**Carbon Intensity**

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Carbon intensity is key performance indicator that is frequently used to compare the amount of CO2 emitted due to a given activity and provides a basis for comparison between alternatives. It is typically expressed with respect to grams of CO2 emitted per kWh of electricity produced or consumed, per unit of heat (MJ) created, per km travelled, or economic value ($GDP) realised.

Three common expressions of carbon intensity are discussed.

**Carbon Intensity of Oil and Gas Production**

Carbon Intensity associated with the upstream production of oil and gas is defined as the amount of carbon dioxide (grams if CO2) emitted with respect to the energy of the hydrocarbons produced (MJ). It thus refers only to those emission arising from upstream production operations only (Scope 1 and 2 emissions) and does not include those emissions that arise from the combustion of the products themselves (Scope 3 emissions) (Ranganathan et al., 2004).

(Masnadi et al., 2018) provides a useful comparative study of the carbon intensities of upstream oil production across the world (Figure 1). The analysis shows the large differences between high carbon intensity crudes, typified by increased complexity, heavy oil production, use of extensive flaring and venting and those with the lower carbon intensities with lighter crude types and tighter environmental regulations. The authors highlight the significant carbon dioxide emission savings possible from technology innovation such as remote sensing, use of low carbon energy sources such as solar powered steam generators as well as initiatives such as the World Bank's Global Gas Flaring Reduction Partnership.

Such activities will be essential to minimise future emissions and for the industry to retain its social licence to operate during the energy transition.

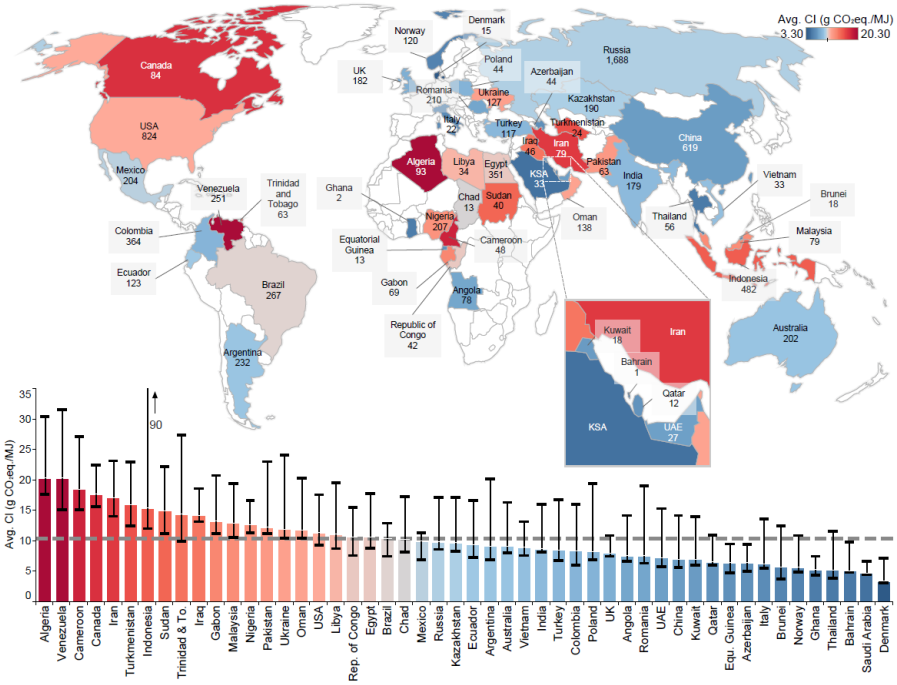



*Figure 1: Upstream Crude Oil Carbon Intensity*

(Masnadi et al., 2018)

**Power Generation**

Carbon Intensity for power generation is commonly defined as the amount of carbon dioxide (grams of CO2) emitted with respect to the energy created (expressed in Kilowatt-hours) and is used to compare the CO2 emissions from alternative power generation sources.

The calculation can be completed either on a life cycle basis, which considers of the operational and embodied carbon dioxide emitted from a power source arising from its construction, operation and decommission or by considering the CO2 arising from operational activities only.

The life cycle basis is more difficult to calculate but is useful for comparing the CO2 emissions arising from fossil fuel and renewable sources and aids future investment decision making while the operational carbon dioxide intensity is more appropriate for day-to-day optimisation and forecasting.

(Edenhofer et al., 2012) presents a useful plot (Figure 2~~Figure 2~~) of the life cycle of carbon intensity in g CO2 per kWh from a range of different electrical generation technologies.

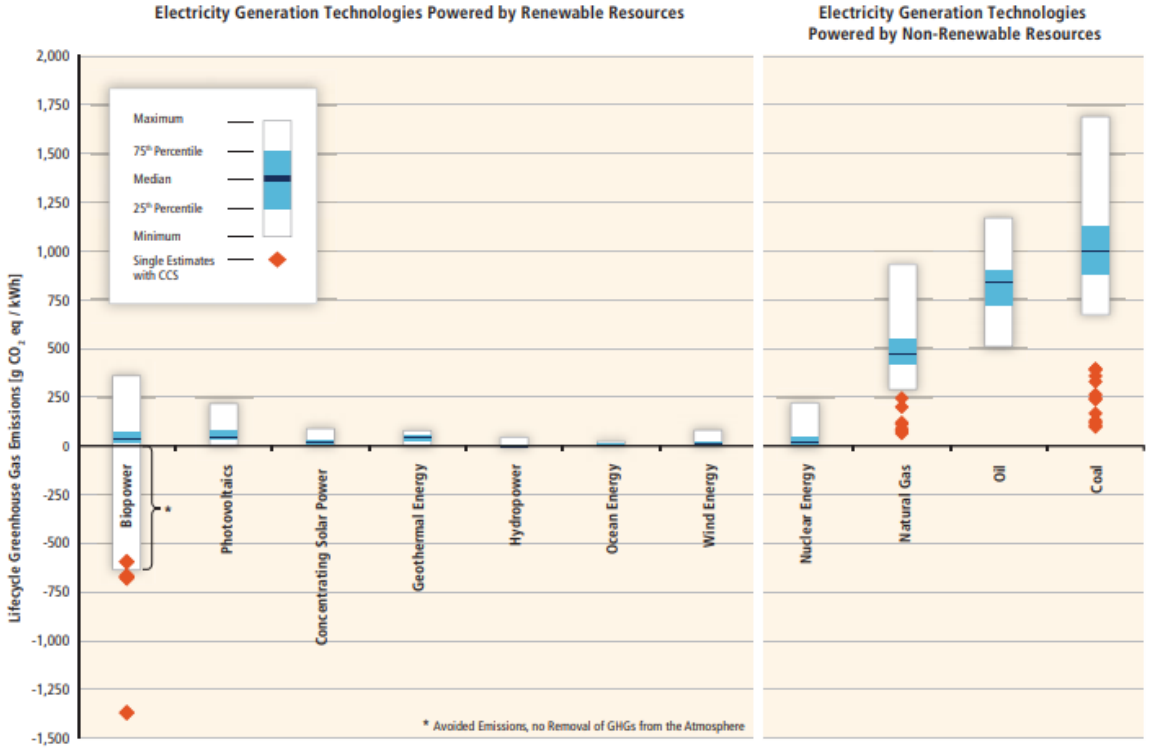
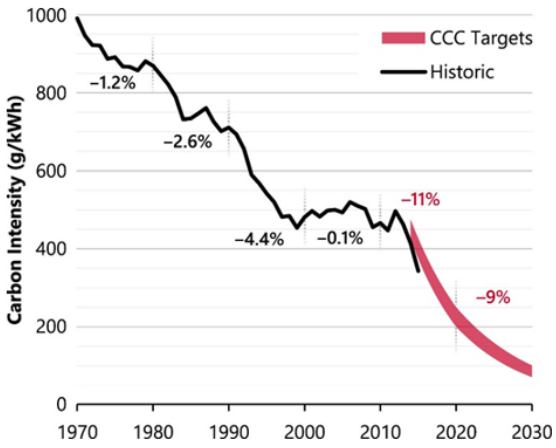



*Figure 2: Estimates of lifecycle g CO2 eq./ kWh* (Edenhofer et al., 2012)

Renewable sources of electricity generation have small but nonzero carbon intensities arising from the emission associated with their construction. Fossil fuel-based electricity generation sources have orders of magnitude higher carbon intensities that can be offset using Carbon Capture Usage and Storage technologies.

Operational CO2 intensity is frequently used to demonstrate the improving CO2 intensity of the UK electricity generation arising from the withdrawal of coal fired power stations and increase in the use of renewables in the UK's electrical system. Figure 3 presents the historic and forecast fall in carbon intensity for power generation.



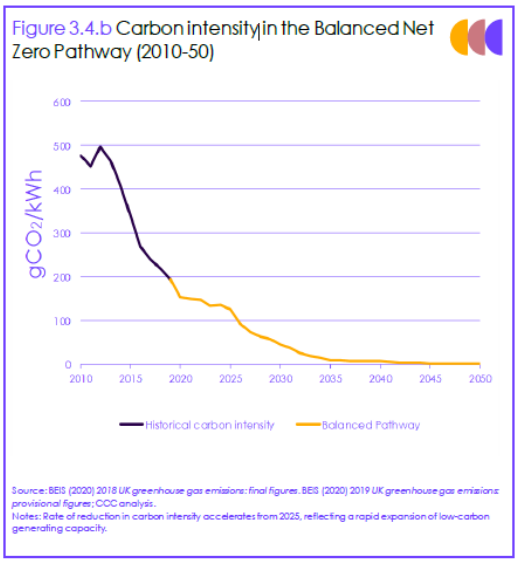




*Figure 3: Historic and Forecast Carbon Intensity (Balanced Net Zero Pathway – 6th Carbon Budget Report)*

(Staffell, 2017),(Committee on Climate Change, 2020)

The significant reduction in Carbon Intensity observed from 1970 to 1980s were a result in the rise in the proportion of nuclear and in the 1990's by the "dash for gas". The recent reductions are due to the rise in renewables.

The 6th Carbon Budget Report shows how this decarbonisation journey is forecast to continue in the 2020s and 2030s with the continued rollout of low-cost renewables and the development of Carbon Capture and Storage as well as increased demand side flexibility that will allow near zero CO2 intensity to be achieved by 2035.

**Economic Efficiency**

Carbon Intensity is also used as a measure of the carbon efficiency of an economy when expressed as grams per CO2 per $ GDP. The relationship between economic growth and rising energy use has long been established and remains a strong effect (Figure 4).

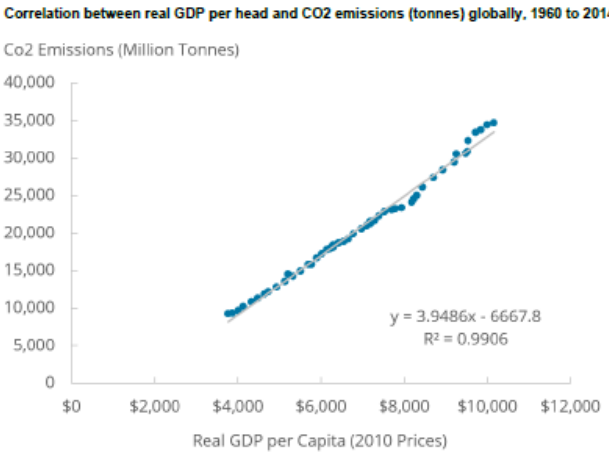



*Figure 4: World GDP per head and CO2 Emissions*

*(Office of National Statistics, 2019)*

The decoupling of carbon emissions from economic growth is therefore an essential requirement to achieve net zero if we are to maintain economic growth along with declining CO2 emissions and some economies across the world have been showing declining carbon intensity with respect to GDP.

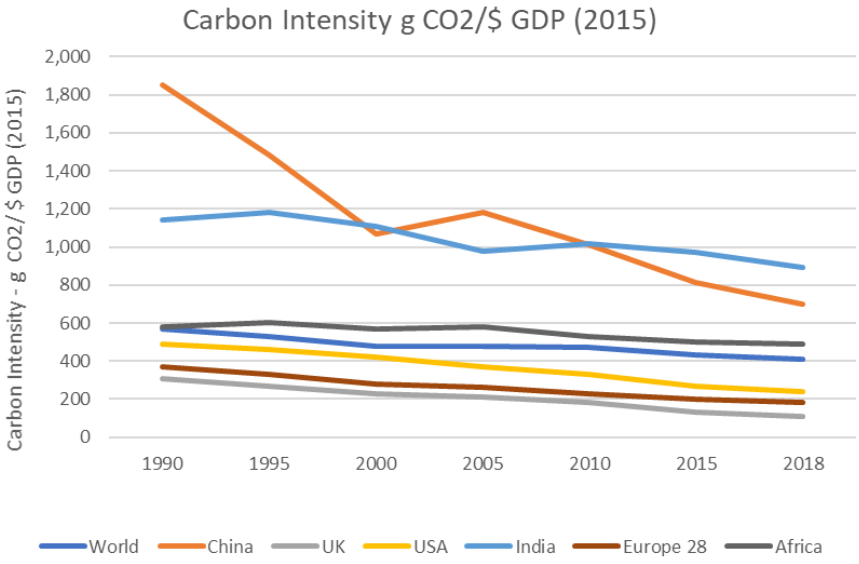



*Figure 5: Selected Country Carbon Intensities, g CO2/ $GDP (2015)*

*(International Energy Agency, 2021)*

Significant reductions in carbon intensity have been observed from China but these are still high when compared to Europe and the USA.

Within the UK, the decline in CO2 emissions has been driven predominately by the improvement in carbon intensity from power generation but also through improvements in energy efficiency achieved in transport and manufacturing. There have also been more structural changes that have seen a relative decline in the UK's manufacturing sector and a rise in the less carbon intensive service sectors (Syed, 2019).

However, this is only part of the story, the UK's 2008 Climate Change Act only requires that the UK's territorial CO2 emissions be reduced, and this does not include those emissions that are arise from outsourced manufacturing activities that provide goods and services that are consumed in the UK.

Once these consumption emissions are included, the total UK CO2 emissions showed an increasing trend from the 1980's and have declined only from 2007 (Figure 6).

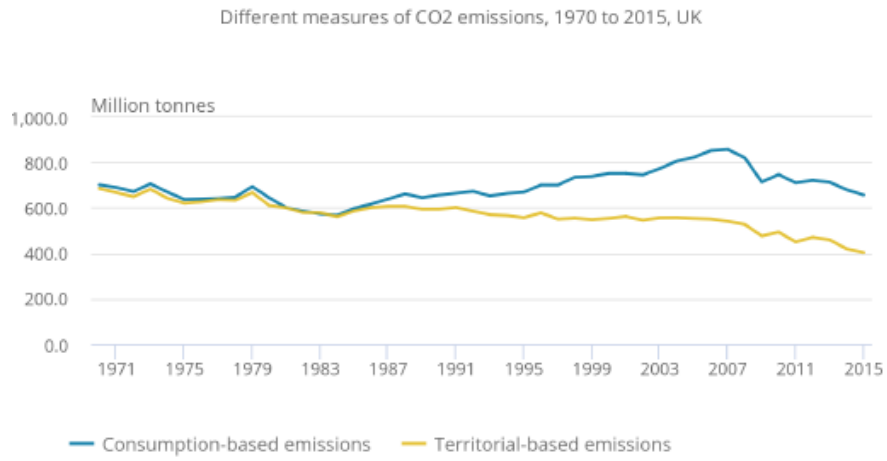



*Figure 6:UK's Territorial and Consumption based emissions history* (Syed, 2019).

Consideration of these consumption emissions is one of the key messages of the 6th Carbon Budget which recommended that the UK should also "involve actions to track and reduce its overseas footprint" (Committee on Climate Change, 2020).

Clearly there is still much to be done to tackle high carbon intensities, by industry and society, both in the UK and Abroad. For the oil and gas industry, activities to reduce scope 1 and 2 emissions are an essential first step to enable retention of its licence to operate, for society, recognition that emissions occur not only territorially from energy generation sources but are also a consequence of our consumption patterns and reducing these emissions may be the hardest of all.

# Bibliography

International Energy Agency. (2021, 3 10). *Data and Statistics*. Retrieved from www.iea.org: https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics

Office of National Statistics. (2019). *The decoupling of economic growth from carbon emissions: UK evidence.* Office of National Statistics.

Committee on Climate Change. (2020). *The Sixth Carbon Budget*. www.theccc.org.uk/publications

Edenhofer, Ottmar., Pichs Madruga, R., Sokona, Y., United Nations Environment Programme., World Meteorological Organization., Intergovernmental Panel on Climate Change. Working Group III., & Potsdam-Institut für Klimafolgenforschung. (2012). *Renewable energy sources and climate change mitigation : special report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Masnadi, M. S., El-Houjeiri, H. M., Schunack, D., Li, Y., Englander, J. G., Badahdah, A., Monfort, J. C., Anderson, J. E., Wallington, T. J., Bergerson, J. A., Gordon, D., Koomey, J., Przesmitzki, S., Azevedo, I. L., Bi, X. T., Duffy, J. E., Heath, G. A., Keoleian, G. A., McGlade, C., … Brandt, A. R. (2018). Global carbon intensity of crude oil production. *Science*, *361*(6405), 851–853. https://doi.org/10.1126/science.aar6859

Ranganathan, J., Corbier, L., Schmitz, S., Oren, K., Dawson, B., Spannagle, M., Bp, M. M., Boileau, P., Canada, E., Frederick, R., Vanderborght, B., Thomson, H. F., Kitamura, K., Woo, C. M., Naseem, &, Kpmg, P., Miner, R., Pricewaterhousecoopers, L. S., Koch, J., … Camobreco, V. (2004). *GHG Protocol Initiative Team World Business Council for Sustainable Development Pankaj Bhatia World Resources Institute World Business Council for Sustainable Development Peter Gage World Resources Institute Revision Working Group Core Advisors*. https://ghgprotocol.org/corporate-standard

Staffell, I. (2017). Measuring the progress and impacts of decarbonising British electricity. *Energy Policy*, *102*, 463–475. https://doi.org/10.1016/j.enpol.2016.12.037

Syed, A. (2019). *The decoupling of economic growth from carbon emissions: UK evidence*. https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/compendium/economicreview/october2019/thedecouplingofeconomicgrowthfromcarbonemissionsukevidence