2

Energy Futures for Australia

Mark Diesendorf

Introduction

Decarbonising the built environment can occur rapidly and effectively if it evolves under a positive guiding vision for Planet Earth and human society. This chapter draws upon the guiding vision of sustainable development, called 'ecologically sustainable development' in Australia. It is defined here as 'types of social and economic development that protect and restore the natural environment and social equity'. 'Development' is interpreted broadly as 'unfolding of human potential' and 'enhancement of human well-being'—it does not necessarily assume endless economic growth on a finite planet. 'Social equity' is interpreted as 'equal opportunity of access to basic needs' (Diesendorf 2001).

At one conceptual level, the drivers of environmental impact are growth in population and economic activity, as well as polluting technologies, as described by the well-known $I = PAT$ identity (Ehrlich & Holdren 1972).

M. Diesendorf (✉)
University of New South Wales, Sydney, NSW, Australia
e-mail: m.diesendorf@unsw.edu.au

P. Newton et al. (eds.), *Decarbonising the Built Environment*,
https://doi.org/10.1007/978-981-13-7940-6_2

This chapter focuses on the technology term *T*, interpreted broadly to include hardware, software and 'orgware', the latter being the organisations and other institutions associated with the hardware.

The sustainable development framework enables us to identify clearly the drivers of the present unsustainable energy system of Australia and indeed most of the world: one that is dominated by fossil fuels. Fossil fuels are not only the major emitters of the principal anthropogenic greenhouse gas, carbon dioxide. They are also the major source of air pollution, with associated impacts on respiratory health; a significant cause of water pollution, water overuse and land degradation; and, as they become scarcer, a cause of rising energy prices and energy insecurity. Because fossil fuels are controlled by large multinational and foreign-owned national corporations, their use diminishes social equity by limiting greatly the control that individuals have over their energy systems.

Incidentally, although nuclear power has lower life-cycle greenhouse gas emissions than fossil fuels, it shares with the latter several of the above types of adverse environmental and social impacts. To these must be added the proliferation of nuclear weapons, the risk of rare but devastating accidents, the burden of managing high-level wastes for hundreds of thousands of years, and very high and increasing economic costs (Diesendorf 2014, Chapter 6; Sovacool 2011).

In contrast, most renewable energy sources, together with energy efficiency, will last for billions of years, have very low environmental impacts (exceptions are some hydro-electric and bioenergy projects) and, except for bioenergy, have no fuel costs and so can stabilise energy prices. Solar photovoltaics (PV) in particular can be implemented on all scales—small (household), medium (precinct, commercial, local community, remote mining) and large (grid-connected renewable electricity power stations)—thus allowing individuals and organisations more choice and autonomy in their energy systems.

Therefore, within the sustainable development framework, the desirable future energy system is based on renewable energy together the minimisation of energy waste by means of energy efficiency and conservation. *Energy efficiency* is using less energy to provide the same level of energy service and is mainly based on efficient design and energy efficient technologies. *Energy conservation* is using less energy to provide a lesser energy service and is mainly behavioural. Both are important in transitioning to sustainable energy (Diesendorf 2014, Chapter 4).

A renewable energy future will be predominantly an electrical future (see section 'Vision of a Sustainable Energy Future'). Renewable energy now supplies 26.5% of global electricity, with 16.4% coming from hydro and the rest from wind, biopower and solar PV in that order (REN21 2018). In 2017, annual global investment in new renewable electricity generation was US$310 billion (of which US$45 billion was in large-scale hydro). Renewable electricity investment is more than double the combined investment in fossil-fuelled electricity (US$103 billion) and nuclear power (US$42 billion) (REN21 2018). Nowadays, renewable energy technologies are mainstream rather than 'alternative'.

The structure of this chapter reflects a backcasting approach. Section 'Vision of a Sustainable Energy Future' offers a vision of a sustainable energy future, considering both supply and demand, and small, medium and large scales. All scales are relevant, because the energy use and associated greenhouse gas emissions of the built environment are determined on one hand by local design of buildings and precincts and the behaviour of building occupants and, on the other hand, by the types of energy inputs from electricity and fuels produced externally. After summarising current trends in energy demand and supply in Australia (section 'Trends in Energy Supply and Demand'), the chapter examines scenarios for transitioning rapidly from the present unsustainable system to a sustainable future (section 'Scenarios for the Sustainable Energy Transition'). It concludes (section 'Overcoming the Barriers to Sustainable Energy') with an outline of barriers and policy options for overcoming them.

Vision of a Sustainable Energy Future

Let's consider a hypothetical situation in (say) 2040. All new buildings constructed from the early 2020s onwards are Zero Net Carbon: that is, they are highly energy efficient and produce onsite, or procure, enough carbon-free renewable energy annually to meet the energy consumption of building operations. Furthermore, new materials, such as laminated timber and eco-cement, have reduced the embodied energy of new buildings. Brick veneer homes are no longer built—instead, in temperate regions of Australia, most walls of buildings comprise three layers, an outer cladding, insulation then thermal mass on the inside.

In the early 2020s, the Building Code of Australia was extended to existing buildings. The latter were retrofitted to increase energy efficiency, although they did not have to reach the standard of Zero Net Carbon. Measures for homes include improved insulation, summer shading, more airtight envelope in winter, greater airflow in summer, solar or heat pump hot water, cool roofs and well-ventilated attics. The majority of buildings have space heating and cooling supplied by heat pumps running on renewable electricity, while a minority use direct solar. The poor thermal mass of the old ubiquitous brick veneer home, which is very difficult to retrofit, is partially compensated by means of rooftop solar PVs where solar access is available. Indeed, rooftop solar PV, together with battery storage and smart controls to adjust the timing of demand, is widespread behind the meter for households, commercial properties and local community micro-grids. Double glazing is mandatory in designated regions with low Winter night-time temperatures. Energy audits are mandatory for the sale and rental of housing and the results must be stated on contracts.

Minimum Energy Performance Standards are applied to appliances and equipment used within buildings. Lighting is fluorescent and LED, cooking is mostly by induction and microwave, and showerheads are water efficient and hence energy efficient.

Electricity from the grid is supplied entirely by renewable sources, most from wind and solar PV, with reliability ensured by minor energy contributions from flexible, dispatchable renewables—concentrated solar thermal (CST) power with thermal storage, pumped hydro (both on-river and off-river) and open-cycle gas turbines operating on renewable fuels—and battery storage technologies. Peaks in demand are small as the result of contracted demand response in smart systems. The simulations justifying the technical feasibility, reliability and affordability of 100% renewable electricity are summarised in section 'Scenarios for the Sustainable Energy Transition'.

In cities, electric public transport, cycling, walking and battery electric vehicles have replaced motor vehicles with internal combustion engines (ICE). For air transport, long-distance rural road transport, gas turbines and some industrial processes, renewable fuels have largely replaced fossil fuels. Renewable fuels include hydrogen produced by electrolysis or thermal decomposition of water using renewable energy, ammonia produced by combining renewable hydrogen with nitrogen from the air, and biofuels such as ethanol and methanol from both dedicated crops and agricultural residues.

Cities have been modified into hierarchical structures of sub-centres and local centres, integrating urban planning and transport planning and so reducing urban travel generally and car travel in particular. Major sub-centres and the Central Business District are linked to one another by fast heavy rail. Local centres are connected to their nearest sub-centre by light rail or bus. Cycleways and pedestrian areas encourage active transport within the centre, sub-centres and local centres, where there are higher population densities. This hierarchical urban structure was originally proposed by White et al. (1978) for Melbourne and reinvented by Newman and Kenworthy (2006)—see the summary in Diesendorf (2014, Chapter 7).

In this sustainable energy future, most transport and heating have become electric, for two principal reasons:

- It is easier and less expensive to transition electricity to renewable sources and technologies than to produce liquid and gaseous renewable fuels.
- Electric motors are much more energy efficient than ICE, and electrically driven heat pumps (e.g. air conditioners, refrigerators, hot water systems) are much more efficient than heating and cooling by direct combustion of fuels.

All the technologies mentioned in this section, except renewable hydrogen and ammonia and solar space cooling, were commercially available in Australia in 2018. The non-commercial exceptions had been proven technically by pilot systems. In 2018, the price of rooftop solar PV was typically less than half the price of retail electricity purchased from the grid, and wind and solar PV farms were competitive with new fossil-fuelled power stations (AEMO 2018; Parkinson 2018). Although batteries, CST and renewable fuels were still expensive in 2018, subsequent government policies fostered their further development, rapid growth in sales and big reductions in prices. In 2040, renewable energy, together with various forms of storage and of course energy efficiency and conservation, comprise by far the least expensive energy systems.

Having sketched a technically and economically feasible sustainable energy future, this chapter next considers recent trends and the present situation of energy in Australia and then in section 'Scenarios for the Sustainable Energy Transition' how to transition from the present to the desirable future.

Trends in Energy Supply and Demand

Primary energy comprises the forms of energy obtained directly from nature, before they are converted to other forms. It includes both fossil fuels and renewable energy. The combustion of primary fossil fuels is the principal source of GHG emissions from the energy sector. During the 32-year period from 1975–1976 to 2007–2008 Australia's primary energy consumption was characterised by rapid, consistent growth. After that it plateaued, with a dip around 2014.

The traditional energy flow diagram (Fig. 2.1) starts with primary energy on the left, then flows through transformation processes (e.g. combustion in a power station) in the middle of the diagram—to provide on the right-hand-side, after substantial energy losses, the final energy consumption or end-use energy. This in turn provides the energy services we demand: for example, a warm home in winter, hot showers and cold food.

This direction of flow is conceptually the opposite of that needed for efficient transformation of the fossil energy sector to sustainable energy. To do this, we must start by considering what energy services we really need and then provide them by integrating energy efficiency and conservation with renewable energy. In electricity generation from fossil fuels, reducing the demand for one unit of end-use energy substitutes

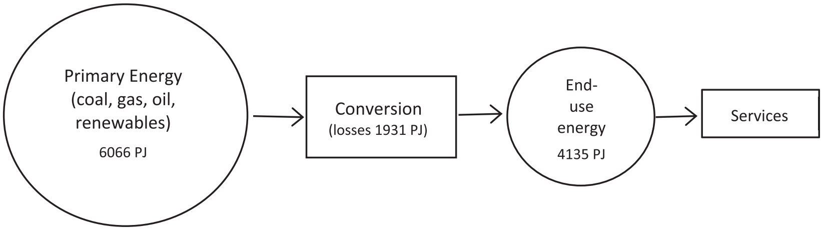

Fig. 2.1 Flow diagram for energy production and consumption in Australia 2015–2016 (*Source* Author, drawn from data provided in Ball et al. 2017. *Notes* 1. Exports and imports not shown. 2. The majority of the conversion losses occur in electricity generation and are due to combustion at the power station; oil refining and transport by ICE also have large losses)

for three to four units of energy in primary fossil fuels. This is because of the low efficiency of conversion of fossil fuels into electricity, typically 25–30% including transmission and distribution losses.

Electric vehicles are approximately three times as efficient as equivalent ICE vehicles at the point of use (Office of Energy Efficiency & Renewable Energy website). However, if they are charged from a grid that is supplied predominantly by coal, the savings in primary energy and hence GHG emissions may be modest or even non-existent in some cases. If charged by renewable energy, the savings are large.

The challenge of cutting GHG emissions can be addressed most effectively firstly in the choice of the types and degrees of energy services required, for example the temperature of one's home in Winter, and secondly at the stage of final energy consumption, that is, end-use energy (Fig. 2.2). The categories Coal, Oil, Gas and Renewables refer to non-electricity fuel uses; the Renewables category includes solar hot water, firewood for home heating and landfill gas, but not solar PV which is included in the Electricity category. Unfortunately, Australian energy statistics do not break down end-use energy into the categories Electricity, Transport and Heat. However, a rough idea can be obtained from Fig. 2.2 by noting that most Oil is used for transport and most Gas is used for heat (supplemented by a little Coal).

In a sustainable energy future, the size of the pie would be reduced by energy efficiency and conservation, and almost all of the Coal, Oil and Gas categories would be replaced by electricity. On the supply side, the

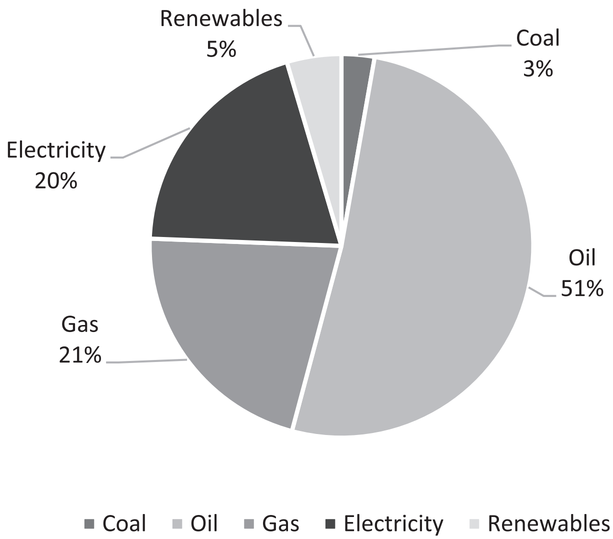

Fig. 2.2 Total end-use energy by fuel in Australia, 2015–2016 (*Source* Author, drawn from data provided by Department of Environment and Energy [2017], Table H1. *Note* Total final energy consumption or end-use energy in 2015–2016 was 4135 PJ)

non-electricity end-use energy may comprise some direct solar heating and cooling, and some renewable fuels for air transport, long-distance rural road transport and a few industrial uses.

Electricity supply from the grid peaked in 2010 and then declined steadily until 2015 (Fig. 2.3). The increased rate of decline in GHG emissions from electricity from mid-2012 to mid-2014 corresponds to the two-year period of the carbon price. After the carbon price was terminated in mid-2014, emissions rose again, peaked around mid-2016 and since then have fallen, resulting from the rapid growth in rooftop solar assisted by the Small-scale Renewable Energy Scheme (SRES), the growth in wind farms driven by the Large-scale Renewable Energy Target (LRET) policy and 'the increasing decrepitude of aging coal fired power stations' (Saddler 2018b, p. 6).

Coal is still the major contributor to Australia's electricity generation, although it has declined from 83% in 2000–2001 to 63% in 2015–2016. Table 2.1 shows the generation mix in 2015–2016 and

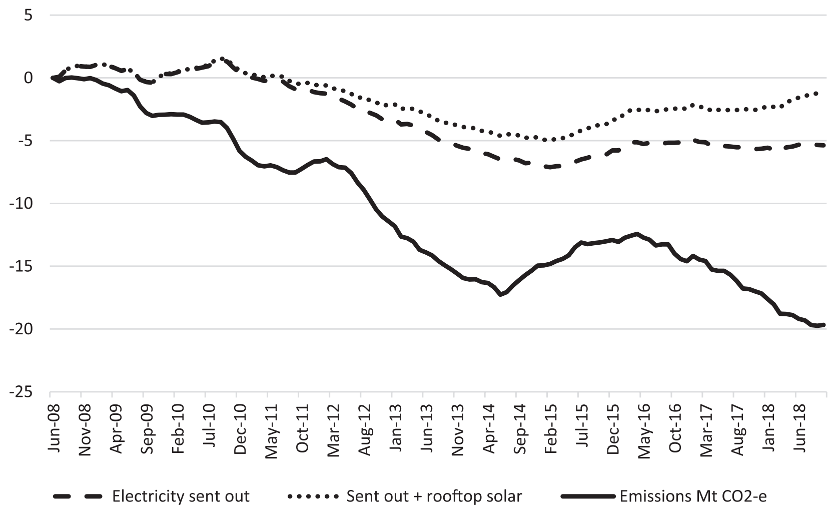

Fig. 2.3 Changes in electricity generation sent out and corresponding emissions, Australia, 2008 to 2018 (*Source* Drawn from data provided in Saddler 2018a. *Note* All expressed as percentage change in annual values, relative to totals for the year ending June 2008)

the average annual growth rates of electricity technologies over the previous decade. At the time of writing (November 2018), there is much uncertainty about the future growth rate of large-scale renewable electricity after LRET is reached in 2020. In the federal government, neither of the two major political parties has proposed an alternative driver of renewable electricity. However, in 2018 the Victorian, Queensland, South Australian and Australian Capital Territory governments have policies to facilitate the growth of renewable electricity.

There is also uncertainty about future growth in small-scale renewable electricity. The Australian Competition & Consumer Commission (ACCC 2018) has recommended the immediate abolition of SRES, although its contribution to retail electricity prices is much less than each of wholesale electricity prices and network prices.

In the spirit of backcasting, the next section investigates how the Australian energy system could be transitioned from the present fossil fuel dominance to the sustainable future envisioned in section 'Vision of a Sustainable Energy Future'.

Table 2.1 Australian electricity generation[c] by fuel type, 2015–2016

Technology	Share in 2015–2016 (%)	Average annual growth rate[a] (%)
Fossil fuel		
Black coal	44	−1.6
Brown coal	19	−1.2
Gas	20	5.3
Oil[b]	2.2	7.7
Renewables		
Hydro	6.0	0.6
Wind	4.7	19
Bioenergy	1.5	−0.5
Solar PV	2.7	59

Source Extracted from data provided in Ball et al. (2017, Table 4.2)
Notes
[a]Average taken over the decade ending 2015–2016
[b]Mostly diesel at remote locations
[c]Total generation in 2015–2016 estimated to be 257 TWh

Scenarios for the Sustainable Energy Transition

The principal Australian national energy and carbon emission scenarios are summarised in Table 2.2.

Since most energy supply in a sustainable energy future is likely to be delivered as electricity, the latter merits special attention. Concerns about reliability have been allayed by hourly simulations of the operation of large-scale electricity systems with high penetrations of variable renewable energy into the grid. Table 2.2 lists electricity simulations either for the whole of Australia (with hypothetical transmission links joining all States) or for the misnamed National Electricity Market (NEM), which spans the interconnected eastern and southern states, but does not include the State of Western Australia or the Northern Territory which are isolated from the NEM and each other. The scenarios establish pathways for approaching sustainable energy.

The electricity simulations have hourly (or half-hourly) time-steps where supply and demand are balanced, and span 1–6 years. They demonstrate that 100% renewable electricity systems can operate reliably without base-load power stations and without vast amounts of storage. Reliability, which is a property of the whole system and not

Table 2.2 Australian energy and carbon scenarios

Reference	Type of scenario	Electricity simulation model	Type of model
Saddler, Diesendorf and Denniss (2007)	Stationary energy, end-point	No	Bottom-up, forecasting + backcasting
Wright and Hearps (2010)	Stationary energy	Yes	In-house simulation
Elliston, Diesendorf and MacGill (2012)	Electricity, end-point	Yes	NEMO (open source simulation originally developed in-house)
Kelp and Dundas (2013)	Electricity, dynamic	No	ACIL Allen's PowerMark LT & RECMark
Turner, Elliston and Diesendorf (2013)	Electricity, dynamic	No	Australian Stocks & Flows Framework, includes life-cycle emissions
Elliston, MacGill and Diesendorf (2013)	Electricity, end-point	Yes	NEMO simulation
AEMO (2013)	Electricity, end-point	Yes	Probabilistic and time-sequential models
Elliston, MacGill and Diesendorf (2014)	Electricity, end-point	Yes	NEMO simulation
ClimateWorks Australia (2014)	All energy	No	Bottom-up sectoral models brought together into a national economic model
Wolfram, Wiedmann and Diesendorf (2016)	Electricity, dynamic	No	Scenario-based hybrid LCA
Elliston, Riesz and MacGill (2016)	Electricity, end-point	Yes	NEMO simulation
Teske et al. (2016)	All energy, dynamic	No	Bottom-up integrated energy balance
Lenzen et al. (2016)	Electricity, end-point	Yes	In-house simulation
ENA and CSIRO (2017)	Electricity, dynamic	No	Roadmap
Blakers, Lu and Stocks (2017)	Electricity, end-point	Yes	NEMO variant simulation
Hamilton et al. (2017)	Electricity, dynamic	No	In-house model of life-cycle emissions
Howard et al. (2018)	Electricity, dynamic	No	In-house model of life-cycle emissions

Note An 'end-point' scenario considers a single year at the end of a transition; a 'dynamic' scenario considers the time evolution of the transition with multiple time-steps between start and end-point individual power stations, can be achieved with high penetrations of *variable* renewables, wind and solar PV, whose fluctuations can be balanced by *dispatchable* renewables—for example CST with thermal storage, existing conventional hydro, pumped hydro (both on-river and off-river) and open-cycle gas turbines using renewable fuels—together with batteries. (A *dispatchable* power station is one that can supply electricity upon demand [Diesendorf 2018].) Reliability can be further increased by contracted demand response, increased diversity of renewable energy technologies and geographic diversity of wind and solar farms, together with a few new transmission links (Diesendorf & Elliston 2018).

Some of the electricity scenarios include costings (e.g. Elliston, MacGill & Diesendorf 2013; Elliston, Riesz & MacGill 2016). Both these studies and recent auction prices for wind and solar farms suggest that a large-scale sustainable electricity system will provide reliable electricity for a levelised cost of energy (LCOE) that's the same or less than that of a new fossil-fuelled electricity system.

The cost of electricity from rooftop PV for households and commercial sites is less than half that of retail electricity from the grid and so is being implemented rapidly in Australia by electricity users who have significant daytime demand. Adding batteries to these systems is not yet economical for most users, however battery prices are declining rapidly as the scale of manufacturing increases. In 2017, 12% of new rooftop PV systems had batteries (SunWiz 2018).

Overcoming the Barriers to Sustainable Energy

The principal barriers to the rapid growth of renewable energy are no longer technological nor, with a few exceptions, economic. The exceptions that are still expensive include batteries, renewable liquid and gaseous fuels and CST, but costs are falling rapidly for these technologies too. The principal barriers result from the institutions of the old energy system, defended by incumbents, and the difficulty of changing them (Hess 2014). 'Institutions' includes existing organisations, laws, regulations, standards and business models. Hence, while continuing technical improvements will always be required, much of the research and development needed now is in non-technical areas.

Specific barriers, that must be overcome by research, development and policy changes at state and federal government levels, and associated policy options include:

- mandating Zero Net Carbon for all new homes;
- extending the Building Code of Australia to existing buildings and further strengthening it;
- mandating published energy audits for sale and rental of all inhabited buildings;
- expansion of the scope of Minimum Energy Performance Standards and energy labelling to all energy-using appliances and equipment;
- implementing compensation to low-income earners for possible price rises resulting from some of the above improvements—these could include strengthening tenants' rights and legislating increases to pensions and unemployment benefits;
- solar access legislation;
- facilitating the growth of community renewable energy and microgrid projects via seeding grants and legislating the right to interconnect and to receive a fair price for electricity sold to the grid;
- legalising the direct sale of small-scale renewable electricity between neighbouring households at 230 volts, with appropriate safety standards and checks;
- permitting large Virtual Power Plants to sell directly into the wholesale electricity market;
- implementing government-backed power purchase agreements and/or reverse auctions with contracts-for-difference for wind and solar farms in all states and territories;
- providing an additional federal government funding allocation to the Australian Renewable Energy Agency specifically for dispatchable renewable electricity and other forms of energy storage;
- revising the NEM rules to include, for example, a GHG reduction objective, changing the wholesale spot price settlement time from 30 min to the dispatch time of 5 min, and permitting Local Network Credits (Rutovitz et al. 2018);

- facilitating the growth of smart grids;
- integrating urban planning and transport planning;
- requiring government transport funding to be split equally between roads and public transport;
- secure funding for maintaining and upgrading the electricity grid and extending it where really necessary.

In addition, it would be valuable to have a carbon price, to internalise the adverse environmental, health and economic impacts of fossil fuel use, but both major political parties in Australia reject this at present.

Overcoming the barriers and speeding up the transition require prompt action in several spheres—all levels of government, business, industry, commerce, professional organisations, education, training, information, applied research, taxation, design and planning. An important element is the reintroduction of climate risk and liability strategies into the planning of cities, buildings, energy systems, and other infrastructure. Leaving it to the unguided market is a recipe for failure.

References

ACCC 2018, *Restoring electricity affordability and Australia's competitive advantage*, Australian Competition & Consumer Commission.

AEMO 2013, *100 per cent renewables study—modelling outcomes*, Australian Energy Market Operator, viewed 11 November 2018, <http://www.environment.gov.au/climate-change/publications/aemo-modellingoutcomes/>.

AEMO 2018, *Integrated system plan for the national electricity market*, July, viewed 11 November 2018, <https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf/>.

Ball, A, Ahmad, S, McCluskey, C, Pham, P, Pittman, O, Starr, A et al. 2017, *Australian energy update 2017*, Department of Environment and Energy, Canberra, <https://www.energy.gov.au/publications/australian-energy-update-2017>.

Blakers, A, Lu, B & Stocks, M 2017, '100% renewable electricity in Australia', *Energy*, vol. 133, pp. 471–482.

ClimateWorks Australia 2014, *Pathways to deep decarbonisation in 2050: how Australia can prosper in a low carbon world*, ClimateWorks Australia, viewed 11 November 2018, <https://www.climateworksaustralia.org/sites/default/files/documents/publications/climateworks_pdd2050_technicalreport_20140923.pdf>.

Diesendorf, M 2001, 'Models of sustainability and sustainable development', *International Journal of Agricultural Resources, Governance and Ecology*, vol. 1, pp. 109–123.

Diesendorf, M 2014, *Sustainable energy solutions for climate change*, Routledge-Earthscan, London, and NewSouth Publishing, Sydney.

Diesendorf, M 2018, 'Is coal power "dispatchable"?' *RenewEconomy*, 22 August, viewed 11 November 2018, <https://reneweconomy.com.au/is-coal-power-dispatchable-71095/?utm_source=RE+Daily+Newsletter&utm_campaign=c1c15f122d-EMAIL_CAMPAIGN_2018_08_22_03_03&utm_medium=email&utm_term=0_46a1943223-c1c15f122d-24195345/>.

Diesendorf, M & Elliston, B 2018, 'The feasibility of 100% renewable electricity systems: a response to critics', *Renewable & Sustainable Energy Reviews*, vol. 93, pp. 318–330.

Ehrlich, PR & Holdren, J 1972, 'A Bulletin dialogue on "The Closing Circle": critique', *Bulletin of the Atomic Scientists*, vol. 28, no. 5, pp. 16, 18–27.

Elliston, B, Diesendorf, M & MacGill, I 2012, 'Simulations of scenarios with 100% renewable electricity in the Australian National Electricity Market', *Energy Policy*, vol. 45, pp. 606–613.

Elliston, B, MacGill, I & Diesendorf, M 2013, 'Least cost 100% renewable electricity scenarios in the Australian National Electricity Market', *Energy Policy*, vol. 59, pp. 270–282.

Elliston, B, MacGill, I & Diesendorf, M 2014, 'Comparing least cost scenarios for 100% renewable electricity with low emission fossil fuel scenarios in the Australian National Electricity Market', *Renewable Energy*, vol. 66, pp. 196–204.

Elliston, B, Riesz, J & MacGill, I 2016, 'What cost for more renewables? The incremental cost of renewable generation—An Australian National Electricity Market case study', *Renewable Energy*, vol. 95, pp. 127–139.

ENA & CSIRO 2017, *Electricity network transformation roadmap*, Energy Networks Australia, viewed 11 November 2018, <http://www.energynetworks.com.au/roadmap/>.

Hamilton, N, Howard, B, Diesendorf, M & Wiedmann, T 2017, 'Computing life-cycle emissions from transitioning the electricity sector using a discrete numerical approach', *Energy*, vol. 137, pp. 314–324.

Hess, DJ 2014, 'Sustainability transitions: a political coalition perspective', *Research Policy*, vol. 43, pp. 278–283.

Howard, BS, Hamilton, N, Diesendorf, M & Wiedmann, T 2018, 'Modeling the carbon budget of the Australian electricity industry's transition to renewable energy', *Renewable Energy*, vol. 125, pp. 712–728.

Kelp, O & Dundas, G 2013, *Electricity sector emissions: modelling of the Australian electricity generation sector*, Technical report, ACIL Allen Consulting, viewed 11 November 2018, <https://www.environment.gov.au/system/files/resources/65462f51-a20a-4f35-bdd0-d88d6ee5ac4e/files/electricty-sector-emissions.pdf>.

Lenzen, M, McBain, B, Trainer, T, Jütte, S, Rey-Lescure, O & Huang, J 2016, 'Simulating low carbon electricity supply for Australia', *Applied Energy*, vol. 179, pp. 553–564.

Newman, P & Kenworthy, J 2006, 'Urban design to reduce automobile dependence', *Opolis: An International Journal of Suburban & Metropolitan Studies*, vol. 2, no. 1, Article 3, viewed 11 November 2018, <http://repositories.cdlib.org/cssd/opolis/vol2/iss1/art3/>.

Office of Energy Efficiency & Renewable Energy undated, *Fuel economy*, US Department of Energy, viewed 11 November 2018, <http://www.fueleconomy.gov>.

Parkinson, G 2018, 'Australia could be at 86% wind and solar by 2050—on economics only', 10 July, *Renew Economy*, viewed 11 November 2018, <https://reneweconomy.com.au/australia-could-be-at-86-wind-and-solar-by-2050-on-economics-only-34915/>.

REN21 2018, *Renewables 2018 global status report*, REN21 Secretariat, Paris.

Rutovitz, J, Oliva, HS, McIntosh, L, Langham, E, Teske, S, Atherton, A et al. 2018, 'Local network credits and local electricity trading: results of virtual trials and the policy implications, *Energy Policy*, vol. 120(C), pp. 324–334.

Saddler, H 2018a, *National energy emissions audit—electricity update August 2018*, Australia Institute, Canberra.

Saddler, H 2018b, *National energy emissions audit—electricity update February 2018*, Australia Institute, Canberra.

Saddler, H, Diesendorf, M & Denniss, R 2007, 'Clean energy scenarios for Australia', *Energy Policy*, vol. 35, pp. 1245–1256.

Sovacool, BK 2011, *Contesting the future of nuclear power*, World Scientific, Hackensack, NJ.

SunWiz 2018, *Australian battery market report 2018*, viewed 11 November 2018, <https://www.solarchoice.net.au/blog/over-20000-battery-storage-system-installed-in-aus-in-2017-sunwiz/>.

Teske, S, Dominish, E, Ison, N & Maras, K 2016, *100% renewable energy for Australia–decarbonising Australia's energy sector within one generation*, report prepared by ISF for GetUp, viewed 11 November 2018, <https://www.uts.edu.au/sites/default/files/article/downloads/ISF100%25AustralianRenewableEnergyReport.pdf>.

Turner, GM, Elliston, B & Diesendorf, M 2013, 'Impacts on the biophysical economy and environment of a transition to 100% renewable electricity in Australia', *Energy Policy*, vol. 54, pp. 288–299.

White, D, Sutton, P, Pears, A, Mardon, C, Dick, J & Crow, M 1978, *Seeds for change: creatively confronting the energy crisis*, Conservation Council of Victoria and Patchwork Press, Melbourne.

Wright, M & Hearps, P 2010, *Australian sustainable energy zero carbon Australia stationary energy plan*. University of Melbourne Energy Research Institute and Beyond Zero Emissions, Melbourne.

Wolfram, P, Wiedmann, T & Diesendorf, M 2016, 'Carbon footprint scenarios for renewable electricity in Australia', *Journal of Cleaner Production*, vol. 124, pp. 236–245.