Evaluating the benefits of hydropower

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McWILLIAMS *energy*

Understanding power systems

- To maximise value from hydro we need to configure them to provide optimum support to the grid.
- Power systems are changing rapidly: hydro is less about power and energy, and more about stability and security.
- Hydro engineers and developers need to understand the role hydro will play in future energy systems.

The energy transition

- Wholesale decarbonisation of electricity is happening.
- Traditional fossil-fuelled generation is on the way out.
- New renewables are taking over.
- Gas-fired generation may still be needed for back-up, but many nations are committed to “net-zero” carbon.
- Future power systems will look very different.

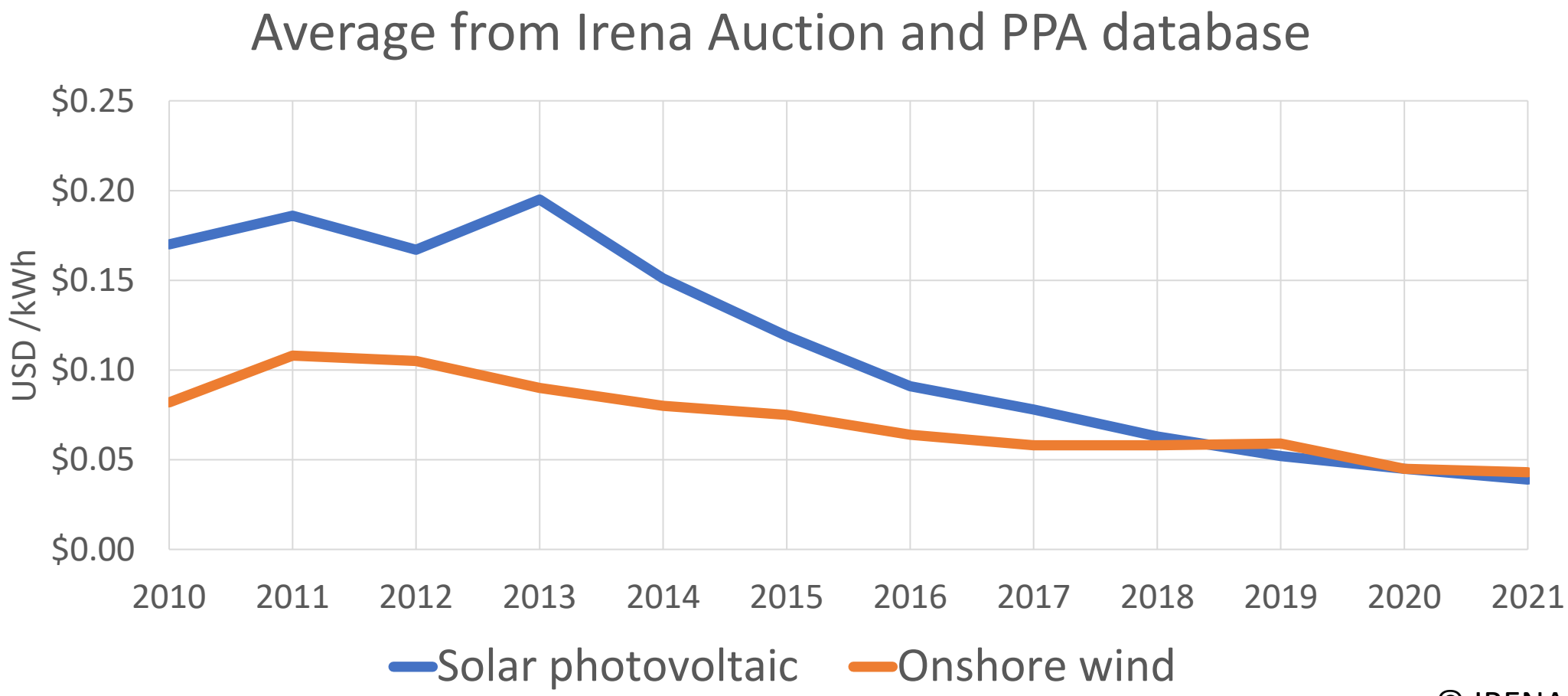
What's driving this transition?

- Initially renewable energy was driven by political regulation and public sentiment.
- Commitments under 2015 Paris Agreement still drive the decarbonisation agenda.
- However with the cost of renewable energy falling, economics is starting to drive change.

The cost of vRE?

- In many countries variable Renewable Energy (vRE) is now the cheapest source of energy.
- Recent PV tenders in Portugal and Abu Dhabi were won with prices as low as US¢ 1.3 / kWh.
- In USA sub-US¢ 2.0 / kWh for wind is common (although this would probably be US¢ 3.0 / kWh without subsidy)
- Few technologies can compete with these energy prices.

The falling cost of vRE



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Shape of future power systems

- Traditional power systems featured relatively stable demand and predictable generation.
- Most of the generators were capable of supplying continuous base-load.
- Storage hydro could be used for peaking, and pumped storage for arbitrage.
- Storage hydro is virtually the only despatchable low carbon generation for future power systems.

Traditional generation mix

Technology	Constant	Predictable	Dispatchable	Low Carbon
Steam (coal / oil)	Yes	Yes	(Yes)	No
Open Cycle Gas Turbine	Yes	Yes	Yes	No
Combined Cycle Gas Turbine	Yes	Yes	(Yes)	No
Reciprocating (diesel / HFO)	Yes	Yes	Yes	No
Nuclear	Yes	Yes	No	Yes
Hydroelectric with storage	(Yes)	(Yes)	Yes	Yes
Hydroelectric: run-of-river	No	No	(Yes)	Yes

Future generation mix

Technology	Constant	Predictable	Dispatchable	Low Carbon
Nuclear	Yes	Yes	No	Yes
Hydroelectric with storage	(Yes)	(Yes)	Yes	Yes
Hydroelectric: run-of-river	No	No	(Yes)	Yes
Solar Photovoltaic	No	No	No	Yes
Solar Thermal	(Yes)	No	(Yes)	Yes
Wind	No	No	No	Yes
Tidal Stream	No	Yes	No	Yes
Tidal Range	No	Yes	(Yes)	Yes
Biomass / MSW	Yes	Yes	(Yes)	Yes
Geothermal	Yes	Yes	No	Yes

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Valuing energy

- In the past, energy (kWh) was the main basis for trading electricity.
- Variations in demand resulted in peak and off-peak pricing, although most retail sales were at a single tariff.
- Generators could be compared on the basis of energy cost – either tariff or levelized cost of energy (LCOE).
- Energy is no-longer a good basis for comparing generators – sometimes energy has little value.

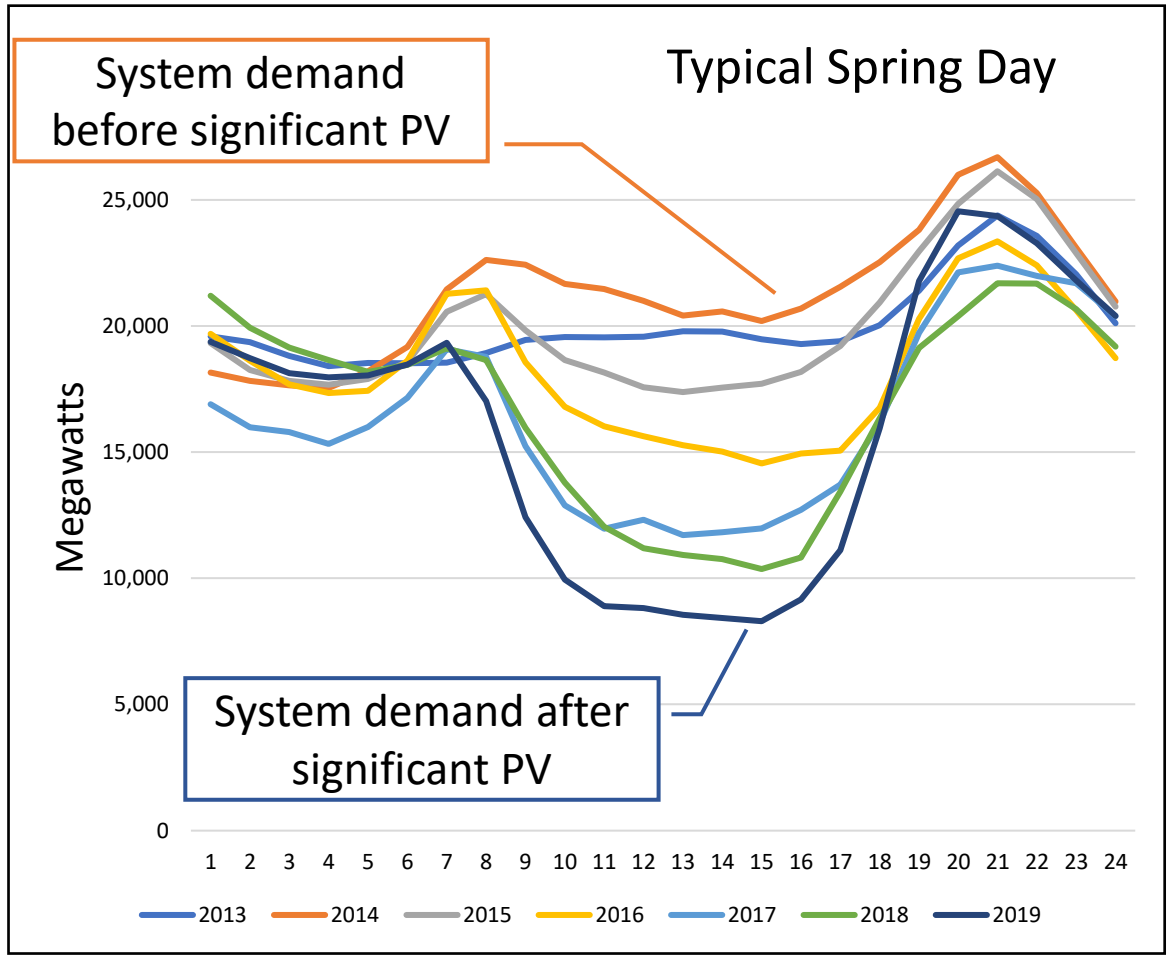
The Duck's getting fatter

In 2013 CAISO* created the duck curve: they expected the transmission system demand to drop by 40% in 2020 on a sunny spring day due to distributed solar PV generation.

The duck is getting fatter more quickly than expected, and by 2019 demand was already reduced by 57%.

By Spring 2019 maximum ramping rates had reached over 15 GW in 3 hours.

Over-supply has become a problem.



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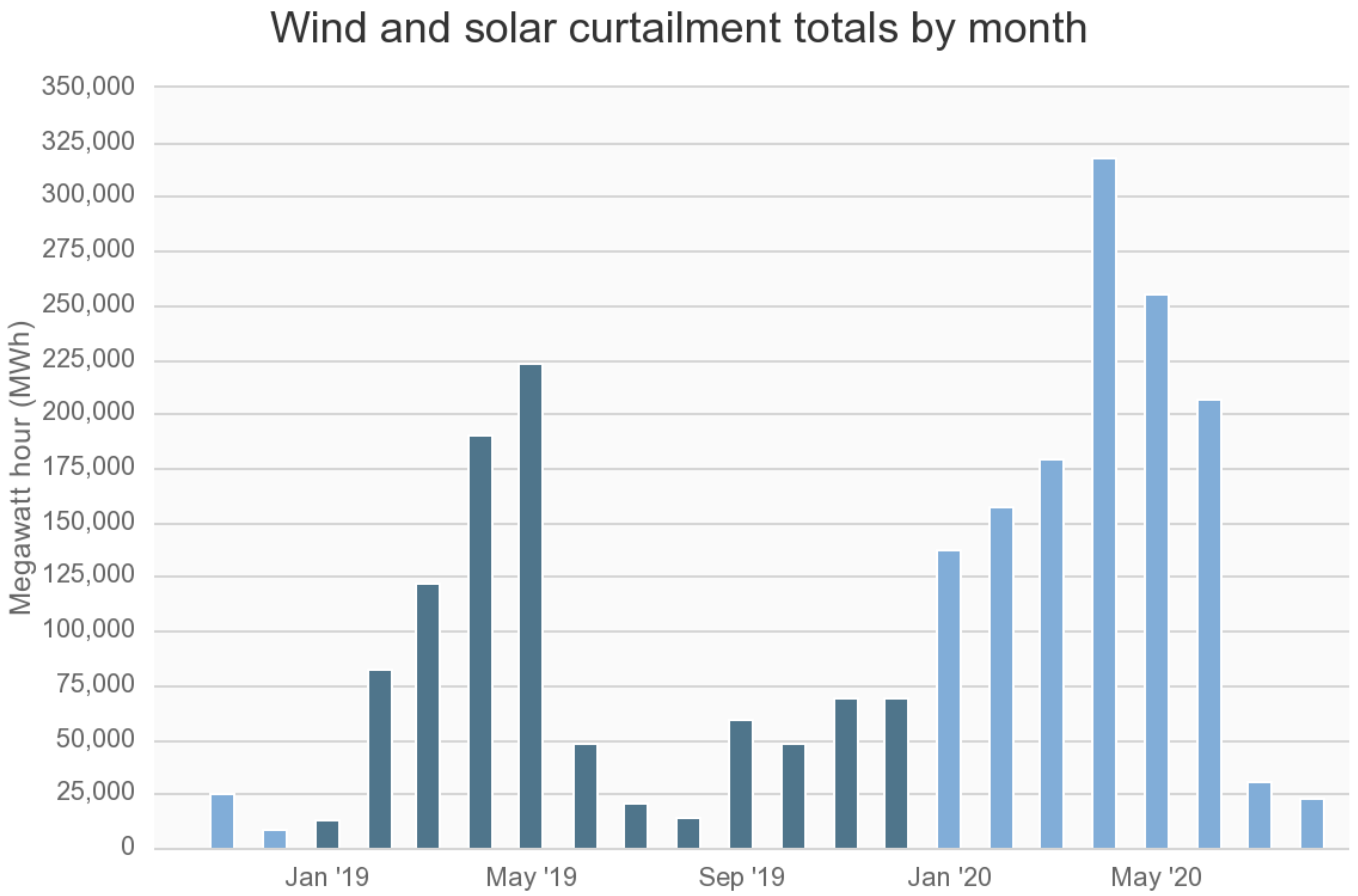
Source: data from IEA / CAISO

*CAISO is the California Independent System Operator

Curtailment of vRE is common…

On CAISO's system curtailment of renewable energy sources due to over-supply has become common, especially in the spring months.



Source: CAISO

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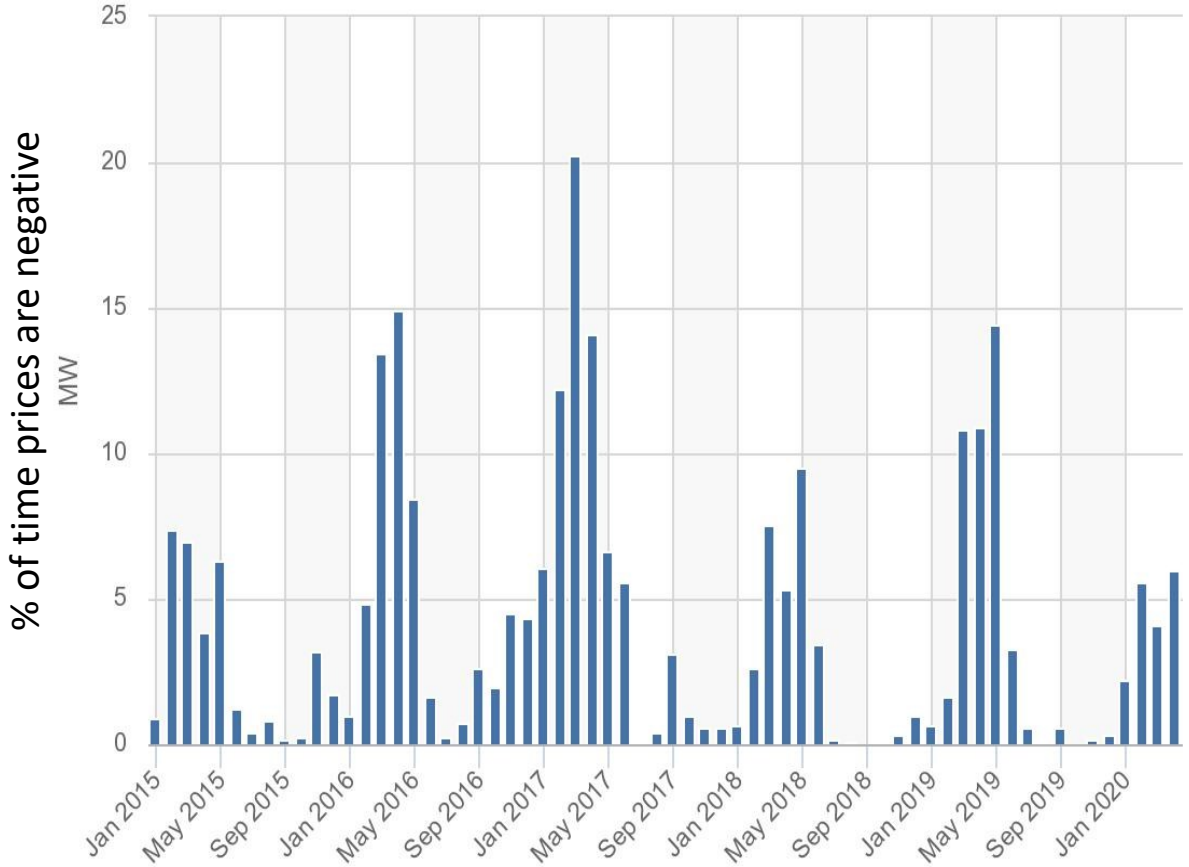
…and prices turn negative

With over-supply and curtailment comes negative energy prices.

In some months prices are negative 10% to 15% of the time.

vRE is becoming cheap, but it is also losing its value.

Energy cost is not a good way of comparing technologies, since the value to the grid depends on when and where energy is produced, and how dependable it is.



Source: CAISO

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Paying for retail energy

- Consumers are installing behind-the-meter generation to restrict the amount of energy they buy from the grid.
- Grid balancing costs are rising with vRE penetration.
- Balancing costs cannot be subsumed in energy tariffs.
- Future tariffs will comprise a connection cost and a (low) energy tariff.
- Marginal cost of most future generation is zero or negative (in the case of nuclear), so possibly energy will be free.

Benefits of Hydropower

Activity	Service	Hydro	PSP
Balancing	• Day ahead scheduling • Load following / dispatch • Automatic frequency response • Fast ramping • Arbitrage (intra-day storage) • Bulk energy storage (multi-day) • Footroom (load turn-up)	✓ ✓ ✓ ✓	✓ ✓ ✓ ✓ ✓ ✓ ✓
Rate of change of frequency	• Inertia	✓	✓
Voltage management	• Reactive power control (location specific)	✓	✓
Transmission management	• Constraint alleviation (location specific)	✓	✓
Reconstruction	• Blackstart • Fine variable control	✓ ✓	✓ ✓

Pumped storage and some hydro can provide many of these services at zero load, hence without displacing vRE

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How to value benefits

- Generation was traditionally valued using least cost system expansion software (eg WASP, ASPLAN), or cost-benefit analysis, but this only values power and energy related benefits.
- Economic value of ancillary services needs to be added; studies include US DoE study for valuing PSP, and XFLEX Hydro in Europe.
- Value of multi-purpose benefits and negative impacts should be added.
- Ideally national macro-economic impacts should be included.

Options for valuing ancillary services

- Some studies use market valuations – often based on auctions; but few markets reflect the cost of services from new facilities.
- Estimate the cost of equivalent services from stand-alone facilities.
- The system operator can compare the value of providing all required services from a blend of technologies.
- Valuation is complex – it changes as the system evolves, particularly with asynchronous vRE penetration and decommissioning of large steam plant.

Conclusions

- Hydro cannot compete with low energy prices of vRE
- Energy will not be the basis of trading electricity
- Hydro offers much more to the system than just energy
- Valuation should be based on total system benefits
- Ideally include macro-economic benefits to the nation
- **All energy is not equal**.