THE UNIVERSITY OF MELBOURNE

Technology Investment Roadmap Discussion Paper

Response from the University of Melbourne

June 2020

Executive Summary

The University of Melbourne welcomes the opportunity to provide comment on the *Technology Investment Roadmap Discussion Paper*. The Discussion Paper gives a thorough overview of the technologies that could be utilised to transition Australia to a productive and low emissions future. The Discussion Paper rightly articulates that no single technology can deliver on emissions targets, but a strategic combination, supported by requisite skills, knowledge and materials, will be essential. The University also endorses the focus on 'hard to reach' sectors, such as buildings and transport.

Predicting the forward path of technology is notoriously difficult. As technologies are improved and their usage increases, costs will come down. At a national level, it is almost impossible to suggest what technologies should be prioritised other than noting that active pursuit of technological developments by industry, supported by collaborating universities, leads to direct improvements and, critically, to Australia's capability to absorb technology from other parts of the globe. However, there are gaps that can be confidently identified, which, if filled, would complement activities that are underway. For instance, a focus on demand-side initiatives in energy would complement manifold activities on the supply side.

The development of a policy and investment framework to ensure the success of Australia's energy transition is a crucial public interest undertaking. The University of Melbourne has research centres and faculties with diverse capabilities in this area, some of which are already collaborating with government agencies on technology development, research, assessment and policy formation. These include the Melbourne Energy Institute, the Peter Cook Centre for CCS Research, the Melbourne Sustainable Society Institute, and the Australian-German Energy Transition Hub, amongst others.

As an institution, the University has committed to achieving carbon neutrality before 2030. As a public-spirited enterprise, the University is also committed to mobilising its expertise and convening power to help find solutions to assist Australia to meet its emissions reductions targets. The technologies and knowledge being developed by University researchers, industry, government agencies and partners can contribute to achieving emissions reductions while boosting jobs, export industries, community well-being, productivity, and environmental sustainability.

Please see the list of University of Melbourne contributors to this submission at Appendix A. For more information or to discuss the submission, please contact Professor Mark Cassidy, Dean, Melbourne School of Engineering, on 03 8344 6619 or mark.cassidy@unimelb.edu.au.

Key Recommendations

1. **The University recommends stronger consideration of building social acceptability and testing feasibility of new technologies in future stages of Australia's low emissions technologies planning.**
2. **In concert with the focus on energy supply technologies, the Roadmap should include measures to reduce energy demand domestically through efficiency technologies and industrial transformation.**
3. **The University recommends the addition of technologies to the priority shortlist (see below).**
4. **Technology investment should include a focus on security/reliability, particularly through developing the modelling and simulation tools required to test and support system-wide deployment.**
5. **Amongst other measures, the Roadmap should identify existing agencies that are driving private sector investment and utilise new National Cabinet processes to coordinate enabling financial policies.**
6. **The investment framework should incentivise low-carbon technologies as well as investments in grid reliability and resilience.**
7. **The Technology Investment Roadmap should recognise economic and workforce planning and industry development for communities impacted by technology transition.**
8. **The Roadmap should include measures to encourage and facilitate research partnerships as an enabler of initial and continuing technology deployment. Such as, the introduction of a collaboration premium of up to 20 per cent for the non-refundable tax offset to lift engagement and partnership between industry and research institutions on complex deployment challenges.**
9. **The Roadmap should facilitate the development of an integrated energy system and an associated integrated energy marketplace, with a smart, low-carbon electricity grid as the backbone infrastructure. A future pipeline of integrated energy specialists should also be supported through teaching and learning, training, and research activities**
10. **Stretch goals under the Roadmap should be evaluated for their economic and social benefits and framed as 'socio-economic stretch goals'.**
11. **The Roadmap should include greater clarity on the timeframe and nature of Australia's hydrogen target to drive investment.**
12. **The Roadmap should co-develop complementary technologies, such as CCS, firmed renewables and long duration energy storage (such as electrical and thermal), as part of the $2/kg hydrogen stretch goal.**

Responses to Discussion Paper Questions

a) The challenges, global trends and competitive advantages that should be considered in setting Australia's technology priorities.

The task faced by all nations transitioning to low emissions technologies is formidable and pressing. Australia starts out with the inevitable challenge of geographical distance, with subsequent higher costs of transporting future zero or low-carbon fuels, low-carbon materials and manufactured products. However, a strategic approach – as seen in the Technology Investment Roadmap process – also highlights diverse opportunities and advantages to offset the challenges iterated in the Discussion Paper.

Social acceptability of new technologies

Social acceptability or feasibility of new technologies is a significant challenge for technology planning. The Discussion Paper notes social acceptance as a secondary issue and as a barrier to deployment (p35). However, social feasibility is a primary and fundamental enabling condition for successful technological deployment. Research shows that the success of innovative technologies is shaped by public/community participation, and the degree to which end users feel they have a stake in the transition, social significance and benefits. The integration of a particular technology into its social and built environment can determine the success or failure of that technology.

Recommendation 1: The University recommends stronger consideration of building social acceptability and testing feasibility of new technologies in future stages of Australia's low emissions technologies planning.

Major companies moving fast on emissions reductions

Recent analyses, including in Intergovernmental Panel on Climate Change (IPCC) publications, are indicating that the emissions reductions will need to be deeper and faster to meet the Paris Agreement goals. Major global businesses including BHP and Rio Tinto are moving faster and more successfully with emissions reductions than anticipated, and are adopting strong emission reduction targets such as net zero by 2050. These companies are making commitments and acting not only on their own emissions, but on Scope 3 or value chain emissions in their sectors. These trends will advantage technologies that can deliver deep emission reductions over relatively short periods of time, and reductions across value chains in Australia and globally.

An opportunity for clean industry clusters

Co-location of CO_2-intensive industries – such as steel, cement and paper – with clean energy production – such as hydrogen and gas with CCS – presents an opportunity for Australia to reduce infrastructure costs, create jobs and spur local co-investment. Clean energy clusters could stimulate regional economies and, on that basis, attract a higher level of community support. This approach will require substantial technical planning and upfront investment, guided by policies to ensure co-investment security. The availability of geological CO_2 storage capacity would be a factor in the location of a cluster, as it is the case for the CarbonNet project in Victoria. Successful examples of clean industry clusters can be found in the United Kingdom, Europe and in the United States.

Boundless plains of potential power and negative emissions

Australia possesses vast availability of land and renewable energy sources (wind, solar, water, geothermal) to produce the cheap, zero-carbon electricity necessary to produce low-cost clean hydrogen (for instance the $2/kg stretch goal), as well as other zero-carbon fuels, and zero-carbon materials and goods. The low cost of production could offset the transportation costs that arise on account of Australia's geographic distance from trading partners.

Equally, Australia is well-placed in terms of available geological sites for carbon sequestration together with a very significant capacity to sequester carbon in soils with permanence. The latter is also the key to Australia adopting a world-leading position with negative emissions.

Lower demand can reduce emissions

The Discussion Paper illustrates the need for combined approaches to the low emissions energy transition, but places a strong emphasis on the 'supply' side. The University recommends the Roadmap should include stronger wording and measures for the 'demand' side of the energy equation, such as incentivising the use of energy efficient technologies and improvements to building envelops in Australian building codes to achieve emission abatement cost-effectively.

Potential for reduced demand can also be seen in Australia's primary industries, which are an economic strength as well as a large source of emissions. Higher energy efficiency and decentralised energy supply for industrialised chicken, pig and flower farms with heat or cooling in their processes would achieve significant reductions and be an area for Australian global leadership.

Recommendation 2: In concert with the focus on energy supply technologies, the Roadmap should include measures to reduce energy demand domestically through efficiency technologies and industrial transformation.

Australian expertise in carbon sequestration

A competitive advantage for Australia in the land sector is expertise and experience in emissions and sequestration from forests and woodlands management and protection. In Australia and in the Asia Pacific region there is high- and low-cost potential of global significance for emissions reduction from avoided deforestation (forest protection), afforestation and reforestation, and land management through Indigenous fire management and other practices. There is much good work in this regard happening with philanthropic funding, such as Restore Australia and The Nature Conservancy.

Also significant is the opportunity to sequester carbon permanently in soils. This is potentially Australia's greatest chance for low cost negative emissions. However, there is a gap in our understanding of what governs the rate of sequestration and how to cheaply measure the sequestered carbon. This gap needs to be filled (geological sequestration is covered later in this submission).

Research strengths aligned with emerging markets

Australia's research capabilities in technologies can be tapped to improve domestic energy efficiency and open new export markets:

- Australia's existing research capability in combustion offers the potential for low carbon fuels to be integrated into existing combustion processes.
- Australia has research strengths in heat pumps, which have negative greenhouse gas emissions abatement costs and high commercial readiness index. East Asia is leading and rapidly growing as a heat pump market. Matching our research strengths to new domestic manufacturing capabilities is an opportunity that could be incorporated into the Roadmap.

b) The shortlist of technologies that Australia could prioritise for achieving scale in deployment through its technology investments.

Technologies proposed as additions

The shortlist of priority technologies in the Discussion Paper (Figure 7) is comprehensive.

Recommendation 3: The University recommends the addition of the following technologies to the shortlist.

Under Buildings (combined with air source and ground source heat pumps)

- Seasonal solar thermal energy storage
- Precinct level heating and cooling
- Photovoltaic thermal system

Under Transport:

- Aerospace technologies (carbon neutral fuels; sustainable aerospace propulsion systems)
- Shallow geothermal pavements

Under Agriculture and Land Use:

- Focus on building up our soil carbon
- Reduction of feed lot emissions
- Indigenous fire management
- Avoided deforestation (including REDD+)[1]
- Reforestation and afforestation
- Solar photovoltaic combined with ground source heat pump (for heating and cooling)
- Technologies to address livestock methane[2]
- Technologies to enhance fertiliser-use efficiency[3]

[1] REDD+ is an international framework for reducing emissions from deforestation and forest degradation, conservation of existing forest carbon stocks, sustainable forest management and enhancement of forest carbon stocks: https://redd.unfccc.int.

[2]The Australian livestock industries contribute around 10% of national GHG emissions, mainly as enteric methane. Reducing livestock methane can also improve productivity. Recent discoveries have shown that >80% reductions in methane are possible. Research into slow-release technology is required to determine the quantity of active ingredient for this method to be deployed at industrial scale (and in different Australian climates).

[3]Enhanced efficiency fertilisers can reduce environmental losses. But technologies using polymer-coated fertilisers are now banned in the EU as they contribute micro-plastics into the soil on breakdown. New biological or biodegradable slow-release fertiliser products are urgently needed to improve nitrogen fertiliser use

Comments on the shortlist

Gas generation

The Discussion Paper includes gas generation on the shortlist as a priority electricity generating technology. The University notes the importance of combatting fugitive methane emissions from oil and gas. Methane emissions are of increasing importance in controlling Australia's global footprint. The National Greenhouse Gas Inventory currently uses a Global Warming Potential from methane of 25 based on the IPCC Fourth Assessment Report. The IPCC Fifth Assessment Report indicates that the GWP of methane is higher, between 28 and 36. Reductions can be achieved by better well completion practices, and improved monitoring and maintenance of equipment leakage.

Solar technologies

The Discussion Paper includes solar technologies on the shortlist as a priority electricity generating technology. The University notes that with the significant increase in the use of renewable energy in agriculture there is also surplus power generated. For example, the cotton industry uses solar energy to pump irrigation water, but most of these solar panels are not grid connected. As water is only pumped during the irrigation season, there are at least 4 to 6 months of energy being generated and unused. There is potential to convert this excess renewable energy to hydrogen, but the technology would need to be economic at small-scale.

Geothermal energy

The Discussion Paper lists geothermal energy as a priority technology for electricity and process heat. The University of Melbourne is partnered with the Latrobe Valley Authority, with funding from the Victorian Government, to investigate geothermal energy for process heat in the Gippsland region. This is an example of a potential area for co-investment by Australian and State governments and other organisations.

Heat pumps

The Discussion Paper lists heat pumps at numerous points in the shortlist. More specifically, ground source heat pumps (GSHP) technology has seen tremendous increase in the last decade in Australia. It delivers benefits including: tapping into shallow geothermal energy, providing energy efficiency regardless of location, and providing efficient heating and cooling.[4] [5] The use of 'energy foundations' in buildings has been piloted in Australia, and used in Europe.

Comments on the reliability and security of shortlisted technologies

Prioritised technologies should be considered with respect of their ability to support system security and reliability, for which sophisticated, whole-system modelling tools need to be developed both for the electricity grid and for the whole energy system.

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efficiency and reduce nitrous oxide, ammonia and nitrate leaching losses from agriculture, which contribute to greenhouse gas emissions.

[4] Aditya, G & Narsilio, G (2020) *Environmental assessment of hybrid ground source heat pump systems*. Geothermics 87 (September):101868. https://doi.org/10.1016/j.geothermics.2020.101868.

[5] Lu, Q., Narsilio, G.A., Aditya, R., Johnston, I.W. (2017). *Economic analysis of vertical ground source heat pump systems in Melbourne*, *Energy.*

Refinement of the technology priority shortlist should simultaneously consider the need to invest in technology aimed at understanding the reliability and security component of the 'energy trilemma' (reliability, sustainability, affordability). It will be crucial to develop modelling, simulation and optimisation tools (for both planning and operation), and operation and control platforms, for technology configurations that become the backbone of Australia's future energy infrastructure. This is particularly relevant to:

- Integrated energy systems (such as electricity-gas-hydrogen systems), which will be essential to facilitate the development of future energy technologies, including for low-carbon exports.
- A low-carbon electricity grid that is fully integrated with other energy sectors (transport, buildings, industry) and vectors (gas and hydrogen). In this regard, failures of the electrical grid will mean propagation onto the rest of the energy system with catastrophic consequences. On the other hand, the flexibility coming from other energy infrastructure can support a more secure and resilient operation of the future electricity grid.
- Distributed energy marketplaces, which allow full exploitation of the flexibility of distributed energy resources, buildings and electrified transport in providing energy and grid services and large-scale decarbonisation.

Recommendation 4: Technology investment should include a focus on security/reliability aspects, particularly through developing the modelling and simulation tools required to test and support system-wide deployment.

c) Goals for leveraging private investment.

Private investment in new energy systems has the potential to transform 'business as usual', by encouraging the uptake of proven technologies and the trial of innovative technologies. The leveraging mechanisms for private investment should be significantly strengthened through the Roadmap.

Strengthen existing institutions, including key agencies

Institutions that enable market innovation, commercialisation, and diffusion should be substantially strengthened to drive private sector investment. Both ARENA and the Clean Energy Finance Corporation have successful track records. With a broader funding base these agencies can leverage private sector investment in the Asia Pacific region to benefit Australian technologies and businesses and Australia's international aid and development programs. This would also assist other nations meet their Paris Agreement goals, in turn generating more market opportunities for Australia. The Renewable Energy Target could be strengthened to continue leveraging private sector investment into renewable energy, and should be extended to include storage and other technologies to provide grid reliability and resilience. Meanwhile, a broader strategic focus on lowering emissions, including and beyond renewables, is important as part of a trajectory to the long-term target of net zero emissions.

Technology uptake and private sector investment in low carbon technologies can also be accelerated by policy settings in the public financial agencies including Federal and State Treasuries and Treasury Corporations. A potentially effective approach would be to have the

National Cabinet consider and implement approaches across Treasuries. The work of 'The Central Banks and Supervisors Network for Greening the Financial System' to better manage climate risk and catalyse clean economies is highly relevant, as is the work of the Australian Council of Financial Regulators.

Recommendation 5: Amongst other measures, the Roadmap should identify existing agencies that are driving private sector investment and utilise new National Cabinet processes to coordinate enabling financial policies.

Recommendation 6: The investment framework should incentivise low-carbon technologies as well as investments in grid reliability and resilience.

d) What broader issues, including infrastructure, skills, regulation or, planning, need to be worked through to enable priority technologies to be adopted at scale in Australia.

A technology transformation for towns and regions

Australian and international research highlights the significant economic growth and job creation potential of a well-planned transition to a zero-carbon economy. Technology development can address the social externalities of deindustrialisation and job losses, particularly in regional areas that lack diversification and economic resilience. The challenge will be to coordinate technology deployment at scale, and the concurrent creation of jobs and opportunities.[6]

Investment will flow unevenly and be concentrated in particular regions unless there are strong policies and programs to support new industry development. Regional communities such as the LaTrobe Valley in Gippsland, central NSW and central Queensland have substantial opportunities to deploy new technology, transform local employment and develop diversified economies. The European Smart Specialisation processes have proven successful for communities in transition in some parts of Europe and could be more widely deployed in Australia alongside technology innovation.[7]

Recommendation 7: The Technology Investment Roadmap should recognise economic and workforce planning and industry development for communities impacted by technology transition.

Research is the backbone of the technology transition

Australia's research workforce and infrastructure can be pivotal to the success of new energy technologies. The University concurs with the Discussion Paper comments regarding Stage 5 (Efficient Deployment Pathways) that 'finding pathways to the deployment of priority

[6] *Just Transition of the Workforce, and the Creation of Decent Work and Quality Jobs*, United Nations Framework Convention on Climate Change: https://unfccc.int/sites/default/files/resource/Just%20transition.pdf.

[7] An Australian example is the Smart Specialisation Strategy project which has been driven by the Latrobe Valley Authority with partners from the University of Melbourne and RMIT University since 2016. The project is driving innovation and new employment projects with local industries in the Gippsland region in the wake of the disruption caused by the closure of the Hazelwood power station.

technology will require partnerships with industry and private sector capital, including universities, who are one of the largest investors in research'.

The Roadmap should include measures to encourage and facilitate research partnerships as a key enabler of initial and continuing technology deployment. This is illustrated by the selected examples below:

- In agriculture, a full farm systems analysis (based on lifecycle assessment) is essential to ensure that the technologies achieve productivity gains, profitability, and whole-of-systems net reduction in emissions.
- As discussed in the Discussion Paper, having a secure and sustainable water supply is crucial to hydrogen production, and also to CCS and other technologies. Research is required to reduce the cost of seawater desalination and to improve wastewater treatment to address this barrier.
- Increasing soil organic matter, and its associated soil carbon, is a no-lose strategy. Not only can soils sequester carbon from the atmosphere, but soils that are high in soil organic matter are more productive and resilient to an increasingly variable climate. The major challenge to quantifying changes in soil carbon is the cost of sampling and measurement. Australia needs further research into remote sensing methods that can account for changes in carbon stocks.
- Soil carbon change is very slow, often taking at least five years to measure statistically significant change above inherent variability, sampling and measurement error. Research is required using more dynamic measurement methods to determine management practices that have a material impact on soil carbon change. This will enhance deployment by providing stronger evidence to land managers on practices shown to increase soil carbon.
- Agricultural industries are working to lower emissions, led by the red meat industry in Australia which has committed to the carbon neutral 2050 target. Research collaboration with agricultural industries is essential to provide the underpinning technological advances to allow key industries to move towards carbon neutral production. This includes the use of solar PV and geothermal heat pumps to reduce heating and cooling bills and emissions.

One way to lift the level of engagement between industry and research institutions – and thus pave the way for successful deployment of low-emission technologies over short, medium and long terms – would be to introduce, for instance, a collaboration premium of up to 20 per cent for the non-refundable tax offset. While potentially outside the direct scope of the Technology Investment Roadmap, this recommendation would align and coordinate intention and outcomes across policy areas.

The recommendation for a collaboration premium was one of six recommendations made by the expert panel of the Review of the R&D Tax Incentive.[8] The panel anticipated that it would help to break down cultural barriers between industry and research, as well as generating spill-over benefits and disruptive innovations. A collaboration premium was also

[8] https://www.industry.gov.au/data-and-publications/review-of-the-rd-tax-incentive

recommended in Innovation and Science Australia's Australia 2030: Prosperity through Innovation Strategic Plan.[9] Similar initiatives elsewhere, for example in the UK, have significantly boosted innovation and technology development in low-carbon electricity and gas grids.

Recommendation 8: The Roadmap should include measures to encourage and facilitate research partnerships as an enabler of initial and continuing technology deployment. Such as, the introduction of a collaboration premium of up to 20 per cent for the non-refundable tax offset to lift engagement and partnership between industry and research institutions on complex deployment challenges.

Need for technical skills and industry standards

As noted in the Discussion Paper, the Roadmap must anticipate the workforce, public engagement and regulatory infrastructure necessary for deploying new technologies over the short, medium and long terms. This should include building pipelines of sufficiently expert STEM graduates, builders, tradespersons and energy professionals to design and install technologies, and disseminate information to users and investors about new options.

Public and community awareness, support, and engagement is crucial for the innovation process. One way of raising wider awareness may be to establish large infrastructure projects to showcase available technologies and educate the public and other stakeholders.

Additionally, in many emerging technologies (such as solar and ground source heat pumps, seasonal thermal storage, hydrogen reticulation and use) new industry standards and design guidelines suitable for the Australian climate are required.

Development of integrated energy system, marketplace and modelling

The Roadmap should facilitate the development of an integrated energy system and an associated integrated energy marketplace, with a smart, low-carbon electricity grid as the backbone infrastructure. This will be key to facilitating the successful deployment of future energy technologies. Integrated systems would also intrinsically benefit from the flexibility and resilience from interactions among infrastructures.

Development of suitable modelling tools for such integrated energy systems is a grand challenge and as crucial as the development of the infrastructure itself. This should be addressed by research on technical, economic, and social aspects, to support decision-making at the regulatory and policy levels. In order to develop the required skills, substantial efforts should be dedicated towards teaching and learning, training, and research activities and programs in the research sector and industries.

Recommendation 9: The Roadmap should facilitate the development of an integrated energy system and an associated integrated energy marketplace, with a smart, low-carbon electricity grid as the backbone infrastructure. A future pipeline of integrated energy specialists should also be supported through teaching and learning, training, and research activities.

[9]https://www.industry.gov.au/sites/default/files/May%202018/document/pdf/australia-2030-prosperity-through- innovation-full-report.pdf?acsf_files_redirect, p74.

e) Where Australia is well-placed to take advantage of future demand for low emissions technologies, and support global emissions reductions by helping to deepen trade, markets and global supply chains.

Australia is particularly well-placed to lead in the areas of: CCS (carbon capture and storage); shallow and deep geothermal technologies; energy geostructures; solar PV; low-carbon and zero-carbon fuels; and agricultural industries technology.

f) Economic stretch goals that could help establish pathways for cost-effective deployment of priority technologies.

The University concurs with the Discussion Paper's recognition that developing 'ambitious but achievable stretch goals' will call for partnerships between Government, industry, research institutions and others with relevant commercial or technical expertise.

The University submits that economic stretch goals should also be evaluated for their social benefits. It would be useful to frame these as socio-economic stretch goals, to bring questions of societal and community benefits (including jobs and growth) more clearly into the frame.

Recommendation 10: Stretch goals under the Roadmap should be evaluated for their economic and social benefits and framed as 'socio-economic stretch goals'.

Clarify the $2/kg hydrogen stretch goal

Australia has a number of comparative advantages that position hydrogen production and export as an economically attractive and sustainable industry. The aim of a $2/kg price for hydrogen is admirable. However, if Australia is to be a world leader in this resource the stretch goal requires clarifications. In light of the pace and breadth of activities in different countries concerning technology development and potential sources of hydrogen, the stretch goal should be clarified to state:

- The timeframe by which Australia should aim to achieve the $2/kg price point; and
- The nature of the target, specifically that the target requires clean hydrogen, whether produced from fossil fuels with CCS, or from renewable energy.

Recommendation 11: The Roadmap should include greater clarity on the timeframe and nature of Australia's hydrogen target to drive investment.

Integration of hydrogen with complementary technologies

Further to the hydrogen stretch goal, the University submits that the achievement of low-cost, low-carbon hydrogen should be used for decarbonisation of future fuels for domestic use as well as export.

The $2/kg hydrogen stretch goal should be integrated with technology progress and deployment of CCS, firmed renewables and long duration energy storage. As such, these goals should be co-developed. A hydrogen energy system can provide long-duration storage and renewables firming; while, in turn, renewables can support the target of low-cost low-carbon hydrogen. The flexibility of an integrated electricity-hydrogen system can also be exploited to provide security and resilience to the electricity grid and the whole energy system, which are

essential for the implementation of all future technologies. CCS technology could also complement these technologies as it provides further energy system integration means and decarbonisation paths.[10]

Recommendation 12: The Roadmap should co-develop complementary technologies, such as CCS, firmed renewables and long duration energy storage (such as electrical and thermal), as part of the $2/kg hydrogen stretch goal.

Specific notes on Discussion Paper text and figures

- It is noted by the IEA (Figure 12 in the Discussion Paper) that 'Methane Emissions from Oil and Gas' are not on track. There should be a category of 'Monitoring and reducing fugitive emissions from oil and gas' listed under 'Mining and industrial equipment'. This should also be included in Figure 21.
- The use of CO_2 in algal production for animal food, human food and pharmaceuticals (in addition to biofuels) should be included in Figure 16.
- In Figure 7, 'ground source heat pumps' should be made more specific under "Buildings" (rather than just heat pumps).
- In Appendix A, 'heat pumps' seems to be considered only for heating, but ground source heat pumps technology can do both heating and cooling. The use of any sort of infrastructure in contact with the ground (e.g. all the metro expansions, new buildings foundations and basements, green developments) can use these geostructures to be part of efficient heating and cooling systems.

[10] The University of Melbourne has world-leading expertise in these areas, and ongoing collaborations with Cambridge, Leeds, Berkeley and UC San Diego and industry partners.

Appendix A

Contributors to the University of Melbourne submission

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