



# The 10 Gigawatt Vision

How renewable energy can power jobs  
and investment in the Northern Territory



**International \* Energy**

Published by Beyond Zero Emissions Inc.  
Ross House  
Suite 4.7, 247 Flinders Lane  
Melbourne Victoria 3000

First published June 2019

*The 10 Gigawatt Vision: How renewable energy can power jobs and investment in the Northern Territory* should be attributed to Beyond Zero Emissions.

This publication is licenced under the Creative Commons Attribution 3.0 Australia License. In essence, you are free to copy, distribute and adapt the work, as long as you attribute the work and abide by the other license terms.



To view a copy of this licence, visit:

<https://creativecommons.org/licenses/by-nc-sa/3.0>

This document is available for download from <http://bze.org.au>

Requests and inquiries should be directed to [info@bze.org.au](mailto:info@bze.org.au)

Beyond Zero Emissions acknowledges that we work on Aboriginal land. We pay our respects to their Elders past, present and emerging.

This document is printed with ecoStar+ – it is an environmentally responsible paper made carbon neutral, the fibre source is FSC Recycled certified. ecoStar+ is manufactured from 100% post consumer recycled paper in a process chlorine free environment under the ISO 14001 environmental management system. To find out the environmental savings and benefits of using recycled paper, visit [www.thinkrecycled.com.au](http://www.thinkrecycled.com.au) and use our eco-calculator.



# Repowering our Regions



Beyond Zero Emissions (BZE) is an internationally recognised climate change think tank, providing independent and ambitious climate change solutions for Australia.

Our flagship research program shows how all sectors of the Australian economy can decarbonise, repower and benefit from the transition to zero emissions. These Zero Carbon Australia (ZCA) plans cover renewable energy and electricity; energy efficient buildings; sustainable transport; agriculture, farming and land use; and industry.

Through volunteer-powered research we show that a thriving, zero emissions society is achievable and affordable now, and that Australia can become a renewable energy superpower.

Beyond Zero Emissions is using our existing ZCA research to develop blueprints for repowering fossil-dependent regions with renewable energy, zero-carbon industries, agriculture and land use.

The Northern Territory **10 Gigawatt Vision** is part of our **Repowering our Regions** program. We have already published reports for Port Augusta in South Australia and will shortly release a plan for Collie in Western Australia. Plans for the Hunter Valley in New South Wales, regional Queensland and rural Victoria are all soon to start.

*Repowering Port Augusta: a blueprint for replacing coal with solar that galvanised a five-year community campaign resulting in the South Australian Government backing a 100% renewable energy solution for the town.*

Our blueprints will support regional communities to identify zero-carbon opportunities and empower them to act.

Each blueprint draws from our award-winning body of research. They are:

- led by our world-class researchers and community of local experts
- tailored to the unique character and needs of each region
- practical and deliverable
- bold, energising and inspiring
- empowering, giving communities the information they need to build support for rapid decarbonisation and to inspire people to act.

Collectively, these blueprints will show how Australia can be a renewable energy superpower in the zero-carbon global economy.

# Support our work

## Donate

Your support will enable our community of climate experts to continue delivering climate solutions that inspire hope and action. We make your dollars work hard to produce high-impact solutions by pairing our world-class research team with enthusiastic and capable volunteers from academia, business and government. With your tax-deductible donation we can deliver more successes like these:

**[Electrifying Industry](#)**: is global first report showing how manufacturing can fuel switch to renewable electricity. The report was launched at a one-day seminar attended by more than 200 leaders in industry and renewable energy.

**[Rethinking Cement](#)**: the world's first report showing how cement can be decarbonised. This has generated international and national interest and support across the construction and infrastructure sector.

**[Stationary Energy Plan](#)**: this pioneering report changed the conversation on renewables in Australia, showing governments, businesses and communities that 100% renewable electricity is possible.

**[Electric Vehicle Report](#)**: shows how Australia can easily and affordably match and even top the UK's lead on electric vehicles. The report has been endorsed by the ACT and Queensland governments.

**[Renewable Energy Superpower](#)**: a report that has become the spoken ambition of Australian climate leaders.

**[Zero Carbon Communities Guide](#)**: a guide to inspire confidence and action at the local level.

## Volunteer

Beyond Zero Emissions is powered by volunteers: engineers, scientists, economists and communicators all contribute their time and expertise to develop and promote climate solutions that support a rapid transition to zero emissions.

You can support our bold vision for a Zero Carbon Australia by donating your time with us. Opportunities exist for motivated and capable volunteers across cities and regions. Many of our volunteers make new friends, expand their professional network and learn new skills while doing interesting and impactful work with us.

## Partner

We have successfully translated findings from our research into commercial projects for a select group of clients who share our values and ambition. We can deliver these solo or in partnership with other organisations. Selective commercial work provides an important opportunity for us to translate our visionary research into direct outcomes.

Contact us via our website to find out more about how you can support our work by making a donation, volunteering or partnering with us.

[www.bze.org.au](http://www.bze.org.au)

## Endorsements

*'BZE have for years been the pathfinder, mapping the possibilities for our rapid, and inevitable, transition to a low-carbon society... The Zero Carbon Australia Electric Vehicles Plan [2016] is another vital piece of the jigsaw we must complete to make that transition, but particularly important given the need to move away from our social and economic reliance on ICE technology in a large continent with a widely dispersed population.'*

*Ian Dunlop, Member of the Club of Rome*

*'[BZE's Buildings Plan, 2013] comprehensively proves how we can reduce our buildings emissions, and demonstrates how individuals can contribute. The leadership shown by Beyond Zero Emissions is what the world needs, effective communication of practical applications to solve our current climate crisis.'*

*Jigar Shah, Clean energy entrepreneur and author of "Creating Climate Wealth: Unlocking the Impact Economy"*

*'[BZE's Stationary Energy Plan, 2010] is a timely and aspirational report that deserves the widest attention and debate, particularly by political and industrial decision makers.'*

*General Peter Gration, AC, OBE, FTSE, Former Australian Chief of Defence*

# Contributors & acknowledgments

## About the Environment Centre NT

The Environment Centre NT (ECNT) is the peak community sector environment organisation in the Northern Territory.

ECNT works to protect and restore biodiversity, foster sustainable communities and encourage a shift to renewable energy to reduce climate change impacts. ECNT is independent, professional, and works hard to represent the interests of their members and supporters in creating a sustainable future for the Territory.

The Environment Centre NT partnered with BZE to produce the **10 Gigawatt Vision** to raise awareness of the potential jobs and revenue opportunities for Territorians in a zero-carbon economy.



## Donations

NR Peace and Justice Fund

Lenko Family Foundation

Melliodora Fund (Sub-fund of the Australian Communities Foundation)

The Pace Foundation

The Hamer Family Fund

The Mullum Trust

Olsvik

Many monthly and occasional donors



## Strategic Oversight

Vanessa Petrie (CEO, Beyond Zero Emissions)

## Lead author

Michael Lord

## Research team

Brian Chapman

Eren Fraser

Lachlan Rule

## Editors

Madeleine Brennan

Lachlan Rule

Heidi Lee

Madeline Townsend

## Advisory committee

Eytan Lenko (Chair, Beyond Zero Emissions)

Shar Molloy (Director, Environment Centre NT)

## Expert consultation & review

Alan Langworthy

Graham Davies

Karrina Nolan, Director Original Power

Scott Hamilton, Director H4CO & Panel Member, Australian - German Energy Transition Hub

## Graphic design

Cari Gray, Paperplane Collective





## Key Messages

*Wind and solar power are now the cheapest forms of electricity generation* and the adoption of renewable energy is accelerating globally. We are approaching a critical tipping point where demand for fossil fuels suddenly plummets.<sup>1</sup>

The Northern Territory has an exceptional opportunity to prosper in this new era by converting abundant sunshine into renewable energy. *By 2030, the NT Government could help drive investment in 10 gigawatts* of renewables – 20 times more than the current renewable energy target.

By pursuing the **10 Gigawatt Vision**, the Northern Territory can put renewable energy at the centre of a sustainable growth strategy that *creates over 8,000 new jobs and over \$2 billion* in revenue by 2030.

An ambitious renewables strategy can spark a vibrant manufacturing sector in the Territory, with export opportunities in energy infrastructure, zero-carbon manufacturing and minerals processing.

Remote communities can participate in and share in the revenues of renewable energy systems sited on their land. There will also be opportunities for *Aboriginal-owned enterprises to install and operate community energy systems* or use renewable energy to power small-scale businesses.

*Cheaper renewable energy can reduce living costs for all Territorians.* Home electricity bills could fall by a third by 2030 and electric vehicles could save households as much as 80% off transport fuel bills.

Downstream mineral processing, powered by renewable energy, can enable the Territory to *extract more value from its mineral resources*. Some of the extra revenue can be reserved to alleviate environmental problems caused by mines and pay for long-term remediation.

By switching to renewable energy, the mining sector can become safer, healthier and more sustainable. *By 2030, NT mines could be 100% electric, eliminating gas and diesel use.*

The Northern Territory can become a major exporter of renewable energy. *Annual exports of hydrogen, electricity and minerals processing could be worth over \$2 billion per year by 2030.*

The **10 Gigawatt Vision** is a *sustainable alternative to economic strategies based on fossil fuels*. The shale gas industry is financially unstable and totally unsuited to the needs of the coming zero-carbon economy. Achieving the **10 Gigawatt Vision** has the potential to create many more jobs than the shale gas industry.

The **10 Gigawatt Vision** prevents *over 20 billion tonnes of carbon emissions* from entering the atmosphere and accelerating global warming – this emissions saving is four times more than the emissions from the Carmichael coal mine proposed by Adani in Queensland<sup>2</sup>.



# Contents

<b>Executive Summary</b>	<b>6</b>
Benefits	6
Opportunities	6
Recommendations	7
Protecting the environment and supporting Indigenous development	9
<b>1 - Introduction</b>	<b>10</b>
<b>2 - The rise of renewables</b>	<b>12</b>
<b>3 - The 10 Gigawatt Vision</b>	<b>15</b>
<b>4 - Opportunities</b>	<b>21</b>
Opportunity 1: Renewable hydrogen	22
Opportunity 2: Renewable energy exports	24
Opportunity 3: Renewable powered manufacturing	27
Opportunity 4: Minerals processing	29
Opportunity 5: Renewable powered mine sites	36
Opportunity 6: Reduced cost of living	39
Opportunity 7: Repower remote communities	40
<b>5 - Conclusion &amp; Recommendations</b>	<b>43</b>
<b>Endnotes</b>	<b>48</b>
<b>Appendix 1 - Shale gas and fracking is a risky bet</b>	<b>56</b>



# Executive Summary

This report presents a bold future for the Northern Territory: one that is compatible with addressing climate change and the Territory's need for sustainable economic development. Beyond Zero Emissions demonstrates that the Northern Territory can build 10 gigawatts of renewable energy by 2030 – 10 times more than the Territory's current generation capacity, and 20 times more than the current renewable energy target.

This vision puts the Territory at the forefront of the global transition away from fossil fuels and towards renewable energy. This transition is already underway, driven by international climate action and the remarkable fall in the cost of renewable energy (2 - The rise of renewables). Large-scale solar and wind energy is now the cheapest form of new electricity generation in Australia, and rapidly getting cheaper.

*"In the Northern Territory, the real potential for job creation is in the energy intensive industries that lower cost renewable energy may attract."*

*Northern Territory Government, 2017<sup>3</sup>*

Implementation of the **10 Gigawatt Vision** will attract billions in private investment, creating more than 8,000 jobs during a 10-year build-out (3 - The 10 Gigawatt Vision). But its real potential is as a catalyst for wider, long-lasting economic renewal. Unlike previous capital-intensive projects in the Territory, renewables provide the foundation for permanent jobs in diverse new industries (4 - Opportunities). This strategy will attract new residents as well as boosting NT Government revenue.

This report presents key renewable energy opportunities and provides recommendations for policy reform (5 - Conclusions & Recommendations) to advance the **10 Gigawatt Vision**.

## Benefits by 2030

The benefits of the **10 Gigawatt Vision** are powered by building over 10 gigawatts of clean, renewable energy generation by 2030. This means:

- >8,000 new jobs
- >\$2 billion annual new revenue
- 80% saving in household transport bills
- 30% saving in household electricity bills
- Eliminating carbon pollution from towns, communities, mines and manufacturing
- Providing safer, healthier, more affordable and secure places to live and work.

## Opportunities

The construction and operation of large-scale of renewable energy will itself create a major industry. This will also be an enabler for a fantastic range of renewable-powered energy intensive activities, such as the following opportunities outlined in detail in this report in Table 1.

**Table 1: Summary of opportunities for the 10 Gigawatt Vision**

Opportunities	Energy Requirements (GW)
1. <b>Renewable hydrogen</b> Capture 2/3 of the national hydrogen boom	4.87
2. <b>Renewable energy exports</b> Connect NT to the NEM & Asia	3.2
3. <b>Renewable powered manufacturing</b> Electrify and expand industry	0.2
4. <b>Mineral processing</b> Electrify and expand minerals processing	0.71
5. <b>Renewable powered mines</b> Electrify energy used on mine sites	0.3
6. <b>Reduced cost of living</b> Cheaper electrical and transport bills	1.0
7. <b>Repower remote communities</b> Electrical microgrids and enterprises	0.01
<b>Total</b>	<b>&gt;10</b>





## Recommendations

1. Launch 10 Gigawatt Vision with an ambitious plan and marketing strategy.
2. Progress a wide range of technologies to support building 10 gigawatts of renewables in the NT.
3. Set up a business renewables service matching renewable energy providers with customers, including larger organisations such as mines.
4. Establish 100% renewable remote communities and support Indigenous-owned renewable enterprises.
5. Create incentives and programs for 100% renewable manufacturing.
6. Set targets for mines to transition to 100% renewable energy, including electric machinery and vehicles.
7. Create incentives for downstream processing of minerals within the Northern Territory.
8. Plan and fund supporting infrastructure.
9. Reform mining regulation to ensure both efficient decision-making and higher standards of environmental and cultural heritage protection.
10. Lobby for federal support for the 10 Gigawatt Vision.





# Protecting the environment and supporting Indigenous development

The **10 Gigawatt Vision** relies in part on the vastness of the Northern Territory, and the owners of the land will be integral to its success. Around half of the Territory is owned and managed by Traditional Owners, with more than 250,000 km<sup>2</sup> of land and water subject to native title determinations.<sup>4</sup> An economic development strategy based on renewable energy must place Indigenous people at its centre. As Joe Morrison, former CEO Northern Land Council has emphasised:

*“Indigenous agencies have got to be in the planning wheelhouse; they’ve got to be able to plot the course of their own development, rather than having to negotiate with third parties which want access to Indigenous land”.*

*Northern Land Council, 2017<sup>5</sup>*

The principle of free, prior and informed consent (FPIC) should be a cornerstone of engaging with Traditional Owners about their land. FPIC ensures that Traditional Owners have ‘equal opportunity’ to engage with any proposed project on their land or which impacts their land. Equal opportunity means equal access to financial, human, linguistic and material resources in order for communities to fully and meaningfully engage in the process.

Benefits to Indigenous communities must be planned at the outset, and not dependent on hopes of prosperity “trickling down”. Canada and New Zealand already have successful track records of renewable energy projects facilitating Indigenous benefit, including part-ownership of renewable energy resources. This First Nation’s experience can guide the participation of Traditional Owner groups in the coming energy revolution.<sup>6</sup>

Parts of the **10 Gigawatt Vision** propose an increase in mineral processing or implicitly endorse the continuation of mining powered by renewable energy. Both types of projects have the potential to bring jobs and investment to regional areas.

Unfortunately, there are many examples of mines failing to benefit Indigenous communities in terms of health and education, jobs and general community well-being. Some of the most disadvantaged NT Indigenous communities are near mines, including Borrooloola (Glencore Xstrata’s McArthur River Mine), Jabiru (ERA’s Ranger Mine) and Yirrkala (Rio Tinto’s Gove mine and bauxite refinery).<sup>7</sup>

Several Territory mines have also left a legacy of pollution and health risks. The Independent Monitor for the McArthur River Mine has highlighted a number of issues including the risk of acid and metalliferous contamination of the McArthur River from the tailings dam.<sup>8</sup> Mount Todd gold mine pollutes the Edith River near Katherine with acid and metalliferous drainage.<sup>9</sup> Ranger Uranium Mine has left a plume of radioactive contaminated water below its tailings dam.<sup>10</sup> The East Finnis River receives ongoing contamination from Rum Jungle Mine decades after its closure, despite ‘best practice’ rehabilitation.<sup>11</sup>

During the inquiry into hydraulic fracturing at public hearings, community forums and in many of the submissions received, the community expressed a lack of confidence in the current regulatory framework. The Panel agreed this lack of confidence was justified and that reforms are needed to the NT’s regulatory regime.<sup>12</sup>

The economic vision presented in this report is an opportunity to avoid the failures of the past and contribute to better environmental, social and cultural outcomes for all Territorians. But these outcomes depend on a strategy that embeds the principles of ecologically sustainable development at the outset. This is particularly important for developments involving mining or mineral processing where proponents and the NT Government will need to work hard to address community concerns and earn people’s trust. A proportion of additional revenues generated by processing minerals must be used to alleviate existing problems.



# 1 - Introduction

Facing an uncertain future in the face of climate change, fossil fuel dependency and insecure employment, the Northern Territory needs some big new ideas. Repowering minerals mining, manufacturing and industry with 100% renewable energy, creating over 8,000 jobs and increasing annual revenue by more than \$2 billion by 2030 is exactly the solution needed. The **10 Gigawatt Vision** outlines the jobs, investment and policy direction needed to secure a clean, healthy and vibrant renewable -powered future for Territorians.

For most of this century, the Territory government has spent beyond its means, and it urgently needs new sources of income.<sup>13</sup> Public debt is expected to treble in five years from 2017.<sup>14</sup> A larger workforce would help, but the Territory is struggling to attract new long-term residents. For a few years, the Ichthys LNG boom brought new workers and boosted government revenue. But with the end of construction came the bust. Investment dried up, many workers left the Territory and budget problems returned.

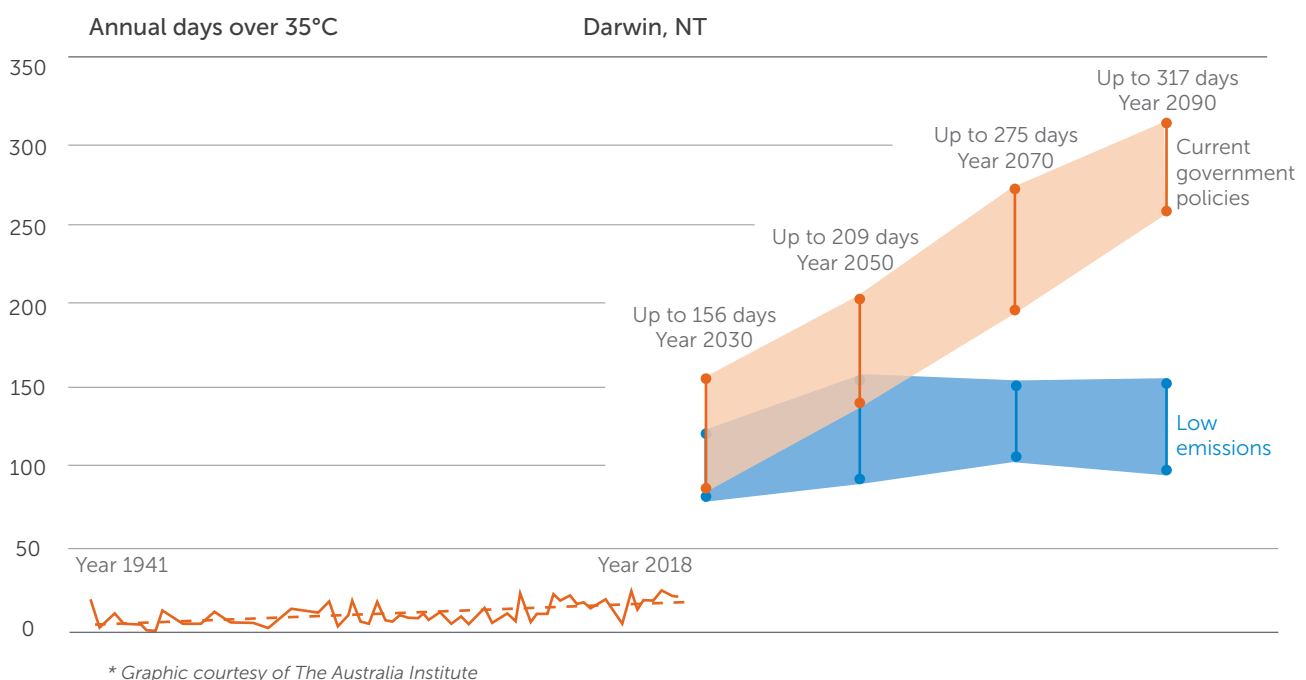
The Territory has a larger stake than most in successful climate action. CSIRO projections show increasing intensity of extreme events such as storms, cyclones, floods, droughts and bushfires.<sup>15</sup>

Projections for extreme heat are particularly alarming: in just 30 years the temperature in Darwin could exceed 35°C on the majority of days (Figure 1). The impact of a harsher climate will be felt disproportionately by vulnerable populations, including Aboriginal people.

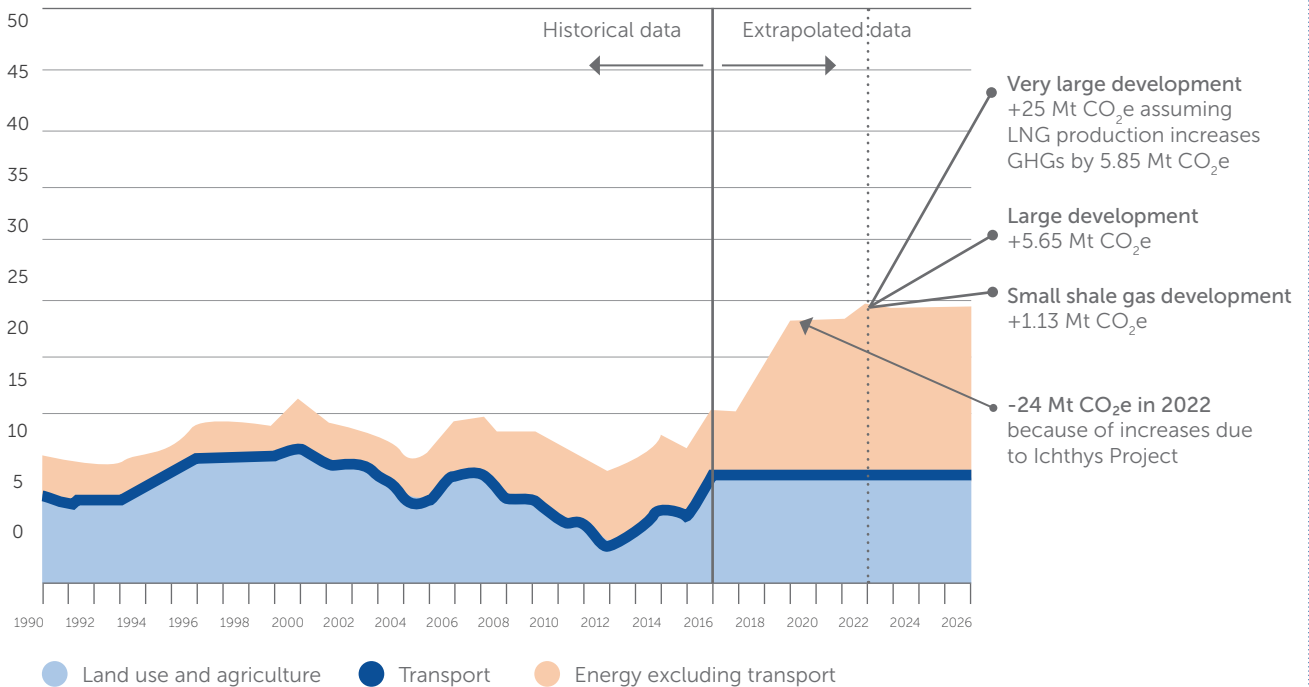
Faced with this troubling future, the Territory should be leading efforts to tackle climate change. Instead, it is pursuing the opposite course – drastically increasing greenhouse gas emissions. The Ichthys LNG project has already increased NT’s annual emissions to nearly 25 million tonnes, and this could double to 50 million tonnes if the LNG and shale gas industries really take off (Figure 2, p11). This would represent emissions of almost 200 tonnes per person – four times those of Qatar, the country with the world’s highest per capita emissions.

The **10 Gigawatt Vision** is a better solution to jobs and revenue for the Territory. As one of the sunniest places in the world, the Territory has almost unlimited potential to generate renewable energy. Its political stability and track record in hosting ambitious infrastructure projects also make it a sound choice for large capital investment. In short, the Territory has all the ingredients to become a global powerhouse in renewable energy.

**Figure 1: CSIRO and Bureau of Meteorology projections for increases in extreme heat days due to global warming<sup>16</sup>**



**Figure 2: Greenhouse gas emissions in the Northern Territory are set to rise steeply due to gas projects<sup>17</sup>**



Ironically, local abundance of natural gas has not made energy any cheaper in the Territory. A typical electricity customer faces some of the highest bills in the country – 24% higher than the national average.<sup>18</sup> Even this hides the true cost to Territorians. The NT Government subsidises electricity but won't say by how much. In remote communities, energy costs are much higher still.

The latest new idea for the Territory is shale gas extracted by fracking. In 2018, the government lifted its moratorium on fracking, and gas companies plan to start exploring the Beetaloo Basin in late 2019.<sup>19</sup> The government hopes the industry will attract investment, workers and prosperity. This is not a long-term solution.

The **10 Gigawatt Vision** is a better opportunity to deliver prosperity to Territorians without risking public health, increasing emissions and devastating the environment.

NT's shale gas industry is getting going just as many international investors are losing patience with a sector notorious for failing to deliver financial returns. Fracking is also incompatible with Australia's international climate commitments, and the human imperative to reduce the catastrophic risks of global warming. Appendix 1 outlines the limitations of fracking to provide the solutions for communities and business that Territorians need.

# 2 - The rise of renewables

Many of us alive today will witness the end of the fossil fuel era. Coal, gas and oil have driven industrialisation, but are now making way for cheaper, cleaner renewable energy. This transition is as momentous, and as unstoppable, as the switch from wind and water power towards coal in the early 19th century.

*"We have reached an inflection point where, in some cases, it is more cost effective to build and operate new alternative energy projects than to maintain existing conventional generation plants."*

*Roadmap to Renewables, Northern Territory Government, 2017<sup>27</sup>*

## Economic realities

Fossil fuels will be trapped in a pincer movement, with economics on one side and climate action on the other. The cost of renewable energy has been falling steeply for decades, and solar power is now 80% cheaper than only 10 years ago.<sup>20</sup>

Wind and solar power are now the cheapest forms of electricity generation in many countries, including Australia. In fact, they are now often cheaper than existing coal and gas power plants – even when the cost of building those plants has been paid off.<sup>21</sup>

*"Batteries co-located with solar or wind projects are starting to compete, in many markets and without subsidy, with coal- and gas-fired generation for the provision of dispatchable power"*

*George Bilicic, Lazard Power, 2018<sup>22</sup>*

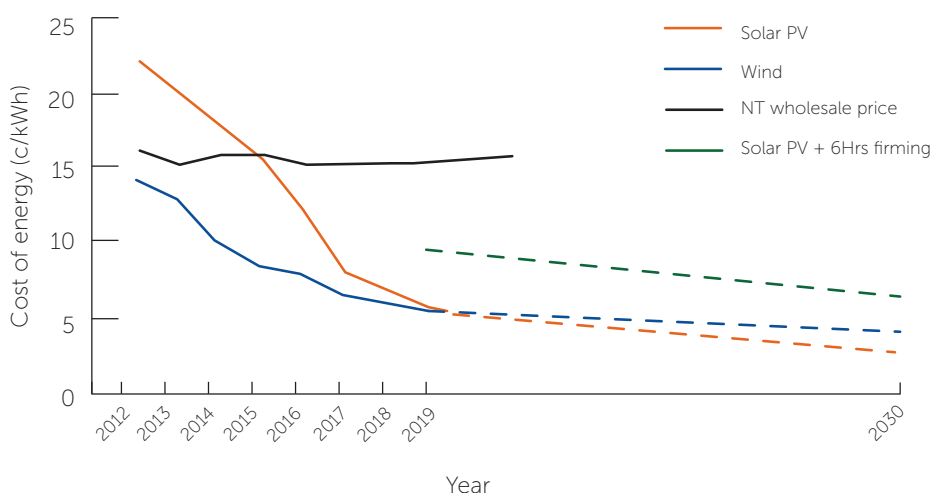
The cost of solar PV has fallen 84% since 2010,<sup>23</sup> and electricity from large-scale solar can now be produced for as little as 5-6 cents per kilowatt hour (c/kWh) in Australia, well below the average market price (Figure 3).<sup>24</sup> This compares to the Territory's average wholesale price of 15 c/kWh and at least 20 c/kWh for diesel in remote communities.<sup>25</sup>

CSIRO has found that solar is cheaper than gas even with the addition of two hours of energy storage in batteries or six hours energy storage via pumped hydro.<sup>26</sup> Solar PV and battery costs are set to continue their steep decline. By 2030, solar PV could fall by 50% and solar PV firmed with two hours of battery storage will be around half the cost of gas generation (Figure 3).

Renewable electricity at this price will completely rewrite energy economics.

The other major problem for the fossil fuel industry is the growing momentum behind international climate action, by governments, investors and corporations, described as follows.

**Figure 3: The cost of renewable energy in Australia has plummeted and will continue to fall.**





## Government policy

Every country in the world is currently signed up to the 2015 Paris Climate Agreement - aiming to hold the rise in global temperature to well below 2.0°C and to pursue every effort to limit the rise to 1.5°C.<sup>28</sup> Achieving the latter target is vital if we want to avoid the significantly graver impacts of a 2 degree increase.<sup>29</sup> To achieve either target, most reserves of fossil fuels must remain in the ground, and new fossil fuel developments are out of the question.<sup>30</sup>

*"Now is not the time for a medium-sized economy to test global tolerance for free riders."*

*Innes Willox, CEO of the Australian Industry Group<sup>31</sup>*

Many governments are ramping up their climate policy. Most large economies now have ambitious renewable energy targets, including major importers of Australia's fossil fuels such as China and India.<sup>32</sup> More and more countries also impose costs on carbon pollution, and China now runs the world's largest emissions trading scheme.<sup>33</sup> Australia will come under increasing political pressure to put a price on carbon. Trading allies such as the European Union are already discussing carbon tariffs as a way of penalising countries without credible carbon policy.<sup>34</sup>

## Investor action

Financial institutions understand that international climate policy puts fossil fuel industries at risk. Mark Carney, the Governor of the Bank of England, has even stressed the risk of fossil-fuel companies collapsing.<sup>35</sup> The Investor Group on Climate Change has called the Paris Agreement an "unambiguous market signal" of the end of fossil fuels.<sup>36</sup>

Responding to this signal, institutional investors have divested more than \$US6 trillion of fossil fuel investments.<sup>37</sup> Institutional investors are now joining forces to demand more ambitious climate action.

*"Smart investors can see that investing in companies that rely solely or heavily on constantly replenishing reserves of fossil fuels is becoming a very risky decision."*

*Professor Nicholas Stern, former World Bank Chief Economist<sup>38</sup>*

The Investor Agenda, a group of 415 investors representing over US\$32 trillion in assets, has called on governments to put a price on carbon, abolish fossil fuel subsidies and phase out thermal coal power.<sup>39</sup> Another investors' initiative, Climate Action 100+, has persuaded many of the world's largest corporate emitters including BHP, Glencore and Rio Tinto to commit to strategies aligned with the Paris Agreement.<sup>40</sup>

## Business initiatives

Many large businesses are surpassing governments in their level of climate ambition. Some of the world's leading companies aim to source 100% of their electricity from renewable sources, and Apple, Google and Microsoft have already achieved this goal.<sup>41</sup> More than 500 global corporations have joined the Science Based Targets initiative which requires them to set emissions reduction targets in line with the Paris Agreement. Signatories include many household names such as Coca-Cola, Gap, IKEA, L'Oreal, Nestlé, Sony and Walmart. Some such as Mars and Sony have even committed to eliminating their indirect (Scope 3) emissions.

For now, the fossil fuel industry remains bullish about its long-term prospects. One BP projection is that by 2040, coal, gas and oil will provide 75% of the world's energy.<sup>42</sup> But the history of technological transition would make unsettling reading for BP and its peers.

Faced with a disruptive technology, an industry's downfall can be swift. The demise of Kodak has become the symbol for this phenomenon, but there are many other examples, such as the impact of the internet on postal services. In 2001 the US Postal Service had a record year, delivering 104 billion pieces of first-class mail.<sup>43</sup> Now it delivers just half that amount – unable to compete with faster, cheaper online communication.

The fate of US mail may be a taste of things to come for the fossil fuel sector. In fact, the recent turmoil in the gas turbine sector in the face of cleaner, cheaper renewables (see Appendix 1), suggests the tide may already have turned.

Fossil fuels also face increasing legal challenges.<sup>44</sup> A court case early in 2019 saw the first Australian decision against a new coal mine on climate grounds. A NSW court dismissed an appeal against the rejection of the proposed mine, basing part of its reasoning on the increased greenhouse gas emissions it would cause.<sup>45</sup>

This powerful combination of governments, investors and business is driving industry towards a zero-carbon future. With the economics also in their favour, the transition to renewables could be swift, and fossil fuel investments could quickly become liabilities.

*"If some companies and industries fail to adjust to this new world, they will fail to exist."*

*Mark Carney, Governor of the Bank of England.<sup>46</sup>*

This energy transition will have profound effects across the economy. Sectors such as manufacturing, mining and transport will be transformed in perhaps the biggest wave of change since the industrial revolution.

Clear, decisive action towards repowering the NT on 100% renewable energy can be taken today. Governments, business and communities will all play a part in securing a strong, healthy, enviable position for Territorians at the forefront of the global clean energy economy.

# 3 - The 10 Gigawatt Vision



The Northern Territory has great advantages in the new era of renewable energy. It has potential for sustainable development: access to cheap capital, a skilled workforce and experience with complex engineering projects. But above all, it is one of the sunniest places in the world.<sup>47</sup>

This report presents a vision for the NT to capture these advantages: a vision in which the Territory builds **10 gigawatts of renewable energy by 2030 for the benefit of all Territorians**. This is a ten-fold increase in the Territory's current capacity to generate electricity from all sources.

This is a vision where the NT establishes itself as a leader in renewable energy, becoming a destination of choice for companies wanting to set up smart, clean operations, powered by renewable energy. Products made in the Territory will be internationally recognised as sustainable, with low embodied emissions.

These economic benefits to Territorians will also deliver a range of lifestyle and environmental improvements, including eliminating carbon

pollution from towns, communities, mines and factories; providing safer workplaces; and delivering healthier, more affordable and secure places to live.

By 2030, the **10 Gigawatt Vision** is projected to provide:

- More than 8,000 new jobs
- More than \$2 billion annually in new revenue
- 80% saving on household transport bills
- 30% saving on household electricity bills

A **10 Gigawatt Vision** can provide the basis of a new economic strategy for the Territory. A strategy which sees the NT become a renewable energy superpower, and a home of industry powered by renewables. Ten gigawatts of renewable energy could stimulate the NT economy and catalyse economic development in a number of sectors and across remote and regional areas.

The economic opportunities of implementing the **10 Gigawatt Vision** are described in more detail in 4 – Opportunities.



## Building the 10 Gigawatt Vision

Ten gigawatts is ten times the Territory's current electricity generation capacity, and more than twenty times the renewable capacity foreseen by the NT's current renewable energy target.

Installing 10 gigawatts of renewables is not a particularly challenging undertaking – at least in terms of scale, cost or land required. More than 3.7 gigawatts solar was installed in Australia in 2018 alone and more than 4 gigawatts is expected in 2019.<sup>48</sup> In Australia, there are now several renewable energy project proposals at the gigawatt scale including the Asian Renewable Energy Hub in the Pilbara (15 gigawatts – Box 1), the Kennedy Energy Park in north Queensland (1.2 gigawatts) and the Walcha Energy Hub in NSW (4 gigawatts).

Ten gigawatts of large-scale solar would cost around A\$20 billion in 2019 prices<sup>49</sup> (and possibly much less in 10 years' time). This is a far smaller sum than Australia's recent gas projects such as the A\$54 billion Ichthys LNG project. Solar power can also be constructed more quickly than most types of generation, with even large-scale projects often taking only a year. Currently renewables in the NT cost 30-50% more than elsewhere in Australia, but this premium is likely to disappear as the industry scales its development.

Until now, the Northern Territory has missed out on the renewables boom taking place elsewhere in Australia. But the region has effectively unlimited potential to generate solar power. The NT Government calculated that 450 MW of solar PV requires an area equivalent to just 0.08% of the Victoria River Downs cattle station.<sup>50</sup> This means 10 gigawatts would require just 1.8% of the same cattle station – or 157 km<sup>2</sup> – a minute fraction of the Territory's surface area. Even solar power equating to Australia's entire generation capacity would take up just 0.06% of the Territory (837 km<sup>2</sup>).

Just like the Ichthys project, and renewables projects around Australia such as the 15 gigawatts Asian Renewable Energy Hub (Box 1), the **10 Gigawatt Vision** will be paid for with private investment. The government's role is to create the environment to stimulate this investment, and we propose some policies in Section 5. Increasingly renewable energy projects are getting off the ground once they have signed a power purchase agreement (PPA) with a major customer such as a manufacturer. This means policies to support the **10 Gigawatt Vision** and policies to encourage energy intensive projects will be mutually reinforcing.

There are huge solar and wind renewable energy resources in the Territory. Solar PV potential in the Territory is among the best of anywhere in the world, with average outputs of over 1,600kWh/kWp (Figure 4, p17). Both Bureau of Meteorology and Windlab modelling shows there are good wind resources in the southern parts of the Territory (Figure 5, p17).

### Box 1: Asian Renewable Energy Hub<sup>51</sup>

The Asian Renewable Energy Hub in the Pilbara, WA, is an international consortium proposing to build the world's largest renewable energy project with 8.5 gigawatts of wind and 6.5 gigawatts of solar generation. This would generate significantly more electricity than Australia's entire 2020 renewable energy target of 33,000 GWh.

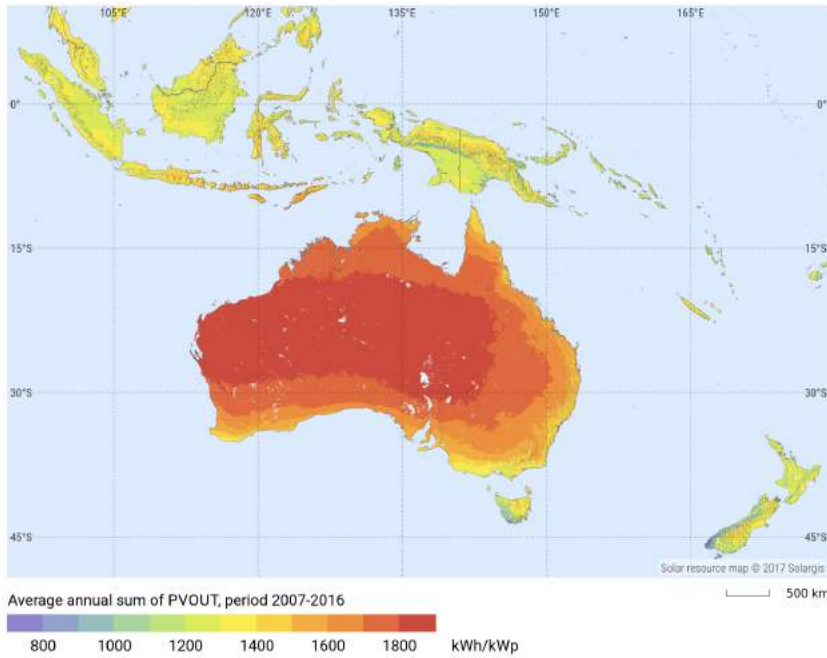
The consortium plans to sell this electricity to three types of customer:

- mines and mineral processors
- renewable hydrogen export industry
- Indonesia via an undersea cable.

The Asian Renewable Energy Hub has been granted Major Project status by the WA Government and has the backing of powerful interests including Macquarie Bank. Project construction is planned to begin in 2023.

Figure 4: Solar PV power generation potential for Australia<sup>52</sup>

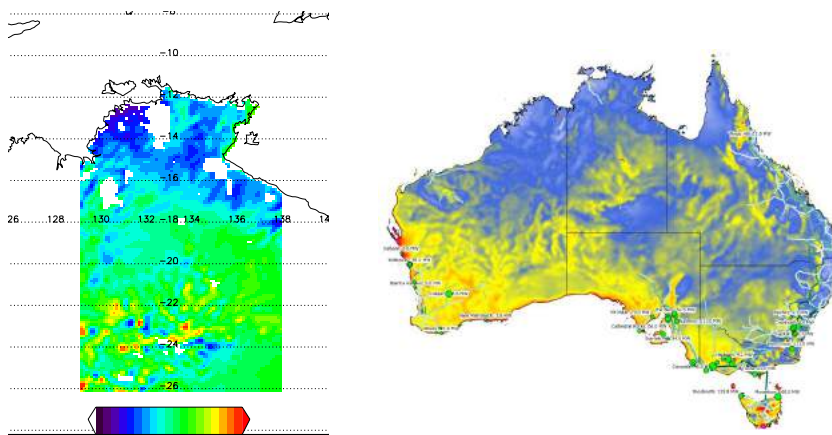
(annual output of 1kW panel)



This map is licensed by Solargis under the Creative Commons Attribution license (CC BY-SA 4.0).

Figure 5: Potential wind resource in NT<sup>53,54</sup>

LHS: BOM modelling with green areas viable and yellow/red areas very good for wind power. RHS: Windlab modelling with yellow areas good for wind energy.



## Towards a 100% renewables target

In the short-term (2020-2025) progress towards 10 gigawatts will rely largely on solar PV due to its low cost and NT's abundant sunshine. But as the number of renewable energy projects increase the role of other supporting technologies will grow.

In the medium term (2025-2030) the goal for the NT should be a 100% renewable grid. Several in-depth analyses have found this is feasible in Australia – including studies by Beyond Zero Emissions (2010)<sup>55</sup>, the Australian Energy Market Operator (2013),<sup>56</sup> the Institute for Sustainable Futures (2016)<sup>57</sup> and CSIRO (2016).<sup>58</sup>

This report does not set out a detailed development plan for a 100% renewable grid for the NT. However, we assume it will require changes to regulation and market rules. We expect it will depend on the right combination of affordable and mature technologies, some of which are summarised in Table 2 (p19).

Our assessment of these technologies is positive and we recommend that their potential is investigated in greater detail.

1. The NT will require systems that store energy during sunny periods, releasing it when needed. Batteries, pumped hydro, solar thermal and stored hydrogen will compete for this role, and all are affordable and viable in the NT.<sup>59</sup>
2. There will be a need for renewable energy technologies that generate electricity at different times to solar PV. Solar thermal power is one clear

candidate as it stores energy and can generate through the night, and would work well in the NT. Other supporting technologies worth examining in more detail in the NT context are geothermal and tidal and, in particular, wind.

3. Demand management can play an important grid-balancing role which is functionally similar to energy storage. By creating large new users of electricity, such as metals processors, the NT can create large potential sources of demand management. This means that realising the opportunities highlighted in this report will support the operation of an electricity system powered by renewables.
4. New transmission connections would improve the resilience of the whole grid. Increasing the capacity of transmission lines between Darwin and Katherine would open up the possibility of solar PV or solar thermal near to Katherine. Even more exciting would be a new transmission connecting Darwin to Alice Springs or other parts of the NT. This would facilitate renewable energy development in a large part of the NT including remote locations.

This type of long-distance transmission is becoming more viable thanks to the decreasing cost of High Voltage Direct Current (HVDC) cables.<sup>60</sup> In fact, the evolution of this technology means it is now feasible to consider connecting NT to both the National Electricity Market and south-east Asia. The potential benefits of such a scheme are explored in **Opportunity 2**.



**Table 2: Using a range of commercially-available technologies, the NT could achieve a 100% renewable grid by 2030.**

Technology	Comments	Grid function
Solar PV	Solar PV turns light into electricity. As mentioned already, the NT has huge solar potential. The very low cost of the technology, which is still falling, and an abundance of sunlight means solar PV will produce the majority of the NT's renewable energy.	Generation
Demand management	Renewable grids will benefit from flexible consumption – users able to manage their electricity demand according to availability. Large-scale electrification projects of the type proposed in this report will provide an valuable source of demand management, and many will be able to shift some consumption to the middle of the day.	Balancing
Electricity transmission	Transmission to opening up new areas of the NT to renewable energy projects. Potential projects include upgrading the connection between Katherine and Darwin, a new HVDC cable between Alice Springs and Darwin or to mines and mineral processing facilities.	Balancing
Batteries	Batteries are falling in price even faster than solar PV – 80% since 2010. Bloomberg New Energy Finance expects battery costs to fall another two thirds by 2030 (to A\$93/kWh). <sup>61</sup> Existing large battery systems include the 100 MW Tesla battery in South Australia. Batteries of 25 MW and 30 MW are now being built in rural Victoria.	Storage (short-term)
Renewable hydrogen (fuel cells & turbines)	Renewable electricity can power an electrolyser, producing hydrogen. This hydrogen can then be used to generate energy in either a fuel cell or a gas turbine. Hydrogen provides long-term energy storage and security during longer periods of cloudy weather.	Storage (long-term)
Pumped hydro	Pumped hydro is the most widely-implemented technology for electricity grid storage. A team at the Australian National University has identified more than 1,500 possible pumped hydro sites in the NT – only a tiny fraction of which would be needed in a 100% renewable grid. <sup>62</sup> Many of these potential sites are within 200km of the Darwin-Katherine and Alice Springs grids, and include abandoned mines.	Storage (medium-term)
Solar thermal power	Solar thermal power is the alternative technology for converting sunshine into electricity. It is at least twice as expensive as solar PV but has the advantage that it can produce electricity on demand at any time of the day. Large solar thermal plants are operating in North and South America, Africa and Asia, and several gigawatts are under construction.	Generation + storage
Wind	Wind power costs are similar to solar PV in places that are sufficiently windy. The potential of wind power in the NT is often disregarded due to low wind speeds in the north of the region. However, various models, including the DNV GL Wind Mapping System, suggest there is a usable wind resource in the NT's south, including around Alice Springs. <sup>63</sup> This is supported by Bureau of Meteorology data based on satellite measurements for wind speeds at 80 metres (Figure 6). <sup>64</sup> More in-situ wind monitoring is needed to assess the potential of wind power in the NT.	Generation
Geothermal	GeoScience Australia and others have shown the NT has abundant natural resources to support geothermal power <sup>65</sup> – an extremely mature technology which can generate electricity around the clock and on demand. Suitable sites lie close to Darwin and Alice Springs. <sup>66</sup> In the right location, geothermal power is cheaper than gas generation. <sup>67</sup>	Generation

## The importance of getting started

Despite the Territory's potential for renewable generation it currently has the lowest proportion of renewables of any jurisdiction in Australia – just 5%. Recently efforts have been made to increase this proportion. For example, the government has approved the Territory's first large-scale solar project, a 25 MW plant near Katherine, and Power and Water Corporation has successfully installed 10 MW of solar in 25 remote communities.

Much more will need to be done to achieve the government's current 50% renewable target – let alone the **10 Gigawatt Vision**. This report promotes the grander ambition because it enables game-changing projects like generating hydrogen for export. But such projects become much more likely once the Territory has significant experience of installing renewables and their local costs are reduced. Once investors see renewables working well at the megawatt scale, they will be more inclined to back them at the gigawatt scale.

Whatever the target, the Territory needs urgently to ramp up renewables development. This will require the creation of market conditions to attract private investment and drive down local renewables costs. Fortunately, the NT Government does not need to reinvent the wheel - there are already successful models that can be replicated.

For example, reverse auctions were pioneered in Australia by the ACT to achieve its target of 100% renewable energy. The Victorian Government has since borrowed the ACT's model to support its own renewable energy target. In both ACT and Victoria, reverse auctions have attracted competitive bids, driving down the cost of solar and wind without placing an onerous burden on government.

It is also important that any regulatory framework encourages renewable energy power purchase agreements (PPAs). Increasingly in Australia, PPAs are helping to stimulate new renewable energy development and business models.

# 4 - Opportunities

Opportunities made possible by the NT's outstanding renewable resources are detailed in this chapter. Opportunities 1-4 relate to increasing export revenue through the expansion and development of energy, industry and minerals processing sectors. Electrifying and improving existing energy systems in towns, remote communities and mine sites is described in Opportunities 5-7. Refer to Table 3 for a summary.

## Opportunity 1: Renewable hydrogen

The global export market for renewable hydrogen is set to boom, driven by demand from East Asia. The NT is an ideal location for making renewable hydrogen, and could capture two-thirds of the national expansion of this industry by 2030.

## Opportunity 2: Renewable energy exports

The NT could sell its renewable electricity directly to customers in Indonesia and the rest of Australia. Modern HVDC cables have made such long interconnections technically and economically feasible.

## Opportunity 3: Renewable powered manufacturing

With smart policy support a large proportion of renewable energy infrastructure can be manufactured in NT. In addition, manufacturers aiming to establish their sustainability credentials will be attracted to the NT's abundance of clean energy.

## Opportunity 4: Mineral processing

NT could use renewable energy to process its manganese, zinc and other minerals, adding significant value to its exports and creating thousands of jobs.

## Opportunity 5: Renewable powered mines

Energy for mining is typically very expensive, and therefore susceptible to being undercut by renewables. Development of a strategy to replace all NT mines' fossil fuel generation with renewables, and then to electrify all mine machinery and vehicles will make mines healthier and more cost effective.

## Opportunity 6: Reduced cost of living

Building renewables at the multi-gigawatt scale will reduce the cost of electricity even more. Transport costs will fall significantly with the switch to electric vehicles and the advent of cheap, renewable electricity.

## Opportunity 7: Repower remote communities

Many small towns in the NT rely on expensive diesel energy. By switching to 100% renewable microgrids they can cut emissions, save money and become self-sufficient in energy. This also creates opportunities to set up Aboriginal-owned enterprises to install and operate microgrids.

Table 3: The 10 Gigawatt Vision provides the basis for future economic development in the NT

Opportunities	Energy required (GW)	New operations and maintenance jobs	Construction jobs	Economic benefits
1. Renewable hydrogen	4.9	960 direct jobs 2,830 indirect jobs		\$590 million direct economic contribution (>\$2.9 billion FOB)
2. Renewable energy exports	3.2	200	766	\$840 million in exports
3. Renewable powered manufacturing	0.2	200 (clean manufacturing)	820 (renewable energy build out)	-
4. Mineral processing	0.7	750	1,500	\$800 million in additional exports
5. Renewable powered mines	0.3	-	-	Securing 3,600 mining sector jobs by making sites safer, healthier and more sustainable
6. Reduced cost of living	1.0	-	Included with renewable energy build out	Reducing household electricity bills by >30%
7. Repower remote communities	0.01	-	Included with renewable energy build out	Cheaper energy, Aboriginal-owned energy businesses.
<b>Total</b>	<b>&gt;10 GW</b>	<b>&gt;8,000 jobs</b>		<b>&gt;\$2 billion revenue</b>



# Opportunity 1: Renewable hydrogen

Renewable hydrogen will play an important role in the zero-carbon economy, and global demand is set to boom.<sup>68</sup> The Northern Territory is well-placed to establish an industry producing renewable hydrogen, supplying domestic and Asian markets. The NT could capture two-thirds of the national expansion of the renewable hydrogen industry by 2030.

## Renewable hydrogen in the zero-carbon economy

Conventional hydrogen production involves significant carbon emissions but with the falling cost of renewable energy it is becoming economical to make renewable hydrogen with zero emissions (Box 2). Renewable hydrogen has an important role to play in the transition away from fossil fuels and demand is set to boom.

The Hydrogen Council foresees a global hydrogen market worth US\$1.25 trillion by 2050,<sup>69</sup> which would make it one of the world's largest industries. Much of the demand for hydrogen will come from countries such as Japan and South Korea that see imported renewable hydrogen as central to their low-carbon futures.<sup>70</sup> Both countries are planning "hydrogen economies" with Japan targeting 31,500 hydrogen fuelling stations and 5.3 million homes run on hydrogen by 2030.<sup>71</sup>

Japan and South Korea have only modest ability to generate energy from renewable sources, so will rely partly on imports from countries like Australia that can make renewable hydrogen cheaply.<sup>72</sup> A report for the Australian Renewable Energy Agency (ARENA) estimates Australia could supply at least 20% and 11% of future hydrogen demand in Japan and South Korea respectively.<sup>73</sup>

Australia's hydrogen export industry has enthusiastic cross-party support.<sup>74</sup> Some proponents of the hydrogen export industry see it as a way of extending the future market for Australia's fossil fuels. This ignores the fact that Japan and South Korea want zero-carbon hydrogen as part of their decarbonisation strategies.<sup>75</sup> If they had long-term interest in hydrogen from fossil fuels, they could make it themselves from gas they already import.

## Box 2: Renewable hydrogen: costs, uses and transport

Today most hydrogen is made from a fossil fuel feedstock, principally natural gas. This method of hydrogen production accounts for about 2% of global greenhouse gas emissions. Hydrogen can also be made by passing an electric current through water, causing it to split into oxygen and hydrogen. If the electricity comes from renewable sources, this produces renewable hydrogen with no emissions. The Hydrogen Council envisages that globally by 2030, 250–300 TWh of surplus solar and wind energy could be converted to hydrogen.<sup>76</sup>

### Cost of renewable hydrogen

CSIRO estimates that by 2025 the cost of producing hydrogen with electrolysis in Australia will fall to \$2.29–2.79/kg. At this rate it will be competitive with hydrogen from fossil fuels.<sup>77</sup> This cost is dependent on the low cost of renewable energy in Australia, which CSIRO assumes will fall to 4 cents/kWh by 2025.

### Market for renewable hydrogen

The global market for renewable hydrogen will be driven by three areas of demand:

1. Replacing existing hydrogen feedstock in ammonia and other products – a market worth US\$140 billion in 2018.<sup>78</sup>
2. Hydrogen is a versatile fuel that can be used in electricity generation, heating and transport. ARENA estimated the future market for hydrogen as an energy source could be worth up to A\$80 billion by 2030, and over A\$300 billion by 2040.<sup>79</sup>
3. Renewable hydrogen can displace fossil fuels in the manufacture of products like steel, methanol and a wide range of organic chemicals. Producing today's global steel output with hydrogen-based methods would require 112 million tonnes of hydrogen – worth about US\$280 billion.

### Transporting hydrogen

The success of a renewable hydrogen export industry is dependent on the commercialisation of a means of transporting hydrogen over long distances. Either liquefaction or ammonia synthesis are likely to be the most cost-effective.<sup>80</sup>

## NT renewable hydrogen prospects

By 2030, Australia could be exporting a million tonnes of hydrogen every year, and up to three times that amount by 2040.<sup>81</sup> This would create a new national export market worth up to \$4.4 billion by 2030.<sup>82</sup> A hydrogen industry of this size could employ 1,400 people across Australia, with additional indirect employment of around 4,300.<sup>83</sup> Most of these jobs would be in regional locations with high solar irradiance and access to land.

The Territory is well-placed to capitalise on the hydrogen export market thanks to:

- exceptional renewable energy resources enabling zero-emissions hydrogen at low cost
- existing infrastructure and experience in LNG exports, transferable to a hydrogen industry
- existing trading relationships with customers in East Asia.

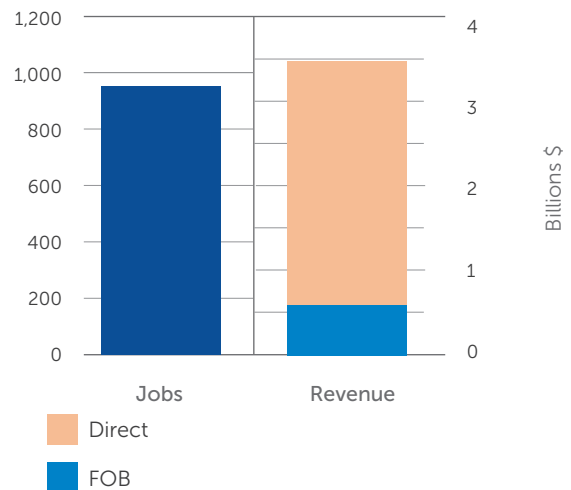
These advantages mean the Territory will be able to export hydrogen to East Asia at a lower cost than most competitors.<sup>84</sup> It is an ambitious and achievable aim for the Territory to capture two-thirds of Australia’s hydrogen export industry. Based on the above projections, and as summarised in Figure 6, by 2030 this would lead to:

- 960 direct jobs in the hydrogen production and export industry
- 2,830 new jobs created indirectly
- \$590 million direct economic contribution
- Over \$2.9 billion FOB (Free on Board, or the value of goods at purchase).<sup>85</sup>

Producing this amount of hydrogen would require around 5.5 gigawatts of renewable energy capacity.

The Chief Scientist, Dr Alan Finkel, has identified the NT - as Australia’s sunniest jurisdiction - as having “enormous potential” to produce hydrogen, and supply Japan and South Korea.<sup>86</sup>

**Figure 6: NT could develop an export industry worth \$2.9 billion a year by 2030 and create 960 direct jobs**



## Opportunity 2: Renewable energy exports

By achieving the **10 Gigawatt Vision**, the NT can become a renewable electricity export hub of national and international significance. As an energy export hub, NT could sell its electricity directly to customers in Asia and the rest of Australia. Realising this opportunity involves building not just renewable energy, but major new High Voltage Direct Current (HVDC) transmission lines as described below and illustrated in Figure 7 (p25). Exporting renewable energy has the potential to create 966 jobs<sup>87</sup> and deliver \$850M annual export revenue.

Becoming an export hub is not essential to the wider vision of NT becoming a renewable energy powerhouse. The NT could decide to continue with only local grids and still realise the other opportunities presented in this report. But by connecting to other networks, the Territory can unlock greater economic potential and spread the benefits to more remote communities.

This opportunity requires two stages of transmission link construction, as described below. The first stage involves expanding NT's internal electricity network, creating a unified grid stretching from Darwin to Alice Springs and incorporating towns such as Katherine and Tennant Creek. In the second stage, the NT grid would be connected with Indonesia and/or the National Electricity Market.

### Stage 1 – Creating the Darwin-Alice Springs grid

The new transmission line between Darwin and Alice Springs would create a renewable energy corridor between the two towns. This corridor would become the site of the full range of suitable renewable energy projects including solar PV, solar thermal, wind and geothermal. The cable would open up a large area of the NT to renewable developments, and projects could be sited to benefit local users including remote communities, mines and mineral processing facilities. This also creates opportunities for communities and pastoralists to benefit by sharing the revenues of renewable projects on their land.

#### Darwin to Katherine

Increasing the capacity of transmission between Katherine and Darwin would open up the region around Katherine to renewable energy development. This region is better suited to solar thermal power which works best with a reliable resource of direct sunlight. Power and Water Corporation is currently considering duplicating the existing Darwin to Katherine transmission line.

#### Katherine to Alice Springs

A new transmission line connecting the Darwin-Katherine network with Alice Springs would create a single grid down the backbone of the NT. This transmission line was mooted by NT Government in 2017 and informal calculations suggest a 200 MW link would cost around \$500 million.<sup>88</sup>

The transmission line would open opportunities for renewables development in the Beetaloo sub-basin – the area of most interest to fracking companies. The Beetaloo area is suitable for solar energy and is also one of the best areas in the NT for geothermal energy. The **10 Gigawatt Vision** creates sustainable economic alternatives to fracking for Indigenous communities and pastoralists in this region.

### Stage 2 – Linking NT to Indonesia and the NEM

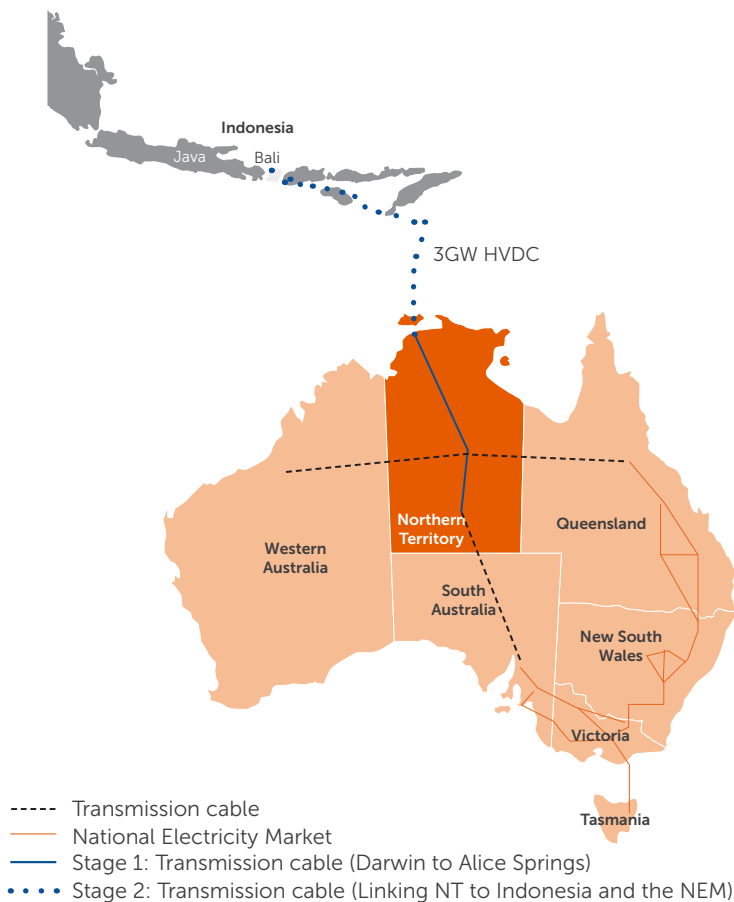
#### Northern Territory to Indonesia

The Northern Territory could become a major exporter of electricity to south-east Asia. This would involve an under-sea HVDC cable connecting the Northern Territory to Indonesia's Java-Bali grid. Eventually this could connect NT with the south-east Asian super-grid proposed by the Association of Southeast Asian Nations (ASEAN).<sup>89</sup>

By exporting electricity, Australia could contribute significantly to development and emissions abatement in Indonesia. Not only is Indonesia one of Australia's nearest neighbours, but it faces challenges in supplying electricity to its large and growing population. At the same time, Indonesia aims to increase the proportion of electricity powered by renewables from 7.4% today to 23% by 2025.<sup>90</sup> Indonesia's energy minister acknowledges that achieving this target, let alone a longer-term 100% renewable goal, will be difficult.<sup>91</sup>

Although Indonesia has hydropower and geothermal resources, it has a number of disadvantages in renewable generation. These disadvantages include weak wind energy resources, less suitable land and poorer solar resources compared to Australia. With a transmission link, Indonesia would gain access to Australia's sunnier and windier locations and a much broader geographic range to smooth the variable output of renewables.<sup>92</sup>

**Figure 7: Possible transmission lines connecting NT to Indonesia and the rest of Australia**



## The benefits of an Indonesian-Australian interconnection

The consortium behind the 15 gigawatts Asian Renewable Energy Hub (Box 1, p16) has explored in detail the viability of exporting renewable electricity to Indonesia via a cable from Western Australia.<sup>93</sup> They have concluded that not only is the project technical feasible,<sup>94</sup> but they could supply Indonesia with electricity 10% cheaper than their current cost.<sup>95</sup>

In 2017, the Pilbara Development Commission also examined transmission to Indonesia from north-west Australia.<sup>96</sup> The commission explored the feasibility of a \$6 billion, 3 gigawatts cable following a 2,000km under-sea route with a diversion to avoid the deepest parts of the Java Trench (the deepest trench in the Indian Ocean). The study assumed the link would be fed entirely by 3 gigawatts of solar PV and found it could supply Indonesia with competitively-priced electricity within just five to 10 years.<sup>97</sup> Adding significant amounts of battery storage would make the project even more attractive.

There are advantages in the Indonesian interconnection leaving Australia from NT rather than WA. Firstly, the cable could take a more direct route as it would not have bend around the Java Trench. Secondly, NT is closer to the National Electricity Market and a larger, more geographically spread NEM would benefit all eastern states by smoothing out the variability of renewable generation.

The University of Melbourne and Monash University have assessed the economic impact of a transmission link connecting central Northern Territory with Bali. The study modelled incremental construction culminating in an enormous 43 gigawatts connection by 2050, and found the link would bring economic and environmental benefits to both countries.<sup>98</sup> For Indonesia, it would lower the cost of a long-term transition to 100% renewable energy, as well as reducing the level of curtailment of local solar and wind energy. For the Northern Territory and Australia, the benefit would be a new multi-billion dollar export for the post-fossil fuel era.



## The benefits of a NT-National Electricity Market interconnection

The University of Melbourne/Monash University study also explored the impact of a ground cable connecting central Northern Territory to the nearest point of the National Electricity Market (NEM) in Townsville, Queensland.<sup>99</sup> The modelling found that this connection also has a positive impact by reducing the variability of renewable generation across the NEM. All Australian consumers would benefit because the NT's solar output would occur later in the day compared to the eastern states.<sup>100</sup>

Figure 7 (p25) shows two other possibilities for the connection to the rest of Australia. Firstly, an alternative link to the NEM in Port Augusta in South Australia – already the site of a burgeoning renewable energy industry. Secondly, a connection to the Pilbara, the proposed site of the 15 gigawatts Asian Renewable Energy Hub.

All of these connections are made viable by HVDC cables (Box 3).

### Box 3: High voltage direct current (HVDC) cables

HVDC cables are capable of transmitting electricity long distances with fewer losses than regular AC transmission cables. HVDC cables have fallen in cost in recent years and are often more cost-effective than AC cables for distances over 200 kilometres

HVDC has become a common method of interconnecting distant grids and is playing a major role in restructuring international energy markets. Many thousands of kilometres of HVDC cable are now in operation, the longest being a 3300 km line in China with a capacity of 12 gigawatts.<sup>101</sup>

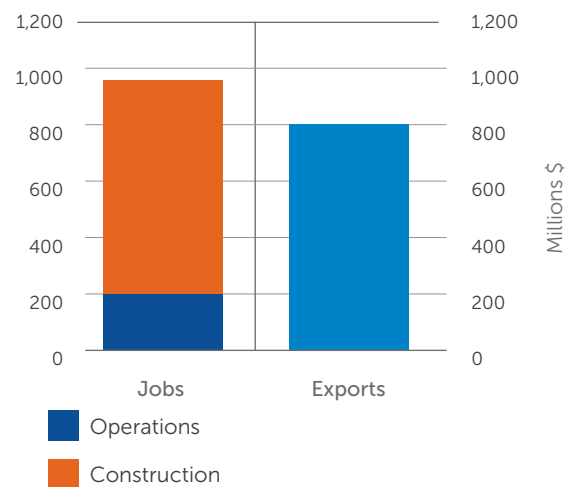
HVDC can be laid on the sea floor to a maximum depth of 3.5 km. (The deepest point between NT and Java is only 2km.)

## NT Renewable energy export prospects

The economic opportunity for the Territory is to develop a significant export industry. The beneficiaries of this industry would be widely distributed across the NT, particularly in the Darwin to Alice Springs corridor. Both traditional owners and pastoralists could share in the revenue of projects sited on their land.

Figure 8 shows what it could mean in terms of jobs and annual export revenue if a 3 gigawatts connection were built. The employment figures for capital works are based on the economic modelling carried out by the Pilbara Development Commission for a project of the same size including battery storage. Annual revenue is based on the 3 gigawatts system operating at 40% capacity and supplying electricity to Indonesia at 8 c/kWh.

**Figure 8: Jobs and revenue generated through 3GW export project**



# Opportunity 3: Renewable powered manufacturing

With abundant availability of cheap renewable energy, the NT can become an attractive location for manufacturers aiming to reduce energy costs and establish their green credentials. Local manufacturers can follow hundreds of other companies, such as Apple, Google, Commonwealth Bank of Australia, Carlton & United Breweries and Unilever Australia by committing to 100% renewable energy. These businesses see an opportunity to increase their credibility with customers and investors at the same time as reducing energy costs.

Already many leading businesses around Australia have been reducing their electricity bills by 20 to 50% by signing renewable energy power purchase agreements.<sup>102</sup> Through such deals they secure long-term price assurance, eliminating the risk from fluctuating energy prices. Hundreds of other companies are installing rooftop solar panels or even building their own renewable energy plants off-site.

Renewable technologies are mature enough to power even the most energy-hungry manufacturers. Both of Australia's steelmakers, BlueScope and Liberty One Steel, have turned to renewables as a way of lowering costs. Sun Metals in Queensland has built a massive 125 MW solar farm and is now considering adding wind and batteries. The company reports that the lower energy costs from solar have helped safeguard the future of its zinc refinery.<sup>103</sup>

*"In the Northern Territory, the real potential for job creation is in the energy intensive industries that lower cost renewable energy may attract."*

*Northern Territory Government, 2017<sup>104</sup>*

## Electrifying industry

Sourcing renewable electricity in itself does not tackle emissions from a factory's direct consumption of fossil fuels. Many facilities burn natural gas to produce heat. But gas use can be eliminated by switching to renewable energy, particularly renewable electricity.<sup>105</sup>

As Beyond Zero Emissions 2018 report *Electrifying Industry* showed, all types of manufacturing can be electrified. The report describes how renewable electrical heating technologies can replace fossil fuels in production of a wide range of materials including food, beer, glass, bricks and cast metal.<sup>106</sup>

Switching to electrical heat brings many benefits. It is possible to halve the energy input into many industrial

processes, due to the efficiency of electrical heating. Electrical heating also allows us to make things in a smarter way. It can speed up production, be more precisely controlled and is well-suited to next-generation manufacturing such as 3D printing.

Another advantage for a small economy like the NT is that many electrical heating technologies, such as heat pumps, can be installed as small, modular units. This can help foster an economy of reduced scale as smaller equipment requires less space, and facilities can be decentralised and sited close to raw material sources or product markets.

## NT renewable powered manufacturing prospects

Many types of manufacturer could be drawn to the NT by cheap renewable energy. The specific opportunity for downstream minerals processing is discussed in detail in the next section. Other potential growth sectors include:

### Renewable energy manufacturing

10 gigawatts of renewable energy will require substantial amounts of equipment, creating many opportunities for manufacturing in the NT.

For example, based on estimates by The Climate Institute, building 7 gigawatts of large-scale solar by 2030 would create a peak workforce of 280 manufacturing jobs.<sup>107</sup> In addition, construction of 1.7 gigawatts wind energy would create a peak workforce of 540 jobs to manufacture wind turbines and components.<sup>108</sup>

Other renewable technologies can support more manufacturing jobs. For example, solar thermal power stations require thousands of glass mirrors: a single 100 MW plant needs 12,000 tonnes of glass.<sup>109</sup> These mirrors, or simply their glass surface, could be manufactured in the NT. Glass production can be powered entirely by renewable electricity.<sup>110</sup>

Other opportunities in renewable energy manufacturing include battery assembly, racks for solar panels and power cables. Local company, Energy Renaissance, has plans to build a major lithium-ion battery factory in Darwin.<sup>111</sup>

Targeted industry support will be needed to ensure these manufacturing jobs are created in the NT, rather than overseas or elsewhere in Australia. In the United States, consistent tax policy and local industry support boosted the share of domestically-sourced equipment in the wind industry from 25% in 2008 to 72% in 2012.<sup>112</sup>

Similar policies can work in Australia. The Victorian Renewable Energy Target combined with local content requirements has led to the creation of manufacturing jobs in Victoria.<sup>113</sup> A wind turbine manufacturer in Portland has doubled its workforce from 100 to 200, and Vestas has announced it will open a new factory in Geelong to produce wind turbine hubs and drive trains.<sup>114</sup>

### 3D printing

3D printing is a computer-controlled process for creating objects by adding material layer by layer. The process is becoming popular for the manufacture of complex and bespoke items such as medical implants and machine parts. 3D printers are powered by electricity, so can easily be made renewable. Darwin-based 3D printing company, SPEE3D, is hoping to set up a 3D printing factory in Darwin, making metal machine parts. This type of service could be valuable to NT-based businesses such as mines and minerals processing, as it would enable them to speed up the process of acquiring replacement parts.

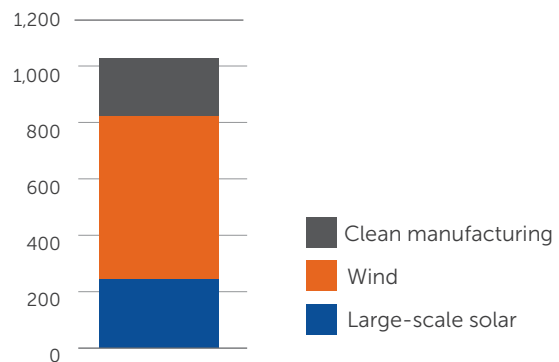
### Recycling

With China and India restricting imports of Australia's waste, our lack of domestic recycling facilities has become apparent. Everyday useful waste products like plastic, paper and glass are being dumped in landfills or stockpiled. These materials can all be recycled using renewable electricity. The NT could establish itself as Australia's renewable energy-powered recycler, re-using the country's waste and saving it from landfill. Some of the recycled material could then be shipped to manufacturers in Asia, while some could become raw material for new NT-based manufacturing. The Territory could also develop industries to recycle renewable energy equipment such as solar panels and batteries.

### Manufacturing jobs

Figure 9 shows that over 1,000 manufacturing jobs could be created, mostly in the wind and solar PV sectors. A smaller number of manufacturing jobs could be created in other manufacturing sectors such as recycling and other renewable technologies. We have conservatively estimated 200 extra jobs in these areas, not including downstream processing (Opportunity 4). However, given the diversity of opportunities it is impossible to predict what types of manufacturer will be attracted to the NT once it becomes a renewable energy powerhouse - and therefore, hard to estimate potential jobs.

**Figure 9: Potential jobs in manufacturing stimulated by the 10 Gigawatt Vision (peak workforce)**



# Opportunity 4: Minerals processing

The NT minerals sector is worth more than \$3.5 billion – a significant proportion of the gross state product of \$26.2 billion. The Territory's most important minerals are manganese, gold, zinc, lead and bauxite.<sup>115</sup> New mines are due to start extracting other minerals including copper, lithium and rare earth metals. Demand is expected to remain strong for all these metals, especially those like manganese, zinc and lithium used in the production of renewable technologies and batteries.

The NT is missing out on most of the value of minerals processing. Nearly all its minerals are exported,<sup>116</sup> leaving downstream processors and manufacturers elsewhere to capture most of their economic value. For example, NT's exports of manganese ore are worth around A\$1.6 billion, this is processed elsewhere into manganese products worth more than A\$5 billion.

We describe three new renewable-powered minerals processing opportunities with the potential to create 2,250 new jobs and deliver \$800M annual export revenue altogether:

- NT Manganese prospect 1 – a manganese alloy smelter powered by renewable energy
- NT Manganese prospect 2 – a facility producing high-purity manganese with renewable energy
- NT zinc prospect – a zinc refinery

We also outline the opportunity of critical minerals, exploring the potential of processing wastes from both mining and refining. This is a sector NT could decide to lead, with potentially highly significant long-term benefits.

There are great benefits to be delivered by addressing the environmental and health costs of practices in the processing sector, to ensure future industry has a positive impact on workers and communities.

## Downstream processing opportunity

The NT could use renewable energy to process manganese, zinc and other minerals, adding significant value to its exports. Minerals processing in the NT is sometimes discussed in the context of gas-fired power. But most refining processes are largely electrified, making it straightforward and cheaper to bypass gas and go renewable.

Unlike mines, refineries require a resident workforce – employees who stimulate the local economy by spending their wages close to where they live. The payroll tax from these employees would be a welcome addition to the NT Government's revenue.

This opportunity is gaining national attention. In 2018, the Australian Government's Resources 2030 Taskforce recommended that governments "develop strategies to enhance and grow competitive downstream processing industries in key regional centres."<sup>117</sup> Western Australia is already taking up this challenge. Three lithium refineries are being built there, and several recent reports have highlighted the enormous potential for WA to develop industries processing a range of metals.<sup>118</sup>

Australia has a track record of building on the success of domestic mining to develop downstream industries in metals manufacturing. For example, the extraction of bauxite in Cape York led directly to the development of Gladstone's alumina and aluminium industries.<sup>119</sup>

International experience shows that local access to resources does not automatically lead to comparative advantage in mineral processing.<sup>120</sup> However, the NT has other attractions for businesses interested in establishing downstream processing, including:

- a trusted government and good industrial relations
- a stable competitive economy<sup>121</sup>
- access to low cost finance
- large areas with sustainable development potential
- experience of successfully delivering complex engineering projects
- Australia's proven ability in downstream processing (aluminium, zinc, lead, nickel and copper).

As efforts to decarbonise the global economy gather pace, NT has an even bigger trump card: its abundant, cheap renewable energy.

*"Renewable energy is the way that Australia can once again become a cheap energy superpower and industries like aluminium smelting will relocate onshore."*

*Bloomberg New Energy Finance, 2018<sup>122</sup>*

## Renewable energy advantage

The processes for transforming minerals into useful products have one thing in common – they are energy intensive. To meet the demands of a zero-carbon economy, the energy for minerals processing will need to be renewable. This is being increasingly recognised by investors and the businesses that buy processed minerals.



Another high-profile champion of Australian renewable energy, Sanjeev Gupta, from Liberty OneSteel, is backing his vision of a thriving renewable-powered Australia manufacturing sector with a billion dollar renewable energy program. The company will build 1 gigawatts of solar energy and more than 200 MW of energy storage to power the steel operations in South Australia, Victoria and New South Wales.

*“We see Australia with its incomparable energy resource – as the natural home for expansion of energy-intensive industry, with renewables to play an integral role.”*

*Sanjeev Gupta, Liberty OneSteel, 2018<sup>123</sup>*

Sun Metals has also recognised the potential for renewables to power mineral processing. The company has built a 125 MW solar farm to supply its zinc refinery in Queensland. This investment in solar power has enabled Sun Metals to justify a \$300 million expansion, creating 350 jobs during construction and 100 permanent jobs upon completion.<sup>124</sup>

Metals processors using renewable energy can get a double benefit: lower energy costs and higher product value. Already aluminium made using renewable energy attracts a higher price, and companies like Alcoa and Rio Tinto have launched certified low-carbon aluminium products.<sup>125</sup>

*“We have a goal to substantially decarbonise our business by 2050. We maintain a strong focus on energy efficiency and productivity to deliver incremental improvements, but this is not enough. We know we need to look at larger transformative opportunities for emissions reduction.”*

*Rio Tinto, 2018<sup>126</sup>*

The NT has an opportunity to become a leader in minerals processing using renewables. This would have many benefits in the Territory, including:

- providing secure jobs to a resident labour force
- attracting new migrants to NT with a far higher chance of settling permanently
- creating a highly skilled workforce
- attracting high levels of investment
- adding value to NT resources, especially due to growing demand for low-emissions goods
- boosting NT Government revenues, helping to balance the budget.

The NT Government can encourage refineries to set up in the Territory by using tax incentives and other policies. This is not about picking winners. It is about the government creating a business and energy environment that attracts private companies with expertise in minerals processing. Some specific opportunities for manganese, zinc and critical minerals follow.

*“The use of renewables could be expanded to other types of metal processing ...creating a new industry in Australia where ore is processed right here using Australia’s low cost renewable energy sources, rather than have the raw product exported and processed offshore using fossil fuel based energy”*

*ARENA, 2019<sup>127</sup>*

## Manganese

### NT manganese ore production

NT supplies 16% of the world’s manganese – 4.1 million tonnes of ore in 2017-18. Most of NT’s manganese comes from the GEMCO mine on Groote Eylandt (3.4 million tonnes).<sup>128</sup> A smaller mine at Bootu Creek produced 0.7 million tonnes in 2017-18.<sup>129</sup> Early in 2019 a licence to explore for manganese on Winchelsea Island was granted to a joint venture led by the Anindilyakwa Advancement Aboriginal Corporation.

Manganese is the Territory’s biggest mineral export earner – more than \$1.6 billion in 2017-18. However, NT derives none of the value from processing manganese ore.<sup>130</sup> Over 90% is shipped overseas for processing into manganese alloys. About 10% of GEMCO’s output is sent to the TEMCO manganese alloy plant in Tasmania.<sup>131</sup>

Manganese alloy and high-purity manganese use and production is outlined in Box 4 (p31).

## Box 4: Manganese use and production

### Manganese alloys

About 85% of manganese is made into ferromanganese or silicomanganese. These manganese alloys are a vital component of steel, improving its strength and hardness.<sup>132</sup>

Manganese alloys are produced in an electric arc furnace using coke as a reducing agent,<sup>133</sup> and have high embodied emissions. On average the manufacture of 1 tonne of ferromanganese produces 6 tonnes of carbon dioxide – 60% of which are due to electricity consumed in the furnace.<sup>134</sup> Tasmania's TEMCO plant is able to reduce these emissions by relying mostly on low-carbon hydroelectricity.<sup>135</sup>

### High-purity manganese

The remaining 15% of manganese is processed into types of high-purity manganese, such as manganese sulphate, electrolytic manganese metal and electrolytic manganese dioxide. These materials are used in alkaline and lithium-ion batteries, as well as some speciality metals. The market for these materials, which are typically worth three times more than manganese ore,<sup>136</sup> is expected to boom, driven by growing demand for batteries.<sup>137</sup>

CSIRO has developed a low-energy process for producing high-purity manganese, removing the need for the ore to be roasted at up to 1000C. With the new process, the production of manganese sulphate requires net zero energy. For electrolytic manganese metal, most of the energy required is electricity (to power electrolysis) and can be supplied by low-cost renewables.

There are currently no Australian producers of high-purity manganese. However, a company called Element 25 plans to commercialise the CSIRO process, using renewable electricity to produce high purity manganese in Western Australia.<sup>138</sup> A second WA company, Pilbara Metals Group, plans to produce manganese sulphate and lithium manganese oxide.<sup>139</sup>

### NT Manganese prospect 1 – a manganese alloy smelter powered by renewable energy

<b>Added annual value:</b>	A\$250 million
<b>Renewable capacity:</b>	250 MW
<b>New jobs:</b>	850 (alloy smelter) 550 (renewable energy)

The NT could use renewable energy to transform local manganese ores into higher value alloys with low embodied emissions. A single manganese smelter similar to the existing TEMCO plant in Tasmania would produce 170,000 tonnes of manganese alloy per year. This would require about 375,000 tonnes of manganese ore (7% of NT production) and add around A\$250 million to its value.<sup>140</sup> The new facility would provide 350 ongoing jobs<sup>141</sup> and several hundred more during construction.

Manganese alloys are produced through electrolysis, requiring 3500 kWh of electricity per tonne of product. The proposed smelter would have an electrical power requirement of 100 MW (600 GWh per year assuming 75% capacity and 170kT production). This energy could be provided by renewable energy capacity of around 250 MW. Construction and operation of this renewable energy infrastructure would create about 525 temporary jobs and another 25 permanent positions.

### NT Manganese prospect 2 – a facility producing high-purity manganese with renewable energy

<b>Added annual value:</b>	A\$225 million
<b>Renewable capacity:</b>	110 MW
<b>New jobs:</b>	300 (high-purity facility) 240 (renewable energy)

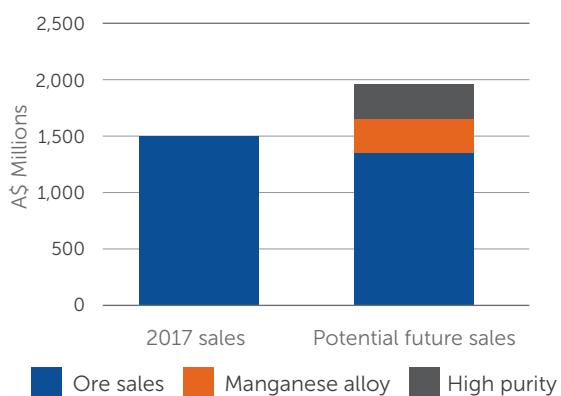
Electrolytic manganese metal and electrolytic manganese dioxide are crucial materials for the explosion in demand for lithium-ion batteries. They are a higher margin product than manganese ore or alloy, fetching prices above A\$2,800 per tonne.<sup>142</sup> Demand for EMD is expected to grow particularly quickly, and could increase 10-fold by 2025.<sup>143</sup>

NT could host a plant producing 100,000 tonnes of EMM and EMD per year (equivalent to the low end of Element 25's plans). This would require 175,000 tonnes of manganese ore<sup>144</sup> (just 3% of NT production) and add A\$300 million to its value. The new facility would provide 100 ongoing jobs,<sup>145</sup> and several hundred more during construction.

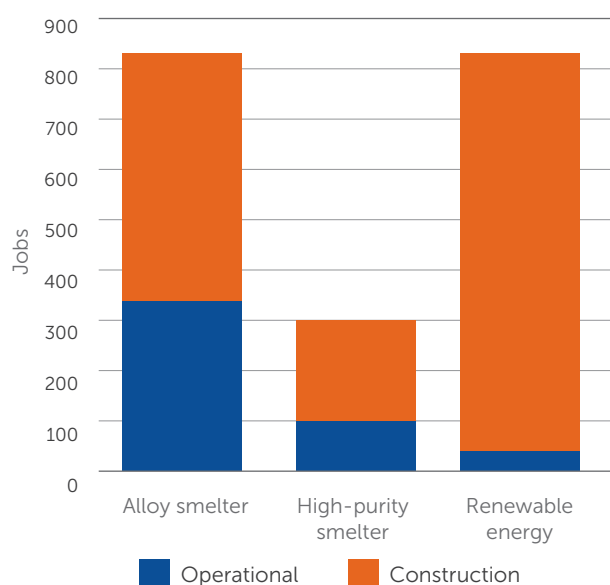
For 1 tonne of electrolytic manganese dioxide, we need 2,650 kWh. A facility producing 100,000 tonnes per year would have a power requirement of 40 MW and an energy consumption of 265 GWh per year. This energy could be provided by renewable energy capacity of around 110 MW. Construction and operation of this renewable energy infrastructure would create about 230 temporary jobs and another 11 permanent positions.

A summary of revenue opportunities of establishing two mid-sized processing facilities is in Figure 10, and total manganese jobs creation in Figure 11.

**Figure 10: Establishing two mid-sized processing facilities could add \$A470 million to the value of NT's manganese exports**



**Figure 11: Establishing two mid-sized processing facilities creates hundreds of jobs**



## Zinc

### NT zinc ore production

NT has one of the world's largest zinc resources at the McArthur River Mine 70 kilometres southwest of Borroloola. This mine, operated by Glencore, produced 210,000 tonnes of zinc concentrate in 2017, with a capacity of 5 million tonnes.<sup>146</sup> A small percentage of this concentrate is sent to Tasmania for smelting (Box 5, p33), with the rest exported overseas. These smelters capture a significant proportion of the value of NT's zinc as well as other minerals contained in the concentrate.

### Zinc use and production

Zinc is the world's fourth most-used metal, primarily used as a coating on iron and steel to protect against corrosion. It is also used in the manufacture of plastics, ceramics, medicinal products and many types of battery.

Mined ore is usually converted on-site into zinc concentrate through a process of crushing and screening, grinding, flotation and dewatering. Zinc refineries then convert zinc concentrate into zinc metal by roasting, leaching, purification and electrolysis.<sup>147</sup> Typical zinc production requires an energy input of 5.5 MWh per tonne (not including mining).<sup>148</sup> Of this 75-80% is electrical energy, mostly to power electrolysis.<sup>149</sup>

On average making a tonne of zinc produces emissions of 3.1 tonnes of carbon dioxide,<sup>150</sup> though this figure is strongly dependent on the carbon intensity of the electricity. For example, zinc made at Nyrstar Hobart has low emissions as the electricity comes mostly from hydropower.<sup>151</sup> The emissions from zinc processing can be reduced by as much as 90% by using zero-carbon electricity.

## Box 5: Australia's zinc smelters

International evidence shows that zinc smelting can be competitive in high wage countries,<sup>152</sup> and there are currently two profitable zinc smelters in Australia.

### Nyrstar, Hobart

There has been a zinc smelter in Hobart since 1916. Today it is owned by Nyrstar and has the capacity to produce 280,000 tonnes of zinc per year. Nyrstar Hobart has historically sourced most of its zinc concentrate from Queensland and locally in Tasmania, though it supplements this with imports from all over the world.<sup>153</sup> Nyrstar Hobart employs around 600 people including contractors.

### Sun Metals, Queensland

In 1996, Korea Zinc Company built the Sun Metals Zinc Refinery 15km west of Townsville. In 2018, Sun Metals built a 125 MW solar farm to provide around 30% of its electricity requirements. This investment in solar power has helped to justify a \$300 million expansion, increasing the refinery's capacity to 270,000 tonnes per year.

## NT zinc prospects – a zinc refinery

<b>Added annual value:</b>	A\$328 million
<b>Renewable capacity:</b>	340 MW
<b>New jobs:</b>	1,100 (refinery) 740 (renewable energy)

NT could establish a zinc smelter producing low-emissions zinc using renewable energy. In fact, the mine's previous owners considered such a facility.<sup>154</sup> Here we propose a smelter with an annual output capacity of 200,000 tonnes of zinc metal – slightly smaller than Nyrstar's operation in Hobart.

A smelter of this size would require a feed of 370,000 tonnes of zinc concentrate – 95% of the output of the McArthur River Mine in 2017. As outlined in Box 6 (p34) this mine has caused significant environmental and heritage problems, some of which are ongoing.

The NT Government must implement reforms to require outstanding environmental performance and ensure some of the additional revenue earned from processing zinc is dedicated to alleviating existing problems.

If this is not possible, there are other potential sources of concentrate as Australia holds the world's largest reserves of zinc – 27% of the global total. There are a number of potential new zinc mines in the NT, as well as the Mount Isa mine across the border in Queensland, which has a slightly larger output than McArthur River (418,000 tonnes in 2017).

**Value added:** The average price of zinc in 2018 was A\$3,900 per tonne.<sup>155</sup> The price has recently dipped but strong demand for zinc is expected in the medium to long term.<sup>156</sup> Prospects for Australian zinc smelters have improved as an environmental crackdown in China has seen refineries there cut production or shut down entirely.<sup>157</sup>

Typically zinc smelters capture 40% of the metal's value.<sup>158</sup> Based on this assumption, and on recent prices and production, NT's revenue from zinc would be A\$491 million. However, if NT's zinc were to be smelted within the Territory, its value would rise to A\$819 million, an increase of 67% (Figure 12, p34).

**Energy requirements:** Energy typically accounts for at least 40% of the cost of zinc production.<sup>159</sup> A 200,000-tonne zinc smelter would have an electrical power requirement of about 100 MW, consuming 800 GWh per year (assuming 85% capacity).<sup>160</sup> This energy could be provided by renewable energy capacity of around 340 MW.

**Employment:** Nyrstar Hobart employs 600 people and expansion of Sun Metals' refinery will create 350 construction jobs and 100 ongoing positions. We have assumed a NT refinery will create 800 construction jobs and 300 permanent positions. The required renewable energy would create an additional 710 jobs in construction and 34 on-going operational jobs (Figure 13, p34).



Figure 12: Zinc sales

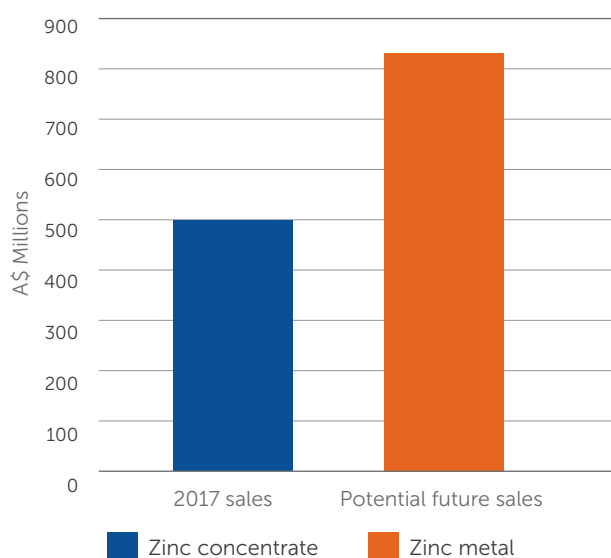
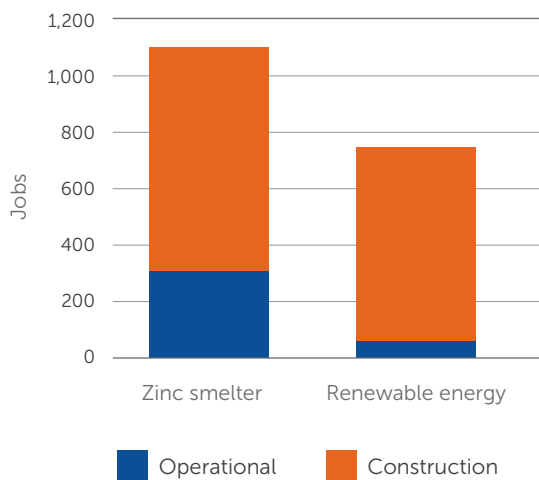


Figure 13: Additional zinc processing jobs



### Box 6: McArthur River Mine – a history of harm

The McArthur River Mine has been strongly resisted through legal action by Traditional Owners in the Borroloola area due to a history of environmental harm. Adverse impacts include uncontrolled seepage of acid and metals into waterways and spontaneous combustion of the pyrite in the waste rock, releasing toxic sulphur dioxide fumes, impacting the local community. Future risks include the potential failure of the tailings storage embankment and the failure of revegetation and continued erosion of the McArthur River diversion.<sup>161</sup> The Independent Monitor has identified a high risk that the mine's security bond will not be enough to pay for post-closure rehabilitation and monitoring that could last 1,000 years.<sup>162</sup> The financial burden of ongoing remediation will likely fall to the Northern Territory Government and the taxpayers.

The Garawa, Gudanji, Marra and Yanuwa peoples must participate in the decision-making process about the mine's future, through representatives chosen by them in accordance with their own procedures. Any closure plan or further approvals for the McArthur River Mine must be accepted by these groups.<sup>163</sup>

This report outlines an opportunity for greater processing of the mine's ores within the Territory. However, it is imperative that some of value added from any downstream processing of the mining minerals is directed towards improving rehabilitation outcomes. This includes consideration of the environmental case for a complete pit back fill as presented by the Mineral Policy Institute.<sup>164</sup>

## Critical minerals

Countries classify certain minerals as 'critical' when they are strategically important but also scarce or vulnerable to supply disruption. Critical minerals include rare earth elements,<sup>165</sup> tungsten, rhenium, niobium, indium, cobalt, vanadium, germanium and gallium.<sup>166</sup> These elements have unique properties that make them essential to the energy transition as they make irreplaceable components of renewable energy systems, electric vehicles, batteries and electronics.

Interest is growing in Australia's emerging critical minerals sector. In March 2019, the Federal Government released Australia's Critical Minerals Strategy, which states an ambition for Australia to become a world leader in the extraction and processing of critical minerals.<sup>167</sup> This ambition was supported by a report by Geoscience Australia, *Critical Minerals in Australia: A Review of Opportunities and Research Needs*, which showed that Australia is likely to possess significant quantities of critical minerals.<sup>168</sup> The Coalition of Australian Governments has now made a commitment "to harness the emerging opportunities the critical minerals sector offers including opportunities to develop and grow downstream industries".<sup>169</sup>

### NT critical minerals prospects

Critical minerals present a third opportunity for NT to move from mining to making, powered by renewable energy. In 2020 Arafura Resources expects to start the NT's first critical minerals project, extracting and processing neodymium and praseodymium (two rare earth elements) at a site north of Alice Springs. A potential vanadium project at Mount Peake is also at the planning stages.

But NT's opportunity to develop a critical minerals industry does not depend on opening new mines.

Most critical minerals are by-products of processing other minerals including zinc, manganese, bauxite and gold – all of which are mined in the NT. It is highly likely that NT is already inadvertently mining and exporting several critical minerals. Although the mining companies aren't paid for this mineral content, processors overseas extract and sell it.<sup>170</sup>

The additional untapped value can be significant. It has been estimated that the potential value of rare earth elements contained in ore from BHP's Olympic Dam exceeds that of all the metals that are currently extracted from the mine.<sup>171</sup>

Geoscience Australia has identified both McArthur River Mine and Groote Eylandt as likely sources of critical minerals.<sup>172</sup> For example, zinc ore often contains critical minerals including germanium, cadmium, gallium and indium. A new zinc refinery in the NT (Opportunity 3) could extract these valuable metals. They could also potentially be extracted from existing mine wastes<sup>173</sup> – perhaps providing an economic incentive to deal with environmental problems related to mining overburden.

Several technologies are used to extract critical minerals. Nyrstar already extracts cadmium at its Hobart refinery as part of the purification process. In Norway Nyrstar uses three 2.5 MW electric plasma furnaces (powered by renewable energy) to heat zinc refinery wastes to 1,300°C, extracting a range of critical minerals including indium and germanium.<sup>174</sup>

Currently there is insufficient understanding of the extent of the critical mineral resources across Australian deposits.<sup>175</sup> The NT's first step in implementing a critical minerals strategy should be to investigate the critical mineral content of mined ores and overburden. There is also a need for new technologies to economically extract critical minerals, a strategy that would also place NT at the forefront of this sector.

# Opportunity 5: Renewable powered mine sites

The mining sector's high energy consumption – mostly natural gas and diesel for running machinery and generating electricity – accounts for 15% of Australia's greenhouse gas emissions.<sup>176</sup> In the NT mining produces 3.2 million tonnes of CO<sub>2</sub>, more than all vehicles, homes and power stations combined.<sup>177</sup>

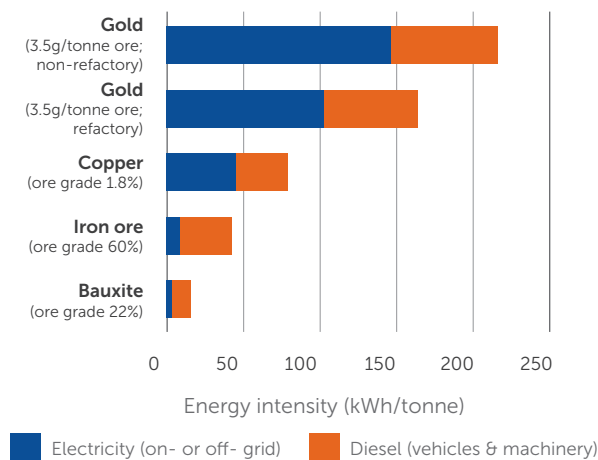
Mines use diesel-powered vehicles and equipment for excavating, loading and transporting ore and waste rock. On-site processing, such as crushing and separation, is usually electrically powered. The energy to run mines often accounts for a third of their operating costs, or more for mining of metal such as copper, gold and zinc, which involve on-site processing to concentrate ores. Energy at these mines is predominantly consumed as electricity (Figure 14).<sup>178</sup>

The advent of affordable renewable energy and battery technology present two related opportunities for the mining sector:

- replacing fossil fuel generation of electricity with renewables
- electrifying diesel fuelled vehicles and equipment.

**Figure 14: Quantity and type of energy used at mines to extract and concentrate minerals.**

The energy for metals with minimal on-site processing, such as iron ore) is primarily consumed as diesel; the energy for metals with significant on-site processing (manganese, zinc, copper, gold) is primarily consumed as electricity.



Benefits of powering mines with renewable energy include jobs for more than 3,600 people working in mines in the Northern Territory in cleaner, healthier work environments.

## Renewable mining

Mines pay some of the highest electricity costs of any industry. Electricity is particularly expensive for those relying on diesel generators which typically pay 20-40 c/kWh.<sup>179</sup> Diesel accounts for 80% of this cost,<sup>180</sup> meaning mining businesses are highly exposed to changes in its price.

Over the last decade the price of diesel has fluctuated from \$0.40/L to \$1.25/L (excluding GST, excise and transport costs).<sup>181</sup> This fluctuation has caused the energy cost of metal mining to swing between \$5.54/tonne and \$17.03/tonne.<sup>182</sup> In addition to the financial risk of using diesel, mines must also tackle the logistical challenges and costs of transporting and storing large volumes of fuel.

By integrating renewable energy into their systems mining companies can reduce their economic and operational risk. Solar PV at mine sites is now cheaper than diesel generation and provides long-term price certainty. Mines also tend to have access to adjacent land suitable for behind-the-meter solar generation.

*"We support greater use of renewable energy and other cost effective low-emission technologies, and improved energy efficiency, including in our own operations."*

*International Council on Mining & Metals, 2015* <sup>183</sup>

Despite its advantages the Australian mining sector has been hesitant to adopt renewable energy. This is partly the inertia of a conservative industry familiar with fossil fuel generation and lacking experience of renewable energy. But there are genuine barriers, such as the complexity and expense of constructing solar farms in remote, inhospitable locations. Also, a solar farm with a 25-30 year lifetime may not pay for itself within the shorter lifetime of many mines. Diesel systems, because they are modular and mobile, don't need to be paid off during mine's lifetime.

The renewables industry is addressing these issues. Companies such as SunSHIFT have developed modular solar PV systems which are largely assembled off-site.<sup>184</sup> These systems are also moveable, so they can be packed up and moved at the end of a mine's life, just like a diesel generator. This creates the possibility of leased solar panels, which do not add to a mine's capital expenditure and removes a known carcinogen from mine sites (refer Box 7).

The mining sector is starting to trust renewables and embrace the opportunity of lower cost energy. A few mines have started to install hybrid energy systems which combine solar PV, batteries and fossil fuel generation to provide reliable 24-hour supply. Hybrid systems are equivalent to community microgrids such as the one at Coober Pedy (Box 8), and enable fossil fuel generation to be turned off for long periods. One early adopter, the Degussa copper mine in WA has installed a hybrid system in which 10MW solar PV and battery storage supplies 90% of daytime electricity needs, saving 5 million litres of diesel per year.

More Australian mines are now following suit. Century Mine northwest of Mount Isa has installed a portable solar system that provides power at 12 c/kWh, compared to 40 c/kWh for diesel generation.<sup>185</sup> This kind of cost saving is encouraging other miners to increase their renewable ambition. Granny Smith gold mine in Western Australia is planning a 24 MW solar array with 2 MW battery storage,<sup>186</sup> and Fortescue is planning to build at least 60 MW of solar PV to power its Pilbara iron ore operations.

While hybrid systems are the most viable for now, the economic advantage of renewables at mines will grow rapidly. According to an ARENA report, by 2022 the combination of 8 c/kWh renewable electricity and energy storage at less than 50 c/kWh will make the complete replacement of fossil fuel generators economically viable.<sup>187</sup>

### Box 7: Diesel pollution at mines

Diesel pollution is a known carcinogen and creates a health risk for mineworkers, particularly those who work underground. Monitoring at mine in Western Australia found levels of diesel particulates about 100 times higher than in a busy, urban street.<sup>188</sup>

The threat of legal action by workers affected by exposure to diesel exhaust fumes has been described as a "ticking time bomb" on a par with asbestos.<sup>189</sup> Despite these dangers, diesel is heavily subsidised, and the Australian mining industry gets nearly \$7 billion in fuel tax credits every year.<sup>190</sup>

### Box 8: Coober Pedy renewable hybrid project

Coober Pedy, South Australia's famous opal mining town, is home to one of Australia's most innovative remote power systems. The ARENA-backed project combines 4 MW wind, 1 MW solar, a 500 kWh battery, two flywheels and control systems.

The town's existing diesel generators were retained to provide remaining supply and backup. In the first year of operation the mix of renewables and storage was able to reduce diesel use by over 70%.<sup>191</sup> There are extensive periods during which the system operates on 100% renewable energy.<sup>192</sup>

Coober Pedy is in a low-lying, inland region not usually associated with high winds, yet the two wind turbines have performed well. Although the average wind speed at ground-level is not enough to justify a wind turbine, the average wind speed at 80 metres elevation of over 7.6m/s represents a good wind resource.

Although the Coober Pedy system works well, the SA Government learned a lot about how to lower costs in this type of project, including the importance of open tenders. Lower costs could have been achieved by several alternative proposals including one from Siemens which proposed using hydrogen storage and generation.<sup>193</sup>



## Electrified mining

Electric alternatives are now available for all types of mining equipment including loaders, drill rigs, excavators and personnel carriers. Electric trucks are available up to 42 tonnes and they're getting bigger all the time.<sup>194</sup>

Electric mining equipment currently has higher upfront costs but is cheaper to run and maintain. It also greatly improves safety and working conditions by eliminating much of the pollution, noise, heat and vibration produced by diesel machinery. The benefit and costs savings are greatest in underground mines where up to 40% of energy goes on powering ventilation systems to remove pollutants.

The first all-electric mine is due to begin operating in 2019 at Borden Lake in Canada, where the mine operators expect to save US\$9 million on energy bills.<sup>195</sup> Other mines are following suit, supported by the rapid commercialisation of electric mining equipment. Swedish manufacturer Epiroc aims to electrify all its underground machines in just five years.<sup>196</sup> By 2040, the International Council on Mining and Metals hopes diesel vehicles will be eliminated from mining altogether.<sup>197</sup>

*"Ten years from now, I'd think we'll go from 90 to 100% reliance on diesel to less than 20%, the rest will be using batteries. If all the equipment was developed now, I'd want to pretty much convert our all mines at once."*

*Tony Makuch, CEO of Kirkland Lake Gold (Canadian mining company).<sup>198</sup>*

Trials of electric utility vehicles are currently taking place at the Fosterville underground gold mine in Victoria in early 2019 and of light utility vehicles at Olympic Dam copper mine in South Australia.<sup>199</sup>

The biggest challenge in the transition to electric mining is hauling thousands of tonnes of material out of the ground. This task is usually carried out by enormous (100 tonne plus) trucks, which would be hard to power with current battery technology.

This has led to renewed interest in alternative haulage systems such as conveyor belts and trolley systems whereby electrified trucks are connected to a power grid with overhead cables. This type of system is being tested by Swedish mining company Boliden at Sweden's largest open pit copper mine.<sup>200</sup>

One economic analysis of a trolley system estimates a 35% reduction in the cost of haulage, due to the combined effect of savings in the cost of energy, labour and maintenance.<sup>201</sup>

## NT renewable power mining prospect

The future of mining is all-electric and the NT Government has an opportunity to lead the transition and establish the world's first all-electric mining sector, powered by renewables. This involves switching from gas and diesel-fuelled electricity generation (currently 165 MW at remote NT mines)<sup>202</sup> and converting to all-electric vehicles and machinery powered by renewable energy.

There will be many benefits to the NT mining of going all-electric, including:

- removing the serious risk to health posed by diesel particulates, and the associated risk of litigation
- providing jobs in construction and operation of renewable energy systems
- reducing NT's greenhouse gas emissions
- enabling the mining sector to reduce its operational energy costs and remove the cost and logistical difficulty of transporting and storing diesel
- lower maintenance costs of electric vehicles
- reducing strain on public roads resulting from transporting diesel.

An NT mining sector powered by renewables could be achieved with policies to achieve the following staged objectives at new and existing mines:

### New mines

- Electricity generation initially required to be 70% renewable and 100% renewable after 10 years.
- For vehicles and machinery - underground mines required to be 100% electric at the outset, surface mines required to be 70% renewable at the outset, 100% within 10 years.

### Existing mines

- Incentives and requirements to progressively replace fossil fuel generation with renewables, aiming for 100% renewable electricity in 10 years.
- Phase-out of all diesel-fuelled machinery and vehicles within 10 years.

## Opportunity 6: Reduced cost of living

The cost of living is higher in the Northern Territory than anywhere else in Australia.<sup>203</sup> The **10 Gigawatt Vision** can bring benefits to everyone in the NT: household transport bills can be 80% cheaper with electric cars and renewable energy. Household utility bills can be 30% lower with domestic solar and removing gas appliances.

### Electricity bills

Despite significant government subsidies, Territorians have some of the highest electricity bills of any Australians.<sup>204</sup> This is partly because, at 15 c/kWh, the NT has the highest wholesale price of electricity (cost of generation), except for South Australia.<sup>205</sup>

In Australia, the contracted price for new solar and wind projects is typically less than 6 c/kWh, and for large-scale solar PV a contract price of 4c/kWh is becoming achievable in the right locations.<sup>206</sup>

The current cost of renewable energy projects in the NT is above the national average, especially in remote areas. However, with the development of a large-scale renewables industry including local manufacturing, NT renewables costs will be able to match or beat those elsewhere in Australia.

The need to balance the grid at all times, through supporting renewable technologies and energy storage, will add an additional cost of around 2.5 c/kWh.<sup>207</sup> Taking this firming cost into account, we can expect the wholesale price of renewable electricity in the Territory to fall to 6.5 c/kWh before 2030 if it adopts an ambitious renewables strategy. If other system costs remain stable, this will result in a residential price of around 18 c/kWh (Table 4).

### Electric vehicles

Electric vehicles are already cheaper to own and run than petrol or diesel cars.<sup>208</sup> Within the next five years they will likely be cheaper to purchase. Car makers see 2025 as the tipping point for electric vehicles and are starting to phase out their petrol and diesel models.<sup>209</sup> Several overseas governments have announced an end to the sale of petrol and diesel cars by 2040 or earlier.

The large distances covered by some NT drivers no longer presents a problem for electric vehicles. By 2022, an average EV is expected to travel 440km on a single charge, and several models already go much further than this.<sup>210</sup> With only a small number of major roads, the NT will require only minimal charging infrastructure between towns.

The main advantage of electric personal transport is much cheaper running costs. Currently in the NT it costs \$16.31 in fuel to drive 100 kilometres in a typical petrol/diesel car. This means the average household with 1.6 cars spends \$3,398 per year.

Electric vehicles will bring this cost down substantially. On average, an electric vehicle consumes 18 kWh in travelling 100 kilometres. With cheap renewable energy, the average NT household would spend just \$672 per year – an 80% saving.

For people in remote communities travelling into regional centres, electric vehicles represent an opportunity to almost completely eliminate ongoing transport costs. When paired with community-owned renewable generation, electric vehicles will enable people accessing towns like Alice Springs or Katherine to use cheap surplus energy to fuel their vehicles. A great many remote communities are within the 440km charge range of a regional centre.

If all personal transport were electrified, the electricity required to run it could be generated by 200 MW of solar PV – just 2% of the 10 gigawatt target. What's more, electrified transport would eliminate exposure to fluctuating oil prices, as well as the risk of a disruption to the supply of fuel from overseas. All Territorians, but particularly those in remote communities, would enjoy the benefits of making their own energy for transport, and no longer paying significantly more for petrol and diesel than other Australians.<sup>211</sup>

**Table 4: Large-scale renewable energy in the NT will lead to large reductions in household bills<sup>212</sup>**

	2019	2030	Savings
Wholesale price of electricity	14.99 c/kWh	6.5 c/kWh	8.49 c/kWh
Retail price of electricity	26.42 c/kWh	17.93 c/kWh	8.49 c/kWh
Average annual household electricity bill*	\$1,747	\$1,186	\$561
Average annual household transport bill* by switching fuel vehicle to electric vehicle	\$3,398	\$672	\$2,726
<b>Total Annual average saving per household*</b>			<b>\$3,287</b>
<b>Total Annual Territory-wide savings</b>			<b>\$295M</b>

\*Assuming 89,959 households and 1.6 cars<sup>213</sup> per household

# Opportunity 7: Repower remote communities

Most remote communities in the Northern Territory rely on diesel generation for electricity. This is not only one of the most polluting ways to generate electricity, but also expensive. The cost of diesel generation in small communities can be up to twice that of NT's electricity grids. This high cost creates an incentive to find cheaper renewable alternatives and means technologies that are not yet commercially viable elsewhere may be economic.

Remote communities will benefit from a detailed feasibility into microgrid solutions for their energy needs, such as the LNP's allocation for reliable energy for bush communities.<sup>214</sup> The Solar Energy Transformation Program (SETuP), run by the Power and Water Corporation, has installed 10 MW of solar panels in 25 remote NT communities, aiming to reduce diesel use by 15%. For Nauiyu (Daly River) they are going further, aiming to reach 50% renewables with 1 MW of solar and 2 MWh battery storage.<sup>215</sup>

However, the technology is now available to enable remote communities to eliminate diesel. Here we propose a near-100% renewable microgrid for Yuendumu, a remote community of around 700 people, 300 kilometres north-west of Alice Springs. Any proposed renewable project in a remote community must work closely with land councils and other stakeholders to ensure that Aboriginal enterprises and residents participate and benefit.

## Renewable energy for Yuendumu

Currently, Yuendumu's daily electricity demand of around 13 MWh relies on one diesel generator. In 2017, the SETuP program installed a 500 kW solar array which now provides about 20% of the town's energy.

Yuendumu could almost entirely replace diesel by installing a renewable hydrogen microgrid. This energy system would integrate solar PV, wind turbines, batteries and hydrogen fuel cells. Such a system would have similarities with the existing renewable hybrid projects in Australia, such as the one at Coober Pedy (Box 8, p37). Wind and solar energy would meet most electricity demand, with a battery system providing short-term energy storage and grid balancing services.

Yuendumu has an exceptional solar resource of 26 MJ/m<sup>2</sup> and, according to climate models, annual average wind speeds at 80 metres elevation are above 7 m/s – certainly enough to justify a wind turbine<sup>216</sup> (Figure 5, p17). The average wind speeds at ground level in Yuendumu are similar to those at Coober Pedy where wind turbines perform well.<sup>217</sup>

## Renewable microgrid

The innovative part of the proposed solution for Yuendumu is a hydrogen system to displace diesel generation (Figure 15). This would involve:

- an electrolyser to make hydrogen using solar and wind energy
- hydrogen storage tanks
- a hydrogen fuel cell to produce electricity (or alternatively a hydrogen-fired microturbine).

The electrolyser would run when the electricity generation exceeded demand from customers/batteries. Such periods are frequent, and this energy is essentially free because it would be otherwise lost. For example, the Coober Pedy microgrid (Box 8, p37) spills 40% of the renewable energy it generates.<sup>218</sup> The falling costs of electrolysers and fuel cells have made hydrogen microgrids feasible for off-grid locations. Belgian company Tiger Power is installing solar-battery-hydrogen systems in remote communities in Uganda.<sup>219</sup> The systems are designed to provide secure 24-hour renewable electricity without diesel back-up.

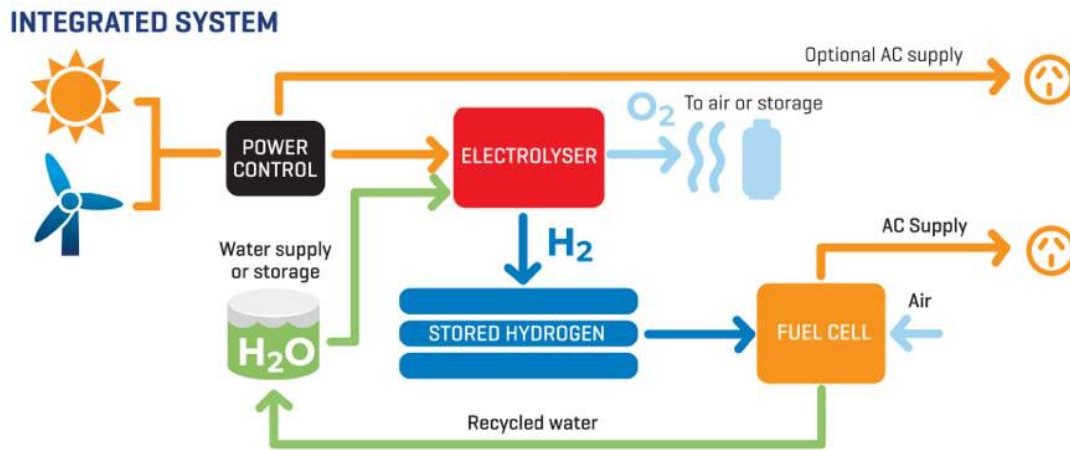
Australian company ANT Energy Solutions specialises in the design and development of renewable energy systems using hydrogen fuel cells. They are able to provide 100% renewable microgrids that provide cheaper energy for remote communities.

Australia's first hydrogen microgrid, at a gas operation centre in Jandakot (WA), is expected to be operational before the end of 2019.<sup>220</sup> Community-based hydrogen microgrids are being explored for several Australian towns including the Daintree community in Queensland.

Other projects around Australia are showing how excess renewable energy can be converted into hydrogen which is later used to generate electricity. For example, in Port Lincoln (SA) a 15 MW electrolyser will produce hydrogen using cheap solar and wind energy. The hydrogen will fuel a 10 MW hydrogen-fired turbine and a 5 MW hydrogen fuel cell, both supplying power to the grid.

We have modelled a microgrid for Yuendumu that is over 95% renewable (Table 5, p41). At least initially, the existing diesel generator would remain to ensure secure round-the-clock supply. However, over time as confidence and understanding grows, the town could move towards a 100% renewable energy system, meeting all energy requirements from sun and wind with integrated hydrogen (Figure 16, p42).

Figure 15: Overview of an integrated renewable hydrogen microgrid



\*Graphic courtesy of ANT Energy Solutions

## Capital and operating cost of renewable hydrogen microgrid

The estimated cost of the microgrid is \$10.7 million, a figure which includes a 40% remote location premium. Over a 25-year design life the system can deliver electricity for around 32 c/kWh – likely to be less than the current cost of diesel generation. The best way of achieving the lowest cost is by running an open tender process and accessing innovation grants, such as the \$50 million federal fund available for exploring the feasibility of microgrids in remote communities.

A successful project in Yuendumu could be used as a springboard for 100% renewable microgrids in remote communities throughout the Territory. Experience with the renewable hydrogen system would also provide useful lessons for NT’s larger electricity grids.

This proposed project is also an excellent opportunity to set up Aboriginal-owned enterprises to install and operate community energy. This creates an opportunity for local training and employment, learning from existing projects in the communities of Ngurrara and Kurnturlpara in the NT’s Barkly region.

The Yuendumu community might also want to explore the benefits of installing a larger renewable electricity system than the one proposed here. With additional electricity generation it could charge electric vehicles, many of which are now capable of reaching Alice Springs on a single charge. Electric vehicles would not only reduce the cost of transport but could provide the town’s battery storage service. Renewable electricity could also power new businesses in the town such as ecotourism, food processing and land management projects.

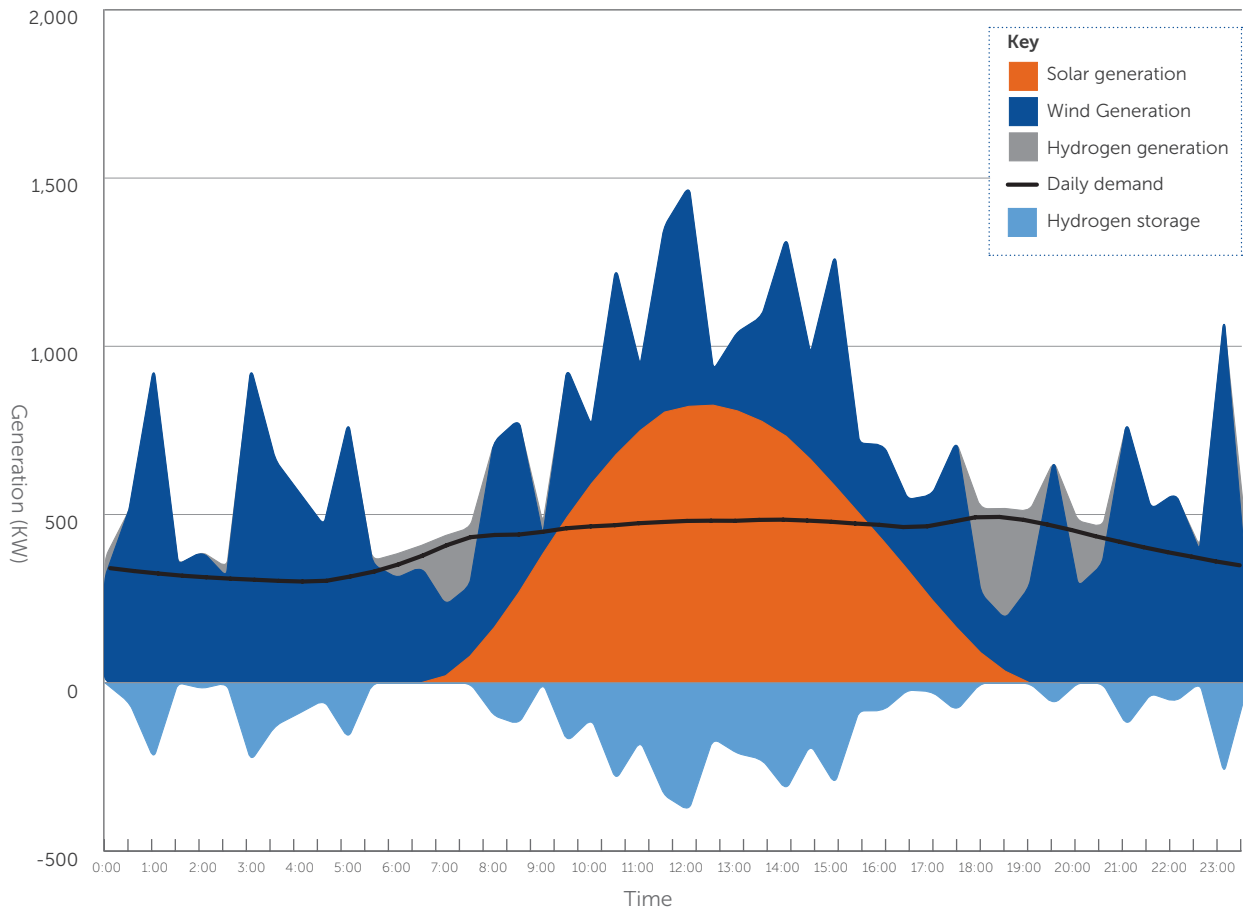
Table 5: Components and costs of renewable / hydrogen microgrid for Yuendumu.\*

Technology	Capacity	Average daily output	Cost (\$ millions)
Solar PV	1.3 MW	7.1MWh	1.5
Wind (1 turbine)	1.5 MW	13 MWh	4.1
Battery	250 kW	1 MWh	0.4
<b>Hydrogen system</b>			
Electrolyser	500 kW	-2 MWh	1.5
Storage	10 MWh		0.7
Fuel cell	300 kW	1.7MWh	0.5
Diesel	Existing system	1.6MWh	N/A
Balance of plant (control systems, flywheels, capacitors)	n/a	N/A	2
<b>Total</b>			<b>10.7</b>
<b>Levelised cost of electricity</b>			<b>31.7 c/kWh</b>

\* Electrolyser and fuel cell costs from ANT Energy Solutions. Other costs from CSIRO’s GenCost 2018. Assumptions included in costs: 40% premium for remote location; 7% cost of capital; solar PV efficiency decline 0.8%; OPEX of 10% (high to take account of remoteness and complexity; large generation certificates worth \$20 in 2020, \$15 in 2023 and then to \$10 in 2025.



Figure 16: Typical daily generation from Yuendumu renewable hydrogen microgrid



\*Hydrogen storage refers to the electrical energy produced by the fuel cell. This is less than the solar/wind energy going to storage going due to a round trip efficiency of about 34%. This efficiency can be improved if use can be found for the heat energy lost from the fuel cell.

# 5 - Conclusion & Recommendations

Global energy markets are changing rapidly. The rise of renewables is remaking our understanding of the global energy system. Renewables are already the cheapest source of energy in the market, with prices continuing to fall. As new means of using, storing and transporting energy emerge, jurisdictions willing to embrace these changes will flourish. Jurisdictions slow to change risk missing out on one of the great economic opportunities of the century.

The Northern Territory is blessed with renewable riches. As one of the sunniest regions in the world, the Northern Territory has an opportunity to reconfigure the way its economy works: away from expensive, dirty fossil fuels and towards abundant, cheap and clean energy from the sun.

Opening up the Territory to the fracking industry is not the answer to the challenges the region faces (see Appendix 1). Investing scarce resources into establishing an expensive and risky unconventional gas industry is not only incompatible with the Paris Agreement's goal of limiting global temperature increases to 1.5°C but poses significant direct risks to Territorians. The fracking industry has a short and shameful history of environmental damage, community harm and financial failure.

The **10 Gigawatt Vision** addresses both economic growth and climate change. Implementing this vision would expand industry, while eliminating carbon pollution from towns, communities, mines and manufacturing.

Our solution provides Territorians more than 8,000 new jobs in safer, healthier workplaces, and over \$2 billion in annual revenue. This means more affordable and secure places to live and work, with household bills dropping 80% for transport and 30% on electricity bills.

We have shown how the Territory can seize the opportunities presented by cheap and abundant renewable energy to fuel a new wave of sustainable, well-paid jobs. The **10 Gigawatt Vision** presented above describes a Territory in which abundant sunshine fuels our neighbour's energy needs, more of the value of the region's mineral resources flows to locals, the cost of living is lower and exciting new opportunities in high value manufacturing are created.

Significant change requires foresight, leadership and the right policies.

Achieving the **10 Gigawatt Vision** can become a central pillar of the NT's economic development. It will require long-term commitment from the NT Government and creative and ambitious policy initiatives to give businesses and investors the confidence they need to invest.

A **10 Gigawatt Vision** will also require engagement, negotiation and informed consent of Traditional Owners across the Territory. The vision can support Indigenous peoples' aspirations for economic development through providing opportunities such as community ownership of renewable infrastructure.<sup>221</sup>

This report provides a bold vision for the Northern Territory: one that is compatible with addressing climate change and the Territory's need for sustainable economic development.

What is now needed is strong leadership. The NT Government needs to act with ambition, with confidence, and with the resolve to drive a policy agenda that incentivises investment in a renewable energy boom that benefits all.

## Recommendations

### 1. Launch the **10 Gigawatt Vision** with an ambitious plan and marketing strategy

We propose that the government takes a proactive role in shaping NT's economic future as a global leader in the transition to a zero-carbon economy.

*We recommend the NT Government announces a major new strategy to establish NT as the Renewable Energy Territory.* This strategy should involve a target to build multiple gigawatts of renewables while growing clean-tech industry and reducing energy costs for all.

This over-arching strategy must be backed up with an integrated range of policies designed to attract investment. It should also include the creation of a **10 Gigawatt Vision** brand, to be promoted as a part of the Territory's identity and commitment to a sustainable future. *This marketing strategy will help attract businesses who are ready for the zero-carbon future.*

### 2. Progress a wide range of technologies to support building 10 gigawatts of renewables in the NT

*The NT Government should incentivise and invest in non-solar renewable energy and supporting technologies, including energy storage options, such as pumped hydro, and new transmission lines.*

The NT's transition to renewable energy will be dominated by low cost solar PV. Achieving the full potential outlined in this report will also require a range of supporting technologies. These technologies are all viable in the Territory, but the extent of their potential, particularly wind, is not yet well understood.

### 3. Set up a service matching renewable energy suppliers with customers

Businesses across Australia are increasingly securing access to renewable energy with no upfront cost by signing power a purchase agreement (PPA) with an installer, who funds and builds a wind or solar farm.

The NT Government can play a role in bringing together renewable energy projects with potential large customers, such as mines and manufacturers.

*We recommend leveraging the Business Renewables Centre, ensuring it includes NT projects and is relevant to large customers such as mines, that may be remote and temporary.* The NT Government should also ensure there are no regulatory or market barriers to PPAs.

### 4. Establish zero-carbon remote communities and support Indigenous owned renewable projects

The Solar Energy Transformation Program run by the Power and Water Corporation is extending solar power to some remote communities. *The ambition of this program should be greatly increased* – targets of under 50% are no longer innovative. With a combination of solar PV, batteries and stored hydrogen a small community can be 100% renewable (Opportunity 7). This would be a world-leading program, eligible for funding from ARENA and the Clean Energy Finance Corporation.

*The NT Government must support Indigenous enterprises to be equity partners in remote 100% renewable projects.* This model is already working in the NT. Access to affordable community owned energy has helped Ngurrara and Kurnturlpara to grow from two permanent adults to 30–40 adults and children living on Country.<sup>222</sup>

## 5. Create incentives and programs for 100% renewable manufacturing

Throughout the world, governments attract businesses by offering incentives. South Australia offers interest-free loans, payroll tax holidays, and cheap land to targeted companies.<sup>223</sup> Australia's Export Credit Agency gave substantial financial support to the Ichthys LNP project. *The Territory should consider ways to incentivise renewable-powered manufacturers.*

*The NT Government must also ensure that a substantial proportion of renewable energy equipment is manufactured within the Territory.* The United States was able to increase the share of domestically-sourced equipment in the wind industry from 25% in 2008 to 72% in 2012.<sup>224</sup> The Victorian Renewable Energy Target sets a local content requirement of 64%, as well as a target of 90% for local operations.

## 6. Set targets for mines to transition to 100% renewable energy, including machinery and vehicles

Given their high energy bills, mining companies have been surprisingly slow to adopt renewable energy. This is beginning to change as they become more familiar with the technology (Opportunity 5). Mines are also starting to realise the benefits of replacing diesel equipment with electric equivalents (Opportunity 5).

The NT Government must accelerate this change with the aim of making the Territory the global leader in renewable power mining. *The government should introduce twin targets which can be linked to mining approvals and government support:*

- a. *All mines to progressively replace fossil fuel generation with renewables, aiming for 100% renewable electricity by 2030.*
- b. *All mines to switch from diesel vehicles and machinery to electric equivalents by 2030.*

## 7. Create incentives for downstream processing of minerals within the Northern Territory

Despite the benefits of increasing minerals processing within the Territory, the NT and Australian Governments provide few incentives for this. For example, under the current system, states and territories get none of the extra GST from increasing the value of minerals through downstream processing.<sup>225</sup>

Policy mechanisms for increasing minerals processing require careful analysis. The Territory can learn from an extensive international history of successful and unsuccessful interventions.

*Some policies the NT Government can consider are:*

*Differential royalties on processed and unprocessed minerals.* The Territory could charge a higher royalty on unprocessed minerals compared to processed minerals. This would incentivise local beneficiation and discourage exports of unprocessed minerals.

*Domestic reservation policy.* The Territory could establish a domestic reservation policy for minerals, akin to Western Australia's natural gas policy. The policy would require a proportion of some minerals to remain within NT until they are processed into metals. This would have the effect of reducing the cost of minerals to entities with an interest in downstream processing.

*Enforce local processing.* A robust form of intervention would be simply to require mining companies to carry out some mineral processing within the Territory. A similar policy was pursued by the Western Australian Government in the 1990s and more recently by countries including South Africa, Chile and Indonesia.<sup>226</sup> Before approving new or expanded mines, the government could impose conditions requiring a level of downstream processing within the Territory.



## 8. Plan and fund supporting infrastructure

Many large industrial ventures in Australia receive significant assistance from public money. For example, the \$54 billion Ichthys LNG project received millions in export credits and hundreds of millions in loans from the Government-owned Export Finance and Insurance Corporation.<sup>227</sup>

*Financial assistance should be provided to the 10 Gigawatt Vision and the business opportunities it creates.* The best option for such assistance is often planning and funding of supporting infrastructure. One example might be an HVDC transmission line between Darwin and Alice Springs. Other possibilities are ports, road and railways to facilitate transport of minerals.

*The government should ensure that any public funding of infrastructure assists multiple users.* Infrastructure projects of this type will be eligible for federal assistance from sources such as the Northern Australia Infrastructure Facility (NAIF) and the Infrastructure Investment Program.

## 9. Redraft mining regulation to ensure both efficient decision-making and higher standards of environmental and heritage protection

*Amendments to the approvals process and regulatory system can ensure the Territory is seen as an attractive region for investment while creating higher standards of environmental and heritage protection.* Recent reforms in both Western Australia and Queensland have shown these two objectives need not be in conflict.

Regulatory reforms in the Northern Territory should aim to:

- simplify and speed up the approvals system for renewable energy projects and renewably-powered business ventures
- ensure that Traditional Owners have equal opportunity to engage with any proposed project which impacts their land, and that the principle of prior and informed consent informs engagement with Traditional Owners
- ensure proper rehabilitation of mine sites, and the closing of loopholes which have allowed mining companies to avoid their responsibilities (Box 9, p47). Queensland's Environmental Chain of Responsibility laws provides a partial model in this regard.

## 10. Lobby for federal support for the 10 Gigawatt Vision

The Northern Territory receives more federal funding (per capita) than any other jurisdiction. The NT's successful and sustainable economic development will improve its balance sheet and reduce its reliance on the Commonwealth. The Federal Government therefore has a good reason to support the Territory's 10 Gigawatt strategy. *The Territory should lobby the Federal Government to:*

- provide financial assistance with infrastructure funding to support the establishment of renewably-powered industries
- include the Northern Territory as a central part of the national hydrogen strategy, and ensures it receives its share of strategy funding
- open talks with the Indonesian Government about a mutually-beneficial interconnector to export renewable electricity from the Northern Territory
- consider changes to the GST regime so that NT can share in the financial benefits of adding value to mineral exports through downstream processing.

## Box 9: Reform recommendations for the rehabilitation of mining and resources projects

**The following reform recommendations are informed by Lock the Gate's submission (no. 9) to the 'Parliamentary inquiry into the rehabilitation of mining and resources projects as it relates to Commonwealth responsibilities':**

1. The NT needs Chain of Responsibility Legislation based on that recently enacted in Queensland. Proposed law reforms would protect the NT Government and taxpayers in the event a miner goes bankrupt, defaults or threatens to default on its rehabilitation obligations.
2. Undertake a comprehensive review of NT's security deposit/bond calculator to ensure it covers the full cost of mine rehabilitation and reflects industry best practice. Make all bond calculations, including the methodology, public.
3. Set and enforce mandatory progressive rehabilitation targets (and introduce material penalties in the event of default) across all mine sites in the NT to maximise the area of rehabilitation during the mine's operational life.
4. Legislate a legal prohibition on final landforms including open pit voids, out of pit waste dumps and above ground tailings storage facilities to ensure that the public's expectations are met in regards to minimising the long-term impacts of mining.
5. Close the current loophole that allows mining companies to place sites in perpetual care and maintenance, thus avoiding fulfilling rehabilitation and financial obligations.
6. Adopt the International Council on Mining and Metals/industry mine closure planning guidance to design and mandate the submission of stand-alone closure plans as part of the mining lease approval process.
7. Prior to the return of any bond, undertake an independent assessment of the operator's performance against completion criteria and the level of residual risk and the associated residual risk payment in order to manage the long-term post closure risk.

# Endnotes

1. Mercure, J.-F., H. Pollitt, J. E. Viñuales, N. R. Edwards, P. B. Holden, U. Chewpreecha, P. Salas, I. Sognnaes, A. Lam & F. Knobloch, *Macroeconomic impact of stranded fossil fuel assets*, Nature Climate Change volume 8, pages 588–593 (2018)
2. Forcey, T., Jan 2018. *Submission regarding aspects of the Draft Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*.
3. *Roadmap to Renewables*, Northern Territory Government, 2017.
4. Central Land Council - Submission 24 to the Joint Standing Committee on Northern Australia - *Inquiry into engaging Traditional Owners in the economic development of Northern Australia*. [www.aph.gov.au/Parliamentary\\_Business/Committees/Joint/Northern\\_Australia/TraditionalOwners/Submissions](http://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Northern_Australia/TraditionalOwners/Submissions)
5. Keynote Speech: Joe Morrison, CEO Northern Land Council, Cairns Queensland Australia 19 June 2017. [www.nlc.org.au/uploads/pdfs/Morrison\\_Keynote\\_Northern\\_Australian\\_Development\\_Conference\\_Cairns-062017.pdf](http://www.nlc.org.au/uploads/pdfs/Morrison_Keynote_Northern_Australian_Development_Conference_Cairns-062017.pdf)
6. O'Neill, L., Thorburn, K. and Hunt, J., 2019. *Ensuring Indigenous benefit from large-scale renewable energy projects: Drawing on experience from extractive industry agreement making and the importance of policy settings*.
7. RDA Northern Territory SEIFA Index of Disadvantage. [profile.id.com.au/rda-northern-territory/seifa-disadvantage-small-area](http://profile.id.com.au/rda-northern-territory/seifa-disadvantage-small-area)
8. Independent Monitor Environmental Performance Annual Report 2016 McArthur River Mine.
9. [www.abc.net.au/news/2017-01-25/wet-weather-mount-todd-gold-mine-discharging-contaminated-nt/8210388](http://www.abc.net.au/news/2017-01-25/wet-weather-mount-todd-gold-mine-discharging-contaminated-nt/8210388)
10. CSIRO, 2008 *Ranger Tailings Storage Facility: Review of hydrogeological issues for a wall lift to RL+54m*, M. G. Trefry.
11. ABC News, 31 May 2016. *Rum Jungle uranium mine in NT polluting environment 45 years after closure*. [www.abc.net.au/news/2016-05-30/rum-jungle-uranium-mine-in-nt-polluting-environment-45-years-on/7460666](http://www.abc.net.au/news/2016-05-30/rum-jungle-uranium-mine-in-nt-polluting-environment-45-years-on/7460666)
12. Northern Territory Government, *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory: Regulatory Reform*. [frackinginquiry.nt.gov.au/inquiry-reports?a=494300](http://frackinginquiry.nt.gov.au/inquiry-reports?a=494300)
13. Northern Territory Government, 2018. *A plan for budget repair. Interim report – an independent assessment of the Northern Territory’s fiscal position and medium-term outlook*.
14. Ibid
15. Northern Territory Government, 2018. *Climate Change Mitigation and Adaptation Opportunities in the Northern Territory - Discussion Paper*.
16. Bureau of Meteorology (2019) Climate data online, <http://www.bom.gov.au/climate/data/index.shtml>; CSIRO and Bureau of Meteorology (2018) Climate projections, provided on request.
17. Northern Territory Government, 2018. *Climate Change Mitigation and Adaptation Opportunities in the Northern Territory - Discussion Paper*.
18. AEMC, 2018 *Residential Electricity Price Trends, Final report*, 21 December 2018.
19. Ibid
20. Financial Review, 22 Mar 2019. *NT drillers poised for fracking restart*. [www.afr.com/business/energy/nt-drillers-poised-for-fracking-restart-20190320-p515v7](http://www.afr.com/business/energy/nt-drillers-poised-for-fracking-restart-20190320-p515v7)
21. International Renewable Energy Agency. [www.irena.org/costs](http://www.irena.org/costs)
22. Lazard, 2018. *Lazard’s Levelized Cost of Energy Analysis*. Also *Renew Economy*, 19/11/18. *Know your NEM*. [reneweconomy.com.au/know-your-nem-the-impact-of-federal-alp-policy-some-speculation-35698/](http://reneweconomy.com.au/know-your-nem-the-impact-of-federal-alp-policy-some-speculation-35698/)
23. George Bilicic, global head of Lazard’s Power, Energy & Infrastructure Group; *Lazard press release*, 8 Nov 2018. [lazardltd.gcs-web.com/news-releases/news-release-details/lazard-releases-annual-levelized-cost-energy-and-levelized-0](http://lazardltd.gcs-web.com/news-releases/news-release-details/lazard-releases-annual-levelized-cost-energy-and-levelized-0)
24. BloombergNEF, 23/3/19. *Battery Power’s Latest Plunge in Costs Threatens Coal, Gas*. [about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/](http://about.bnef.com/blog/battery-powers-latest-plunge-costs-threatens-coal-gas/)
25. *Renew Economy*, 27/6/18. *Australia solar costs hit “extraordinary” new lows – \$50s/MWh*. [reneweconomy.com.au/australia-solar-costs-hit-extraordinary-new-lows-50s-mwh-27007/](http://reneweconomy.com.au/australia-solar-costs-hit-extraordinary-new-lows-50s-mwh-27007/)
26. Graham, P.W., Hayward, J, Foster, J., Story, O.1 and Havas, L. 2018, *GenCost 2018*. CSIRO, Australia
27. Ibid
28. Ibid

29. George Bilicic, global head of Lazard's Power, Energy & Infrastructure Group; *Lazard press release*, 8 Nov 2018. [lazardltd.gcs-web.com/news-releases/news-release-details/lazard-releases-annual-levelized-cost-energy-and-levelized-0](http://lazardltd.gcs-web.com/news-releases/news-release-details/lazard-releases-annual-levelized-cost-energy-and-levelized-0)
30. United Nations Treaty Collection. CHAPTER XXVII ENVIRONMENT 7.d *Paris Agreement*, Paris, 12 December 2015. Retrieved 7/4/19 from [treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg\\_no=XXVII-7-d&chapter=27&clang=\\_en](http://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en).
31. IPCC, 2018: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels*. World Meteorological Organization, Geneva, Switzerland.
32. Muttitt, G., 2016. *The Sky's Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel Production*. Oil Change International.
33. Financial Review, 22 Aug 2018. *Pulling out of Paris climate deal would be a slap to trade partners*. [www.afr.com/news/pulling-out-of-paris-climate-deal-would-be-aslap-to-trade-partners-20180822-h14c02](http://www.afr.com/news/pulling-out-of-paris-climate-deal-would-be-aslap-to-trade-partners-20180822-h14c02)
34. REN21, *Renewables 2018 – Global Status Report, Renewable Energy Policy Network for the 21st Century*, 2018.
35. The Climate Group, Dec 2018. *China launches world's biggest carbon market*. Retrieved 17/6/18 from [www.theclimategroup.org/news/china-launches-world-s-biggest-carbon-market](http://www.theclimategroup.org/news/china-launches-world-s-biggest-carbon-market).
36. Nordhaus, W., 2015. *Climate clubs: Overcoming free-riding in international climate policy*. *American Economic Review*, 105(4), pp.1339-70.
37. Mark Carney, Governor of the Bank of England. *Speech at International Climate Risk Conference for Supervisors*, Amsterdam, April 2018.
38. The Conversation, 7/6/18. *How \$6 trillion of fossil fuel investments got dumped thanks to green campaigners*. Retrieved 7/7/2018 from [theconversation.com/how-6-trillion-of-fossil-fuel-investments-got-dumped-thanks-to-green-campaigners-97620](http://theconversation.com/how-6-trillion-of-fossil-fuel-investments-got-dumped-thanks-to-green-campaigners-97620)
39. Ibid
40. Carbon Tracker, 4 Dec 2013. *Wasted capital and stranded assets press release*. [www.carbontracker.org/wasted-capital-and-stranded-assets-press-release/](http://www.carbontracker.org/wasted-capital-and-stranded-assets-press-release/)
41. Investor Group on Climate Change, *2018 Global investor statement to governments on climate change*. 14/12/18, [www.carbonpricingleadership.org/news/2018/12/13/2018-global-investor-statement-to-governments-on-climate-change](http://www.carbonpricingleadership.org/news/2018/12/13/2018-global-investor-statement-to-governments-on-climate-change)
42. Climate Action 100+, <http://www.climateaction100.org/>
43. RE100 website; IRENA, *Corporate sourcing of renewable energy: market and industry trends*, International Renewable Energy Agency, 2018.
44. [www.bp.com/en/global/corporate/energy-economics/energy-outlook.html](http://www.bp.com/en/global/corporate/energy-economics/energy-outlook.html)
45. US Postal Service, 2018. *First-Class Mail Volume Since 1926*. <http://about.usps.com/who-we-are/postal-history/first-class-mail-since-1926.htm>.
46. Centre for Policy Development, 2016. *New legal opinion and business roundtable on climate risks and directors' duties*. [cpd.org.au/2016/10/directorsduties](http://cpd.org.au/2016/10/directorsduties)
47. Gloucester Resources Limited v Minister for Planning [2019] NSWLEC 7.
48. The Guardian, 17 Apr 2019. *The financial sector must be at the heart of tackling climate change*. [www.theguardian.com/commentisfree/2019/apr/17/the-financial-sector-must-be-at-the-heart-of-tackling-climate-change](http://www.theguardian.com/commentisfree/2019/apr/17/the-financial-sector-must-be-at-the-heart-of-tackling-climate-change)
49. NT has consistent sunshine, with low levels of seasonal variability compared to most regions.
50. Renew Economy, 14 Jan 2019. *Booming solar market triples in 2018, set to deliver "Hazelwood + Liddell" by 2020*. [reneweconomy.com.au/booming-solar-market-triples-in-2018-set-to-deliver-hazelwood-liddell-by-2020-2020/](http://reneweconomy.com.au/booming-solar-market-triples-in-2018-set-to-deliver-hazelwood-liddell-by-2020-2020/)
51. Based on figures in Graham, P.W., Hayward, J, Foster, J., Story, O.1 and Havas, L. 2018, GenCost 2018. CSIRO, Australia. Asian Renewable Energy Hub expects 11GW to cost \$22 billion.
52. Northern Territory Government, 2017. *Roadmap to Renewables*, Fifty per cent by 2030.
53. The Asian Renewable Energy Hub, [www.asianrehub.com](http://www.asianrehub.com)
54. Solargis under the Creative Commons Attribution license (CC BY-SA 4.0)
55. Commonwealth of Australia , Bureau of Meteorology, [www.bom.gov.au](http://www.bom.gov.au)
56. Windlab modelling, [www.windlab.com](http://www.windlab.com)
57. [bze.org.au/research](http://bze.org.au/research)
58. AEMO 2013, *100 Per Cent Renewables Study – Modelling Outcomes*. [www.environment.gov.au/system/files/resources/d67797b7-d563-427f-84eb-c3bb69e34073/files/100-percent-renewables-study-modelling-outcomes-report.pdf](http://www.environment.gov.au/system/files/resources/d67797b7-d563-427f-84eb-c3bb69e34073/files/100-percent-renewables-study-modelling-outcomes-report.pdf)



59. Teske, S., Dominish, E., Ison, N. and Maras, K. (2016) *100% Renewable Energy for Australia – Decarbonising Australia’s Energy Sector within one Generation*. Report prepared by ISF for GetUp! and Solar Citizens, March 2016.
60. Energy Networks Australia and CSIRO, 2016. *Electricity Network Transformation Roadmap: Key Concepts Report*.
61. Lovegrove, K. et al. *Current and projected LCOE of solar and wind compared to coal etc*. IT Power, 2018.
62. Northern Territory Government, 2017. *Roadmap to Renewables*, Fifty per cent by 2030.
63. Bloomberg New Energy Finance, June 2018. *New Energy Outlook*.
64. Northern Territory PHES Atlas. October 11, 2017. <http://re100.eng.anu.edu.au/research/re/site/nt.php>.
65. *Australian Renewable Energy Mapping Infrastructure*. Australian Renewable Energy Agency. [www.nationalmap.gov.au/renewables/](http://www.nationalmap.gov.au/renewables/)
66. Bureau’s weather forecasting model (ACCESS) assimilates vast quantities of satellite and in situ observations of variables including wind speed. The model provides the best available estimate of wind speed in the absence of actual observations. At 80m elevation It shows large areas of NT with average annual wind speed above 6m/s and some locations above 8m/s.
67. Beardsmore, G., 2007. *Geothermal energy potential of the Northern Territory*. Northern Territory Geological Survey, Record, 4.
68. Beardsmore, G., 2007. *Geothermal energy potential of the Northern Territory*. Northern Territory Geological Survey, Record, 4.
69. Lazard, 2018. *Lazard’s Levelized Cost of Energy Analysis*.
70. Mazengarb, M. *Renewable hydrogen getting cheaper, Australia could lead global market*, Renew Economy, 5 June 2019
71. *Hydrogen - Scaling Up*, Hydrogen Council, November 2017.
72. Ibid
73. Presentation from Japan’s Ministry of Economy, Trade and Industry. Accessed 3/12/18 at [http://www.meti.go.jp/english/press/2017/pdf/1226\\_003a.pdf](http://www.meti.go.jp/english/press/2017/pdf/1226_003a.pdf)
74. *Opportunities for Australia from Hydrogen Exports*, ACIL Allen Consulting for ARENA, 2018.
75. Ibid
76. Financial Review, 22 Jan 2019. *Hydrogen the ‘next big employer’: Labor announces \$1 billion plan*. [www.afr.com/news/hydrogen-the-next-big-employer-labor-announces-1b-plan-20190122-h1acms](http://www.afr.com/news/hydrogen-the-next-big-employer-labor-announces-1b-plan-20190122-h1acms)
77. Nagashima, M., 2018. *Japan’s Hydrogen Strategy and its Economic and Geopolitical Implications*, Etudes de l’Ifri.
78. *Hydrogen - Scaling Up*, Hydrogen Council, November 2017.
79. Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) *National Hydrogen Roadmap*. CSIRO, Australia
80. About half of all hydrogen is produced to make ammonia. Hydrogen is also an important chemical in industries such as pharmaceuticals, glass-making and electronics.
81. *Opportunities for Australia from Hydrogen Exports*, ACIL Allen Consulting for ARENA, 2018.
82. Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) *National Hydrogen Roadmap*. CSIRO, Australia.
83. *Opportunities for Australia from Hydrogen Exports*, ACIL Allen Consulting for ARENA, 2018.
84. Ibid
85. Ibid
86. Ibid
87. Figures based on high scenario in *Opportunities for Australia from Hydrogen Exports*, ACIL Allen Consulting for ARENA, 2018.
88. ABC News, 24/11/18. *NT’s solar sector faces sunny future as Channel Island gas turbines head to retirement*. [www.abc.net.au/news/2018-11-24/solar-renewable-energy-northern-territory-target-generation/10493962](http://www.abc.net.au/news/2018-11-24/solar-renewable-energy-northern-territory-target-generation/10493962)
89. Pilbara Development Commission, 2017. *Evaluating the potential to export Pilbara solar resources to the proposed ASEAN grid via a subsea high voltage direct current interconnector*.
90. Personal communication with Alan Langworthy and based on informal calculations by ABB.
91. ASEAN Centre for Energy. <http://www.aseanenergy.org/programme-area/apg/>
92. International Energy Agency. *Indonesia National Energy Policy*. [www.iea.org/policiesandmeasures/pams/indonesia/name-140164-en.php](http://www.iea.org/policiesandmeasures/pams/indonesia/name-140164-en.php)
93. The Jakarta Post, 30 May 2018. *Indonesia races against time in renewable energy*. [www.thejakartapost.com/news/2018/05/30/discourse-indonesia-races-against-time-in-renewable-energy.html](http://www.thejakartapost.com/news/2018/05/30/discourse-indonesia-races-against-time-in-renewable-energy.html)

94. Guenther, M., 2018. *Challenges of a 100% Renewable Energy Supply in the Java-Bali Grid*. International Journal of Technology, 9(2), pp.257-266.
95. Asian Renewable Energy Hub. asianrehub.com
96. The biggest barrier is political – whether Indonesia will give unequivocal and consistent support to the project. The inter-connection therefore depends on a strong relationship with Indonesia.
97. Personal communication with Intercontinental Energy.
98. Pilbara Development Commission, 2017. *Evaluating the potential to export Pilbara solar resources to the proposed ASEAN grid via a subsea high voltage direct current interconnector*.
99. Pilbara Development Commission, 2017. *Evaluating the potential to export Pilbara solar resources to the proposed ASEAN grid via a subsea high voltage direct current interconnector*.
100. Wang, C., Dargaville, R. and Jeppesen, M., 2018. *Power system decarbonisation with Global Energy Interconnection—a case study on the economic viability of international transmission network in Australasia*. Global Energy Interconnection, 1(4), pp.507-519.
101. The NEM interconnects five regional market jurisdictions – Queensland (QLD), New South Wales (NSW), Victoria (VIC), South Australia (SA), and Tasmania (TAS).
102. Wang, C., Dargaville, R. and Jeppesen, M., 2018. *Power system decarbonisation with Global Energy Interconnection—a case study on the economic viability of international transmission network in Australasia*. Global Energy Interconnection, 1(4), pp.507-519.
103. Bloomberg News, 2 Jan 2019. *World's Biggest Ultra-High Voltage Line Powers Up Across China*. www.bloomberg.com/news/articles/2019-01-02/world-s-biggest-ultra-high-voltage-line-powers-up-across-china
104. Beyond Zero Emissions, 2018. *Electrifying Industry*.
105. Queensland Government, 2017. *Media statement: 210 new jobs as Sun Metals solar powers North Queensland Clean Energy Boom*.
106. *Roadmap to renewables*, Northern Territory Government, 2017.
107. Industrial solar thermal also has good potential for low-temperature (<200C) processes.
108. Beyond Zero Emissions, 2018. *Electrifying Industry*.
109. The Climate Institute, 2011. *Clean Energy Jobs in Regional Australia: Snapshot Queensland*. [http://www.climateinstitute.org.au/verve/\\_resources/cleanenergyjobssnapshot\\_queensland.pdf](http://www.climateinstitute.org.au/verve/_resources/cleanenergyjobssnapshot_queensland.pdf)
110. The Climate Institute, 2011. *Clean Energy Jobs in Regional Australia: Snapshot Queensland*. [http://www.climateinstitute.org.au/verve/\\_resources/cleanenergyjobssnapshot\\_queensland.pdf](http://www.climateinstitute.org.au/verve/_resources/cleanenergyjobssnapshot_queensland.pdf)
111. Ingenia Online, May 2004. *Concentrating solar power for sustainable electricity generation*. www.ingenia.org.uk/Ingenia/Articles/bc861439-a6dd-4c11-87e2-ebaed7d2e72a
112. Beyond Zero Emissions, 2018. *Electrifying Industry*.
113. Energy Renaissance [renaissanceone.com.au/category/northern-territory/](http://renaissanceone.com.au/category/northern-territory/) .
114. U.S. Department of Energy, 2012 *Wind Technologies Market Report*. [www1.eere.energy.gov/wind/pdfs/2012\\_wind\\_technologies\\_market\\_report.pdf](http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf)
115. The Victorian Industry Participation Policy (VIPP) applied to the auction and a local content target of 64% for was set for all projects, as well as target of 90% for local operations and 90% for local steel.
116. Premier Daniel Andrews, Media Release, 14 Feb 2019. *Wind Turbines Bring Manufacturing Jobs to Geelong*.
117. Northern Territory Department of Primary Industries and Resources, 2018. *2016-17 Data - Mineral Extraction Statistics*. [dpir.nt.gov.au/mining-and-energy/mines-and-energy-publications-information-and-statistics/mineral-production-statistics](http://dpir.nt.gov.au/mining-and-energy/mines-and-energy-publications-information-and-statistics/mineral-production-statistics).
118. Especially since the closure of the Gove Alumina Refinery in 2014.
119. Commonwealth of Australia, 2018. *Resources 2030 Taskforce Australian resources— providing prosperity for future generations*.
120. For example, Regional Development Australia (RDA) Perth, 2018. *Lithium Valley - Establishing the Case for Energy Metals and Battery Manufacturing in Western Australia*
121. Australian Government, 2019. *National Resources Statement*.
122. Hausmann, R., Klinger, B. and Lawrence, R., 2008. *Examining beneficiation (No. 162)*. Center for International Development at Harvard University.

123. Australia is the second most attractive region in the world for mining investment according to the *Fraser Institute's Survey of Mining Companies* 2018.
124. Financial Review, 19 June 2018. *BNEF report says renewables can make Australia a cheap energy superpower again.*
125. Renew Economy, 2 May 18. *Gupta signs up solar farm to power Victoria steelworks.* [reneweconomy.com.au/gupta-signs-up-solarfarm-to-power-victoria-steelworks-38761/](http://reneweconomy.com.au/gupta-signs-up-solarfarm-to-power-victoria-steelworks-38761/)
126. Australian Mining, 10/12/18. *Sun Metals \$300m zinc refinery expansion to create hundreds of jobs.* [www.australianmining.com.au/news/sun-metals-300m-zinc-refinery-expansion-to-create-hundreds-of-jobs/](http://www.australianmining.com.au/news/sun-metals-300m-zinc-refinery-expansion-to-create-hundreds-of-jobs/)
127. Reuters, 2 Aug 2017. *Hydro-powered smelters charge premium prices for 'green' aluminium.* [www.reuters.com/article/us-aluminium-sales-environment/hydro-powered-smelters-charge-premium-prices-for-green-aluminum-idUSKBN1AI1CF](http://www.reuters.com/article/us-aluminium-sales-environment/hydro-powered-smelters-charge-premium-prices-for-green-aluminum-idUSKBN1AI1CF)
128. Rio Tinto, *Our approach to climate change* 2018 [www.riotinto.com/documents/RT\\_Our\\_approach\\_to\\_climate\\_change\\_2018.pdf](http://www.riotinto.com/documents/RT_Our_approach_to_climate_change_2018.pdf)
129. ARENA CEO Darren Miller, 26 March, 2019. [arena.gov.au/news/element-25-to-trial-making-metal-using-renewable-energy/](http://arena.gov.au/news/element-25-to-trial-making-metal-using-renewable-energy/)
130. South32 Annual Report 2018.
131. Northern Territory Government, October 2018. [core.nt.gov.au/\\_\\_\\_data/assets/pdf\\_file/0008/377621/Manganese-Factsheet.pdf](http://core.nt.gov.au/___data/assets/pdf_file/0008/377621/Manganese-Factsheet.pdf)
132. Some minimal processing of raw ore into slightly more refined lump ore does take place.
133. South32 Annual Report 2018.
134. Westfall, L.A., Davourie, J., Ali, M. and McGough, D., 2016. *Cradle-to-gate life cycle assessment of global manganese alloy production.* The International Journal of Life Cycle Assessment, 21(11), pp.1573-1579.
135. Corn cobs, straw, palm kernel shells and charcoal all have potential to replace coke as the reductant in the production of ferromanganese. See for example Supriyatna, Y.I., Zulhan, Z. and Triapriani, Y., 2018, January. The ferromanganese production using Indonesian low-grade manganese ore using charcoal and palm kernel shell as reductant in mini electric arc furnace. In IOP Conference Series: Materials Science and Engineering (Vol. 285, No. 1, p. 012022). IOP Publishing.
136. Westfall, L.A., Davourie, J., Ali, M. and McGough, D., 2016. *Cradle-to-gate life cycle assessment of global manganese alloy production.* The International Journal of Life Cycle Assessment, 21(11), pp.1573-1579.
137. South32 Annual Report 2018.
138. Assuming manganese price of US\$6.38/dmtu and EMM price of US\$2,000/T. [price.metal.com/Manganese](http://price.metal.com/Manganese)
139. Moore Stephens, 2018. *Manganese. Is it the Forgotten Battery Mineral?*
140. Element 25 [www.element25.com.au/](http://www.element25.com.au/)
141. Pilbara Metals Group. <http://pilbarametalsgroup.com>
142. Assuming 2.2 tonnes manganese ore is required for 1 tonne alloy. Also, assuming manganese ore at A\$277.50/tonne and manganese alloy at A\$2,080/tonne. Various refs including [price.metal.com/Manganese](http://price.metal.com/Manganese)
143. ABC News, 24/2/12. *Contractors cut in Temco shutdown.* [www.abc.net.au/news/2012-02-23/temco-reviews-job-futures/3847488](http://www.abc.net.au/news/2012-02-23/temco-reviews-job-futures/3847488)
144. [www.spglobal.com/platts/en/market-insights/latest-news/metals/090718-china-electrolytic-manganese-metal-export-prices-rangebound-amid-mixed-sentiment](http://www.spglobal.com/platts/en/market-insights/latest-news/metals/090718-china-electrolytic-manganese-metal-export-prices-rangebound-amid-mixed-sentiment)
145. CRU Group, 21/5/18. *Manganese metal price hikes – a storm in a teacup?* [www.crugroup.com/knowledge-and-insights/spotlights/2018/manganese-metal-price-hikes-a-storm-in-a-teacup/](http://www.crugroup.com/knowledge-and-insights/spotlights/2018/manganese-metal-price-hikes-a-storm-in-a-teacup/)
146. Galaxy Ventures Into Electrolytic Manganese Dioxide (EMD) Production [www.ewind.es/2010/02/25/galaxy-ventures-into-electrolytic-manganese-dioxide-emd-production/4258](http://www.ewind.es/2010/02/25/galaxy-ventures-into-electrolytic-manganese-dioxide-emd-production/4258)
147. Estimate based on Pilbara Metals group reports 32 jobs for 40kt/yr MnSo4 plant, with additional jobs for subsequent processing into EMM/EMD which requires electrolysis.
148. Glencore Annual Report, 2017.
149. Benavides, P.T., Dai, Q., Sullivan, J.L., Kelly, J.C. and Dunn, J.B., 2015. *Material and Energy Flows Associated with Select Metals in GREET 2.* Molybdenum, Platinum, Zinc, Nickel, Silicon (No. ANL/ESD-15/11). Argonne National Lab.(ANL), Argonne, IL (United States).
150. Boulamanti, A. and Moya, J.A., 2016. *Production costs of the non-ferrous metals in the EU and other countries: Copper and zinc.* Resources Policy, 49, pp.112-118.

151. Benavides, P.T., Dai, Q., Sullivan, J.L., Kelly, J.C. and Dunn, J.B., 2015. *Material and Energy Flows Associated with Select Metals in GREET 2*. Molybdenum, Platinum, Zinc, Nickel, Silicon (No. ANL/ESD-15/11). Argonne National Lab.(ANL), Argonne, IL (United States).
152. Nuss, P.; Eckelman, M.J. *Life Cycle Assessment of Metals: A Scientific Synthesis*. PLoS ONE 2014, 9, e101298
153. Nyrstar, 2018. Nyrstar Hobart Triennial Public Environment Report 2015 – 2017
154. Boulamanti, A. and Moya, J.A., 2016. Production costs of the non-ferrous metals in the EU and other countries: Copper and zinc. *Resources Policy*, 49, pp.112-118.
155. Nyrstar, 2018. Nyrstar Hobart Triennial Public Environment Report 2015 – 2017.
156. Mining Technology, McArthur River Mine. [www.mining-technology.com/projects/mcarthur](http://www.mining-technology.com/projects/mcarthur)
157. Kitco. [http://www.kitco.com/charts/zinc\\_historical\\_large.html](http://www.kitco.com/charts/zinc_historical_large.html). Using conversion rate of 1AUD = 0.73 USD.
158. Financial Post, 5/6/18. *The Second Coming of Zinc*. [business.financialpost.com/business-trends/the-second-coming-of-zinc](http://business.financialpost.com/business-trends/the-second-coming-of-zinc)
159. Ibid.
160. Nyrstar, 2009. *Introduction to Zinc and Lead Smelting Business*. [www.nyrstar.com/~media/Files/N/Nyrstar/results-reports-and-presentations/english/2009/zincleadsmelting.pdf](http://www.nyrstar.com/~media/Files/N/Nyrstar/results-reports-and-presentations/english/2009/zincleadsmelting.pdf)
161. Boulamanti, A. and Moya, J.A., 2016. *Production costs of the non-ferrous metals in the EU and other countries: Copper and zinc*. *Resources Policy*, 49, pp.112-118.
162. Sun Metals consumes 900,000 MWh of electricity per year to produce 225,000 tonnes of zinc.
163. ERIAS, 2015, Independent Monitor—*Environmental Performance Annual Report 2014—McArthur River Mine*. Prepared by ERIAS Group Pty Ltd (ERIAS) for the NT Minister of Mines & Energy and the NT Dept. of Mines & Energy, Melbourne, VIC, October 2014
164. *Draft Environmental Impact Statement*, 2017. McArthur River Mine Overburden Management Project accessed from [ntepa.nt.gov.au/environmental-assessments/register/mcarthur-river-mine/mcarthur-river-mine-overburden-management-project-2018/draft-environmental-impact-statement](http://ntepa.nt.gov.au/environmental-assessments/register/mcarthur-river-mine/mcarthur-river-mine-overburden-management-project-2018/draft-environmental-impact-statement)
165. [blogs.crikey.com.au/northern/2017/07/27/never-ceded-countries-garawa-gudanji-marra-yanyuwa-people-speak-truth-power/](http://blogs.crikey.com.au/northern/2017/07/27/never-ceded-countries-garawa-gudanji-marra-yanyuwa-people-speak-truth-power/)
166. Mudd, G., 2016. *The Macarthur River Project: The Environmental Case for Complete Pit Backfill*, Mineral Policy Institute.
167. Rare earth elements are a group of 17 chemically similar metals used in wind turbines, magnets and batteries.
168. Mudd, G. M., Werner, T. T., Weng, Z.-H., Yellishetty, M., Yuan, Y., McAlpine, S. R. B., Skirrow, R. and Czarnota K., 2018. *Critical Minerals in Australia: A Review of Opportunities and Research Needs*. Record 2018/51. Geoscience Australia, Canberra.
169. *Australia's Critical Minerals Strategy*, Commonwealth of Australia, 2019.
170. Mudd, G. M., Werner, T. T., Weng, Z.-H., Yellishetty, M., Yuan, Y., McAlpine, S. R. B., Skirrow, R. and Czarnota K., 2018. *Critical Minerals in Australia: A Review of Opportunities and Research Needs*. Record 2018/51. Geoscience Australia, Canberra.
171. Australian Government, 2019. *National Resources Statement*.
172. Mudd, G. M., Werner, T. T., Weng, Z.-H., Yellishetty, M., Yuan, Y., McAlpine, S. R. B., Skirrow, R. and Czarnota K., 2018. *Critical Minerals in Australia: A Review of Opportunities and Research Needs*. Record 2018/51. Geoscience Australia, Canberra.
173. Mudd, G. M., & Jowitt, S. M. 2018. *Growing Global Copper Resources, Reserves and Production: Discovery is Not the Only Control on Supply*. *Economic Geology*, In Press.
174. Mudd, G. M., Werner, T. T., Weng, Z.-H., Yellishetty, M., Yuan, Y., McAlpine, S. R. B., Skirrow, R. and Czarnota K., 2018. *Critical Minerals in Australia: A Review of Opportunities and Research Needs*. Record 2018/51. Geoscience Australia, Canberra.
175. *Significant quantities of indium are contained in mining and mineral processing wastes in Australia*. See Werner, T. T., Mudd, G. M., & Jowitt, S. M. 2015. Indium: Key Issues in Assessing Mineral Resources and Long Term Supply from Recycling. *Applied Earth Science (Trans. Inst. Min. Metall. B)*, 124, 213–226.
176. Nyrstar, 2017. *Valorisation of zinc smelter leach products*. <http://prometia.eu/wp-content/uploads/2014/02/Valo-leach-products-PROMETIA-nov2017final.pdf>
177. Mudd, G. M., Werner, T. T., Weng, Z.-H., Yellishetty, M., Yuan, Y., McAlpine, S. R. B., Skirrow, R. and Czarnota K., 2018. *Critical Minerals in Australia: A Review of Opportunities and Research Needs*. Record 2018/51. Geoscience Australia, Canberra.



178. *National Inventory by Economic Sector 2016*, Australia's National Greenhouse Accounts. Commonwealth of Australia 2018.
179. *National Inventory by Economic Sector 2016*, Australia's National Greenhouse Accounts. Commonwealth of Australia 2018.
180. Norgate, T., N. Haque, 2010, *Energy and greenhouse gas impacts of mining and mineral processing operations*, *Journal of Cleaner Production*, 18, 266-274.
181. ARENA, 2017. *Renewable Energy In The Australian Mining Sector: White paper*.
182. Ibid
183. Ibid
184. Ibid
185. International Council on Mining & Metals, 2015 Statement on Climate Change. [www.icmm.com/en-gb/news/2015/icmm-issues-statement-on-climate-change](http://www.icmm.com/en-gb/news/2015/icmm-issues-statement-on-climate-change)
186. SunSHIFT [www.sunshift.com](http://www.sunshift.com)
187. Renew Economy, 2018. *Australia becoming the global centre for renewables for mines*. [reneweconomy.com.au/australia-becoming-global-centre-renewables-mines-45845/](http://reneweconomy.com.au/australia-becoming-global-centre-renewables-mines-45845/)
188. Australian Mining, 5 Feb 2019. *Gold Fields to install massive hybrid solar facility at Granny Smith*. [www.australianmining.com.au/news/gold-fields-to-install-massive-hybrid-solar-facility-at-granny-smith-mine/](http://www.australianmining.com.au/news/gold-fields-to-install-massive-hybrid-solar-facility-at-granny-smith-mine/)
189. ARENA, 2017. *Renewable Energy In The Australian Mining Sector: White paper*.
190. ABC News, 15/09/18. *Cancer risk from diesel fumes in underground mines prompts fears of industrial health disaster*. Retrieved 13/12/18 from [www.abc.net.au/news/2018-09-15/mining-industry-confronted-over-cancer-risk-from-diesel-fumes/10209762](http://www.abc.net.au/news/2018-09-15/mining-industry-confronted-over-cancer-risk-from-diesel-fumes/10209762)
191. TUC, 26/10/18. *Bosses must protect workers from the "ticking time bomb" of diesel exhaust*. [www.tuc.org.uk/news/bosses-must-protect-workers-%E2%80%9Cticking-time-bomb%E2%80%9D-diesel-exhaust](http://www.tuc.org.uk/news/bosses-must-protect-workers-%E2%80%9Cticking-time-bomb%E2%80%9D-diesel-exhaust)
192. [www.acf.org.au/budget\\_2018\\_19\\_investment\\_in\\_a\\_healthy\\_environment\\_cut\\_to\\_bare\\_bones\\_while\\_fossil\\_fuel\\_subsidies\\_continue](http://www.acf.org.au/budget_2018_19_investment_in_a_healthy_environment_cut_to_bare_bones_while_fossil_fuel_subsidies_continue)
193. Energy Developments, *Coober Pedy Renewable Hybrid Project First Year Performance Report* September 2018.
194. Ibid
195. Ombudsman SA, 2016. <http://www.ombudsman.sa.gov.au/wp-content/uploads/District-Council-of-Coober-Pedy.pdf>
196. Epiroc, 14/11/18. *Second generation of the Epiroc zero-emission fleet presented at Power Change Days*. [www.epiroc.com/en-au/newsroom/2018/second-generation-of-the-epiroc-zero-emission-fleet-presented-at-power-change-days](http://www.epiroc.com/en-au/newsroom/2018/second-generation-of-the-epiroc-zero-emission-fleet-presented-at-power-change-days)
197. Mining Magazine 2016. *Goldcorp and Sandvik deliver all-electric mine*. Mining Magazine. London, Aspermont Limited. 21. World Business Council.
198. Bloomberg, 14/11/18. *Electric Vehicle Revolution Goes Underground With Mine Truck*. [www.bloomberg.com/news/articles/2018-11-14/electric-vehicle-revolution-goes-underground-with-mining-trucks](http://www.bloomberg.com/news/articles/2018-11-14/electric-vehicle-revolution-goes-underground-with-mining-trucks)
199. Bloomberg, 14/11/18. *Electric Vehicle Revolution Goes Underground With Mine Truck*. [www.bloomberg.com/news/articles/2018-11-14/electric-vehicle-revolution-goes-underground-with-mining-trucks](http://www.bloomberg.com/news/articles/2018-11-14/electric-vehicle-revolution-goes-underground-with-mining-trucks)
200. [www.afr.com/business/mining/iron-ore/bhp-joins-other-big-world-miners-in-testing-electric-vehicles-at-olympic-dam-20181106-h17lkx](http://www.afr.com/business/mining/iron-ore/bhp-joins-other-big-world-miners-in-testing-electric-vehicles-at-olympic-dam-20181106-h17lkx)
201. Australian Mining. *BHP introduces light electric vehicles to Olympic Dam*. [www.australianmining.com.au/news/bhp-introduces-light-electric-vehicles-olympic-dam/](http://www.australianmining.com.au/news/bhp-introduces-light-electric-vehicles-olympic-dam/)
202. International Mining, 22/2/18. *Trolley assist in Europe – Boliden Aitik trial will utilise four Cat trucks*. [im-mining.com/2018/02/22/trolley-assist-europe-boliden-aitik-trial-will-utilise-four-cat-trucks/](http://im-mining.com/2018/02/22/trolley-assist-europe-boliden-aitik-trial-will-utilise-four-cat-trucks/)
203. Mining3, 12/9/18. *The electric dream*. [www.mining3.com/the-electric-dream/](http://www.mining3.com/the-electric-dream/)
204. Northern Territory Government, 2017. *Roadmap to Renewables, Fifty per cent by 2030*.
205. NT News, 2 Oct 2017. *Cost of living higher in the Northern Territory than anywhere else in Australia*.
206. AEMC, 2018 *Residential Electricity Price Trends*, Final report, 21 December 2018.
207. AEMC, 2018 *Residential Electricity Price Trends*, Final report, 21 December 2018.
208. Financial Review, 13 Jun 2018. *Energy expert to Tomago Aluminium: Buy cheap wind and solar power*.
209. [www.csiro.au/en/News/News-releases/2018/Annual-update-finds-renewables-are-cheapest-new-build-power](http://www.csiro.au/en/News/News-releases/2018/Annual-update-finds-renewables-are-cheapest-new-build-power) & <http://re100.eng.anu.edu.au/publications/assets/100renewables.pdf>

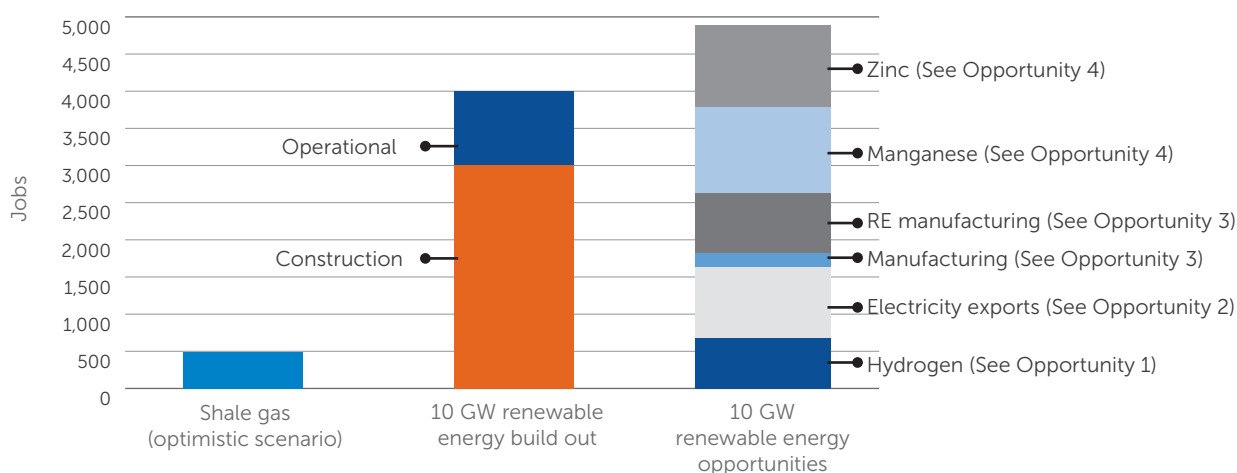
210. The Drive, 13 Feb 2019. *Electric vehicles now cheaper to own than petrol, diesel cars in Europe*. thedriven.io/2019/02/13/electric-vehicles-now-cheaper-to-own-than-petrol-diesel-cars-in-europe/
211. JP Morgan, October 2018. *Driving into 2025: The Future of Electric Vehicles*.
212. Clean Technica, 27 Oct 2018. *US Electric Car Range Will Average 275 Miles By 2022, 400 Miles By 2028*. cleantechnica.com/2018/10/27/us-electric-car-range-will-average-275-miles-by-2022-400-miles-by-2028-new-research-part-1/
213. To be sustainable the adoption of electric vehicles must occur hand-in-hand with the transition to renewables.
214. Electricity prices from AEMC, *2018 Residential Electricity Price Trends*, Final report, 21 December 2018.
215. profile.id.com.au/australia/car-ownership?BMID=160
216. www.theaustralian.com.au/nation/politics/budget-2019-pm-tags-50m-for-bush-power-microgrids/news-story/8f3f2d7c8973840deff7e63dff71cd
217. Australian Renewable Energy Agency, *Northern Territory Solar Energy Transformation Program*. arena.gov.au/projects/northern-territory-solar-energy-transformation-program/
218. Solar and wind figures from Australian Renewable Energy Mapping Infrastructure nationalmap.gov.au/renewables/. Wind figures supported by BoM ACCESS model
219. Bureau of Meteorology, *Climate statistics for Australian locations: Yuendumu and Coober Pedy*.
220. Energy Developments, *Coober Pedy Renewable Hybrid Project First Year Performance Report* September 2018.
221. PV magazine, 20 Nov 2018. *World's first, solar-hydrogen powered mini-grids in Uganda*. www.pv-magazine.com/press-releases/worlds-first-solar-hydrogen-powered-mini-grids-in-uganda/
222. Energy Source & Distribution, 4 Oct 2018. *Nel awarded contract for Australia's first hydrogen microgrid*. www.esdnews.com.au/nel-awarded-contract-for-australias-first-hydrogen-microgrid/
223. O'Neill, L., Thorburn, K. and Hunt, J., 2019. *Ensuring Indigenous benefit from large-scale renewable energy projects: Drawing on experience from extractive industry agreement making and the importance of policy settings*.
224. Indigenous Business Australia. *Case study – Manungurra Aboriginal Corporation*. <http://www.iba.gov.au/investments/case-studies/case-study-manungurra-aboriginal-corporation>
225. Regional Development Australia (RDA) Perth, 2018. *Lithium Valley - Establishing the Case for Energy Metals and Battery Manufacturing in Western Australia*.
226. U.S. Department of Energy, . [www1.eere.energy.gov/wind/pdfs/2012\\_wind\\_technologies\\_market\\_report.pdf](http://www1.eere.energy.gov/wind/pdfs/2012_wind_technologies_market_report.pdf)
227. Regional Development Australia (RDA) Perth, 2018. *Lithium Valley - Establishing the Case for Energy Metals and Battery Manufacturing in Western Australia*.
228. Article 103, Law of the Republic of Indonesia Number 4 of 2009 on Mineral and Coal Mining. House of Representatives of the Republic of Indonesia and the President of the Republic of Indonesia, 2009.
229. Peel, M., Campbell, R. and Denniss, R., 2014. *Mining the age of entitlement*. The Australia Institute.

# Appendix 1 - Shale gas and fracking is a risky bet

The Northern Territory Government inquiry into shale gas found that a fracking industry would generate revenue and jobs. Under the most optimistic scenario, the government would get an extra \$143 million in tax each year and more than 500 jobs would be created.<sup>1</sup>

Achieving the **10 Gigawatt Vision** has the potential to create many more jobs than the shale gas industry (Figure A.1).

**Figure A.1: Achieving the 10 Gigawatt Vision has the potential to create many more jobs than the shale gas industry**



Given the Government's annual expenditure of around \$6 billion<sup>2</sup> and the NT's population of 250,000, these are not impressive numbers.<sup>3</sup> But the riskiness of the fracking industry gives reason to doubt even these modest projections. Box A.1 (p57) shows just how quickly the fossil fuel economy can falter, and Box A.2 (p58) describes how the shale gas industry in particular is a risky sector.

A warning also comes from Australia's main experience to date with the unconventional gas sector – coal seam gas in Queensland. In 2014, the Queensland Government projected that taxes and royalties from the coal seam gas industry would boost state revenues by more than A\$500 million by 2016. In reality, they received less than 10% of this amount as the industry failed to match expectations.<sup>4</sup>

If this type of performance were repeated in the NT, there is a very real risk that the NT Government would not even recoup the costs of funding associated infrastructure and operating the world's most extensive regulatory regime for shale gas.

*"If shale gas is such a great business, why isn't it creating value for shareholders?"*

*Doug Terreson, energy analyst Evercore ISI<sup>5</sup>*

<sup>1</sup> ACIL Allen, 2017. *The Economic Impacts of a Potential Shale Gas Development in the Northern Territory. Appendix 16 to Scientific Inquiry into Hydraulic Fracturing in the Northern Territory.*

<sup>2</sup> Northern Territory Government, 2018. *A plan for budget repair. Interim report – an independent assessment of the Northern Territory's fiscal position and medium-term outlook.*

<sup>3</sup> This estimate looks more realistic than the industry's claim that fracking could lead to a long-term employment boost of 6300 jobs in the NT and additional revenues to the NT Government of up to \$460 million a year.

<sup>4</sup> Queensland Government. (2018). *Budget Papers (and historical).* budget.qld.gov.

<sup>5</sup> McLean, B. 2018. *Saudi America: The Truth About Fracking and How It's Changing the World*



### Shale gas – NOT part of a clean transition

Natural gas, especially shale gas, is not a clean fuel or a transition fuel to a zero-carbon economy. Gas is 75% carbon, so when burned, it generates carbon dioxide. In some cases, it is actually one of the most climate-disrupting forms of energy. That's because some natural gas always escapes during extraction, transportation and processing. Methane, the principal component of natural gas, is 28-34 times more potent than carbon dioxide as a greenhouse gas.<sup>6</sup>

With a leakage rate of only 3.2%, natural gas is a worse climate pollutant than coal.<sup>7</sup> This rate is likely to be exceeded by many fracking operations, as gas does not just leak but is deliberately vented at various stages of the extraction process. Although fugitive emissions represent lost income for the gas companies, it can be more economical to allow

them to escape than to invest in equipment and processes to contain them. This has proven to be the case in Queensland's coal seam gas industry where large amounts of methane is vented.<sup>8</sup>

Australian oil and gas production facilities, including the coal seam gas industry, do not even reliably measure their fugitive emissions.<sup>9</sup> However at shale gas sites in the US, emissions ranging from 2 to 17% have been measured.<sup>10</sup>

Developing NT's shale gas and oil could release over 20 billion tonnes of carbon emissions – four times more than the Carmichael coal mine proposed by Adani in Queensland.<sup>11</sup> Annual emissions from the shale gas industry (high scenario) would be over 100 times greater than potential emissions savings under the NT's renewable energy target in 2030.<sup>12</sup>

6 Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V. and Midgley, P.M., 2013. *Climate change 2013: The physical science basis*.

7 Alvarez, R.A., Pacala, S.W., Winebrake, J.J., Chameides, W.L. and Hamburg, S.P., 2012. Greater focus needed on methane leakage from natural gas infrastructure. *Proceedings of the National Academy of Sciences*, 109(17), pp.6435-6440

8 Forcey, T., Jan 2018. *Submission regarding aspects of the Draft Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*.

9 Day, S., Dell'Amico, R. et al., "Field measurements of fugitive emissions from equipment and well casing in Australian coal seam gas fields." 2014

10 Frankenberg, C. et al., "Airborne methane remote measurements reveal heavy-tail flux distribution in Four Corners region", PNAS 2016. <http://www.pnas.org/content/113/35/9734.full>

11 Forcey, T., Jan 2018. *Submission regarding aspects of the Draft Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*.

12 Ogge, M., The Australia Institute. *Fracking and Northern Territory emissions Briefing paper*, April 2018



## Box A.1: Shale gas: would you invest?

The fracking industry has tried to establish itself in many countries, but so far it has had major success in only one: the United States. But few people realise that even there, the industry rests on shaky financial foundations.

Few US shale gas companies have ever made more than they spend. Between 2006 and 2014, the 16 largest publicly-traded fracking companies in the US spent \$80 billion more than they made selling in gas and oil.<sup>13</sup> None generated excess cash flow. In other words, they were financial flops.

The underlying problem is how quickly a shale well's production declines. In only its third year, a typical well produces 70% less than its first year (Figure A.2)<sup>14</sup>. This drives a constant effort to find and drill new wells, and therefore an insatiable need for new investment.

Some believe the only reason the US fracking industry still exists is because of the huge flows of cheap credit available since the global financial crisis, and the dearth of alternative investment opportunities.<sup>15</sup> Some investors have lost a lot of money. In 2016, Australia's BHP wrote off a A\$10 billion stake in US shale oil and gas.<sup>16</sup>

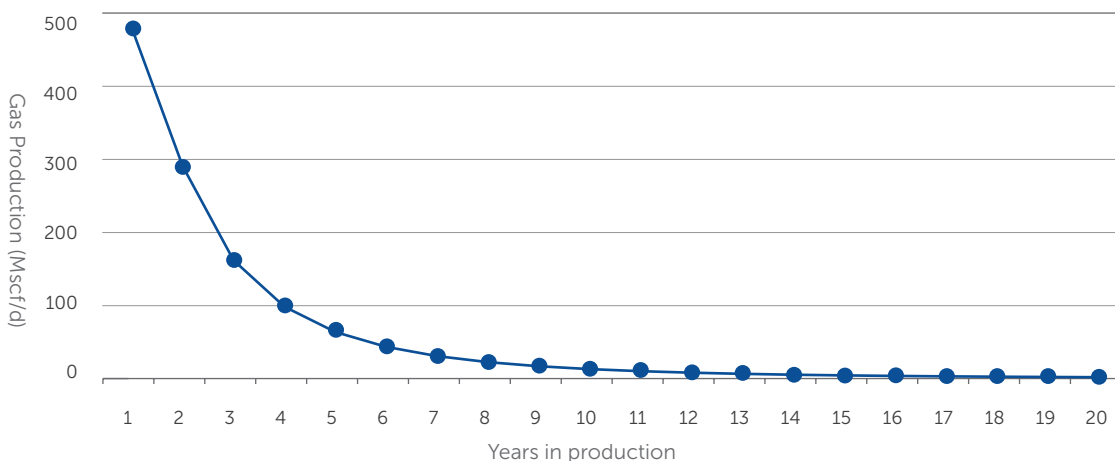
Other investors are so sceptical they won't touch the sector. Jim Chanos, an American hedge-fund manager, says "the industry has a very bad history of money going into it and never coming out." John Hempton, the founder of Australian hedge fund Bronte Capital simply believes: "the economics don't work".<sup>17</sup>

Wall Street may have finally lost patience with the US shale industry. Concern about banks' exposure to fracking firms has led US financial regulators to tighten lending standards and the flow of investment is drying up. In 2018, fracking interests were able to raise only half the funds they did in 2007, and fracking companies are being forced to cut costs.<sup>18</sup>

This fragility of shale gas economics persists in spite of enthusiastic support from US Government policy. A carbon price would make things a lot worse. A price of just A\$40 on a tonne of carbon dioxide would add more than A\$2 to the cost of a gigajoule of gas.

The fracking industry has public costs in terms of regulation and impacts on local economies (see below). Its financial track record should make us question whether these public costs are worth it.

Figure A.2: Steep well decline of a shale gas field



13 McLean, B. 1/9/2018. *New York Times*. *The Next Financial Crisis Lurks Underground*. [www.nytimes.com/2018/09/01/opinion/the-next-financial-crisis-lurks-underground.html](http://www.nytimes.com/2018/09/01/opinion/the-next-financial-crisis-lurks-underground.html)

14 Cook, P., Beck, V., Brereton, D., Clark, R., Fisher, B., Kentish, S., Toomey, J. and Williams, J., 2013. *Engineering energy: Unconventional gas production: A study of shale gas in Australia*.

15 McLean, B. 2018. *Saudi America: The Truth About Fracking and How It's Changing the World*

16 ABC News, 15/01/2018. *BHP Billiton reveals further \$10.3 billion shale oil write-down*. [www.abc.net.au/news/2016-01-15/bhp-billiton-reveals-further-shale-oil-write-down/7090530](http://www.abc.net.au/news/2016-01-15/bhp-billiton-reveals-further-shale-oil-write-down/7090530)

17 McLean, B. 2018. *Saudi America: The Truth About Fracking and How It's Changing the World*.

18 *The Australian*, 26 Feb 2019. *Frackers' funds dry up as Wall St back away*.

## Box A.2: A warning from the gas turbine sector?

Corporate history is full of Kodak moments – companies whose inadequate response to change led to their sudden demise. The transition to renewables threatens similar disruption and the recent fortunes of the gas turbine sector may provide a glimpse of things to come.

Until recently, the world's three major gas turbine manufacturers, Siemens, GE and Mitsubishi Heavy Industries (MHI) faced the future with confidence. As late as 2017, each predicted strong growth in demand for their turbines, which they saw as an essential backup to variable renewable energy.<sup>19</sup>

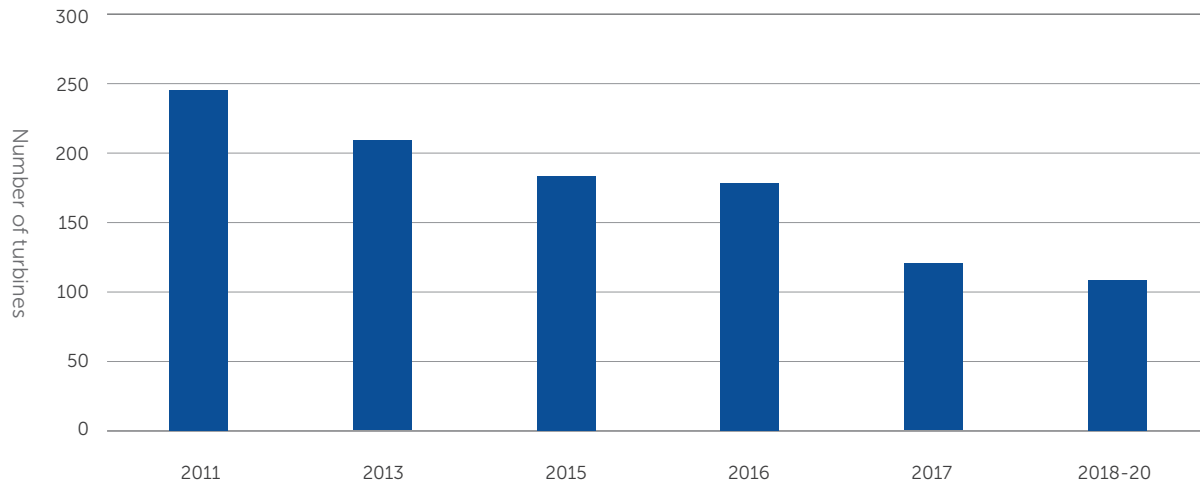
Instead, the falling cost of renewables is overwhelming the sector. A steady decline in demand for gas turbines since 2011 has suddenly gathered pace, and sales fell by 28% in the last year alone (Figure A.3).<sup>20</sup> This has led to many thousands of job losses at the three main companies and their prospects look doubtful. A member of Siemens' management board said "the market is burning to the ground".<sup>21</sup>

The big three have been forced to change strategy. MHI announced it would focus on servicing existing turbines rather than selling new ones due what it called "the rapid shift away from fossil fuels and towards renewable energy".<sup>22</sup>

Electricity from solar and wind is now cheaper than gas in nearly all circumstances,<sup>23</sup> and increasingly batteries, not gas, are supplying backup. Things will only get harder for the gas turbine makers as the cost of both renewables and batteries continues to fall.

By 2025, batteries are expected to be half today's cost – US\$100 per kilowatt hour.<sup>24</sup> As one veteran analyst of the gas turbine industry commented: "If it gets there, that will be the end of peaking gas turbine plants".<sup>25</sup>

Figure A.3: Number of large gas turbines sold globally.



<sup>19</sup> Carbon Commentary, Jan 2018. 'Burning to the ground': The carbon bubble in gas turbines. Retrieved 5/7/2018 from [www.carboncommentary.com/blog/2018/1/26/burning-to-the-ground-the-carbon-bubble-in-gas-turbines](http://www.carboncommentary.com/blog/2018/1/26/burning-to-the-ground-the-carbon-bubble-in-gas-turbines)

<sup>20</sup> International Turbomachinery, 5/7/18. Tough Times for Gas Turbines. Retrieved 30/11/18 from [www.turbomachinerymag.com/tough-times-for-gas-turbines](http://www.turbomachinerymag.com/tough-times-for-gas-turbines)

<sup>21</sup> Janina Kugel quoted by Reuters, 17/11/17. Siemens to cut 6900 jobs to tackle flailing turbines business. Retrieved 30/11/18 from [uk.reuters.com/article/us-siemens-power-restructuring/siemens-to-cut-6900-jobs-to-tackle-flailing-turbines-business-idUKKBN1DG257](http://uk.reuters.com/article/us-siemens-power-restructuring/siemens-to-cut-6900-jobs-to-tackle-flailing-turbines-business-idUKKBN1DG257)

<sup>22</sup> Carbon Commentary, Jan 2018. 'Burning to the ground': The carbon bubble in gas turbines. Retrieved 5/7/2018 from [www.carboncommentary.com/blog/2018/1/26/burning-to-the-ground-the-carbon-bubble-in-gas-turbines](http://www.carboncommentary.com/blog/2018/1/26/burning-to-the-ground-the-carbon-bubble-in-gas-turbines)

<sup>23</sup> Lazard 2018. Lazard's Levelised Cost of Energy Analysis Version 12.0.

<sup>24</sup> Bloomberg, Dec 2017. The Latest Bull Case for Electric Cars: the Cheapest Batteries Ever. Retrieved 30/11/18 from [www.bloomberg.com/news/articles/2017-12-05/latest-bull-case-for-electric-cars-the-cheapest-batteries-ever](http://www.bloomberg.com/news/articles/2017-12-05/latest-bull-case-for-electric-cars-the-cheapest-batteries-ever)

<sup>25</sup> Mark Axford, Axford Consulting quoted in International Turbomachinery, 5/7/18. Tough Times for Gas Turbines. Retrieved 30/11/18 from [www.turbomachinerymag.com/tough-times-for-gas-turbines](http://www.turbomachinerymag.com/tough-times-for-gas-turbines)

## Economic and social risks of shale gas

A significant shale gas industry in the NT is certain to bring investment, but at what cost? The risk is of disruption to the regional economy and social cohesion from large influxes of capital and non-resident workers.<sup>26</sup> Local experience shows how this leads to steep increases in the cost of housing and other essentials, causing difficulties for residents and businesses in other sectors. Local infrastructure and services such as schools and hospitals become stretched, leaving the government pick up the pieces.

A shale gas industry will heavily impact Aboriginal communities. Fifty-one per cent of the NT is covered in exploration licences for oil and gas, and if all this went ahead, much of the Aboriginal owned land would have country polluted by the shale gas industry.<sup>27</sup>

*"Our land is part of who we are. And there's a lot of pain when you see your country scarred like that. It's not reversible."*

AMELIA TELFORD, Seed National Director<sup>28</sup>

The Ichthys LNP project has given NT direct experience of the destabilising effect of a sudden flood of capital and workers. At the peak of construction, the Baldwin Point facility near Darwin required 8000 workers, but now only 300 are needed to run it. Thousands of former workers have left the Territory, and their departure, combined with a sharp fall in spending on goods and services needed during construction, has led to an economic slowdown.<sup>29</sup>

The Ichthys project also led to a boom and bust in Darwin's property sector. House prices fell by 19.4% in the three years to June 2018, with further falls expected in coming years. The value of real estate transactions in the Territory fell 53%, from \$2.25 billion to \$1 billion, with a corresponding decline in stamp duty revenue.<sup>30</sup> The post-Ichthys hangover has been felt keenly by the government, with the Territory's budget going deep into the red.<sup>31</sup>

Regional Queensland suffered similar effects from the coal seam gas industry. In the town of Miles, median weekly rental prices for a three-bedroom home jumped from \$200 in 2008 to \$550 in 2012. House prices and real estate activity spiked during the boom leading some Miles locals, particularly young people on lower wages, to leave town. Once the boom was over, the gas workforce left too, and the population crashed.

A 2014 survey in the Queensland region at the centre of CSG development found that only 7% of locals "embraced" it. Most were 'resisting', 'not coping' or 'only just coping' with the presence of the local gas industry.<sup>32</sup>

*"[The coal seam gas industry] has been a complete and utter disaster for the town."*

David Sweetapple, Miles resident<sup>33</sup>

A shale gas industry is likely to have other longer-term impacts. Indeed, the NT inquiry pointed out the risk of adverse impacts on businesses in the pastoral, agricultural, horticultural and tourism industries, as they lose workers and pay more for goods and services. In Queensland, according to The Australia Institute, there has been a loss of 1.8 jobs in the agricultural industry for every new job created in coal seam gas.<sup>34</sup>

26 Murray, C.K., *The Australia Institute. Gas and the Wide Bay Burnett Economy*, October 2018.

27 Seed Mob, <https://nt.seedmob.org.au/>

28 'Amelia Telford is protecting country', *Dumbo Feather*, 3 September 2013, via <https://www.dumbofeather.com/conversations/amelia-telford-protecting-country/>

29 CommSec. *State of the States. Commonwealth Bank*, October, 2018.

30 Breen, Jacqueline. "NT Property Sale Prices Slide \$1.2 billion after LNG Boom Ends." *ABC News*. July 29, 2018. [www.abc.net.au/news/2018-07-29/property-sale-prices-drop-billion-northern-territory-lng-boom/10048784](http://www.abc.net.au/news/2018-07-29/property-sale-prices-drop-billion-northern-territory-lng-boom/10048784)

31 2018-19 Budget Overview. Darwin: Northern Territory Government, 2018.

32 Walton, A.et. al. (2014). *CSIRO survey of community wellbeing and responding to change: Western Downs region in Queensland*. CSIRO Technical report: CSIRO, Australia. [gisera.csiro.au/wpcontent/uploads/2018/01/CSIRO-survey-of-Community-Wellbeing-and-responding-to-change-Western-Downs-region-in-Queensland.pdf](http://gisera.csiro.au/wpcontent/uploads/2018/01/CSIRO-survey-of-Community-Wellbeing-and-responding-to-change-Western-Downs-region-in-Queensland.pdf)

33 Clarke, Gemma. "A Decade Ago You Couldn't Even Rent a Caravan. Now Miles Has Been Devastated." *News.Com*. March 26, 2018. [www.news.com.au/finance/business/mining/miles-the-coal-seam-ghost-town/news-story/3923c38654f0ab9e3e4ed703d1de2d52](http://www.news.com.au/finance/business/mining/miles-the-coal-seam-ghost-town/news-story/3923c38654f0ab9e3e4ed703d1de2d52).

34 Murray, C.K., *The Australia Institute. Gas and the Wide Bay Burnett Economy*, October 2018