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Innovation, Productivity and the Net Zero Economy

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Innovation, Productivity and the net Zero Economy

1. Role of innovation in driving productivity growth
2. Twin challenges of pandemic and transition to net zero
3. Need for 'green innovation'
4. Whole system approach
5. Role of institutions and government

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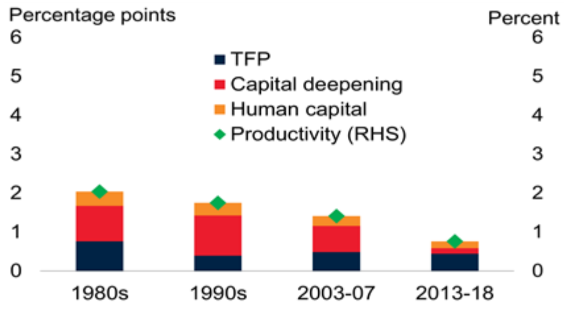
Productivity drives long term growth

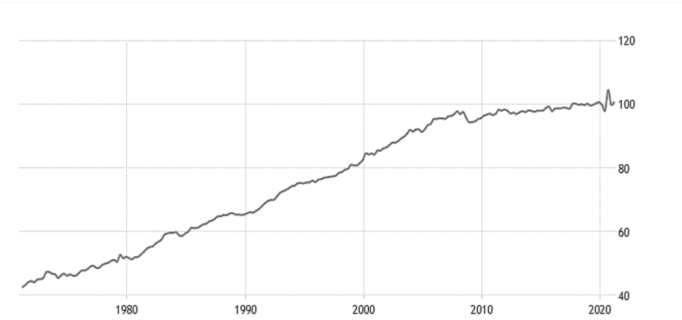
Productivity growth 1980-2018

Source: World Bank, 2020



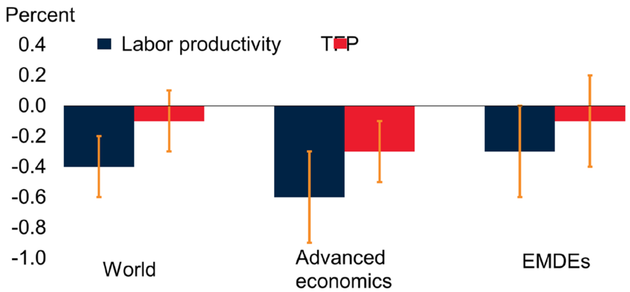
UK productivity 1973-2018

Source: Statista, 2020



Change in productivity following shock events

Source: World Bank, 2020



- Growth is sustained through productivity improvement and technological change.

"Research has consistently found that more than 50% of economic growth in developed economies cannot be accounted for by accumulation of production inputs, such as labour and capital, and that between 40%-60% of the growth has been driven by growth in total factor productivity"
[Phelps, Dynamism, 2020]

- Productivity has declined steadily over the past 40 years – this challenge is particularly acute for the UK over the last two decades.
- Pandemics and other shock events are associated with a slowdown in productivity.
- However, there are signs of a new tech / innovation boom: not just remote working, but the mRNA technology that supported vaccines, DeepMind protein-folding algorithm, SpaceX Starships program, Nuclear Fusion

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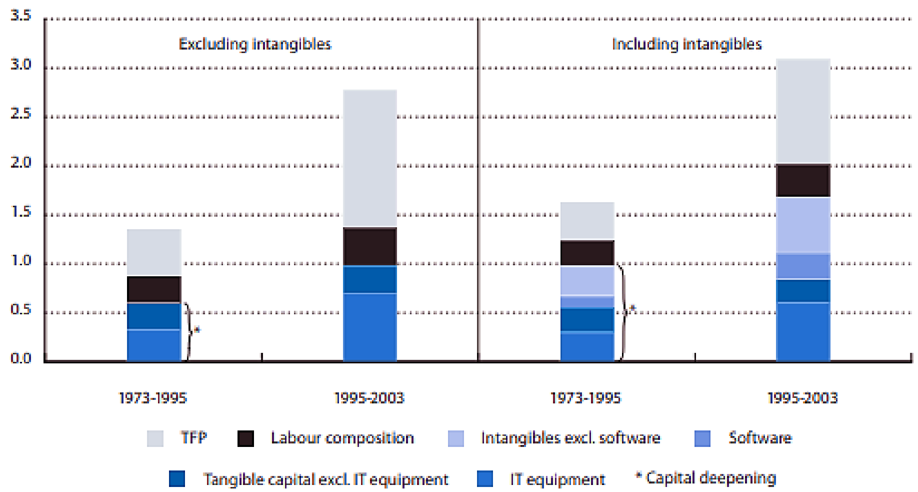
How do we reverse the slowdown in productivity?

Contributions to US output growth per hour worked (percentage points)

Source: Corrado et al, 2009



"The literature on economic growth and particularly endogenous growth [e.g. Romer, 2018] has identified knowledge expansion and innovation as a key propellant. However, investment in R&D is not sufficient and policies aiming to boost growth should also provide for well functioning labour, product and financial market"
[Uppenberg, Innovation and economic growth, 2009]

- Innovation, including investment in R&D, historically have led to improvement in productivity.
- There is difference between adoption of innovation originating abroad, 'imported innovation', and 'indigenous innovation', which is innovation generated by a given economy on its own.
- Both types of innovation can contribute to productivity growth but they are distinct in terms of what factors may lead to such innovation and the impact that innovation has on other economic variables and social outcomes.

"Innovation is the major, if not the most important, sources of growth in GDP per capita in the long run"
[Phelps and Bojilov, 2020]

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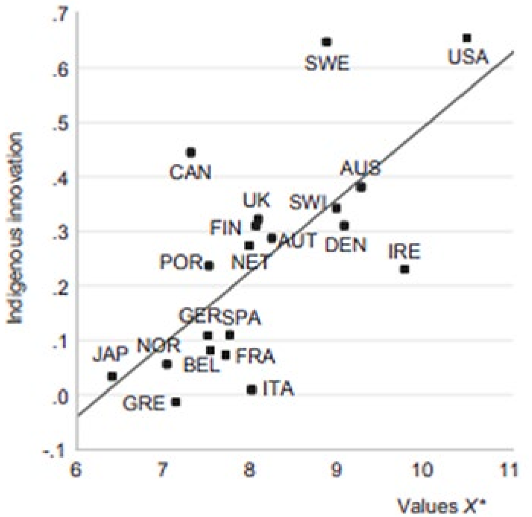
Imported innovation vs Indigenous innovation

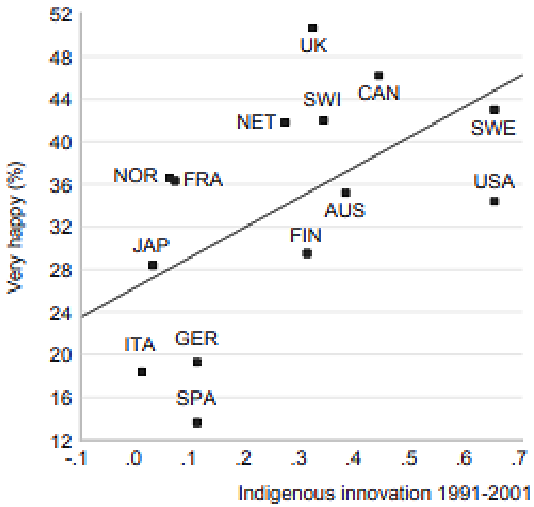
Relationship between values and innovation

Source: Phelps, Dynamism, 2020



Relationship between "happiness" and indigenous innovation

Source: Phelps, Dynamism, 2020



- Imported innovation relies on the degree of openness of a country, trade and capital flows, level of migration, population growth and technology transfer (either at a corporate level or via international institutions / intergovernmental agreements).
- Indigenous innovation expands its production possibility and frontier through a stream of new ideas, new products and new production methods by innovators/ scientists and then is gradually diffused over the rest of the economy by business people and entrepreneurs.
- A country can enable such innovation in several ways:
  - through supportive institutions;
  - by promoting competition;
  - with an education system that develops and rewards talent;
  - from values and beliefs such as trust, willingness to take initiative and risks, and desire to achieve on the job.
- In terms of outcomes, analysis has shown that higher level of indigenous innovation leads to stronger economic growth, higher job satisfaction and higher measured happiness.

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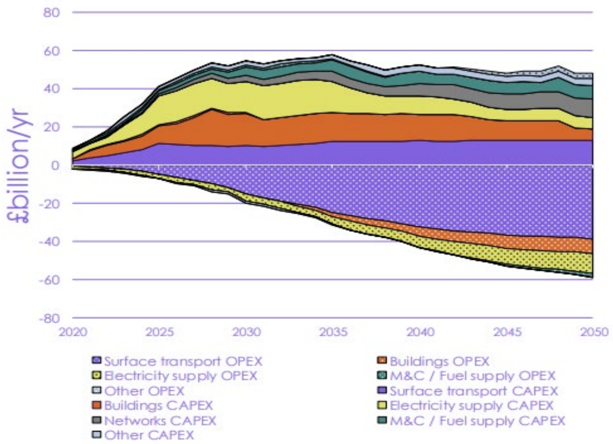
Challenge of net zero also requires significant innovation

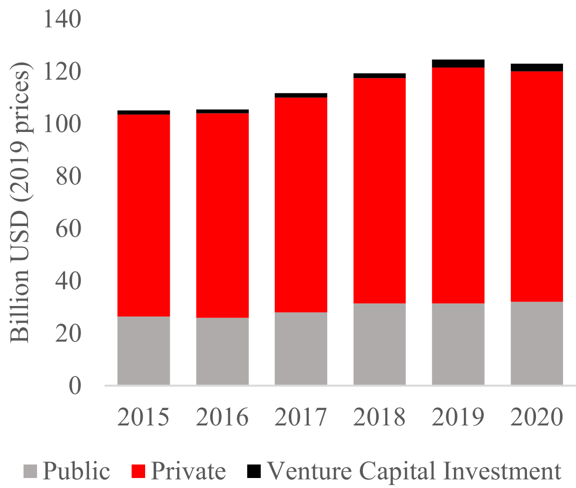
Capital investment costs and operating costs savings in the balanced pathway [UK]

Source: CCC analysis



Energy R&D spending by sector [Global]

Source: World Energy Investment 2021



- The UK has committed to achieve net zero emissions by 2050, with Scotland making a commitment to the same goal by 2045.
- Much decarbonisation has already been achieved; however, significant acceleration of efforts and important policy changes must be made in order to reach the target.
- A sustainable and resilient recovery from the Covid-19 crisis will require boosted investments in clean innovation and its diffusion, together with complementary and inter-dependent investments in physical, human, natural and social capital.
- Investment in innovation [through public and private R&D, and venture capital] has increased over past 5 years but is still less than one tenth of overall capital investment in the sector. It needs to increase by a factor of 3 to 4 to set us on a path to achieve net zero targets.

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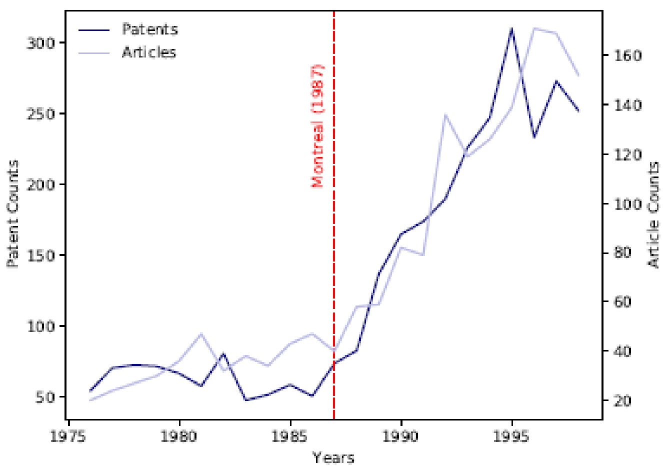
‘Green innovation’ requires support: “induced technical change”

“The theoretical evidence suggests that action at scale and across the economy, via a coordinated set of policies and institutions, is required in order to tackle the multiple market failures that coexist, and shift the trajectory of economies so that path dependence favours clean innovation and investment. Given the environmental and substantial economic costs of locking-in to dirty assets and infrastructure, time scales and rates of change must be at the centre stage of policy assessments”
[Stern, 2021]

Counts of Patents and Articles mentioning CFC Substitutes

Source: Dugoua, 2021



- Innovation is not spontaneously environmentally friendly:
  - firms whose production / innovation has been in polluting technologies in the past prefer to innovate in polluting technology in the future (‘path dependence’);
  - hence, the need for government intervention to direct innovation towards green technologies (not take the place of private firms, but should act through incentives).
- There are different levers government can use:
  - carbon tax and carbon tariffs,
  - direct subsidies,
  - technology transfers,
  - R&D grant funding support, and tax instruments (tax incentives for R&D)
  - Procurement contracts and
  - Industrial policy [‘DARPA model’ and ‘Missions Innovation’].

“Sustainable growth can be achieved with: (i) temporary taxes/subsidies that redirect innovation; (ii) optimal policy involves both “carbon taxes” and research subsidies; (iii) delay in intervention is costly, longer transition phase with slow growth”
[Acemoglu, Aghion, Bursztyn, Hemous, 2012].

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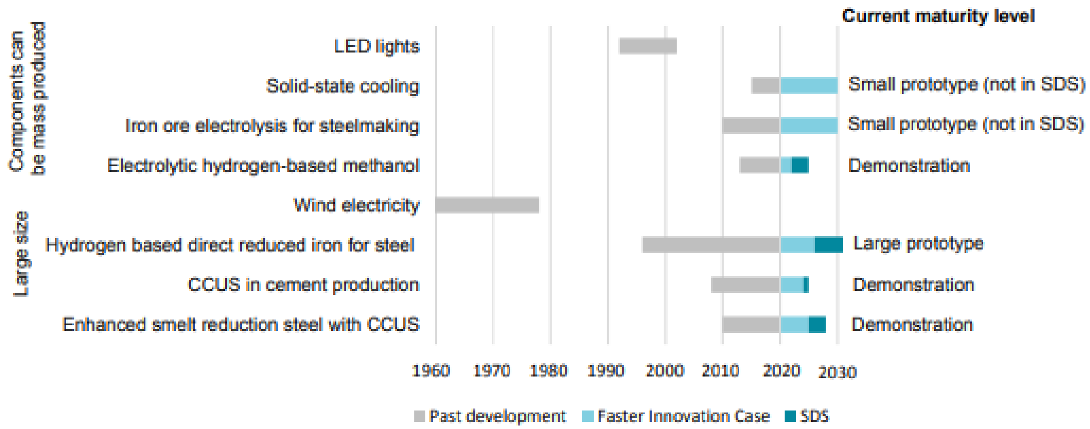
Induced technological change could lead to faster innovation scenarios

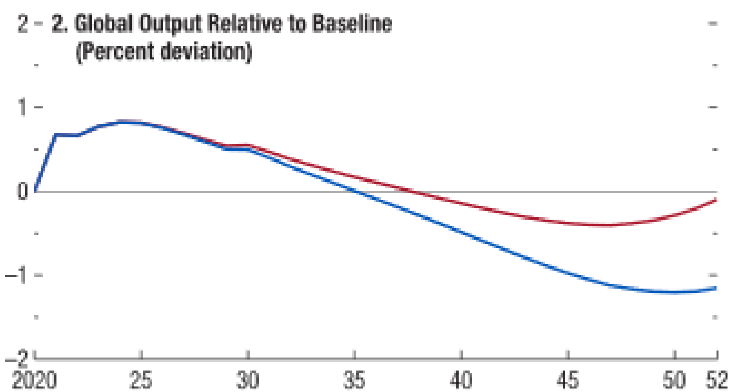
Period from first prototype to market introduction for selected technologies



Source: IEA, 2020

Impact of increased R&D subsidy and endogenous technical change

Source: IMF, 2020



- In the Faster Innovation Case, CO2 savings from technologies currently at the prototype or demonstration stage would be more than 75% higher in 2050 than in the Sustainable Development Scenario, and 45% of all emissions savings in 2050 would come from technologies that have not yet reached the market.
- Such rapid deployment would require successful innovation cycles that are more rapid than any seen in recent energy technology history.
- Key clean energy technologies at demonstration or large prototype stage today would need to reach markets in six years from now at the latest, which is twice as fast as in the Sustainable Development Scenario.
- IMF estimates endogenous technological change in response to higher R&D subsidy to reduce carbon price needed by almost half with benefits primarily after 2030

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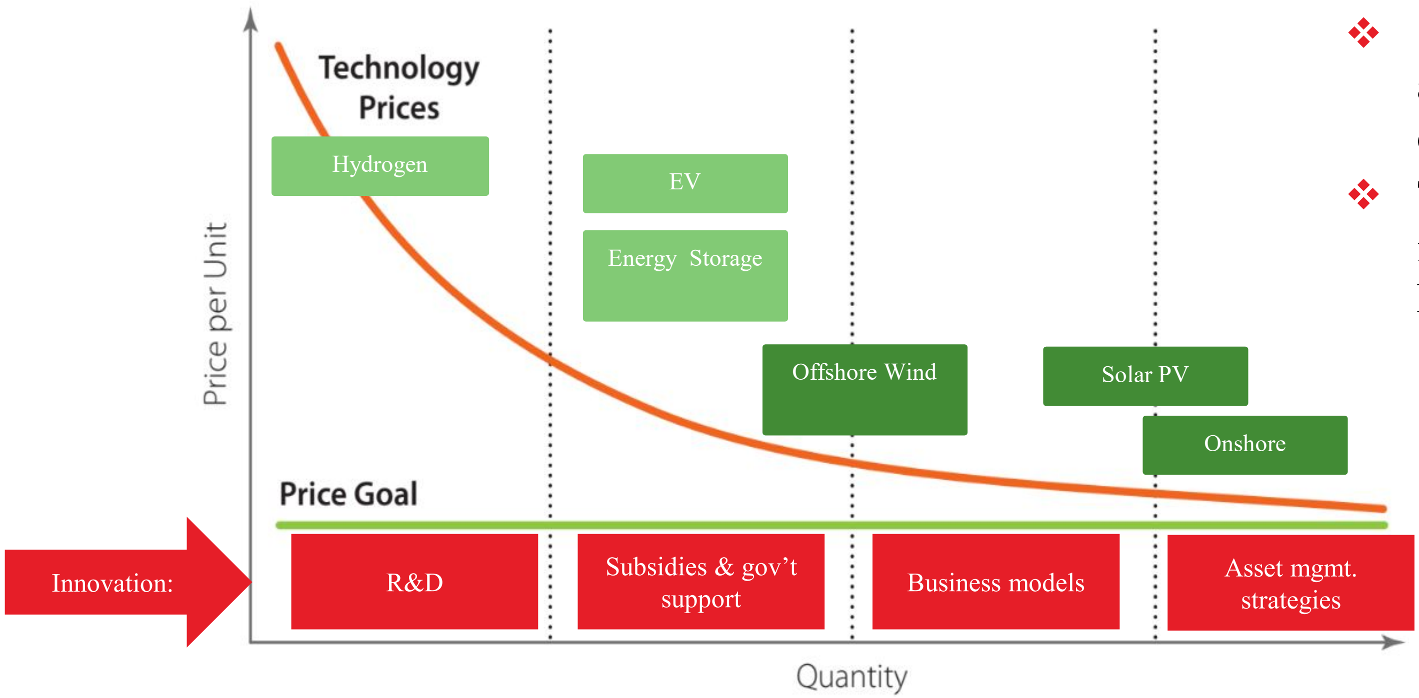
How does ‘Green Innovation’ look like?

Impact and effects of innovation on technology costs



- Innovation can lead to lower costs [e.g. LCOE, price per unit etc.]
- Innovation can develop new products / technologies
- Innovation can unlock faster and wider deployment / capacity
- Sources of innovation are different across the spectrum of technologies dependent on their maturity
- Types of government support and incentives required are not homogenous

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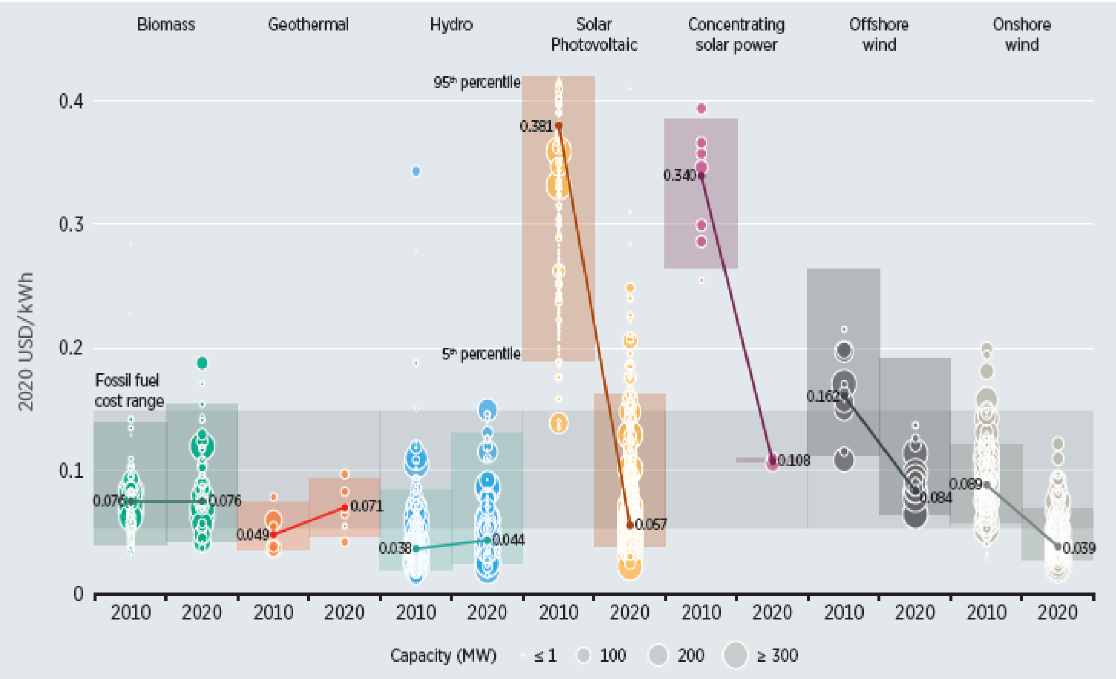
We have seen significant cost reduction in renewable energy tech already…

Global LCOEs from newly commissioned, utility-scale renewable power generation technologies, 2010-2020

Source: IRENA renewable cost database



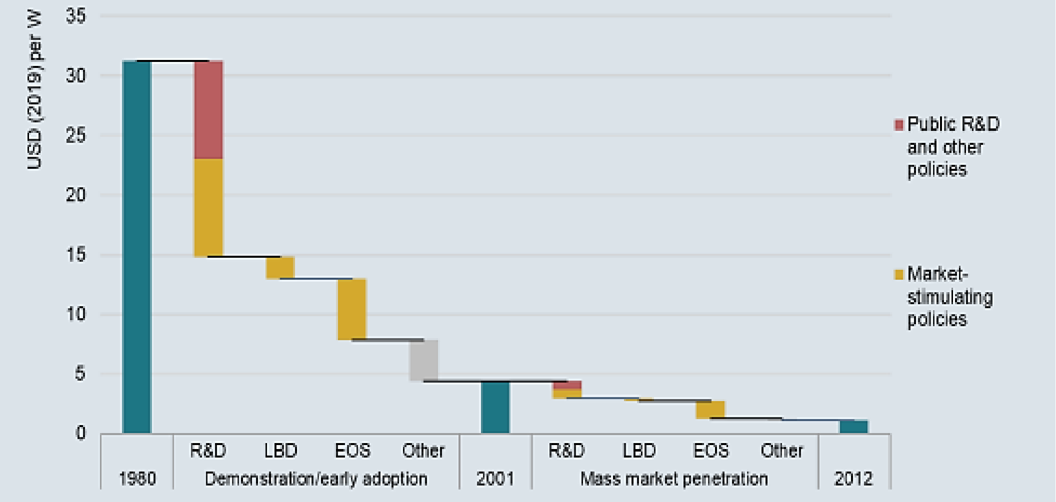
- Solar PV, onshore wind and offshore wind have shown significant reductions in LCOE in the past, and now they are comparable with conventional sources.

Generation source	LCoE in 2010 (USD/kWh)	LCoE in 2020 (USD/kWh)	Change in LCoE 2010-2020
Offshore wind	0.162	0.084	-48%
Onshore wind	0.089	0.039	-56%
Solar PV	0.381	0.057	-85%
CSP	0.340	0.108	-68%
Biomass	0.076	0.076	0%
Geothermal	0.071	0.075	0%

Pathway to cost reduction: onshore wind and solar

Contributions to solar PV cost declines by high-level mechanism and driver

Source: IEA calculations based on Kavlak, McNerney and Trancik (2018)



Notes: R&D = learning-by-researching; LBD = learning-by-doing; EOS = economies of scale. Other includes externally driven input prices and costs. Assumption: R&D funding was equally split between public and private sector and equally impactful on costs.

- What are the drivers for cost reduction?
- How much is innovation driven?
- Solar PV:
  - decline in module prices (fallen by 93% since 2010);
  - increased efficiency;
  - economies of scale from manufacturing;
  - technology optimised.

- Onshore Wind:
  - fall in WTG prices and BoP costs;
  - reduction in opex with competition in O&M providers, more experience, improved proactive maintenance;
  - CF increase due to better technology, better siting and reliability, higher HH and swept area.

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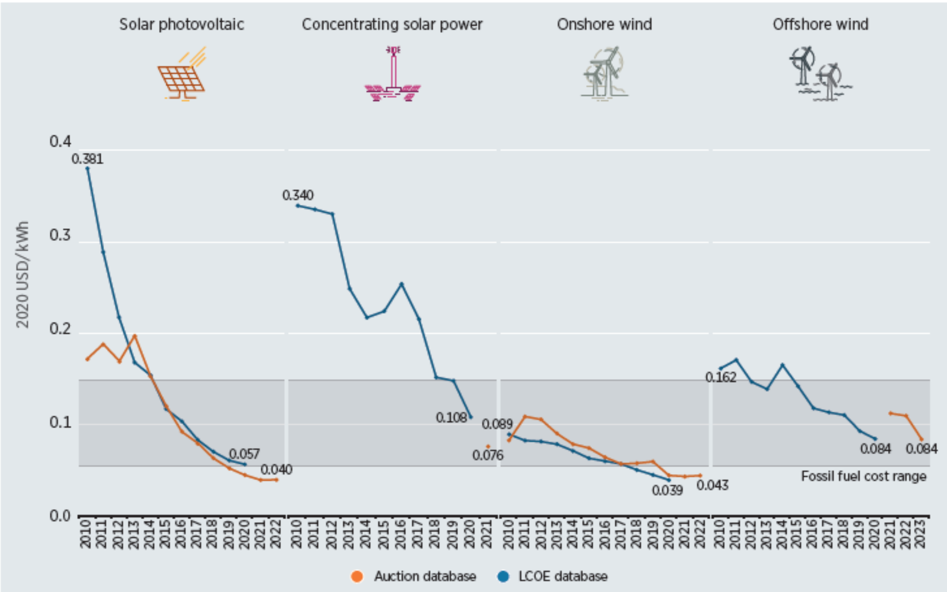
Pathway to cost reduction: offshore wind

The global wighted-average LCOE and PPA/auction prices for solar PV, onshore wind, offshore wind and CSP, 2010-2023

Source: IRENA renewable cost database



Source: IRENA Renewable Cost Database
Note: The thick lines are the global weighted average LCOE, or auction values, by year. For the LCOE data, see Figure ES2 note. The band that crosses the entire chart represents the fossil fuel-fired power generation cost range.

- Offshore wind:
  - more experienced developers;
  - robust regional supply chain and O&M bases;
  - attractive cost of capital;
  - streamlining of manufacturing;
  - regional manufacturing and service hubs; and
  - economies of scale.

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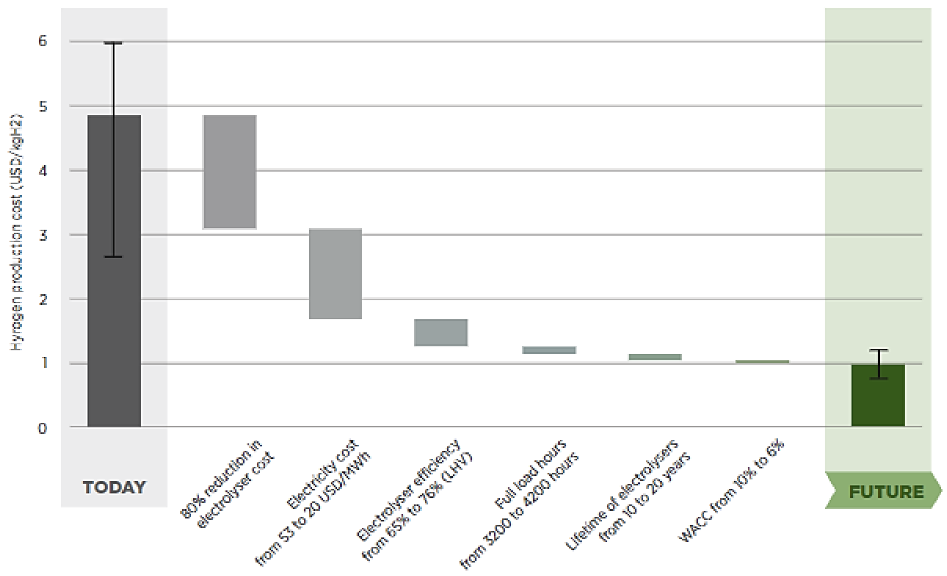
Green hydrogen – is the same path possible?

Green hydrogen cost reduction pathway



Note: 'Today' captures best and average conditions. 'Average' signifies an investment of USD 770/kilowatt (kW), efficiency of 65% (lower heating value – LHV), an electricity price of USD 53/MWh, full load hours of 3200 (onshore wind), and a weighted average cost of capital (WACC) of 10% (relatively high risk). 'Best' signifies investment of USD 130/kW, efficiency of 76% (LHV), electricity price of USD 20/MWh, full load hours of 4200 (onshore wind), and a WACC of 6% (similar to renewable electricity today).

Source: IRENA analysis, 2020

- A combination of cost reductions in electricity / electrolysers, combined with increased efficiency and operating lifetime, can deliver 80% reduction in hydrogen cost.
- Barriers to cheap green H2:
  - electrolyser cost – capex and opex;
  - electricity cost;
  - electrolyser efficiency (technology development);
  - full load hours;
  - electrolyser lifetime;
  - cost of capital.

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Path to cheap green hydrogen: how to unlock innovation

Cost & efficiency of electrolyser

- Technological innovation
- Streamlining manufacturing
- Exploiting resources more efficiently

Cost of electricity

- Cheaper renewable electricity from wind and solar

Investment & capital

- Innovation in business models
- Reliable & stable routes to market

Regulations & market structure

- Government and policy support
- Attractive market structures
- Permitting and overlapping environmental drivers

Lifetime of electrolyser

- Technological innovation
- Focus on R&D
- O&M innovation
- Asset management

Coordination & circular economy

- Government and policy support
- Integration into other technologies – e.g. overall OSW farm design
- Connection to consumers

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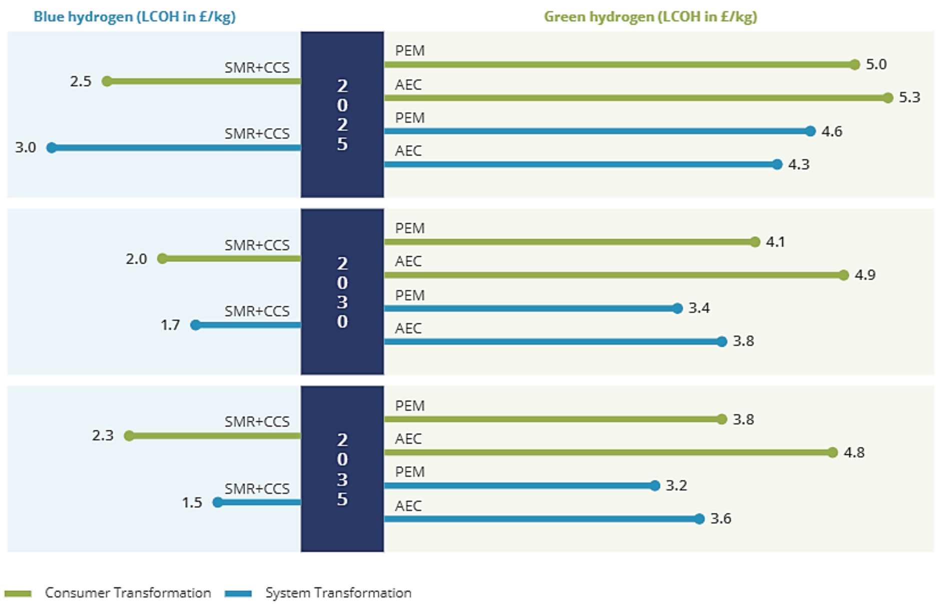
Blue hydrogen: enabler to net zero

Blue hydrogen and green hydrogen's LCOH forecasts

Source: Deloitte analysis



Note 1: SMR – Steam Methane Reforming; PEM – Proton Exchange Membrane Electrolysis Cells; AEC – Alkaline Electrolysis Cells.
Note 2: Blue hydrogen production costs in the Consumer Transformation scenario appear to increase between 2030 and 2035. This is because the cost model is based on FES 2020's required new production capacity figures, which fluctuate between 2025 and 2050.

- Blue hydrogen:
  - Smaller opportunity for cost reduction achievable
  - Potentially higher capacity deployed in short to medium term
  - Likely to be cheaper than green hydrogen until 2035;
  - Can also be viewed as a route to unlock cheap green hydrogen;
  - Enables use of existing infrastructure for gas, saving on new infrastructure costs.
- Opportunities across the supply chain:
  - CCUS
  - Storage
- In the EU most support for Green Hydrogen – opportunity to lead in blue hydrogen

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Innovation beyond technology progress

"There is evidence that business model innovation have contributed significantly to productivity growth across firsm in the UK between 2003 and 2017 and that financial innovation contributed to more than 20% of reduction in LCOE for wind technologies over the past 20 years."

Understanding this pathway is something Arup has been working on behalf of The World Bank Group to develop a comprehensive approach for Governments across the world to assess if an offshore wind market is an option for them, and can be part of their energy strategy to work towards net zero. Looking at four key factors – strategy, policy, frameworks and delivery – we've outlined the core elements that must be considered and assessed to understand if a market can be established.

- The pandemic has forced people and businesses to work in different ways, become more innovative and flexible, focussed and efficient.
- That approach can now be harnessed and followed to help build back better and enable a green recovery in the UK's energy sector.
- An integrated approach to innovation, from technology to processes, management, financial management and planning, is required.
- This means innovation cannot simply be focussed on technological development and advancement but also on business management, processes, analysis and decision making.
  - **Financial innovations** to develop new instruments to fund innovation and new technologies, reducing the risk and cost of capital
  - **Policy innovation** is also critical as knowledge management ensures that new innovations flow to users and to the development of new products, to increase the chances of innovations being adopted by users and decision makers.
  - **Social innovation** contributes to civic empowerment and improved collaboration, and adapt to local context and strive for society's well-being.
  - **Business model innovation** – how organisations change their approach to value creation and value capture.

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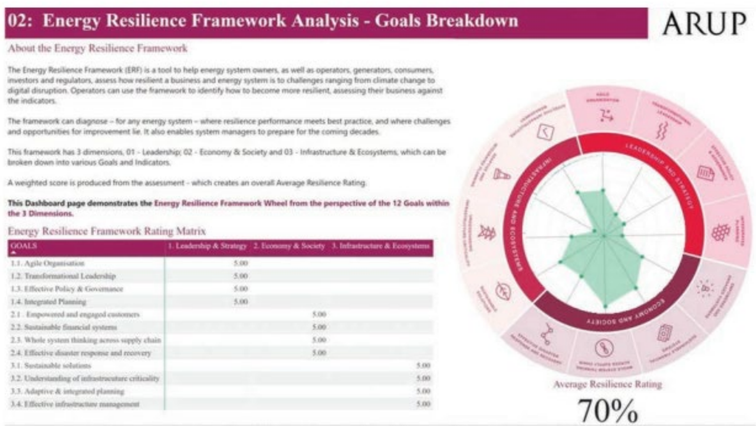
Innovation and ‘missions’ policy

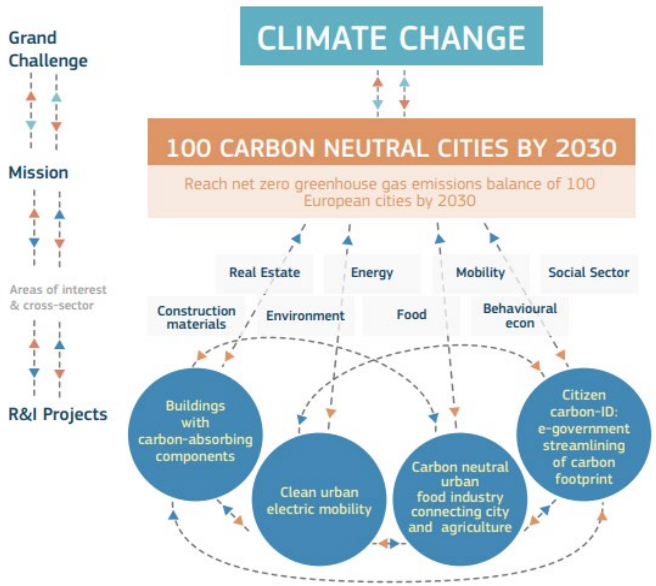
Energy Resilience Framework

Source: Arup, 2021



Mission roadmap for 100 Carbon Neutral Cities By 2030,

Source: Mazzuccato, 2018



- A sustainable and resilient recovery from the Covid-19 crisis will require boosted investments in clean innovation and its diffusion, together with complementary and inter-dependent investments in physical, human, natural and social capital.
- The achievement of these objectives requires a whole-economy approach with strong, coordinated and long-term policies and institutions, providing credibility and direction for private investment.
- Change on the pace and scale necessary also requires a broader “missions” approach, appreciating also the importance of aligning all actors in the national and international innovation system.
- New technology is not sufficient: we need to take into account and address the ‘institutions’ and the ‘frameworks’ required for the transition to net zero; this means creating new markets, incentives and leveraging public-private-partnerships to fund projects.

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Conclusions

- We need a boost in productivity to achieve net zero. Innovation is key to improve productivity and to develop the right technologies to achieve net zero:
    - learn from previous successes: how did renewable achieve cost reduction?
    - ‘indigenous innovation’ will bring most benefits to a country: is hydrogen [green and blue] and/or CCUS an opportunity for the UK?
- Focus on whole system and circular economy, not just net zero and carbon emissions reductions:
    - bring in digital and recycling (nature based solutions) to support a transition;
    - the benefits are not just about economy (GVA or jobs) – it is about social benefits;
    - new metrics are needed.
- Innovation is not just technology: it is about frameworks, institutions, skills and business models; we need to take into account and address the ‘institutions’ and the ‘frameworks’ required for the transition to net zero; this means creating new markets, incentives and leveraging public-private-partnerships to fund projects (e.g. DARPA model to ARIA?).

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