CARBON TRACKER METHODOLOGIES

Electric Utilities

About Carbon Tracker

The Carbon Tracker Initiative is a team of financial specialists making climate risk real in today's capital markets. Our research to date on unburnable carbon and stranded assets has started a new debate on how to align the financial system in the transition to a low carbon economy.

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Carbon Tracker Methodologies

Overview of methodologies and metrics for the alignment assessments which complement Indicator 6 of the Disclosure Framework within the Climate Action 100+ Net Zero Company Benchmark.

As a research partner to Climate Action 100+ (CA100+), Carbon Tracker Initiative conducts financial analysis and has developed a set of alignment assessments to help investors identify, quantify, and assess stranded asset risks for 69 focus companies, covering:

- 36 upstream oil & gas exploration and production companies' investment plans, and
- 33 electric utilities' announced retirement schedules of coal & gas fired electricity generation to assess their alignment with the goals of the Paris Climate Agreement.

Full details of Carbon Tracker Initiative's research and methodologies and full company-level engagement profiles are available on and please direct questions and enquiries to ca100@carbontracker.org.

Table of Contents

1 Carbon Tracker – Research and Analysis

We carry out scenario analysis to examine and understand how potential changes to supply and demand will impact the future of fossil fuel-exposed companies and projects. This analysis helps the investment community better understand the financial implications of tackling climate change.

1. Our analytical research identifies the highest cost, riskiest investments enabling greater scrutiny by analysts, asset owners, investors, policy makers and financial regulators.
2. Our regulatory research builds the case for reform of the financial regulatory system to improve transparency of climate-related financial risks and articulates the key changes to be made.
3. We provide expert insight for those engaging with energy companies around future strategy and capital expenditures.

Our research is grounded in conventional financial analysis and focuses on forward-looking material issues. As a not-for-profit research house, we are free from the constraints that would be imposed by a commercial financial research business model. This allows us to challenge business-as-usual approaches that we consider to be unsustainable in the face of the unprecedented challenge posed by climate change.

2 The need to reduce emissions

Emissions of greenhouse gases will need to fall significantly if the world is to avoid catastrophic levels of global warming. Such constraints will have profound effects on the supply of and demand for fossil fuels, which account for the largest human source of greenhouse emissions.

For *existing assets*, our research can highlight those assets which are most at risk of becoming stranded through the energy transition, as society looks to restrict global warming to well below 2°C and strives to limit the warming to 1.5°C, as per the goals of the Paris Agreement. There are already examples of coal mines, coal and gas power plants, and other hydrocarbon reserves which have become stranded by the low-carbon transition.

For *potential new investments*, our research aims to prevent stranded assets arising by identifying capital investments which may not yield the expected returns as the world decarbonizes. Our focus is therefore on advancing the energy transition through the stewardship of capital, with the intention of preventing it being wasted.

Our research publications are freely available on our website www.carbontracker.org as well as on research platforms such as Bloomberg, FactSet, Refinitiv and S&P Capital IQ.

3 Carbon Tracker's least-cost framework

Carbon Tracker's lens is that of the market – assessing which potential fossil fuel developments do not make economic sense and might destroy value in the energy transition, at the same time as taking the planet into a progressively more dangerous climate.

Underlying this analysis is the logic that in a world of limited demand, the lowest cost supply options will be most competitive and the higher cost options may fail to deliver economic returns – in other words, becoming economically "stranded".

By using classic supply and demand curves, we can illustrate what proportion of potential capex is on low-cost projects that would still be needed in a low carbon world, and what proportion is on high-cost projects that would not. Investment in the latter runs a greater risk of destroying value.

Retirement of coal and gas-powered electricity power generation. In a series of reports since 2017[1], Carbon Tracker has explored the financial implications for the power and utility sector of the shift to a lower carbon economy in line with international carbon commitments. We have examined the risks to fossil fuel fired powered generation by assessing the volume and pace of retirements of unabated[2] coal and gas-fired electricity generation capacities that Paris Agreement aligned climate scenarios make clear must be wound down first.

By using classic supply and demand curves, we can illustrate the relative cost competitiveness of coal or gas-fired generation assets and hence which plants will be able to stay economic for longer in a low carbon world that requires an almost complete phase-out of coal and gas-fired generation by 2040 and 2050 respectively. Investment in the higher cost generation runs a greater risk of stranding assets and destroying value.

[1] This workstream and modeling were developed by Carbon Tracker's Power & Utilities team in 2016-2018 and have been continuously updated and enhanced. The model provides current and forward-looking estimates of the (short and long-run) marginal cost, gross profitability, relative competitiveness, phase-out year and stranded asset risk in a below 2°C scenario.
[2] Unabated power generation is without any use of carbon emission removal technologies.

4 Carbon Tracker – Alignment Assessments

Carbon Tracker has developed eight alignment assessments to help investors identify, quantify, and assess stranded asset risks for 69 CA100+ focus companies.

- *Four assessments focused on investment and capital allocation plans for 36 upstream oil & gas exploration and production companies in a carbon emission constrained world, and*
- *Two sets of two assessments (for a total of four) focused on whether announced retirement schedules of coal & gas fired generation capacity (respectively) for 33 utility companies are aligned with the goals and ambitions of the Paris Climate Agreement.*

These assessments analyze companies' capital expenditures (CAPEX) and economic output from legacy fossil fuel-fired power generation and new prospective unsanctioned oil & gas exploration and production activities, hence, carbon-emitting assets relative to a range of climate change restricted scenarios. The analysis gives investors additional insights on the relative adequacy and alignment of company actions with the goals of the Paris Agreement.

These independent alignment assessments complement Indicator 6 of the Disclosure Framework within the CA100+ Net-Zero Company Benchmark to help investors assess oil & gas companies announced upstream capital expenditure plans and electric utility companies' asset retirement plans for their coal and gas generation capacity.

Demand scenarios. In our oil & gas and electric utility modeling, we use the following demand scenarios from the International Energy Agency (IEA) to proxy different levels of transition risk.

International Energy Agency (IEA) demand scenarios used by Carbon Tracker
Announced Pledges Scenario (APS). The APS assumes that in addition to following through with their policies, governments will also deliver on the promises that have yet to be passed into law. In other words, it looks into what stakeholders are saying they will do. *Source: IEA, World Energy Outlook 2022*
Stated Policies Scenario (STEPS): Our business-as-usual proxy. STEPS is consistent with c.2.7°C warming (50% chance) and describes a projection of the future energy system whereby already enacted, and already announced yet to be enacted, legislation on climate change is assumed to continue, but not be developed further. *Source: IEA, World Energy Outlook 2020. Source: IEA, World Energy Outlook 2022*
Net Zero Emissions By 2050 Scenario (NZE): A faster decarbonization pathway, equivalent to 1.5°C of warming in this century with little overshoot (i.e., limited reliance on post-2050 negative emissions). As the name suggests, net zero is reached by 2050. *Source: IEA, Net Zero Emissions by 2050 (2021).*

Source: 'Adapt to Survive' (Carbon Tracker, 2021)

5 Power & Utilities' retirement of fossil fuel powered electricity generation

Carbon Tracker's four assessments seek to help investors evaluate whether announced retirement schedules for coal and gas-fired electricity generation assets from 33 CA100+ utility focus companies are in alignment with the carbon emission constraints required to meet the goals and ambitions of the Paris Climate Agreement

These assessments are relevant to Indicator 5 (Decarbonization Strategy – Target Delivery), as well as in some part Indicator 6 (Capital Alignment) where analysis of company decarbonization strategies requires the assessment of companies planned investments. The CTI electric utility assessments provide further, more specific analysis that complements the broader assessment of Disclosure provided by the Transition Pathway Initiative's framework, exploring specific details of particular plants or assets. CTI goes beyond assessing the presence of a credible disclosure on the companies decarbonisation strategy to more deep review the quality of such strategies. CTI builds our own regional models for assessing companies' strategies against the IEA scenarios.

These assessments are based on Carbon Tracker's proprietary in-house modeling of Paris-aligned asset-level phase out schedules that identify the year when each coal and gas unit can be retired in an economically efficient manner. Our modeling highlights the risk to investors of high-cost carbon-intensive projects and changing costs of renewable energies to help identify when building new renewables will be cheaper than operating existing coal and gas plants – methodology explained below.

To be Paris-aligned Carbon Tracker requires electric power & utility companies to publish:

- A coal and gas retirement schedule consistent with a credible climate scenario (such as IEA's Net-Zero by 2050 scenario (NZE); and
- A retirement date (year) assigned to each coal and gas unit respectively.

Carbon emissions from the utility sector are primarily driven by coal and gas-fired generation activities of which coal is by far the most significant and is responsible for about 80% of the sector's total carbon emissions and more than 90% when also including gas - hence both generation categories must be phased out to achieve climate targets.

Coal and gas-fired generation retirement schedules are vital to ensure companies collectively meet the global temperature goals in the Paris Agreement because:

- climate change is about absolute emissions rather than emissions intensity,
- long-term retirement schedules will likely minimize out-of-market payments,
- growing clean generation capacity without retiring fossil capacity could create a negative investment signal in the future, and
- publicly announcing a retirement date is less likely to be reversed.

Our analysis assumes carbon capture and storage (CCS) technologies will not be available to extend the lifetimes of coal and gas capacity, as costs will likely be prohibitively expensive and only viable based on tax subsidies without a price on carbon emissions.

Hence, we analyze unabated (i.e., no CCS) coal and gas-fired generation where under IEA's Net Zero Emissions by 2050 Scenario (NZE) ~95% of unabated gas-fired phased-out globally by 2035 and unabated coal will be (~99%) phased-out globally by 2040. However, different regions will have different phase-out dates and trajectories for coal and gas generation, which are accounted for in our modeling.

6 Coal and gas-fired electricity generation retirement assessments

For the CA100+ Net Zero Company Benchmark, we have developed two sets of assessments (for a total of four) to evaluate the retirement schedules of coal and gas-fired power capacity, respectively, and their alignment with demand constraints required to meet the more ambitious goal of the Paris Climate Agreement.

The CA100+ Net Zero Company Benchmark categeorises company assessments into traffic light colours with Green, indicating that the company meets the expectations set out in the title of the Indicator, Amber, indicating that the company partially meets this criteria, and Red, indicating that the company does not meet the expectations of the Indicator.

Alignment assessments – coal and gas-fired electricity generation	**Traffic light assessment options: Indicating the level of misalignment with the Paris Climate Agreement goals**
Indicator 1) Unabated Coal Phase-out Alignment With a 1.5°C Pathway: The company has announced a full phase-out of unabated coal units by 2040 that is consistent with Carbon Tracker Initiative's interpretation of the IEA's Net Zero Emissions by 2050 Scenario.	Green: Full retirement of coal fired generation fleet consistent with CTI's interpretation of a Paris-aligned pathway (NZE) Amber: Full retirement of coal fired generation fleet has been announced, which is not consistent with CTI's interpretation of NZE Red: Partial retirement Unannounced/ insufficient data on retirements
Indicator 2) Unabated Gas Phase-out Alignment With a 1.5°C Pathway: The company has announced a full phase-out of unabated gas units* by 2050 that is consistent with Carbon Tracker Initiative's interpretation of the IEA's Net Zero Emissions by 2050 Scenario.	Green: Full retirement of unabated gas fired generation fleet consistent with CTI's interpretation of a Paris-aligned pathway (NZE) Amber: Full retirement of unabated gas fired generation fleet has been announced, which is not consistent with CTI's interpretation of a Paris-aligned pathway (NZE)

	Red; Partial retirement Unannounced/ insufficient data on retirements *This leaves open a role for other abatement technologies such as gas to hydrogen conversion beyond 2050.
Indicator 3) Coal Capacity Alignment With a 1.5°C Pathway: The company's operating and planned coal capacity (in percentage terms) is aligned with Carbon Tracker Initiative's interpretation of the IEA's Net Zero Emissions by 2050 Scenario.	% of unabated coal generation capacity Green: 100% of the company's operating and planned coal capacity is consistent with the Paris Agreement goals or the company has already phased out all coal capacity Amber: 75-99% of the company's operating and planned coal capacity is consistent with the Paris Agreement goal of limiting global warming to 1.5C Red: 0-75% of the company's operating and planned coal capacity is consistent with the Paris Agreement goal of limiting global warming to 1.5C
Indicator 4) Gas Capacity Alignment With a 1.5°C Pathway: The company's operating and planned gas capacity (in percentage terms) is aligned with Carbon Tracker Initiative's interpretation of the IEA's Net Zero Emissions by 2050 Scenario. Note: our current benchmark methodology assumes that all unabated gas generation must be phased out (or abated) by 2050 under NZE. At present, we scale down IEA scenarios to regional grid level and therefore do not take into consideration local grid constraint issues. There are various scenarios for getting to net-zero, some of which imply significant amounts of BECCS, and prolongs the lifetime of gas plants. Carbon Tracker takes the view that the role for BECCS should be minimal.	% of unabated gas generation capacity Green: 100% of the company's operating and planned gas capacity is consistent with the Paris Agreement goals or the company has already phased out all gas capacity Amber: 75-99% of the company's operating and planned gas capacity is consistent with the Paris Agreement goal of limiting global warming to 1.5C Red: 0-75% of the company's operating and planned gas capacity is consistent with the Paris Agreement goal of limiting global warming to 1.5C

The **first** set of assessments analyzes whether the goals and ambitions of the Paris Agreement are integrated into the company's power generation strategy. These assessments show the comprehensiveness of the company's announced coal and gas-fired generation capacity retirement schedules as an indication for the companies' preparedness for the transition to a low carbon power system.

We examine whether the companies have developed and disclosed:

- *a full phase-out retirement schedule for all coal / gas-fired generation capacities with assigned retirement years that are consistent with the demand constraints outlined in the IEA's* Net Zero Emissions by 2050 *scenario,*
- *a full retirement schedule with inconsistent retirement years,*
- *an only partial retirement schedule, or*
- *provided no or insufficient information to assess.*

The **second** set of assessments are based on Carbon Tracker's modeling and show the % share of companies' current and planned coal or gas-fired generation capacity retirements that are consistent with the goals and ambitions of the Paris Climate Agreement. The calculations are done for capacity in megawatt (MW). *The smaller the share of consistent coal or gas retirement schedules the higher the transition risk for the companies.*

7 Carbon Tracker's fossil fuel generation retirement analysis

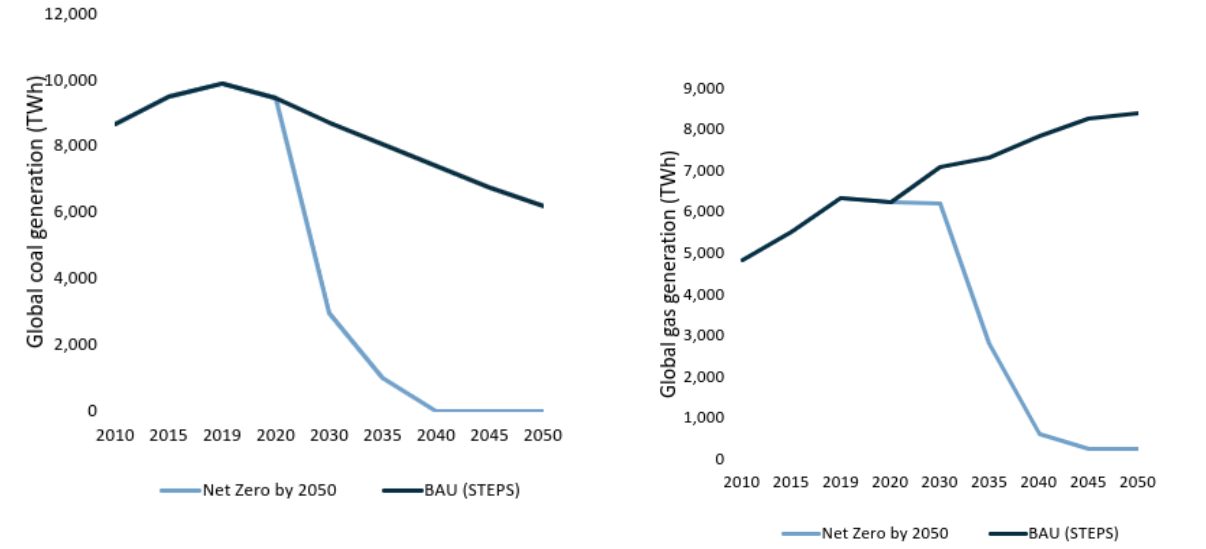
The analytics are based on Carbon Tracker's techno-economic asset-level simulation coal and gas models that are using reasonable assumptions about commodity prices (fuel, power, and carbon), variable and fixed operations and maintenance costs (O&M) and policy outcomes (out-of-market revenues and control technologies costs):

- Global Coal Power Economics Model (GCPEM). GCPEM is a proprietary techno-economic simulation model which covers ~95% of global operating, under-construction, and planned coal-fired capacity[3].
- Global Gas Power Economics Model (GGPEM). GGPEM is a proprietary techno-economic simulation model which covers ~45% of global operating, under-construction, and planned gas-fired capacity in the EU, Australia, United Kingdom, United States, South Korea, Japan and Vietnam.[4]

Our Net Zero Emissions by 2050 modeling identifies the year when a coal or a gas unit needs to be retired and the amount of stranded asset risk associated with keeping the unit open. The primary asset-level inventory data builds on the Global Energy Monitor's[5].

[3] The coal model, methodology, and assumptions are discussed in-depth in https://carbontracker.org/wp-content/uploads/2021/06/Coal-Methodology-2021_June21.pdf
[4] The gas model, methodology, and assumptions are discussed in-depth in https://carbontracker.org/wp-content/uploads/2021/10/Gas-Methodology-2021.pdf
[5] For further information about the GPCT and WEPP see https://endcoal.org/global-coal-plant-tracker/ and https://www.spglobal.com/platts/en/products-services/electric-power/world-electric-power-plants-database, respectively.

ELECTRIC UTILITIES - BUSINESS AS USUAL (BAU) VERSUS NET ZERO EMISSIONS BY 2050 PATHWAYS FOR COAL AND GAS



Source: IEA scenario data, Carbon Tracker analysis

We define a stranded asset as the difference between the NPV of operating cashflows in a business as usual (BAU) scenario and a scenario, such as IEA's Net Zero Emissions by 2050, that is consistent with the global temperature goals in the Paris Agreement.

- Firstly, we identify the amount of capacity that is required to fill the generation requirement in the Net Zero Emissions by 2050. Under the Net Zero Emissions by 2050, coal generation without carbon capture and storage (CCS) is phased out globally by 2040 (~99%) and gas generation will be almost entirely phased out by 2050 (~94%).
- Secondly, we rank the coal and gas-fired generation units to develop a retirement schedule, based on the authority, region, or grid responsible for maintaining security of supply. The units are ranked based on the Long Run Marginal Cost (LRMC) or operating cashflows.
    - **Coal:** The coal units with the highest LRMC or lowest operating cashflows are phased-out until the aggregated asset level generation reaches the limits set out in the Net Zero Emissions by 2050.
    - **Gas:** Acknowledging that flexible gas turbine generation is necessary for fulfilling peak load electricity demand and other grid balancing services, units are also ranked by their turbine technology, capacity factor and operating cost to determine their potential to become a peaking power plant (peaker).
- Thirdly, we calculate the cash flow of every operating and under-construction unit in both the Net Zero Emissions by 2050 and BAU outcomes to understand stranded asset risk.
    - **Coal:** Stranded asset risk under the Net Zero Emissions by 2050 is defined as the difference between the NPV of operating cash flows in the BAU scenario (which

includes announced retirements in company reports or otherwise assumes a minimum lifetime of 40 years) and the NPV of operating cash flows in the Net Zero Emissions by 2050 scenario.

- **Gas:** Stranded asset risk is then defined as the difference between the NPV of operating cash flows in the BAU scenario (which includes announced retirements in company reports or otherwise assumes a lifetime of 50 years for steam turbines, and 30 years for other technologies; or 25, whichever is later) and the NPV of operating cash flows in the Net Zero Emissions by 2050.

Carbon prices. We only include carbon prices where they are implemented or have been approved and will be implemented in the future. In regions where stringent pollutant emission limits exist, we assume the installation of pollution control technologies and the relevant capital and operation costs across those plants that are non-compliant.

Levelized Cost of Energy, but no system analysis. For clarity, our modelling is based on Levelized Cost of Energy (LCOE) to compare power generation technologies. We have not conducted a systems analysis, which would require a detailed grid-by-grid analysis of the impact of removing, and potentially replacing, each asset over time. While the limitations of using LCOE analysis for understanding the economics of power generation have been well documented, this provides a simple proxy for when new investments in coal power no longer make economic sense and when investors and policymakers should plan and implement a coal or gas power phase-out. We would also note that many companies themselves conduct such analyses, including in their integrated resource plans, thus, it may be useful to ask the companies for their view on what is possible from a system point of view.

All together, we believe this work further tailors Carbon Tracker's approach to the economics of the low-carbon transition to the needs of the investors, providing both greater detail and granularity on individual plants, and big picture assessments of the pace at which companies are transitioning by winding down their most carbon-intensive assets - coal and gas plants. It helps pose a simple question to companies: *if they in fact intend to meet emission reductions and/ or net zero targets, then they need to wind-down their coal and gas fleets, so can they now specify by how much, and when?*

Metrics. Carbon Tracker has developed the following metrics to track and monitor whether companies' announced retirements of coal and gas-fired generation capacity are in alignment with the pathways from a credible climate constraint scenario that meets the goals of the Paris-Alignment.

Relative Alignment (in percentage) – Primary alignment indicator for CA100+ - The share of a company's future generation capacity (including retirements and new additions) that is aligned with the energy demands of the Net Zero Emissions by 2050. *The lower the relative alignment, the higher the transition risk for the company*. This is calculated by summing total capacity aligned with Net Zero Emissions by 2050 between 2021 and 2040 for coal (2021 to 2050 for gas) divided by total capacity under a BAU scenario. A company's phase-out schedule can be either; in alignment with, behind or ahead of the Net Zero Emissions by 2050 schedule shown as *100% = perfect alignment, whereas <100% if behind the* Net Zero Emissions by 2050 *schedule and >100% if ahead of the* Net Zero Emissions by 2050. This metric enables us to compare utilities of very different scales.

Absolute Unalignment (in Giga Watt, or GW) - The yearly total capacity in GW unaligned with the energy demands of the Net Zero Emissions by 2050. This is calculated by summing the difference between the company's annual coal capacity in a business-as-usual (BAU) scenario and in Net Zero Emissions by 2050. This metric enables us to identify the companies with the largest unaligned generation capacity at risk for stranding and hence, where policy changes can be most impactful.

Share of analyzed units with announced retirement that is in alignment with Net Zero Emissions by 2050 (in percentage) - where the company has announced retirement year for its generation units, we show the share of the company's units where the retirement schedule is aligned with the goals of the Paris Climate Agreement.

For further discussion about Carbon Tracker's methodology, please see our most recent coal report "Do Not Revive Coal: Planned Asia coal plants a danger to Paris", and most recent gas report "Put Gas on Standby" – both authored by Carbon Tracker (2021).

See more information in the following Carbon Tracker reports:

Oil & Gas

2 Degrees of Separation, Transition risk for oil and gas in a low carbon world, 2017

2 Degrees of Separation, Company-level transition risks, 2018

Breaking the Habit, 2019

Fault Lines, 2020

Adapt to Survive, 2021

Power & Utilities

Powering down coal: Navigating the economic and financial risks in the last years of coal power, 2018,

Making it Mainstream, 2019

Powering down Coal, 2019

How to waste over half a trillion dollars: The economic implications of deflationary renewable energy for coal power investments, 2020

Do Not Revive Coal: Planned Asia coal plants a danger to Paris, 2021

Put Gas on Standby, 2021

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