THE UNIVERSITY OF MELBOURNE

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The Future of Hydrogen in Australia: some thoughts

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Michael Brear
Director
Melbourne Energy Institute

Outline

1. Preliminaries
2. Inputs and scenarios
3. Parametric dependence of the LCOH
4. Wind and solar farm dynamics
5. Integration of renewable electricity and hydrogen
6. Closing thoughts

Australian energy vectors*

Electricity

- Consumption = 250 TWh p.a. = 900 PJ p.a.
- Typical wholesale price = 80 $/MWh

Coal

- Consumption = 1900 PJ p.a.

Natural gas

- Consumption = 1500 PJ p.a.
- Typical wholesale price = 8 $/GJ = 29 $/MWh

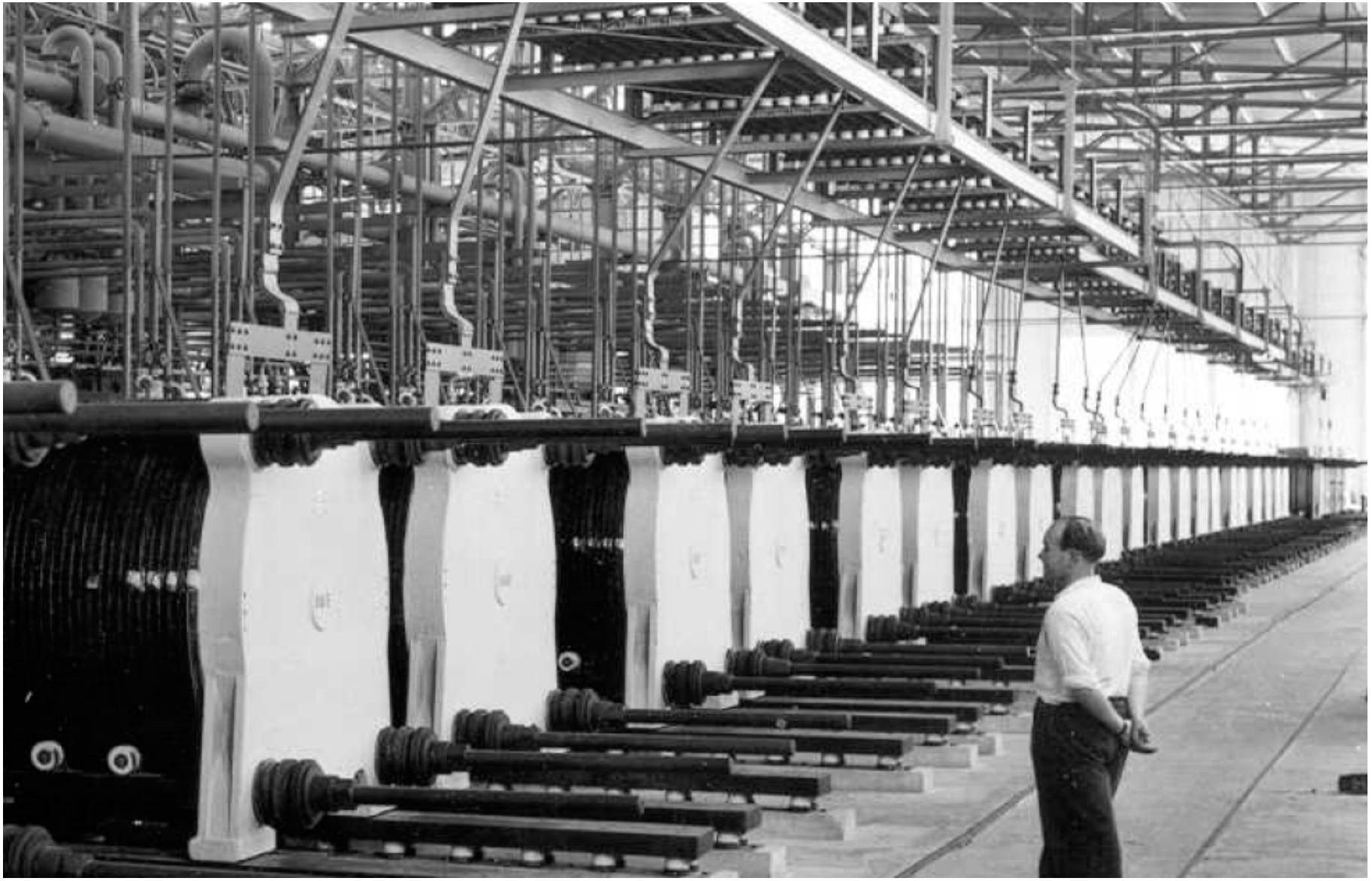
Oil (which mainly becomes gasoline, diesel and kerosene)

- Liquid fuel consumption = 2300 PJ p.a.
- Typical (refined product) wholesale price = 1 $/lt = 30 $/GJ

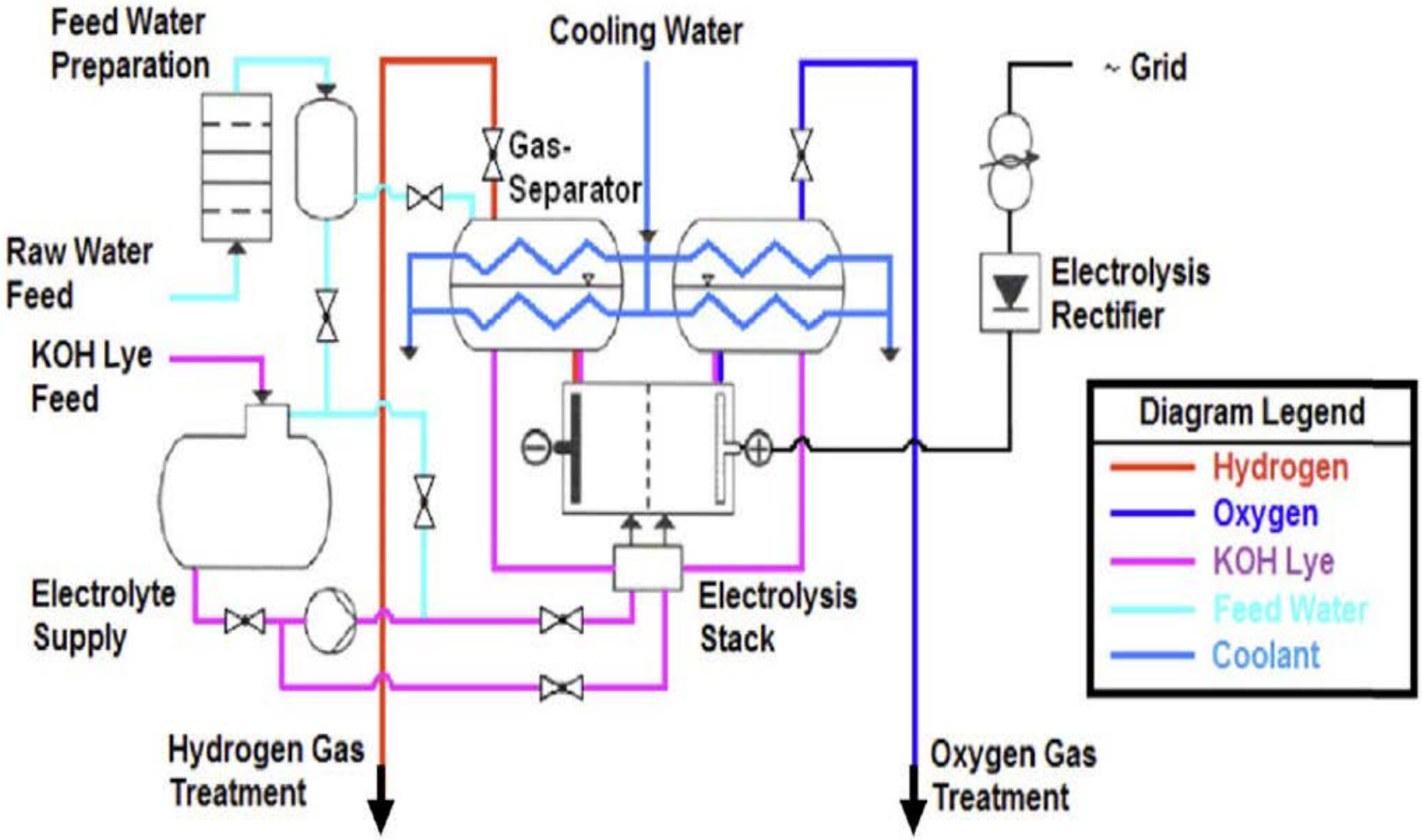
- Remarkable that so much of the national debate is on electricity / coal given the scale of fossil fuel use!

*Australian Energy Update, 2018, Department of Environment and Energy

Industrial electrolysis isn’t new – 135MW alkaline plant in 1940 Norway



Alkaline electrolysis is *relatively* straightforward



Inputs and scenarios

- The Levelised Cost of Hydrogen (LCOH):

$$LCOH\left(\frac{\$}{GJ}\right) = \frac{\left(\text{capital costs}\right) + \left(\text{electricity costs}\right) + \left(\text{other operating costs}\right)}{\left(\text{production of hydrogen}\right)}$$

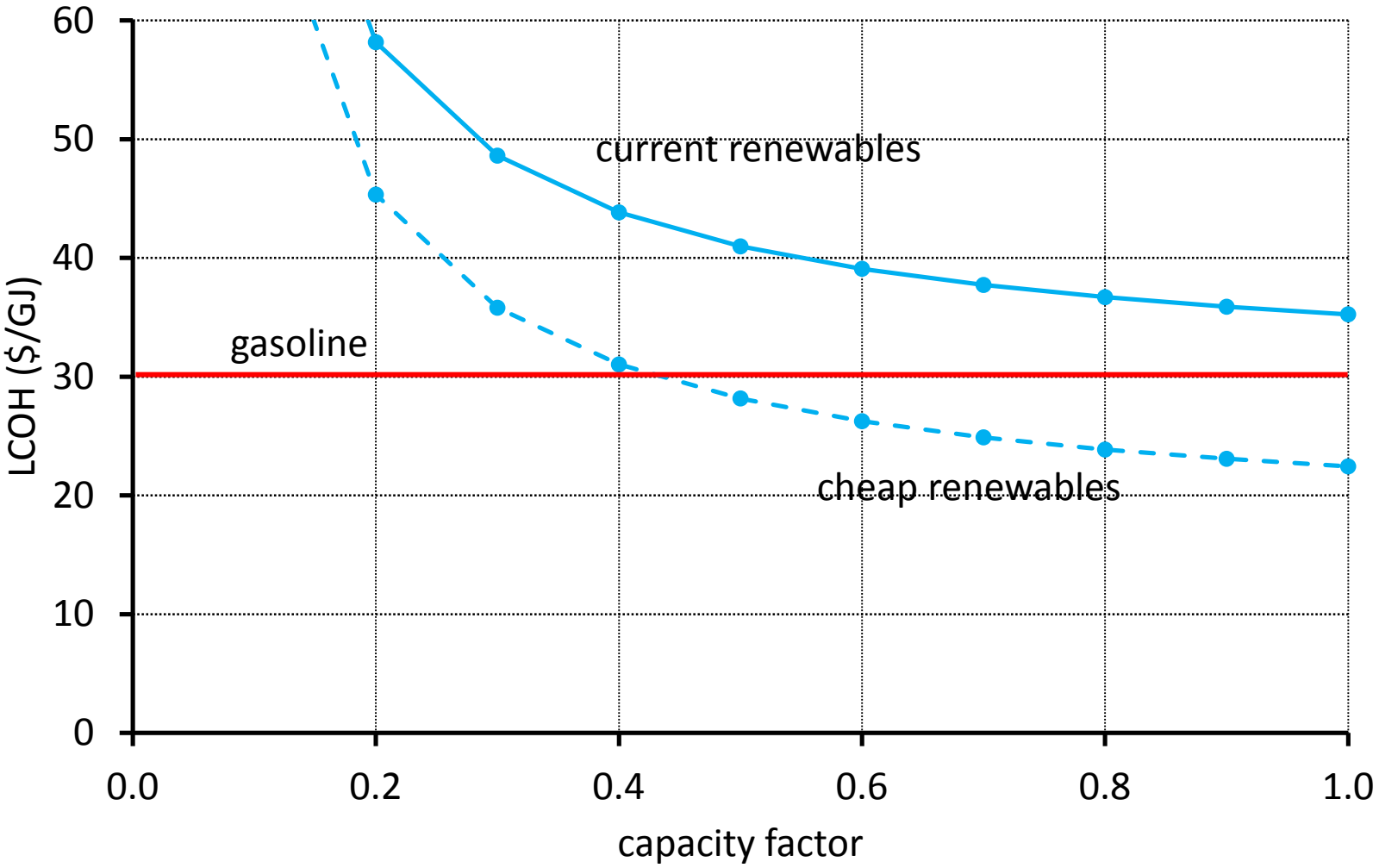
- Electrolyser inputs, unless specified otherwise:
  - capital cost = 1 $/W
  - cost of capital = 10%
  - O&M = 4 $/MWh
  - efficiency = 65%

- We define 2 renewable generation scenarios:

1. *Current*
   - Solar: 25% capacity factor, 1.4 $/W
   - Wind: 40% capacity factor, 1.6 $/W
   - wind and solar = 65 $/MWh unsubsidised
   - 10% cost of capital

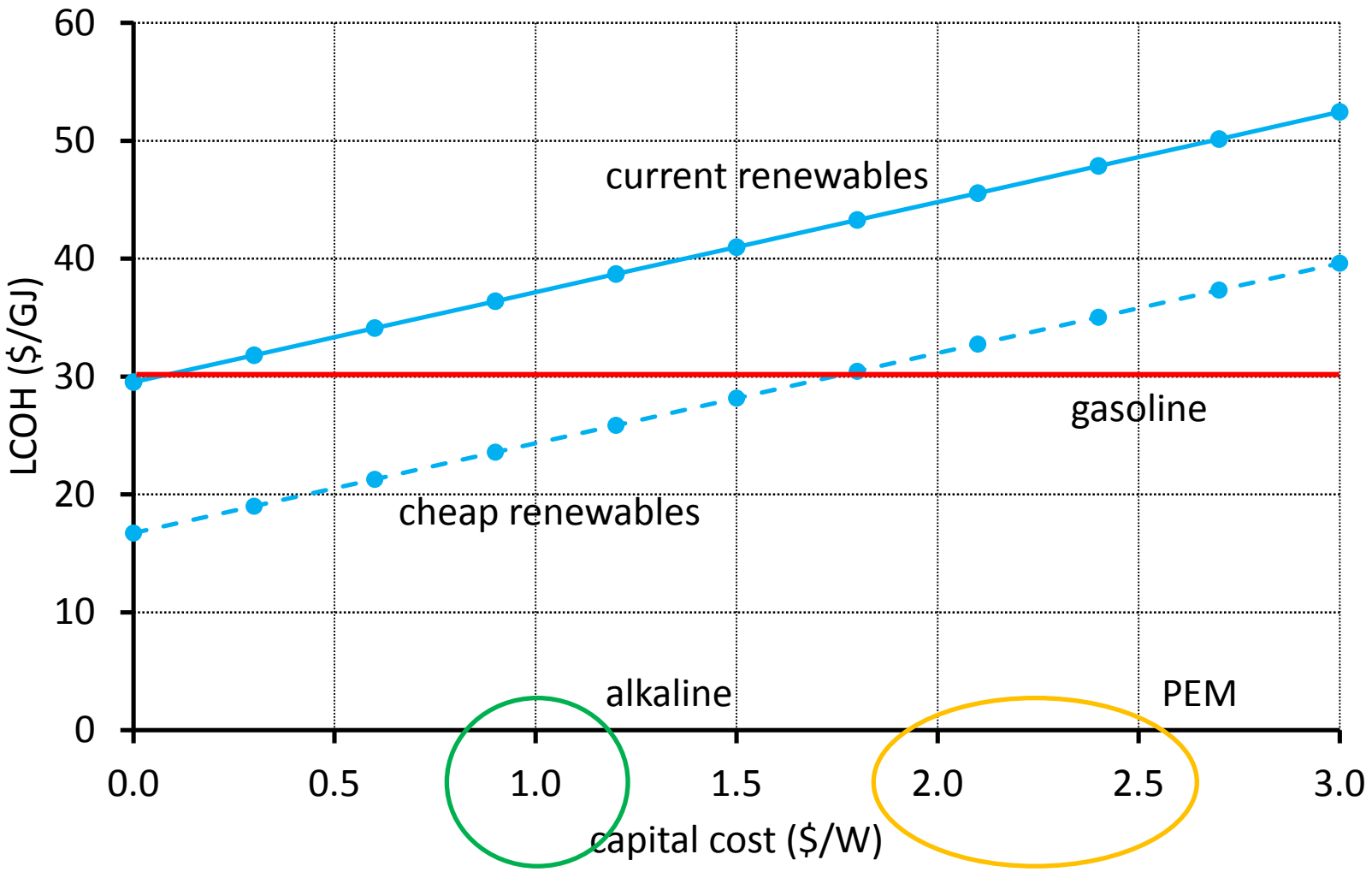
2. *Cheap renewables: a rough estimate of their unsubsidised cost in 2030*
   - wind and solar = 35 $/MWh unsubsidised
   - due to a combination of capital cost reductions and a 5% cost of capital

Parametric dependence of the LCOH – capacity factor



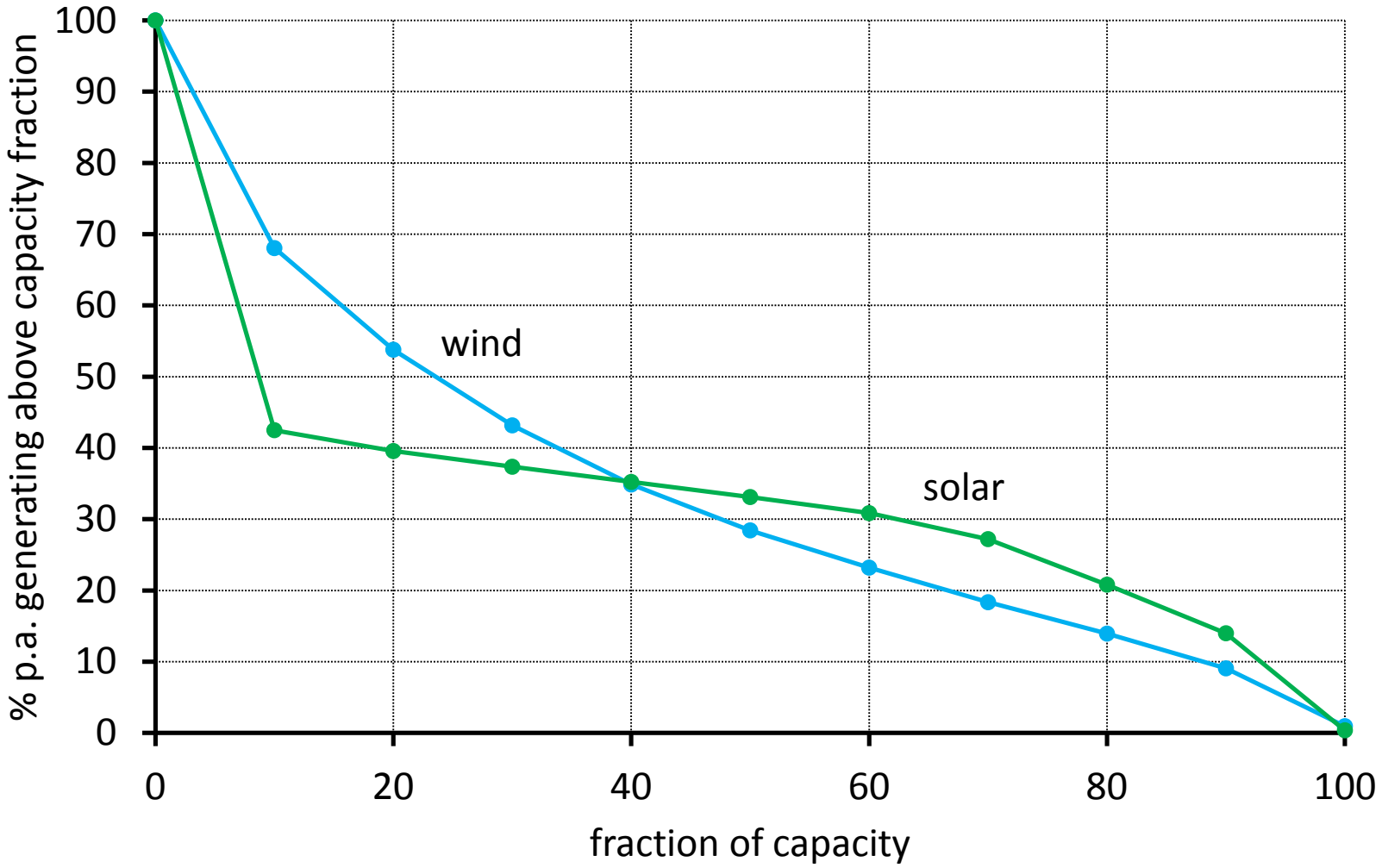
- LCOH doesn't reduce much further for capacity factors above about 50% – require operation in this regime.

Parametric dependence of the LCOH – capital cost



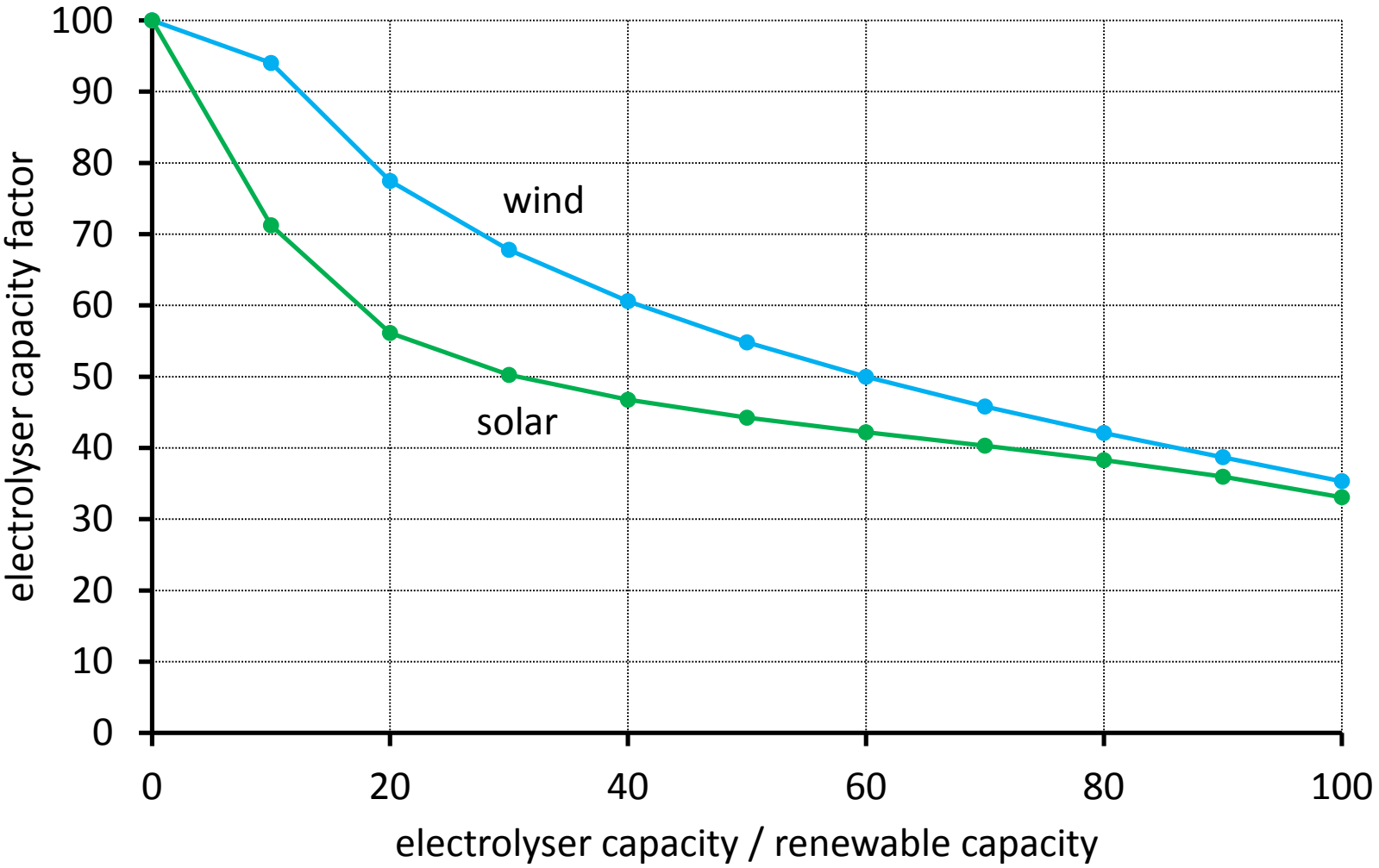
- Alkaline electrolysis appears to have a significant advantage relative to PEM electrolysis.

Wind and solar farm dynamics



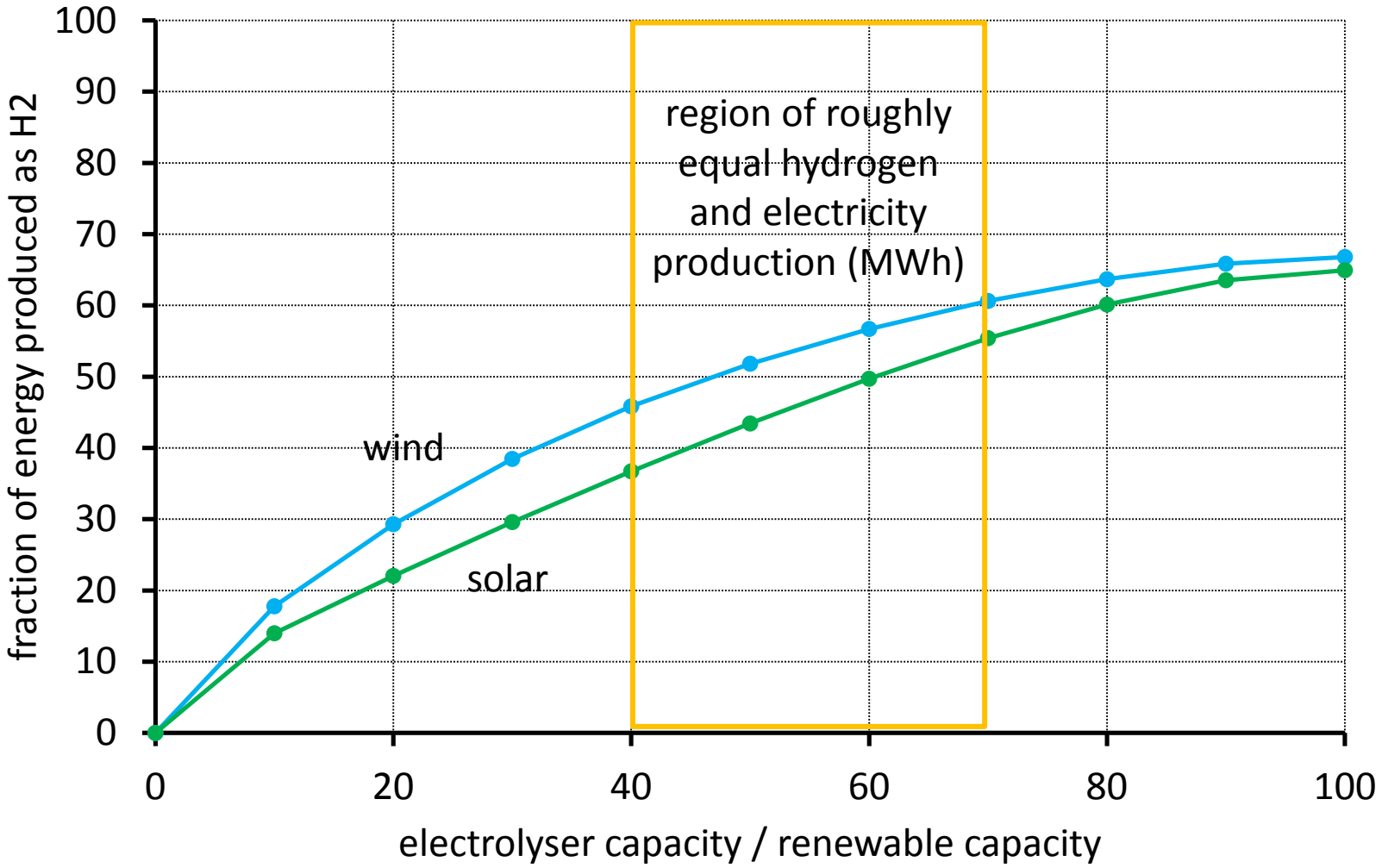
- This graph shows the proportion of the year that two operating farms generate above some fraction of their full capacity.

Capacity factor of a sub-scale electrolyser next to a renewable plant



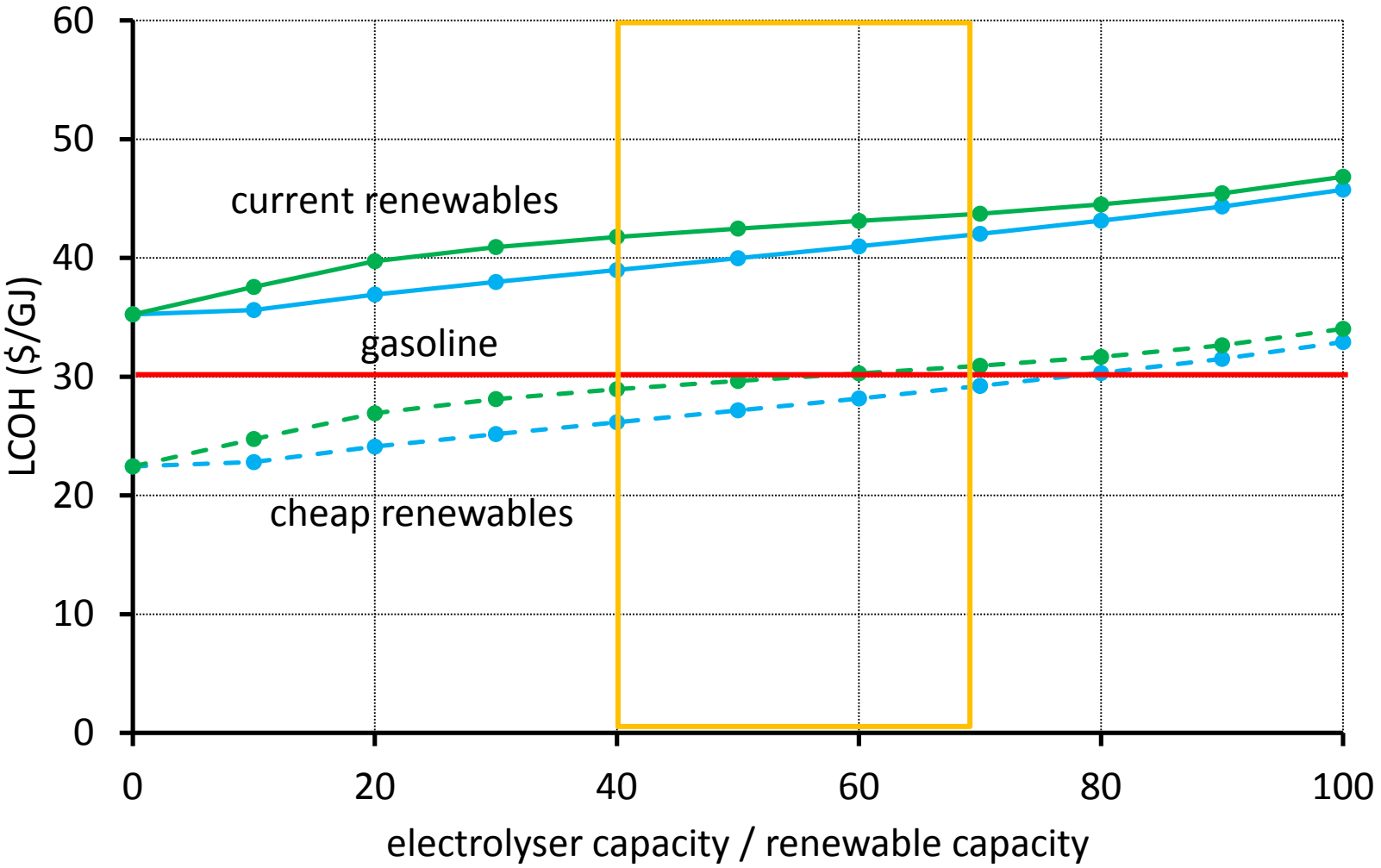
- CF of sub-scale electrolyser relatively high due to renewable generation above its capacity.
- CF of electrolyser tends to that of the renewables when their capacity becomes equal.

Fraction of energy produced as hydrogen from a renewable plant



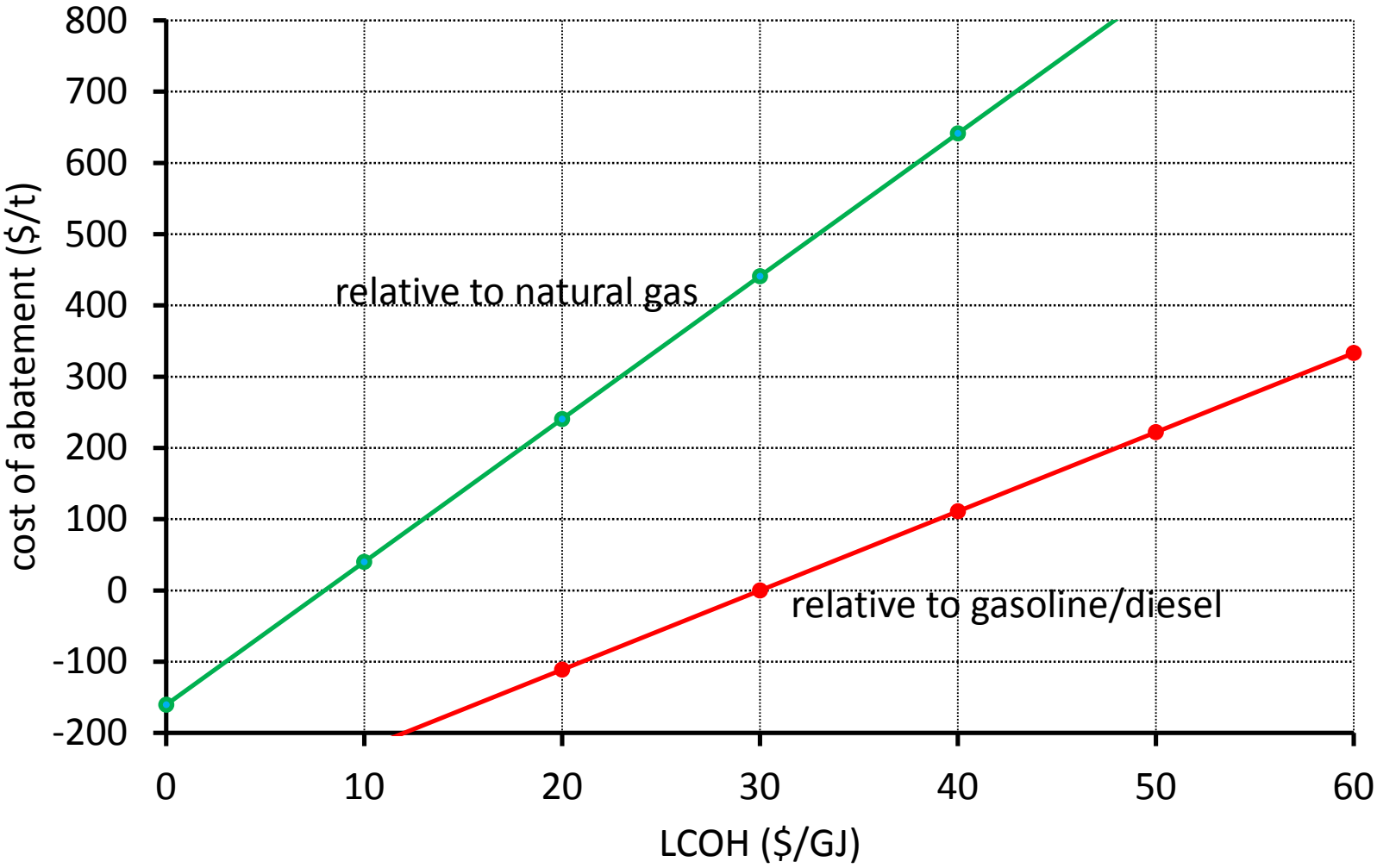
- Small electrolysers don't make much hydrogen, even with high CF!
- Energy fraction tends to electrolyser efficiency when its capacity equals the renewable plant.

LCOH from alkaline electrolysis next to a wind or solar farm



- Small electrolysers cheaper because of their higher CF.
- Opportunity to match and even beat gasoline on price – all about the electricity price!

Cost of abatement of green hydrogen



- Costs of abatement gets large quickly – achieving close-to-parity with the fossil equivalent unsubsidised is therefore essential, and a particular challenge for displacing natural gas.

Closing thoughts

- The production of hydrogen from renewable energy has good prospects, particularly in decarbonising transport:

    1. LCOHs that are competitive with conventional liquid fuels appear achievable, *even without subsidy*, should renewable electricity prices continue to fall;

    2. hydrogen production on an energy basis could be comparable to the remaining renewable electricity – important given the scale of the liquid fuel market;

    3. hard to see how hydrogen will compete on price with natural gas, but this may change as policy and technology evolves.

- Alkaline electrolysis has significant capital cost advantages over PEM, and large scale (i.e. >100MW) alkaline electrolysis isn't new.

A proposition - is this a good investment ***right now***?

- X GW (i.e. big) wind or solar farm with X/4 to X/2 GW alkaline electrolyser
  - electrolyser on-site or elsewhere, depending on the economics: comparing cost of energy transmission via electricity and pipe/truck, effect of grid congestion, etc.
  - electrolyser provides ancillary services to help firm the grid: additional revenue not modelled in today's presentation;
  - electrolyser maybe also sells oxygen: more revenue again;
- Hydrogen used to decarbonise land, sea and air transport, either domestically or internationally:
  - full electrification unlikely for medium-to-heavy duty land, sea and air transport;
  - if the economics work, clean H2 can be made into liquid fuels, such as dimethyl ether, methanol, synthetic hydrocarbons and ammonia;
  - direct use of hydrogen not essential: oil refineries are already big hydrogen consumers, for hydrogenation and desulphurisation, and methanol is already blended with gasoline in many markets globally.

Thankyou