Hedging Financial Risk for Solar Power Generators - Solar Derivatives

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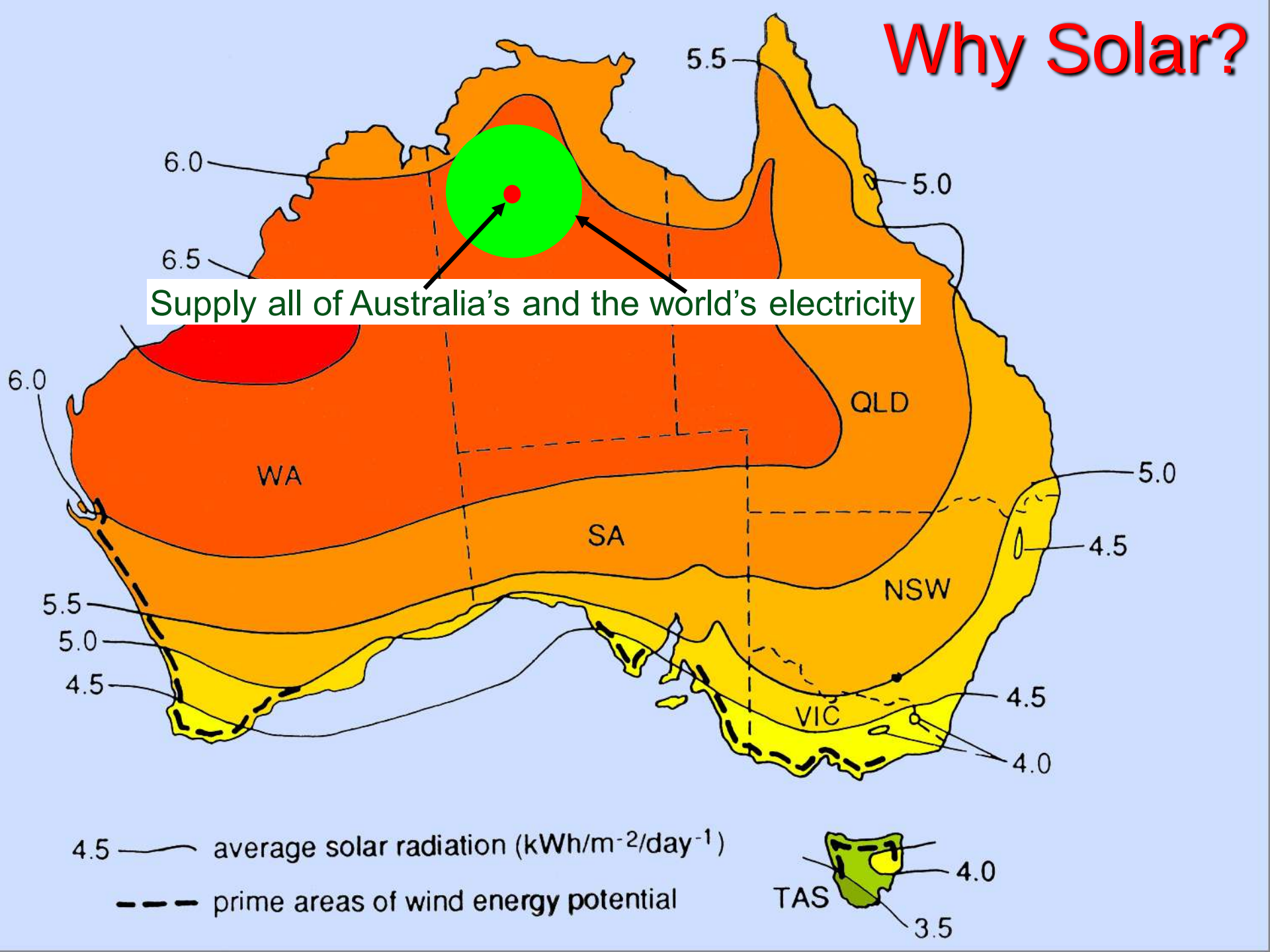
Why Solar?


Supply all of Australia's and the world's electricity
5.5
6.0
5.0
6.5
6.0
QLD
WA
5.0
SA
4.5
NSW
5.5
5.0
4.5
4.5
VIC
4.0
4.5 average solar radiation (kWh/m-2/day-1)
prime areas of wind energy potential
TAS
4.0
3.5

Solar Generation as Baseload

- General consensus that solar power is one of the cleanest energy technologies.
- Nevertheless, in Australia, investment in large-scale **Solar Power Generation (SPG)** is impeded by the current NEM setup rather than lack of progress in design of efficient photovoltaic panels.

AEMO's highest priority is security of supply. This discriminates against 'intermittent' SPG.

Solar Generation as Baseload cont.

According to existing guidelines*:

- Any generation facility with total capacity greater than 30MW in one connection point must be registered either as a Market Scheduled or Market Semi-Scheduled Generator.
- Due to highly intermittent nature of solar generation it is not possible to supply uninterrupted power 24 7.

*NEM GENERATOR REGISTRATION GUIDE, available from www.aemo.com.au

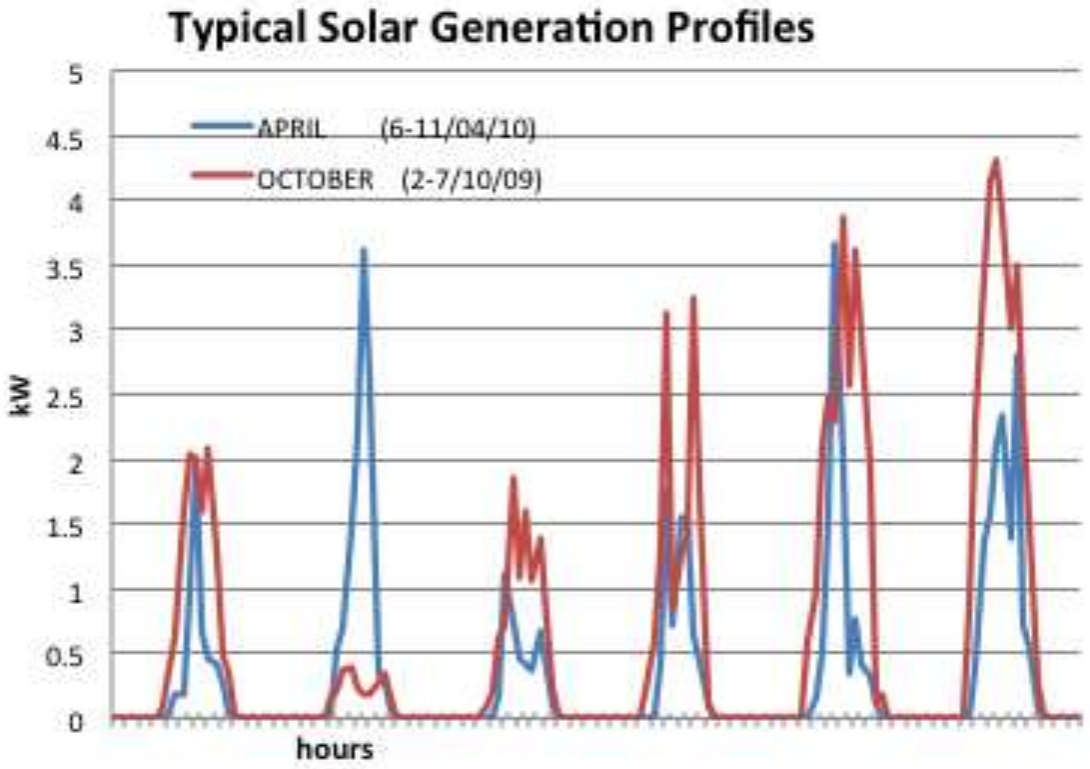
The Solar Generator

- In theory has valuable peak generation, but can't function like a gas-fired peaking plant due to intermittent supply.
- If not participating in the NEM bidding process must be content with selling as embedded generation or market non-scheduled.

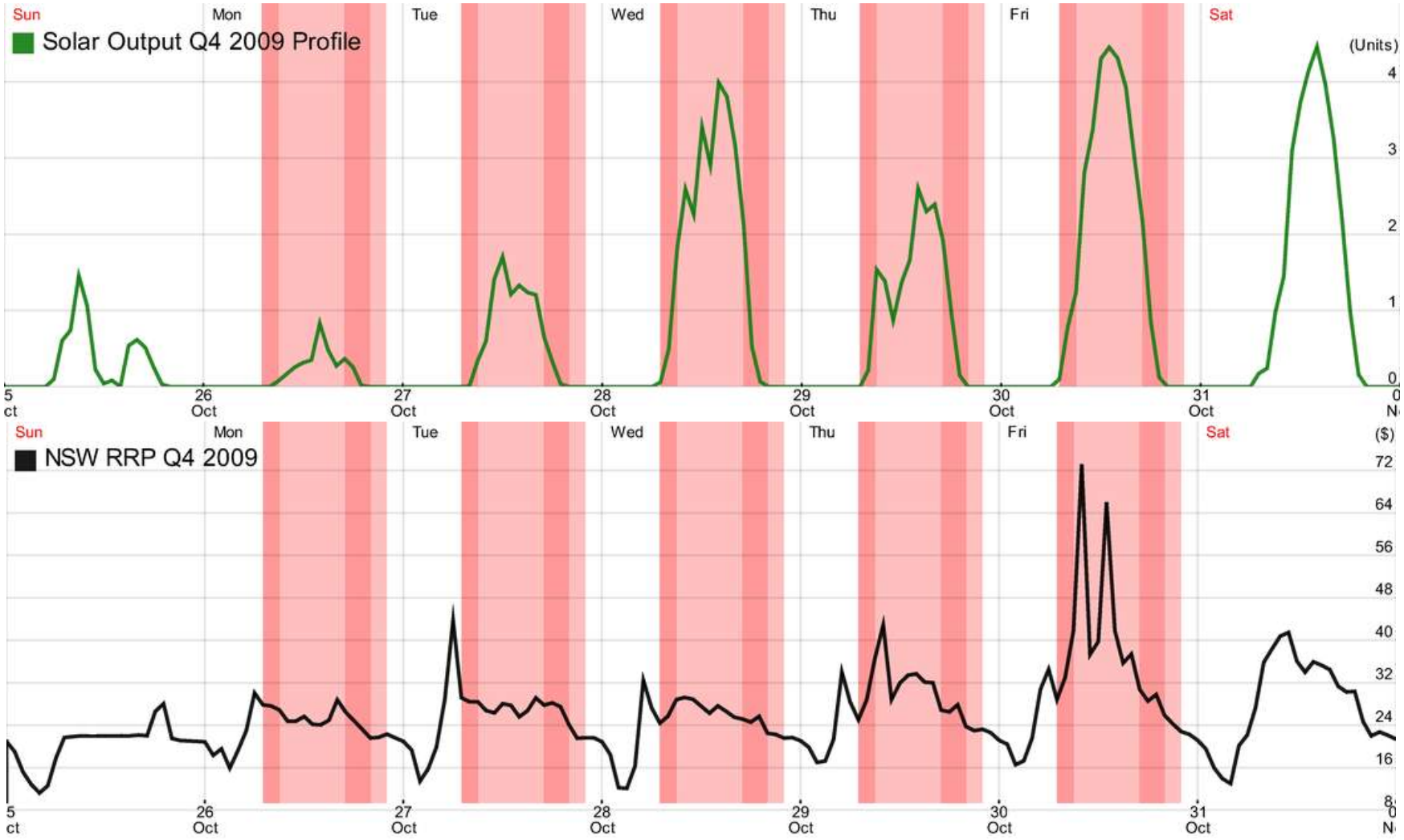
Test Data

- Wenona School in Nth Sydney.
- Installation: Kyocera 205W panels, 6.15 kWp.
- We wrote software to extract data for one year into a single CSV file.
- This data has been used as a proxy for a large-scale solar plant in NSW.
- RRP and State Load-AEMO web site

Two sunny weeks



Solar Output and NSW RRP



Exchange-traded Solar Contracts (ETC)

Standardised Contract Parameters:

- Contract Tenure: Quarter;
- RRP ($\boldsymbol{P_i}$);
- State-based total number of hours (per Quarter) between sunset and sunrise ($\boldsymbol{N_T}$)**
- For Options- Strike is defined as $\boldsymbol{\alpha}$-percentile of the output ($\boldsymbol{W_\alpha}$) against which the Option pays premium.

**http://members.iinet.net.au/~jacob/risesetsyd.html

Solar Floor

The Payoff is defined as:

$$P_F = \frac{\sum_{i=1}^{N_T} P_i \times Max[W_\alpha - L_i, 0]}{\sum_{i=1}^{N_T} 1_{W_\alpha > L_i}}$$

Here:

L_i – normalised power output for a given tick ***I***;

And:

$$1_{W_\alpha > L_i} = \begin{Bmatrix} 1, & W_\alpha > L_i \\ 0, & W_\alpha \le L_i \end{Bmatrix}$$

The total Solar Floor settled value will be:

$$P_F^S = N_T P_F$$

Solar Future

- We'll define a quarterly Solar Future within the same framework, by using 50%-quantile $\boldsymbol{W_{50\%}}$ which will cover deviations in the output in either direction:

$$F = \sum_{i=1}^{N_T} P_i L_i - N_T X_S$$

- Here:

$\bar{P}_Q$ - is a quarterly peak average price;

$X_S = \bar{P}_Q W_{50\%}$ - Solar Future's Strike

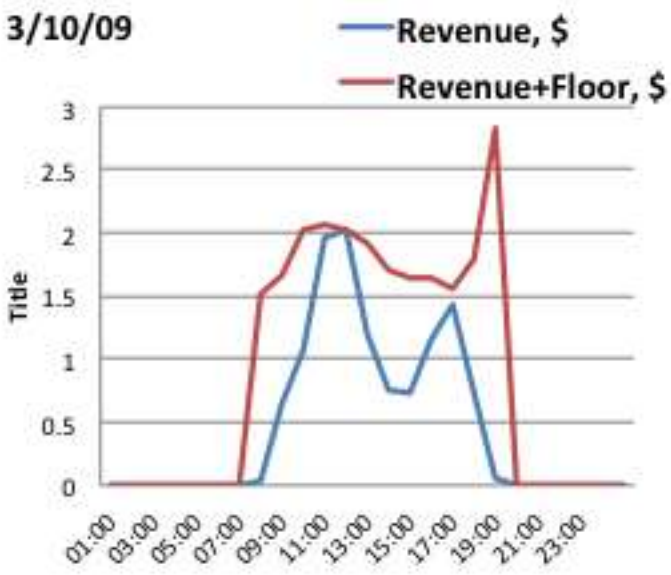
Solar Swaption-follows d-cypha definition but based on the number of daylight hours rather than MWh.

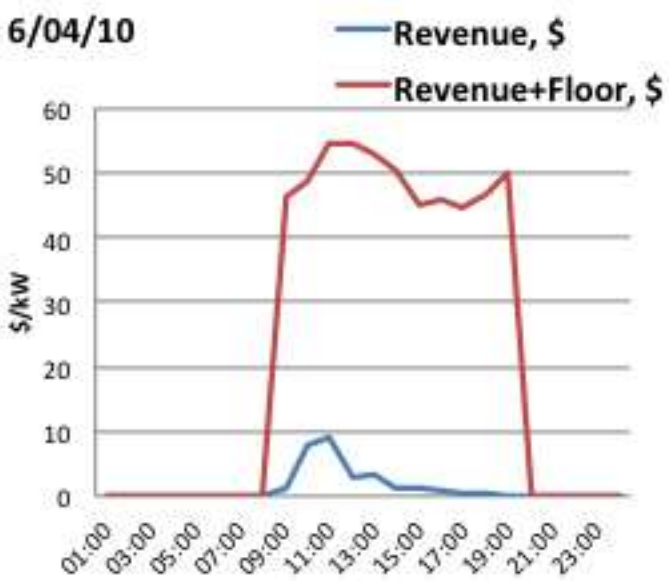
Quarterly prices

Quarter	Number of daylight hours N_T	$ Floor price	$ Settled Floor Value	$ Futures Strike Price	$ Futures Contract settled value, *F*
Q409	1259	1.084	1365.146	28.638	73069.271
Q210	955	1.956	1868.030	8.386	-70.315
Q310	1006	3.668	3689.814	9.709	-964.127

- Q110 was corrupted and was unusable for modeling;
- Results were normalised on maximum nominal output of SPG.

‘Naked’ and protected one-day position





OTC Solar Derivatives

- OTC Contracts could be customer-tailored therefore number of daylight hours (N_T) can be nominated for specific location. Therefore *OTC Floor* and *OTC Swaption* can be defined exactly like respective ETC but with bilaterally-agreed tenor.
- *Solar Swap.*

This contract is analogous to the *ETC Future* but with corresponding discounting (d_i- discount curve):

$$V_{Swap} = \sum_{i=1}^{N_T} d_i (P_i L_i - N_T \bar{P}_T W_{50\%})$$

Where $\bar{P}_T$ is price average over corresponding Swap tenor N_T

Solar Asian Options

The Holder will be compensated through re-averaging of SPG output over pre-specified averaging period (number of daylight hours) $\boldsymbol{N_A}$. $\bar{P}_A$ - is the price average, corresponding to output.

- *Vanilla Solar Asian:*

$$\begin{Bmatrix} Call_{As} \\ Put_{As} \end{Bmatrix} = \bar{P}_A \times \begin{Bmatrix} Max[\frac{1}{N_A}\sum_{i=1}^{N_A} L_i - W_\alpha, 0] \\ Max[W_\alpha - \frac{1}{N_A}\sum_{i=1}^{N_A} L_i, 0] \end{Bmatrix}$$

- *Solar Price-Weighted Asian:*

$$\begin{Bmatrix} PWCall_{As} \\ PWPut_{As} \end{Bmatrix} = \bar{P}_T \times \begin{Bmatrix} Max[\frac{1}{\bar{P}_A N_A}\sum_{i=1}^{N_A} P_i L_i - W_\alpha, 0] \\ Max[W_\alpha - \frac{1}{\bar{P}_A N_A}\sum_{i=1}^{N_A} P L_i, 0] \end{Bmatrix}$$

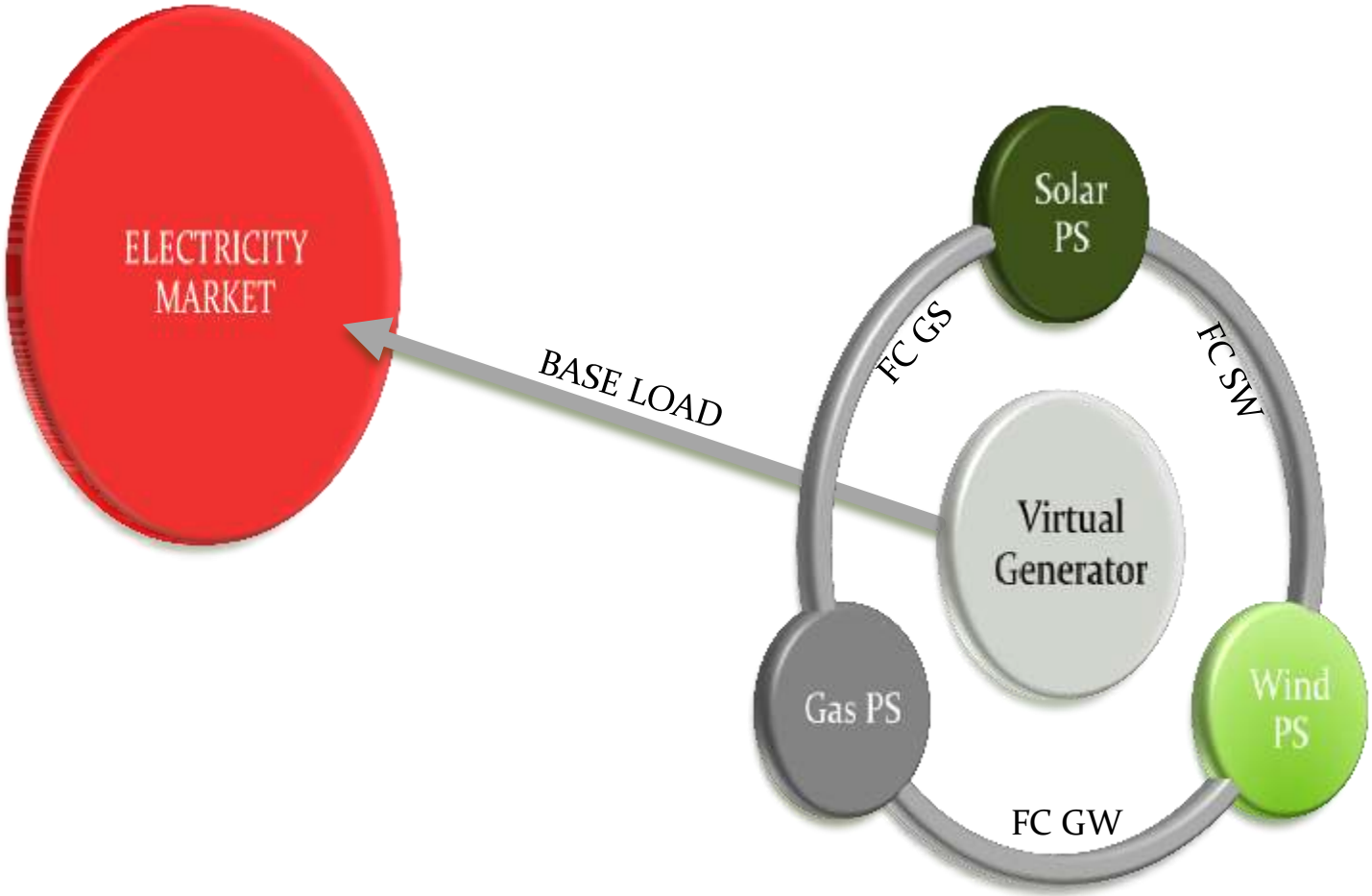
Current Approach

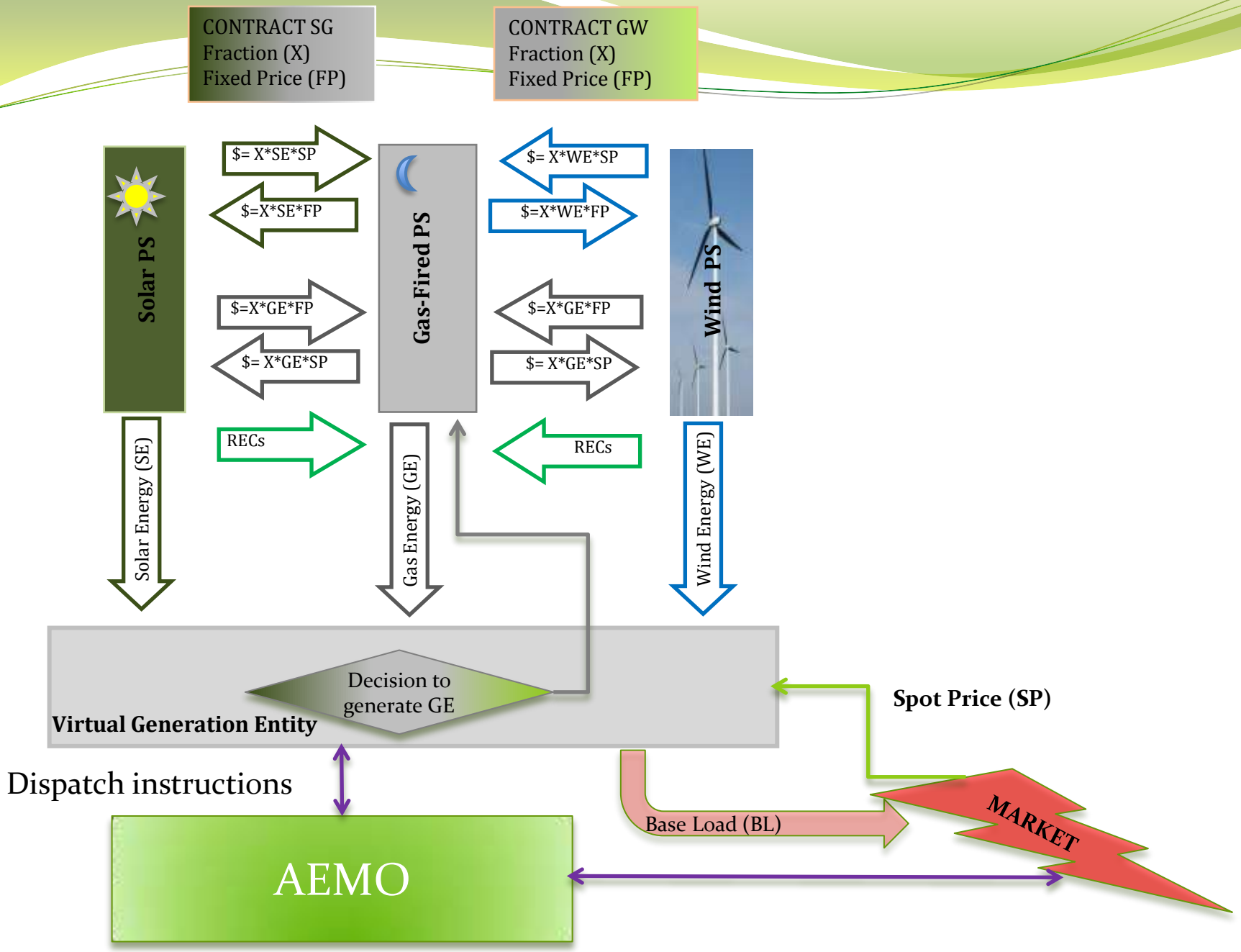
- At present the work around is to build supplementary traditional-fuel generation or energy storage facility connected at the same connection point.
- These solutions are purely technical and require significant additional infrastructure investment.

Our Solution

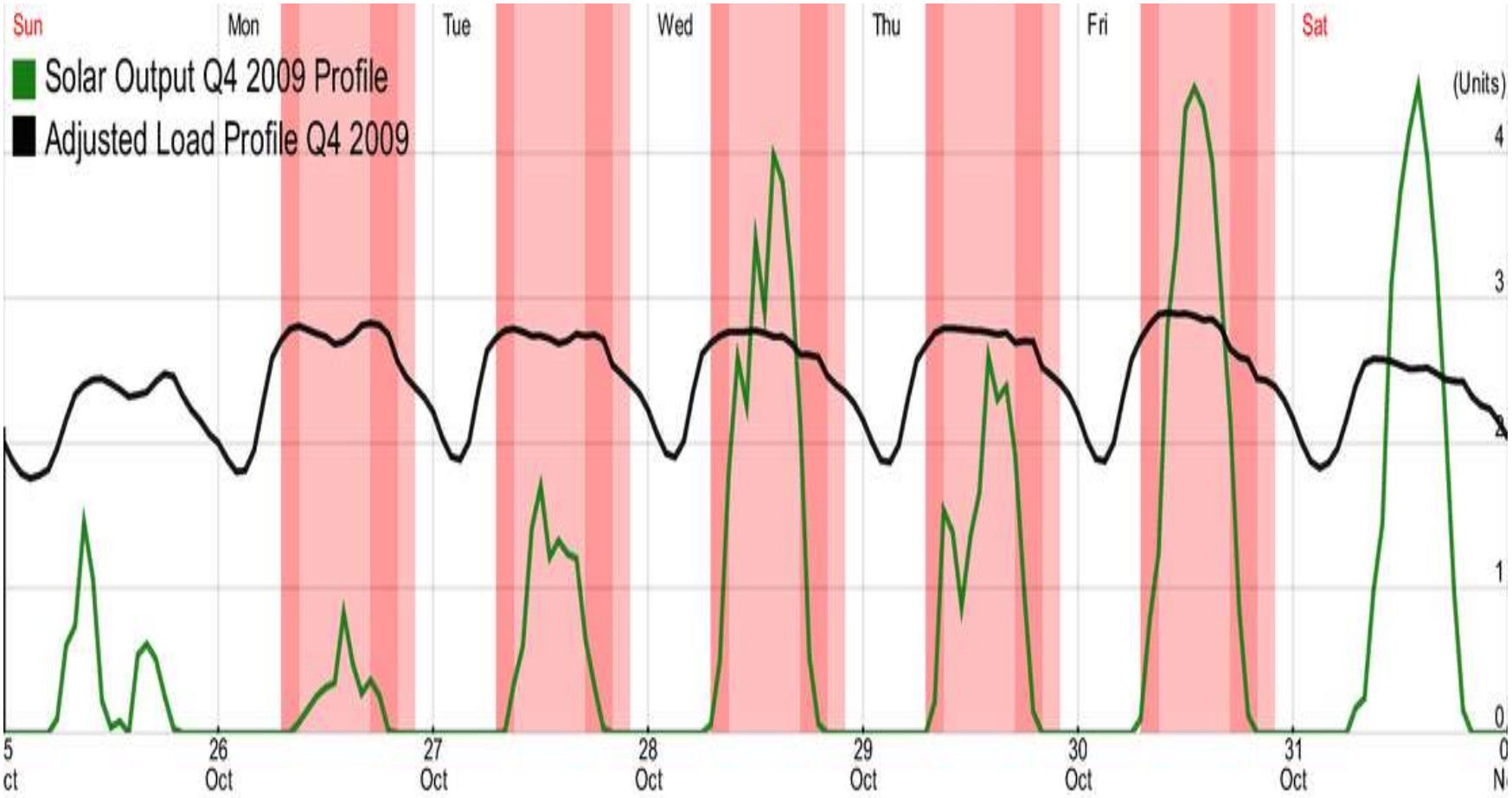
- Market-based financial solutions that does not require any new construction effort.
- Set of financial contracts acting as insurance and hedging instruments: **Solar Derivatives**
- They link financially link physically separated SPG and a rapid ramping generator (e.g. gas-fired) in a single NEM entity.
- The contracts will compensate each party for the intermittence in supply due to exogenous events.
- The parties will submit bids to a **Virtual Generator** which in turn be bidding into the NEM as a single entity.

Virtual Generator

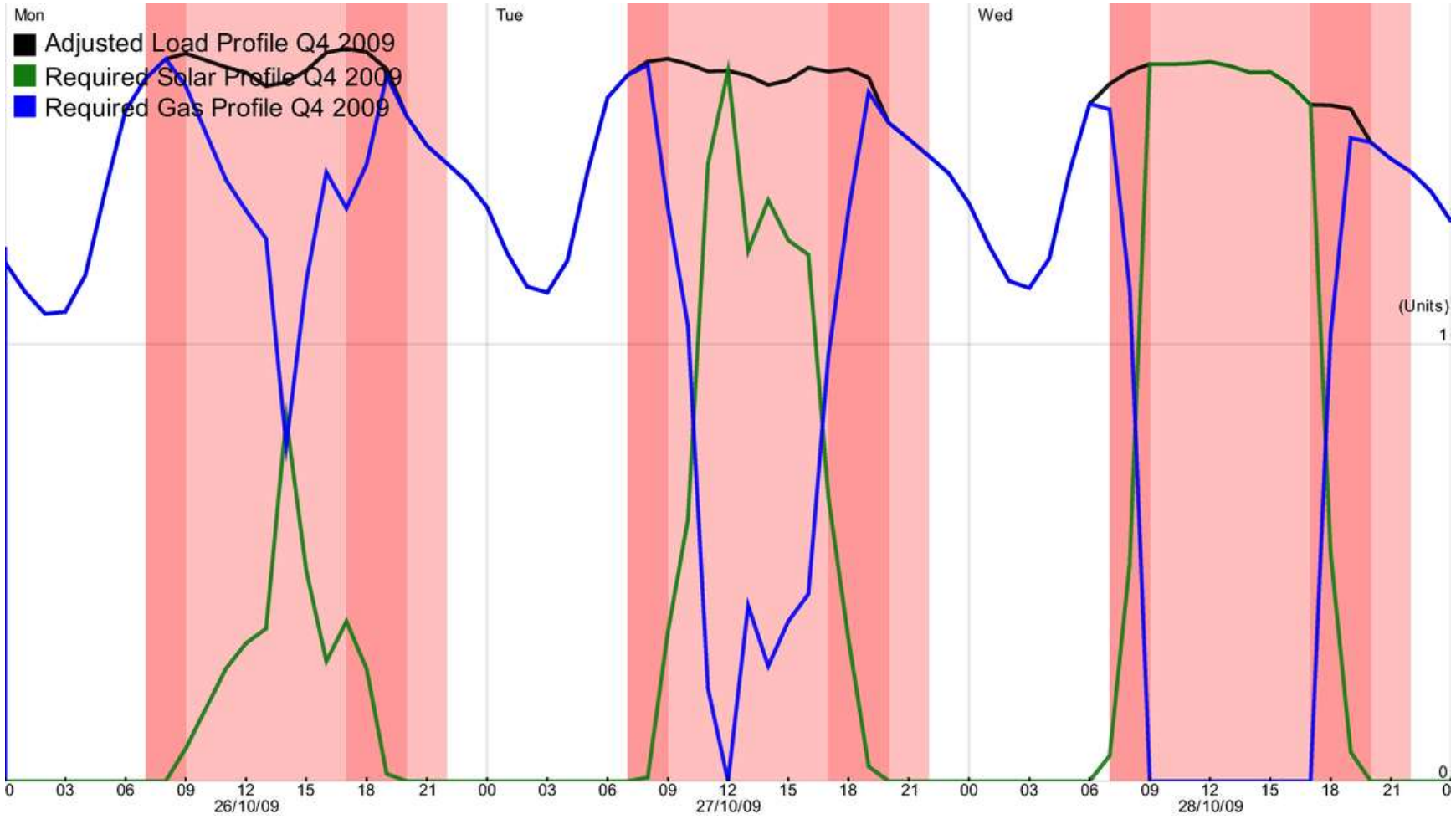



CONTRACT SG
Fraction (X)
Fixed Price (FP)
CONTRACT GW
Fraction (X)
Fixed Price (FP)
Solar PS
Gas-Fired PS
Wind PS
$= X*SE*SP
$=X*SE*FP
$= X*WE*SP
$=X*WE*FP
$=X*GE*FP
$= X*GE*SP
$=X*GE*FP
$= X*GE*SP
RECs
RECs
Solar Energy (SE)
Gas Energy (GE)
Wind Energy (WE)
Decision to generate GE
Virtual Generation Entity
Spot Price (SP)
Dispatch instructions
Base Load (BL)
MARKET
AEMO

Adjusted State Load vs Solar Output



Combining Solar and Gas profiles



Backtesting

- Gas Swap is constructed same as Solar Swap due to its 'Complimentary Profile';
- For both Swaps average price for non-zero output has been used (to capture "super-peaks");
- No discounting;
- REC Prices are approximate only.

	Q409	Q210
Solar Swap	$176.12	$73.04
Gas Swap	$22.00	$26.35
REC Price	$30.00	$35.00
REC Obligation	3.64%	5.98%

Backtesting

	Q409		Q210	
	Solar	Gas	Solar	Gas
Generation	2208	1202	2351	1413
Pool Revenue ($)	480,396	29,284	69,138	41,247
RECs Earnings ($)	66,240	-1,313	82,286	-2,957
Swap Solar ($)	-264,116	264,116	-4,719	4,719
Swap Gas ($)	-3,767	3,767	-999	999
Swap Fraction	25%	25%	25%	25%
RECs Transferred ($)	-1,313	1,313	-2,957	2,957
Virtual Generator 2.5% ($)	-12,010	-732	-1,728	-1,031
Total ($)	466,343	96,835	143,371	47,348

- Data availability and quality provided limited scope for backtesting;
- Summer 'spike' revenue transferred to Gas generator via swap;
- Winter Solar pool revenues down due to missing afternoon peaks.

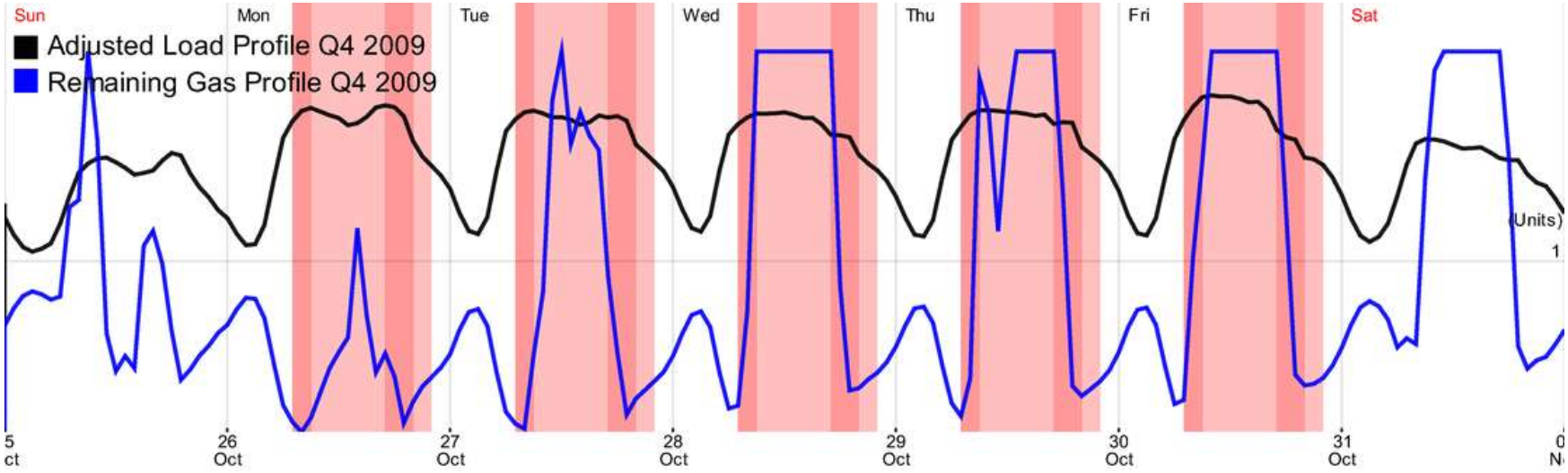
Actual Implementation

In practice, the actual implementation would feature:

- *Hopefully, more accurate data provided by bigger SPG*;
- Load forecasts rather than actual profiles;
- Optimisation used for setting contract ratios;
- Use REC forward curve.

The Gas-fired Generator

- Will participate in the scheme if the financial rewards are sufficient.
- Is contracting out the least valuable parts of its capacity – it is left with a favourable profile.



Remaining Gas-fired Profile (Capacity less profile 'sold' to Virtual Generator)

The Virtual Generator

- Now has baseload profile – can contract firm or use bidding strategies and back them up with reliable generation;
- Can aggregate several sources of solar, wind and gas-fired generation as required;
- Has the potential to become a `gentailer', supplying `green' power via retailing agents or directly.

Acknowledgement

We are thankful to:

- Autonomous Energy Pty Ltd , for providing access to one of their installations.
- TTA, for assistance with preparing price/load curves in *etaView*®
- Dean Price, Manager, d-cyphaTrade, for general and very useful feedback

Thank You

Questions?