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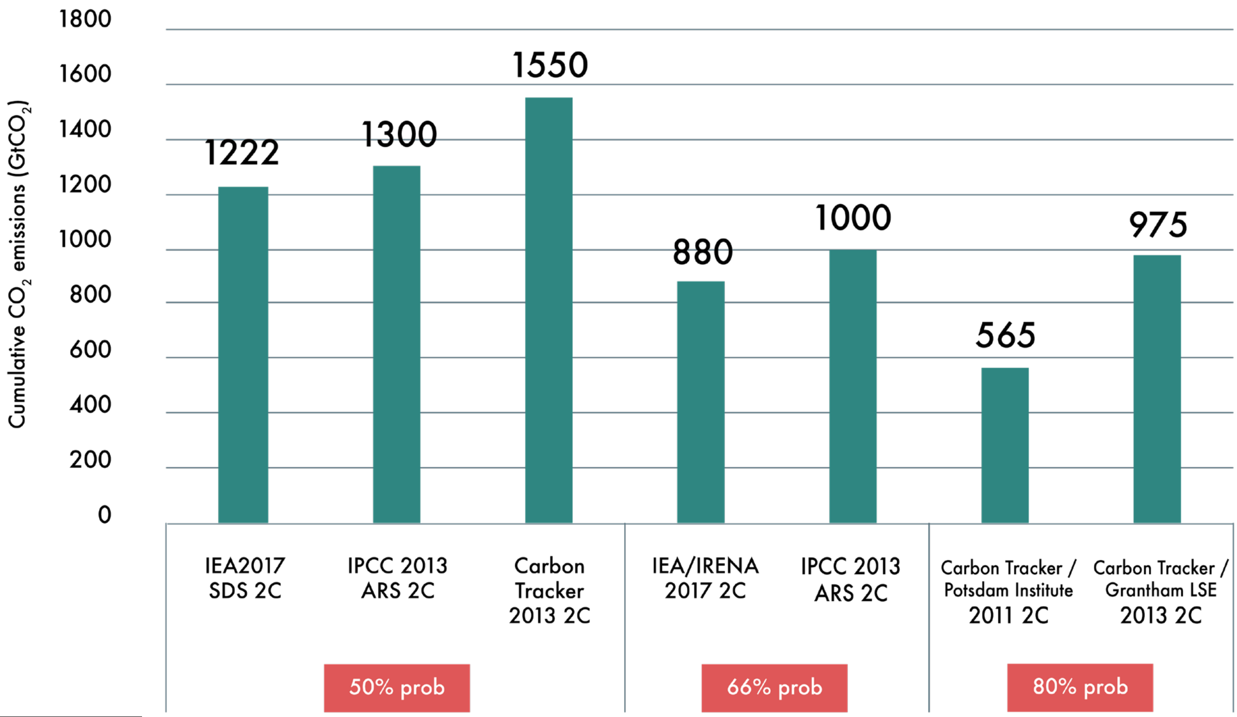
CARBON BUDGETS EXPLAINER

As low-carbon policies and technologies continue to advance, companies, investors and policymakers are increasingly turning to carbon budgets as a core component for analysing the potential implications of a carbon constrained future. Carbon Tracker has been a significant force in mainstreaming the concept of a carbon budget, applying the science developed by the world's leading academics and climate experts. Consequently, this document outlines the variables that must be ascertained before calculating the size of a carbon budget and what that budget might mean for the fossil fuel sector.

What lies beneath: Comparing 2°C budgets

A carbon budget is the cumulative amount of carbon dioxide (CO_2) emissions permitted over a period of time to keep within a certain temperature threshold. Figure 1 shows a range of carbon budgets as published by different institutions in the energy and climate change sector that it is projected will keep average increases in global temperature to within 2°C. As it is, these 2°C budgets are not immediately comparable, however. There are a host of variables that must be checked and amended before comparing 2°C carbon budgets across institutions, which are outlined in this brief.

Figure 1: A number of differences lie beneath 2°C budgets published by different institutions[1i]



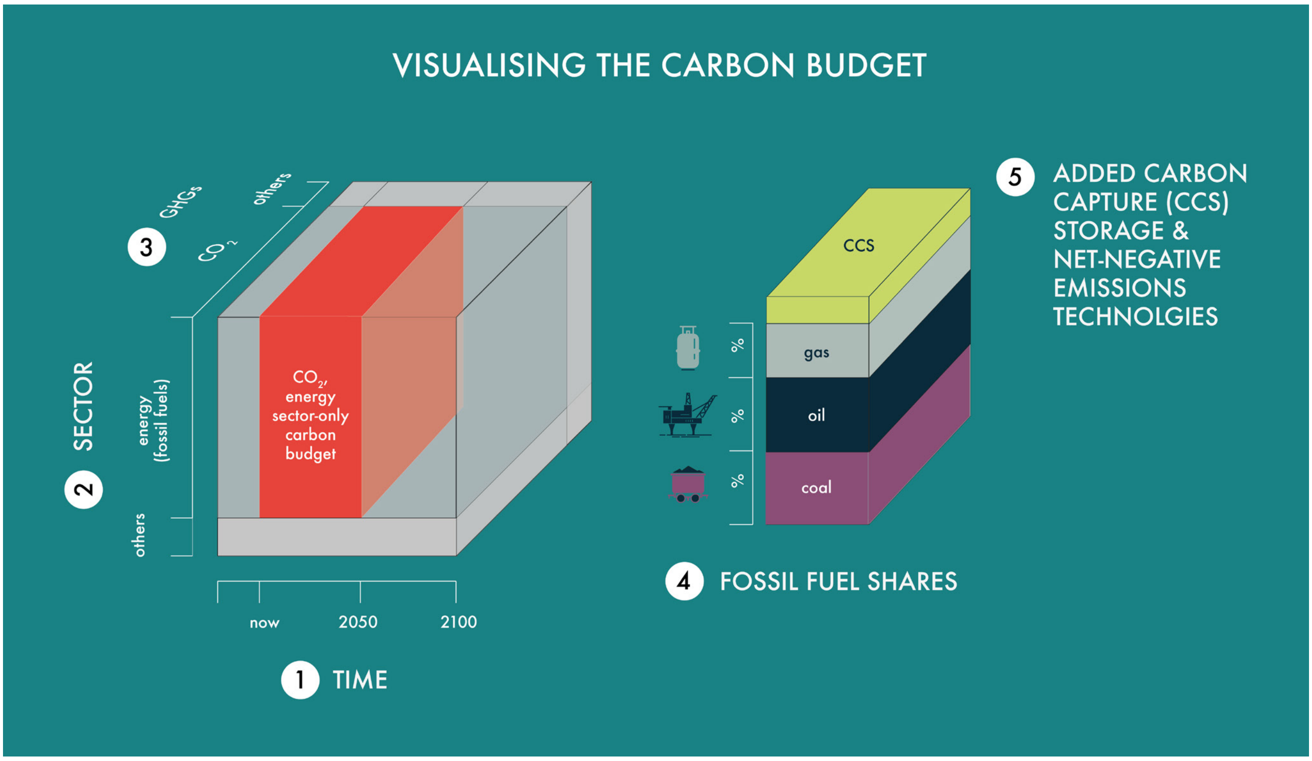
1 *The SDS carbon budget is a Carbon Tracker estimate based on Figure 3.12 on the 2017 WEO.*

There are a number of core assumptions associated with modelling climate outcomes which are fundamental to determining the outputs. In other words, the underlying climate models will have characteristics or variables which will set the overall size of the carbon budget. These include:

- The likelihood of the temperature outcome. The Intergovernmental Panel on Climate Change (IPCC) default is "likely" defined as greater than 66%[ii], but others such as the International Energy Agency (IEA) typically apply 50% probability when discussing scenarios[iii].
- Climate sensitivity. Science is constantly evolving and our understanding of the precise responses of the earth's climate system is being improved. The level of climate sensitivity – the change in global mean near-surface air temperature that would result from a doubling of the atmospheric CO_2 concentration - assumed in climate models has been refined over time which has updated the carbon budgets we have used. (The IPCC Fifth Annual Report (AR5) broadened the range of likely climate sensitivity to between 1.5°C to 4.5°C[iv], however recent studies have suggested the range could be far narrower[v]).

Visualising the carbon budget

This diagram depicts how the variables discussed below can trim portions of the overall emissions budget to arrive at a specific carbon budget for fossil fuels under a specific scenario:



Watch the video animation 'Visualising the carbon budget' on www.carbontracker.org

Variable 1. Time frames

Firstly, it is important to determine an overall starting point for the carbon budget. The Paris Agreement's central aim is to keep global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to keep within 1.5°C of warming.[vi] Specifying the level of 'pre-industrial emissions' aims to provide a baseline from which anthropogenic activity began influencing greenhouse gas (GHG) concentrations in the atmosphere. How the 'pre-industrial level' is interpreted, however, can vary. To date, 1850-1900 has been the preferred baseline by institutions including the IPCC. However, some studies have suggested a 1720-1800 baseline would be more appropriate because GHG concentrations have been increasing since industrialisation began around 1750.[vii] Others argue that baselines should be taken from natural climate model simulations, i.e. those that exclude anthropogenic forcings.[viii]

The selection of pre-industrial baseline is important because it can impact the size of the remaining budget for each temperature threshold and, therefore, the likelihood of breaking through that budget.[ix] This is particularly important for 1.5°C budgets which are more constrained than for higher temperature goals.

It goes without saying that attempting to distinguish anthropogenic from natural forcings hundreds of years ago is a complex science. The IPCC is said to be working on a recommended definition as part of its work on 1.5°C pathways due to be released in 2018. Until that point, those attempting to set and calculate decarbonisation targets in line with the Paris Agreement must choose one pre-industrial level and work from there. This uncertainty is no cause for a lack of action, but simply one in a range of variables that must be selected, as highlighted in this piece.

Next, one has to allow for the period that has already passed from the pre-anthropogenic emissions baseline to the start of the period being debated. Usually this will be 1-2 years prior to the publication date incorporating the most recent annual emissions data available. For example, the IEA and IPCC have different start years. The IPCC's most recent carbon budgets were published in its AR5 back in 2013, so have a start year of 2011. Whereas the IEA publishes annual budgets and so have a start year of 2015/2016 in its most recent documents. Given the annual emissions from all anthropogenic sources are approaching 40GtCO_2, this means that the 4 years gap has a significant impact of reducing any forward-looking carbon budget by 160GtCO_2.

Finally, a cut-off point in terms of the time period is needed as well. It is worth noting that shorter scenarios running to 2035 or 2050 may be developed using climate models which model warming impact to the end of the century in 2100, (to reflect the persistent nature of CO_2 in the atmosphere). This means that a carbon budget for the next couple of decades may have inbuilt assumptions around longer term efforts to mitigate emissions, including deployment of technologies such as Carbon Capture and Storage (CCS).

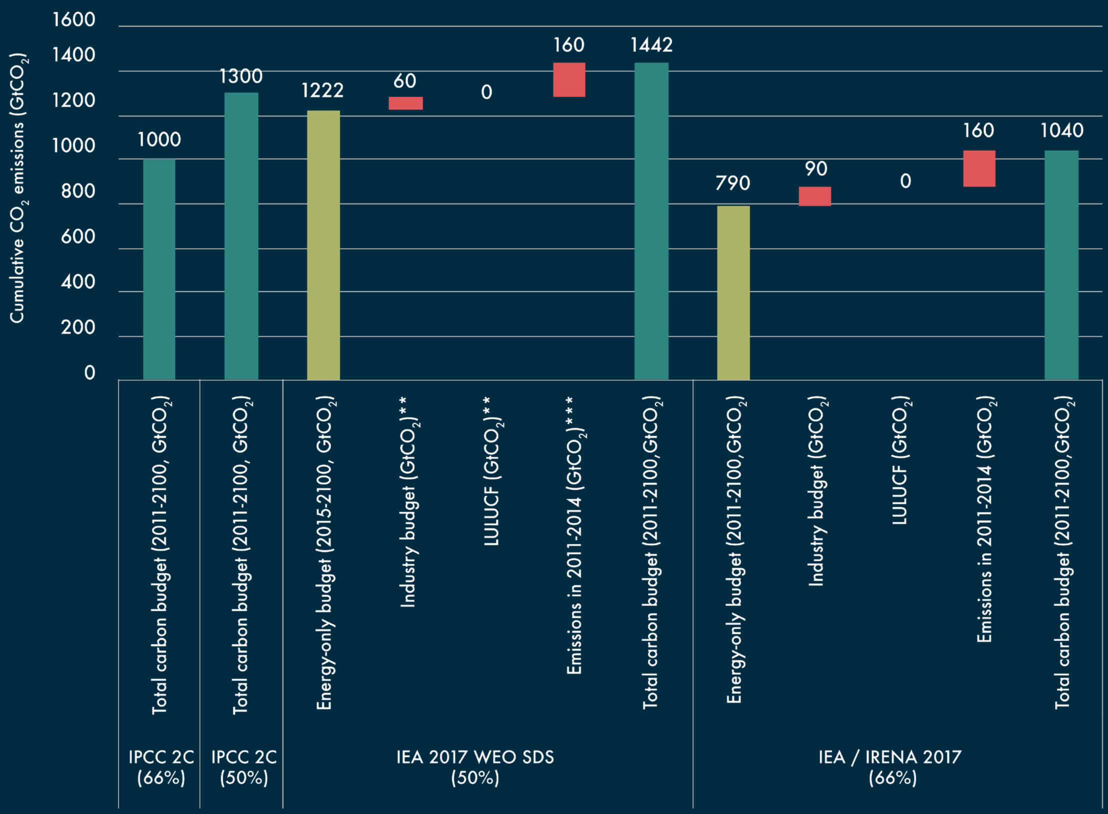
Variable 2. 'Energy only' or 'total' carbon budget?

The carbon budgets published by the IEA and the IPCC are not immediately comparable. The IEA refers to carbon budgets for the energy sector only, which is the largest single source of anthropogenic CO_2 emissions through the burning of coal, oil and gas. In contrast, the IPCC's budgets are for all anthropogenic sources of CO_2. This means the IPCC includes CO_2 budgets for heavy industries and land use, land use change and forestry (LULUCF), which are excluded from the IEA budgets. The IEA make estimates for CO_2 emissions for these sectors however, which can then be deducted from IPCC budgets to make them comparable – refer to Figure 2 below.

Example: Comparing IEA and IPCC 2°C carbon budgets

Figure 2 adjusts the IEA's 2017 2°C Sustainable Development Scenario (SDS) and the higher probability (66%) 2°C scenario published jointly with IRENA for variables 1 and 2 to give an idea of how the two compare to the IPCC's budgets when they are converted into total carbon budgets. The chart shows that the IEA's SDS allocates less of a CO_2 budget to heavy industries than the IRENA 2°C scenario, while both see LULUCF having a net-zero impact on cumulative CO_2 emissions over the time period. According to the assumptions made in the chart, both IEA scenarios equate to a slightly larger carbon budget than the IPCC estimate with the equivalent likelihood/probability attributed to it.

Figure 2: Comparing IEA and IPCC 2°C carbon budgets[2]



2 *Based on Carbon Tracker estimates of IEA and IPCC publications.*

Variable 3. Non-CO_2 greenhouse gases (GHGs) mitigation

CO_2 is the largest contributor to climate change, but a number of other GHGs are also significant, e.g. methane, nitrous oxides and F-gases. With every carbon budget calculated, one must also assume a level of warming deriving from these non-CO_2 GHGs. If one assumes a higher level of success in mitigating non-CO_2 GHGs, then this leaves space for a higher carbon budget, and vice versa.

This is evidenced in the IPCCs carbon budgets in the table in Table 1. Single figure carbon budgets from the IPCC's Representative Concentration Pathway (RCP) scenarios are more frequently used than the ranges resulting from the 'Simple model, WGIII scenarios'. In these runs, however, the difference between the high- and low-end carbon budgets is largely due to varying assumptions about mitigation of non-CO_2 forcing on climate change. For carbon budgets delivering a 66% chance of keeping to 2°C, for example, this results in a large range from 750-1400GtCO_2. For another example, one could look to the high profile paper by Prof. Richard Miller and his paper on 1.5C pathways. This paper was widely covered in the global media because it estimated a 1.5C carbon budget that was far larger than previous estimates.[x] One important reason for this was that the authors applied a scenario in which non-CO_2 GHGs were mitigated very strongly.[xi]

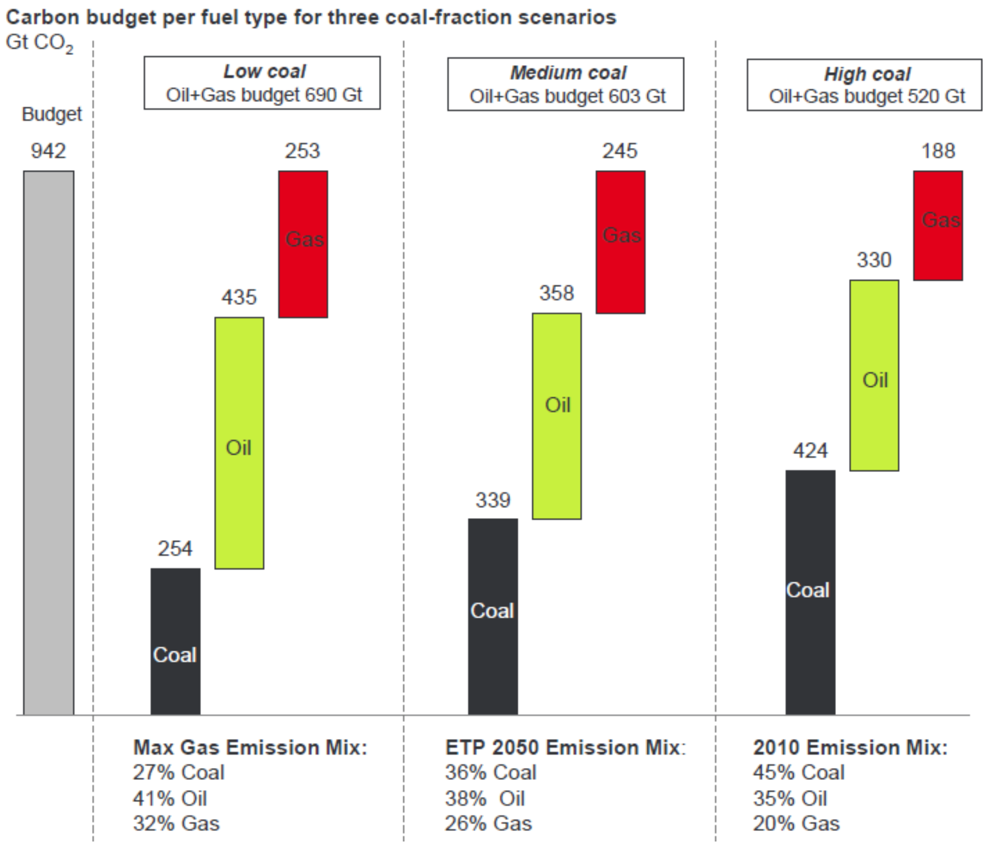
Cumulative CO_2 emissions from 1870 in GtCO_2									
Net anthropogenic warming [a]	<1.5°C			<2°C			<3°C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000
Cumulative CO_2 emissions from 2011 in GtCO_2									
Complex models, RCP scenarios only [c]	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios [d]	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. [e]	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 [f]: 3670 to 7100 GtCO_2 (reserves) and 31300 to 50050 GtCO_2 (resources)									

Table 1: IPCC (2013) AR5 carbon budget estimates

Variable 4. The split of coal vs oil vs gas

Once the absolute level of the 2°C carbon budget has been calculated, one can vary what this might mean for each of the fossil fuels depending on one's view of their relative future prospects. For example, a few years ago Rystad Energy did a study for the Norwegian Government that tested scenarios allocating Low, Medium and High budgets to coal and adjusted oil and gas accordingly – refer Figure 3.[xii] This approach resulted in coal being allocated anything between 27% and 45% of the 2°C carbon budget. For reference, the IEA's 2017 Sustainable Development Scenario (SDS) sees coal, oil and gas allocated 36%, 37% and 28% of the 2°C emissions budget to 2040.

Figure 3: Exploring how Low, Medium and High carbon budgets for coal affect allocations for oil and gas (Rystad 2013)



Variable 5. Carbon capture and storage (CCS) and net-negative emissions technologies

In addition to acquiring a larger hypothetical share of the 2°C carbon budget at the expense of the other fossil fuels (Variable 4), the lifespan of coal, oil and gas could be extended by CCS and net-negative emissions technologies. Most energy modelling to date certainly has optimistic allocations of both technologies.

CCS is more suitable to large point sources, hence it has no direct application to transport with its many mobile emitters. Instead, the primary link to oil to date has been using the injection of CO_2 for Enhanced Oil Recovery (EOR). This raises a question about the net-carbon impact of CCS for this application as it is results in the increased extraction of hydrocarbons. Bioenergy is another option for applying CCS, which is being developed not just to reduce emissions but to try and deliver negative emissions at scale. Being an end of pipe solution means that CCS always increases the costs of existing technologies.

In the IEA's 2017 SDS, 210GW of coal fired power plants (of 1150GW) and 165GW (7%) of gas fired power plants are fitted with CCS by 2040. Furthermore, over 10% of industry capacity is also assumed to be fitted with CCS. An ambitious roll-out of CCS is not uncommon, particularly for more carbon constrained scenarios. For example, the Energy Transitions Commission, a body led by Shell and other energy companies, assume 7-8GtCO_2 are captured by 2040.[xiii] To put this figure into context, 21 CCS projects will capture 37mtCO_2 in 2018.[xiv]

Carbon Tracker's modelling has shown that CCS is likely to be prohibitively expensive to significantly extend the demand profiles for coal, oil and gas, particularly in the power sector where increasingly cheap alternatives are available.[xv] It is Carbon Tracker's contention that while any upside delivery of CCS would be a benefit to mitigating CO_2 emissions, relying on the nearterm growth of what remains a speculative technology is highly risky. Net-negative emissions technologies, which feature quite heavily in the IPCC's modelling[xvi], are not expected to feature until the second half of the 21st century, by which point the political and economic landscape may mean these technologies are feasible.

The 1.5°C target

Following the ambition of the COP21 Paris Agreement there is ongoing work to understand the implications and feasibility of limiting anthropogenic warming to 1.5°C. Recent academic studies estimate the 1.5°C carbon budget is likely to be 200-415GtCO_2 from 2011 to 2100 for different likelihoods.[xvii] The IPCC AR5 estimates for the same time period are slightly higher – from 400-550GtCO_2. In both instances, however, removing the CO_2 emissions from the fossil fuel sector from 2011 to date leaves very little budget left for the sector to the end of the century.

The IPCC will publish a report in 2018 on 1.5°C emissions pathways. An early version of this document was leaked to the media in January. This working document confirmed that there is a 'high risk' temperatures are not kept to 1.5°C of warming, and that 'with a 66% probability, it [the 1.5°C target] lies beyond our capabilities'.[xviii] Having any chance of hitting the 1.5°C target requires drastic, immediate cuts in fossil fuel use, as indicated by the work of initiatives like Mission 2020.

References

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[ii] *https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html*

[iii] *IEA World Energy Outlook reports.*

[iv] *https://www.scientificamerican.com/article/ipcc-revises-climate-sensitivity/*

[v] *https://www.washingtonpost.com/news/energy-environment/wp/2018/01/17/climate-scientists-say-they-may-be-able-to-rule-out-the-worst-case-scenarios-and-the-best-ones/?utm_term=.dc1680900301*

[vi] *http://unfccc.int/paris_agreement/items/9485.php*

[vii] *http://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0007.1*

[viiii] *https://andrewdking.weebly.com/blog-posts/what-baseline-should-we-use-in-our-paris-target-global-warming-analyses*

[ix] *https://www.nature.com/articles/nclimate3345*

[x] *https://www.nature.com/articles/ngeo3031*

[xi] *http://www.cicero.uio.no/no/posts/nyheter/commentary-did-15c-suddenly-get-easier*

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[xiii] *http://energy-transitions.org/sites/default/files/BetterEnergy_fullReport_DIGITAL.PDF*

[xiv] *http://www.globalccsinstitute.com/status*

[xv] *https://www.carbontracker.org/reports/expect-the-unexpected-the-disruptive-power-of-low-carbon-technology/*

[xvi] *https://www.carbonbrief.org/two-degree-climate-target-not-possible-without-negative-emissions-scientists-warn*

[xvii] *https://www.nature.com/articles/nclimate2572*

[xviii] *http://www.dw.com/en/opinion-goodbye-to-an-unrealistic-climate-goal/a-42158075*

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About Carbon Tracker
Carbon Tracker is an independent financial think tank that carries out in-depth analysis on the impact of the energy transition on capital markets and the potential investment in high-cost, carbon-intensive fossil fuels.

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