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Farhad Billimoria, Visiting Reseach Fellow, OIES and
Rahmatallah Poudineh, Lead Senior Research Fellow, OIES

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Decarbonized Market Design: An Insurance Overlay on Energy-Only Electricity Markets

Farhad Billimoria

Visiting Research Fellow, Oxford Institute for Energy Studies, Oxford, UK

Rahmatallah Poudineh

Lead Senior Research Fellow, Oxford Institute for Energy Studies, Oxford, UK

Abstract

In the face of challenges to energy-only market design under the electricity sector transition, an option considered by many jurisdictions is to incorporate some form of centralized capacity mechanism to respond to shortfalls in the market provision. For example, the UK government has already introduced a formal capacity market. In Germany and Belgium, strategic reserve mechanisms have already been approved and will be introduced shortly. Other markets, such as the National Electricity Market of Australia, are also considering enhancing their existing strategic reserve mechanisms, which would see more standardized and continual procurement of capacity by a noncommercial central agency. Under a market transition where generation is increasingly stochastic and decentralized, two key issues emerge with the above approaches. First, centralized mechanisms put increased focus on the efficiency of central authority decision making and the alignment between performance outcomes for reliability and agency incentives. Second, existing capacity mechanisms require the central agency to infer consumer preferences for reliability, something that is very challenging in practice. This is especially relevant in markets where the value of lost load is increasingly differentiated among different consumers. In this paper, we propose a new model for electricity market design—*the insurer-of-last-resort model*—that works as a risk overlay on an existing energy-only market. This model unbundles energy and reliability and incorporates insurance-based risk management concepts with the aims of (1) aligning incentives for centralized decision making and (2) allowing revealed consumer preferences to guide new capacity deployment.

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1. Introduction

The classic challenge for electricity market design is to provide *reliable and secure* electricity at *least cost* to consumers while promoting *consumer preference*.[1] The current market transition towards decarbonization combined with technology development has introduced variable and decentralized forms of generation that bring opportunities and challenges for market design.

On the positive side, the low marginal costs of wind and solar PV (photovoltaic) generation mean that when available, they have the potential to provide low-cost electricity to consumers. However, their variability and intermittency also mean that reserves of dispatchable generation are required when renewable resources are unavailable—*the reliability (*or *resource adequacy) challenge*. The asynchronous nature of most forms of renewable energy has also introduced challenges in keeping a complex electric system stable and secure—*the system security challenge*. Finally, the growth of distributed energy resources means that consumers have increasingly elected to self-source a portion of their energy supply, rather than relying on a centralized grid—*the consumer preference challenge*.

The appropriateness of an energy-only market design compared to alternative designs has been debated ever since the introduction of competitive energy markets (Cramton and Stoft, 2006; Cramton and Ockenfels, 2012; Hogan, 2005; Joskow, 2006; Schweppe et al., 1988). More recent studies have focussed on the additional complexities that intermittent and variable renewables bring to energy-only design, including the potential for further pricing volatility (Riesz et al., 2016), interactions with environmental policies (Simshauser and Tiernan, 2018), and the risk of disorderly retirement of legacy dispatchable plant (Nelson, 2017). Joskow (2013) also concluded that revenue adequacy has emerged as a problem in many liberalized electricity markets.

In the face of these challenges, a variety of solutions have been proposed to redesign electricity markets. These range from abandoning the market and returning to centralized government-run models to market-based coordination across energy and capacity, wholesale and retail markets, informed by an underlying market-based carbon price (see Peng and Poudineh 2017 for a detailed discussion). A common option considered by many electricity markets with energy-only designs is, however, to incorporate some form of capacity mechanism to provide the *missing money*[2] necessary for resource adequacy. For example, forward capacity auctions are in place in many US jurisdictions such as PJM (Pennsylvania-New Jersey-Maryland) and ISO (Independent System Operator) New England and were introduced in the UK in 2015. Alberta is also in the process of shifting to a capacity market design (Anstey and Gammons, 2015; Doorman et al., 2016).Centralised strategic reserve mechanisms have been approved and will be introduced in Germany and Belgium shortly. The National Electricity Market of Australia, is also considering enhancements to their existing strategic reserve mechanisms (AEMC, 2018c).

A capacity market design is based on the assumption that electricity is a multi-attribute commodity and the energy-only design does not provide or undervalues the capacity dimension of electricity despite its importance for reliability. While this paper does not to take a position on whether it is necessary to value the capacity dimension of electricity, we argue that capacity procurement by a noncommercial central entity presents its own challenges and inefficiencies. These include regulatory capture and gaming (Anstey and Gammons, 2015), high complexity (Wood et al., 2018), and overprocurement (Newbery and Grubb, 2014). Furthermore, in the absence of revealed consumer preferences, current approaches

[1] In this paper we distinguish the concept of reliability (also called resource adequacy) from that of system security and stability. This is discussed in more detail in Section 2.

[2] It is argued that under scarcity market designs, the high prices needed to provide adequate investment incentives are deemed politically unacceptable. As such, the revenues available to generators under these designs are argued to be insufficient to cover all of their costs. This phenomenon has been termed the “missing money” problem (Doorman et al, 2016).

to resource adequacy rely on estimates of the value of customer reliability, which is a challenging task given the heterogeneity of end users and the subjectivity of putting a value on electricity consumption.

This invites the question of what other alternative designs can be implemented to ensure reliability and adequacy of electricity supply. One potential answer would be to stick within the energy-only paradigm (given the advantages of energy-based pricing) but base price differentiations on other features of the commodity to ensure system reliability and security while promoting consumer preference. For example, Keay and Robinson (2017) advocated a two-market solution in which electricity market price is differentiated based on the source of generation (dispatchable versus nondispatchable).

In this paper, we propose a new model for electricity market design—*the insurer-of-last-resort model*—that is intended to work as a risk overlay on an existing energy-only market. Critical to this model is the centrality of consumer preferences in delivering an economically efficient signal for reliability. Therefore, this model, conceptually, shares similarities with the consumer preference oriented design of electricity market proposed by Keay and Robinson (2017). Nonetheless, it is also different in many respects. First, our model offers a whole-of-system approach to resource adequacy that specifically takes into account consumer preferences around risk, cost, and value of reliability services. Second, unlike Keay and Robinson (2017), we do not suggest a technological differentiation of electricity price, as this increases the complexity of market operation and is unlikely to address the reliability issue of energy-only market design. Third, this model is intended to work as an enhancement to the current market design, rather than a broad-scale replacement of it; it aims to retain the benefits and advantages of the core energy-only design.

In Section 2, we identify the challenges for energy-only electricity market design and potential gaps from the perspective of resource adequacy. In Section 3, we examine the challenges and incentive structure of centralized capacity mechanisms. In Section 4, we introduce the *insurer of last resort* model and outline an initial design and structure. In Section 5 we assess potential implementation challenges and suggest mitigation measures. Section 6 provides the concluding remarks.

2. Energy-only electricity market—current limitations

The ability of an energy-only or scarcity-pricing model to provide resource adequacy has been debated globally since the introduction of competitive electricity markets. A substantial literature has been devoted to the classic debate between energy-only market designs and designs with a capacity mechanism.[3] These concerns have been given new relevance under the current energy transition, which has seen the introduction of variable, intermittent, and distributed forms of energy.

This section does not seek to prove the case one way or the other, but to highlight circumstances under which the scarcity-pricing framework may not always be able to provide the required response in the time frame required to maintain electric system reliability and security.

We distinguish the concept of *reliability* (also called resource adequacy) from that of *system security* and stability. *Reliability* refers to the ability of generation and transmission capacity to meet consumer demand (Finkel et al., 2017). *System security* refers to the ability of the power system to tolerate disturbances and maintain a stable operating state for electricity supply following a disturbance. This paper is focussed on the former, but also highlights interactions between the two concepts.

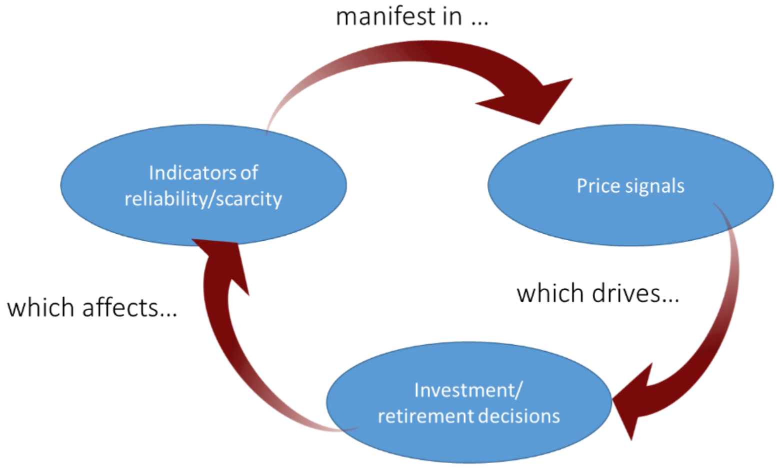
2.1 Energy-only market design

At the core of an energy-only market framework is a price signal for scarcity of electricity supply. It is based on the assumption that all generators can recover their variable and fixed costs by selling energy

[3] See Simshauser (2018c) for a comprehensive review of the literature on energy-only vs capacity market design. See also de Vries and Heijnen (2008); Doorman et al. (2016); Hogan (2005); Joskow (2008).

into a market that is priced on a marginal basis (i.e., the market price is set at the marginal cost of energy at any particular time) and market price can increase significantly when the balance between supply and demand becomes tight. Therefore, the price of energy and associated ancillary services is the primary metric upon which participants are expected to make commercial, operating, and investment decisions (see Figure 1). Under the current design, the needs of the system are expected to be met when all participants individually manage their exposure to wholesale price risk (AEMC, 2017b; Cramton, 2017; Schweppe et al., 1988; Simshauser, 2018b).

Figure 1: Generalised model for reliability under energy only market design



Source: Billimoria and Poudineh (2018).

2.2 Challenges to energy-only market design

2.2.1 Disorderly retirement and investment

Variable renewable energy sources enable low-marginal-cost generation when the wind or solar resource is available but require reserves of dispatchable generation when the resource is not available.[4] Sustained low marginal costs on a system basis could present a dynamic where it is no longer economical for a dispatchable plant to remain online (Nelson, 2016, 2017; Nelson et al., 2017). This could result in a withdrawal of dispatchable capacity on either a permanent (e.g., plant retirement) or semipermanent (e.g., plant mothballing) basis, which could result in insufficient capacity to meet demand (Wood and Blowers, 2017). Furthermore, the challenges of revenue adequacy in many liberalized wholesale electricity markets (especially in the US and Europe) are complicated by the expansion of subsidized intermittent generation (Joskow, 2013).

With decisions on retirement or mothballing left solely to the market participant, generators can withdraw without notice to the market. This may leave insufficient time for new plant development and construction to bridge the gap left by that withdrawal. A case in point was the permanent retirement of the 1600 MW Hazelwood Power Station in Victoria with less than three months notice to the market. While the market responded by increasing capacity and availability, it was unable to fully offset the loss in the time required, and there was a need for emergency reserves to bridge the gap (Billimoria and Poudineh, 2018).

In a market where energy retailing is contestable, even if longer notice is provided, new investment in dispatchable generation may be impacted by the following factors:

[4] The use of the term *generation* is intended in a broad context in this paper and includes traditional dispatchable generation sources but also energy response from demand-side resources or storage.

- *Capital adequacy and the credit profile of the market participant.* In a contestable retail market, nonintegrated market participants may lack the creditworthiness or capital adequacy to access suitable financing or provide the necessary offtake to underpin new generation investment (Nelson and Simshauser, 2013; Simshauser et al., 2014; Tian, 2015). This leaves them reliant on their competitors to provide risk management product liquidity.
- *Contractual liquidity and transparency.* This suggests that large integrated players are the parties most likely and able to construct such capacity, with nonintegrated players reliant on contract markets to provide hedging and risk management (AEMC, 2017b). Contract liquidity is important to the functioning of the market, and history has shown that liquidity can vary over time (AEMO, 2018b; Simshauser, 2018c).
- *Forward pricing indicators.* Higher renewable penetration may increase the likelihood of lower forward prices for electricity (Billimoria and Poudineh, 2018; Nelson, 2017a). This may impact the decision to build new dispatchable capacity.
- *The decision about source of generation.* This decision can be impacted by cost differentials between dispatchable and alternative sources of generation, renewable subsidies or other pro-renewables policies, or broader environmental mechanisms (Nelson, 2018; Nelson et al., 2014).
- *Uncertainty about revenue adequacy.* The impact of variable and intermittent forms of generation can force the remaining dispatchable fleet to recover costs from fewer, higher-priced events (Riesz et al., 2014).
- *Fuel contracting and transportation.* Access to and cost of securing fuel and associated transport can impact the economics and efficacy of new investment (ACCC, 2017, p. 15).
- *Marginal price impacts and portfolio-level considerations*. For example, the cannibalization of a participant's existing fleet can impact its decisions about investment in enhancing capacity (ACCC, 2017; de Vries and Heijnen, 2008; Nelson and Simshauser, 2013).
- *Capital market factors such as the cost of debt, financing availability, and capital structures.* These factors are important considerations for investment (Simshauser, 2010).
- *Broader policy, carbon market policy (Simshauser and Tiernan, 2018), and sectoral uncertainty.* These can colour participant risk perceptions, which can impact the decision to commit capital.

2.2.2 Effect of pricing distortions on the scarcity price signal

The energy-only framework relies on a clear and transparent pricing signal for energy scarcity. However, on a practical level, a range of conditions can distort electricity price signals:

- *Interactions with environmental and renewable energy policies.* The energy price signal can be distorted through interactions with broader environmental and renewable-energy policies and government interventions (Simshauser, 2018a; Peng and Poudineh, 2017).
- *Extra-market hedging and risk management.* Risk management options, such as weather derivatives, may be available outside of electricity markets (AEMC, 2017a; Savage and Conboy, 2018). The counterparty to such risk products is typically not a generator. While retailers may be able to hedge risks using these products, there is no corresponding incentive to add new capacity to meet the other side of the hedge. Hence the market as a whole does not benefit from generation capacity additions when weather derivative are used.
- *Market power.* The exercise of market power can also have an impact on the wholesale price signal and marginal spot prices in an energy-only framework. ACCC (2018) found that elevated prices in the National Electricity Market of Australia (NEM) have generally been driven by high and entrenched levels of concentration in the market (along with fuel source cost factors).

Chattopadhyay and Alpcan (2016) found that high renewable penetrations in a concentrated market increase the exercise of market power.

3. Centralized mechanisms—challenges, designs, and incentives

Economic equilibrium is critical to the proper functioning of the energy-only design (de Vries and Heijnen, 2008; Hirth et al., 2016), and practical implementation factors can force markets out of equilibrium for sustained periods (Bidwell and Henney 2004).[5] This can leave gaps in provision of reliability and security as markets adjust to new commercial and operating dynamics.

To address the risk of gaps in system provision, a variety of centralized mechanisms have been adopted across many international markets. Doorman et al. (2016) identified seven types of capacity mechanism used in markets around the world. Many of these mechanisms involve a central party making decisions or setting parameters in one form or another. For example:

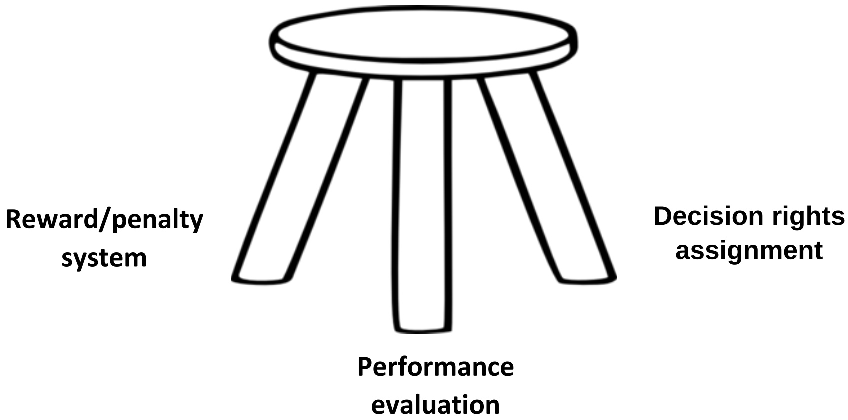
- *Capacity auction mechanisms,* such as those run by PJM and New England ISO, involve a central party (typically the ISO) constructing a demand curve. The methodologies for developing the demand curve differ but generally involve a resource adequacy requirement (Bushnell et al., 2017; Cramton, 2017).
- *Retailer ex-ante obligations* typically involve a central authority setting the volume of physical capacity that is required, which is often based on a forecast of demand and required reserve margins (Doorman et al., 2016).
- *Retailer ex-post obligations* typically involve central parties setting reserve adequacy criteria. For example, in France, the central transmission service operator is required to set a security factor—a margin to cover residual contingencies—which affects the level of the retailer's reliability obligation (RTE, 2014; Wood et al., 2018).
- *Strategic reserve mechanisms* require a central authority to determine the volume of capacity required or to develop a demand curve upon which the strategic reserve procurement takes place (Doorman et al., 2016).

3.1 The central authority—decision making and incentives

To assess the effectiveness of decision making and incentives in electricity market design, we examine market frameworks and design from the perspective of organizational architecture. Organizational architecture theory posits that there are three core elements to a system—like the three legs of a stool (see Figure 2): the allocation of decision rights to those best placed to make the decision, the measurement of that decision-making performance, and a reward and penalty structure that provides the right incentives (Brickley et al., 1995; Brickley et al., 2004; O'Connor and Martinsons, 2006; Smith, 2001; Zimmerman and Yahya-Zadeh, 2011). An effective system must ensure that all three legs are aligned so that the stool remains in balance.

[5] Schweppe et al. (1988) identified five conditions for a successful market: (1) a supply side with varying costs that increase with demand, (2) a demand side with varying demands that can adapt to price changes, (3) a market mechanism for buying and selling, (4) no monopsonistic behaviour on the demand side, and (5) no monopolistic behaviour on the supply side. Relaxation of these assumptions in a practical context means that energy-only markets with an administrative value of lost load do not have a stable equilibrium (Bidwell and Henney, 2004; Roques, 2008).

Figure 2: Organizational alignment



Source: Adapted from Brickley et al. (2004).

In a market-based coordination, such as a gross pool design, decision rights for resource adequacy are allocated to market participants. Individual market participants (generators or retailers) hold decision rights with respect to their own financial exposures. They are able to make commercial and investment decisions with respect to their own portfolios in order to manage their financial exposures and risks in the electricity market. Participants can evaluate their performance by assessing financial, trading, and operational positions, risks, and exposures. In doing so, a participant must assess its exposures with respect to a range of system conditions including peak conditions and value of lost load (VOLL) pricing. Incentives and penalties are financially based. For example, a retailer under-hedging its exposure to VOLL could incur hefty financial losses, while over-hedging may result in excessive costs. Participants are thus incentivized to strike the right balance in order to maximize financial rewards.

In theory, resource adequacy for the system is ensured if each individual participant is able to appropriately assess and manage its own risks and exposures. However, in practice, distortions and imperfections are often introduced by external policies, capital and financial markets, and fuel markets which have the potential to affect the alignment between performance measures for reliability and the incentive mechanism.

A natural question that follows is, what about centralized mechanisms? What incentives and decision frameworks influence the centralized party in exercising its functions? How well aligned is the balance between decision-making, performance evaluation, and incentives?

In deregulated markets, the central party to which decision rights are assigned is typically a noncommercial entity, such as the ISO, for which the incentives of the central authority in exercising strategic functions are indirect and nonpecuniary. A central authority faces neither financial penalties for overinvestment or underinvestment nor rewards for striking the right balance.

The penalty and reward structure is indirect in nature. There are potentially strong political pressures to avoid underinvestment and lost load events. This can lead to risk aversion and a tendency to overprotect the system—to the detriment of consumer costs and efficiency (Newbery and Grubb, 2014; Wood and Blowers, 2017; Wood et al., 2018). On the other hand, the central party may face criticism or stakeholder pressure from energy market participants if costs are considered excessive. On both sides, the incentive to act is indirect—the financial implications of decisions are not directly borne by the party itself but by others. Typically, consumers bear the ultimate financial brunt of either overinvestment (through additional energy costs) or underinvestment (through the financial impact of an unreliability or lost-load event).

If the centralized mechanism is only intended to be used on rare occasions, then perhaps this is a manageable risk and a workable market design. If, however, the mechanism is intended to be comprehensive, sustaining, or commonly used, the direct alignment between the performance evaluation and incentives takes on increasing importance. In such situations, an indirect incentive structure may challenge the efficiency of centralized decisions. This has been a major shortcoming of many electricity market reform proposals to date.

3.2 Reflecting consumer preferences

The second challenge of existing centralized approaches in electricity markets relates to the incorporation of consumer preferences in decision making. At a high level, electricity wholesale market frameworks attempt to provide the same basic level of reliability to all consumers (Kurlinski et al., 2008).[6] Many designs look to central agencies to make decisions on behalf of consumers relating to the reliability needs and safety margins of the system.

This approach is based on the assumption that both the reliability and security of the grid are quasi-public goods (Bushnell et al., 2017; Keay, 2016). When a traditional centralized grid was the only viable source of electricity, this approach was understandable and rational (Abbott, 2001) because consumers had limited alternatives. Under current conditions, in which consumers have more options for complete or partial self-supply, system security remains a (quasi-)public good, but it appears less justifiable to consider system reliability in the same light.

Security has, to some extent, both non-rivalry and non-excludability properties. A secure system is relied on by both consumers and generators, and consumption of it by some users usually does not reduce its availability to others (partial non-rivalry). Furthermore, the lack of security in one region or area has the potential to affect others (AEMC, 2017c), meaning that it is difficult for one participant to opt for a lower level of security without affecting others (non-excludability). Thus there is limited ability to differentiate between participants with respect to system security. Technically, system security is best thought of as a prerequisite to participation in a centralized grid. Economically, it is best provided by creating a price signal for products that are crucial for system security.

The concept of reliability as a public good, however, can be increasingly challenged as it relates to a balancing of supply and demand (Keay, 2016; Keay and Robinson, 2017; Kiesling and Giberson, 2004). With the introduction of distributed energy resources, the provision of energy from decentralized sources (even on the customer’s premises) is now viable. Rooftop PV, distributed storage, and energy management systems have opened up options for consumers with regards to the provision of electricity. The costs of decentralized technologies (generation and storage) are expected to reduce over time, strengthening the case for large-scale deployment. Forecasts suggest that by 2040 over 45 per cent of energy supplied in the NEM will be from decentralized sources (Bloomberg New Energy Finance, 2017). This also holds true for many other electricity markets, which suggests the potential for increased differentiation between consumers as to their supply preferences and dependence on centralized grid reliability.

Existing load control and communications technology also allows for differentiated tiers of reliability (Bushnell et al., 2017; Kurlinski et al., 2008). Some consumers may place a high value on reliability and experience high financial impacts from a lost load event, while others may be less sensitive to supply interruption. Such customers may also be able to provide a reliability service to the market via demand response schemes. Market designs should enable consumers to exercise choice and ensure that their preferences for reliability are reflected in the market on a consistent and sustained basis.

[6] For example, in the NEM, the National Electricity Rules prescribe the standard for reliability at 0.002% of unserved energy per region or regions per financial year.

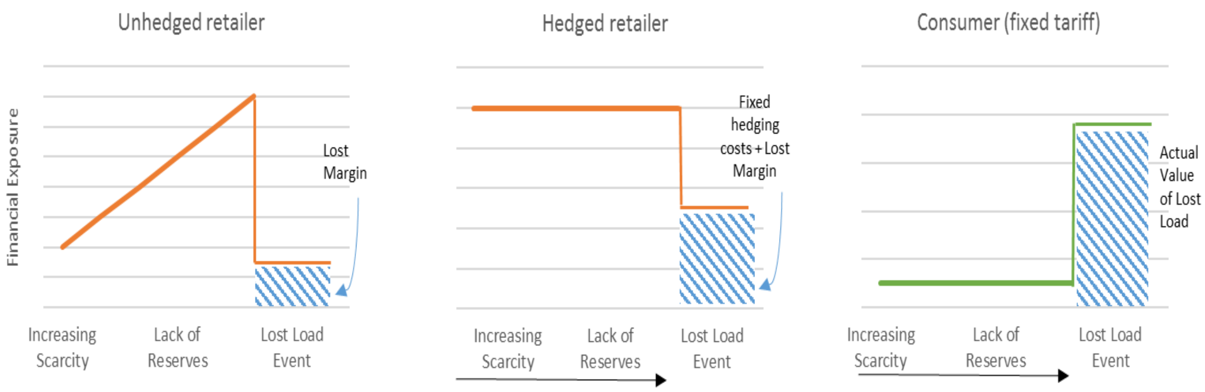
3.3 Lost load events

The third issue of existing market design is a further misalignment in the incentive/penalty regime for actual lost load events. We define lost load events, in this context, as situations where load is involuntarily shed for reliability reasons (i.e., unserved energy—where generation resources are insufficient to meet demand). This is distinguished from interruptions related to system security or the distribution network.

For retailers and generators, a lost load event means that no energy is delivered, thus consequences are limited to lost margin or opportunity cost. It is consumers that bear the financial consequences of lost load events. However, consumers, who rely on the grid, have no decision rights with respect to rectifying the issue (e.g., via new capacity). There is also no insurance mechanism to pass these exposures on to those with the decision rights and/or the ability to rectify them. The energy-only design allocates the financial impact of reliability-related outages almost entirely to consumers, without providing them the ability to manage or transfer the risk, and fails to incorporate distinct consumer preferences for reliability (Fumagalli et al., 2004; Kurlinski et al., 2008).

Figure 3 illustrates the financial exposure for consumers and market participants. Unhedged retailers would face increasing financial exposure through scarcity pricing up to the point of an actual lost load event. On the occurrence of a lost load event, the financial exposure is primarily related to the lost-retail margin. A retailer that is perfectly hedged, either on a contractual or vertically integrated basis, would be protected against scarcity pricing, and on a lost load event, its exposure would be primarily related to the costs of hedging (e.g., cap premiums paid, fixed costs of peaking generation) plus the lost retail margin. Consumers are typically protected from scarcity prices through fixed tariffs, but face losses based on the actual VOLL of an outage (e.g., activity or business interruption) (Kurlinski et al., 2008).

Figure 3: Financial exposures in a lost-load event



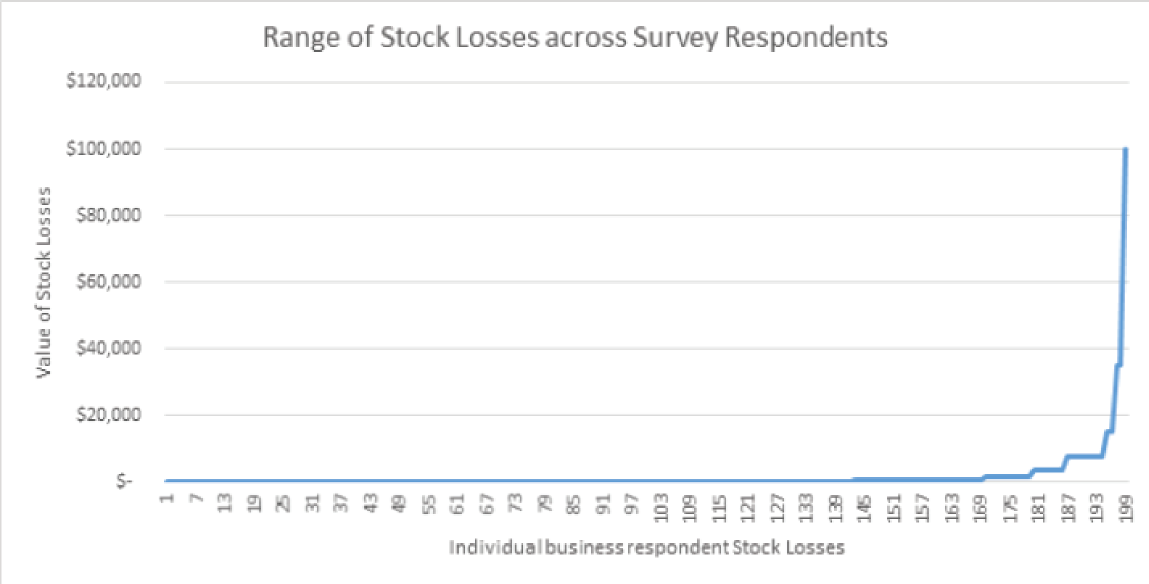
Source: authors

The 2016 blackout in South Australia provides an indication of the differentiated economic impacts across a range of participants (Business SA, 2016). While this blackout has been attributed to system security events (AEMO, 2017a), it nevertheless provides a useful case study of the value of lost load.

- Of the estimated AU$367 million in total costs, almost a third was borne by four big businesses.
- The costs of lost inventory or stock ranged from AU$0 to AU$100,000 (see Figure 4).

Electricity consumers also had limited offsets or insurance against losses. Of the businesses that had business interruption insurance, 54% were not covered and only 12% were fully covered.

Figure 4: Cost impacts of the South Australia blackout



Source: Business SA (2016).

3.4 Managing system-level resource adequacy during transition

Based on the above, we suggest four considerations for the design of appropriate mechanisms to manage the resource adequacy challenge under the electricity market transition:

- the ability to manage transition events and market shocks
- the need to reflect differentiated consumer preferences for reliability
- better alignment of loss and decision-making rights for lost-load events
- a direct economic risk framework for centralized procurement of reserve.

Overall, the incorporation of variable renewables has made system balancing of generation and demand increasingly probabilistic.

In markets where the value consumers place on reliability, and the financial impacts of a lost load event, are uniformly distributed and easily predictable, an appropriately designed capacity market might be justifiable to provide investment certainty relative to existing alternatives. However, this is hardly the case in markets that are transitioning towards more distributed and decentralized energy resources (including storage) and increasingly variable and stochastic forms of generation. In such energy systems, increasing differentiation between the value placed on reliability and the ability to manage and transfer outage risk may need further consideration.

Managing reliability in electricity markets is concerned with the operational and financial management of low-probability or tail-risk events. Risk management principles aim to transfer risk to parties best able to bear them. Risk transfer for tail-risk events often takes place through insurance arrangements (Manove, 1983). The insurer’s business model involves balancing the income from customer premiums and investment income (from its insurance asset pool) against the liability risk of payout, representing a commercial model for the management of tail risk. Insurers use sophisticated risk analysis techniques to analyse tail event probability and exposure. Further, in order to maintain viability with customers and manage risk of loss, the insurer typically maintains high creditworthiness.

Insurance concepts are already incorporated in existing electricity markets like the NEM. Energy derivative products such as options or caps are in essence a form of price insurance for retailers. Retail energy contracts can often work as a form of insurance or hedging—where customers are hedged from the risk of extreme price volatility. We propose to expand the notion of insurable risks in the electricity market to incorporate reliability concepts and protection for lost load events. The model would operate in a similar manner to social or public insurance schemes in place across a variety of event risks. Certain social insurance schemes have the dual purpose of providing financial compensation and undertaking loss-limiting activities in the sector. An example is the Transport Accident Commission in Victoria (TAC, 2017), a motor vehicle injury compensation scheme which is responsible for managing compensation but also for promoting road safety and accident prevention. By having financial exposure to losses, the insurer is naturally incentivized to limit loss events (Greyson, 2008; Manove, 1983). Mills (2003) suggested that the historical involvement of insurance and risk management industries in other sectors has aided in loss prevention, in some cases through direct investment in loss-limiting activities.

4. An insurance-based model for reliability and security

In this section, we propose a new model for electricity market design. The *insurer-of-last-resort model* is intended to promote consumer preference and overcome the challenge of centralized capacity mechanisms by introducing a financial risk and reward structure for the central authority that makes decisions over capacity and reserves.

Reliability insurance unbundles the concepts of energy and reliability, and allows consumers to set preferences for the latter. Fumagalli et al. (2004) introduced the concept of reliability insurance, in the context of distribution network utilities, as a means of overcoming existing weaknesses with respect to outage loss allocation and consumer preferences. Reliability insurance in this paper applies on a whole-of-system level, extending prior work done with respect to insurance schemes for curtailment priority (Chao and Wilson, 1987; Deng and Oren, 2001; Manove, 1983). The concept involves a commercially mandated central authority offering insurance coverage for lost-load events. Consumers have a choice on whether and at what level of coverage to participate. They would pay premiums based on the level of coverage, and if a reliability lost-load event occurred, the central insurer would provide compensation based on that coverage level.

4.1 Conceptual design

The scheme would involve the establishment of a commercially mandated central insurance company (the insurer of last resort or IOLR). The company would offer last-resort electricity interruption insurance to electricity consumers. The objective of the company would be to manage the insurance compensation scheme, but it would also be enabled to undertake loss-limiting activities in the electricity system (such as investing in new generation resources) where it is economically efficient to do so.[7]

The extent of insurance coverage—whether it includes both reliability and security events or only reliability—is a critical decision. As mentioned previously, reliability is easier to differentiate between consumers, given appropriate load-control technology, whereas security is more a characteristic of the system as a whole at any particular time. Thus we propose that the coverage is focussed on reliability events as a means of achieving resource adequacy goals. We propose that system security is more appropriately dealt with by setting appropriate pricing signals that incorporate the full range of system services—such as inertia or system strength, appropriate network development, and operational security measures (such as under/over frequency protection and relay schemes) (see Billimoria and Poudineh, 2018).

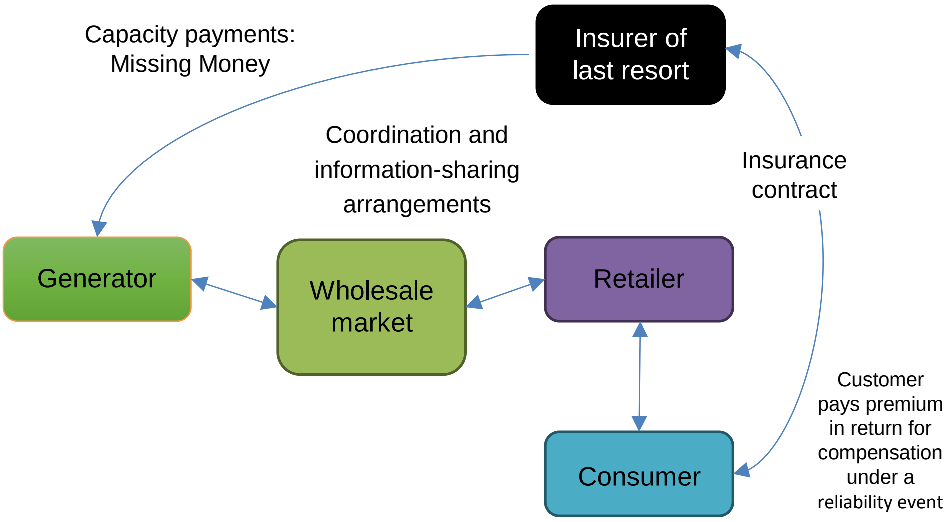
Where the IOLR observes a reliability gap, the company would be able to take steps to execute capacity contracts with new generation or demand-response resources to provide missing money (see Figure

[7] Throughout the paper, we have referred to generation resources, though this could also include demand response, energy storage, or other forms of resource addition.

5). However, its commercial focus would restrict this to situations where the capacity resource can specifically improve reliability and where the all-in cost of those contracts is cheaper than the loss-adjusted risk of payout. Faced with the question of whether it is economically efficient to add capacity at a cost of $X million in order to reduce the risk of reliability lost load by Y% (or Z hours), the central insurer would be required to weigh the cost of additional capacity contracting against the benefits of reduced reliability compensation. This removes the issue of inefficient decision making in the existing centralized approaches, such as a capacity market run by the system operator.

The insurer model works as an overlay on top of existing market signals, rather than replacing them. The insurer would be tasked with assessing the gap between what the market is naturally delivering through scarcity price signals and the energy-only design, and the levels of reliability required for the system as a whole. By doing so, it does not interfere with the current market frameworks and instead provides residual or backstop procurement where the energy-only design does not provide the required response.

Figure 5: Insurer-of-last-resort model

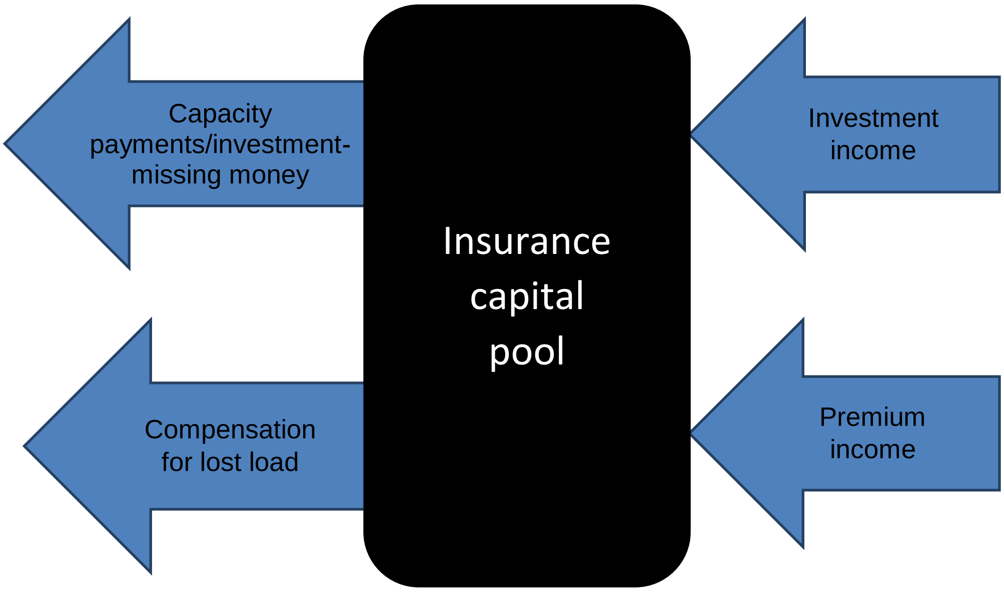


Source: authors

4.2 Business model

The business model for the insurer would involve the investment of a capital base (the insurance capital pool) and management of loss events. Primary sources of cash outflows would include compensation payments, capital investments, and payments for capacity contracts. Primary sources of cash inflows would include premium income and investment income (see Figure 6).

Figure 6: Flows into and out of an insurance capital pool



Source: authors

4.3 Price discovery process for reliability insurance premiums

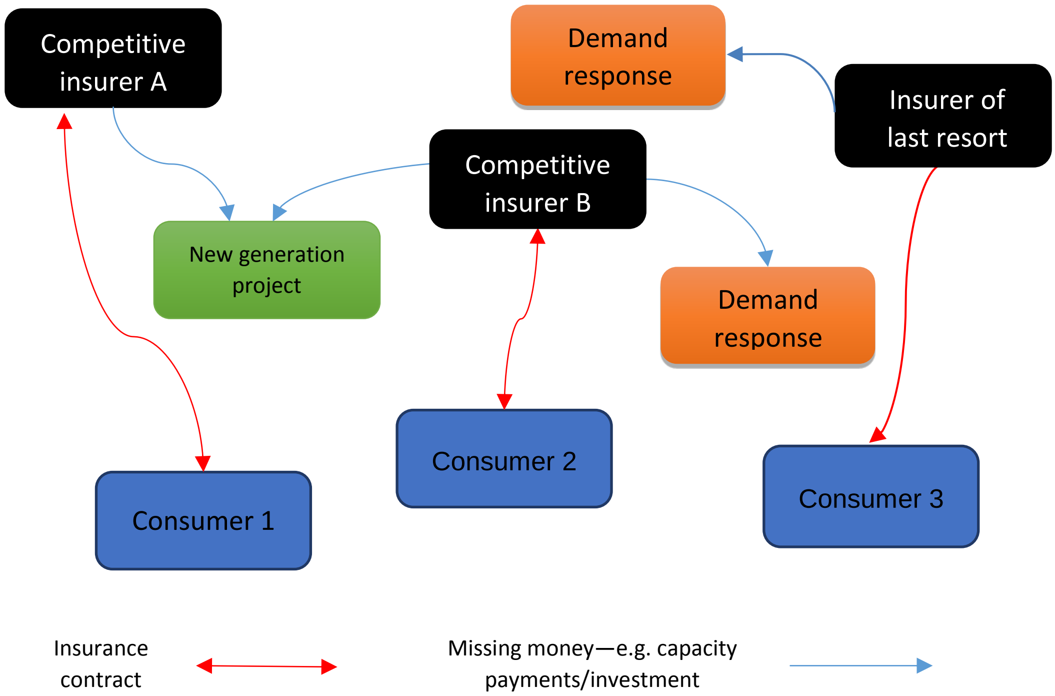
The market model of insurance is an important consideration. Although we propose the establishment of an IOLR, we do not suggest a monopoly market for reliability insurance. On the contrary, we argue that a competitive market is possible, as our model allows other players to offer competing insurance products to the IOLR (see Figure 7). These can range from commercial insurance providers to major integrated utility companies.

An important consideration is whether the insurer would be able to enter into risk management and hedging arrangements outside of the energy market. For example, would the IOLR be allowed to enter into weather derivative contracts if they were deemed to be the cheapest and most efficient alternative for hedging supply interruption risk?

There is a tradeoff here between making efficient capital allocations and preserving the preventive insurance element of the design. If the IOLR is precluded from investing in weather derivatives products, this would prevent it from limiting its losses in the cheapest manner, resulting in inefficiency. On the other hand, if the IOLR is allowed to enter into this contract, it would not be providing missing money into the electricity market that could be used to underpin new generation capacity.

In the interests of preserving efficiency and limiting market distortions, it makes sense to keep an open investment mandate for the IOLR. In any case, the investment mandate, objectives, and process for the capital pool would need to be subject to close prudential regulation, monitoring, and oversight.

Figure 7: Competitive providers under an insurer-of-last-resort model



Source: authors

As is currently done with some business interruption insurance contracts, commercial insurance providers will be able to offer coverage to consumers, who can choose between rates and coverage offered by other providers and those offered by the IOLR. These providers would compete to offer reliability insurance to consumers and to deploy investment capital into new capacity. Further consideration would need to be given to the size of the market, market structures, and competitive dynamics.

If the creation of a competitive market for reliability insurance is not possible at the outset—or the market is not ready for competitive price discovery—regulatory protections, transparency, and oversight would be required. A staged and transitional approach to a fully competitive model would also allow industry and consumers to become familiar with and educated on the new model. The level of regulatory oversight and control can vary as follows:

- The premium is set by an independent regulator.
- The premium is set by the insurance body but reviewed by an independent body.[8]
- The premium is set by the market, but the principles and rate setting are reviewed and approved by the regulator.

The approach to price regulation of reliability insurance products could be closely aligned with that of social insurance schemes currently in place. Many of these insurance mechanisms adopt rate-setting principles based on an actuarial approach which, on a generalized level, aims to ensure that the overall level of insurance premium is sufficient to cover the long-term liabilities of the compensation scheme (PwC 2000; Fronsko and Woodroffe 2017). This means that the insurance provider sets insurance

[8] In Victoria, the assistant treasurer now has discretion to request the Essential Services Commission to provide an independent review of the Transport Accident Commission's proposed premium each year (TAC, 2015).

premiums via an actuarial approach by (1) estimating potential losses (and reserving against them), (2) assessing investment returns from its asset base, and (3) quantifying the level of premium required to remain solvent and provide a sufficient return on capital (Grossi and Kunreuther, 2005; Hill, 1979; Insurance Europe, 2012). A regulated approach to premium setting would require some or all of these assumptions, metrics, and components to be reviewed and/or approved by a regulator with respect to prudential operating and loss reserving standards.

4.4 Capacity procurement and investment

This model would develop an economic signal for investment in reliability and security driven by revealed consumer preferences. The goal of the insurer is not to guarantee reliability or security, but to make economically efficient decisions on resource adequacy.

The insurer would be able to enter into loss-limiting arrangements for the purposes of improving reliability and/or security. The insurer would contribute missing money to new capacity projects that the existing market design is not able to incentivize through the energy-only design. This could work in a similar manner to capacity mechanism frameworks—with the key difference being an economic incentive structure. The type of investment[9] made by the insurer could include capacity payments, direct investment, or other forms of investment, including the following:

- new generation, refurbishment, or capacity expansion of existing plant
- arrangements to fund emergency demand response
- energy storage
- transmission interconnector investment
- funding of special protection schemes.

One of the benefits of this model is that it allows for an integrated approach to generation and transmission development. The IOLR has the option to consider funding interconnectors to the extent that this would improve reliability outcomes (either together with or as an alternative to funding new generation). Such alternatives may only otherwise be considered on a strategic basis with government funding.

Given that a new generation/capacity project has a range of potential revenue streams in the market (e.g., energy, ancillary services), the insurer would not necessarily need to underwrite all revenues of a new generation project. In other words, the insurer only provides the missing money.

The IOLR could follow a variety of approaches to capacity procurement: a formal standardized periodic tender process, a more ad-hoc and targeted portfolio-driven reserve procurement approach, or a combination of the two (see Figure 8). A more targeted approach is potentially better suited to loss mitigation, allowing the IOLR to focus on projects that have a strong chance of reducing the frequency of supply interruptions. On the other hand, a more standardized tender project could allow for more efficient pricing as result of standardization and a competitive tender process. A suitable compromise may be for the IOLR to define a set of targeted reliability criteria and run a tender that would assess projects against those criteria. An example of such a procurement process was the recent demand response pilot project conducted by the Australian Renewable Energy Agency (ARENA) and the Australian Energy Market Operator (AEMO), which involved the procurement of a portfolio of emergency demand response reserve over a multi-year timeframe based on criteria including whether the response is in regions with potential shortfalls, technology diversity, and response times (ARENA, 2017).

[9] For simplicity, we have termed any investment as capacity, though not all investments made by the IOLR have a capacity element.

Figure 8: Capacity procurement approaches

Source: authors

One of the benefits of this design is that funding from IOLR could impose obligations on the awardee relating to provision of the reserve—for example, minimum availability requirements or requirements on outage scheduling (as is often the case with existing capacity markets). Any new capacity project underwritten by the IOLR could also have coordination arrangements with the ISO to allow the ISO to enable the resource when required. This would allow some further control by the operator of the times and conditions under which these specified reserves are required to be made available (e.g., peak times for reliability reserves). This would aid the achievement of reliability goals and overcome one of the key criticisms of capacity mechanisms: that they do not capture all of the system attributes relevant to achieving reliability (Yaffe and Tabak, 2018).

4.5 Customer participation

A sufficient competitive dynamic for provision and pricing of insurance will also need to be ensured. The consumer's ability to elect coverage would mean that demand is elastic, encouraging supplier pricing discipline. An important question is whether customer participation in our proposed reliability insurance scheme should be mandatory or voluntary. Many social insurance schemes have mandatory participation, while commercial insurance is generally voluntary. Overall, we prefer voluntary participation for a number of reasons:

- It allows customers to clearly dictate preferences for reliability, including electing not to purchase the insurance product.
- It allows demand to be elastic, encouraging supplier pricing discipline and enhancing the competitive dynamic.
- It forces the IOLR (and other insurance providers) to take a commercial approach to service delivery, coverage, and pricing.
- It reduces the reliance on government regulation to keep a level playing field by encouraging a natural balance between supply and demand.

Without voluntary participation, it also becomes very difficult to specify the efficient level of compensation. This is because, in such a case, the compensation for lost load events would be based on the VOLL rather than explicit user choice. This makes the system inefficient as customers have differing VOLLs. Therefore, it is most efficient (and effective) to allow customers to elect the coverage they seek in the same way as coverage amounts can be set for other insurance schemes. Those with a higher VOLL may decide to seek higher coverage, in return for a higher premium. As is the case with other types of insurance, commercial pressures may mandate minimum insurance requirements (for example, property and infrastructure projects are typically required to obtain certain types of insurance—e.g., construction risk, operating risk, or business interruption—as a precondition to obtaining financing).

Under a voluntary participation model, consumers would need to evaluate their need for electricity during scarcity as well as the frequency of such conditions (Doorman et al., 2016). This approach has practical implications, as discussed in Section 5.

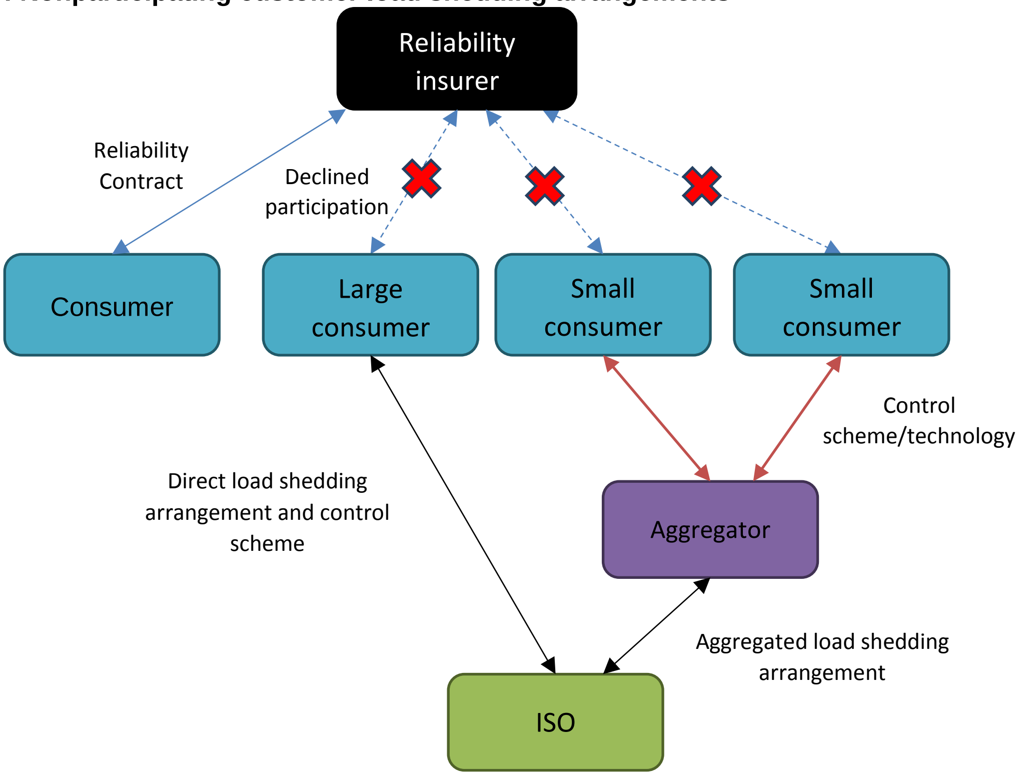
A voluntary participation model must, however, mitigate the impact of free-riding (Abedi and Haghifam, 2013; Fumagalli et al., 2004)—a phenomenon that occurs when consumers elect not to participate in the insurance mechanism but benefit from preventive actions taken to benefit those who do participate. For example, a consumer may elect not to take up reliability insurance but may benefit from improved reliability resulting from preventive measures undertaken by the IOLR (such as providing capacity contracts for new resources).

Measures are available to mitigate the impact of free riding on the reliability insurance scheme. Customers that decline to participate would then form part of a load shedding scheme and be available for disconnection by the system operator during a reliability event. This could be implemented through protection schemes or through coordination with demand response aggregators or administrators. A customer would need to have smart metering and control technology installed and a line of communication (either direct or indirect) to the system operator (see Figure 9).[10] Some customers may be able to self-protect (e.g., through distributed energy resources or storage) or may already be part of demand response schemes with this technology already deployed. The participation election would need to be made in advance in order to allow for resource coordination. Furthermore, customers that decline to participate would need to be fully informed and educated on the implications of nonparticipation.[11]

[10] Smart meter and load control technology already enables customers (either directly or through an aggregator) to provide contingency frequency control services—essentially through an interruption to all or part of their load. Over 180 MW of response is already actively participating in contingency markets in the NEM (Grover, 2018).

[11] Abedi and Haghifam (2013) also suggest that alternative contract structures may be able to mitigate against 'free riding' issues. However, these structures are catered towards an integrated distribution utility and may be less relevant in contestable retail markets.

Figure 9: Nonparticipating customer load shedding arrangements



Source: authors

4.6 Business objectives and ownership base

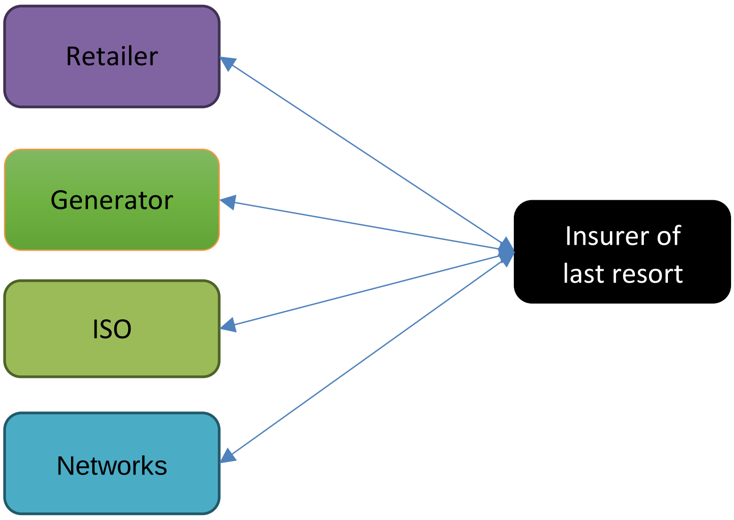
The insurer is initially funded through capital contributions from its ownership base. The determination of the ownership base is an important consideration. The potential universe of capital contributors includes governments, energy market participants, commercial insurance providers, and external investors. Government ownership must involve clear governance protocols to prevent political or government intervention in the insurer's business model and decision-making process (Fronsko and Woodroffe, 2017). Energy industry participants may also have an important role in the ownership base, as would the insurance industry, which would be able to add sector and risk management expertise. Commercial funding would require that a sufficient commercial rate of return is built into the financial and revenue structure. Ownership of the insurer by its policyholders may also be possible via a mutualised structure. This would mean that excess profits would flow back to policyholders, which in this case would be energy consumers.

The vision, objectives, and governance structure should be focussed on the independent, commercial provision of services. Important issues for consideration include stakeholder engagement, board structure, and independence and oversight.

4.7 Information and transparency

In order for the reliability insurer to make informed assessments of tail risk probability and magnitude, an open and transparent information exchange needs to take place between the insurer, the system operator, and market participants (see Figure 10). Thus, this model relies on information-sharing protocols between these parties. From an information and assessment perspective, the central insurer's role would be similar in effect to the role of a central capacity market procurement agency, which in many jurisdictions is the system operator itself. Lack of transparency would make it difficult for an IOLR to assess gaps in resource adequacy and price the insurance product efficiently.

Figure 10: Coordination and information-sharing protocols



Source: authors

The NEM provides an example of how transparency of information can enable implementation of this model. First, the AEMO provides a range of demand and availability forecasts on a short-, medium-, and long-term basis to guide participants (AEMC, 2017b). Second, a detailed and comprehensive database is made publicly available with information on bidding, dispatch, and availability of all wholesale generation and demand (AEMO, 2018a). Third, the public regulatory determination process and regulatory investment test framework provide transparency on network augmentation. Finally, AEMO periodically provides assessments of demand and supply balance (AEMO, 2017b, 2018c). The ISO is naturally incentivized to share information with the IOLR, as the reliability insurance scheme is complementary to their role. Additional measures such as notice requirements on retirement and withdrawal of capacity (AEMC, 2018a; Nelson, 2017b) may be necessary to provide sufficient transparency for the IOLR to be able to operate its business model.

5. Implementation, complexity, and political challenges

There can be two key criticisms of this model. First, some research suggests that electricity consumers don't want this level of choice. In the NEM, Stenner et al. (2015) assessed potential consumer take-up of cost-reflective tariffs and argued that consumers have an aversion to making any sort of choice. AEMC (2018b), Wood et al. (2018), and Wood and Blowers (2017) further suggested that consumers view the market as too complex as it is, and may not respond well to further price complexity. This is an important issue not just for this design, but for contestable retail markets more generally. The approach to educating consumers and implementing their preferences would need careful management. It is likely that, at least initially, most small consumers (residential and small-to-medium enterprises) would be best served by having some insurance coverage, given the need to have load shedding protocols in place. The retailer could undertake the billing and pass the insurance premium on to consumers as part of their retail bill, without the need for separate correspondence or engagement. Over time, as options for self-supply and backup power emerge (either individually or on an aggregated basis), consumers could be progressively educated as to their alternatives. This could also be perceived and marketed as a way for consumers to reduce their overall bill. This would be a key part of the implementation of this type of scheme.

For some consumers, it may be more appropriate for this scheme to be canvassed as part of a broader insurance discussion. For example, energy-sensitive businesses could examine reliability insurance as part of their overall business insurance arrangements. A careful, coordinated, and staged approach to consumer engagement and education is required for robust implementation of this scheme. Arguably, however, this is increasingly required in the market in any case, given the growth of distributed energy resources in the grid (Gangale et al., 2017).

Moreover, the application of reliability insurance in electricity markets is not new, and consumers are becoming familiar with these initiatives. The reliability insurance concept was initially applied to an integrated distribution utility model, where the distribution utility would effectively serve as the insurer with respect to distribution network events. This would guarantee a specific quality of service at the network level and incent utilities to make investments in network reliability. This concept has been adopted by many markets around the world, including Australia. Distribution network service providers in the NEM have implemented this concept through guaranteed service levels, which allow customers to claim compensation if specific reliability metrics are not met (ESC, 2015; QCA, 2014). Customers are able to opt for different levels of service, and this is reflected in the charges they pay. The model can be readily adapted for other electricity market segments such as wholesale markets (Fumagalli et al., 2004; Wilson, 1997).

The second criticism is that politicians are often reluctant to make energy policy that allows for differentiation between reliability service levels across consumers. While this might be true in some places, in other places such schemes are already established. For example, trials currently underway in Western Australia aim to allow consumers to select different levels of service with different pricing implications (Horizon Power, 2017). The Horizon Power Ahead program is a pilot project in Western Australia that tests consumer engagement for different pricing models. Consumers are offered discounts on their electricity bill in return for keeping usage below a certain level.

The ARENA-AEMO demand response program provides another example of how alternative procurement and pricing models can encourage consumers to play a role in reliability. The pilot project procured 200 MW of emergency demand response over a three-year period, based on a pricing structure that had fixed and variable elements. Under emergency or reliability conditions, the system operator could trigger these demand-side resources with either 10-minute or 30-minute notification.

There are also suggestions that, in some circumstances, energy consumers may be willing to take on increased outage risk. For example, a recent submission by the Energy Users Association of Australia stated, in response to the recent exercise of strategic reserves function in the NEM, that 'members now faced with very large bills are saying that they would have preferred the risk of them having an interruption to their power supply than pay the amounts they are now asked to' (EUAA, 2018).

The issue of equity (which is a concern of policy) can also be better dealt with in this model. A conventional capacity market can lead to inequitable distribution of system fixed costs among different classes of consumers. However, in our model, those who benefit more from system reliability of the central grid have more incentive to protect themselves from interruption and thus contribute more towards the cost of reliability provision. As with regard to affordability, it is an issue that exists irrespective of the market design. We do not advocate distorting a price signal to address affordability. The government can offer a discount for reliability insurance to fuel-poor consumers, similar to existing schemes such as the Warm Home discount in the UK, where some consumers receive a one-off discount on their electricity bill during the cold months.

Overall, however, the applicability of this scheme will depend on how engaged consumers are in the market in question, and how ready to make such choices. Hybrid solutions that offer reliability insurance alternatives to the more engaged portion of the consumer base (such as businesses) and centralized mechanisms for the remainder may also be possible.

6. Conclusions

Existing energy-only market design has faced a number of conceptual and practical challenges under the recent energy transition. Increasingly, the response of many jurisdictions faced with these challenges is to incorporate centralized capacity mechanisms to deal with potential shortfalls in resource adequacy under a market-based approach.

However, capacity procurement by a noncommercial central entity presents its own challenges and inefficiencies. First, it puts increased focus on the efficiency of central authority decision making and the alignment between performance outcomes for reliability and agency incentives. Second, existing capacity mechanisms require the central agency to infer consumer preferences for reliability which is a very challenging task in practice. Moreover, the existing market arrangement allocates the financial impact of reliability-related outages entirely to consumers, without providing them the ability to manage or transfer the risk.

We propose an *insurer of last resort* model that would incorporate insurance-based risk management concepts and allow consumer preferences for system reliability to be directly incorporated into centralized resource adequacy decision making. This would serve as an overlay on existing market design with the aim of aligning incentives for centralized decision making and allowing revealed consumer preferences to guide new capacity deployment. Key issues that will require attention include the extent of coverage, regulatory model, and governance. Competitive models of insurance provision may also emerge to enhance competition in prices and coverage.

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