The Enduring Role of Hydrocarbons for Climate Change Measures

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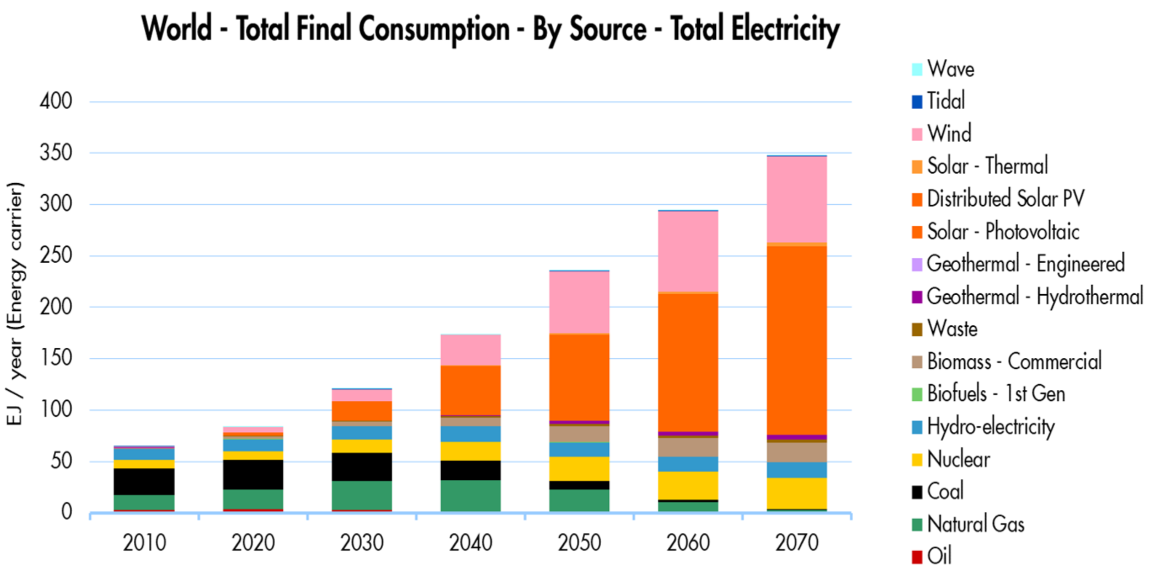
As part of many governments' stimulus packages to counter the global recession caused by the Corona pandemic, extra focus is given to a green recovery. Its aim is to stimulate achieving the goals of the Paris Agreement on climate change to limit the increase in the global average temperature to well below 2ºC and pursuing efforts to limit the temperature increase to 1.5ºC above pre-industrial levels. More momentum is developing for aiming at the more ambitious 1.5°C target, which means that global greenhouse house emissions need to peak as soon as possible and, while within an overall strong efforts to reduce CO_2 emissions, finding a balance between unavoidable anthropogenic emissions and removal of greenhouse gases by sinks like carbon capture and storage as well as nature based solutions. Stronger calls and commitments for reaching net zero emissions by around 2050 are now rising, and the question is posed how much fossil fuels will remain required and for how long to enable this transition. Many scenarios show that electrification is key, but that molecules will remain required in any energy system of the future. This paper examines how much fossil energy will remain required, if any, in such world by taking wind power generation as an example.



Graph 1: World Total final electricity consumption by source (Source: Shell Analysis, Sky Scenario)

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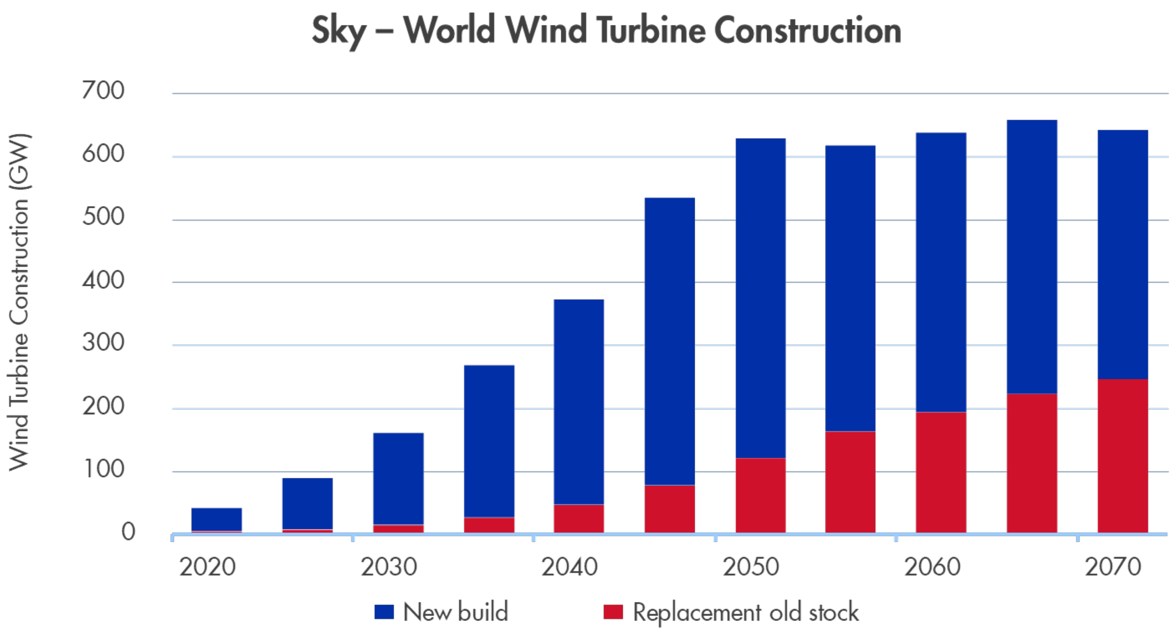
This case study is based on the wind power projections in the Sky scenario[1], which achieves a well below 2°C target with 85% probability and with additional nature-based solutions 1.5 °C with a 50% probability.

The Sky scenario illustrates a technically possible, but challenging pathway for society to achieve the goals of the Paris Agreement. It describes a set of mutually reinforcing drivers being accelerated by society, market and governments and include a step change in the energy efficiency in the demand sectors, a tripling in the rate of electrification with new energy sources like solar and wind growing up to fifty fold, the prolific use of carbon pricing mechanisms and a wide adoption of Carbon Capture and Storage (CCS) on bioenergy.

How many wind turbines need to be constructed each year?

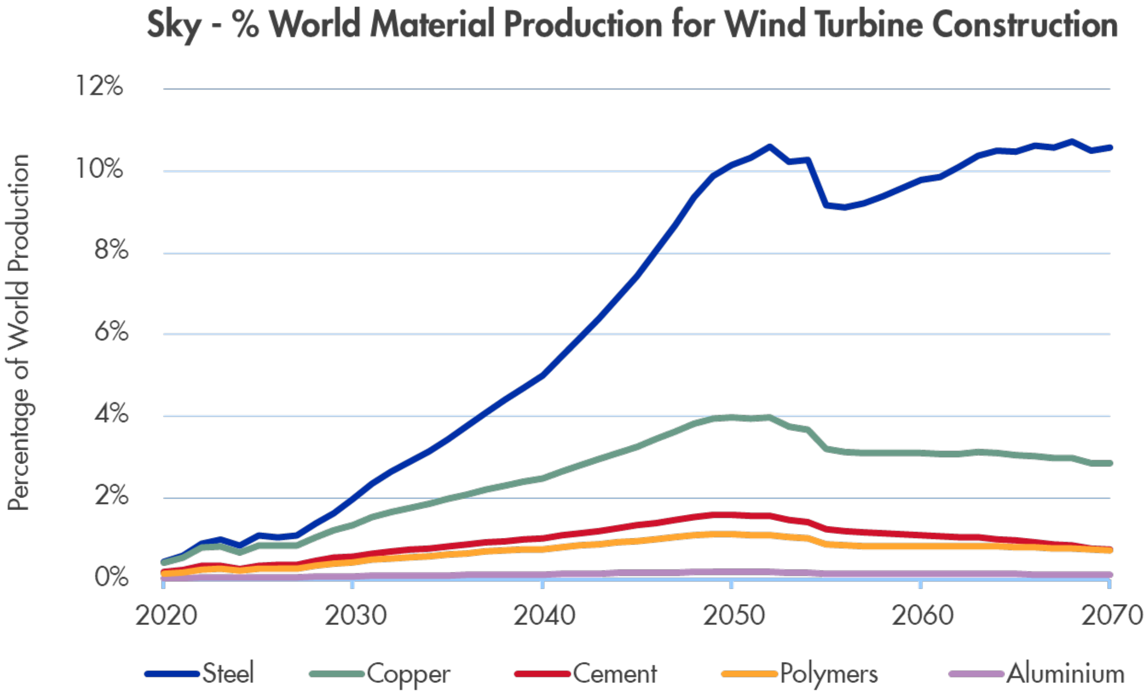
Presently, around 60 GW of new wind capacity is installed but this needs to be three times as much by 2030, and 11 times more by 2050, plateauing around 650 GW per year. Capacity additions will need to grow by some 8.5% annually to 2050s. Today, about 90% of the market for wind turbines is new builds, but by 2070 around 40% will be to replace old turbines (Graph 2).



Graph 2: World wind turbine construction requirements (Source: Shell Analysis, Sky Scenario)

[1] www.shell.com/skyscenario Scenarios are not predictions, plans, or policy proposals – they simply explore what might happen given the assumptions made in the scenario. The Sky scenario paints a technically plausible pathway for achieving the goals of the Paris Agreement.

In spite of the strong energy and material efficiency assumptions in the Sky scenario, seeing only a 10% increase in materials consumption per capita by 2070, the world will still need to produce 50% more core materials like steel, cement, copper, aluminium and polymers, than today. With the energy transition, a significant redirection of materials requirement towards Wind construction will happen with market shares for key materials doubling between now and 2025, increasing fivefold thereafter towards 2050 (Graph 3). Steel will see strongest pull with a tenfold increase for wind park construction. As offshore wind's share is projected to increase from around 10% today to 80% by 2070 in the Sky scenario, more steel will be required, especially with the share of floating wind going up. However, offshore wind will need less cement than onshore wind.

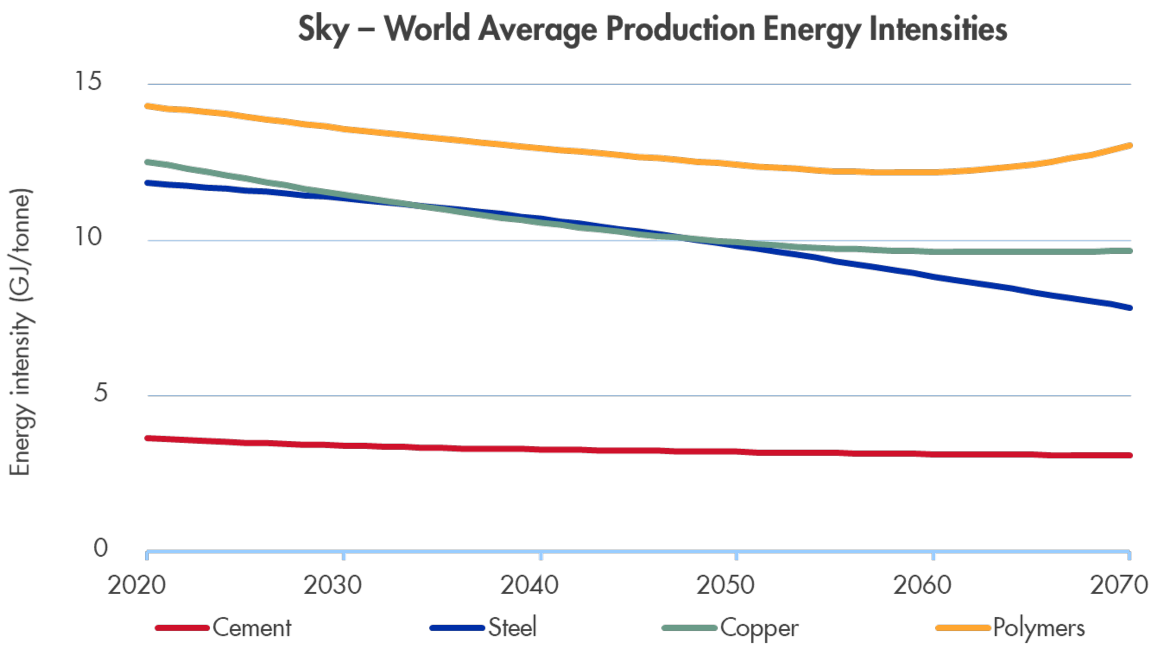


Graph 3: Materials required for wind turbine construction as percentage of global material production assuming today's technologies (Source: Shell Analysis, Sky Scenario)

How much further scope in energy and material Efficiency?

Before we can assess how much and what type of energy is required to construct wind turbines in the future, we need to have a look at the scope for energy and material efficiency. Key is recycling and the use of low or zero carbon energy. But there are practical limits in how much can be recycled because of e.g. impurities in special alloys, logistics, scale and economics. Energy and emissions reduction do not always go hand-in-hand. For instance, compared with a coal fired blast furnace, steel production using green electricity for an Electric Arc Furnace with 100% scrap feed, would theoretically use about 5.5 times less energy input per tonne of steel and emit negligible CO_2. Emissions could be mitigated via CCS or through green hydrogen direct reduction of iron method, but the hydrogen route could use 15% more energy per tonne (source-to-product). Practical limits in recycling, limit secondary production to around 35% of crude steel production, reducing the potential efficiency gain for steel production to around a factor 2. Aluminium and copper also have significant theoretical scope for efficiency improvements through recycling, but also here there are practical limits and the use of those materials in wind park construction are a few orders of magnitudes less than steel.

Other fabrication methods, like for cement, are already approaching theoretical efficiency, and emission reduction is expected to be more economic through CCS. Possible efficiency and emission improvement routes for polymers are plastics recycling and using biomass upgrading to feedstock. However, the latter process will need overall more energy input, increasing again the amount of energy required to produce a tonne of polymers (Graph 4).

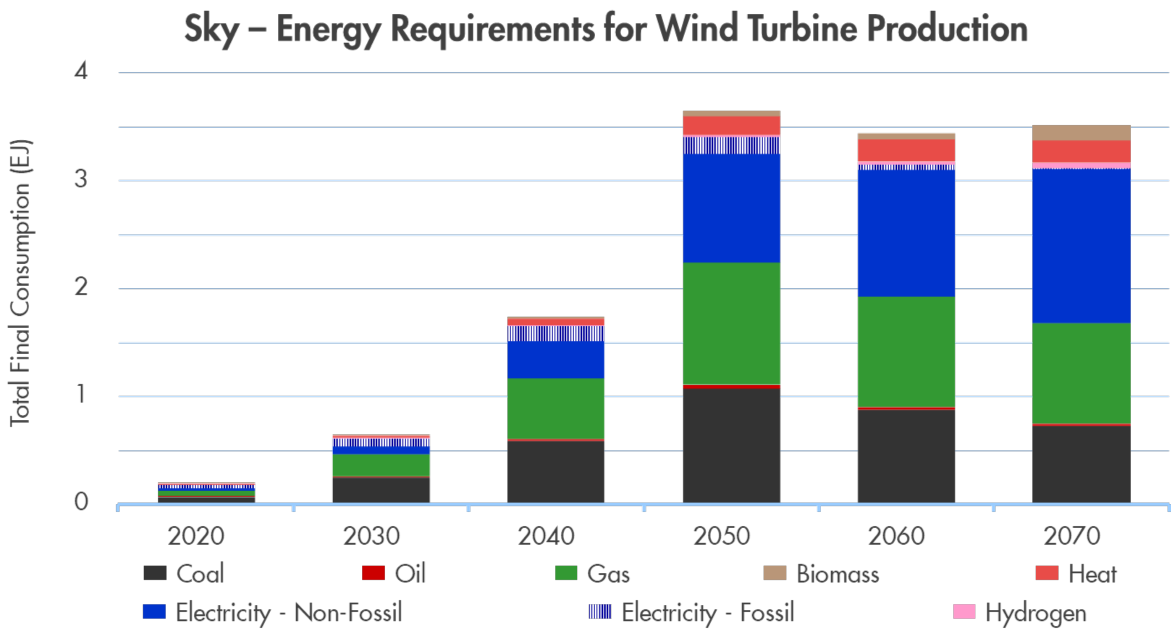


Graph 4: World average source to product energy intensities 2020 to 2070 (Source: Shell Analysis, Sky Scenario)

What type of energy is required for producing wind turbines?

It is estimated that over 80% of energy used today to construct wind turbines comes from fossil fuels, but that could be half by 2070 as new technology and more renewable electricity is used. Electricity's share of energy input is about 28% today, but that may ultimately be over 50% by the second half of the century. Today, two-thirds of electricity used comes from fossil fuel power generation. But as renewables grow, it will drop to negligible by 2070. Nevertheless, fossil fuels will remain an important contributor to build wind turbines due to limitations in efficient material production (steel, cement, non-ferrous metals, resins), but its share will dwindle to around 50% of energy input by 2070 (Graph 5).

Today, approximately 68% of related CO_2 emissions come from iron and steel, 20% from cement, 9% from plastics and 3% from non-ferrous metals. With an increasing share of (floating) offshore wind, over 90% of emissions may come from steel, 4.5% from plastics and 2.5% from cement by 2070 if unabated. Even unabated, the annual construction of around 650GW wind turbines in the second half of the century will emit about 0.6 Gt per year while the emissions avoided compared with gas fired power generation will be over 11 Gt per year. Some $650 bln pa abatement costs[2] might be avoided by wind generation compared with gas generation by 2070.



Graph 5: Energy requirements to construct wind turbines 2020 to 2070 (Source: Shell Analysis, Sky Scenario)

Concluding Remarks

Given increasing societal momentum in willing to meet the goals of the Paris Agreement, coupled with the continuing cost reduction in wind and solar, the energy transition will be unstoppable and be spearheaded in power generation. Despite policy efforts to increase economic, material and energy efficiency, the demand for materials will grow as economy and population grows. Due to practical limits in energy service efficiency, hydrocarbons will continue to be needed over the coming decades in the production processes of building out renewables. Sectors like steel, cement and chemicals are likely to continue using coal and gas as fuel or feedstock as the most economical option, while abatement options like CCS are deployed.

The case study on wind power in this paper illustrates that although 80% fossil fuels are required in building out wind power today, with the increase in renewables and different production processes, that share of fossil input is expected to come down to 40% by 2070. Even if unabated,

2 Based on ~$85/tonne CCS costs by 2070

emissions avoided are multiple orders of magnitudes greater over the lifetime of a wind turbine. The avoided abatement costs make wind (and solar) a preferred cost effective solution.

However, the shift to low/no CO_2 emitting energies alone will not be sufficient to meet the goals of the Paris Agreement, and in addition large-scale carbon capture and storage of remaining fossil, but foremost bio-energy, hydrocarbons (BECCS) will be essential.

Writer's Profile

W.L. Thomas

Mr. Thomas was part of Shell's Scenarios Team, which is part of the Group Corporate Strategy Department. He lead a team responsible for worldwide energy analysis and long-term global energy scenarios, and advised Shell's Executive Committee and the Board and its businesses on a wide range of energy issues, including oil & gas markets and pricing, global supply & demand for all energies, regulations, energy policy and industry structure. He has been with the Shell group of companies for over 35 years, with prior international positions in drilling operations, subsurface reservoir management, upstream commercial and regulatory affairs in gas. Presently, he is a non-executive director at MARIN, a world leading maritime research institute in the Netherlands, and on the Advisory Board of the Buccaneer, an accelerator for innovation on sustainable energy in the maritime sector. He is a Fellow of the Energy Institute of the UK and Distinguished Fellow of the IEEJ. He is a former Chairman of The UK National Committee of the World Petroleum Council and of the British Institute of Energy Economics. Wim holds a postgraduate degree in Maritime Technology, Delft University, The Netherlands.