Electricity Supply in a Commodity Market Structure

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Electricity will come increasingly from renewables such as solar and wind. These technologies are disruptive with near zero greenhouse gases, near zero cash cost and often subsidized capital costs. They are being introduced into a standard commodity market structure, with quite different qualities and cost structures.

This paper examines commodity market structures using a novel graphical approach to relate Price and Supply with an implied Demand point.

From this analysis prerequisites for a successful longer term market structure are developed. These conditions are compared with a changing electricity market. New market structures are proposed.

In macroeconomics Supply and Demand are shown in Figure 1 on a two dimensional basis, with an implied Price point.

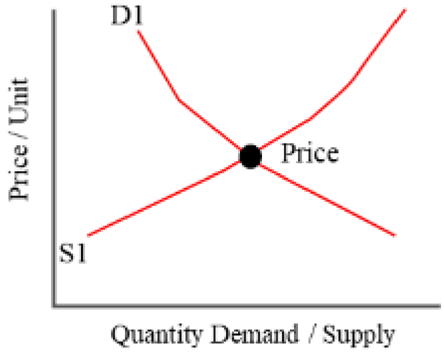

Figure 1. Traditional Relationship between Supply, Demand and Implied Price.

Using ceteris paribus, with all other things being equal, particular changes are examined, one step at a time.

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This methodology gives a broad overview, but does not always describe conditions close to the intersection, as the level of inventory (and demand) can have an effect, as shown in Figure 2.

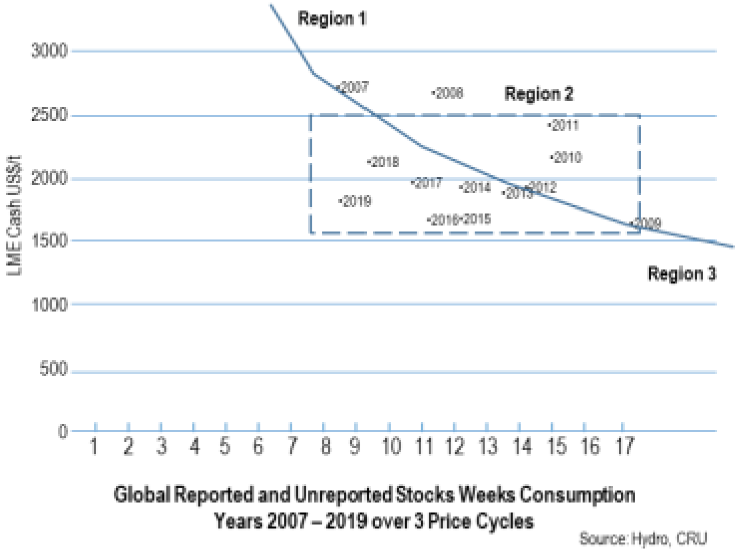


Figure 2. Changes in Inventory Levels and London Metal Exchange price for Aluminium in the period 2007 to 2019

In Region 1

Stock levels are low and demand largely determines the price. This situation can arise either by a dominant company or companies controlling supply or due to capacity shortages in the short term.

In Region 2

Supply is greater than demand and the price is not sensitive to inventory levels This is the usual situation. The price is then determined by an auction, with supply dependant on the cost of production and other less significant factors.

In Region 3

There is excess inventory and producers are price takers.

I Well established Mineral Commodity Markets

The history of these markets is one of moving from producer pricing to contracts and more recently to spot pricing. An outline is provided by Crowson (2013) is described in Table 1 for a range of metal commodities.

Iron Ore	Until the mid-2000s most trade was based on longer-term contract prices. In 2007, an especially large gap opened up between the spot price and the benchmark contract price as demand outstripped that of supply. Producers increased supply of the spot market. This started a move to negotiate existing

	contracts and to trade on the basis of shorter-term contracts or in the spot market. The move to spot sales accelerated from the end of 2011 as the sharp fall in the spot price at that time encouraged buyers to push for contracts to be renegotiated to shorter terms. More recently, the spot price has increased due to increasing demand.
Aluminium	Initially the dominant company set a Producer price and others followed. The US Producer price (Alcoa) was dropped in 1986. Then Alcan's World price then became the yardstick for prices outside USA. London Metal Exchange (LME) spot pricing began in 1979 and has progressively superseded producer pricing globally.
Copper	Central Africa and Chilean producers set a producer price between 1961 and 1996, when this collapsed. Most sales outside the USA have subsequently been based on spot LME prices. Within the USA producer pricing continued well into the 1980s.
Nickel	International Nickel posted its world producer price until Dec 1987. LME quotations began in late 1978. For much of the 1970s there was heavy discounting from posted producer prices, and the free market prices were more reliable guides to transaction prices. LME spot quotations now dominate.

Table 1. Basis of Iron Ore, Aluminium, Copper and Nickel Prices

This paper provides a graphical approach of relating Price and Supply and an implied Demand point relationship. It has proved to be robust even when global demand has increases by 50% for aluminium and 32% for iron ore in the period 2007 to 2019. This method is quite different to the mathematical approaches taken in Knittell and Pindyck (2016) and Math (1961). The approach builds on the initial frameworks outlined in Crowson (2013), Department of Treasury (2014), and Cunningham (2019) and draws out key requirements that are needed for a stable commodity market.

Under these conditions it is useful to compare the supply curve based on the cash costs of all producers, plotted on a 100% capacity basis, and prices over many years as shown in Figure 3. Usually the all in cash cost including sustaining capital is used. The implied demand point is approximated where they meet.

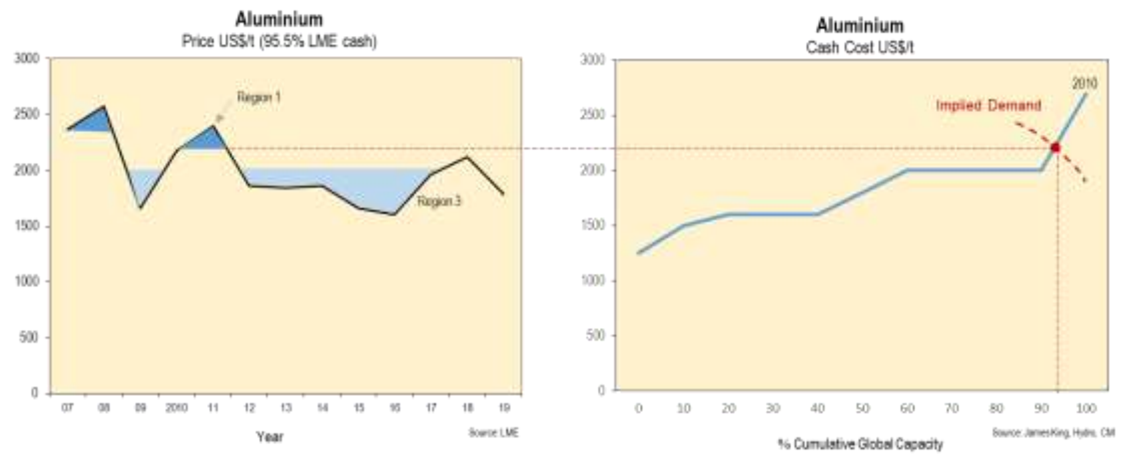


Figure 3. Price and all in cash cost curve for Aluminium for Year 2010

The relationships are also illustrated for multiple years by Figures 4 for aluminium and Figure 5 for iron ore, Figure 6 for copper and Figure 7 for nickel.

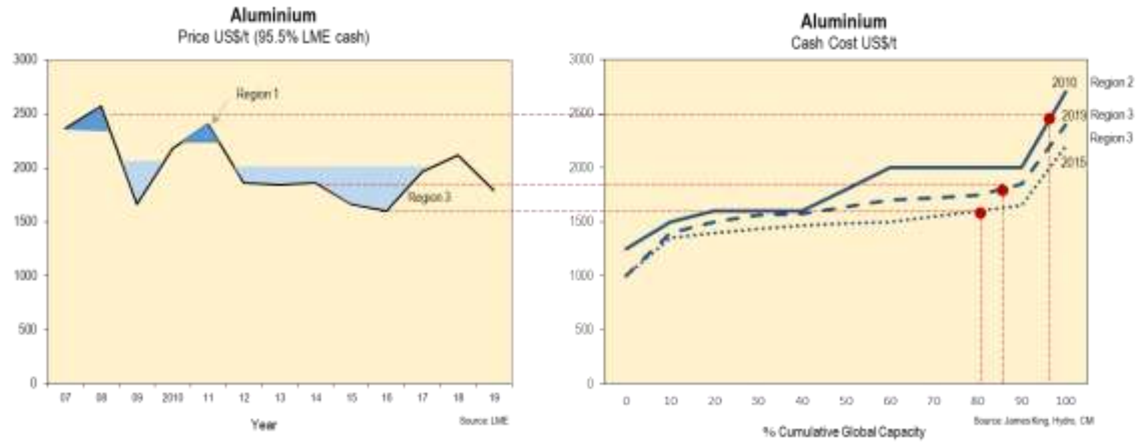


Figure 4. Price and all in cash cost curve for Aluminium for Years 2010, 2015, and 2019

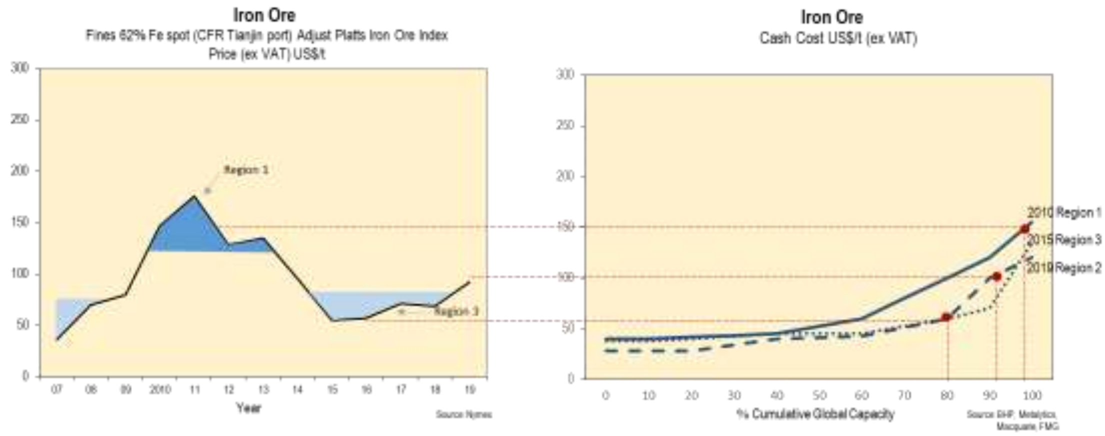


Figure 5. Price and all in cash cost for Iron Ore for Years 2010, 2015, and 2019.

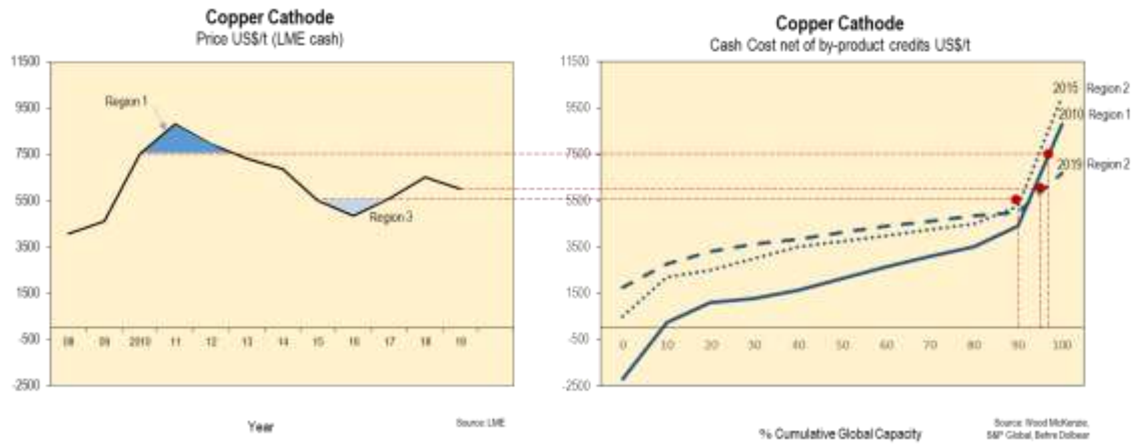


Figure 6. Price and all in cash cost for Copper for Years 2010, 2015, and 2019

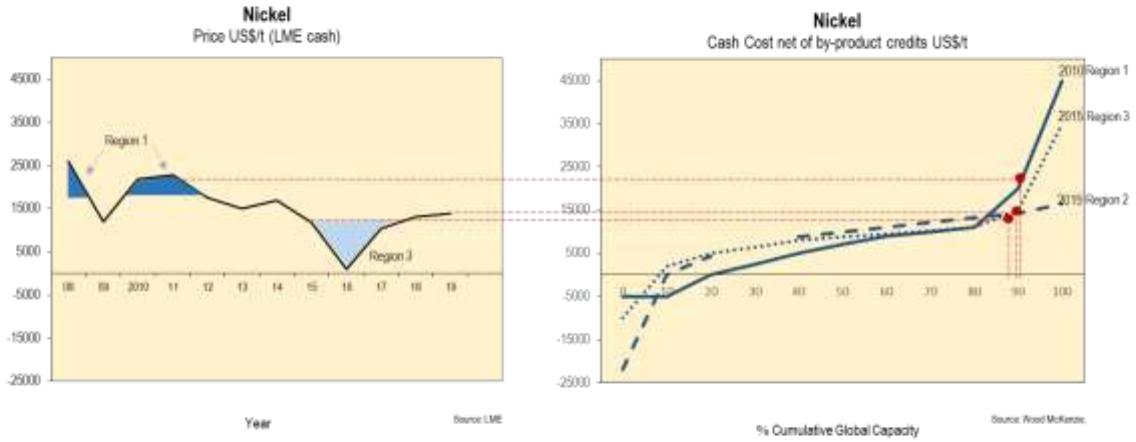


Figure 7. Price and all in cash cost for Nickel for Years 2010, 2015, and 2019

On inspection, when inventories are in balance, prices generally are in the range of 90% of Global Capacity. Higher and lower points on Capacity curve arise when inventories depart from normal levels. The capacity point defined by the implied demand, including inventory effects, can range up to 100% when demand is high and inventories low and down to 80% when demand, due to changes in global GDP, and inventories. Generally an excess of at least 10% longer term capacity and 5% in inventories is needed so as to maintain the market stability.

Another perspective on the relationship between price and costs at 90% along with capacity utilisation curve can be obtained by examination of the relationships for copper and nickel over long periods when LME pricing was well established. Results are shown in Figure 8 for copper and Figure 9 for nickel. These graphs show a close relationship, except when there is a shortage of inventory in Region 1. For these commodities, the relationship is steady, even as costs have increased due mainly to decrease in the quality of ore bodies being mined, or as in nickel, alternative routes to develop a nickel in product are developed.

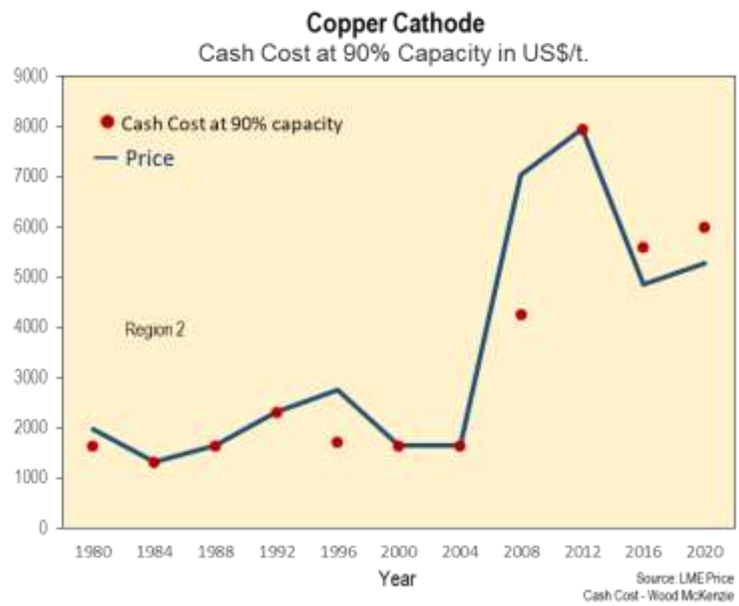


Figure 8. Relationship for copper between price and cash cost at 90% capacity.

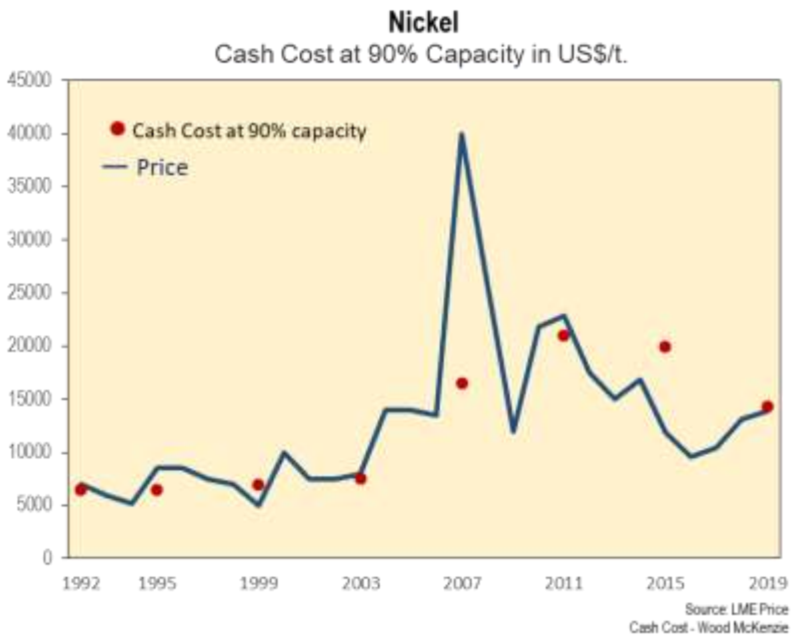


Figure 9. Relationship for nickel between price and cash cost at 90% capacity.

II Characteristics of Global and Regional Commodity Markets.

Clearly the above commodity markets have remained competitive for many years, and most trade is via these markets. Kominers (2020) provides a basis for such markets.

On analysis, these markets fits his criteria as the market place structures have a focus on improving efficiency, liquidity and fairness. In addition these markets are organised with market places that combine rules for participation and infrastructure to facilitate interactions and transactions.

Key characteristics of these market structures include

- They are centred at freight hubs, so that prices include freight.
- The attributes of the product are clearly defined. Limited Quality changes are included, and can be assessed based on a value in use, for example 99.5% and 99.7% aluminium.
- Generally, there is an excess of capacity such that the market can work over the price cycles.
- All lower cost producers endeavour to maximize production, so as to reduce fixed costs.
- Over many years, gradual and step improvements have been made by some existing and all new entrants. The reduction in cash cost has often negated the effects of inflation. On this basis, comparisons can be based on historical prices.
- New entrants, with sufficiently low cash costs have been able to enter the market while justifying their capital costs, whilst some higher cost producers have gradually exited the market.
- The shape of the cash cost curve close to global capacity is generally steeper than in the main part of the curve. In this region there are a number of small disparate producers. It takes some time before highest cost producers exit the market due to the cost and complexity of closure.

- There is sufficient transparency such that speculation, hedging and controlling inventory levels do not influence the market signals significantly when there is sufficient inventory, and if it occurs can be rectified.
- It is generally possible to identify the maximum capacity of the total producers in the market.
- There are no dominant cartels producers who can influence price upwards or dominant customer cartels who can influence the price downwards.
- The market rules are transparent and covers the majority of trade of the commodity.
- Trading through the market usually results in the best option for both buyers and sellers.

III Future Directions of these Commodity Markets

There will be possible changes in the future due to

- Future cost reductions of the higher cash cost producer may not be greater than inflation. In this case prices will rise as is evident in copper and nickel.
- The high capital costs of new Western plants, with increased costs to meet sustainability objectives, may not be justified by the margin available from the market.
- Changes in the broader exchange rates, preferential tariffs, government distortions to preference particular producers, production technologies or particular consumers that could distort the market and lead to reduced production.
- The emergence of new markets for new products, such as Low-Carbon Aluminium or steel produced from hydrogen, will require imposition of an ideology and regulatory constraints. It is likely that separate markets will evolve to trade these products.
- Introduction of other factors that differentially influence the costs, such as disruptive technologies with different product qualities, externally imposed regulations and support for environmental, political and other market regulations. In some cases, this will create a complex market that does not have a clear focus.

If these changes are large, the ability of the market to operate in a fair and transparent manner is impeded. In this case, participants will lose confidence in the market and others forms of market will evolve.

A market becomes complex when it is managed to try and balance a wide range of different and competing interests. This form of market becomes a rule book of regulation and compromise. In time it will become unstable and will collapse through inadequate investment in some of the less attractive products that are needed by customers but are not favoured by the ideology.

In Australia at present there are a number of examples of Complex Markets for commodities. These include East Coast gas, where gas is in short supply influenced by environmental issues of fracking and even conventional exploration and development. In these cases, governments are limiting development based on perceived effects on the water table. This in turn is affecting the availability of gas for peaking power generation. Another is the management of the Murray Darling Basin water flows through the creation of a market for water that is intended to balance environmental flows of two quite different river systems, and a variety of farming interest.

A third market is the National Energy Market (NEM), which is discussed in detail.

IV Future Electrical Markets

The electricity market in Eastern Australia, NEM, is now governed by a multitude of rules such that the definition of the market is unclear and is at a breaking point. The Energy Security Board (2020) notes ".. the energy system is changing. .. Rapid changes are underway. ..There is uncertainty as to whether the existing mechanisms are sufficient to support the needs of the system. Similar changes occurring in Australia and the adoption of distributed rooftop solar photovoltaic systems is remarkable. This means that the changes to the NEM design are likely to be the first in the world to meet these needs."

The present NEM market has evolved from State based simple order of merit cash cost dispatch models. Facilities were operated mainly by State Government instrumentalities to supply hubs close to major industrial load centres. Key features were:

- An operating philosophy of supplying low cost base load power for Process Industries so that they could develop and supply international markets. This then provided the electrical infrastructure to supply the Commercial and Residential customer base in an economical manner.
- The Process Industries include mining, mineral processing, smelting as well as paper, fertilizer, petrochemical, oil refineries, fertilizer works, building products and associated services and transport. When started, these industries were world scale and world class. They are exposed to the commodity markets discussed above as well as oil and gas markets. As customers they dominated the demand from the electrical market, although pricing was not always transparent.
- The State Government entities optimized their total system so as to reduce supply costs while providing capital for further expansion, and
- Australian power costs were reasonable and based largely on base load coal fired generation, with some non-export gas for short term back up and some hydro generated in Tasmania and in the Snowy tied in with water developments.

From the 1980's the systems evolved as some Governments privatized (or corporatized). The systems were separated into generation, transmission and retail distribution. The state systems gradually became interconnected for security of supply reasons, but limitations in the grid have led to different hub prices.

Starting with the initial privatizations of base load coal stations in Victoria the original few companies each adopted a similar strategy so as to improve the then low availabilities of their generators. These actions were successful and world standards were obtained. The overall effect was to create a surplus of capacity. When the operators bid for power within the existing order of merit system the resulting price for most of the time was usually set by the highest cash cost producer. Some peak demand was determined by the costs of open or closed cycle gas generation.

In time, the single generator and transmission model changed with the emergence of a few large entities controlling the market. A few now have large base load coal generators, some smaller peak load gas generators, and some solar generation. Hydropower is supplied by Government entities.

The market continued to evolve with:

- Some fuel sources including black coal and gas have been linked to world market prices to justifying bidding practices.

- At times bidding prices have fluctuated widely both in the short term and on a daily basis. These prices have not been related to cash cost of supply, and are generally a function of the market design.
- Some bidding practices appear to be unsatisfactory. This includes exerting market power across entities and with generation mix optimization. In addition, hydropower, with a very low cash cost, sets the price from 10 to 30% of the time, at a significant price. Australian Energy Market Operator.(2017-2020), and
- A recent push to introduce major disruptive technologies based on weather dependent renewable solar and wind power, with near zero cash costs, has been encouraged by governments so as to lower greenhouse gas production. Subsidies and preferential treatment have been introduced. Under some subsidies they are profitable and encouraged a rapid buildup.

  However, regulation of these intermittent renewable sources has not kept up with necessary changes in the grid and the market.

Future trends include:

- Generation of base load power from coal will continue to fall in the next ten years from approx. 85% to 67.5% on a generation basis and to 49% on an installed capacity basis. This results in the power profile generated from coal changing such that in the middle of the day some has been provided by an increasing level of zero cash cost solar and wind power. As a result, there have been some major system breakdowns, outages, loss of efficiency and increased emissions as the coal (non-load following nuclear technology would be similar) produced using a high temperature burning process is not suited to large daily fluctuations in load.

  The phasing out of the coal fired base load stations and the need for back-up power is illustrated in Figure 10(a) and 10(b). Aurora Research (2019).

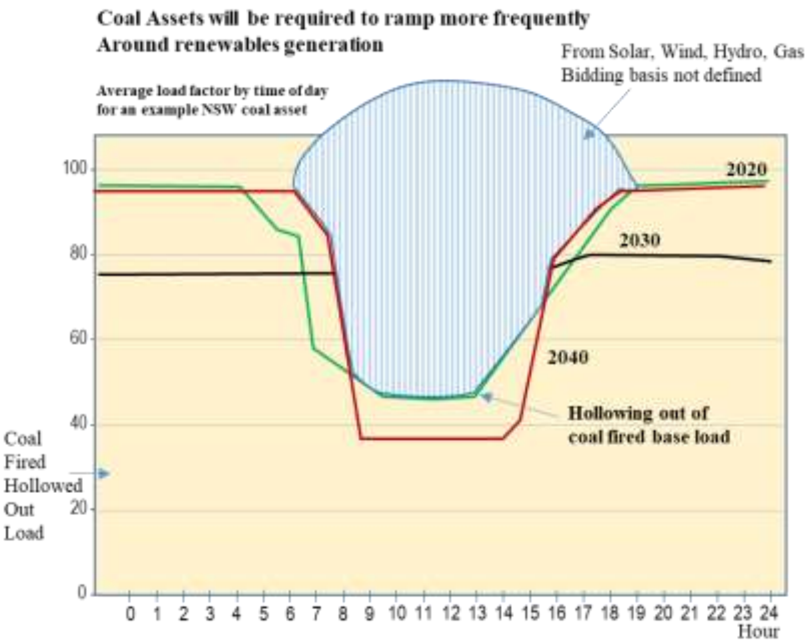
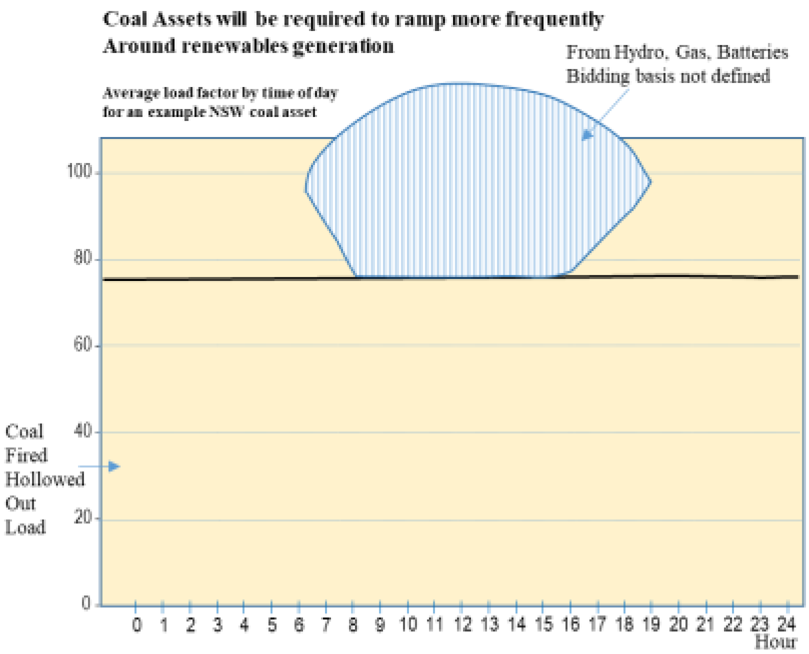


Figure 10(a)

Ramp of Coal Fired Generation when Days are Sunny and Windy



Source. Estimate by author

Figure 10(b)
Steady Coal Fired Generation when Days are Cloudy and Still

This hollowing out also leads to an increase in outages for coal fired generation as well as n a significant loss of revenue. This will change even further in the coming years and will bring forward major closures of this equipment, without satisfactory alternatives in place. All operators appear not to be spending capital in step wise improvement of assets and performance. This deterioration is also apparent in other Process Industries which have a similar age assets in minerals and petrochemical industries, but are losing confidence in the NEM market.

Transmission has also become a limitation as solar and wind are often not generated close to existing electricity hubs. There is also now a need for electricity to flow both ways on transmission lines in the same day, resulting in additional costs and complexity. Also allocating costs to particular generation types is difficult.

In the future, there will be much larger requirement for storage (i.e. inventory) systems. With a very limited ability to store electricity, apart from hydroelectricity, and the present unreliability of base load generation, present and projected base load installed capacity is not nearly enough to guarantee a stable and transparent market.

Types of storage use, period and possible charging mechanisms for weather dependent renewables are shown in Table 2.

Type AEMO (2020).	Purpose AEMO (2020)	Period McKinsey (2016)	Possible bid basis	Charge to
Shallow	Capacity, Ramping,	Up to 2 hours (batteries, inertia).	Service and design out the	Specific to specific entrant

	Frequency and voltage control, so as to avoid instability		present peak prices being applied.	
Medium	Intra-day shift from peaks	4 hour (batteries). 6-12 hour (pumped hydro) 2-3 hour (gas)	Peak lopping driven both in Demand and Supply side management	Averaged over all weather dependant renewables. Market signals are not clear. Charging time of day pricing for Commercial and Residential consumers needs to be implemented.
+ Transmission	Interconnectivity of grid			Averaged over all weather dependant renewables to and from hubs.
Deep	Long periods of lower than expected down turns of weather dependent renewables	24 hour (pumped hydro) Flow systems		Policies required to optimise and charge energy deployment .
+ Transmission	Interconnectivity of grid			Averaged over all weather dependant renewables

Table 2 Storage characteristics

In most circumstances the larger time storage systems are not yet proven or economic at sufficient scale. The "hope" to date is that these systems will be absorbed by the total market, or that the capital costs will be subsidised or paid by government. However the rules of bidding are not clear or agreed.

As examples,

- The regulator is endeavouring to force an obligation on the base load coal generation operators not to shut within a 42 month period. However there is no obligation (subject only to transmission capability) on intermittent power supply to provide any level of storage over the daily cycle and they can bid on a 5 minute window.

- The hollowing out of base load generation is resulting in negative power prices as these stations bid to stay on line. This is a distortion of the market that gives unrestricted access to intermittent weather dependent sources, even though the market needs to encourage the provision of more storage.

- Control of some market failures through the use of over generous caps on prices.

- The wide variety of Governments giving favourable treatment to specific suppliers, or systems, with incentives or capital cost relief, distorting the basis of competition (and the ultimate fate of the market).

- The present system rewards poor operating performance of individual and collective generators as lost revenue is sometimes more than compensated by price increases on lower supply.

Due to these imposed regulations, the market has responded with very high or very low power prices, leading to considerable threats to the viability of most globally exposed Process Industries. These industries collectively employ up to 250 000 direct and indirect employees. However it is not apparent that in the future NEM design the impact on these industries is being assessed.

With a lack of clarity in the shape and complexity of the future market, misleading signals are being sent to existing and future players and consumers. Without a concept of the future market structure, and a concept of available capacity, it is also impossible to define the future basis of completion.

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IV Options for Change

Currently, there are multiple attempts to adjust market rules through more regulations so as to avoid the most recent emergency. Few of these regulations are customer focused or recognize the nature of the customer base. However, there is no longer term solution to address the issue that there is insufficient Capacity and Storage to ensure that the market is driven by costs, as is normal in a balanced mature commodity market.

The longer-term solution must recognize the two different types of supply and two different customer demands. At present, and possibly in the future depending on competitiveness, Process Industries and associated services represent 50% of the total use of electricity and require steady 24 hour 7 day week base load electricity. Kjar (2019). This aligns with base load power generation of 67.5% and declining as process industries close due to power prices that are not globally competitive. The remaining Residential and Commercial market is variable and operates largely during the day. This aligns with future generation using renewables, supported by batteries and hydro during the shoulder and night periods.

It would appear sensible to restructure the market into two. Base load would be regulated and centred on competition based on cash costs of production, with requirements on performance and improvements. Weather dependant renewables would be based on a separate regulated market that recognized that most of the supply has near zero marginal cost of production and considerable changes to storage and transmission is required. There would be limited interaction between the two markets. This would also allow each market to be subject to appropriate emissions controls or taxes, matched to customer outcomes.

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