures which incentivise, increase access, ease of use or desirability of active or public transport and 'push' measures which dis-incentivise, reduce access, ease of use or desirability of private vehicle transport.

### 10.3.2 GHG Abatement

The GHG abatement potential of this option is based on saving 1,967 TJ of petrol and 208 TJ of diesel per annum. The abatement potential is estimated to be 157.4 ktCO2e in 2031

42 http://www.eeca.govt.nz/biodiesel-grants accessed 09/06/2011

### 10.3.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | The cost of transport and vulnerability to fuel prices rises will decrease for Auckland residents as alternative transport options are developed. |
| Productivity: | Reduced travel time for staff and goods will increase productivity. |
| Local air quality: | Overall there will be fewer emissions to air across Auckland. |
| Health and wellbeing: | Aucklanders will see reduced respiratory and obesity related illnesses from increased active transport. |

### 10.3.4 Implementation options

There are a range of options available to Council at relatively low cost. While a price signal provided by the NZ ETS will increase fuel prices, complementary measures will be required to overcome information barriers and to remove existing incentives which seek to encourage private vehicle transport.

Potential "push" measures include:

- Strategic road pricing including congestion charges;
- Maximum car parking requirements for new developments;
- Increasing car parking charges; and
- Prioritising short stay car parks over commuter car parks.

Potential "pull" measures include:

- Provision of quality information about public transport services;
- Increase the use of public transport through the provision of a high quality, safe and integrated network of services, fares and ticketing;
- Proactively market public transport in order to increase use by existing passengers and attract new users;
- Develop travel plans which identify existing travel choices and opportunities for reducing the level of vehicle travel needed;
- Encourage households and businesses to take advantage of improvements to communications technology that reduce the need for travel, including (but not limited to) removing barriers to working from home, and supporting teleworking initiatives and telecentres; and
- Develop and implement a strategy to encourage greater occupancy of vehicles and increased use of high occupancy vehicles.

Table 21 Role of Council in Travel Demand Management

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Strategic road pricing | ☑ | ☑ | ☑ | ☑ | ☑ | | | |
| Car parking controls | | | ☑ | ☑ | ☑ | | | |
| Provision of information and marketing | ☑ | ☑ | ☑ | ☑ | | ☑ | | |
| Travel Plans | ☑ | ☑ | ☑ | ☑ | | ☑ | | |
| High occupancy vehicles | ☑ | ☑ | ☑ | | | | | |

### 10.3.5 Costs

This policy covers the extensive application of behavioural change measures such as travel plans, community road safety projects, and area wide travel planning, resulting in significantly reduced car trips to CBD and higher levels of public and active transport. Also included in this policy is the increase in parking charges in the CBD by 50% to 2041 (in real terms), as well as the application of a ‘congestion charge’ of $6, similar to that used in London.

The revenue generated from the increase in parking levies and introduction of a congestion charge is forecast to offset the cost of the implementation of travel demand programs. Overall, approximately $17.8 million per annum is expected to be raised from this policy package.

## 10.4 Option T2 – Active transport infrastructure

### 10.4.1 Description

Active transport infrastructure encourages modal shift away from private vehicles by providing dedicated and safe routes for walking and cycling. Active transport infrastructure may also include broader urban design principles which encourage active transport through the consideration of access, connectivity and permeability of town centres into account.

Walking is an appropriate mode for short local trips (under 2km), for connections between modes, and at the start and end of longer journeys. The most common short journeys are to school, to and from public transport, within the CBD to and around town centres, and to local shops for convenience goods. Cycling is an appropriate mode for short to medium distances (under 10km) as an alternative to cars and as a form of recreation.

Active transport is an essential and widely used mode of transport that is often the quickest and cheapest way to make short trips. Active transport also contributes to improvements in public health, reduced congestion and vibrancy and economic success of town centres.

Active mode trips, including walking in Auckland in 2006 accounted for 9.5 per cent of the region's trips.

### 10.4.2 GHG Abatement

The GHG abatement potential of this option is based on saving 263 TJ of petrol and 54 TJ of diesel per annum. The abatement potential is estimated to be 23.5 ktCO2e in 2031.

### 10.4.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | The cost of transport and vulnerability to fuel prices rises will decrease for Auckland residents as alternative transport options are developed. |
| Productivity: | Reduced travel time for staff and goods will increase productivity. |
| Energy security: | A reduced reliance on imported fossil fuels will improve Auckland's energy security. |
| Local air quality: | Overall there will be fewer emissions to air across Auckland. |
| Health and wellbeing: | Aucklanders will see reduced respiratory and obesity related illnesses from increased active transport. |
| Pride and connection between people and place: | Increased levels of active transport create a more activated and lively public environment and greater connections between residents and their urban environment. |

### 10.4.4 Implementation options

Auckland Council will have a role in the provision of active transport infrastructure as well as ensuring that the infrastructure is integrated into broader transport planning. The NZ ETS and rising fuel prices will also provide greater incentive for Aucklanders to increase active transport. There is therefore an important role for Auckland Council to ensure that spatial planning is able to facilitate the shift. Potential options include:

- Develop and implement local walking and cycling strategies to maximise the throughput of pedestrian and cyclists as priority users for local trips, including travel between public transport, shops, education, recreational, businesses, other facilities and residential areas;

- Complete a regional cycle network to a consistent standard that also includes connections through town centres;
- Prepare separate forward work programmes for investment in improving walking and cycling networks;
- Ensure adequate provision is made for walking and cycling facilities, including facilities at public and commercial destinations, in all transport projects especially those involving public transport facilities and growth centres;
- Review transport infrastructure design standards and policies to ensure that improvements to pedestrian and cyclist safety are fostered; and
- Ensure footpaths are provided at a standard which encourages their use.

Table 22 Role of Council in Active Transport

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Regional cycle network | ☑ | ☑ | ☑ | ☑ | | ☑ | | |
| Active transport strategies | | | ☑ | ☑ | | | | |
| Provision of walking and cycling facilities at destinations | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | | |
| Review transport infrastructure design standards | ☑ | ☑ | ☑ | ☑ | ☑ | | | |
| Footpath standards | ☑ | ☑ | ☑ | | | ☑ | | ☑ |

### 10.4.5 Costs

This policy assumes a high level of public investment in walking and cycling infrastructure – with a particular focus to complete 100% of the regional cycle network. Further actions of this policy include encouraging greater walking and cycling through widespread measures such as reduced speed limits for cars, cycle priority at traffic signals, reallocation of road space, extension of public bicycle schemes and provision of increased end-of-trip facilities.

Arup has assumed this to be in the order of $43 million per annum, in addition to the costs associated with the ‘do something’ scenario.

## 10.5 Option T3 – Public transport infrastructure

### 10.5.1 Description

The provision of public transport infrastructure is perhaps the most important policy in terms of facilitating a shift away from private vehicle transport. Provision of public transport infrastructure is also the joint responsibility of

Auckland Council and central government therefore the extent of Council's influence is greater than across other sectors. The provision of public transport infrastructure is also recognised a key complementary measure to the ETS. Without public transport, the public will have no choice but to incur a carbon price rather than to switch to a low carbon option.

The most appropriate type or extent of public transport infrastructure for Auckland has not been identified as part of the study. Instead the study relies upon previous work undertaken to inform the Auckland Regional Land Transport Strategy in identifying the following infrastructure options of regional significance:

- CBD Rail Link;
- Rail electrification with 10 minute services and connection of the rail system to Manukau City Centre and Onehunga;
- Northern Busway extension to Orewa;
- Airport rail loop;
- Avondale-Southdown rail connection;
- Panmure-Botany-Manukau City Centre RTN/QTN;
- Henderson-Westgate-Albany bus RTN/QTN; and
- North Shore Rail.

### 10.5.2 Potential GHG abatement

The GHG abatement potential of this option is based on saving 924 TJ of petrol, offset by an increase of 200 TJ in diesel as more bus trips are made. The abatement potential is estimated to be 43.4 ktCO2e in 2031.

### 10.5.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | The cost of transport and vulnerability to fuel prices rises will decrease for Auckland residents as alternative transport options are developed. |
| Productivity: | Reduced travel time for staff and goods will increase productivity. |
| Local air quality: | Overall there will be fewer emissions to air across Auckland. |
| Social equity and access to resources: | Improved access to public transport will improve equity of access to jobs and services for all Aucklanders. |

### 10.5.4 Implementation options

The role of Auckland Council in delivering the public transport infrastructure crosses a range of implementation mechanisms from lobbying central government for funding to developing strategies and designs, directly funding some components.

Table 23 Role of Council in Public Transport Infrastructure

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Public Transport Infrastructure provisions | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ |

### 10.5.5 Costs

This study has assumed that the public sector will fund all new investment in public transport infrastructure. The level of capital investment required is currently unknown. For the purposes of this study, Arup has assumed the cost of these public transport infrastructure measures to cost $2 billion in addition to $10 billion assumed under the ‘do something’ scenario. This is an indicative figure only and has only been included do reflect the relative magnitude of the cost of this option. Further detailed refinement of these costs and business case is required for individual projects to determine the cost of abatement more accurately.

In addition to this new infrastructure, Auckland Council would fund a reduction by 50% in all public transport fares. Based on existing public transport revenue, and the increase in public transport trips associated with this policy, Arup has estimated this to cost approximately $26 million per annum.

## 10.6 Option T4 – Improved vehicle efficiency

### 10.6.1 Description

Improving vehicle efficiency will result in reduced carbon emissions without necessarily any change in behaviour. Engine technology has advanced considerably since the 1970s with vehicles purchased today likely to be more than 22% more efficient than vehicles purchased in 1979. Therefore this measure is likely to occur without any intervention by Auckland Council. However, the abatement from improved efficiencies may be maximised by:

- Ensuring new vehicles purchased meet the best available technology in terms of fuel efficiency;
- Encouraging higher rates of turnover and retirement of the least fuel efficient vehicles within the fleet; and
- Encouraging regular maintenance and ecological driving practices to optimise vehicle efficiency during operation.

### 10.6.2 Potential GHG abatement

The GHG abatement potential of this option is based on saving 2,083 TJ of petrol and 1,023 TJ of diesel per annum. The abatement potential is estimated to be 258.5 kt$CO_2$e in 2031.

### 10.6.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living: | Improved vehicle efficiency will deliver a direct reduction in household expenditure on fuel and travel. |
| Cost of doing business: | Improved vehicle efficiency will deliver a direct reduction in business expenditure on fuel and travel. |
| Energy security: | A reduced reliance on imported fossil fuels will improve Auckland's energy security. |
| Local air quality: | Overall there will be fewer emissions to air across Auckland. |

### 10.6.4 Implementation options

Auckland Council has a number of options to improve the efficiency of the Auckland vehicle fleet through making high efficiency vehicles more attractive through reduced registration fees, tax rebate, parking charges and tolls.

Encouraging the retirement of older vehicles has been attempted through scrappage schemes in a number of countries with a dual objective of reducing GHG emissions and stimulating domestic car manufacturing industry. This effectiveness of this option has varied between countries and in terms of GHG emissions abatement is highly dependent on the underpinning assumptions about what constitutes an old inefficient vehicle and a new efficient vehicle. In any case a number of schemes have been highly criticised due to the high cost of abatement. An advocacy role and information provision is therefore considered more appropriate for Auckland Council in encouraging vehicle turnover in this context.

Public awareness and training campaigns to change driver behaviour to encourage more efficient operating speeds or "ecological" driving is also an option.

Table 24 Role of Council in improved vehicle efficiency

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Incentivising high efficiency vehicles | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | | ☑ |
| Encouragement of retirement of inefficient vehicles | | ☑ | ☑ | ☑ | | | | |
| Ecological driving | | ☑ | ☑ | ☑ | | | | |

### 10.6.5 Costs

For the purposes of this document it is assumed that no additional expenditure is required on energy efficiency as a result of policy package measures. That is, it is assumed that vehicle owners will replace cars at an annual 5% turnover the new most efficient vehicle on the market. While there may be an argument to subsidise early retirement, for the purposes of this strategy, subsidies are better off directed towards electric vehicles from a GHG perspective.

## 10.7 Option T5 – Freight Consolidation Centres

### 10.7.1 Description

Freight consolidation centres (FCC) are distribution centres, situated close to a town centre, shopping centre or construction sites, at which part loads are consolidated. This allows for a lower number of consolidated loads to be delivered to the target area for the ‘final mile’ of the urban leg of the delivery. Freight consolidation centres help achieve greater efficiency through optimisation of land use, faster deliveries and in the case of the construction industry reduced material and time wastage. This concept is illustrated in Figure 33 which shows a typical retail centre goods supply system compared to a consolidated delivery approach in Figure 34.

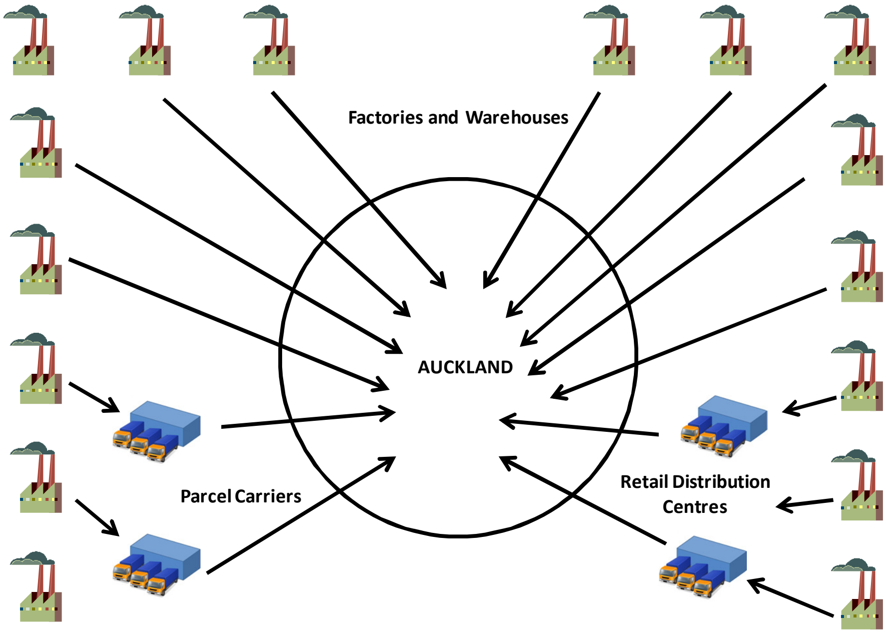


Figure 33 Typical retail centre goods supply channels[43]

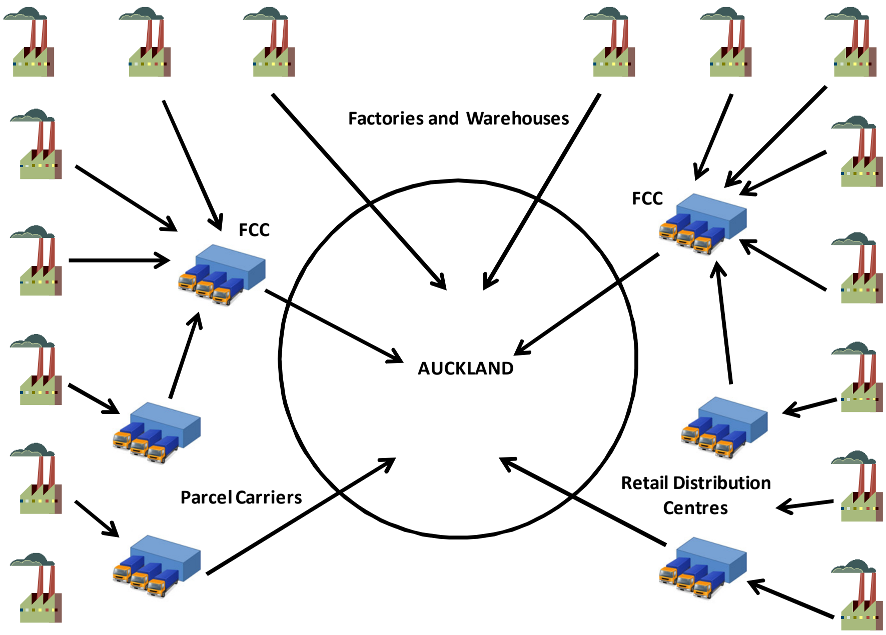


Figure 34 Consolidated delivery approach to supply channels[43]

The viability of freight consolidation centres will depend upon their relative location to markets, their distance from the suppliers and the distance from consumers. There are many existing examples of centres which serve major airports as well as temporary centres which are established to serve large construction projects.

[43] Reproduced from Transport and Travel Research, Freight Consolidation Centre Study Main Report Prepared for UK Department for Transport, 14th July 2010

### 10.7.2 GHG abatement

This report assumes that the freight supply system of Auckland is restructured using such consolidation centres so as to achieve a 5% reduction in freight kilometres travelled[44]. In reality the extent of the reduction will depend upon a number of factors including the industries that are target and the way in which logistics services are contracted (either directly or indirectly as part of a broader contract).

Reductions of up to 75% have been reported for centres established to service construction projects. However centres targeting large corporations with existing efficient freight logistics systems are less efficient with much lower reductions in the range of 2.5% reported. Freight Consolidation Centres are therefore more effective when targeted at retail centres, construction projects or industrial park with small consignment loads.

The GHG abatement potential of this option is based on saving 193 TJ of petrol and 2,357 TJ of diesel per annum. The abatement potential is estimated to be 247.7 ktCO2e in 2031.

### 10.7.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of doing business: | Coordinated delivery services should reduce transport costs for business. |
| Productivity: | Less congestion on major roads will improve business productivity. |
| Local air quality: | Overall there will be fewer emissions to air across Auckland. |

### 10.7.4 Implementation options

Research suggests that for freight consolidation centres to be viable on a purely commercial basis require a significant level of throughput. Therefore operators may experience shortfalls during the start up period before the potential business-as-usual levels of throughput are reached. There is therefore a role for Auckland Council to assist operators during the initial periods through various policy levers to attaining the required level of throughput earlier and/or provide subsidies during the shortfall period. These include:

- Mandate use of an FCC for new developments;
- Provide financial incentives to FCC operator;
- Provide financial incentives (e.g. reduced business rates) to companies who demonstrate they manage their supply chain only to accept deliveries from vehicles that are fully consolidated;

[44] As per VIBAT model which assumes HCV matrix movements for all O-D pairs reduced by 5% to reflect benefits of improved fleet management and reduction in empty running.

- Prioritise access for FCC vehicles via bus lanes, bus gates, road charging rates;
- Mandate use of an FCC for existing retail areas; and
- Provide land or facility for the operation of an FCC.

Table 25 Role of Council in Freight Consolidation Centres

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Mandate use of FCC for new developments | | | | ☑ | ☑ | | | |
| Financial incentives to FCC operators | | | | ☑ | | ☑ | | |
| Financial incentives to businesses | | | | ☑ | | ☑ | | |
| Prioritise access | | | | ☑ | ☑ | | | |
| Mandate use of FCC for existing retail areas | | | | | ☑ | | | |
| Provide land or facility | | | | | | | ☑ | |

### 10.7.5 Costs

The extent of investment required to achieve this reduction is largely unknown and would be subject to a detailed investigation. However case studies in the UK[45] suggest that there is a viable business case for the establishment of freight consolidation areas. For the purposes of this study, Arup has assumed that five FCC's will be introduced, to be co-funded 50/50 by the public sector and industry. To achieve the abatement specified above, this would require an initial capital investment of approximately $13.7 million, with an ongoing annual cost of $2.5 million.

This policy has also assumed the construction of a new freight rail line between Avondale train station to the Auckland Freight Centre at Southdown – a required capital investment of $1 billion, in addition to the costs associated with the 'do something' scenario.

45 Scott Wilson Ltd, 2010, *Freight Consolidation Centre Study*, South East Scotland Transport Partnership

## 10.8 Option T6 – Biofuels

### 10.8.1 Description

This option is a suite of measures to ensure that Auckland maximises the use of biofuels in land transport vehicles. Although biofuel collection, processing and supply has greenhouse gas impacts, they are significantly lower than those from conventional oil based fuel products.

By encouraging every aspect of the biofuel supply chain Auckland will improve the likelihood of meeting the GHG abatement potential. There are additional opportunities outside those included in this option such as the cultivation of energy crops; however for the purposes of this study the abatement potential has not considered these feedstocks.

The amount of biofuel available to Auckland has been based on reports by SCION[46]. Rather than the amount of biomass feedstock potentially captured within Auckland, Arup has assumed that Auckland gets a share of potential national biofuels proportional to GDP (around 18PJ).

Although it is highly likely that biofuel will be used more widely within Auckland in 2031 than they are now, the Naïve Business as Usual projections by URS do not include any emission reduction from biofuel. Although in reality much of the biofuel use could be attributed to the New Zealand Emissions Trading Scheme, for the purposes of this study they will be attributed to Auckland Council's actions.

### 10.8.2 Potential GHG abatement

The GHG abatement potential of this option is based on saving 5,352 TJ of petrol and 4,032 TJ of diesel per annum. The abatement potential is estimated to be 762.7 ktCO2e in 2031.

This excludes emissions associated with the production of the biofuel which are assumed to be accounted for within the growth in the manufacturing and industrial sector.

### 10.8.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

[46]P. Hall and J. Gifford, 2008, *Bioenergy Options for New Zealand: Situation Analysis: Biomass Resources and Conversion Technologies*, SCION, Energy Group
P. Hall and M. Jack, 2008, *Bioenergy Options for New Zealand: Pathways Analysis*, SCION, Energy Group

| | |
|---|---|
| Cost of living and cost of doing business: | This measure will deliver lower fuel costs to business and households in the long term. |
| Employment: | This initiative will develop a new industry with new employment opportunities. |
| Energy security: | A local biofuels industry will buffer Auckland from price fluctuations in the oil market. |
| GHG emissions beyond Auckland: | A strong biofuels industry in Auckland will help to realise emission reductions in other areas of New Zealand and potentially offset emissions that would otherwise be associated with the extraction and refining of fossil based transport fuels. |
| Social capital and community resilience: | The availability of locally produced fuels will improve community resilience. |
| Community representation and leadership: | There are significant opportunities for Auckland to lead the biofuels industry, and reap the rewards of doing so. |

### 10.8.4 Implementation

Arup has identified several implementation measures required to ensure a strong biofuels industry in Auckland. These include:

- Coordinating and advocating for collection of currently under-utilised organic waste from urban and rural areas (e.g. garden waste, forestry residues, agricultural residues);
- Encouraging the development of biofuel conversion and processing facilities in the Auckland region through advocacy and/or financial incentives;
- Encouraging and / or regulating the provision of biodiesel and bio-ethanol at service stations; and
- Leading by example by procuring biofuels for Council operated vehicles (e.g. buses, fleet vehicles).

Table 26 Role of Council in Option T6 – Biofuels

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Encouraging building owners | | ☑ | ☑ | ☑ | ☑ | | | |

### 10.8.5 Costs

The costs for biodiesel have been based on the Bioenergy Options reports by SCION[47]. These costs are estimated at $59.40 / GJ for bio-ethanol and $34.50 / GJ for diesel. These costs are based on large scale industry that has a mature supply chain.

In terms of today's petrol and diesel prices these biofuels are more expensive. However, projections by the Ministry of Economic Development have petrol reaching this bio-ethanol price by the year 2014 and diesel reaching this biodiesel price by the year 2013.

## 10.9 Option T7 – Electric vehicles

### 10.9.1 Description

This policy option aims to facilitate the widespread adoption of plug-in electric vehicles in Auckland. Electric vehicle (EV) technologies are developing at a rapid pace, potentially offering a near-term low-GHG alternative to the petrol and diesel powered vehicles of today. With adequate investment in the necessary infrastructure, and supportive government policy, a transition to EV's and plug-in hybrid electric vehicles (PHEV's) and could be achieved in Auckland by 2031. This would provide many economic, environmental and social benefits including lower operational and maintenance costs, no pollutant emissions, lower overall GHG emissions and reduced dependence on imported oil.

This study has considered a gradual increase in the uptake of EV's and PHEVs over the planning horizon, reaching 80% of all new light passenger and commercial vehicles purchased by 2031, and comprising approximately 50% of the total light passenger and commercial vehicle fleet in Auckland by 2031. The costs of necessary charging infrastructure have been considered including domestic (at-home or work) charging units, public charging units (installed at public locations such as shopping centre car parks), and high-speed (service station type) charging facilities. It has been assumed that there will be no requirements to upgrade the electricity generation, transmission and distribution infrastructure, assuming effective use of smart metering to facilitate off-peak charging and integration of EV charging requirements into normal electricity infrastructure investment.

[47] Available at http://www.scionresearch.com/general/science-publications/science-publications/technical-reports/bioenergy/bioenergy-options , last accessed on the 9/6/2011

The assumptions underlying the estimates of cost and benefits have been adapted from a detailed investigation into the economic viability of electric vehicles in metropolitan New South Wales, Australia[48] and applied to forecasts of Auckland's vehicle fleet and driving characteristics over the planning horizon.

### 10.9.2 Potential GHG abatement

The GHG abatement potential of this option is based on saving 15,024 TJ of petrol and 2,478 TJ of diesel per annum. There is however an increase of 4,167 TJ of electricity per annum. The abatement potential is estimated to be 1,201.2 ktCO2e in 2031.

### 10.9.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Cost of living and cost of doing business: | EV owners will benefit from reduced fuel and vehicle maintenance costs. |
| Employment: | Increased employment in EV infrastructure supply and installation. |
| Energy security: | Decreased dependency on imported fuel sources. |
| Local air quality: | Decreased local air emissions from fossil fuelled conventional vehicles. |
| Endurance: | Electric vehicles are an enduring technology beyond fossil fuels. |

### 10.9.4 Implementation options

The key constraints to the widespread adoption of electric vehicles in Auckland include the availability of EV charging infrastructure, the greater vehicle cost and limited product range when compared to conventional Internal Combustion Engine (ICE) vehicles, and the constrained EV supply to the region.

Globally, government policy to encourage the uptake of EV's has been aimed at both supporting industry supply of EV technology and infrastructure and encouraging consumer demand, through a range of mechanisms including the following[49]:

- Supporting the development of the technology (particularly batteries);

[48] AECOM, *Economic Viability of Electric Vehicles*, Department of Environment and Climate Change, 4 September 2009
[49] As above

- Supporting the electricity network to adjust to the additional demand from EVs;
- Providing charging infrastructure; and
- Making EVs more attractive to consumers (through subsidising the vehicle and reducing operating costs – free parking, free charging).

Some examples of international policies which could be adopted in Auckland include:

- Provision of incentives for EV owners including direct subsidies against EV purchase costs, tax credits for EV purchasers, reduction in parking charges for EV vehicles, reduction in toll charges for EV vehicles, low cost or free public charging facilities.
- Establishing programs for purchasing large numbers of EV's at discount rates for government and private vehicle fleets.
- Provision of grants to fund EV trial and demonstration projects involving the deployment of EV's and charging infrastructure across the city, from which valuable lessons and data can be obtained to guide larger scale implementation.
- Introduction of policies to support the provision of charging infrastructure across the city including expedition of permits for installing charging outlets, creating incentives for employers to install charging outlets, and installing EV charging outlets in government buildings.
- Introduction of regulatory instruments which require electric utilities to move toward a plan to support EV deployment, including smart grid integration.
- Provision of grants to local manufactures to produce efficient EV batteries, charging infrastructure and other components.

It is recommended that Auckland Council adopts a combination of supply side and demand stimulus policies to address the key constraints outlined above.



### 10.9.5 Costs

The estimated net capital cost of EV's and infrastructure over the 20 year planning horizon is approximately $2.8 billion. These costs will be distributed between government, business and the community depending on the implementation measures adopted.

By the end of the 20 year planning horizon, the EV's are estimated to reach price parity with ICE's, and the lower maintenance costs of the EV fleet is estimated to offset the costs of any additional infrastructure required. Beyond 2031, it is estimated that this option will not produce any net ongoing costs, and in fact will produce a net saving when compared to a situation in which only ICE's are used.

## 10.10 Metric based indicators

The overarching aim of most of the above mentioned transport policy packages is to induce a modal shift away from private vehicle use to more sustainable modes of travel such as public transport, walking and cycling. The remainder are focused on improving transport efficiency, and increasing the utilisation of less carbon intensive transport fuels (such as electricity and biofuels).

The implementation of these options could therefore be measured in terms of the percentage of total trips made by private vehicles (compared with public and active transport trips), the average fuel efficiency of the vehicle fleet, the number of electric vehicles registered on Auckland's roads, and the amount of biofuels used in the transport sector.

If all policy options are implemented as proposed it is estimated that by 2031 over 10% of all Auckland trips will be made by public transport, with an associated reduction in the number of private vehicle trips.

| Metric | 2009 (baseline) | 2020 | 2031 |
|---|---|---|---|
| **Proportion of Total Trips by Mode on Auckland's Road network (%)** | | | |
| Private Vehicle (Private and Commercial) | 83.9% | 80.1% | 76.4% |
| Public Transport (Bus, Ferry, Rail) | 3.8% | 7.1% | 10.4% |
| Active Transport (Walking and Cycling) | 9.1% | 9.6% | 10.1% |
| Freight Trips | 3.3% | 3.2% | 3.1% |
| **Increase in private vehicle VKTs on 2006 levels (%)** | 8.7% | 17.4% | 26.0% |
| **Fraction of Total Light Passenger and Light Commercial Vehicle Fleet Comprised of Electric Vehicles** | ~ 0% | 11.0% | 48.4% |
| **Proportion of transport fuels purchased within Auckland (%)** | | | |
| Petrol | 52.7% | 36.7% | 22.7% |
| Diesel | 45.9% | 50.9% | 55.2% |
| Other (natural gas/LPG) | 1.1% | 1.1% | 1.0% |
| Biofuels | ~ 0% | 7.7% | 14.4% |
| Electricity | 0.3% | 3.7% | 6.7% |

# 11 Waste

## 11.1 World's leading practice

The safe disposal or reuse of waste is a challenging urban problem for many city governments. Beyond the direct pressure on available land for landfill, waste produces a number of by-products and pollutants that present risks to healthy urban living. Arup's best practice research outlines a few options for waste reuse or recycling, waste minimisation and waste to energy solutions.

Starting with food and garden waste at a domestic level, Vancouver is implementing a city wide green waste collection scheme, starting with garden waste, then raw food scrap and will finally extend to cooked food scraps. The collection scheme is being rolled out in conjunction with the expansion of a composting plant in the Vancouver area. The output from the plant will be fertilizer sold back to local growers, community gardens or individuals that grow fruit and vegetables locally.

In Helsinki, the local government is acting at a prevention stage, issuing permits for waste disposal, resulting in the prevention of waste formation. This initiative extends beyond households to include small and medium-sized business.

Oslo is implementing an extensive waste to energy scheme, using sewage to produce biogas to power the city's municipal buses. The biogas will be created from a mixture of biomethane and biogas from the incineration of kitchen waste from the capital's restaurants and domestic kitchens. The pilot project is being tested on 80 of the city's buses and if successful will be expanded to 400. The project is estimated to save 44 tonnes of $CO_2$ per year and per bus.[50]

Auckland is already pursuing a few key waste management and minimisation policies, such as the introduction of kerbside recycling and separation of bins in households, biogas production from sewage facilities in the Auckland area and waste minimisation strategies that are adopted by approximately 77% of all territorial authorities, including Auckland. [51]

Moving forward, New Zealand will be looking to consolidate the knowledge of best practice amongst councils, promoting regional cooperation, considering increased funding and drawing more heavily from international best practice for new initiatives. [52]

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[50] http://www.guardian.co.uk/environment/blog/2009/jan/27/biomethane-energy accessed 09/06/2011

[51] Ministry of the Environment, Targets in the New Zealand Waste Strategy: 2006 Review of Progress, 2006.

[52] Ibid.

## 11.2 Option W1 – Waste to Energy

### 11.2.1 Description

This policy option is the development of a waste to energy plant to treat all of Auckland's Municipal Solid Waste (MSW) and Commercial and Industrial Waste (C&I). While the landfills that are used to dispose Auckland's waste are highly effective at capturing methane, alternative processes are much more effective from a greenhouse gas perspective by generating more energy from the waste and avoiding the release of methane into the atmosphere.

There is also a large opportunity for recycling waste and waste minimisation in Auckland[53]. Recycling has been shown to have a higher environmental benefit than all current waste to energy technologies[54] so the policy option is focused at maximising recycling rates before any waste to energy occurs.

For the purposes of this study the waste to energy plant would include an upfront Materials Recovery Facility (MRF) to maximise recycling rates and a thermal treatment plant (e.g. incineration, gasification or pyrolysis) to generate electricity and heat which would be exported to a nearby industrial facility/s. It should be noted that with some of these industrial processes there is also the opportunity to convert the waste into biofuel rather than electricity and heat.

Treatment processes that work on organic material (e.g. anaerobic digestion, bio-stabilisation) could also be a GHG reduction option for Auckland. However using these processes may lead to a smaller energy yield from Auckland's waste steam and so have been excluded.

Rather than a thermal treatment process it could also be possible to use a pre-treatment process that creates a substitute fuel (referred to as RDF or SRF) for use in industrial facilities (e.g. cement kilns). Typically these processes have high levels of emissions abatement as large industrial facilities typically use the cheapest fuels (e.g. coal) which are high emissions intensive.

### 11.2.2 Potential GHG abatement

The GHG abatement potential of this option is based on offsetting 1159 TJ of electricity and 1738 TJ of natural gas as well as reducing net emissions from waste by 332 $ktCO_2e$ per annum.

The abatement potential is estimated to 822.4 $ktCO_2e$ in 2031 and 24,355.3 $ktCO_2e$ over the lifetime of the initiative.

### 11.2.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.



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[53] Auckland Council, *Auckland Council Waste Assessment Overview*

[54] J.G. Pickin et al, 2002, *Waste Management Options to Reduce Greenhouse Gas Emissions from Paper in Australia*, Atmospheric Environment Issue 36

| | |
|---|---|
| Employment: | The upfront sorting of waste requires a substantial workforce and energy business also presents new opportunities. |
| Energy security: | The energy generated at the waste to energy facility will reduce energy imports and increase capacity of distributed energy. |
| Waste to landfill: | The waste to energy option could reduce Auckland's waste to landfill by up to 85%. |
| Off-site emissions: | The waste to energy initiative reduces the potential emissions associated with generating energy and landfill, both of which may occur beyond Auckland. |
| Endurance: | Converting waste to energy is an enduring solution that captures the value of waste which is a constant urban output. |

### 11.2.4 Implementation

The implementation of this measure will take significant effort from Council. One of the first major steps will be to identify preferred technology provider/s and operators for the new integrated waste management facilities.

A concurrent step in developing this initiative is likely to be identifying suitable sites for integrated waste management facilities. These facilities will be significant in their land take and will require substantial setbacks from sensitive receivers. At the same time the business case will be improved significantly if there are nearby industrial facilities with a large requirement for process heat.

The scale of abatement assumed in this study can only be achieved if commercial waste is also treated by the facility. This will require significant advocacy from council and will most likely also require incentives of one kind or another. For the purposes of this study it has been assumed that Council gives the waste management facility an operational incentive so they can offer gate fees that are competitive with landfill.

The final significant measure in implementing this option is to monitor the environmental performance of the waste management facilities to ensure they are meeting air quality, water quality and diversion rate targets.

Table 27 Role of council in Option W1 – Waste to Energy

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Site selection and planning | | ☑ | ☑ | ☑ | | | | |
| Procurement of waste services | | | ☑ | ☑ | | ☑ | | |
| Encouragement of business to use waste to energy | | ☑ | | | ☑ | | | |
| Monitoring of waste treatment provider | ☑ | | | | ☑ | | | |

### 11.2.5 Costs

Arup estimates that the cost of the integrated waste treatment facilities to be approximately $562m. The facilities would receive income from electricity, heat and recyclates, and it is likely that this scheme could operate without government subsidies. There may still be a requirement for operational subsidy from Government and/or an increase to the current levy charged to households and businesses for the disposal of waste. Arup estimates that the additional subsidy /increase in disposal levy would be around 600% or roughly $90/t of waste.

## 11.3 Option W2 –Sewage to Energy

### 11.3.1 Description

Auckland’s waste water treatment system already treats a significant proportion of the City’s biosolids with anaerobic digestion to generate biogas and eventually electricity with small reciprocating engines. A desktop review of Auckland’s wastewater treatment systems identified over 10MW of biogas generators in operation across the City. The remainder of Auckland’s waste water is treated by other processes that do not generate biogas.

This policy option is to expand and optimise this practice such that it meets the potential energy yield of biosolids in Auckland. Arup estimates there is potential additional capacity for approximately the same amount of generation as already exists across the region[55]. This estimate is similar to that by SCION[56] which was roughly 150% additional capacity.



[55] Arup estimates there is capacity for 21MW of biogas generators based on a number of assumptions around biosolid content of wastewater, volatile solid content, biogas yield rates, and capacity factor. This yield could also be expressed as a total of 393TJ of biogas per annum.

[56] P. Hall and J. Gifford, 2008, *Bioenergy Options for New Zealand: Situation Analysis: Biomass Resources and Conversion Technologies*, SCION, Energy Group

### 11.3.2 Potential GHG abatement

The GHG abatement potential of this option is based on generating 61 TJ of electricity and offsetting the use of 81 TJ of natural gas per annum.

The abatement potential is estimated to be 5.5 $ktCO_2e$ in 2031 and 167.4 $ktCO_2e$ over the lifetime of the initiative.

### 11.3.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Energy security: | The energy generated at the sewage to energy facility will reduce energy imports and increase capacity of distributed energy. |
| Off-site emissions: | The waste to energy initiative reduces the potential emissions associated with generating energy and sewage treatment, both of which may occur beyond Auckland. |
| Endurance: | Converting sewage to energy is an enduring solution that captures the value of a constant urban output. |



### 11.3.4 Implementation

The first step in implementing this option is to identify all of the existing wastewater treatment facilities that are currently adopting waste to energy technologies the barriers to further utilising this resource including Watercare facilities and other industrial facilities.

For Council's assets operated by Watercare there is likely to be a role for direct investment and management of sewage to energy initiatives which will likely provide a financial return particularly where upgrades are occurring as a matter of course.

Table 28 Role of council in Option W2 –Sewage to Energy

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Identifying opportunities for optimisation | ☑ | ☑ | ☑ | | | | | |
| Watercare investment | | | | | | ☑ | ☑ | ☑ |

### 11.3.5 Costs

The costs for this measure have been based on biogas generators and not the waste water digesters themselves. This assumption is based on the presumption that the existing waste water treatment facilities without biogas will require upgrade before 2031 regardless of this measure.

Arup estimates the costs to be around $15m for the capital investment and an additional $1m per annum for maintenance of the systems.

## 11.4 Metric based indicators

The waste policy options aim to develop energy plants which utilise solid waste and biosolids waste streams from the region. This has the dual benefit of reducing the amount waste sent to landfill, and generating a renewable energy source. The implementation of these options could therefore be measured as the fraction of total solid waste generated which is sent to landfill (i.e. not recycled or used for energy generation), and the installed generation capacity of sewage to energy plants in Auckland.

Table 29 Metric-based indicators – Waste

| **Metric** | **2009 (baseline)** | **2020** | **2031** |
|---|---|---|---|
| % Total Waste Generated Sent to Landfill | Not known | 64% | 85% |
| Installed Sewage to Energy Generation Capacity | 10.7MW | 16MW | 21MW |

# 12 Carbon Sequestration

## 12.1 World's leading practice

Carbon sequestration refers to the capture and long term secure storage of greenhouse gases which have already been emitted. Sequestration has been widely identified as an important component of mitigation efforts in terms of its ability to reduce future as well as legacy emissions already in the atmosphere. Sequestration can occur via either:

- The capture of GHG emissions from combustion or other industrial processes in geologic formations or deep oceans; or
- The bio-sequestration of greenhouse gases already in the atmosphere by terrestrial or marine photosynthesis and long-term storage of the carbon-rich biomass.

In terms of best practice, South East Queensland has adopted a spatial approach and has mapped GHG sequestration potential through vegetation retention or enhancement throughout the region. Once the mapping of areas suitable for sequestration is completed, local government can use non-statutory means or amend planning schemes to reflect mapped areas identified as being suitable for bio-sequestration through vegetation retention and enhancement.

The Australian Capital Territory Government has also recognised the sequestration potential of biochar. Biochar is a carbon rich material generated from pyrolysis of organic waste which can be applied as a soil conditioner. The carbon derived from waste is then sequestered in soil or biomass. The carbon would otherwise be emitted to atmosphere via either landfill gas predominantly as methane or as carbon dioxide if other waste to energy technologies (including landfill gas) were adopted. The Australian Capital Territory Government is working with leading researchers and tertiary institutions to determine the agronomic, carbon sequestration, and life cycle greenhouse gas emission benefits of using biochar in the local region. This research will assess biochar made from locally specific feedstocks including wood waste, biosolids, household organics and process engineered fuels.

The New Zealand Emissions Trading Scheme is a significant lever in delivering incentives for GHG sequestration through forestry as, under the ETS, sequestration allows for the issuing of permits that can then be sold on.

## 12.2 Option S1 - Riparian land management

### 12.2.1 Description

Riparian planting represents a huge potential bio-sequestration opportunity for Auckland. For riparian planting to be eligible to earn GHG credits under the ETS (and therefore be commercially viable), the area needs to be planted in forest species; be at least 30m wide with crown cover at least 30% and greater than one hectare in size.

Using existing Auckland Council State of the Environment monitoring information, it can be estimated that there are 19,350 hectares of riparian land that is potentially available for planting of forest species under the provisions of the ETS. This estimate is based on the extent of non-forested riparian areas on permanently flowing rivers in rural areas.[57]. This policy option is to encourage the planting of this land by 2030. As the annual GHG sequestration of trees peaks when the trees are between 15 to 20 years old these riparian land forests would need to be managed / harvested after 2031 to ensure they are sequestering their full potential of GHG.

For the purposes of this study it has been assumed that the planting in riparian areas is Douglas Fir and that the planting is achieved within six years. The choice of Douglas Fir as the species is based solely on maximising the amount of carbon sequestered over the medium term (up to 50 years). There may be other considerations that are taken into account when selecting appropriate species for riparian planting; in particular the volume of carbon stored by different species over the long term (> 50 years) is not clear.

### 12.2.2 Potential GHG abatement

The abatement potential is estimated to be 423 kt$CO_2$e in 2031 and 10,226 kt$CO_2$e over the lifetime of the initiative.

### 12.2.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | The planting and management of riparian re-vegetation projects would be a large employment given the scale of this measure. |
| Water quality: | Riparian planting will help reduce pollutant loads (e.g. sediment, nutrients and chemicals) discharged in run-off from adjacent agriculture. |
| Biodiversity: | Riparian planting of native forests will have an important role in increasing ecological value and fostering biodiversity. |
| Endurance | Investment in environmental restoration provides a long term legacy for the community. |

[57] Neale, M.W. 2011. Riparian planting opportunities for carbon sequestration in Auckland (Memorandum). Auckland Council.

| | |
|---|---|
| Cultural co-benefits | This initiative is likely to provide benefit against all the cultural co-benefits: engaging and strengthening community organisations; strengthening visual identity and connection with place; renewing significant landscape features and sites; engaging local knowledge and demonstrating leadership. |

### 12.2.4 Implementation

The planting of native forest in riparian lands will be encouraged by the Central Government's Emissions Trading Scheme which allows for emission units to be created by sequestration projects.

However there are many other benefits to this activity that could potentially be worthwhile incentivising (i.e. ecological value). For the purposes of this study it has been assumed that the businesses planting the forests bear the full costs. The financial benefit to the businesses from the NZ emissions trading scheme have not been included in the cost of abatement calculations.

Table 30 Role of Council in Option S1 - Riparian land management

| **Implementation Mechanism** | **Role of Council** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| Identify priority riparian zones based on both catchment health and GHG sequestration potential. | | | | ☑ | | | | |
| Regulate damage and removal of new or existing riparian vegetation | | | | | ☑ | | | |
| Incentivise riparian forestation on private property and fund initiatives on Council land. | | | ☑ | | | ☑ | | |

### 12.2.5 Costs

The initial capital costs to fence and plant the available 19,350 hectares of riparian land is assumed to be $373m ($54m for fencing and $319m for planting. Ongoing maintenance costs are assumed to be 1% of the capital.

## 12.3 Option S2 – Forestation of marginal land

### 12.3.1 Description

Planting forest on marginal land (i.e. land that it is not sustainable to use for rural production activities) represents a further bio-sequestration opportunity for Auckland. Similar to riparian zones, forestation of marginal land will produce environmental benefits in addition to carbon sequestration, and may be eligible to earn GHG credits under the ETS.

Auckland Council has estimated a marginal land area of 65,325ha with potential for forestation. This policy option is to encourage the planting of this land by 2030. As with the riparian land management option, marginal land forests would need to be managed to maintain high GHG sequestration potential as the vegetation ages.

It is noted that the portion of this land that is currently covered by forest species, and the portion already captured under the riparian land management option is unknown. These factors would need to be determined to gain a better understanding of the GHG sequestration potential and cost of these land management options.

For the purposes of this study it has been assumed that the planting on marginal land areas is native forest. Although it would be possible to plant species that sequester more GHG these species would not necessarily have the same benefit to local ecological values.

### 12.3.2 Potential GHG abatement

The potential abatement is unknown at this stage and will depend on the outcomes of future investigations including those recommended above.

### 12.3.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | The re-vegetation and management of marginal lands would be a large employment given the scale of this measure. |
| Biodiversity: | Re-vegetation of marginal lands will have an important role in increasing ecological value and fostering biodiversity. |
| Endurance: | Investment in environmental restoration provides a long term legacy for the community. |
| Cultural co-benefits: | This initiative is likely to provide benefit against all the cultural co-benefits: engaging and strengthening community organisations; strengthening visual identity and connection with place; renewing significant landscape features and sites; engaging local knowledge and demonstrating leadership. |

### 12.3.4 Implementation

The planting of native forest on marginal lands will be encouraged by the Central Government's Emissions Trading Scheme which allows for emission units to be created by sequestration projects.

However there are many other benefits to this activity that could potentially be worthwhile incentivising (i.e. ecological value). For the purposes of this study it has been assumed that the businesses planting the forests bear the full costs. The financial benefit to the businesses from the NZ emissions trading scheme have not been included in the cost of abatement calculations.

Table 31 Role of Council in Option S2 – Forestation of marginal

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| Identify priority areas for marginal land forestation. | | | | ☑ | | | | |
| Incentivise marginal land forestation on private property and fund initiatives on Council land. | | | ☑ | | | ☑ | | |

## 12.4 Option S3 – Biochar

### 12.4.1 Description

Biochar is the product of thermal degradation (350-500 degrees Celsius) of organic material (e.g., green waste, manure) in the absence of air (pyrolysis) and is distinguished from charcoal by its use as a soil amendment.

Biochar has potential as a carbon sequestration method and has the additional benefit of potentially improving the physical quality and water holding capacity of soils. In addition, this method can aid farmers in meeting their carbon emission obligations by January 2015.

Substantial research has focused on its potential role in carbon sequestration, reducing greenhouse gas emissions, renewable energy, waste mitigation and as a soil amendment.

Auckland Council (through RIMU) is funding PhD research (beginning late 2011) investigating the agronomic and environmental benefits of Biochar through field trial studies in vegetable growing regions of Pukekohe (a region which tends to be carbon deficient).

The focus of this project would be to engage growers and community groups in field trials on Biochar, and demonstrate how various potential benefits can be obtained using Biochar derived from plant or other feed stock material to lock carbon in soil (carbon sequestration), improve farm productivity, as well as reduce nutrient leaching, in the organic matter depleted vegetables growing region of Pukekohe.

An added benefit for both the farmer who applies Biochar in the soil, and for the environment is that the carbon in Biochar remains locked up in the soil for many years longer than, for example, carbon applied as compost, mulch or crop residue. This will aid the farmers in meeting the 2015 carbon emission obligations.

### 12.4.2 Potential GHG abatement

The potential abatement is unknown at this stage and will depend on the outcomes of future investigations including those recommended above.

### 12.4.3 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

Employment: Bio-char has the potential to create a new economic activity and related employment.

Productivity Bio-char has been demonstrated to improve the productivity of agricultural land, including marginal growing lands.

### 12.4.4 Implementation

Table 32 Role of Council in Option S3 – Biochar

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Monitor | Advocate | Coordinate | Strategise | Regulate | Fund | Provide services | Manage Assets |
| | | ☑ | | | | | | |

## 12.5 Option S4 – Marine Sequestration

The carbon stored and sequestered by our oceans and coasts, is entering the climate debate in a big way.

According to a recent UNEP report of all the carbon captured by living organisms globally, 55% is captured by marine and coastal organisms. Of this carbon sequestered in the marine environment, between 50 and 71% is stored in coastal vegetated habitats such as mangroves, saltmarshes and seagrasses.

However, these eco-systems are being lost at an incredibly rapid rate, as much as 7% annually, and most could be lost within two decades.

The main reasons blamed are unsustainable resource use practices, poor watershed management, poor coastal development practices and poor waste management. Threats are not always marine-based, and poor water quality resulting from land-based activities is a major reason for the degradation of marine carbon sinks. Losing these ecosystems not only erodes their natural capacity for carbon sequestration, but also affects human health, food security and economic development. Potential measures to enhance and restore the capacity of marine ecosystems to sequester carbon include:

- Encourage sustainable, environmentally sound ocean-based production, including algae and seaweed;
- Curtail activities that negatively impact the ocean's ability to absorb carbon;
- Catalyse the natural capacity of blue carbon sinks to regenerate by managing coastal ecosystems for conditions conducive to rapid growth and expansion of seagrass, mangroves, and saltmarshes.

In the first instance Auckland Council could establish a project to examine which marine species are the fastest and most effective in taking up carbon, informed by Department of Fisheries data on carbon sequestration.

### 12.5.1 Potential GHG abatement

The potential abatement is unknown at this stage and will depend on the outcomes of future investigations including those recommended above.

### 12.5.2 Key Co-benefits

A full analysis of co-benefits for each option is appended to this report. Key co-benefits are summarised below.

| | |
|---|---|
| Employment: | Marine sequestration has the potential to create new economic activity and related employment as well as to contribute to the sustainability of existing marine based industries. |
| Productivity: | Marine sequestration may improve the productivity of existing marine based industries and ensure the ongoing viability of local marine based food resources |
| Water quality: | Marine sequestration has the potential to improve the region's water quality through the enhancement of the region's wetland systems. |
| Biodiversity: | Marine sequestration has the potential to improve biodiversity through the regeneration of the Region's estuaries and coastal wetlands including mangrove saltmarshes which are often nurseries for juvenile fish and provide important breeding and feeding areas for birds. |

| | |
|---|---|
| Sites of significance: | Maori have strong cultural, traditional and historic links with wetlands and inland waterways. These *taonga* (treasures) are spiritually significant and closely linked to the identities of the *tangata whenua* (people of the land). |

### 12.5.3 Implementation

Table 33 Role of Council in Option S3 – Biochar

| Implementation Mechanism | Role of Council | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Monitor** | **Advocate** | **Coordinate** | **Strategise** | **Regulate** | **Fund** | **Provide services** | **Manage Assets** |
| | | ☑ | | | | | | |

## 12.6 Metric based indicators

The overall impact of sequestration within the region may also be established directly through the use of continuous monitoring. Auckland is one of the few cities which do not currently have measured data on atmospheric GHG concentrations.

Direct measurements are needed to understand the temporal and spatial patterns of fuel and energy use by urban dwellers and to quantify the role of plant processes. Such quantifications are important for creating parameters and validating urban emission/distribution models, and to support development of urban emission reduction strategies such as this carbon reduction strategy.

Development of a long-term continuous monitoring programme for GHG concentrations (ensuring at least a minimum of 5 years data for trend analysis) and carbon source apportionment covering the Auckland region to accurately quantify carbon emissions is needed.

Auckland Council is funding a PhD research project which quantifies atmospheric GHG fluxes and measures their temporal variability at annual, seasonal and diurnal scales, and determines the proportion of anthropogenic, biogenic and geogenic GHG sources and sinks.

This project could form one of a small number of projects which can inform development of a long-term continuous monitoring programme for GHG in the Auckland region, to guide programme design, site selection, identify GHG hotspots, major sources and spatial distribution of carbon emissions.

# 13 Other options

There are a range of other options which have not been further explored within this strategy for various regions. These include measures within the agricultural sector, community air and sea travel and the industrial process emissions occurring at the Glenbrook Steel Mill.

## 13.1 Agriculture

Emissions occurring within the agriculture sector are as a result of enteric fermentation and fertiliser use. Emissions associated with energy use within the agriculture sector are included within manufacturing and industrial options.

This strategy does not directly identify specific policy options for agricultural emissions which require intervention by Auckland Council. Notwithstanding, emissions within the agricultural sector could be expected to decrease due to:

- The inclusion of agriculture within the NZ ETS which will provide an economic incentive to shift to low GHG practices; and
- Likely reduction in agricultural activity within Auckland as a result of expansion of metropolitan boundaries.

Any abatement occurring as a result of the above would be additional to the abatement identified within this strategy.

## 13.2 Transport – Air

Emissions associated with air travel are projected to increase according to population growth. No specific policy interventions have been identified. Emissions reductions within this sector may occur as a result of a worldwide shift to biofuels or a decrease in air travel which may occur following spike in world oil prices. However, demand for air travel is increasing which may also increase air travel related emissions in the short term.

Any abatement occurring as a result of the above would be additional to the abatement identified within this strategy.

## 13.3 Industrial process emissions

The industrial process emissions attributed to Auckland are solely as a result of the reductions of iron sand reaction occurring within the Glenbrook Steel Mill which produces carbon dioxide from coal via a non combustion reaction. This reaction is stoichiometrically fixed. Without changing its process or reducing production, no abatement could occur.

Detailed analysis of opportunities to alter Glenbrook's process is outside of the scope of this strategy. Notwithstanding, there may be opportunities for capture of this relatively pure source of carbon dioxide for sequestration utilising algae, which could have a variety of uses including biofuels and/or biopolymers.

Any abatement occurring as a result of the above would be additional to the abatement identified within this strategy.

# 14 Behaviour Change

## 14.1 Scope

The extent to which the GHG reductions modelled in this report are realised will in part be determined by the extent to which residents, businesses and other community users engage with the initiatives and change their behaviours and choices.

The BAU baseline underpinning this study assumes that consumption patterns and behaviours contributing to GHG emissions will not increase significantly in Auckland. Experience in other countries is that consumption does increase with wealth unless deliberate strategies are in place to limit this growth. If Auckland does follow a trend of increasing consumption (for example more energy use or car-based travel) bigger reductions could be required in other areas in order to meet Council's GHG reduction target.

The modelling also makes assumptions about community uptake of technology. Whilst these assumptions are conservative, a level of behaviour change will still be required to achieve the predicted change and therefore achieve the project outcome. More rapid and/or extensive uptake of technology (beyond that assumed in the modelling) could deliver better outcomes which would position Auckland well to contribute to the national target by 2050.

Whilst it would be a fallacy to imply that Auckland Council can change people's behaviours, there is a significant body of research and evidence demonstrating that people can be inspired to change themselves given the right enabling conditions. It is therefore recommended that Auckland Council plan for, invest in and lead a behaviour change program designed to create the conditions for change and therefore meet the GHG reduction target.

It is not within the scope of this study to propose a behaviour change strategy for Auckland. However this section provides some background and key ideas to inform future development of a behaviour change strategy, including some best practice examples from around the world.



## 14.2 Best Practice Examples

### 14.2.1 Low Carb Lane Project in the UK

The Low Carb Lane project commenced as a project to reduce energy emissions in one house in a 'typical' street in the UK. The project team began to engage with residents of the street and quickly realised that although residents were struggling to make ends meet week to week and the cost of energy was a significant household outgoing they were not interested in emissions reduction. They also learnt that residents were united in concerns about money, and about the physical decline of the street and corresponding deterioration of community spirit.

The Low Carb Lane project was therefore designed to engage the community around the twin concerns of money and community pride – and in doing so achieve emissions reduction.

Key outcomes included:

- A television-based ‘home energy dashboard’, which residents can use to understand where their energy is used and so take control of use;
- SaverBox - a ‘pay-as-you-save’ scheme designed to remove financial barriers to installing energy-efficient home improvements;
- ‘Four Steps to 60%’ – an information program for energy reduction based on local data:
    - 10% reduction through more efficient appliances;
    - 20% reduction with loft or cavity-wall insulation;
    - 15% by generating energy, perhaps through solar panels or wind power; and
    - 15% through behavioural changes including switching the TV off stand-by at night, boiling less water in the kettle, and understanding how to control energy bills.

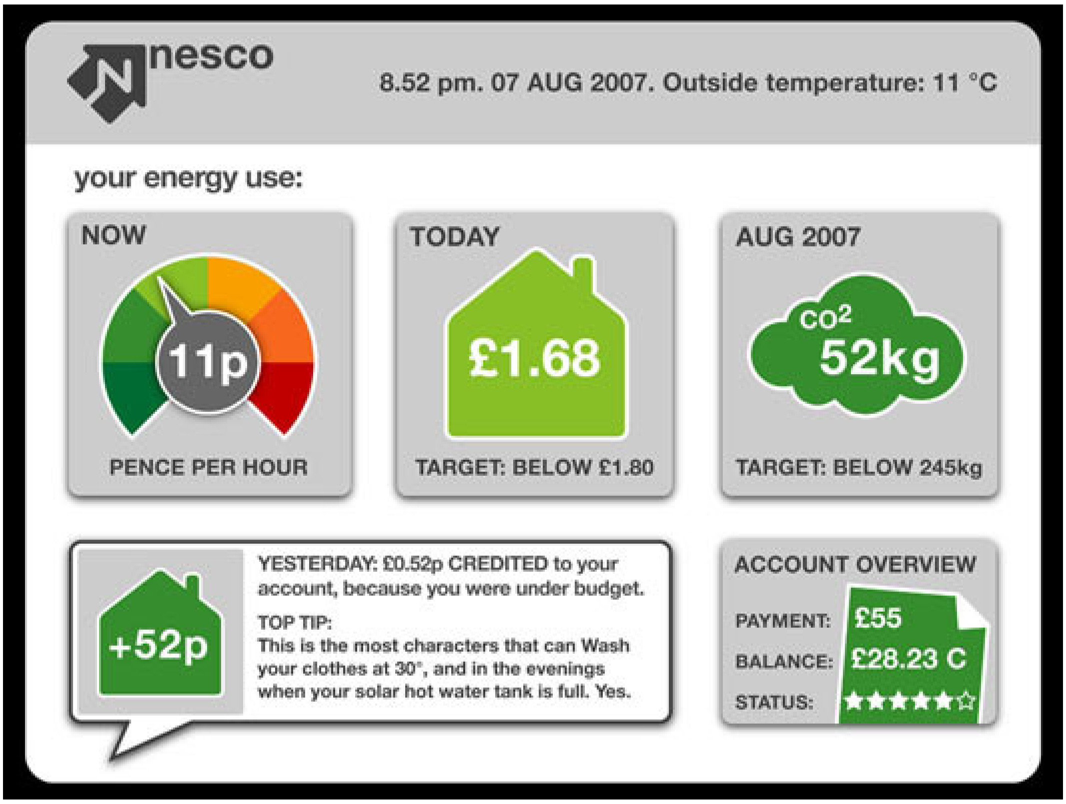


Figure 35 The Low Carb Lane TV-based Energy Dashboard

The key learning from the project was the need to engage people about the issues they are passionate about and through this, define some shared goals.

### 14.2.2 Climate Generation and Climate Cool

Climate Cool is an initiative of the British Council to engage and inspire young people in SE Asia in emissions reduction initiatives. It utilises websites and social media to inform and connect grassroots youth groups. The interactive web site includes relevant content, encourages networks to engage in climate action-oriented networks and enables online debate and interaction.

Other successful initiatives to engage young people and community members in direct climate action include Powershift, Australian Youth climate coalition, 10:10 and 350 Aotearoa.

These initiatives are all underpinned by the idea that people can be inspired to change when they are informed about acting in their own lives, and that a groundswell of community based change can be created. The initiatives also demonstrate the power of social media and virtual networks.

### 14.2.3 Green Building Council

The Green Building Council of New Zealand is one of a global network of organisations that are owned by the property industry and have the charter of transforming the industry through market-led change. One of the objectives of the GBCNZ is "providing enablers for our members to actively lead the market". Green Building rating system seek out and reward market leaders in building sustainability and create common language and greater certainty for tenants and prospective building owners.

The success of the Green Building Council is evidenced by changing market practices and expectations around waste and recycling, water and energy efficiency, air quality and cyclists facilities, amongst other things. In many countries regulators are following the lead of the GBC, making mandatory those practices that began as exemplary.

### 14.2.4 Twin Streams

Project Twin Streams began in 2003 as a large-scale environmental restoration and stormwater management project, whose primary goal was to engage the community in environmental restoration and behaviour change. Informed by Local Agenda 21, the project was designed to create conditions where people could become connected to their local streams and then develop an understanding of the connection between the health of the streams and wider sustainability issues, including the impacts of lifestyle and individual behaviours on the environment.

In addition to extensive areas of stream rehabilitation, the project has spawned a number of off-shoot initiatives. One of these is the Sustainable Household / Sustainable Living Program which aims to engage participating communities in changes to their own households or environment. The program engages at both a household and community group level with activities and initiatives relevant to the local community. It has achieved measurable outcomes.

The program demonstrates the power of local community groups in influencing change.

## 14.3 Ideas for a Behaviour Change Strategy

### 14.3.1 Theory

The notion of how new ideas are socially infused, has been studied for more than a century. In 1962 Rogers published the Diffusion of Innovation which became a seminal text for behaviour change. The uptake to digital technologies over the past two decades, and the opportunities they present for rapid dissemination of information, has provided much fuel for the behaviour change theorists. The apparent challenges of engaging the community in behaviour change around environmental protection and sustainability have also attracted much attention.

Ideas and theories of note include:

- Community based social marketing, notably the work of Doug McKenzie-Mohr's;
- The work of Futerra Sustainability Communications Group, particularly their succinct publication “Sizzle”;
- Malcolm Gladwell’s ‘The Tipping Point’ and the subsequent “Made to Stick’ by Dan and Chip Heath;
- Self Determination Theory; and
- Social Learning Theory.

Common to the contemporary behaviour change theories is the recognition that the greatest barrier to social change, and at the same time, greatest motivator, is personal gain. Change must resonate with people’s individual goal and values, it must deliver benefits they understand and care about, and for most people change must be relatively easy and must not pose a risk of social discomfort or alienation. A successful behaviour change program needs to be designed to tick these boxes.

A review of current thinking and best practice examples suggests that sustainability behaviour change initiatives gain traction when:

- The behaviour is communicated as contributing to a relevant and inspiring vision rather than a fix for an overwhelming problem;
- The focus is shifted from getting people to care about the issue at hand, to aligning the issue with their existing concerns and values;
- People can observe leadership and hear about their peers adopting and benefitting from the new behaviour; and
- Perceived barriers to uptakes are overcome and rewards are evident.

Rogers’ work in 1962 included an analysis of how ideas diffuse in a community, as communicated in the curve below. The four requirements described above can assist the diffusion of change beyond the Innovators and Early Adopters (or in the case of Sustainability the ‘converts) to the wider community.

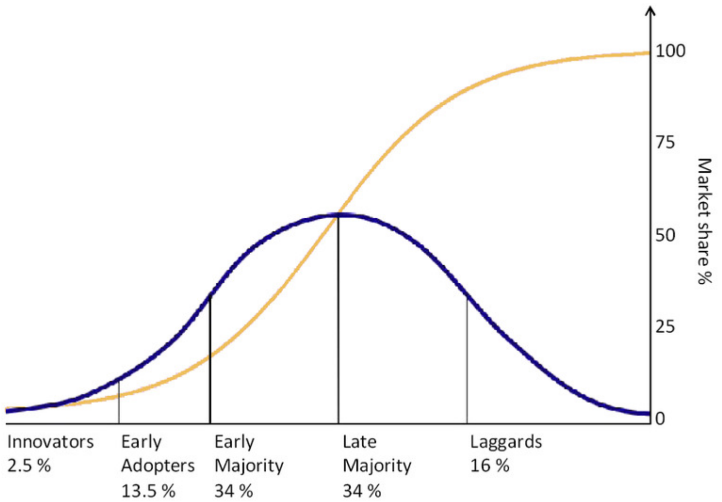


Figure 36: Diffusion of ideas. Source: Wikipedia, from Rogers.

### 14.3.2 Vision

If Martin Luther King's opening lines in 1963 had been "I have a problem" history would have taken a very different course. The challenge in engaging the community with GHG reduction has been the discourse around the problems and bleak outlooks, rather than a positive vision for the future. And a low-carbon community is a positive vision: cleaner air; lower energy bills; fitter, healthier people; local food production; less commuting time and greater community independence.

"Sizzle" by the Futerra Sustainability Communications Group, identifies the need to describe a climate change 'heaven' via a short vision that creates a positive, visual and locally relevant future that the community can aim for. The vision should create a sense of hope, progress and passion, but most of all it needs to capture people's attention and imagination and align with their personal hopes for the future.

Futerra contend that once a consumer actively engages with the vision, they are also able to engage in a discussion about the choice or alternative possibility, in this case the climate change 'hell' and the big but tangible steps or plans that will lead to heaven instead of hell; and. Finally, people who have engaged with the vision are more likely to commit to personal actions that will contribute to the vision.

This suggests that Council may need to frame the proposed targets and proposed initiatives to achieve that target as a Vision of Auckland in twenty or thirty years. We propose the Vision could be presented as a simple snapshot of the attractive features of Auckland's economy, lifestyle, environment and technology use in a low carbon future. The GHG Reduction Strategy can then be discussed in terms of the tangible steps that will deliver that future.

### 14.3.3 Personal Alignment and Benefit

The Low Carb Lane case study provides an excellent example of the potential for change when the change is aligned with community concerns, and the seemingly impossibility of change when it is unaligned.

Self-determination theory (SDT) recognises the importance of intrinsic motivation for psychological health and well-being. People feel self-determined when they believe their behaviour has been driven by their own choices, values, and interests. Intrinsic motivation satisfies our needs to feel competent, connected with others and in control of our lives. On the other hand when people perceive their behaviour as being controlled by some external event, person, or force, they feel a loss of power and self-determination.

A sustainability behaviour change program is therefore best framed around choice and on engaging intrinsic motivation by focussing on the co-benefits that are aligned with community concerns and motivators, rather than focussing simply on emissions reduction. Numerous co-benefits are identified throughout this report, some of which will be successful motivators for the community.

It is recommended that Council undertake research to develop a clear understanding of the community's key motivators (which will include financial benefit/fuel security, but may also include community improvement, social capital, air quality and health and other personal motivators). These motivators will inform the design of appropriate programs to deliver technologies and promote behaviour change. The design of a television based energy meter for the Low Carb Lane project is an example of how this can work.

### 14.3.4 Leadership

*The majority of people prefer to follow rather than lead change. Behaviour change is therefore reliant on people becoming inspired to change by what their peers have achieved. This can be achieved by leadership and by dissemination of stories.*

The Diffusion of Ideas recognises the importance of Innovators and Early Adopters in creating change. Social Learning Theory tells us that people learn through observation, firstly imitating leaders or superiors and over time, as their understanding of underlying concepts grows, adopting the behaviour of peer role models.

An effective behaviour change program must therefore allow space for, and foster, community leaders of change. Council itself can position itself as an innovator and leader of change, taking advantage of its influence, large workforce and asset base. This has been done effectively by other Governments around the world. Opportunities for Council leadership include:

- Transform Council's vehicle fleet to electric vehicles and bio-fuel as appropriate;
- Use 100% renewable power in Council facilities, including on-site generation;
- Eliminate use of Council vehicles for private commuting, and incentivise staff to use public or active transport;
- Improve the energy and water efficiency of all Council properties, including social housing stock;

- Install real-time displays in Council and public facilities;
- Direct Council greenwaste to bio-fuel production or waste to energy converters; and
- Set and report on attainment of sustainability targets for Council operations.

In particular, the greening of Council's building portfolio represents a significant opportunity to lead industry and market change because of the sheer size and breadth of the portfolio.

It is also recommended that Council invest in initiatives that target and reward 'GHG leaders' within the community. Initiatives that have been adopted elsewhere include:

- Small incentive grants for business and community groups wanting to undertake transformational projects;
- Free promotion of businesses providing GHG services to the community;
- 'Rewards' such as cheaper parking for electric vehicles, rates reductions for green buildings; and
- A Mayoral Awards Program that recognises innovators who are contributing to Auckland's future targets.

Brisbane City Council provides some example of initiatives to foster leaders within the community in the arena of sustainability.

### 14.3.5 Stories and Peer Norming

Having engaged the leaders, and commenced a momentum of change, stories and examples of peer norming are required to disseminate the stories of the leaders to the rest of the community, particularly the Early Adopters. Web and social media initiatives such as Climate Cool rely on both the sharing of stories to inspire others to act and on local groups who meet locally.

Community-based social marketing is informed by research that indicates that initiatives to promote behaviour change are usually more effective when carried out at the community level, involving direct contact with people. This supports a finding of the Twin Streams project review that initiatives to reach out via community leaders and networks appeared more effective than door-to-door engagement.

It is recommended that Council actively seek out opportunities to disseminate stories and examples of sustainable behaviour through existing community structures. One method will be the use of websites and social media such as Facebook, LinkedIn and Twitter to gather and disperse stories. Engagement with existing networking organisations, Sustainable Business Network, Chambers of Commerce, the Auckland Executive Club and with community organisations will also be central to this strategy.

This process could be underpinned flagship stories that can be used to engage and inspire others. Chip and Dan Heath[58] identify the importance of stories that are "simple, unexpected, concrete, credible and emotional" for the dissemination of

[58] Made to Stick, Chip and Dan Heath, 2007

ideas. Options include a reality-television program that is a competition between households, streets or businesses towards the Council's GHG target. This will draw out real stories, and demonstrate how changes can be made.

### 14.3.6 Removing the Barriers

Even with the best motivation for change, people must have the ability and capacity to accommodate the new technology or behaviour. This speaks to physical resources and needs, including time, money, physical demands and a difficulty factor of learning the new.

The Saver Box initiative created for Low Carbon Lane is an example of a mechanism specifically designed to address physical, in this case financial, barriers to change. This initiative also delivered benefit in terms of energy savings, providing long term appeal for residents. Pay-back schemes such as these are increasingly being used for sustainable change, particularly for building retro-fits.

Incentives are another commonly used approach to overcome the barriers to change. However it is important to weigh up the pros and con of incentives, which sometimes help and sometime hinder. There is some evidence that when an incentive is withdrawn participants often have lower motivation to adopt the behaviour than if the incentive were not offered initially. Design of an effective incentive program must honour the receiver, in essence saying "we know you are motivated to change, but that it is hard, so we are trying to help you", instead of the less honourable implication that the receiver does not care and so must be paid to care.

It may also be that an external trigger is required to remind, encourage or prompt a new behaviour, at a time when both the motivation and ability exist.[59]A number of research studies into the value of something as simple as a smiley or sad face on an energy bill, with energy reduction hints, can motivate small changes in behaviour.

For each individual initiative described in this report, consideration must be given to delivery strategies that can stimulate motivation and ability, and prompt change. The following initiatives are just some options that may be appropriate.

- Loans similar to Saver Box, where the recipient can utilise future utilities savings to pay back the loan.
- Competitions between Boards, neighbourhoods or streets for the biggest reductions in consumption, travel and other aspects of the strategy. Prizes might be local community projects and improvements.
- Use of infomatics and real time information displays in public spaces and large buildings or via web and smart phone apps, to create feedback loops between behaviours and progress towards the target.
- Making new infrastructure visible and accessible in preference to old infrastructure. For example site bike paths, bike parking, electric vehicle charging stations and public transport access in visible locations around the CBD, which are easier to access and more visible than car parking areas.

[59] Adapted from Rogers, Diffusion of Innovation, 1962 and Fogg, A Behaviour Model for Persuasive Change.

### 14.3.7 Pricing and regulation

Finally, pricing and regulation has a role to influence behaviour change, particularly for the approximately 16% of the community who resist change. The downside of pricing and regulation is that it can send heavy messages, limit choice and achieve minimum compliance only. However a positive example of the success of this approach is the use of demand management and metering of water which has been shown to achieve reductions of up to 25% reduction in household water use. This recognises the importance of true pricing which reflects the value of resources, and the price of managing emissions.

Some examples of pricing or regulatory approaches that could assist the GHG strategy include:

- Minimum efficiency standards for building, appliances, cars etc;
- Inverted block/tiered pricing for water and energy that penalises over-use and peak demand;
- Congestion charges and or peak hour tolls for road infrastructure; and
- Higher registration fees for fossil-fuel cars.

# 15 Summary of results

## 15.1 GHG Abatement

The policy options outlined above have the potential to reduce Auckland's emissions by **38.0%** based on 1990 levels by 2031. This excludes additional abatement which could be achieved by behaviour change as well as other measures within the agricultural, industrial process and air travel sectors.

The potential abatement modelled for this study is illustrated in the wedge diagram shown in Figure 37 below which indicates the contribution of the different policy sectors to the overall target. The upper level in the chart is the 2031 nBaU projections without ETS and forestry (refer Figure 38), and the coloured wedges demonstrate the contribution of each proposed group of initiatives in reducing this level towards the target.

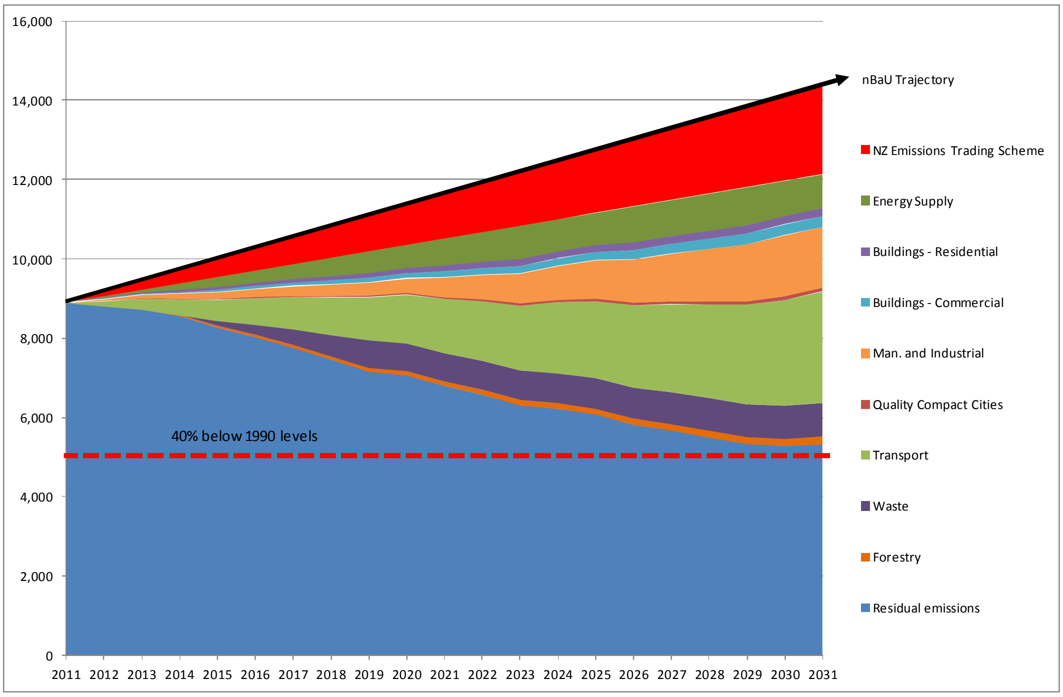


Figure 37 Wedge diagram of potential GHG abatement to 2031.

The comparison of the baseline, projections under nBaU, projections with GHG abatement measures and the 2031 target are presented in Figures 38 and 39, showing the net emissions where forestry sinks are subtracted.

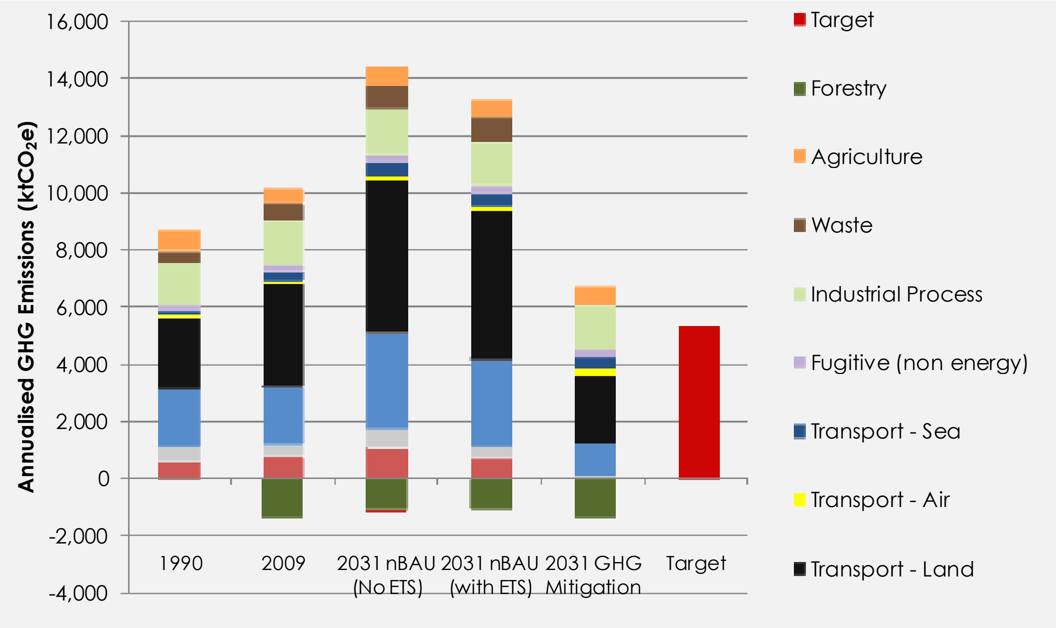


Figure 38 Baseline, projections with and without measures and target

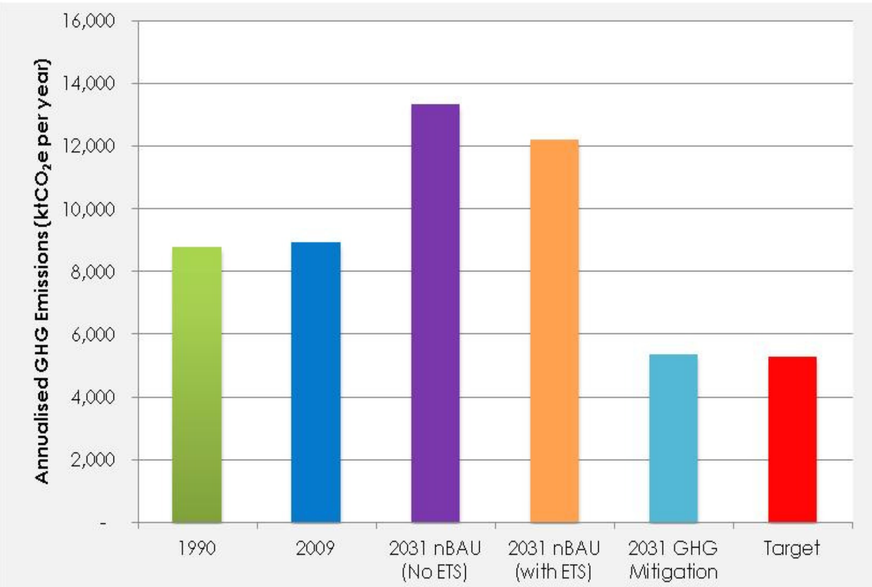


Figure 39 Net baseline, projections with and without measures and target (subtracting forestry sinks)

## 15.2 Cost of Abatement

### Cost of Initiatives

The strategy provides a high level estimate of the capital costs, operating costs and potential energy savings for each initiative over the period from 2011 to 2031. These are shown in Table 34 as both nominal cost and present value. The total capital costs are estimated as $39.4 billion (nominal cost) and $20.7 billion (present value), whilst the lifetime energy savings accrued result in an estimated present value of $57.9 billion. For most of the initiatives the ongoing savings outweigh the capital costs such that there is likely to be a significant overall positive cost benefit to Auckland from this investment.

Table 34 Estimated Nominal Value, Present Value and Net Present Value

| Sector | Nominal Value ($Billion) | | | Present Value (2011 $Billion) | | | Net Present Value (2011 $Bn) |
|---|---|---|---|---|---|---|---|
| | Capital Cost | Operating Cost | Energy Savings | Capital Cost | Operating Cost | Energy Savings | |
| Government | $19.1 | $3.9 | $0.2 | $10.1 | $1.3 | $0.1 | -$11.3 |
| Community | $15.1 | $1.0 | $185.8 | $7.7 | $0.4 | $34.5 | $26.4 |
| Business | $5.2 | $9.6 | $124.9 | $2.9 | $2.1 | $23.3 | $18.3 |
| **TOTAL** | **$39.4** | **$14.5** | **$310.9** | **$20.7** | **$3.8** | **$57.9** | **$33.3** |

In the above analysis, Present Value represents the value in 2011 dollars of future expenditure (capital and operating) associated with the proposed initiatives. Present Value is also applied to projected savings in fuel and energy expenditure. Net Present Value is the aggregate value of these costs and savings in 2011 dollars. Noting that Net Present Value includes the energy and fuel savings only and specifically excludes other operational or productivity cost benefits that may be accrued. These values have been calculated using generally accepted economic tools for determining the present, or discounted, value of money.

The $39.4 billion ($20.7bn PV) represents the total capital spending that would be required in order for the initiatives to proceed. A high level cost structure developed for this report assumed that around $19 billion would be contributed by either Central Government or Auckland Council, $5 billion by business/industry and $15 billion by the community.

It is important to note that these amounts are not fully additional to Business as Usual expenditure. In many cases the cost of the initiatives will overlap with required and/or planned spend, such as expenditure on transport infrastructure and building upgrades. For example $11 billion of the estimate relates to transport initiatives which Council is proposing to deliver anyway. However it was beyond the scope of this study to quantify the gap between Business as Usual expenditure and the proposed initiatives.

High level life-cycle cost analysis was also undertaken to determine the potential operational cost benefits for each element of the strategy and who would benefit from this saving. This analysis focussed on differences in energy consumption over the life of the infrastructure compared to a business as usual approach.

For example, the reduced energy consumption from residential retrofits is allocated as a cost saving to the community. The analysis also quantified the relative savings from fuel switching initiatives, for example petrol costs versus electricity costs for a shift towards electric vehicles.

The above assumptions indicate a significant mismatch between who pays and who saves with the majority of the capital costs assigned to government whilst the majority of savings are realised by the community and business. In practice there is potential to shift some of the cost to the private sector, such as through direct capital investment or longer term value uplift mechanisms, and user pays options. Again it was beyond the scope of this study to prepare detailed business cases for each option. However numerous tested models exist around the globe that could be applied in the Auckland context.

The assessment indicates an overall benefit in the order of $33bn (net present value) from the investment, This benefit is achieved via estimated savings in fuel and energy costs of  $310.9 billion in nominal costs over the life of the investment and $57.9bn in 2011 dollars (present value). These represent an ongoing saving to government, businesses and residents, which will have direct economic benefit for the city and region.

In addition to GHG abatement, the majority of the options would also yield significant co-benefits, particularly in terms of health and productivity. These are identified in this study but have not been quantified in terms of economic benefit. The experience of other global cities has been that these co-benefits can contribute significantly to the overall business case, in terms of economic and social benefit.

It is recommended that Auckland Council undertake feasibility studies or preliminary business cases for the various initiatives to:

- Quantify the order of cost above Business as Usual funding requirements;
- Determine funding models that align cost with beneficiary;
- Quantify the value of co-benefits; and
- Explore the relative cost or benefit of different program options and delivery models.

In many cases these feasibility studies would be required anyway to explore the feasibility of Business as Usual infrastructure proposals, such as the Transport Plan.

## Relative Cost of Abatement

Arup combined the capital cost estimates with the life cycle energy cost estimates and the estimated emissions reduction to determine the relative cost of abatement for each initiative. The detailed assumptions are outlined in Table 35 and Table 36. The cost of abatement for each policy option is summarised in a cost of abatement curve in Figure 40 below[60].

The net present value of each initiative is determined as the present value of the capital and operational costs minus the present value of energy savings. Initiatives which fall below the horizontal axis have the least cost of abatement and provide a positive return on investment (or a net present value greater than zero).

The width of the bar represents the GHG abatement potential of each initiative and the area of each bar the total net present value of the abatement.

Figure 3 therefore provides a visual indication of the relative cost benefit of each initiative in terms of GHG reduction. The chart indicates that the three individual initiatives likely to deliver the largest benefit in terms of emissions reduction are

[60] The horizontal axis in the cost of abatement curve represents the total lifecycle abatement (as opposed to the annualised abatement) and therefore is equivalent to the area of the wedges presented in the wedge diagram; however this chart is broken down by initiative.

retrofit of manufacturing and industrial buildings, electric vehicles and bio-fuels. All three of these options sit in the cost-positive sector of the chart.

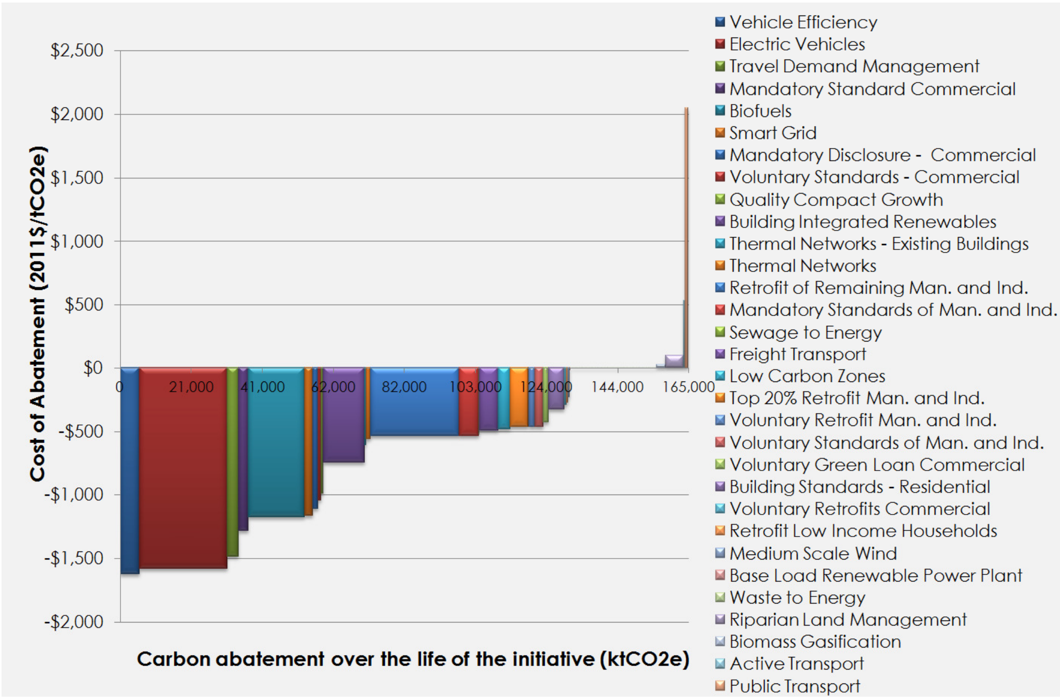


Figure 40 Cost of abatement curve

Figure 3 depicts a high cost of abatement for public transport and active transport initiatives. This is to be expected and does not imply that public transport has a negative cost benefit. It merely indicates that the energy savings from public transport do not by themselves payback the significant capital costs. As with all initiatives, the only financial benefits included within the cost of abatement curve are benefits associated with fuel and electricity savings.

However, it is widely accepted that there are a range of wider benefits associated with public transport and active transport that would contribute to its business case including productivity benefits through travel time savings, reduced road congestion and improved health and air quality. Indeed, it is standard practice in New Zealand and elsewhere for transport infrastructure to undergo detailed cost benefit analysis as part of feasibility studies including consideration of wider economic benefits. Such a study was beyond the scope of this report.

A tabularised summary of the results of each option and in total is presented in Table 35 and Table 36 below.

Table 35 Summary of Results – GHG

| Initiative Number | Initiative Description | Lifetime GHG Savings | GHG Savings in 2031 | % GHG Reduction on 1990 Levels | % GHG Reduction on 2031 BaU levels | Cost of abatement | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Government | Community | Business | Total |
| | | ktonne CO2e | ktonne $CO_2$e | % | % | 2011$ per tonne $CO_2$e | | | |
| E1 | Large scale renewable baseload power plant | 196.1 | 5.9 | 0.03% | 0.05% | $408.3 | $0.0 | -$428.0 | -20 |
| E2 | Medium scale wind | 651.6 | 14.6 | 0.08% | 0.12% | $0.0 | $0.0 | -$62.9 | -63 |
| E3 | Thermal networks (new buildings) | 1,254.1 | 42.1 | 0.24% | 0.35% | $35.2 | $0.0 | -$595.6 | -560 |
| E4 | Thermal networks (existing buildings) | 524.8 | 18.0 | 0.10% | 0.15% | $0.0 | $0.0 | -$605.0 | -605 |
| E5 | Building integrated renewables | 11,928.6 | 456.1 | 2.57% | 3.75% | $0.0 | -$747.4 | $0.0 | -747 |
| E6 | Low carbon precincts | 3,611.1 | 145.3 | 0.82% | 1.19% | $0.0 | $0.0 | -$481.8 | -482 |
| E7 | Biomass cogeneration | 2,688.9 | 82.7 | 0.47% | 0.68% | $0.0 | $0.0 | $26.2 | 26 |
| E8 | Smart grids | 2,283.8 | 86.5 | 0.49% | 0.71% | $1,478.3 | -$1,107.5 | -$1,595.2 | -1,224 |
| R1 | Standards for new residential buildings | 4,517.4 | 194.0 | 1.09% | 1.59% | $225.5 | -$549.8 | $0.0 | -324 |

| Initiative Number | Initiative Description | Lifetime GHG Savings | GHG Savings in 2031 | % GHG Reduction on 1990 Levels | % GHG Reduction on 2031 BaU levels | Cost of abatement | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Government | Community | Business | Total |
| | | ktonne CO2e | ktonne $CO_2e$ | % | % | 2011$ per tonne $CO_2e$ | | | |
| R2 | Retrofit existing homes | 512.3 | 15.6 | 0.09% | 0.13% | $604.7 | -$611.0 | -$268.5 | -275 |
| C1 | Voluntary standards - commercial | 884.0 | 30.7 | 0.17% | 0.25% | $0.0 | $0.0 | -$1,041.6 | -1,042 |
| | Mandatory disclosure - commercial | 1,530.6 | 51.1 | 0.29% | 0.42% | $0.0 | $0.0 | -$1,106.7 | -1,107 |
| | Mandatory standard Commercial | 2,722.1 | 102.3 | 0.58% | 0.84% | $0.0 | $0.0 | -$1,283.2 | -1,283 |
| C2 | Voluntary retrofits commercial | 607.4 | 20.6 | 0.12% | 0.17% | $0.0 | $0.0 | -$291.9 | -292 |
| | Voluntary Green Loans Commercial | 1,622.5 | 61.9 | 0.35% | 0.51% | $0.0 | $0.0 | -$425.3 | -425 |
| I1 | Voluntary standards of Man. and Ind. | 2,455.8 | 89.2 | 0.50% | 0.73% | $0.0 | $0.0 | -$462.1 | -462 |
| | Mandatory standards of Man. and Ind. | 5,682.1 | 214.1 | 1.21% | 1.76% | $0.0 | $0.0 | -$533.4 | -533 |
| I2 | Top 20% retrofit Man.and Ind. | 5,299.3 | 192.5 | 1.08% | 1.58% | $0.0 | $0.0 | -$465.5 | -466 |
| | Voluntary retrofit Man. And Ind. | 1,766.4 | 64.2 | 0.36% | 0.53% | $0.0 | $0.0 | -$465.5 | -466 |
| | Retrofit of remaining Man. and Ind. | 25,748.3 | 970.4 | 5.47% | 7.97% | $0.0 | $0.0 | -$534.3 | -534 |

| Initiative Number | Initiative Description | Lifetime GHG Savings | GHG Savings in 2031 | % GHG Reduction on 1990 Levels | % GHG Reduction on 2031 BaU levels | Cost of abatement | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Government | Community | Business | Total |
| | | ktonne CO2e | ktonne $CO_2e$ | % | % | 2011$ per tonne $CO_2e$ | | | |
| T1, 2, 3, 5 | Transport (Auckland Transport Network)[61] | 12,696.5 | 590.8 | 3.33% | 4.85% | $2,109.9 | -$861.4 | -$1,025.0 | 223 |
| T4 | Improved vehicle efficiency | 5,556.8 | 258.5 | 1.46% | 2.12% | $0.0 | -$1,482.1 | -$140.6 | -1,623 |
| T6 | Biofuels | 16,398.9 | 762.7 | 4.30% | 6.27% | $0.0 | -$725.7 | -$448.2 | -1,174 |
| T7 | Electric vehicles | 25,447.7 | 1,201.2 | 6.77% | 9.87% | $42.0 | -$1,444.6 | -$176.5 | -1,579 |
| Q1 | Quality Compact Growth | 554.5 | 25.8 | 0.15% | 0.21% | $0.0 | $149.8 | -$1,138.4 | -989 |
| W1 | Waste to energy | 24,355.3 | 822.4 | 4.63% | 6.76% | $76.9 | $19.2 | -$93.3 | 3 |
| W2 | Sewage to energy | 167.4 | 5.5 | 0.03% | 0.04% | -$524.9 | $0.0 | $0.0 | -525 |
| S1 | Riparian land management | 5,191.3 | 211.5 | 1.19% | 1.74% | $0.0 | $0.0 | $99.6 | 100 |
| | **Total** | **166,856** | **6,736** | **37.95%** | **55.34%** | **$207** | **-$489** | **-$377** | **-$659** |



[61] Transport initiatives on Auckland's road network include initiatives T1 - T5 and a "do something" initiative. The "do something" is defined as the transport network changes that would be required in any case to accommodate business as usual growth in transport demand including an estimated $11 billion in planned investment in public transport, travel demand management and road network upgrades. To determine the total abatement from all initiatives on Auckland's road network, an aggregate of all transport initiatives including "do something" has been modelled by Auckland Council's transport model. Table 35 and Table 36 present this aggregated abatement for the purposes of establishing the overall contribution to the target. Conversely, the cost of abatement curve in Figure 40 presents the modelled output for individual initiatives excluding "do something" representing the difference between the individual initiatives.

Table 36 Summary of Results – Capital Costs and NPV

| Initiative Number | Initiative Description | Capital Costs (Nominal Value) | | | | NPV ($2011) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Government | Community | Business | Total | Government | Community | Business | Total |
| | | $Million | | | | $Million | | | |
| E1 | Large scale renewable baseload power plant | $0.0 | $0.0 | $96.7 | $96.7 | -$24.5 | $0.0 | $25.6 | $1.2 |
| E2 | Medium scale wind | $0.0 | $0.0 | $448.5 | $448.5 | $0.0 | $0.0 | $20.0 | $20.0 |
| E3 | Thermal networks (new buildings) | $22.5 | $0.0 | $88.0 | $110.5 | -$12.3 | $0.0 | $207.9 | $195.6 |
| E4 | Thermal networks (existing buildings) | $0.0 | $0.0 | $22.2 | $22.2 | $0.0 | $0.0 | $64.0 | $64.0 |
| E5 | Building integrated renewables | $0.0 | $10,809.7 | $0.0 | $10,809.7 | $0.0 | $2,789.1 | $0.0 | $2,789.1 |
| E6 | Low carbon precincts | $0.0 | $0.0 | $614.3 | $614.3 | $0.0 | $0.0 | $509.5 | $509.5 |
| E7 | Biomass cogeneration | $0.0 | $0.0 | $362.7 | $362.7 | $0.0 | $0.0 | -$27.0 | -$27.0 |
| E8 | Smart grids | $2,341.0 | $0.0 | $0.0 | $2,341.0 | -$1,262.0 | $945.5 | $1,361.8 | $1,045.2 |
| R1 | Standards for new residential buildings | $646.0 | $2,769.0 | $0.0 | $3,414.9 | -$370.5 | $903.3 | $0.0 | $532.9 |

| Initiative Number | Initiative Description | Capital Costs (Nominal Value) | | | | NPV ($2011) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Government | Community | Business | Total | Government | Community | Business | Total |
| | | $Million | | | | $Million | | | |
| R2 | Retrofit existing homes | $74.2 | $0.0 | $227.2 | $301.4 | -$130.1 | $131.4 | $57.8 | $59.1 |
| C1 | Voluntary standards - commercial | $0.0 | $0.0 | $47.0 | $47.0 | $0.0 | $0.0 | $353.2 | $353.2 |
| | Mandatory disclosure - commercial | $0.0 | $0.0 | $52.2 | $52.2 | $0.0 | $0.0 | $563.9 | $563.9 |
| | Mandatory standard Commercial | $0.0 | $0.0 | $174.0 | $174.0 | $0.0 | $0.0 | $740.0 | $740.0 |
| C2 | Voluntary retrofits commercial | $0.0 | $0.0 | $201.1 | $201.1 | $0.0 | $0.0 | $69.1 | $69.1 |
| | Voluntary Green Loans Commercial | $0.0 | $0.0 | $603.4 | $603.4 | $0.0 | $0.0 | $153.6 | $153.6 |
| I1 | Voluntary standards of Man. and Ind. | $0.0 | $0.0 | $27.3 | $27.3 | $0.0 | $0.0 | $424.1 | $424.1 |
| | Mandatory standards of Man. and Ind. | $0.0 | $0.0 | $60.7 | $60.7 | $0.0 | $0.0 | $635.2 | $635.2 |
| I2 | Top 20% retrofit Man.and Ind. | $0.0 | $0.0 | $49.3 | $49.3 | $0.0 | $0.0 | $922.1 | $922.1 |
| | Voluntary retrofit Man. And Ind. | $0.0 | $0.0 | $16.4 | $16.4 | $0.0 | $0.0 | $307.4 | $307.4 |

| Initiative Number | Initiative Description | Capital Costs (Nominal Value) | | | | NPV ($2011) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Government | Community | Business | Total | Government | Community | Business | Total |
| | | $Million | | | | $Million | | | |
| | Retrofit of remaining Man. and Ind. | $0.0 | $0.0 | $262.8 | $262.8 | $0.0 | $0.0 | $2,883.3 | $2,883.3 |
| T1, 2, 3, 5 | Transport (Auckland Transport Network) | $15,506.9 | $0.0 | $6.9 | $15,513.7 | -$8,656.5 | $3,534.1 | $4,205.5 | -$916.9 |
| T4 | Improved vehicle efficiency | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 | $2,662.4 | $252.6 | $2,915.0 |
| T6 | Biofuels | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 | $3,847.4 | $2,376.2 | $6,223.6 |
| T7 | Electric vehicles | $475.8 | $1,500.6 | $901.2 | $2,877.7 | -$341.3 | $11,735.5 | $1,433.7 | $12,827.9 |
| Q1 | Quality Compact Growth | $0.0 | $0.0 | $0.0 | $0.0 | $0.0 | -$28.6 | $217.1 | $188.5 |
| W1 | Waste to energy | $0.0 | $0.0 | $561.7 | $561.7 | -$569.0 | -$142.2 | $690.7 | -$20.5 |
| W2 | Sewage to energy | $15.1 | $0.0 | $0.0 | $15.1 | $29.9 | $0.0 | $0.0 | $29.9 |
| S1 | Riparian land management | $0.0 | $0.0 | $373.0 | $373.0 | $0.0 | $0.0 | -$166.9 | -$166.9 |
| | **Total** | **$19,081** | **$15,079** | **$5,196** | **$39,357** | **-$11,336** | **$26,378** | **$18,280** | **$33,322** |

## 15.3 Metric based indicators

A consolidated summary of the metric based indicators presented throughout this report is presented below.

Table 37 Summary of metric based indicators

| Metric | 2009 (baseline) | 2020 | 2031 |
|---|---|---|---|
| **% Energy Supplied by Renewables Generated within Auckland** | 0% | 17% | 48% |
| **% Properties with Smart Grid Access** | 0% | 50% | 100% |
| **Energy Consumption by Residential Sector (electricity and natural gas) per capita (per annum)** | 3.21 GJ/capita (per annum) | 2.07GJ/capita (per annum) | 1.40GJ/capita (per annum) |
| **Energy Consumption by Commercial Sector (electricity and natural gas) per unit GRP (per annum)** | 0.76 TJ/$M GRP (per annum | 0.69TJ/$M GRP (per annum) | 0.65TJ/$M GRP (per annum) |
| **Energy Consumption by the Manufacturing and Industrial Sector (electricity and natural gas) per unit GRP (per annum)** | 1.69TJ/$M GRP (per annum) | 1.32TJ/$M GRP (per annum) | 0.8TJ/$M GRP (per annum) |
| **Proportion of Total Trips by Mode on Auckland's Road network (%)** | | | |
| Private Vehicle (Private and Commercial) | 83.9% | 80.1% | 76.4% |
| Public Transport (Bus, Ferry, Rail) | 3.8% | 7.1% | 10.4% |
| Active Transport (Walking and Cycling) | 9.1% | 9.6% | 10.1% |
| Freight Trips | 3.3% | 3.2% | 3.1% |
| **Increase in private vehicle VKTs on 2006 levels (%)** | 8.7% | 17.4% | 26.0% |
| **Fraction of Total Light Passenger and Light Commercial Vehicle Fleet Comprised of Electric Vehicles** | ~ 0% | 11.0% | 48.4% |
| **Proportion of transport fuels purchased within Auckland (%)** | | | |
| Petrol | 52.7% | 36.7% | 22.7% |
| Diesel | 45.9% | 50.9% | 55.2% |
| Other (natural gas/LPG) | 1.1% | 1.1% | 1.0% |
| Biofuels | ~ 0% | 7.7% | 14.4% |
| Electricity | 0.3% | 3.7% | 6.7% |
| **% Total Waste Generated Diverted from Landfill** | Not known | 64% | 85% |
| **Installed Sewage to Energy Generation Capacity** | 10.7MW | 16MW | 21MW |

# 16 Conclusion and next steps

Auckland's GHG target is achievable. And in achieving the target, Auckland will attain other city goals. Notably, the strategies for GHG reduction outlined in this study describe a liveable city, one that has better air quality, fewer cars, activated streets, greater job diversity, improved resilience and healthier people. The GHG strategy will enable Auckland to rightly claim its place as a leading city in the fight to tackle climate change.

When compared with other cities in New Zealand, Australia and North America, Auckland already has a relatively low GHG footprint. However the majority of developed countries are experiencing an upward trend in consumption of power, fuel and other resources and Auckland is no different in this regard. The GHG strategy seeks to accommodate the desired improvements in liveability with technologies and spatial planning approaches that de-couple growth in GHG consumption from increasing prosperity.

Preliminary modelling indicates that, over time, the majority of the proposed GHG reduction strategies will have a net positive economic outcome for the city, delivering savings to residents and businesses alike. This suggests that the GHG target will not be a brake on economic growth and may actually stimulate greater investment.

Initiation of the transition to a low-GHG Auckland will require leadership and courage from Council. The strategy requires investments that have long pay-back periods, it may require new taxing and rating regimes in order to realise returns on investment, and it will require changes in the personal decisions people make about travel and consumption.

The first steps in delivering this strategy is to ensure that the Auckland Plan enables the initiatives described in the strategy, and to identify and eliminate planning and development processes that could hinder the strategy.

Other next recommended steps include:

- Finalise an implementation timeline for the strategy, identifying dependent projects and potential quick wins;
- Identify catalyst projects that Council can commence in the short term;
- Prepare detailed implementation plans for key aspects of the strategy, which would address current gaps in knowledge or modelling and develop more sophisticated funding and delivery mechanisms for the individual initiatives (Council has commenced this via commissioning of an energy strategy); and
- Plan and commence a community engagement and behaviour change program, initially targeting innovators who may lead change.

The strategy provides a path, and an imperative, for Auckland to secure its long term future through investment in the reduction of both GHG emissions and energy costs. By doing so Auckland will realise its goals of becoming a global city and the world's most liveable city.

# Appendix A

## Methodology: Baseline And Projections

# A1 Overview

To inform the baseline and projections Arup reviewed previous studies undertaken by Maunsell AECOM and URS. These studies provided estimates of emissions for various years and various emission sectors including both projections and backcasting. A summary of the methodologies adopted is presented in Table 38 below.

Table 38 Previous Studies' Methodologies

| Methodology Component | Maunsell AECOM ARC GHG Futures Stage 1as - Baseline Data Review | URS GHG Now - Regional GHG Inventory Projections |
|---|---|---|
| Baseline Year(s) | 2001, 2006 | 2009 |
| Sector Breakdown | Residential, Commercial, Industrial, Transport, Agricultural, Waste | Kyoto Sectors plus gas consumption and electricity consumption total |
| Baseline Methodology - Stat E | 2001,2006 Energy Data from MED | 2010 Energy data from MED |
| Baseline Methodology - Transport | CCP methodology based on vehicle km travelled determined from vehicle registrations in ARC and generic fuel consumption data | 2010 Energy data from MED |
| Baseline Methodology - Ag | Assumed 8% of national inventory | Based on livestock counts and farm types from "farming community" |
| Baseline Methodology - LULUCF | Not included | Plantings since based on rates sourced from MAF and NEFD |
| Baseline Methodology - Waste | Supplied by CCP (black box) | Based on nationals rates of per capita waste disposal with standard landfill emission factor |
| Backcasting/projection year | 1990, 2040 | 2025, 2040 |
| Backcasting/projection methodology-Stat E (non electricity) | Trends established between 2001 and 2006 for energy consumption by industry per capita and projected/backcasted based on changes in population | Various: per capita trends, per $GRP trends, change in oil price, GHG price, fuel consumption trends |

| Methodology Component | Maunsell AECOM ARC GHG Futures Stage 1as - Baseline Data Review | URS GHG Now - Regional GHG Inventory Projections |
|---|---|---|
| Backcasting/projection methodology-Electricity consumption | Trends established between 2001 and 2006 for energy consumption by industry per capita and projected/backcasted based on changes in population | Based on population growth |
| Backcasting/projection methodology-Transport | Trends established between 2001 and 2006 for energy consumption by industry per capita and projected/backcasted based on changes in population | Various: per capita trends, per $GRP trends, change in oil price, GHG price, fuel consumption trends |
| Backcasting/projection methodology-Ag | Not altered from baseline | Based on trend of national annual growth rate |
| Backcasting/projection methodology-LULCF | Not included | Based on trend of national annual growth rate |

## A1.1 1990 Baseline

In order to determine the 1990 baseline and therefore 40% reduction target, Arup adopted the Maunsell AECOM backcasting estimate. The backcasting methodology adopted for energy related emissions was based on observed trends in fuel consumption between 2001 and 2006 for the residential, commercial and industrial sector and transport which have been recorded by the Ministry for Economic Development since 2001. For the agricultural sector emissions were assumed to have remained constant over this period. Emissions associated with waste were assigned to Auckland based on the waste generated within the community which was assumed have increased in line with population trends.

The 1990 baseline allows for an assumption of zero forestry GHG sinks in accordance with the Kyoto Protocol accounting rules which have also been adopted by the NZ Emissions Trading Scheme rules for accounting of forestry credits.

## A1.2 2009 Baseline

Arup also adopted a 2009 baseline in order to provide a more detailed understanding of emissions including sectoral and spatial distribution. The 2009 baseline adopts the total 2009 GHG emissions as estimated by URS, but reallocates emissions by sector.

The broad sectoral distribution between residential, commercial and industrial was based on the Energy End Use Database prepared by EECA. The Energy End Use Database provides a breakdown of fuel consumption by sector for the Auckland Region based on 2007 data. Arup used this data to determine the relative emissions distribution between the commercial, residential and manufacturing and industrial sectors which was applied to the URS 2009 stationary energy emissions baseline.

The URS values for stationary energy were also compared to the EECA End Use Database as presented in below.

Table 39 Comparison between URS and EECA values for stationary energy consumption within Auckland Region (TJ)

| Source | Electricity | Natural Gas | LPG | Petrol | Diesel | Coal | Fuel oil | Wood | Solar | Total E |
|---|---|---|---|---|---|---|---|---|---|---|
| URS (2009) | 32,792 | 17,577 | - | - | - | 1,398 | - | 1,347 | - | 53,114 |
| EECA (2007) | 35,062 | 20,023 | 1,596 | 987 | 2,814 | 4,012 | 551 | 10,373 | 87 | 74,431 |
| % | -6.9% | -13.9% | | | | -187% | | -670% | | -40% |

While the electricity and natural gas consumption values are relatively consistent, there is a large discrepancy in other fuel usage. This is mainly due to the exclusion of consideration of petrol, diesel and LPG as a stationary energy fuel source within the URS baseline. Further wood consumption is accounted for by URS within the forestry sector assuming that wood consumption for stationary energy consumption is generated from wood harvested within the Auckland Region. The EECA results suggest that this underestimates the wood combustion within Auckland.

To address these discrepancies, Arup has reallocated the petrol and diesel consumption assigned to transport by URS to stationary energy sectors according to the breakdown between transport and stationary energy petrol and diesel provided by EECA. This results in the same total emissions as per the URS baseline.

Emissions from wood were reallocated from the forestry sector to stationary energy. This still has the effect of underestimating wood combustion related emissions when compared with EECA but provides consistency with the URS projections.

The additional LPG and coal consumption identified within the EECA estimates remains unaccounted for.

## A1.3 2031 Projections

The range of projections considered by URS is indicative of the wide range of potential scenarios which may affect emissions growth. Arup chose to project emissions based on population growth for the residential and private transport sectors and by $GRP for other stationary energy and transport sectors. Waste estimates and fugitive emissions were increased based on population growth, while agricultural sector emissions and forestry emissions were projected based on the continuation of existing trends identified by URS. Industrial process emissions were kept constant over the period assuming that the Glenbrook Steel Mill does not increase production.

# Appendix B

## Methodology: Distribution of Commercial, Manufacturing and Industrial Emissions

# B1 Overview

In order to distribute energy consumption across local boards for 2009 and projections in 2031, a number of data items were required. The methodology Arup has used to allocate commercial and industrial stationary energy consumption across the City involves the following:

1. Establish energy consumption by sector with the following:
    - Gross Regional Product ($ mil of GRP) in 2009 and 2031
    - Energy by GRP (TJ/$mil) in 2009 and 2031
    - Total emissions in 2009 and 2031
2. Use 2009 census data (employment figures) to allocate energy consumption by sector across local boards in Auckland.

There are two major studies that are relied upon for Arup's methodology. In regard to economic modelling by commercial and manufacturing sector, the following study was used:

- *Economic Futures for the Auckland Region* (Parts 1 and 2) – a study of the potential and possible trajectories that the economy of the Auckland region will encounter in a twenty-five-year period, from 2006 to 2031.[62]

  The study provided projections in employment and GRP for 2031 and segregated figures by sectors. Additionally, the study provided energy intensity figures by sectors as TJ per $mil GRP.

In regard to energy consumption by sector, the following study was used:

- *The End Use Energy Database* developed for EECA – a top-down economic model that attributes energy consumption by fuel and sector (e.g. manufacturing, commercial).[63]

  Calculations based on the database provided emission factors by categories for 2009 and 2031.

Census data from *Statistics New Zealand* is used within the model to provide a count of employees in 2009 by sectors according to ANZSIC (2006) classifications. These are segregated by local boards in Auckland.

Consolidation of the datasets discussed above, were required to establish total emissions by commercial and industrial sectors across local boards in Auckland.



[62] Available at http://www.knowledgeauckland.org.nz/home/publications, last accessed on 10/6/2011

[63] Available at http://enduse.eeca.govt.nz/ , last accessed on 5/5/2011

# B2 Sector categorisation

The EECA database and census data from Statistics New Zealand were segregated according to ANZSIC (2006) categories. However, the Economic Futures study categorised sectors according to ANZSIC (1993). For the purposes of the distribution, all sectors were firstly converted to ANZSIC (2006), as shown by Table 40.

Table 40 Sector and ANZSIC (2006) code classification (based on Economic Futures)

| Category | Sector | ANZSIC (2006) codes |
|---|---|---|
| Commercial | Accommodation, restaurants and bars | H44 Accommodation, H45 Food and Beverage Services |
| Commercial | Business services | L66 Rental and Hiring Services (except Real Estate) |
| Commercial | Central government administration, defence, public order and safety services | O77 Public Order, Safety and Regulatory Services, O75 Public Administration, O76 Defence |
| Commercial | Communication services | J58 Telecommunications Services |
| Commercial | Cultural and recreational services | J55 Motion Picture and Sound Recording Activities, J56 Broadcasting (except Internet), J60 Library and Other Information Services, R89 Heritage Activities, R90 Artistic Activities, R91 Sport and Recreation Activities |
| Commercial | Education | P80 Preschool and School Education, P82 Adult, Community and Other Education, P81 Tertiary Education |
| Commercial | Finance | K62 Finance |
| Commercial | Health and community services | Q84 Hospitals, Q87 Social Assistance Services, Q85 Medical and Other Health Care Services, Q86 Residential Care Service |
| Commercial | Insurance | K63 Insurance and Superannuation Funds |
| Commercial | Local government administration services and civil defence | O75 Public Administration |
| Commercial | Personal and other community services | O77 Public Order, Safety and Regulatory Services, S96 Private Households Employing Staff, S95 Personal and Other Services, D28 Water Supply, Sewerage and Drainage Services |
| Commercial | Printing, publishing and recorded media | C16 Printing |
| Commercial | Real estate | L67 Property Operators and Real Estate Services |
| Commercial | Retail trade | G41 Food Retailing, G39 Motor Vehicle and Motor Vehicle Parts Retailing |
| Commercial | Services to finance and investment | K64 Auxiliary Finance and Insurance Services |
| Commercial | Wholesale trade | F33 Basic Material Wholesaling, F34 Machinery and Equipment Wholesaling, F35 Motor Vehicle and Motor Vehicle Parts Wholesaling, F36 Grocery, Liquor and Tobacco Product Wholesaling |
| Commercial | Air transport and services | I52 Transport Support Services, I50 Other Transport, I49 Air and Space Transport, I53 Warehousing and Storage Services |
| Commercial | Water and rail transport | I47 Rail Transport, I48 Water Transport |
| Commercial | Road transport | I46 Road Transport |
| Industrial | Basic metal manufacturing | C21 Primary Metal and Metal Product Manufacturing |

| Category | Sector | ANZSIC (2006) codes |
|---|---|---|
| Industrial | Beverage, malt and tobacco manufacturing | C12 Beverage and Tobacco Product Manufacturing |
| Industrial | Construction | E30 Building Construction, E32 Construction Services, E31 Heavy and Civil Engineering Construction |
| Industrial | Dairy product manufacturing | C11 Food Product Manufacturing |
| Industrial | Furniture and other manufacturing | C25 Furniture and Other Manufacturing |
| Industrial | Machinery and equipment manufacturing | C24 Machinery and Equipment Manufacturing |
| Industrial | Meat and meat product manufacturing | C11 Food Product Manufacturing |
| Industrial | Mining and quarrying | B10 Exploration and Other Mining Support Services, B08 Metal Ore Mining, B06 Coal Mining |
| Industrial | Non-metallic mineral product manufacturing | C20 Non-Metallic Mineral Product Manufacturing |
| Industrial | Other food manufacturing | C11 Food Product Manufacturing |
| Industrial | Paper and paper product manufacturing | C15 Pulp, Paper and Converted Paper Product Manufacturing |
| Industrial | Petroleum and industrial chemical manufacturing | C17 Petroleum and Coal Product Manufacturing, C18 Basic Chemical and Chemical Product Manufacturing |
| Industrial | Rubber, plastic and other chemical product manufacturing | C18 Basic Chemical and Chemical Product Manufacturing, C19 Polymer Product and Rubber Product Manufacturing |
| Industrial | Structural, sheet and fabricated metal product manufacturing | C22 Fabricated Metal Product Manufacturing |
| Industrial | Structural, sheet and fabricated metal product manufacturing | C21 Primary Metal and Metal Product Manufacturing |
| Industrial | Textile and apparel manufacturing | C13 Textile, Leather, Clothing and Footwear Manufacturing |
| Industrial | Transport equipment manufacturing | C23 Transport Equipment Manufacturing |
| Industrial | Water supply | D28 Water Supply, Sewerage and Drainage Services |
| Industrial | Wood product manufacturing | C14 Wood Product Manufacturing |
| Industrial | Dairy cattle farming | A01 Agriculture |
| Industrial | Fishing | A04 Fishing, Hunting and Trapping, A02 Aquaculture, A03 Forestry and Logging |
| Industrial | Forestry and logging | A03 Forestry and Logging |
| Industrial | Horticulture and fruit growing | A01 Agriculture |
| Industrial | Livestock and cropping farming | A01 Agriculture |
| Industrial | Other farming | A01 Agriculture |
| Industrial | Services to agriculture, hunting and trapping | A05 Agriculture, Forestry and Fishing Support Services, A04 Fishing, Hunting and Trapping |

Where Economic Futures sectors were a subset of ANZSIC codes, employment figures were divided evenly to an ANZSIC code. The same principle was applied when employment figures from census data as per the ANZSIC code was a subset of Economic Futures sectors.

# B3 Emissions distributions by Economic Futures category

Economic Futures provided energy intensity figures by sectors as TJ per $ mil of GRP and projected GRP growth. Total emissions per category can then be calculated based on emission factors derived from EECA.

Total emissions in 2009 and 2031 per category were calculated with the following formula applied:

$$e_{EcF} = EF_{EECA} \times EI_{EcF} \times GRP_{EcF}$$

Where:

> $e_{EcF}$ is the emissions per Economic Futures category.
>
> $EF_{EECA}$ is the emission factor derived from EECA per Economic Futures category.
>
> $EI_{EcF}$ is the energy intensity (TJ / $ mil of GRP) from Economic Futures per Economic Futures category.
>
> $GRP_{EcF}$ is the gross regional product ($ mil) from Economic Futures per Economic Futures category.

Emissions were then normalised according to the emissions study performed by URS. Normalisation was undertaken to provide consistency across past study emission data. The normalisation factors applied are as per Table 41, Commercial and Industrial sectors were categorised as according to Table 40.

Table 41 Comparison between EECA and Economic Futures energy consumption estimates

| | **URS Study** | | **Economic Futures** | | **Normalisation Factors** | |
|---|---|---|---|---|---|---|
| | **Annual Emissions (tCO2e)** | | **Annual Emissions (tCO2e)** | | **%** | |
| | **2009** | **2031** | **2009** | **2031** | **2009** | **2031** |
| **Commercial** | 850 | 1,058 | 1,940 | 2,298 | 44% | 46% |
| **Industrial** | 1,808 | 2,722 | 1,584 | 1,957 | 114% | 139% |

The emissions per Economic Futures category ($e_{EcF}$) were then normalised to be consistent with the total emission reported in the URS Study.

# B4 Employment distribution

For the purposes of both the commercial and industrial model, Arup used the census full-time employment (FTE) data provided by Statistics New Zealand in 2009, and projected it to 2031 using the projected data from Economic Futures study. However, as Economic Futures only provided 2006 employment data, a simple linear regression was applied to 2006 and 2031 data and 2009 employment figures were determined.

For each ANZSIC (2006) category, a normalisation factor was then applied to census employment data to be equivalent to the employment data in Economic Futures. Normalisation to Economic Futures was required as the study contained a 2031 projection of employment by sector.

To calculate the normalisation factor for each ANZSIC (2006) category, the following formula was applied:

$$u_{emp} = \frac{\sum n_{census}}{\sum n_{EcF}}$$

Where:

$u_{emp}$ is the employment normalisation factor for each ANZSIC (2006) category.

$n_{census}$ is total employees per local board based on census data (summed for all of Auckland).

$n_{EcF}$ is total employees in Auckland based on Economic Futures (summed for all of Auckland based on sector conversions).

Employment normalisation factors were applied to employee data per category and local board in 2009 and 2031.

# B5 Emissions distribution by ANZSIC categories

With employment figures normalised ($u_{emp}$) and projected across all local boards for 2009 and 2031, and total emissions calculated across Economic Futures categories ($e_{EcF}$), an emissions per employee (per Economic Futures category) could be calculated. This factor can be applied for each ANZSIC (2006) category to calculate the emissions across all local boards for 2009 and 2031.

The following formula was applied for each ANZSIC (2006) category:

$$e_{norm} = \frac{e_{EcF}}{n_{EcF}} \times u_{emp} \times n_{census}$$

Where:

$e_{norm}$ is the total normalised (refer to Table 40) emissions per ANZSIC (2006) category.

$e_{EcF}$ is the total emissions per Economic Futures category.

$n_{EcF}$ is total employees in per local board based on Economic Futures.

$u_{emp}$ is the employment normalisation factor for each ANZSIC (2006) category.

$n_{census}$ is total employees in per local board based on census data.

## Appendix C

# Methodology: Distribution of Residential Emissions

# C1 Overview

The methodology Arup has used to allocate residential stationary energy consumption across the City involves the following:

1. Establish average energy consumption by end use
2. Establish variables in energy consumption including type, size, occupancy, household income and heating fuel type
3. Use census data to allocate energy consumption across Auckland

There are two major studies of energy consumption that are relied upon for Arup's methodology:

- The HEEP study by BRANZ – a 10 year study of energy consumption in households across New Zealand including many within Auckland[62,63,64]; and;
- The End Use Energy Database developed for EECA – an top-down economic model that attributes energy consumption by fuel to end uses (e.g. lighting) by sector (e.g. households)[65]

Although the two studies appear to be relatively consistent at a national level[66] they differ significantly for Auckland. Table 42 below shows a comparison between the average energy consumption from HEEP and the average energy for a household in Auckland from the EECA End Use Energy Database[67].

Table 42 Comparison between EECA and HEEP energy consumption estimates for Auckland Households

| **Parameter** | **EECA end use database** | | **HEEP study by BRANZ** | | **Difference between EECA and HEEP** | |
|---|---|---|---|---|---|---|
| | **Annual consumption (kWh / dwelling)** | **Proportion electrical** | **Annual consumption (kWh / dwelling)** | **Proportion electrical** | **Annual consumption** | **Proportion electrical** |
| Average energy use | 13,587 | 69% | 10,660 | 75% | 22% | -9% |
| Average hot water energy use | 4,010 | 78% | 3,580 | 65% | 11% | 17% |



[62] BRANZ, 2004, *Energy Use in New Zealand Households: Report on the Year 8 Analysis for the Household Energy End-use Project (HEEP)*
[63] BRANZ, 2005, *Energy Use in New Zealand Households: Report on the Year 9 Analysis for the Household Energy End-use Project (HEEP)*
[64] BRANZ, 2006, *Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)*
[65] Available at http://enduse.eeca.govt.nz/ , last accessed on 5/5/2011
[66] M.Patterson, G. McDonald, 2009, *Updating the EECA Energy Database: Data, Assumptions and Methodology*, EECA
[67] The average household energy was derived by taking the total energy from the End Use Database and dividing by the number of households in Auckland in 2006.

| Parameter | EECA end use database | | HEEP study by BRANZ | | Difference between EECA and HEEP | |
|---|---|---|---|---|---|---|
| | Annual consumption (kWh / dwelling) | Proportion electrical | Annual consumption (kWh / dwelling) | Proportion electrical | Annual consumption | Proportion electrical |
| Average space heating energy use | 3,296 | 32% | 3,190 | 51% | 3% | -60% |
| Cooking | 909 | 69% | 650 | Unknown | 28% | Unknown |
| Lighting | 1,134 | NA | 1,460 | NA | -29% | NA |
| Refrigeration | 1,445 | NA | 1,030 | NA | 29% | NA |
| Other appliances (e.g. entertainment, washing machine etc) | 1,857 | NA | 750 | NA | 60% | NA |

Arup's model for residential energy use used factors based on both of these studies. Where the HEEP study allowed for more refined inputs (such as heat loss factor by housing type) these were selected over the BRANZ equivalent. These inputs were space heating, domestic hot water and appliances.

Each of the end uses for energy in households is assumed to vary depending on household and dwelling characteristics. The end use categories and variables that the model incorporates are shown below in Table 43.

Table 43 Household and Dwelling variables taken into account

| Variable | Dwelling type | Occupancy | Number of rooms | Income | Heating fuel type |
|---|---|---|---|---|---|
| Space heating | Impacts on average heat loss factor assumptions. | No impact | Impacts on area assumed to be heated | Impacts on what level the dwelling is under heated | Determines heating fuel assumed |
| Domestic Hot Water | No impact | Proportion of hot water consumption is attributed per occupant | No impact | No Impact | No impact |
| Lighting | Attached housing over 4 storeys is assumed to have common area lighting | No impact | Impacts on area assumed to be lit and therefore overall consumption | No impact | No impact |
| Appliances | No impact | Impacts on appliance ownership assumptions | No impact | Impacts on appliance ownership assumptions | No impact |

| Variable | Dwelling type | Occupancy | Number of rooms | Income | Heating fuel type |
|---|---|---|---|---|---|
| Cooking | No Impact | Proportion of cooking consumption is attributed to occupancy | No impact | No impact | No impact |
| Common area services | Attached housing over 4 storeys is assumed to have a lift | No impact | No impact | No impact | No impact |

In the instance of common area services, neither the EECA end-use database nor HEEP include any relevant figures for lifts, common area lighting or car park ventilation, which are all significant contributors to energy consumption in medium and high rise apartment buildings. In this instance the methodology from the Green Building Council Australia's Multi Unit Residential Rating Tool V1 was used.

Census data from Statistics New Zealand is used within the model which gives a count of dwellings:

- By board;
- By dwelling type;
- By number of rooms;
- By household income;
- By number of occupants;
- By heating fuel use.

As the fine detail of these statistics would mean that many households would be confidential due to low numbers, Arup split the tables into those that are determined by occupancy and those that are determined by dwelling size.

# C2 Space heating

Heating demand calculations can be explained by the following formula

$$HD_n = RM_n \times \frac{A_{dw}}{RM_{dw}} \times HLF_{dw} \times DH_{16} \times In_n \div 0\mathrm{A}_{\mathrm{dw}}$$

Where:

$HD_n$ is heating demand in dwelling $n$

$RM_n$ is number of rooms in dwelling $n$

$RM_{dw}$ is the average number of rooms for the type of dwelling

$A_{dw}$ is the average area for the type of dwelling

$HLF_{dw}$ is the heat loss factor for the type of dwelling

$DH_{16}$ is the number of heating degree hours for a 16 ºC set point

$In_n$ is the household income quintile factor for under heating

$OA_{dw}$ is the over allocation of heating fuels by census responses for the type of dwelling in the Auckland local board

The heat loss factors used in the calculations are:

- 3.8 W/ΔT/$m^2$ for separate houses after 1990, after 1978, all attached houses and all apartments; and
- 5.2 W/ΔT/$m^2$ for separate houses constructed before 1978
- 3.4 W/ΔT/$m^2$ for attached dwellings

The assumptions about the average size of dwellings are:

- 170 $m^2$ for separate houses built after 1990 (30% of separate houses)
- 132 $m^2$ for separate houses built after 1978 (10% of separate houses)
- 119 $m^2$ for separate houses built before 1978 (60% of separate houses)
- 100 $m^2$ for attached dwellings

The Household income factors for under heating are:

- 82% under heating for households in income quintile 1
- 87% under heating for households in income quintile 2
- 94% under heating for households in income quintile 3
- 91% under heating for households in income quintile 4
- 89% under heating for households in income quintile 5

Degree hours for a 16ºC set point and the under-heating for household income factors were calculated based on figures shown in Table 44. It was assumed that a dwelling is made up of 40% living space, 40% bedroom space and 20% unheated space like laundries, studies, garages etc.

Table 44 Degree hour assumptions

| **Time of day** | **Proportion of homes with heating turned on** | | **Degree hours** | | |
|---|---|---|---|---|---|
| | **Living areas** | **Bedroom areas** | **14 ºC set point** | **16 ºC set point** | **18 ºC set point** |
| Morning (7 am to 9am) | 37% | 16% | 3,419 | 5,151 | 6,813 |
| Day (9am to 5pm) | 26% | 8% | 7,806 | 17,001 | 25,938 |
| Evening (5pm to 11pm) | 89% | 39% | 9,966 | 15,719 | 20,623 |
| Night (11pm to 7 am) | 18% | 16% | 13,735 | 20,005 | 25,308 |

The over allocation factor is the proportion of households that use more than one fuel to heat their homes in that particular dwelling type in that particular Auckland Board. These factors were calculated based on Census Data.

Energy consumption associated with heating demand was estimated using the following formula

$$HE_n = \frac{HD_n}{EF_n}$$

Where:

$HE_n$ is the heating energy required by dwelling $n$

$HD_n$ is the heating demand for dwelling $n$

$EF_n$ is the efficiency of the heating system used by dwelling $n$

The heating system efficiencies assumed for the calculations are:

- 90% efficiency for electric space heating;
- 80% efficiency for pipe and bottle gas;
- 60% for wood; and
- 83% for other fuels.

# C3 Domestic hot water

Domestic hot water demand calculations can be explained by the following formula

$$\mathrm{HWD_n} = \mathrm{OC_n} \times \mathrm{HWD_{occ}} + \mathrm{HWD_{dw}}$$

Where:

$HWD_n$ is hot water demand in dwelling n

$OC_n$ is the number of usual residents in dwelling n

$HWD_{occ}$ is the amount of hot water demand required for personal hygiene

$HWD_{dw}$ is the amount of hot water demand required for other household activities

The assumptions for personal hygiene hot water usage are shown in Table 45 below.

Table 45 Assumptions for personal hygiene domestic hot water consumption

| Parameter | Showers | Baths | Total |
|---|---|---|---|
| Usage (number per person per day) | 0.9 | 0.14 | NA |
| Assumed flow rate (L/minute) | 9.5 | NA | NA |
| Average shower time (minutes) | 8.4 | NA | NA |
| Volume of water per shower / bath (L) | 79.8 | 150 | NA |
| Warm water usage (L per person per day) | 71.82 | 21 | 92.8 |

| | | | |
|---|---|---|---|
| Energy demand (kWh per person per year)[68] | 686.1 | 200.6 | 886.7 |

Energy consumption associated with hot water demand was estimated using the following formula:

$$HWE_n = {HWD_n}/{EF_n}$$

Where:

$HWE_n$ is the heating energy required by dwelling $n$

$HWD_n$ is the heating demand for dwelling $n$

$EF_n$ is the efficiency of the hot water system used by dwelling $n$

The hot water system efficiencies assumed:

- 90% efficiency for electric hot water; and,
- 80% efficiency for pipe and bottle gas.

It was assumed that 67.8% of households use resistive arc electric hot water and 32.2% of households use pipe or bottle gas tanks or instantaneous systems.

# C4 Lighting

Lighting energy consumption calculations can be explained by the following formula

$$\mathrm{L_n} = \mathrm{RM_n} \times \frac{\mathrm{L_{dw}}}{\mathrm{RM_{dw}}}$$

Where:

$L_n$ is lighting energy consumption in dwelling $n$

$L_{dw}$ is the total lighting energy consumption for Auckland households from the EECA End Use Database

$RM_n$ is number of rooms in dwelling $n$

$RM_{dw}$ is the number of rooms in Auckland dwellings from Census Data

# C5 Appliances

For the purposes of the residential energy model Arup used the data provided by BRANZ[69] on their HEERA model, which can be used to predict ownership rates of different household appliances. BRANZ research into the average energy

[68] Base on the heat capacity of water (4.1876 kj / L∆T) an average 45 degree temperature change for domestic hot water and a 50% makeup of domestic hot water in warm water for personal hygiene.
[69] BRANZ 2006, *Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)*, BRANZ

consumption associated with appliances was then cross referenced with these ownership rates to estimate annual consumption for each household.

The HEERA model provides a base value (or intercept) for appliance ownership and then provides factors based on a number of household attributes. The following parameters to estimate appliance ownership:

- Floor area;
- Equalised income and income quintile;
- Life stage;
- Occupancy;
- Dwelling age; and,
- Tenure type.

The inputs Arup used for the model for life stage and tenure type were estimated by board and based on Census data. Dwelling age was assumed to be 60% built before 1978 for all boards. Income and occupancy were calculated by board, by dwelling type, by income quintile, by number of usual residents based on Census data.

From the HEERA model Arup developed a number of factors that were used to distribute appliance energy consumption across Auckland. These can be explained in the following formula:

$$\mathrm{App_n} = \mathrm{App_{dw}} + \mathrm{OC_n} \times \mathrm{App_{occ}} + \mathrm{In_n}$$

Where:

$App_n$ is appliance electricity consumption in dwelling *n*

$App_{dw}$ is the electricity consumption unrelated to income or occupancy as estimated by Arup using the HEERA model for the local board of dwelling *n*

$OC_n$ is the number of usual residents in dwelling *n*

$App_{occ}$ is the electricity consumption related to occupancy as estimated by Arup using the HEERA model

$In_n$ is the electricity consumption related to income quintile as estimated by Arup using the HEERA model

## C6 Cooking

Cooking consumption calculations can be explained by the following formula[70].

$$\mathrm{Ck_n} = \mathrm{OC_n} \times \frac{50\% \times \mathrm{Ck_{dw}}}{\mathrm{OC_{total}}} + 50\% \times \mathrm{Ck_{dw}}$$

Where:

[70] This methodology was developed by the Green Building Council of Australia (GBCA) for the Green Star Multi Unit Residential Version 1 rating tool.

$Ck_n$ is hot water demand in dwelling *n*

$OC_n$ is the number of usual residents in dwelling *n*

$OC_{total}$ is the total number of usual residents in Auckland dwellings

$Ck_{dw}$ is the total cooking energy consumption in Auckland dwellings according to EECA end use database

# C7 Common area services

Common area services were assumed to be constant within dwelling types irrespective of size, income or number of people usually resident. The common services included within the model are lifts and common area lighting.

Lift energy consumption was estimated using the methodology and benchmarks from the Green Building Council of Australia (GBCA) Green Star rating tool for Multi Unit Residential Buildings. It can be explained in the following formula:

$$\mathrm{Lft_n} = \frac{\mathrm{Trp_{avg}} \times \mathrm{Dis_{avg}}}{\mathrm{V_{avg}}} \times \mathrm{Lft_{power}} + \mathrm{Lft_{standby}} \times \left(8760 - \frac{\mathrm{Trp_{avg}} \times \mathrm{Dis_{avg}}}{\mathrm{V_{avg}}}\right)$$

Where:

$Lft_n$ is lift energy consumption per attached dwelling four storeys and above

$Trp_{avg}$ is the number of lift trips per dwelling per year (assumed to be 2555)

$Dis_{avg}$ is the average distance the lift travels per trip (assumed to be 24.5m)

$V_{avg}$ is the average velocity the lift travels (assumed to be 1m/s)

$Lft_{power}$ is the average power consumed when the lift is active (assumed to be 10kW)

$Lft_{standby}$ is the average power consumed when the lift is inactive (assumed to be 150W)

Common area lighting estimates can be based on the following formula:

$$\mathrm{CL_n} = \mathrm{A_{dw}} \times \mathrm{CL_{m2}}$$

Where:

$CL_n$ is common energy consumption per attached dwelling four storeys and above

$Trp_{avg}$ is the number of lift trips per dwelling per year (assumed to be 2555)

$Dis_{avg}$ is the average distance the lift travels per trip (assumed to be 24.5m)

# Appendix D

## Methodology: Distribution of Transport Emissions

# D1 Overview

Arup used the following methodology to distribute the private vehicle related GHG emissions:

1. Outputs from Auckland Council's ASTM3 model were used to generate average annual VKTs for private vehicles during weekdays by
    - Local board of origin
    - Local board of destination
    - Trip type:
        - Home-based work (HBW)
        - Home-based education (HBE)
        - Home-based shopping (HBSh)
        - Home-based other (HBO)
        - Employers business (EB)
        - Non-home-based other (NHBO)
2. VKTs for EB were excluded as they are not considered to represent private vehicle travel
3. VKTs for NHBO were excluded as they are not able to be assigned to a place of residence.
4. A proxy values for total VKTs travelled by private vehicles to and from and to each board was determined from the remaining VKTs. These values exclude NHBO travel and travel on the weekends but are considered representative of the relative difference between VKTs travelled to and from each board.
5. A proxy emission factor ($tCO_2e$ per proxy VKT was determined using the total private vehicle emission baseline for 2009 divided the remaining VKTs.
6. This factor was used to assign emissions to local board based on either place of residence (local board of trip origin) or place of interest (local board or place of destination).

# Appendix E

Cost of GHG Abatement Model

# E1 Introduction

The techno-economic evaluation used by Arup in assesses the financial, technical and environmental performance of GHG related initiatives and summarises these performance assessments in a single figure called “Cost of Abatement”.

This figure can be compared across all initiatives, from energy efficiency, energy generation, waste treatment, bio-sequestration and fuel switching to give an understanding of which initiatives should be given priority over others.

# E2 Methodology

The model uses several different financial and technical parameters to develop a cash flow and emissions savings over the life of the initiative. The inputs into the model used to forecast these parameters are:

- Weighted Average Cost of Capital (WACC) or discount rate;
- Capital cost;
- Maintenance cost/savings;
- Start year, implementation period and total life of initiative;
- Energy savings / consumption (e.g. petrol, diesel, natural gas, electricity);
- GHG emissions savings / consumption (e.g. bio-sequestration,
- Degradation / growth in efficiency / effectiveness over time;
- Projections for electricity, gas, REC and GHG offset prices; and,
- Emissions intensity of grid electricity over time.

These inputs are used to project energy, GHG and costs over time as mentioned above. The projections are then used to estimate a range of financial and technical criteria including:

- Total lifetime cost, energy and GHG savings;
- Average annual cost, energy and GHG savings;
- Net Present Value – that is the value of the investment in the current year taking into account the cost of capital;
- Internal Rate of Return – that is the discount rate at which the Net Present Value is 0; and,
- Marginal Cost of Abatement (explained below).

**Marginal Cost of Abatement**

$$Marginal\ Cost\ of\ Abatement = \frac{NPV}{NPCQ}$$

Where:

| | | |
|---|---|---|
| Cost of Abatement | = | Cost of GHG abatement over lifespan of technology ($/t$CO_2$e) |
| NPV | = | Net Present Value of cash flow including capital and operating expenditure and energy savings over lifespan of technology ($) |
| NPCQ | = | Net Present GHG abatement Quantity from offset of Electricity over lifespan of technology (t$CO_2$e) |

Figure 41 Marginal Cost of Abatement methodology

## E2.1 Assumptions

For the purposes of this study Arup has made several assumptions around future electricity prices, gas prices and emissions intensity of grid electricity.

Retail energy prices have been based on existing prices paid by residential, business and large consumer users and projected into the future using the following sources / assumptions:

- Average annual wholesale electricity, natural gas, coal, were based on modelling from the Ministry of Economic Development’s (MED) Outlook 2010 report;
- Average annual retail petrol and diesel prices were based on modelling from the Auckland Regional Council, *Price Forecasts for Transport Fuels and other Delivered Energy Forms*, January 2009 (WP 2010/05);
- An increase to electricity network charges at 2% additional to inflation after this year;
- A constant relationship between wholesale and retail natural gas.

The emissions intensity of electricity was based on the projections from MED’s Outlook report.

# Appendix F

## Methodology: Transport Policy Packages

# F1 Introduction

Arup conducted a transport assessment of the Auckland Region as part of the Auckland Greenhouse Gas Strategy. This assessment was focused on understanding the potential for reducing GHG emissions by reducing car dependency and increasing public transport usage, to contribute to the Mayor's greenhouse gas emission reduction target.

# F2 Methodology

A number of different policy packages were proposed by Arup in conjunction with Auckland Council to reduce the total carbon emissions resulting from transport on Auckland's road network. These packages are described in the table below:

| Policy Package | Description |
|---|---|
| Do Something | A series of measures covering a number of transport disciplines, including:<br>- Application of behavioural change measures such as workplace and school travel plans<br>- Full implementation of Auckland Public Transport Network Plan 2016<br>- Completion of State Highway network, Regional Arterial Roading Plan (RARP) and Neilson Street upgrade<br>- Quality compact growth scenario B – Intensive Expansion<br>This would be the expected transport outcomes based on planned expenditure |
| Travel Demand Management | Do Something measures, as well as:<br>- Ongoing and increasing application of intensive behavioural change measures<br>- Increase in parking charges in the CBD by 50% to 2041 (in real terms)<br>- Introduction of a $6 CBD congestion charge |
| Public Transport | Do Something measures, as well as:<br>- Completion of current passenger rail programme with the addition of CBD tunnel and frequency increases<br>- Completing remainder of the proposed Rapid Transit Network (RTN) using buses<br>- A reduction by 50% in all public transport fares |

| Policy Package | Description |
|---|---|
| Active transport | Do Something measures, as well as:<br>- Completion of 100% of the regional cycle network<br>- Encouragement of greater walking and cycling through widespread measures such as:<br>- reduced speed limits for cars<br>- cycle priority at traffic signals<br>- reallocation of road space<br>- extension of public bicycle schemes<br>- provision of increased end-of-trip facilities |
| Urban Planning | Do Something measures, as well as:<br>Quality compact growth scenario C – Dispersed Containment |
| Freight Transport | Do Something measures, as well as:<br>- Introduction of freight consolidation centres<br>- Construction of new Avondale-Southdown railway line |
| Electric vehicles | - Facilitation of the widespread adoption of plug-in electric vehicles (80% of all new vehicles purchased in 2031 are electric vehicles) |
| Vehicle efficiency | - Expected efficiency improvements in the Auckland Road network fleet by 2031 (natural replacement of old low efficiency vehicles to more efficient vehicles) |
| Biofuels | - Based on SCION estimates of total available biomass waste |

Auckland Council traffic engineers modelled the forecast vehicle kilometres travelled (VKTs) in 2031 under each of the above policy packages (using the ART3 model) for the following transport modes:

- Private Vehicle
- Passenger Bus
- Passenger Train
- Ferry
- Light Commercial Vehicles
- Heavy Commercial Vehicles
- Active Transport (i.e. walking and cycling)

Existing (2006) VKTs for each mode were provided by Auckland Council using New Zealand census data collected in that same year. 2031 VKTs under the 2031 nBAU scenario were determined by scaling up the existing VKTs by population growth for private vehicles, bus, active transport, ferry and rail and by economic growth for commercial vehicles.

A number of variables were utilised to determine the total energy saved from each policy package:

- The reduction in total trips by mode for each policy package with respect to 2031 nBAU

- An energy efficiency factor for each mode (in terms of TJ/km)
- The proportion of fuel type used by each mode (e.g. the Auckland vehicle fleet uses 86% petrol, 13% diesel and 1% LPG

# Appendix G

Co-benefit Benchmarks

| | ECONOMIC | | | | | ENVIRONMENTAL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Co-benefits** | Cost of living | Cost of doing business | Employment | Productivity | Energy security | Local air quality | Water quality | Biodiversity | Waste to landfill | Off-site emissions (beyond Auckland) |
| **Description** | Likely decrease or increase in cost of living measure. | Likely decrease or increase in cost of doing business | Likely increase or decrease in employment opportunities | Likely increase or decrease in productivity | Like change in reliability of power supply | No of days when particulates exceed acceptable standards | Likely change in measures of water quality (stream and recreation) | Likely change in vegetation cover and connectivity | Likely increase or decrease in quantity of waste to landfill | Likely increase or decrease in emissions elsewhere as a direct result of initiative |
| **Energy Supply** | | | | | | | | | | |
| E1 Large scale renewable baseload power plant | -1 | -1 | 1 | 0 | check with Michelle | 1 | 0 | -1 | 0 | 1 |
| E2 Medium scale wind | -1 | -1 | 1 | 0 | check with Michelle | 1 | 0 | -1 | 0 | 1 |
| E3 Thermal networks for new commercial precincts | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| E4 Thermal networks for existing buildings | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| E5 Building integrated renewables | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| E6 Low carbon precinct | 0 | -1 | 1 | 0 | 1 | 1 | 0 | -1 | 1 | 1 |
| E7 Biomass cogeneration (wood processing) | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| E8 Smart grids | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| **Residential** | | | | | | | | | | |
| R1 Standards for new dwellings | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| R2 Residential retrofit | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| **Commercial** | | | | | | | | | | |
| C1 Standards for new buildings | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| C2 Commercial retrofit | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| **Manufacturing & Industrial** | | | | | | | | | | |
| C1 Standards for new buildings | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| C2 Manufacturing and industry retrofit | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |

| Co-benefits | | ECONOMIC | | | | | ENVIRONMENTAL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cost of living | Cost of doing business | Employment | Productivity | Energy security | Local air quality | Water quality | Biodiversity | Waste to landfill | Off-site emissions (beyond Auckland) |
| **Quality compact growth** | | | | | | | | | | | |
| Q1 | Quality compact growth | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| **Transport** | | | | | | | | | | | |
| T1 | Travel demand management | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| T2 | Active transport infrastructure | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| T3 | Public transport infrastructure | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| T4 | Improved vehicle efficiency | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| T5 | Freight consolidation centres | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| T6 | Biofuels | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| T7 | Electric vehicles | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Waste** | | | | | | | | | | | |
| W1 | Waste to energy | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| W2 | Sewage to energy | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| **Carbon Sequestration** | | | | | | | | | | | |
| S1 | Riparian land management | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| S2 | Forestation of marginal land | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| S3 | Biochar | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| S4 | Marine sequestration | | | | | | | | | | |
| **Behaviour change** | | | | | | | | | | | |
| | Community based behaviour change program | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |

| | | SOCIAL | | | | | CULTURAL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Co-benefits** | Health and well-being | Housing affordability | Social equity and access to resources | Social capital and community resilience | Endurance | Pride and connection between people and place | Sites of significance and visual impact | Local Knowledge | Community representation and leadership | **Total Score** |
| | **Description** | Changes to lifestyle related health, due to exercise, nutrition, environmental factors etc | Chaneg in number of households paying more than 25% of income in mortgage or rental payments | Likelihood of change in disparity between poor and wealthy and vulnerability of poor | Potential to engage and enhance existing community organisations in deliverying initiaitive | Extent to which initiative delivers sustained benefits over time | Potential of iniative to improve/ impact community pride in Auckland | Protection of cultural sites, geo-physical identity and landmarks. | Use and or development of local resources and knowledge | Potential to engage with community leaders and support development of community leaders. | |
| **Energy Supply** | | | | | | | | | | | |
| E1 | Large scale renewable baseload power plant | 0 | 0 | -1 | 0 | 1 | 1 | -1 | 0 | 0 | |
| E2 | Medium scale wind | 0 | 0 | -1 | 0 | 1 | 1 | -1 | 0 | 0 | |
| E3 | Thermal networks for new commercial precincts | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | |
| E4 | Thermal networks for existing buildings | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | |
| E5 | Building integrated renewables | 0 | -1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | |
| E6 | Low carbon precinct | 0 | -1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| E7 | Biomass cogeneration (wood processing) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | |
| E8 | Smart grids | 0 | -1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| **Residential** | | | | | | | | | | | |
| R1 | Standards for new dwellings | 1 | -1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | |
| R2 | Residential retrofit | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | |
| **Commercial** | | | | | | | | | | | |
| C1 | Standards for new buildings | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | |
| C2 | Commercial retrofit | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | |
| **Manufacturing & Industrial** | | | | | | | | | | | |
| C1 | Standards for new buildings | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | |
| C2 | Manufacturing and industry retrofit | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | |

| Co-benefits | | SOCIAL | | | | | CULTURAL | | | | Total Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Health and well-being | Housing affordability | Social equity and access to resources | Social capital and community resilience | Endurance | Pride and connection between people and place | Sites of significance and visual impact | Local Knowledge | Community representation and leadership | |
| **Quality compact growth** | | | | | | | | | | | |
| Q1 | Quality compact growth | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | |
| **Transport** | | | | | | | | | | | |
| T1 | Travel demand management | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | |
| T2 | Active transport infrastructure | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | |
| T3 | Public transport infrastructure | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| T4 | Improved vehicle efficiency | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| T5 | Freight consolidation centres | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| T6 | Biofuels | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | |
| T7 | Electric vehicles | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| **Waste** | | | | | | | | | | | |
| W1 | Waste to energy | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| W2 | Sewage to energy | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | |
| **Carbon Sequestration** | | | | | | | | | | | |
| S1 | Riparian land management | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | |
| S2 | Forestation of marginal land | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | |
| S3 | Biochar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| S4 | Marine sequestration | | | | | | | | | | |
| **Behaviour change** | | | | | | | | | | | |
| | Community based behaviour change program | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | |

| | ECONOMIC | | | | | ENVIRONMENTAL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Co-benefits** | Cost of living | Cost of doing business | Employment | Productivity | Energy security | Local air quality | Water quality | Biodiversity | Waste to landfill | Off-site emissions (beyond Auckland) |
| **Description** | Likely decrease or increase in cost of living measure. | Likely decrease or increase in cost of doing business | Likely increase or decrease in employment opportunities | Likely increase or decrease in productivity | Like change in reliability of power supply | No of days when particulates exceed acceptable standards | Likely change in measures of water quality (stream and recreation) | Likely change in vegetation cover and connectivity | Likely increase or decrease in quantity of waste to landfill | Likely increase or decrease in emissions elsewhere as a direct result of initiative |
| **Metrics** | Auckland CPI benchmarked against National CPI | Develop composite measure based on cost of energy, transport and wages. | Employment as a differential of New Zealand average. | Local measure of multi-factor productivity (only national measure at present) | Hours without supply annually (measured as number of customers affected x time without supply) | Existing measures by Council | Finalise appropriate indicator with Council | Change in land cover indicator for Auckland, based on State of Environment reporting | Tonnage from Council records | None |
| **Proposed measure / 2011 benchmark** | 1137 at March 2011, compared to 1146 nationally. Score = 0.99 | NA | 8.0% at March 2011, compared to 6.6% nationally. Score = 1.2. | Auckland measure not available | NA | Benchmark of 20 days in 2010 | | Need to extract specific measure for Auckland from National dataset | 1.0 tonners/person (annually) | Subjective |
| **Source** | www.stats.govt.nz | www.stats.govt.nz | www.stats.govt.nz | www.stats.govt.nz | energy regulator | Auckland City Council | Auckland City Council | Ministry for the Environment | Auckland City Council | NA |

| SOCIAL | | | | | CULTURAL | | | |
|---|---|---|---|---|---|---|---|---|
| Health and well-being | Housing affordability | Social equity and access to resources | Social capital and community resilience | Endurance | Pride and connection between people and place | Sites of significance and visual impact | Local Knowledge | Community representation and leadership |
| Changes to lifestyle related health, due to exercise, nutrition, environmental factors etc | Change in number of households paying more than 25% of income in mortgage or rental payments | Likelihood of change in disparity between poor and wealthy and vulnerability of poor | Potential to engage and enhance existing community organisations in deliverying initiaitive | Extent to which initiative delivers sustained benefits over time | Potential of iniative to improve/ impact community pride in Auckland | Protection of cultural sites, geo-physical identity and landmarks. | Use and or development of local resources and knowledge | Potential to engage with community leaders and support development of community leaders. |
| Aggregate score derived from health states reporting by ARPHS | Number of households paying more than 25% of income in mortgage or rental payments | Gini measure or other accepted measure | None | None | None | Values based mapping could be developed as a benchmark | None | None |
| To be agreed | Determine current Auckland Benchmark | Gini coefficient for Auckland, as stand alone measure in proportional to NZ overall (0.36 AHC in 2010) | Subjective | Subjective | Subjective - or use resident surveys | | Subjective | Subjective |
| Auckland Regional Public Health Service | www.stats.govt.nz | Household Incomes Report, Ministry for Social Development | | | | Council GIS records | | |

# Appendix H

## Solar Resource Analysis

# H1 Introduction

Arup conducted a GIS-based solar resource assessment of the Auckland Region As part of the Auckland Greenhouse Gas Strategy. This assessment was focused on understanding the potential for building integrated renewable energy technologies to contribute to the Mayor's greenhouse gas emission reduction target.

The following appendix provides an overview of the steps that were undertaken by Arup to assess this resource and some example outputs from the GIS database that was generated as part of the assessment.

# H2 Methodology

The methodology used in the Auckland Greenhouse Gas Strategy solar mapping has three major components. They are:

- Solar irradiance mapping; and,
- Technology parameters.

## H2.1 Solar Irradiance

The solar resource at any one site is one of the major determining factors of the viability of installing solar power technology. The diurnal and seasonal characteristics of solar radiation are a major determinant in the energy generated in a year by any one technology.

Two different measures of solar radiation were considered:

- Direct Normal Irradiance (DNI); and,
- Global Horizontal Irradiance (GHI).

To estimate the variation in solar radiation across the region, Arup adopted the ArcGIS Spatial Analyst Solar Analysis tool. This tool derives predictions of hourly values for total solar radiation, based on daily and seasonal shifts of the sun angle, along with variations in elevation, orientation (slope and aspect), and shadows cast by topographic features. The tool does not take into account other climatic factors including cloud cover.

A 3D model of the Region was developed based on LiDar data provided to Arup by Auckland Council. In order to process the 3D model the Auckland region was broken into a grid with approximately 1000 components.

The local boards of Franklin, Waitekere Ranges and Devonport were not able to be included due to the absence of LiDar data. The results are therefore considered conservative.

The total annual predicted GHI and DNI values across the region were calibrated by comparing the observed annual average values for GHI with the ArcGIS predicted value at the same location to ensure that all climatic factors were considered.

To highlight roof spaces with good solar access the following areas were identified:

- Areas within building footprint;
- Areas receiving over 80% of the DNI of an unshaded flat site;
- Areas greater than 11m$^2$ to ensure that the areas identified are large enough to support at least 1kWp of solar PV or 1 residential scale solar hot water system.

## H2.2 Technology performance

The technologies considered by the solar resource assessment include evacuated tube solar hot water and mono-crystalline photovoltaic panels. These technologies were chosen as they are the most efficient[69] variations of the two major building integrated solar energy technologies currently commercially available.

The type of technology used for each building within the region was a by the lowest cost of abatement. In Auckland this was assumed to be solar hot water. Therefore the solar resource mapping is based on installing solar hot water up until the point where the internal hot water demand is likely to be met.

This point at which the internal hot water demand is met is determined by estimates of Gross Floor Area (GFA) and by a hot water demand factor based on land use typology (i.e. residential, industrial and commercial). Arup estimated the hot water demand factors using the EECA end use database figures for total hot water demand by land use typology in the Auckland region and estimates of total GFA based on GIS databases that included building footprint and height.

The factors incorporate the buffer areas required by evacuated tube technology to avoid overshadowing if the arrays were tilted at 35º above horizontal, for walkway access and hot water tanks.

Characteristics for solar hot water in Auckland assumed for this study are summarised in Table 43 below.

Table 43 Solar hot water characteristics

| **Parameter** | **Unit** | **Value** |
|---|---|---|
| Orientation | Degrees from North | 0º |
| Tilt | Degrees above horizontal | 35º |
| Net space efficiency | % | 37% |
| Annual heat generation | kWh/m$^2$ | 800 |
| Capital cost in 2011 | 2011$NZ/m$^2$ | $1,100 |
| Capital cost in 2015 | 2011$NZ/ m$^2$ | $8,000 |

The remainder of roof space with solar access was assumed to be suitable for solar PV. The characteristics of solar PV in Auckland assumed for this study are summarised in Table 44 below.

[69] These technologies have been assessed as the most efficient in Auckland. Results will vary geographically, particularly for solar hot water.

Table 44 Solar PV characteristics

| Parameter | Unit | Value |
|---|---|---|
| Orientation | Degrees from North | 0º |
| Tilt | Degrees above horizontal | 30º |
| Net space efficiency | % | 60% |
| Efficiency of solar PV panel | $m^2$/ kWp | 7 |
| Annual electricity generation | kWh/kWp | 1,370 |
| Annual degrade factor | % | 0.5 |
| Capital cost in 2011 | 2011$NZ/kWp | $6,500 |
| Capital cost in 2015 | 2011$NZ/kWp | $4,000 |

The assumed technology hierarchy and characteristics were then mapped over the solar irradiance analysis to estimate a number of items including total potential energy generation.

## H3 Results

The resource assessment estimated that the Auckland region solar resource could support up to 1,572MWp of solar PV and 680ha of solar hot water. These technologies would be capable of generating or offsetting up to 6,105 GWh of electricity and 1,037 GWh of natural gas based on the existing split of electricity and natural gas use for solar hotwater with the region.

An approximate 80% reduction has been applied in the final abatement under the assumption that 100% of the available area with good solar access will not be used. An overview of results of the solar resource mapping is shown below in Figure 42.


Figure 42 Example output from the Auckland solar resource mapping

# Appendix I

## Quality Compact Growth: Scenario Analysis

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| **I3** | **Summary and Conclusions** | | **20** |

# I1 Scenario Analysis

The Technical Report prepared by Arup for Auckland Council's Greenhouse Gas Reduction Strategy included consideration of the potential Greenhouse Gas 'footprint' of a number of land use scenarios. The baseline scenario was a naive Business as Usual (nBAU) scenario, which assumed no change in current land use patterns. Scenario analysis was also undertaken for four theoretical land use scenarios for 2031 defined in the report *Scenarios for Auckland Plan Modelling,* namely:

- Scenario A – Intensive Containment
- Scenario B – Intensive Expansion
- Scenario C – Dispersed Containment
- Scenario D – Dispersed Expansion

In each case the analysis considered the potential Greenhouse Gas Emissions arising from land use and transport patterns associated with the scenario.

## I1.1 Scenario Definition

This section describes the four 2031 land-use scenarios and associated modelling inputs, based on the criteria and assumption defined in *Scenarios for Auckland Plan Modelling.*

Underpinning all scenarios are the following key model inputs:

- future population of 2.3 million people at 2051;
- future employment of 900,000 people at 2051; and
- an integrated transport network for each land use.

The composition of the four scenarios is determined by a combination of two key factors, namely: the proportion of new residential development outside existing urban area, and the relative increase in density.

A depiction of each scenario in terms of these two factors is shown in Figure 1. A more detailed summary of each of the four 2031 land-use scenarios is also provided in the following pages.

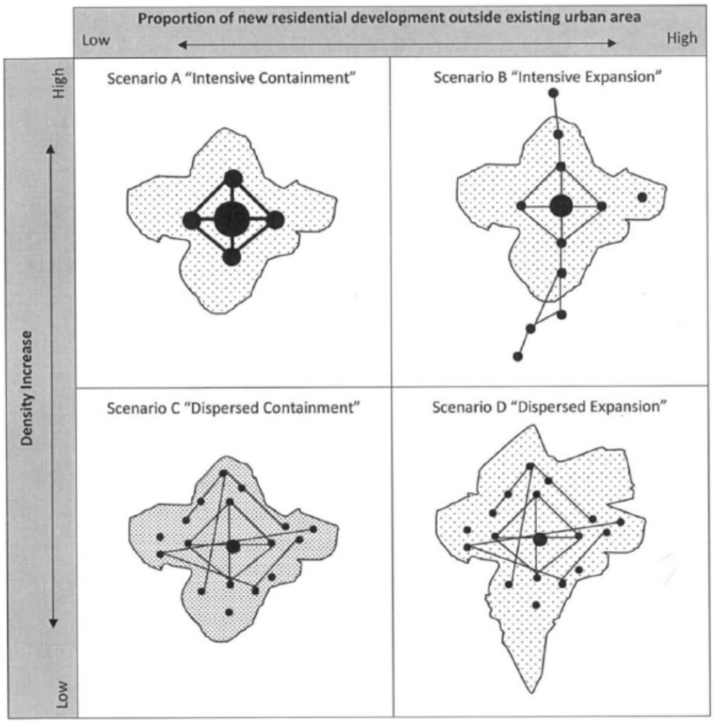



Figure 1 Four land-use scenarios by new residential development and density increase

**Scenario A – Intensive Containment**

Scenario A considers the growth of Auckland to be concentrated in a number of networks of centres, corridors and future urban areas.

The following characteristics of the Intensive Containment Scenario are as follows:

- *Residential growth* – high-density residential growth occurring mainly in the CBD and its fringes, with a majority of residents being within sub-regional and town centres. Growth within land corridors are limited, with no new capacity for rural, coastal and satellite areas.

  Future Urban Areas as defined by the RGS/RPS provide further capacity for residential growth and mixed use or town centre development.

- *Commercial growth* – retail and office-based business occurring in the CBD and its fringes, with an increase in employment in sub-regional and town centres. Future Urban Areas as defined by the RGS/RPS provide further capacity for industrial, warehouse and distribution activities business land

- *Transport network change* – includes broad improvements across the network. An emphasis is placed on public transport, walking and cycling and behaviour change programs. The Rapid Transport Network (RTN) and Quality Transport Network (QTN) is expanded with increased frequencies of services, as well having an integrated ticketing and fare system.

  Regional freight networks are improved, as well as regional arterials. The construction of additional road capacity is otherwise limited.

**Scenario B – Intensive Expansion**

Scenario B considers the growth of Auckland to be concentrated within existing urban areas, particularly in centres and corridors.

The following characteristics of the Intensive Expansion Scenario are as follows:

- *Residential growth* – Growth of high-density residential occurring mainly in the CBD and its fringes (as per Scenario A). However, a majority of residential growth is focussed at key growth centres, and in Future Urban Areas as defined by the RGS/RPS.

  Increased capacity for residential growth is provided for infill suburban areas (with high amenity), costal and rural towns, beyond current scheduled Greenfield sites and satellites. Rural and countryside living is reduced.

- *Commercial growth* – retail and office-based business occurring in the CBD and its fringes. However, a majority of employment growth is focussed at key growth centres, and in Future Urban Areas as defined by the RGS/RPS.

- *Transport network change* – an approach to intensify expansion in centres and along corridors. The RTN and QTN are extended to provide high capacity services to support centres, corridors, coastal areas, ridgelines, urban fringes and rural settlements.

  Coastal areas are supported by an extended ferry network. New expansion areas are supported by further road networks and public transport services. Growth areas are supported by increased transit orientated development, walking and cycling infrastructure.

**Scenario C – Dispersed Containment**

Scenario C considers low density growth of Auckland occur in existing urban areas, as well as dispersing the growth across a number of centres and corridors.

The following characteristics of the Dispersed Containment Scenario are as follows:

- *Residential growth* – low-density residential growth occurring in a number of small growth centres, as well as increased capacities in larger centres. Residential growth is largely dispersed in these areas. Some high-density residential growth occurs in the CBD and its fringes. Existing capacity occurs for future urban areas, coastal and rural towns, and satellite areas.

- *Commercial growth* – a moderate increase of retail and office-based business occurring in the CBD and its fringes. Greater employment growth occurs in within the existing urban footprint and is widely dispersed.

- *Transport network change* – provides for a transport system that supports a wide dispersion of growth in a large number of centres and urban areas. The system considers a greater distribution of goods and services.

  Public transport bus services are extended and have high frequencies across towns. Extensive arterial and local road network improvements are made for high levels of traffic for new areas.

**Scenario D – Dispersed Expansion**

Scenario D considers a dispersion of low-density growth in existing urban areas and across many centres and corridors.

The following characteristics of the Dispersed Expansion Scenario are as follows:

- *Residential growth* – extensive residential growth occurs in a number of coastal and rural towns, especially those with high amenity. Extensive growth also occurs in Greenfield land all across Auckland, beyond the current scheduled.

  High-density residential growth occurs in the CBD and its fringes, but less than all other Scenarios. The scenario also accounts for existing capacity for existing town centres, suburban infill, and future urban areas. Additionally, no growth occurs within corridors.

- *Commercial growth* – an increase of retail and office-based business occurring in the CBD and its fringes. Additional business centres are provided at existing centres to provide for more employment.

  Extensive business development occurs in Greenfield land all across Auckland, beyond the current scheduled.

- *Transport network change* – requires a transport system that supports for further distances to travel for employment, business and residential areas (due to the wide dispersion of growth).

  Expansion of public transport bus services for new expansion areas, supported by increased park and ride facilities. Ferry network is expanded to support growth in coastal areas. New regional freight routes are required. Road infrastructure is increased to support new areas in the south and north of Auckland.



## I1.2 Methodology

The scenario analysis determined probable changes in GHG emissions associated with transport and stationary energy consumption as a result of the land use scenarios. Consideration of agricultural, forestry, industrial process and fugitive emissions has been explicitly excluded.

### I1.2.1 Transport

For the purposes of this study, transport emissions for Auckland were calculated based on fuel sales data and do not correspond directly to travel on Auckland’s road network. This is especially true for freight transport which represents greater than 50% of fuel sales but less than 5% of vehicle kilometres travelled (VKT) on Auckland’s road. For the purposes of estimating the impact of Quality Compact Growth on Auckland’s emissions commercial and freight transport emissions were assumed not to vary for each scenario.

Private transport emissions were assumed to mostly occur on Auckland’s road network and therefore variation in private VKTs under each scenario was used to indicate the variation in private vehicle emissions.

The following methodology was used to establish the variation in private vehicle emissions for each scenario:

1. Establish baseline emissions for 2009 for private vehicle travel

2. Establish baseline private vehicle VKTs from ASTM3 for 2006
3. Scale VKTs by population increase between 2006 and 2009 to establish baseline VKTs for 2009 (This assumes that VKTs per person does not vary and is consistent with the nBaU projection methodology).
4. Determine factor for GHG emissions per private VKT
5. Establish private VKTs for each scenario for Auckland Council
6. Determine total GHG emissions for each scenario based on factor established in 4 above. (This assumes that GHG emissions per VKT does not vary over period to 2031, this is likely to change based on improved vehicle efficiencies and fuel switching measures but is addressed elsewhere in the technical report)
7. Distribute private vehicle emissions for nBaU and each scenario based on home location for:
   - Home based Work Trips
   - Home Based Shopping Trips
   - Home Based Education Trips and
   - Home Based Other Trips
8. Determine emissions intensity (GHG emissions per person) using population data

### I1.2.2 Residential

The following residential information was used to supporting the compilation of the emissions associated with the four scenarios:

- Total household numbers by ART3 housing type categories, and by local boards in 2009 and 2031 for each of the four scenarios;
- Average household occupancy rates by ART3 housing type categories, and by local boards in 2009 and 2031 for each of the four scenarios;
- Average income by ART3 housing type categories, and by local boards in 2031 for each of the four scenarios; and
- Detached or attached housing percentage splits by each local board in 2031 for each of the four scenarios. It should be noted that housing splits assumed average dwelling areas of 118.8m$^2$ and 132m$^2$ for attached and detached housing respectively.

ART3 housing type categories have been described in Table 1.

Table 1 ART3 Category Descriptions

| ART3 No. | ART3 Category Description |
|---|---|
| HH1 | 1 adult, not working or retired |
| HH2 | 1 adult, working |
| HH3 | 2 adults, none working or retired |

| ART3 No. | ART3 Category Description |
|---|---|
| HH4 | 2 adults, 1 working |
| HH5 | 2 adults, both working |
| HH6 | 3+ adults, none or 1 working |
| HH7 | 3+ adults, 2 working |
| HH8 | 3+ adults, 3+ working |

The following methodology was applied to compile the residential emissions of each scenario.

1. Determine energy-use factors based on the methodology of the main report, determined for the following end-uses:
    - *Electricity* – appliances, cooking, domestic hot water, lighting, and space heating;
    - *Gas* – cooking, domestic hot water, and space heating.
2. Establish total energy end-use by local board for the following end-uses;
    - *Appliances* – base dwelling, energy-use per resident, and energy factor per household income level;
    - *Cooking* – base dwelling, and energy-use per resident;
    - *Domestic hot water* – base dwelling, and energy-use per resident;
    - *Lighting* – energy-use per room (regardless of detached or attached);
    - *Space-heating* – energy-use per room (dependent on detached or attached), energy factor per household income level, fuel efficiency, and percentage breakdown of fuel-type use per board as per 2006 data.
3. Apply the following 2031 emission factors, as per the main report:
    - Electricity (0.066 kg $CO_2$e/kWh),
    - Gas (0.192 kg $CO_2$e/kWh)

### I1.2.3 Commercial, Manufacturing and Industrial

To calculate the commercial emissions, emissions have been directly projected from the original results of 2009 baseline and 2031 projected baseline emissions. Total employment numbers were projected by ASP3 industry, commercial type categories and local boards for 2009 and 2031 for each of the four scenarios.

The following methodology was applied.

Establish ANZSIC category equivalents to ASP3 categories, as described below.

Table 2 ASP3 Category and ANZSIC Equivalents

| ASP3 No. | ASP3 Category Description | ANZSIC Category Equivalents |
|---|---|---|

| ASP3 No. | ASP3 Category Description | ANZSIC Category Equivalents |
|---|---|---|
| E1 | Industrial | C Manufacturing |
| E2 | Business Services | K Finance & Insurance, L Property & Business services, I Taxi Services, P Cultural & Recreational Services, Q Personal & Other Services |
| E3 | Wholesale Trade | F Wholesale Trade, I Transport & Storage |
| E4 | Retail Trade | G Retail Trade, H Accommodation, Cafes & Restaurants, I Travel agency services |
| E5 | Central Government Admin & Defence | M Government Administration & Defence |
| E6 | Agriculture | A Agriculture, Forestry & Fishing, B Mining |
| E7 | Utilities | I Transport & Storage |
| E8 | Construction | E Construction |
| E9 | Pre-school & Primary Education | N Pre-school education, Primary education, Combined primary & secondary education, Special school education |
| E10 | Secondary Education | N Secondary education |
| E11 | Tertiary Education | N Higher education, Technical & further education, Other education |
| E12 | Hospitals | O861 Hospitals, Psychiatric Hospitals, Nursing homes |
| E13 | Medical Practices | Accommodation for the aged & religious organisations |
| E14 | Public Services | O Health & Community Services, P Cultural & Recreational Services, Q Personal & Other services |

1. Normalise total 2031 full-time employees (for each scenario) to the baseline 2031 full-time employee numbers.
2. Determine applicable emission factors by taking the total 2009 and 2031 baseline emissions per ASP3 category and dividing by the total 2009 and 2031 baseline full-time employees per ASP3 category.
3. Apply the 2009 and 2031 emission factors per ASP3 category to full-time-employee numbers by ASP3 category and by local board for each of the four scenarios.

# I2 Results

## I2.1 Overview

The results below show the GHG emissions from stationary energy and road transport energy consumption only.

Table 3 Overview of Results

| 2031 Scenario | Residential | Commercial | Manufacturing and Industrial | Private Transport | Non-private Transport | TOTAL AUCKLAND |
|---|---|---|---|---|---|---|
| nBAU | 706 | 914 | 2,814 | 1,285 | 2,643 | 8,361 |
| Scenario A | 628 | 946 | 2,690 | 1,237 | 2,643 | 8,145 |
| Scenario B | 643 | 946 | 2,690 | 1,231 | 2,643 | 8,153 |
| Scenario C | 643 | 946 | 2,690 | 1,184 | 2,643 | 8,106 |
| Scenario D | 637 | 946 | 2,690 | 1,550 | 2,643 | 8,466 |

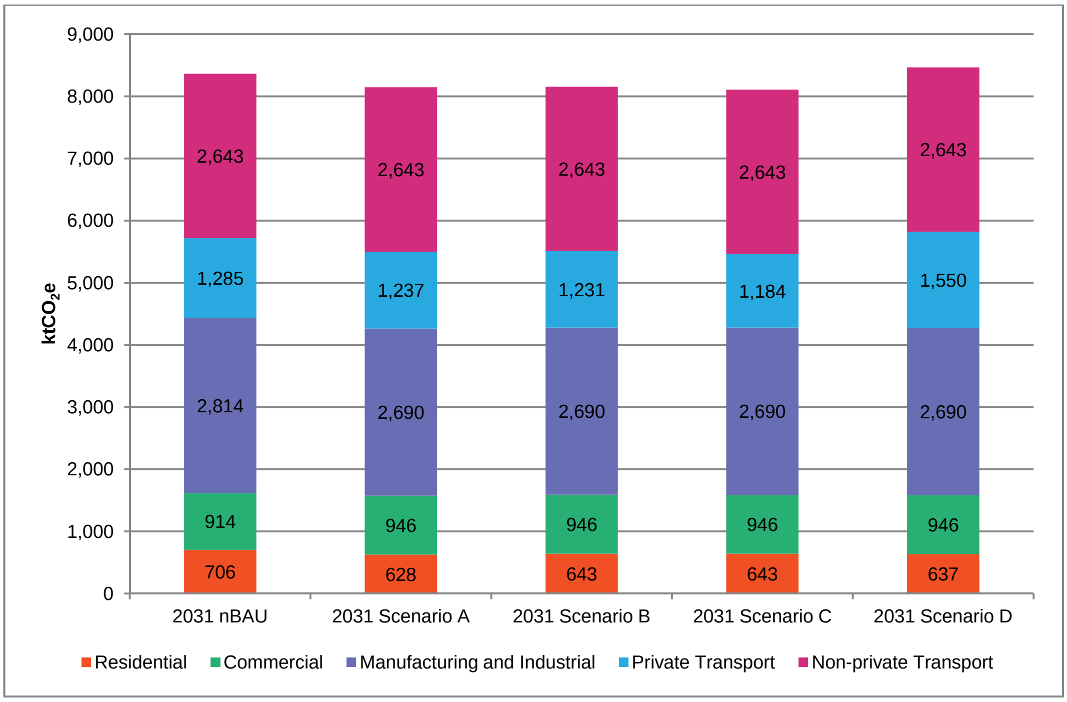



Figure 2 Overview of Results

These results indicate that:

- Scenario A shows a reduction 2.6% in total GHG emissions compared to nBaU
- Scenario B shows a reduction 2.5% in total GHG emissions compared to nBaU
- Scenario C shows a reduction 3.0% in total GHG emissions compared to nBaU

- Scenario D shows an increase of 1.3%  % in total GHG emissions compared to nBaU

All scenarios show a shift in industry towards commercial and away from manufacturing and industrial sectors which reduces business emissions by 2.5% in all scenarios compared to nBaU.

There is no significant difference in total residential emissions under each scenario. However, all scenarios show a reduction in residential emissions due to changes in urban form.

Scenario A has the lowest total GHG emissions for the residential sector, followed by Scenario B, with Scenario C and D the highest.  However differences in the residential are relatively insignificant.

Private transport related emissions vary the most significantly across the sectors with Scenario D showing a 20.6% increase and Scenario C a 7.9% decrease on nBaU.

The results suggest that a trend towards a more compact urban form with effectice transport networks will support a reduction in GHG emissions.

## I2.2 Results by Local Board

### I2.2.1 nBaU

The nBaU scenario represents the trend in emissions should emission intensity per person remain constant for residential and private transport emissions and emission intensity per unit GRP remain constant for industry. In reality this scenario will not likely occur due to constraints in land area and transport networks.  The results however are present here to represent a baseline with a distribution equivalent to current emissions distribution

In general, the majority of emissions within each local board are from industry.

The boards with the highest total emissions intensity are Franklin and Manurewa. By total emissions however, the greatest emissions exist in Maungakiekie – Tamaki, mainly from a large amount of emissions from the manufacturing and industrial sectors.

In regards to emission intensities, each local board is similar with respect to residential emissions, however the highest private transport emissions are observed in Rodney, Upper Harbour and Franklin.

The results by local board for nBaU are presented in Table 4 and below as well as the following maps.

Table 4 nBaU results by local board (total emissions)

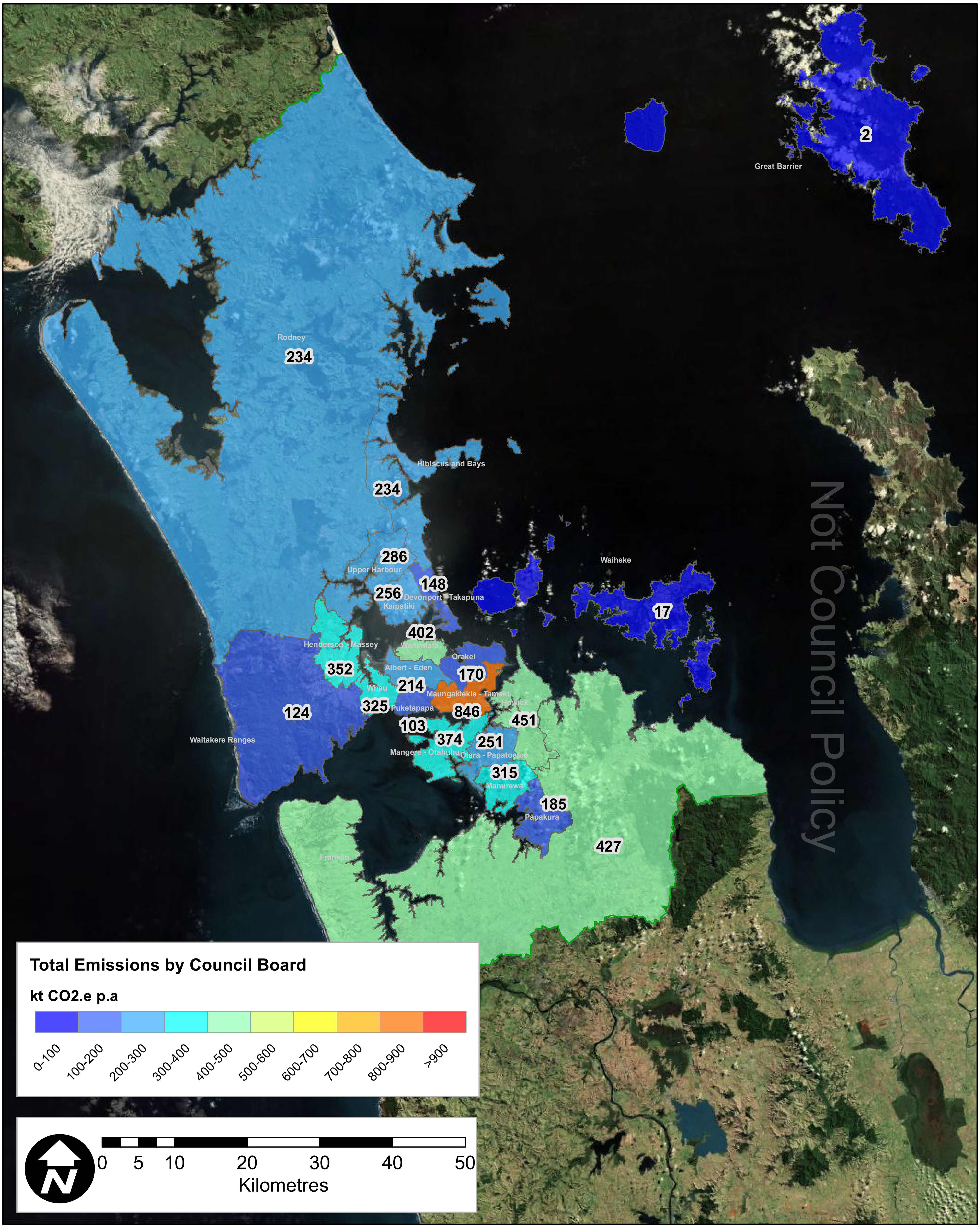
| **Local Board** | **GHG Emissions 2031 (ktCO2e)** | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Rodney | 28.1 | 109.9 | 96.4 | 234.4 |
| Hibiscus and Bays | 49.8 | 92.1 | 92.1 | 234.0 |
| Upper Harbour | 24.1 | 197.6 | 64.7 | 286.4 |

| Local Board | GHG Emissions 2031 (ktCO2e) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Kaipatiki | 44.5 | 143.8 | 68.0 | 256.3 |
| Devonport - Takapuna | 31.5 | 66.5 | 50.3 | 148.4 |
| Henderson - Massey | 52.7 | 216.0 | 83.4 | 352.1 |
| Waitakere Ranges | 24.9 | 43.8 | 54.9 | 123.6 |
| Great Barrier | 0.7 | 1.0 | 0.0 | 1.6 |
| Waiheke | 5.1 | 11.6 | 0.0 | 16.7 |
| Waitemata | 34.9 | 286.9 | 80.4 | 402.1 |
| Whau | 36.5 | 237.3 | 51.6 | 325.4 |
| Albert - Eden | 48.7 | 94.4 | 71.0 | 214.1 |
| Puketapapa | 26.5 | 42.7 | 33.8 | 103.1 |
| Orakei | 44.7 | 67.4 | 57.4 | 169.5 |
| Maungakiekie - Tamaki | 34.2 | 752.9 | 59.1 | 846.3 |
| Howick | 64.2 | 290.8 | 96.4 | 451.4 |
| Mangere - Otahuhu | 28.9 | 294.3 | 50.8 | 374.1 |
| Otara - Papatoetoe | 32.2 | 162.3 | 56.8 | 251.2 |
| Manurewa | 38.0 | 221.3 | 55.3 | 314.6 |
| Papakura | 22.6 | 117.5 | 45.1 | 185.2 |
| Franklin | 32.8 | 277.2 | 117.4 | 427.3 |
| **TOTAL** | **705.6** | **3,727.3** | **1,285.0** | **5,717.9** |

Table 5 nBaU results by local board (GHG Emissions Intensity)

| Local Board | GHG Emissions Intensity 2031 | | |
|---|---|---|---|
| | Residential **($tCO_2e$ per resident)** | Commercial and Industrial **($tCO_2e$ per employee)** | Private Transport **($tCO_2e$ per resident)** |
| Rodney | 0.40 | 4.69 | 1.37 |
| Hibiscus and Bays | 0.43 | 3.38 | 0.79 |
| Upper Harbour | 0.39 | 4.52 | 1.05 |
| Kaipatiki | 0.39 | 3.50 | 0.60 |
| Devonport - Takapuna | 0.42 | 1.80 | 0.67 |
| Henderson - Massey | 0.37 | 5.34 | 0.59 |
| Waitakere Ranges | 0.38 | 4.81 | 0.84 |
| Great Barrier | 0.52 | 2.70 | 0.00 |
| Waiheke | 0.46 | 3.27 | 0.00 |
| Waitemata | 0.39 | 1.52 | 0.89 |
| Whau | 0.37 | 7.11 | 0.52 |
| Albert - Eden | 0.37 | 1.84 | 0.55 |
| Puketapapa | 0.37 | 3.00 | 0.47 |

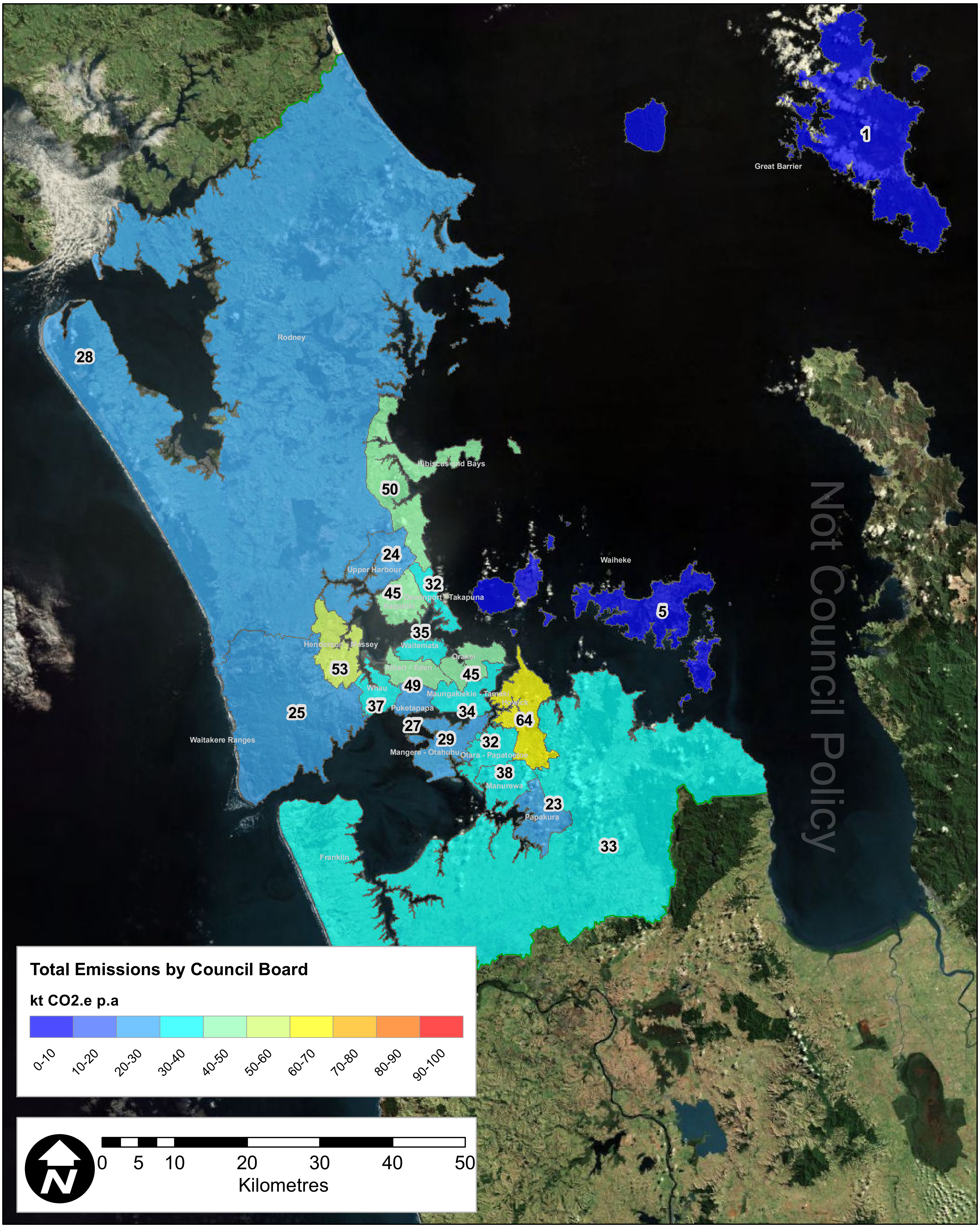
| **Local Board** | **GHG Emissions Intensity 2031** | | |
|---|---|---|---|
| | Residential **($tCO_2e$ per resident)** | Commercial and Industrial **($tCO_2e$ per employee)** | Private Transport **($tCO_2e$ per resident)** |
| Orakei | 0.42 | 2.45 | 0.54 |
| Maungakiekie - Tamaki | 0.36 | 7.86 | 0.62 |
| Howick | 0.40 | 5.02 | 0.59 |
| Mangere - Otahuhu | 0.26 | 5.99 | 0.46 |
| Otara - Papatoetoe | 0.31 | 4.17 | 0.55 |
| Manurewa | 0.34 | 9.12 | 0.50 |
| Papakura | 0.38 | 5.99 | 0.76 |
| Franklin | 0.39 | 9.84 | 1.40 |




# 2031 Total Emissions by Council Board - Total (Energy Related Emissions)

Scenario: nBAU

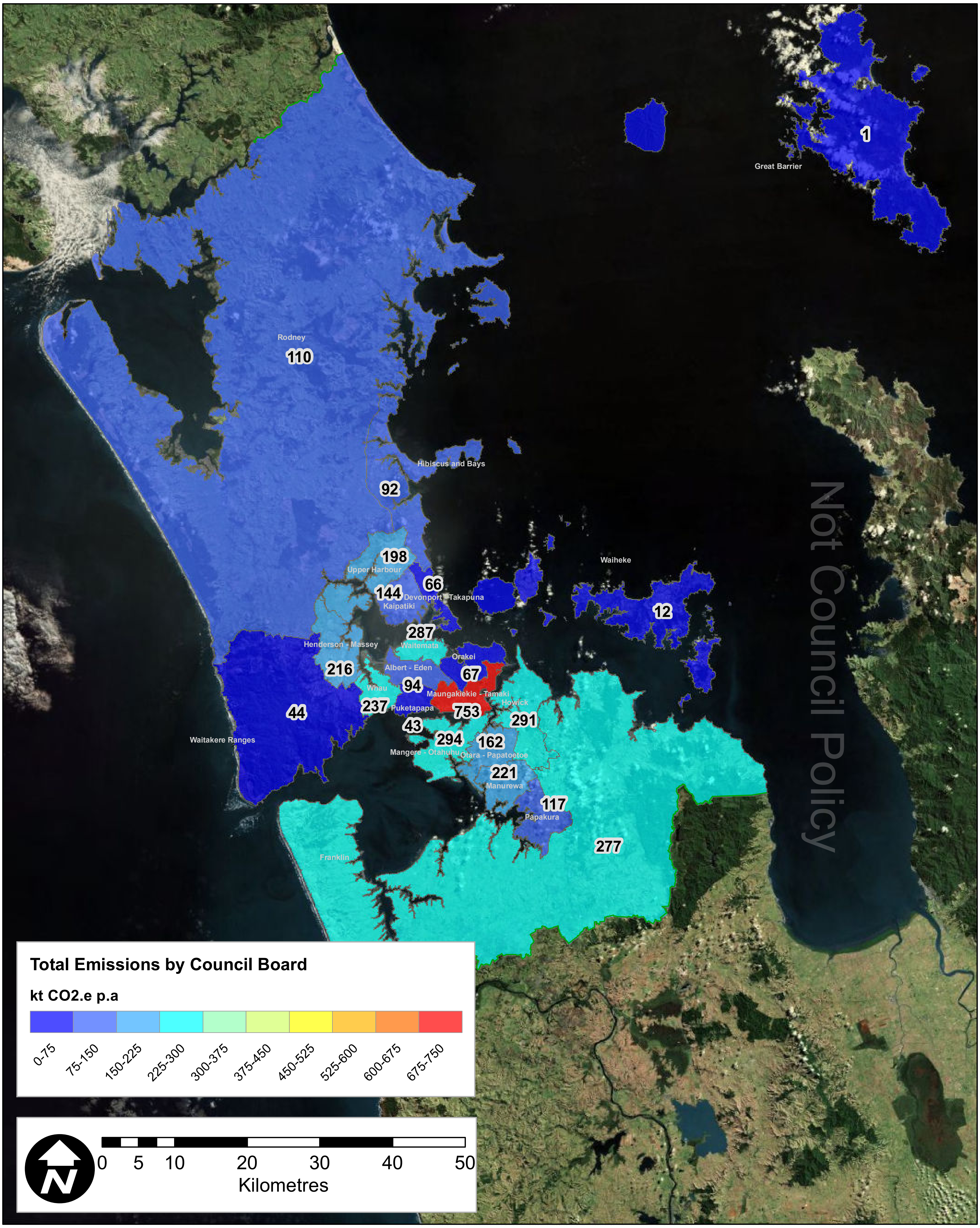
ARUP




# 2031 Total Emissions by Council Board - Residential Sector

Scenario: nBAU

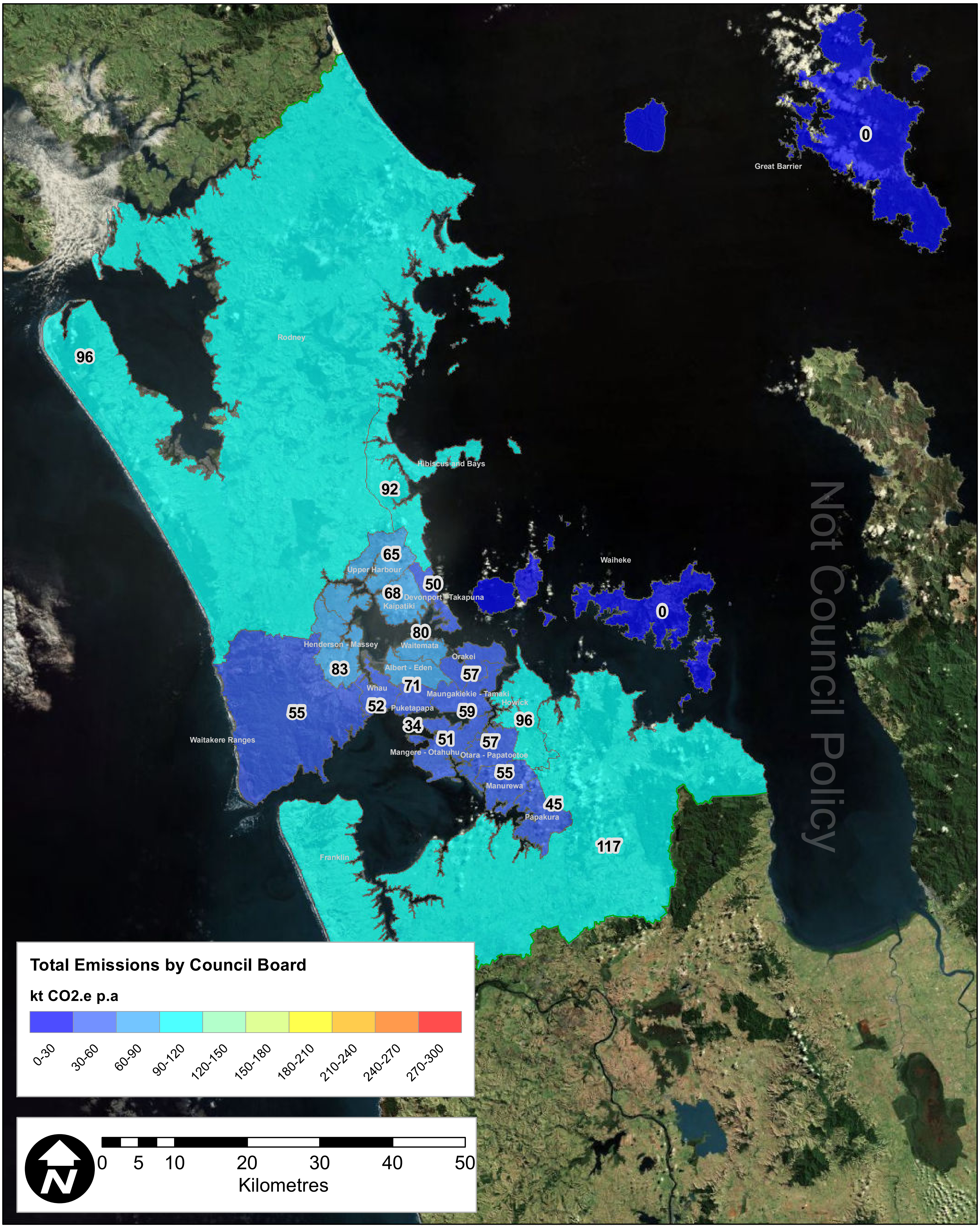
ARUP




# 2031 Total Emissions by Council Board - Commercial and Industrial Sector

Scenario: nBAU

ARUP




# 2031 Total Emissions by Council Board - Private Transport Sector

Scenario: nBAU

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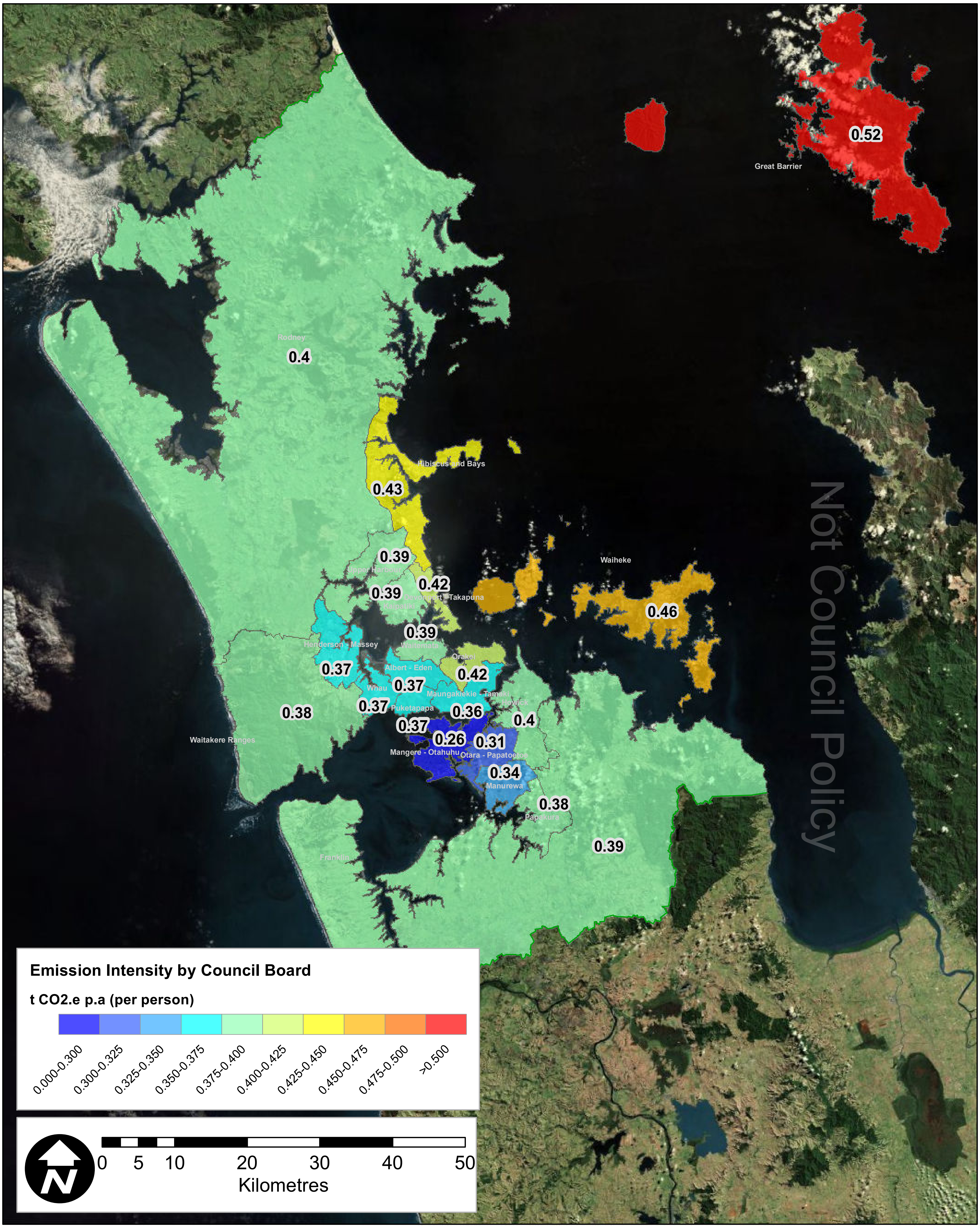
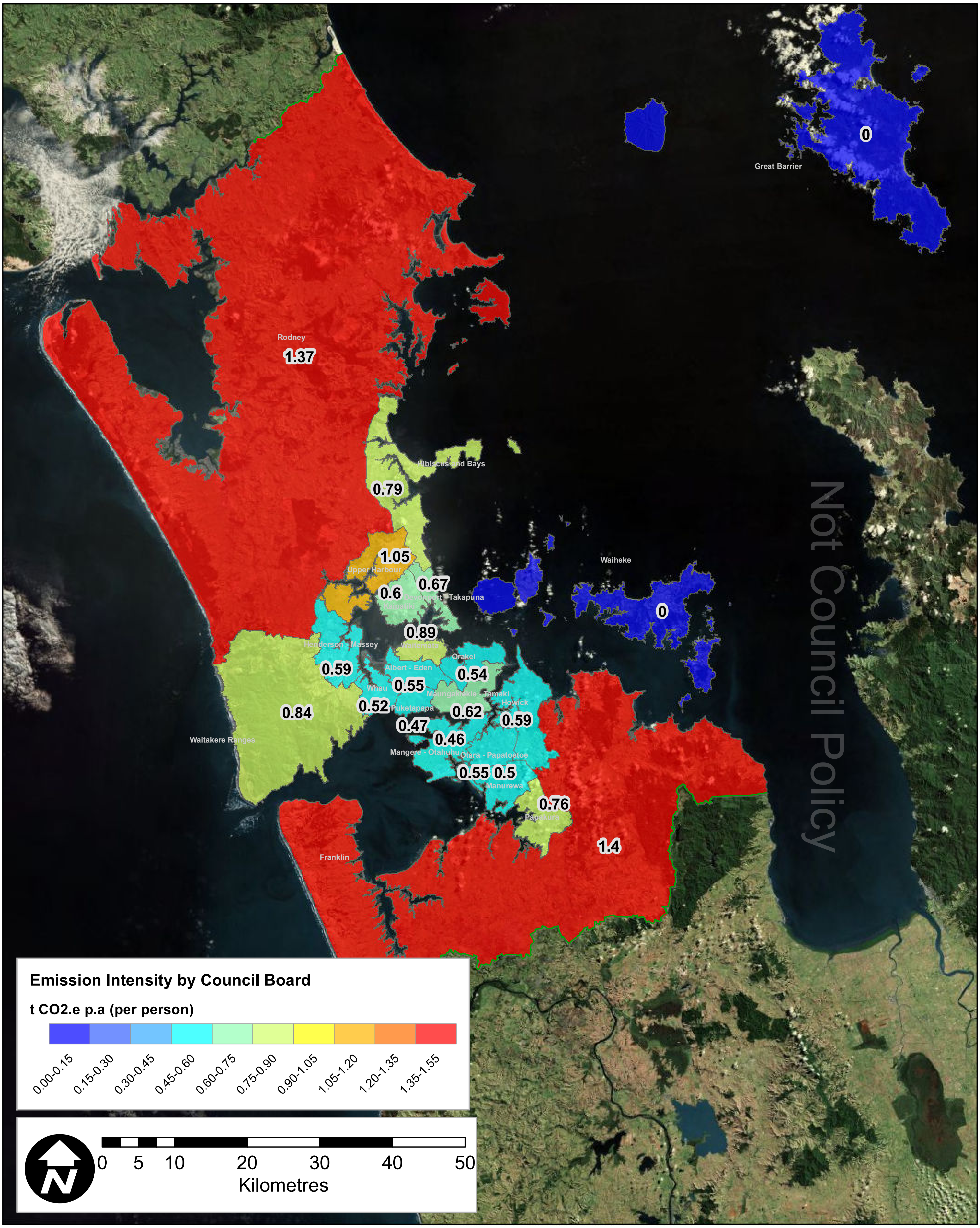



# 2031 Emission Intensity by Council Board - Residential Sector

Scenario: nBAU

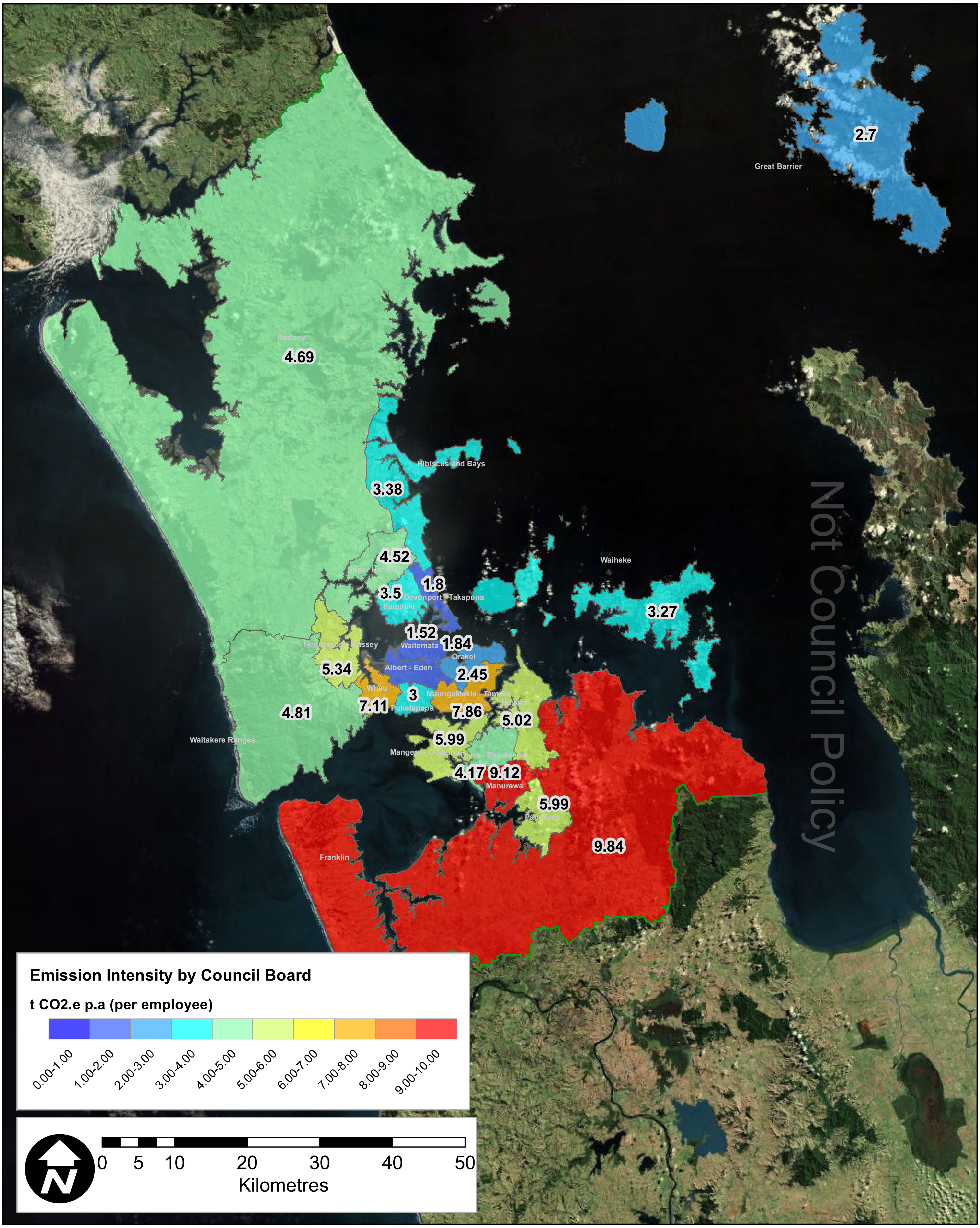
ARUP




# 2031 Emission Intensity by Council Board - Private Transport Sector

Scenario: nBAU

ARUP




# 2031 Emission Intensity by Council Board - Commercial and Industrial Sector

Scenario: nBAU

ARUP

### I2.2.2 Scenario A – Intensive containment

Scenario A presents lower total emissions across Auckland compared to the nBAU. Proportionally, commercial and industrial emissions generally contribute to the majority of total emissions.

Unlike the nBAU, commercial and industrial emissions are spread quite evenly throughout each local board. However, the largest of commercial and industrial emissions occurs in Maungakiekie – Tamaki, Waitemata (>300 kt$CO_2$e), attributed to Scenario A's concentrated growth in the CBD and its fringes. With respect to commercial and industrial emission intensities, the outer-western and southern local boards show the highest intensities.

In regards to emission intensities, each local board is similar in terms of residential emissions, however the highest private transport emissions per person are observed in Rodney, and Franklin. This is likely due to the lack of viable public transport infrastructure servicing these regions where the intensity of growth is centralised rather than around the rural, coastal and satellite areas.

The results by local board for Scenario A are presented in Table 4Table 6 and below as well as the following maps.

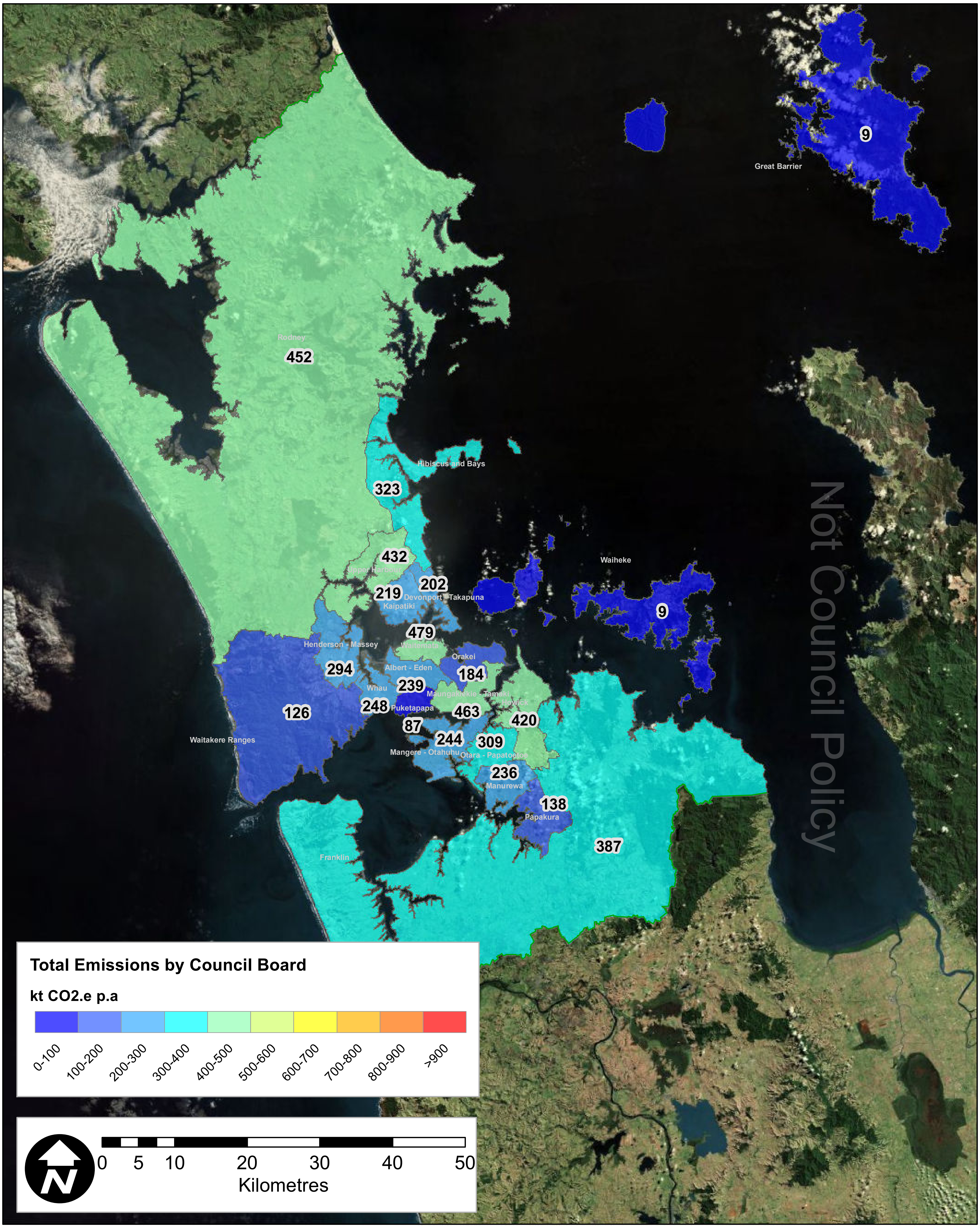
Table 6 Scenario A results by local board (total emissions)

| **Local Board** | **GHG Emissions 2031 (kt$CO_2$e)** | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Rodney | 45.5 | 221.1 | 185.0 | 451.5 |
| Hibiscus and Bays | 49.8 | 177.0 | 96.1 | 322.9 |
| Upper Harbour | 50.6 | 261.4 | 120.6 | 432.5 |
| Kaipatiki | 32.0 | 136.3 | 50.8 | 219.1 |
| Devonport - Takapuna | 25.6 | 131.5 | 45.4 | 202.5 |
| Henderson - Massey | 38.1 | 187.0 | 68.8 | 293.9 |
| Waitakere Ranges | 19.8 | 64.8 | 41.6 | 126.3 |
| Great Barrier | 2.0 | 7.1 | 0.0 | 9.1 |
| Waiheke | 2.2 | 7.1 | 0.0 | 9.2 |
| Waitemata | 39.6 | 368.7 | 70.7 | 479.0 |
| Whau | 27.1 | 181.6 | 38.9 | 247.5 |
| Albert - Eden | 41.1 | 142.3 | 55.8 | 239.2 |
| Puketapapa | 16.3 | 47.8 | 22.8 | 86.9 |
| Orakei | 32.2 | 110.9 | 41.0 | 184.2 |
| Maungakiekie - Tamaki | 27.4 | 391.3 | 44.7 | 463.4 |
| Howick | 50.0 | 290.7 | 79.7 | 420.5 |
| Mangere - Otahuhu | 18.9 | 187.5 | 37.5 | 243.9 |
| Otara - Papatoetoe | 26.2 | 236.9 | 46.0 | 309.0 |
| Manurewa | 23.1 | 170.9 | 42.0 | 235.9 |
| Papakura | 18.9 | 84.6 | 34.2 | 137.7 |

| Local Board | GHG Emissions 2031 ($ktCO_2e$) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Franklin | 41.9 | 229.3 | 116.0 | 387.1 |
| **TOTAL** | **628.3** | **3,635.7** | **1,237.4** | **5,501.5** |

Table 7 Scenario A results by local board (GHG Emissions Intensity)

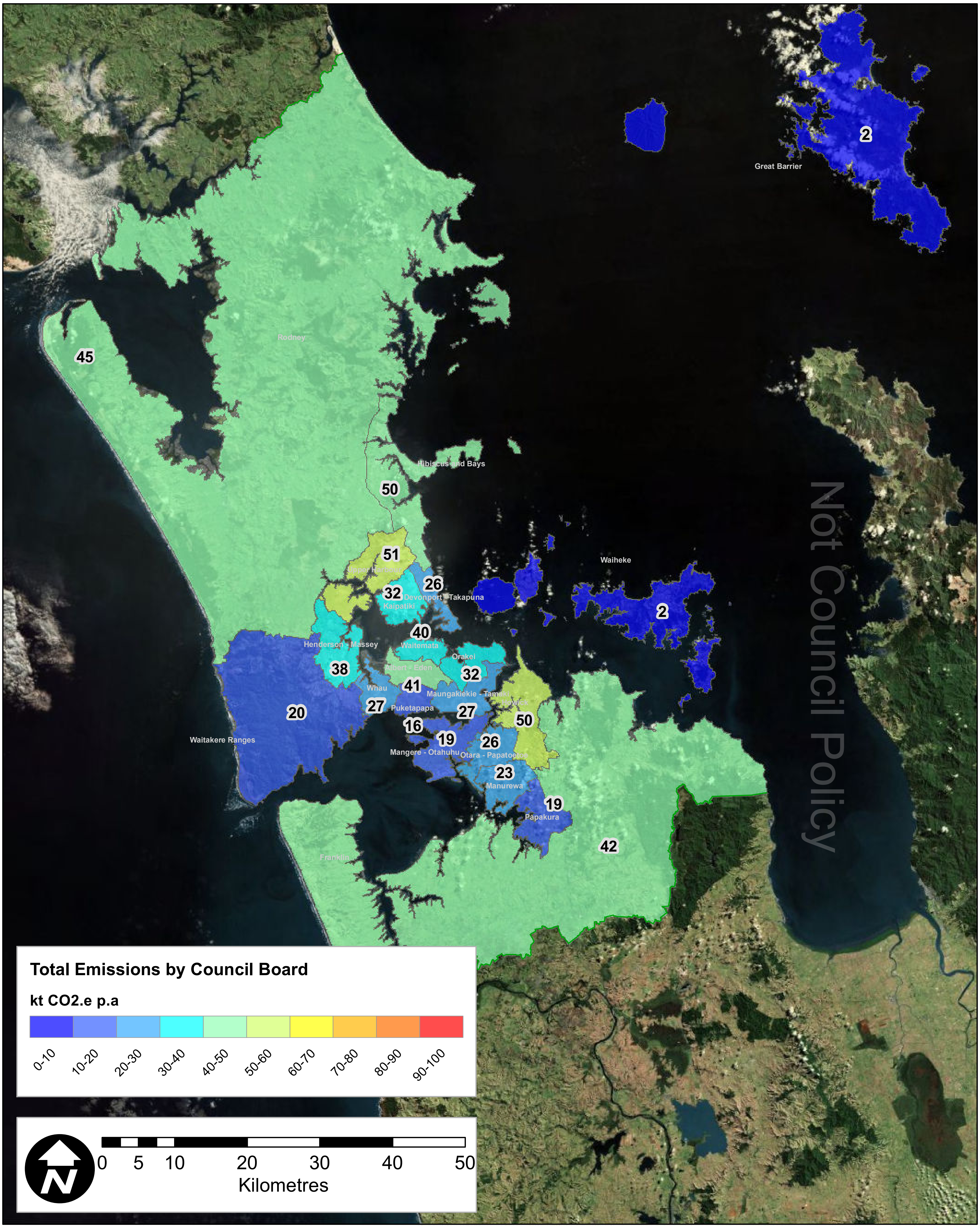
| Local Board | GHG Emissions Intensity 2031 | | |
|---|---|---|---|
| | **Residential** ($tCO_2e$ per resident) | **Commercial and Industrial** ($tCO_2e$ per employee) | **Private Transport** ($tCO_2e$ per resident) |
| Rodney | 0.32 | 6.47 | 1.30 |
| Hibiscus and Bays | 0.36 | 4.62 | 0.69 |
| Upper Harbour | 0.35 | 3.65 | 0.84 |
| Kaipatiki | 0.34 | 4.36 | 0.53 |
| Devonport - Takapuna | 0.35 | 2.76 | 0.62 |
| Henderson - Massey | 0.34 | 4.94 | 0.61 |
| Waitakere Ranges | 0.33 | 6.14 | 0.69 |
| Great Barrier | 0.32 | 3.46 | 0.00 |
| Waiheke | 0.34 | 3.46 | 0.00 |
| Waitemata | 0.32 | 2.18 | 0.57 |
| Whau | 0.33 | 6.71 | 0.47 |
| Albert - Eden | 0.34 | 2.55 | 0.46 |
| Puketapapa | 0.34 | 3.97 | 0.47 |
| Orakei | 0.36 | 3.14 | 0.45 |
| Maungakiekie - Tamaki | 0.32 | 6.30 | 0.52 |
| Howick | 0.36 | 5.68 | 0.57 |
| Mangere - Otahuhu | 0.32 | 5.12 | 0.63 |
| Otara - Papatoetoe | 0.32 | 4.84 | 0.56 |
| Manurewa | 0.33 | 5.98 | 0.60 |
| Papakura | 0.34 | 5.37 | 0.61 |
| Franklin | 0.34 | 6.36 | 0.93 |




# 2031 Total Emissions by Council Board - Total (Energy Related Emissions)

Scenario: A

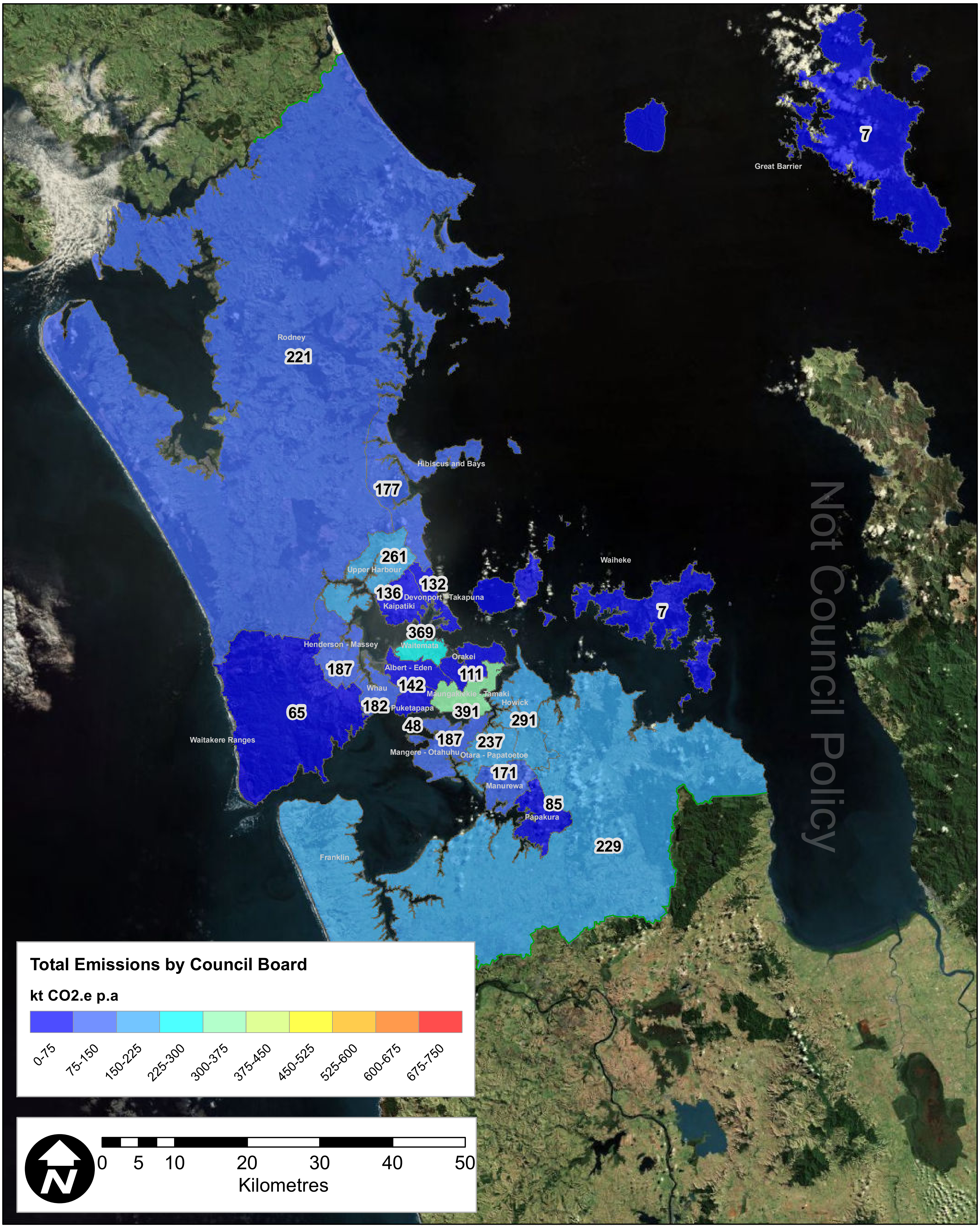
ARUP




# 2031 Total Emissions by Council Board - Residential Sector

Scenario: A

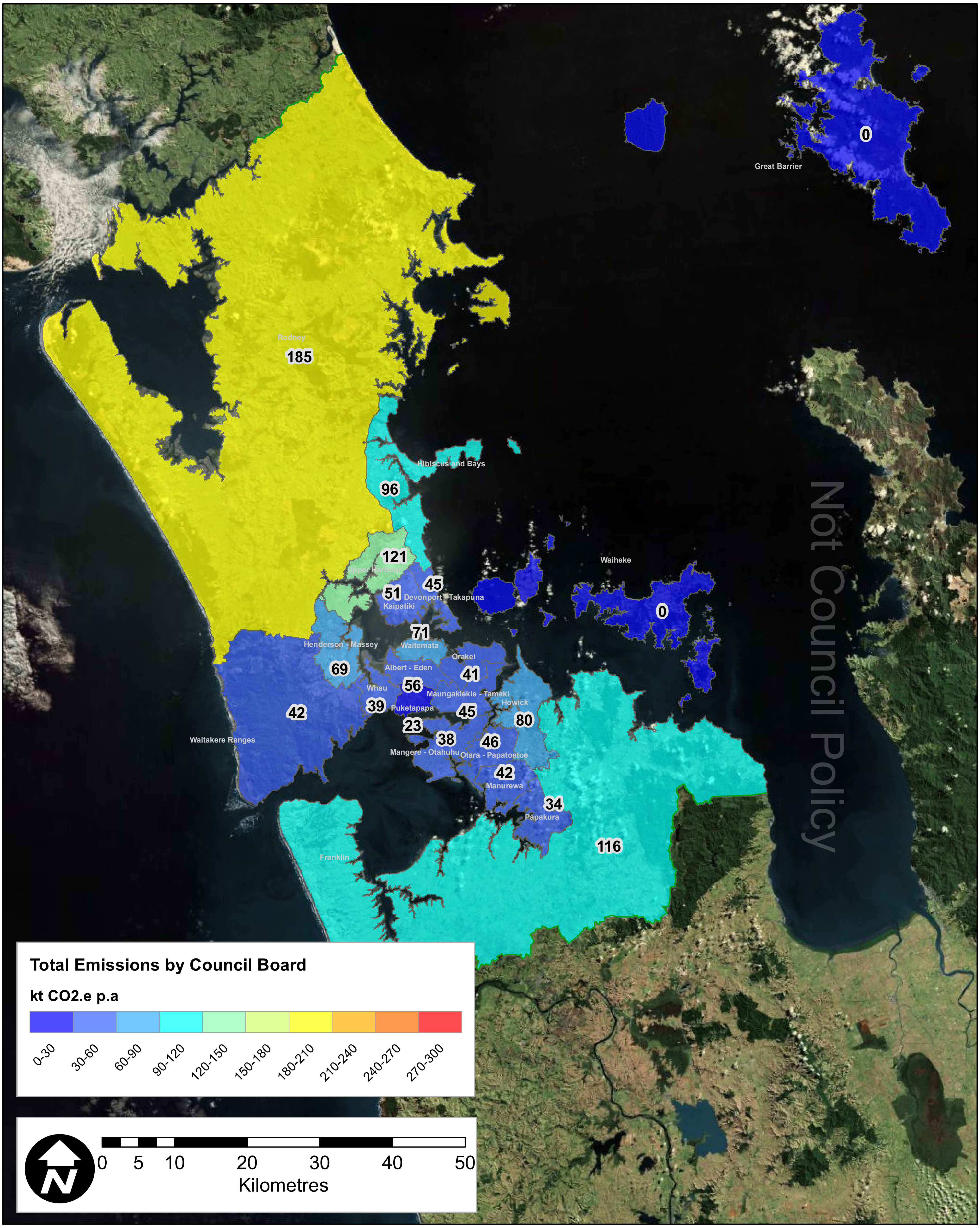
ARUP




# 2031 Total Emissions by Council Board - Commercial and Industrial Sector

Scenario: A

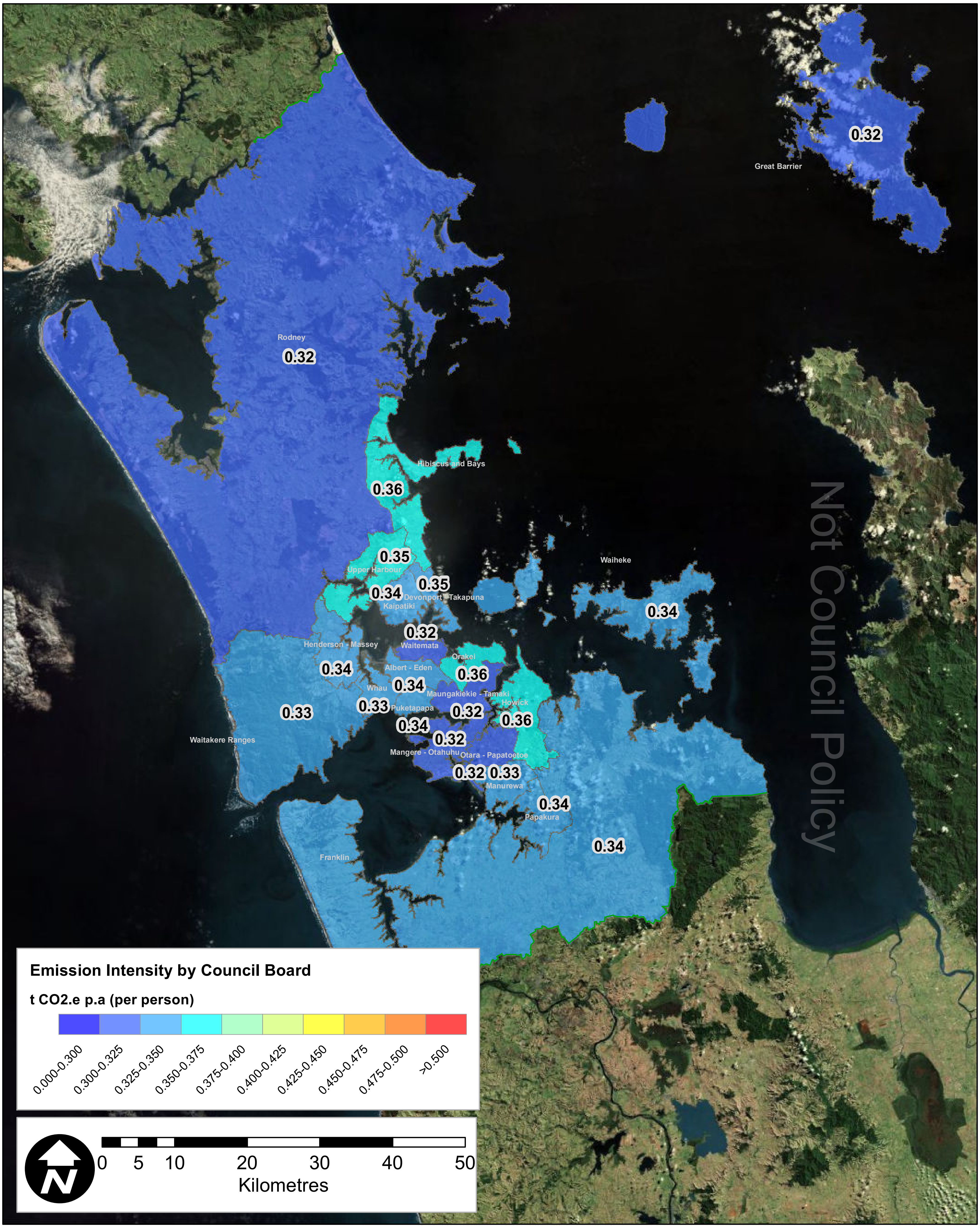
ARUP




# 2031 Total Emissions by Council Board - Private Transport Sector

Scenario: A

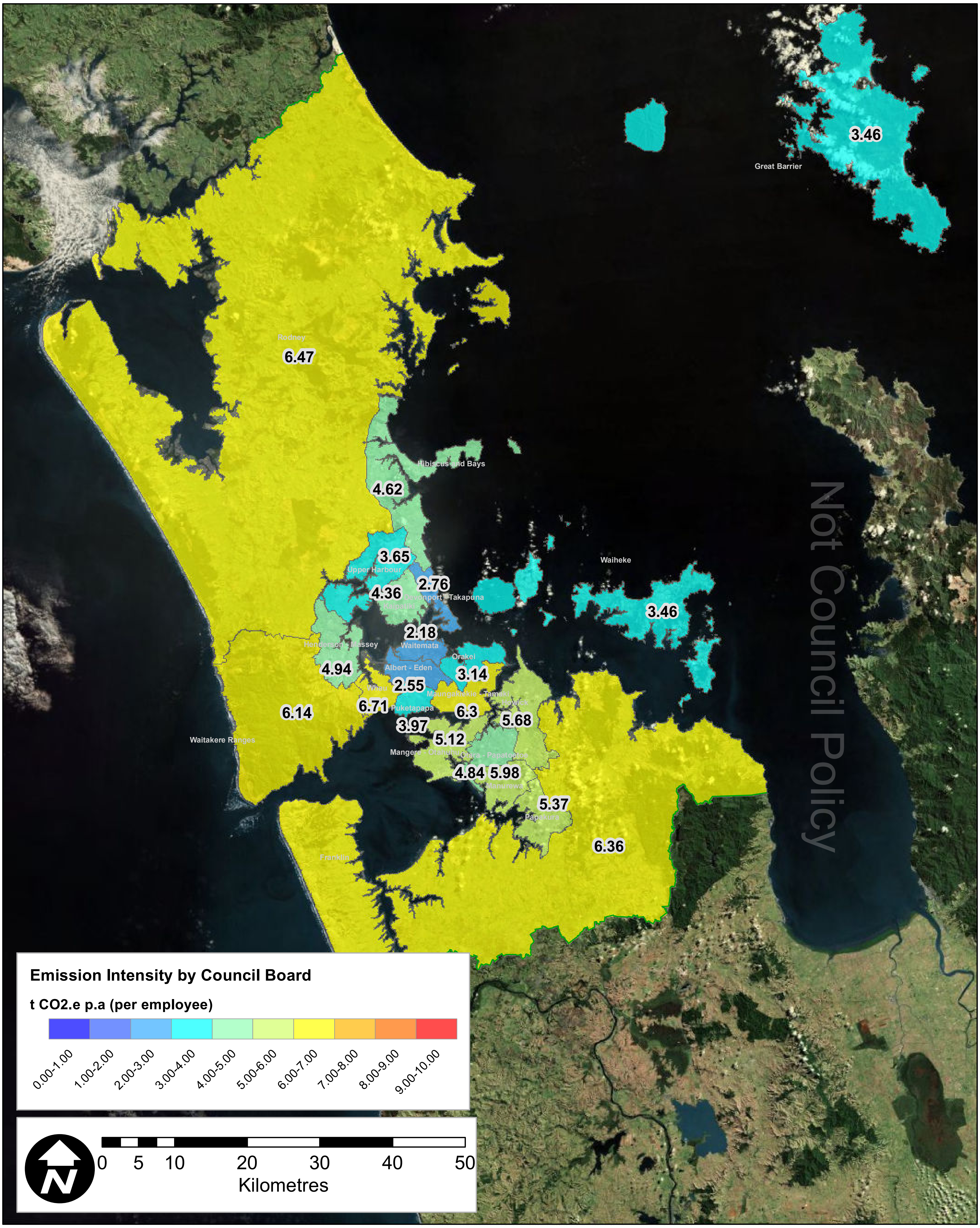
ARUP




# 2031 Emission Intensity by Council Board - Residential Sector

Scenario: A

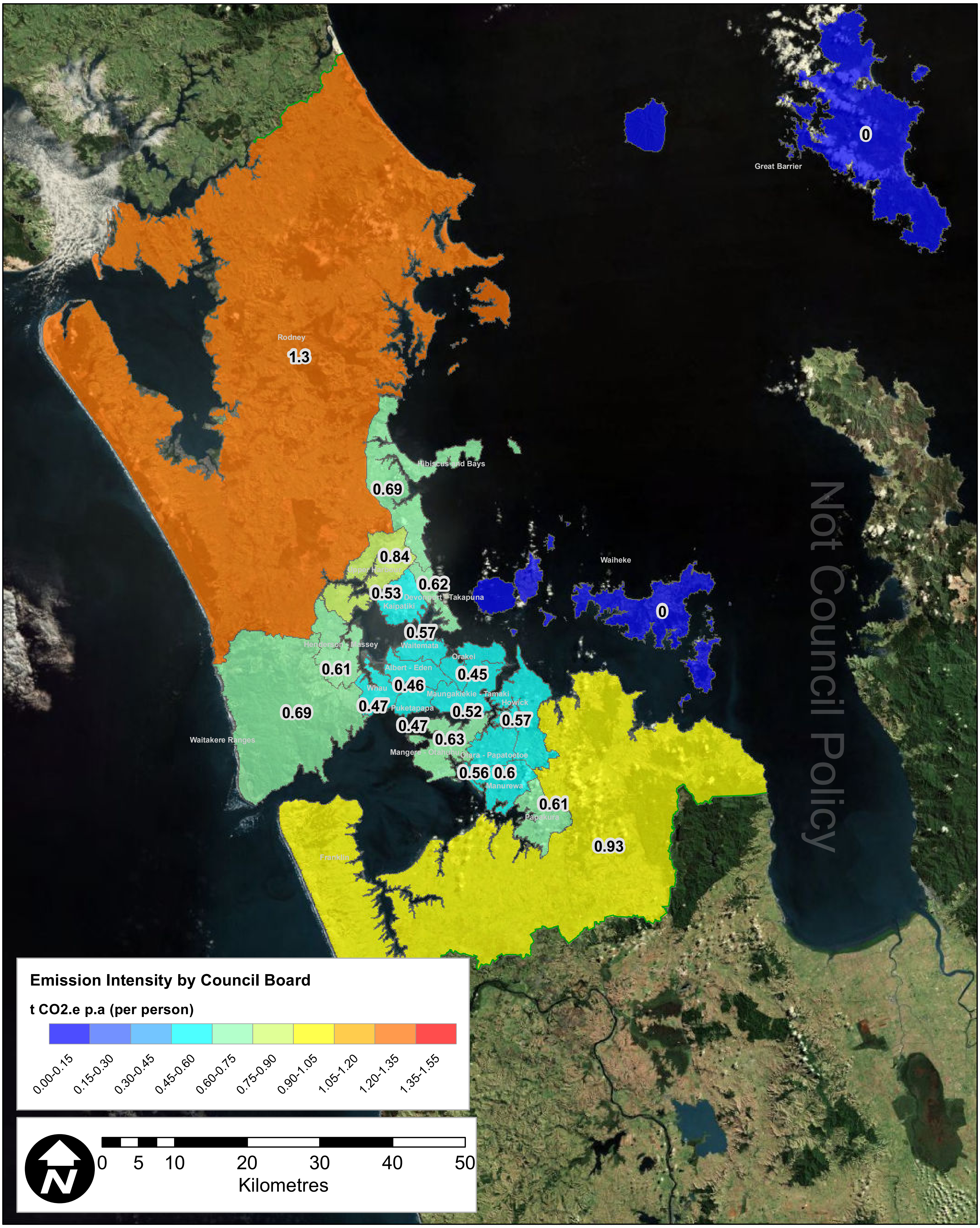
ARUP




# 2031 Emission Intensity by Council Board - Commercial and Industrial Sector

Scenario: A

ARUP




# 2031 Emission Intensity by Council Board - Private Transport Sector

Scenario: A

ARUP

### I2.2.3 Scenario B – Intensive expansion

Scenario B represents lower total emissions across Auckland compared to the nBAU and in total is not significantly different from Scenario A. Proportionally, commercial and industrial emissions generally contribute to the majority of total emissions in all local boards.

Commercial and industrial emissions are generally spread evenly throughout each local board and there is no single board that contributes to a high proportion of commercial and industrial emissions. However, the largest emissions are within Maungakiekie – Tamaki, Waitemata, and Howick (>300 kt$CO_2$e), explained by Scenario A's concentrated growth in the CBD and its fringes.

Rodney and Franklin also show large commercial and industrial emissions, due to a majority of employment growth being focused at key growth centres and Future Urban Areas in these local boards. For the same reason, larger residential emissions occur in Rodney, Franklin, Hibiscus and Bays, Upper Harbour and Howick, contributing over 40 kt$CO_2$e per each board.

Residential sector GHG emissions intensities in each local board are similar. As with Scenario A, the highest private transport GHG emissions per person are observed in Rodney, and Franklin. The higher emissions in these areas may be explained by the support of further road and public transport networks to facilitate the new expansion areas in the Future Urban Areas.

Results by local board for Scenario B are presented in Table 4Table 8 and below as well as the following maps.

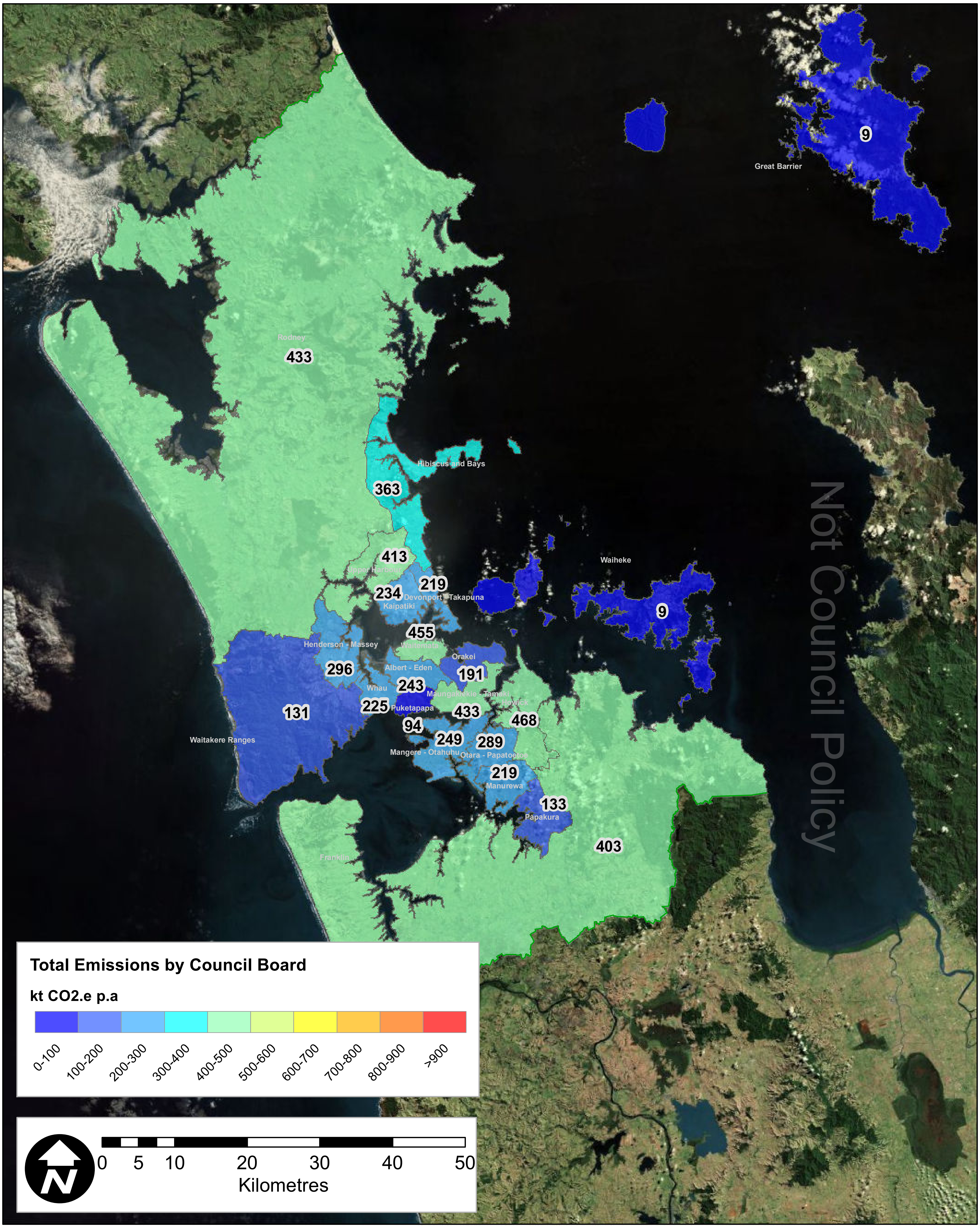
Table 8 Scenario B results by local board (total emissions)

| **Local Board** | **GHG Emissions 2031 (kt$CO_2$e)** | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Rodney | 42.0 | 233.3 | 158.1 | 433.5 |
| Hibiscus and Bays | 57.5 | 200.8 | 105.1 | 363.4 |
| Upper Harbour | 46.3 | 262.1 | 104.9 | 413.4 |
| Kaipatiki | 34.8 | 145.9 | 52.8 | 233.5 |
| Devonport - Takapuna | 26.4 | 144.6 | 47.9 | 218.9 |
| Henderson - Massey | 39.1 | 186.4 | 70.3 | 295.7 |
| Waitakere Ranges | 22.3 | 62.6 | 45.9 | 130.8 |
| Great Barrier | 2.0 | 7.1 | 0.0 | 9.1 |
| Waiheke | 2.2 | 7.1 | 0.0 | 9.2 |
| Waitemata | 36.9 | 350.1 | 67.7 | 454.7 |
| Whau | 24.1 | 162.8 | 37.7 | 224.6 |
| Albert - Eden | 42.5 | 143.6 | 57.1 | 243.2 |
| Puketapapa | 19.2 | 49.6 | 25.4 | 94.2 |
| Orakei | 35.2 | 111.8 | 44.1 | 191.1 |
| Maungakiekie - Tamaki | 24.5 | 367.5 | 41.4 | 433.4 |
| Howick | 60.8 | 312.3 | 94.6 | 467.8 |

| Local Board | GHG Emissions 2031 ($ktCO_2e$) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Mangere - Otahuhu | 20.1 | 189.1 | 39.8 | 249.0 |
| Otara - Papatoetoe | 25.0 | 218.5 | 45.2 | 288.7 |
| Manurewa | 22.8 | 153.8 | 42.7 | 219.4 |
| Papakura | 17.7 | 83.1 | 32.5 | 133.2 |
| Franklin | 41.8 | 243.8 | 117.6 | 403.2 |
| **TOTAL** | **643.3** | **3,635.8** | **1,230.9** | **5,509.9** |

Table 9 Scenario B results by local board (GHG Emissions Intensity)

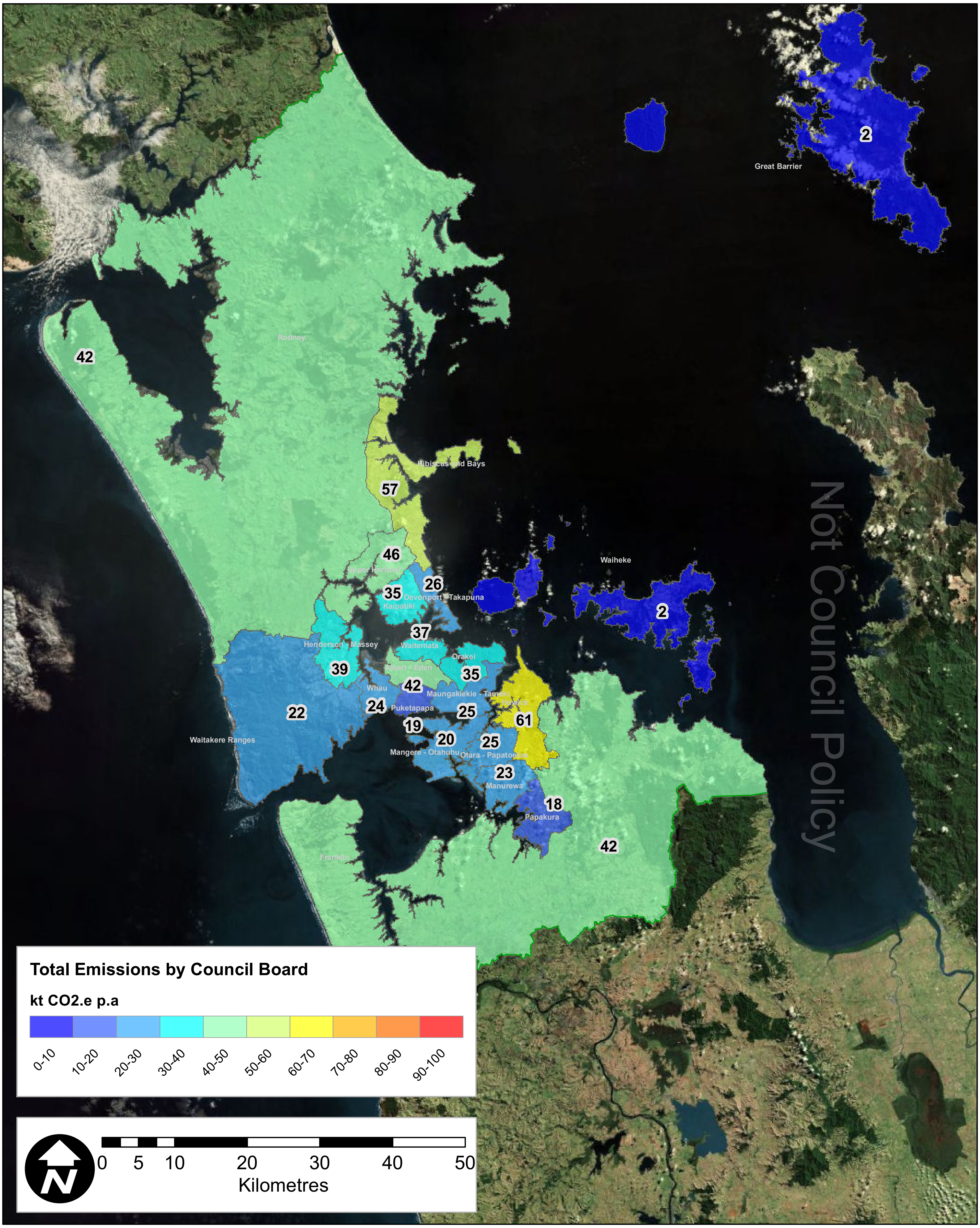
| Local Board | GHG Emissions Intensity 2031 | | |
|---|---|---|---|
| | **Residential** ($tCO_2e$ per resident) | **Commercial and Industrial** ($tCO_2e$ per employee) | **Private Transport** ($tCO_2e$ per resident) |
| Rodney | 0.32 | 5.92 | 1.22 |
| Hibiscus and Bays | 0.36 | 4.65 | 0.66 |
| Upper Harbour | 0.36 | 3.97 | 0.82 |
| Kaipatiki | 0.35 | 4.51 | 0.52 |
| Devonport - Takapuna | 0.35 | 2.93 | 0.64 |
| Henderson - Massey | 0.34 | 5.06 | 0.61 |
| Waitakere Ranges | 0.33 | 5.90 | 0.68 |
| Great Barrier | 0.32 | 3.46 | 0.00 |
| Waiheke | 0.34 | 3.46 | 0.00 |
| Waitemata | 0.33 | 2.15 | 0.60 |
| Whau | 0.33 | 6.60 | 0.53 |
| Albert - Eden | 0.35 | 2.51 | 0.47 |
| Puketapapa | 0.35 | 3.91 | 0.46 |
| Orakei | 0.37 | 3.27 | 0.46 |
| Maungakiekie - Tamaki | 0.33 | 6.16 | 0.55 |
| Howick | 0.37 | 5.57 | 0.57 |
| Mangere - Otahuhu | 0.33 | 5.06 | 0.64 |
| Otara - Papatoetoe | 0.33 | 4.69 | 0.59 |
| Manurewa | 0.34 | 5.82 | 0.63 |
| Papakura | 0.35 | 5.42 | 0.64 |
| Franklin | 0.34 | 6.12 | 0.95 |




# 2031 Total Emissions by Council Board - Total (Energy Related Emissions)

Scenario: B

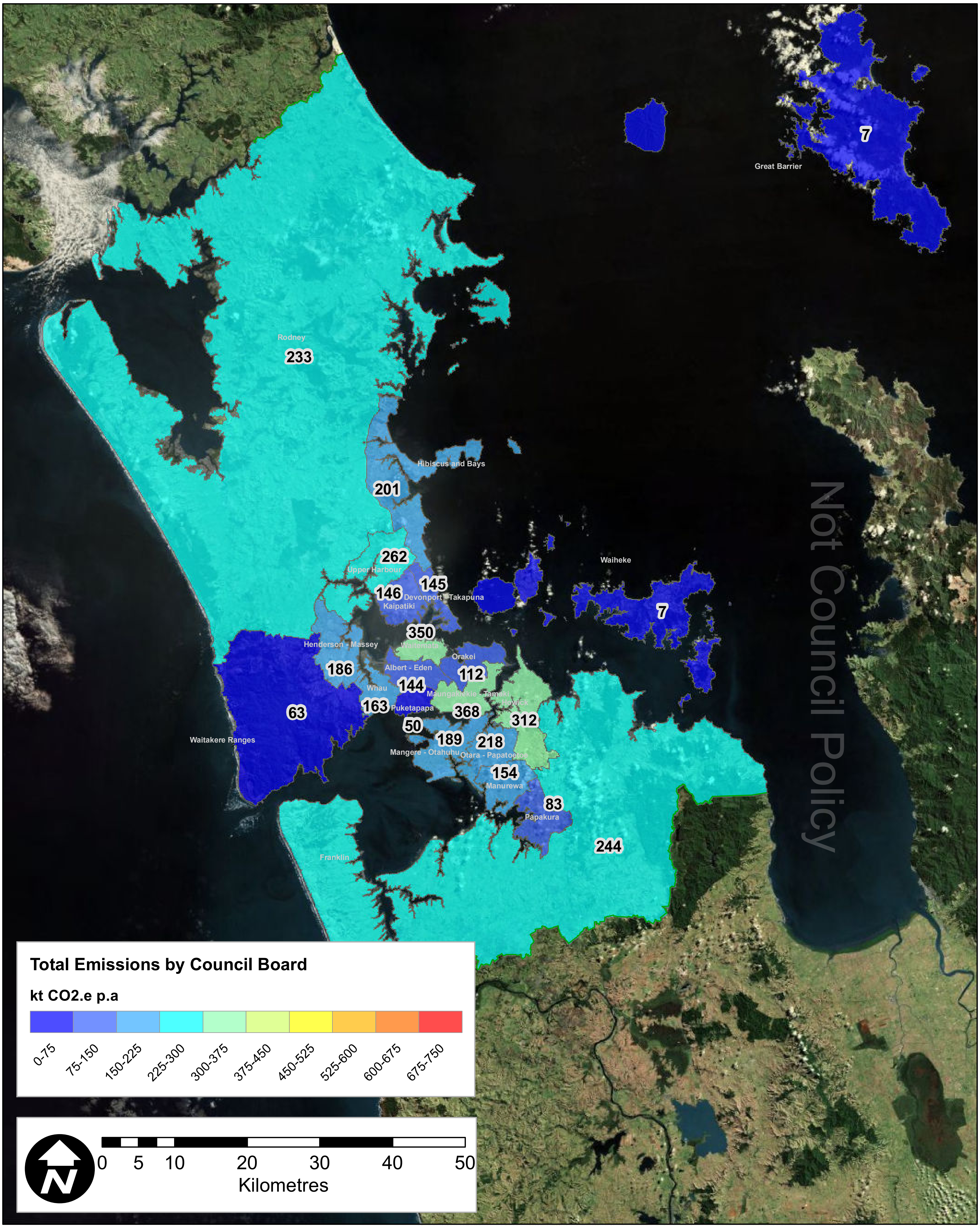
ARUP




# 2031 Total Emissions by Council Board - Residential Sector

Scenario: B

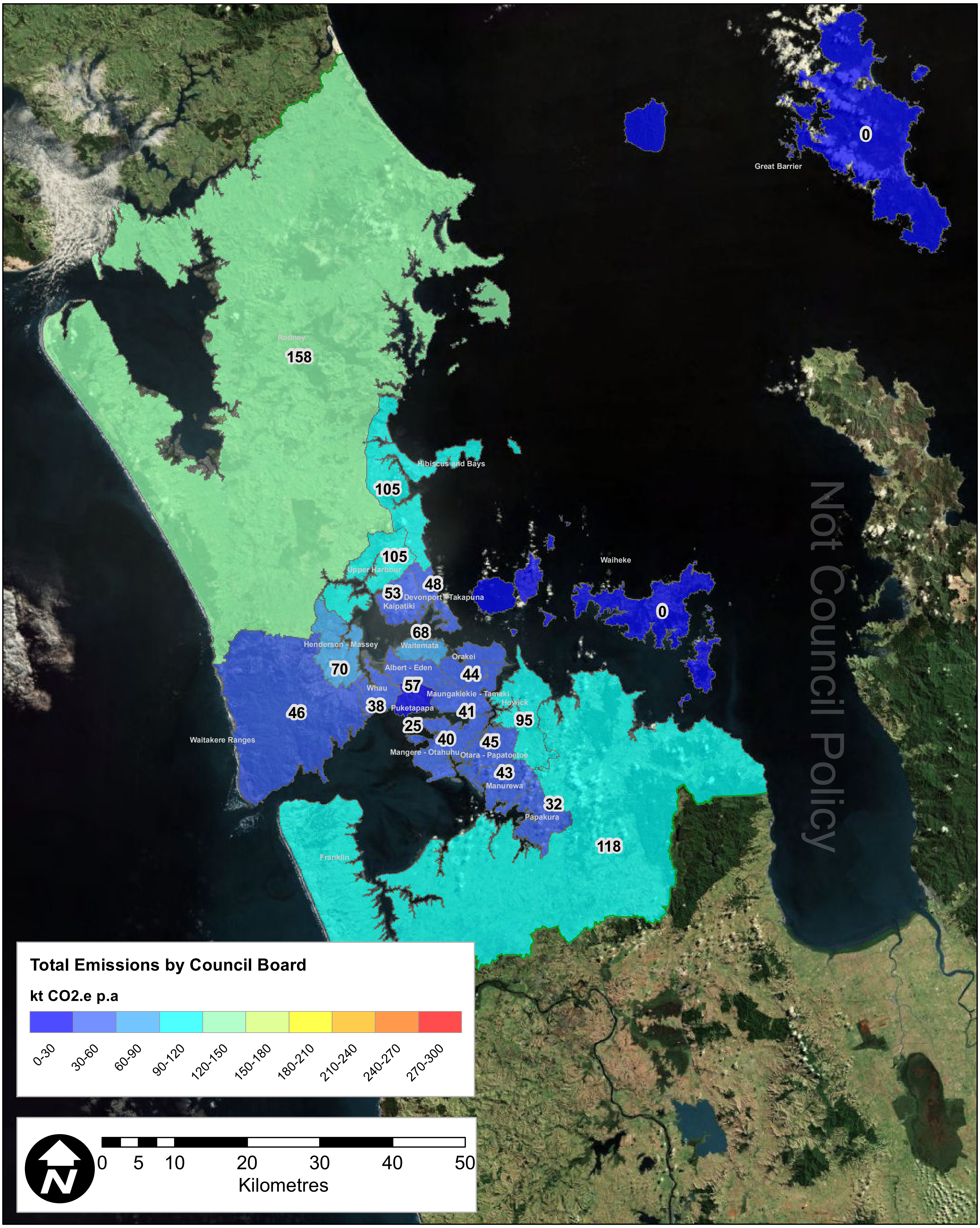
ARUP




# 2031 Total Emissions by Council Board - Commercial and Industrial Sector

Scenario: B

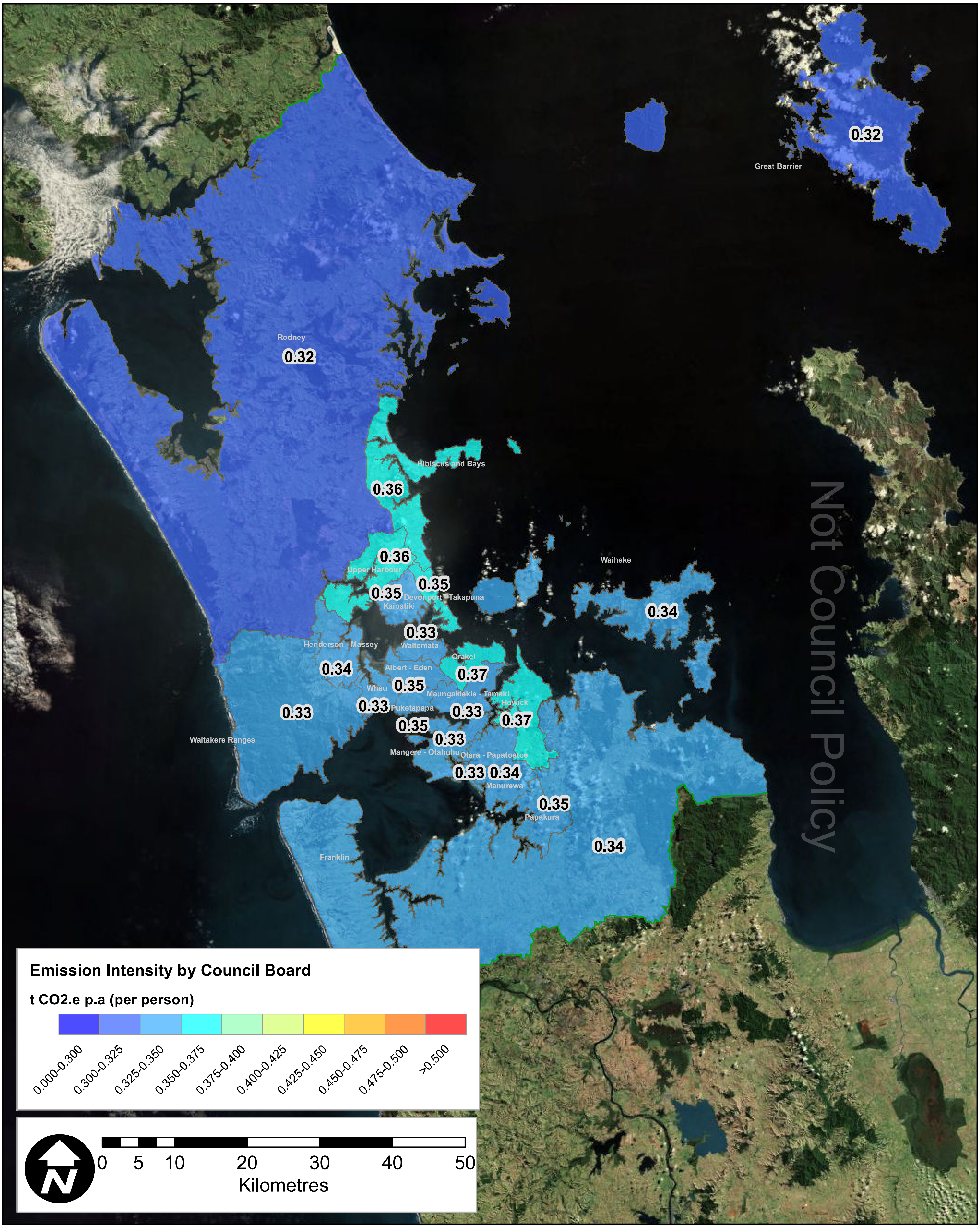
ARUP




# 2031 Total Emissions by Council Board - Private Transport Sector

Scenario: B

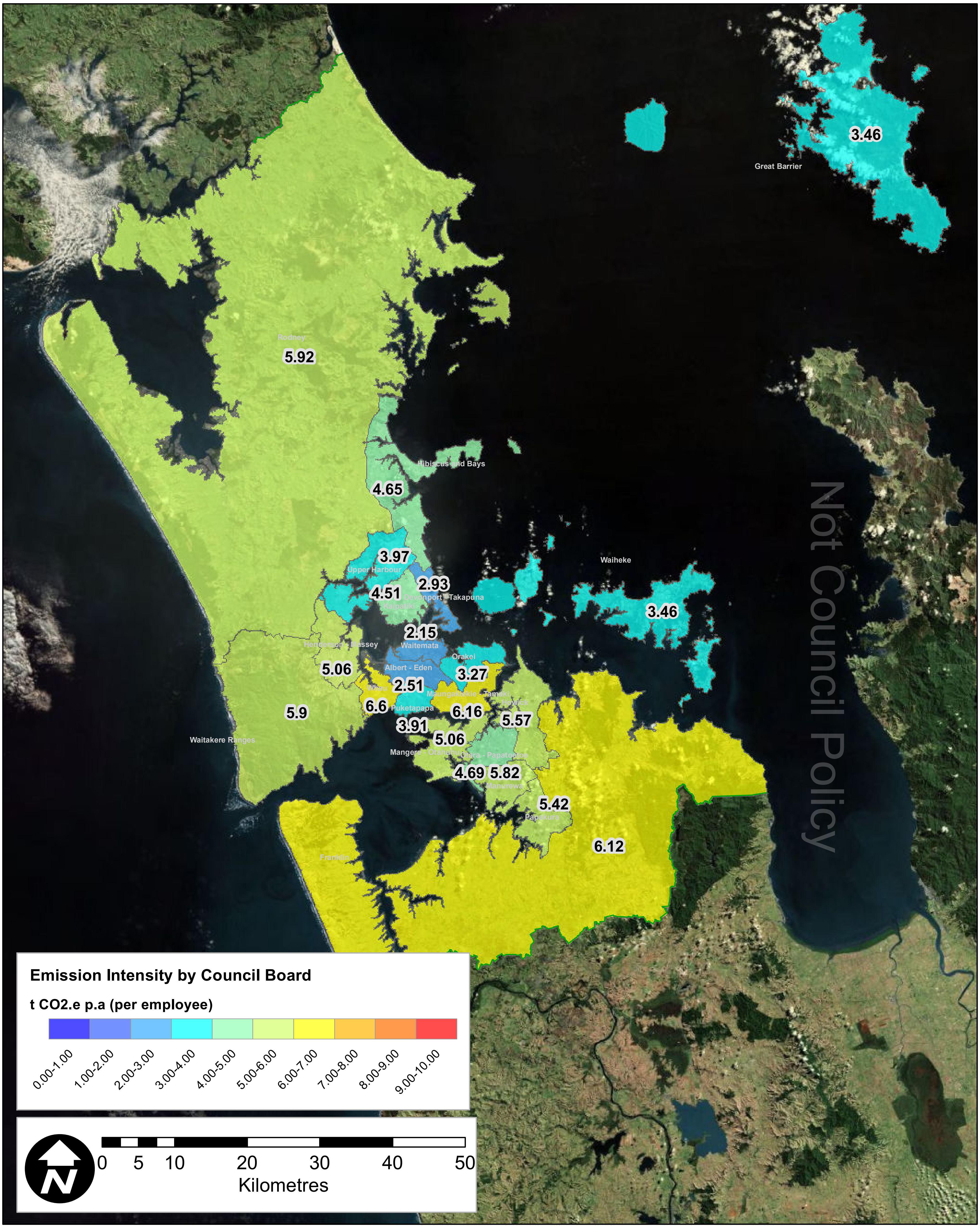
ARUP




# 2031 Emission Intensity by Council Board - Residential Sector

Scenario: B

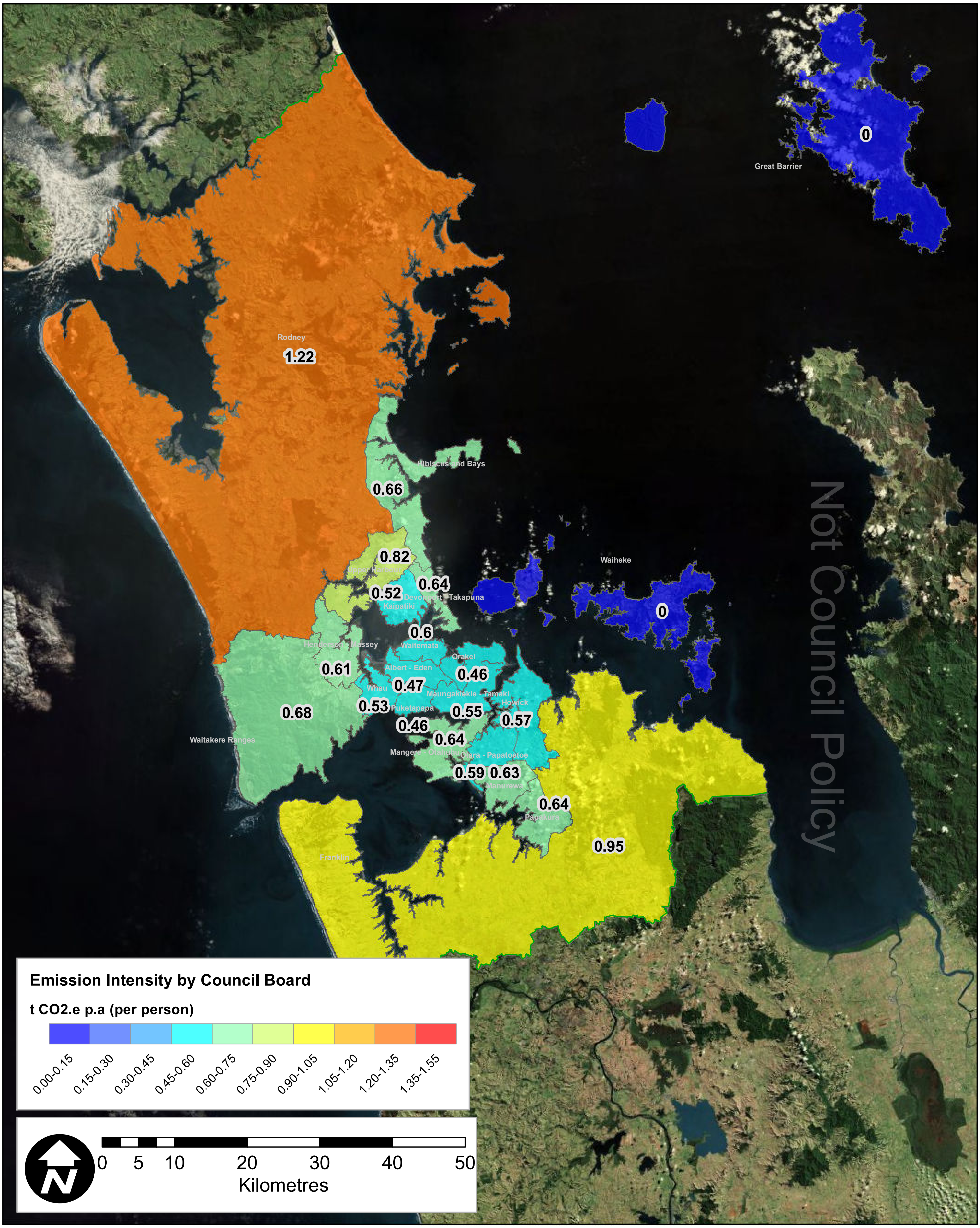
ARUP




# 2031 Emission Intensity by Council Board - Commercial and Industrial Sector

Scenario: B

ARUP




# 2031 Emission Intensity by Council Board - Private Transport Sector

Scenario: B

ARUP

### I2.2.4 Scenario C

Scenario C presents lower total emissions across Auckland compared to the nBAU. Proportionally, commercial and industrial emissions generally contribute to the majority of total emissions.

Commercial and industrial emissions are generally spread evenly throughout each local board and there is no single board that contributes to a high proportion of commercial and industrial emissions. However, the largest emissions are within Maungakiekie – Tamaki, Waitemata, and Howick.

Scenario C considers employment and residential occurring at existing and planned Future Urban Areas. In the same way, larger proportions of commercial and residential emissions occur in these areas, being Rodney, Franklin, Hibiscus and Bays, Upper Harbour and Howick.

In regards to emission intensities, the highest private transport emission intensities are observed in Rodney, and Franklin. This may be explained by a transport system that has to support for a wider dispersion of growth. Additionally, Scenario C considers extensive road improvements for an expectation of high traffic levels in these areas. As for commercial and industrial emission intensities, intensities are broadly similar and dispersed across local boards, even in coastal areas, which is accounted by the employment growth model considered by Scenario C.

Results by local board for Scenario C are presented in Table 4Table 10 and below as well as the following maps.

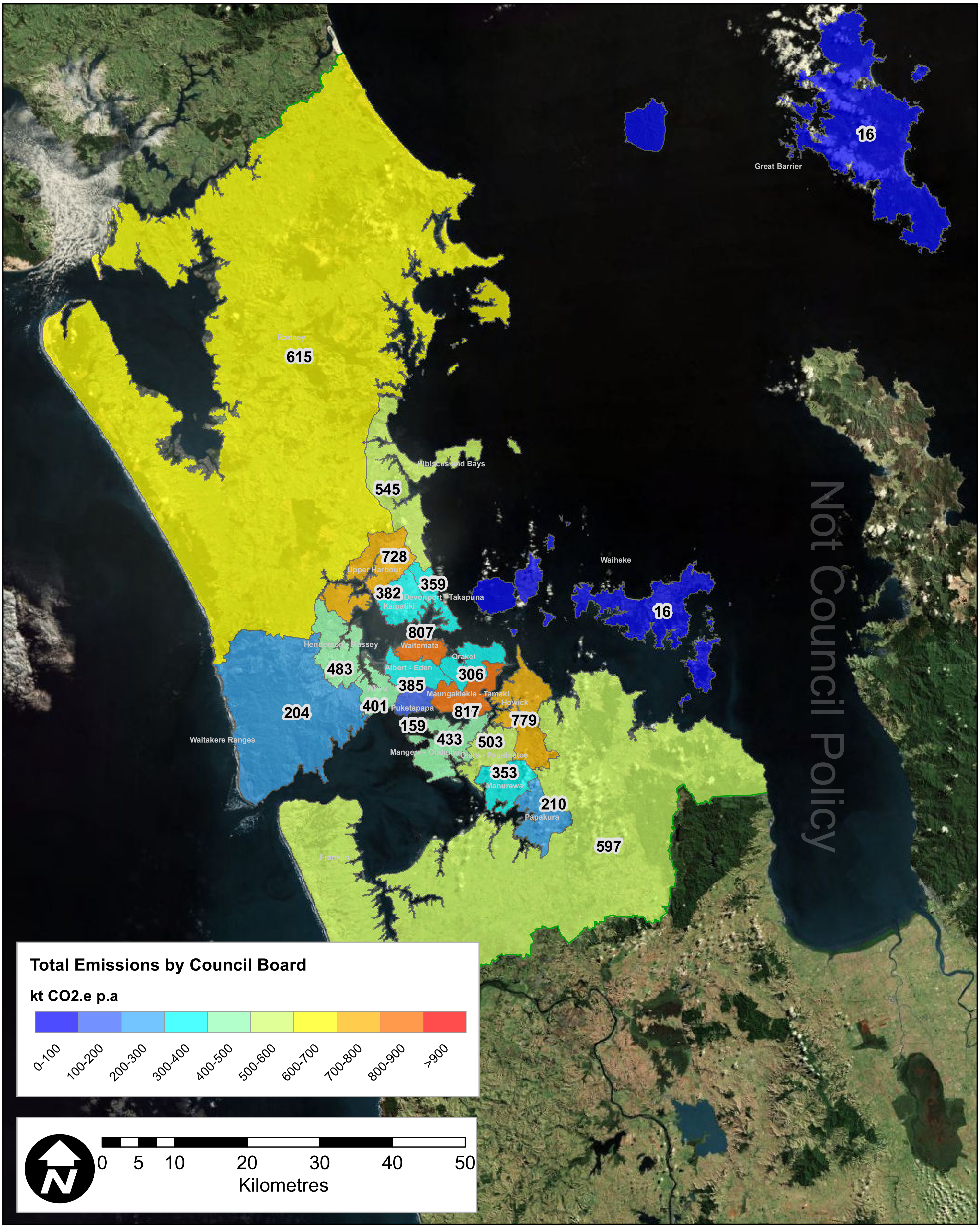
Table 10 Scenario C results by local board (total emissions)

| **Local Board** | **GHG Emissions 2031 (ktCO2e)** | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Rodney | 37.7 | 215.6 | 146.5 | 399.8 |
| Hibiscus and Bays | 57.3 | 193.7 | 99.9 | 350.9 |
| Upper Harbour | 47.3 | 290.7 | 99.5 | 437.4 |
| Kaipatiki | 34.5 | 150.0 | 48.0 | 232.5 |
| Devonport - Takapuna | 26.8 | 143.5 | 44.8 | 215.1 |
| Henderson - Massey | 38.4 | 188.8 | 67.4 | 294.6 |
| Waitakere Ranges | 22.0 | 68.8 | 44.8 | 135.6 |
| Great Barrier | 2.0 | 7.1 | 0.0 | 9.1 |
| Waiheke | 2.2 | 7.1 | 0.0 | 9.2 |
| Waitemata | 38.4 | 351.5 | 66.2 | 456.0 |
| Whau | 24.0 | 169.7 | 37.5 | 231.2 |
| Albert - Eden | 43.1 | 141.5 | 58.5 | 243.2 |
| Puketapapa | 19.9 | 56.3 | 26.3 | 102.5 |
| Orakei | 37.0 | 112.7 | 43.4 | 193.1 |
| Maungakiekie - Tamaki | 26.6 | 373.4 | 43.3 | 443.3 |
| Howick | 62.5 | 311.6 | 93.0 | 467.1 |

| Local Board | GHG Emissions 2031 (ktCO2e) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Mangere - Otahuhu | 20.0 | 186.1 | 40.7 | 246.9 |
| Otara - Papatoetoe | 24.3 | 216.5 | 45.7 | 286.4 |
| Manurewa | 22.1 | 145.3 | 40.8 | 208.2 |
| Papakura | 17.3 | 80.6 | 31.2 | 129.1 |
| Franklin | 39.6 | 225.4 | 107.0 | 372.0 |
| **TOTAL** | **642.8** | **3,635.8** | **1,184.5** | **5,463.1** |

Table 11 Scenario C results by local board (GHG Emissions Intensity)

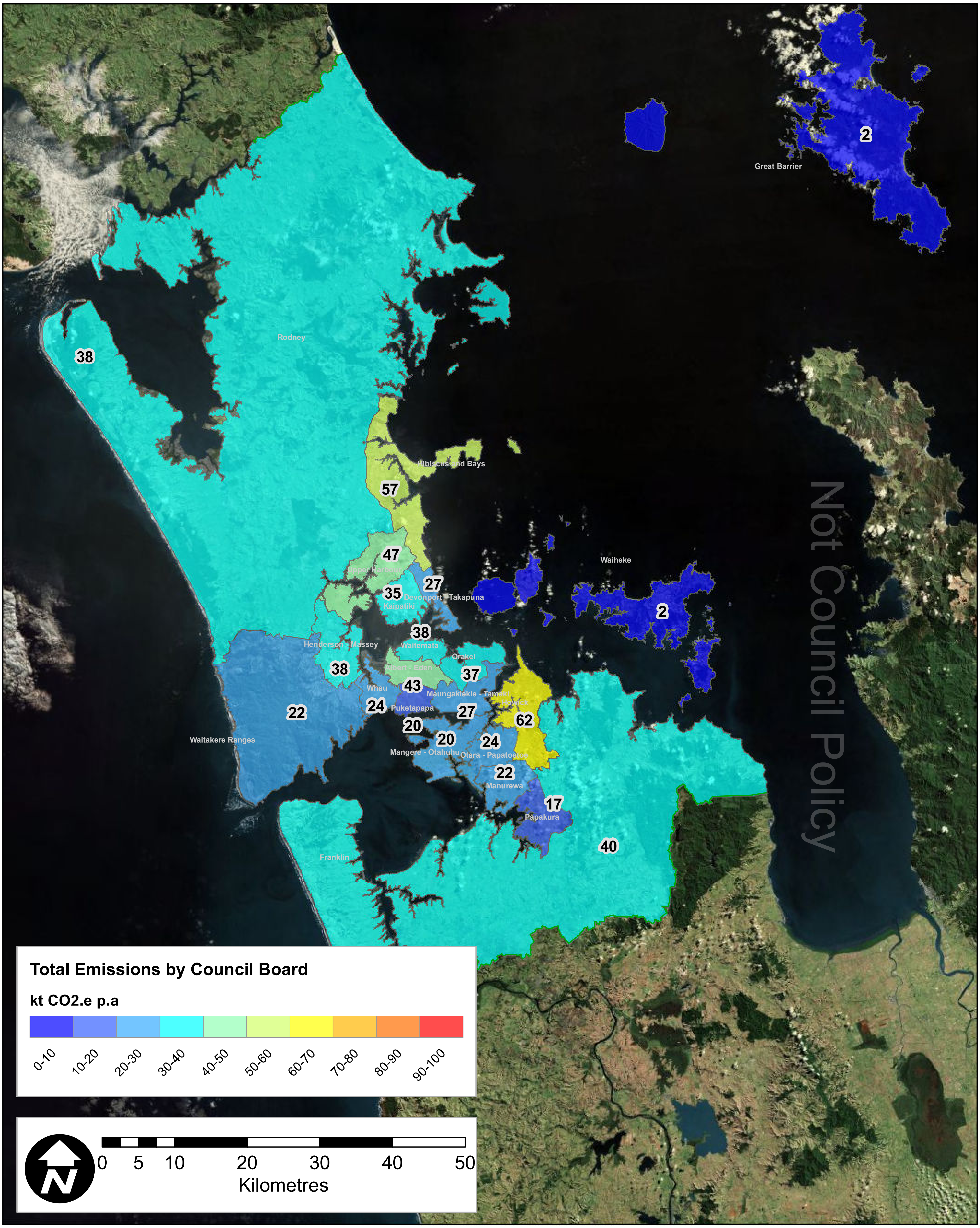
| Local Board | GHG Emissions Intensity 2031 | | |
|---|---|---|---|
| | **Residential** ($tCO_2e$ per resident) | **Commercial and Industrial** ($tCO_2e$ per employee) | **Private Transport** ($tCO_2e$ per resident) |
| Rodney | 0.32 | 6.05 | 1.26 |
| Hibiscus and Bays | 0.36 | 4.55 | 0.63 |
| Upper Harbour | 0.36 | 4.19 | 0.76 |
| Kaipatiki | 0.35 | 4.52 | 0.48 |
| Devonport - Takapuna | 0.35 | 2.96 | 0.59 |
| Henderson - Massey | 0.34 | 5.11 | 0.60 |
| Waitakere Ranges | 0.33 | 6.06 | 0.68 |
| Great Barrier | 0.32 | 3.46 | 0.00 |
| Waiheke | 0.34 | 3.46 | 0.00 |
| Waitemata | 0.32 | 2.14 | 0.55 |
| Whau | 0.33 | 6.75 | 0.52 |
| Albert - Eden | 0.35 | 2.45 | 0.47 |
| Puketapapa | 0.35 | 4.08 | 0.46 |
| Orakei | 0.37 | 3.21 | 0.43 |
| Maungakiekie - Tamaki | 0.33 | 6.08 | 0.53 |
| Howick | 0.37 | 5.50 | 0.55 |
| Mangere - Otahuhu | 0.33 | 5.00 | 0.66 |
| Otara - Papatoetoe | 0.33 | 4.71 | 0.61 |
| Manurewa | 0.34 | 5.85 | 0.63 |
| Papakura | 0.35 | 5.44 | 0.63 |
| Franklin | 0.34 | 6.21 | 0.92 |




# 2031 Total Emissions by Council Board - Total (Energy Related Emissions)

Scenario: C

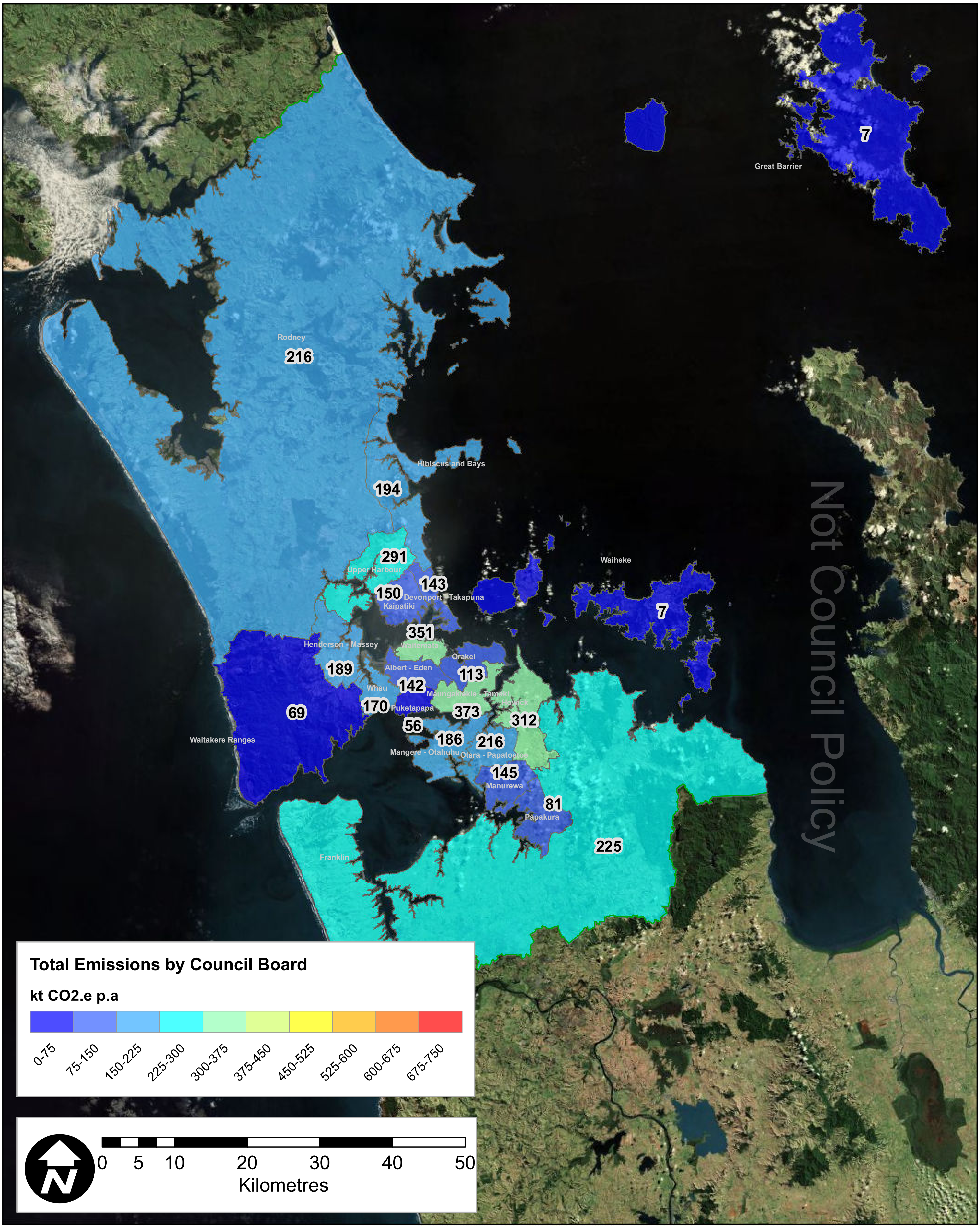
ARUP




# 2031 Total Emissions by Council Board - Residential Sector

Scenario: C

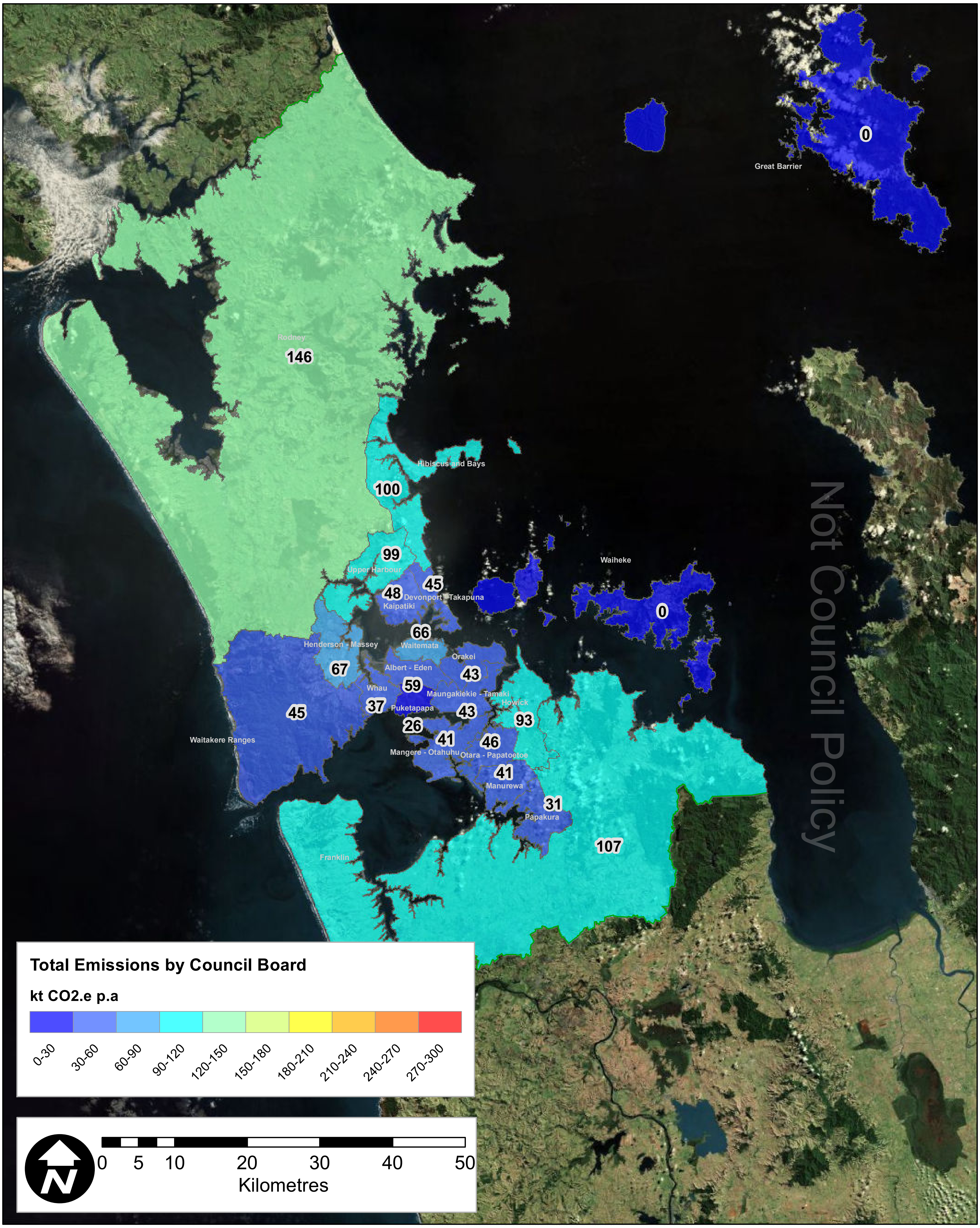
ARUP




# 2031 Total Emissions by Council Board - Commercial and Industrial Sector

Scenario: C

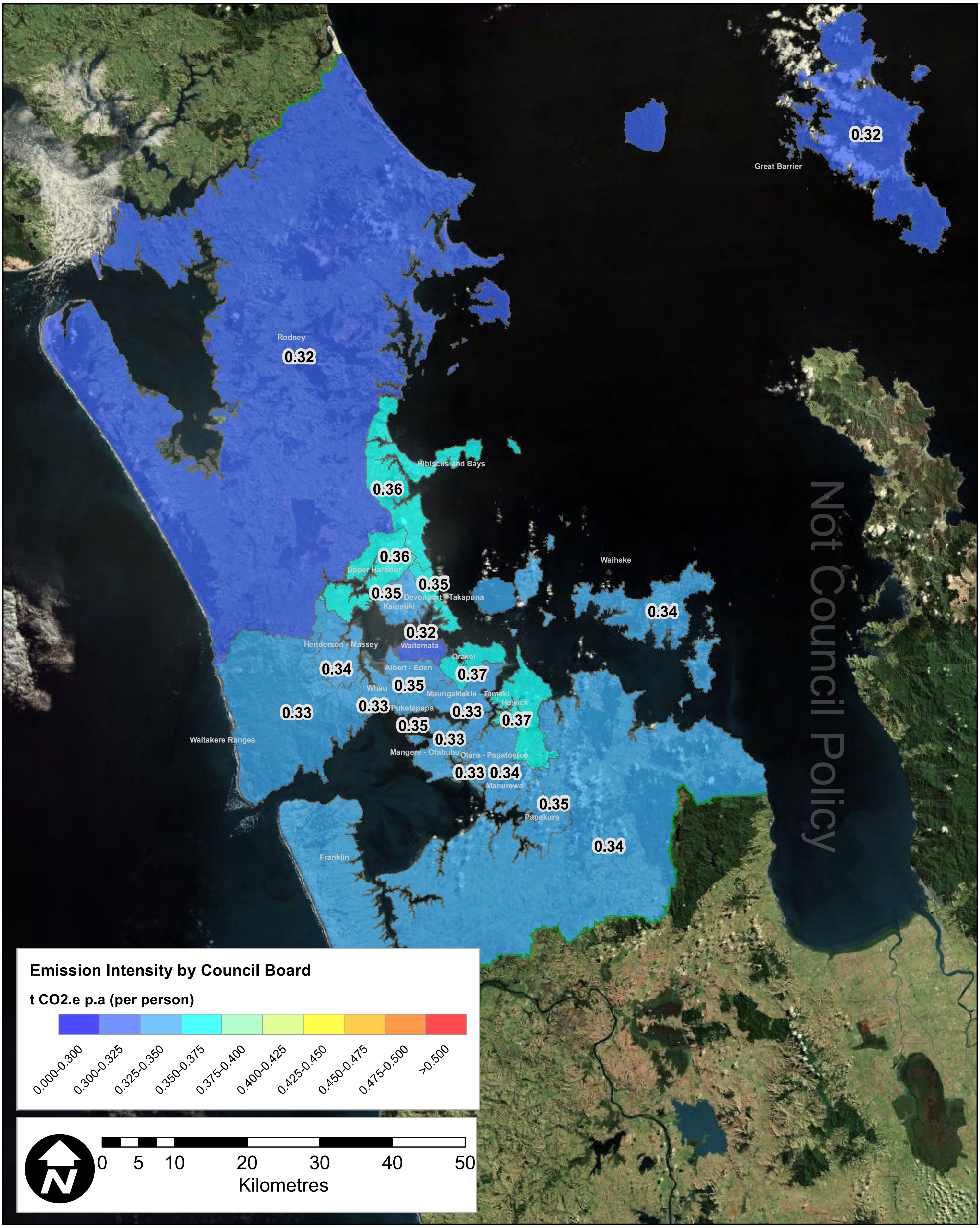
ARUP




# 2031 Total Emissions by Council Board - Private Transport Sector

Scenario: C

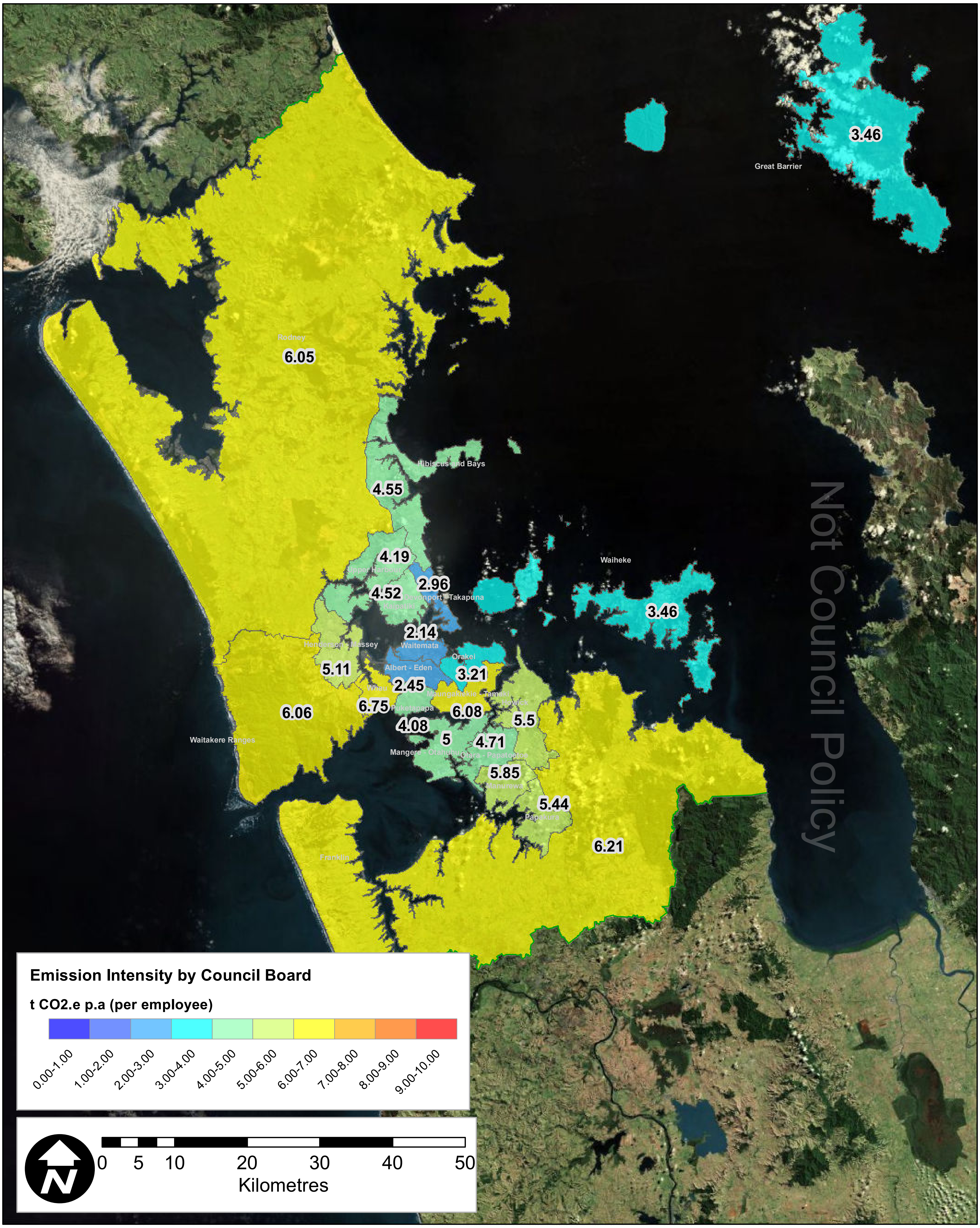
ARUP




# 2031 Emission Intensity by Council Board - Residential Sector

Scenario: C

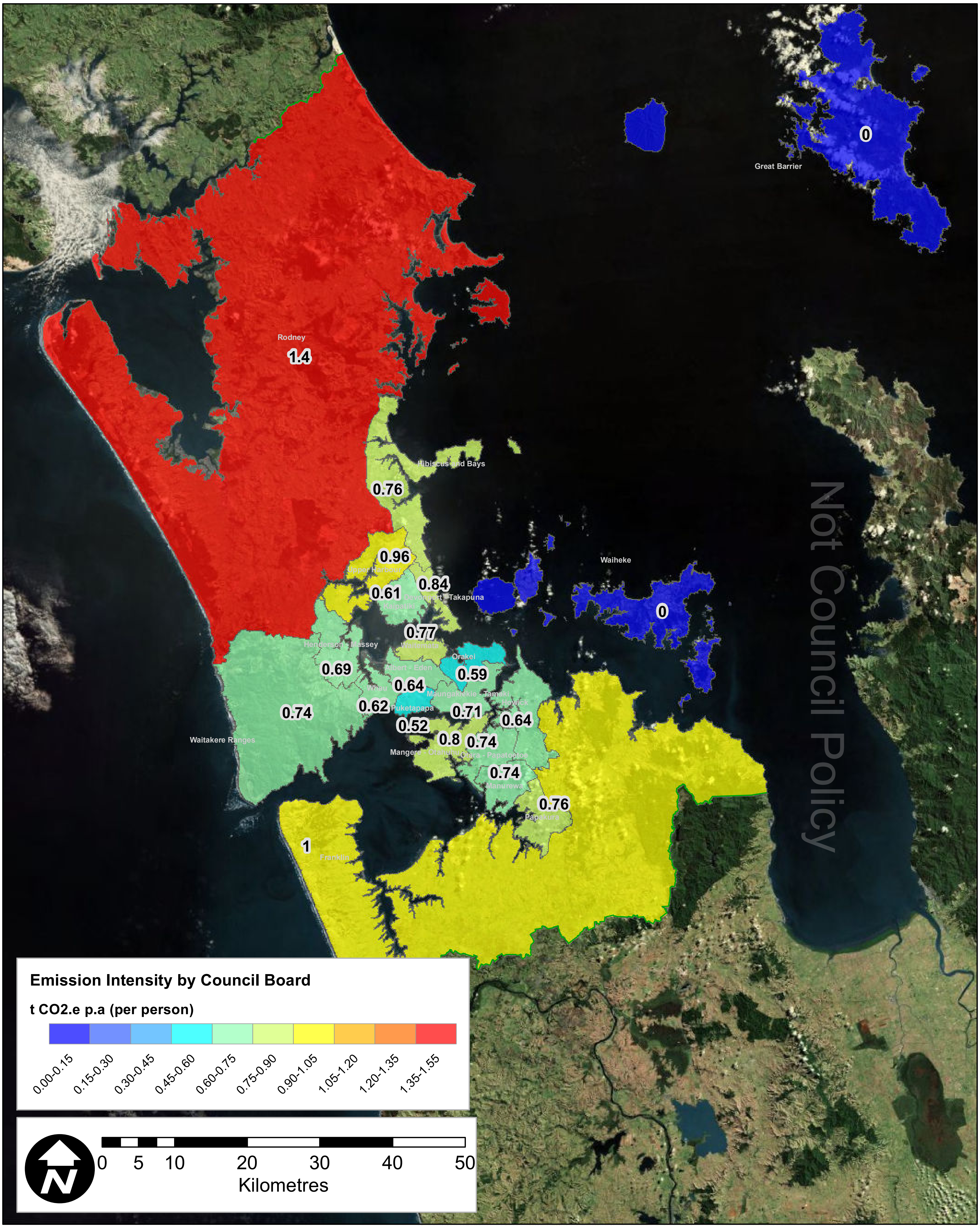
ARUP




# 2031 Emission Intensity by Council Board - Commercial and Industrial Sector

Scenario: C

ARUP




# 2031 Emission Intensity by Council Board - Private Transport Sector

Scenario: C

ARUP

### I2.2.5 Scenario D

Scenario D presents higher total emissions across Auckland compared to the nBAU. Proportionally, commercial and industrial emissions generally contribute to the majority of total emissions.

Commercial and industrial emissions are generally spread evenly throughout each local board and there is no single board that contributes to a high proportion of commercial and industrial emissions. However, the largest emissions are within Maungakiekie – Tamaki, Waitemata, and Franklin (>300 kt$CO_2$e), explained by Scenario A's concentrated growth in the CBD and in all existing areas and Future Urban Areas.

Considering Scenario D's model of extensive growth in Greenfield land across Auckland and beyond scheduled, the boards of Upper Harbour, Rodney, and Howick present the highest residential emissions and have similarly larger commercial and industrial emissions. Likewise, private transport emissions are the greatest across all of Auckland in Rodney and Franklin, which may be accounted for by the road and public transport infrastructure being expanded to support these new areas.

The extensive growth in Future Urban Areas in Scenario D are also reflected in these areas regarding private transport and commercial and industrial emission intensities. In particular, Rodney and Franklin show the highest emission intensities. These high emission intensities are attributed to Scenario D requiring a transport system that supports further distances for employment travel.

Additionally, due to extensive business development occurring in Greenfield land beyond the current scheduled, areas such as Waitakere Ranges and Hibiscus and Bays also show high emission intensities.

Results by local board for Scenario D are presented in Table 4Table 12 and below as well as the following maps.

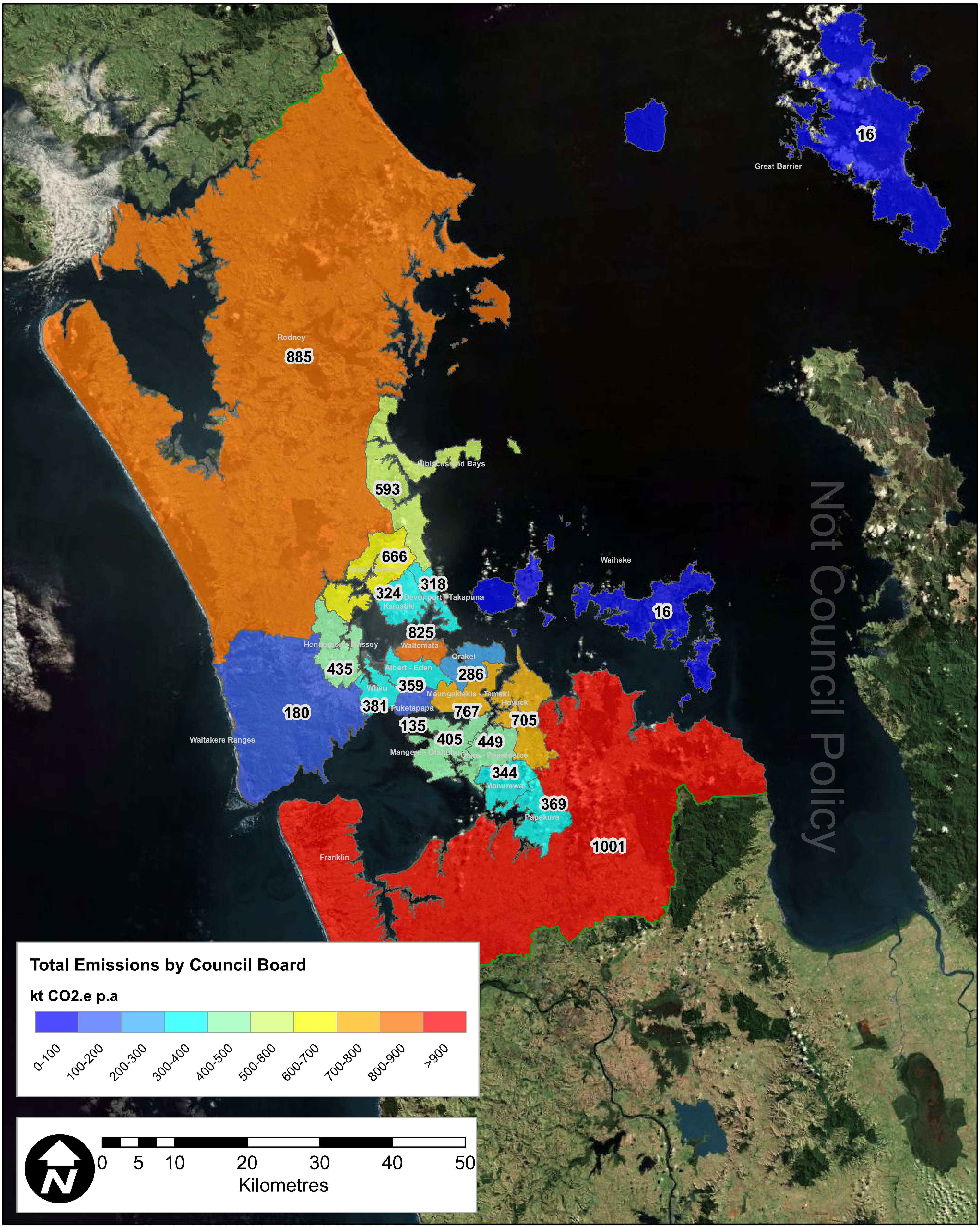
Table 12 Scenario D results by local board (total emissions)

| Local Board | GHG Emissions 2031 (kt$CO_2$e) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Rodney | 66.7 | 268.5 | 281.6 | 616.8 |
| Hibiscus and Bays | 61.9 | 199.7 | 131.4 | 393.0 |
| Upper Harbour | 45.0 | 249.8 | 121.3 | 416.0 |
| Kaipatiki | 24.3 | 127.5 | 44.2 | 196.0 |
| Devonport - Takapuna | 20.6 | 124.3 | 49.2 | 194.1 |
| Henderson - Massey | 30.7 | 170.6 | 63.1 | 264.5 |
| Waitakere Ranges | 17.4 | 61.6 | 39.2 | 118.3 |
| Great Barrier | 2.0 | 7.1 | 0.0 | 9.1 |
| Waiheke | 2.2 | 7.1 | 0.0 | 9.2 |
| Waitemata | 32.5 | 357.2 | 77.6 | 467.4 |
| Whau | 18.6 | 163.0 | 36.1 | 217.7 |
| Albert - Eden | 31.3 | 133.8 | 59.7 | 224.8 |

| Local Board | GHG Emissions 2031 ($ktCO_2e$) | | | |
|---|---|---|---|---|
| | Residential | Commercial and Industrial | Private Transport | TOTAL |
| Puketapapa | 14.9 | 48.7 | 22.7 | 86.4 |
| Orakei | 29.8 | 104.0 | 48.1 | 181.8 |
| Maungakiekie - Tamaki | 20.0 | 351.0 | 44.6 | 415.6 |
| Howick | 50.3 | 283.2 | 88.4 | 422.0 |
| Mangere - Otahuhu | 13.9 | 178.2 | 35.1 | 227.2 |
| Otara - Papatoetoe | 17.6 | 195.5 | 40.4 | 253.6 |
| Manurewa | 20.4 | 139.4 | 44.8 | 204.6 |
| Papakura | 24.1 | 145.7 | 53.6 | 223.4 |
| Franklin | 92.8 | 319.7 | 269.1 | 681.6 |
| **TOTAL** | **636.7** | **3,635.8** | **1,550.3** | **5,822.9** |

Table 13 Scenario D results by local board (GHG Emissions Intensity)

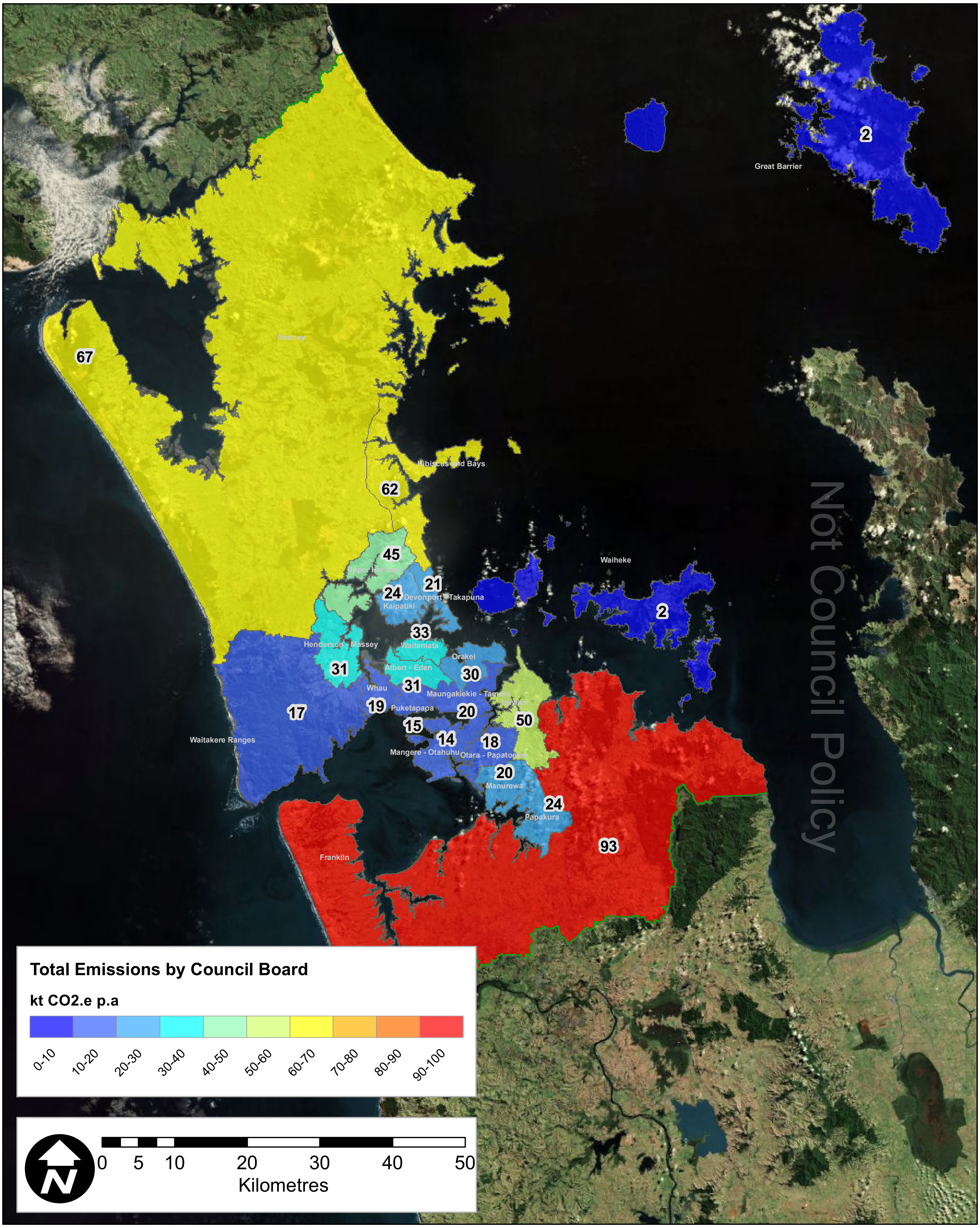
| Local Board | GHG Emissions Intensity 2031 | | |
|---|---|---|---|
| | Residential ($tCO_2e$ per resident) | Commercial and Industrial ($tCO_2e$ per employee) | Private Transport ($tCO_2e$ per resident) |
| Rodney | 0.33 | 5.66 | 1.40 |
| Hibiscus and Bays | 0.36 | 4.82 | 0.76 |
| Upper Harbour | 0.36 | 3.96 | 0.96 |
| Kaipatiki | 0.34 | 4.39 | 0.61 |
| Devonport - Takapuna | 0.35 | 2.65 | 0.84 |
| Henderson - Massey | 0.33 | 5.21 | 0.69 |
| Waitakere Ranges | 0.33 | 6.09 | 0.74 |
| Great Barrier | 0.32 | 3.46 | 0.00 |
| Waiheke | 0.34 | 3.46 | 0.00 |
| Waitemata | 0.32 | 2.14 | 0.77 |
| Whau | 0.32 | 6.65 | 0.62 |
| Albert - Eden | 0.33 | 2.43 | 0.64 |
| Puketapapa | 0.34 | 3.94 | 0.52 |
| Orakei | 0.36 | 3.06 | 0.59 |
| Maungakiekie - Tamaki | 0.32 | 6.07 | 0.71 |
| Howick | 0.36 | 5.55 | 0.64 |
| Mangere - Otahuhu | 0.32 | 5.07 | 0.80 |
| Otara - Papatoetoe | 0.32 | 4.75 | 0.74 |
| Manurewa | 0.34 | 5.96 | 0.74 |
| Papakura | 0.34 | 4.87 | 0.76 |
| Franklin | 0.35 | 6.62 | 1.00 |




# 2031 Total Emissions by Council Board - Total (Energy Related Emissions)

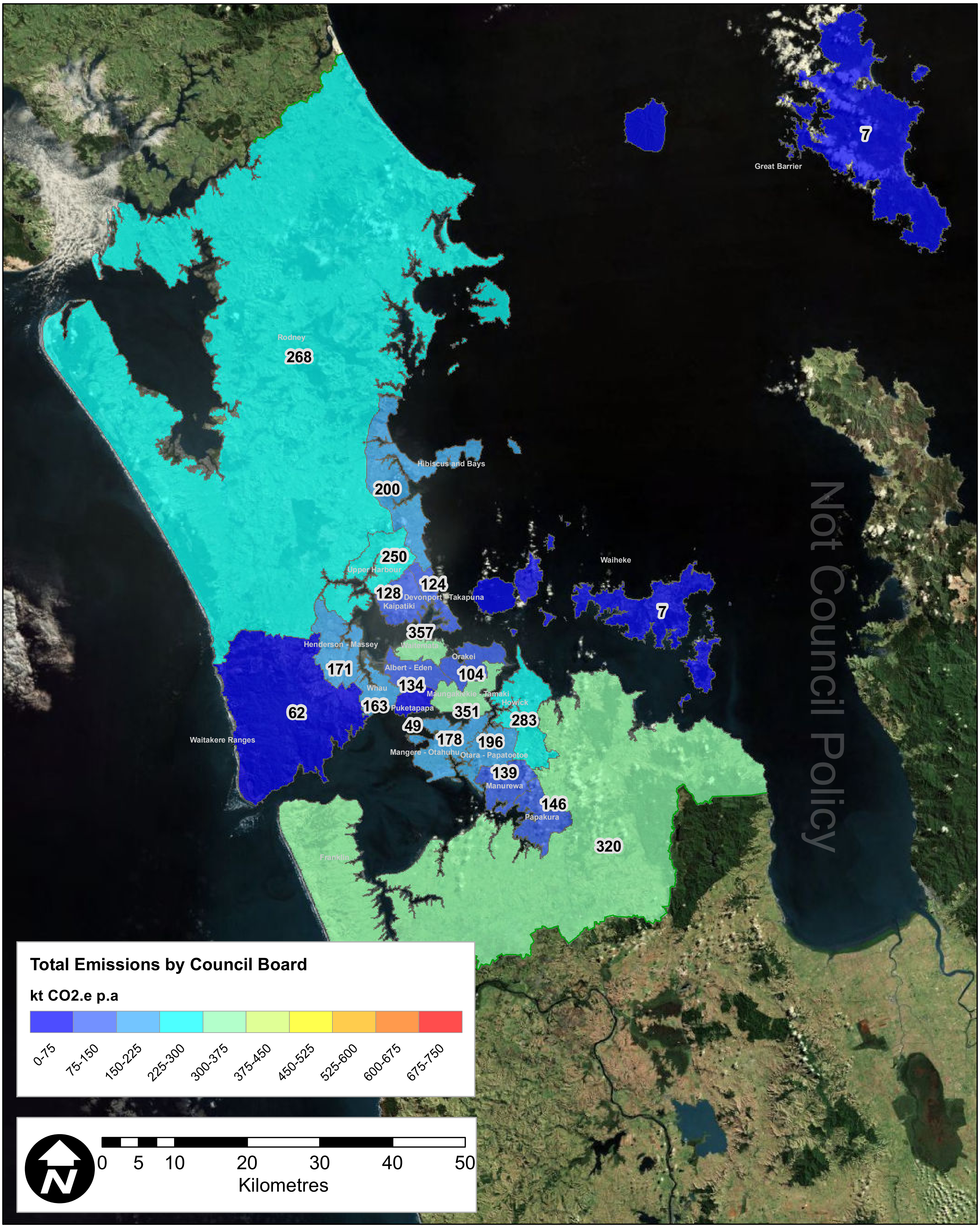
Scenario: D

ARUP




# 2031 Total Emissions by Council Board - Residential Sector

## Scenario: D

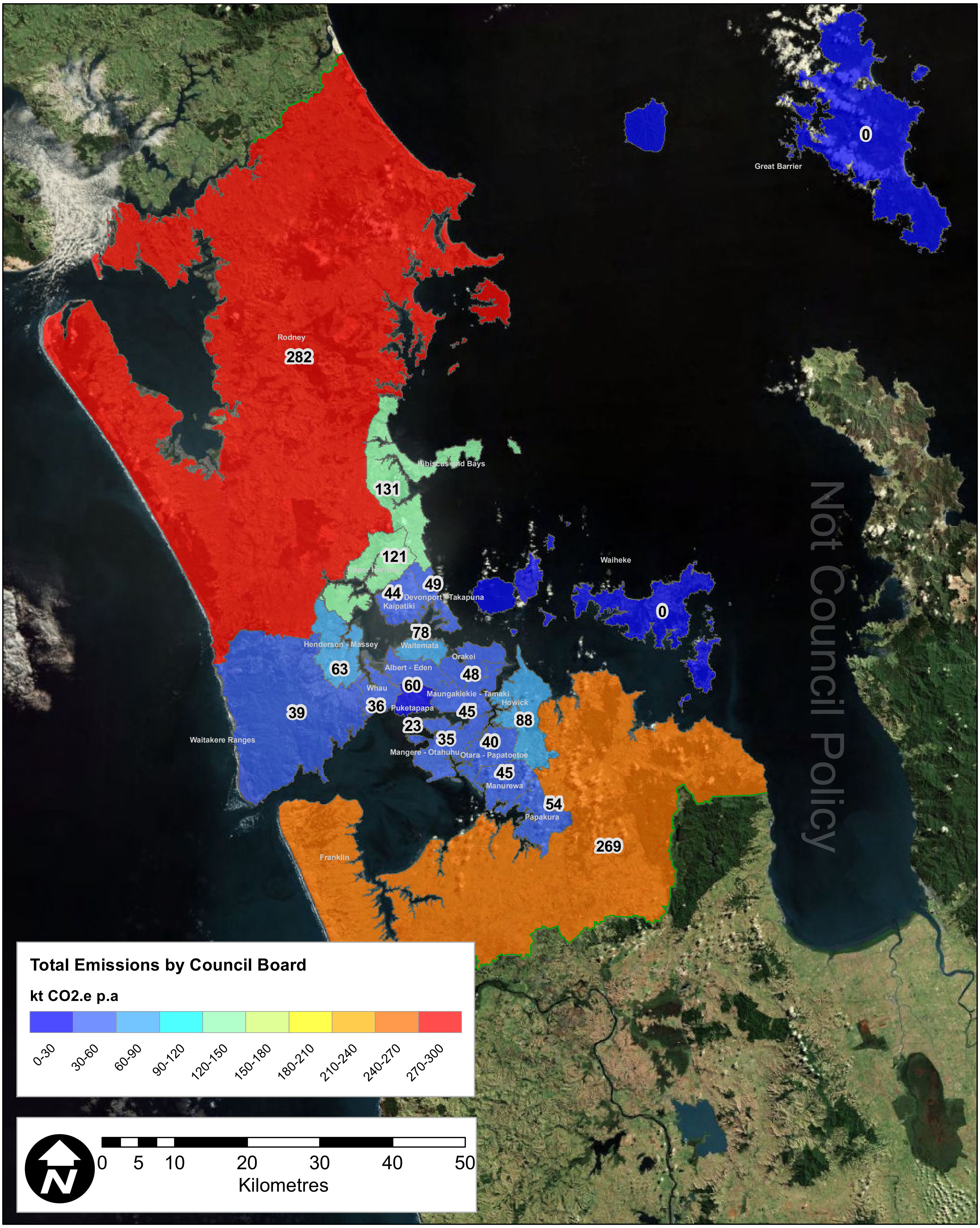





# 2031 Total Emissions by Council Board - Commercial and Industrial Sector

Scenario: D

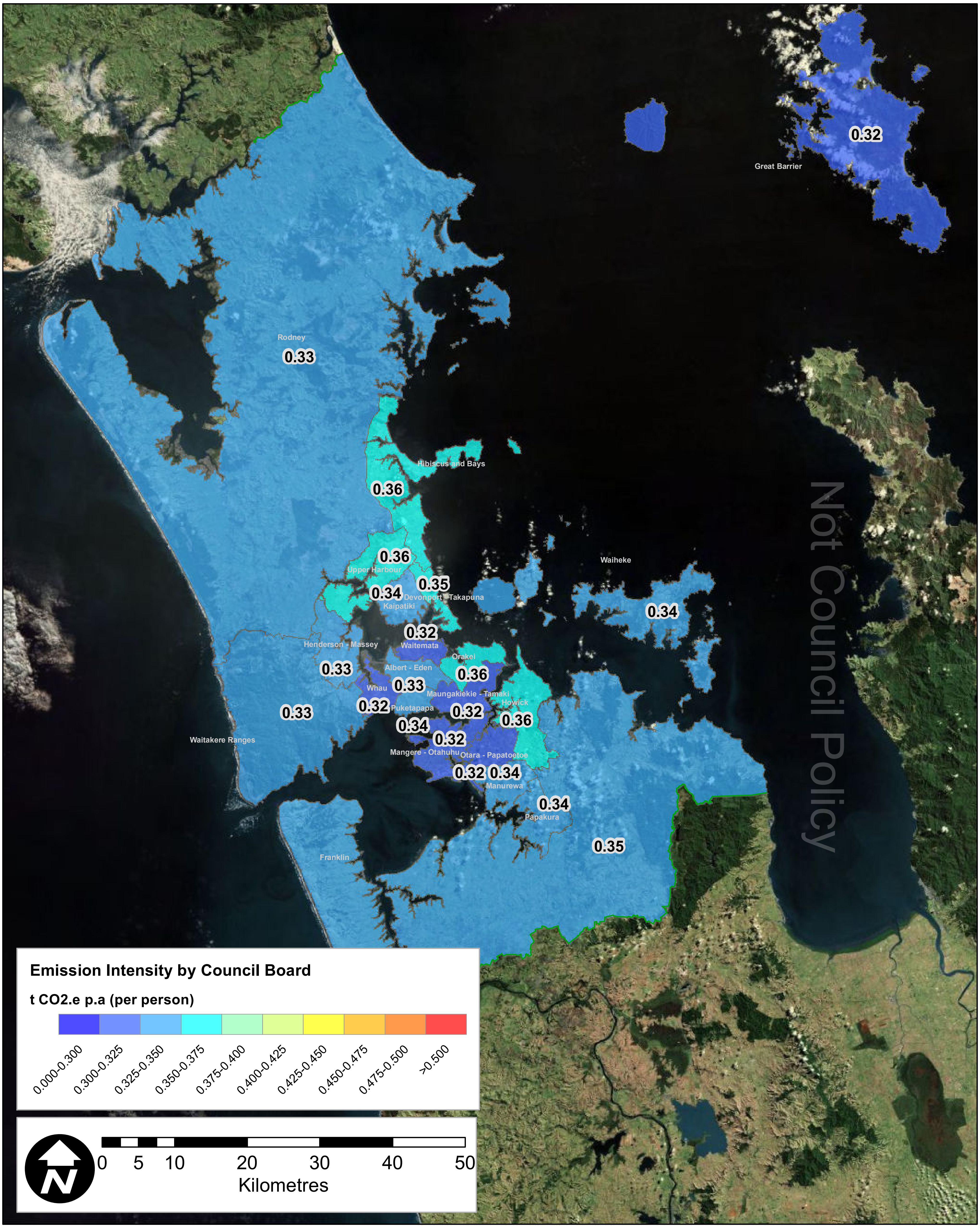
ARUP




# 2031 Total Emissions by Council Board - Private Transport Sector

Scenario: D

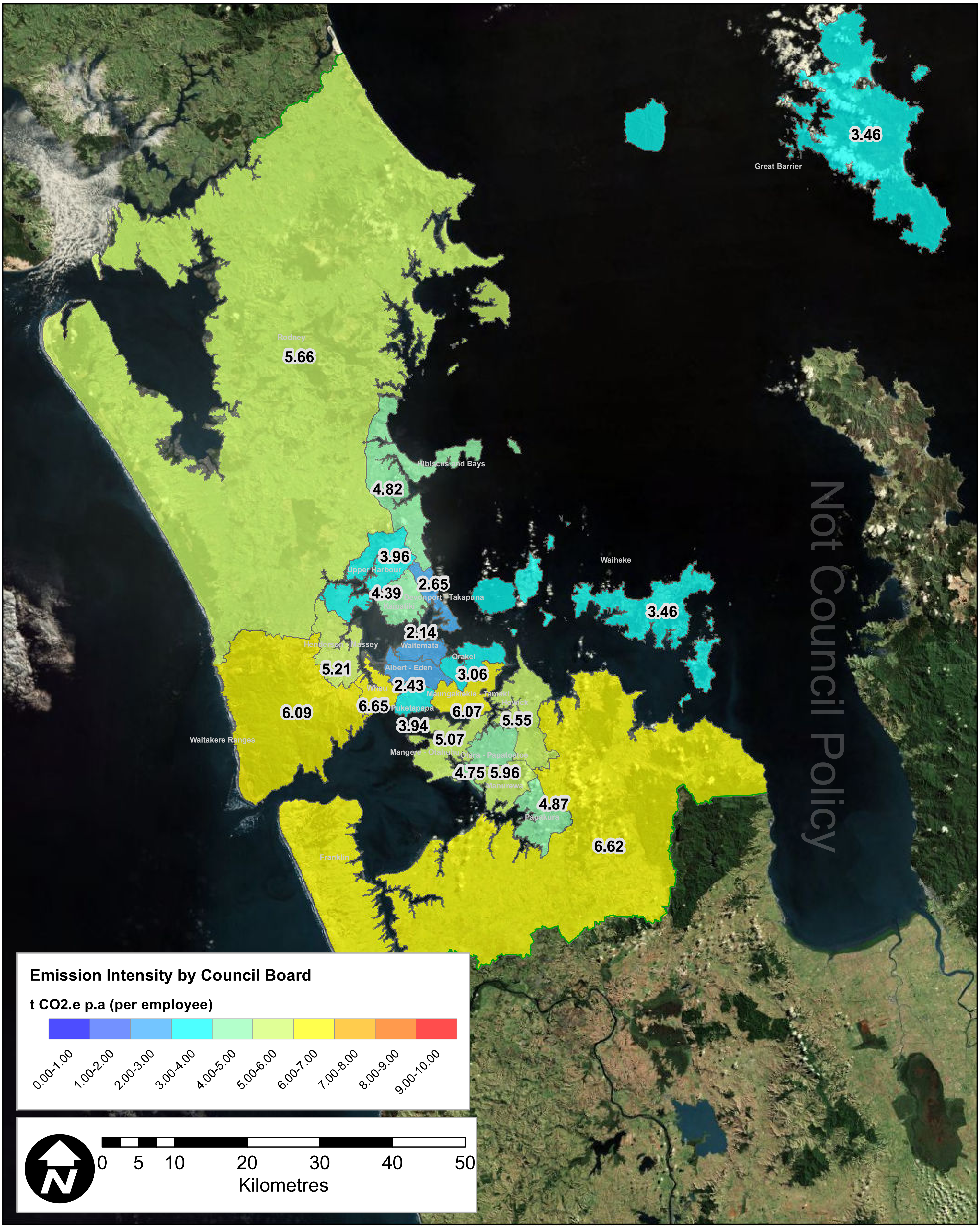
ARUP




# 2031 Emission Intensity by Council Board - Residential Sector

Scenario: D

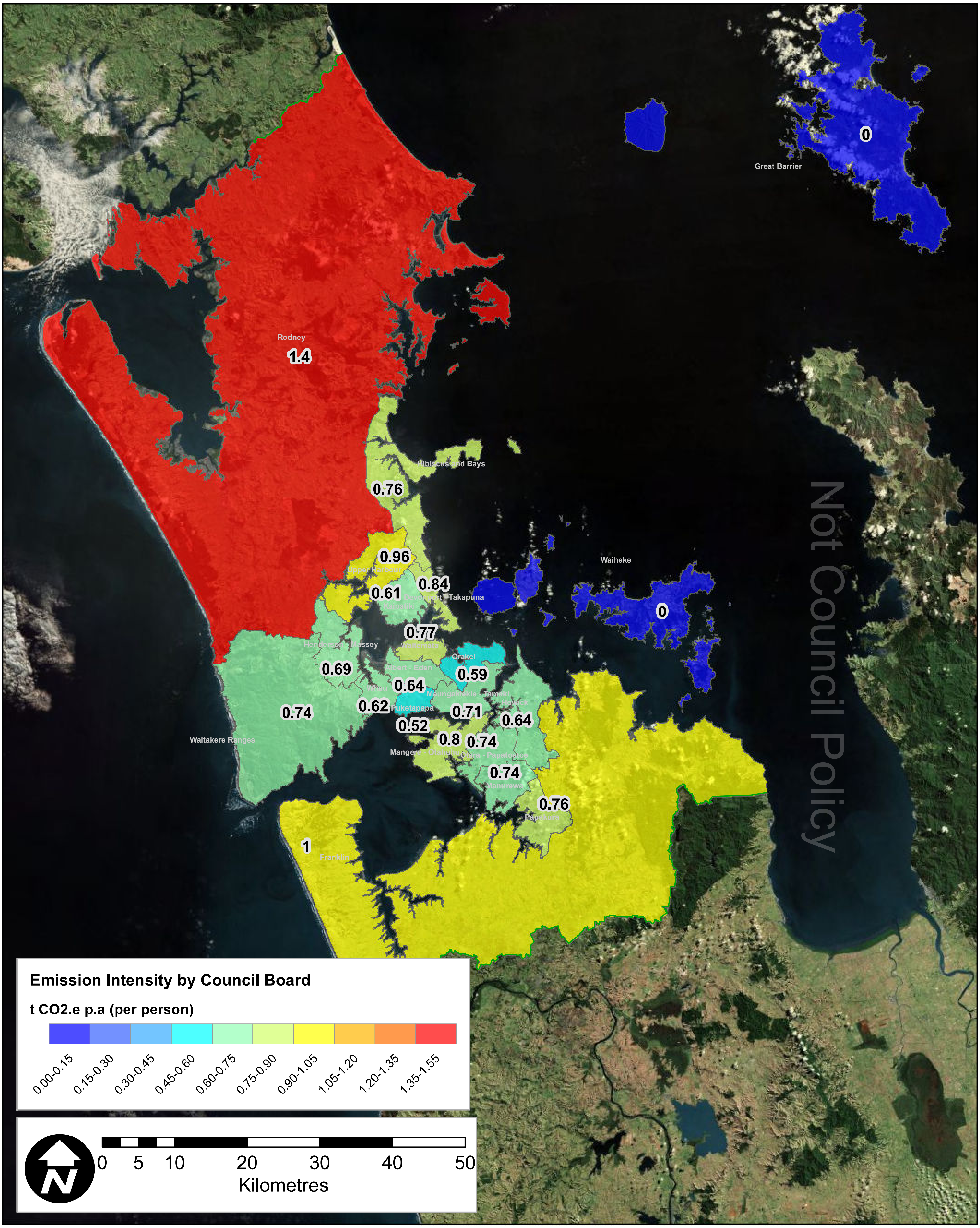
ARUP




# 2031 Emission Intensity by Council Board - Commercial and Industrial Sector

Scenario: D

ARUP




# 2031 Emission Intensity by Council Board - Private Transport Sector

Scenario: D

ARUP

# I3 Summary and Conclusions

The nBaU scenario assumes that land space is unlimited and that growth occurs at the same emissions intensity, land use intensity and travel intensity as per the baseline. However, in reality, land use patterns will need to change so that population and economic growth can be maintained within the physical constraints of land space and transport networks.

Auckland Council has identified four scenarios of such change:

- Scenario A – Intensive Containment
- Scenario B – Intensive Expansion
- Scenario C – Dispersed Containment
- Scenario D – Dispersed Expansion

Each scenario identifies urban form and transport network requirements which are possible within the Auckland context and provide for sustained population and economic growth.

Scenario A, B and C result in a reduced total GHG emissions compared to nBaU, while Scenario D shows an increase. The increase in emissions under Scenario D is due entirely to an increase in private transport emissions due to the dispersed nature of development. This offsets any potential reductions in other sectors.

All scenarios have a reduction in employment related emissions due to the shift in industry composition from manufacturing and industrial to commercial. The commercial sector produces fewer emissions per unit of economic growth and employee. The reduction in industry emissions does not vary with scenario but has a different distribution across local boards.

All scenarios also have a reduction in residential emissions as a result of largely as a result of an increase in people per household under all scenarios. Scenario A has the lowest residential emissions.

In terms of emission intensity, a comparison of the residential emissions intensities across the scenarios is presented in Table 14 below.

Table 14 Residential energy related GHG emissions intensities

| Local Board | Residential Emissions ($tCO_2e$ per person) | | | | |
|---|---|---|---|---|---|
| | nBAU | Scenario A | Scenario B | Scenario C | Scenario D |
| Rodney | 0.40 | 0.32 | 0.32 | 0.32 | 0.33 |
| Hibiscus and Bays | 0.43 | 0.36 | 0.36 | 0.36 | 0.36 |
| Upper Harbour | 0.39 | 0.35 | 0.36 | 0.36 | 0.36 |
| Kaipatiki | 0.39 | 0.34 | 0.35 | 0.35 | 0.34 |
| Devonport - Takapuna | 0.42 | 0.35 | 0.35 | 0.35 | 0.35 |
| Henderson - Massey | 0.37 | 0.34 | 0.34 | 0.34 | 0.33 |
| Waitakere Ranges | 0.38 | 0.33 | 0.33 | 0.33 | 0.33 |
| Great Barrier | 0.52 | 0.32 | 0.32 | 0.32 | 0.32 |
| Waiheke | 0.46 | 0.34 | 0.34 | 0.34 | 0.34 |
| Waitemata | 0.39 | 0.32 | 0.33 | 0.32 | 0.32 |

| Local Board | Residential Emissions ($tCO_2e$ per person) | | | | |
|---|---|---|---|---|---|
| | nBAU | Scenario A | Scenario B | Scenario C | Scenario D |
| Whau | 0.37 | 0.33 | 0.33 | 0.33 | 0.32 |
| Albert - Eden | 0.37 | 0.34 | 0.35 | 0.35 | 0.33 |
| Puketapapa | 0.37 | 0.34 | 0.35 | 0.35 | 0.34 |
| Orakei | 0.42 | 0.36 | 0.37 | 0.37 | 0.36 |
| Maungakiekie - Tamaki | 0.36 | 0.32 | 0.33 | 0.33 | 0.32 |
| Howick | 0.40 | 0.36 | 0.37 | 0.37 | 0.36 |
| Mangere - Otahuhu | 0.26 | 0.32 | 0.33 | 0.33 | 0.32 |
| Otara - Papatoetoe | 0.31 | 0.32 | 0.33 | 0.33 | 0.32 |
| Manurewa | 0.34 | 0.33 | 0.34 | 0.34 | 0.34 |
| Papakura | 0.38 | 0.34 | 0.35 | 0.35 | 0.34 |
| Franklin | 0.39 | 0.34 | 0.34 | 0.34 | 0.35 |

These show that residential emissions are relatively independent of scenario and location. This is mostly due to the relative equal performance of different types of urban form on a per person basis. In this context, emissions savings made by reducing the size of housing is offset by the reduced occupancy of such dwellings. That is, a fully occupied large dwelling will likely perform similarly on a person basis compared to smaller apartment style dwelling with fewer occupants.

Transport related emissions are far more sensitive to location with Scenario D having the greatest emissions intensities in almost all local board as presented in Table 15 below.

Table 15 Private transport related GHG emissions intensities

| Local Board | Residential Emissions 2031 ($tCO_2e$ per person) | | | | |
|---|---|---|---|---|---|
| | nBAU | Scenario A | Scenario B | Scenario C | Scenario D |
| Rodney | 1.37 | 1.30 | 1.22 | 1.26 | 1.40 |
| Hibiscus and Bays | 0.79 | 0.69 | 0.66 | 0.63 | 0.76 |
| Upper Harbour | 1.05 | 0.84 | 0.82 | 0.76 | 0.96 |
| Kaipatiki | 0.60 | 0.53 | 0.52 | 0.48 | 0.61 |
| Devonport - Takapuna | 0.67 | 0.62 | 0.64 | 0.59 | 0.84 |
| Henderson - Massey | 0.59 | 0.61 | 0.61 | 0.60 | 0.69 |
| Waitakere Ranges | 0.84 | 0.69 | 0.68 | 0.68 | 0.74 |
| Great Barrier | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Waiheke | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Waitemata | 0.89 | 0.57 | 0.60 | 0.55 | 0.77 |
| Whau | 0.52 | 0.47 | 0.53 | 0.52 | 0.62 |
| Albert - Eden | 0.55 | 0.46 | 0.47 | 0.47 | 0.64 |
| Puketapapa | 0.47 | 0.47 | 0.46 | 0.46 | 0.52 |
| Orakei | 0.54 | 0.45 | 0.46 | 0.43 | 0.59 |
| Maungakiekie - Tamaki | 0.62 | 0.52 | 0.55 | 0.53 | 0.71 |
| Howick | 0.59 | 0.57 | 0.57 | 0.55 | 0.64 |
| Mangere - Otahuhu | 0.46 | 0.63 | 0.64 | 0.66 | 0.80 |

| Local Board | Residential Emissions 2031 ($tCO_2e$ per person) | | | | |
|---|---|---|---|---|---|
| | nBAU | Scenario A | Scenario B | Scenario C | Scenario D |
| Otara - Papatoetoe | 0.55 | 0.56 | 0.59 | 0.61 | 0.74 |
| Manurewa | 0.50 | 0.60 | 0.63 | 0.63 | 0.74 |
| Papakura | 0.76 | 0.61 | 0.64 | 0.63 | 0.76 |
| Rodney | 1.37 | 0.93 | 0.95 | 0.92 | 1.00 |

Therefore, the transport related emissions will dominate the performance of any one scenario.  Notwithstanding the quality of urban form is extremely important in terms of encouraging

- maximum emissions efficiency for each typology;
- the occupancy of new dwellings is near capacity; and
- businesses are attracted to residential areas to ensure that daily needs are able to met without the need for commuting.