Assessing the Carbon Abatement Reduction Potential in Auckland's *Energy Resilience and Low Carbon Action Plan*

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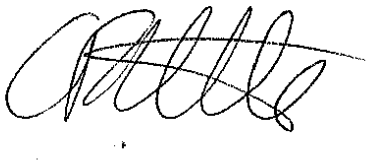
Approved for Auckland Council publication by:    Name: Greg Holland Position: Manager, Research, Investigations and Monitoring
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Assessing the Carbon Abatement Reduction Potential in Auckland's *Energy Resilience and Low Carbon Action Plan*

Arup

Executive summary

Arup was engaged by Auckland Council to undertake modelling to assess the carbon abatement reduction potential in Auckland's *Energy Resilience and Low Carbon Action Plan*.

Auckland's *Energy Resilience and Low Carbon Action Plan* contains a number of '*measures of success'* under five '*transformation areas'*.

The objectives of the analysis were to:

- Demonstrate how Auckland Council's target of 40 per cent reduction in greenhouse gas emissions by 2040 can be achieved;
- Assess the contribution of each of the transformation area and measures of success to the overall reduction
- Reflect the impact of population growth projections (which are the basis of the Auckland Plan);
- Reflect the impact of Gross Regional Production (GRP) projections as advised by Auckland Council;
- Revise assumptions and interpretations that Arup and Auckland Council has previously made; and
- Engage stakeholders in confirming the approach to applying strategies and targets.

The following table describes the transformation areas and the detail behind the measures of success which have been modelled.

Table 1 Relationship between transformation areas and measure of success

Transformation area	Element	Measures of success	Description and assumptions
Transforming energy supply and demand	**Energy supply**	National renewables grid mix	By 2040, 99% of electricity will be generated by renewable sources.
		Auckland region renewables (new installations – solar, wind, geo, biomass, waste to energy)	This is based on understanding the potential yield of biomass resources in the Auckland region and beyond, roof space in the Auckland region, availability of waste etc.
Transforming our built environment and green infrastructure	**Energy demand reduction – residential buildings**	Retrofit residential buildings	As described in the 2013 Low Carbon Action Plan, homes improved to a recognised sustainability standard (HomeStar)
		New residential buildings	As described in the 2013 Low Carbon Action Plan, homes built to a recognised sustainability standard (HomeStar)
		Appliances improvement (including smart grid)	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the Department of Energy (USA).

Transformation area	Element	Measures of success	Description and assumptions
	Energy demand reduction – commercial buildings	Retrofit commercial buildings	As described in the 2013 Low Carbon Action Plan, commercial buildings retrofitted to a recognised sustainability standard (Green Star).
		New commercial buildings	As described in the 2013 Low Carbon Action Plan, commercial buildings built to a recognised sustainability standard (Green Star).
		Appliances improvement (including smart grid)	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the Department of Energy (USA).
	Energy demand reduction – manufacturing and industrial sector	Retrofit manufacturing & industrial buildings	Adopts the same building fabric and building services improvements as the Arup 2011 Technical report – 40% reduction by 2040, which is consistent with advice from Council stakeholders (Schneider, Siemens and Phillips).
		New manufacturing & industrial buildings	As described in the 2013 Low Carbon Action Plan, manufacturing & industrial buildings retrofitted to a recognised sustainability standard (Green Star).
		Industrial processes	45% improvement by 2040, which is in line with the Siemens energy efficiency roadmap, as well as breakthrough technologies identified by Worldsteel Institute.
Transforming the way we travel	**Transport movements**	Light vehicles modal shift (private & commercial)	25% reduction in vehicle kilometres per person by 2040 due to demand reduction measures: Auckland Council modelling for non-price travel demand management, plus congestion charging, improvements in active transport and public transport infrastructure.
		Freight demand reduction	Based on 5% reduction from improved utilisation (e.g. through use of consolidation centres).
	Vehicle efficiency	Light vehicles	Assumes annual vehicle efficiency improvements of 3.5% for internal combustion engines. This is faster than the historic 2.5% improvements. Also accounts for slow increase in the number of vehicles, which has been the historic trend.
		Heavy vehicles	Assumes annual vehicle efficiency improvements of 2% for internal combustion engines and a steady number of heavy vehicles in the Auckland fleet. The efficiency improvement is faster than the historic 0.1% annual improvement.
		Alternative fuels – biofuels / electric	By 2040, 25% of total light vehicle fleet is electric. This means around 54% of cars being introduced into Auckland will be electric by 2040.

Transformation area	Element	Measures of success	Description and assumptions
Transforming to zero waste	**Reduction in waste to landfill**	Waste to energy	As described in the 2013 Low Carbon Action Plan.
		Sewage to energy	As advised by WaterCare, by 2040 there is 7.7 MW of installed capacity.
Transforming forestry, agriculture and natural carbon assets	**Sequestration**	Ecological corridors sequestration	As described in the 2013 Low Carbon Action Plan.
		Carbon sequestration from forests	As per the Arup 2011 Technical Report, accounting for 41,329ha of forest.

Results

The results are summarised in Table 1 below as per cent reductions compared to the 2009 baseline.

Table 1 shows:

- Absolute per cent reduction in each emissions source compared to 2009
- Per capita per cent reduction for those emissions sources that increase with residential population, and
- Per $GRP million per cent reduction for those emissions sources that increase with economic activity.

Note that per capita and per $GRP million reductions are greater than total (absolute) reductions. That is, Auckland must aim to become more efficient per person and per economic output in order to achieve its 40 per cent emissions reductions target while growing its population in line with the Auckland Plan.

The results are also summarised in the abatement 'wedge chart' (Figure 1), which shows the contribution of each transformation area and the extent to which the aggregated reduction is able to reach the prescribed targets.

Some observations include:

- That if all abatement measures of success were implemented by 2040, residual emissions will be approximately 40 per cent lower than 1990 baseline levels (or around 48 per cent lower than 2009 levels).
- That the achievement of all the listed measures of success will constitute a 53 per cent reduction in emissions when compared to the projected BAU emissions (excluding forest sequestration) in 2040.
- That the 'built environment and green infrastructure' transformation area (Transforming our built environment and green infrastructure) makes the most contribution to GHG reductions (amounting to around 2,700 ktCO_2e by 2040).
- Auckland makes significant GHG reductions during the assessment period to 2040 when population and economic growth considerations are taken into account, with the aggregate amount of GHG reductions placing Auckland Council on a trajectory to achieve a 40 per cent reduction by 2040, or a 50 per cent prediction by 2050.

Table 2 Results – reduction compared to 2009 baseline

	Total			Per capita			Per $GRP (millions)		
Reduction compared to 2009 baseline	**by 2020**	**by 2030**	**by 2040**	**by 2020**	**by 2030**	**by 2040**	**by 2020**	**by 2030**	**by 2040**
Buildings									
Residential	9%	30%	31%	28%	53%	60%	-	-	-
Commercial	23%	63%	57%	-	-	-	36%	75%	76%
Manufacturing & Industrial	4%	23%	33%	-	-	-	20%	47%	61%
Transport									
Light Vehicles	11%	37%	70%	30%	58%	83%	-	-	-
Heavy Vehicles	40%	40%	37%	-	-	-	50%	59%	64%
Waste	9%	36%	95%	29%	58%	97%	-	-	-
Agriculture	5%	29%	59%	-	-	-	21%	52%	76%
TOTAL EMISSIONS									
Business as usual emissions	10,620 $ktCO_2e$	10,817 $ktCO_2e$	11,407 $ktCO_2e$	5.9 tCO_2e pp	5.1 tCO_2e pp	4.7 tCO_2e pp	150.1 tCO_2e p $GRPm	125.3 tCO_2e p $GRPm	110.7 tCO_2e p $GRPm
Residual emissions after abatements	8,579 $ktCO_2e$	6,852 $ktCO_2e$	5,381 $ktCO_2e$	4.8 tCO_2e pp	3.2 tCO_2e pp	2.2 tCO_2e pp	121.2 tCO_2e p $GRPm	79.4 tCO_2e p $GRPm	52.2 tCO_2e p $GRPm

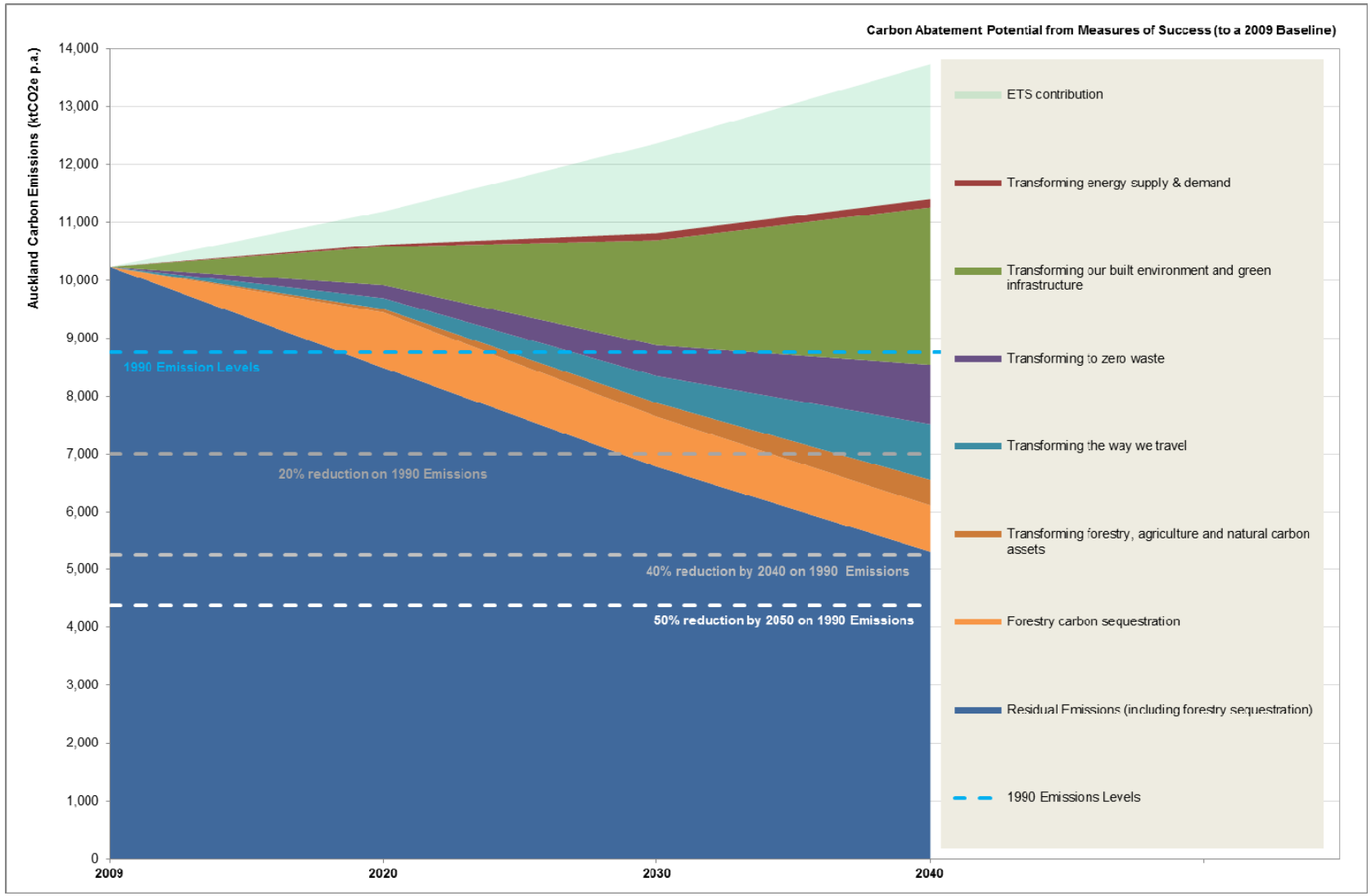

Figure 1 Carbon abatement potential from combined measures of success per transformation area

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1.0 Introduction

1.1 Background

Auckland Council has a vision to guide Auckland to become the world's most liveable city and critical to this vision it is to create the context to ensure energy resilience – securing access to clean, efficient and affordable energy whilst also reducing our greenhouse gas (GHG) emissions.

The guiding framework for this initiative is the emerging *Auckland Energy Resilience and Low Carbon Action Plan* (the Action Plan) which outlines a series of *'measures of success'* to guide this process; structured within six '*transformation areas'* as follows:

- Transforming energy.
- Transforming our built environment.
- Transforming to zero waste.
- Transforming the way we travel.
- Transforming forestry and agriculture.
- Transforming to a green economy.

It should be noted that it was agreed with Auckland Council, that not all measures of success in the *Low Carbon Action Plan (Draft V9)* were analysed. Many lacked quantitative information to underpin a carbon reduction potential, had no timeframes, or required extensive research and investigations prior to any possible calculations.

To ensure the robustness of the Plan as it journeys through the stakeholder consultation processes and documented iterations, Auckland Council engaged Arup to update elements to inform ongoing discussions, particularly those scheduled for June 2013.

1.2 About this report

The scope of this report and project was to update specific elements of the Action Plan including:

- An update of the 'business as usual' GHG emission projections to align with the Auckland Plan timeframes of 2020, 2040 and 2050.
- An update of the GHG emissions targets set out in the Auckland Plan relative to the revised 2009 inventory baseline based on 1990 levels.
- Determination of the projected carbon abatement potential of a list of identified measures of success within the Action Plan.

The outputs are designed to inform ongoing discussions with Auckland Council councillors as important stakeholders in the Plan development process.

The scope of the work does not include analysis of specific Actions within the Plan or their specific contribution to the Plan targets, associated benefits & costs, or possible co-benefits. These items could potentially be investigated in a possible second project stage.

2.0 Business as usual emission projections

This section provides the Business As Usual (BAU) emissions and projections for Auckland Council, in particular, for the following:

- The previous baseline emission for 2009, and
- New BAU projections for 2020, 2030, 2040, and 2050.

The projections are broken down by reporting sector and are provided in numeric form in Table 3 and illustrated in Figure 2 and Figure 3.

The BAU projections have been developed on the basis of several basic assumptions which are further detailed in the appendices. Of particular note are the following:

- Projections are primarily based on population and $GRP (Gross Regional Product) growth. The sources of these growth factors are obtained from:
    - **Population**: Statistics New Zealand (2010) Customised model for Auckland Plan, High Population Projection, Job-01056 (as discussed with Auckland Council in November 2013, for all projection years)
    - **$GRP**: (2011) GDP Outputs from the Economics Futures Model, EFM Output by Industry – High projection (as discussed with Auckland Council in November 2013, for years 2020, 2030, and 2040).

      Note: 2040 and 2050 data was assumed by accounting for a 3.8 per cent increase in GRP per capita every ten years (based on the projection from 2020 to 2030).
- Previous analysis over-estimated carbon sequestration from forestry. The current analysis seeks to moderate (but not remove) this over-estimation. The present analysis removes only pre-1990 forests to be in-line with the Kyoto protocol in claiming carbon sequestration (i.e. assuming that pre-1990 forests have reached a steady state for carbon sequestration).
- Year-specific electricity emission factors determined from electricity generation and consumption by fuel type align with the aforementioned Arup analysis and based on data from MED Outlook 2011 Modelling Results[1].

2.1 General observations by reporting sector

Table 3 and Figure 2 present the business as usual projections by reporting sector (end use). Figure 3 aggregates these emissions into the International Panel on Climate Change (IPCC) reporting sectors. Figure 4 shows the same information as Figure 2 (excluding forestry) presented in a wedge diagram.

[1] MED Outlook 2011, http://www.med.govt.nz/sectors-industries/energy/energy-modelling/modelling/new-zealands-energy-outlook-reference-scenario/

This analysis allows other observations such as:

- Emissions associated with Stationary Energy (both Residential and Commercial) remain relatively constant despite population growth.
- Stationary Energy (Manufacturing and Industrial), which reflects stationary and process energy use, is increasing.
- Land Transport emissions also grow considerably due to population growth.
- Other Transport-related emissions also grow, but remain relatively small in the aggregate.
- The emission projections for Industrial Process (Non-Energy Emissions) remain constant based on assumptions from the previous Arup analysis.
- The contribution of forestry reduces over time as the BAU projections assume forestry sequestration has decreased post-2008.

Table 3 BAU projections (2020, 2031, 2040, 2050) by reporting sector

Year	**1990**	**2009**	**2020**	**2030**	**2040**	**2050**
Reporting Sector	**$ktCO_2e$**	**$ktCO_2e$**	**$ktCO_2e$**	**$ktCO_2e$**	**$ktCO_2e$**	**$ktCO_2e$**
Stationary Energy - Residential	538	798	877	824	892	1,007
Stationary Energy - Commercial	611	392	399	371	413	485
Stationary Energy - Manufacturing and Industrial	1,994	2,009	2,311	2,656	3,129	3,654
Transport - Rail	0	5	6	7	9	10
Transport - Land	2,456	3,573	3,173	2,769	2,447	2,164
Transport - Air	105	162	206	243	279	314
Transport - Sea	211	325	413	487	558	628
Fugitive (Non-Energy Emissions)	146	225	286	337	387	435
Industrial Process (Non-Energy Emissions)	1,539	1,539	1,539	1,539	1,539	1,539
Waste	400	618	785	925	1,061	1,192
Agriculture	760	590	625	658	693	730
Forestry	0	-956	-868	-795	-729	-668
BAU EMISSIONS TOTAL (excluding Forestry GHG Sequestration)	**8,760**	**10,237**	**10,620**	**10,817**	**11,407**	**12,157**
% difference (to 2009)	-14%	-	4%	6%	11%	19%
BAU EMISSIONS TOTAL (including Forestry GHG Sequestration)	**8,760**	**9,281**	**9,752**	**10,022**	**10,678**	**11,489**
% difference (to 2009)	-6%		5%	8%	15%	24%

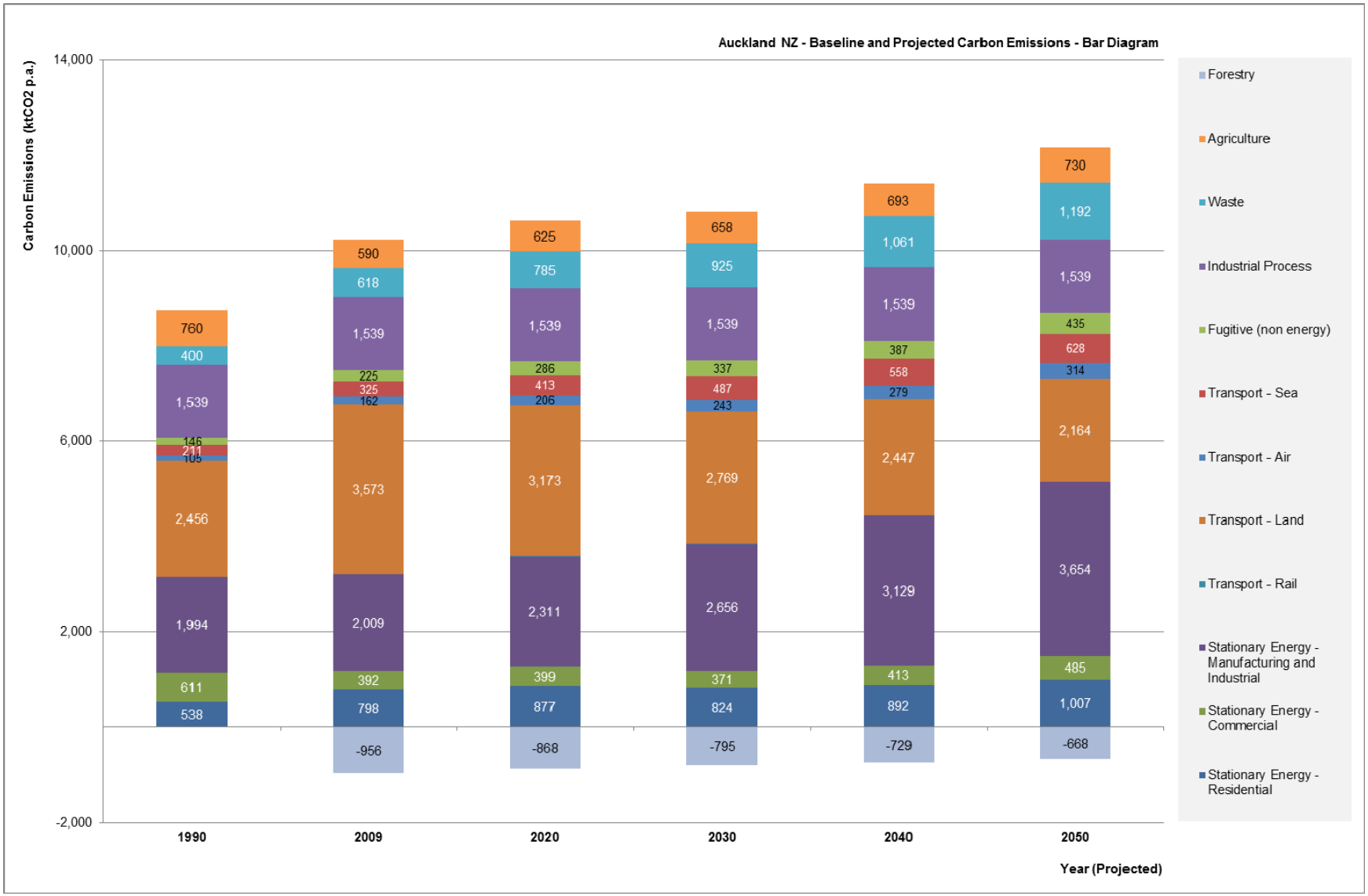

Figure 2 Auckland projected BAU carbon emissions (1990-2050) – by reporting sector

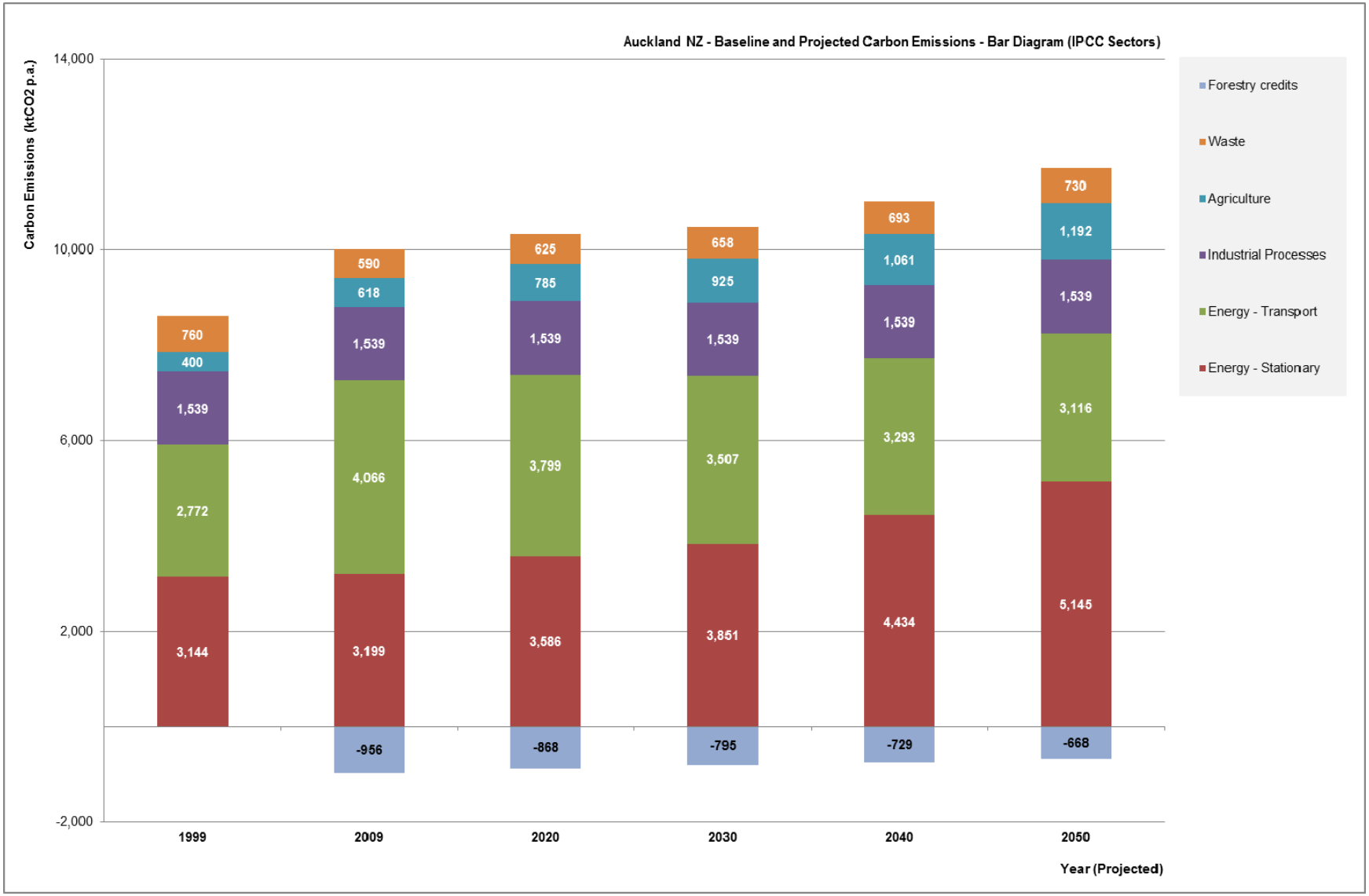

Figure 3 Auckland projected BAU carbon emissions (1990-2050) – IPCC sectors

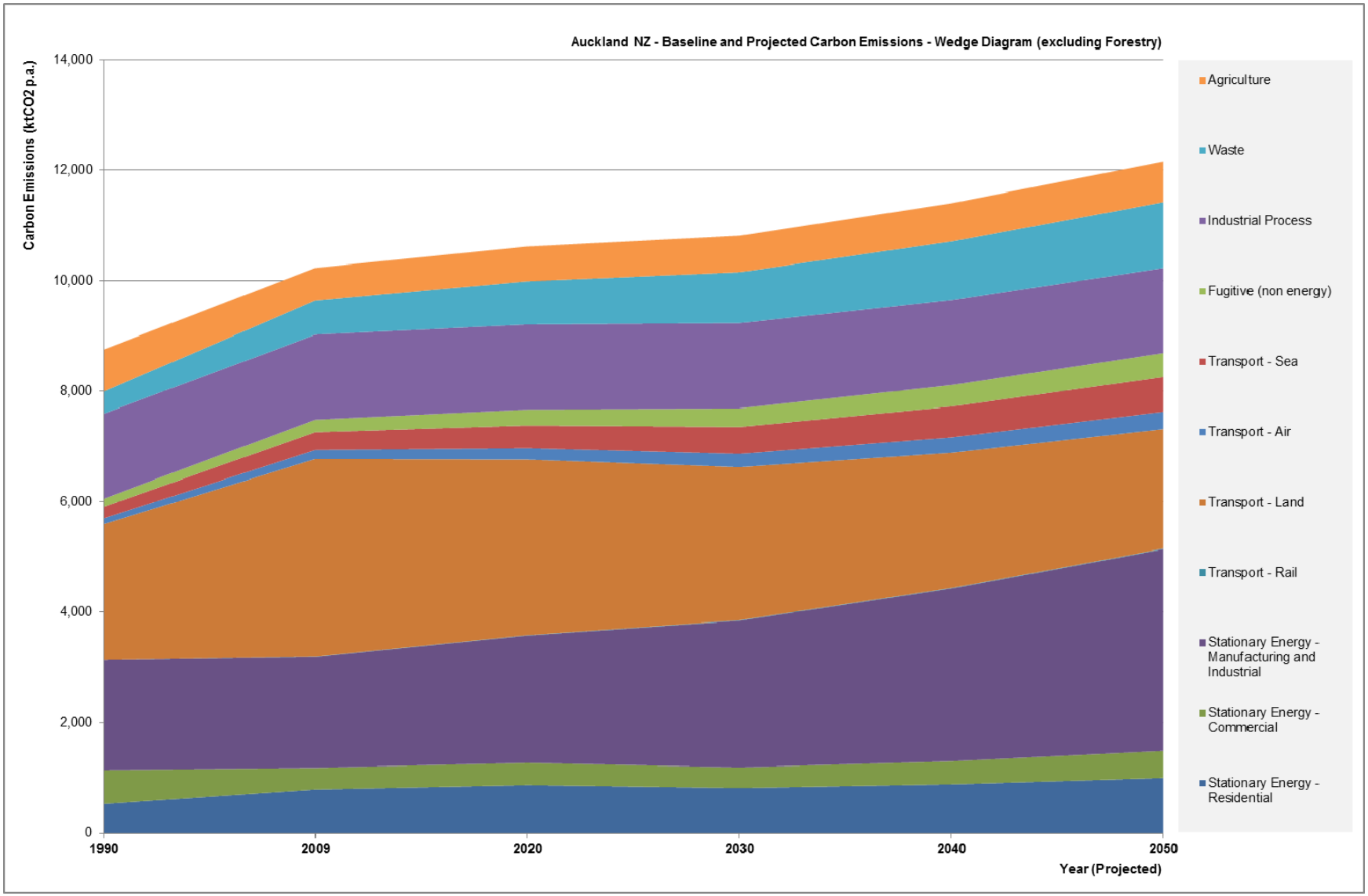

Figure 4 Auckland projected BAU carbon emissions (2009-2050) wedge diagram (excluding forestry)

2.1.1 BAU growth factor context - population and $GRP

The BAU projections are better understood in the context of associated temporal changes in both population and $GRP growth factors which underpin the calculations.

Table 4 compares how BAU emissions change in relation to population and GRP projections. Emissions do not increase as quickly as population and economic activity (i.e. GRP).

Table 4 Temporal comparison of growth factors

(Population and $GRP) and emission projections (compared to 2009 baseline)

Year		**1990**	**2009**	**2020**	**2030**	**2040**	**2050**
Sector Category	**Units**						
Population	People	918,796	1,418,845	1,803,000	2,125,000	2,436,900	2,738,700
	% change compared to 2009	- 35%	-	+27%	+50%	+72%	+93%
$GRP	$millions	-	$58,929	$70,769	$86,333	$103,086	$120,272
	% change compared to 2009	-	-	+20%	+47%	+75%	+104%
BAU EMISSIONS TOTAL (excluding Forestry GHG Sequestration)	% change compared to 2009	-14%	-	+4%	+6%	+11%	+19%
BAU EMISSIONS TOTAL (including Forestry GHG Sequestration)	% change compared to 2009	-6%	-	+5%	+8%	+15%	+24%

2.1.2 Emissions intensity observations

The relative emission intensity has been calculated for both population and economic output (using the proxy of $GRP[2]) based on the same growth factors used for the BAU projections. These intensity figures are based on two factors: the ratio of $GRP to population growth, and the electricity emissions intensity factor (which decreases at a faster rate from 2020 to 2031, compared to 2031 to 2050).

The BAU emission intensity (per capita and per unit of economic output) is presented in Table 5, Figure 5 and Figure 6 for both gross (excluding forestry) and net (including forestry).

The major observation is that the emission intensity per capita and per unit of economic output falls over time. This implies that the absolute increase in emissions over time under BAU is as a result of both population and economic growth and NOT as a result of the increase in individual or business emission intensity.

Table 5 Emissions intensity BAU projections - per capita and economic output

BAU EMISSIONS TOTAL (excluding Forestry GHG Sequestration)	**1990**	**2009**	**2020**	**2031**	**2040**	**2050**
Emissions Per Capita (*$kgCO_2e$ per capita*)	9,534	7,215	5,890	5,091	4,681	4,439
Emissions Per Unit of Economic Output (*tCO_2e tonne per $m GRP*)	-	174	150	125	111	101
BAU EMISSIONS TOTAL (including Forestry GHG Sequestration)	**1990**	**2009**	**2020**	**2031**	**2040**	**2050**
Emissions Per Capita (*$kgCO_2e$ per capita*)	9,534	6,541	5,409	4,716	4,382	4,195
Emissions Per Unit of Economic Output (*tCO_2e tonne per $m GRP*)	-	157	138	116	104	96

[2] Note: $GRP could not be determined for Auckland in 1990, and has been omitted for comparison

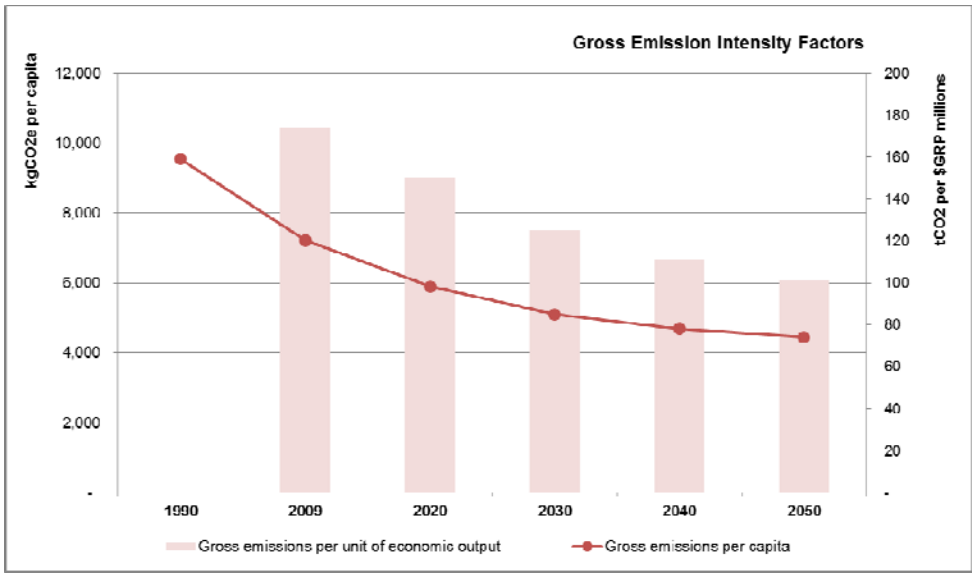

Figure 5 BAU emissions (excluding forestry sequestration) intensity projections – per capita and economic output

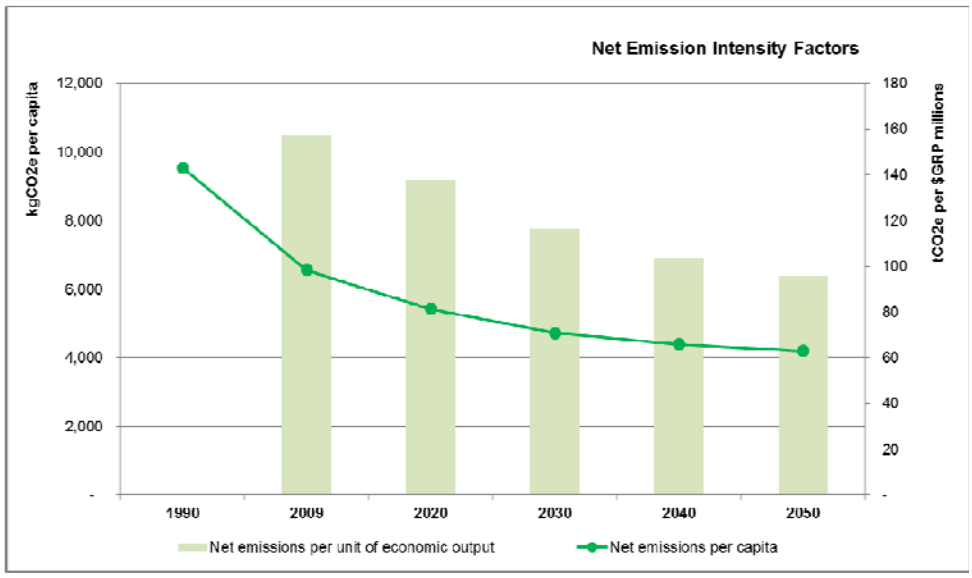

Figure 6 Emissions intensity BAU projections (including forestry sequestration) - per capita and economic output

2.1.3 BAU projections by transformation area

The BAU emissions were also projected in the context of the transformation areas outlined by Auckland Council (2013) *Auckland Energy Resilience and Low Carbon Action Plan (Draft V9)*.

These projections by transformation area have been provided in Table 6 and Figure 7. These show that the greatest contribution comes from '*Transforming the way we Travel*' followed by '*Transforming energy supply and demand'* and '*Transforming our built environment and green infrastructure*'.

Note that the emission totals for each transformation area cannot be aggregated to provide a total because there is overlap between transformation areas. For example, there is significant overlap

between the Energy Supply and Built Environment transformation areas. It is not correct to add these together. This is illustrated in Table 6, which shows the separate contribution of each transformation area to the 2009 baseline inventory which added together is greater than the whole.

Table 6 BAU projections by transformation area

Transformation areas	Sectors included		1990	2009	2020	2031	2040	2050
	Sector	Sub-sectors	$ktCO_2e$	$ktCO_2e$	$ktCO_2e$	$ktCO_2e$	$ktCO_2e$	$ktCO_2e$
Transforming Energy Supply & Demand	Stationary Energy: Residential, Commercial, Manufacturing and Industrial	Within all sectors	3,144	3,199	3,586	3,851	4,434	5,145
Transforming Our Built Environment And Green Infrastructure	Stationary Energy: Residential, Commercial, Manufacturing and Industrial	Commercial (Buildings), Manufacturing and Industrial (Buildings), All Residential	538	3,008	3,586	3,851	4,434	5,145
Transforming To Zero Waste	Waste	Within all sectors	400	618	785	925	1,061	1,192
Transforming The Way We Travel	Transport: Rail, Land, Air, Sea	Within all sectors	2,772	4,066	3,799	3,507	3,293	3,116
Transforming Forestry, Agriculture And Natural Carbon Assets	Agriculture	Within all sectors	760	590	625	658	693	730
Transforming To A Greener Economy	-	-	-	-	-	-	-	-

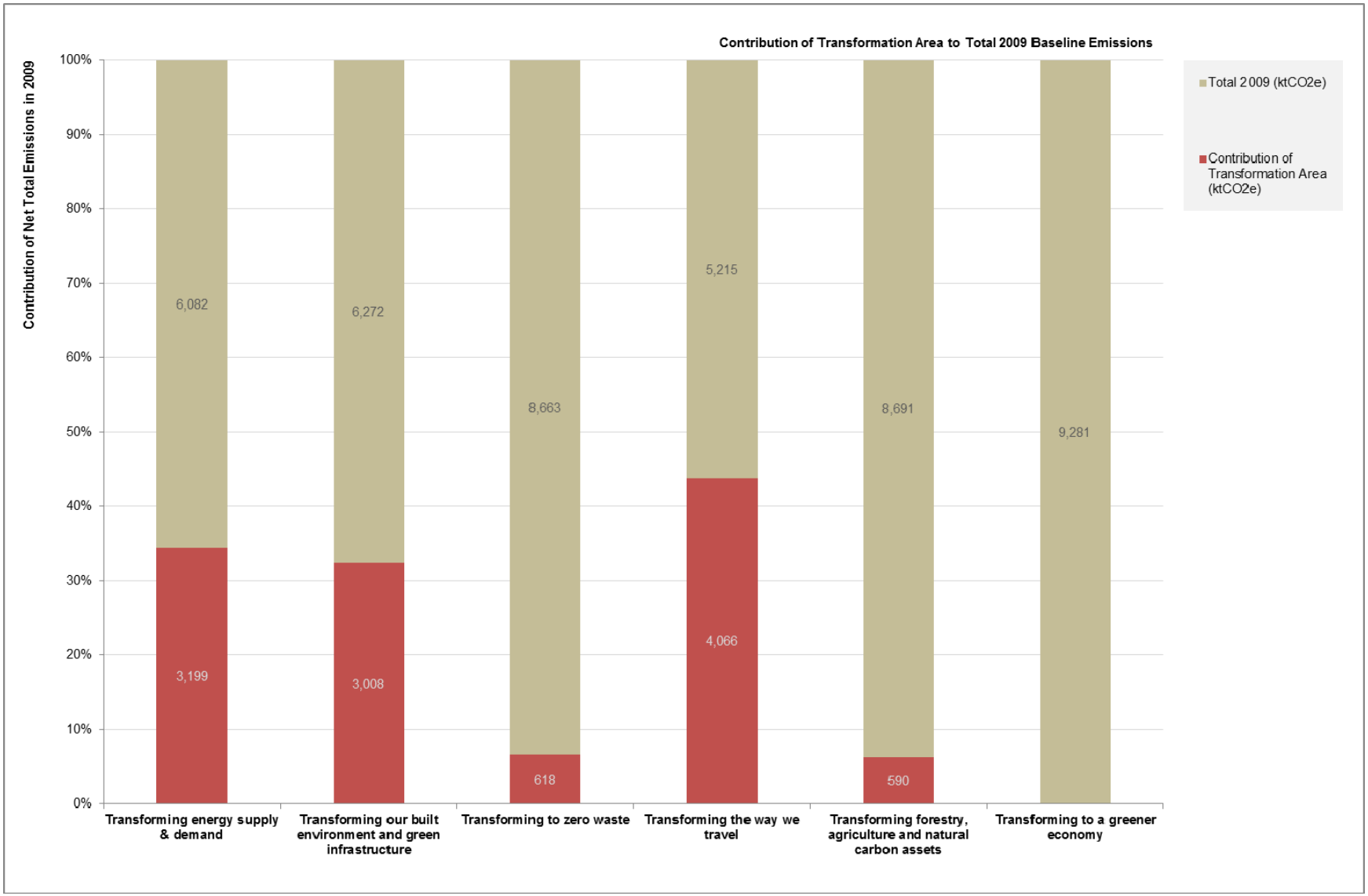

Figure 7 Contribution of transformation area to total 2009 Auckland baseline inventory

3.0 Updated targets to 2009

Auckland Council has set a number of emission reduction targets relative to 1990 emissions levels via the Auckland Plan. These include:

- A 10-20 per cent emission reduction by 2020 based on 1990 levels.
- A 40 per cent emission reduction by 2040 based on 1990 levels.
- 50 per cent emission reduction by 2050 based on 1990 emission levels.

In actual terms, this requires significant reduction in emission levels in 2020, 2040 and 2050. Figure 8 describes the percentage reduction of total projected emissions required in these years, in order to achieve the targets stated above.

It indicates that in order to achieve the final target, 56 per cent of the projected emissions in 2050 must be mitigated – this is a substantial reduction of emissions.

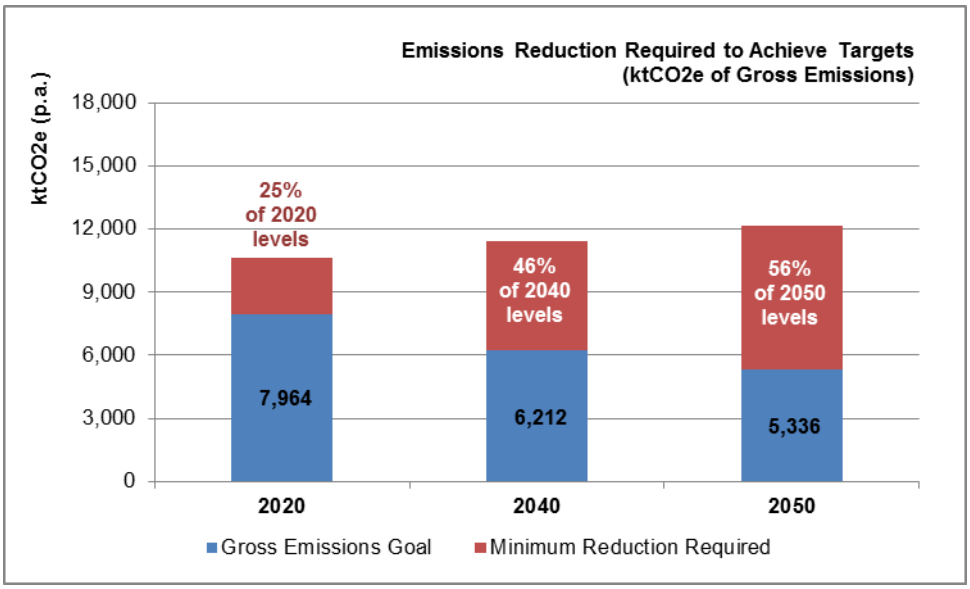

Figure 8 Emissions reduction required to achieve targets

To further contextualise the new targets, these have been translated to GHG reduction targets per capita in Auckland, which is as follows:

- A reduction of 1-1.5 tonnes CO2e per capita at 2020 (13-21 per cent reduction of BAU 2020 levels).
- A reduction of 2.2 tonnes CO2e per capita at 2040 (35 per cent reduction of BAU 2040 levels)..
- A reduction of 2.6 tonnes CO2e per capita at 2050.(40 per cent reduction of BAU 2050 levels).

4.0 Carbon abatement potential of measures of success

Arup undertook an analysis of the carbon abatement potential of a set of measures of success, which are a combination of those in the following studies:

- Arup (2011) *Auckland Council – Potential policy options to reduce greenhouse gas emissions: Technical Report*
- Auckland Council (2013) *Auckland Energy Resilience and Low Carbon Action Plan (Draft V9)*

Furthermore, Arup, in discussion with Auckland Council have identified a range of new or revised measures of success for this project (Table 7). The measures of success used in this project are described in the following table and grouped into the transformation areas described in the *Low Carbon Action Plan (Draft V9)* and in Section 2.1.3 of this report.

Table 7 Carbon abatement measures of success

Transformation area	Element	Measure of success	Description and assumptions
Transforming energy supply and demand	**Energy supply**	National renewables grid mix	By 2040, 99% of electricity will be generated by renewable sources.
		Auckland region renewables (new installations – solar, wind, geo, biomass, waste to energy)	This is based on understanding the potential yield of biomass resources in the Auckland region and beyond, roof space in the Auckland region, availability of waste etc.
Transforming our built environment and green infrastructure	**Energy demand reduction – residential buildings**	Retrofit residential buildings	As described in the 2013 Low Carbon Action Plan, homes improved to a recognised sustainability standard (HomeStar)
		New residential buildings	As described in the 2013 Low Carbon Action Plan, homes built to a recognised sustainability standard (HomeStar)
		Appliances improvement (including smart grid)	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the Department of Energy (USA).
	Energy demand reduction – commercial buildings	Retrofit commercial buildings	As described in the 2013 Low Carbon Action Plan, commercial buildings retrofitted to a recognised sustainability standard (Green Star).
		New commercial buildings	As described in the 2013 Low Carbon Action Plan, commercial buildings built to a recognised sustainability standard (Green Star).
		Appliances improvement (including smart grid)	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the Department of Energy (USA).

Transformation area	Element	Measure of success	Description and assumptions
	Energy demand reduction – manufacturing and industrial sector	Retrofit manufacturing & industrial buildings	Adopts the same building fabric and building services improvements as the Arup 2011 Technical report – 40% reduction by 2040, which is consistent with advice from Council stakeholders (Schneider, Siemens and Phillips).
		New manufacturing & industrial buildings	As described in the 2013 Low Carbon Action Plan, manufacturing & industrial buildings retrofitted to a recognised sustainability standard (Green Star).
		Industrial processes	40% improvement by 2040, which is in line with the Siemens energy efficiency roadmap, as well as breakthrough technologies identified by Worldsteel Institute.
Transforming the way we travel	**Transport movements**	Light vehicles modal shift (private & commercial)	25% reduction in vehicle kilometres per person by 2040 due to demand reduction measures: Auckland Council modelling for non-price travel demand management, plus congestion charging, improvements in active transport and public transport infrastructure.
		Freight demand reduction	Based on 5% reduction from improved utilisation (e.g. through use of consolidation centres).
	Vehicle efficiency	Light vehicles	Assumes annual vehicle efficiency improvements of 3.5% for internal combustion engines. This is faster than the historic 2.5% improvements. Also accounts for slow increase in the number of vehicles, which has been the historic trend.
		Heavy vehicles	Assumes annual vehicle efficiency improvements of 2% for internal combustion engines and a steady number of heavy vehicles in the Auckland fleet. The efficiency improvement is faster than the historic 0.1% annual improvement.
		Alternative fuels – biofuels / electric	By 2040, 25% of total light vehicle fleet is electric. This means around 54% of cars being introduced into Auckland will be electric by 2040.
Transforming to zero waste	**Reduction in waste to landfill**	Waste to energy	As described in the 2013 Low Carbon Action Plan. (By 2040, achieving 100% of waste diverted from landfill).
		Sewage to energy	As advised by WaterCare, by 2040 there is 7.7 MW of installed capacity.
Transforming forestry, agriculture and natural carbon assets	**Sequestration**	Ecological corridors sequestration	As described in the 2013 Low Carbon Action Plan.
		Carbon sequestration from forests	As per the Arup 2011 Technical Report, accounting for 41,329ha of forest.

4.1 General findings – by transformation area

The results are summarised in the table below (as per cent reductions compared to 2009 levels) and in the abatement 'wedge chart' (showing the contributions of each transformation area) in Figure 9. The measures of success combine to achieve around 40 per cent reduction compared to 1990 levels (which are approximately equivalent to 2009 levels).

Table 8 shows:

- Absolute per cent reduction in each emissions source
- Per capita per cent reduction for those emissions sources that increase with residential population, and
- Per $GRP million per cent reduction for those emissions sources that increase with economic activity.

It is useful to note that per capita and per $GRP million reductions are greater than total (absolute) reductions. That is, Auckland must aim to become more efficient per person and per economic output in order to achieve its 40 per cent emissions reductions target while growing its population in line with the Auckland Plan.

Table 8 Carbon abatement results

	Total			**Per Capita**			**Per $GRP (millions)**		
Reduction compared to 2009 baseline	**by 2020**	**by 2030**	**by 2040**	**by 2020**	**by 2030**	**by 2040**	**by 2020**	**by 2030**	**by 2040**
Buildings									
Residential	9%	30%	31%	28%	53%	60%	-	-	-
Commercial	23%	63%	57%	-	-	-	36%	75%	76%
Manufacturing & Industrial	4%	23%	33%	-	-	-	20%	47%	61%
Transport									
Light Vehicles	11%	37%	70%	30%	58%	83%	-	-	-
Heavy Vehicles	40%	40%	37%	-	-	-	50%	59%	64%
Waste	9%	36%	95%	29%	58%	97%	-	-	-
Agriculture	5%	29%	59%	-	-	-	21%	52%	76%

When considering the results, it is important to remember that the assessment period is projected to be one of rapid population and economic growth in Auckland, and it is in this context, that Auckland Council is trying to manage and reduce emissions.

The carbon reduction contribution of each transformation area is discussed in detail in Table 10 to Table 14 below, however Table 9 provides high level findings.

Figure 9 and Figure 10 present the carbon reduction contribution in the form of ‘wedge’ diagrams (Figure 9 is including the contribution of the ETS and Figure 10 excludes this contribution). The wedge diagrams show the contribution of each transformation area and the extent to which the aggregated reduction is able to reach the prescribed targets.

Figure 11 presents the same data in an alternative form showing the emission levels at each point in time and the contribution made by the ETS, the measures of success and forestry.

Some observations include:

- That if all abatement measures of success were implemented by 2040, residual emissions will be approximately 40 per cent lower than 1990 baseline levels (or around 48 per cent lower than 2009 levels).
- That the achievement of all the listed abatement measures of success will constitute a 53 per cent reduction in emissions when compared to the projected BAU emissions (excluding forest sequestration) in 2040.
- That the ‘built environment and green infrastructure’ transformation area (Transforming our built environment and green infrastructure) makes the most contribution to GHG reductions (amounting to around 2,700 ktCO_2e by 2040).

Table 9 and Figure 9 further illustrate that:

- Auckland makes significant GHG reductions during the assessment period to 2040 when population and economic growth considerations are taken into account, with the aggregate amount of GHG reductions placing Auckland Council on a trajectory to achieve a 40 per cent reduction by 2040, or a 50 per cent prediction by 2050.
- The contribution of the New Zealand Emissions Trading Scheme (ETS) in carbon reduction is included in the BAU projections. The additional ETS ‘wedge’ demonstrates the additional emissions which would be added to BAU (and require mitigation) if no ETS was in place.

  Since Arup’s 2011 report, the nature of the New Zealand ETS has changed, particularly regarding the price of carbon. This has dropped from $50 per tCO2 to $25 per tCO2 with a ‘two-for-one’ scheme (effectively making the price $12.50 per tCO2 in 2013). Arup has accounted for this by using MED Outlook 2011 data (‘No Emissions Constraint’ scenario) as part of the grid electricity factors used in modelling.

Table 9 Measures of success

Carbon abatement potential by transformation area and aggregated

Transformation area	**GHG Reduction Potential ($ktCO_2$-e p.a.)**			**GHG Reduction Potential (% of BAU projection)**		
	2020	**2030**	**2040**	**2020**	**2030**	**2040**
Transforming energy supply and demand	62	143	165	0.6%	1.3%	1.4%
Transforming our built environment and green infrastructure	666	1,817	2,719	6.3%	16.8%	23.8%
Transforming to zero waste	224	533	1,029	2.1%	4.9%	9.0%
Transforming the way we travel	186	464	962	1.7%	4.3%	8.4%
Transforming forestry, agriculture and natural carbon assets	35	214	423	0.3%	2.0%	3.7%
Transforming our economy to a high growth low carbon future	-	-	-	-	-	-
Total Reductions	**1,173**	**3,170**	**5,298**			
BAU Emissions (excluding Forest Sequestration)	10,620	10,817	11,407			
Forestry Carbon Sequestration	956	868	795			
Residual Emissions (after reductions)	**8,579**	**6,852**	**5,381**			
ETS Contribution[3]	*572*	*1,555*	*2,326*			

[3] The ETS Contribution represents the difference between the MED 2011 Outlook 'No carbon constraints' scenario and the projected BAU.

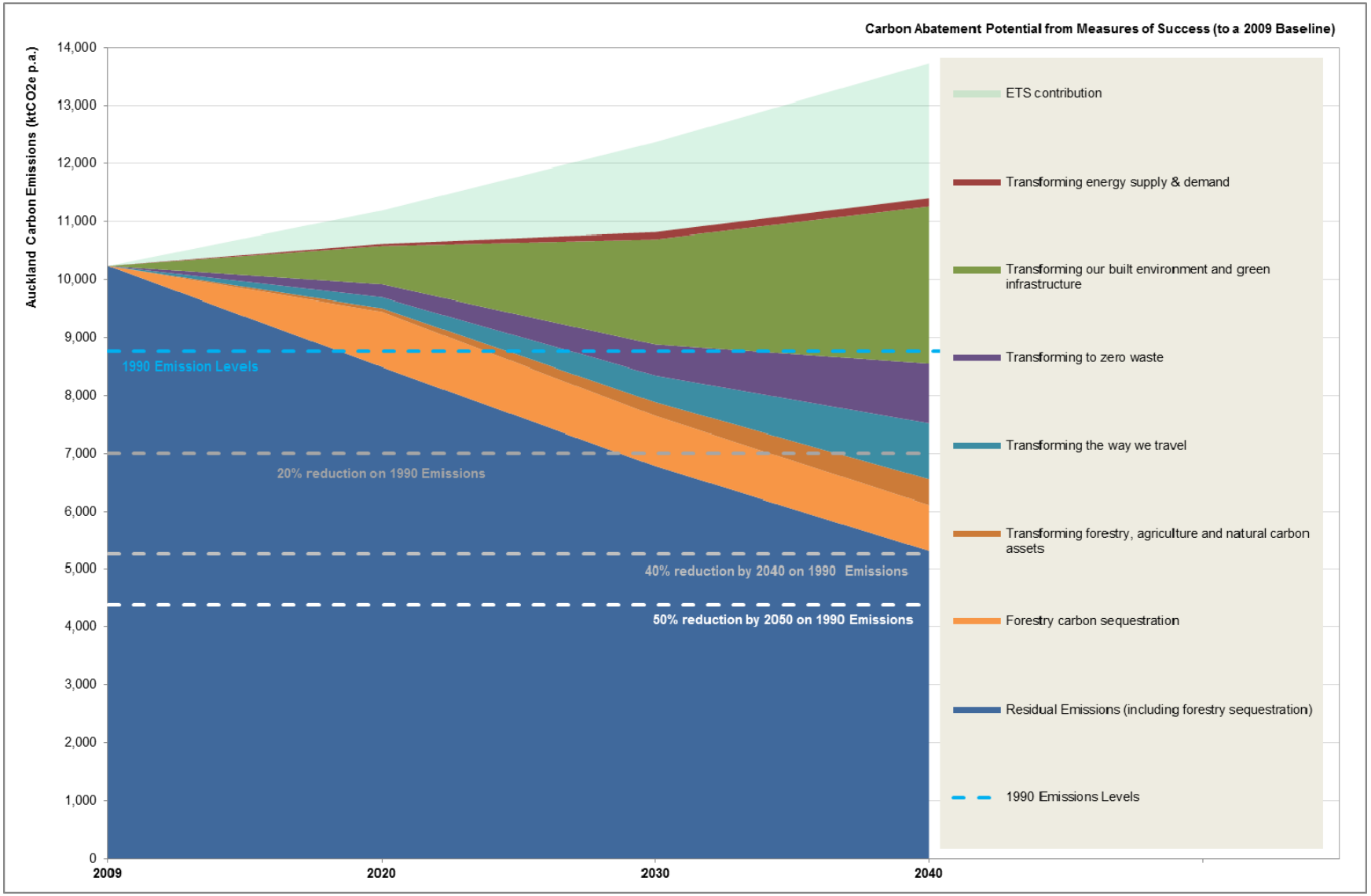

Figure 9 Measures of success – carbon abatement potential by transformation area and aggregated (including ETS contributions)

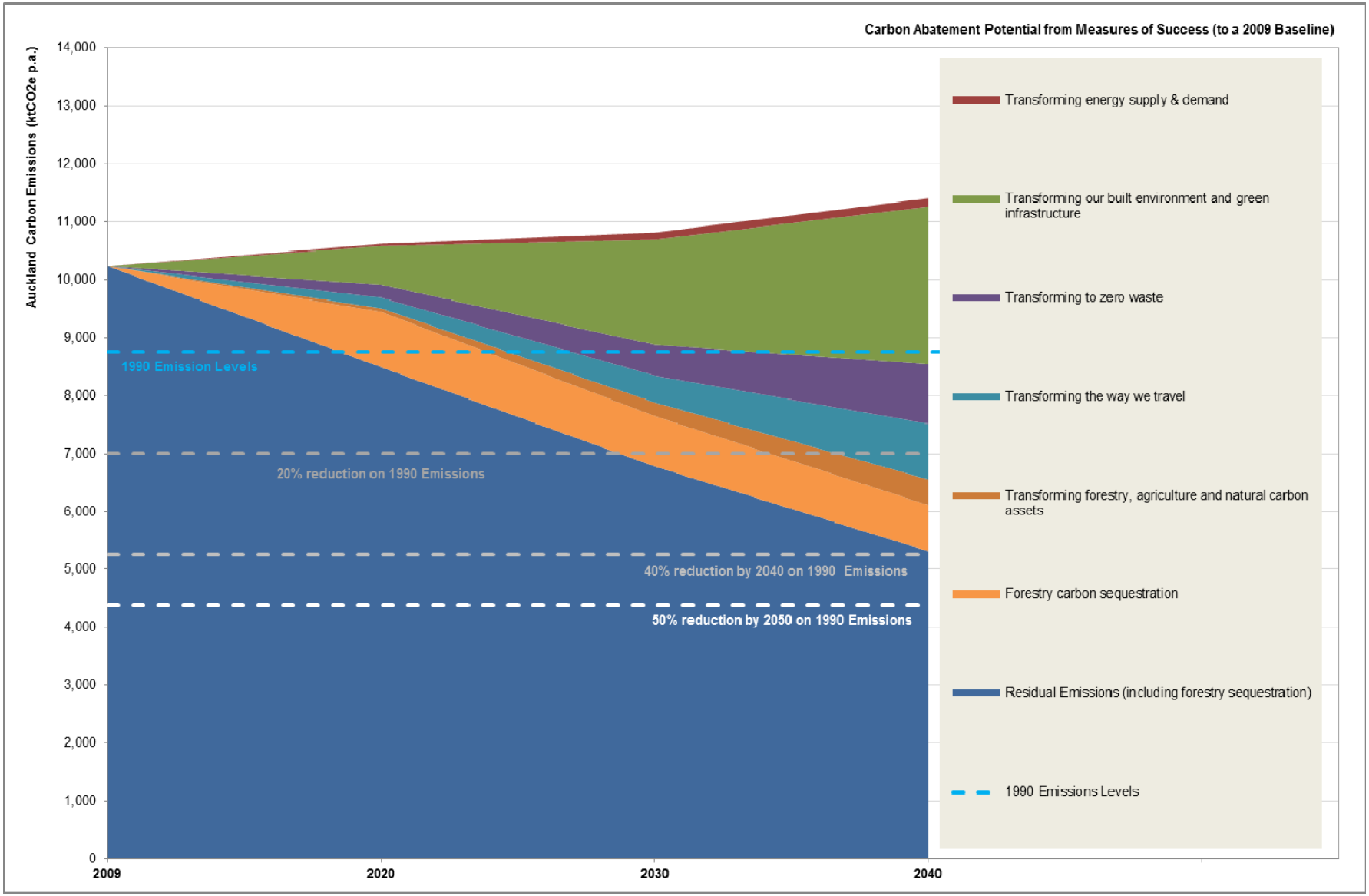

Figure 10 Measures of success – carbon abatement potential by transformation area and aggregated (including forest sequestration)

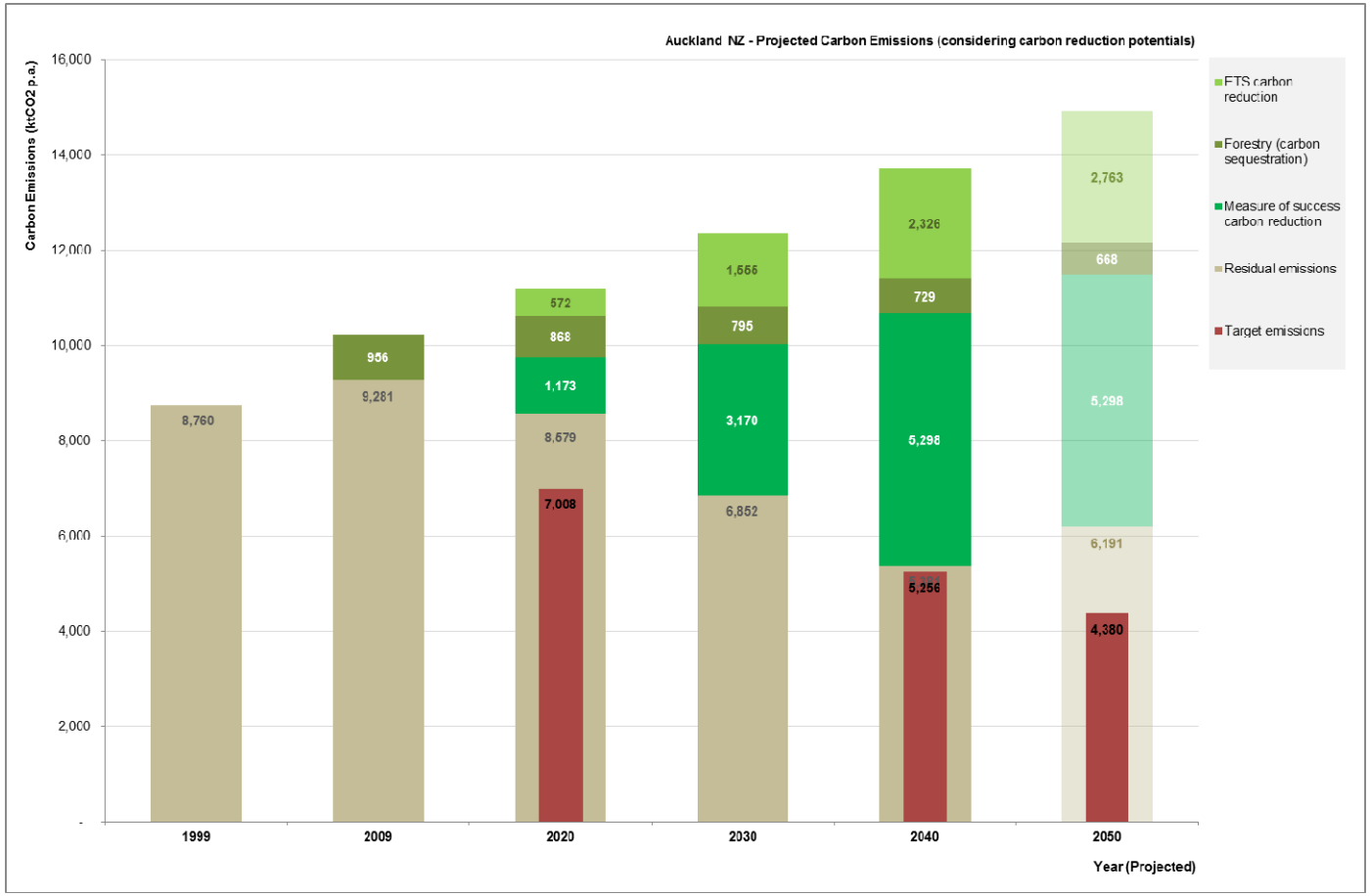

Figure 11 Projected carbon emissions (considering carbon reduction potential from NZ ETS and measures of success)[4]

[4] The graph shows 2050 emissions. While the residual emissions and ETS contributions are projected in line with population and GRP, the abatements, forestry sequestration and ETS have been from 2040 to illustrate the gap between residual emissions and Auckland Council target emissions, were the same measures to be carried forward to 2050.

4.1.1 Transforming energy supply and demand

The Energy Supply and Demand transformation area reflect Auckland's expected population growth, the anticipated associated increase in energy demand, and how the City may develop a secure, diversified energy supply.

Table 10 presents the carbon reduction potential for the measures related to energy supply and demand.

Table 10 Carbon reduction potential – transforming energy supply and demand

Measure of Success	Description and assumptions	Carbon reduction potential			
		2020	2030	2040	Units
National renewables grid mix	By 2040, 99% of electricity in New Zealand will be generated by renewable sources.	3	63	71	ktCO2e reduced
		0.0%	0.6%	0.6%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Auckland region renewables (new installations – solar, wind, geo, biomass, waste to energy)	Based on potential yield of biomass resources in the Auckland region and beyond, roof space in the Auckland region, availability of waste etc.	59	80	95	ktCO2e reduced
		0.6%	0.7%	0.8%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

The underpinning assumptions used to determine the carbon reduction potential for this transformation area are presented in Appendix B (as EN-1 to EN-2).

It should be noted that the impact of changing the New Zealand electricity grid to 99 per cent of renewables by 2040 reduces emissions from electricity used in buildings. This means that the majority of emissions reductions are attributed to "Transforming our Built Environment and Green Infrastructure". This is discussed in the next section of the report.

4.1.2 Transforming our built environment and green infrastructure

The Built Environment and Green Infrastructure transformation area reflects Auckland Council's ambition to manage the energy demand and associated GHG emissions of the City's residential and commercial built environment. Table 11 presents the carbon reduction potential for the measures related to this area[5].

Table 11 Carbon reduction potential

Transforming our built environment and green infrastructure

Measure of Success	Description and assumptions	Carbon reduction potential			
		2020	2030	2040	Units
Retrofit residential buildings	As described in the 2013 Low Carbon Action Plan, homes improved to a recognised sustainability standard (HomeStar)	92	115	147	ktCO2e reduced
		0.9%	1.1%	1.3%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
New residential buildings	As described in the 2013 Low Carbon Action Plan, homes built to a recognised sustainability standard (HomeStar)	50	128	174	ktCO2e reduced
		0.5%	1.2%	1.5%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Appliances improvement (including smart grid) for residential sector	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the US Department of Energy.	Included in carbon emissions in retrofit and new buildings			-
Retrofit commercial buildings	As described in the 2013 Low Carbon Action Plan, commercial buildings retrofitted to a recognised sustainability standard (Green Star).	77	178	165	ktCO2e reduced
		0.7%	1.6%	1.4%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
New commercial building standards	As described in the 2013 Low Carbon Action Plan, commercial buildings built to a recognised sustainability standard (Green Star).	15	35	63	ktCO2e reduced
		0.1%	0.3%	0.6%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

[5] It should be noted that the measures associated with improving the Council's portfolio (as identified in the *Low Carbon Action Plan (Draft V9)* were excluded from the analysis due to the overlap with the measures described above, and the minimal (but relatively symbolic) energy and carbon reductions.

Measure of success	Description and assumptions	Carbon reduction potential			
		2020	2030	2040	Units
Appliances improvement (including smart grid) for commercial sectors	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the US Department of Energy.	Included in carbon emissions in retrofit and new buildings			-
Retrofit manufacturing & industrial buildings	Adopts a 40% reduction by 2040, which is consistent with advice from Council stakeholders.	67	250	320	ktCO2e reduced
		0.6%	2.3%	2.8%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
New manufacturing & industrial buildings standards	As described in the 2013 Low Carbon Action Plan, manufacturing & industrial buildings retrofitted to a recognised sustainability standard (Green Star).	57	151	291	ktCO2e reduced
		0.5%	1.4%	2.5%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Industrial processes improvements (steel industry)	45% improvement by 2040, which is in line with the Siemens energy efficiency roadmap[6], as well as breakthrough technologies identified by Worldsteel Institute[7].	154	462	693	ktCO2e reduced
		1.4%	4.3%	6.1%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Industrial processes improvements (all other industries)	45% improvement by 2040, which is in line with the Siemens energy efficiency roadmap[8], as well as replacement of coal with biomass energy for cement industries.	155	498	867	ktCO2e reduced
		1.5%	4.6%	7.6%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

The underpinning assumptions used to determine the carbon reduction potential for this transformation area are presented in Appendix B (as BD-1 to BD-11).

The carbon reduction potential in this transformation area is primarily derived from significantly improving the energy usage from buildings in commercial and residential sectors, as well as building and process energy usage in the manufacturing and industrial sector. The transformation area also takes into account 99 per cent of renewables in the New Zealand grid electricity emission factor – this is discussed also in the previous section.

Observations of particular note are the following:

[6] http://www.siemens.com.au/ptf-energy-casestudies-efficiency

[7] http://www.worldsteel.org/publications/fact-sheets.html

[8] http://www.siemens.com.au/ptf-energy-casestudies-efficiency

- The retrofitting of existing buildings (residential, commercial, and manufacturing and industrial facilities) contributes to 632ktCO_2e of reductions by 2040, and the influence of improved building standards for new buildings (residential, commercial, and manufacturing and industrial facilities) contributes to 528ktCO_2e of reductions by 2040.
- The improvement in industrial processes, particularly in the steel industry, contributes 1,559ktCO_2e of reductions by 2040;
- By 2040, reduction in electricity usage in the built environment contributes to 17 per cent of the reductions in this transformation area; and
- By 2040, reduction in gas usage in the built environment contributes to 26 per cent of the reductions in this transformation area.

4.1.3 Transforming to zero waste

The Zero Waste transformation area reflects Auckland Council's ambition to minimise and, where this is not possible, divert from the waste landfill or better utilise the City's waste 'assets' for ongoing uses.

The *Low Carbon Action Plan (Draft V9)* provides a measure of success target to achieve 100 per cent diversion of waste from landfill by 2040.

Table 12 Carbon reduction potential – transforming to zero waste

Measure of success	**Description and assumptions**	**Carbon reduction potential**			
		2020	**2030**	**2040**	**Units**
Zero waste targets	Achieving 100% of waste being diverted from landfill in 2040 (remaining 30% by 2020, and 60% by 2030).	224	533	1,029	ktCO2e reduced
		2.1%	4.9%	9.0%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

The GHG reduction potential described above is from only one Measure of Success which is to divert 100 per cent of total Auckland waste from landfill as presented in Appendix B as assumption WA-1.

Currently, Auckland diverts 57 per cent of all its waste from landfill and the remaining landfill waste will be around 1,061kt of waste in 2040. If this Measure of Success can be achieved, approximately 97 per cent of all emissions from waste in 2040 will be avoided.

It has been assumed that some GHG emissions will still occur from the composting of a large proportion of the organic waste diverted from landfill.

It should be noted that the following measures of success were excluded from the analysis due to the depth of research required to underpin such analysis, and due to the overlap with energy and GHG emission reduction activities in associated industries.

- Number of mandatory NZ product stewardship schemes in place.

- Waste wise practices and philosophies (including cradle to cradle thinking) underpin behaviour and curricula from preschool to tertiary institutes.
- Number of zero waste marae.

4.1.4 Transforming the way we travel

The Way We Travel transformation area reflects Auckland's dependence upon private vehicles as the primary mode of transport, the associated GHG emission footprint and general exposure to potential future oil price volatility. Table 13 describes the carbon reduction potential from a range of carbon abatement measures relating to transport.

Table 13 Carbon reduction potential – transforming the way we travel

Measure of success	Description and assumptions	Carbon reduction potential			
		2020	2030	2040	Units
Light vehicles modal shift (private & commercial)	25% reduction in vehicle kilometres per person by 2040 due to: - transport funding tools - improvements in active transport and - improvements public transport infrastructure.	86	201	338	ktCO2e reduced
		0.8%	1.9%	3.0%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Freight demand reduction	Based on 5% reduction from improved utilisation (e.g. through use of consolidation centres).	10	30	53	ktCO2e reduced
		0.1%	0.3%	0.5%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Vehicle efficiency improvements (light and heavy)	Annual vehicle efficiency improvements for internal combustion engines: - 3.5% for light vehicles; - 2% for heavy.	49	94	248	ktCO2e reduced
		0.5%	0.9%	2.2%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Alternative fuels – biofuels	By 2040, 14% of total light vehicle fleet kilometres travelled is running on 100% biofuels. Assumes biofuels have a 75% reduction in carbon.	25	70	111	ktCO2e reduced
		0.2%	0.7%	1.0%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Electric vehicles	By 2040, 25% of total light vehicle fleet is electric. This means around 54% of cars being introduced into Auckland will be electric by 2040.	16	68	213	ktCO2e reduced
		0.1%	0.6%	1.9%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

The underpinning assumptions used to determine the carbon reduction potential for this transformation area are presented in Appendix B (as TR-1 to TR-5).

Overall, implementing measures to influence transportation in 2040 achieves 962ktCO_2e of carbon abatement in 2040. A large proportion of this abatement can be achieved through the modal shift of light vehicles through mechanisms such as transport funding tools (such as congestion charging) and improving public transport. However, significant effort should be made on the performance of vehicles themselves, which may include the improvement of vehicle efficiency, or the use of alternative fuels (biofuel or electric).

4.1.5 Transforming forestry, agriculture and natural carbon assets

The Forestry, Agriculture and Natural Carbon Assets transformation area reflects the opportunity for Auckland Council to pursue ambitious methods of emissions abatement. The contribution of these measures of success are detailed in the Table 14below.

Table 14 Carbon reduction potential

Transforming forestry, agriculture and natural carbon assets

Measure of success	**Description and assumptions**	**Carbon reduction potential**			
		2020	**2030**	**2040**	**Units**
Ecological corridors sequestration	100% of planned ecological corridors are planted by 2040.	32	209	416	ktCO2e reduced
		0.3%	1.9%	3.6%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Reduction in agricultural energy use	By 2040, a 40% reduction in agricultural energy use (per unit of production) is achieved.	4	5	7	ktCO2e reduced
		0.0%	0.0%	0.1%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)
Carbon sequestration from forests	The sequestration of Auckland forests (excluding pre-1990 forests)	956	868	795	ktCO2e reduced
		9.0%	8.0%	7.0%	% carbon reduced compared to projected BAU emissions (excluding forest sequestration)

The underpinning assumptions used to determine the carbon reduction potential for this transformation area are presented in Appendix B (as AG-1 to AG-3).

The results highlight that carbon sequestration from forests and ecological corridors is a major contribution to achieve the targeted reductions for Auckland in 2040.

4.1.6 Transforming our economy to a high growth low carbon future

Transforming Our Economy to a High Growth Low Carbon Future reflects Auckland Council's vision to pursue a 'green growth' strategy which seeks to create jobs and grow the economy whist reducing costs and environmental impact.

Auckland Energy Resilience and Low Carbon Action Plan (Draft V9) includes 12 measures of success for this. All measures of success were excluded from the analysis due as their contribution to the emission reduction targets is not measurable. These are:

- Sustainability city ranking (e.g. Green City Index)
- Number of Auckland-based firms reporting on sustainability
- R&D expenditure of importance to Green Grow vs. all R&D expenditure
- Gross Value Add in Environmental Goods and Services (EGS) sector vs. all sectors
- R&D employment all sectors
- Turnover of EGS sector vs. all sectors
- Investment $ in clean-tech organisations and projects (from banks)
- Patents of importance to Green Growth (environmental patents) vs. all patents
- Employment in the EGS sector vs. all sectors
- Graduates with defined clean-tech skills (sciences, engineering)
- Skills mix of migrants aligned to clean-tech ambition
- Maori business reporting

Appendix A Baseline projections: assumptions and methodology summary

Baseline projections

To ensure consistency in projecting baseline emissions for Auckland, Arup have applied the same methodology in the Auckland Carbon Strategy. Additionally, the same assumptions were applied where the same data for projected years (2020, 2040 and 2050) was available as per the 2031 data used in the original strategy.

The following section provides the assumptions and a broad methodology regarding the projections seen in this report.

Assumptions

Baseline projections were primarily based on two factors; population and $GRP projected growth, and projected electricity emission factors.

- **Population and $GRP projected growth**

  As per Table 4, the projections were mainly based on population and $GRP growth in 2020, 2040 and 2050. Projected values of population and $GRP were obtained from

  - **Population**: Statistics New Zealand (2010) Customised model for Auckland Plan, High Population Projection, Job-01056 (as discussed with Auckland Council, for all projection years)
  - **$GRP**: (2011) GDP Outputs from the Economics Futures Model, EFM Output by Industry – High projection (as discussed with Auckland Council, for years 2020, 2030, and 2040).

    Note: 2040 and 2050 data was assumed by accounting for a 3.8 per cent increase in GRP per capita every ten years (based on the projection from 2020 to 2030).

- **Projected electricity emission factors**

  Electricity emission factors will be projected to change between 2009 and 2050. As per the original methodology, Arup derived electricity emission factors based on data from *MED Outlook 2011*. The derivation of these factors is explained in the methodology table following this page.

- **Auckland Transport projections for Auckland Plan Scenario G**

  As transport emissions have been projected on population and $GRP growth factors, and the projections account for some natural improvements (or general industry improvements) in vehicle efficiency. To account for these improvements, Arup modelled transport vehicle kilometres travelled based on fleet size and vehicle efficiency projections in New Zealand and Auckland.

Methodology

The following table describes the methodology applied to the various items (i.e. sectors, electricity emission factors), to obtain baseline projections of carbon for Auckland.

<table>
<tr><th rowspan="2">Sector</th><th rowspan="2">Factor</th><th colspan="3">Methodology</th></tr>
<tr><th>2020</th><th>2040</th><th>2050</th></tr>
<tr><td>Electricity emission factor</td><td>-</td><td colspan="2">1) Use electricity generation (by fuel) and electricity emissions from generation (by fuel) from MED Outlook 2011, Reference tab (data only available up to 2040).
2) Normalise electricity emissions and generation to consumption (with consumption data obtained from MED Outlook 2010, and from previous Arup methodology).
3) Derive electricity emission factors for projected years.</td><td>As data from MED Outlook 2011 is only projected to 2040, the electricity generation factor for 2040 was adopted for 2050.</td></tr>
<tr><td>Residential</td><td>Population</td><td colspan="3" rowspan="3">1) Projected energy-use growth (by fuel) as a ratio between future population or $GRP levels against ECCA 2009 End-use Data.
2) Derivation of sector-specific emission factors.
3) Normalisation of values to account for difference between URS Carbon Now 2009 carbon and EECA End-use derived carbon.
4) Multiplication of normalised projected energy-use and sector-specific emission factors to obtain carbon projected baselines.</td></tr>
<tr><td>Commercial (Buildings and Other)</td><td>$GRP</td></tr>
<tr><td>M&I Buildings and Processing</td><td>$GRP</td></tr>
<tr><td>Transport Road - Rail, Air, Sea</td><td>Population</td><td colspan="3">1) Emissions from 2009 baseline were projected against population.</td></tr>
<tr><td>Transport Road – Private Vehicles, Passenger Bus, Freight, Commercial Vehicles,</td><td>-</td><td colspan="3">1) Vehicle kilometres travelled (VKT), trips and person trips for light and heavy vehicles were projected based on fleet size and vehicle efficiency projections in New Zealand and Auckland
2) Apply energy efficiencies of vehicles, accounting for vehicle improvements over time without any funding programs.
3) Apply projected mix of fuel use by transport type.
4) Multiplication of projected fuel use by transport type with emission factors.</td></tr>
<tr><td>Fugitive (non-energy)</td><td>Population</td><td colspan="3">Projected carbon as a ratio between future population or $GRP levels against 2009 levels.</td></tr>
</table>

Sector	Factor	Methodology		
		2020	2040	2050
Waste	Population			
Industrial Process (non-energy)	No factor applied	As per previous methodology, assume industrial process emissions kept constant over the period assuming that the Glenbrook Steel Mill does not increase production.		
Agriculture	Specific equation	As per previous methodology, projection based on the continuation of existing trends identified by URS.		
Forestry	Specific equation	It should be noted that in this sector, the previous 2009 carbon sequestration included pre-1990 forests. In discussions with Auckland Transport, Arup have removed all pre-1990 forests to be in-line with the Kyoto protocol in claiming carbon sequestration (i.e. assuming that pre-1990 forests have reached a steady state for carbon sequestration). It should also be noted that this may also be an over-estimation, as there is no available data to account for any post-1990 forests that were forests pre-1990, but were reforested. From this update of 2009 carbon sequestration values, Arup's previous projection methodology was applied. The projection is based on the continuation of existing trends identified by URS, with the assumption from New Zealand's Greenhouse Gas Inventory 1990-2008, Auckland Ministry for Environment, that the carbon sequestration from forestry decreased by 15.7% between 1990 and 2008 – applying this into the future. Hence, the following equation was applied: $C_n = C_{1990}\, 0.848^{(n-1990)}$, where C = carbon sequestered, n = projected year		

Targets

The original targets stated by Auckland are as follows:

- 10%-20% by 2020 based on 1990 emission levels
- 40% by 2040 based on 1990 emission levels
- 50% by 2050 based on 1990 emission levels

To develop the new targets based on 2009 emission levels, a 'target' emission level was derived for each projected year based on the targets above. The percentage reduction of this amount compared to 2009 emission levels was then used as the new targets

Appendix B Carbon reduction potential: assumptions and methodology summary

The following table details the assumptions and outlined methodology in estimating carbon reduction potentials, as described in the main body of the report.

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming energy supply & demand	EN-1	National renewables grid mix	By 2040, 99% of electricity in New Zealand will be generated by renewable sources.	62%	93%	99%	The following grouped measures of success are inter-related and overlapping, the following methodology has been applied to develop grid electricity emission factors: 1) Determine contribution of Auckland electricity generation by fuel-type, as a proportion of total NZ electricity generation. Assume that the total electricity generated by Auckland (regardless of fuel source-type) will remain the same. 2) From MED Outlook 2011 energy generation data, reverse calculate emission factors (EF). 3) Assign percentage contributions based on percentage of renewables in NZ grid. Determine the new total electricity provided by Auckland by fuel-type. 4) Determine the new total electricity generated by NZ by fuel-type. Assume only Wind generated electricity is included in the NZ electricity mix, and that Solar PV is directly used by buildings. 5) Deduct Solar PV contribution from energy consumption of all sectors (proportionally as per source data) from EECA end-use. 6) Re-determine the emissions based on the reverse calculated EFs in Step 2. Apply normalisation factor from consumption to generation electricity figures, to account for distribution losses (approximately 3-5% depending on year). 7) Reverse calculate electricity consumption EF for NZ, and apply to all electricity uses in model.
	EN-2	Auckland region renewables (new installations – solar, wind, geo, biomass, waste to energy)	Based on potential yield of biomass resources in the Auckland region and beyond, roof space in the Auckland region, availability of waste etc.	21% of Auckland elec. generated is renewable	83% of Auckland elec. generated is renewable	98% of Auckland elec. generated is renewable	

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming our built environment and green infrastructure	BD-1	Retrofit residential buildings	Takes into account % of Auckland's existing housing stock retrofitted to sustainable standard.	40%	65%	90%	Apply assumption of an average 50% reduction in total electricity kWh for % of existing residential homes (not including appliances), applied to normalised EECA end-use electricity data for 'sector 'Households'. This is applied to only existing homes. **Reference:** This assumes 5 Homestar as the new standard, equivalent to assumed baseline industry average of a 2 Homestar rating.
			Average Homestar rating of all of Auckland's housing stock	5 out of 10 stars	7 out of 10 stars	-	This overlaps with the above. Assumes existing buildings would be 2 Star HERS, and achieving 5 stars a 60% kWh reduction, and 7 stars a 77% reduction. **Reference:** Climate Zone 23 from NatHERS Star Band.
	BD-2	New residential buildings	Takes into account % of Auckland's new housing stock built to sustainable standard.	50%	80%	95%	Apply assumption of an average 25% reduction in total electricity kWh for % of new residential homes, applied to normalised EECA end-use electricity data for 'sector 'Households'. Applied only to new homes. **Reference:** This assumes 7 Homestar as standard, equivalent to assumed baseline industry average of a 2 Homestar rating, which was picked as the projection of baseline emissions assumes current technology.
			Average Homestar rating of Auckland's Homes (constructed after 2013)	6 out of 10 stars	8 out of 10 stars	-	This is an overlaps with the above. Assumes new buildings would be 2 Star HERS, and achieving 6 stars a 69% kWh reduction, and 8 stars a 85% reduction. **Reference:** Climate Zone 23 from NatHERS Star Band.
	BD-3	Appliances improvement (including smart grid) for residential sector	Assumes adoption rate for existing homes as follows.	50%	75%	100%	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the US Department of Energy. • Applicability factor of 29% on total electricity in new homes, with a 14% reduction on baseline. • Applicability factor of 29% on total electricity in existing homes, with a 7% reduction in 2020 and linearly improving to 14% in 2040.
			Assumes adoption rate for new homes as follows.	100%	100%	100%	

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming our built environment and green infrastructure	BD-4	Retrofit commercial buildings	Accounts for the average of NABERSNZ rating of Auckland's buildings as follows.	4 out of 7 stars	6 out of 7 stars	-	Apply energy improvements based on NABERS Melbourne. NZ GBCA advised that they will not be releasing quantitative benchmarks for NABERS NZ. **Reference:** Assume that average is currently 3 NABERS stars and improves to 4. (30% kWh reduction), and that to 6 Stars. (80% kWh reduction).
	BD-5	New commercial building standards	% of Auckland's new commercial and industrial buildings being built to a recognised sustainable building standard	40%	65%	95%	These two original targets overlap – modelling ensures no double counting, and the greatest reduction applies. 1) Apply assumption of an average 20% reduction in total electricity kWh for % of commercial and industrial buildings (as per normalised EECA end-use electricity data). **Reference**: First tier reduction (6 points in ENE-1) from Bishop. R. (2013) *Behind the energy-use figures*, Build 135- April/May 2013 2) Apply energy improvements based on NABERS Melbourne. NZ GBCA advised that they will not be releasing quantitative benchmarks for NABERS NZ. **Reference:** Assume that average is currently 3 NABERS stars and improves to 4. (30% kWh reduction), and that to 6 Stars. (80% kWh reduction).
			Average Greenstar rating for Auckland's office and industrial buildings (constructed after 2013)	5 star	6 stars	-	
	BD-6	Appliances improvement (including smart grid) for commercial sectors	For office equipment (PC) is applicable to 4.6% of electricity.	30% energy reduced	65% energy reduced	80% energy reduced	Accounts for smart grid connection, and improved energy efficiency standards for appliances, as indicated by studies published by the US Department of Energy.
			For office equipment (non-PC) is applicable to 5.0% of electricity.	20% energy reduced	40% energy reduced	60% energy reduced	
			For office refrigeration is applicable to 8.5% of electricity.	25% energy reduced	40% energy reduced	60% energy reduced	
	BD-7	Retrofit manufacturing & industrial buildings	Adopts the following adoption rates.	30%	100%	100%	Consistent with advice from Council stakeholders (Schneider, Siemens and Phillips), a linear increase to 40% reduction in energy for industrial or manufacturing facility. (Assumes 20% in 2020, and 30% in 2030).

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming our built environment and green infrastructure	BD-8	New manufacturing & industrial buildings standards	% of Auckland's new commercial and industrial buildings being built to a recognised sustainable building standard	40%	65%	95%	These two original targets overlap – modelling ensures no double counting, and the greatest reduction applies. 3) Apply assumption of an average 20% reduction in total electricity kWh for % of commercial and industrial buildings (as per normalised EECA end-use electricity data). **Reference**: First tier reduction (6 points in ENE-1) from Bishop. R. (2013) *Behind the energy-use figures*, Build 135- April/May 2013 4) Apply energy improvements based on NABERS Melbourne. NZ GBCA advised that they will not be releasing quantitative benchmarks for NABERS NZ. **Reference:** Assume that average is currently 3 NABERS stars and improves to 4. (30% kWh reduction), and that to 6 Stars. (80% kWh reduction).
			Average Greenstar rating for Auckland's office and industrial buildings (constructed after 2013)	5 star	6 stars	-	
	BD-9	Industrial processes improvements (steel industry)	The following improvements in carbon emissions for the steel industry.	10%	30%	45%	Consistent with Siemens energy efficiency roadmap, as well as breakthrough technologies identified by Worldsteel Institute.
	BD-10	Industrial processes improvements (all other industries)	The following improvements in carbon emissions for other manufacturing and industrial facilities (non-electricity or gas fuels).	10%	30%	45%	Process efficiency is consistent with the Siemens energy efficiency roadmap. Additional improvements include the replacement of all coal use in cement industries with the use of biomass (to a limit of 20%, Moses P.M. Chinyama (2011) *Alternative Fuels in Cement Manufacturing*, Alternative Fuel
	BD-11	Streetlighting	Achieve reduction in energy use in street lighting (P and V category luminaires) relative to a 50 million kwh pa 2011/12 benchmark)	20%	40%	-	1) Assume that 50 GWh p.a. is the reference usage of street lighting in Auckland Region for 2009. Assume no future growth in energy use. 2) Determine total reduction on 2009 electricity baseline usage amount at given year (2040 has same reduction).

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming to zero waste	WA-1	Zero waste targets	Achieving 100% of waste being diverted from landfill in 2040, using the following targets of remaining waste avoided to landfill.	30%	60%	100%	1) Refer to Auckland Council Waste Assessment 2011, determine current landfill diversion rate (57%) and organic composition in landfill (19%), and existing % of organics in diverted waste (15%) 2) Determine baseline waste projections (population), based on 2009, with same diversion rates. 3) Change % diversion to landfill rates for 2020, 2030, and 2040. 4) Determine total amounts of diverted waste, landfill waste, and organics diverted. 5) Assume 50% of diverted organic waste is to AD, and 50% to composting. 6) Apply EF of 0.17 (NGA Factors 2012) to compositing (assumed as composting is now significant). 7) Determine difference of baseline emissions compared to new emissions.

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming the Way we Travel	TR-1	Light vehicles modal shift (private & commercial)	25% reduction in vehicle kilometres per person by 2040 due to: - congestion charging - improvements in active transport and - improvements public transport infrastructure.	-	-	-	1) Projects vehicle fleet based on historic vehicle growth. 2) Assumes 3.5% annual internal combustion engine (ICE) efficiency improvements (faster than historic 2.5% rate). 3) Includes BAU electric vehicle (EV) projections based on 2013 VFEM projection data. 4) Assumes that the fuel efficiency of scrapped vehicles is 25% worse than the fuel efficiency of the remaining fleet.
Transforming the Way we	TR-2	Vehicle efficiency improvements (light and heavy)	Light vehicles – annual vehicle efficiency improvements for internal combustion engines.	-	-	-	Assumes 3.5% annual internal combustion engine (ICE) efficiency improvements (faster than historic 2.5% rate).

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
			Heavy vehicles – annual vehicle efficiency improvements for internal combustion engines.	-	-	-	1) Assumes a steady number of heavy vehicles in the fleet. 2) Assumes 2% annual internal combustion engine (ICE) efficiency improvements (faster than historic 0.1% rate). This is in line with projections by the Rocky Mountain Institute which suggests 45% savings can be achieved by 2050 (http://www.rmi.org/RFGraph-heavy_truck_efficiency). 3) Assumes that the fuel efficiency of scrapped vehicles is 10% worse than the fuel efficiency of the remaining fleet. 4) Assumes no alternate fuel heavy vehicles.
	TR-3	Freight demand reduction	Based on 5% reduction from improved utilisation (e.g. through use of consolidation centres).	-	-	-	Applies a 5% reduction from improved utilisation (e.g. through use of consolidation centres) on heavy commercial and light commercial vehicle VKTs.
	TR-4	Alternative fuels – biofuels	By 2040, 14% of total light vehicle fleet kilometres travelled is running on 100% biofuels.	3% of VKTs on biofuels	7% of VKTs on biofuels	14% of VKTs on biofuels	Assumes biofuels have a 75% reduction on ICE CO_2 emissions. Assumes 2% of the light vehicle fleet is EVs by 2020, 8% by 2030 and 25% by 2040. This implies that approximately 54% of new light vehicle sales are EVs by 2040. Assumes EVs have an energy efficiency of 0.2 kWh/km (based on IEA report, http://www.iea.org/publications/freepublications/publication/EV_PHEV_Roadmap.pdf).
	TR-5	Electric vehicles	By 2040, 25% of total light vehicle fleet is electric. This means around 54% of cars being introduced into Auckland will be electric by 2040.	2% of light vehicle fleet are EVs	8% of light vehicle fleet are EVs	25% of light vehicle fleet are EVs	

Area	Ref No.	Action	Description	by 2020	by 2030	by 2040	Details of main assumptions and outlined methodology
Transforming forestry, agriculture and natural carbon assets	AG-1	Ecological corridors sequestration	% planned ecological corridors planted	30%	80%	100%	1) Refer to Auckland Carbon Strategy, Option S1, using 19,350 hectares of potential Douglas fir riparian land 2) Assume 100% of this land is used for ecological corridor purposes 3) Apply measures of successes to hectare amount, using URS Carbon Now calculator 4) Determine carbon sequestration potential for future years (accounting for aging of riparian land).
	AG-2	Reduction in agricultural energy use	The following targets are a % reduction in energy (kwh/unit of production) and water use (ML/unit of production) intensity in the agricultural sector	20%	30%	40%	1) Assumes reduction of energy intensity in agricultural production is equivalent to total energy reduction (as projections increased by $GRP) 2) Apply target reduction to normalised electricity, petrol and diesel fuel consumption for building and non-building purposes in sectors of 'Dairy Agriculture' and 'Non-dairy Agriculture' in EECA end-use data. 3) Assume minimal impact on carbon emissions regarding water use intensity reduction
	AG-3	Carbon sequestration from forests	The sequestration of Auckland forests (excluding pre-1990 forests)	-	-	-	As calculated in baseline projections. Arup's previous projection methodology was applied. The projection is based on the continuation of existing trends identified by URS, with the assumption from New Zealand's Greenhouse Gas Inventory 1990-2008, Auckland Ministry for Environment, that the carbon sequestration from forestry decreased by 15.7% between 1990 and 2008 – applying this into the future. Hence, the following equation was applied: $C_n = C_{1990}\, 0.843^{(n-1990)}$, where C = carbon sequestered, n = projected year