Net Zero Transition: from Paris to Glasgow and Beyond

BloombergNEF

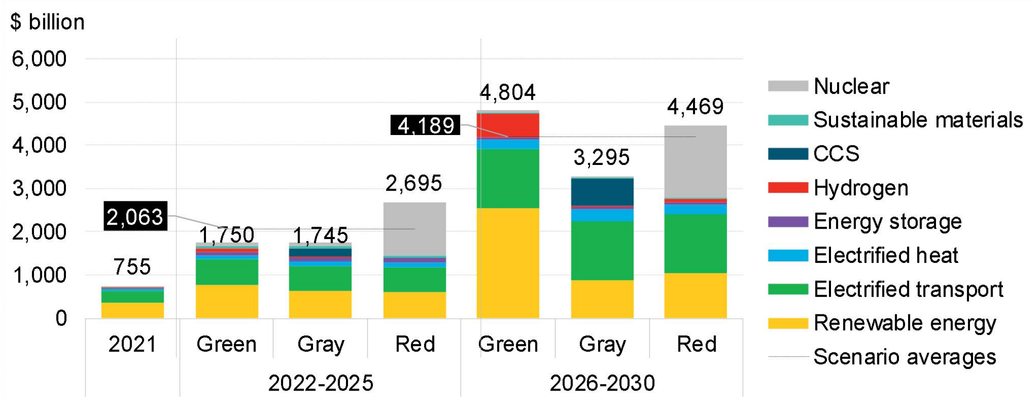
The November 2021 Glasgow Climate Pact reaffirmed the 2015 Paris Agreement with a stronger emphasis on limiting the global average temperature rise to 1.5°C by the end of this century relative to pre-industrial levels. To achieve this, global emissions will have to reach net zero by mid century. This report examines whether the emissions reduction targets set by countries are aligned with achieving this goal. It also examines three scenarios for how the world could eliminate energy emissions.

- The global average surface temperature has already risen by an average of 1.1°C. Based on current trends, we are on track to run out of the emissions budget to stay within 2°C of warming in 2044. As soon as 2028, we will have exhausted the emissions budget to stay within 1.5°C. If all countries' 2030 emission reduction targets, including conditional targets and long-term decarbonization targets such as China's goal of carbon neutrality before 2060, are achieved, the world will likely be in line with a rise of 1.8°C by the end of this century.
- To achieve global net zero, every sector of the energy economy needs to eliminate emissions completely by mid-century. There can be no free riders. Even the hardest-to-abate sectors will need to adopt carbon-free solutions, only turning to carbon removals where absolutely necessary. In our latest New Energy Outlook, we have constructed three scenarios compliant with net-zero carbon budgets for each sector of the energy economy that achieves the Paris Climate Agreement and satisfies the principle of an orderly transition, with the rate and timing of abatement varying depending on the current emissions trajectory and available abatement options in the near term.
- Green Scenario describes a pathway where greater use of clean electricity in the end-use economy is complemented by so called "green hydrogen" produced from water, using electrolyzers powered by wind and PV. Gray Scenario has emissions from fossil fuels abated using post-combustion carbon capture and storage technology, in addition to growth in electricity use and renewable power. Red Scenario deploys smaller, more modular, nuclear to complement wind, solar and battery technology in the power sector, and

manufacture so-called red hydrogen with dedicated nuclear power plants.

- The decade to 2030 will play a critical role in the pathway to net-zero global emissions by 2050. Around 78% of the abatement this decade is likely to be achieved by the power sector. The availability of economic solutions, such as wind, solar and batteries, means the power sector can cut emissions more quickly than other industries.

Figure 1: 2021 investment in energy transition versus required annual investment in 2022-25 and 2026-30 under net-zero scenarios

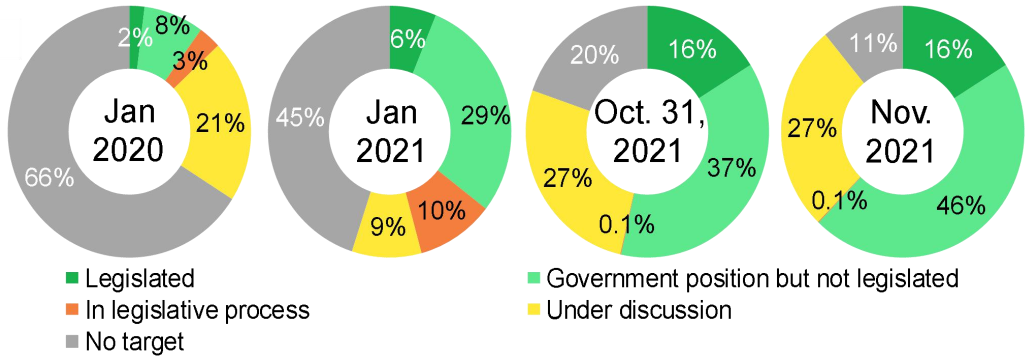


Source: BloombergNEF

1. From Paris to Glasgow

The Paris Agreement resulting from the 2015 United Nations Climate Change Conference, COP21, committed the world to "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels". To explore the implications of the 1.5°C stretch goal of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) in 2018 published a special report on Global Warming of 1.5°C. The IPCC report concluded that meeting the 1.5°C stretch goal of the Paris Agreement will require that global greenhouse gas emissions fall to 'net zero' by mid-century. After publication of this report, many governments around the world started announcing net zero goals.

Figure 2: Global greenhouse gas emissions covered by net-zero and carbon neutrality targets



Source: WRI CAIT, BloombergNEF. Note: Includes land use, land-use change and forestry, 2018

By the end of October 2021, on the eve of COP26 in Glasgow, almost 80% of global emissions were covered by these decarbonization goals (including goals in force or under discussion). During COP26 new announcements by countries such as India and Vietnam pushed the coverage to almost 90%, although the target date of these decarbonization goals widely vary.

The Glasgow Climate Pact's first three mitigation elements further reinforced the Paris Agreement 1.5°C stretch goal by stating:

"15. Reaffirms the long-term global goal to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

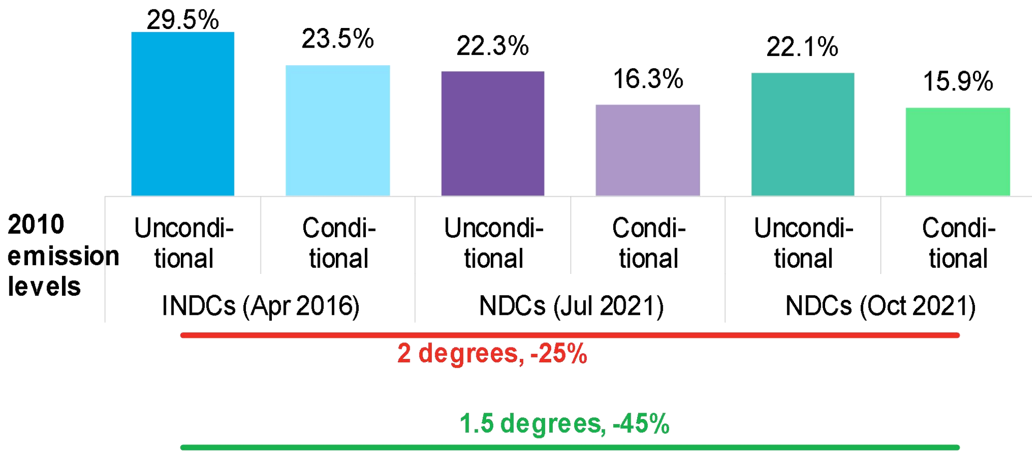
16. Recognizes that the impacts of climate change will be much lower at the temperature increase of 1.5°C compared with 2°C, and resolves to pursue efforts to limit the temperature increase to 1.5°C;

17. Also recognizes that limiting global warming to 1.5°C requires rapid, deep and sustained reductions in global greenhouse gas emissions, including reducing global carbon dioxide emissions by 45 per cent by 2030 relative to the 2010 level and to net zero around mid-century, as well as deep reductions in other greenhouse gases;"

While momentum for achieving net zero has increased, countries' 2030 emission reduction targets – the so-called Nationally Determined Contributions (NDC) under the Paris Agreement – are still not on target to reduce global emissions by 45% by 2030 relative to 2010. However, the NDCs are gradually becoming more ambitious. Before the Paris Agreement, the world was on track to 4-5°C of global warming by the end of the century. Subsequently, the 2016 Intended Nationally

Determined Contributions (the predecessor to NDCs) would have meant that 2030 emissions were 23.5-29.5% above 2010 levels, meaning a temperature increase of some 3 °C by century-end. However, the latest set of commitments made by the start of COP26 bring the world closer to imply some 2.7 °C of warming. This would still mean global emissions in 2030 are 22% higher than 2010 levels, or 16% higher if developing countries' conditions on financial and other support are met.

Figure 3:Change in global greenhouse gas emissions from 2010 levels implied by climate plans



Source: UN NDC Synthesis Reports, BloombergNEF.

Some announcements have been more optimistic, with the International Energy Agency estimating that the most recent pledges would be in line with a rise of 1.8 ° C. However, this analysis takes account of countries' long-term plans, assuming they begin to take sufficient action now to achieve those goals (which isn't the case for many nations), as well as the Global Methane Pledge.

2. The carbon budget for energy

In this section we consider the carbon budget for the energy sector. Energy emissions rose 0.9% year-on-year in the five years to 2020. Based on current trends, we are on track to run out of emissions budget to stay within 2°C of warming in 2044. And as soon as 2028, we will have exhausted the emissions budget to stay within 1.5°C. This underlines the need for immediate, concrete policy action to accelerate decarbonization today: achieving mid-century climate goals will not be sufficient, unless intermediate milestones are also hit.

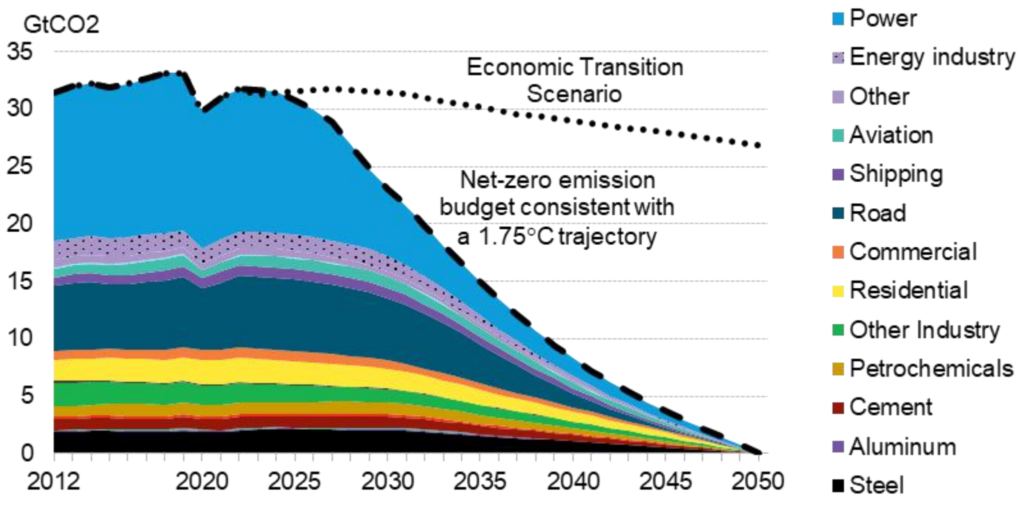
To achieve global net-zero, every sector of the energy economy needs to eliminate emissions completely by mid-century. There can be no free riders. Even the hardest-to-abate sectors will need to adopt carbon-free solutions, only turning to carbon removals where absolutely necessary.

We have constructed net-zero carbon budgets for each sector of the energy economy that achieves the Paris Climate Agreement and satisfies the principle of an orderly transition, with the rate and timing of abatement varying depending on current emissions trajectory and available abatement options in the near term.

The resultant budget requires emissions to fall 30% below 2019 levels by 2030, and to drop 75% by 2040 to reach zero in 2050. The power sector goes fastest, following a 1.6°C equivalent budget that sees emissions down 57% from 2019 levels in 2030, and then 89% in 2040.

Road transport emissions drop 11% by 2030 before this accelerates during the 2030s to reach 80% below 2019 levels in 2040. Residential and commercial buildings follow a more linear trajectory, down 16% below 2019 levels by 2030 and 58% by 2040. Harder-to-abate sectors such as aviation, steel and cement go slowest, capping emissions growth this decade before a linear decline to zero mid-century.

Figure 4:Energy emissions and net zero carbon budget, by sector



Source: BloombergNEF

3. Getting on track to 2030

The years between now and 2030 are critical in the race to net zero. For the world to get on track, there will need to be an immediate, unprecedented acceleration in deployment of existing technologies, such as renewable energy and electric vehicles. In parallel, new technologies need to be commercially demonstrated and scaled up, in order to be ready for massive deployment before the decade is out.

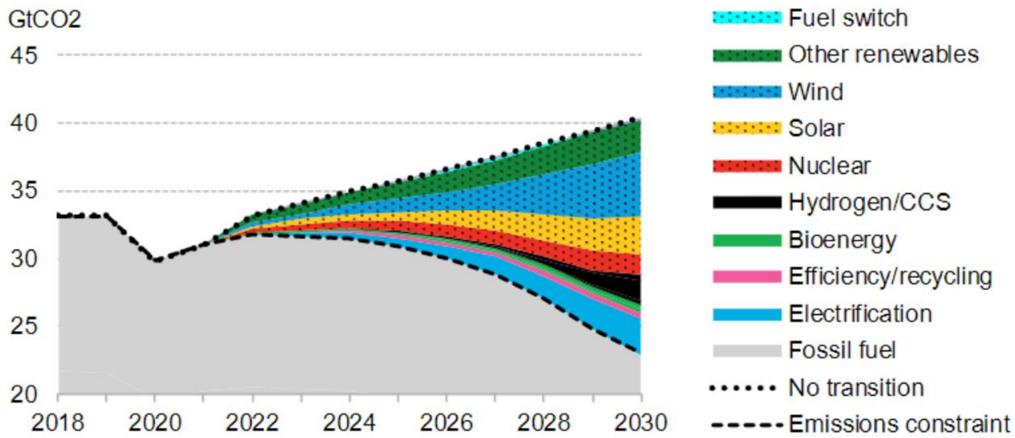
More than three quarters of the abatement effort in this period falls to the power sector and the faster deployment of wind and solar PV. Another 16% is achieved via greater use of electricity in transport, building heat and to provide lower-temperature heat in industry. Greater recycling in steel, aluminum and plastics accounts for 4%, and growth of bioenergy for sustainable aviation fuel and shipping another 1%.

Getting on track for the power sector, means adding up to 505GW of new wind, 455GW of new solar and 245GWh new battery storage on average every year to 2030 under our Green Scenario. This is over 5.2-times the amount of wind capacity added in 2020, 3.2-times the amount of solar and 26-times the amount of battery storage. By 2030, that adds up to a total of 5.8TW of installed wind, 5.3TW of installed PV, and 2.5TWh of batteries. These totals are up eightfold, ninefold and 176-fold from 2020 levels, respectively. At the same time, more than 100GW of coal-fired capacity needs to retire on average each year so that by 2030 coal-fired power is 67-72% below 2019 levels. Capital flows need to accelerate markedly too. New investment in wind and solar capacity has been flat at around $300 billion per year for several years. This figure needs to rise to between $763 billion to $1.8 trillion per year between 2021 and 2030 depending on scenario, to get on track for net zero.

Getting on track for transport means adding an average of 35 million electric vehicles each year so that by 2030 there are 355 million EVs and emissions from the road segment are 11% below 2019 levels. At the same time, sustainable aviation fuels need to increase to 10% of total jet fuel use by 2030, and greater emphasis needs to be placed on operational efficiency in shipping as well as increasing biofuels use to 4% of fuel consumption.

Getting on track for buildings means adding an average of 18 million new heat pumps each year to 2030, or 186 million by the end of the decade, while also continuing to improve building efficiency.

Figure 5:Total energy emissions and abatement to 2030, by source, all scenarios



Source: BloombergNEF

Getting on track for industry means increasing the amount of aluminum that is recycled by 67% from 2020 levels. For steel the required improvement in recycling is 44% more by 2030 compared with 2020 levels. And for plastics, recycling needs to rise 149% from 2020 levels by 2030. This scrap is then feedstock for lower-energy and lower-emissions secondary production, which accounts for 43% of total steel, 37% of aluminum and 22% of plastics production in 2030.

Getting on track also means increasing electricity to 50% of energy use in lower-temperature processes this decade.

Hydrogen, CCS and new nuclear technologies do not play a meaningful abatement role in the 2020s, but getting them to scale is a critical task for this decade. In our Green Scenario, 1.9TW of electrolyzers need to get deployed by 2030 to kickstart the hydrogen sector. In our Gray Scenario, 936Mt of carbon capture and storage is in place by 2030. In our Red Scenario, the first small modular nuclear reactors are online by 2027, and 390GW are deployed by 2030. Without hitting these milestones, it will be difficult to achieve the rates of deployment needed in the respective scenarios in the 2030s and 2040s.

4. Getting to net-zero in 2050

The central feature of each scenario is the switch to electricity in the end-use economy. This reduces direct emissions in transport, buildings and industry, and despite increasing electricity demand and emissions upstream in the power sector, electricity generation is generally cleaner than downstream fossil-fuel use, resulting in a net reduction. At the same time, ongoing deployment of zero-carbon power improves this equation over time.

All scenarios include increased recycling for steel, aluminum and chemicals, as well as faster consumer uptake of rooftop PV systems and small batteries. We include carbon removal alongside CCS to offset residual emissions in this process, and a small amount of removal in the next decade for sectors where we don't see viable abatement options, such as in cement production.

In our Green Scenario, clean electricity accounts for 61% of total abatement to 2050. Greater electricity use in the form of electric vehicles, heat pumps, and lower-temperature industrial processes adds another 23%. Hydrogen in the end-use economy accounts for a further 10% of total abatement. This includes high-temperature heat in industrial processes such as steel making, chemicals and cement; aviation, shipping, some road and rail, and hydrogen used in boilers for space and water heating. Combining hydrogen in power generation and the end-use economy, it makes up almost a quarter, or 19%, of total emissions reduction.

Abatement in the Gray Scenario is again dominated by clean power, which accounts for 61% of total emissions reductions to 2050. This time carbon capture and storage (CCS) allows coal and gas to continue to play a significant role. Combining CCS in power generation and the end-use economy, it makes up 18% of total emissions reduction to net-zero in this scenario. Bioenergy in the end-use economy plays a larger role in this scenario, particularly in aviation and shipping, accounting for 3% of total abatement. Increased recycling and secondary manufacturing in industry accounts for a further 3%, and a small amount of blue hydrogen in industry and transport, at 3%.

Abatement in the Red Scenario looks similar to abatement in the Green Scenario, apart from a change in the power sector, where a nuclear renaissance reduces the volume of renewables, and its higher capacity factor and limited flexibility negates the need for hydrogen-fired generation to meet seasonal demand, but increases the use of batteries. Clean electricity accounts for 61% of total abatement to 2050. Of this, wind power makes up 41%, solar 20%, nuclear 26% and other zero-emissions power, including hydro, some 13%.

4.1 Final energy consumption

Final energy consumption declines in each of our scenarios as a combination of demand-side energy efficiency, more recycling, a shift away from oil products, and greater use of electricity means less energy is needed even as demand for mobility, heating and manufacturing grows with population and wealth.

In each of our scenarios, a shift to electricity in the end-use economy plays a central role in the transition, increasing to around 49% of final energy consumption by 2050. This shift is most prominent in road transport, where electric vehicles come to dominate, and in buildings, where conventional oil- and gas-fired heating systems are replaced with electric ones. There is also a switch to electricity in low-temperature industrial processes. This 'electrification' increases overall electricity demand by around 47% above the background trajectory in each of our scenarios.

The consumption of coal, gas and oil products in final energy declines dramatically in each of our scenarios. Totaling around 68% of final energy today, fossil fuels drop to 30% in our Gray Scenario by 2050, and just 13% in our Green and Red Scenarios, where they are used only as chemical feedstock.

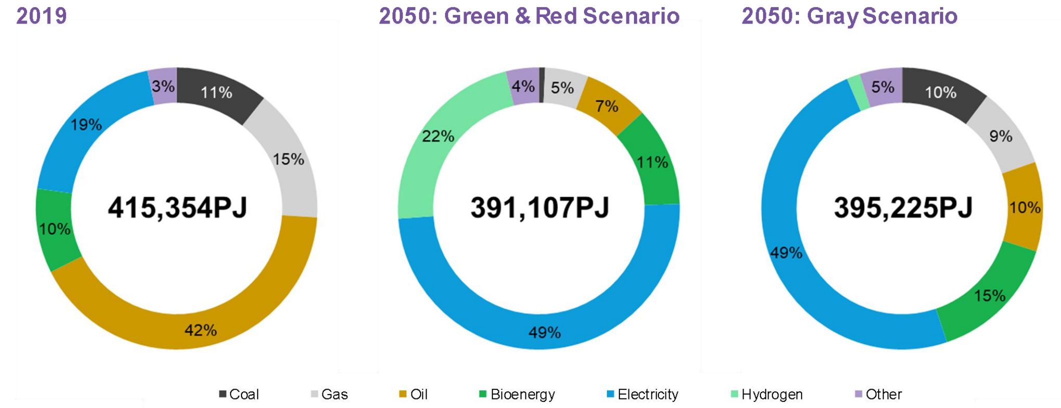
In our Gray Scenario, coal and gas maintain a share of 10% and 9% of final energy in 2050.This is because carbon capture and storage technology allows coal and gas to continue to be used for heat production in industry. In contrast, oil products drop to 10% of final energy in this scenario from 42% today, as oil in road transport and shipping benefit little from CCS.

Hydrogen emerges as part of the final energy mix in each of our scenarios. It plays a minor role in our Gray Scenario, with just 190Mt of demand in 2050, and a major role in our Green Scenario, where demand reaches 1,318Mt and around 22% of total final energy consumption, up from less than 0.002% today.

The single biggest use of hydrogen in our Green Scenario is the power sector, with 553Mt, or 42% of demand, in 2050. Hydrogen consumption in the end-use economy is 766Mt in both the Green Scenario and Red Scenario. Of the end-use sectors, hydrogen is used most in industry, at 341Mt in 2050, some 40% of which goes to steel production. A further 161Mt is used in the transport sector, largely in aviation, which accounts for 95Mt, or 59%. There is another 30Mt of hydrogen for medium and heavy commercial vehicles. The use of hydrogen in buildings is smaller, standing at 102Mt in 2050 – two-thirds of which goes to residential buildings. As electrolyzer technology improves, we assume that the electricity required to produce one ton of hydrogen falls from 53MWh today to 45MWh in 2050. That means hydrogen manufacturing in our Green and Red Scenarios requires between 34,396TWh and 59,264TWh of electricity generation. To put these figures in context, making hydrogen in our Green Scenario needs around 1.9 times more electricity than is produced worldwide today. To make the hydrogen for our Red Scenario requires 1.5 times as much.

Overall electricity use, including power used to make hydrogen, increases 3.7 times from 2019 levels in our Red Scenario to 96,417TWh in 2050. This figure is even higher in our Green Scenario, where electricity demand increases 4.6 times from 2019 levels to 121,549TWh in 2050. Taken together, about 71% of total final energy in our Green Scenario comes directly or indirectly from electricity by mid-century.

Figure 6:Final energy consumption



Source: BloombergNEF

4.2 Primary energy supply

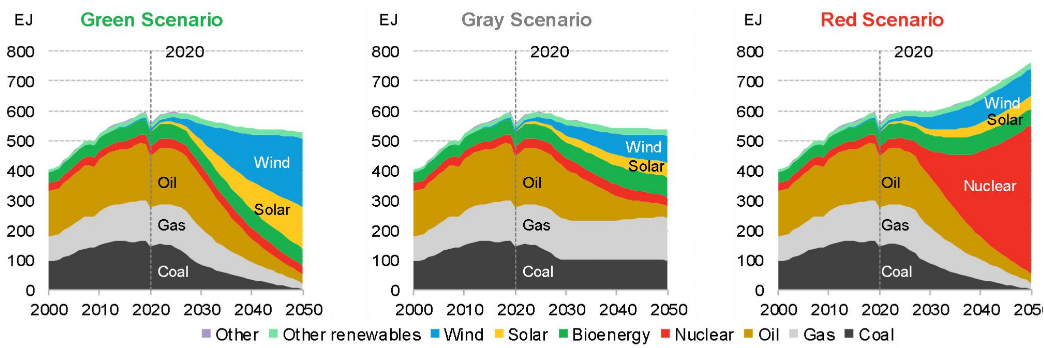
Each of our net-zero scenarios describes major transformations in the primary energy supply. In our Green Scenario, wind, PV, hydro and other renewables make up 28% of primary energy in 2030, some 62% in 2040 and 85% in 2050. This is up from just 12% today, or just 1.3% if we count just wind and solar. At the same time, fossil fuels drop at around 7% per year from 2019 to make up 10% of supply in 2050.

In the Red Scenario, nuclear fuel grows to dominate primary energy supply, making up 66% in 2050. This outsized role reflects the low conversion efficiency of nuclear fuel to nuclear power and nuclear power to hydrogen. In the Gray Scenario, where widespread use of post-combustion carbon capture and storage means coal and gas in particular can continue to be used, fossil fuels decline 2% a year but still make up 52% of primary energy in 2050.

Fossil fuels currently account for around 83% of total primary energy. This figure includes all the energy losses as fossil fuels are transformed into electricity, or refined, and then used to supply the end-use economy. Today, around 53% of primary energy is lost in transformation before it can do anything useful. In each scenario, peak demand for fossil fuels is brought forward, with oil and coal never again reaching pre-pandemic highs.

The speed and timing of decline across oil, gas and coal differs among the three fuels, and by scenario. Oil is alone in seeing significant, long-term decline in all three scenarios, whereas coal and gas have a lifeline in CCS in the Gray Scenario. Policymakers must manage these declines carefully, considering multiple strategic goals and needs, for example, to transition capital flows away from these sectors and minimize stranded assets; to achieve a just transition for workers and communities, and to preserve economic sectors of national importance where possible.

Figure 7:Primary energy supply



Source: BloombergNEF

Coal declines quickly and early in our Green and Red Scenarios, down 5% year on year to as little as 3,807Mt in 2030 – that's as much as 45% below 2019 levels. It then continues to fall all the way to 110Mt in 2050 as decarbonization ramps up in heavy industry. The use of CCS in our Gray Scenario significantly slows coal's decline from around 2027, as the technology supports ongoing demand growth in power generation and high-temperature industries like steel and cement.

Oil is hit hard in all three scenarios. Demand recovers post-pandemic but it doesn't again reach pre-crisis levels. By 2030, demand is at 85-87 million barrels per day (mbd), depending on the scenario, from around 97mbd in 2019. By 2050, the switch to electric vehicles, sustainable aviation fuel and hydrogen reduces oil demand in our Green and Red Scenarios to just 15mbd of feedstock. Even in our Gray Scenario, oil declines as it is mostly used in the transport sector where CCS can offer little support. In this scenario demand falls to 21mbd in 2050

Gas continues to see some modest growth this decade, rising up to 1% per year to a peak in 2026 or 2027, depending on the scenario. This is supported by a small amount of operational coal-to-gas fuel switching in the power sector. In our Green Scenario and Red Scenario, total gas demand declines to 518 billion cubic meters in 2050, as hydrogen and other zero-carbon fuels displace gas in buildings, industry and electricity generation. In the Gray Scenario, the use of CCS in power and industry allows gas demand to recover from a low of about 3,400bcm in 2034, to 3,754bcm, or 4.2% above 2019 levels, by 2050.

Overall, our scenarios describe strong decoupling of energy and emissions from economic growth. Final energy consumption relative to GDP falls 62% between 2019 and 2050. This translates into 3.1% year-on-year decline in the energy intensity of GDP. Between 2000 and 2018, final energy intensity only fell 1.3% per annum on average. Primary energy intensity of GDP falls even more strongly, down 65% between 2019 and 2050 in our Green Scenario, 64% in our Gray Scenario and 49% in our Red Scenario.

5. Investment required

Large investments in energy infrastructure are needed for the energy transition, with capital flowing away from fossil fuels and toward clean power and other climate solutions. Despite uncertainty around overall cost of each pathway, we estimate required investment in energy supply and infrastructure of between $94 trillion and $175 trillion over the next three decades. To achieve this, annual investment will need to more than double, from around $1.7 trillion per year today, to somewhere between $3.1 trillion and $5.8 trillion per year on average over the next three decades.

For the Green Scenario, around 56% of all investment goes to the production, storage and transport of hydrogen. Power generation, storage and the grid take another 35%, and fossil fuels the remaining 9%. In contrast, the Red Scenario requires s55% of investment flows to the power sector, 35 percentage points of which goes to power generation – both renewables and nuclear. Hydrogen makes up to 34% and fossil fuels 11%. Again, in the Gray Scenario investment in power generation, energy storage and the grid makes up the bulk of investment, at 57%, fossil fuels account for 20% and CCS some 15%. The final 8% goes to hydrogen.