Environmental markets, financial markets, and experimental economics – some Australian perspectives

Some thoughts on environmental market design, including a preliminary discussion of an experiment investigating the MRET market conducted jointly by the University of NSW (Sydney) and George Mason University (Washington DC)

Prepared for the SIRCA Business Breakfast Briefing program.
10th December 2003

Karel Nolles
Manager, Environmental Markets, Australian Financial Markets Association
SIRCA PhD Scholar, UNSW
Director, Aton Consulting Pty Ltd

karel@aton.com.au
P.O. Box 539, North Ryde, NSW 1670 AUSTRALIA
Level 31, ABN Amro Tower, 88 Phillip St, Sydney

Table of Contents:

Thanks and Disclaimers:

The work discussed in this paper is a combination of material prepared in my role with the Australian Financial Markets Association (AFMA), my private consulting capacity (via Aton Consulting), and work (mostly the experimental work) conducted in my capacity as a PhD student at the UNSW.

Unless otherwise referenced all opinions are my own, and do not reflect the policy of any of those organisations.

My thanks for the financial and in-kind support allowing the development of the experimental software and the conduct of the experimental runs both here and at the George Mason University labs are extended to (in alphabetic order).

- Assoc. Professor Michael Briers, CEO of SIRCA
- Professor Branko Celler, Head of School of Electrical Engineer, UNSW
- Assoc. Professor Hugh Outhred, School of Electrical Engineering, UNSW
- Professor Stephen Rassenti, Director,
  Interdisciplinary Centre for Economic Science, GMU
- Professor Greg Whitred, Dean, Faculty of Commerce and Economics, UNSW

“The design and conduct of auctioning institutions has occupied the attention of many people over thousands of years. The Greek historian Herodotus, who described the sale of women to be wives in Babylonia around the fifth century B.C, gave one of the earliest reports of an auction. During the closing years of the Roman Empire the auction of plundered booty was common. In China, the personal belongings of deceased Buddhist monks were sold at auction as early as the seventh century A.D” (Milgrom and Weber 1982)

1 Why apply experimental economics to the environmental markets?

As the quote above makes clear, markets and auctions have been in use for millennia. It is somewhat surprising then to realise that the theory of market design and behaviour remains a considerable distance behind the practice. In major market reform processes, such as electricity, policy makers have had to make “best guesses” between a bewildering array of possible design decisions, without having clear theory to guide those choices. The considerable differences in structure between different electricity markets around the world is testament to what (Surry 1996) only slightly facetiously referred to as the “great electricity experiment.”

This theory lag is discussed with some elegance by (McMillan 1994) in the context of the US Spectrum Auctions[1]. “Theory has limits” he writes, and further “theory sometimes shows that there are effects that work in opposite directions from each other … and implementing a particular theory may require information that is unavailable.” In the absence of a developed discipline of “Market Engineering”, capable of predicting market performance “post-construction” with a similar level of forensic certainty as that expected from Civil Engineers when constructing bridges, the use of experimental economics techniques to test market performance before going “live” should be an important part of the policy maker’s toolkit.

Since the early 1980’s the use of “market based instruments” to facilitate least cost implementation of environmental policy has become relatively popular. Active academic discussion of the application of environmental markets commenced in the early 1970’s, with theorists such as (Montgomery 1972) outlining the potential efficiency benefits of such markets.

Although a significant number of environmental markets now exist around the world (see Table 1 for a partial list), few have a significant length of trading history uninterrupted by significant changes in structure. The collective experience that has been gathered suggests that in the environmental markets area, the differences between “perfect market” theory and “practical market” reality is particularly large. Putting together an environmental market – particularly one that drives significant new investment to solve some particularly environmental issue – is a harder task that was initially anticipated.

[1] The US Spectrum auction were among the world’s most theoretically analysed auctions prior to their implementation. However as (McMillan 1994) points out the actual performance was vastly different to the still performed in reality very poorly compared to theoretical predictions.

Despite the problems, the gains from implementing environmental policy via a market instrument can be significant – with some empirical studies suggesting a cost reduction of more than 50% compared to traditional "command and control" type regulation. (Ellerman, Joskow et al. 2003).

Environmental markets have generally been implemented by government agencies different from those agencies traditionally associated with the oversight and management of financial (and other) markets. This has meant that some key lessons from the design and performance of financial and major commodity markets have not been heeded in the design of many environmental markets.

Table 1: A partial table of implemented environmental markets

Traded item/category	Countries	Traded item/category	Countries
CO_2	Denmark Norway Sweden United Kingdom	Wetlands	USA
		Fisheries	Australia Canada Iceland Netherlands New Zealand USA
NO_x	Canada Switzerland USA		
SO_2	USA	Air quality	Canada Chile Poland Singapore USA
Water qual. trading	Australia USA		
Hunting	Canada Mexico		
Land use	France New Zealand USA	Other	Canada (maple grove permits) USA (permits for lead in gasoline)

Extracted from: (Randall 2003)

In part this is because of the understandable reluctance of government departments with an environmental focus to become involved in questions of market regulation, management and surveillance on an ongoing basis.

While understandable, this is **also a dangerous position to take**.

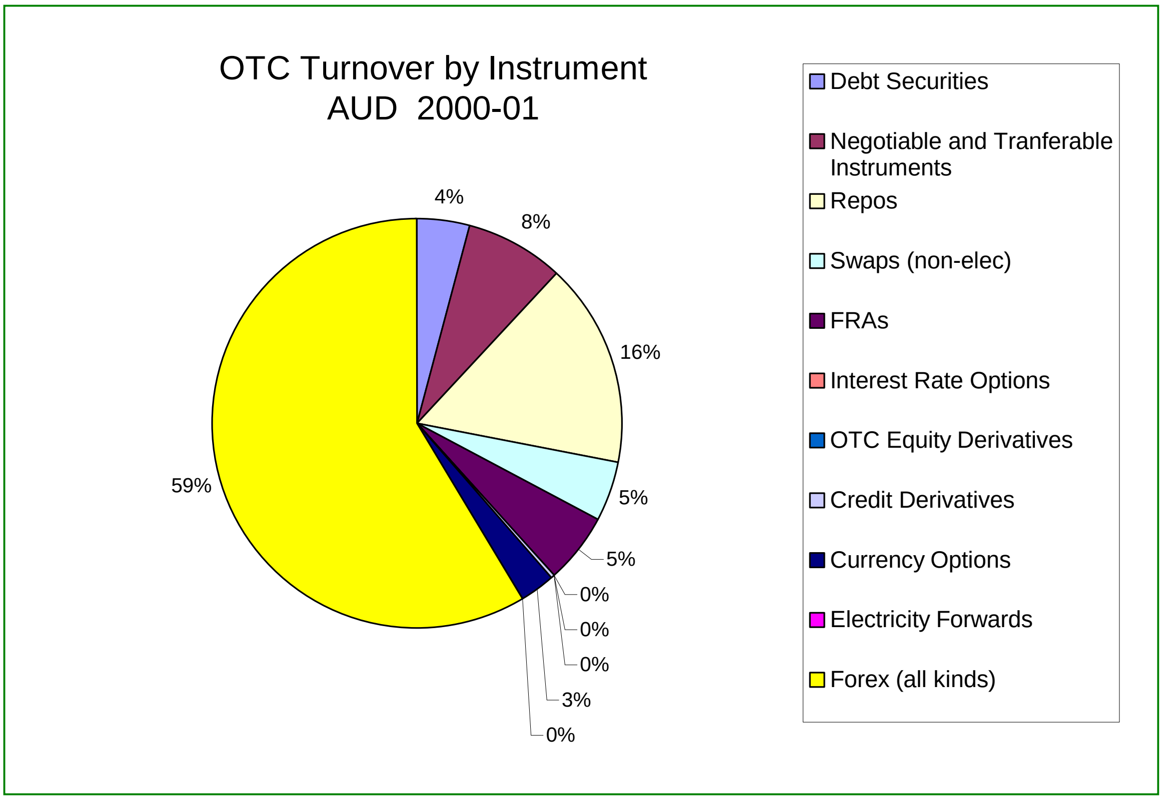
The theoretical benefits of using markets to implement environmental policy rest on the assumption that the market is efficient. An efficient market requires (at least) **good design (market institution), good regulation and appropriate surveillance and monitoring. That the market performs efficiently is the bedrock upon which public and participant acceptance of market-based environmental schemes rests.**

The calls currently heard in the US electricity policy debate to go "back to the future" by re-regulating the industry following the North Eastern blackouts and the Californian electricity price rises is a good example of the difficulties that can arise from allowing poor market designs to "go live" and be tested "in situ".

1.1 Some perspective on the size of environmental markets in Australia

According to (Australian Financial Markets Association 2001) the total turnover in Over the Counter (OTC) financial markets in 2000-01 was around $31 Trillion (AUD). The break-up of that turnover across the major products is shown in the following chart.

Figure 1: OTC Turnover by instrument. Extracted from (Australian Financial Markets Association 2002)



As this shows, the dollar turnover in the OTC Electricity market is very small compared to other financial markets – on this breakdown it appears as “0%” although of course this is simply due to rounding. It is in fact around 0.35%

The largest environmental market currently trading in Australia is the Mandatory Renewable Energy Target (MRET) market – which comprises in turnover a volume of around 3% of the size of the physical electricity market (the National Electricity Market – the NEM). The NEM in turn is about 20% smaller in volume than the OTC Electricity Forwards market.

We can conclude that compared to the overall volumes of trade in the financial markets, the largest environmental market in Australia has a market share of around 0.01%. Other markets would be another order of magnitude smaller. These markets are thus clearly relatively small and could be reasonably expected to be very “thin” with infrequent trading. There is some question if markets of this size can in fact be made to operate efficiently. It is certainly the case that careful market design is required to give such markets a realistic chance of reaching an efficient equilibrium in a reasonable timeframe.

1.2 Small but interesting

Despite their small size, there are a number of interesting environmental markets emerging in Australia, including various forms of Greenhouse Gas Emissions trading (with the recently developed NSW Greenhouse Gas scheme and the voluntary Greenpower schemes being the main examples) and the Federal Governments Mandatory Renewable Energy Target (MRET) Renewable Energy Certificate (REC) market. Looking globally, environmental markets can be considered "boutique" – no two markets are identical, and the market design principles applied have not yet settled to any commonly agreed set of standards.

For the academic interested in investigating the interactions between market institution, practice and efficiency, these markets provide a fascinating set of case studies. For the academic interested in "whispering in the ear of princes", these markets provide many examples of questionable practices where advice can be usefully proffered.

Also worth considering (and generally ignored by the policy makers involved) is the forward trading of environmental instruments. In all three of the markets mentioned above forward trading of some description is actively occurring[2] - and at least in the case of the NGAC scheme, forward trading was occurring well in advance of the actual launch of the spot market. In fact, as at this date, only a very small number of NGACs have actually been created, and no spot trades have occurred at all.

The points to be taken from this are:

- at least some aspects of any market or auction design should be expected to **require alteration**, as real-world results become available.
- Where possible, market or auction designs should be **experimentally tested** before being implemented.
- Market performance should be formally reviewed, with particular consideration given to any changes over time in the secondary market dynamics.
- Running markets and auctions is **not a "fire & forget" task**.
- The performance of an environmental market is the output of all the components, including the forward market, the secondary market, and any institutional issues. Simply concentrating on the design of the instrument and a registry is not enough to ensure an efficient market results.

[2] Since the majority of entities involved in these markets are AFMA members, AFMA as taken pro-active steps to bring introduce financial market style procedures to those markets. AFMA has for example developed and operated an "Environmental Market Revaluation Curve" on a weekly basis for over a year, publishing surveyed prices on 5 environmental instruments for periods out to 5 years ahead. AFMA has also issued recommended documentation for both spot and forward trading of RECs.

2 Experimentally investigating the Mandatory Renewable Energy Target market

The Australian Mandatory Renewable Energy Target (MRET) market has a number of characteristics that attract an experimental economics investigation. Before proceeding to discuss the work currently being conducted jointly by the University of NSW and George Mason University, some discussion of the market institution of the MRET market is valuable.

2.1 The Design of the MRET

The (Renewable Energy (Electricity) Act 2000) and the (*Renewable Energy (Electricity) (Charge) Act 2000)*, created the MRET scheme with a commencement date of 1 April 2001. The legislation requires all electricity retailers and direct large consumers to source additional energy from new renewable energy sources, rising on a sliding scale from an initial 300GWh's per annum (2001) to an eventual 9500GWh's per annum (2010).

To put some relative measure on the magnitude of the plan – 300 GWh's per annum is approximately equal to a 34 MW flat load for the year, 9500 GWh's per annum is approximately equal to a 1,084 MW flat load for the year.

To demonstrate compliance under the scheme, electricity retailers must purchase (or self generate) and acquit to the regulator each year Renewable Energy Certificates (RECs) up to the value of their compliance burden. A REC is proof of the generation of 1 MWh of electricity from an eligible form of "renewable" energy (as defined in the act and certified by the Office of the Renewable Energy Regulator (ORER)).

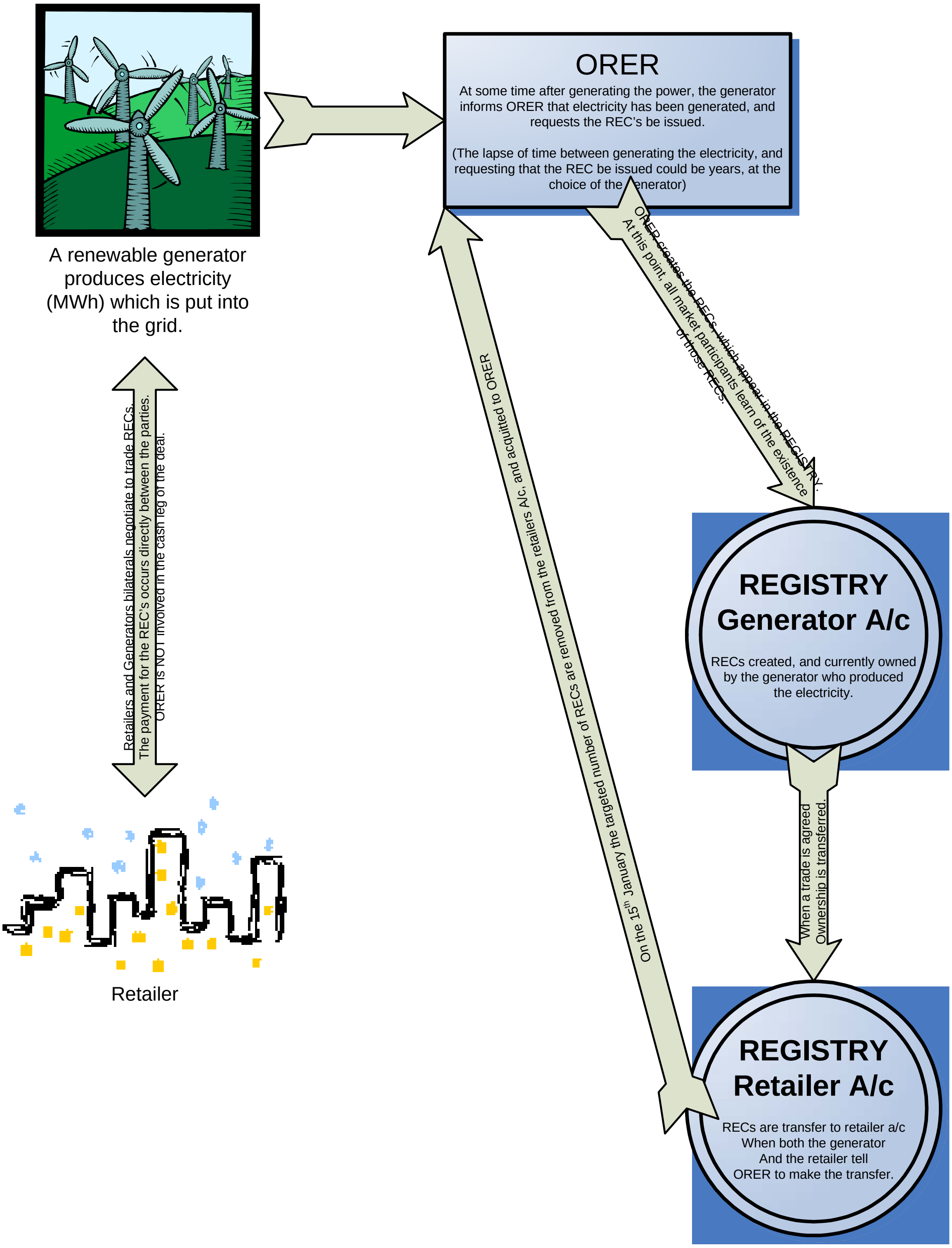
Retailers must surrender their targeted number of RECs to the ORER on the 15th February each year. In the event that a retailer cannot surrender the required number of certificates, the Legislation makes provision for a leeway of 10% and 3 year banking. In the event that the retailer is still not compliant a financial penalty (currently $40 / MWh pre-tax[3]) is applied for any shortfall[4].

To summarise the essential market structure:

- RECs certify the generation of 1MWh of electrical energy from a renewable source
- RECs are created an indefinite time after the generation has occurred, at the choice of the generator.
- Once created, the REC appears in the registry, and the entire market knows how many RECs in total have been created.
- RECs expire once they are surrendered to ORER.
- RECs that are not surrendered have an indefinite life (ie: they may be 'banked' to use for compliance in future periods.)
- Electricity that has been generated but not yet used to create RECs may also be "banked" for an indefinite period. Since there is no record of the amount of power generated, this quantity is UNKNOWN to the market. (This is a critical design point, as shall shortly be discussed.)

[3] Which in practical terms equates to $57 post-tax.
[4] A leeway of 10% and a 3 year redemption period are offered as an incentive to achieve compliance.

The retailers and generators negotiate (mostly bilaterally or through one of a small number of brokers) to purchase the RECS. The following diagram summarises the process.



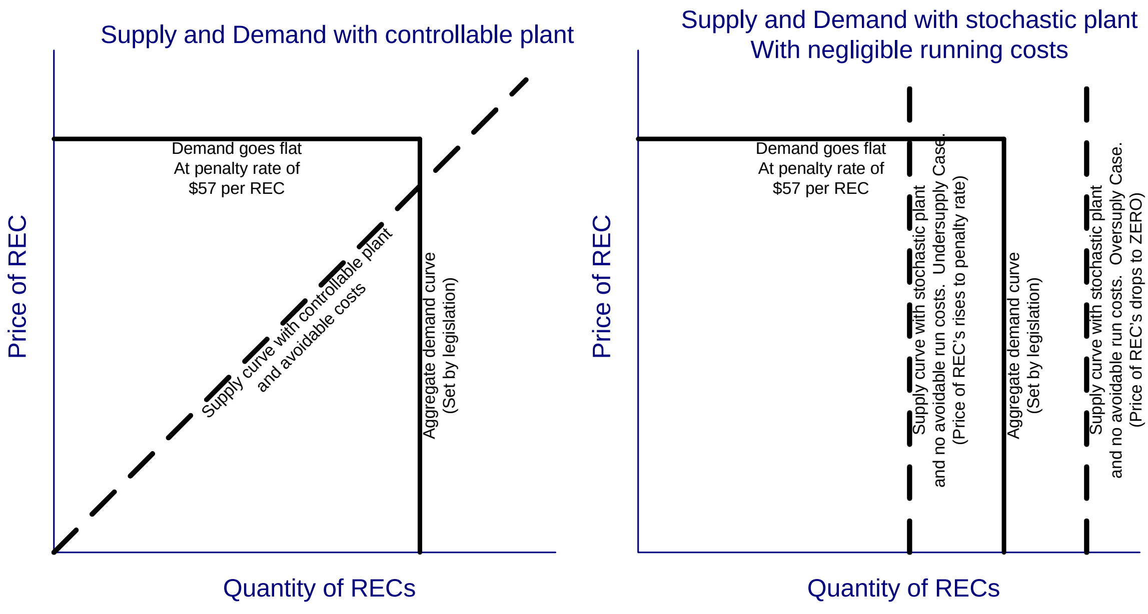
It should also be noted that supply and demand of RECs are both variable and to some extent uncertain. The supply of REC's includes supply from generation with stochastic output, such as wind turbines. While aggregate demand is specified under the act, the demand of any individual retailer is unknown until their share of electricity sales is known, and this cannot be defined with certainty until post the 31st December each year.

Certain generators (in particular hydropower stations that were already extant when the MRET scheme was launched) were assigned "baselines", which means that they cannot create RECs until they have generated to some threshold level. Electricity generated above the baseline is eligible for conversion to RECs. The size of these baselines is confidential, and not known to the market. Estimating them is a major preoccupation of market participants.

Market participants in many markets can make short term adjustment to changes in prices, however in the REC market no such short term adjustments are possible. As (Chupka 2003) points out, the demand for RECs from retailers is driven by their sales of electricity to end-use consumers, and thus is essentially non-controllable from the perspective of the retailers. In economic terms, the demand curve is vertical, up to the $57 per REC penalty rate.

It is also important to note that in the short term the supply of RECs is relatively inelastic – at least in so far as RECs are being generated from renewable sources with a stochastic output (such as wind farms or solar power). As REC producers, hydropower, biomass and certain other forms of "renewable" energy enjoy the advantage of controllability, and having such producers in the market is a key element of ensuring that the market has an achievable equilibrium position.

A REC market that consisted ONLY of stochastic plant would have near vertical supply and demand curves, and would be prone to enormous price volatility between the maximum rate ($57 per REC) and Zero, as shown in the following figure.



2.2 The issues

The key policy issue is the ability of the MRET market to provide the target quantity of renewable energy at the minimum price. The motivation for using a market to provide incentive for the renewable sector was to achieve this cost minimisation objective. This requires the market to reach an equilibrium price that provides the correct incentive for new generation – that is – not too low (so that insufficient generation investment occurs), and not too high (driving over-investment).

However the market design is such as to raise at least some questions about the ability of the market to reach that equilibrium correctly. The major issues that are being considered in the current experimental work are:

2.2.1 Information Problem around the timing of REC creation

Since generators can produce electricity (and incur the cost of generation) some considerable time prior to creating the associated RECs, there is an information problem in the market. Market participants cannot know how much generation has already occurred and is "overhanging" the market. This could mean for example that generators as a group tend of over-produce RECs, since the price prevailing in the market may not accurately reflect the true supply/demand balance. Once over-generation has occurred, given that the costs are sunk, the incentive upon generators is to sell those RECs at any positive price to attempt to recoup at least SOME of the generation cost, and thus the price in the market could be expected to fall rapidly as an oversupply of RECs seeks to meet a vertical demand curve.

2.2.2 Banking and annual acquittal dates

There are good reasons for believing that an annual REC market (where there is no borrowing or banking) will have difficulties achieving a stable equilibrium, and would be subject to price swings. Experimental work conducted by (Ishikida, Ledyard et al. 2000) has clearly shown the price volatility that can result in environmental markets from "hard" annual acquittals without flexibility mechanisms. Given uncertainties about both demand and supply, the market will face considerable information problems in any particular period. For this reason both banking and borrowing was built into the MRET design.

However, having unlimited banking into the future raises the possibility of a market imbalance being constantly "rolled over" into future periods, thus introducing other price distortions. This raises the suggestion that banking should be allowed to prevent annual price spikes, but not allowed indefinitely to ensure that all the supply is forced to pass through in market in a relatively well known timeframe.

2.2.3 The role of the forward markets

The MRET legislation essentially created a tradeable instrument and a registry, and was silent upon the resulting market structures. At no point is forward trading of REC's mentioned, and yet it is the forward market that provides the revenue protection required to make investments into renewable plant.

It is also sometimes argued that whatever problems exist in the market structure (such as the indefinite banking and the information problem around the timing of REC creation) can be overcome through the price signals from the forward market. This appears to put considerable faith in the forward market to correct underlying difficulties, particularly since the forward market has been almost totally ignored by policy makers.

Thus questions arise about the ability of forward markets to assist to overcome the structural difficulties previously discussed.

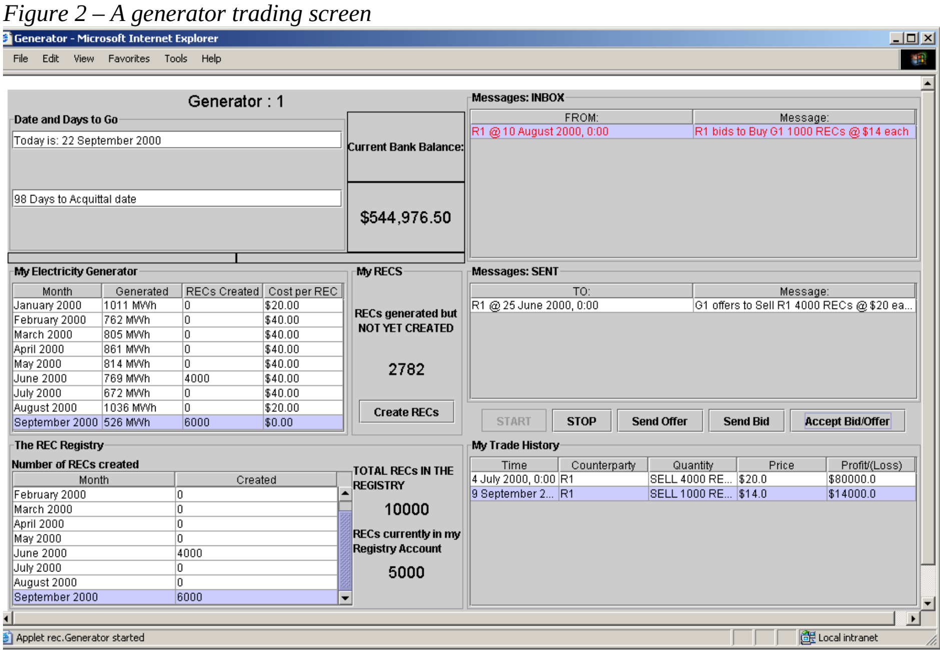
2.3 The experimental design

The ability of the MRET market to achieve a meaningful equilibrium is being examined experimentally in a series of experiments by the UNSW and GMU – conducted both in Sydney and in the GMU lab in Washington DC. In the experiments groups of 8 or 10 students are placed into a computer network based "MRET Market". The participants are assigned the roles of either a renewable generator or an electricity retailer, and are then able to bilaterally send bids/offers to trade.

Participants are remunerated (in real dollars) at the end of the experiment in proportion to how many "experimental dollars" are in their bank account at the end of the experiment. The experiments are setup in such a manner that if a participant did nothing (that is, either as a retailer refused to purchase any RECs, and just paid the penalty fee each year, or as a generator just run the generator and never sold RECs), then their cash balance at the end of the experiment would be E0.

Examples of typical trading screens are shown below.

Figure 2 – A generator trading screen



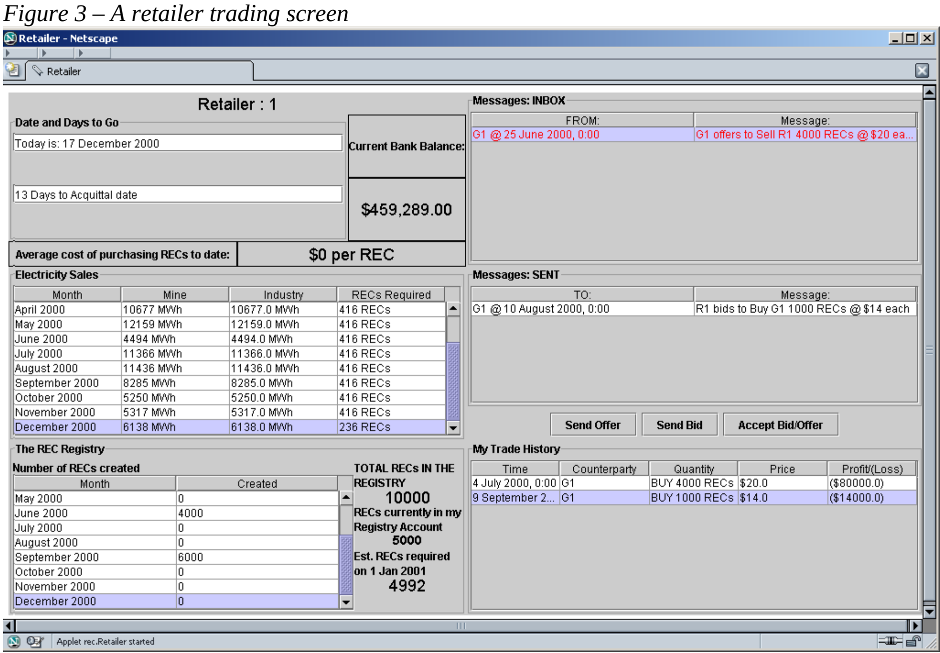
Generators earn money by producing electricity and then creating and selling RECs. They incur a cost at the end of each month representing the run costs. The generators can control their output level by switching on or off their generator. Although the facility exists within the experiment to apply fixed costs each month (ie: Costs that are incurred regardless of if the generator is operating or now), for the experiments conducted to date it was assumed that generators had a variable run cost only.

Participating in the experiments can be relatively lucrative – a successful trader might walk out after two hours with USD50 in their pocket, and so a considerable number of GMU students consistently volunteer to be experimental participants as their "uni job". In our experiments we used both "new" experimental subjects (who had never participated in an experiment previously) and "experienced" subjects (who had participated in at least 3 other economic experiments previously.)

In both cases the experiment consisted of firstly a training session (where participants were introduced to the trading environment, how to conduct trades, etc), and then on the following day were brought back to the lab for the main experimental runs.

Thus over time some cohorts of subjects got to run the experiment up to four (4) times.

Figure 3 – A retailer trading screen



Electricity retailers earn money each month automatically from electricity "sales", which appears to the participant as a variable incoming cash flow each month. From this cash they must purchase RECs from generators.

In order to be tractable, the experiment runs for 5 experimental years, from 1/1/2000 to 30/12/2004. Each experimental year comprises 12 months of 30 days. This takes about 2 hours to complete.

Trading occurs in a bilateral manner – each participant can send a bid or offer to any other participant (one at a time), who may then accept the bid/offer. (If they do not wish to accept, they do nothing, and the bid/offer lapses after 1 experimental month.)

Being an experiment allows us to set the underlying cost functions with absolute certaininty, and thus know not only that an equilibrium price exists, but exactly what it is. The experiment allows generators to have up to 5 cost/quantity production bands (that is, different $/MWh production costs depending on the amount of power produced), and thus with 4 generators it is possible to create a supply curve with up to 20 "steps".

Similarly the experiment allows determination of the maximum output each month for each generator, so the output can set to mimic a range of plant from a fully stochastic plant (where output varies each month in a random manner – such as for a wind turbine), through to a baseload generator (producing a consistent amount of power each month).

2.4 The experimental results

The experimental runs have not yet been completed, and thus not all treatments have been conducted. A range of parameters – including stochastic generation, variable retail sales, and other complex cases have been tried.

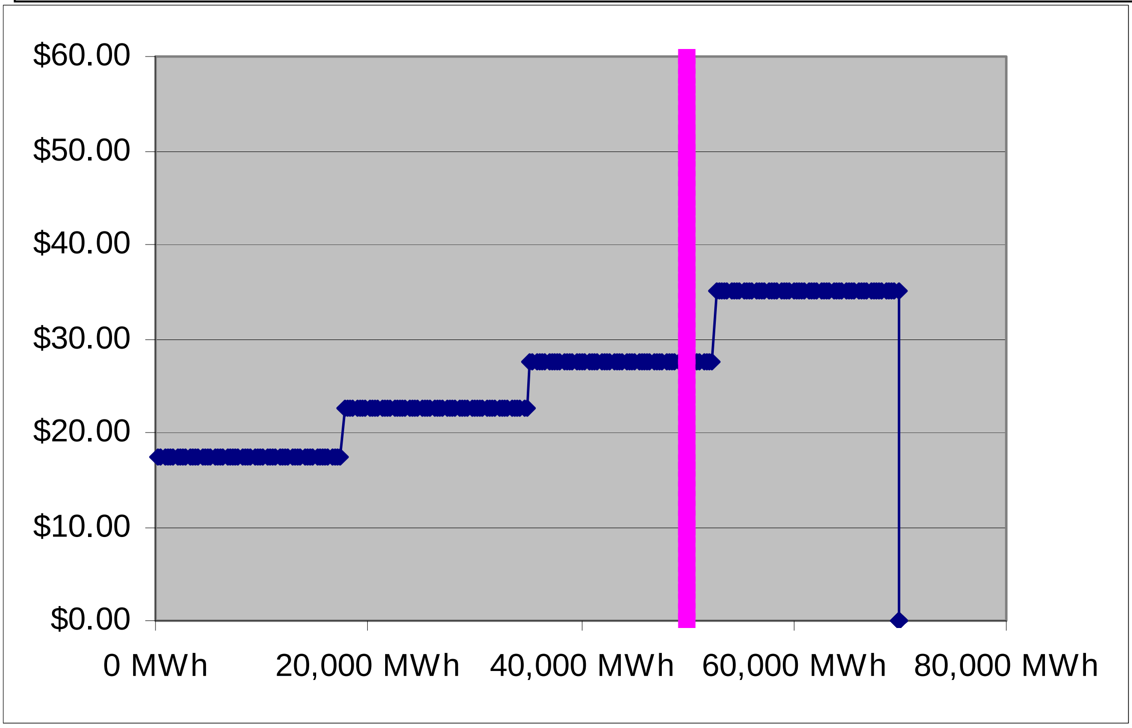
In no case to date have the experimental markets achieved the theoretical equilibrium price.

Realising that the participants had difficulty in environments with variability, a series of experiments were conducted using the simplest possible MRET environment. That is, one where:

- There are 4 identical retailers, with constant sales each month. (Thus it is known to all retail participants exactly what their REC targets are at all times)
- There are 4 identically sized generators, with a constant maximum output each month, and a single known cost of production for each.
- The REC target is constant each year, and known by all retailers.

The supply-demand balance for this case is shown in the figure below.

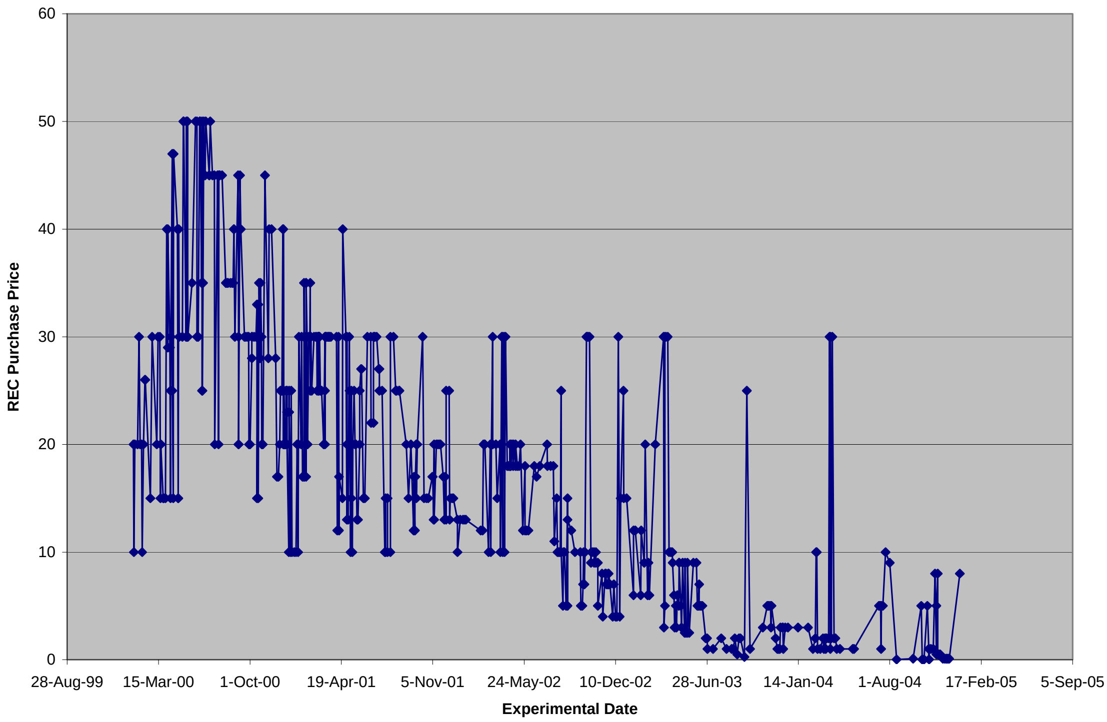
Figure 4 – Supply and demand parameters for the "Simple MRET" case



As can be seen from the above, the equilibrium price should be around $27.50 per REC.

Four runs of the experiment were conducted (so participants had multiple chances to experience the market dynamics and to learn from their experiences). The trading results from the final run are shown in the figure below.

Figure 5 – Experimental results for the final run (experienced participants) in the simple MRET market.



It can be clearly seen that the equilibrium price is not obtained, and that overgeneration of RECs occurs. This pattern of early withholding of registering RECs by generators (thus forcing prices high) was consistently repeated in all experimental runs.

The typical pattern would appear to be as follows:

- Generators generate electricity (thus enabling them to create RECs) but withhold actually creating those RECs in the registry.
- Thus an overhang of generation builds up, since there is no signal to generators that the target has already been met.
- At some point generators begin to bring that prior generation into the REC market, and the REC registry then shows the market that a considerable number of RECs are appearing.
- At this time Retailers realise that there are more RECs than previously expected, and Generators find they have already incurred the generation cost for surplus RECs. As a result Generators become prepared to sell at any positive price, and the price crashes.

3 Conclusions

This is preliminary work on an experimental series that has not been completed.

The experiments conducted to date do not include forward trading, which is very much a factor of the real MRET market.

However while allowing for the preliminary nature of the experiments, it is interesting to note that stable market outcomes have not resulted under any of the parameter sets investigated to date, including the simplest case of static generator and retailer outputs with experienced participants.

This would suggest that the market structure as tested does not promote the easy discovery of the equilibrium position.

Further work will be conducted on this market institution both at the UNSW and at the GMU labs in 2004.

4 References:

(Renewable Energy (Electricity) Act 2000). Renewable Energy (Electricity) Act. Commonwealth of Australia.

Australian Financial Markets Association (2001). 2001 Australian Financial Markets Report - Overview. Sydney, AFMA**:** 68.

Australian Financial Markets Association (2002). 2002 Australian Financial Markets Report - Overview. Sydney, AFMA**:** 64.

Chupka, M. W. (2003). "Designing Effective Renewable Markets." The Electricity Journal **2003**: 46-57.

Ellerman, D., P. Joskow, et al. (2003). Emissions Trading in the U.S. Experience, lessons and considerations for Greenhouse Gases, PEW Center on Global Climate Change**:** 72.

Ishikida, T., J. Ledyard, et al. (2000). "Experimental testbedding of a Pollution Trading System: Southern California's RECLAIM emissions market." Report for Californian Government.

McMillan, J. (1994). "Selling Spectrum Rights." The Journal of Economic Perspectives **8**(3): 145-162.

Milgrom, P. and J. Weber (1982). "A theory of auctions and competitive bidding." Econometrica **50**(5): 1089-1122.

Montgomery, W. D. (1972). "Markets in licenses and efficient pollution control programs." Journal of Economic Theory **5**: 395-418.

Randall, A. (2003). Market-based Instruments - International Patterns of Adoption, Remaining Challenges, and Emerging Approaches. AARES 2003, Canberra.

Surry, J., Ed. (1996). The British Electricity Experiment - Privatization: The record, the issues, the lessons. London, EarthScan.