BofA SECURITIES

Thematic Investing

"Transwarming" World: Net Zero Primer

Thematic Investing

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The biggest challenge, and opportunity of our times

This is the decade of climate action and COP26 will be the tipping point of the race to reach net zero emissions – the balance of reducing and removing carbon emissions from the atmosphere. To achieve it, a transition to clean technologies in all sectors at an unprecedented pace would be required, with the steering of governments and willingness of society. This is the last decade to act. Absolute water scarcity is likely for 1.8bn people, 100mn face poverty, and 800mn are at risk from rising sea levels by 2025. Climate migration could reach 143mn from emerging markets, driven by extreme weather[1]. At the same time, $5tn of annual investments, $2tn of R&D, 42mn green economy jobs, and a cleaner planet could generate an unprecedented global opportunity[2].

Good COP(26), bad COP: Everything we need to ask

Climate action is not black & white and we ask the tough questions, such as: Is it even possible to get to net zero? Yes, but slow, expensive and uneven. How much will it cost? $150tn over 30Y, 2x current global GDP[2]. Will it be inflationary? Yes, expect 1-3% pa shock[3]. What are the bottlenecks? Geopolitics, climate wars and EM. Do we have the resources? Nickel and Lithium are just two that could be in deficit as soon as 2024. Is green technology really green? Not initially. Are markets factoring the risk? Yes! Cost of equity is 10% lower for high ESG scores companies, new energy issuance is 70bps higher than investment grade, and 37% of EM investors plan to cut fossil exposure.[3]

Tech, economy and markets meet to solve a $150tn crisis

At an estimated $150tn over 30 years, boosting funding sources to $5tn a year is equivalent to the entire US tax base, or 3x the COVID-19 stimulus this decade[2]. But it can be done, with technology, economy, markets and ESG joining forces. Exponential cost reductions in wind, solar and batteries technologies have made renewables the cheapest form of energy in areas producing >90% of global electricity. Market appetite is chipping in too. Labelled bonds and loans jumped to > $3tn this year, with $3 in every $10 of flows into global equities going into ESG, which will support climate-friendly investments, as well as funding new ones needed to further decarbonize our planet like green mining, green hydrogen or carbon capture.[4] Finally, we see central and commercial bank balance sheets funding rising by c. $500bn p.a. Yes, this will create up to 3% inflation shock, but this could be partially absorbed by green economy GDP boost.[3]

$69tn cost, $5tn annual investment opportunity

The potential impact of no action could be significant: >3% of GDP lost every year by 2030, growing to $69tn by 2100; and c.5% of global equity stock market value ($2.3tn) wiped out permanently by climate policy re-pricing, with a potentially extreme hit to corporate earnings for certain sectors.[5] However, the need for energy transition investment to rise to >$5tn per year will create opportunities.[2] This is net positive for enablers like utilities, industrials, renewables, industrial gases & batteries deployed at scale, such as green hydrogen, green mining, and carbon capture.

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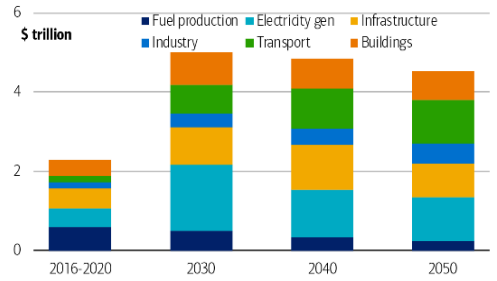
Source
1.World Bank
2.IEA
3.BofA Global Research
4.BloombergNEF, BofA Global Research
5.Moody's Analytics, BofA Global Research

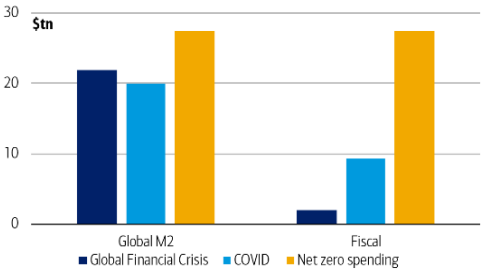
Net Zero in 9 Charts

Exhibit 1: Net Zero in 9 Charts
Everything you need to know about COP26

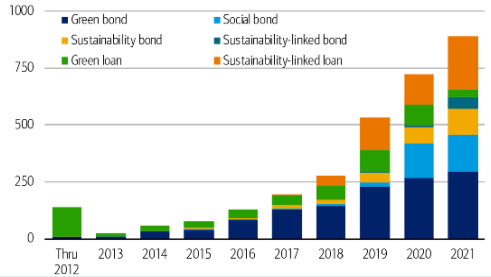
1) How much will it cost? $5tn p.a, for 30 years, $150tn in total



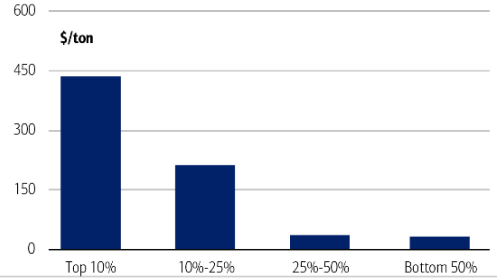
2) Who will pay for it? everyone! Governments, private sector, the consumers....



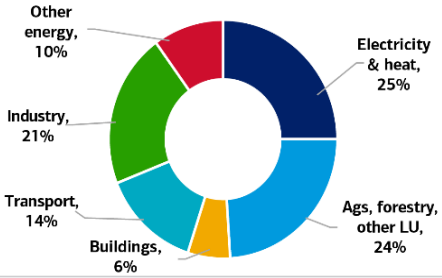
3) ...And the capital markets: labelled bonds and loans and already accumulated to $3t



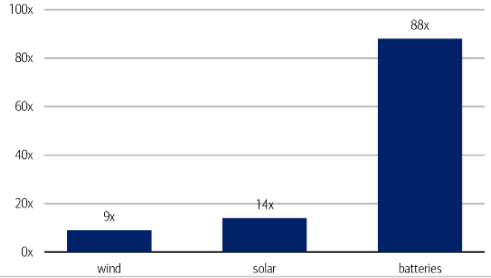
4) Average carbon tax of $150/t could fully pay the $5tn bill. DM needs to subsidise EM



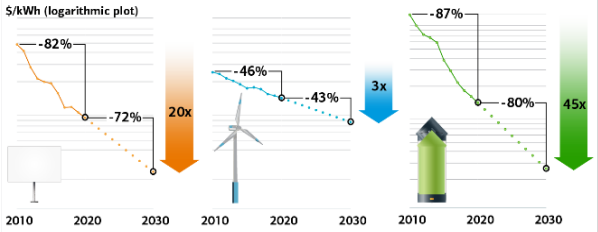
5) Which industries will be affected? Ag, Electricity and Industry are the most emitting sectors



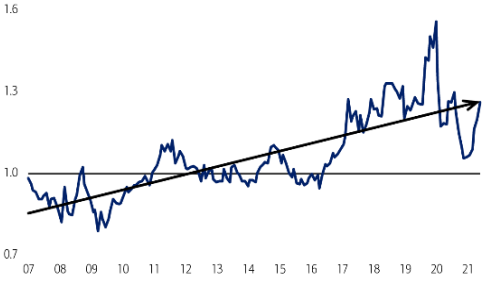
6) How much renewables needed? 9x, 14x and 88x wind solar and battery capacity by 2050...



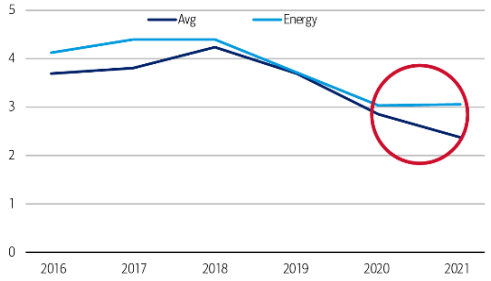
7) ...But the good news are that costs of renewables are dropping



8) Capital markets reward it! Companies with the highest overall ESG ranks trade at a roughly 25% premium



9) And so will credit markets. new energy issuance coupons is 70bps higher than investment grade



Source: 1) International Energy Agency (2021), Net Zero by 2050, IEA, Paris; 2) Haver, IMF, IEA, BofA Global Research; 3) Bloomberg NEF; 4) World Bank, BofA Global Research; 5) EPA, IPCC (2014); 6) IEA; 7) RethinkX; 8) MSCI, FactSet, BofA US Equity & Quant Strategy; 9) BofA Global Research estimates, ICE Data Services LLC

The Net Zero Cheat Sheet

Table 1: The Net Zero cheat sheet
The road to net zero emissions raises several recurring questions and debates on what's required, timelines, and implications.

The Key Questions we're asked	The key answers you need
What is COP26?	The 26th UN Climate Change Conference ('Conference Of the Parties')
What is net zero?	A zero balance of greenhouse gases added and removed from the atmosphere.
Why do we need net zero?	Climate change. Reaching net zero CO2 by 2050 could limit global warming to 1.5°C.
Are we on track to achieve it?	Not yet, but commitments are rising: country commitments to achieve net zero cover >70% of global CO2 emissions.
Is net zero even possible?	Yes, but required this decade to achieve: a 50-80% reduction in CO2 by 2030 (vs 2020), and 100% by 2050 in all sectors.
What industries to be affected?	All sectors need to decarbonise, but Energy related emissions in transport, industry, and heating account for ~77% of global emissions, thus the energy transition is key.
How much renewable energy needed?	~4x the 2020 installations of wind and solar generation capacity to >1,000gw per year - for 30 years; 27TWh-42TWh capacity globally in 2050 (9-14x 2020 levels)
How many EVs and batteries?	EV penetration: >60/100% *sales* by 2030/35; 85-100% of all road transport vehicle *fleet* by 2050, requiring up to 88x battery manufacturing capacity (14TWh)
How much will it cost?	Around $150tn total, $5tn a year over 30 years, 2-3x current annual energy investments
How and who will pay for it?	Private & Public sources via a combination of corporate bond issuance ($3tn labelled bonds), commercial bank balance sheet capacity, government debt
Will a carbon tax be required?	Yes, an average of $150/t expected over 20 years to achieve required emissions reductions, with 2040-50 price influenced by carbon capture effectiveness
What is the economic impact?	1-3% inflation, 0.3-0.5% GDP uplift pa to 2030 at elevated funding of $5tn a year
Will capital markets reward it?	Yes. 2021 is on track for record ESG fund inflows (30% of global equities), cost of equity for high ESG scoring companies is 10% lower than poorly-ranked peers
Will companies trade higher?	Yes. P/E multiples for companies with the top 20% ESG scores have risen from a 20% discount to bottom quintile peers to a 25% premium today
Will debt markets reward it?	Yes. The average coupon for new energy issuance in 2021 is now 70bps higher than for overall USD investment grade issuance despite similar ratings
Will (clean) technology save the day?	Around 50% emission-reductions to 2050 are expected to come from technologies already in commercial deployment (e.g. renewable energy, electric cars, heat pumps).
Are clean technologies "clean"?	Most are not upfront, owing to higher mineral content; EVs use 6x higher mineral content (and currently take two years to become "greener" than combustion engines) and wind power 9x higher than gas for example
Will geopolitics get in the way?	Possibly. Restrictions over raw material access, and economic policy tools such as carbon border taxes risk "Climate Wars" between global superpowers.
Do we have enough raw materials?	Only with new capacity and recycling. Shifting to a metals intensive economy at the pace required for net zero could see nickel/lithium deficits by 2024/2026. >90% of the material processing is in Asia, requiring local supply chains to scale up.
How will net zero impact business and consumers?	The majority (60%) of emission reductions will require the active involvement of consumers/businesses (e.g. switching to electric cars, heat pumps)
What could go wrong?	Behaviour change, finance, rate of change in EMs, lack of global compliance and how to monitor and track emissions reduction are key challenges to deliver net zero.

Source: BofA Global Research, BloombergNEF, IEA

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The COP26 handbook. What do we need to know?

Q. What is COP26?

A: The UN's Climate Change Conference ('Conference Of the Parties'), in its 26th year. Country members of the UN's Framework Convention on Climate Change (now ~200) meet to negotiate and commit to levels of greenhouse gas emission reductions and actions to mitigate climate change. The significance of COP26 is the first such conference where countries are due to update their emissions reduction pledges (nationally determined contributions, NDCs) since their inception at the Paris version of the conference in 2015. More net zero targets are expected, climate finance for emerging markets, and specific policies around the use of coal, renewable energy, electric vehicles and curtailing deforestation. Thus, the success of COP26 will be determined by the levels of country commitments to reach net zero, the specific policies and finance that will be mobilised to achieve it.

Q: What is net zero?

A: A measure of carbon neutrality through a balance of reducing and removing carbon emissions from the atmosphere. The word "net" is the key. This means that whilst eliminating emissions to zero would be ideal, not every activity has to be zero emission to be compliant in a net zero economy. However, greenhouse gases that continue to be emitted would need to be captured and removed from the atmosphere.

Q: Why do we need net zero?

A: Climate change. Global average temperatures are now 1.1°C above pre-industrial levels, with the last decade hotter than any period in 125,000 years, making extreme weather events more frequent and severe. Reaching net zero CO2 by 2050 (and other greenhouse gas emissions by 2060-70) could limit global warming to 1.5°C, considered the threshold that could mitigate the extent of global sea level rises, drought and hunger (source: IPCC).

Q: Are we on track to achieve it?

A: Not yet, but commitments are rising. The good news: country commitments to achieve net zero cover >70% of global CO2 emissions; within that, >100 of the world's largest emitting companies have committed to reaching net zero thus far (accounting for ~25% of global emissions between them). The bad news: just 10 country commitments were in legislation as of September 2021, and many of the country pledges announced have long-term targets without 2030 commitments. ~85% of the gap to reach the 2030 requirement of the 1.5°C goal, per the Paris Agreement, remains (sources: BNEF, IEA, Climate Action Tracker).

Q: Is net zero even possible, and how?

A: Yes, but action is required this decade. Achieving net zero requires a significant reduction of greenhouse gas emissions in all sectors of the economy: a 50-80% reduction in CO2 by 2030 (vs 2020), and 100% by 2050 to reach the 1.5°C goal. To achieve it, solutions focused on decarbonisation of energy-related emissions in transport, industry and heating (at an unprecedented scale) are sought in particular, as they account for 77% of global emissions (the largest of the "emissions wedges"), but alternative substitute products and processes in agriculture and land use/forestry are required for the remainder. These require substantial investment, technological and behaviour changes to transition to zero carbon alternatives at scale, raising several policy, economic challenges as to the most efficient pathway (sources: BNEF, IEA, World Resources Institute).

Q: How much renewable energy might be required for net zero? How many EVs and batteries?

A: ~4x the current (2020) annual installations of wind and solar generation capacity – >1,000gw per year – for 30 years. Cumulative installed capacity of variable renewables

required in 2050 could be between 27TWh-42TW, 9x and 14x 2020 levels respectively (sources: IEA, BNEF). A: The proportion of car sales would reach 64% battery of fuel cell EV by 2030 (and 30% of trucks); reaching 100% of all road vehicles by 2050, powered by renewable electricity and requiring 14 TWh battery manufacturing capacity (88x more than the installed capacity in 2020) (source: IEA).

Q: How much will it cost?

A: The energy transition to a net zero greenhouse gas (GHG) economy by 2050 will be a very expensive exercise, estimated by the IEA at $150tn of total investment, over a period of 30 year. At $5tn p.a, the IEA see it costing as much as the entire US tax base every year for 30 years. BNEF has a higher estimate that the total investment needed for energy supply and infrastructure could be as high as $173tn through 2050, or up to $5.8tn annually, which is nearly three times the amount invested on an annual basis today.

Q: Who will pay for it and how?

A: A combination of corporate bond issuance, commercial bank balance sheet capacity, government debt, and carbon taxes will likely be required to achieve full decarbonization. It will be very challenging to boost funding resources to the $5tn a year required to get to net zero emissions, but there is plenty of scope to increase current funding of $500bn a year. BNEF estimates that through July 2021, over $3trn in labelled bonds and loans have been issued. This includes $623bn in labelled bonds in 2021 (through August), and another $265bn in green and sustainability-linked loans. We expect $1trn in labelled bond issuance in 2021 (including $900bn in green, social and sustainability bonds plus at least $100bn in sustainability-linked bonds). The consumer will also need to contribute, through taxes. Decarbonisation bill of $5tn a year is equivalent to 25% of current global tax revenues ($20tn); assuming that global tax revenue grows at the 10y average over the next 30 years and a progressive spending path, the decarbonization bill would amount to 15% of global tax revenues by 2030, meaning accommodating climate action finance likely required far beyond fiscal budgets.

Q: What is the economic impact of net zero?

A: Elevated net zero funding could be inflationary, but the impact looks manageable at 1% to 3% per annum depending on central bank monetization rates, particularly if government spending is targeted and contributes to accelerate the rate of global GDP growth. The IEA also has a productive outlook for their net zero scenario, where the change in the annual growth rate of GDP accelerates by somewhere between 0.3% and 0.5% on a sustained basis over the next 10 years as a result of a shift to a green economy.

Q: Will capital markets reward investment?

A: Yes, the capital markets are voting in favour and rewarding companies with high ESG scoring. 2021 is on pace for a record ESG influx, with $3 in every $10 of flows into global equities going into ESG. P/E multiples for companies with top quintile MSCI ESG scores have risen from historically as low as a 20% discount to bottom quintile peers to a 25% premium today. The cost of equity for companies with the highest ESG scores based on MSCI is 120bps or 10ppt lower than poorly-ranked peers. Equally we see this trend through the credit markets, through lower cost of debt. As an example, the average coupon for new energy issuance in 2021 is now 70bps higher than for overall USD investment grade issuance despite similar ratings.

Q: Will (clean) technology save the day?

A: Around half of the emission-reduction requirements to 2050 are expected to come from technologies already in commercial deployment (e.g. renewable energy, electric cars, heat pumps), albeit some at a cost premium to conventional alternatives in the short term, expected to reduce with scale. The remaining 50% of emission reductions are reliant on technologies at prototype or testing stages, yet to be deployed in volume, such as green hydrogen, biofuels, carbon capture and storage (CCS), particularly focused

on decarbonising heavy industry. All would require accelerated innovation, R&D and policy focus to reach net zero, and the share/scale of their deployment is likely to vary globally, influenced by resource availability, industrial strengths and geopolitics (sources: Breakthrough Energy Ventures, IEA).

Q: What technologies are the most likely or urgent in the short term?
A: Energy & transportation are likely to come first. Why? Economics, not climate change. Exponential cost reductions in wind (-53%) and solar (-89%) in the past decade have made their deployment the cheapest form of energy in countries with 2/3rds of the global population and 90% of world electricity generation. EV battery costs fell 89% too, bringing cost parity with internal combustion engine (ICE) vehicles by 2024 or sooner (BNEF). Renewable energy and electrification of transport are expected to be deployed at scale given their relative maturity – as high as 9-14x additional energy generation capacity would be necessary in 2020-2030, and >60% of global car sales would need to be EV by 2030 to reach net zero by 2050 per IEA.

Q: Will geopolitics get in the way?
A: Bold COP26 climate action plans could dramatically alter the global geopolitical balance. A fast transition to electric vehicles could impact or even destabilise oil-sensitive economies. A renewables surge could affect regions dependent on coal & gas exports, while a shift to more vegetarian diets could impact farming and the political landscape globally, not to mention costs and growth rates which some EMs cannot afford. Regionally, we note that both the US and China are the global leaders in investment in clean energy, as the world's largest two economies are engaged in a competition for climate leadership. Strategic competition for climate leadership between China and the US should help drive global emissions down, but keep in mind local politicians in the remaining 193 countries – and their constituents – will also have to be willing and able to embark on the net zero journey.

Q: Are we heading to resources scarcity, when heading to achieve Net Zero?
A: Only with a combination of recycling, and more efficient extraction and supply chains. Only 70% of the lithium required to 2030 is available with current supply for example: more mining and recycling will be required. Also, there is geopolitical risk given the concentration of production: >75% of lithium, cobalt and rare earth production is in three countries, and refining of critical materials is currently dominated by China (>90% of rare earths for example).

Q: How will net zero impact business and consumers?
A: The majority (60%) of emission reductions will require the active involvement of consumers/businesses (e.g. switching to electric cars, heat pumps), with a further 10% expected from behaviour change (e.g. switching modes of transport, reducing excessive energy use, materials efficiency gains and higher recycling). The remaining 30% would come from low-carbon energy/fuels requiring less or no input from consumers, such as increasing share of renewable energy generation feeding national grids.

Q: What could go wrong?
A: Further challenges remain: 1) achieving the level of behaviour change required in sufficient time (policy measures are needed); 2) the lack of global compliance and consensus on a carbon price and how to enforce it; and 3) how to monitor emissions and reduction globally to track progress. More positively, innovations in satellites, blockchain for traceable supply chains, and regionally deployed policies, such as the EU's carbon border adjustment mechanism, are all steps to mitigate those risks.

Did you know?

- To keep within 1.5°C would require a 50-80% reduction in CO2 emissions by 2050 [1]
- 85% of the gap to reach the 2030 requirements per the Paris Agreement remains [2]
- The energy transition to a net zero economy by 2050 will cost $150tn in total over three decades... as much as the entire US tax base every year, for 30 years [3]
- But everyone will chip in – among the financial systems, central banks' balance sheets and private markets, there is plenty of scope to increase current funding of $500bn a year [4]
- At the macro level, the inflation impact will not be insignificant, but it looks manageable at 1% to 3% per annum depending on central bank monetization rates [4]
- The green energy transition could contribute to accelerate the rate of global GDP growth by 0.3% to 0.5% per annum [4]
- To get to net zero, the share of electricity in power consumption could rise from 20% to 50% of energy requirements, requiring 70-122TWh of electricity generation depending on the mix of end-uses [1]
- Running into resources scarcity: an electric vehicle has 6x more mineral input than a combustion engine alternative, and an onshore wind plant requires 9x more mineral resources than a gas-fired power plant [3]
- Recycling is a must. Moving to EV means nickel and lithium, for example, could be in deficit in 2024/2026 [5]
- For lithium, cobalt and rare earth elements, the top three global producers control >75% of current output of the materials: Australia, DR Congo and China [3]
- The concentration is even higher for refining & processing operations where China dominates across the board, with a share of 35% of nickel, 50% of lithium, 70% of cobalt and 90% of rare earth elements in 2019 [3]
- Of all industry sectors, Technology has the most full Scope 1-3 commitments (51% of companies), and Construction the lowest (8%) [3]
- But Tech ranks among the worst of the Service/Consumer sectors when looking at Scope 3 emissions [6]
- A single Bitcoin purchased for ~$50,000 has a carbon footprint of 270 tons, the equivalent of 60 ICE cars [7]
- 2021 is on track for a record ESG influx, with $3 of every $10 of flows into global equities going into ESG [4]

- P/E multiples for companies with top quintile MSCI ESG scores have risen from as low as a 20% discount to bottom quintile peers historically to a 25% premium today [4]
- The cost of equity for companies with the highest ESG scores based on MSCI is 120bps or 10ppt lower than poorly-ranked peers [4]
- The average coupon for new energy issuance in 2021 is now 70bps higher than for overall USD investment grade issuance despite similar ratings [4]
- In a recent survey, 37% of EM respondents see themselves reducing exposure to oil & gas in the next three years – oil & gas represents 20% of their index! [4]

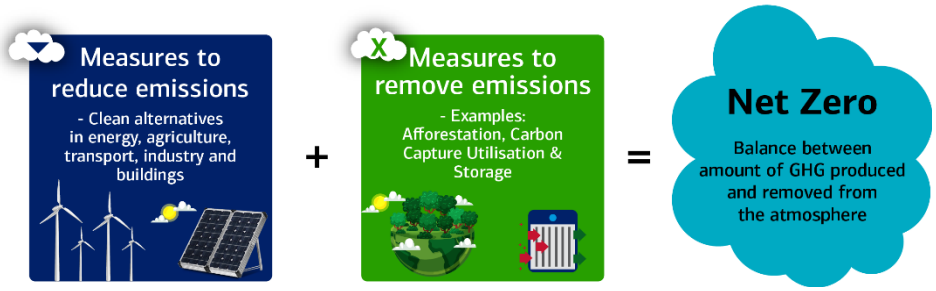
Sources: [1] *IEA, BNEF,* [2] Climate Action Tracker, [3] *IEA,* [4] BofA Global Research, [5] *BNEF, Roland Berger, IEA,* [6] ICE Data Services LLC, BofA US Equity & Quant Strategy, [7] *EPA, CBECI, BofA Global Research estimates*

What is net zero?

What is Net Zero? The balance of reducing *and* removing emissions

A number of academic and research studies are emerging, demonstrating potential pathways to keep global warming within 1.5°C. All require rapid reduction in greenhouse gas emissions, notably reaching "***net zero***" by 2050. Net Zero is a measure of carbon neutrality through a balance of eliminating and removing carbon emissions from the atmosphere. The word "net" is the key. This means that whilst eliminating emissions to zero would be ideal, not every activity has to be zero emission to be compliant in a net zero economy. However, those that continue to emit greenhouse gases would need to be captured and removed from the atmosphere.

Exhibit 2: Net Zero: a measure of carbon neutrality by reducing *and* removing emissions
To achieve net zero requires a combination of reducing direct emissions and/or removing them from industrial activity or atmospheric emissions with nature or technology based solutions



Source: Green Match, BofA Global Research

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Good COP / Bad COP? What is COP26, and what is expected?

The United Nations hold a Climate Change Conference every year attended by the ~200 country members of the UN's Framework Convention on Climate Change. Referred to as the Conference of the Parties (COP), this year being the 26th such conference. Countries negotiate and commit to levels of emissions reductions, and how they'll be financed and implemented. The country emissions reduction pledges ("Nationally Determined Contributions", or NDCs) were launched in 2015 at COP21 in Paris, where countries agreed to review and update them every five years, with COP26 being the first such update due. Thus, the success of COP26 will be determined by the levels of country commitments to reach net zero, the specific policies and finance that will be mobilised to achieve it. What's expected from COP26 (per the official COP26 website):

1) **The What: Net Zero**: Countries are due to submit 2030 emissions reductions targets to remain on track to achieve net zero by 2050. Several nations have already pre-announced their targets such as China (committing to peak emissions by 2030 and net zero by 2060, announced September 2020), and the most recent pledge from the UAE to reach net zero by 2050 (October 2021).

2) **The How: Climate Action**: To deliver the mid-long dated targets, specific policies and actions are expected, many of which are due to be announced and publicised at or ahead of COP26, specifically accelerating the phase out of coal, curtailing deforestation, speeding up the transition to electric vehicles, and encouraging investment in renewable energy.

3) **Climate Finance**: In addition to funding their own targets, developed nations committed in 2009 to mobilise $100bn per year to emerging markets on climate action by 2020; per the OECD's latest figures (2019), $80bn was spent, with COP26 expected for nations to increase the figure to bridge the gap, as well as begin negotiations for the next financing milestone and how it can be delivered (e.g. via aid, grants and trade). The UN's Environment Programme estimate adaptation costs alone in developing countries will reach $140-300bn

by 2030, and $280-500bn by 2050. Africa alone could require $3tn climate action investment by 2030 (source: Climate Policy Initiative).

Where do we stand with climate change?

A combination of accelerating temperatures in recent decades (increasing the frequency and impact of extreme weather events), more comprehensive scientific research into the effects of climate change have amplified the call from the public, governments, investors and corporates to take action to mitigate the potential impacts and costs. To do so, pathways to 'net zero' emissions are being proposed or in some cases legislated by governments and corporates at an increasing rate and pace, with the goal of eliminating or removing emissions to have zero further release of greenhouse gases into the atmosphere. Most commit to doing so by 2050, but have short term economic, social and political implications to all industry sectors. To achieve it will require a combination of policy, accelerated deployment and investment in clean technologies – not all of which are ready to be deployed at scale immediately, and behaviour change from several parties. Whilst not yet on track to achieve net zero (per Climate Action Tracker), increased national and industry pledges in the build-up to the United Nations 26th Climate Change Conference (COP26) in October 2021 are reducing the gap.

Current State of Climate: Warming world and extreme weather

The UN's Intergovernmental Panel on Climate Change (IPCC) 6th assessment report released in August 2021 gave a detailed scientific account of the worsening state of climate change. This highlighted in summary: 1) the last decade was hotter than any period in 125,000 years, 2) scientists can now link specific weather events to human made climate change, and their frequency is set to increase, 3) at the current rate of emissions, the carbon budget (volume of CO2 emissions to limit global warming to 1.5℃ as set out in the Paris Climate agreement) will be exceeded within a decade at the current rate of emissions, 4) reaching net zero emissions by 2050 could stabilize temperatures thereafter, but some effects such as sea level rise could remain irreversible.

IPCC Climate Assessment Report 6: Strong & Rapid GHG reductions required

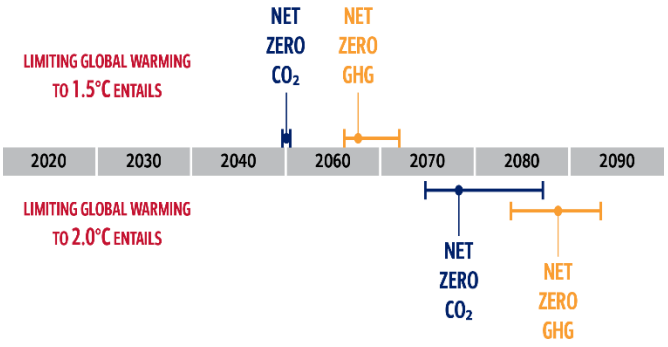
"Recent changes in the climate are widespread, rapid, intensifying and unprecedented in thousands of years. Unless there are immediate, rapid and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C will be beyond reach.

It is indisputable that human activities are causing climate change, making extreme climate events: heat waves, heavy rainfall and droughts more frequent and severe. Climate change is already affecting every region on Earth in multiple ways. The changes we experience will increase with further warming.

There is no going back from some changes in the climate system, however some could be slowed and others could be stopped by limiting warming. To do so, strong, rapid and sustained reductions in CO2, methane, and other greenhouse gases are necessary to reduce the consequences of climate change and improve air quality".
IPCC 6th Assessment Report, August 2021.

Exhibit 3: To limit global warming to 1.5-2°C requires reaching net zero by 2050/2070

The goal of reaching a net zero emission economy by 2050 would require immediate action this decade to reduce CO2 and other greenhouse gas emissions



Source: IPCC, World Resources Institute

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Financial Risks of Climate Change: $69 trillion even if within 2°C

The IPCC project that the remaining CO2 emissions (or "carbon budget") that could limit global warming to 1.5-2°C would be around 500 and 1,350gt CO2 respectively. This implies that at the current annual emissions of 42gt CO2, it would be reached in 12 and 32 years respectively. Even with the significant emissions reductions required to maintain within that range, Moody's estimate a financial cost of $54-69 trillion cost to the economy by 2100 resulting from health, water, air quality and extreme weather related damage. Exceeding this level of global warming could lead to costs far higher; in excess of $150 trillion by 2100 per Nature Communications.

What would be required to decarbonize our planet?

Unprecedented shift to new & emerging Cleantech

Achieving the scale and pace of transformation net zero would require a new industrial revolution with existing and new technologies deployed for both energy and fuel production, and end use applications/industries dependent on it. These two areas both require substantial investment, technological and behaviour changes to transition to zero carbon alternatives at scale, raising several policy, economic challenges as to the most efficient pathway. We outline the potential scale of clean technologies required based on various sources, and arising debates/choices.

Energy Production: Clean Electricity a given; the balance of hydrogen, nuclear, bioenergy and Fossil with CCS uncertain

Clean Energy Volumes for a Net Zero world?

Electricity: share of final energy consumption rises from 20% in 2020 to 49% (IEA), requiring ~71TWh electricity (+3x vs 2020);

Hydrogen: adding a significant share of green hydrogen for energy use, would almost double the electric requirement to 122TWh (assuming 40% of total energy

from green hydrogen, per BNEF); annual hydrogen demand could grow from ~90mt per year in 2020 to between 500mt (IEA) and 1,300mt (BNEF) per year

Wind & Solar: whilst it took 20 years to reach 1,000Gw installed solar/wind generation capacity, reaching net zero could require 1,400Gw additional capacity **every year** 2020 to 2050; total renewable installed capacity required in 2050 could be between 27TWh-42TWH, 9x and 14x 2020 levels respectively (sources: IEA, BNEF)

Battery energy storage: up to 3TW of battery storage would be required to balance renewable energy supply and demand in 2050 to offset the risk of intermittent energy (+172x vs the 18Gw installed in 2020), sources: IEA, BNEF)

Nuclear: to provide predictable reliable base energy, annual nuclear capacity additions could rise to >24gw annually 2030-50, (triple that of 2010-20) to rise from 5% of total energy to 11% of supply in 2050. New technology such as Small Modular Reactors (SMR) could enable this more cost effectively than legacy infrastructure.

Fossil Fuels: decline from 79% of total energy supply in 2020 to between 10% (BNEF) and 22% (IEA) in 2050; implying coal peaked in 2015, oil in 2019, and gas peaks in 2027 (BNEF).

CCS: as such, Carbon Capture and Storage (CCS) technologies could rise 190x vs 2020 to capture 7.6gt CO2, 90% of which from the remaining fossil fuel activity; reducing fossil fuel use would as such reduce CCS requirements, but ~1gt of direct air capture may still be required for abating fossil/historical emissions (IEA)

Key Debates that this creates:

How can total energy supply be flat or less in a growing population/economy? 1) Doubling the rate of energy efficiency from 2% to 4% yielding more output for less input, and 2) switching to energy with overall higher efficiency (direct electrification where possible).

Can renewable energy power ALL our global needs? Theoretically yes (per MIT, the sun alone produces 173 quadrillion watts of power, 10,000x global power generation's current needs), but challenges are how to harness and store that energy cost effectively to ensure available energy at all times, meaning 1) the scale of generating capacity would be vast, requiring significant additional infrastructure and land use to accommodate the US, and 2) the sources are variable/intermittent (10-25% variability for Solar, 30-40% wind) requiring technologies to balance energy supply and demand.

What can mitigate against intermittency of renewable electricity? Utilising additional energy storage with batteries (higher efficiency, limited capacity/duration), or via clean molecule-based alternatives such as hydrogen or ammonia derived from it (lower efficiency, longer duration, better for seasonal storage), or retaining a minimum base energy from other zero carbon alternatives such as nuclear or fossil energy with CCS if proven.

Why not use electrification for all energy needs? Some sectors or end-use applications are harder to switch to electrified alternatives owing to cost or technical/equipment limitations. Road transport (battery/fuel cell EVs), and heating buildings (green hydrogen and/or electric heat pumps) have viable alternatives albeit at early stages of deployment. Shipping/aviation (owing to range/weight limitations of batteries) and industrial sectors pose the biggest challenge. Where fossil fuels are used for heating and as a feedstock raw material

into their processes, they perform an ancillary purpose that's harder to replace with electrification alone, without engineering and equipment advances (for example steel, cement, glass and petrochemicals production). Alternative equipment (such as electric arc furnaces) and feedstocks are at an early development stage, with fossil fuels required in the interim.

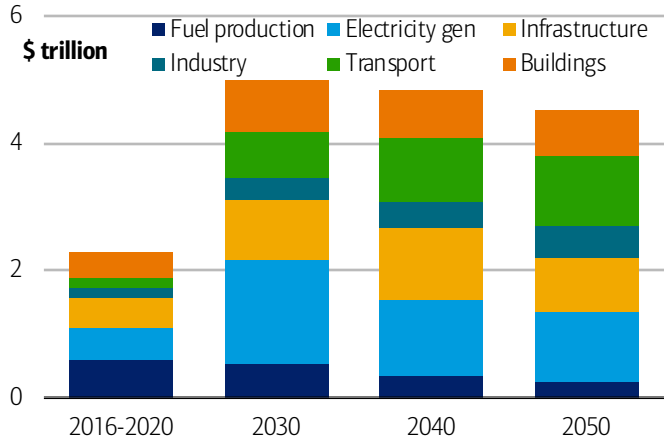
Why doesn't fossil fuel use go to zero in all net zero scenarios? Assumptions vary over 1) the level of baseload despatchable fossil energy required that can deliver power instantly and how it can be replaced, 2) the scale and viability of CCS technologies to abate emissions from fossil energy extraction, and 3) the viability technologically and economically of alternatives such as hydrogen.

What might Net Zero cost? Can we spare 0.4% GDP per year to save the planet?

The IEA's Net Zero scenario would require a $5tn annual energy sector investment by 2030 – double that of the average 2016-20 spend of $2.3tn – but reducing to $4.5tn pa by 2050, owing to the higher share of capex required upfront to fund the growth in electricity systems. This would represent an additional 0.4% GDP growth each year or 4% by 2030 – adding an economy the size of Japan to the global economy if such scale of investment was mobilised. The annual/total investment requirements vary in alternative net zero pathways based on the mix of energy production and consumption assumed. BNEF for example estimate delivering net zero could cost range between $92tn and $173tn (or $3.1-5.8tn per year on average between 2020-2050), with lower cost options utilising more existing fossil fuel assets with carbon capture technologies, compared to the most expensive scenarios more weighted to renewable energy and green hydrogen.

Exhibit 4: Annual capital investment required on the path to net zero

The IEA has recently suggested that economic sectors will have to invest trillions of dollars to decarbonize: doubling current energy spend per year



Source: International Energy Agency (2021), Net Zero by 2050, IEA, Paris

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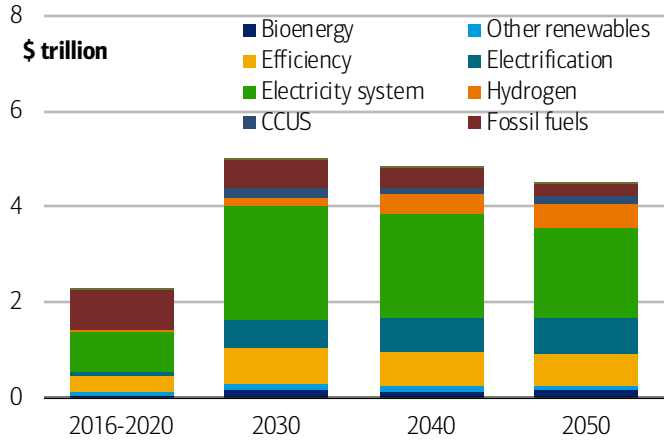
Exhibit 5: Annual capital investment required on the path to net zero

The majority of the investment will target electricity systems and electrification of activities



Source: International Energy Agency (2021), Net Zero by 2050, IEA, Paris

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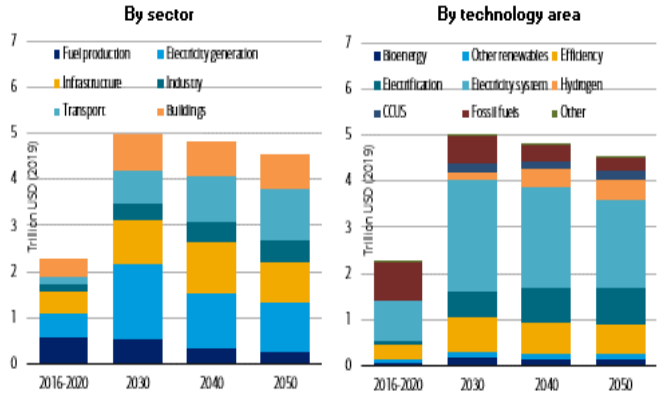
The electricity generation and transportation sectors will likely lead with the biggest investments to decarbonize over the next 10 years. The focus will then shift to harder to abate sectors as the solutions to decarbonise become more viable and economic: infrastructure and industry between 2030-40, and the agricultural sector investment skewed more heavily in the 2040s to achieve the net zero emissions targets per IEA. Looking at the breakdown of expenses, the majority of the investment will likely target electricity systems and the electrification of various human activities, with hydrogen gaining ground into the 2040s.

Exhibit 6: IEA: Energy spend doubles to $5tn pa to reach Net Zero
Widespread clean energy production and infrastructure spending would be required for net zero, increasing annual energy spend to $5tn by 2030, $3tn of which electricity related (vs $0.9tn in 2016-20)



Source: International Energy Agency (2021), Net Zero by 2050

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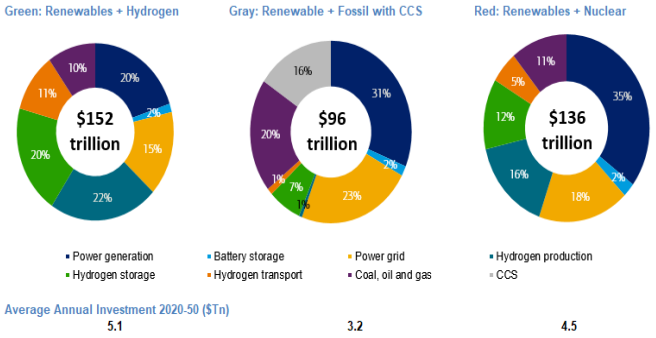
Exhibit 7: BNEF: $3-5tn pa depending on hydrogen/nuclear/CCS mix
Varying the mix of hydrogen, CCS and nuclear in the energy mix ranges the investment required from $96-$150tn 2020-2050 as the mid-point of net zero scenarios but could reach as high as $173tn, $5.8tn pa to 2050



Source: BlooombergNEF; cumulative spend to reach net zero ($tn) in three alternative scenarios

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