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A legal-economic framework of electricity markets: Assessing Australia's transition

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Abstract
Recent years have seen a surge in renewable generation investment in many countries, displacing traditional fossil-fuel generation at scale. The continuation of this clean energy transition is however threatened by outdated electricity market frameworks, which were not designed for large amounts of intermittent, zero-marginal cost generation. Clean energy transitions have amplified existing problems of liberalized wholesale markets and introduced new ones, including but not limited to maintaining system resilience and reliability and ensuring adequate future investment levels. Addressing these challenges will be central to a successful transition and requires a detailed understanding of the dynamic processes between electricity system objectives, legal frameworks, and market economics. We develop an integrated legal-economic model of electricity market design under transition conditions. The model proposes preferred pathways to proactively address major changes in electricity system objectives and the discrepancies between these objectives and market outcomes demonstrated on the example of Australia.

Keywords: Electricity market economics, market frameworks, law and regulation

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1) Introduction

Electricity generation landscapes are rapidly changing around the world. Advances and cost reductions in renewable electricity generation and storage technologies have fueled an unprecedented energy transition in the power generation sector. Over the past decades the share of non-hydro renewable generation has increased to 13% (20% total renewables) in the US (U.S. EIA, 2022), about 22.7% (34.6% total renewables) in the European Union (EC, 2021), and 23.6 % (31.4% total renewables) in Australia (OpenNEM 2022). This transition is far from over. By 2030, large shares of coal, nuclear and oil generating capacity is expected to be exiting in these markets (U.S. EIA, 2022; AEMO, 2021).

Electricity consumption is predicted to increase worldwide in the next decades, hand in hand with economic development, and a shift towards higher reliance on electricity in the energy mix, fueled by the electrification of transport and industrial processes. (Csereklyei et al. 2016) This ongoing transition poses a major challenge to our electricity systems and markets, which were originally not designed to accommodate high levels of intermittent, low or zero marginal cost generation (Joskow, 2019).

The challenge regulators and generators face are severalfold, arising from an engineering, business model and regulatory angle. These include operational challenges of maintaining system security and reliability throughout the successful integration of renewables into the grid, as well as questions of electricity market economics, such as affordability, ensuring adequate future investment levels, valuing dispatchability and flexibility, examining the role of reserve markets, long-term contracts and levels of vertical integration in the system.
The legal frameworks shaping and managing electricity markets have been slow to adjust to technological development and are often identified as barriers to energy transitions (Verbong and Geels, 2007; Unruh 2000).

We develop a novel, integrated legal-economic model to unpack the dynamic interplay between legal frameworks, policy instruments, market outcomes and electricity system objectives, which can be applied to key economic challenges for electricity markets arising under transition conditions to help identify avenues for targeted reforms. We demonstrate this model on the example of the Australian National Electricity Market (NEM).

If regulators and policymakers intend to reach the long-term goal of ‘ensuring access to affordable, reliable, sustainable and modern energy for all’ (UN Sustainable Development Goal 7), then electricity market regulation will need to dynamically evolve along with, or be designed to anticipate technological and market changes, and actively facilitate the transition process.

2) Electricity market design in a transition context

Electricity provision is an essential service – blackouts or brownouts carry substantial economic, political and social costs. In modern electricity systems, the overall objective is to supply reliable, affordable and sustainable electricity for everyone at all times (see also UNSDG 7). How we manage the electricity supply system – including generation, transport through networks, down to end-supply to the customer – is greatly influenced by historical electricity market designs as well as by existing infrastructure layouts.

Up until the mid-1990s in many countries, including for example, the United States, Australia and the majority of the member states of the European Union, electricity supply was enabled through vertically-integrated, publicly or investor-owned utilities. These monopoly utilities often managed the entire value-chain and were regulated by public service commissions in the U.S. (Borenstein and Bushnell, 2015). In Australia, state-owned electricity commissions managed the operation of the state electricity systems (Abbott, 2006; Kallies, 2016).

The 1990s witnessed a range of countries embarking on electricity market reforms to move from electricity provided by vertically-integrated monopolies to a mixture of liberalized and regulated wholesale and retail markets providing the same service (Joskow, 1998). Electricity market liberalization is characterized by the legal and administrative separation of networks functions, from generation and supply (Joskow, 2008).[1] Especially in the European context, this separation is also referred to as "unbundling".

The degree of liberalization has varied in different jurisdictions (Kallies, 2021). More often, wholesale markets (generation) were liberalized, while networks, and sometimes supply to the end user, remain regulated. Parts of the United States opted for example to restructure their wholesale, but not their retail markets. Starting from 1996, the electricity generation systems of Australia's eastern states were gradually organized into an energy-only wholesale market called the National Electricity Market (NEM) (Godden and Kallies, 2021), while networks remained regulated. Retail competition is encouraged, but not yet fully realized in all of the participating states. Market liberalization endeavors were based on the expectation that liberalized markets can deliver electricity more economically than regulated rate-of-return markets (Borenstein and Bushnell, 2015).

Moving away from the old rate-of-return wholesale market regulation requires a major market framework change that has profound impacts on the ownership structure and business model of generators, and subsequently on operational decisions, profitability, investment and exit decisions. Under the rate-of-return regime, electricity prices are set by the regulator[2],

[1] The discussion over the merits and drawbacks of vertical integration has been extensive (Burger et al., 2019a; Spengler, 1950; Hart and Moore, 1990; Williamson, 1975; Joskow, 1985 & 1987; Bushnell et al., 2008; Baldick and Kahn, 1993) and relates to market competition, efficiency and the system objective of electricity affordability. The fundamental premise is whether efficiencies gained by vertical integration (through reducing transaction costs, preventing double marginalization, enabling more efficient investment into infrastructure) outweigh the costs to society resulting from reduced competition and increased market power. The degree of vertical integration and required unbundling in any electricity market is determined by competition law and regulation. In a transitioning system, different models of integration provide different economic incentives for different type of generators.

[2] Similar models still operate for the regulated network businesses.

allowing utilities to *"recover their prudently-incurred operating costs and a regulated return on capital investment" (Borenstein and Bushnell, 2015: 438).* In fully liberalized wholesale electricity markets however, there is – in theory - no guaranteed return on either investments or on operating costs. The wholesale clearing price of electricity is determined by supply and demand forces on the market. The market price – the basis of revenue for all generators - is set by the bid of the last generator, which is dispatched to meet demand. In theory, this price will be at or above the marginal production cost of that generator (Borenstein, 2000). In practice however, bilateral contracts and financial hedging (future markets) are an integral addition to liberalized wholesale markets, aimed at mitigating the risk of both sellers (generators) and buyers (retailers). In Australia, for example long-term power purchase agreements of up to 10 years are not uncommon (Simshauser and Gilmore, 2022).

The marginal cost of electricity generation refers to the short-run operating cost that a generator incurs in providing an additional MWh of electricity to meet demand. While for fossil fuel generators the greatest share of their marginal cost is the cost of fuel, solar and wind generators have not fuel costs at all. This makes their marginal cost very low or close to zero. In simplified terms, generators are dispatched from the lowest to the highest bid -while observing security constraints- until demand is met. It is worthwhile to note however, that both bidding under the marginal costs (to get dispatched, especially if generators have other sources of revenue than the market) and above (in scarcity situation when market power can be exercised) are very common. If the marginal cost of electricity generation is thus significantly below average costs, which was the case for many countries (including large parts of the U.S. and Australia) in the 1990s, competitive markets would result in lower electricity prices, providing strong political incentives to forge ahead with market liberalization (Borenstein and Bushnell, 2015) .

The generation landscape at the time of market liberalization was usually characterised by large, predominantly base-load plants, and passive end-users (Csereklyei et al., 2021). The market design was based on the assumption that marginal costs of production are non-zero. In a transitioning electricity system, this assumption does no longer necessarily hold true. The past decade has seen both the exit of base-load plants, and the market entry of large-scale renewable generation in most developed countries. In Australia for example, renewably-powered electricity generation has increased from 12.2 % in 2012 to 31.4% by 2021 (OpenNEM, 2022), with wind, solar and hydro generation contributing the majority of renewable electricity generation. The surge in wind and solar installations was due to both federal and state level support policies and the rapid and substantial decline in the cost of these generators. As a result, especially in areas with high natural renewable energy endowments new technologies became highly competitive.

Wind and solar generation, in particular, are characterised by both intermittency and near zero marginal operating costs (Joskow, 2019). These characteristics give rise to several engineering and economic challenges when it comes to integrating large quantities of renewably-generated electricity into the grid. Liberalized wholesale market frameworks, (irrespective of the existence of capacity markets, or other payment mechanisms) were not designed to handle high shares of intermittent, zero or low marginal cost generation in the electricity mix. Unsurprisingly, the increased penetration of distributed energy resources (DER) is disrupting the markets (Eid et al., 2016; Burger et al., 2019a; Burger et al., 2019b; Corneli and Kihm, 2015) and making it difficult for regulators to meet market objectives and functions.

Joskow (2019) in his overview of the US markets argues that there are two key resource allocation functions that wholesale markets have to perform. The first, so called short-run function, is to "*provide for the efficient real-time operation of existing generating capacity, clear supply and demand at efficient wholesale prices that represent the marginal cost of supply at any moment, and do so while maintaining the reliability of the system*" (Joskow, 2019:292). The second, so called long-run function, is to ensure that "*market prices and price expectations provide efficient long-run profit expectations and incentives to support efficient decentralized investments in new generating capacity and efficient retirements of existing generating capacity*" (Joskow, 2019:292). In other words, liberalized wholesale markets work through price signals to meet the electricity system objectives of reliability and affordability, which we will unpack in more detail in Section 3.

In a market with a large proportion of renewable generation, both the short-run and the long-run resource allocation functions can be influenced. While in the short-run or day-to-day operations the impact of renewables mostly materialises through the increased cost of and need for frequency control services and fast-ramping generators, their long-run economic effect is profound. High shares of wind and solar generation may result in successive periods of near zero or even negative wholesale prices. This development has been repeatedly observed for example in the Australian state of South Australia. The extent of these prices depends on the market price floors that are (or are not) in place. These price developments have both short-run and long-run implications with respect to operating decisions, efficient investments and exit decisions of all generators.

It has long been argued in the literature that price signals in especially liberalized wholesale markets might fail to provide adequate long-run investment incentives (Cramton and Soft, 2006; Joskow, 2008; Joskow, 2007; Newbery 2016), particularly in the presence of price caps (Joskow, 2013; Astier and Lambin, 2019). This is often called the "missing money" problem. The fundamental reason for this development is that during periods of high demand and scarce supply market prices do not rise high enough to reflect the scarcity value of electricity supply (Joskow, 2007). This can be due to "*price caps, limited demand-side participation or out-of-market operations by the system operato*r" (Joskow, 2019:293). Increased shares of renewable generation are not the root of this problem. However, the appearance of zero-marginal cost renewables is further exacerbating it by putting a strong downward pressure on long-run wholesale prices.[3]

Why then are we seeing strong investment into further renewable capacity, if markets may not be providing the relevant price signals? It is notable, that renewable investment and generation have been heavily subsidized and incentivized in many countries. Examples include e.g. (the now cut-back) feed-in-tariffs in Germany, which guarantee a rate of return

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[3] Optimal investment into future generation capacity and corrective mechanisms to avoid underinvestment has been the focus of extensive research (Joskow and Tirole, 2007; Borenstein and Holland, 2005; Crew and Kleindorfer, 1976; Leautier 2016; Stoft, 2002; Hogan, 2015; Cramton and Stoft, 2006 & 2008; and Cramton and Ockenfels, 2011; Burger et al., 2019b; Joskow, 2008). The adequacy problem, or to "*provide the amount of capacity that optimizes the duration of blackouts"* (Cramton et al., 2013:30) is therefore also a market design issue pre-dating, but exacerbated by the increased share of renewable generation. The problem is discussed in the context of the choice between energy-only markets, capacity markets, capacity renumeration mechanisms (CRM), and demand response mechanisms (DR). While a number of regulators implemented different forms of capacity markets, it is highly debated whether other forms of CRM and DR (Astier and Lambin, 2019) would be more efficient in addressing the above problem.

for every MWh fed into the grid,[4] or the Renewable Energy Target (RET) in Australia, which requires retailers to buy certificates issued to renewable generators for every MWh produced, therefore ensuring financial incentives for renewable generators.[5] Newer contract-for-difference models of renewable support have been implemented in the UK[6] and in some jurisdictions of Australia, such as Victoria and the Australian Capital Territory (ACT)[7]. In many liberalized wholesale markets, renewables are thus, at least initially, shielded from (especially low) wholesale market prices through revenue sources granted by external policies.

System reliability and affordability are undeniably impacted by the changing generation profile, not only through potentially inefficient market entry and exit decisions, but also by the failure of many markets to put economic value on dispatchability, flexibility and location, as dispatchability was historically a positive externality of fossil fuel- and nuclear-based generation mixes. Similarly, due to the lack of early market incentives, new generation was often placed at suboptimal locations from a systems perspective, leading to network congestion. Firming requirements for renewable generation were often not anticipated or implemented, leading later to system security challenges.

There is an argument that long-run adequate investment levels will be reached through efficient scarcity pricing as supply decreases and bid prices increase. However, this type of reasoning does not try to co-optimise reliability, affordability and sustainability (see further Section 3), and might not address the urgency of transition pressures or the fact that electricity provision is an essential service. Markets face a dilemma, how to *ensure enough readily available clean generation capacity without impacting on affordability*?

Economies of scale and technological development also brought disruptions into how consumers are acting and behaving on the market with the emergence of the so-called prosumer. Prosumers are households who are owners of distributed energy resources (DER), and whose role from the viewpoint of the market operator alternates between net consumer and net producer (Parag and Sovacool, 2016; Rosen and Madlener 2016). Prosumerism shifts responsibility for supply at least partially to consumers, changes the physical reality of the electricity system by introducing two-way flows, and ultimately impacts the ability of the system to achieve affordable and reliable supply to all consumers. This new type of phenomenon gives market operators the task of planning for both the consumption and the production arising from prosumer households. Traditionally, electricity generated by DER is accounted for as negative demand in the market. This “negative demand” has resulted in a significant deepening of the so called “duck curve” over the past ten years in nearly all liberalized markets, requiring greatly increased flexibility from baseload-profile plants, while resulting in their decreased economic viability.

The ability of a system to respond to rapid technological changes is rooted in the structure of the regulatory framework, and its overarching objectives. The next section introduces a formalised model of electricity system objectives, frameworks and economics.

[4] German Feed-in-Tariff Act (2000), [Erneuerbare Energien Gesetz]. Please note that FITs under the Act have now largely moved to a reverse auction scheme.
[5] Renewable Energy (Electricity) Act 2000 (Cth).
[6] See, https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference.
[7] More details below.

3) An integrated legal-economic model of wholesale electricity markets

Electricity markets have been designed to achieve essential service outcomes – there is a public expectation that the lights will stay on. Consequently, a tight regulatory framework surrounds electricity markets, to ensure reliability, sustainability and increasingly, sustainability of electricity supply. The following section summarizes the role of law and economic incentives in, and introduces an integrated legal-economic model of wholesale electricity markets, and demonstrates potential corrective regulatory mechanisms on the example of Australia.[8]

3.1 The role of law in energy markets

Law and regulation create and shape the market by establishing a "substructure of rules and other institutional and normative devices" (Prosser, 1999:197) through which incentive-based market mechanism plays out. Legal scholars engaging with the role of law in the wake of system disruptions have identified the "challenge of constructing regulatory environments that are fit for purpose" (Brownsword et al., 2016:5). In light of decarbonization imperatives, the role of lawmakers is to ask the question, are our regulatory systems surrounding electricity provision still fit for purpose? If they are not, at what level of decision/law making are interventions necessary, including but not limited to changes in institutional settings, objectives, obligations, and operational rules. If interventions are needed, lawmakers have to determine the optimal time to carry them out. Among others, Heffron et al. (2018), call for forward-thinking regulations to address the urgent need to reduce carbon emissions, rather than ex-post attempts to 'fix a problem'. This focus on anticipating and constructing suitable future regulatory regimes in the light of transitions should inform market design.

Electricity systems can be seen as techno-institutional complexes (Unruh, 2000), where institutions, norms and technology have co-developed, remain interdependent and slow to adapt, leading to path dependence and inertia (Geels et al., 2016). Today's market legal frameworks have been designed for traditionally nuclear or fossil fuel-based large centralized generation, delivering energy to a passive consumer. A commitment to sustainability as a system objective is challenging all of these premises – we see electricity systems transitioning to high shares of renewable generation, decentralized supply structures and new patterns of consumer engagement (prosumers). Others have identified the centrality of changing governance frameworks for energy system change (Nilsson et al., 2011, Kuzemko, 2016). Addressing these barriers however, requires a detailed understanding of the interplay of legal frameworks and market behavior.

3.2 Electricity system objectives

Electricity system objectives evolve over time. We define the system objectives as follows: reliability is the continuous ability of the system meet energy demand. This is wider concept than electricity system security, which refers to the ability of the system to continue operations in the face of disruption. Inevitably though, the two concepts are interconnected in the long run; a reliable system must be secure. Sustainability and affordability respectively relate to providing clean, preferably zero-carbon electricity to all customers at the lowest price, which still guarantees/provides sufficient supplier investment incentives and

[8] While we acknowledge the central role of politics on the design of energy market frameworks, we here concentrate in the relationship of markets and the law. We see potential to further develop our framework to take account of political dynamics.

operational security. Affordability is centred around consumer interest. System reliability and affordability work best in the long-run if the welfare of suppliers and consumers are co-optimised. These objectives are conditional on each other, but at the same time create competing priorities for regulators and legislators.

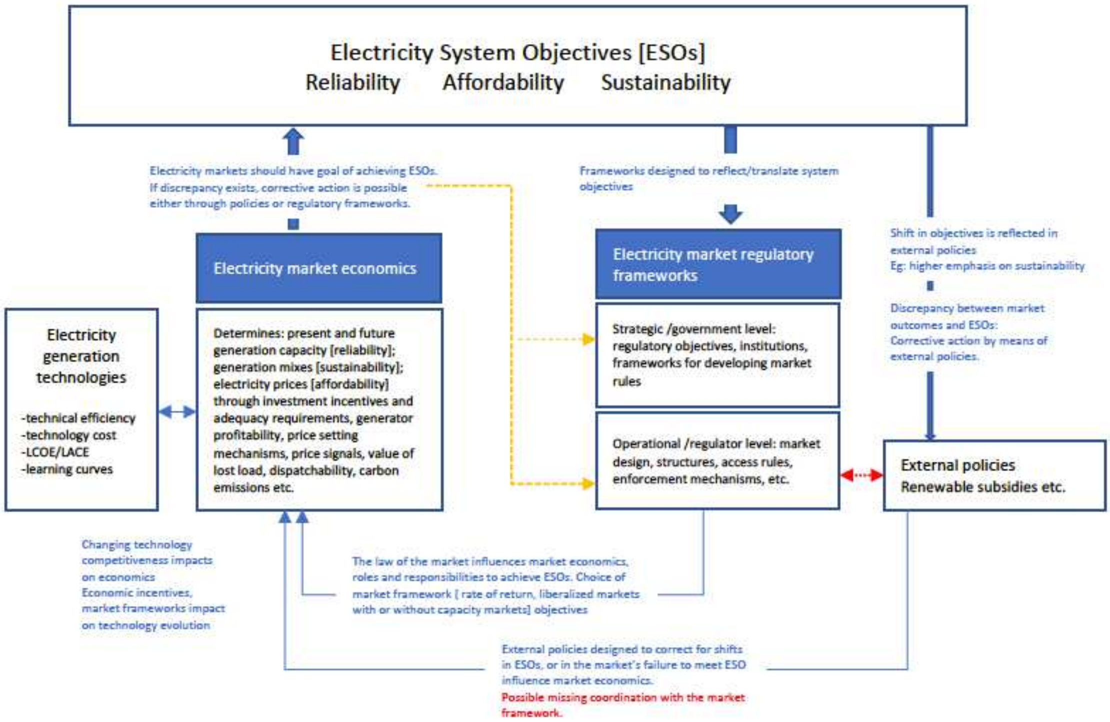

Figure 1: A legal-economic framework of the electricity market: Arrows represent interactions, the dotted red arrow signifies a potentially missing connection. The orange arrows represent a feedback loop from market outcomes to regulatory frameworks. The interactions take place across the legal, political and market environment.

Legal and regulatory frameworks for electricity markets should, in theory, reflect and translate electricity system objectives [ESOs] into regulation/law. However, this is not always the case. The question how many, and which of the ESOs are translated into market regulatory framework objectives, is critical to understanding which electricity system pathways and path dependencies will arise in the future. For example, sustainability as a market objective, may [e.g. Germany, UK], or may not [e.g. Australia] be translated into the market regulatory frameworks.

3.3 Levels of law in electricity market frameworks

We identify two distinct levels of law in our electricity market framework. Law in its strategic role formalizes market objectives in legislative provisions, which influence the rights, powers and obligations of market institutions, market participants and other stakeholders. Law at this level determines the orientation (and the possible reorientation) of a regulatory system (Kallies, 2016; McHarg, 2013; Gunningham, 2012), i.e. how and through which institutions law determines the purpose (objectives) of the market.

The operational level of law setting includes any law and regulation that are needed to enable and enforce the market, which will shape the underlying economics of the market. This includes for example the choice between liberalized markets vs. rate-of-return wholesale markets by setting up the rules through which generators and networks are reimbursed. This level of law also includes rules for vertical disaggregation (unbundling), securing of ownership structures and securing the financial structures for electricity trade, including, for example, specific structures for market access rules, network price controls, and licensing regimes for market participants (Gunningham, 2012).

The levels of law in electricity markets are interdependent. Regulatory objectives set at the strategic level influence the ability of lawmakers and regulators and their choice of instruments to achieve these objectives. In other words, alignment between system and market objectives will make it easier for decision-makers to carry out effective framework changes at the operational level. Germany's legislators, for example, could introduce special third-party access rules for renewables (at the operational level), because legislated market objectives already included a commitment to support sustainable energy systems.

Besides operational regulatory frameworks, electricity market economics will also be determined by ongoing technological development, and the change in the cost and value of the electricity generated by certain technologies. The market outcomes can be measured against the objectives of the electricity system. These outcomes include long-run average market prices measured against the objective of affordability, adequate present and future generation capacity measured against reliability, generation mix measured against sustainability.

3.4 Responding to disruption

Should the present market frameworks be inadequate to meet the system objectives, to deal with incoming technologies or the changed conditions these technologies create on the market regulatory response can occur through two different ways:

1. Through the legal/market frameworks that govern the economics of the market.
2. Through external policy instruments.

We define an **external policy** as a specific legislated solution (e.g.: subsidies or other renewable support instruments) that is not part of the market framework, but is created to address or remedy a market failure that hinders the reaching of a system objective. We have seen a range of these policies introduced to achieve sustainability objectives. Market frameworks and external policies may fall under different institutional responsibilities, especially where energy and environment sit under different ministerial portfolios, or where federal and subnational level policymakers have split responsibilities (in federated states).

While Figure 1 only describes the wholesale market, the generation sector is interlaced with other parts of the system, such as transmission and retail. Consequently, the regulatory framework of the market also guarantees and regulates the enablers of the markets. Thus, regulation around ancillary markets, network access and transmission are a critical part of the system, albeit not the focus of this paper. Major changes in the generation landscape and wholesale market behaviour have a direct impact on the operations of and investment requirements into ancillary markets as well as networks.

Addressing the discrepancy between system objectives and the real market outcomes through either external policies or market reform has advantages and disadvantages. Often, given the slowness and the complexity of change to market frameworks, the second option is preferred by policymakers, as it offers quick and visible solutions. However, a lack of integration of external policy instruments and market frameworks, as will be seen in the Australian example, can lead to perverse and unanticipated outcomes. Introducing changes to market frameworks requires more planning and will result in a long-run change in the (investment, bidding, generating) behaviour of market participants.

We argue that if meeting one of the system objectives is permanently jeopardised or it can be anticipated with high certainty that it will be jeopardised, then an operational or strategic (or both) framework level change is preferable (orange arrow in Figure 1) over a quick policy fix. The market regulator/operator is best positioned to identify the need for strategic or operational market framework change, which may be acted upon either by governments or regulators.

Should major changes to system objectives occur, these need to be reflected in the strategic level market frameworks, otherwise attempts to achieve such objectives through external instruments or incorporate them into the operational level of law setting may result in uncoordinated outcomes. Regulatory responses initiated to achieve key system objectives should be clear and comprehensive instead of piecemeal, to ensure long-run regulatory certainty/stability which is a prerequisite of market investment.

There is no "playbook" as to which economic or market failure should be addressed how, but rather at which level of regulation. Establishing the right market-regulatory feedback process will enable governments aided by regulators to meet their responsibility of maintaining reliable, affordable and sustainable provision of electricity (essential service), as well as facilitating the transition and establishing a vision a future electricity system. We demonstrate the above framework on the example of Australia's electricity market transition to show how a lack of working feedback loops between external instruments, markets and their legal frameworks, has the potential to disrupt transition efforts and endanger system objectives.

4) Australia's Electricity Market Transition: An application

The National Electricity Market includes the states of New South Wales, Victoria, Tasmania, Queensland, South-Australia and the ACT. It covers an interconnected physical electricity system stretching along the east coast of Australia. In this paper, we illustrate clean electricity transition challenges associated with a lack of coordination between markets and their legal frameworks, and external instruments, on the example of the NEM, which it is an energy-only market.

4.1 National Electricity Market regulatory frameworks

The NEM governance framework is highly complex, with four key national institutions sharing governance responsibilities under the oversight of a ministerial council comprised of all national and federal energy ministers. This structure is owed to the state origin of the electricity system. Creating a unified, 'national' framework for a sector that was traditionally state regulated, required the adoption of "mirror legislation" agreed upon by all participating states and territories.[9] The central legislation, adopted by all participating jurisdictions, is

[9] *Electricity (National Scheme) Act 1997* (ACT), *Electricity – National Scheme (Tasmania) Act 1999* (TAS); *Electricity – National Scheme (Queensland) Act 1997* (Qld); *National Electricity (Victoria) Act 2005* (Vic); *National Electricity (New South Wales) Act 1997* (NSW); *National Electricity (South Australia) Act 1996* (SA).

setting out objectives and institutional frameworks of the NEM, is the National Electricity Law (NEL). The NEL enables the creation of delegated legislation, called the National Electricity Rules (NER), which set out most of the detailed regulatory frameworks for the NEM.

States, in their National Electricity Acts, can and do diverge from the national scheme. For example, the Victorian legal instruments implementing the NEL in Victoria, the National Electricity (Victoria) Act 2005 (Vic), in part 3 expressly modifies the NER for the Victorian context, by opting out of the NEM metering regime and provides for solar feed-in special rules. The National Electricity (South Australia) Act 1996 (SA), has special provisions for the Retailer Reliability Obligation in part 7A. In addition to adopting the NEL, all states retain their own electricity industry acts,[10] which regulate licencing conditions for electricity industry participants, but also safety standards and consumer protections. Additionally, we can observe states passing electricity industry legislation which allows them to circumvent NEM frameworks. Examples include a 2020 amendment to the National Electricity (Victoria) Act 2005 (Vic), which allows the Victorian state government to fast-track transmission projects outside of the NEM framework. Similarly, the NSW Electricity Infrastructure Investment Act 2020 (NSW), allows the state to override NEM rules under certain conditions. We will discuss the impact of these changes n 4.3 below.

As described above, our model distinguishes between strategic and operational levels of electricity market regulations. Central to the strategic level is the institutional infrastructure of an electricity market and, most importantly, its objectives – the aims it was installed to achieve. The National Electricity Objective for the NEM (s7 NEL) stipulates that:

> "The objective of this Law is to promote efficient investment in, and efficient operation and use of electricity services for the long term interests of consumers of electricity with respect to –
> (a) price, quality, safety, reliability and security of supply of electricity; and
> (b) the reliability, safety and security of the national electricity system."

These objectives cover the reliability and affordability aspects we have set out in our framework – they are essential service legacy objectives. In addition, efficiency objectives, reflect the shift to markets and competition (Haines and McConnell, 2016). A sustainability objective is not contained.

The operational level of the electricity market framework is predominantly contained in the NER. In Australia's NEM, an intricate framework of National Electricity Rules sets out detailed rules for wholesale market participation, network planning, investment and access. These rules apply equally to all sources of generation, as the National Electricity Rules contain an express commitment to technology neutrality as an objective of market design (NER 3.1.4(a)(3).)

The aforementioned objectives also determine the scope of the responsibilities of the respective market institutions, including:

- The Australian Energy Market Operator (AEMO), which is responsible for operating the wholesale market and the electricity system, including ancillary services and network planning.
- The Australian Energy Market Commission (AEMC), which reviews and develops the NEM by conducting market reviews and making and amending the NER.

[10] Eg,: *Electricity Act 1996* (SA); *Electricity Act 1994* (Qld); *Electricity Industry Act 2000* (Vic); *Electricity Supply Industry Act 1995* (Tas) ; *Utilities Act 2000* (ACT); *Electricity Supply Act 1995* (NSW).

- The Australian Energy Regulator (AER), which monitors and enforces market rules.

A new institution, the Energy Security Board, was created in 2017 and is comprised of all three market bodies, with the chair of AEMC acting as its chair. The ESB has an advisory function and has been tasked by the ministerial council with developing a post-2025 market design for the NEM.

Changes to the NEL require amendment legislation, which has to be adopted in all participating jurisdictions. In practice this means that all parties to the NEM have to agree to the amendment. Changes to the NER on the other hand are passed by the AEMC, who will conduct a rule-making process following a rule-change proposal. Rule changes can be proposed by anyone other than AEMC, and, while traditionally AEMO and AER have been major proponents, increasingly we see this option being used by non-governmental organisations, such as for example the Total Environment Centre,[11] or Climate Works12, seeking to adapt the rules to enable energy transitions. In addition, the Ministerial Council can propose rule changes in particular following market reviews by the AEMC. However, any changes to the rules have to be aligned with the market objective. Outside the standard rule change process by the AEMC, the ESB can recommend rule changes to the ministerial council, which, in turn can recommend the making of the rule by the relevant South Australian Minister. Importantly, the scope of any changes is bounded by the market objective (see s90F NEL). Rule change proposals go through a submission and consultation process, but ultimately, the AEMC provides the final draft and needs to be "satisfied that the rule will, or is likely to, contribute to the achievement of the national electricity objective" (NEL s88). The AEMC can, if not satisfied, propose a preferable final rule (NEL s91A).

4.2 The impact of external sustainability instruments on market economics in Australia

While sustainability is not a legislated objective of the NEM, political pressures, both domestic and international, have culminated in a number of external climate policies and commitments by state and federal government, with far reaching consequences to market economics. These climate policies have been the major drivers of renewable energy uptake in the NEM. Arguably, they reflect the expectation that electricity system delivers sustainable energy.

Much has been written about the highly politicised nature of Australian climate policy (e.g. Simshauser, 2018). The federal government, as signatory to Australia's international climate commitments, responsible for climate policy making, is yet to create a durable and consistent commitment to climate reduction policies. Over the last 20 years we have seen federal renewable energy support, more generally emissions reductions policy, created and then cut back by the federal government. (Simshauser & Gilmore 2022) In response, state governments often stepped in to address the policy vacuum and to support their budding renewable energy industries. Increasingly, we also see state and federal governments underwriting investment, as recently happened with the Kurri Kurri gas plant (Taylor, 2021a). While the lack of coordinated federal energy and climate policy is key impediment of successful transitions, the threat of poorly designed or executed policies is can cause a similar

[11] Such as a rule change request for a distributed energy resources rule change in 2020 https://www.aemc.gov.au/rule-changes/network-planning-and-access-distributed-energy-resources.
[12] such as a rule change request for connecting embedded generation https://www.aemc.gov.au/rule-changes/connecting-embedded-generators.

setback (see the failure of the “underwriting new generation investment” (UNGI) program of the federal government).

Renewable energy support through external policies

The federal government of Australia has committed to 43% emissions reductions by 2030 compared to 2005 levels (Commonwealth of Australia, 2022)[13], and to net zero emissions by 2050 (Commonwealth of Australia, 2021). In addition, all state governments pledged climate targets and/or renewable energy targets (such as a 50% by 2030 commitments by Victoria, NSW and SA). In Australia, the electricity sector is the single most important source of emissions, with 33.4% of emissions originating from there. (Australian Government, 2021). A clean energy transition in the power generation sector is therefore central to achieving these reductions. Consequently, renewable energy support polices have played a central role in the emissions reduction efforts. In particular, the federal RET, a renewable portfolio scheme, has been the dominant driver behind renewable generation investment in Australia (Nelson et al., 2022). Additionally, a range of other policies, in particular state subsidy schemes for rooftop solar, and increasingly, reverse auction schemes employed by the State of Victoria and the ACT[14] have contributed to continued renewable energy uptake. A short-lived carbon pricing scheme[15] also supported the energy transition. Simultaneously, increased worldwide demand for renewable infrastructure resulted in a major decrease in the cost of technology over the past decade (Lazard, 2021), further accelerating technology deployment.

These polices were crucial for urgently addressing climate change and enabled renewable generation to successfully enter a path-dependent market designed for predominantly non-zero marginal cost fossil fuel generation and network infrastructure, with large, centralised generation layout and major load centres.

As a result, Australia has now clearly embarked on a path to a more sustainable electricity system with 31.4 % of electricity generated from renewables in 2021 (up from 12.2% in 2012). While different states transition at a different pace, the percentage of renewables in electricity generation is rising across all of Australia’s NEM (Csereklyei et al. 2021), with intermittent wind and solar generation providing the bulk of new capacity additions to the system. This development resulted in major technological and market economics challenges, that were not proactively addressed by the NEM decision-makers.

Resource allocation decisions in wholesale and ancillary markets

Zero marginal cost generation exerts a downward pressure on wholesale prices (eg: Csereklyei et al., 2019 for Australia). Increasingly high shares of renewable generation recently began to manifest in periods of zero or negative wholesale prices (e.g. in South Australia). These price developments are however not felt similarly across all generation technologies, as policy interventions may shield select technologies from the market

[14] For Victoria, see the *Victorian Renewable Energy Auction Scheme* (https://www.energy.vic.gov.au/renewable-energy/victorian-renewable-energy-auction-scheme); for the ACT see how the ACT’s renewable energy reverse auctions work: (https://www.environment.act.gov.au/energy/cleaner-energy/how-do-the-acts-renewable-energy-reverse-auctions-work)
[15] *Clean Energy Act 2011* (Cth), now repealed.

outcomes. For example, the large-scale renewable energy target, a federal scheme, requires liable entities such as energy retailers and large emitters to source an annually determined percentage of the electricity they purchase from renewable sources. This requires them to purchase renewable energy certificates, issued to generators for each MWh renewable energy generated under the federal RET, and then surrender them as evidence of meeting their targets.(Nelson et.al., 2022) Therefore, irrespective of the market wholesale price, renewable generators participating in the RET scheme have additional sources of revenue that helps to recover their investment costs and allow for profits.[16] A small-scale RET accompanies the LRET, and supports small renewable installations. Other standard instruments have an even more pronounced effect of providing guaranteed source of income. For example, the already mentioned reverse auction schemes work as contracts-for-difference schemes (Nelson et al., 2022). Generators contract for a guaranteed rate-of-return over a certain number of years. Feed-in-tariffs were in Australia predominantly deployed to provide fixed rates of return to small-scale rooftop solar owners.

As described in Section 2, the presence of price caps in liberalised markets, coupled with the policy driven influx of zero marginal cost intermittent generation may lead to inefficient resource allocation decision. In case of the NEM, the effect is twofold:

Firstly, it remains an open question whether the market can incentivise sufficient investment over the next decades in the optimal (and optimally placed) generation mix, including renewable generation, fast-responding batteries and other system-firming capacity, without the presence of substantial government subsidies or external policies. While the past years have seen an influx of renewable generation capacity, the RET is no longer being expanded beyond 2020 and will close in 2030. This means that the prices have dropped and new demand is mostly due voluntary commitments by emitters. At the same time, AEMO (2021) projects that up to 122 GW of new variable renewable generation capacity will be required in the NEM by 2050.

Secondly, current short- and long-run price signal developments in the NEM are contributing to the untimely and unplanned exits of large, predominantly coal-fired base load plants (Rai et al., 2019). Increased renewably-powered generation impacts baseload coal (and gas) plants through lowered wholesale prices, decreased dispatch times and higher ramping (up and down) requirements. Between 2012 and 2017 approximately 5.6 GW coal-fired capacity has been retired (Burke et al. 2019). Similarly, coal generator closure dates have been brought forward recently. The operators of the biggest coal power station in NSW, Earing, have announced a 2025 closure (Origin, 2022), whereas the closure date of Yallourn power station has been brought forward to 2028 (from 2032) (EnergyAustralia, 2021). In addition, AGL announced that it would bring forward closures of two further coal-powered plants in NSW and Victoria by at least 5 years (AGL, 2022). AEMO (2021) predicts that up to 14 GW coal capacity could exit by 2030, which number is considerably higher than anticipated.

While long-term power purchase agreements and financial hedging contracts are an essential part of the market these agreements are not shielded in the very long-run either from market price trends. It is notable, that approximately 80% of the renewable investments between 2016-2021 were covered by long-run (+10 year) power purchase agreements, and only 20% were spot market exposed (Simshauser and Gilmore, 2022). The NEM has an active forward

[16] Please note that the RET is no longer expanded from 2020. From 2020 to 2030, the target stays the same. Post 2030 no credits will be available under the RET.

derivatives market for Swaps and Caps (Simshauser and Gilmore, 2022), which play a significant role in providing investment certainty.

Sufficient investments in generation capacity, and efficient, well-timed exits are not enough to maintain system reliability. Investments into networks (both transmission and distribution) will be a critical to maintain the long-run functionality and reliability of the NEM. Networks in Australia are regulated and network operators receive a regulated return on their investments. An investment will be approved by the AER if it either furthers reliability or affordability, that is market benefit (Godden and Kallies, 2012). While networks have been incentivised to invest for projected future peak performance (Nepal, et al., 2014), the investment framework has not been successful to incentivise renewable friendly network investment.

While the long-run investment and divestment challenges of the wholesale market are more pressing from a system security and reliability point of view, the unexpected influx of renewables has also left its mark on the operation of ancillary markets. Ancillary service costs have seen an 8-fold increase in the NEM (AER, 2021) during the past ten years, while the system firming requirements are becoming an increasingly important issue. As mentioned earlier, state governments have introduced legislation that allows them to sidestep the NEM frameworks. Addressing the reliability issues caused by renewable investment, Victoria has since used its amendment to the National Energy (Victoria) Act 2005 (Vic) to allow investment into the Victorian Big Battery, which provides System Integrity Protection services (Victorian Government, 2020), clearly signalling that the electricity market legal frameworks have not adapted to ensure system reliability in time.

Australia is considered a success story for small-scale solar photovoltaic adoption – and the associated rise of the prosumer. Best et al., (2018) show that the small-scale renewable energy target scheme was the main driver of small-scale solar uptake in Australia. Recent numbers show that Australia now has over 12 GW installed solar rooftop capacity (APVI, 2022). The impact of these developments on the NEM have been profound. Solar rooftop solar generation does not clear through the NEM, and thus is accounted for as "negative demand" during the sunny hours of the day. The resulting "duck curve" phenomenon, or the drastic decrease of operational demand during the middle of the day introduced both pricing and engineering problems.

As seen, Australia's NEM is experiencing a number of well-known challenges to electricity market transitions. The next section introduces the resulting market regulatory responses.

4.3 Regulatory response to address market issues

In theory, market regulatory response happens when system objectives are in jeopardy.

The National Electricity Market and its wider frameworks were implemented at a time when the techno-economic characteristics of the electricity generation sector were markedly different. Over the last 10 years, the inability of this system to address the impact of technological change in a timely manner has become much clearer.

Despite clear disruptions in recent years, the roles and responsibilities of the market institutions and their objectives remain unchanged. This is not to say that the NEM institutions do not respond to disruptive change. The AEMC rule change proposal process, but also their market reviews, are, in theory, responsive to change. The AEMC has clarified in a stakeholder guide to the market objective that it takes climate mitigation and adaptation risks into account when assessing a rule change proposal in light of the NEO (AEMC, 2019). While adaptation risks refers to changes in the physical world, mitigation risks are described as including the responses and likely responses of policymakers, consumers and investors. These risks will be acknowledged where they "manifest due to the issue of climate change" and impact "on price, quality, safety, reliability and security of supply of energy or energy services. (AEMC, 2019: 8/9). The focus on manifestation of a risk, however, may not be enough to address issues proactively, and as set out below, the rule change program so far is reinforcing this perception.

The AEMC has repeatedly emphasised technology (or competitive) neutrality of different generation technologies when assessing rule changes or providing market reviews. Achieving transition or sustainability objectives is considered external to the scope of AEMC's work. In particular, there is an expectation that a technology neutral framework is flexible enough to address technological change and that "a change in technology should not require a change in regulatory arrangements" (see eg, AEMC, 2018a: 6). This expectation, however, does not hold up to the reality of a market framework which is not coping with the increase of renewable generation in the system.

While rule change proposals from market bodies or other entities are an important tool to bring about improvements, these proposals usually address specific operational problems. There have been a flurry of smaller rule changes in the past years]at the operational level of law. Among others, some recent rule change examples include defining NEM settlement rules under low, zero and negative demand conditions (AEMC, 2021a), caused by behind the meter generation, the introduction of an integrated resource provider concept (AEMC, 2021b) in order to allow integrating mixed technology types behind a connection point, and two new FCAS markets (very fast raise and lower) responding to the need of more variation in system frequency (AEMC 2021c).

To bolster long-run system security, a retailer reliability obligation was introduced to compel retailers to contract or invest in future expected demand (NER ch 4A). In a similar vein, to mitigate the impact of early coal generator exits, a notice requirement of 42 months before closure was introduced (AEMC, 2018b). Additional transitional measures, considered in the market redesign process by the ESB outlined below include a wholesale demand response mechanism (AEMC, 2020) and an interim out-of-market reserve procurable by AEMO (Reliability Panel, 2020).

At the same time prosumers are made "visible" through registration requirements (AEMC 2018c) and may be required to allow operators to remotely constrain and control their generating assets. Additionally, aggregator roles were introduced to bundle and operate prosumers' assets as generation or demand side response as early as 2012 (AEMC, 2012).

While numerous regulations and laws are being introduced, the questions market institutions involved in market design should ask are, in what framework design can renewable and non-renewable generators in the long run recover their investment costs and operate profitably?

There is a lack of proactive change anticipating the ongoing transition. Only with the creation of the ESB in 2017 have pressing questions about market design changes been addressed in a structured way. In response to the major market design challenges, the council of ministers directed market institutions to develop suitable market reforms for transition scenarios. The ESB (2021) is in the process of developing several reform proposals to address these issues for the post 2025 market.

At the time writing, key ESB market design suggestions focus on four main areas (see ESB, 2022). Firstly, they seek to address the problem of resource inadequacy through proposed jurisdictional strategic reserves, while capacity mechanisms are also discussed. Secondly, reforms seek to improve the integration of DER, discussing a number of potential reforms to reward consumers for flexible demand and generation. Thirdly, proposed solutions to system security issues and the operation of ancillary markets are discussed under the heading of essential system services. Finally, the ESB reforms consider addressing transmission and access issues through congestion management mechanisms in renewable energy zones. All of these reform proposals are at early stages and may or may not become legislation. They clearly identify the key concerns and areas, market design has to target.

A common thread between all these reforms proposals is their reactivity. In other words, we see reform proposals focusing on current market problems, rather than proactively addressing future market challenges. This behaviour is exemplified by the orange arrows in Figure 1. Even though market institutions are well-aware of the potential impact of climate policies on the electricity market (e.g., AEMC, 2009, 2018a), reforms are often considered too late. For an infrastructure sector with long investment timelines, and, even more crucially, for an essential service, where policymakers cannot risk disruption of service, this inbuilt reactivity is problematic.

State government clearly recognise the threat of this disruption. In 4.1 we described the different jurisdiction-specific legislative responses seeking to ensure that regulatory frameworks respond to market signals and do not provide a barrier to state-level commitments to climate and renewable energy targets. Despite their flexibility, jurisdiction-specific regulations can lead to a highly fragmented national electricity market framework.

We therefore argue that the NEM framework should consider implementing a more formalised link between electricity market frameworks and the external policies impacting them (red arrows in Figure 1). Such mechanisms exist, for example, in the United Kingdom – where the Energy Act 2013 (UK) requires the government to issue Strategy and Policy Statements, which link regulatory decision making with the delivery of policy outcomes. In Australia, the energy ministerial council can already provide policy directions to AEMC by issuing statements of policy principles (NEL s8), however, this pathway has been underused (Vertigan et al., 2015), and is, again, constrained by the national electricity objective.

The discussion on whether we need a sustainability objective in the NEM is a long-standing one. Changes to market objectives and guiding principles – such as for example the inclusion of sustainability instead of technology neutrality into the NEL - would have to be agreed by all jurisdictions, then initiated by the South Australian Energy Minister, passed by the South Australian Parliament, and then mirrored in all other participating jurisdictions.[17] Even though there were repeated calls for changes to the NEO to introduce sustainability objectives (Cantley-Smith, 2009; Wright, 2011; Kallies, 2016) similar to those for example in the UK

[17] passed in Parliament in all other states and federal level.

and Germany[18], these are yet to be realised. Without a change in objectives, external instruments may continue to be necessary to achieve sustainability and climate goals. From an integrated model perspective, we recommend legislating and including sustainability into the market objectives to align overall system objectives with the main instrument that seeks to achieve them – the NEM. Regulators are already balancing a range of competing objectives – both 'market' efficiency objectives and legacy essential service objectives of safe, secure and reliable supply. In other words, multiple objectives are already a defining feature of modern electricity markets, and other market frameworks such as the aforementioned German and UK ones, have managed to implement green objectives. Sustainable energy is in the 'long-term interests of consumers' and the NEO should expressly reflect this preference.

5) Conclusion and Policy Implications

In this paper we introduce a novel, legal-economic framework of electricity market transitions, which allows researchers and policymakers to identify preferred avenues for targeted reforms to address discrepancies between electricity market outcomes and systems objectives. As demonstrated on the example of Australia, current clean energy transitions efforts are in danger of failing in the long run, as the electricity system objectives of reliability, affordability and sustainability are not simultaneously achieved.

The reasons for discrepancies between the desired levels of long-run reliability (including but not limited to system security and investment adequacy), sustainability (carbon neutral electricity generation mix) and affordability, arise from different sources. These include new technologies that disrupt the market and do not fit regulatory frameworks of an earlier era, or they can be the unintended consequences of major policy actions seeking to address changes in system objectives without changes to regulatory frameworks. These mismatches materialise in known economic and system challenges such as investment inadequacy, the lack of economic value on dispatchability and flexibility or the rise of prosumerism.

In this paper we identified distinct avenues through which regulation can respond to emerging or existing economic and system operational problems. Addressing major changes in system objectives, or a discrepancy between market outcomes and system objectives should first happen at the strategic level of legal frameworks to enable institutions and policymakers to incorporate the new mandate into their goals, objectives and responsibilities. This allows to effectively target actual discrepancies in the context of regulatory frameworks. Laws and regulations of the market should be aligned with the long-run objectives of the system: in other words, they should be "fit for purpose", while ensuring welfare maximisation to all market participants. While external policies offer a quick solution to a perceived problem, they often result in perverse outcomes.

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[18] The *Electricity Act 1989* (UK) s3A has been amended several times and contains cascading objectives committing primarily to 'protect the interest of consumers where possible by promoting effective competition'. Consumer interest is expressly specified as including their interest in emissions reduction. Secondary objectives include a reference to a 'diverse and reliable supply of electricity', 'energy efficiency' and the 'environmental impacts of the electricity industry'. The German *Electricity Industry Act 2005* (Germany) in section 1 para 1 sets out that that 'the objective of this Act is to ensure the provision of, to the extent possible, safe, cost effective, consumer friendly, efficient and environmentally compatible on-grid public supply of electricity, gas and hydrogen, *which is increasingly based on renewable energy sources.* [emphasis added, transl by authors].

The energy transitions will continue to challenge the ability of the market to achieve all of its objectives simultaneously. A well-functioning electricity market is one that is able to cope with the anticipated effect of such transitions on system objectives. Without injecting flexibility and establishing appropriate regulatory feedback mechanisms into the correct level of regulatory frameworks; markets will struggle to achieve electricity system objectives. At the same time, markets require regulatory stability. This is particularly necessary in markets relying on large infrastructure investments by private entities.

In this game of chickens, the hard part is to know when to flinch, that is, to realize when system objectives become unattainable, or the current system is heading down towards this long-run outcome. While major regulatory changes will disrupt the market, they may be needed from time to time. Such changes however will likely alter the behavior of all participants and lock in new techno-economic pathways. Many electricity systems are now at the point when such changes are necessary to avoid jeopardizing sustainable, affordable and reliable future electricity systems.

Addendum: Australian state and federal energy ministers have in August 2022 agreed to put an emissions objective into the National Energy Objectives. At this stage there are no details or timelines for this amendment available.

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