The Great Reallocation

Capital expenditure on energy production

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1. Executive Summary

Contrary to popular belief, the buildout of renewable energy supply does not require a surge in capital expenditure (capex). As fossil fuel capex falls, the net growth in capex is only 2% a year, in line with the past seven years, and much lower than in the decade after 2000.

Mainstream framing compares apples and pears. The standard formulation by the International Energy Agency (IEA) or the International Renewable Energy Agency (IRENA) is that a surge in capex is required to build the renewable energy system.[1] However, they include the growth in end-use capex for renewables but not the decline in end-use capex for fossil technologies. To compare like with like we restate the data to look only at capex on energy supply.

The great reallocation. Energy supply capex on renewables and fossil fuels in 2023 was about the same, at US$1.1 trillion each.[i] Over the next seven years, renewable capex will roughly double and fossil fuel capex will roughly halve under the core IEA scenarios of Announced Pledges (APS) and Net Zero Emissions (NZE). Falling fossil fuel capex will therefore provide half of the growth in renewable capex.

Growth in renewable capex. Renewable capex has been growing at 6% a year since 2015, and to get to the IEA's APS scenario of $1.8 trillion in 2030, capex will need to grow at 7% a year. Given the superior economics of renewables, that seems very achievable.

Decline in fossil fuel capex. Fossil fuel capex has been falling at 3% a year since 2015, and to get to the IEA's APS scenario of $0.7 trillion in 2030, capex will need to fall at 5% a year. In light of the increasing evidence of peaking of fossil fuel demand, that seems reasonable.

We have the money. Total 2030 energy supply capex under the APS scenario is $2.5 trillion, which would require annual growth in capex of 2% from 2023 levels of $2.2 trillion, lower than expected GDP growth of 3%, and lower than the annual increase in energy supply capex from 2000–2010 of 9%. Meanwhile, global capital formation in 2022 was $27 trillion, so the additional capex of $360 billion is only 1% of global capex.

Why is change possible. The falling cost of renewable technologies and the decline in fossil fuel capex help smooth the path to the transition. Meanwhile, fossil fuel companies are paying out high dividends,[2] and this helps investors reallocate the capital.

Most of the growth happens this decade. The main increase in renewable capex will take place this decade, stabilize in the 2030s and then fall back as capex moves from expansionary to maintenance.

There is still work to be done. The key now is to ensure that capex moves from generation to grids, and from developed markets to emerging markets. The primary impediments to change are policy and expertise rather than the volume or availability of capital.

Why does this matter? The transition to a more distributed, secure, low-carbon energy system is coming and the capital requirements are far more manageable than orthodox analysis suggests.

[i] All currency in this report is in US dollars.

2. Problems with the Standard Analysis of Capex

The mainstream framing of capex in the energy transition is that a huge surge of capital expenditure is required to drive the transition. The implication is that the transition is expensive, and it will be difficult to find the money. However, this framing is misleading, as we show below.

There are a number of issues that conventional analysis faces: not comparing like with like; not having a fair point of comparison; taking a conservative view on future renewable costs despite substantial contrary evidence; modeling excessive complexity; and continuing to emphasize business-as-usual (BAU) scenarios after years of incorrect forecasts. Analysts also tend to use capex as a proxy for cost, which is misleading.

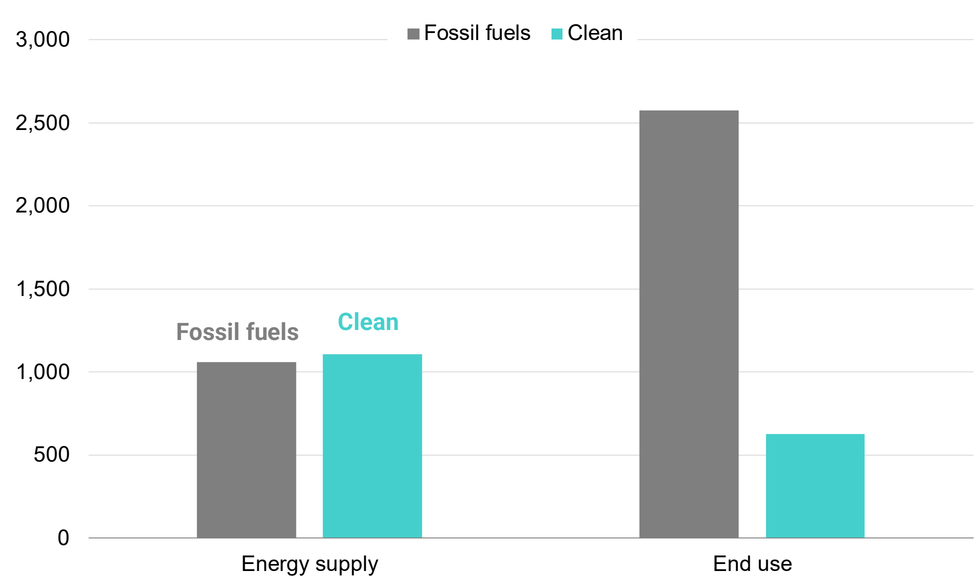
As a starting point we take IEA data for 2023 as published in their World Energy Investment (WEI) analysis.[3] The issues we identify are not universal among all analysis, but it is important to be aware of them.

Not comparing like with like

There are four main areas of capex in the energy transition:

- Clean energy supply. Solar panels, grids, and so on. $1.1 trillion in total in 2023.
- Fossil fuel energy supply. Oil and gas wells, refineries, and coal power stations. Just under $1.1 trillion in 2023.
- Clean energy end use. Efficiency, EVs, electrification. $0.6 trillion in 2023 according to the IEA.
- Fossil fuel end use. Internal combustion engine (ICE) cars, boilers, and so on. $2.6 trillion for those sectors (mobility, buildings, steel and cement) which McKinsey analyzed in detail in 2020.[4]

Exhibit 1: Capital expenditure 2023E



Source: IEA for energy supply and clean end-use capex in 2023, McKinsey for end-use capex for mobility, buildings, steel, and cement in 2020, RMI assumptions on the share from fossil fuels.

The standard approach used by the IEA and IRENA counts fossil fuel and clean supply capex but only clean end-use capex, and not fossil fuel end-use capex. In the New Energy Outlook, BNEF includes EV in its clean energy capex but does not include ICE cars in the fossil fuel capex.[5]

However, the capex on fossil fuel end-use devices (ICE cars, boilers, and so on) is the largest part of the system. As a result, the standard approach counts rising capex on clean energy but not falling capex on fossil fuel energy.

Not using the right point of comparison

The second error is to take a point of comparison which is not reasonable. For example, a McKinsey report in 2021,[6] adds up all the capex required for energy and agriculture over 30 years and compares it to capex today. It merits quoting in full: "Capital spending on physical assets for energy and land-use systems in the net-zero transition between 2021 and 2050 would amount to about $275 trillion, or $9.2 trillion per year on average, an annual increase of as much as $3.5 trillion from today."

However, this is an unfair comparison because GDP and energy services are both growing, and energy capex would grow in either a clean or a fossil fuel-based system. An accurate comparison would be with a BAU scenario, not with the present. We find out only later in the report that the gap between a BAU scenario and an energy transition scenario is, in reality, only $1 trillion a year.

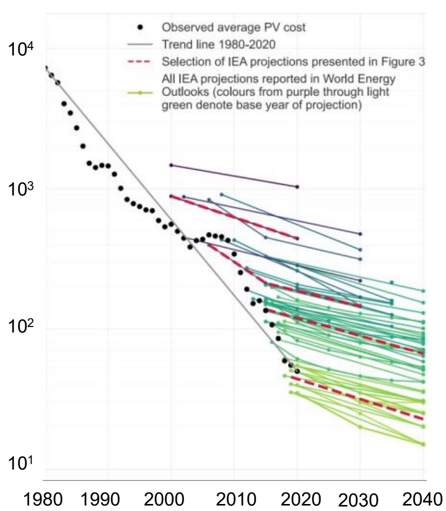
In addition, there is of course the longstanding point that conventional analysis does not include the externality costs of global warming and pollution.

Understating cost falls

Year over year, mainstream forecasts have overestimated future renewable energy system costs. A key reason is the frequent failure to include learning rates. As set out by Oxford academics,[7] the learning rate describes the process whereby the cost of core renewable technologies like solar or batteries falls by around 20% for every doubling of deployment.

The IEA for example has consistently underestimated future solar costs as in the chart from Oxford INET.

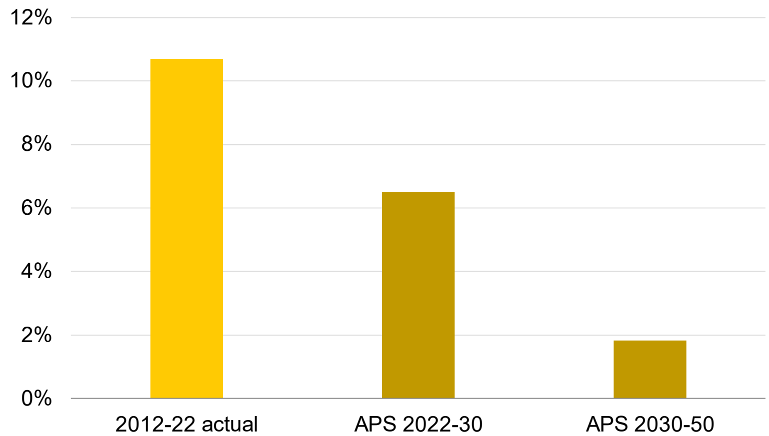
Exhibit 2: IEA forecast solar costs levelized cost of energy $/MWh



Source: Oxford INET

Solar capital costs have been falling at 11% a year for the past decade according to BNEF. In the APS scenario, the IEA expects cost falls to reduce to 6.5% a year this decade and then to below 2% a year after 2030.

Exhibit 3: Annual decline in solar capital cost per MW



Source: BNEF (past), IEA APS for US and China forward

Moreover, it is likely that the forecast costs of grid expansion are too high. Grid enhancing technologies, digitization, and lower electricity demand growth because of efficiency are all likely to reduce expected capex.

Assuming technology stagnation

The larger and longer the scope of the model, the more the assumptions that need to be made. Modelers are asked to model the likely incremental capex on steel machinery in 2050 in a renewables versus fossil fuel scenario. Or to calculate spending on CCS plants in 2050 without realizing that technology evolution is likely to mean that few of them will be needed.

Moreover, modelers often use 2023 solutions to solve endgame problems such as how to provide the last 10% of electricity generation in a renewable based system. This leads them to include large amounts of capex for hydrogen and CCS, when in reality we are more likely to have superior solutions with technology driven learning curves like demand side response and electrification. Theoretical solutions based on today's technology to solve future problems tend to be very expensive. In practice, we will figure it out as we go along.

In reality, modelers struggle to forecast costs and system structures after 2030. The result is that it is very easy to get lost in the technical complexity of the models.[8]

Using business-as-usual (BAU) scenarios

Many forecasters have BAU scenarios which they take as their central framing. For example, the IEA has the Stated Policies (STEPS) scenario.

However, in a world of rapidly falling renewable costs and rapidly rising policy pressure, BAU scenarios are no longer credible. They are best seen as a normative scenario — useful to inform us of what would happen if we failed to act.

For example, under the IEA STEPS scenario, renewable capex in 2030 is projected to be about the same as it was in 2023. For a technology enjoying rapid growth, low costs, rising political support, and significant potential, that is simply not credible.

Overstating the significance of capex

It is inaccurate to compare capital costs on fossil fuels and on renewables without some very serious qualification. There are three main weaknesses in a direct comparison:

- **What share of the capex is captured**. The fossil fuel capex that is captured in the IEA analysis is only 31% of spending on oil and gas. But it is over half of renewable costs.
- **Maintenance capex is not the same as growth capex**. It is not fair to compare the maintenance capex of the fossil fuel system with the expansionary capex of the renewable system. Fossil fuel demand has peaked and we are bouncing along a plateau. If there is no growth, it follows that, at a system level, all capex is in fact maintenance. Equally, the renewable system is being built out. Almost all capex on generation for example is expansionary.
- **Commodity capex is not the same as technology capex**. As Oxford INET have shown,[9] the cost of fossil fuels has not changed over time; in short, technology gains have been offset by decline rates and the need to exploit ever more complex reserves. In contrast, the capital cost per unit of renewables falls over time as the result of the learning curve.

Fossil fuels

Capital expenditure that we capture in standard analysis is only part of the costs of the fossil fuel system. Others include profits paid to fossil fuel producers (calculated by the IEA to be $2-4 trillion every year[10]), subsidy costs (calculated by the IMF to be $7 trillion in 2022, including pollution and global warming costs of $4 trillion[11]), and the capital expenditure on the railways, ports, ships, and trucks that are needed to ferry around 15 billion tons of fossil fuels every year.

The IEA shows us for example in the 2023 net zero roadmap that capital costs of $1.1 trillion are only 31% of the total spending on oil and gas of $3.5 trillion.[12] Given that fossil fuel demand is stagnant, it would be more reasonable to take the annual fuel cost as the cost of the fossil fuel system.

Renewables

Capital costs make up a much larger share of the total renewables cost because solar and wind do not need to be shipped from one of the globe to the other, freeing up both money and emissions. Moreover, all the costs of building out the renewable system are clear today, while a large amount of fossil fuel costs have already been incurred.

For example, the IEA calculated that in the United States 53% of the levelized cost of energy of a utility-scale solar plant is capital equipment and a further 27% is financing costs.[13] Only 20% is operational costs.

Comparison

As a result, it is not fair to compare the capital costs of fossil fuels with renewables. The captured capital costs of fossil fuels are only the tip of the iceberg.

3. How to Simplify Capex

We suggest an approach to calculating capex that streamlines the calculations and improves accuracy. The adjustments are not difficult and can be made direct from the IEA data. The solution is to separate out end-use capex, and divide the energy supply capex into fossil and clean. Below, we use the IEA APS scenario to demonstrate the difference in what that means for required investment by 2030.

Separate capex on energy supply from end use

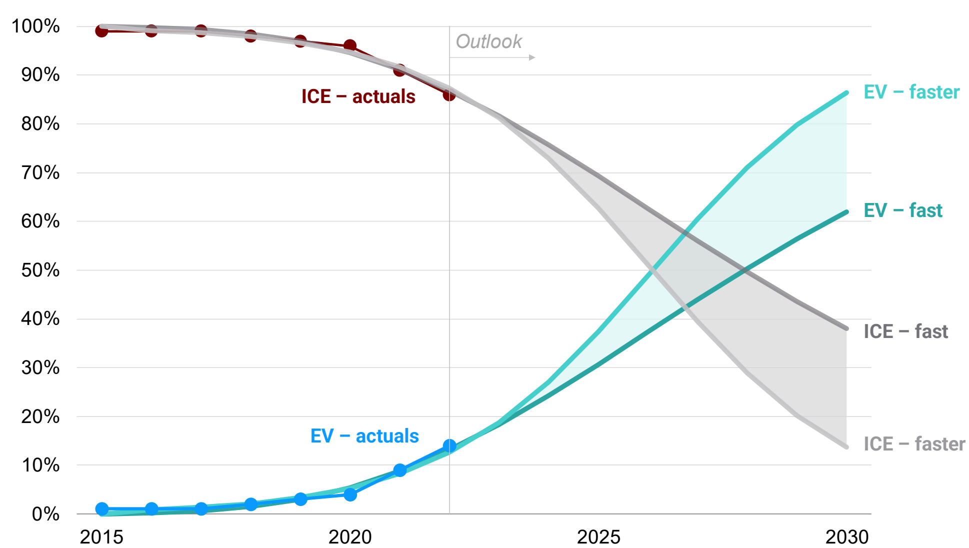
There are two main areas of capex that we propose to separate out in this analysis: efficiency ($380 billion in 2023) and end-use capex ($250 billion in 2023).

Efficiency capex is best seen as a normal cost of doing business. As the majority of the energy system today is based on fossil fuels, it is likely that much of it will be spent on optimizing their use.

End-use capex is so complex that we believe it is best understood and analyzed separately. As a general point it may turn out that spending on renewable end-use capex is not higher over time than spending on fossil fuel end-use capex.

A classic example would be the car sector. Models from a decade ago assumed that EV costs would be higher than ICE costs. Increasingly, models now assume EV have already reached (in China) or will shortly reach price parity. To a large degree this is simply a case of replacing one capital cost with another. Once capital costs are similar, the difference between fossil fuel and renewable-based solutions is simply a question of replacement of the old by the new — also a reallocation story. The chart below of EV and ICE market share illustrates the point.

Exhibit 4: EV and ICE market share



Source: RMI X-Change: Cars[14]

Split energy supply capex into fossil and clean

The second adjustment is to split energy supply capex into fossil and clean capex. This involves a relatively small tweak to the IEA data because they split into capex on fuel (with a small amount of clean capex) and power (with a small and falling amount of fossil capex).

- Fuels: Clean fuels are added to the clean costs. In 2023 for example, this was $17 billion.
- Power: Fossil fuel power costs are added to fossil costs. In 2023 for example this was $98 billion.

Assume “change” as the base case

The third simplifying assumption is to take the change scenarios as the most likely because they reflect the empirical reality of technology driven learning rates. In the case of the IEA, that means the APS (Announced Pledges) and the NZE (Net Zero) scenarios.

We only look at the STEPS (Stated Policies) scenario as a normative option. The STEPS scenario is a highly improbable “what if” scenario, assuming that humanity stops innovating, stops increasing policy pressure, and abandons attempts to solve climate change and energy poverty.

Be aware of the limitations of capex

If you wish to do a holistic comparison between the costs of the fossil fuel system and that of the renewable system, then it is necessary to consider non-capital costs and restate the numbers for a steady state environment. Simply looking at capex will not give you the answer.

This will be the subject of a separate report on the total costs of the energy transition. Initial indications from the IEA and Oxford INET are that an energy transition would cost $12 trillion less than maintaining the fossil fuel system.

4. Implications of Adjusted Capex

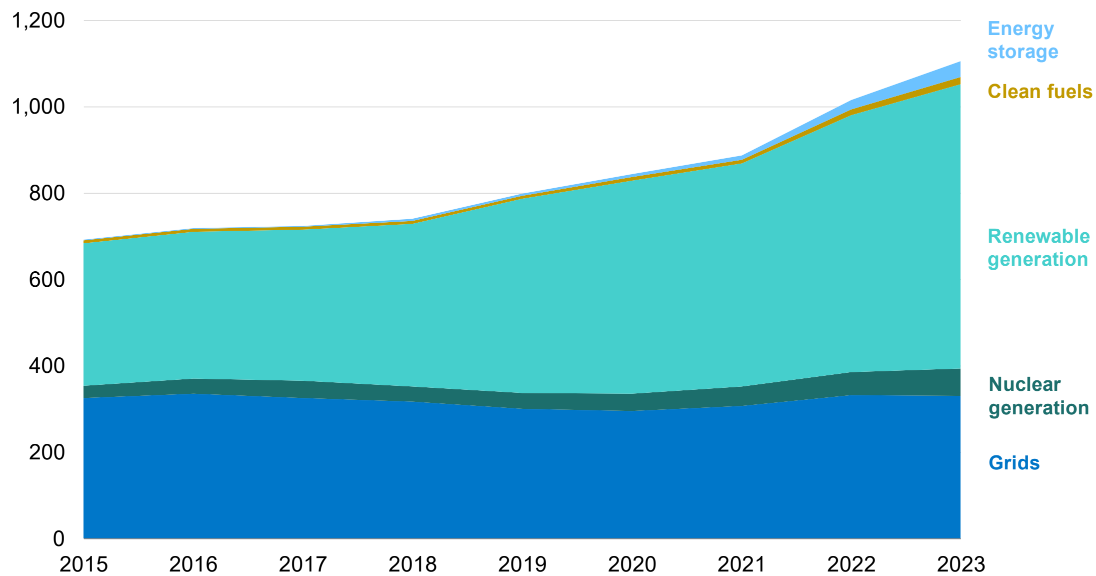
We believe the IEA's APS scenario is the most realistic starting point for analyzing the likely future of capital expenditure. Taking that as our starting point, we consider the growth of clean capex, the decline of fossil capex, and the net impact.

Clean capex growth is on track

Developments since 2015

Clean capex has been growing at 6% a year since 2015, led by capex on generation.

Exhibit 5: Capex on cleantech 2015-23 (billion $)



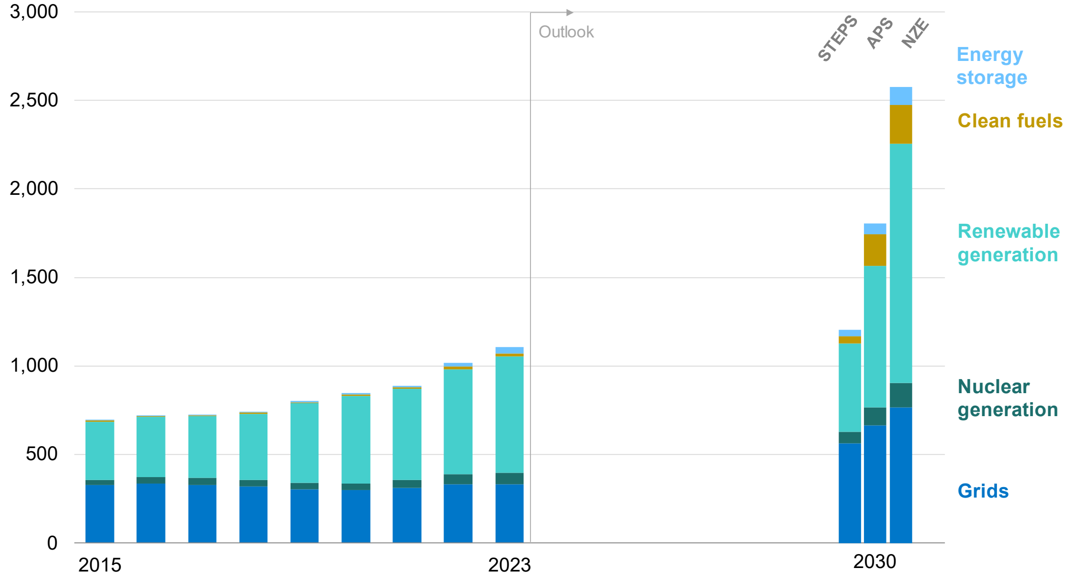
Source: IEA WEI 2023

Plans for 2030

The STEPS scenario implies essentially no growth in clean energy capex.

The APS scenario implies annual growth of clean energy capex of 7%, and the NZE implies annual growth of 13%.

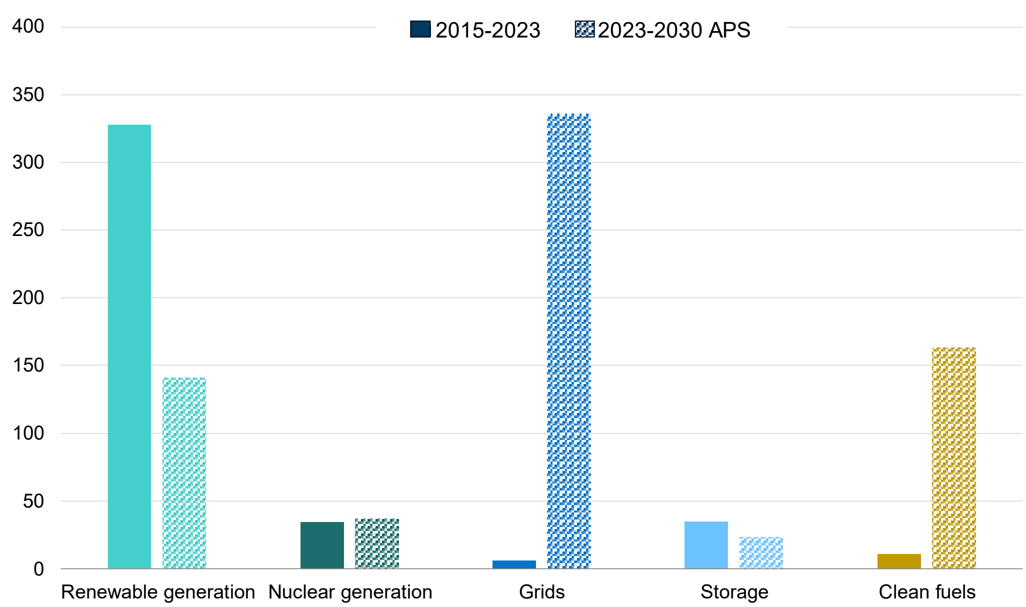
Exhibit 6: Future capex on clean energy (billion $)



Source IEA WEO 2023

There is however a change in the allocation of capital. The main driver over the past 8 years has been generation. Under the APS, this is expected to change so that the growth of capex on renewable energy generation falls, and the main driver of clean capex is spending on grids.

Exhibit 7: Change in capex 2015-23 versus 2023-30 under APS (billion $)



Source IEA WEO 2023

Two things stand out in the APS framing:

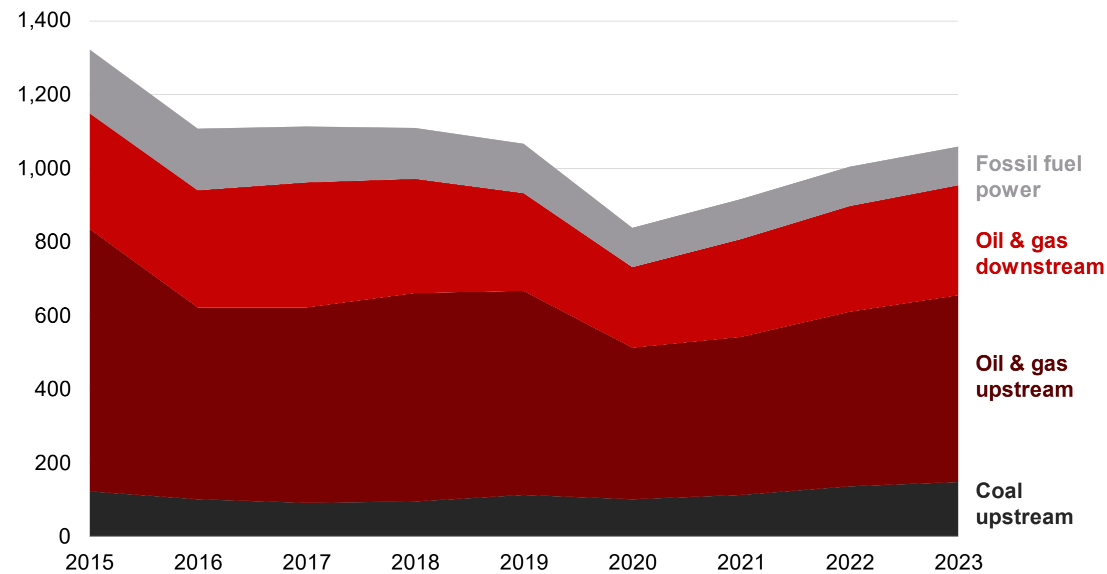
- Future capex growth in the APS scenario is 7% a year, which is only a little above the 6% growth rate we have seen for the past 8 years.
- There is however a switch in growth from generation to grids. That means it is now key for governments to get involved as they typically have a greater role to play in the modernization of grids than has been required for the expansion of generation.

Fossil fuel capex will continue to decline

Developments since 2015

Fossil fuel capex has been falling at 3% a year in the 8 years since 2015, albeit the COVID shock caused a bump in the data. As the chart below shows, 2023 capex is still below 2019 levels.

Exhibit 8: Fossil fuel capex 2015-23 (billion $)



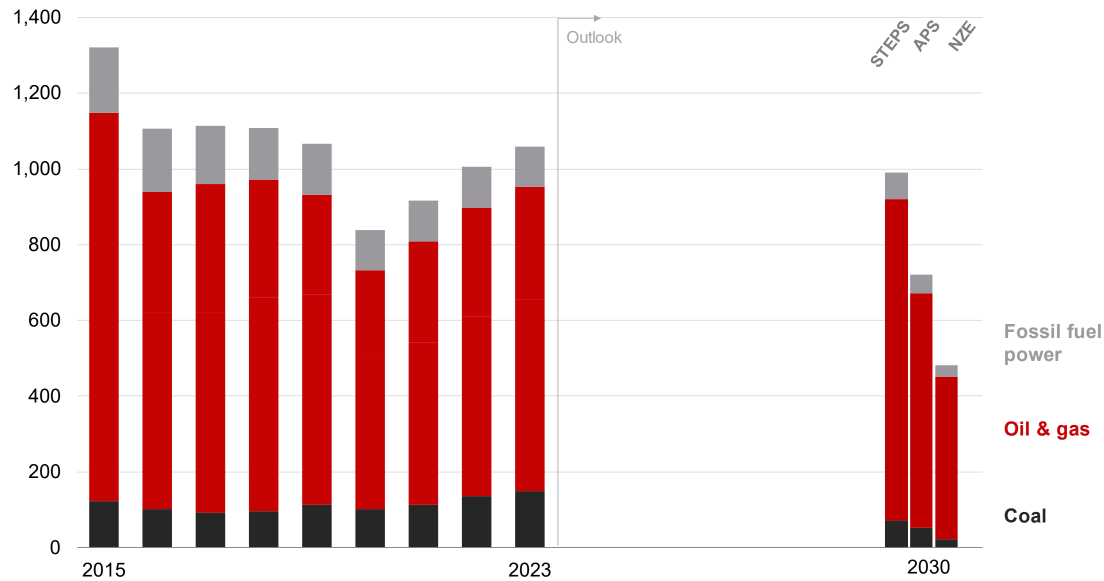
Source: IEA WEI 2023

Plans for 2030

Under the STEPS scenario, fossil fuel capex would fall by 1% a year. That then is the best the fossil fuel sector can hope for.

Under the APS fossil fuel capex falls at 5% a year. And under NZE it falls at 11% a year.

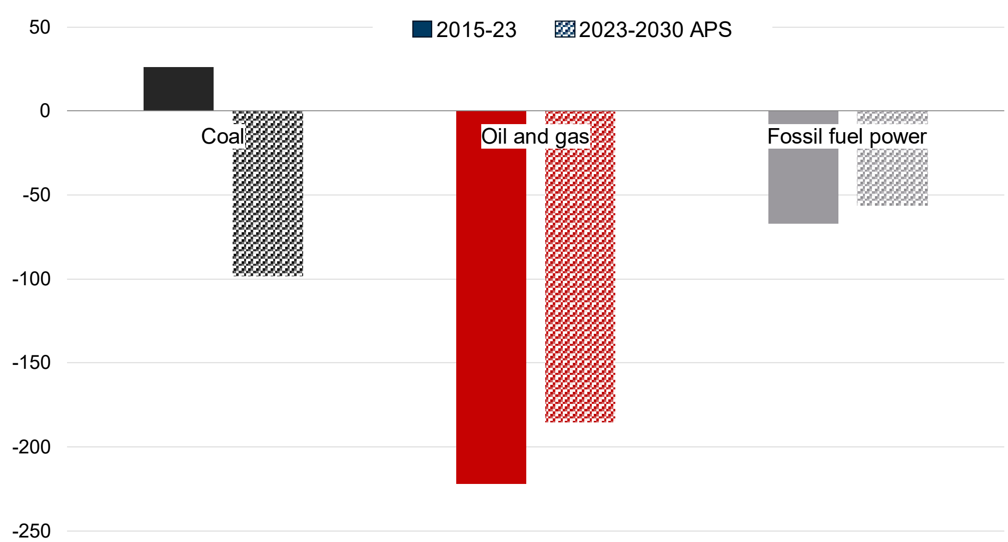
Exhibit 9: Future fossil fuel capex (billion $)



Source: IEA WEO 2023

The detail shows that the APS scenario is highly achievable, and probably understates the change. The decline in oil and gas capex under APS is lower than it has been for the past 8 years, and the change at the margin comes from coal capex moving from growth to decline.

Exhibit 10: Change in capex (billion $)



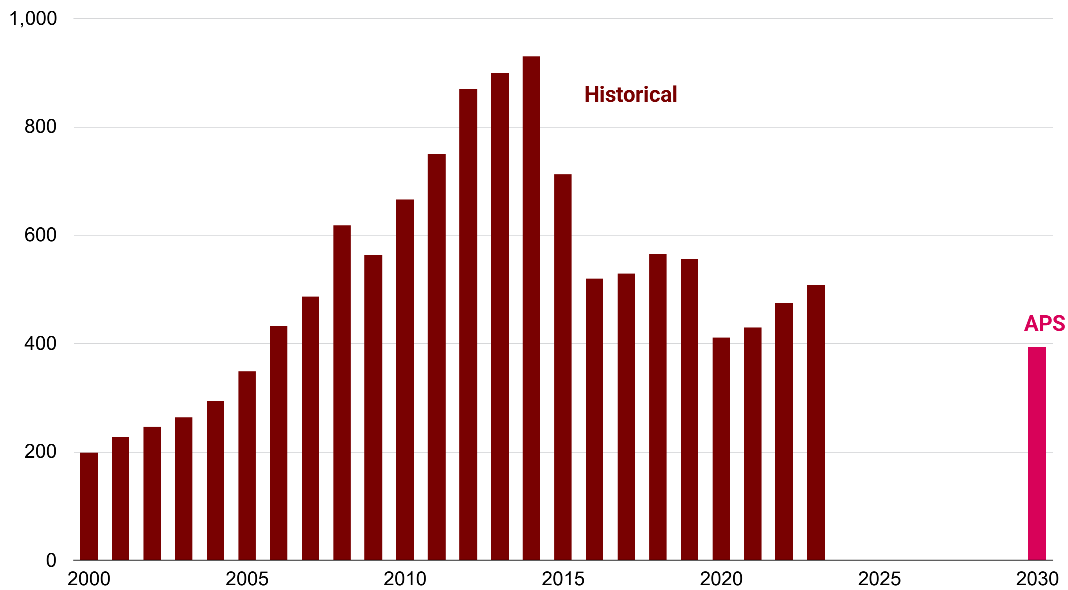
Source: IEA WEO 2023

It is normal for fossil fuel capex to decline, as the IEA has been pointing out for a while. This might be something that fossil fuel advocates might want to reflect on, as they routinely argue that we are underspending on fossil fuel capex. We are underspending if we want to return to the old world of the 2000s, but not for the new reality of the 2020s.

The fall in future capex is a little higher than in the past with an annual fall of 5% expected versus 3% before. However, this is reasonable given that fossil fuel demand is peaking. The fear of stranded assets is likely to weigh increasingly upon the appetite of investors to deploy new capital in the stagnant fossil fuel system. As the reality of peak demand becomes more accepted, fossil fuel capex is likely to fall even more rapidly.

If we look at fossil fuel capex on oil and gas upstream over the long term we see a much cleaner picture. Capex grew steadily to a 2014 peak and has been coming down in fits and starts ever since.

Exhibit 11: Oil and gas upstream capex 2000–2030 (billion $)



Source: IEA WEI 2016, WEI 2023, RMI adjustments

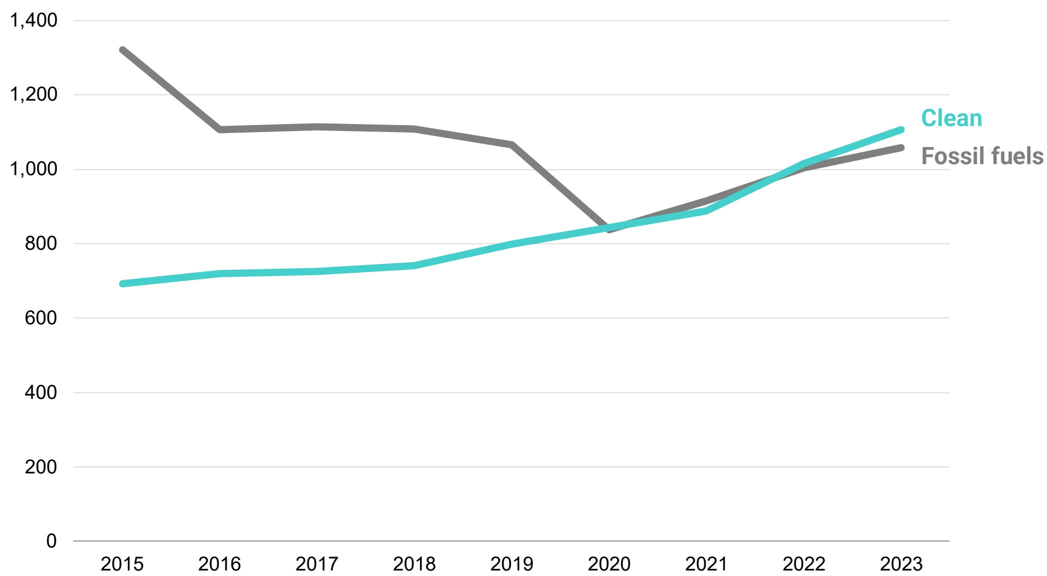
Total capex growth is lower than GDP growth

We show below that the expected growth of total capex on energy supply from 2023-2030 is only 2% a year, lower than expected annual GDP growth of 3%.

Developments since 2015

Since 2015, total capex on energy supply has grown at 1% a year. Of the total growth in capex on renewables from 2015 to 2023 of $414 billion, two-thirds, or $263 billion, came from a reduction in capex on fossil fuels.

Exhibit 12: Capex on fossil fuels and clean energy (billion $)



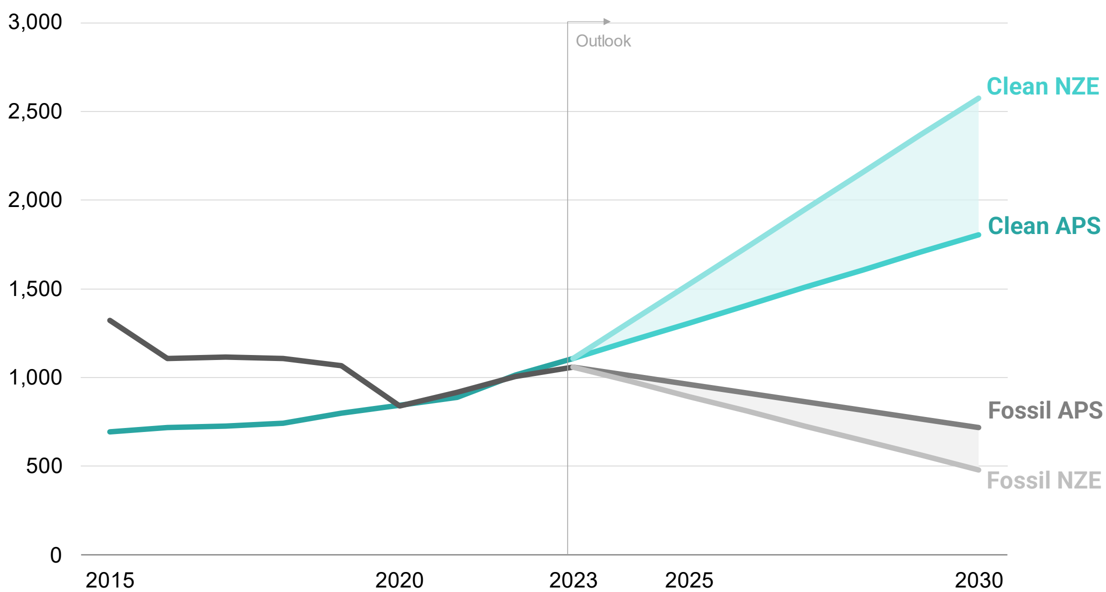
Source: IEA WEI 2023

Plans for 2030

As we have noted, fossil fuel capex will continue to fall and renewables capex will continue to rise.

That gives us a classic way of framing the future of energy supply capex in the chart below between the APS and NZE scenarios. In broad terms the capex on renewables will double and that on fossil fuels will halve.

Exhibit 13: Capex on energy supply to 2030 (billion $)



Source: IEA WEI 2023, RMI adjustments

Under APS, the growth in total energy supply capex would be $361 billion, which is annual growth of only 2% a year, up from 1% a year in the past 8 years. Half of the growth in clean supply capex would come from a reallocation from fossil fuel capex.[ii]

Under NZE, the total growth in energy supply capex would be $891 billion, which is 5% a year. Approximately 39% of the growth in clean capex would come from the decline in fossil fuel capex.

Energy supply capex is not a constraint on the energy transition

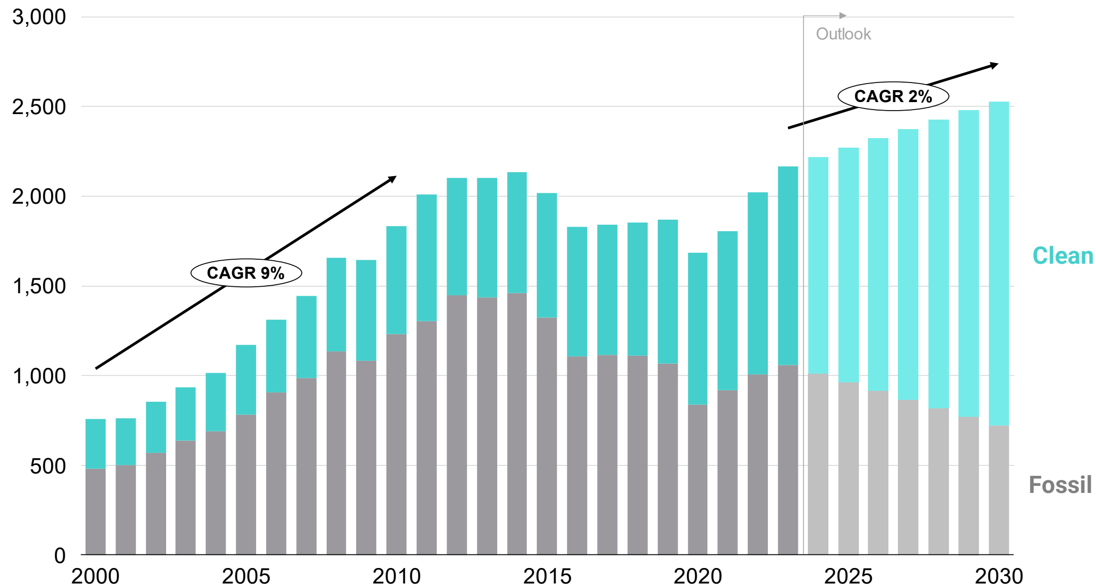
A number of factors lead us to conclude that the level of capex required for the energy transition is very feasible under APS, and also feasible under NZE.

- Total capital formation for all sectors in 2022 was $27 trillion according to the World Bank.[15] Within this framing, energy supply capex of $2.2 trillion is less than 10% of the total. And the additional requirements for capex are just 1%–3% of the total. There is no shortage of capital.
- According to the IMF, annual expected GDP growth is 3%, which is higher than the 2% expected energy supply capex growth under the APS.
- Annual spending on military capex is $2-2.5tn, and annual spending on roads is in the region of $1tn.
- Annual energy supply capex growth has been running at 1% a year in any event, so an increase to 2% under APS is not a major surge in capital deployment.
- From 2000 to 2010, energy supply capex grew at 9% a year, driven mainly by fossil fuel capex.
- Expected capital costs for renewables are likely overstated. After 2030, solar and wind costs are forecast to fall at only 1%–2% a year in the APS model. Meanwhile the huge surge in grid costs may not be necessary if digitization and grid-enhancing technologies are able to reduce grid expansion requirements.
- Renewables are a more attractive investment. The economics are superior and so growth keeps happening. As it widely appreciated, almost all of the capex on electricity generation for example is now going into renewables.
- The fossil fuel peak is becoming increasingly apparent. That will discourage investment in more fossil fuels because of the fear of stranded assets.

The longer-term perspective shows therefore a very gentle rise in total capex.

[ii] It is clear of course that this reallocation process is not smooth and it not one we should expect the incumbent fossil fuel sector to do. But the reallocation of capital out of sectors in decline and into those enjoying growth is something at which financial markets excel.

Exhibit 14: Investment in energy supply under APS (billion $)

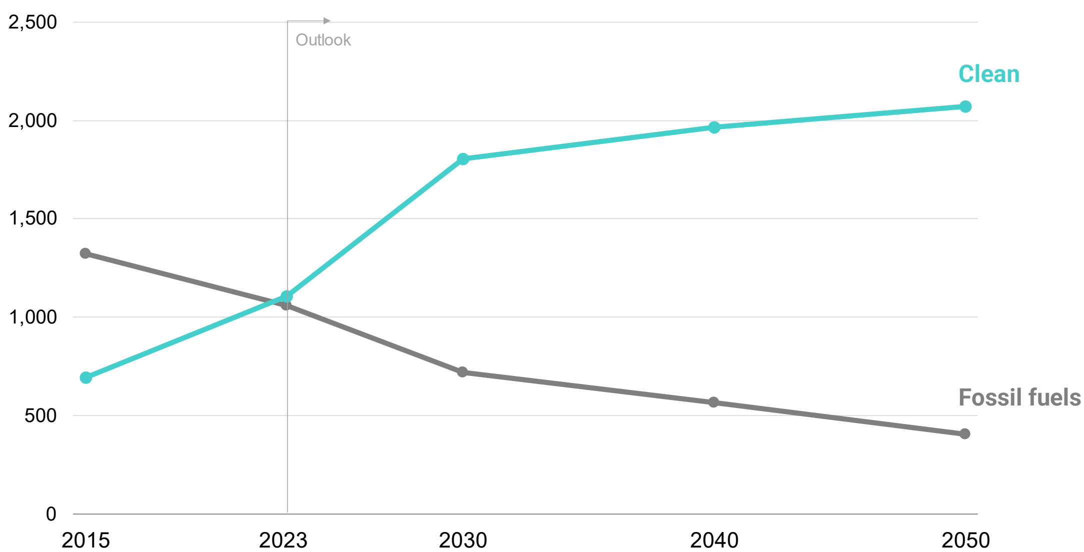


Source: IEA WEI 2016, WEI 2023, RMI adjustments

Most of the remaining change will happen this decade

If we look at IEA expectations for energy supply capex in the decades to 2040 and 2050, it is clear that the main change happens this decade. Specifically, there is little growth in renewable generation capex after 2030. After 2030, most of the growth comes in grids and in storage.

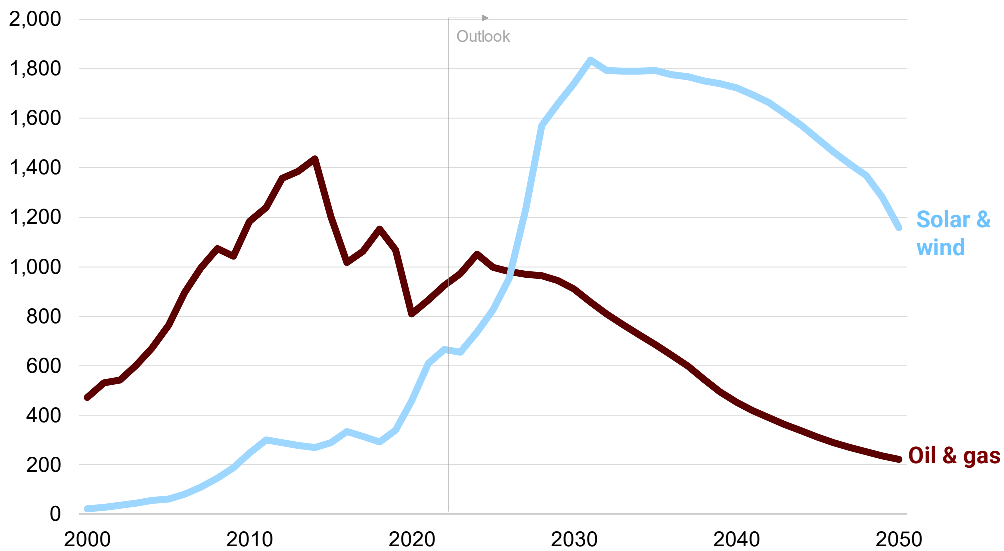
Exhibit 15: Capex on fossil fuels and clean energy supply, long term (billion $)



Source: IEA WEO 2023 APS scenario, RMI adjustments. 2040 and 2050 are decadal averages

We can also get a sense of the likely 2030s peak in clean capex by looking at the Rystad data for solar and wind capex compared to oil and gas capex. They forecast that the increase in solar and wind capex will be over by the end of the decade. Meanwhile oil and gas capex is in a long slow decline.

Exhibit 16: Capex on oil and gas versus solar and wind (billion $)



Source: Rystad 1.6 degree scenario

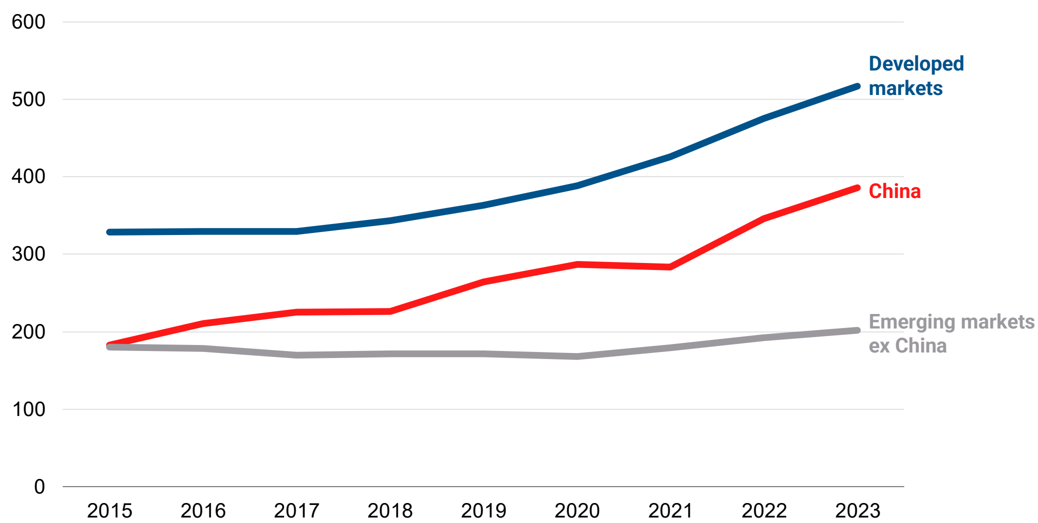
Still work to be done in the emerging markets

When it comes to the analysis of capex in emerging markets, we are constrained in our analysis by the fact that the IEA does not break out detail at a country level. Each country is different and challenges are always specific. Therefore we plan to address this issue in more detail in a separate analysis on the energy transition opportunity for emerging markets. Here we summarize the top-level data, while noting that specific countries or regions may face other issues.

Developments since 2015

The IEA does split the world into three helpful groups; advanced economies (developed markets); China; and 'emerging and developing economies other than China' (described below as "emerging markets" for the sake of simplicity). Over the past eight years, 95% of the change in capital expenditure on clean energy supply has taken place in developed markets and China.

Exhibit 17: Capital expenditure on clean energy by region (billion $)

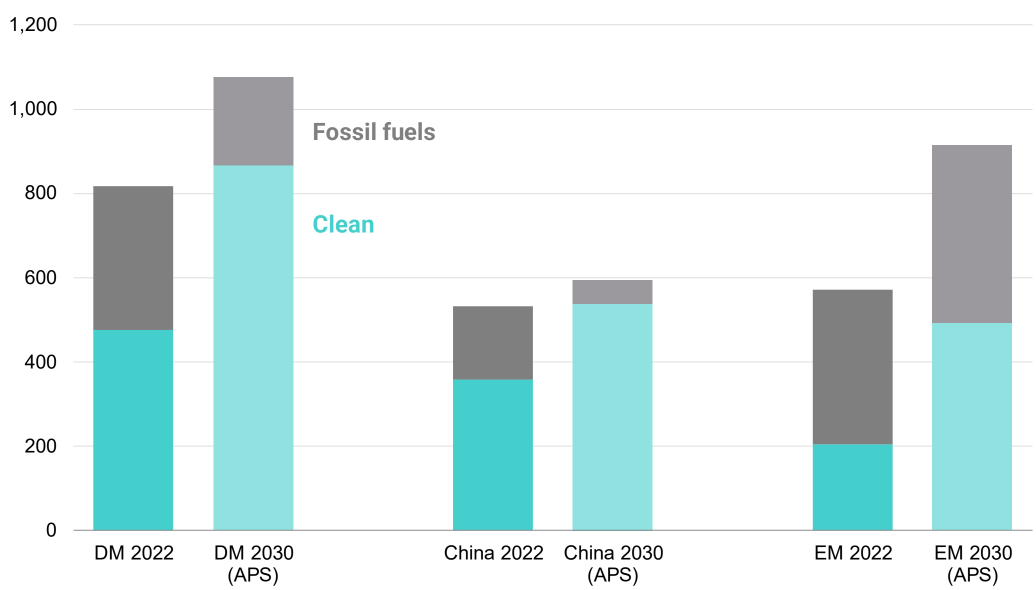


Source: WEI

Plans for 2030

Under the APS scenario, emerging markets require the largest increase in renewables capex. Capex on clean energy needs to more than double by 2030, and grow at a compound annual growth rate (CAGR) of 12% in total.

Exhibit 18: Energy supply capex by region (billion $)



Source: IEA WEO 2023. DM is developed markets. EM is emerging markets excluding China.

There are good reasons to argue that this increase in capex is feasible:

- The emerging markets are the only region where fossil fuel capex is forecast to rise under APS. Falling capex on fossil fuels would help to finance renewable capex. The growth in total capex in the emerging markets is only a CAGR of 6%.
- Policymakers are well aware of the issue, and organizations like the World Bank are changing their approach in order to direct more capital toward the emerging market renewable sector.
- Technology shifts usually move from wealthy countries to less wealthy ones. As demand starts to peak in wealthier counties, companies will typically shift to emerging markets in pursuit of the growth. This is what happened with the internet and with mobile phones.

However, feasible is not the same as actual. And this type of analysis serves once more to remind us of the necessity to work hard to deploy capital in the emerging markets, as set out in more detail by Lord Nicholas Stern, chair of the Grantham Institute on Climate Change and the Environment.[16] As many have noted, that requires a combination of local policy action and global technology and financing support. Good policy and external support can help prevent emerging markets from betting on yesterday's technology – technology which is rapidly being abandoned by wealthier countries.

5. Appendix: Comparison with Other Capex Forecasts

Capex forecasts for the energy transition have been made among others by the IEA, IRENA, McKinsey, the Energy Transitions Commission (ETC),[17] BNEF,[iii] and Rystad.[18] The differences between them are quite wide mainly because they are examining different issues, but the substantive differences are small in comparison with the gap identified above between energy supply capex and total spending on fuels. Differences between the forecasts include:

- Total energy system capex or energy supply capex (e.g., McKinsey focuses on total energy system capex).
- Renewable capex or renewable and fossil capex (e.g., the ETC focuses on renewable system capex).
- 2030 capex or a 2020–50 average (e.g., IRENA takes a 2020–50 total).
- Current baseline or BAU baseline (e.g., McKinsey initially frames the transition against a 2020 baseline).
- What is included in the energy system capex (e.g., Rystad does not include grid capex in its standard renewable capex numbers).

Rather than itemizing the differences minutely, it is fair to say that they can all broadly be reconciled back to the IEA totals.[iv] The major differences tend to lie in the capex expected on end uses, which are subject to the many uncertainties noted above.

Therefore, we illustrate the IEA data before and after adjustments.

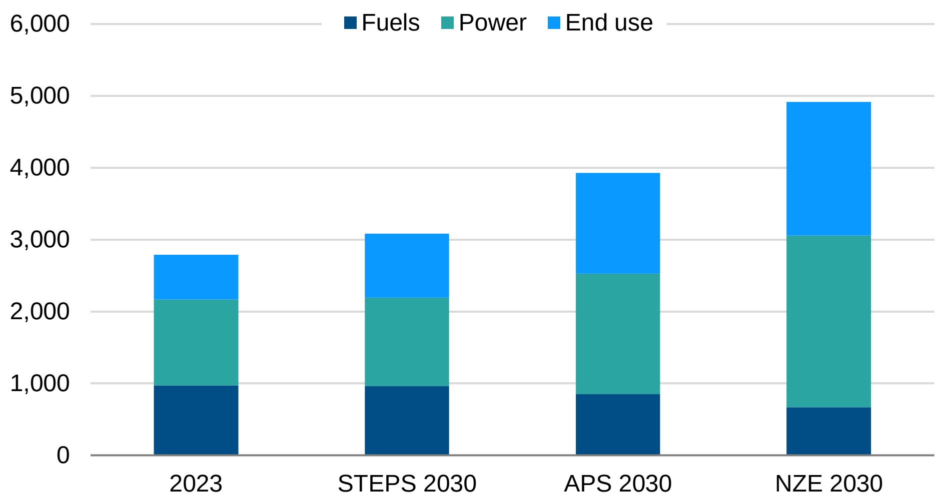
The standard story

The IEA splits energy capex into three buckets — fuels, power, and end use. Under the APS or the NZE this implies a "surge" in capex on energy — from $2.8 trillion in 2023 to $4 to $5 trillion by 2030.

[iii] BNEF's 2022 *New Energy Outlook* is the standard approach and includes EV capex as part of renewable costs. A different approach, more similar to our framing, is taken by a more recent BNEF report, *Financing the Transition*.

[iv] For a more detailed analysis of this issue, see the Annex in ETC's 2023 report *Financing the Transition*.

Exhibit 19: The standard IEA narrative capex (billion $)

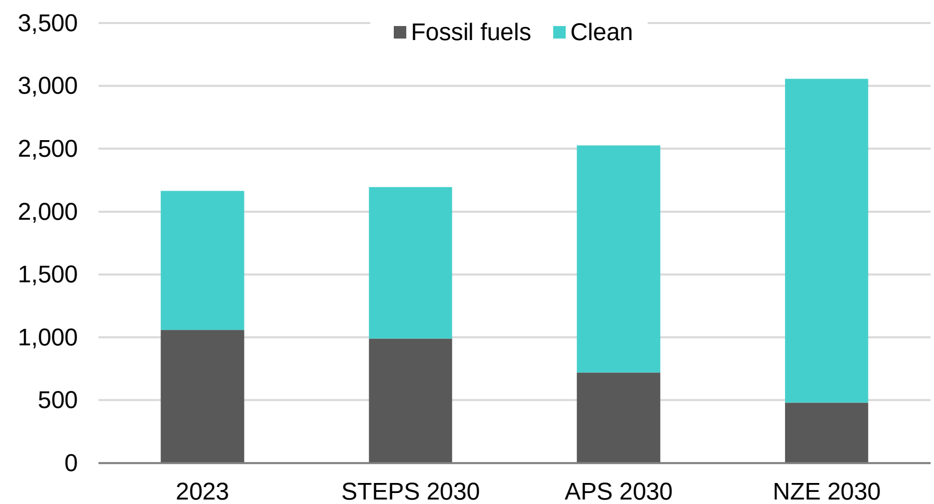


Source: IEA WEO 2023

The adjusted story

However, it is unreasonable to include the rise in clean end-use capex without the decline in fossil fuel end-use capex.[v] When we look only at energy supply capex, the increase in capex is much less dramatic. From $2.2 trillion to $2.5–$3 trillion.

Exhibit 20: Adjusted IEA capital flows (billion $)



Source: IEA WEI, RMI estimates

[v] In technical terms, some end-use renewable capex is said to be incremental over fossil fuel capex. However, the methodology and assumptions are not clear, and in any event we believe this end-use capex is best treated separately.

6. Endnotes

[1] *World Energy Outlook 2023*, IEA, 2023, https://www.iea.org/reports/world-energy-outlook-2023; and *World Energy Transitions Outlook 2023*, IRENA, https://www.irena.org/Publications/2023/Jun/World-Energy-Transitions-Outlook-2023.

[2] As noted by the *World Energy Investment 2023, IEA*: "Between 2010 and 2019, three-quarters of cash outflows were typically invested into new supply. This is now less than half, with the majority going to dividends, share buybacks and debt repayment."

[3] *World Energy Investment 2023*, IEA, 2023, https://www.iea.org/reports/world-energy-investment-2023.

[4] *The Net Zero Transition: What It Would Cost, What It Could Bring*, McKinsey, 2021, https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring.

[5] *New Energy Outlook*, BNEF, 2022.

[6] *The Net Zero Transition: What It Would Cost, What It Could Bring*, McKinsey, 2021, https://www.mckinsey.com/capabilities/sustainability/our-insights/the-net-zero-transition-what-it-would-cost-what-it-could-bring.

[7] *Empirically Grounded Technology Forecasts and the Energy Transition,* Institute for New Economic Thinking at the University of Oxfor*d, 2021.* https://www.inet.ox.ac.uk/publications/no-2021-01-empirically-grounded-technology-forecasts-and-the-energy-transition/

[8] *The Eight Deadly Sins of the Energy Transition,* RMI, 2023, https://rmi.org/the-eight-deadly-sins-of-analyzing-the-energy-transition/

[9] *Empirically grounded technology forecasts and the energy transition, Institute for new economic thinking at the University of Oxford, 2021.* https://www.inet.ox.ac.uk/publications/no-2021-01-empirically-grounded-technology-forecasts-and-the-energy-transition/

[10] Oil rents share of GDP, World Bank, https://databank.worldbank.org/metadataglossary/adjusted-net-savings/series/NY.GDP.PETR.RT.ZS.

[11] Fossil fuel subsidies 2023, IMF, 2023, https://www.imf.org/en/Topics/climate-change/energy-subsidies.

[12] *Net Zero Roadmap 2023: A Global Pathway to Keep the 1.5°C Goal in Reach*, IEA, 2023, https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach.

[13] Cost of Capital Observatory, IEA, 2023, https://www.iea.org/reports/cost-of-capital-observatory/tools-and-analysis.

[14] *X-Change: Cars*, RMI, 2023, https://rmi.org/insight/x-change-cars/.

[15] Gross Capital Formation, World Bank, accessed January 2024, https://data.worldbank.org/indicator/NE.GDI.TOTL.CD.

[16] *Finance for Climate Action: Scaling Up Investment for Climate and Development*, the independent high level expert group on climate finance, 2022, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/11/ IHLEG-Finance-for-Climate-Action-1.pdf.

[17] *Financing the transition*, ETC, 2023, https://www.energy-transitions.org/wp-content/uploads/2023/03/ETC-Financing-the-Transition_MainReport-.pdf

[18] Global energy scenarios 2023, Rystad Energy, 2023.