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Pathway report

ACT 2050 emissions modelling – land use

Prepared for:

ACT Government

7 June 2017

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VERSION CONTROL

Version	Date	Author	Project Director
1.0	7 June 2017	Brett McKay	Charlie Knaggs

EXECUTIVE SUMMARY

The ACT Government has committed to a target of net zero carbon emissions by 2050. This target is enshrined in the *Climate Change and Greenhouse Gas Reduction Act 2010*. Point Advisory was engaged by the ACT Government's Environment, Planning and Sustainable Development Directorate to model emissions reduction pathways within the land sector to assist the ACT in meeting this target. This report presents the outcomes of Point Advisory's analysis.

Reference case

Point Advisory modelled a 'reference scenario' to gain an understanding of the ACT's current emissions trajectory to 2050 based on existing policy settings. The reference scenario provides the basis for modelling carbon reduction and sequestration actions to set the ACT on a pathway to achieve its net zero target.

Reference case modelling involved establishing an emissions 'baseline' (derived from the ACT's most recent land sector greenhouse gas inventory from 2014). The ACT's land sector inventory is, in turn, based on the Commonwealth Government's National Greenhouse Gas Inventory (NGGI).

The impacts of existing policy settings were then modelled and combined with the baseline to forecast 'business as usual' emissions out to 2050. The major sources of data and information for the land sector inventory, and the reference case assumptions used, are summarised in Table 1. These sources are taken directly from the component parts of the NGGI.

Table 1: Summary of reference case emissions and sequestration to 2050

Description		Reference case (medium scenario)
Emissions sources		
Deforestation	When forests are cut down, the carbon stored in the trees is lost, either immediately (from burning) or over time (as wood decays). Deforestation was predicted to be due to the conversion of forest land to urban areas. Most deforestation emissions are from the development of Molonglo, which has 283 hectares of forest land at risk. Majura Valley and Gungahlin have 119 and 33 hectares at risk, respectively. Under different scenarios, between 30% and 90% of this at-risk forest could be cleared due to urban expansion.	Urban expansion results in emissions of between 2 and 2.4 kt CO_2-e per year between 2025 and 2040, when Molonglo is earmarked for development.
Enteric emissions	Emissions from cattle as a result of their digestive processes. A general trend of decline in cattle numbers in the ACT has led to reducing emissions from enteric emissions, expected to level out by 2020 and remaining constant until 2050.	Enteric emissions account for 15.2 kt CO_2-e of emissions each year from 2020 to 2050.
Agricultural soils	Soil emissions as a result of urine and dung from grazing animals, organic fertilisers, nitrogen leaching and runoff, and atmospheric deposition.	A marginal source of emissions, consistently around 2.4 kt CO_2-e emissions per year.
Manure management	Negligible source of emissions – not included.	Contribution of less than 0.1 kt CO_2-e emissions per year.

	Description	Reference case (medium scenario)
Field burning of agricultural residues	Negligible source of emissions – not included.	Contribution of less than 0.1 kt CO_2-e emissions per year
Liming	Negligible source of emissions – not included.	Contribution of less than 0.1 kt CO_2-e emissions per year
Sequestration sources		
Afforestation / reforestation	The conversion of land from grassland or settlements to forest land. Reforestation describes land that recently had forest cover, lost it and is being restored to forested status, whereas afforestation describes land that has been clear for a long period of time.	A conversion of grassland to plantations stimulated a large amount of afforestation and reforestation over the period 1998 to 2010, however as these forests reach maturity, impact from afforestation is predicted to decrease to zero by 2020 (and remain at that level subsequently).
Forest management	Plantations throughout the ACT are predominantly comprised of softwoods. The growth cycles and wood production of plantations result in net sequestration of carbon under 'forest management'. Plantations in the Lower Cotter Catchment are planned for conversion to native forest by 2037, resulting in an 8% decrease in total plantation area in the ACT.	The conversion of the Lower Cotter plantations to forest leads to a decrease in sequestration to just under 8 kt CO_2-e per year in wood and wood products, remaining steady from 2020 to 2050.
Emissions and sequestration (fluctuating) sources		
Grazing land management	The management of grasslands (generally, agricultural land) leading to changes in levels of soil carbon or woody biomass stocks change as a result of practices such as tilling, fertiliser use and irrigation.	Predicted to remain relatively constant from 2020 to 2050, at around 3 kt CO_2-e of sequestration per year.
Cropland management	The flux of carbon stored on cropland as a result of management practices including crop types and rotation, stubble management, tillage techniques, fertiliser application, soil ameliorants, application of green manures and changes in land use.	The average sequestration since 1990 was -0.017 kt CO_2-e, and thus is a negligible component of the inventory.

The combination of the above assumptions around carbon emissions and sequestration lead to a reference case emissions trajectory for the ACT land sector of between -2.3 and 18.8 kt CO_2-e per year under the medium scenario as sources of sequestration are cancelled out by larger sources of emissions from deforestation and enteric emissions. The reference case emissions trajectory is shown in Figure 1 below.

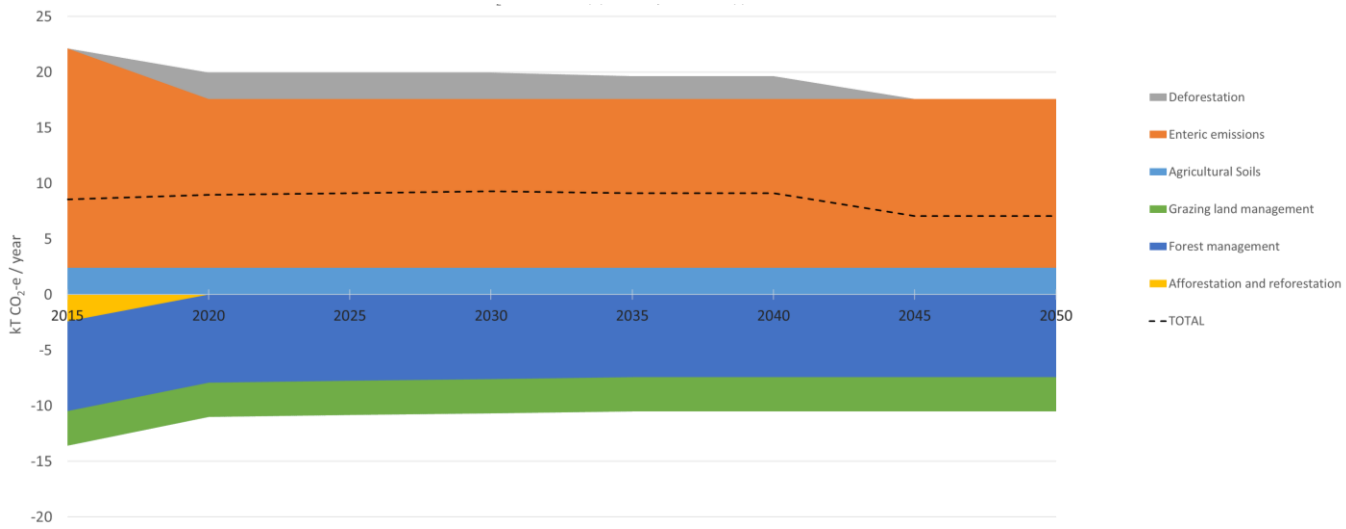


Figure 1 ACT land sector reference case emissions, 2015 to 2050 (medium scenario)

Options analysis

An options assessment was conducted to assess the range of opportunities for emissions reductions and carbon sequestration in the ACT. A scan was conducted to identify the full range of opportunities available. These opportunities were then screened based on their abatement / sequestration potential, along with other factors including practicality of implementation and technology limitations. Based on this assessment, Table 2 summarises the options that were shortlisted for inclusion in the pathway modelling.

Table 2: Summary of options investigated to reduce emissions and increase sequestration opportunities

Option description	Additional benefits	Policy	Technology	External factors / limitations
Enteric emissions reduction through herd management				
Applying the Cattle Herd Method from the ERF scheme to reduce enteric emissions from cattle.	Produces Australian Carbon Credit Units (ACCUs) for the landholder, providing additional revenue generated from improving herd performance.	Dependent on the landholder to undertake project in line with the ERF methodology.	Suitable for some herds, depending on cattle age and farming techniques used.	ACT Government can encourage landholders to subscribe to such practices but cannot exert direct influence. ACT Government would need to acquire and surrender project ACCUs.
Limiting deforestation				
Planning and development to ensure deforestation from urban expansion is limited.	Preserves natural environments creating amenity; protects biodiversity; and has climate change resilience benefits.	Requires strategic urban planning to incorporate forest cover into new suburbs.	Dependent on urban planning, population growth and densification of suburbs.	Highly dependent on population growth pressures. Consumer preferences historically favour land expansion over densification.

Option description	Additional benefits	Policy	Technology	External factors / limitations
Afforestation / reforestation				
Foresting urban areas.	Has many cultural and environmental benefits to the local population including reducing the urban heat island effect and improving air quality.	Government-owned land can be directly controlled. For private land, other mechanisms would be required to encourage foresting.	Limited by area available, and constrained by utilities, structures and other land use impacts.	Requires input and support from private landholders. Limited impact due to limited available area. May lead to increased fire risk.
Foresting rural (agricultural) areas.	Improves ecosystem health and biodiversity on the land. Conversely, can decrease the efficiency of farming practices.	Can leverage the existing ERF scheme, however requires landholder engagement.	Often requires management activities such as removing feral animals or changes to livestock grazing practices.	Wholly dependent on private landholders. May lead to increased fire risk.
Foresting river corridors.	Enhances river corridor health, promoting water quality and biodiversity and preventing erosion.	Government-owned land can be directly controlled.	Limited by the ability of the ecosystem to support large trees.	Relatively small amount of land available (8,000 ha that has no forest). Most land is already somewhat forested – limited sequestration opportunity.
Foresting other land (broadacre).	Dependent on specific area.	Large amount of land available for afforestation.	Limited by the ability of the ecosystem to support large trees.	Wholly dependent on private landholders. Limited by land zoned to future urban areas and other conflicting land uses.

Pathway to zero emissions

The land sector is set apart from the other sectors in the ACT greenhouse inventory due to the large potential for sequestration it presents that can be used to offset emissions from other sectors to allow the Territory to achieve net zero emissions by 2050 or earlier. However, without careful management, the land sector could actually be a net emitter that will make the ACT's net zero target more difficult to achieve.

The optimal pathway for the land sector is shown in Figure 2. The recommended optimal pathway in the land sector has two key areas of focus:

- Limiting emissions due to deforestation
- Procuring additional land for afforestation and reforestation projects, in the urban environment, along river corridors, on agricultural land and on broadacre zoned land.

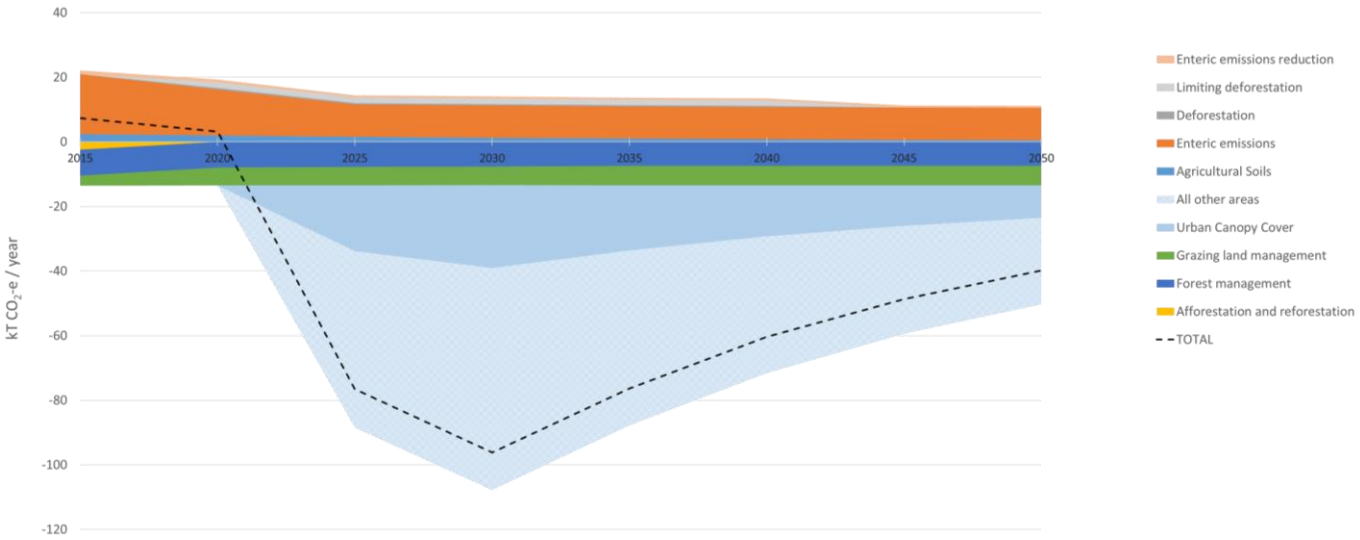


Figure 2 Optimal pathway for the ACT land sector, 2015 to 2050

It should be noted that sequestration from afforestation and reforestation occurs over the period in which the forest grows, typically around 30 years. Beyond this, not much additional sequestration is achieved as the forest reaches a 'steady state'. As such, land will need to be reforested or afforested on an ongoing basis if sequestration is to be achieved beyond 2050 (noting that this may present significant challenges in terms of land availability).

The specific options included in the proposed pathway are:

- **Limiting deforestation** - Targeting the development of Molonglo in particular could dramatically reduce the magnitude of emissions associated with deforestation in the ACT over the period to 2050. Abatement from limiting deforestation occurs over the times during which development is planned, and requires early engagement with urban planners and developers before the commencement of development activities.
- **Urban forest** - An urban forestry strategy could initially be targeted towards the northern suburbs of Canberra, where tree cover is less pronounced, and as low as 10% in some suburbs. Increasing forest cover in the urban environment would require specific strategies considering bushfire risks and other constraints relating to an urban environment.
- **Other forest land** - Increasing the forest cover in other areas would require separate strategies and programs for river corridors, agricultural land and broadacre zoned land. There is additional potential, if such land cannot be procured from these areas, to consider areas in ACT reserves that do not have forest cover.

Recommendations

To pursue the optimal pathway, Point Advisory recommends the following:

- Engage early with the strategic planning team to determine a way of limiting deforestation emissions associated with the expansion of new suburbs.
- Conduct a feasibility study into the ability to increase the urban forest within Canberra, to more accurately define an achievable target of urban forest cover and a policy suite for achieving this goal.
- Wherever possible, protect existing stocks of forest throughout the ACT.
- Educate and encourage landholders to undertake land management practices that sequester carbon in trees and soils on private lands.
- Conduct detailed assessments to identify suitable land for afforestation or reforestation projects in the ACT.

CONTENTS

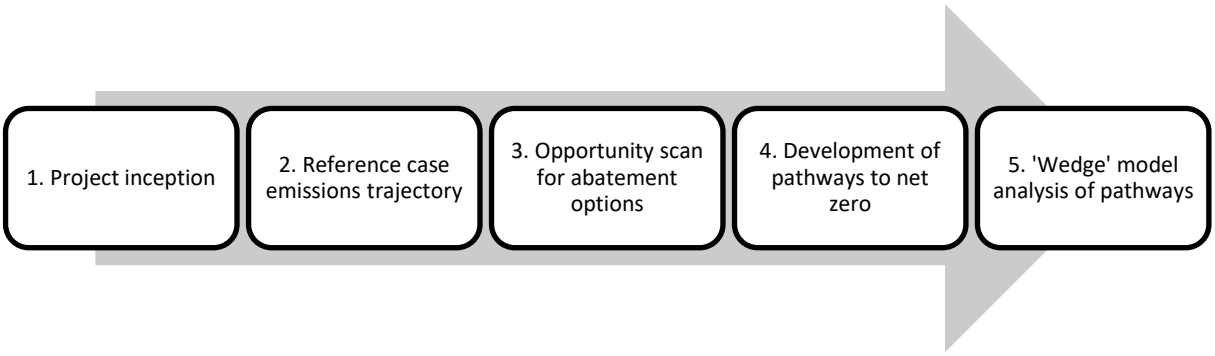
1 OVERVIEW

1.1 Background

The ACT Government has committed to a target of net zero carbon emissions by 2050. The target is enshrined in the *Climate Change and Greenhouse Gas Reduction Act 2010*.

Point Advisory was engaged by the ACT Government's Environment, Planning and Sustainable Development Directorate to model emissions reduction pathways for the land sector to enable the ACT to meet this target.

This engagement involved the following key steps:



Land sector emissions and sequestration modelling is based on the carbon accounting techniques used in the National Greenhouse Gas Inventory (NGGI), managed by the Australian Department of the Environment and Energy.

1.2 This report

This report summarises the outcomes of Point Advisory's modelling of pathways to net zero emissions for the land sector, and acts as a guide for the associated Emissions Reduction Model – Land Sector (the model). This report builds on prior work conducted for this engagement as summarised in two reports:

- ACT 2050 emissions modelling – land sector reference model
- ACT 2050 emissions modelling – land use emissions reduction options.

This report includes the following:

- Definitions of key terms and concepts related to the land sector
- The reference-case emissions and sequestration trajectory to 2050 (the 'business as usual' emissions trajectory)
- The quantification of options selected for emissions reductions and sequestration
- The pathways available for the ACT to reach net zero emissions by 2050 (noting that the cross-sectoral approach is dependent upon additional sequestration opportunities in the land sector).

A separate analysis was conducted by Point Advisory to estimate the potential carbon sequestration potential from afforestation and reforestation projects within 100 kilometres of the ACT. Results of this assessment are summarised in the report titled *"Reforestation and afforestation opportunities within 100 km of the ACT"*, but are not included in the pathway analysis presented in this report because the land is outside of ACT's geographic and carbon accounting boundary. However, the Executive Summary of the report has been included in Appendix 2 for completeness.

1.3 Modelling

Three versions of the emissions modelling are provided (low, medium and high) for both the reference case emissions trajectory and each carbon abatement opportunity to account for the inherent uncertainty involved in projecting future emissions:

- The 'high' scenario is the one that result in higher emissions – i.e. those that are pessimistic in terms of climate change mitigation, with relatively low levels of emissions abatement and sequestration from reference case policies and technologies.
- The 'medium' scenario is considered the most likely under the current settings.
- The 'low' scenario accounts for elevated levels of ambition, with high levels of abatement and sequestration and low level of emissions.

1.4 Key assumptions and limitations

The compilation of emissions reduction pathways is based on key assumptions driving the reference case emissions and sequestration modelling for the land sector.

- Land use in the ACT was assessed using spatial data from the ACTMapi website for land zoning and future urban areas, and from the Carbon Farming Initiative Mapping Tool 2015 forest layer. An estimation of forest cover was obtained using these datasets.
- Pathways and options were determined in consultation with the ACT Government. Options that were unlikely to influence the register were not considered further in this assessment.
- Natural fluxes in seasons along with long-term climate trends (for example drought and bushfires) result in the natural temporary growth and decline in density and extent of forest cover. For the purposes of this assessment, these natural fluctuations are assumed to cancel each other out over the period to 2050, and are therefore not included in modelling.
- All existing forest land in the ACT is mature forest and would not contribute to further sequestration in the inventory.
- Carbon accounting methodologies may change in the future, for example a better estimation technique for soil carbon.
- Forest cover is defined by a canopy cover of 20 %, over a minimum area of 0.2 hectares and with trees at least 2 metres in height.
- Forest wild fires (biomass burning) also have not been incorporated into the emissions model, given that *Background Paper 1: New emissions estimation methods for Land Use, Land Use Changes and Forestry and Agriculture* recommended in 2016 that natural disturbances (including fires) should not be reported under the National Inventory, to better align Kyoto and UNFCCC reporting (FullCAM and Agriculture Inventory Expert Advisory Panel, 2016).
- All pathways have been modelled to commence in 2020, to allow sufficient time for strategy, policy and operational considerations. Any delays, for example in securing land for afforestation, would shift the carbon sequestration periods, and securing land may be more difficult over time due to increasing competition of land uses.

2 LAND SECTOR EMISSIONS ASSESSMENT

2.1 Context

Carbon-related activities in the land sector can give rise to carbon emissions and carbon sequestration. This includes the carbon sequestration by forests and grasslands, and carbon embodied in wood products from plantations. For this analysis, the land sector includes agricultural activities.

Within the land sector, a large degree of uncertainty exists around both emissions and sequestration, and is heavily influenced by:

- climate - drought, fire and temperature and its impact on the growth and decline of forests;
- urban development - depending on population growth and urban planning (densification and expansion)
- land management practices and their impact on ecosystem carbon

To provide a basis for estimating emissions abatement and sequestration options in the ACT, a spatial analysis was conducted using the following sources:

- The Carbon Farming Initiative Mapping Tool forest layer from 2015, accessed on 31 March 2017
- ACT district boundaries and the planning cadastre obtained from ACTMapi.

Table 3 below summarises land zoning within the ACT according to the planning cadastre and the 2015 CFI Mapping Tool forest layer. The proportion of forest area for each land type is presented as an indication of future forest potential, but is subject to additional considerations regarding the constraints of the land use type (for example, urban land is constrained by existing roads and buildings).

Table 3: Land use and forest data for ACT (2015 data)

	Total area (ha)	Forested area (ha)	Forested %
Total area of ACT	235,790	140,702	60%
Total urban area (assessed)	25,719	4,000	16%
Total rural zoned land (minus plantations)	16,890	620	4%
Total river corridor land	11,997	3,760	31%
Total broadacre land	10,500	1,590	15%
Other land (designated and mountains)	12,000	-	-
ACT reserves – maintained by ACT Government*	146,601	121,678	83 %
Total cropland area in ACT (ABS, 2014/15 Agricultural Commodities)	344 (total crops) (<1%)	0	0

* includes the Googong Foreshore area outside of the ACT

The ACT is Australia's second most forested state or territory, behind Tasmania. This tends to limit the amount of sequestration that could be achieved through reforestation or afforestation activities within the ACT.

2.2 Categories of land sector abatement and sequestration

2.2.1 Change in forest cover

Changes in the amount of forest cover (through deforestation, reforestation or afforestation) result in a change in the carbon sequestered both above and below ground and are recorded in Australia's NGGI. Forest cover is defined in Australia as an area of at least 0.2 ha with trees above two metres in height and at least 20% crown cover. Forest area is mapped annually and made available in the CFI Mapping Tool forest layer.

The NGGI uses 1990 as a baseline for determining forest cover (in line with international carbon accounting rules). Where land that was not forested in 1990 obtains forest cover, it is classed as *afforestation or reforestation* and results in sequestration in the inventory. Where land that had forest cover in 1990 loses its forest cover, it is classed as *deforestation* in the inventory.

Natural fluxes in seasons along with long-term climate trends (for example drought and bushfires) result in the natural growth and decline of forest cover. For the purposes of this assessment, these natural fluctuations are assumed to cancel each other out over the period to 2050 and are therefore not included in modelling.

However, targeted human-induced regeneration projects can increase the forest cover within an area, resulting in additional sequestration being achieved. Such projects could involve removing a suppression activity (e.g. by managing feral animals) or actively managing the area (e.g. by replanting trees).

Deforestation can also be human-induced. Where forest land has been cleared for agriculture or urban development, it results in carbon emissions.

2.2.2 Forest management

Forest management relates to plantations within the ACT, and how their management impacts on net carbon amounts stored in the forest and in wood products. In the ACT, plantations are dominated by softwoods. Radiata pine is a fast-growing species that is most commonly used in plantations in the ACT.

Sequestration from forest management is dominated by the growth of plantation trees, and the embodied carbon in wood products (e.g. lumber and pulp) from plantations. The amount of wood and wood products produced is proportional to the area of plantations and growth rates, subject to appropriate silvicultural management.

Emissions from plantations arise when trees are felled and unutilised wood and harvesting debris decays on site. A lower rate of emissions results from decay of timber and wood products in use.

2.2.3 Grazing land management

Grazing land management comprises the management of permanent grasslands, forest converted to grasslands before 1990, and croplands converted to grassland. Permanent changes in management practices that generate changes in the levels of soil carbon or woody biomass stocks impact on emissions and sequestration under grazing land management. The quantity of carbon stored in both the soil and woody biomass is in a constant state of flux and can be influenced by management activities to a limited degree.

2.2.4 Cropland management

Cropland management covers permanent croplands, forests converted to cropland prior to 1990, and land set aside for crop production, and how the management of this land impacts on the carbon stored in the environment. Management practices include crop types and rotation, stubble management, tillage techniques, fertiliser application, soil ameliorants, application of green manures and changes in land use.

2.2.5 Enteric emissions

Enteric fermentation is a digestive process whereby feed is broken down in the gut of ruminant animals, creating methane in the process. Enteric fermentation is assessed in the inventory primarily based on the number of cattle and sheep in the ACT, with other livestock representing a small portion of emissions.

2.2.6 Agricultural soils

Emissions from agricultural soils consist of direct soil emissions (dominated by urine and dung deposited by grazing animals and organic fertilisers) and indirect soil emissions (nitrogen leaching and runoff and atmospheric deposition).

3 REFERENCE CASE

This section summarises the findings of the reference case assessment compiled for the ACT Government for the land use sector. The reference case trajectory assumes that the ACT Government does not take any **additional** policy action that could have an impact on carbon emissions. ACT policies and planning that are commenced or committed are assumed to continue. The reference case can be considered the 'business as usual' emissions trajectory.

Many components of the reference case trajectory are based on information provided in *Australian Land Use, Land Use Change and Forestry Emissions Projections to 2030* (Department of the Environment, 2015).

Detailed information about the assumptions used to model the reference case for this project are contained in Point Advisory's *"ACT 2050 emissions modelling – land sector reference model"* report. The projected reference case emissions for the land sector in the ACT from 2014 to 2050 is given below in ***Figure 3***.

In the reference case, emissions from forest management and deforestation dominate the inventory, while sequestration from forest management and grazing land management helps to offset these emissions.

The following results are evident from the reference case model:

- Each scenario is dominated by emissions from enteric fermentation and deforestation, and sequestration from forest management.
- Under the **low** reference scenario, emissions from enteric fermentation and deforestation gradually decline over the period, resulting in a net carbon sequestration totalling 2 kt CO_2-e.
- Under the **medium** reference scenario, emissions from enteric emissions and deforestation peak between 2025 and 2040. Beyond 2045, deforestation ends, resulting in net emissions of 7 kt CO_2-e in 2050.
- Under the **high** reference scenario, emissions from deforestation continue through to 2050, resulting in net emissions of 26 kt CO_2-e in 2050.

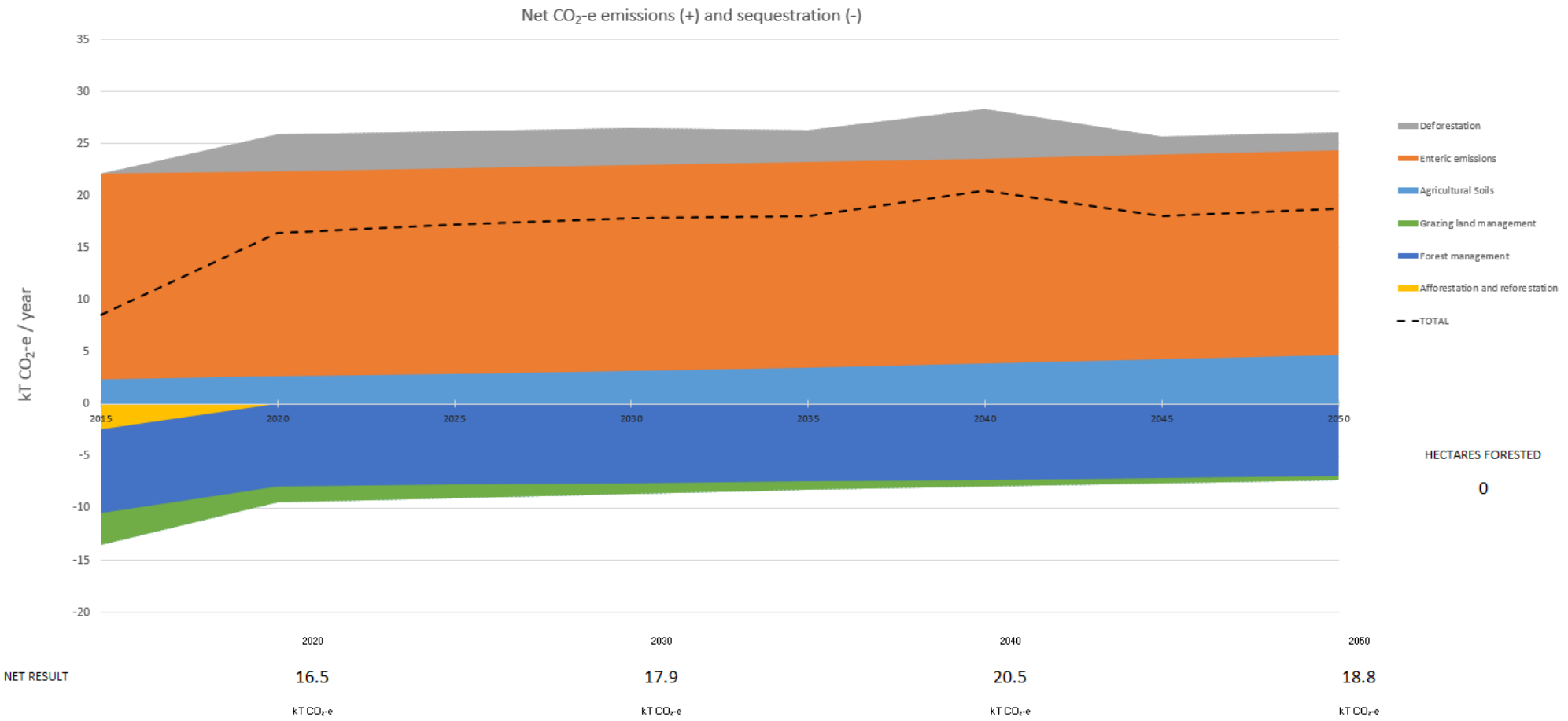


Figure 3 Summary of reference case emissions (positive) and sequestration (negative) in the land sector in ACT from 2015 to 2050: medium scenario

3.1 Reference case emissions

3.1.1 Deforestation

In the reference case, emissions from deforestation occur due to the conversion of forest land to urban land (as a result of planned development) in the areas of Gungahlin, Molonglo and Majura Valley.

Most emissions from deforestation result from the urban development of Molonglo, where 283 hectares of forest land could potentially be cleared. Under the modelled scenarios, between 30% and 90% of this forest is cleared due to urban development. This results in a spike in emissions from deforestation between 2025 and 2040, when these areas are expected to be developed.

Deforestation in Majura Valley only occurs under the high emissions scenario. In the low and medium scenarios, the grasslands in the western section of Majura Valley are developed, and no conversion of forest land to urban land takes place. Under the high scenario, urban development reaches the forests in the eastern section of Majura Valley, where 119 hectares of forest could potentially be cleared.

Emissions from the deforestation of forest land in Gungahlin make up a small proportion of projected emissions, as only 33 hectares of forest could potentially be cleared in this suburb.

3.1.2 Enteric emissions

Emissions from enteric fermentation are steady to 2050, due to a stable population of cattle and sheep over this period.

In 2014-15, the ACT had 46,360 sheep and lambs and 6,367 cattle (ABS, 2016). Cattle numbers in the ACT have declined steadily since 2006, when numbers reached 13,300 (ABS, 2013). While sheep and lambs dominate numbers, beef cattle are the equivalent of 8 to 10 dry sheep equivalent (DSE) units (Adelaide and Mount Lofty Ranges NRM Board, 2017). Enteric fermentation calculations are based on DSE units, hence cattle dominate emissions from this source in the ACT, whereby a reduction of one DSE reduces emissions by around 200 kg CO_2-e (Department fo Agriculture and Food et al, 2013).

3.1.3 Agricultural soils

Emissions from agricultural soils were predicted to remain relatively stable over time, and have accounted for less than 3 kT of CO_2-e abatement since 2010, a small proportion of the inventory.

3.2 Reference case sequestration

3.2.1 Forest management

Forest management provides a steady source of sequestration to 2050 and comes exclusively from commercial plantations in the ACT. At present, the ACT has around 10,350 hectares of plantations, with the majority comprised of softwoods. The area of plantations is expected to decrease by 8% due to the rehabilitation of the Lower Cotter Catchment following the 2003 fires, and thus the sequestration from forest management is also expected to decline by 8% until 2035.

3.2.2 Afforestation and reforestation

Sequestration from afforestation and reforestation is expected to decrease to zero in 2020 due to the slowing growth of established forests and no plans for plantation expansion. This is consistent with the national inventory, and is due to the increasing average age of post-1990 forests (Department of the Environment, 2015).

3.2.3 Grazing land management

Sequestration from grazing land management is predicted to remain constant beyond 2010 in *Australia's LULUCF emissions to 2030* (Department of the Environment, 2015), and this forms the basis of projections within the ACT. Sequestration from grazing land management fluctuates significantly over time, according to land

management practices and the climate. It was assumed in this projection that the area of pasture fertilised does not increase.

3.2.4 Excluded sources

No other categories of emissions or sequestration were included in the land sector inventory as they were deemed to be immaterial. This includes manure management, liming and field burning of agricultural residues, none of which produced any emissions or sequestration in the ACT in 2014. Cropland management is also immaterial to the inventory, as just 65 hectares of broadacre crops exist within the ACT (ABS, 2016).

4 LAND SECTOR ABATEMENT AND SEQUESTRATION OPTIONS

Point Advisory developed a list of emissions abatement and sequestration options that may exist to assist the ACT Government in achieving net zero emissions by 2050.

These options were further refined, and all viable options were modelled to understand the impact they could have on the ACT's land sector greenhouse gas emissions profile over the period to 2050. Summary information on each of the modelled options is provided in this section. Further detail on all options considered can be found in Point Advisory's *"ACT 2050 emissions modelling – land use emissions reduction options"* report.

4.1 Emissions reductions options

Emissions reduction options were targeted at the most material sources of emissions within the land sector. The modelled options are described below.

4.1.1 Enteric emissions

Emissions from enteric fermentation are driven by cattle numbers in the ACT, with other livestock representing a small portion of emissions. By developing projects using the *Beef Cattle Herd Management* method under the Commonwealth Government's Emissions Reduction Fund (ERF), emissions from enteric fermentation can decrease by up to 15%. Using this mechanism to achieve emissions reductions is contingent on the ACT Government acquiring and surrendering the carbon credits created by these projects to claim the abatement.

The *Beef Cattle Herd Management* method involves increasing either the weaning percentage (the percentage of exposed females that weaned a calf) or the average daily weight gain in young cattle. The herd management method is highly dependent on the type of farming operation (e.g. weaning, backgrounding, finishing) and the current level of herd productivity. To comply with the herd management method, property managers in the ACT would be required to initiate new or substantially different activities to achieve improvements in productivity.

The largest opportunities for applying the herd management method in the ACT context are likely to be improving weaning percentages and growth rates in young cattle. Based on the ABS cattle data from 2014/15, it is assumed that most producers in the ACT practice weaning operations, where farms sell weaner calves at approximately 185 days of age. The weaners may be moved into live export or southern supply chains depending on the season and market conditions.

To achieve higher weaning percentages, a variety of options are possible, including:

- Targeted, higher rates of supplementation for breeder cattle
- Segregated heifer management to improve weaning rates on second calf heifers
- Reduced stocking rates (culling unproductive animals) to improve feed quantity for the remaining, more efficient herd
- Installation of fences to allow rotational grazing, as well as approaches to improve feed availability and improve management (herd segregation).

Key assumptions and limitations: Enteric emissions reductions
This option relies on the following: • The calculation of emissions, and emission reductions opportunities, according to the *Beef Cattle Herd Management* Method. • Private landholders would have to sign up to a project using the Beef Cattle Herd Management Method

- The ACT Government would have to retire the Australian Carbon Credit Units (ACCUs) generated by the project.

Key risks: Enteric emissions reductions

- Implementing the Method requires an investment in time and resources and may incur additional costs on the owner of the cattle that are not repaid.

Key co-benefits: Enteric emissions reductions

- The creation and sale of ACCUs will represent an additional revenue source for farmers.
- Farm productivity will be improved by the ERF project mechanism.

4.1.2 Limiting deforestation

Reducing emissions from deforestation arising from urban development depends on urban planning to incorporate existing forests into the design of new suburbs and/or reducing urban encroachment into forested land. This applies to the urban development of the Molonglo, Majura Valley and Gungahlin areas. Of these areas, Molonglo (the largest) was deemed to have the most significant opportunity to avoid deforestation.

Key assumptions and limitations: Limiting deforestation

- Limiting deforestation is based on reducing the amount of land that is deforested due to urban development by 40%, 60% and 80% under the high, medium and low scenarios respectively.
- Forest retention is dependent on the scale of urban development required, based on population demands and the planned density of the area, and may not be possible in some areas.
- Other considerations such as increasing the density of development (initially resulting in greater tree loss) to limit encroachment in the future may have merit in the long-term.

Key risks: Limiting deforestation

- Bushfire risk is a major consideration. Requirements must be met related to bushfire abatement zones, bushfire prone areas and fire management zones.
- While this could not be incorporated into calculations at this level of analysis, the first priority within suburbs is to ensure the safety of occupants and homes – any unsafe trees should be removed.

Key co-benefits: Limiting deforestation

- Mitigation of rises in average temperature due to man-made structures, lowering cooling energy demands in summer and improving resident comfort.
- Reduced negative impacts of development related to air and water quality.
- Enhanced protection of habitats and promotion of biodiversity outcomes.

4.2 Sequestration opportunities: afforestation and reforestation

The amount of land that can be afforested/reforested is constrained by competing land uses. Notwithstanding, afforestation and reforestation presents the largest opportunity for sequestration in the ACT.

4.2.1 Increasing urban forest cover

Afforestation and reforestation can occur in the Canberra urban area, where it is estimated that up to 4,000 hectares of additional forest cover could be achieved under the low emissions scenario. This would double the size of Canberra's current urban forest.

The urban area of Canberra is around 25,720 hectares. The Carbon Farming Mapping Tool assessed the forest land over this area to be equal to approximately 4,000 hectares, or 16% of the total urban area. This number

does not represent the entire canopy /tree cover of Canberra, as it only captures groups of trees that meet the definition of forest.

At present, many cities are creating or updating their urban forest strategies as the benefits of urban forests become more apparent. Urban forests are a key mitigatory of the urban heat island effect, and can lower localised temperatures by up to 11 to 25 degrees Celsius (USEPA, 2016). They also have the beneficial effects of improving air and water quality, while reducing runoff and the need for pavement management. Urban forests also have many cultural, health and social benefits for their aesthetic qualities.

An examination of the distribution of the urban forest in Canberra was conducted by distinguishing three regions – central Canberra, northern Canberra and southern Canberra – and excluding the major reserves of Black Mountain, Bruce Ridge, Mount Ainslie and Mount Majura. The analysis showed that forests covered just 7% to 12% of the land in the suburbs to the south and north of Canberra.

This is consistent with a Statistical Subdivision analysis in i-Tree that estimated a low canopy cover for Weston Creek-Stromlo, Belconnen and Gungahlin-Hall (ranging from 10% to 16%), and moderate cover in South Canberra, Tuggeranong and Woden Valley (ranging from 20% to 28%) (Institute for Sustainable Futures, 2014). I-Tree is a peer-reviewed scientific software from the USDA Forest Service and provides an analysis of the benefits associated with urban forests.

Key assumptions and limitations: Increasing urban forest cover

The option for increasing urban forest cover has been defined based on the following assumptions:

- For this option, modelled scenarios were based on increasing the current urban forest by 25% (high), 50% (medium) and 100% (low).
- The forest cover from the 2015 Carbon Farming Mapping Tool layer has been taken as the baseline forest cover, and it has been assumed that no conversion of urban forest land would take place (and thus all new plantings are additional forest cover).
- For modelling purposes, Canberra's existing forest is assumed to be steady-state (no additional growth). However, in some areas in Canberra, the urban forest is nearing its end of life and will require work to maintain the current level of forest.
- The FullCAM model (the Commonwealth Government's Full Carbon Accounting Model) estimates carbon stock based on above ground carbon (stored in trees), below ground carbon (stored in roots) and carbon stored in debris. It is assumed that the composition of the urban forest is similar to this representation in FullCAM.

Key risks: Increasing urban forest cover

- Bushfires are a major factor when planning tree cover in urban areas in Canberra; Bushfire abatement zones, Bushfire prone areas and fire management zones should all be considered in planning.
- While this could not be incorporated into calculations at this level of analysis, the first priority within suburbs is to ensure the safety of occupants and homes – any unsafe trees should be removed, regardless of any carbon considerations.

Key co-benefits: Increasing urban forest cover

- Mitigation of rises in average temperature due to man-made structures, lowering cooling energy demands in summer and improving resident comfort.
- Reduced negative impacts of development related to air and water quality.
- Enhanced protection of habitats and promotion of biodiversity outcomes.

4.2.2 Afforestation and reforestation of all other areas

Other land targeted for afforestation and reforestation includes:

- Agricultural land – up to 3,000 hectares (18% of total available non-forested land)
- Land along river corridors in the ACT (excluding where this overlaps with the urban area) – up to 5,880 hectares (23% of total available land)
- Broadacre land set aside for potential future development - up to 3,970 hectares (29% of total available land).

The amount of land to afforest/reforest for each land type was estimated based on what was considered achievable. Increasing forest cover in each of these areas would require separate policies and programs.

River corridors comprise 11,997 hectares in the ACT, of which around one third is forested. Under the low emissions pathway, the forested area is increased by 2,740 hectares. As the ACT Government has direct control over these areas, carrying out plantings should be relatively straightforward and is only constrained by available resources and environmental considerations (as not all land may be able to support trees).

Rural-zoned land currently has a low percentage of forest cover (less than 4% of the total 16,890 hectare area). Under the low emissions scenario, an additional 3,000 hectares of this land is afforested/reforested. This is dependent on the management practices of landowners, although the ACT Government could support such practices. Regeneration methods under the ERF could be used to incentivise landowners to increase forest cover on their land, which in turn would count as sequestration in the ACT Government's greenhouse gas inventory.

Around 15% of the 10,500 hectares of broadacre zoned land in the ACT is currently forested. Under the low emissions pathway, the forested area is increased by 3,000 hectares. Due to planned development in the Majura Valley, urban expansion would limit the ability to reforest a large proportion of available broadacre land. The ACT's other large area of broadacre land is around Jerrabomberra, and may also be developed into urban area.

If significant proportions of these areas cannot be unlocked for afforestation and reforestation, the ACT Government may be able to find additional suitable non-forested land in ACT Reserves. Land within 100 km of the ACT was also assessed for its afforestation/reforestation potential in a separate study by Point Advisory. The key findings of this study are provided in Appendix 2 of this report.

Key assumptions and limitations: Afforestation and reforestation of all other areas
Increasing forest cover of other areas within the ACT relies on the following: • The forest cover from the 2015 Carbon Farming Mapping Tool layer has been taken as the baseline forest cover, and no conversion of forest land would take place (and thus all new plantings are additional forest cover). • The protection of native grassland in the ACT is assumed to not limit the land available for reforestation / afforestation. • Slopes and soil type may further restrict land suitable for afforestation / reforestation.
Key risks: Afforestation and reforestation of all other areas
• Bushfires are a major factor when planning tree cover in urban areas in Canberra; Bushfire abatement zones, bushfire prone areas and fire management zones should all be considered in planning. • For afforestation or reforestation of privately owned land, commercial considerations and competing land uses may create barriers.
Key co-benefits: Afforestation and reforestation of all other areas
• Improved water quality in regional ecosystems. • Increased river health and enhanced biodiversity in riparian areas. • Enhanced protection of habitats and promotion of biodiversity outcomes.

4.3 Screened options (no further investigation)

The following options were considered for application in the ACT, but not continued for a variety of reasons including immaterial impact on the inventory or low practicality for implementation.

Forest management

The ACT Government confirmed that no new plantations were planned within the ACT. As such, increasing plantations was not assessed further as a viable sequestration option.

Grazing land management

Due to scarcity of options for improving carbon management farming practices for grazing land, opportunities within grazing land management were estimated not to have a material effect on the ACT land sector inventory, and these options were not assessed further.

Cropland management

The potential sequestration and emissions reduction opportunities through cropland management (application of green manures, soil ameliorants and changes in land use) are not material to the land sector inventory of the ACT.

Agricultural soils

Options to decrease emissions from agricultural soils involve either reducing cattle numbers or reducing fertiliser use. Due to natural fluctuations in soil carbon as a result of farming practices and climate, and the low sequestration potential (under current scientific understanding), agricultural soils were not assessed further.

5 PATHWAY TO ZERO NET CARBON EMISSIONS BY 2050

An interactive model was created to enable users to plot emissions and sequestration options for the land sector in the ACT out to 2050, and to visualise the impact of these opportunities on the territory's emissions trajectory. The 'optimal' pathway, as determined by Point Advisory in consultation with the ACT Government, is shown in Figure 4.

This pathway includes a combined approach of reducing emissions from the land sector while increasing sequestration from reforestation and afforestation activities within the Territory. Specifically, the pathway includes:

- Limiting deforestation as much as possible in new land developments in the ACT.
- Doubling the amount of forest cover within the Canberra urban area.
- Applying afforestation/reforestation projects to river corridors, rural and broadacre-zoned land to the extent of 8,740 hectares (summing the options from section 4.2.2).

As an option, the pathway could also include:

- Maximising use of the *Beef Cattle Herd Management* method (under the ERF) to reduce emissions from enteric fermentation (although, as discussed, the ACT Government may have limited ability to activate this opportunity).

Under this pathway, 12,740 hectares of land is reforested, resulting in net removals of 385 kt CO_2-e over the period 2025 to 2050 (see Figure 4). This land would be a mix of publicly owned land along river corridors, in urban areas and on broadacre zoned land, and privately owned agricultural land.

The pathway does not include maximising afforestation and reforestation within the ACT, as there are many limiting constraints including competing land uses with agricultural land and urban areas. Nor does it include reforesting land outside the ACT due to specific constraints around carbon accounting for sequestration from outside of the ACT's geographic boundary.

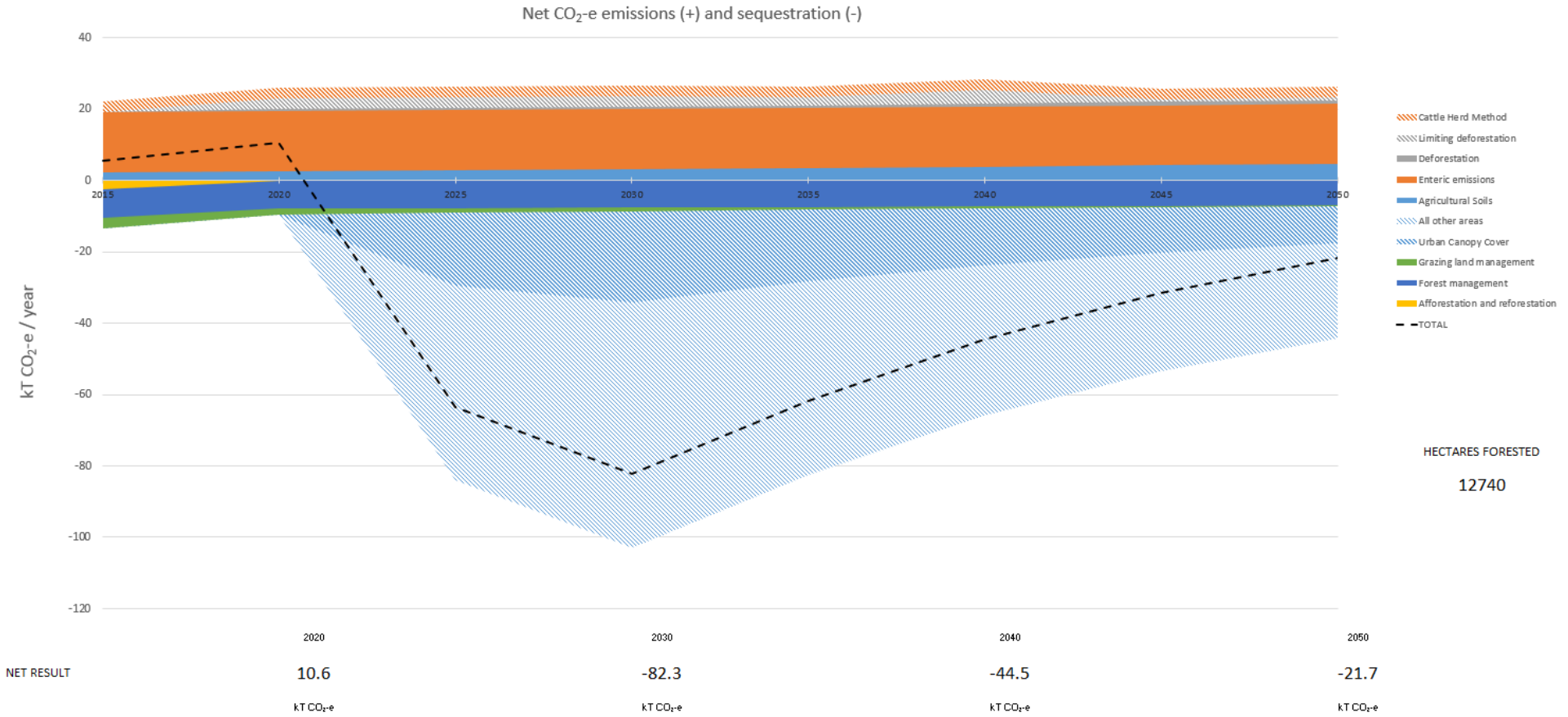


Figure 4 Optimal pathway to net zero emissions for ACT, 2014 to 2050

5.1 Implementing the pathway

Achieving the optimal pathway is dependent on substantially increasing the net area of forest in the ACT. This is based on the balance between avoiding deforestation and driving afforestation and reforestation. Forestry projects are likely to require several years for planning and implementation. For the purposes of conservative modelling to 2050, all projects in the pathway commence in 2020. Delays in projects of up to ten years would shift the maximum growth curve closer to 2050, thereby increasing sequestration in this year, but decreasing it in earlier years. However, the total sequestration from an afforestation or reforestation project is finite, and there is effectively no further sequestration potential for a particular plot of land once its forest reaches steady-state.

Deforestation results in the quick release of carbon emissions, whereas sequestration from afforestation and reforestation occurs over a period greater than 30 years. Thus, avoiding deforestation should be favoured over securing additional land for afforestation and reforestation.

Increasing the size of the urban forest may act to limit population density and result in the need for sprawl, leading to further emissions from deforestation. As such, a comprehensive urban plan is required to balance these demands with the predicted population growth of Canberra. The plan should consider retaining as much existing forest cover as possible, while identifying areas that can be reforested.

Afforestation and reforestation projects on agricultural land may also decrease the number of grazing animals that the land can support. This may act to reduce the ACT's total livestock numbers, thereby also driving down emissions from enteric fermentation.

Securing additional land for afforestation and reforestation along river corridors, in rural areas and on broadacre zoned land is independent of other options.

6 RECOMMENDATIONS

To achieve the optimal pathway and ensure that land sector emissions are kept within predicted ranges, Point Advisory recommends the following:

- Engage early with the strategic planning team to determine a way of limiting deforestation emissions associated with the expansion of new suburbs.
- Conduct a feasibility study into the ability to increase the urban forest within Canberra, to more accurately define an achievable target of urban forest cover and a policy suite for achieving this goal.
- Wherever possible, protect existing stocks of forest (including the urban forest) throughout the ACT, and develop a plan to replace dieback of old trees in the urban forest.
- Educate and encourage landholders to undertake land management practices that sequester carbon in trees and soils on private lands.
- Conduct detailed assessments to identify suitable land for afforestation or reforestation projects in the ACT.

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Appendices

APPENDIX 1 GLOSSARY

ACT	Australian Capital Territory
CO_2-e	Carbon dioxide equivalent (unit of measurement) A standard unit for measuring carbon footprints across a number of greenhouse gases.
ERF	Emissions Reduction Fund
FullCAM	The Commonwealth Government's Full Carbon Accounting Model
kt	kilotonnes
LULUCF	Land use, land use change and forestry
NGGI	National Greenhouse Gas Inventory

APPENDIX 2 SEQUESTRATION OPTIONS OUTSIDE THE ACT

Point Advisory conducted a study to assess, at a coarse scale, the potential for carbon sequestration from afforestation and reforestation activities in the area 100km outside the ACT's boundary. The findings of this study are summarised in the report titled *"Reforestation and afforestation opportunities within 100 km of the ACT"*.

The study involved analysis using geographic information systems to determine the land available for reforestation and afforestation activities in the relevant area. A sample of points within this area were then modelled in the federal government's FullCAM program to determine the approximate carbon sequestration potential within the available land.

The key findings of the analysis are presented in Table 1.

Table 1: Summary findings of analysis

Total area of land available for reforestation and afforestation within 100 km of ACT	2,291,900 hectares
Average sequestration potential of available land over period 2020 to 2050	166.3 tCO_2-e per hectare
Total sequestration potential of available land over period 2020 to 2050	380,871 $ktCO_2$-e

Refer to the *"Reforestation and afforestation opportunities within 100 km of the ACT"* report for more detailed analysis and findings.