The real economics of hydrogen networks: markets, mandates and money

Professor Gordon Hughes

School of Economics, University of Edinburgh

Identifying the issues

Reference framework: complete conversion to hydrogen outside the energy sector - average annual demand of 495 TWh - more than 60% higher than electricity.

- How will hydrogen networks be developed to deliver hydrogen to small and medium customers spread throughout the UK?
- The Government's Net Zero path implies that initially most hydrogen will be produced by steam methane reforming (SMR) equipped with carbon capture and storage (CCS). What much will this cost and does it work?
- How does the expected reliance on offshore wind – or other sources of intermittent generation - affect the design and cost of electrolysis plants to produce hydrogen?
- Is a mandated and rapid conversion compatible with market incentives? How would the arrangements different for a partial rather than a full conversion?

Distribution, transmission & storage

- Only efficient option is to build a new network because area by area conversion of existing network is difficult, slow & expensive.
- New network cost - modern equivalent of existing network £120-£150 billionincluding customer connections..
- Cost of converting customer equipment highly uncertain - range of £100 - £175 billion.
- Hydrogen storage. Salt caverns is best & cheapest option but likely to be a lot of public resistance. Range of costs is from £25 billion for 7 days average cold day to £70 billion for 15 days of 1 in 20 year peak demand.
- Existing gas operators don't have the cashflow and scale required for such a program. Any financing will require government guarantees for debt as well as taxpayer subsidies for customer costs.

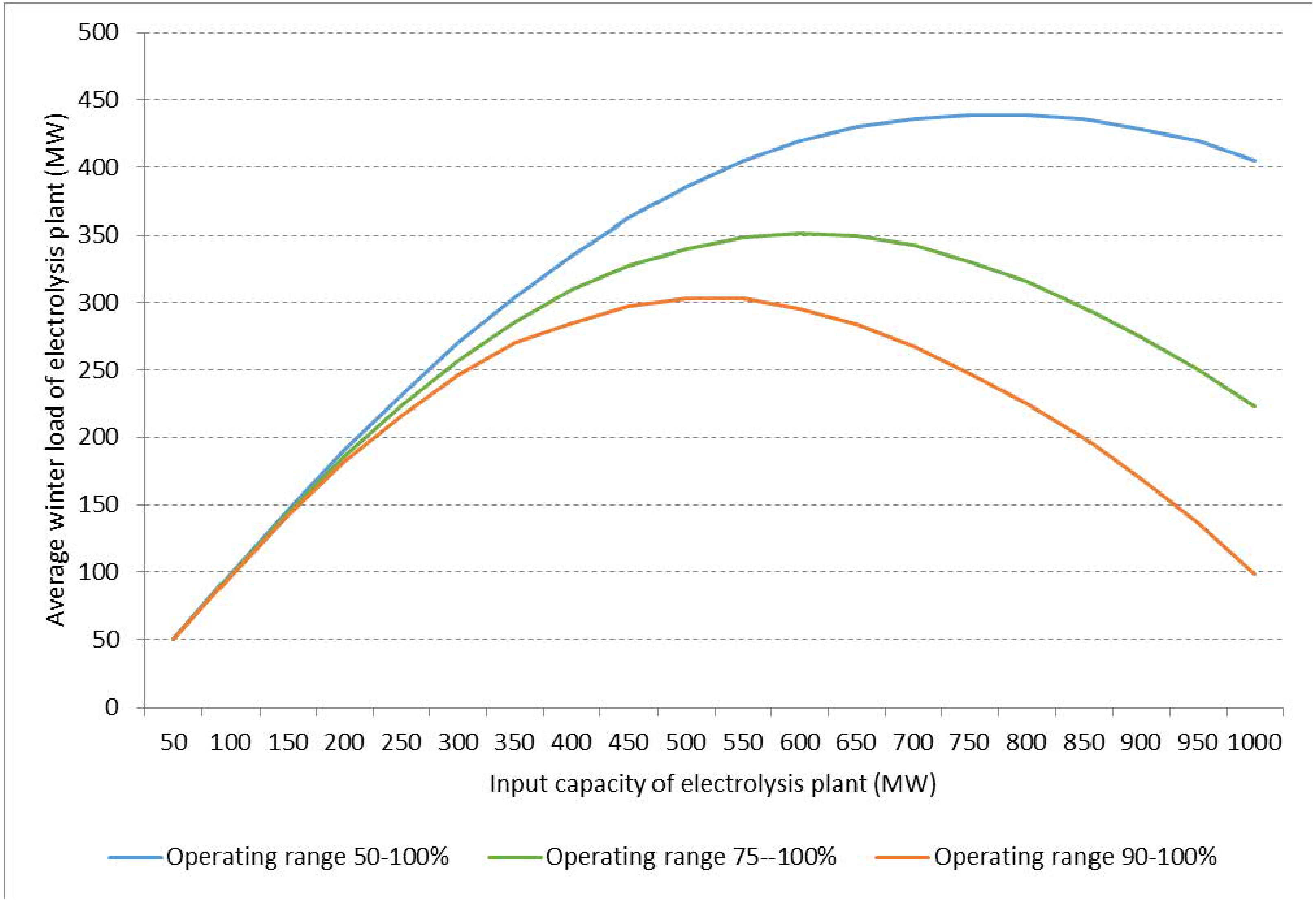
Production: steam methane reforming

- SMR is cheapest and easiest to rollout option for production but no carbon saving without carbon capture & storage (CCS).
- Capex of ~£105 billion assuming 90% CO2 capture + non-gas opex of £22 billion per year - overall cost including gas is more than 5 times the market cost of current gas use.
- CCS projects are notorious for cost over-runs and under-performance. Experience with CCS for gas is much less than for coal. Overall, there are serious doubts about whether this technology will be ready for deployment in the 2030s.
- Major problem of incentives: if SMR is just a stopgap then few investors will build or finance the number of plants required. The government could offer guaranteed 25 year contracts but that will transfer all risk and much of the cost to the Exchequer.

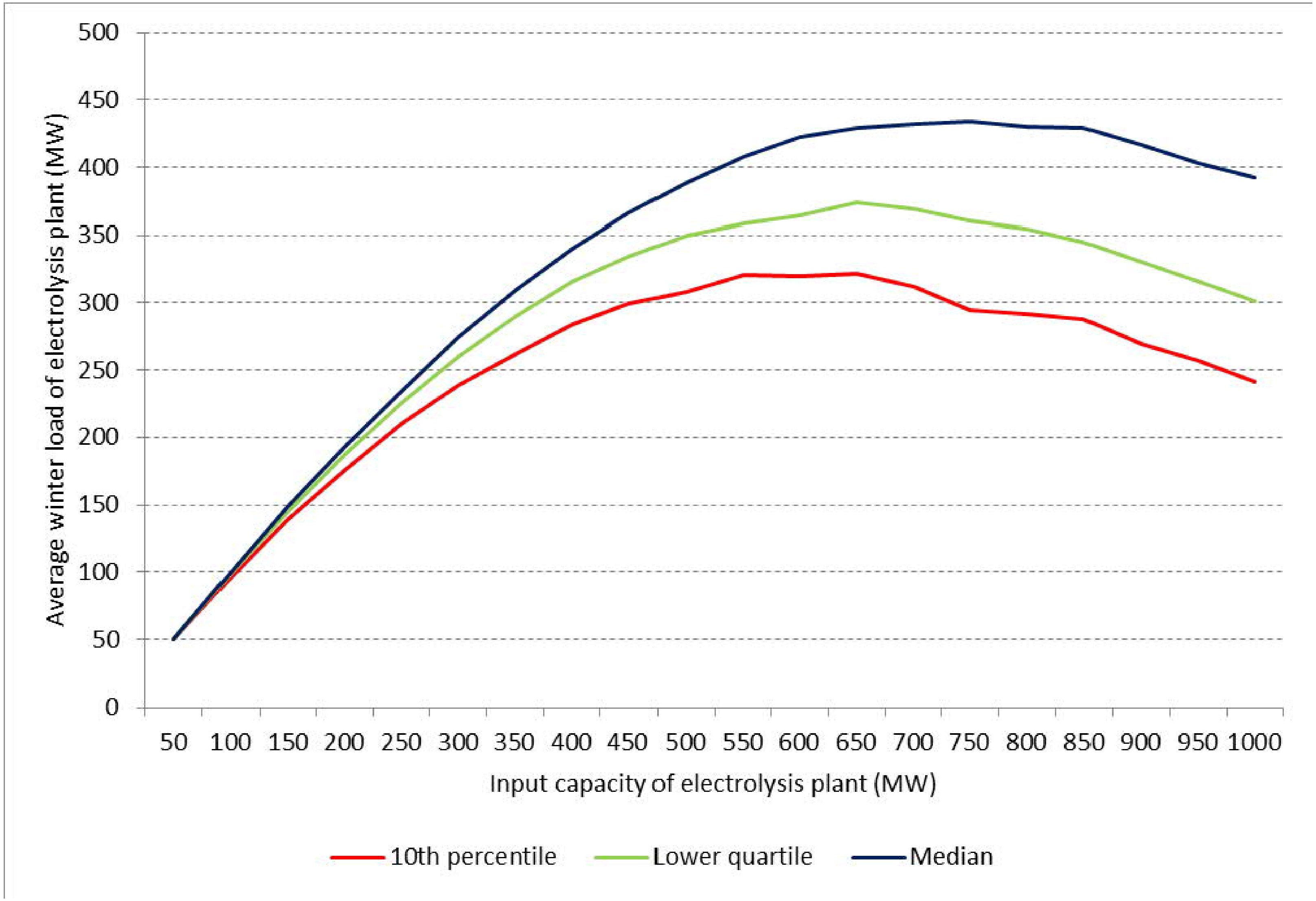
Production: the dream of electrolysis

- Most cost scenarios assume a nuclear-type source of electricity for electrolysis units with large output and a stable load factor. The design problem is quite different when the primary electricity source is intermittent and the efficient operating range is limited.
- The smaller the operating range, the smaller the efficient plant size for a 1 GW source.
- Annual wind variability reduces the safe efficient plant size.
- Electricity capacity required for electrolysis is 2-6 times peak electricity demand so surpluses or shortfalls in generation will destabilise any electricity system/market.
- Capex cost might be £625 billion for nuclear electrolysis or £1,300 billion upwards for electrolysis using offshore wind.
- Simply a fantasy when financial, physical and engineering constraints are examined.

Wind intermittency and electrolysis plant design
(1 GW offshore wind farm)



Annual variability and electrolysis plant design
(1 GW offshore wind farm)



The feasibility of full scale conversion

- The capex costs of conversion using SMR could be financed, though more easily over 25 year than 15 years.
- Serious doubts about both reliance on CCS and the real reduction in CO2 emissions.
- However, the disruption involved would be large. There might be strong resistance to the large increase in heating costs required. Mandating conversion will be very difficult unless most/all of the costs of customer conversions are covered by grants.
- Financing for investments in production, networks and storage will be contingent on government debt guarantees and purchase agreement. In effect most or all risk will be transferred to the Exchequer and taxpayers in one form or another.
- The wider economic effects of full conversion would be (highly) negative by pre-empting or distorting investment in the rest of the economy.

Summary of capex and opex costs
(Conversion of 495 TWh per year)

	Capex cost (£ billion)		Opex cost (£ billlion per year)		Operating life
	Low	High	Low	High	Years
Customer premises conversion	100	175	0	0	15
Transmission & distribution	120	150	2	3	40
Hydrogen storage	25	70	3	7	50
Hydrogen production					
Steam methane reforming	105	150	33	45	25
Electrolysis using nuclear power	625	850	42	60	50
Electrolysis using offshore wind	1450	2000	145	200	25

Options for partial conversion

- Small scale conversion based on either SMR or electrolysis production is financially and physically possible but what would be the point? Any programme focused on domestic heating will require large subsidies to be politically acceptable.
- Developing a limited hydrogen transmission network for specialised industrial or transport use might be considered. Requiring any organisation consuming more than, say, 50 MWh of gas per year to convert would have big effects on the traded chemicals and food industries as well as on the public sector.
- But there is no escaping the reality: hydrogen is a very expensive replacement for natural gas. Rapid conversion will only occur if (a) the costs are heavily subsidised and (b) users can pass on any costs they incur. This means that ultimately most of the costs will fall on taxpayers and domestic heating customers. Both groups are likely be pretty unhappy, thus undermining any support for the programme.