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Clean Energy or Coal, Jobs and Displaced Carbon Emissions at Any Cost? Assessing Australia's Brown Coal v. Solar-Produced Liquid Hydrogen Exports to Japan

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Abstract

In a world shifting to a new global low carbon energy system and economy, renewable energy (RE) generation by Australia for export to its Asian neighbors could be part of a new renewables-driven political economy. We explore the complexities of energy exports and the tensions between the use of fossil fuels versus renewables for energy exports. We first outline Australia's potential in the transition to renewables and its current national energy policy paralysis. The Australian government has entered into an agreement to export hydrogen to Japan in a purpose-built Japanese shipping fleet. However, the agreement is based on using lignite (brown) coal from the ailing Gippsland mining industry. The comparison of solar versus coal-produced liquid hydrogen exports to Japan is assessed against seven lenses or filters: the public interest 'No-net-detriment to Australian consumers' test; Australia's Paris 2015 carbon dioxide (CO2) reduction commitment; other environmental impacts such as production-related emissions and embedded energy in shipping infrastructure; socio/political national benefits to GDP; impact on Australia's energy security; socio/political assessment of impact on Australia's energy-related foreign policy and Australia-Japan relations; and the way that using coal to generate hydrogen for export to Japan undermines Australia's commiment to the 2015 UN Sustainable Development Goals (SDGs).

Keywords: *liquid hydrogen, lignite coal, solar hydrogen generation, hydrogen exports to Japan, UN SDGs, product life cycle emissions*

1. Introduction

Countries are differentially placed in terms of their natural resource and technological capacities for energy generation and export of liquid hydrogen. In this article, we focus on potential exports of liquid hydrogen, the complexities of energy exports and the tensions between the use of fossil fuels versus renewables for energy export. The research engages with the over-arching question of the extent to which exports based on different technologies and energy generation sources (solar v. lignite coal) support Australian and Asian energy equity, access, affordability, security and sustainability; alongside

contributing to global carbon emission abatement and clean energy, in line with the United Nations Sustainable Development Goals (SDGs) (Hoesung Lee, IPCC 2017; REN21 2016)).

In a world shifting to a new global low carbon energy system and economy, renewable energy (RE) generation by Australia for export to its Asian neighbors could be part of a new renewables-driven political economy. This could boost future Australian trade and foreign policy performance, energy and national security and help in the abatement of carbon emissions. Yet, polarized debates and intractable confrontations over energy and climate change policy, have created a policy impasse on Australian alternative domestic energy, and have stymied the shift to new RE exports. Australia risks falling behind in first-mover RE export advantages, and meeting its national carbon emission reduction undertakings made at the Paris 2015 United Nations (UN) Climate Change Conference-COP21 (UNFCCC 2017).

We first outline Australia's potential in the transition to renewables and its current national energy policy paralysis**.** The comparison of solar versus coal-produced liquid hydrogen exports to Japan is assessed against seven lenses or filters: the public interest 'No-net-detriment to Australian consumers' test; Australia's Paris 2015 carbon dioxide (CO2) reduction commitment; other environmental impacts such as production-related emissions and embedded energy in shipping infrastructure; socio/political national benefits to GDP; impact on Australia's energy security; socio/political assessment of impact on Australia's energy related foreign policy and Australia-Japan relations; and Australia's contribution to the 2015 UN Sustainable Development Goals (SDGs); and in particular, SDG 7 Sustainable Energy for All.

2. Australia's potential in the transition to renewables

Australia has been a dominant player in terms of fossil fuel energy supply and the mining boom, which has been key to Australia's continuing high standard of living despite the global financial crisis (Drew 2015; Garnaut 2016a, 5). From the early 2000s the Australian economy benefited from Asian demand for commodities used in steel and energy production, based on extraction of coal, iron ore and liquefied natural gas (LNG) and in particular, China's demand for steel and energy (Conolly and Orsmond 2011, p. 49). While much of the focus of debates on policy and renewables has focused on electricity generation, this discussion addresses the important area of primary energy. Hydrogen has potential to reduce emissions in transport and industry, which constitute a substantial share of global emissions (IEA 2017). In Australia's case, electricity constitutes only twenty percent of energy end use; dwarfed by liquid fuels for engines and transport (47%), and heat (29%) (Lovegrove 2016).

Australia is rich in natural resources and is sixth in the world for exporting energy (Office of the Chief Economist 2015). It is well-positioned with "vast renewable energy resources, good export capabilities and strong relationships with key international markets" (ARENA 2017a). Looking forward, Australia could enhance its role in global energy in a low carbon world, using its potential for low-cost production of energy from promising renewable sources: solar, wind, deep geothermal, wave and tidal (Garnaut 2016a, 10; Drew 2015).

Australia is well positioned in the global push for a new energy paradigm driven by low carbon-emission technology. As author of the Garnaut Climate Change Review (2008, 2010) and independent expert adviser to the Multi-Party *Climate Change* Committee, Ross Garnaut argues, Australia's natural assets in solar power and natural gas constitute important transitional fuels (Garnaut 2016a, 9). Australia's propinquity to Asian energy markets, has great promise for both Australia's domestic transition to low carbon energy and export to Northern neighbours currently reliant on coal-generated electricity (Brinsgeu, 2016; Hinkley et al. 2016; Sovacool, 2016).

New-generation alternative energy technologies are needed to enhance environmental sustainability. RE (solar, wind, geothermal, hydropower, bioenergy and ocean power) currently provides about seven percent of global energy needs (Pike, 2017). These technologies are gaining credibility in efforts to lower carbon dioxide emissions and address climate change. However, competitive 'first mover' advantages mean that the costs of transitioning to a low-carbon economy "will be lower in countries that

move early and establish clear and stable policies" (Garnaut 2016a 4). Opportunities will be greatest in the transition phase and rely on timely innovation coupled with resource availability (Vorath 2015). Investment in renewables is seen as the gateway to new RE domestic and export industries.

> Tradeable renewable energy commodities - such as biofuel, hydrogen or transmitted electricity - will be additional energy intensive industries of the renewable energy era. Abundant, low-cost renewable energy, land availability, and proximity to the emerging Asian region will make Australia a natural home for these industries (Drew 2015, 2).

In May 2017, the Australian Renewable Energy Agency (ARENA) (having survived earlier conservative Coalition Government attempts to discontinue its funding) announced its new four priorities for investment, including RE exports. ARENA aims to drive long-term industry growth and jobs, innovation in future RE export industries, improving cost and efficiency of renewable energy use to supply energy-intensive, large-scale export value chains, and feasibility studies for first-of-a-kind projects. ARENA's focus is on exporting RE as primary energy (for example hydrogen or ammonia) or embodied in processed raw materials, and responding to demand from countries with limited renewable resources of their own (ARENA 2017a). Australia's geographic proximity to ASEAN countries signals the potential of a huge regional RE export market (ASEAN 2017); especially as China steps in as the US is seen to retreat from clean energy (Bradsher, 2017). However, government policy does not necessarily follow this lead on emphasizing RE.

3. Australia's Renewable Energy policy paralysis and the continuing dominance of Big Coal

The development of alternative energy technologies is dependent on domestic politics and policies. Australia has one of the highest per capita emissions, if not the highest in the world[i]. It is a country richly endowed with natural resources including coal and natural gas. Australia is the world's largest coal exporter, fourth largest coal producer, has the sixth largest reserves of gas (in Asia) and is fifth largest exporter of natural gas (Curran 2012). Domestically, between 2014-2015, 63 per cent of Australian electricity generation was from coal (14 per cent from renewables) (Office of the Chief Economist 2016). While Australia's energy mix may be changing in some states such as South Australia, which has supportive state-level government policies encouraging RE and storage, and the Australian Capital Territory which subsidizes RE, foot-dragging national government energy policy has meant that Australia is highly reliant on coal-fired electricity and exports of coal, a major contributor to per capita emissions globally (Garnaut 2016a).

Despite its great potential, Australia's deployment of renewable technologies has been constrained by a "lack of policy support", comparatively low fossil fuel prices and fossil fuel subsidies (REN21 2016b, 38). Others point to policy uncertainty and uncoordinated government interventions (Wood, Blowers and Griffiths 2017) and to a policy impasse as a result of 'policy wars' (Butler 2017). Investment in renewables has been slower in Australia than in countries with more favourable renewables policies such as Germany (Gert Brunekreeft 2014). In Australia, the fossil fuel lobby has been a powerful well-networked and resourced policy lobby, gaining credibility with both sides of politics over the period of the mining boom from 2000-2016. Australian Government policy for commodity-led GDP growth, means economic, export and trade policies and government subsidies have favoured the extractive industries (Bast et al. 2015). Allowing private interests to export gas from the Queensland Gladstone LNG plants responding to global demand for gas, has resulted in export price-linked price hikes for Australian consumers (outstripping those in Europe, the US and Asia), which have also raised energy prices across the board, a boon to coal-based generating companies (Brazalle and Edis 2017). It has also raised the ire of business, since high energy prices are a disincentive to domestic and foreign investment. In fact, "Australia's investment in renewable energy power projects almost stalled from 2013 to 2015, as investors fled the sector on fears

(subsequently validated) that [former Prime Minister] Tony Abbott wanted to abolish the Renewable Energy Target" (Brazzale and Edis 2017 p. 11).

Internationally, Australia is an energy policy laggard (Flannery, Hueston and Stoci 2014). As Nachmany et al. (2015, 18-19) stated (after the election of the current Coalition Government):

> Australia repealed most of its carbon tax and Clean Energy Package, becoming the first developed country to take a legislative step back from acting on climate change.

Recent energy policy in Australia has been in a state of paralysis, after a "decade of toxic political debates, mixed messages and policy backflips" preventing "credible climate change policy" and stalling investment in renewables (Wood and Blowers 2017). Addressing the Press Club in February 2017, Prime Minister Malcolm Turnbull lamented: "The promised emergence of Australia as a low-cost energy superpower if we just slashed climate change regulations has clearly failed to materialize. In fact things have become far worse" (Turnbull 2017). This policy wrangling has impacted Australia's leadership in RE, and by 2016 Australia had fallen from 4th in 2010 to 10th on the Renewable Energy Country Attractiveness Index (RECAI) (Ernst & Young, 2016).

The coal lobby has been successful in securing policy favors from governments on both sides of politics at both federal and state levels in Australia. A lack of transparency surrounds 'Big Energy' political activity, framing of issues, lobbying and agenda-setting on public policy. Continued government support for the coal lobby runs counter to public announcements by energy providers such as AGL, French utility Engie (the owners of recently retired Gippsland Hazelwood coal generator) and iron ore producers like BHP Billiton, reading the signs of high carbon stranded asset risk and publicly moving away from fossil fuel investments. By 2015, global coal use had begun to decline (Morton 2017), and by 2016 coal prices had bottomed out and were half 2011 levels (IEA 2017, 56).

In 2017, Australia's Chief Scientist Alan Finkel's (2017) proposal for a Clean Energy Target was rejected by the Australian Coalition Government. Based on advice from the Energy Security Board, the RET will be retired from 2020. In its place, a National Energy Guarantee will comprise a "reliability guarantee" requiring electricity retailers and large users purchasing electricity directly from the National Electricity Market (NEM) to meet a percentage of load with "flexible and dispatchable resources" and "an emissions guarantee" related to a national emissions target set by the Australian Government (Gilbert and Tobin 2017).

Caving into pressure from the Minerals Council of Australia, subsidies for renewables were dropped and 'technology neutral' auctions of 'continuous power' controversially include 'clean coal' power generation under funding from the green bank [The Clean Energy Finance Corporation] (Morton and Hannan 2017; Parkinson 2017; Schnitter and Fisher 2017). The Turnbull Coalition government has seized upon the availability of cheap coal to argue that under a national energy guarantee, coal should continue to constitute 'baseload power' to offset the intermittency of wind and solar (Kilvert 2017). Meanwhile, business and community interests (including the Australian Energy Market Commission, the Business Council of Australia , the Australian Industry Group, Energy Supply Council, National Farmers Federation and environmental advocacy group the Climate Institute) have called on government for an "emissions intensity target" that could be "technology agnostic". But critics argue this runs the risk of lax emissions baseline targets and loopholes that might divert funding to higher emitting coal industry generation (Brazzale and Edis 2017, p. 11). To sum up, the uncertainty and flip-flop on government's energy and climate change policies has affected investor confidence (Australian Energy Regulator 2017, p. 4), stymying growth of Australia's RE industry and creating a policy context that continues the dominance of fossil fuels.

4. Potential Energy Exports: Hydrogen to Japan

Japan has limited natural resources and virtually all energy is imported (including LNG, coal and oil). As Lovegrove (2016) points out, Japan is a net importer of the majority of energy it consumes at high global levels, while Australia is a net exporter of energy, with 79 percent of all Australian energy use in 2013-14 being exported. In terms of natural assets, Japan has a population of 128 million (compared to Australia's 22 million), an area of only .38 million square kilometers (compared to Australia's 7.7 million square kilometers); and much lower irradiation (1100kWh/m2/year compared with Australia's 2300kWh/m^2/year.

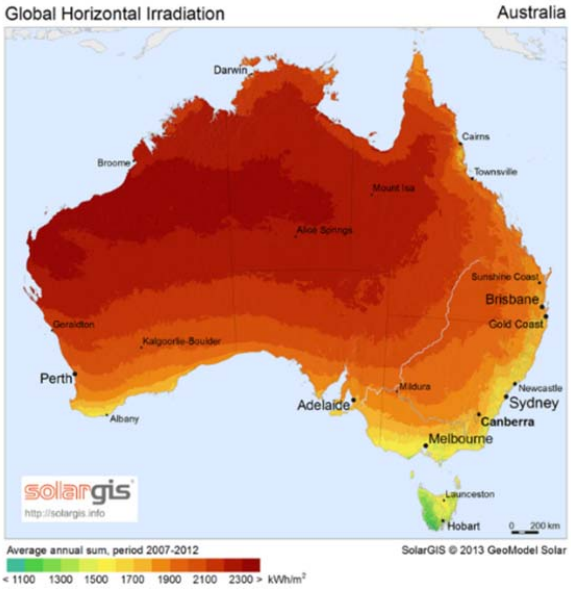
Japan is Australia's main energy export customer (in particular coal and gas), has a history of investment in Australia, and has strong energy security concerns alongside a commitment to addressing climate change (Lovegrove 2016). In 2010, nuclear energy provided over 25 per cent of Japan's electricity but after the 2011 Fukishima nuclear disaster, Japanese sentiment dismissed nuclear energy, motivating the drive for RE. With the Chinese market at its doorstep and its expertise in automotive innovation, Japan is fast-tracking its burgeoning hydrogen fuel cell industry.

Hydrogen can be produced through water electrolysis using either RE (notably solar) or gasifying coal. Japan is building a hydrogen economy and will showcase it at the Japanese 2020 Olympics. In 2016, Japan set a target of 40,000 hydrogen fuel-cell vehicles on the road by 2020 increasing to 800,000 by 2030 and has also committed to reduce the cost of household fuel cells (Wahlquist 2017). Kawasaki Heavy Industries and Iwatani Corp. have partnered with Kobe city to build a liquefied hydrogen import hub by 2020. New systems and legislation are required for transporting hydrogen, including shipping and fuel stations to distribute it for vehicles, households and industries. "For Japan, moving early and aggressively in hydrogen could give its industries an edge as the world plays catch-up" (Irfan 2016). First movers on hydrogen vehicle innovation will be well-positioned for burgeoning Chinese demand for low emission transportation and for global trade in hydrogen-using vehicles.

The same may be said for Australia in exporting hydrogen. RE technologies can develop hydrogen in Australia for shipping to Japan, such as a CSIRO piloted project using solar energy. In 2017 however, the Australian Government signed an agreement with Japan to supply hydrogen generated from brown coal in Latrobe Valley, Victoria, with a pilot project beginning in 2020. Kawasaki Heavy Industries Ltd. will build a test ship, since shipping liquid hydrogen will require a new fleet (News.com.au 2017). Solar and coal hydrogen production are two quite different processes (a third could include hybrid use of both solar and coal).

4.1 Solar

Solar thermal energy maps show Australia's high efficiency solar receptivity as a natural resource solar energy (See figure 1).



Source: By SolarGIS © 2013 GeoModel Solar, CC BY-SA 3.0, https://upload.wikimedia.org/wikipedia/commons/c/ce/SolarGIS-Solar-map-Australia-en.png

Renewable hydrogen production is expected to become cost-competitive with fossil fuel produced hydrogen in the near future. CSIRO has identified solar PV electrolysis systems, as zero-emission technology (Hinkley et al. 2016, p. vi). A CSIRO two-year pilot project aims to convert solar-generated ammonia to hydrogen, enabling hydrogen to be transported more easily as ammonia (which is already traded globally), and then reconverted back to hydrogen for end users. Japan and South Korea are primary target markets, but new markets may also be developed across the Asia-Pacific and Europe using existing infrastructure (CSIRO 2017a).

The Western Australian Pilbara Development Commission is assessing RE projects, including proposals to use solar energy for developing hydrogen in the Pilbara region and then shipping it to Japan. The company, Renewable Hydrogen, plans to establish a small 10-megawatt-hour solar PV. Solar power will generate electricity to create hydrogen, which may also be used to make ammonia (Turner 2015). Renewable ammonia will likely displace fossil fuel-generated ammonia, already used internationally for fertilizer which also has growing markets in India (IEA 2017). Both hydrogen and ammonia, developed from low-cost, low-emission solar-generated electricity, could become important exports for Australia, with ammonia possibly overtaking hydrogen (Garnaut 2016a, 10).

4.2 Coal

Australia has an ageing coal-based electricity generation fleet on average thirty-three years old (Brazzale and Edis 2017, 10). Concerns about the closure of Hazelwood power station in 2017 and declining demand for lignite (less efficient second grade brown coal) in the Victorian La Trobe valley, have brought increased political tensions to a region with already high unemployment and pockets of historically high disadvantage (McKenzie, Pendergast and Parbery, 2017). This region is traditionally dependent on coal-fired electricity generation for jobs and the region is also low on natural solar potential for solar-produced hydrogen; which renders it unsuitable for commercial solar-coal hybrid hydrogen production. In this context, the Victorian State Government has backed the 'Kawasaki Hydrogen Road' plan to use brown coal to produce liquid hydrogen shipped to Japan in a custom-made shipping fleet of tankers. This has been a low-profile partnership with a contract signed at national level by Maritime Authorities from both Australia and Japan in January 2017, for supply to Japan. Notably, any emissions from this process would not show up on Australian coal-fired electricity generation reporting but would be captured on energy mapping; misleading on emissions assessments based only on electricity. "Kawasaki,

Iwatani, J-Power and Shell Japan are backing the project, with the Victorian and Commonwealth governments committing $1m and $2m respectively to the FEED (front end engineering design) study". It also relies on the CarbonNet trial of carbon sequestration into a reservoir in Bass Strait and participation of plant builder Chiyoda Corp and Electric Power Development Company of Japan (Wahquist 2017).

5. Applying the seven lenses

The comparison of solar versus coal-produced liquid hydrogen exports to Japan is assessed against seven key lenses [elaborated in the longer paper]:

5.1 The public interest "No-net-detriment to Australian consumers" test
5.2 Australia's Paris 2015 CO2 reduction commitment
5.3 Environmental impacts such as production-related emissions and embedded energy in shipping infrastructure
5.4 Socio/political national benefits to GDP
5.5 Impact on Australia's energy security
5.6 Socio/political assessment of impact on foreign policy and Australia-Japan relations and ASEAN
5.7 Australia's contribution to UN Sustainable Development Goals (SDGs)

6. Conclusion

The international coal lobby promotes coal to the International Energy Agency as the safest, most reliable and affordable fuel (CIAB 2016). But even with super-critical generators, coal is still a highly pollutant form of energy. Today's carbon-intensive energy infrastructure choices could create path dependency, cementing modes of future energy supply and use, and potentially within a relatively short timeframe, will reflect outmoded technology. Alongside financing hurdles, countries must decide the types of infrastructure and transition investments to be made, which also reduce carbon emissions, and address energy poverty and access problems. Moreover transitions to clean energy need to be underpinned by ethical policy decision-making and public policy (Sovacool, 2013, 2016; Sovacool and Cooper, 2013). Energy trade is reliant on international shipping, and pipelines (and to a much smaller degree, cables) across countries, influencing international relations and geopolitics and raising new more complex security issues (Kuzemko, Keating and Goldthau 2016, 169-91).

Two alternative technologies for the production of hydrogen as a pathway to alternative energy have been explored using solar (renewable) or coal (lignite) as a source of energy. We contrasted coal versus solar energy production of liquid hydrogen for Australian exports to Japan's economy. These were assessed in terms of a series of lenses or filters. Using Gippsland lignite coal for hydrogen production rather than solar power we argue, prioritizes regional jobs over emissions reduction and clean energy in line with SDG 7. This is a short-term political-fix in a region already suffering high unemployment, exacerbated by the 2017 closure of the aged Hazelwood electricity generator.

Using lignite coal for hydrogen production may form part of a politically pragmatic short-term regional jobs strategy, but it fails to recognize natural solar resources to the north in Western Australia and Queensland, also with port facilities for shipped hydrogen to Asian markets at shorter distances. The Gippsland project casts a shadow over Australia achieving emissions reduction targets and contributing to global carbon reduction and meeting Paris undertakings. For Japan, it represents carbon emission displacement back onto Australia, if hydrogen for a 'clean' automotive industry is produced using dirty lignite coal. This occurs at a time when domestic and international agencies and transnational energy corporations have signaled the end of the coal era. As if in a policy time-warp, conservative forces have wielded dominance over Australian domestic policy, after a fifteen-year iron ore, coal and gas mining boom, resulting in policies favoring Big Energy, especially Big Coal. They have restricted alternative

energy development and first-mover advantages for GDP, and the potential to play a proactive role in Australian transitions to clean energy in line with the UN SDGs.

With the world turning to low carbon energy systems, it would seem imperative that Australia catch up and use its strengths in renewably generated energy rather than focusing on squeezing the last drops of profit out of fossil fuels for the fossil fuel lobby. “The low-carbon and environmental sector of the global economy is now valued at around US$5 trillion, and clearly some companies and states perceive a need to be a part of this rapid growth” (Kuzemko, Keating and Goldthau 2016, 28). Even the company Energy Australia, has openly stated that over the next 20 years, older cheaper forms of energy will retire. “That's a reality and that's why we need a plan to transition into those newer forms of energy.” (Morgan 2017).

With international competition to lead in emerging alternative energy technologies, Australia needs to speedily embed itself in the global renewable energy supply chain, before ‘losing out’ to other countries. We have examined how Australia could grasp its RE export leadership potential, via strengthening alternative energy exports based on low emission technologies that may also assist domestic transitions that reduce imported oil used for transport and industry. Whether this can be accomplished in ways that reduce Australia’s emissions in the transition away from dirty coal, is dependent on the transparency and integrity of government policy setting a roadmap to low emission energy. Transparency was ironically a central plank of Australia’s presentation to COP23 in Bonn. New RE-generated energy could protect Australia’s energy security and future position in a low carbon global economy as well as strengthen Australian trade and foreign policy in Asia and assist Asian neighbor countries’ energy transitions, but is open to conjecture in the current Australian policy environment

7. References

AER (Australian energy Regulator (2017, p. 26) *State of the Energy Market May 2017*. Melbourne: AER.

ARENA 2016a. 3-A018 Solar Hybrid Fuels (Stream 2) Summary report: project results and lessons learnt. May, https://arena.gov.au/assets/2017/05/Concentrating-Solar-Fuels-Roadmap-CSIRO.pdf.

ARENA 2017a. Innovating Energy ARENA’s Investment Plan. ARENA, Canberra.

Arup and Siemens 2016 Distributed Energy Systems, https://www.siemens.com/content/dam/internet/siemens-com/fairs-events/fairs/2016/intersolar-2016/DES_Summary%20for%20decision%20makers.pdf.

ASEAN (2017) ASEAN Economic Community, ASEAN, http://asean.org/asean-economic-community/.

Australian PV Institute 2015 Australia’s Bright Solar Future. Greg Watt (Producer), online video, https://vimeo.com/118539501.

Bast, E., Doukas, A, Pickard, S, van der Burg, L and Whieley, S (2015) *Empty Promises G20 subsidies to oil gas and coal.* Overseas Development Institute and Oil Change International, London and Washington.

Bradsher, Keith 2017 China Looks to Capitalize on Clean Energy as U.S. Retreats. The New York Times, 5 June, https://www.nytimes.com/2017/06/05/business/energy-environment/china-clean-energy-coal-pollution.html?rref=collection%2Ftimestopic%2FChina&action=click&contentCollection=world&region=stream&module=stream_unit&version=latest&contentPlacement=10&pgtype=collection,

Brunekreeft, B. (2014) Germany’s green power surge has come at a massive cost. *The Conversation*, 31 October 2014. Accessed at: https://theconversation.com/germanys-green-power-surge-has-come-at-a-massive-cost-33202

Conolly E. and Orsmond, D. (2011) *The Mining Industry: From Bust to Boom*. Research Discussion Paper 2011–08. Canberra: Economic Analysis Department Reserve Bank of Australia.

CSIRO 2017a 3 May, Membrane to fill gap in hydrogen export market. https://www.csiro.au/en/News/News-releases/2017/Membrane-for-hydrogen-fuel-cells.

Curran, C. (2012) Contested energy futures: shaping energy narratives in Australia. *Global Environmental Change*, 22, 236-244.

Drew, Gerard (2015) *Zero Carbon Australia Renewable Energy Superpower*, Fitzroy, Australia: Beyond Zero Emissions.

Ernst & Young. (2016). *RECAI Renewable energy country attractiveness index* (Issue 46, February 2016) http://www.ey.com/GL/en/Industries/Power---Utilities/EY-renewable-energy-country-attractiveness-index-feb-2016, Ernst & Young, London.

DFAT 2017 Japan Country Brief, http://dfat.gov.au/geo/japan/pages/japan-country-brief.aspx.

Dyer, H. (2013) Ethical dimensions of renewable energy, in: M.J. Trombetta, H. Dyer (Eds.), International Handbook of Energy Security, Edward Elgar Publishing, Cheltenham.

Finkel, A. (2017) *Independent Review into the Future Security of the National Electricity Market.* Canberra: Commonwealth of Australia. Accessed at: https://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf

Flannery T, Hueston G, Stoci A (2014) *Lagging Behind: Australia and the Global Response to Climate Change*. Climate Council of Australia Ltd, Potts Point, NSW.

Garnaut, Ross (2016a) Australia After Paris: Will we use our potential to be the energy superpower of the low-carbon world? Public lecture hosted by the Young Energy Professionals, State Theatre Centre of Western Australia, Perth, 21 January.

Gilbert and Tobin (2017) Powering Australia with a National Energy Guarantee: the Australian Government's new energy policy. Accessed at: https://www.gtlaw.com.au/insights/powering-australia-national-energy-guarantee-australian-government-new-energy-policy

Gittens, R. (2017) Still think the economy revolves around mining? *Sydney Morning Herald.*

Accessed at: http://www.smh.com.au/business/comment-and-analysis/minings-economic-contribution-not-as-big-as-you-might-think-20170203-gu4r5l.html

Hancock, L. & Ralph, N. (2017) Title: "Trust me – I'm the Government" - Contestation over Trust and Public Interest in Regulatory Regimes that Favor Big Carbon Energy under review.

Hancock, L, Ralph N, Armand, M., Macfarlane, D, Forsyth, M. Forthcoming. In The Lab: New Ethical and Supply Chain Protocols for Battery and Solar Alternative Energy Laboratory Research Policy and Practice, Journal of Cleaner Production.

Hinkley J, Hayward JA, McNaughton R, Edwards J and Lovegrove K (2016) *Concentrating solar fuels roadmap – final report*. CSIRO, Australia.

Hoesung Lee (2017) *Climate Change and the Sustainable Development Agenda*, IPCC Keynote Presentation to Stocktaking Panel United Nations, New York, 23 March 2017. Accessed at: https://www.ipcc.ch/news_and_events/pdf/170323_keynote_UN_Headquarters.pdf

Hood, M. (2017) Climate activists march to keep coal in the ground. AFP.Accessed at: http://www.france24.com/en/20171104-climate-activists-march-keep-coal-ground

International Energy Agency (IEA) (2017) World Energy Outlook. Accessed at: https://www.iea.org/weo2017/

International Energy Agency Coal International Advisory Board (IEA CIAB) (2016) Discussion report. *38th Plenary Meeting*. International Energy Agency Coal Industry Advisory Board. Accessed at: https://www.iea.org/ciab/papers/CIAB_Plenary_Discussion_Report_November_2016.pdf

Irfan, Umair (2016) Japan Bets on a Hydrogen-Fueled Future, 3 May 2016, https://www.scientificamerican.com/article/japan-bets-on-a-hydrogen-fueled-future/.

Kilvert, N. (2017) Base load power: The dinosaur in the energy debate. *ABC Science*. Accessed at: http://www.abc.net.au/news/science/2017-10-12/renewable-energy-baseload-power/9033336

Kuzemko, Caroline, Michael F. Keating and Andreas Goldthau (2016) The Global Energy Challenge. Palgrave, London.

Lovegrove, K. (2016) Japan – A future market for Australian solar ammonia. NH3 Fuel Conference, Los Angeles, 18-20 September.

Lovegrove, Keith, Muriel Watt, Robert Passey, Graeme Pollock, Joseph Wyder, Josh Dowse (2012) *Realising the Power of Concentrating Solar Power in Australia*. IT Power, for the Australian Solar Institute, http://www.itpau.com.au/realising-the-potential-of-concentrating-solar-power/

McKenzie, F., Fiona, Pendergast, Sam and Parbery, Peter (2017) How regional towns have adapted to major economic shocks, long report part A. Latrobe Region: Trends and Prospects. Planning, Department of Environment and Primary Industries.

Morgan, E., 2017. Energy Australia boss says national plan for renewable energy is solution to high power prices, ABC News, http://www.abc.net.au/news/2017-02-14/energy-australia-boss-worried-about-power-bills/8267070 accessed 13 December 2017.

Morton, Adam 2017 Coal in decline: Adani in question and Australia out of step. The Guardian. https://www.theguardian.com/environment/2017/aug/25/coal-in-decline-adani-in-question-and-australia-out-of-step.

Nachmany, M., Fankhauser, S., Davidová, J., Kingsmill, N., Landesman, T., Roppongi, H., Schleifer, P., Setzer, J., Sharman, A., Singleton, S., Sundaresan, J., and Townsend, T. (2015) *The 2015 Global Climate Legislation Study.* London: The Grantham Institute

News.com.au (2017) Australia to ship hydrogen to Japan, News.com.au, 11 January, www.news.com.au/national/breaking-news/australia-to-ship-hydrogen-to-japan/news-story/f10004fda6acfa557bab4be3081a4b0b.

Office of the Chief Economist 2015. Energy in Australia 2015. Australian Government, https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/energy-in-aust/Energy-in-Australia-2015.pdf.

Office of the Chief Economist 2016 Australian Energy Update 2016. Australian Government, October, https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Pages/Australian-energy-statistics.aspx#.

REN21. (2016) Renewables 2016 Global Status Report. REN21 Secretariat, Paris.

Renewable Energy Policy Network (2016) Renewables 2016 Global Status Report Key Findings, Paris, Renewable Energy Policy Network, www.ren21.net/gsr.

Skirrow, R.G., Huston, D.L., Mernagh, T.P., Thorne, J.P., Dulfer, H., Senior, A.B., 2013. Critical commodities for a high-tech world: Australia's potential to supply global demand. Geoscience Australia, Canberra.

SolarGIS, 2013 GeoModel Solar, CC BY-SA 3.0, Accessed at: https://upload.wikimedia.org/wikipedia/commons/c/ce/SolarGIS-Solar-map-Australia-en.png

Sovacool, Benjamin K. (2013) *Energy and Ethics,* London, Palgrave Macmillan.

Sovacool, B.K. and C. J. Cooper, 2013.The Governance of Energy Megaprojects, Edward Elgar Publishing Ltd., Cheltenham, UK.

Sovacool, B. (2016) How long will it take? Conceptualizing the temporal dynamics of energy transitions, *Energy Research & Social Science* 13 (2016) 202–215

Tuller, H.L. (2017*)* Solar to fuels conversion technologies: a perspective. *Materials for Renewable and Sustainable Energy*, 6(1): 3. Published online 2017 Jan 30. doi: 10.1007/s40243-017-0088-2

Turnbull, M. (2017) Address to the Press Club. Accessed at: https://www.pm.gov.au/media/address-national-press-club

UNDP - United Nations Development Program, (2016) Mapping mining to the Sustainable Development Goals: An atlas. UNDP, World Economic Forum, Columbia Center on Sustainable Investment, Sustainable Development Solutions Network, Geneva. http://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/mapping-mining-to-the-sdgs--an-atlas.htmlUNFCCC 2017 Find Out More About COP21. Accessed at: http://www.cop21paris.org/about/cop21

Vorrath, S. (2015) Coal production subsidies cost Australians $1.8b a year. Accessed at: http://reneweconomy.com.au/coal-production-subsidies-cost-australians-1-8bn-a-year-77543/

Wahquist, C. (2017) Victoria's plans for hydrogen exports to Japan are 'way of making brown coal look green. The Guardian. Accessed at:

https://www.theguardian.com/environment/2017/jan/12/victorias-plans-for-hydrogen-exports-to-japan-are-way-of-making-brown-coal-look-green

Wood, T., Blowers, D. and Griffiths, K. (2017) *Powering through: how to restore confidence in the National Electricity Market*. Accessed at: https://grattan.edu.au/report/powering-through/

[i] Australia's carbon dioxide emissions are similar to France (344 MtCO2/yr), Italy (353 MtCO2/yr) and Turkey (325 MtCO2/yr) – countries all with around three times Australia's population (Flannery, Hueston and Stoci 2014).