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Net Zero by 2050

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1. Introduction

Net zero by 2050 means that the world's anthropogenic emissions of CO_2 will, by that time, be limited to the planet's ability to absorb these emissions, believed to be 2 gigatonnes per year. This is an enormous undertaking; currently these emissions are about 40 gigatonnes, whereof 35 from burning fossil fuels. Many countries, including the European Union, have committed to this goal. This is grounded in a special report from the Intergovernmental Panel on Climate Change (IPCC), which in 2018 issued a report advising that the rise in temperature since the middle of the 19th Century be limited to 1.5 degrees Celsius.[1] To achieve this, net emissions would need to be cut to zero by 2050.

In this article I shall discuss how likely it is that this goal will be achieved, in the light of what has been accomplished with respect to cutting emissions so far. I will not address the scientific basis of the net zero goal except for cursory comments on the high degree of uncertainty on this issue. My take on this is that the question we face is whether high and relatively certain costs of decarbonization are worth the highly uncertain benefits from avoiding the consequences of, again, highly uncertain increase in global average temperature.

2. How are we doing thus far?

The International Energy Agency (IEA) has done us the favor of analyzing what kind of policy measures are needed for the world to achieve the net zero target by 2050. In the 2024 issue of the World Energy Outlook they provide three conceivable emission paths from 2024 to 2050, one that they call "stated policies scenario", which presumably means that we go on pretty much as we have done up to now, a second one called "announced pledges scenario", which presumably includes the climate goals many countries have set themselves and even put on their law books, and a third path leading to the net zero goal.[2] All paths rise for a few years and then decline. The business as usual path ends in 2050 with emissions of about 30 gigatonnes CO_2, way above target. The path resulting from pledges that countries have made, but probably without the ability and even the intention to live up to them, ends slightly above 10 gigatonnes in 2050. The prospects for net zero by 2050 certainly do not look good.

We have seen this movie before. Fifteen years ago the fashionable climate target was 450 ppm, that is, the concentration of CO_2 in the atmosphere should not exceed 450 parts per million to have a 50-50 chance of limiting global warming to 2 degrees Celsius. The IEA at that time also calculated an emission path compatible with this goal and compared it to alternative and, as it turned out, more realistic paths, stretching out in time to 2035.[3] One was labelled "current policies

[1] IPCC (2018): Global Warming of 1.5°C.

[2] IEA (2024): World Energy Outlook, Figure 5.25.

[3] IEA (2012): World Energy Outlook, Figure 8.3.

scenarios". By 2024 the world's emissions turned out to be almost exactly on this path. Then there was another one, "new policies scenarios", which presumably included the climate pledges various countries were making at the time. This path was 3 gigatonnes below the actual emissions in 2024. Finally there was the path compatible with the 450 ppm goal. This path was almost 10 gigatonnes below where we were in 2024.

3. What we need to do to attain net zero 2050

The IEA has listed many things the world needs to do in order to achieve the goal of net zero by 2050. Here is one: "Our pathway calls for scaling up solar and wind rapidly this decade. … For solar PV, this is equivalent to installing the world's current largest solar park roughly every day."[4] Table 1 show how many times we need to increase the production of several critical minerals relative to the 2020 level to satisfy the needs of the "green" transition.[5] In addition there are substantial amounts needed of copper and aluminum. The mining industry is not among the cleanest industries in the world and, in the poorest countries, it employs child labor under hazardous conditions. The "green" transition is not an obviously apt term to apply to an energy transition critically dependent on these minerals; the dirty transition might be a better one.

Table 1. How many times the production of several critical minerals must be increased relative to the 2020 level to satisfy the needs of the "green" transition.

Graphite	Lithium	Cobalt	Nickel	Rare earths
25	42	21	19	7

In 2020, the IEA had the following vision about the net zero by 2050 path: "Total consumption [of fossil fuels] rebounds marginally following its 5 percent drop in 2020 [during Covid-19], but it never returns to 2019 levels in the NZE scenario".[6] It also stated that we would not need to find more oil and gas to stay on this path, a statement received with glee among some climate activists, even in Norway where this crowd doesn't seem to be aware of what it is that supports their home country's high standard of living. It took one year for this wishful thinking to be put to shame: in 2021 the use of fossil fuels had recovered to its 2019 level and has continued to increase from there.

It is one thing to draw up scenarios that lead to some given goal, but quite another to believe whether they will happen. Yet it appears that the IEA harbors some unrealistic beliefs about the possibility of achieving the goal of net zero:

"… the world economy in 2030 is some 40% larger than today but uses 7% less energy".[7] Really? With more people in the world and greater world production? By comparison, from 2000 to 2024 the world's use of energy increased by 1.8 percent per year on average. What is going to be so radically different during the next fifteen years?

4. What is happening to the CO_2 emissions?

Despite all pledges to the contrary, emissions of CO_2 are increasing year by year, as shown in Figure 1. The figure shows emissions from energy production only, but these are the overwhelming part (85-90%) of all man-made emissions. The exceptions are few and easily identified with economic troubles most people would rather be without, like Covid-19 in 2020, the financial crisis in 2008, the Arab oil embargo in 1974, and the second oil crisis in 1979-80. Otherwise, when

[4] IEA (2020): Net Zero by 2050, p. 14.

[5] IEA (2021): The Role of Critical Minerals in Clean Energy Transition, p. 9.

[6] IEA (2020): Net Zero by 2050, p. 60.

[7] IEA (2020): Net Zero by 2050, p. 14.

things are going well in the world economy the CO_2 emissions increase. Nobody should be surprised; fossil fuels still account for over 80 percent of our primary energy, with solar and wind producing less than 3 percent. The necessary change in energy infrastructure to substantially reduce the dependence on fossil fuels is going to be costly and time-consuming. Even the time horizon out to 2050 will likely turn out to be short in that context.

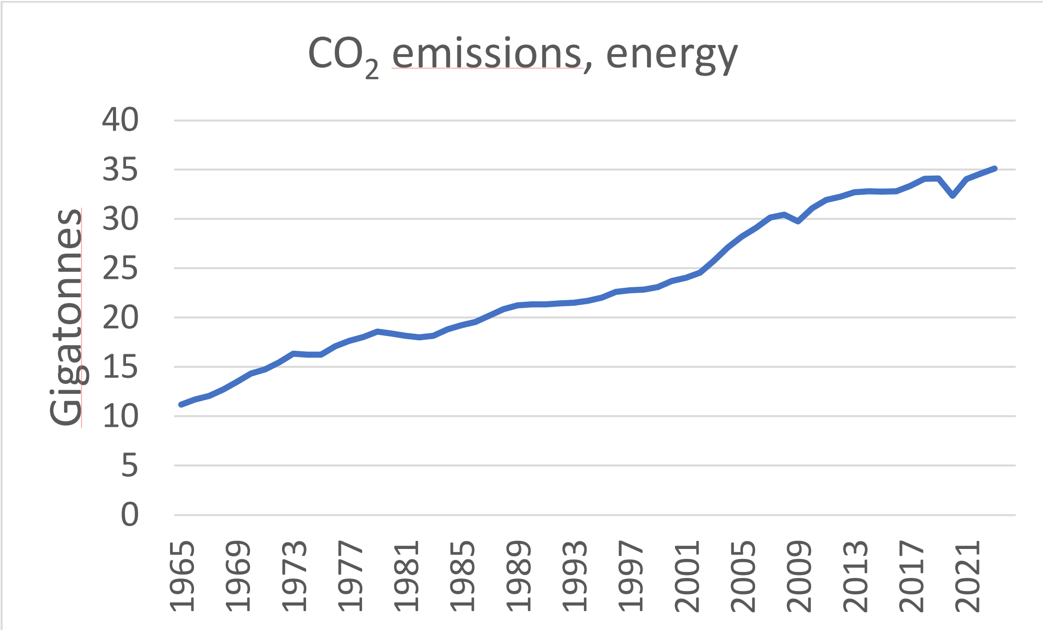

Figure 1: Emissions of CO_2 from energy production1965 – 2024.

But emissions have not increased uniformly everywhere, and it is of interest to see where they increase most. Figure 2 shows the energy-related emissions in rich (OECD) versus developing (non-OECD) countries in 1997 versus 2024. 1997 was the year the Kyoto Protocol took effect. According to this, countries were supposed to reduce their emission levels by 5 percent relative to 1990. We see that the rich countries did reduce their emission levels substantially, but this was more than made up by what happened in the developing countries, so total emissions have increased by 50 percent since 1997. The developing countries were exempt, presumably in recognition of the fact that they were entitled to further economic growth, which is driven by increased use of energy, and where was that going come from if not from fossil fuels? Some also hoped that the rich countries would set an example for the poorer ones to follow, but there has apparently been little of that. A part of the complete picture is that the rich countries are not quite as virtuous as they seem, because they have outsourced much of the production of energy-intensive goods they use (steel, for example) to developing countries. CO_2 emissions are accounted for in the countries where goods are produced and not in the countries where they are finally used.

Table 2 shows the ten countries where emissions increased most in the period 2014 – 2024. It also shows the GDP per capita in these countries and compares it to the GDP in the United States. These countries are, with the exception of Saudi Arabia, either poor or medium rich. We can safely conclude that the highest priority in these countries is to catch up with the rich countries of the world, and for doing so they need economic growth and what fuels it—energy. Where is the energy going to come from? We can safely conclude that climate concerns and cuts in the use of fossil fuels do not rank high on the list of priorities of these countries. As a further sobering thought; 45 percent of humanity lives in just six countries in south and east Asia, four of which we find in Table 2.

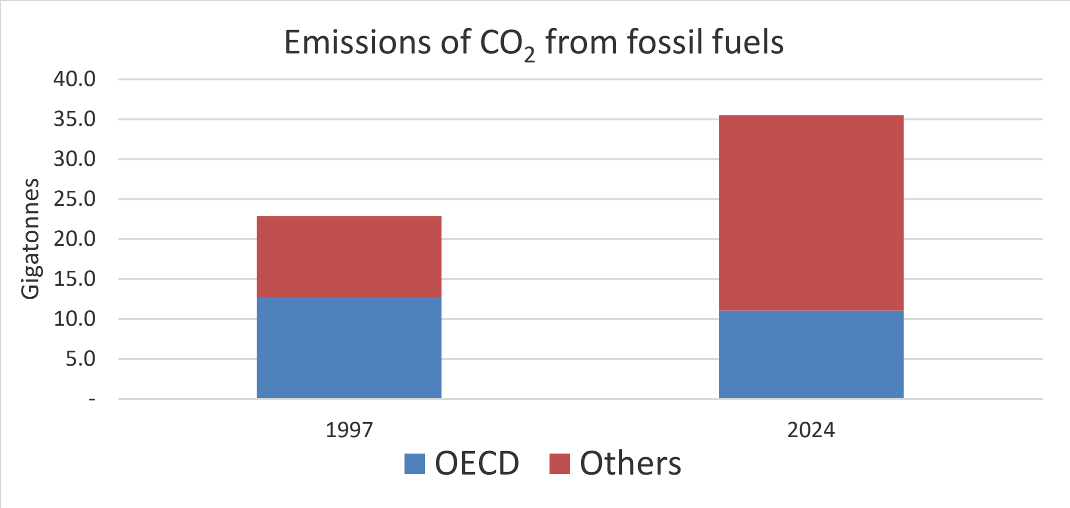

Figure 2: Energy-related emissions of CO_2 in OECD versus non-OECD countries 1997 and 2004.

It is in these countries that the future development of CO_2 emissions will be decided and not in countries like Norway whose less than one promille of world emissions pales into insignificance. Not even the European Union with its 7 percent share of world emissions will achieve a great deal by further cuts. The climate problem, to the extent it is a problem, is a world problem that needs actions on a world scale.

Table 2. Increase in energy-related CO_2 emissions in million tonnes 2014 – 2024.

	Increase in emissions	GDP per capita, ppp	% of US
China	1937.3	27104	31
India	906.5	11159	13
Indonesia	298.3	16448	19
Vietnam	184.0	16386	19
Iran	156.8	18442	21
Russia	129.6	47405	55
Turkey	102.7	43932	51
Saudi Arabia	71.4	71243	83
Iraq	66.9	14464	17
Philippines	66.8	11794	14

5. Europe's green transition

This last remark gets us to the green energy transition that the European countries, including Great Britain, are attempting. Surprisingly, and unfortunately, this is not a transition to nuclear power, a reliable and controllable source of energy that doesn't emit any CO_2, but to wind and solar energy which is entirely subject to the weather and cannot be called upon whenever it might be needed. This type of energy produces only 30-40 percent of the time and not necessarily when we need it. Hence, on windy and sunny days, the owners of these installations are often paid for not producing anything because there is no need for the electricity or even because there are no power lines that can transport the electricity to where it is needed.[8]

We are often told that wind and solar energy is cheap and competitive compared to fossil fuels. This is based on so-called levelized cost of energy, which simply is the cost of the energy divided by the kilowatthours produced. This is gravely misleading. The levelized cost of energy doesn't take into account the backup energy we need when the sun doesn't shine and the wind doesn't blow, nor does it take into account the cost of additional power lines for energy sources that often are far away from where the energy is used. One can find staggering numbers on this in the academic literature. One source reports levelized cost of energy in Germany of 36 US$ per MWh for solar photovoltaic and 40 US$ per MWh for wind. After adjusting the cost for availability and need for backup sources we get the staggering figures of 1380 (solar) and 483 (wind).[9]

Germany is probably the country which has gone furthest in its transition to green energy, but the issue is confounded by the fact that at the same time Germany has decommissioned all its nuclear power plants, which provided an alternative source of carbon-free energy. Since 2000 the generative capacity in the German power industry has been doubled while the production of electricity has stagnated. The new solar and wind installations have mainly replaced the nuclear power plants, with no addition to electricity production. This is reported to have cost 500 billion euros, which amounts to the cost of 40 Olkiluoto nuclear power plants.[10] This would have been enough to cover the entire electricity production in Germany. The Olkiluoto plant became notorious for cost overrun and construction delay, but appears as a good bargain compared to the German wind turbines and solar panels.

So what have the Germans achieved, besides abolishing their nuclear power industry? The use of coal has declined by almost a half from 2000-2007 to 2020-2024, but coal is still a major input in the German power industry; when the wind doesn't blow or the sun doesn't shine the coal power plants are turned on rather than turning the lights off. Over the same period the CO_2 emissions have declined from a little over 800 million tonnes to 600. There is still a far way to go to net zero.

In general, the green transition has turned out to be costly. Figure 3 shows the price of electricity for households 2020 – 2022 versus the share of solar and wind in the production of energy. The positive correlation is obvious. The academic journals are full of papers discussing the decline of wholesale prices, which can even fall below zero when the wind is blowing optimally and the sun is shining from a clear sky, but their fixed costs have to be paid and so does the back-up energy when solar and wind energy is not available. Somehow, unsurprisingly, these costs find their way into the energy bills of households.

6. Norway's climate policy

The Kyoto Protocol stipulated that industrialized countries should by 2012 have cut their CO_2 emissions by 5 percent relative to the 1990 level. Instead, Norway's emissions were almost 30 percent higher. That was perhaps just as well; the increase in emissions was to a large extent due to more petroleum production, and without that there would have been no petroleum fund nor other goodies that came as a result of the formidable income of the petroleum industry. Since 2015 Norwegian emissions have begun to fall and were 15.5 percent lower in 2024, a decline of 0.73 million tonnes per year.

In the spring of 2025 the Norwegian parliament amended the climate law and stipulated that emissions of CO_2 should have fallen by 70 percent by 2035. This is a decline from 38.9 million tonnes in 2024 to 11.7 in 2035, or 2.5 million tonnes per year, more than three times the annual decline

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[8] On the growing need to switch off the Scottish offshore wind parks, see David M. Newbery and Daryl R. Biggar: Energy Policy 191 (2024) 114206.

[9] Robert Idel, Energy 259 (2022) 124905.

[10] Tim Gregory (2025): Going Nuclear. Penguin (UK) and Pegasus Books (US).

in the period 2015 – 2024.

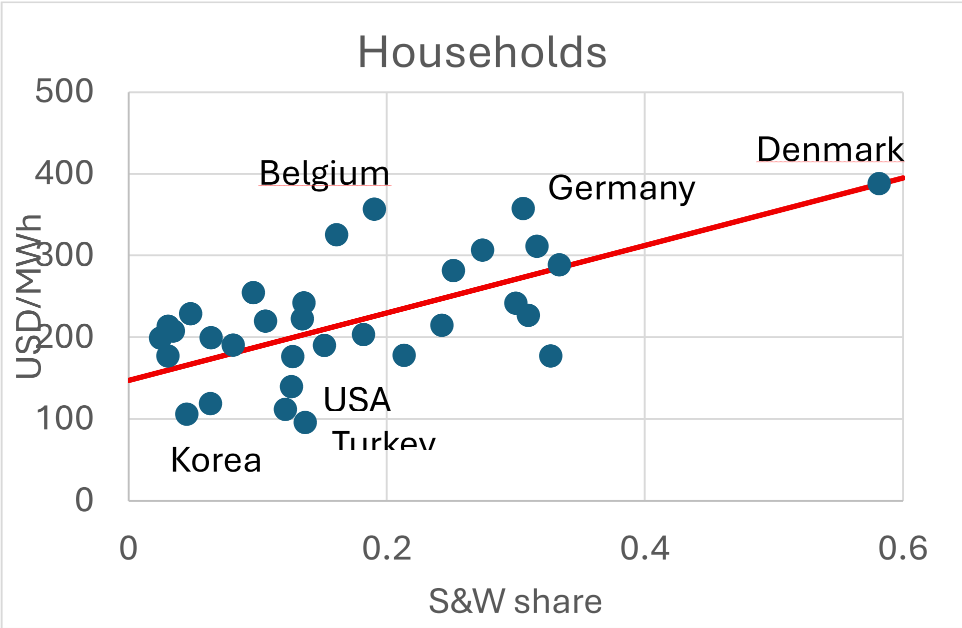

Figure 3: Price of electricity for households versus share of solar and wind in energy production in OECD countries 2020 – 2022.

What kind of miracle medicine will the Norwegian authorities put into use? Maybe more of the same, so what did they do in the period 2015 – 2024? Mainly three things:

- Replacement of gas and diesel cars by battery driven cars
- Replacement of gas turbines by electricity on the petroleum platforms
- Emission quota trading with other countries

About 30 percent of Norwegian cars were battery-driven in 2024, so there is still some way to go with this policy. Battery driven cars make more sense in Norway than in many other places, because they can be charged with electricity from hydropower. Even so, the success of this policy tells us more about the outrageous price level for cars in Norway before the battery driven vehicles came on the scene. In most countries the high cost and inconveniences of these cars have been a major obstacle to their adoption. In Norway the transition to battery driven cars was facilitated by abolishing taxes and fees on these vehicles, which blew a large hole in the government's finances. There are attempts under way to accomplish a similar transition for trucks and heavy duty machinery, but the cost and inconvenience increases as the machines get bigger and more power-demanding.

Replacement of offshore gas with electricity, usually from shore, is among the worst climate policies one can find. The gas saved due to electrification is exported, which provides a zero effect for emissions, or worse, because building the power lines and other facilities requires heavy duty machinery that runs on diesel. The cost is not negligible, and the electricity is diverted from other and better use. But there are still gas-driven platforms waiting to be electrified, and the oil companies love it because they save the CO_2 fees and quota costs. The politicians also love it because the electrification reduces the emissions in Norway, even if they increase the emissions just as much elsewhere.

Some of the reduction in Norwegian emissions have been accomplished by buying emission quotas from other countries, developing countries among them. Some of them are among the most corrupt countries in the world; here we find, for example, both of the republics of Congo. What typically happens is that these countries undertake to plant trees or to reduce their deforestation. There is good reason to wish the Norwegian authorities good luck with the monitoring of this process; do the countries live up to what they say they will do? Furthermore, a new government may reverse the process; deforestation can be resumed quickly. This is what happened when Bolsonaro became president of Brazil.

7. Conclusion

It all boils down to this: Do the benefits of climate policy justify the costs? There are many studies that have tried to answer this question, and they come to different conclusions, which just illustrates how uncertain the benefits are. The climate economist Richard Tol has recently summarized many of these studies.[11] The general conclusions are that the costs are probably greater than the gains, with the gains being highly uncertain, but the costs much less so. Furthermore, there are very large variations between different studies. It all boils down to this simple thing: The costs occur immediately or in any case soon and are relatively easy to predict, while the benefits are uncertain and occur in the future, sometimes in the very distant future.

The uncertainties are many and formidable and sometimes we cannot even be sure of their sign. There is a chain of cause and effects we must go through to evaluate whether or not climate policy makes sense:

1. Is global warming happening? Yes, certainly, but it may well be exaggerated because of the heat island effect and problems with aggregating temperatures from various parts of the planet.

2. Is it caused by increased concentration of CO_2? Possibly; CO_2 is a greenhouse gas, but how potent is it? It is recognized, also by the IPCC, that every additional molecule of this substance has lesser and lesser effect. IPCC finds that the climate sensitivity of CO_2 is somewhere between 2.5 and 4, a wide gap it would seem. It presumably makes considerable difference whether the global temperature increases 2.5 times or 4 times for doubling the CO_2 concentration in the atmosphere. And the natural forces that have affected the climate in the past have hardly gone on vacation. The causes of this natural variability are still poorly understood.

3. Is the observed higher concentration of CO_2 caused by human emissions? Probably, but there are other forces at work. Fluctuations in sea surface temperature are closely correlated with changes in CO_2 concentration in the atmosphere. The trend in the concentration of CO_2 in the atmosphere can be explained by human emissions while the year to year variations appear to be related to variations in sea surface temperature.

4. Are the effects of global warming negative or positive? The little warming that we have had in the northern countries since the Little Ice Age has in my view been for the better. Can we say much more than that the global effects are highly uncertain and will probably vary from place to place? In some places they might be positive, in other places negative. For one thing, global warming has had no negative effect whatsoever on food production, and even the IPCC admits that a higher concentration of CO_2 in the atmosphere has given us a greener planet. If anything, this should be good for food production.

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[11] Richard Tol: Costs and benefits of the Paris climate targets. *Climate Change Economics* 14(4), 2023, special issue on net zero 2050.

So, to conclude, is it really a good idea to destroy our reliable and cheap energy system for the sake of uncertain effects on the climate, effects that could be beneficial rather than bad?