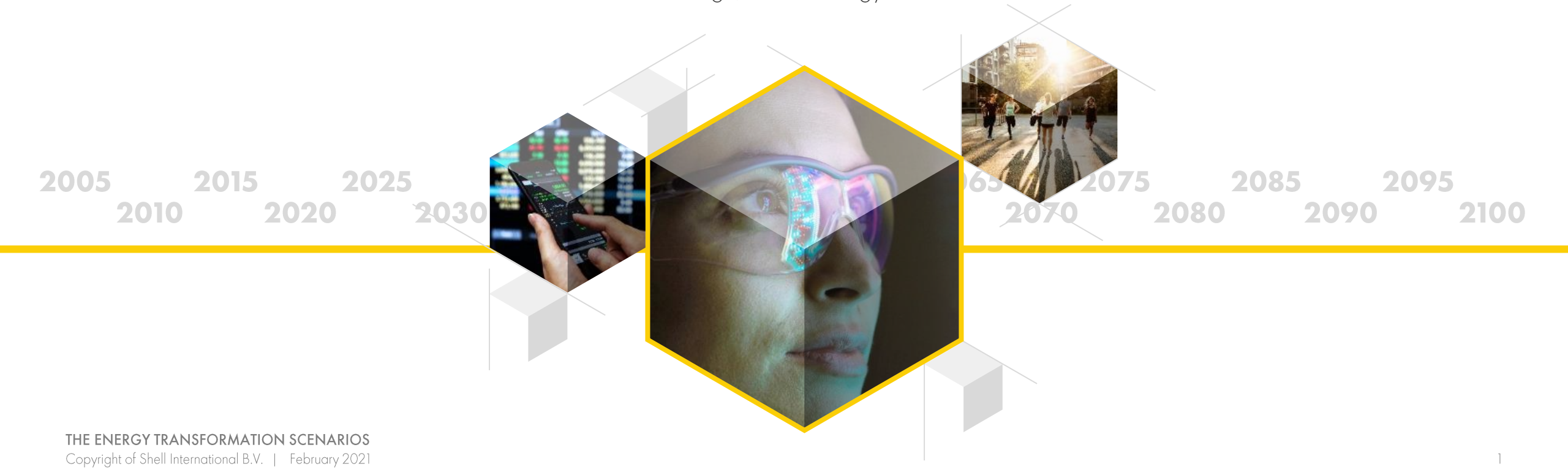
THE ENERGY TRANSFORMATION SCENARIOS

BIEE seminar: Decarbonising the energy system: from a global approach to a UK perspective.

21 April 2021

Martin Haigh, Senior Energy Advisor



Warning: Uncertainties Ahead

Shell's scenarios are not intended to be projections or forecasts of the future. Shell's scenarios, including the scenarios contained in this presentation, are not Shell's strategy or business plan. When developing Shell's strategy, our scenarios are one of many variables that we consider. Ultimately, whether society meets its goals to decarbonise is not within Shell's control. While we intend to travel this journey in step with society, only governments can create the framework for success. The **Sky 1.5** scenario starts with data from Shell's **Sky** scenario, but there are important updates. First, the outlook uses the most recent modelling for the impact and recovery from COVID-19 consistent with a **Sky 1.5** scenario narrative. Second, it blends this projection into existing **Sky** (2018) energy system data by around 2030. Third, the extensive scale-up of nature-based solutions is brought into the core scenario, which benefits from extensive new modelling of that scale-up. (In 2018, nature-based solutions required to achieve 1.5°C above pre-industrial levels by the end of this century were analysed as a sensitivity to **Sky.** This analysis was also reviewed and included in the IPCC Special Report on Global Warming of 1.5°C (SR15).) Fourth, our new oil and natural gas supply modelling, with an outlook consistent with the **Sky 1.5** narrative and demand, is presented for the first time. Fifth, the **Sky 1.5** scenario draws on the latest historical data and estimates to 2020 from various sources, particularly the extensive International Energy Agency energy statistics. As with **Sky**, this scenario assumes that society achieves the 1.5°C stretch goal of the Paris Agreement. It is rooted in stretching but realistic development dynamics today, but explores a goal-oriented way to achieve that ambition. We worked back in designing how this could occur, considering the realities of the situation today and taking into account realistic timescales for change. Of course, there is a range of possible paths in detail that society could take to achieve this goal. Although achieving the goal of the Paris Agreement and the future depicted in **Sky 1.5** while maintaining a growing global economy will be extremely challenging, today it is still a technically possible path. However, we believe the window for success is quickly closing.

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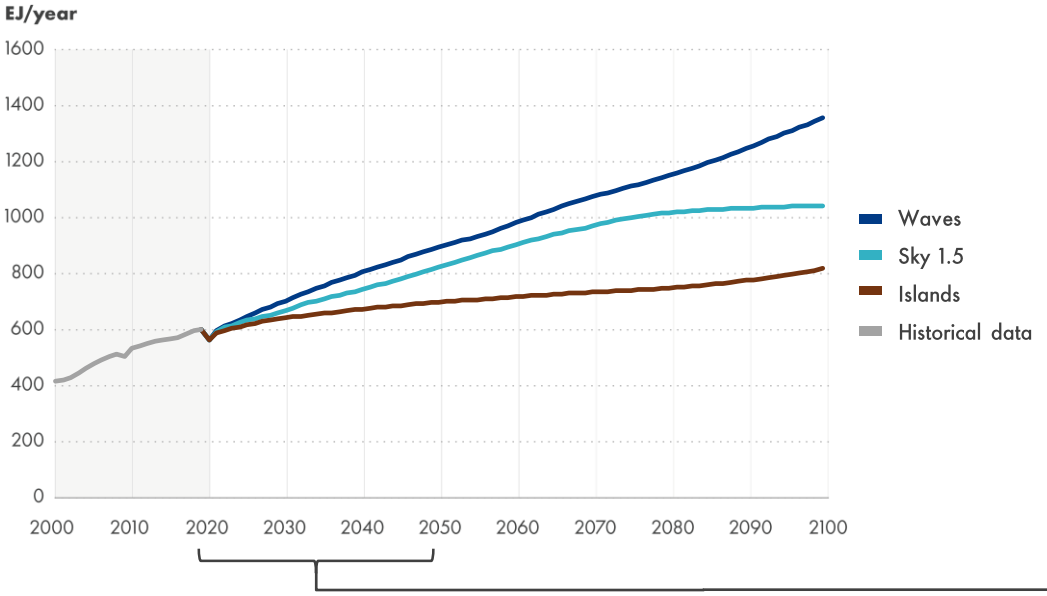
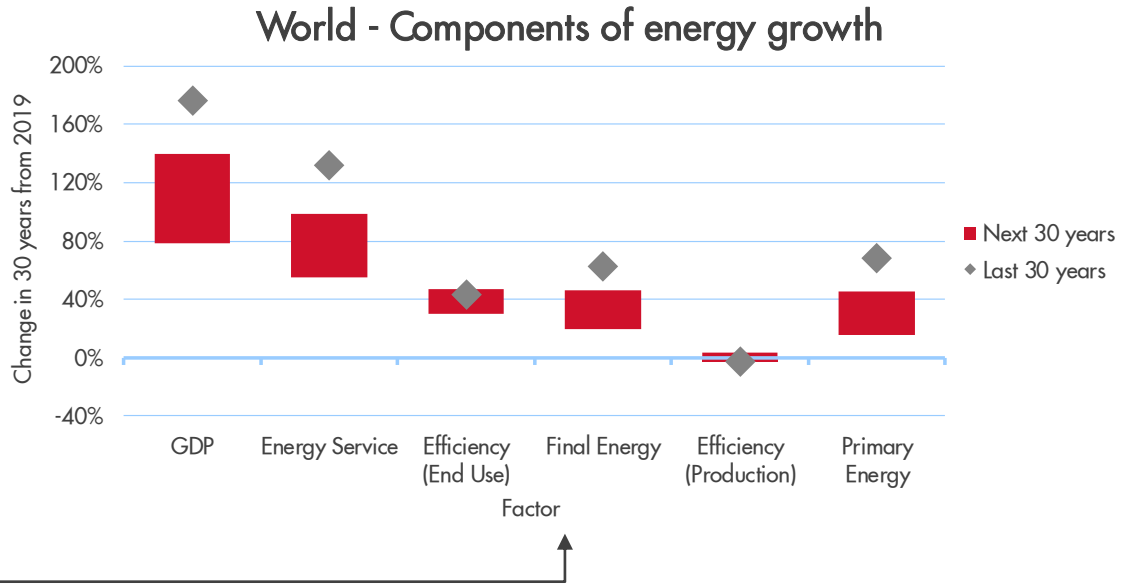
Long-term scenarios anchored in the near-term choices of Wealth (Waves), Security (Islands) and Health (Sky 1.5)

- 10-year time horizon
- Accelerating some changes under way, delaying others
- Wider uncertainty range
- From Wealth to Waves
- From Security to Islands
- From Health to Sky 1.5

Total primary energy demand rises in all of Shell's scenarios, with Sky 1.5 levelling off late-century

Total primary energy

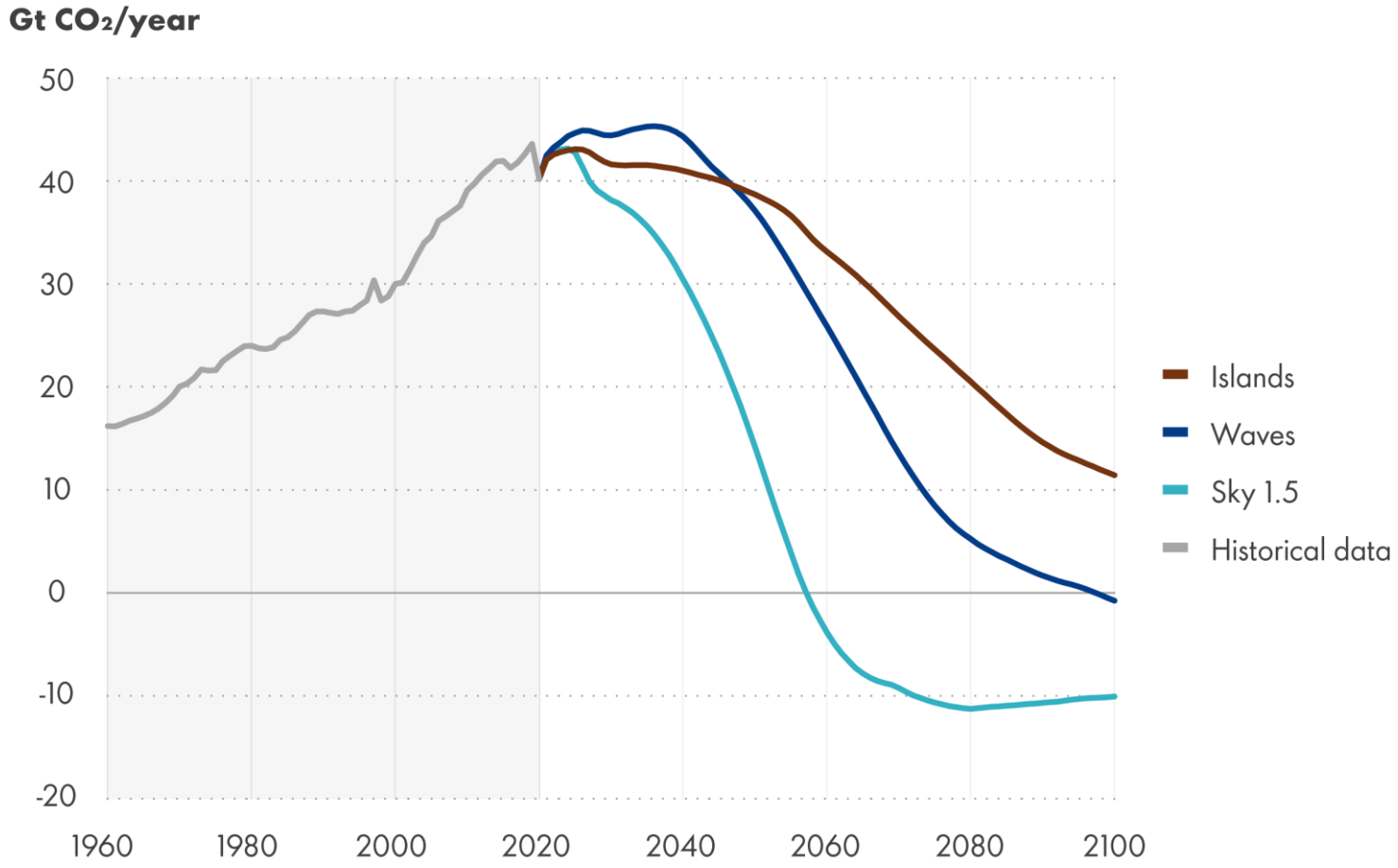




Source: Shell analysis based on data from the IEA (2020) World Energy Balances (Link), all rights reserved

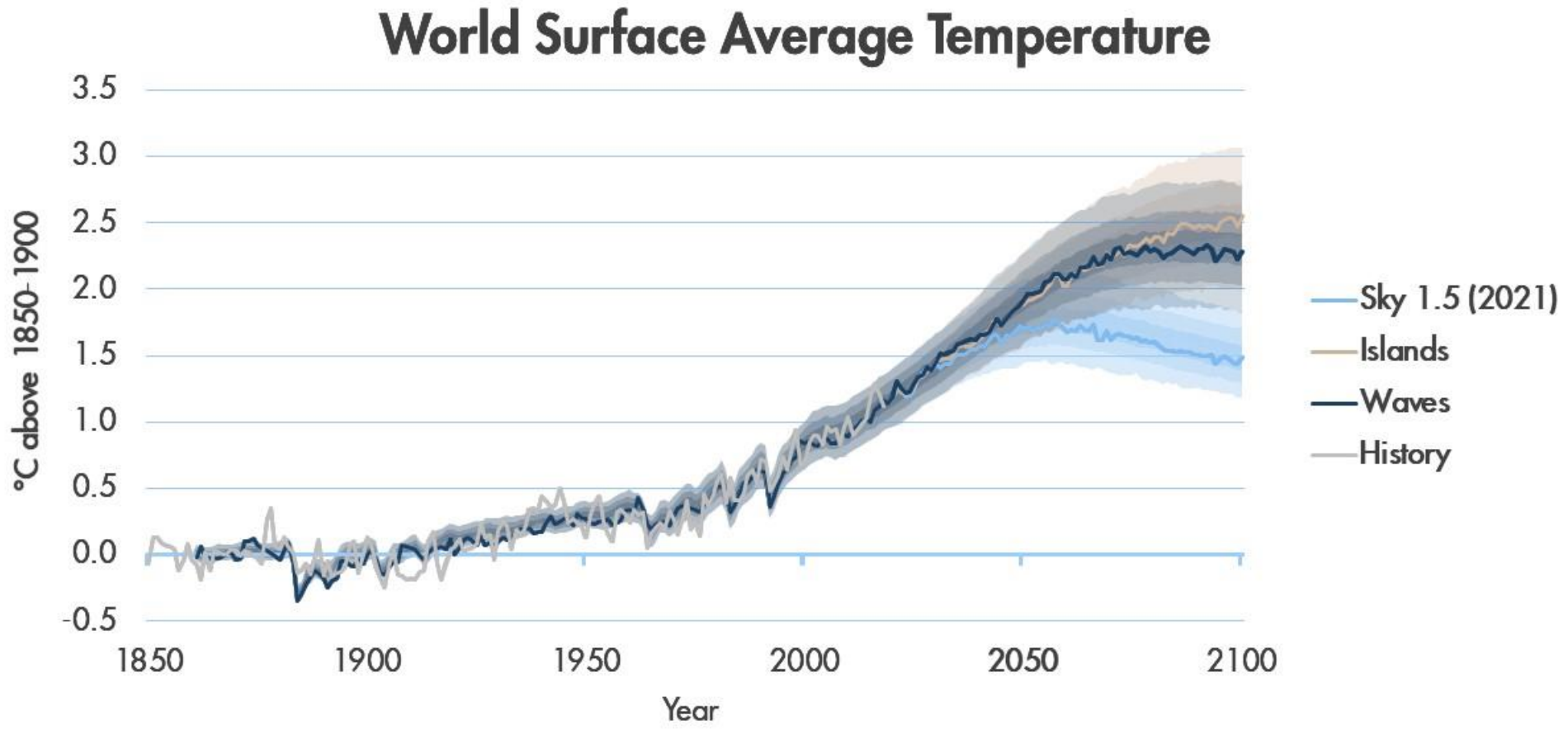
All pathways lead to net-zero CO_2: from the late 2050s (Sky 1.5), or end of century (Waves) or in the first half of the next century (Islands)

CO_2 emissions



Source: Shell analysis based on data from Global Carbon Project (2020) and the IEA (2020) World Energy Balances (Link), all rights reserved

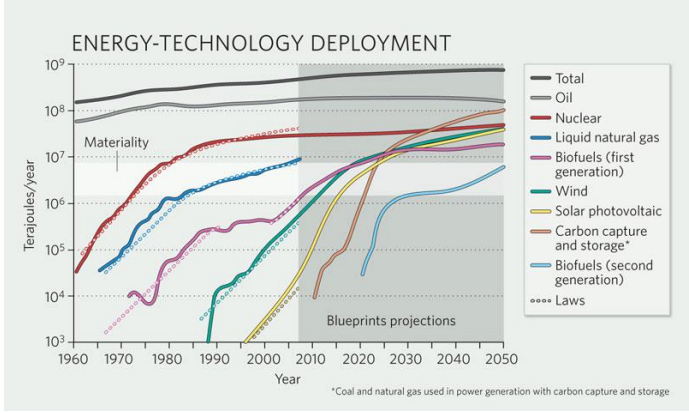
Temperature rise by 2100 in Sky 1.5 (computed by MIT) averages 1.5°C, but in Waves and Islands it's 2.3 - 2.5°C (all ± 0.5°C)

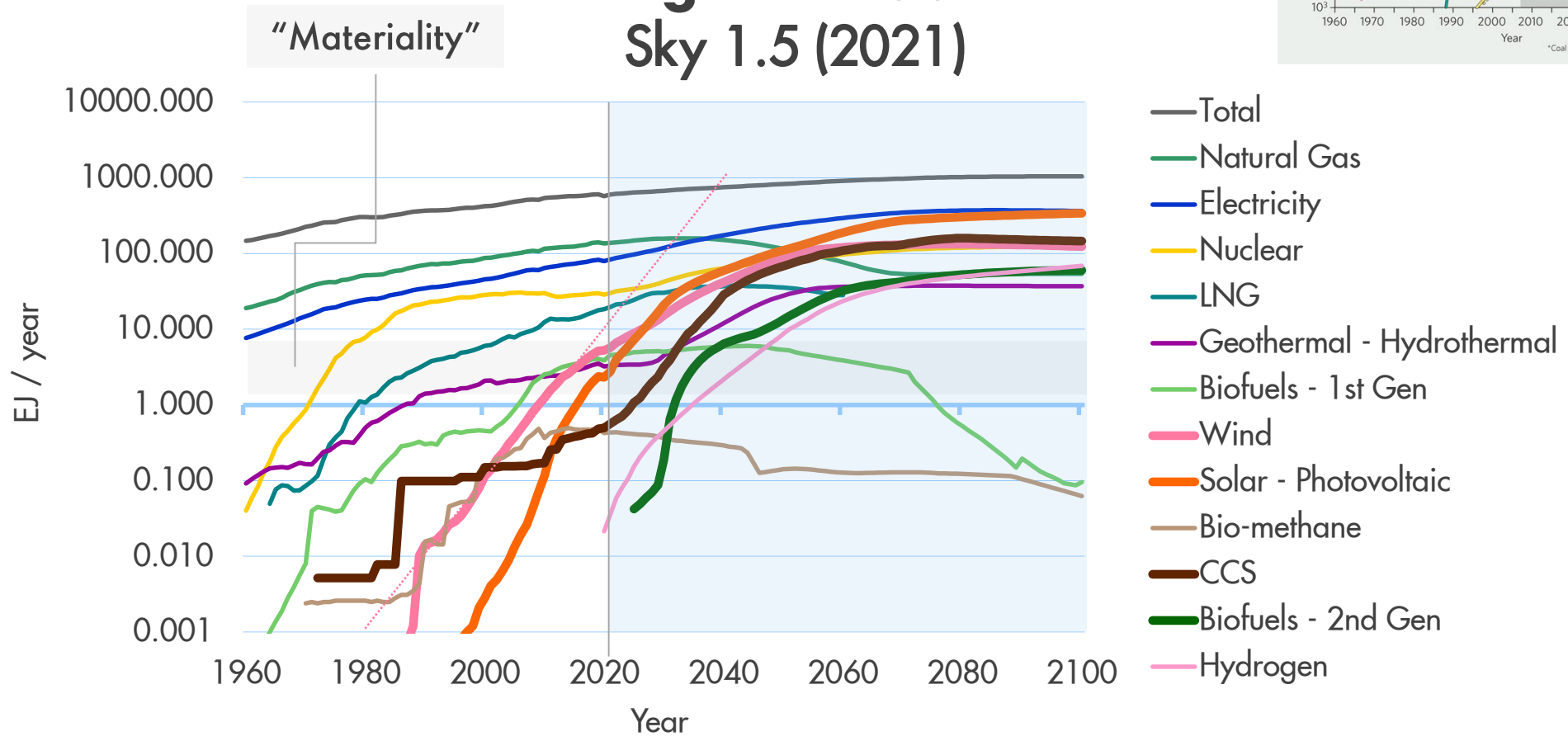


Source: Met Office Hadley Centre [HadCRUT5, December 2020, history], MIT Joint Program on Global Change [scenarios]

The likely (33%-66%) range in 2100 is 2.40-2.64°C for the Islands scenario, 2.19-2.43°C for the Waves scenario, and 1.40-1.59°C for the Sky 1.5 scenario.

Sky 1.5 – Wind, Solar, CCS & 2nd Gen Bio rapidly and simultaneously scaling by 10x – 100x… an unprecedented buildout through to 2100

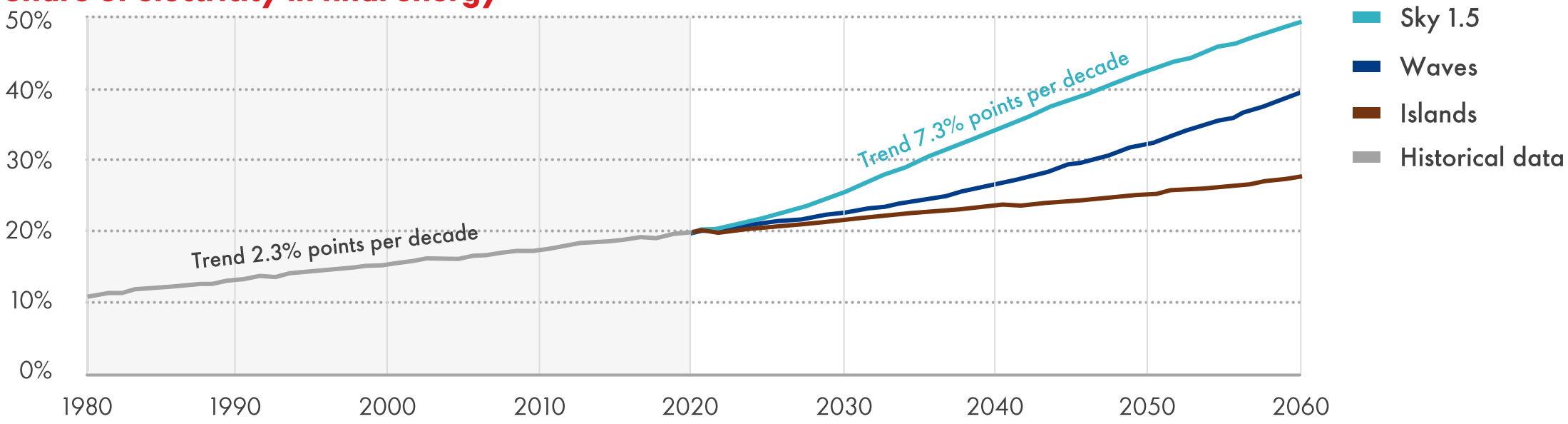




Source: Shell analysis based on data from the IEA (2020) World Energy Balances (Link), all rights reserved
Original chart from: No Quick Switch to Low-Carbon Energy, Kramer & Haigh, Nature (462), 3 Dec 2009

All scenarios see rising electrification of the energy system. Sky 1.5 sees the pace of electrification rise to three times its historical rate

Share of electricity in final energy



600 GW of solar installed in 2010s — 3000 GW of solar installed in 2020s

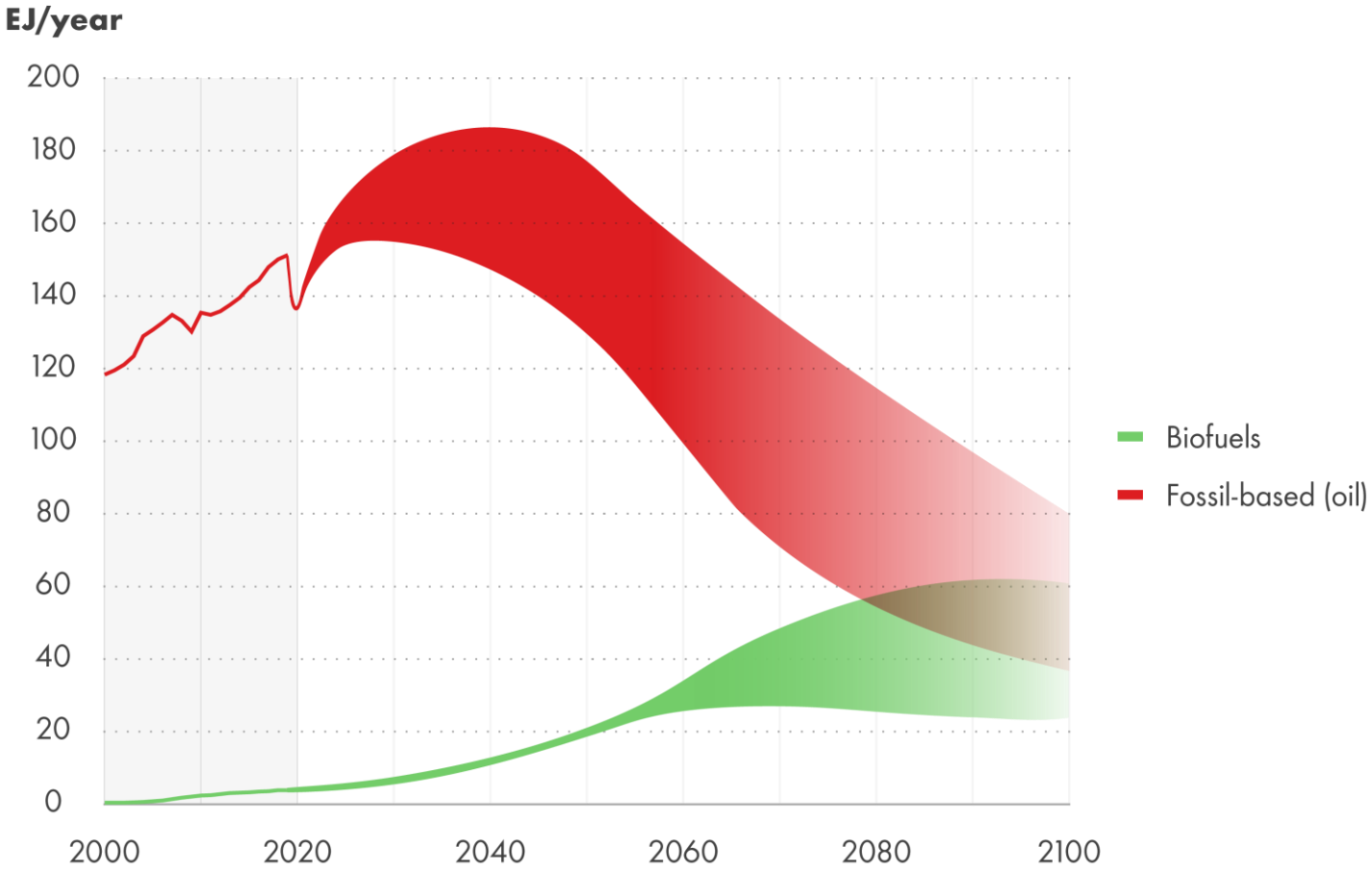
~150,000 3 MW turbines built during the 2010s, mainly onshore — 70,000 10 MW turbines during the 2020s, off-shore focus

No real growth since the turn of the century — Increase by a third in the coming decade and double by 2040.

Source: Shell analysis based on data from the IEA (2020) World Energy Balances (Link), all rights reserved

Oil demand will peak in the next two decades, then goes into decline as substitutes scale up and it concentrates in critical sectors

Liquid fuels demand

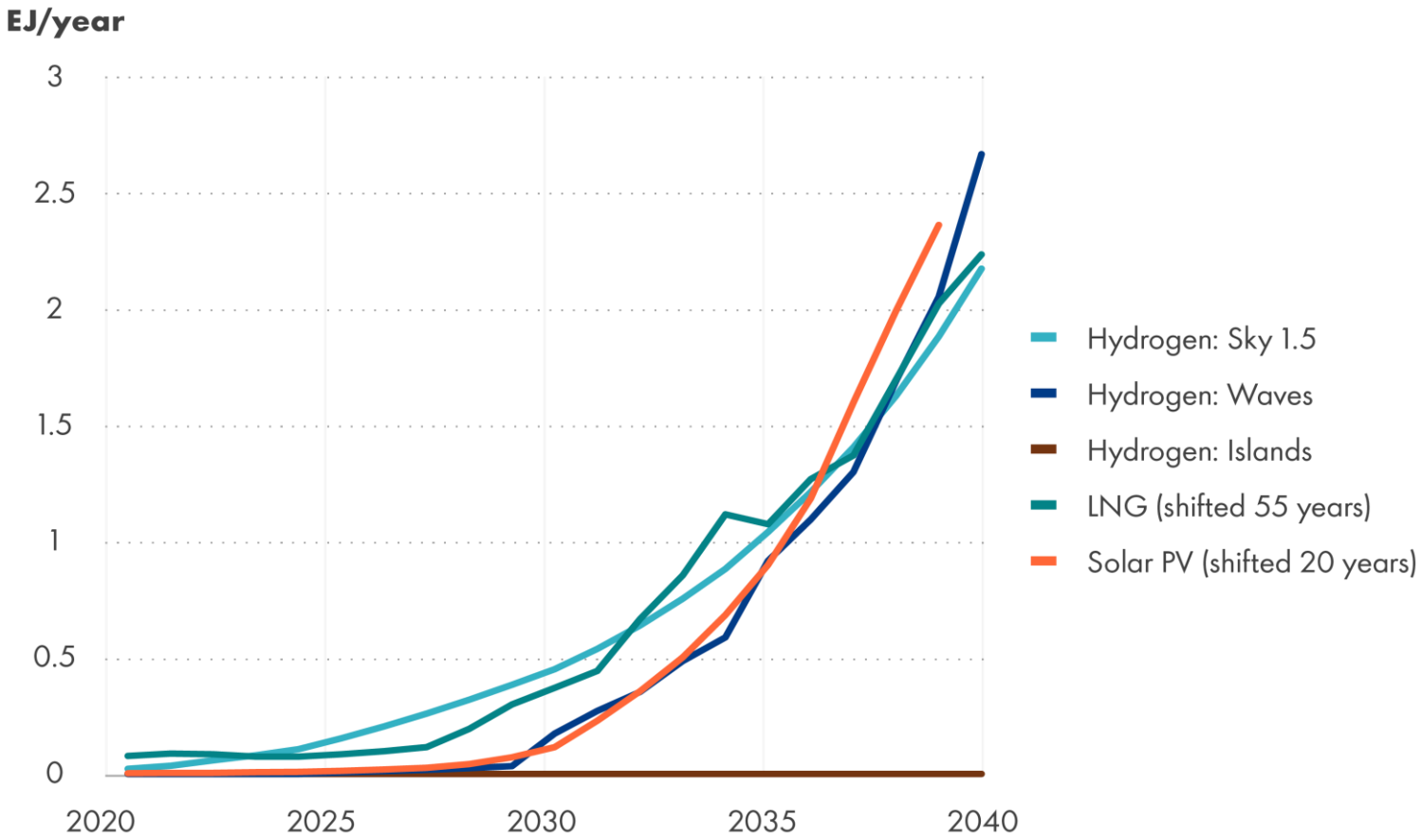


*Oil includes condensate and natural gas liquids

Source: Scenario ranges from Shell analysis based on data from the IEA (2020) World Energy Balances (Link), all rights reserved

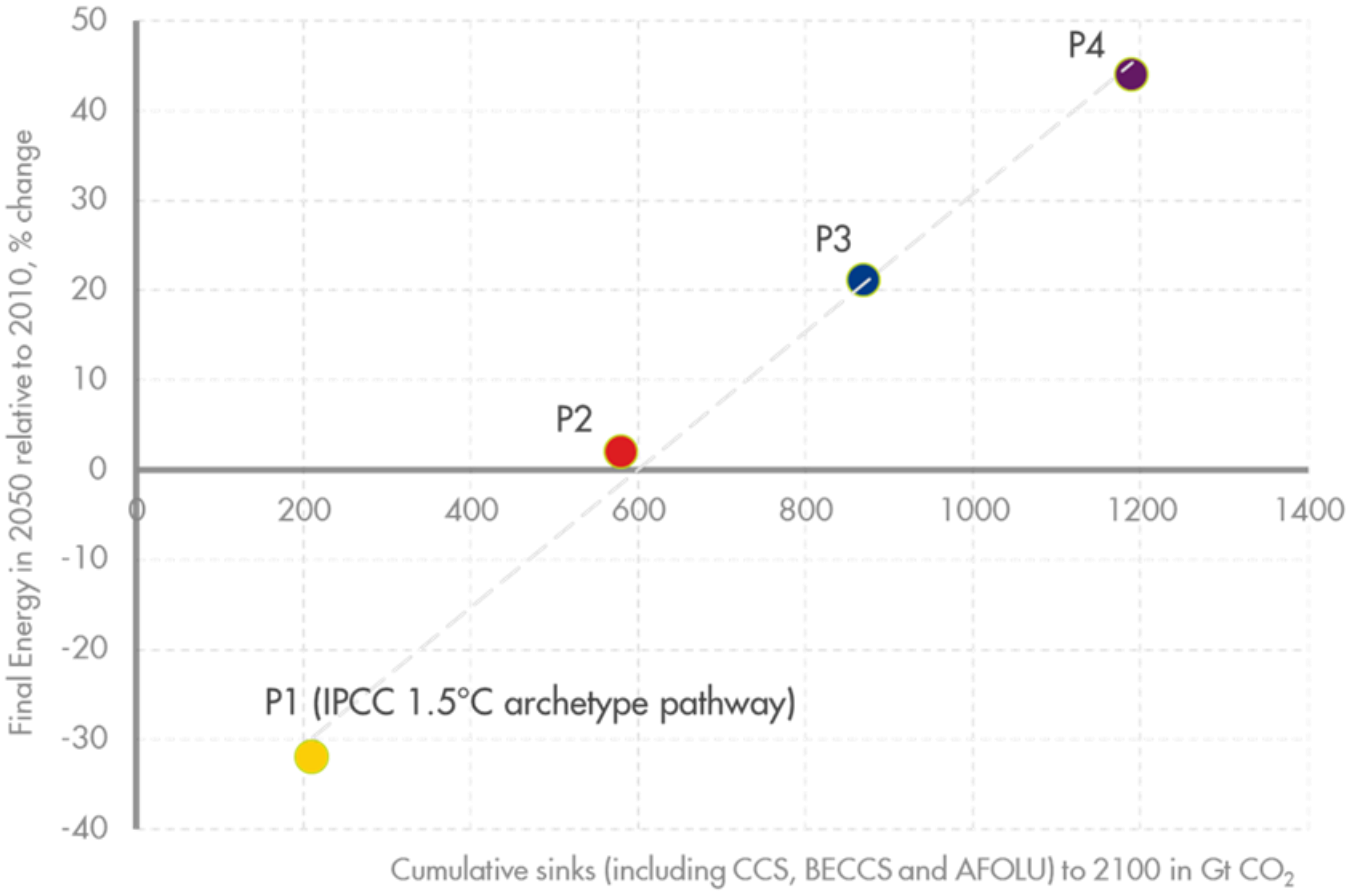
In Sky 1.5 and Waves the emergence of hydrogen (in non-chemical usage) this decade compares against two successful energy technologies, LNG and Solar PV. In two decades, it achieve 2 EJ / year, or 0.3% of TFC

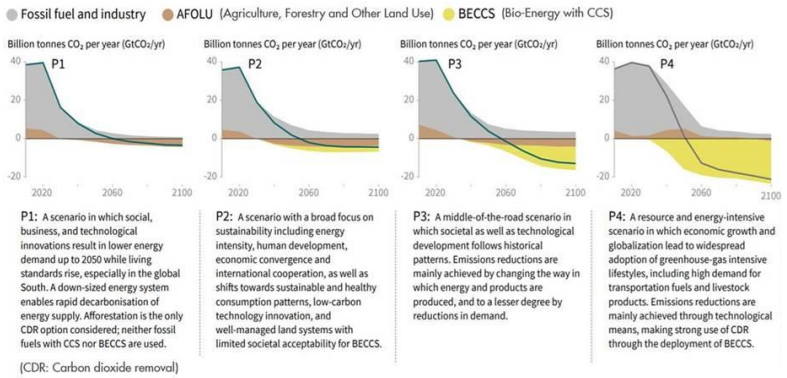
Hydrogen growth vs historical trends



Source: Shell analysis based on data from Rystad Energy and the IEA (2020) World Energy Balances (Link), all rights reserved

IPCC data shows carbon sinks (CCS, BECCS and AFOLU) are vital. Unless energy demand falls dramatically, > 600 Gt CO_2 needs sequestering…

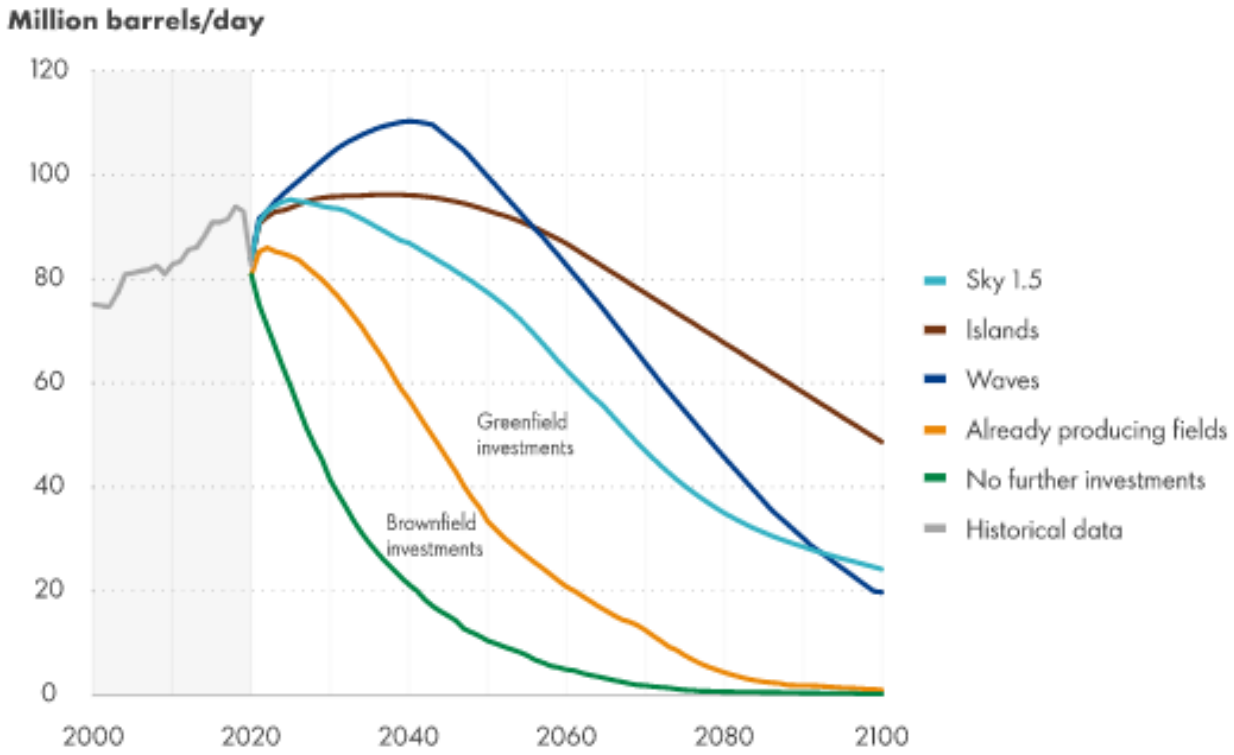




Source: Shell analysis based on IPCC SR15, 2018
https://blogs.shell.com/2021/03/02/the-importance-of-sinks/

Oil demand will peak and then go into decline, but future investments will be needed. Some emissions are unavoidable requiring CO_2 sinks

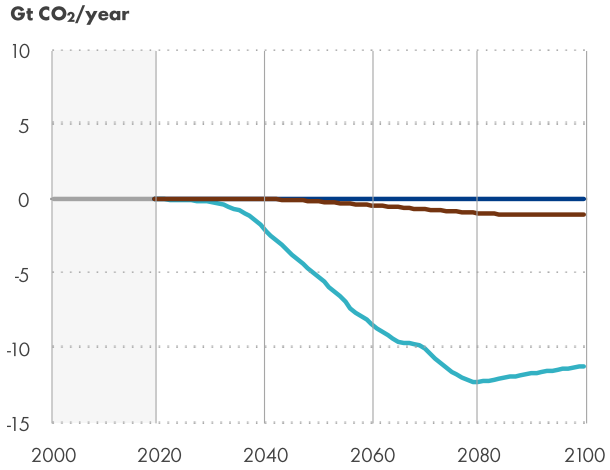
Total oil* production



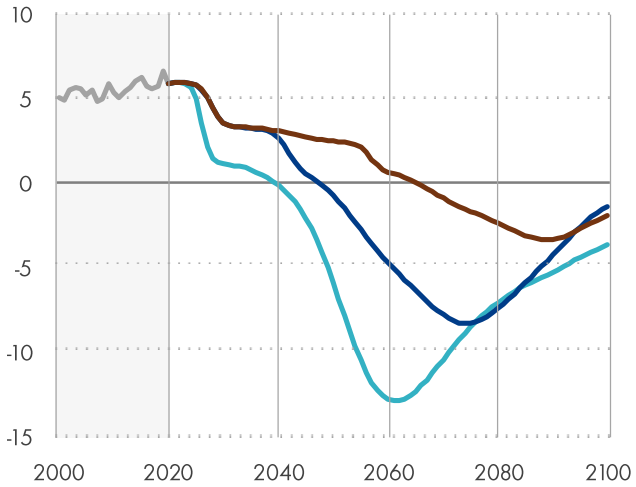
*Oil includes condensate and natural gas liquids

Source: Shell analysis based on Rystad Energy data

Energy-related emissions captured by CCS

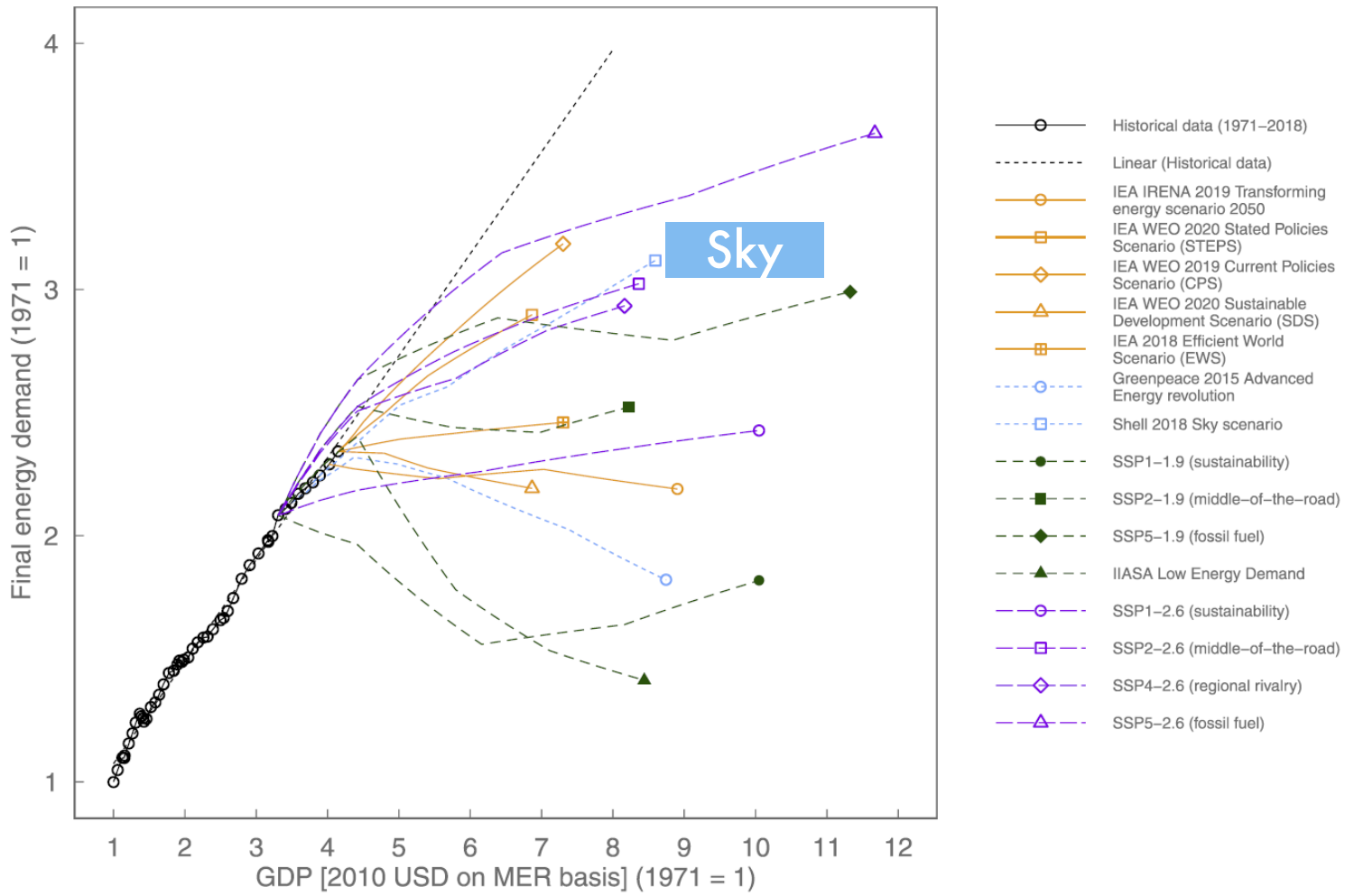


CO_2 removal using nature



Source: Shell analysis based on data from Global Carbon Project (2020)

Energy demand has tracked GDP … what next?



Source: Paper: Energy efficiency and economy-wide rebound effects: A review of the evidence and its implications, Brockway et al, Renewable and Sustainable Energy Review, March 2021

Conclusions from the paper:

- Many climate and energy scenarios project a significant departure from the historical close relationship between global energy consumption and GDP and a move towards absolute decoupling.
- These scenarios assume rapid improvements in energy efficiency through all sectors of the global economy and a shift towards less energy-intensive consumption patterns.
- However, the evidence reviewed in this paper suggests that economy-wide rebound effects could erode more than half of the anticipated energy savings.
- Since the mechanisms contributing to these effects are only poorly captured by the relevant models, global energy scenarios may overestimate the potential for decoupling energy consumption from GDP.
- Large rebound effects may therefore provide one explanation for the historical close relationship between energy consumption and GDP and at the same time may make it more difficult to decouple energy consumption from GDP the future

Questions