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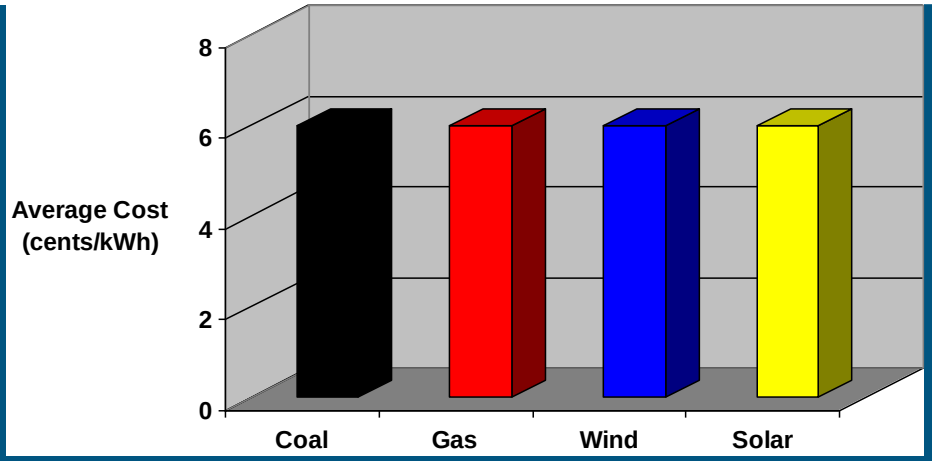

Solar vs Gas and Grid Parity

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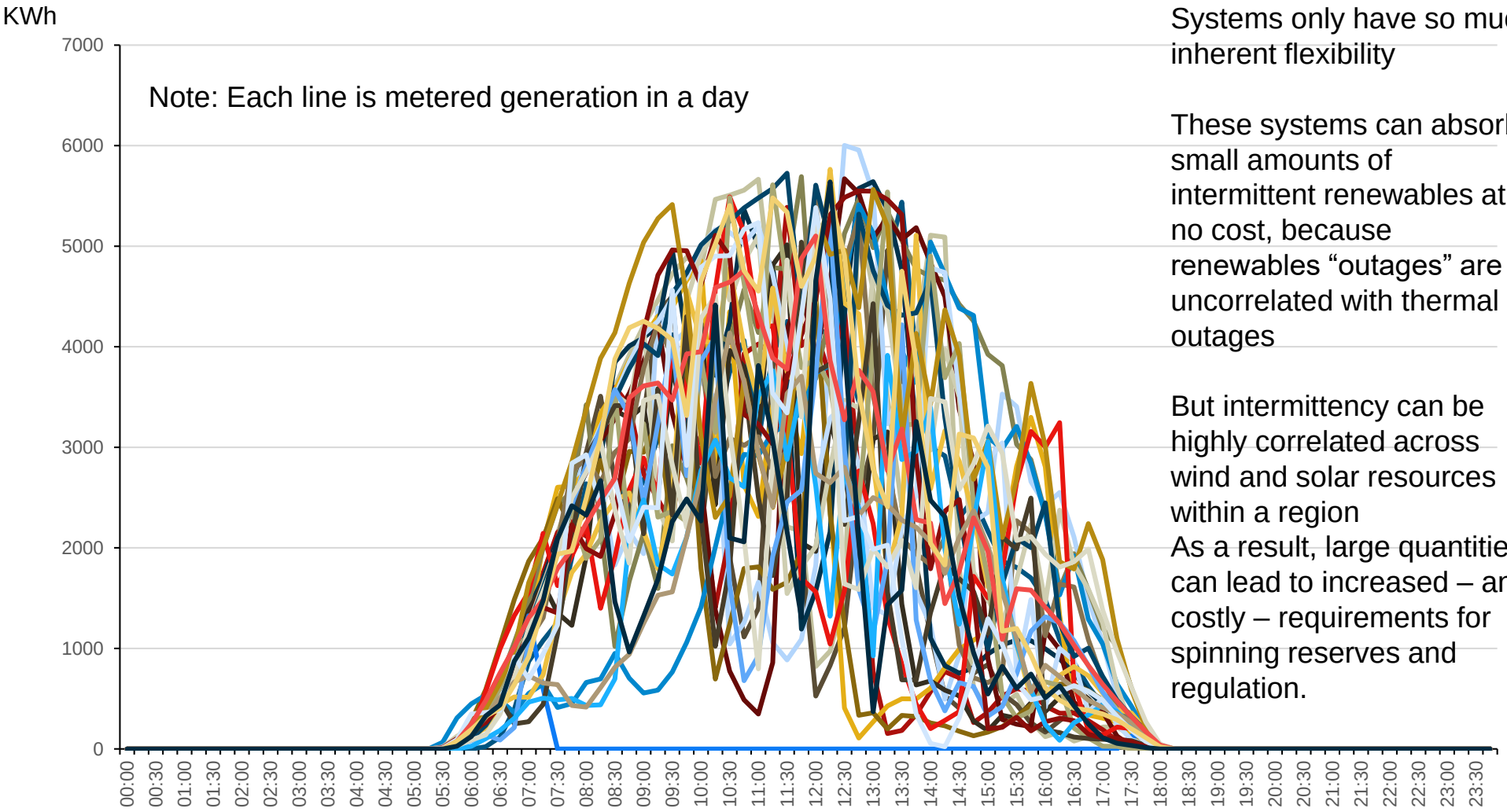
Grid Parity is a Controversial and Confused Topic

- Cost structures differ (fixed vs variable costs) -- consequently optimal operating profile depends on fuel costs – always changing – parity calculation depends on load factor, not a LCOE
- Tax benefits – are they part of “parity” or should parity based on normal taxation?
- Emissions benefits – rarely explicitly valued, but should be
- Intermittency reduces system reliability, needs compensating costs elsewhere – who pays?
- Tariff structures may cross-subsidise rooftop panel adopters – shifting costs to others unfairly?
- Price at which “rooftops sell power back to the grid” may be inconsistent with wholesale generation costs
- Solar systems costs have fallen but industry seems totally in disarray right now – sustainable?
- Who pays for transmission augmentation, extension that may be required by remote RE?
- Who gets benefit of any network cost reduction or reduction in losses (e.g., for rooftop panels)

To talk about “grid parity” without sorting through these issues seems (at best) premature…

Solar generation output, varies materially, imposing costs on the system

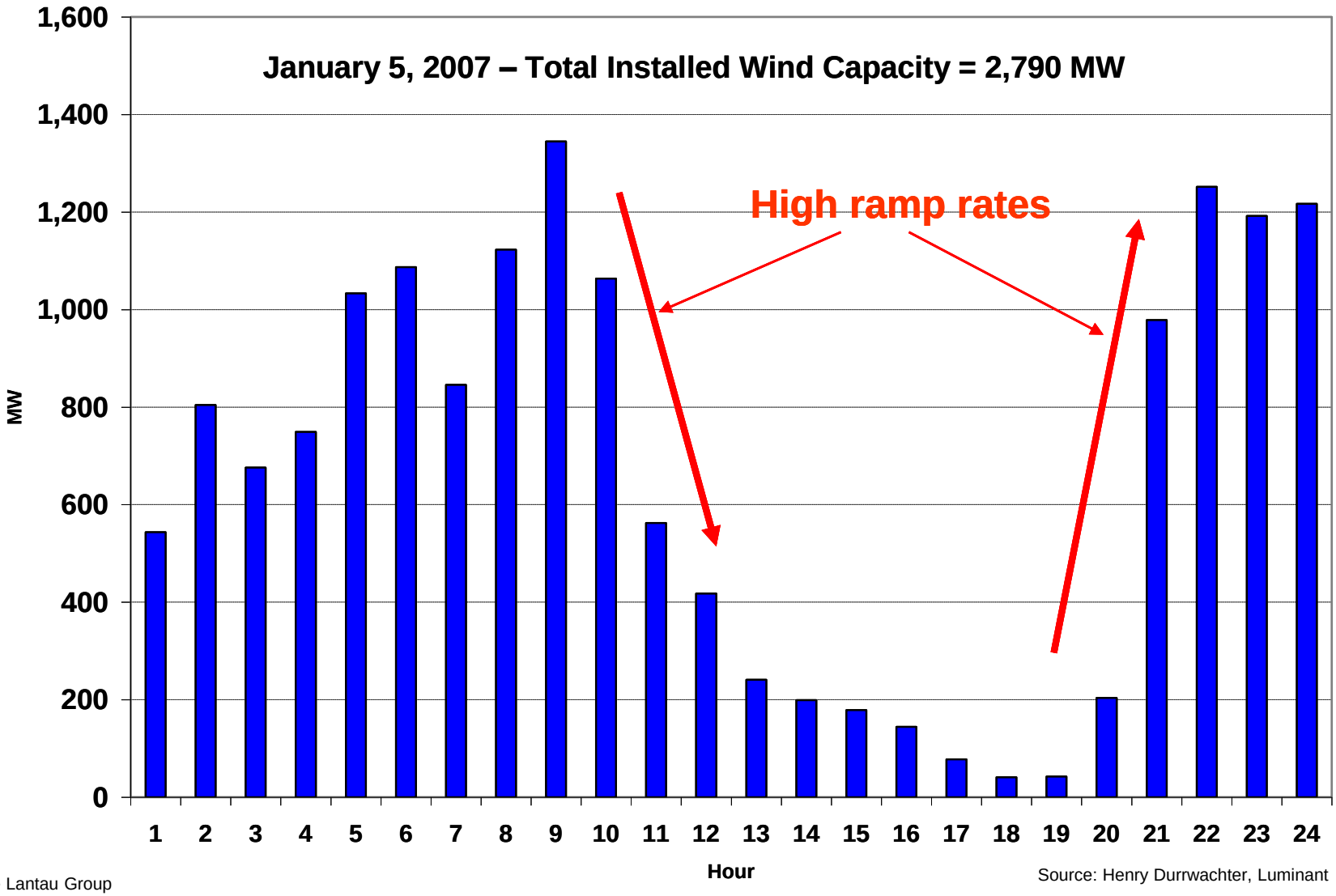


Systems only have so much inherent flexibility

These systems can absorb small amounts of intermittent renewables at no cost, because renewables “outages” are uncorrelated with thermal outages

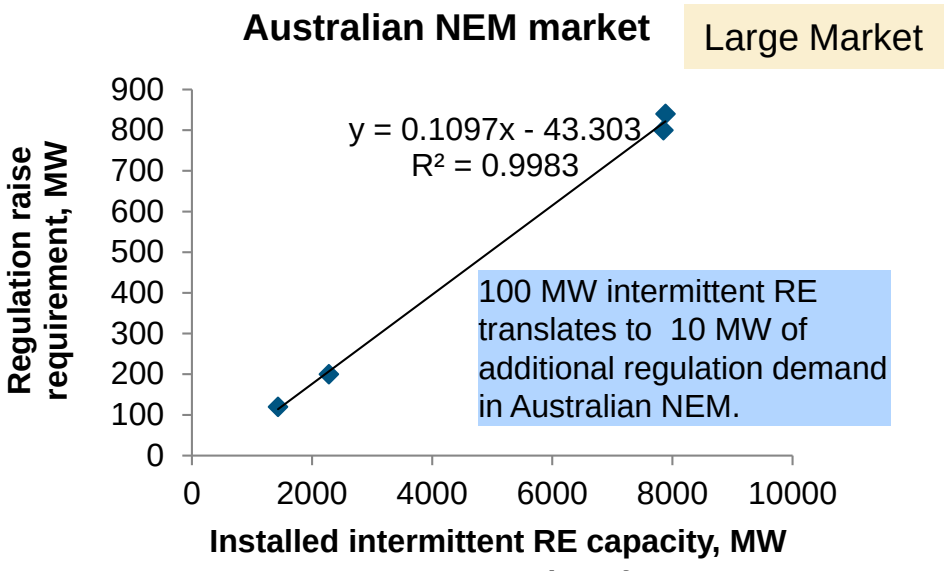
But intermittency can be highly correlated across wind and solar resources within a region
As a result, large quantities can lead to increased – and costly – requirements for spinning reserves and regulation.

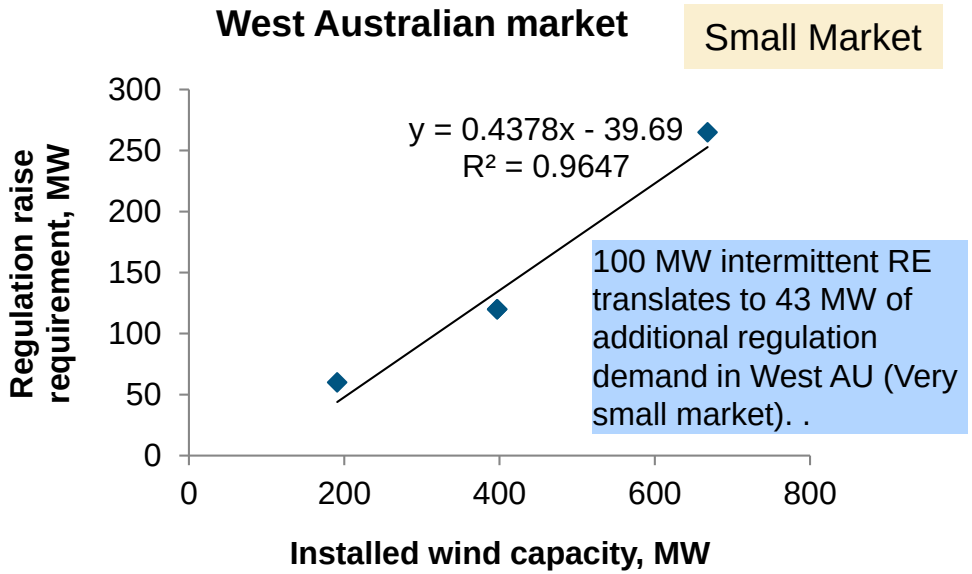
Wind and solar output is intermittent and not always predictable



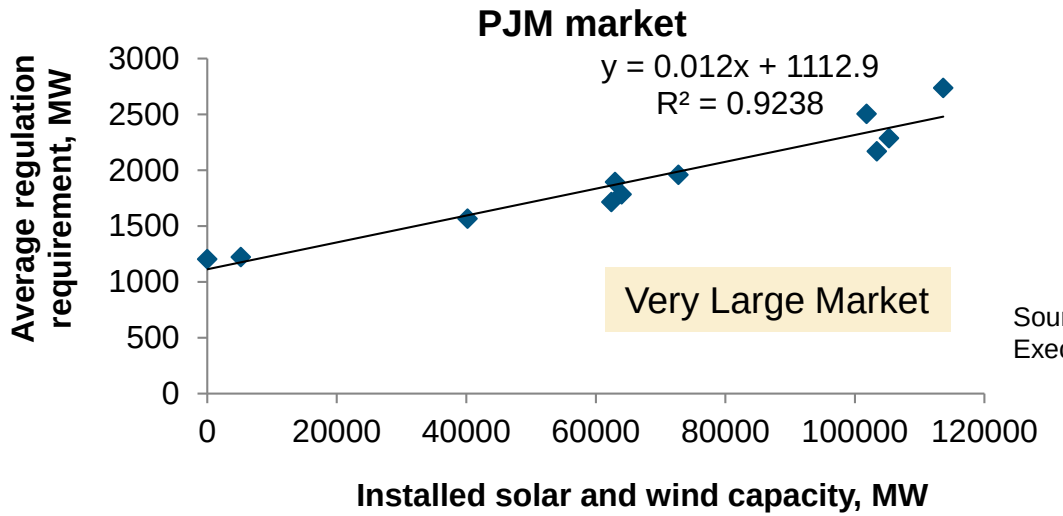
Source: Henry Durrwachter, Luminant

Based on international experience, with additional solar entry, higher regulation demand is required to maintain the same grid reliability





Source: ROAM Report on the Impact of LRET on the costs of FCAS, NCAS and Transmission augmentation

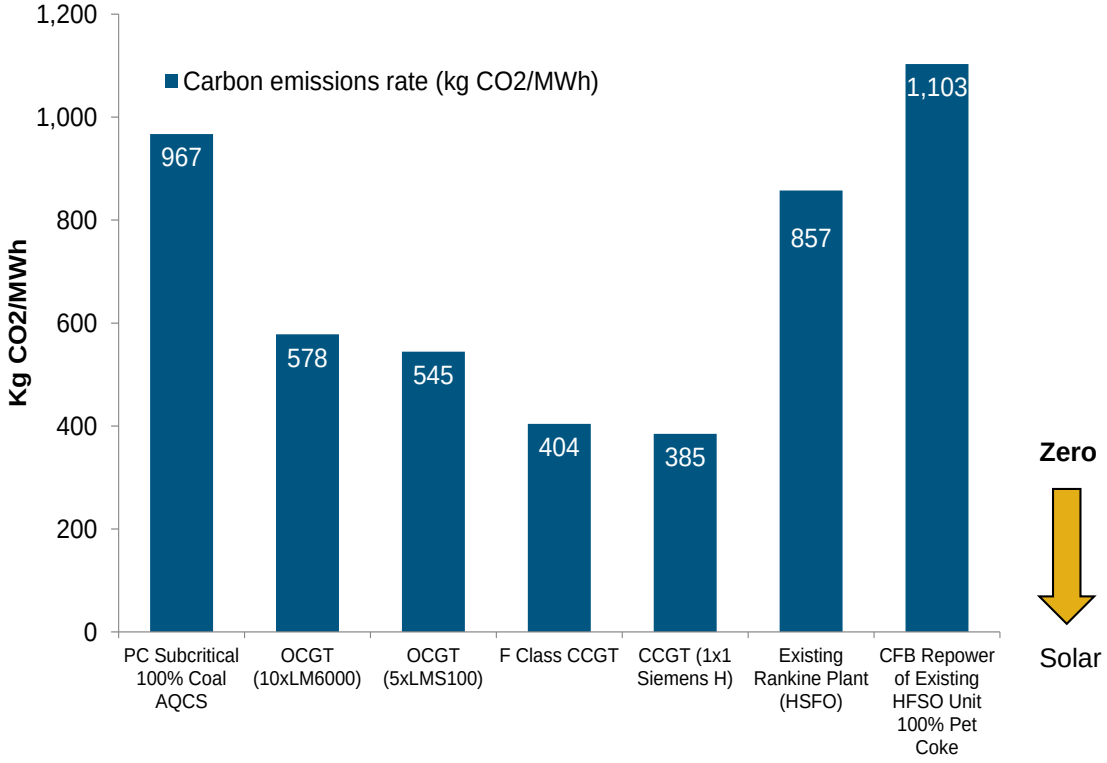


100 MW intermittent RE translates to 1.2 MW of additional regulation demand in PJM – very big market and thus there is diversification effect.

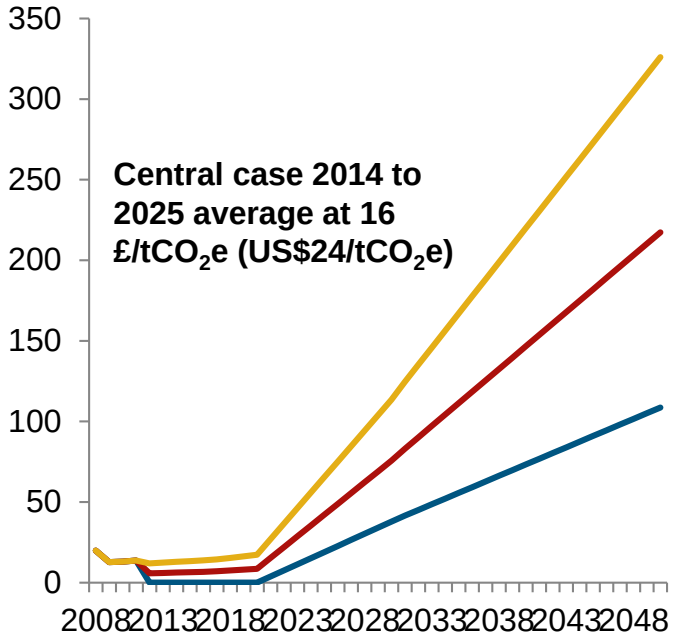
Source: PJM Renewable Integration Study, Executive Summary, March 2014

CO_2 reduction benefits are real, but not explicitly valued

Carbon Dioxide Emission Rates (kG CO2 / MWh)



Projected Value of Carbon Dioxide Emission Reduction 2008-2050 (UK DECC)



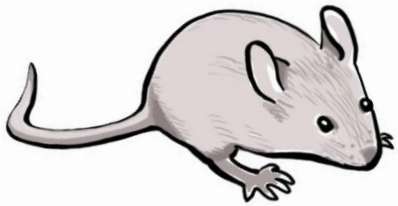
Grid parity without these benefits is harder to reach, but the benefits are real and often underpin societal or policy support for subsidies, feed-in tariffs, or purchasing/contracting obligations

Rooftop solar economics, in contrast, is often distorted by tariffs – frequently made more attractive than the underling economics suggest

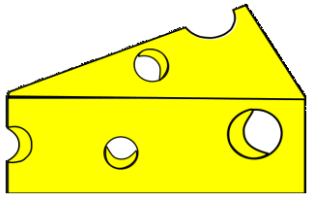
- What if the reduction in costs enjoyed by the customer is greater than the reduction in costs experienced by the power system overall?

- **Someone has to make up the difference!**

- Tariff design matters



Net Metering Customer

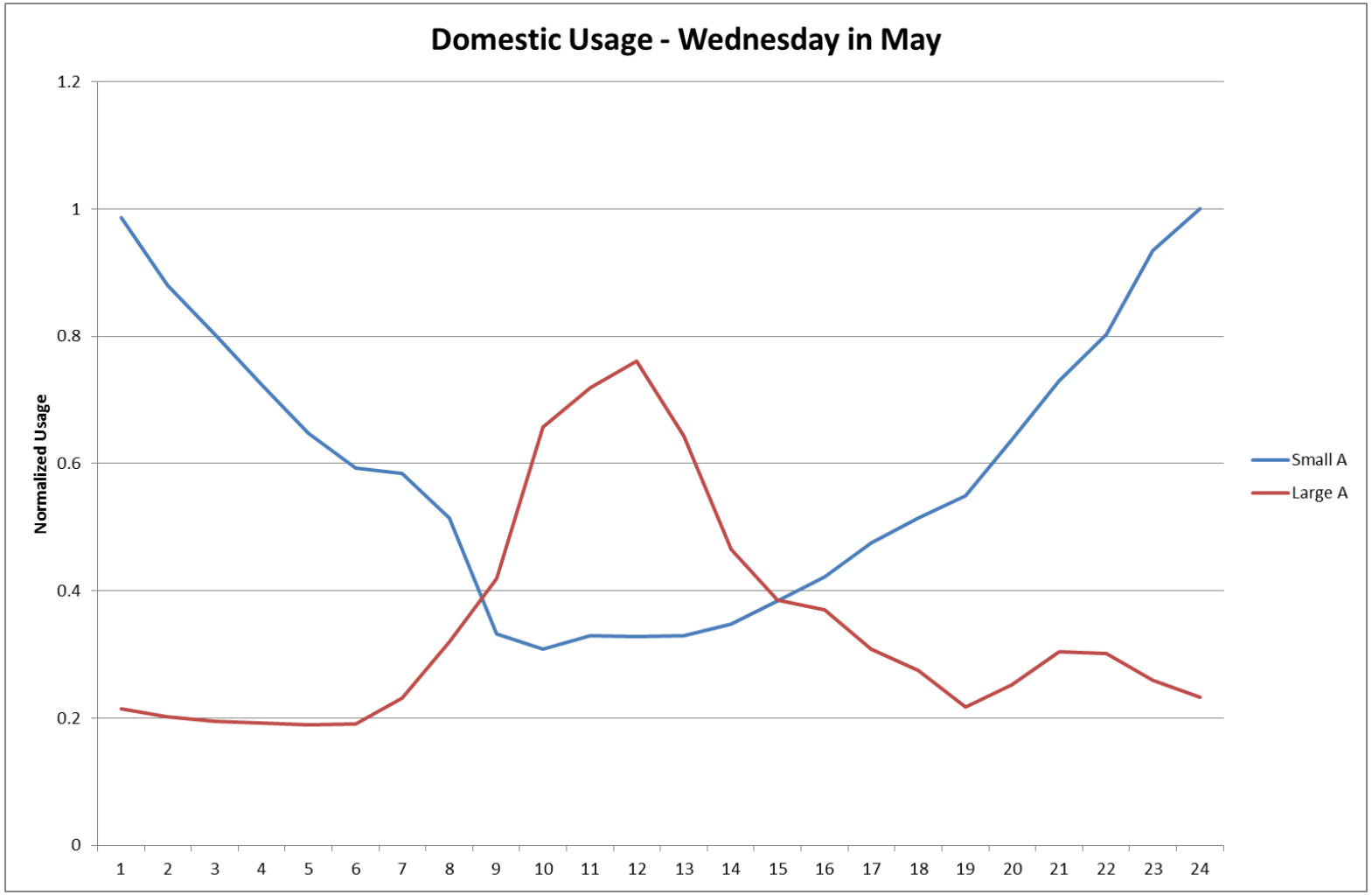


Hidden Net Metering Subsidy

Invoice

Other Customers

Rooftop solar doesn't work for everyone – but why would you want to shift costs to a user who already reduces their demand during the peak – the very thing solar panels are doing for panel adopters?



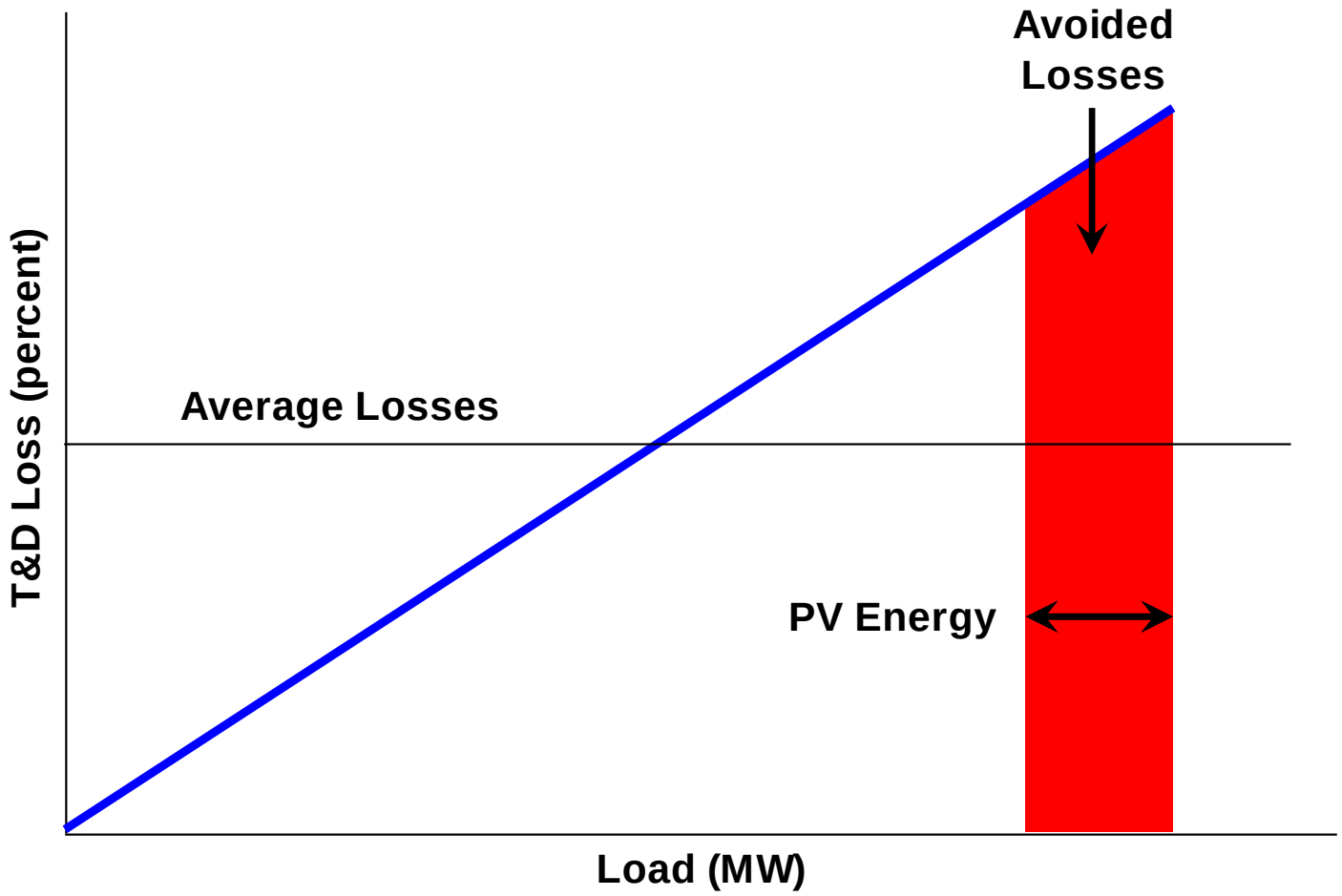
In the US, the solar rooftop business model has come under fire as being a play on bad tariff design – transferring costs to other customers

In the US**,** net metering schemes are **under review** in a number of states, eg:

- **Nevada**: draft decision to discontinue net metering (December 2015)
- **Hawaii**: net metering closed to new participants (October 2015)
- **Minnesota**: under 2013 legislation, utilities may offer a “value of solar” tariff as alternative to net metering
- **Oklahoma**: 2014 legislation prohibited cross-subsidy in favour of distributed generation
- **California**: decision to retain net metering for at least 3 more years (January 2016) but switching to time-of-use
- **Arizona**: ongoing review of net metering by utilities regulator

In Europe, several countries (**Netherlands, Belgium, Italy, Portugal**) have introduced fixed or capacity-based charges for recovery of network costs

Customer-side PV allows the utility to avoid *almost double* the average T&D losses, since losses are roughly proportional to load – where is this counted?



Summary

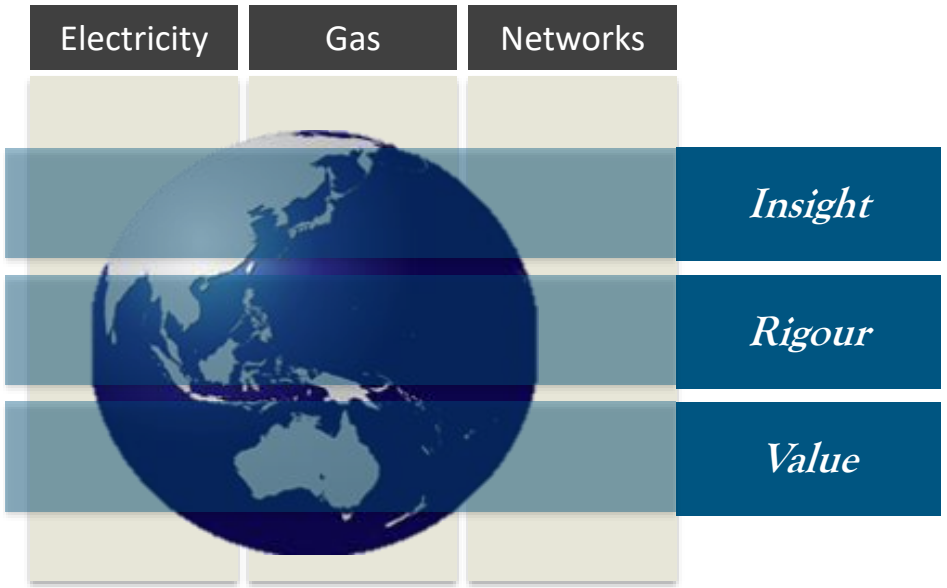
- It's clear that solar is getting closer to "parity" whatever that means, but there are still a lot of areas where – if we truly made apples to apples comparisons – the hurdle would be harder to overcome

- Environmental benefits are key but are often completely omitted as they are not commercially addressable – pity, as CO_2 reduction has value and should be explicit (and may in some cases or under some assumptions be sufficient to swing decisions)

- Ancillary services costs, however, are a large not-so-hidden subsidy, and need more attention

- Net metering will prompt more focus on tariff reforms. Most Asian domestic and commercial tariffs are 100% variable (volumetric) and this is the problem

Thank you



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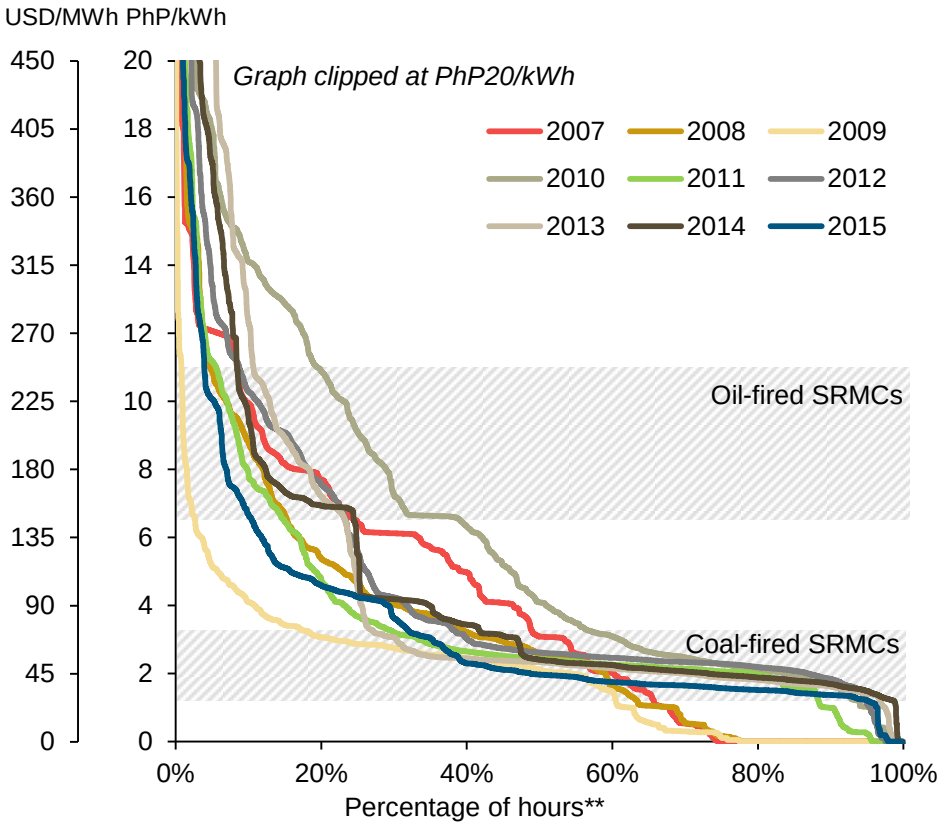
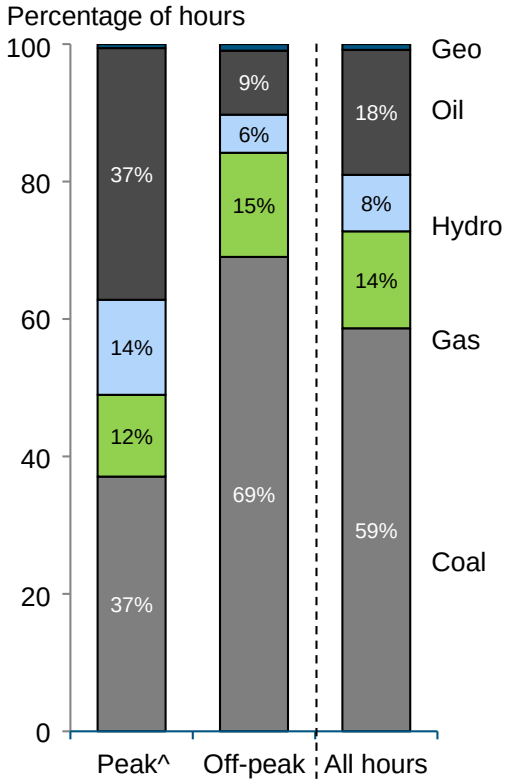
Philippine market prices tend to jump up from coal- to oil-fired costs about 10% to 40% of the time, reflecting the limited intermediate supplies available

Luzon WESM LWAP price-duration curve* (2007-2015 Nominal)



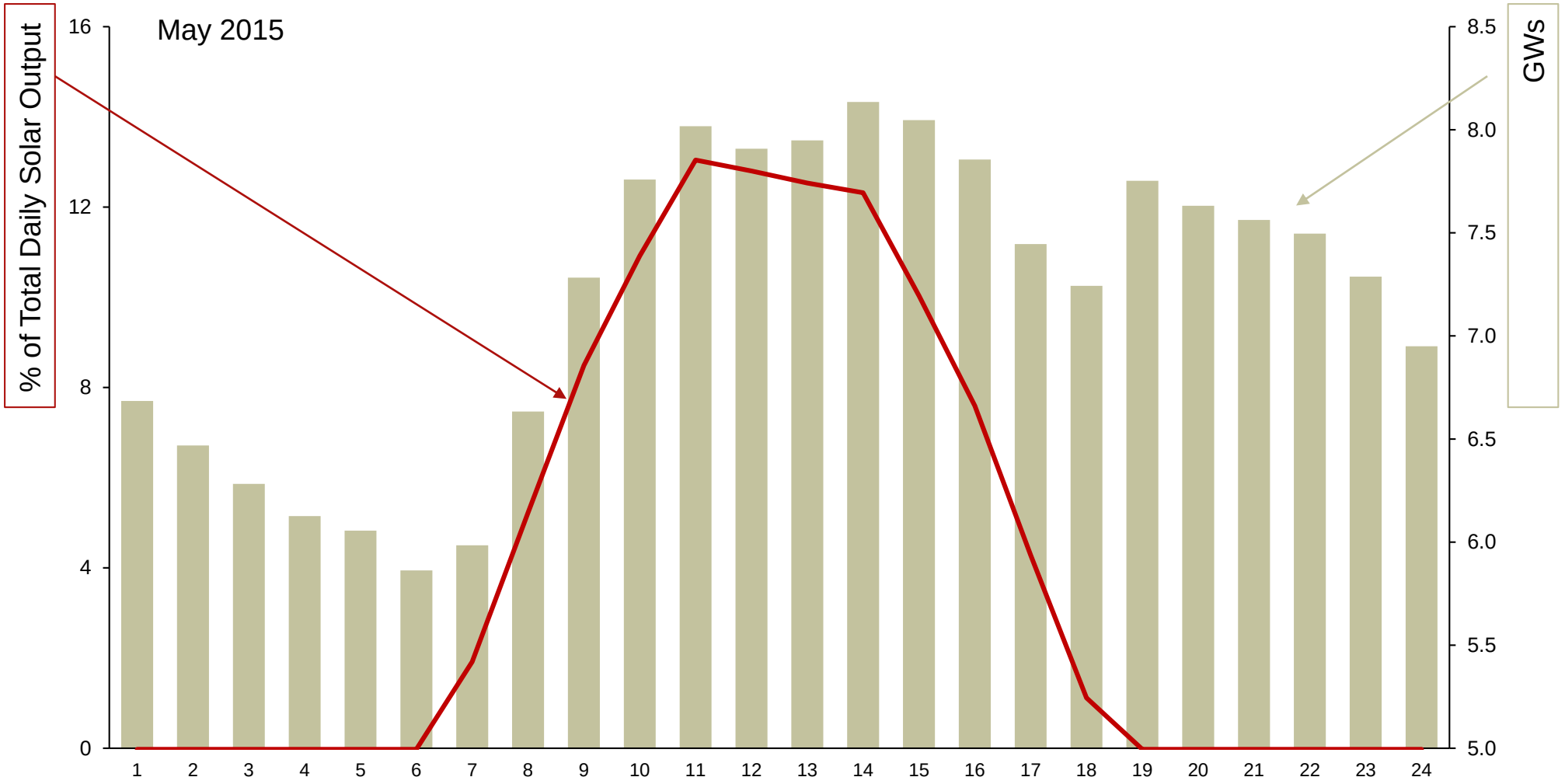
Luzon marginal plant by fuel type (2015)



Prevalence of hours set by coal-fired plant implies that volatility in coal fuel costs has largely been passed through in wholesale power prices.

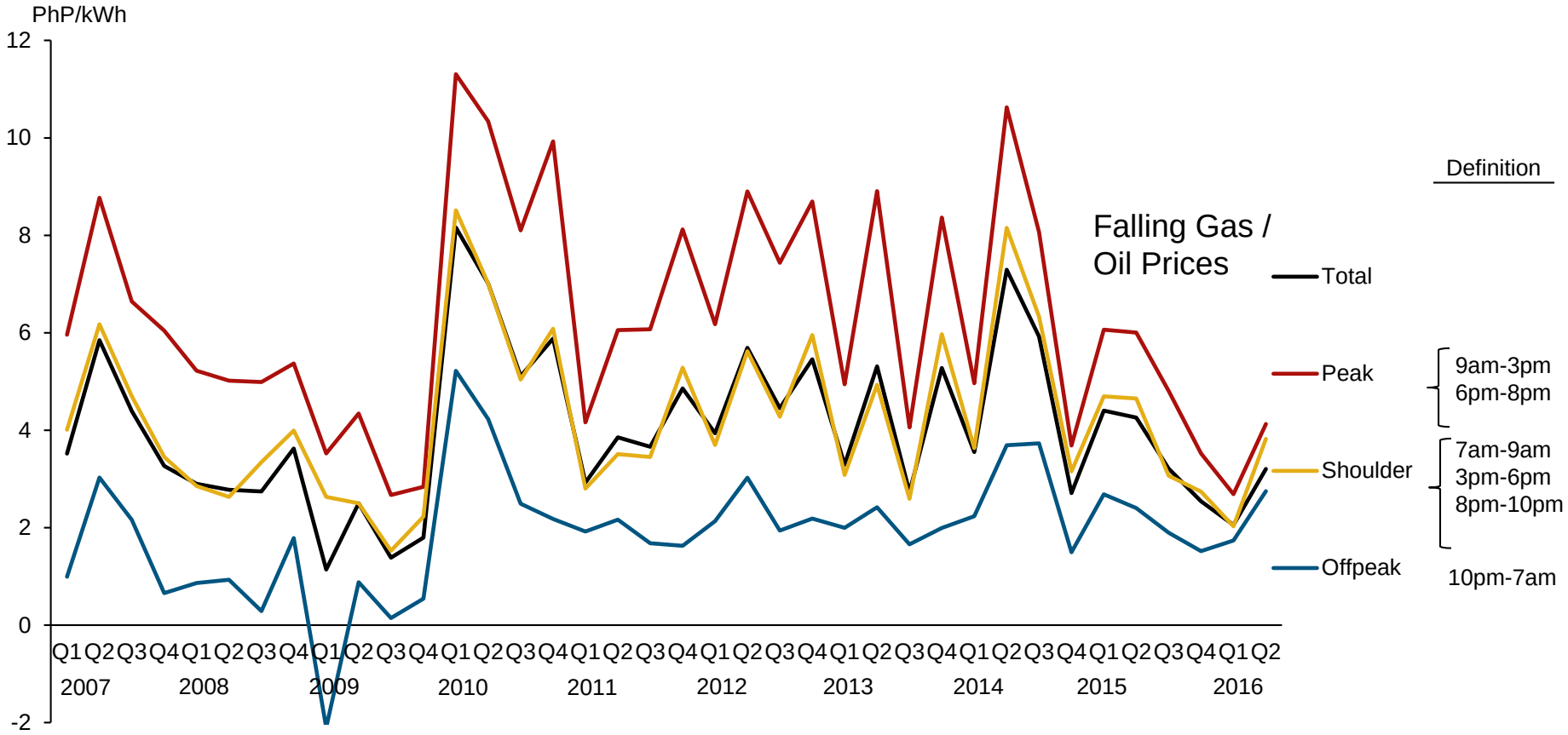
Note: * Average FX rate from 2007 to 2015 used to give USD/MWh. ; ** Excludes administered prices; Graph clipped at PhP0/kWh and PhP20/kWh;
^ Peak defined using NPC definition of hours 10-15, 19 & 20.
Source: PEMC (ex-post); TLG analysis

Solar output vs hourly average demand in Luzon, Philippines



Peak period prices are higher but have come down as oil and gas prices have fallen (and as some new capacity has entered) – reducing solar attractiveness

Time-average quarterly ex-ante prices* in Luzon
(2007-2016)



Note: * Arithmetic average of the hourly ex-ante LWAP in each quarter across WESM months.
Source: PEMC; TLG analysis

DECC's updated short-term traded sector carbon values for policy appraisal in real 2015 terms, £/tCO2e (note DECC was recently abolished in an overhaul)

Year	Low	Central	High
2015	-	5.94	20.79
2016	-	5.91	23.40
2017	-	5.89	26.41
2018	-	6.12	29.86
2019	-	6.35	34.04
2020	-	6.59	39.03
2021	3.92	13.78	46.89
2022	7.85	20.96	54.76
2023	11.77	28.15	62.62
2024	15.69	35.33	70.49
2025	19.61	42.52	78.35
2026	23.54	49.71	86.22
2027	27.46	56.89	94.08
2028	31.38	64.08	101.95
2029	35.30	71.26	109.81
2030	39.23	78.45	117.68

2016 to 2025 simple average is 17 £/tCO2e