ENERGY POLICY PANEL SESSION

The system value of nuclear capacity additions in sustainable development

Chaired by Tim Yeo, Chairman, The New Nuclear Watch Institute

Charles Hart

Senior Researcher, The New Nuclear Watch Institute

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Director, Natural Power

Julia Pyke

SZC Director of Financing, EDF Energy

Kirsty Gogan

Executive Director and Co-Founder, Energy for Humanity

THE NEW NUCLEAR WATCH INSTITUTE

the nuclear institute

ENERGY INDUSTRIES COUNCIL

Pinsent Masons

Pinsent Masons – Welcome

Pinsent Masons

Pinsent Masons Key Facts:

25 Offices on 4 continents

£490m Global turnover

+3,000 Partners and Lawyers

"The system value of nuclear capacity additions in sustainable development"

- Need for clear support from governments for new nuclear power
- Nuclear needs to make its system wide economic case for inclusion in our future energy mix, as do all technologies
- Enjoy the webinar!

__Pinsent Masons__ – supporting delivery of nuclear new build, life extension/MCR, decommissioning and waste management programmes in 4 continents over 3 decades

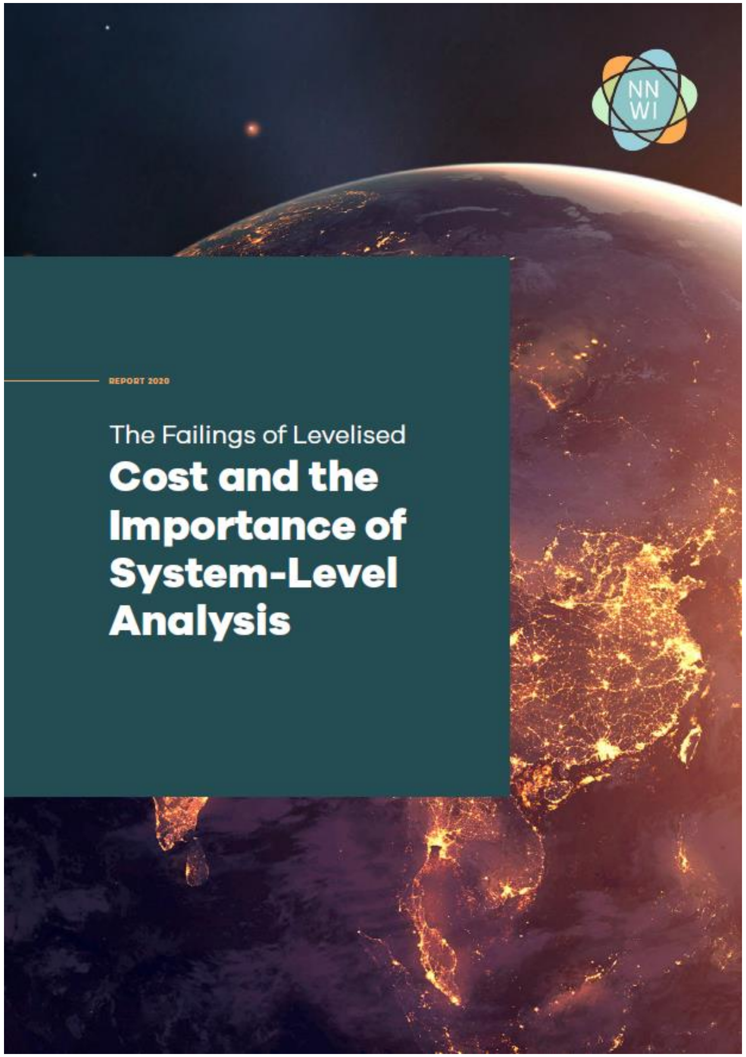
THE NEW NUCLEAR WATCH INSTITUTE

ENERGY POLICY PANEL SESSION

The System Value of Nuclear Capacity Additions in Sustainable Development

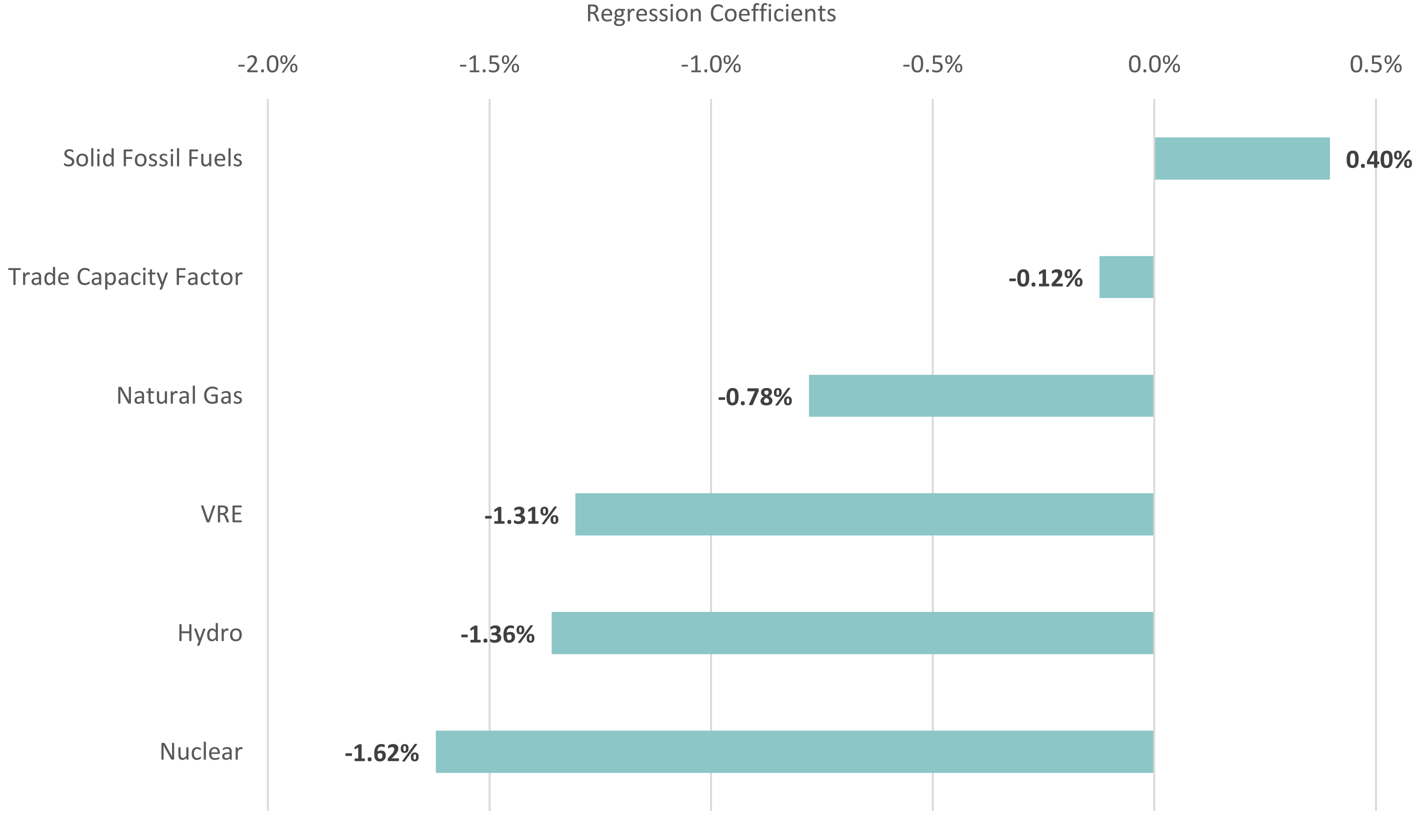
Charles Hart

Senior Researcher, The New Nuclear Watch Institute



System-Level Thinking and its Vital Role in Energy Sector Policymaking in the Context of Decarbonisation

Finding One:
Nuclear Power has the largest Impact on Reducing System-Level Carbon Intensity

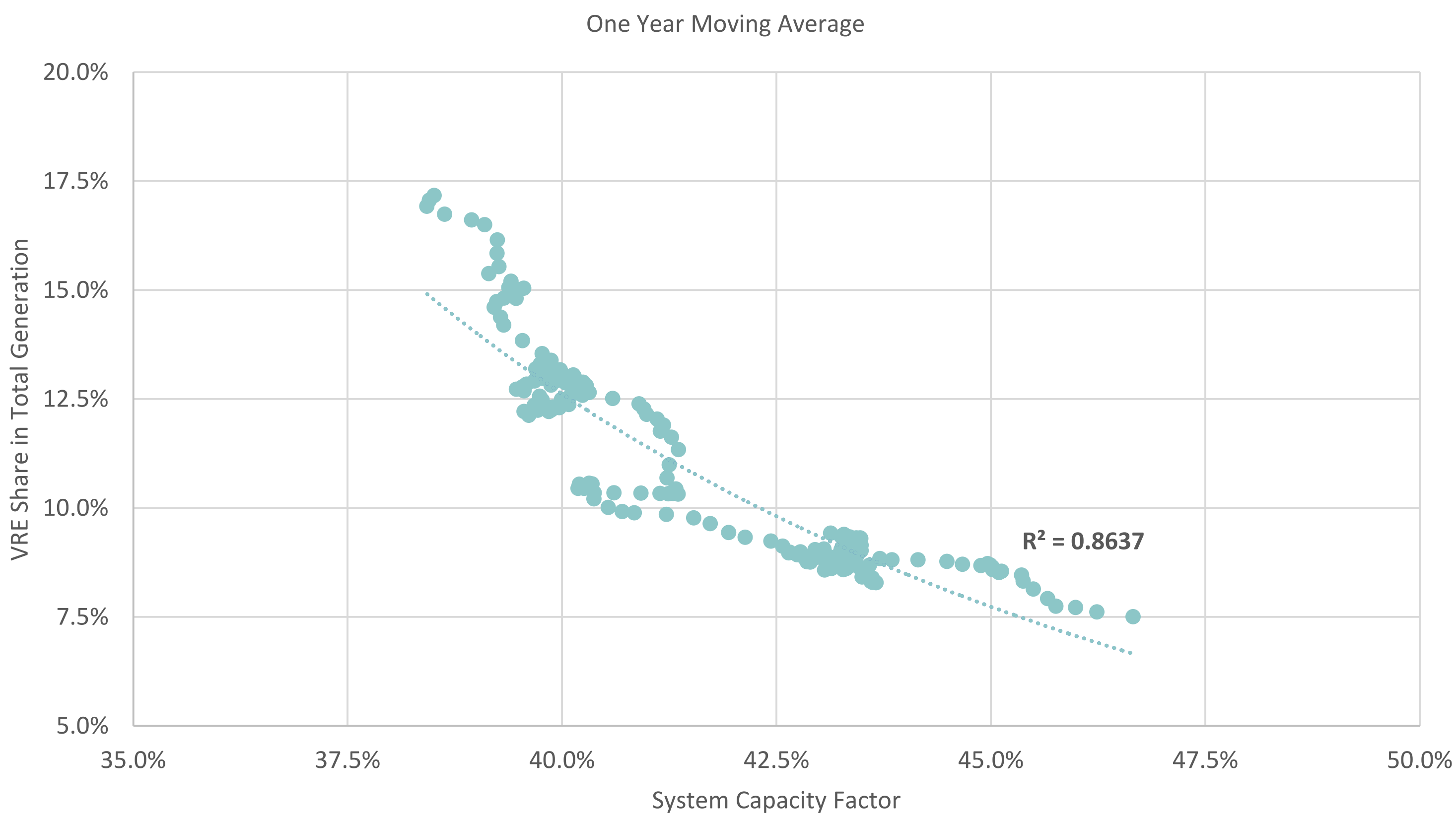


The system carbon intensity impact of nuclear power is 34% greater than that of intermittent renewables on a per-MW of installed capacity basis.

Finding Two:
The Diminishing Carbon Intensity of Natural Gas

The system carbon intensity impact of natural gas is 73% lower in the 'high' intermittent penetration subsample than in the 'low' intermittent penetration subsample.

Finding Three:
System Capacity Factor Decreases as the Share of Intermittent Renewables Increases



There is an inverse relationship between the share of total generation accounted for by intermittent renewables and the capacity factor of the electricity system as a whole.

Nuclear energy as a part of sustainable energy mix

Polina Lion
Chief Sustainability Officer,
State Atomic Energy Corporation Rosatom

21.10.2020

The green square concept

EU sets carbon neutrality target by 2050, some counties declare to reach this goal by 2035/2040

ELECTRICITY GENERATION BY SOURCE

Nuclear | Hydro | Wind, solar

France

Nuclear	Hydro	Wind, solar
71%	12%	7%

Norway

Hydro	Wind, solar
95%	3%

Hungary

Nuclear	Wind, solar
50%	4%

Switzerland

Hydro	Nuclear	Wind, solar
55%	37%	3%

Finland

Nuclear	Hydro	Wind, solar
35%	18%	9%

Portugal

Hydro	Wind, solar
23%	23%

Source: International Energy Agency

NPP project is more than just electricity supply

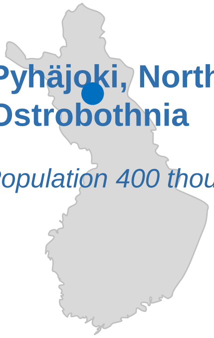
HANHIKIVI-1 NPP

Capacity

1 unit x 1200 MW

to cover nearly **10% of Finland's energy demand**

around 6% growth in low-carbon sources of generation



Pyhäjoki, Northern Ostrobothnia

(Population 400 thous.)

Localization program:

- **About 600 Finish companies registered to participate in the project**
- **Finnish companies are ready to provide equipment, engineering services, etc.**

Jobs & training:

- **4 000 employees to work on site at peak construction**
- **Up to 2 600 jobs during operation in supporting services, 1 700 of them in Northern Ostrobothnia**
- **Training courses for 300 engineers and other specialists in Finland**

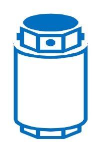
NPP sustainable impact

- Provides 2400 MW of **low-carbon energy** with **a stable supply for 60 years** – enough to power on average 1.8 mln homes*
- Brings **USD 3-4 bn of orders to local industries** during the construction period*
- Creates about **3 000 of new jobs** at the NPP itself and more than 10 000 indirect jobs*
- Operation of all Russian-designed NPPs in the world **saves ~ 210 mln tonnes of CO_2eq emissions per year****

NUCLEAR SECTOR DRIVES INNOVATIONS

Electricity supply in remote and limited grid infrastructure areas

SMR solutions



Efficient use of resources and minimization of nuclear waste

Closed fuel cycle

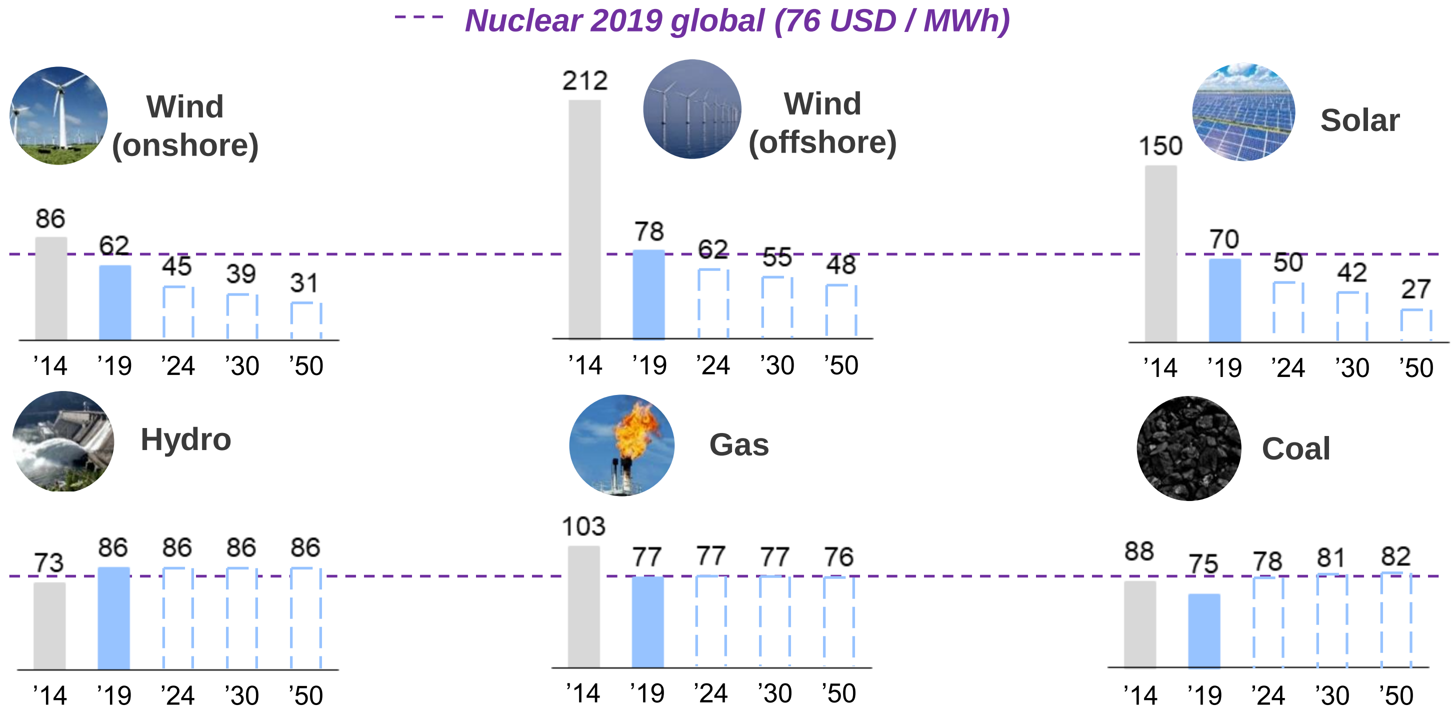
** Rosatom estimates for NPPs (2x1200 MW)*

***Rosatom estimates (based on the world electricity generation structure by source of energy)*

Commercial efficiency should not be overlooked

ROSATOM

LCOE OF DIFFERENT GENERATION SOURCES, USD /MWH



LCOE together with time and budget are crucial to secure competitiveness of existing NPPs and perspective SMR solution.

Source: Bloomberg New Energy Finance, International Energy Agency, Nuclear Energy Agency, National Renewable Energy Laboratory

Energy solution of the future

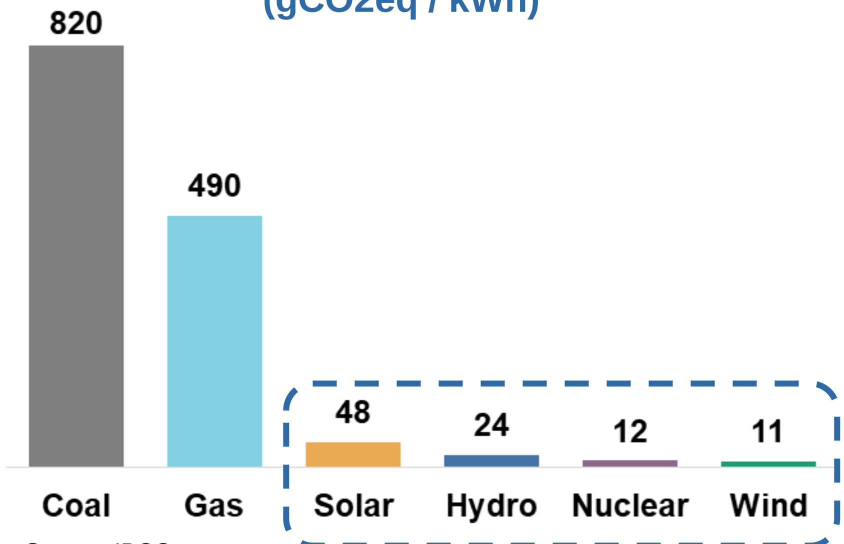
ROSATOM

The main focus of the Climate agenda is COP21 fulfillment and CO2 reduction

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

The long-term goal is to keep the global average temperature increase below 2° C above pre-industrial levels and to pursue efforts to limit the increase to 1.5° C

Lifecycle CO2eq emissions by energy type (gCO2eq / kWh)



Source: IPCC

SUSTAINABLE ENERGY SOLUTION

- Affordable
- Safe and secure
- Low-carbon
- Stable supply

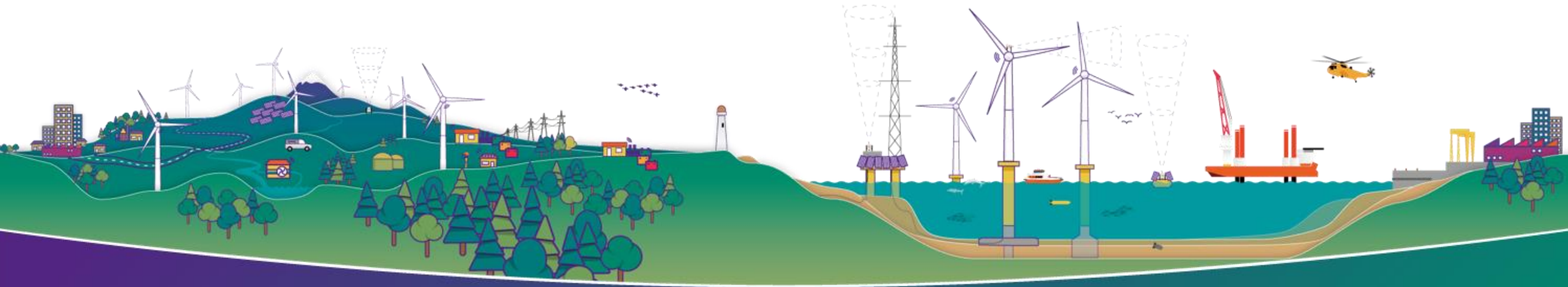
New Nuclear Watch Institute

Webinar : Energy System Costs.

Date: Oct 2020

Produced By: Jeremy Sainsbury OBE

Produced For: NNWI



- Director of Natural Power, renewable consultancy.
- Energy UK Board, plus Generation Cttee and chair of Renewable Cttee.
- Board director of Scottish Renewables for 20 years.
- On Paul Wheelhouse's Renewable Energy Industry Strategy Group.
- South of Scotland Enterprise Board member.
- 32 years in energy sector.
- Still learning.
- Want to ensure the clean energy transition sets the framework for competitive UK economy for the next 50 years.

LCOE is not the only answer but a valid tool ?

- LCOE alone is the wrong .
- So What else ?
  - » Consumer price
  - » System costs
  - » System flexibility
  - » Market framework
  - » Technical (Inertia, Black Start, Frequency response, Grid constraint).
- What is the strongest driver?
  - » System Flexibility
    - Flexible Gas
    - Interconnection
    - Demand side Response
    - Energy Storage
    - CCUS
    - Hydrogen
- Renewables and Nuclear benefit from the same things? Both have weaknesses that flexibility assists.

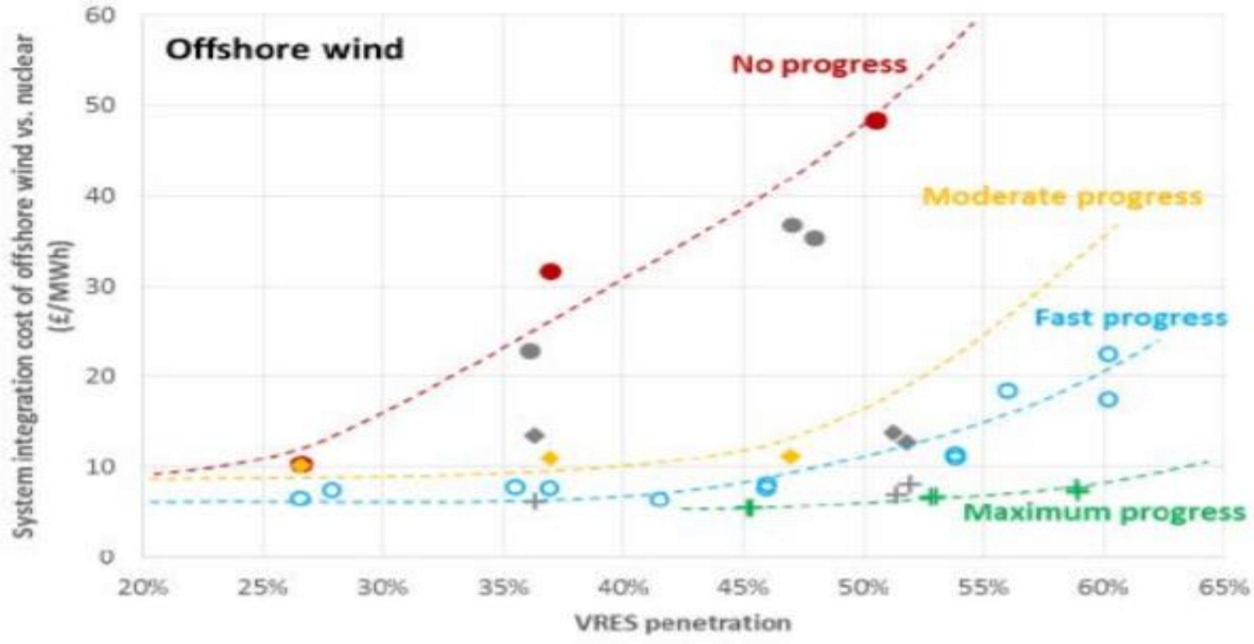
Table 1. System integration costs by driver of cost

Cost driver	Estimated cost (£/MWh)	Cost associated with	Impact at high penetrations
Meeting peak demand	5-10	Back-up capacity for periods of peak demand.	Unlikely to increase significantly.
Using available generation	0-25	Wasted generation when renewables exceed electricity demand.	Increases with more deployment of the same technology.
Balancing requirements (e.g. reserve and response)		Paying for part-loaded plant to remain on the system.	Unlikely to increase significantly.
Networks	0-5	Building new transmission networks to bring renewables to centres of demand.	Dependent on location.

Source: CCC analysis based on Imperial College (2015) *Value of flexibility in a decarbonised grid and system externalities of low-carbon generation technologies* and UKERC (2016) *The costs and impacts of intermittency (2016 update).*

Notes: There is likely to be overlap and double counting of costs, especially at higher penetrations. The costs of 'using available generation' and 'balancing requirements' are grouped to reflect this, though there will also be overlap with capacity costs. For example, back-up capacity can also provide generation for balancing and reserve. 'Impact' refers to per unit costs not aggregate costs. Aggregate costs will increase with renewable penetration, but are likely to remain a small overall proportion of total electricity system costs (see Section 4).

Figure B2.1. Offshore wind integration costs as a function of renewable penetration and system flexibility



Notes: Integration costs are expected to be similar for onshore wind, but will differ for solar as it has a different seasonal generation profile. Estimates of system integration costs are compared to nuclear power, which will have system integration costs of its own, and are for a system with a carbon intensity of 100 gCO_2/kWh. 'No progress' has no added system flexibility. 'Moderate progress' includes 5 GW of new storage, 25% DSR uptake and 10 GW of interconnection. 'Maximum progress' includes 15 GW of new electricity storage, 15 GW of interconnection capacity (15 GW) and 100% uptake of DSR.

Source: Imperial College (2015) *Value of Flexibility in a Decarbonised Grid and System Externalities of Low-Carbon Generation Technologies* & Imperial College (2016) *Whole-system cost of variable renewables in future GB electricity system.*

Look Forward not back to find the answer. Some thoughts to debate.

- New nuclear delivery circa 10 years.
- What do we want/ will the market and system look like then?
- Onshore wind and solar are not the big competitor in the UK. Offshore Wind has both the size, price and load factor. They are the flex technology?
- Need to understand the tipping points in the efficiency of grid curtailment and cost.
- Security of supply needs diversity of supply. How does Hydrogen and CCUS fit?
- What is the most efficient route to market and how does that work in the new system?
- How does nuclear fit in a volatile price structure?

Sizewell C

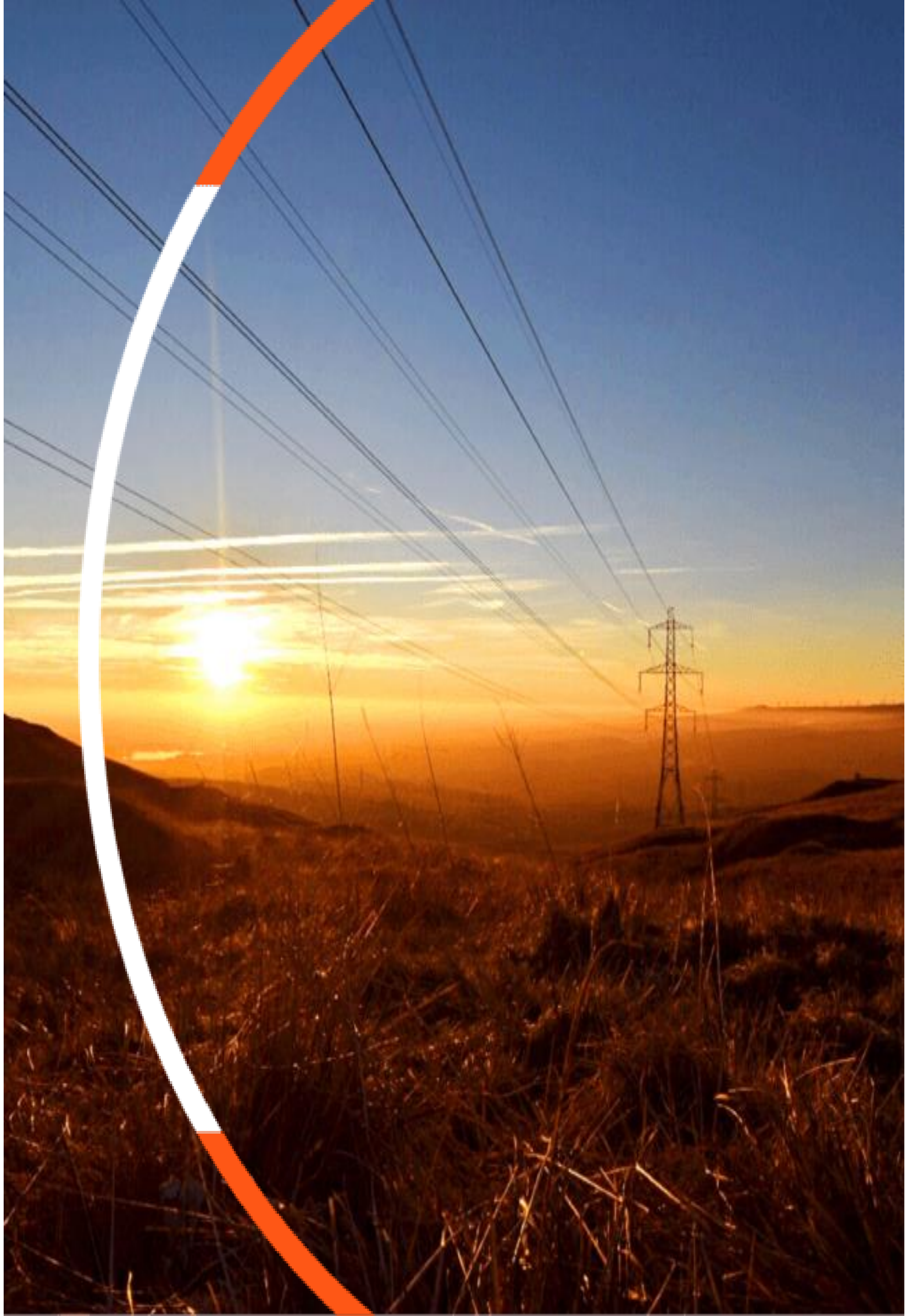
Doing the power of good for Britain

NNWI Energy Policy Session

21 October 2020

JULIA PYKE

Director of Sizewell C Financing & Economic Regulation



Costs of Nuclear

Sizewell C replicates the design of Hinkley Point C…

Repetition —— **Deviation**

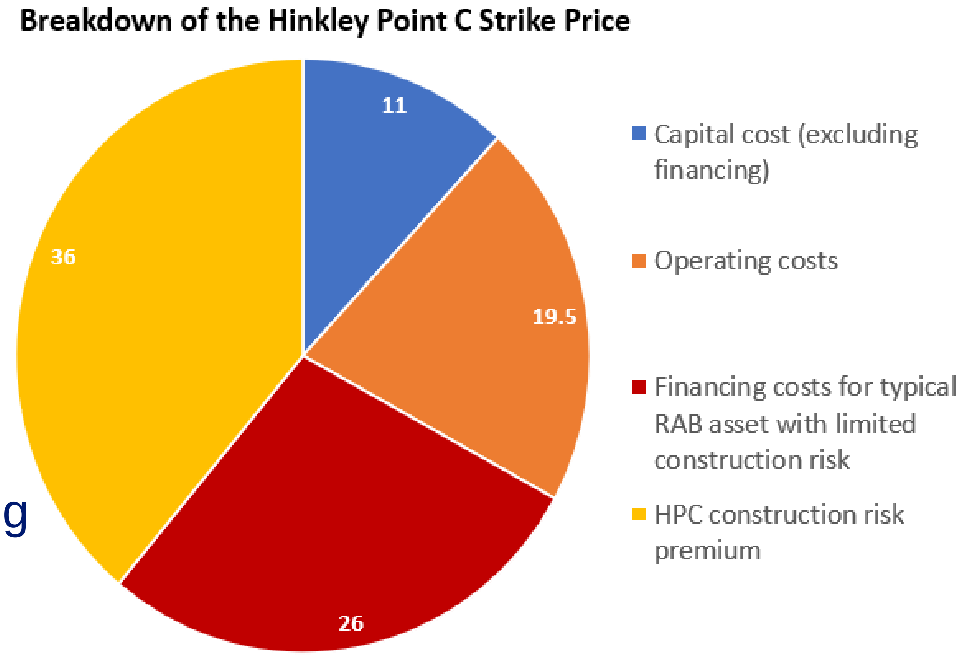
... this reduces both cost and risk

Reducing technical risk by copying Hinkley Point C reduces the cost of financing

Nuclear financing costs are the biggest driver for consumer costs. Sizewell C's reduced risk profile provides an opportunity to reduce the cost of finance: lower consumer bills.

- The cost of finance is a key driver of consumer costs: around two-thirds of HPC Strike Price - of which more than half was due to the construction risk premium for FOAK in UK

- Reduced construction risk profile of copying the HPC detailed design (already approved for the UK) enables a different financing mechanism: significant opportunity for improving consumer value for money – lower bills for consumers

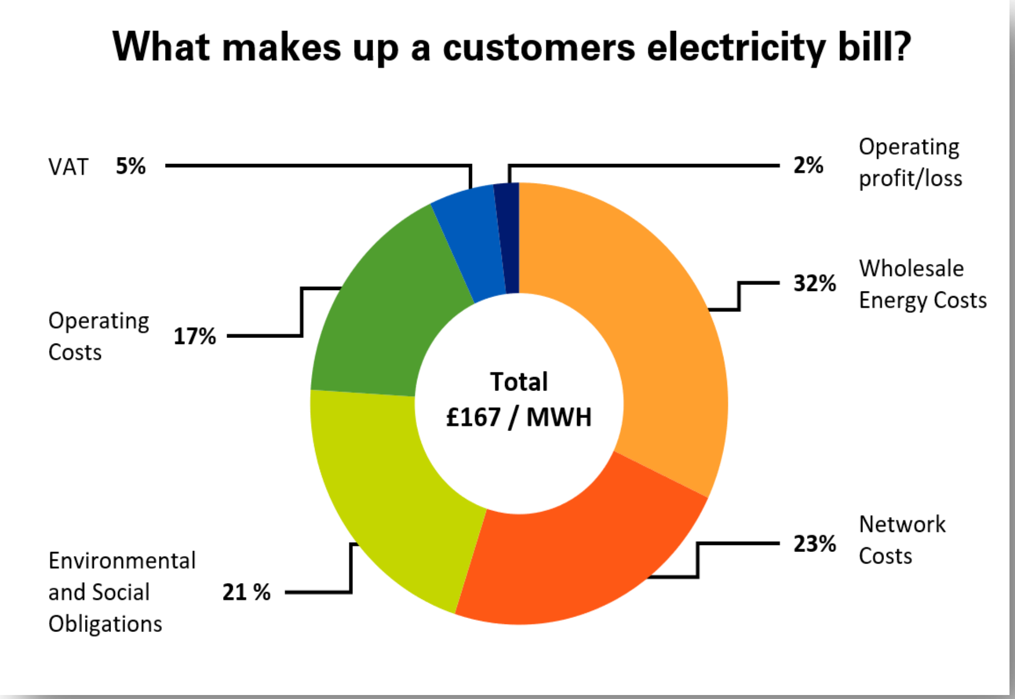


Customers pay for the electricity system – not just the cost of generating electricity

An average customers' bill is equivalent to around £167/MWh (average customers use around 3.5MWs per year)

•Around 40-45% is the cost of generating the electricity. Network costs include balancing the Grid to accommodate intermittent technologies like wind and solar

•Nuclear helps reduce system costs and therefore to reduce consumer bills



Source: www.edfenergy.com/for-home/help-support/what-makes-up-your-bill

Nuclear energy has benefits which help reduce system costs and consumer bills

System costs are lower with the right amount of nuclear..

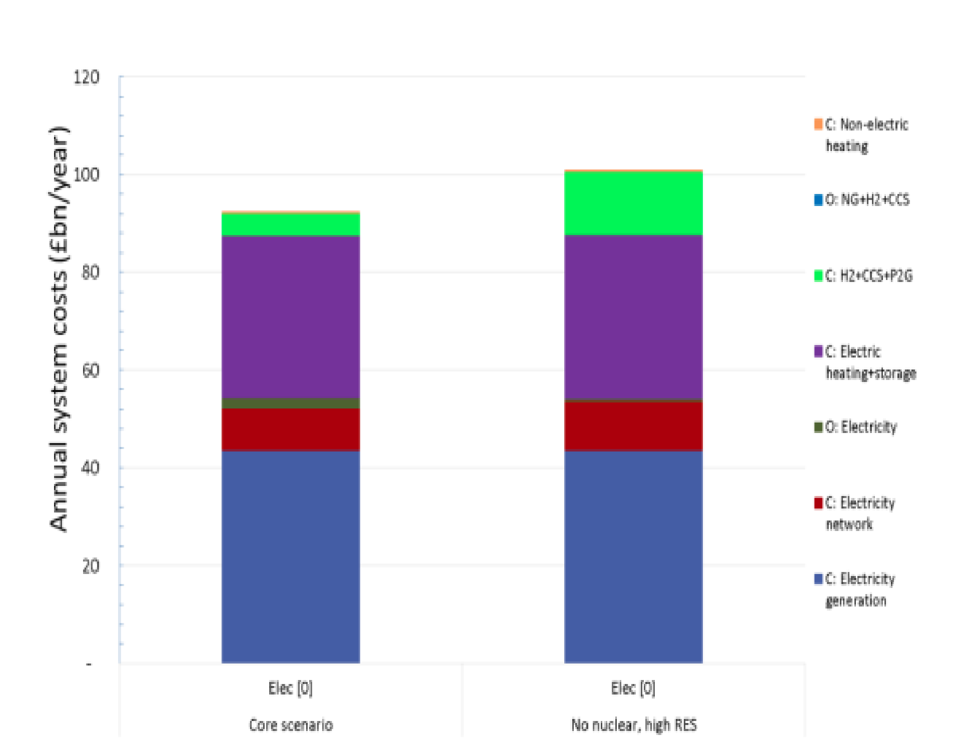


Figure E. 10 System costs of the Electric pathway with and without nuclear technology

Source: Analysis of Alternative UK Heat Decarbonisation Pathways Imperial College (2018)

- Ensuring electricity is available 24 hours a day 365 days a year whatever the weather costs more than the cost of generating electricity: system costs are lower for nuclear than renewables. Although these costs are not included in the Levelised Cost of Energy (LCOE) or Strike Prices quoted in the media, they are an important part of the costs to consumers.

- System costs include impact of intermittent (weather dependent) generation profiles and impacts of the location of generation.

- Reports by the CCC, Imperial College have estimated that the value of these system costs could be £20-30/MWh or more (depending on the technology and the generation system mix).

..adding new nuclear to the UK system at the right price lowers consumer bills (even if the cost of generation is higher than for some renewables)

BEIS Electricity Generation Costs Report (2020)

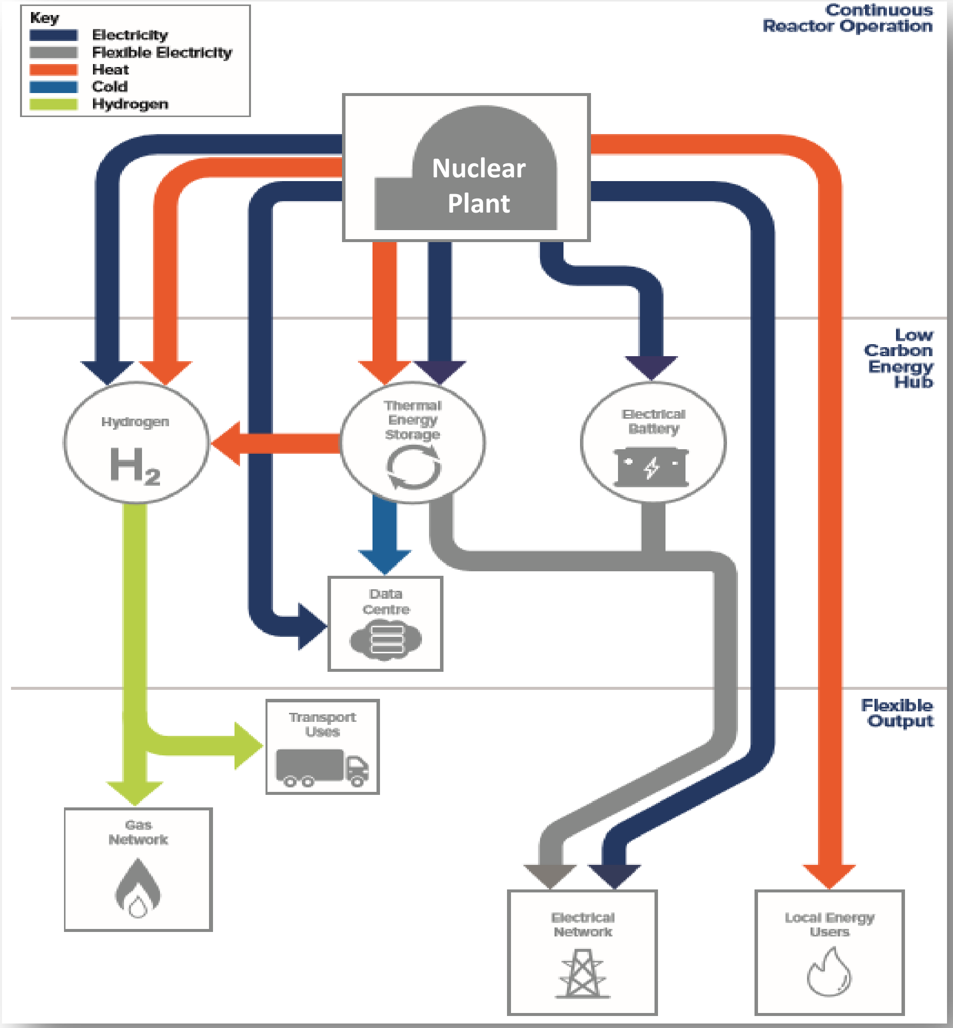
BEIS 'Enhanced Levelised Cost'

	2035	
	LCOE	"Enhanced LCOE"
Offshore wind	41	59 – 79
Onshore wind	42	60 – 87
Solar (large-scale)	33	45 – 61
CCGT+CCS	78	38 – 61

"Enhanced levelised costs serve the same purpose as levelised costs - they provide a straightforward way of consistently comparing the costs of different generating technologies with different characteristics. ***However, unlike levelised costs, they also account for different wider system impacts between technologies due to differences in the timing of their generation, their location and other characteristics. This results in a fairer comparison between technologies.****"*

https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020

Sizewell C can provide clean electricity at a competitive cost and …..



using the (clean) heat will be an additional benefit to consumers

Appendix

Hinkley Point C has revived the UK's New Nuclear industry..

Hinkley Point C is providing economic growth, sustained employment and enhanced skills for the UK

£14bn

To be invested in the UK economy during construction

25,000

Job opportunities created during the construction phase

£1.7bn

Boost to the regional economy during construction so far

1,000

Apprenticeships created during the construction phase

..Sizewell C and Moorside will build on this nuclear renaissance

Sizewell C: Overview

- Sizewell C will comprise of two UK EPR units with a total site capacity of 3,340 MW, located adjacent to Sizewell A and B plants in Suffolk.
- The same key suppliers will be building SZC, according to the same core UK approved, detailed Hinkley Point C (HPC) design aligned to the same safety case.
- This will be done while ensuring suppliers benefit, and more design and manufacturing work is moved into the UK, adding to the national spread of work on HPC and raising the percentage of UK content to 70% by contract value.
- This drives significant reductions in construction costs and in risks relative to Hinkley Point C and to all other First of a Kind (FOAK) in country nuclear projects.
- Sizewell C can deliver firm low-carbon power at a cost that reduces consumer bills and provides the opportunity to develop an energy hub to enhance its contribution to Net Zero.

Where are we with Sizewell C?

- Submitted our **Development Consent Order in June**, after 8 years of consultation.

- Applied for a **Nuclear Site Licence in June** and have applied for environmental consents.

- We look forward to the Government's conclusions on the funding model. **Financial investors (including British pension funds) want to invest.**

- Around **120 UK based companies** have come together in the **Sizewell C consortium.** We are starting contract negotiations with key suppliers for SZC as we move towards financial close.

Cost & Performance Requirements for Flexible Advanced Reactors in Future U.S. Power Markets

New Study Finds Large Markets for Advanced Reactor Plants that Cost Less than $3,000/KW

LUCID
CATALYST

October 2020

U.S. Regional Power Markets Modeled

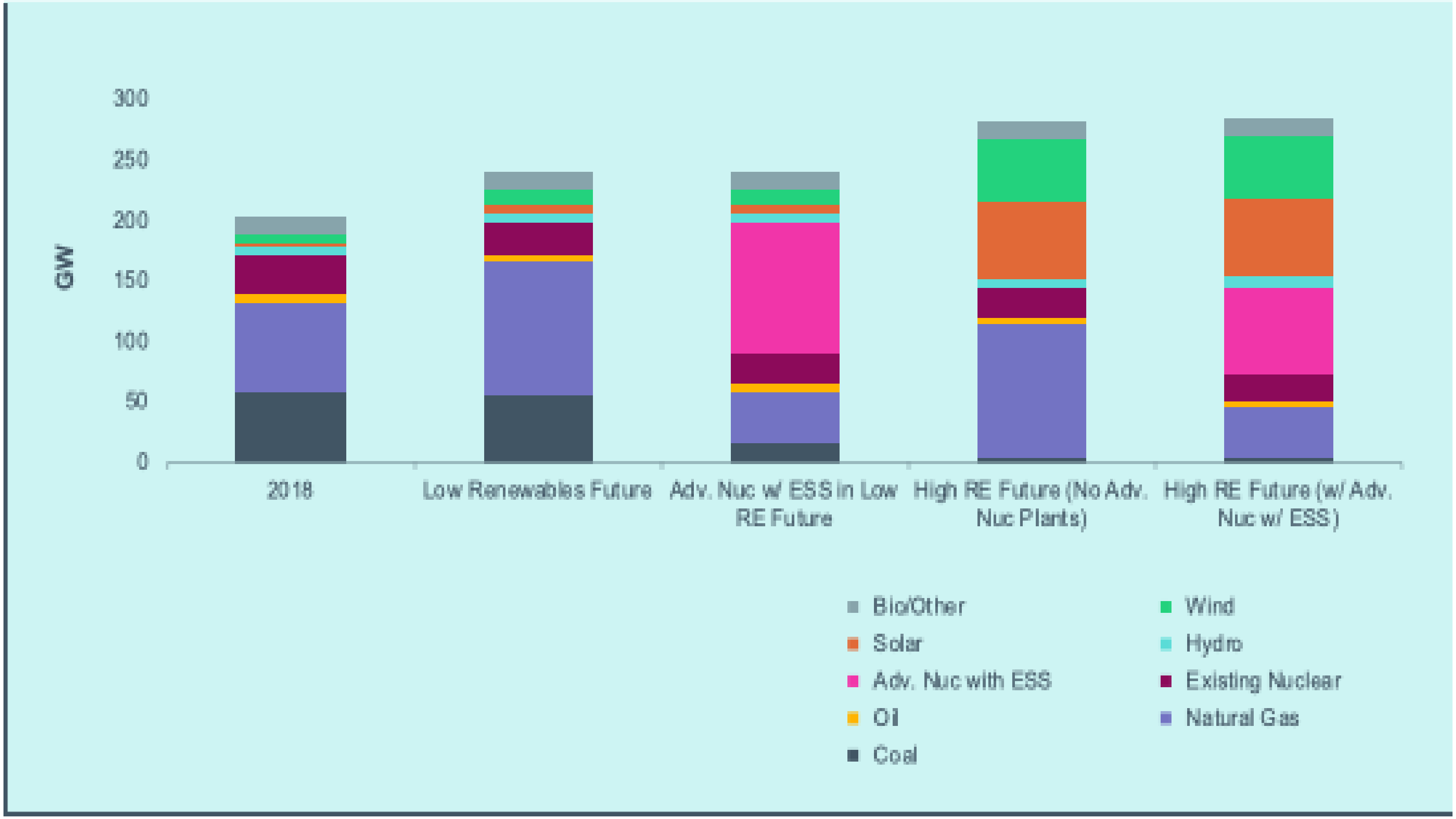
Source: Federal Energy Regulatory Commission

This study is the first to derive the highest allowable capital cost for advanced reactors across four of the major power markets in the United States in 2034.

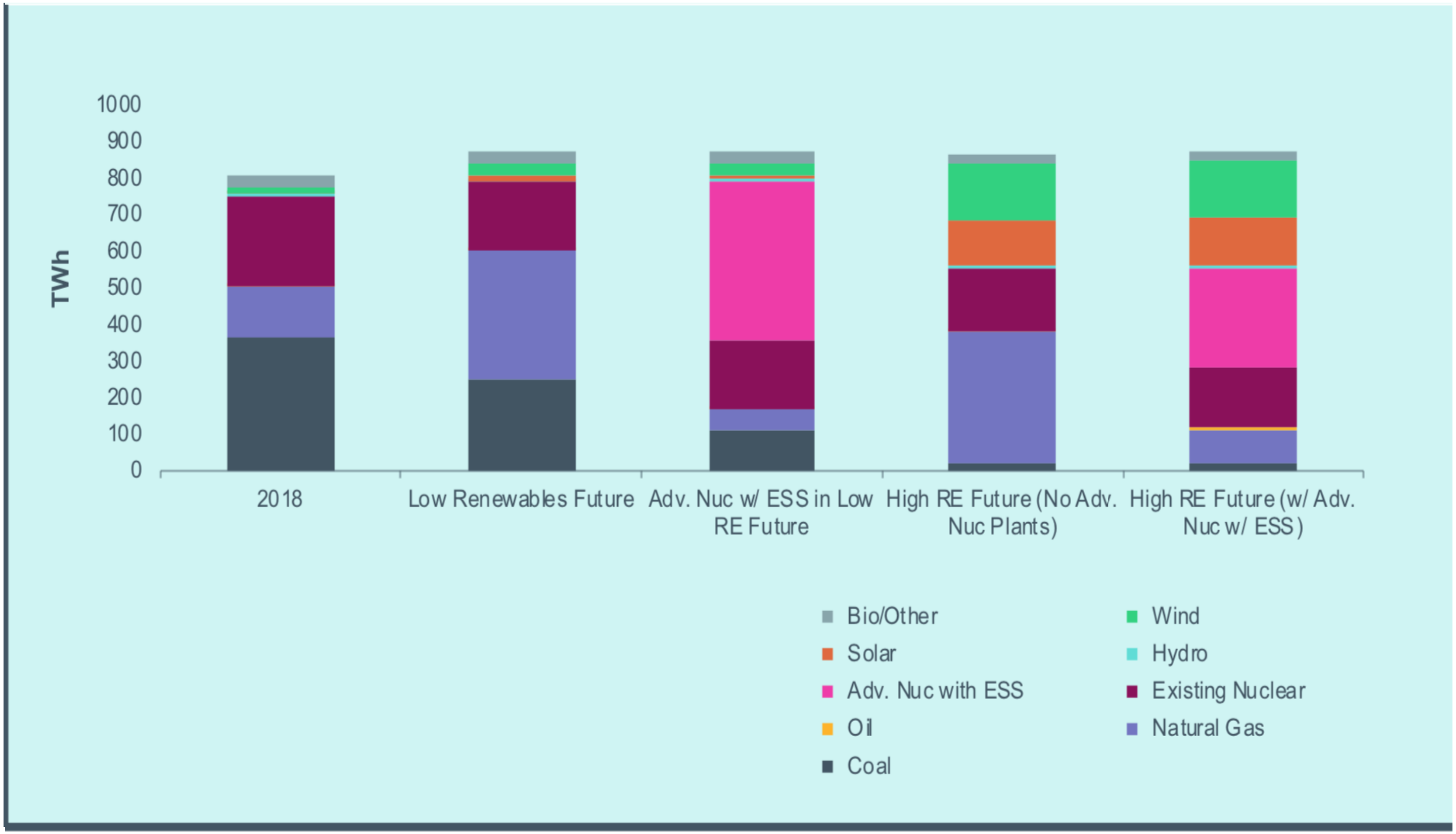
Key Insights from the study include:

- Advanced reactors that cost less than $3,000/kW will be attractive investments for owners.
- There will be large markets for advanced reactors that cost less than $3,000/kW.
- Flexible advanced reactors complement wind and solar in markets with high penetrations of renewables.
- Flexible advanced reactors can enable high penetrations of variable renewables in future energy systems.
- Together, renewables plus advanced nuclear (with thermal energy storage) lower overall system costs, reduce emissions, and improve performance in future U.S. electricity grids.

PJM Installed Capacity



PJM Generation



Average Annual Energy Price in 2034 With and Without Advanced Reactor Fleet

		Average Annual Energy Price
ISO-NE	High RE Future (Without Flexible Adv. Nuclear)	$26.32/MWh
	Fleet Deployment of Flexible Adv. Nuclear	$22.64/MWh
PJM	High RE Future (Without Flexible Adv. Nuclear)	$27.03/MWh
	Fleet Deployment of Flexible Adv. Nuclear	$22.67/MWh
MISO	High RE Future (Without Flexible Adv. Nuclear)	$26.13/MWh
	Fleet Deployment of Flexible Adv. Nuclear	$24.70/MWh
CAISO	High RE Future (Without Flexible Adv. Nuclear)	$38.06/MWh
	Fleet Deployment of Flexible Adv. Nuclear	$29.61/MWh

Total Cost of Serving Annual Load: Energy and Select Capacity Payments

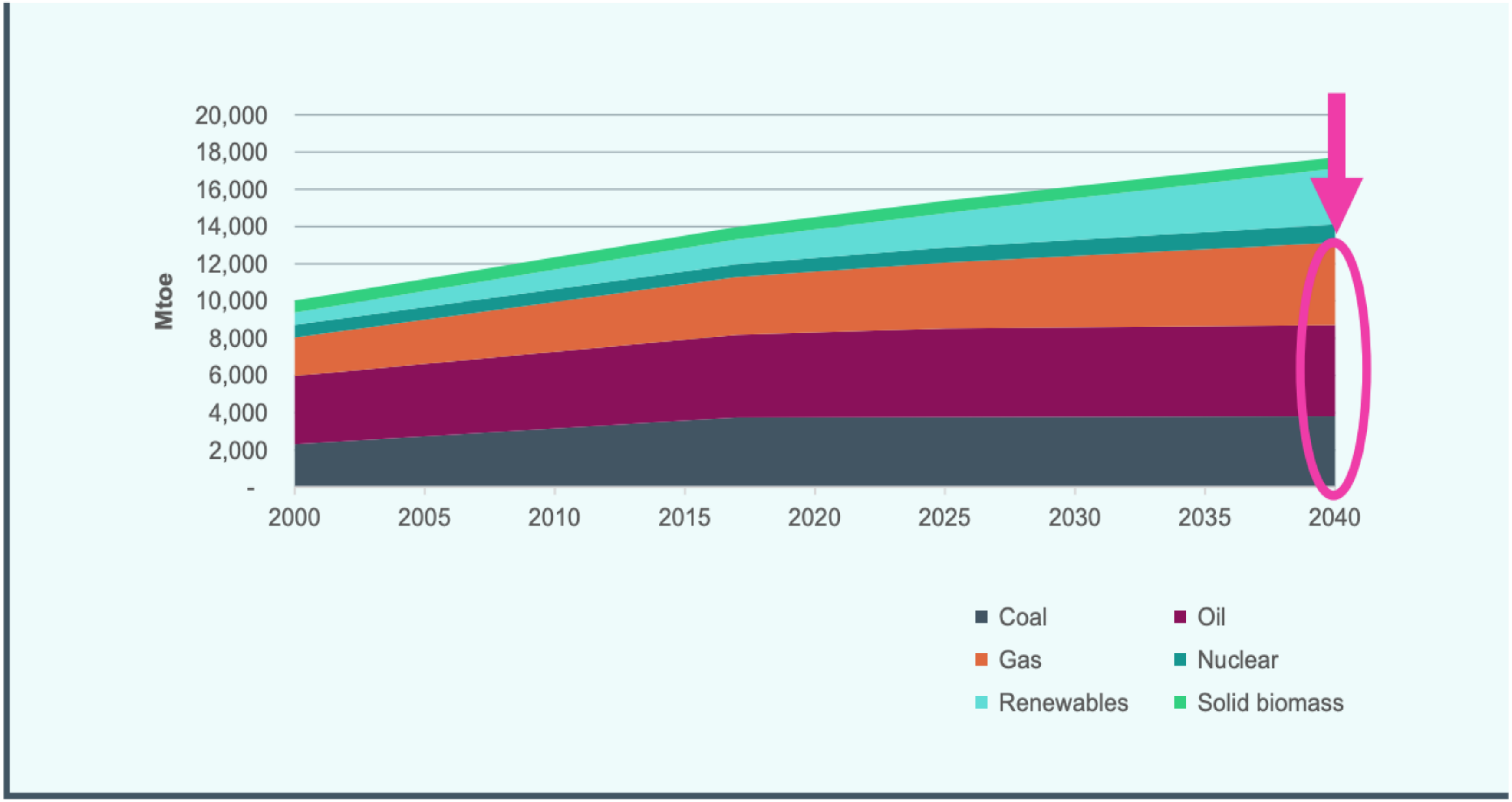
Missing Link to a Livable Climate

How Hydrogen-Enabled Synthetic Fuels Can Help Deliver the Paris Goals

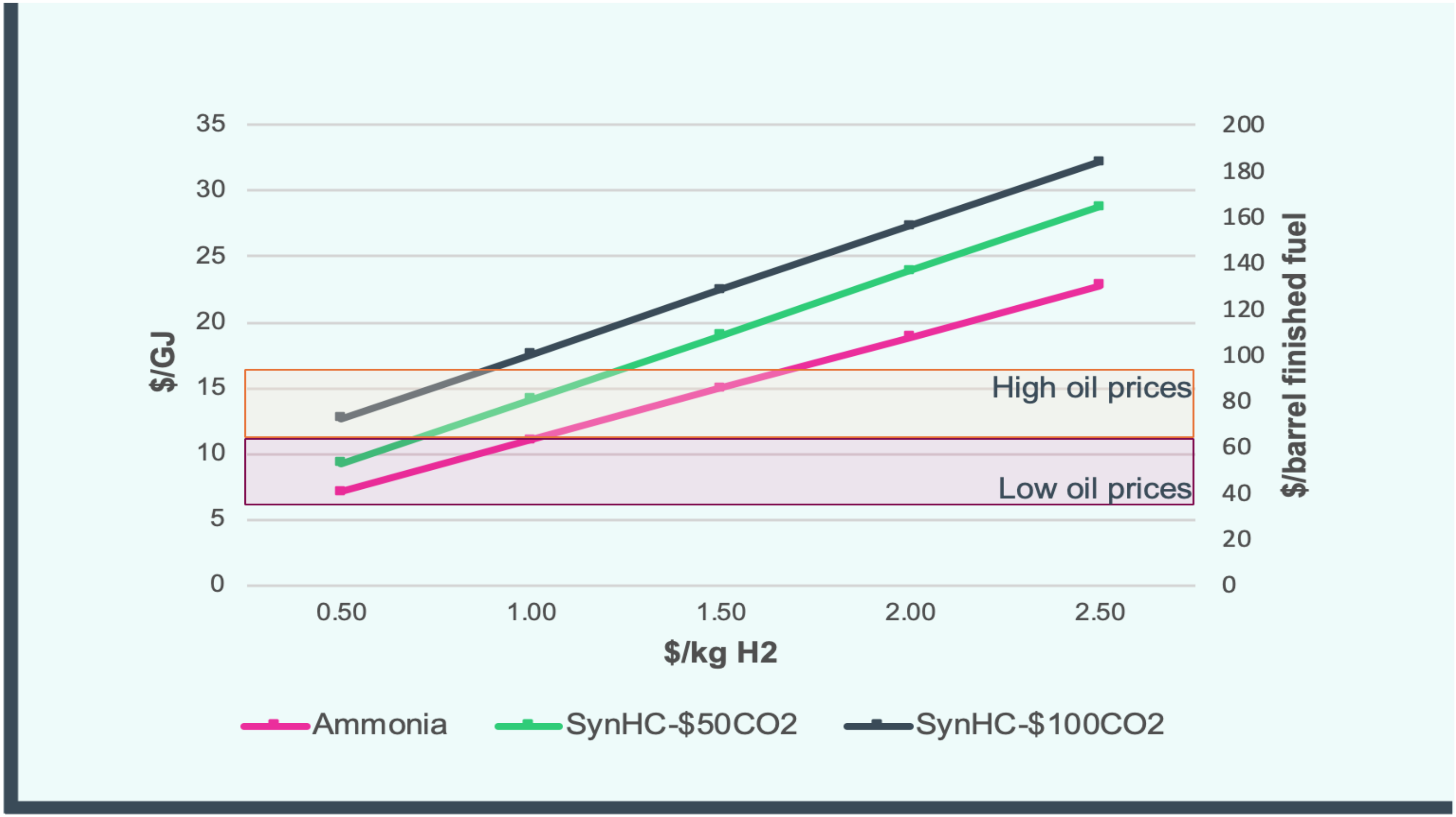
LUCID CATALYST

Thirty years to 2050

Stated Policies Scenario: world energy by source (IEA 2018)

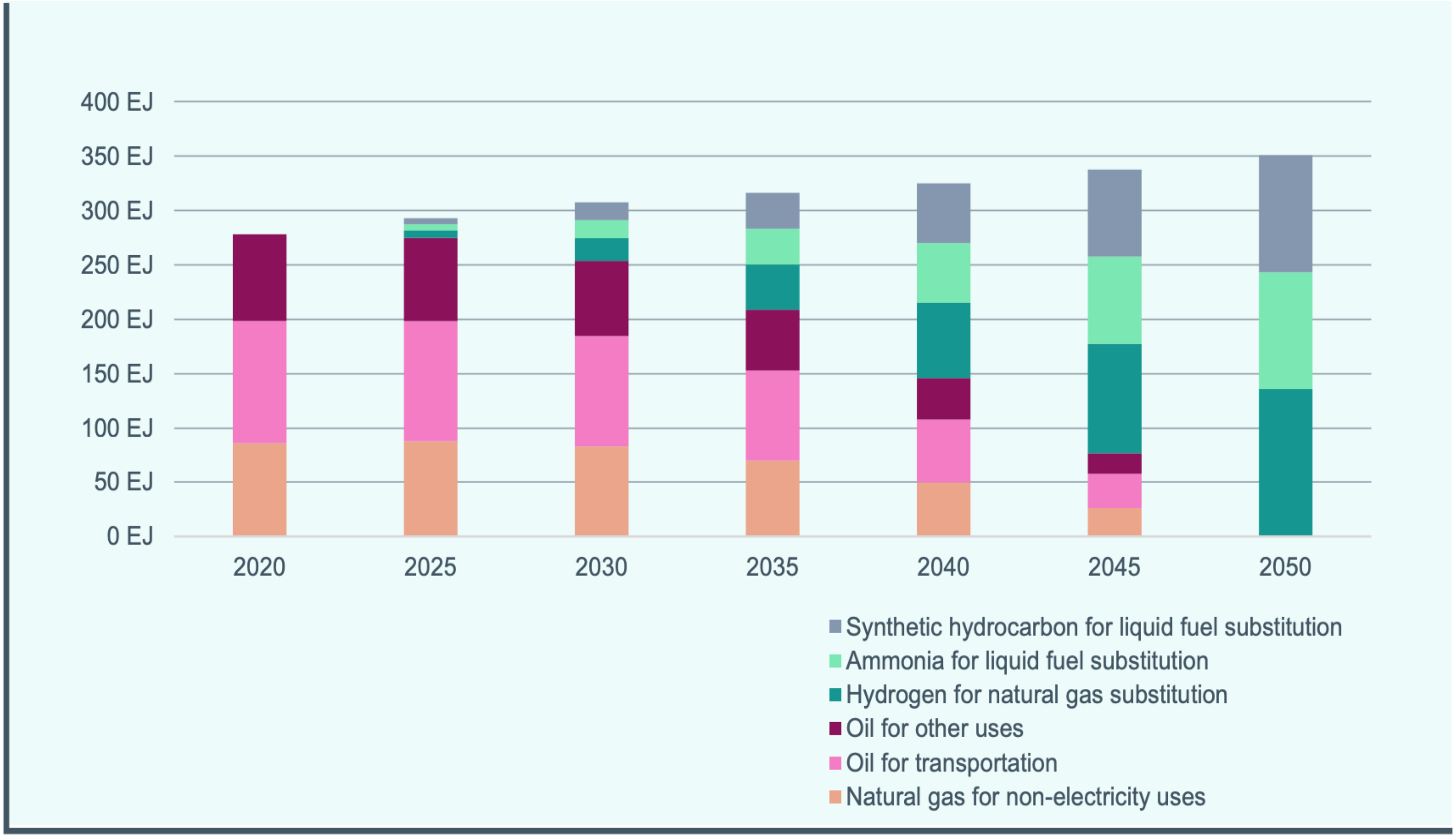


Oil Price "Guardrails' of the Hydrogen Economy ($0.50-$1.50/kg)

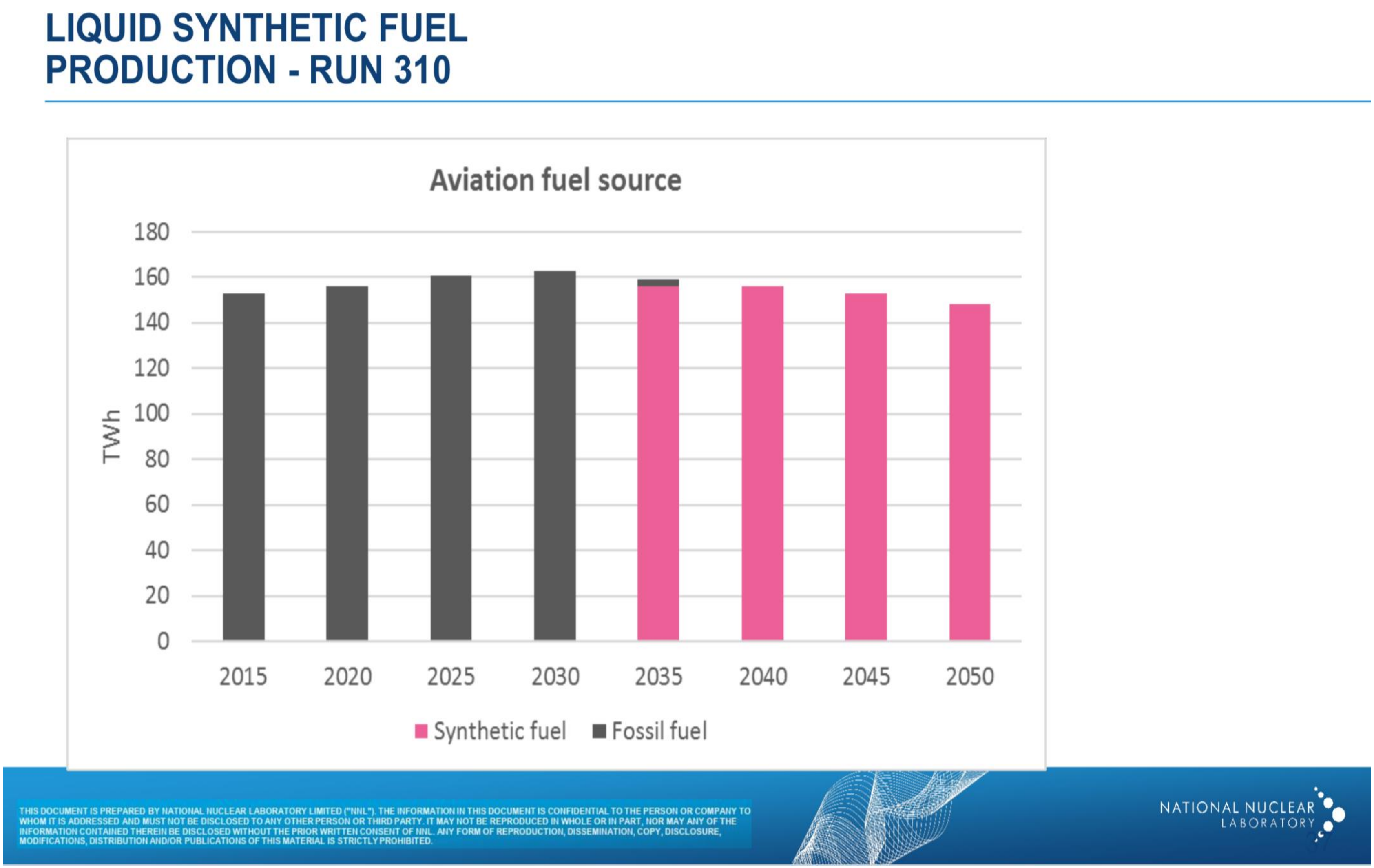


Total Cost of Serving Annual Load: Energy and Select Capacity Payments

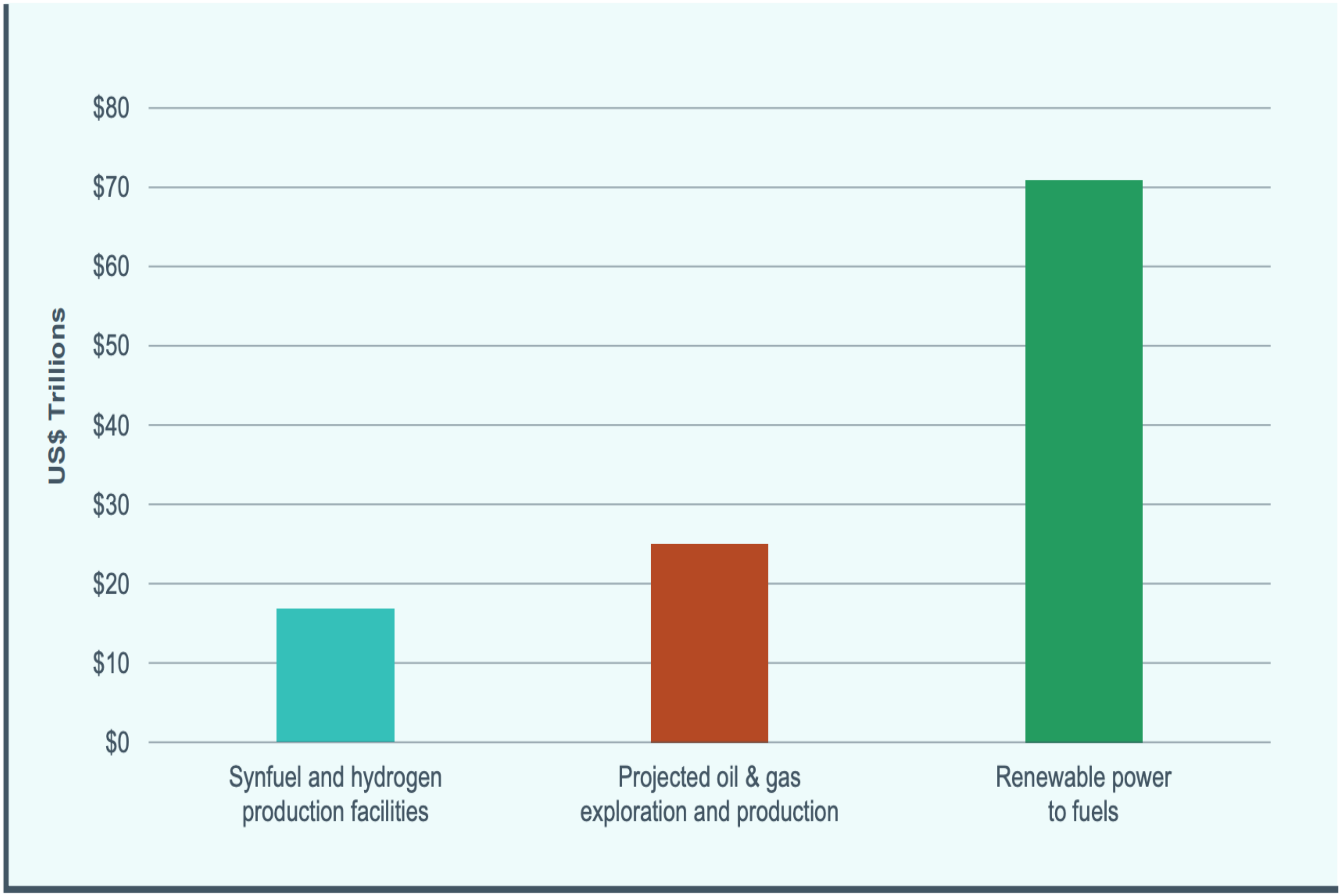
Fuel substitution in different sectors from ultra-cheap hydrogen generated by advanced heat sources 2020–2050



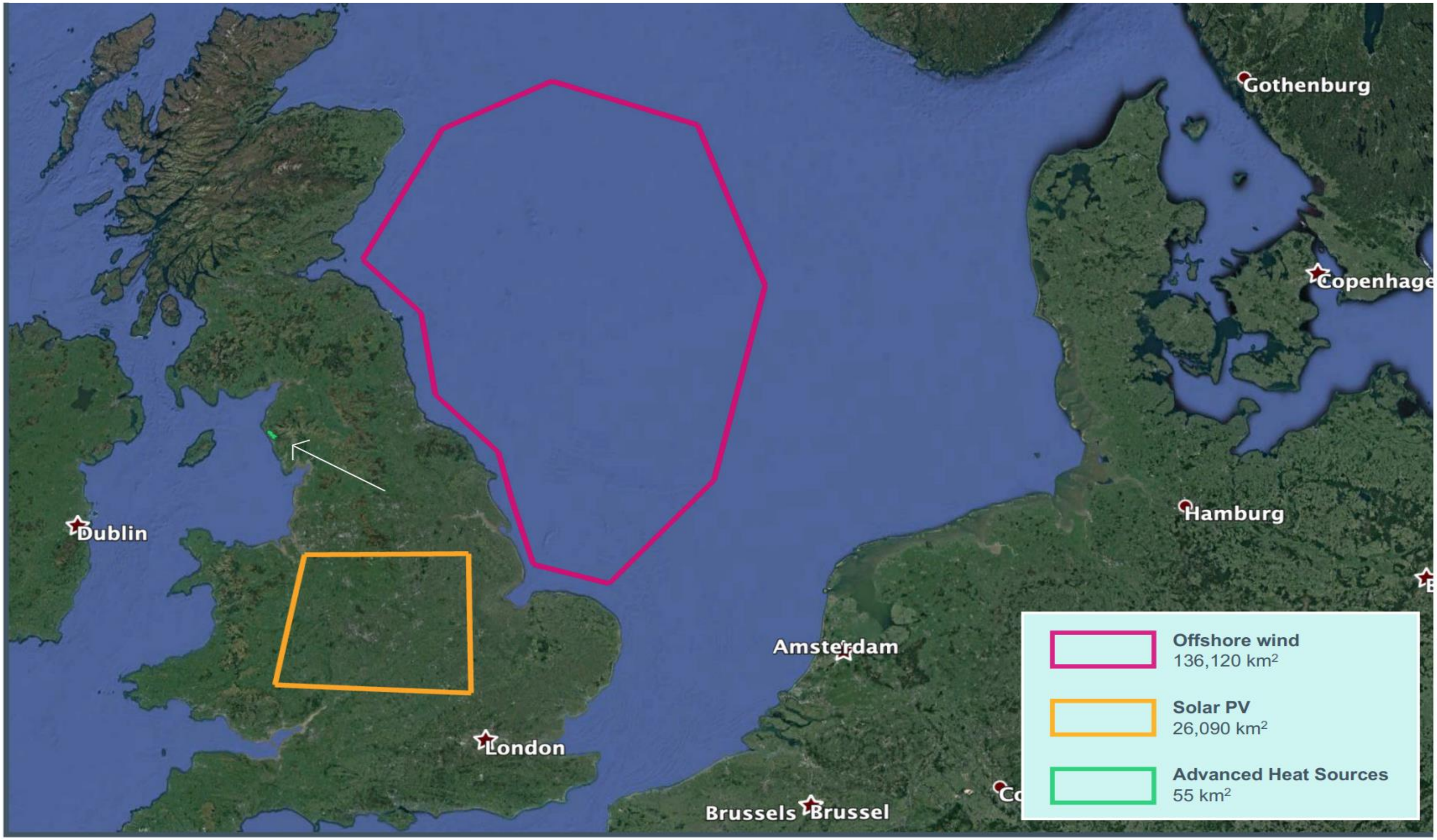
Liquid Synthetic Fuel for Aviation: UK ESME modelling



Comparative investment for fuel substitution by 2050



Comparing the total area required to replace the UK's current oil consumption with hydrogen generated from either wind, solar, or advanced heat sources



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in the UK.

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