Australian National University

9 May 2017

Climate Change Policies Review – Discussion Paper Submissions
2017 Review Branch
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Submission to the Review of Australia's Climate Change Policies by the Australian National University Climate Change Institute and Energy Change Institute

Dear Review Committee

Please find enclosed a submission by the Australian National University (ANU) Climate Change Institute and Energy Change Institute to the Review of Australia's climate change policies.

The mission of the ANU Climate Change Institute (CCI) is to contribute to climate change solutions through innovative, interdisciplinary approaches to research and teaching, drawing on the wealth of expertise across the University, and to connect our work to governments, the private sector and civil society.

The ANU Energy Change Institute (ECI) combines leading research and teaching on the technologies, efficiency, policy, law, sociology and economics of moving to a sustainable and dominantly renewable energy future.

Together the CCI and ECI comprise more than 400 researchers on climate change and energy from throughout the ANU.

We would welcome the opportunity to meet with members of the Review Committee to discuss our submission further.

Yours sincerely,

Professor Ken Baldwin
Director, ANU Energy Change Institute

Professor Mark Howden,
Director, ANU Climate Change Institute

Introduction

The ANU Climate and Energy Change Institutes represent over 400 researchers from throughout the university, including experts on the earth's systems, climate impacts and adaptation, climate change mitigation, institutional responses to climate change and transformational approaches. In the energy sphere, our members' expertise encompasses science, engineering, economics, policy, regulation and sociology.

Given the wide-ranging nature of the Review and the diversity of expert researchers at the ANU, we have chosen to contribute an overall submission, in parallel with some individual researchers who are providing their own submissions in their specific area of expertise.

In this regard we will refer to the following individual submissions by ANU Climate and Energy Change experts:

- Dr Paul Burke's submission provides an analysis of Australia's emissions reduction policies.
- Professor Andrew Blakers' and Dr Matthew Stocks' submission outlines a roadmap to greenhouse neutrality for Australian energy generation and use.

Significant to this review, we wish to emphasise the importance of a climate change policy which includes all dimensions of climate change: climate science, impacts, mitigation, and adaptation. A policy which addresses only mitigation is best considered an emissions policy, rather than a climate change policy.

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Australia’s Future Emissions Targets

Prepared by Professor Frank Jotzo, Crawford School of Public Policy, ANU.

Key message: Longer-term emissions targets are essential to signal Australia’s intent on climate change action to the world community, and to help guide investors’ expectations. The experience of rapid change in energy technologies should inform the decision making process for post-2030 targets.

Australia will be expected to make a commensurate contribution to the global climate change mitigation effort. Australia’s relatively high per capita emissions, high per capita income and large potential to reduce emissions all tend to indicate that a relatively strong emissions reductions target would be considered a commensurate contribution. Australia’s longer term target also needs to be considered in the context that for global temperature stabilization, global emissions need to be net zero in the longer term.

Modelling of the presumed future economic effects of emissions reductions policies has an important role in informing the decision about a national target. In undertaking and evaluating such modelling, it should be kept in mind that the experience with such modelling exercises over the past decade (including government studies in Australia) has consistently been that the availability and cost of low-emissions technologies turn out better than assumed in the modelling. Prominent examples are the drastic reduction in solar PV costs, electricity demand reductions by households, and the emerging technical options to integrate very high shares of renewable energy into the power grid. None of these factors were properly anticipated in the modelling studies of just ten years ago, and hence the estimates of economic costs in these studies were likely too high.

The setting of longer term emissions targets also needs to be seen in the context of broader economic structural change. Much of Australia’s high emissions infrastructure is relatively old, which can help facilitate a transition to a lower emissions economy and ultimately decarbonisation while maintaining economic growth and prosperity.

For further discussion on these points regarding Australia’s future emissions targets

Contact Professor Frank Jotzo, ANU Crawford School of Public Policy at Frank.Jotzo@anu.edu.au or +61 2 6125 4367.

Lack of consideration of health impacts and opportunities with regards to climate change

Prepared by Professor Robyn Lucas, Research School of Population Health, ANU.

Key message: We need to consider the health impacts of climate change and policy responses.

There is not a single health-related climate change policy included in the document, despite health risks being recognised as an important driver of action on climate change.

The set of questions at the end of each section should also include health considerations in addition to jobs, investment, trade competitiveness etc. For example policies to reduce emissions in the transport sector have particular health benefits around improving air quality and also encouraging active transport which has a range of health and other benefits.

Climate change is a major contributor to current and future health inequities; that is, avoidable differences in health between different population groups within Australia. Climate change policies should specifically address what effects they will have on equity, including health equity.

For further discussion on these points regarding health and climate change

Contact Professor Robyn Lucas, ANU Research School of Population Health at Robyn.Lucas@anu.edu.au or +61 2 6125 3448.

Financing emissions reduction technology

Prepared by Dr Matthew Stocks, ANU Research School of Engineering, ANU.

Key message: Low cost finance is critical for lowest emission reduction technology costs.

Low cost finance is critical to minimising the cost of low emission electricity generation. Finance costs are strongly connected to risk. There are several policy approaches that reduce risk for project development and reduce the cost of finance.

a) Reduce risk on the income stream through long term power purchase agreements (PPA)
b) Provide access to low cost finance through government support agencies
c) Provide long term (10+ years) policy direction to reduce risk in long term planning

Policy makers should ensure that their policy decisions are leading to reductions in the cost of finance so that the lowest cost solutions to reducing emissions are enabled.

This piece has relevance to the following questions from the Climate Change Policies Review Discussion Paper.

1. Australia's Paris target: Australia has committed to considering a potential long-term emissions reduction goal for Australia beyond 2030. What factors should be considered in this process?
2. Australia's Paris target: What are the issues in the transition to a lower emissions economy with respect to jobs, investment, trade competitiveness, households (including low income and vulnerable households) and regional Australia?
3. Electricity generation: What are the opportunities and challenges of reducing emissions from the electricity sector? Are there any implications for policy?

Background

Most technologies that support lower emissions (wind, photovoltaics, hydro, solar thermal, pumped hydro storage, batteries) are long lived, high capital investments with no fuel cost and low ongoing maintenance costs. The cost of finance is therefore important to determine project economics. A commonly accepted approach to evaluate the viability of a project is to look at net present value which is the discounted benefits minus costs added together over the life (L) of the project.

$$\text{Net present value} = \sum_{N=0}^{L} \frac{\text{Benefits} - \text{Costs}}{(1+r)^N}$$

If the net present value over the life of the project is positive, it is a worthwhile investment. The term "r" is the discount rate, which in practice is the real cost of finance (interest rate – inflation). The cost of finance means that the future benefits (energy) are discounted due to the need to repay the capital expenditure. The effect of the total discount increases the further into the future the benefit is accrued. The lower the discount rate, the greater the value of the future benefits and the more likely a project will be viable.

The levelised cost of electricity (LCOE) is frequently used to compare energy projects. It is the average price of energy (benefit) that the project needs to receive for the project to break even (net present value = 0). For most renewable projects which have low fuel and maintenance costs it is dominated by the initial capital cost.

$$\textbf{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \approx \frac{\text{Initial Capital Investment}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

The impact of the cost of finance can be clearly seen in a typical example in Figure 1. This shows the levelised cost of a typical long lived (25 year) capital intensive investment (in this case, an off-shore wind farm) as a function of the cost of finance (weighted average cost of capital or WACC). As can be seen from the blue line in Figure 1, if the WACC is 8%, half of the final cost of the generated electricity is due to the finance costs. High capital cost projects require low cost finance to minimise energy costs.

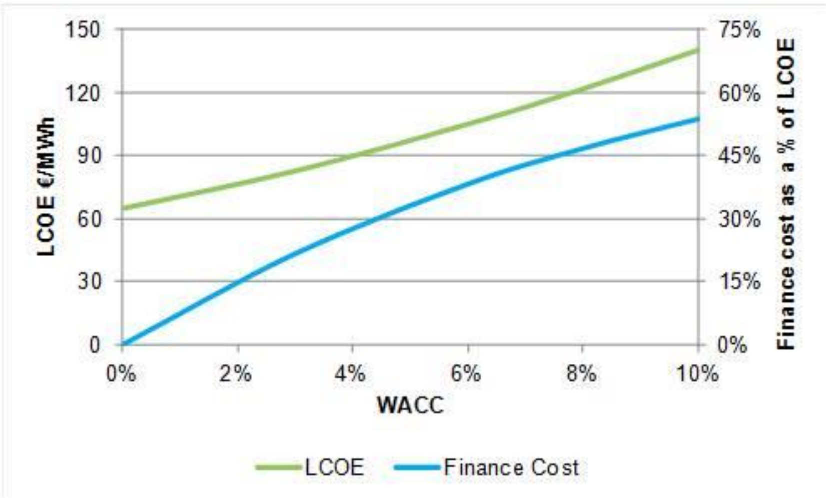

Figure 1. The effect of discount rate (WACC) on the levelised cost of electricity for an off-shore wind farm with a 25 year life (BVG Associates).

Examples of low cost projects

The ACT government reverse wind auctions are an excellent example of where good policy helps to drive down costs. The ACT reverse auctions guarantee a fixed payment for the electricity that is generated with no market variation risk to the project developed. The resulting risk for the income stream is low since the ACT government is a guaranteed customer. The risk is shared between the project developer and the PPA provided. Consequently, financiers can offer lower cost finance due to the reduced income risk.

The second round auction enabled record low wind prices for Australia and NSW. The Hornsdale bid of AUD$77/MWh is equivalent to a real price of AUD$65 (adjusted for inflation of 1.5%). Victoria and Queensland are adopting similar approaches, recognising the benefits to reduced costs of the ACT scheme.

A review of the worldwide record low cost solar projects highlights the importance of power purchase agreements.

1) Dubai, UAE – US$29.9/MWh for 800MW
2) Chile – US$29.1 MWh for 120MW
3) Mexico – US$35/MWh for 426MW
4) USA – US$S39/MWh for 100MW
5) Peru – US$48.5/MWH for 185MW

The PPA does not reduce the capital cost of the project or improve the technology. It reduces income risks and therefore the cost of finance.

Key take-away: do not assume fixed finance costs or discount rates

Policy development around low emissions pathways must consider the cost of finance. Reducing finance has a major impact on the energy cost of capital intensive low emission solutions. Comparisons of different policy options often assume fixed discount rates. Different policy instruments will strongly affect the cost of finance. The lowest cost solutions may develop from the right choice of policy.

Discuss the implication of policy choices on finance costs with key players such as ARENA, the CEFC, project developers and financiers. This should help guide good economic modelling and subsequent policy decisions.

For further discussion on these points regarding financing emissions reduction technology

Contact Dr Matthew Stocks, ANU Research School of Engineering at Matthew.Stocks@anu.edu.au or +61 2 6125 9876.

Electricity generation

Prepared by Professor Ken Baldwin, Director, ANU Energy Change Institute

What are the opportunities and challenges of reducing emissions from the electricity sector? Are there any implications for policy?

Australia's energy generation comprises 35% of greenhouse gas emissions so this sector is a clear opportunity for significant emissions reductions starting in the near term. The challenges and policy implications are summarised below.

How can energy and climate policy be better integrated, including the impact of state-based policies on achieving an effective national approach?

A good starting point to integrate energy and climate policy is to include environmental goals in the National Electricity Objectives, as indicated below. A coordinated national approach is needed that embraces the States to ensure that the goals and structure of the National Electricity Market (NEM) in particular provide a coherent framework.

Are there particular concerns or opportunities with respect to jobs, investment, trade competitiveness, households and regional Australia that should be considered when reducing emissions in the electricity sector?

Because of the disseminated nature of renewable energy, there is enormous opportunity for jobs growth compared to less employment-intensive, conventional centralised electricity generation. In particular, wind farms and solar installations (particularly rooftop) will bring significant employment to regional areas.

Further, in relation to trade, as noted below there is a considerable risk that if Australia does not adopt a carbon pricing mechanism, then other countries may place a price at their borders on Australian imports with a high carbon content.

A further opportunity arises from the collateral health benefits from decarbonising the electricity sector e.g. through improved air quality, as well as indirectly through emissions reductions that mitigate ongoing climate change which has a wide range of effects on human health.

Energy policy

Government policy uncertainty over the last decade has disincentivised investment in the energy sector – and this has pushed up the cost of finance and hence the cost of electricity supply.

What is needed is a bipartisan approach to national energy policy to drive much-needed investments that will last fifty years or more, over which time we will see the complete decarbonisation of the economy.

Government energy policy therefore needs to sit within an overarching framework of climate policy, for which the energy sector is the most rapid pathway to decarbonisation.

It is widely recognised by economists in Australia and around the world that the most efficient way to decarbonise is to employ a carbon-pricing mechanism.

The interim report of the Finkel review of the NEM recommended one type of carbon pricing mechanism – an emissions intensity scheme for the energy sector.

This was based on recommendations by the Australian Energy Market Commission, the Australian Energy Market Operator, the Climate Change Authority and almost universally by big business. More recently, the Electricity Network Transformation Roadmap report by the CSIRO and Energy Networks Australia provided further endorsement of a carbon pricing scheme.

Many major corporations – energy generators, manufacturers and financial institutions – now operate their own projected internal price on carbon so they can plan for an inevitable decarbonised future.

Australia may be forced into implementing a carbon pricing mechanism by other countries which will place a price at their borders on Australian imports with a high carbon content.

Key message: The electricity sector needs a carbon pricing mechanism to efficiently drive decarbonisation.

In addition to carbon pricing, we need to establish much-needed environmental goals in the National Electricity Objectives to achieve decarbonisation.

The energy industry agrees that there is no economic or environmental argument for building a new coal-fired power station in Australia, and the Australian taxpayer should not foot the bill to subsidise one.

Gas will also play a role as a transition fuel, chiefly by helping to meet peak electricity demand.

Increases in Australian gas prices in the short-to-medium term driven by overseas markets will increase the adoption of cheaper renewables such as solar and wind, and will also accelerate electrification to replace domestic and industrial gas use.

As the penetration of renewables increases, there is a need for overcapacity and for storage to address intermittency, and for increased network infrastructure.

Careful attention therefore needs to be paid to smart-grid software, power engineering technologies and strong network interconnection to optimise the integration of renewables with storage, along with demand side response.

Key message: Reform of the NEM needs to include environmental objectives that will lead to a rapid decarbonisation of the sector as a fast track for reducing emissions.

A suggested pathway to 100% renewable electricity follows.

100% renewables pathway

Deployment of wind, solar photovoltaics (PV), pumped hydro energy storage (PHES) and increased high voltage (HV) interconnectors between the states allows the NEM to reach 100% renewable electricity with high reliability and at zero net cost. Wind and PV will replace retiring coal and gas plants at lower cost than the alternative replacement (new coal and gas).

1. Wind and PV constitutes nearly all new generation capacity in Australia, and half the world's new generation capacity (equal to the combined amount of coal, oil, gas, nuclear, hydro and all others)
2. Pumped hydro energy storage (PHES)* constitutes 97% of worldwide energy storage.
3. Wind, PV, PHES and HV interconnectors combine to ensure affordable grid stability.
4. The cost of both wind and PV continues to fall rapidly. There is no end in sight to cost reductions.
5. According to our studies, the cost of electricity ($/Megawatt-hour) from single new-build generators is approximately:

Wind	$65/MWh (in 2016) falling to $50/MWh (2020s)
Solar PV	$79/MWh (in 2016) falling to $50/MWh (2020s)
Supercritical black coal	$66/MWh
Gas	$78/MWh

6. We have modeled the cost of electricity in a 100% renewable electricity system (90% wind and PV plus existing hydro and bio). The cost includes not just the wind and PV, but also pumped hydro storage and high voltage interconnectors between states.
7. At 2016 prices the whole-system cost is $93/MWh. At 2020s prices the cost is $75/MWh.
8. About two thirds of Australia's fossil fuel generators will reach the end of their technical lifetimes by 2036, and will need to be replaced.
9. Wind and PV, supported by HV interconnectors and PHES, will be decisively cheaper in the 2020s than new coal and gas.
10. PHES offers ancillary services including high-inertia, fast-ramping and synchronous capacity for frequency and voltage support.
11. Wide distribution of wind and PV over a million square kilometres to access different weather, coupled with increased HV interconnection and PHES, confers high reliability at modest cost.
12. Any desired degree of grid stability can be achieved at modest cost by adding more off-river PHES at multiple locations (and/or demand management).
13. Rooftop PV will continue to expand as costs continue to reduce.
14. Several thousand people will be employed during 2017 and 2018, and beyond, constructing several gigawatts (GW) of new ground mounted PV, and several more GW of wind, in regional areas.
15. What needs to be done?
    a. Provide a clear retirement schedule for existing coal and gas power stations to allow for smooth uptake of PV and wind. This retirement schedule should be consistent with the national emissions reduction target. Retirement could be accomplished through carbon pricing, an emissions intensity scheme or similar.
    b. Commence planning for large scale construction of PHES and HV systems in the 2020s
    c. Encourage large scale uptake of electric vehicles and electric heat pumps (for low temperature space and water heating).

Key message: Plan for a smooth transition from coal and gas to renewable energy sources. Plan for pumped hydro energy storage and high voltage systems. Encourage large scale adoption of electric vehicles and heat pumps.

* PHES can provide effectively unlimited storage at modest cost, even in dry states such as South Australia. There are hundreds of potential sites outside national parks in all states. Pairs of reservoirs, typically 10 hectares each, are separated by an altitude difference of between 300 and 700 metres, in hilly terrain or ex-mines outside national parks and away from rivers, and joined by a pipe with a pump/turbine. Water circulates between the upper and lower reservoirs in a closed loop to store and generate power. Very little water is required relative to conventional fossil fuel power stations. Existing hydro systems can be fitted with more tunnels, generators and pumps to accomplish the same task.

References

This submission also refers to submissions by the following ECI members:

- Dr Paul Burke: submission on Australia's emissions reductions policies.
- Professor Andrew Blakers and Dr Matthew Stocks: submission for a roadmap to greenhouse neutrality for the Australian energy sector generation and use.

In addition, we refer the Review to the ANU ECI publications website:

http://energy.anu.edu.au/publications

which includes relevant submissions to:

- The Standing Committee on the Environment and Energy inquiry into Modernising Australia's Electricity Grid:

  http://energy.anu.edu.au/files/ANU_ECI_Parlia.pdf

- The Independent Review into the Future Security of the National Electricity Market:

  http://energy.anu.edu.au/files/NEM_Review_ECI_Baldwin_Franklin_3March2017.pdf

- The Senate Select Committee into the Resilience of Electricity Infrastructure in a Warming World:

  http://energy.anu.edu.au/files/ANU%20ECI%20Submission%20SenateSelectCommittee%20StorageElectricityResilience%203Feb2017.pdf

For further discussion on these points regarding electricity generation

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The Built Environment: Cities

Prepared by Professor Barbara Norman, Adjunct Professor ANU Climate Change Institute and Director of Canberra Urban & Regional Futures, Faculty of Arts & Design, University of Canberra.

Introduction

This section of the submission focusses on critical issues concerning how cities can adapt to climate change in Australia.

It is based on *Climate Ready Cities Policy Information Brief 2*, which was prepared by Professor Barbara Norman and released by the Australian Government in December 2016. Key points have been highlighted below but it is recommended that the Review also considers the full Policy Information Brief, available at the following link:

Norman, B, 2016, Climate Ready Cities Policy Information Brief 2 2016, National Climate Adaptation Research Facility, Griffith University, Qld.

What are the opportunities and challenges of reducing emissions for households, SMEs and the built environment? Are there any implications for policy?

Please refer to Professor Andrew Blakers' and Dr Matthew Stocks' submission which outlines a roadmap to greenhouse neutrality for the Australian energy sector. Their submission addresses households, small to medium enterprises and the built environment sectors.

Are there particular concerns or opportunities with respect to jobs, investment, trade competitiveness and regional Australia that should be considered for households, SMEs and the built environment?

Key message: Preparing cities to be "climate ready" is critical to minimising risks to jobs, investment and trade competitiveness, and improving resilience to projected increasing climate change impacts throughout Australia.

Cities are highly vulnerable to the risks of climate change, especially in coastal locations. Climate change impacts on the built environment and major infrastructure (transport, energy) include more heatwaves, extreme rainfall and intense cyclones, harsher fire weather and more severe storm surge associated with sea level rise. The impacts of such changes to the built environment and major infrastructure (transport, energy) will have immediate and damaging effects on urban communities, the urban environment and a city's productivity.

The future stresses and impacts facing large urban centres are multifaceted and will require an integrated approach to long-term planning strategies in order to minimise risks to urban communities. This need for integration may have implications for future urban governance arrangements, including defining the roles of each level of government in development 'climate ready cities.' Effective collaboration between policy makers, city planners and emergency services will facilitate development of appropriate urban disaster prevention strategies.

Adaptation actions and policies will affect the built environment, urban ecosystems and energy, water and transport provision and infrastructure. Adaptation will require and involve actions by all levels of government and engagement with the private sector. Actions will range from policies on national critical infrastructure, to developing capital city plans to designing and building more localised ‘climate smart precincts’. The Organisation for Economic Co-operation and Development (OECD) emphasises the multi governmental nature of climate change adaptation and the important role that cities can play with the support of higher levels of government. A key message is that *local action takes place in the context of national frameworks*.

Integrating climate change adaptation into city management and future urban strategies will require a major effort in coordination and capacity building both within city and wider community understanding.

Future stresses on the built environment will require more resilient buildings and infrastructure. The future is predicted to see an increase in heatwaves, extreme rainfall, intense cyclones, harsher fire weather, coastal storms and sea level rises. All these will affect the built environment, therefore construction of more resilient buildings and infrastructure in future will be required to adapt to these impacts.

Smart Infrastructure at the national and local level. Financial incentives for adaptation can be made available at the city level in partnership with the private sector. Financial arrangements can also be developed so that local urban communities can undertake more preventative actions. The following are some opportunities to develop more ‘climate ready cities’:

- **Major urban planning strategies are a powerful tool to implement climate change adaptation in large urban centres.** Urban and regional plans are constantly being reviewed, which provides the opportunity to embed climate change adaptation polices into the development of large urban centres. For example, guiding the location of urban growth corridors for Sydney, Melbourne and Brisbane into areas of minimum risk from the impacts of climate change (water security, floods, high fire risk, storm surge) will prevent substantial damage and consequent costs into the future. Regeneration strategies will also be required to retrofit existing built environments for climate change.

- **Climate sensitive urban design recognises that on the ground local actions will need to adapt to changing environments**. Measures can include landscape plans to increase shade, local water and energy systems to minimise use and vulnerability and building materials and design such as natural ventilation in warmer climates to reduce heat impacts. Many cities’ responses are focused around urban forest strategies and urban greening strategies. Precinct-based planning can provide the opportunity to integrate these measures on a wider scale.

- **Smart infrastructure at the national and local level will need to increasingly adapt to environmental change.** An example is more localised energy distribution including renewable energy. Financial incentives for adaptation can be made available at the city level in partnership with the private sector (e.g. the City of Melbourne 1200 Buildings program). Financial arrangements can also be developed so that local urban communities can undertake more preventative actions, for example coastal adaptation measures (restoring mangroves and dunes) to reduce coastal erosion and inundation. Energy efficiency will be a priority in a hotter environment, and the Building Energy Efficiency Disclosure Act 2010 already places mandatory disclosure obligations on many commercial buildings.

- **Public investment in quality open space and the public realm is a practical local adaptation response that can have multiple benefits for the community and the environment**. Retaining and improving the quality of local open space can be achieved through integrated plans for ‘living infrastructure’ that protect the health of urban ecosystems facing stress under environmental change. The surrounding urban communities also benefit significantly with good open space providing the opportunity for healthy communities through more active living.

This submission also refers to submissions by the following ECI members:

- Dr Paul Burke: submission on Australia's emissions reductions policies.
- Professor Andrew Blakers and Dr Matthew Stocks: submission for a roadmap to greenhouse neutrality for the Australian energy sector generation and use.

For further discussion on these points regarding Climate Ready Cities

Contact Professor Barbara Norman, ANU Climate Change Institute and The University of Canberra at barbara.norman@canberra.edu.au or +61 2 6201 5644.

Land and Agriculture

Prepared by Professor Justin Borevitz (ANU Research School of Biology), Dr Heather Keith (ANU Fenner School of Environment and Society) and Dr Rebecca Colvin (ANU Climate Change Institute). Reviewed by Professor Mark Howden (ANU Climate Change Institute).

Preamble

The land and agriculture sectors are significant contributors to Australia's greenhouse gas (GHG) emissions, and they also present opportunities to serve as part of Australia's solution to the challenges of climate change.

- **Globally, the land and agriculture sector is a significant source of emissions:** Agriculture, forestry, and other land uses contribute about 24% of global GHG emissions, but emissions from historical human disturbance of the land sector has resulted in 35% of the accumulated anthropogenic emissions[1]. Around 12% of global GHG emissions from 2000 to 2010 were due specifically to deforestation and forest degradation[2].
- **The land and agricultural sector is a significant source of emissions in Australia:** Agriculture directly produced around 16% of Australian GHG emissions (as at 2008). Incorporating on-farm activities, energy use, and land use change, agriculture and land contribute about 28% of Australia's GHG emissions[3].
- **Land is also a significant sink for atmospheric CO_2:** Globally, land has been a net sink for CO_2, absorbing about a quarter of the CO_2 emitted to the atmosphere by human activities over the past three decades[4], however the capacity of land to serve as a sink for CO_2 is weakening, and may reverse in the future[5].
- **Soil carbon is critical:** Soil holds a significantly greater amount of carbon than vegetation, meaning that any changes to soil carbon will have a large effect on land sector emissions[6].
- **Climate change will affect the ability of the land sector to act as a CO_2 sink:** Climate extremes and variability effects, particularly increasing drought, fire and floods, will lead to areas of the land sector becoming a net source of CO_2, and other areas becoming an unstable sink of CO_2[7].
- **Agricultural practices matter:** Changing agricultural regimes can make a contribution to reducing atmospheric GHG concentrations[8], though cost-effective options are needed[9].

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- **Agriculture and forestry are vulnerable to climate change and need to adapt:** Climate adaptation in the agricultural sector will contribute to farm incomes, food security and enhanced natural resource management under a changing climate and create opportunities for agricultural investment and growth in the sector[10].
- **Native forests and other woody vegetation provide large, relatively stable stocks of carbon:** Management of native forests and other woody vegetation to protect and restore carbon stocks is a critical abatement activity, which also has many co-benefits for the environment and provision of ecosystem services[2,13]. However, perverse impacts, such as reduced water availability due to higher water uptake rates from plantation forests compared to crops for example must be recognised and managed[11].

What are the opportunities and challenges of reducing emissions from the land and agriculture sectors? Are there any implications for policy?

Key message: Carbon accounting and management practices can be improved.

Native forest could be protected and managed to secure the carbon stocks held in the biomass and soil, while providing other critical life supporting services and environmental co-benefits. Prioritising management and protection of existing native forests will have the greatest immediate and on-going benefits, while planting new forests will be important for future sequestration as they mature. Protecting native forests, restoration of native vegetation, reforestation and afforestation are important in addressing climate change[12]. However, at present native forest is being harvested and replaced by regenerating trees that remain younger over the harvest rotation and thus store less carbon. Native forests, and particularly old growth forests, have higher stocks of carbon, water, soil fertility, and habitat than new plantings[13]. Most cleared landscapes take hundreds of years without major disturbance to begin to replenish stored carbon stocks[14]. Initiating new plantings in succession is also important for the centuries ahead to begin restoring the carbon lost by deforestation and degradation, but this does not substitute for protection and management of carbon stocks in existing native forests[13].

Carbon accounting systems can be strengthened: Carbon accounting (i.e. the measurement of carbon stocks in soil and biomass) would be improved if it considered land management practices and ecosystem types. Different land, agriculture, and forest management regimes have different outcomes in terms of emissions reductions through time[15]. Presently, carbon accounting measures land use types in order to account for carbon stocks, but does not differentiate based on land management regimes which can vary as much as land use types[16]. The practice of carbon accounting would be improved if land management practices were included given their divergent impacts on carbon stocks. A carbon accounting and management methodology for native forests is required to provide best estimates for national accounting and to

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11 Schrobback, P, Adamson, D & Quiggin, J 2009, 'Turning Water into Carbon: Carbon sequestration vs. water flow in the Murray-Darling Basin', *53rd Annual Conference of the Australian Agricultural and Resource Economics Society, Cairns, 10-13 February 2009,* http://ageconsearch.tind.io//bitstream/47616/2/Schrobback.pdf.

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13 Keith H, Lindenmayer DB, Macintosh A, Mackey BG. 2015. Under what circumstances do wood products from native forests benefit climate change mitigation? PLoS ONE doi:10.1371/journal.pone.0139640.

14 Harmon ME, Ferrell WK, Franklin JF (1990) Effects on carbon storage of conversion of old-growth forests to young forests. Science 247(4943): 699-703.

15 Macintosh, A, Keith, H & Lindenmayer, D 2015, 'Rethinking forest carbon assessments to account for policy institutions', *Nature Climate Change,* vol. 5, no. 10, pp. 946-949.

16 Ajani, JI, Keith, H, Blakers, M, Mackey, BG & King, HP 2013, 'Comprehensive carbon stock and flow accounting: A national framework to support climate change mitigation policy', *Ecological Economics,* vol. 89, no. pp. 61-72.

assess abatement activities. The Intergovernmental Panel on Climate Change (IPCC) is conducting a refinement of inventory practices for consideration at an IPCC Plenary session in May 2019[17]. Improvements to carbon accounting methodologies for Australia and the IPCC could benefit from coordination and cooperation between the Department and the IPCC.

Carbon accounting systems can be strengthened: Biocarbon (carbon held in vegetation, soil) needs to be considered distinct from geocarbon (carbon held in geological deposits) when accounting for carbon stocks and flows. Currently, accounting for GHG inventories is based on flows alone. This is appropriate for geocarbon, where flows are one-way and mostly due to anthropogenic causes and little geocarbon is created on our time scale. Accounting for biocarbon in flows alone and reported as a net flow, however, is inappropriate due to the two-way and cumulative exchange between biocarbon stocks and the atmosphere. Additionally, these flows consist of a mix of natural and anthropogenic sources[18]. Carbon accounting could more accurately reflect changes in GHG concentrations by differentiating between carbon stocks and flows, and managing biocarbon distinct from geocarbon.

There is an opportunity to investigate the potential of Australia's degraded soils to serve as carbon sinks. Degraded soils have high capacity for carbon sequestration[19]. Australia's degraded agricultural lands can be viewed as an opportunity to re-fill the bank after previous losses, which will have the combined benefits of sequestering carbon and providing a sustainable asset for agricultural production. The first priority is amelioration of degrading factors, like erosion, tillage, salinity, and acidification, together with restoration of vegetation and soils. Soil modification with biocarbon from roots, organic matter, biochar, and enhanced rock weathering are also means to increase carbon stocks and fertility of degraded soil, thus further improving carbon sequestration. Complicating factors, including the economic risk and social viability of such initiatives, require consideration to ensure the carbon sequestration potential of Australia's soils is pursued sustainably and equitably.

What can be done to realise further benefits from emissions reduction activities beyond carbon abatement?

Key messages: Promote co-benefits. Improve the Emissions Reduction Fund.

Emissions reduction activities can be recognised for their primary impacts, as well as their significant co-benefits. Actions such as protecting native forests, restoring degraded ecosystems, sustainable agricultural practices and revegetation on agricultural land, which contribute to climate change mitigation, also provide co-benefits beyond emissions reductions[20]. These co-benefits can include outcomes such as: improving soil fertility and productivity; conserving biodiversity; securing water quality and supply; reducing salinity; enhancing nutrient cycling[21]. Focusing on these co-benefits, and promoting projects which realise co-benefits, will emphasise the range of outcomes from emissions reduction activities in land and agriculture. However, costs and dis-benefits must also be recognised, for example the potential of new plantations to require water licences in water-limited catchments such as the Murray Darling Basin[xii].

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[21] David, BL, Uris Lantz, CB & Thomas, WH 2013, 'Climate adaptation as mitigation: the case of agricultural investments', *Environmental Research Letters,* vol. 8, no. 1, pp. 015012.

Actions which have benefits for both mitigation and adaptation can be prioritised to gain enhanced outcomes from investments. Improved land management for agriculture and forests can serve both as mitigation actions and as adaptation actions. For example, on-property stream- or river-side revegetation sequesters carbon (mitigation), and provides erosion protection from extreme weather events (adaptation)[22]. No-till farming limits losses to the atmosphere from soil carbon stocks (emissions reduction) and improves water use efficiency (adaptation)[23]. Restoration of native ecosystems can sequester carbon (mitigation) and increases capacity of ecological processes to adjust to climate extremes and variability (adaptation). Integrating mitigation activities with adaptation in the land sector will generally provide greater benefits for the agricultural productivity and the environment as well as emissions reductions.

Further develop The Emissions Reduction Fund (ERF) systems: end of crediting period. The ERF has a crediting period for carbon sequestration projects of 25 years. In sequestration projects that involve forestry plantations to take up atmospheric carbon into biomass, the fate of this sequestered carbon is not clear at the end of these projects. Harvesting the plantations would undermine the gains made during the sequestration project, or at least reduce average carbon stocks over subsequent rotations. Management at the end of the crediting period is required for sequestration projects under the ERF to ensure GHG reduction gains are long-lasting and therefore effective.

Further develop The Emissions Reduction Fund (ERF) systems: baselines and additionality criteria. The ERF voluntary abatement scheme uses a reverse auction system and requires information about (1) ongoing emissions of a project, and (2) the emissions which would have occurred without the project. Project proponents have better access to this information than the government, meaning that it is possible for proponents to indicate their projects are performing against overly generous baselines (i.e. reporting lower than realistic baselines against which performance is measured)[24]. This is a challenge, as projects that would be occurring regardless without the scheme are likely to receive funding due to both the lack of clear baseline data leading to comparative low costs of projects, and the inability to distinguish projects that are not promoting any significant additional action. To address this, the ERF may be strengthened if it were to avoid funding low-return projects based on poor data, or independent evaluation of baseline data may be instituted. Ideally, the incentive system would be replaced by an emissions tax or emissions trading system[24].

Are there particular concerns or opportunities with respect to jobs, investment, trade competitiveness, households and regional Australia associated with policies to reduce emissions in the land and agricultural sectors?

Key message: Reframe emissions reductions efforts in the land and agriculture sector to focus on sequestration opportunities and co-benefits, as 'soil boom', on par with past mining boom, that links mining and agriculture to create fertile, biodiverse, productive landscapes.

There are economic opportunities in protecting forests which can be recognised. Evidence from the Central Highlands of Victoria show that jobs and investment figures are improved in scenarios with forest conservation for emissions reduction, compared with current practices of

[22] Ryan, RL, Erickson, DL & De Young, R 2003, 'Farmers' Motivations for Adopting Conservation Practices along Riparian Zones in a Mid-western Agricultural Watershed', *Journal of Environmental Planning and Management,* vol. 46, no. 1, pp. 19-37.

[23] Derpsch, R, Friedrich, T, Kassam, A & Li, H 2010, 'Current status of adoption of no-till farming in the world and some of its main benefits', *International Journal of Agricultural and Biological Engineering,* vol. 3, no. 1, pp. 1-25.

[24] Burke, PJ 2016, 'Undermined by Adverse Selection: Australia's Direct Action Abatement Subsidies', *Economic Papers,* vol. 35, no. 3, pp. 216-229.

timber harvesting[25,26]. Additional benefits from valuing forests for carbon storage include protection of ecosystem services, such as water supply and quality, habitat for biodiversity, and recreation. Embracing the economic benefits from forest carbon storage will allow for greater economic opportunities and jobs in regional areas, compared to current practices.

Training in improved land management practices provides opportunity for regional youth. Australia's next generation of higher-tech farmers are increasingly motivated to address climate change[27]. Investment in the regions could be directed toward training young Australians in improved agricultural practices and forest plantation management, including enhancing soils, to develop long-term sustainable land management. This will provide skills to the next generation beyond emissions reductions through climate-stabilising land and agricultural management practices, and will contribute to addressing the challenges for regional Australia of youth out-migration and rural depopulation. Existing institutional structures such as Landcare and regional schools and universities could be supported to provide these opportunities.

An Australian carbon market would be strengthened through inclusion of land and agriculture sector activities, and vice versa[28]. This would encourage innovation and investment in the land and agriculture sectors through competition and commercialisation of practices and technologies. This would also ensure that the substantial GHG contributions from the land and agriculture sectors are effectively included in Australia's policy and market instruments. Land use emissions would fall and net sequestration with cumulative storage will likely emerge.

Policy stability is needed to encourage investment, but so is some degree of reform. Policy uncertainty and instability limit investment. We recognise that we have suggested substantial changes to the current policy approach, and that ongoing review and amendment is important for ensuring appropriate and effective policy for climate stability. To allow for adaptive policy while providing certainty to investors (including investors such as landholders, farmers, forestry managers), thorough consultation with a broad cross-section of constituents is recommended ahead of any significant changes. If Australia is to meet its emissions reduction targets, limits on emissions could be tightened progressively with increasing ambition at each review stage. In particular, engaging across political and ideological lines and genuine incorporation of community perspectives will increase the likelihood of policy outcomes which are widely supported, and are long-lasting.

For further discussion on these points regarding land and agriculture

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[25] NOUS Group & The Wilderness Society 2017. Great Forests National Park: economic contribution of park establishment, park mangement, and visitor expenditure. http://www.greatforestnationalpark.com.au/uploads/1/5/5/7/15574924/nous_gfnp_economic_contribution_study_3_february_2017.pdf

[26] Keith H, Vardon M, Stein JA, Stein J, Lindenmayer D. 2016. Experimental Ecosystem Accounts for the Central Highlands of Victoria. Version 1.0 June 2016. http://fennerschool-associated.anu.edu.au/documents/Ecosystem_Accounts_full_report_v1.pdf.

[27] http://www.farmersforclimateaction.org.au; Buys, L, Miller, E & van Megen, K 2012, 'Conceptualising climate change in rural Australia: community perceptions, attitudes and (in)actions', *Regional Environmental Change,* vol. 12, no. 1, pp. 237-248.

[28] Bryan, BA, Nolan, M, Harwood, TD, Connor, JD, Navarro-Garcia, J, King, D, Summers, DM, Newth, D, Cai, Y, Grigg, N, Harman, I, Crossman, ND, Grundy, MJ, Finnigan, JJ, Ferrier, S, Williams, KJ, Wilson, KA, Law, EA & Hatfield-Dodds, S 2014, 'Supply of carbon sequestration and biodiversity services from Australia's agricultural land under global change', Global Environmental Change, vol. 28, no. pp. 166-181.

Research, development, innovation and technology

Prepared by Associate Professor Matthew Hole, Research School of Physics and Engineering, ANU.

What is the role of research, development, innovation and technology in reducing Australia's emissions? Are there any implications for policy?

Key Message: Providing adequate support for climate and energy research within our Universities is essential to ensure we have the innovation capacity to address our climate change targets.

Investment in research, development, and innovation in clean energy generation and technologies has the capacity to reduce global as well as national emissions. Examples of this span time horizons and scale, from the development and adoption of improved efficiency renewables through to the long term development of fusion power. PERC solar cells, for instance, were developed at the University of New South Wales in 1988-89 by Professor Andrew Blakers and colleagues, and as at 2017 represent 25% of the world market, with the latest International Technology Roadmap for PV projects indicating that they will reach 55% market share over the next decade. This is a major contribution to the global economy and environment.

In concert, climate science research informs the nation of the impact of complementary land use mitigation strategies in reducing Australia's emissions, as well as the local adaptation required in a warming climate. A strong climate and clean energy research portfolio forms a critical part of Australia's global responsibility towards lowering emissions and developing profitable, sustainable agriculture and forestry. The research sector is critical in providing trusted information to the public across a range of dimensions of climate change.

An omission from the Discussion paper is the profile of the University research sector in research, development, innovation and technology in reducing Australia's emissions. The University sector is host to nearly all ARC investment in energy R&D, and a significant fraction of ARENA funded R&D activity. In addition to these schemes, the University sector invests in energy R&D that is Australian government derived, principally through research block grants administered by the Department of Education and Training. Much of this is invested in intellectual capacity by supporting academics, although support is also supplied to professional staff and infrastructure. In some areas of energy research, such as fusion power, Australia's core competency lies entirely in the University sector. The continuing erosion in recurrent support for the University sector limits the capacity of research, development, innovation and technology to reduce Australia's emissions.

Are there particular concerns or opportunities with respect to jobs, investment, trade competitiveness, households and regional Australia associated with policies to reduce emissions in the land and agriculture sectors?

Key Message: Universities educate and train those who will address climate change, reduce our emissions and drive the energy revolution.

A critical function of the University sector is the education and training of a generation of Australians who will inform future Governments about the risks and policy implications to Australia from global warming, and who will crucially implement the low-emissions energy revolution as well as a range of other economic, social and environmental activities which bring sustained prosperity.

For further discussion on these points regarding research, development, innovation and technology

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