GOOD JUDGMENT

August 15, 2022

SUPERFORECASTING LONG-TERM RISKS AND CLIMATE CHANGE

Report prepared by Good Judgment Inc

Good Judgment Inc is the outgrowth of a four-year, $20 million research project run by the US Office of the Director of National Intelligence to see whether crowd-sourced forecasting approaches could deliver more accurate forecasts than existing approaches. The result was decisively positive, with Good Judgment's methodology generating up to an 85% increase in accuracy.[1] In 2013-2014, Good Judgment was compared to 4,300 members of the US Intelligence Community (IC). On the same set of 139 geopolitical forecasting questions, Good Judgment was 34.7% more accurate, although the IC had access to classified information while making their forecasts.[2] Good Judgment continues to work with clients and partners to push the frontiers of forecasting accuracy even further.

METHODOLOGY

To generate the most accurate forecasts available, Good Judgment works with some 180 Superforecasters from around the world whose forecasting accuracy placed them in the top 1-2% of the more than 100,000 forecasters who took part in the US Government research project or on the public forecasting platform Good Judgment Open.

These Superforecasters are a diverse group, with professions ranging from finance to intelligence, management to medicine, and psychology to archaeology. Most have one or more graduate degrees, and a third have doctorates. A third of Superforecasters live outside of the United States and most speak two or more languages.

Good Judgment's Superforecasters analyzed 22 questions related to the long-term risk of climate change. The questions were presented to the Superforecasters under the following categories: future levels of emissions, number of deaths caused by severe weather events (heat, storms, floods, and drought), food (cereal yields and food prices), future of the Amazon biome, cost of solar energy, and the risk of extinction where climate change is a cause thereof. These questions were examined first through a narrower set of objectively falsifiable forecast metrics, followed by a wider discussion of the overarching questions and alternative scenarios.

Halfway through the project, ten subject matter experts examined the initial forecasts and provided the Superforecasters with feedback and additional sources, after which the

[1] https://journals.sagepub.com/doi/abs/10.1177/1745691615577794

[2] http://www.sjdm.org/journal/17/17408/jdm17408.pdf

Superforecasters had the opportunity to consider and react to the expert feedback. This kind of exchange between subject matter experts and forecasting experts leads to the most accurate, well-considered forecasts. We are grateful for the expert feedback from Matthew Burgess, Matthew Ives, Linus Blomqvist, Katrin Burkart, Patrick Kinney, Kieran Hunt, Ertug Ercin, Benjamin I Cook, Chris A Boulton, Andrew Watson. Over the course of this project, 51 Superforecasters made a total of 1,377 forecasts and 1,821 extended comments. This summary is accompanied by 22 comment-format reports that include all Superforecaster commentary for each question.

This summary is structured as follows:

- Each category of questions is presented in a separate section.
- Each section starts with the question, or the **forecast metric**—a sufficiently narrow, specific, and actionable question that can be objectively and unambiguously resolved with an answer in the given time frame. It is followed by **resolution criteria**.
- Accompanying each forecast metric is a table with two to five **potential outcomes** to which the Superforecasters assigned **numeric probabilities**. Those probability values are aggregated[3] and are called the "consensus forecast."
- The consensus forecast and the key arguments are then summarized, including arguments behind the Superforecasters' forecasts, key areas of uncertainty, and developments that, if they occurred, would make the Superforecasters change their forecasts. **Examples of Superforecaster commentary are set off with quotation marks**.

Good Judgment's team of Superforecasters for this project included a smaller **"Red Team"**—Superforecasters who did not themselves forecast, but rather who critiqued the teams' thinking and suggested alternative arguments for consideration. Red Team members highlight new details or new arguments that, in their view, forecasters had not fully considered. This results in forecasts that are better informed by multiple data sets and perspectives.

Superforecasters are not required to agree with each other on their forecasts or their reasoning. Our report, therefore, is an effort to describe the main lines of thinking of a disparate group of forecasting experts.

[3] Aggregation of probability estimates of many individuals to form a consensus probability estimate was shown to result in more accurate forecasts (wisdom-of-the-crowd effect). For further information, please see our journal articles on aggregation algorithms here.

TABLE OF CONTENTS

EMISSIONS

Q1: WHAT WILL BE THE TOTAL CARBON DIOXIDE EMISSIONS IN THE WORLD IN 2023, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Less than 35.00 billion tonnes	2%
B Between 35.00 billion tonnes and 36.50 billion tonnes, inclusive	26%
C More than 36.50 billion tonnes but less than 38.00 billion tonnes	52%
D Between 38.00 billion tonnes and 39.50 billion tonnes, inclusive	17%
E More than 39.50 billion tonnes	3%

Resolution Criteria: The outcome will be determined using data as reported by OWiD. In 2020, total carbon dioxide emissions in the world were 34.81 billion tonnes.

Base Rate

- Prior to a decrease induced by the Covid-19 global pandemic, total CO2 emissions **increased every year** in 2016-2019, from 35.45 billion tonnes in 2016 to 36.7 billion tonnes in 2019. The top 10 emitters are: China, US, EU, India, Russia, Japan, Iran, South Africa, Indonesia, Canada and Brazil.

"2019 was the last Covid-free year, and it was 36.7 (answer option C). I assume that this year, we will roughly revert to the post-Covid norm, after a Covid-related fall, and so option C is the most likely. Even with the Covid fall in 2020, we were barely into option A, so I think option A can basically be ruled out, even if there is a recession. Option E would require a very rapid rise relative to past rises, so it is unlikely as well."

"China emits more than one-quarter of the total global CO2 emissions and its trend is definitely upward, so it is key to this forecast."

Upward Pressures

(i.e., factors that would lead to *higher* total emissions)

- **Availability** of and **demand for fossil fuels**: The Superforecasters expect continued reliance on fossil fuels in the developing world and China and a temporary increase in the use of such energy sources in Europe in 2023.

> Chinese coal plants are running to make goods that are sold to the US/Europe, shifting emissions from West to East. Chinese energy usage will depend on the West's demand."

> The large increase in natural gas prices is a key factor. Coal plant retirements are being postponed. Analysts at ICIS projected 5% higher electricity emissions in Europe as a result. Given that the EU power sector accounts for just over 1 billion tonnes, that means an increase of 0.05 billion tonnes. Chinese mine output is also planned to expand. All in all, I am assuming that 2022 will be a small increase as coal use outweighs economic slowdown, leading to somewhere around 37. I guess that 2023 would then be anywhere between a 2% decrease or a 2% increase."

> The ambitious plans to shift away from the dependency on Russia will take at least three years, and in the meantime, dirtier alternatives are being used, e.g., life extension for mothballed coal plants."

> A recession and higher energy costs may be offset by more use of cheaper, dirtier fuels in 2023."

- **Lack of policy focus**: Geopolitical instability in Europe, political battles in the US, and inflation in much of the world will lead to less focus on climate-focused measures in this period.

> Given that Europe is going back to using coal, a war rages in which Russia is involved, and inflation is eating budgets worldwide, it appears climate fixes are on the backburner."

> Positive impacts will be increasing political pressure and increasing technology solutions (minor in this time frame). Negative impact will be China/Russia vs US/Europe political battles giving cover to inaction/increasing fossil fuel usage."

Downward Pressures

(i.e., factors that would lead to *lower* total emissions)

- **Economic slowdown**: A recession, and especially a downturn in the Chinese economy, e.g., due to Covid lockdowns, could lead to lower CO2 emissions.

> A modest increase from the estimated 36.4 tonnes in 2021 is likely, but not certain. A recession, paired with changing consumer behavior due to high energy costs, could result in a decline."

> While it is true that Europe in particular is taking desperate measures to keep the lights on, which mostly include more coal-fired power, we will probably see a major contraction in economic growth in the developed world and even China. And that will be especially true in energy-intensive industries."

> The final result of this question will depend on how much China's energy usage has been and will be affected by its Covid lockdowns."

- **General trend toward clean energy**: Green transition is not expected to have a major effect in this period.

> It only takes 3% annual growth to get to answer option D. Serious reductions in CO2 emissions won't happen for another 10 years or so."

Q2: WHAT WILL BE THE TOTAL CARBON DIOXIDE EMISSIONS IN THE WORLD IN 2050, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Less than 10.00 billion tonnes	2%
B Between 10.00 billion tonnes and 20.00 billion tonnes, inclusive	10%
C More than 20.00 billion tonnes but less than 30.00 billion tonnes	30%
D Between 30.00 billion tonnes and 40.00 billion tonnes, inclusive	41%
E More than 40.00 billion tonnes	17%

Resolution Criteria: The outcome will be determined using data as reported by OWiD. In 2020, total carbon dioxide emissions in the world were 34.81 billion tonnes.

Base Rate

- Business-as-usual projections put the increase in global carbon dioxide emissions in 2050 to just over 43 billion tonnes. Status quo is around 35 billion, with an **upward trend**.

> I'm having a hard time imagining this not resolving in (at least) answer option D. The only factors that have slowed down growth in the last 30 years were a global recession and a global pandemic. I think it would take some kind exogenous shock to shift away from oil."

> Compared to year 2000, in 2019, according to OWiD, Europe and the US were down about 12%, while India and China were up about 170% and 205%, respectively. Asia on the whole is also up about 125%."

Upward Pressures

(i.e., factors that would lead to *higher* total emissions)

- **Increased demand for energy**: Economic growth, population growth, higher global temperatures all suggest an increased demand for energy, much of which comes from fossil fuels.

> If you look at the list of the largest producers of oil, gas, or coal, some countries don't seem to have a choice in this timeframe to substantially reduce their domestic consumption of fossil fuels. In those places, a growing population and growing domestic demand for energy are going

to continue, while foreign demand for fossil fuels will slowly fall. Growing incomes will drive more demand for energy. Heat will increase the need for air conditioning. What will make poorer countries invest massive amounts to convert away from cheap and abundant domestic energy sources? The less the rest of the world buys their fossil fuels, the cheaper fossil fuel energy will become on their domestic markets and the stronger the incentive for them to continue to use them."

"I'm taking it as a given there will be an increased need for energy by 2050. And it's still going to be easier to use coal and drill for oil than use cleaner energy sources. Even with pronounced and dangerous consequences in severe weather and whatever else unpredictable will happen by 2050, it won't be enough to outweigh the need already baked in."

"Coal usage in lower-income countries will not be reduced. The capacity deficit is so large that while I expect an increase in renewables, I do not expect a decrease in fossil fuels."

"With China planning to peak CO2 emission in 2030, and India and other countries with large populations certainly following that path, I'd say even under the best circumstances, spending some time in >40 billion territory (answer option E) in the next 10 years is a virtual certainty."

- **Positive feedback loops**: One source of uncertainty that could push emission levels higher is the potential triggering of positive feedback loops in some areas of the world.

"I think a major uncertainty is the behavior of major carbon sinks. Tundra, bogs, the oceans, etc. Global warming could trigger outgassing from carbon sinks in a positive feedback loop."

- **Lack of political will** to reduce emissions: Many Superforecasters expect political fragmentation, polarization, and lack of international cooperation to continue in this period (NB: dissenting arguments are offered in the Downward Pressures section below).

"I am fairly skeptical about how seriously governments will attempt to lower emissions, so for a starting estimate, I'm just going to take the 'stated/current policies' forecasts, average them, and then move it down a bit to reflect the fact that only some attempts at lowering emissions will likely occur. Averaging them gets us 38 billion, which would be the upper end of answer option D, but not that far from answer option E."

"Short of external actors forcing lower-income countries to switch over, and paying for it, I don't see how large parts of the world transition to renewables by 2050. My guess is that at some

point we reach a tipping point where that happens; and that tipping point will be further in the future than seems reasonable today."

"China's active and dramatic cooperation would be much needed to get to C. Is that a serious possibility? I would need to see them ceasing to add capacity before I could even entertain that, and they are currently doing the opposite."

"If the decrease in emissions depends on our leaders' actions, one has to wonder if other needs will push climate down the list of priorities."

"Economic constraints, imposed by a period of global slowdown, or tensions caused by inequality, could use up the political capital needed to sustain and intensify climate policy."

Downward Pressures

(i.e., factors that would lead to *lower* total emissions)

- **Technological advancement**: As technologies continue to develop, many Superforecasters expect the issue of renewable intermittency to be addressed and the cost of renewable energy to decrease significantly. This, in turn, will incentivize and speed up the green transition.

"Green energy is getting cheaper than fossil fuels and batteries are getting better. The acceleration of the energy transition is inevitable and key milestones are now in sight."

"Energy projections have generally underestimated clean energy cost declines (as well as actual deployment). Decarbonization is becoming cheaper than previously expected, which also means that government pledges have become much easier to meet."

"Steel and cement account for about 15% of global CO2 emissions; I would expect technological gains here in reducing the carbon emissions quite substantially by 2050."

- **International commitment to reduce emissions**: A minority of just under one third of Superforecasters believe climate policies, propelled by cheaper clean energy and by a generation of climate-conscious voters and policymakers, will help curtain CO2 emissions by 2050.

"The overall trend is toward more climate policy, not less, despite temporary setbacks. This includes policies that are not explicitly about climate change but about local benefits. One example of a climate action co-benefit that may be the actual driver of emission reductions is air quality, which has been important in China, India, and other nations that prioritize quality of life for their growing middle classes. To wit, before 2015, we were headed for a warming of around 4C. Paris put us on track to 2.7C. Glasgow is about 2.4C."

"I think the war in Ukraine will be a strong driver of better energy security, and renewables will form a good part of this. I also felt at COP26 for first time a real urgency was palpable among political leaders. Covid took this away, but I expect it to have returned well before 2050, so that meaningful actions will be in place by then."

"We could see a dramatic increase in commitments to reduce CO2 emissions, combined with cheap clean energy. Clean energy has consistently beaten ambitious cost reduction projections."

FOOD

Q3: WHAT WILL BE THE YIELD OF CEREALS PER HECTARE IN THE WORLD IN 2023, ACCORDING TO THE FOOD AND AGRICULTURE ORGANIZATION (FAO)?

A Less than 3.80 tonnes	2%
B Between 3.80 tonnes and 4.00 tonnes, inclusive	18%
C More than 4.00 tonnes but less than 4.20 tonnes	59%
D Between 4.20 tonnes and 4.40 tonnes, inclusive	19%
E More than 4.40 tonnes	2%

Resolution Criteria: The outcome will be determined using data as reported by the FAO. In 2020, the yield of cereals per hectare was 4.07 tonnes.

Base Rate

- A **linear upward trend with stochastic variations a**round it has been the norm in the past 60 years. The Superforecasters, therefore, have identified 4.1-4.25 tonnes/ha as their baseline.

> When I plug the data into Excel from the past ten years available (2011-20) and extend the trendline from the past 10 years to 2023, I get a value of ~4.25. So if 2023 is a good year, I see a D bin resolution as entirely possible."

- The trend has been up due to **advances in agricultural inputs and techniques**.

> The graph shows the FAO Total Cereals worldwide in tonnes per hectare from 1961-2020. The plot is disarming in that it shows six decades of improvement in the world's ability to increase its cereals output. This is nearly a threefold increase over time due to better seeds, better methods, better equipment and likely because of better storage and distribution."

Downward Pressures

(i.e., factors that would lead to *lower* yields)

- Because this question focuses on a single year, the outcome is susceptible to **outlier events**. For instance, yield losses on already planted areas are possible due to severe weather events.

> Mitigating the upward trend have been, over the last three decades, a drier climate and more extreme temperatures and weather events, e.g., floods and storms. The war in Ukraine will no doubt disrupt the results for 2022, and the pandemic for both 2021-2022. 2023 could very well be a recovery year from the war and the pandemic. On the negative side, drier and more extreme weather will likely weigh against crop results."

- Other **disruptive developments** could play a role, including the war in Ukraine, although its impact will be smaller and less direct than might be expected at first glance (in particular because the relative size of Ukraine's grain production is only a small fraction of the global figure).

> It has been mentioned that yields in Ukraine are higher than average, so a decrease of production there can be expected to lower average yields; however, Ukraine is not that far from the average. A bigger impact would come from a hypothetical change in production in the US, where yields are very high."

> While the war in Ukraine will continue, its global impact on cereal yields will be real but modest."

- **Higher prices for fertilizer and fuel**, on the other hand, as a result of Russia's invasion of Ukraine, may have a larger impact.

> Long-term cereals production per hectare is increasing, and it makes sense to think it will continue in at least the near future. That said, Russia's invasion of Ukraine is harming production in both countries due to the conflict and sanctions. There are also impacts around the world as other farmers can't get inputs like fertilizer, normally provided by those countries. Even if the conflict ends this year, disruptions will ripple out for some time, and this makes me think 2023 will not be a good year either."

"Fertilizers use natural gas, which has seen a price spike in the wake of the invasion of Ukraine. Fertilizer prices have risen accordingly. Prices of gasoline and diesel impact farming economics as well."

"Sanctions on Russia could limit supplies of pesticides, seeds, and fertilizer, leading to lower yields. FAO also has a more extreme scenario: if the war continues, and fertilizers become scarce, higher costs of energy could also reduce yields."

Upward Pressures

(i.e., factors that would lead to *higher* yields)

- The Superforecasters point out the impact of higher fertilizer costs may not be unidirectional because **yield per hectare can remain stable**, or even increase, even when the overall cultivated area decreases.

"A key unknown I am wondering about is whether the current cost issues will in fact have the opposite effect and actually increase yields (rather than the currently hypothesized reduction). What if farmers respond to the price spikes by planting less and focusing on making the most of a small area of land?"

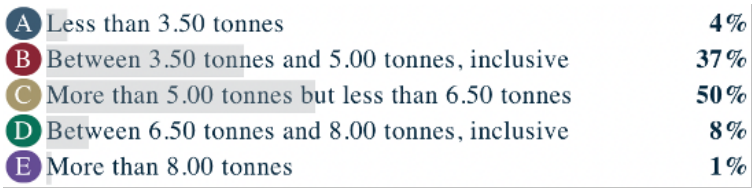
"Fertilizer shortage, supply chain issues, and potential increased climate shifts are factors that should reduce production, but could they actually increase the yield? For example, farmers may plant less and spend their resources on getting the most out of the land they choose to cultivate in 2023."

"A low yield in Ukraine alone would not impact the world yield significantly. Fertilizers can be a bigger issue worldwide, but it may have effect in the longer term and may not have a devastating effect in the first year."

- Ongoing **technological advancement** is likely to offset many of the negative trends.

"While climate change has tremendous potential to reduce yields of specific crops, such as wheat and maize, other crops, such as millet, will experience few impacts. Additionally, identification and implementation of strategies to mitigate climate impacts (breeding, irrigation, fertilization, and increasing the cultivation area of tolerant crops) will potentially minimize any reduction in yields. Localized weather events that devastate yields in a specific region will likely be offset by improved yields elsewhere, at least in the time period of this question."

Q4: WHAT WILL BE THE YIELD OF CEREALS PER HECTARE IN THE WORLD IN 2050, ACCORDING TO THE FOOD AND AGRICULTURE ORGANIZATION (FAO)?



Resolution Criteria: The outcome will be determined using data as reported by the FAO. In 2020, the yield of cereals per hectare was 4.07 tonnes.

Base Rate

- The **upward trend has been remarkably consistent** in the past 60 years, with some fluctuations due to, e.g., yield losses (down) or bumper crops (up).

"The trendline for cereals production has been surprisingly linear and given that it incorporates 60 years of history, I have no reason to think that the next years can significantly alter it, barring some large, unforeseen, and global crises or technological innovation that revolutionizes cereals yield. Thus, extrapolating to 2050, the trend would indicate 5.44 tonnes per hectare."

Upward Pressures

(i.e., factors that would lead to *higher* yields)

- **Population growth**: Increases in yield have so far been correlated with population growth, and many Superforecasters expect the world to continue being able to feed itself in 2050.

"In the last 30 years, the increase in yield is much aligned to the increase in population. The world population of 5.3 billion in 1990 has increased by 47% to 7.8 billion, while yield has increased by 46%. The correlation has been stronger or weaker, but present throughout the last 25-30 years. Based on UN latest projection for 2050, there will be 9.7 billion people, an increase of 25% vs 2020. A 25% increase in yield would mean 5.09 tonnes per hectare."

"People will do whatever is needed to eat, so adaptation here will be as fast as necessary. Costly, yes. Disruptive, yes. Impact on crop yields? Not sure."

"Necessity is the mother of invention: yields will need to improve to feed the masses."

- **Technological development**, including in lower-income countries (LIC): To fulfill the growing demand for food, particularly in the face of increasing climate change effects, humanity will continue to devise solutions, such as better seeds or more efficient farming techniques. Innovation may have its limits, and yields may plateau where its effects have maxed out, but the Superforecasters see enough room for advances in this timeframe.

"There are still crops and regions utilizing their capacity at 45-70%, meaning that opportunities remain to boost yields in some areas."

"The greatest gains in productivity will come from increased farm sizes and economies of scale in LIC. Migration will control the speed, as it did during the industrial revolution."

"To reach Bin E, the global yield would have to approximate the current yield in the US. I expect yields in Africa to increase substantially. Investment in African agriculture from China and the Gulf states will be made both as sound financial decisions and a need to feed their own populations through imports. An example of potential rapid increase through technology is Romania. From 1991 until 2016, their yield was between 2 and 4 tonnes, but shot up to 6.006 by 2018. A change in the type of seeds used and farming methods have dramatically increased production."

"The straight-line regression of the very consistent trend of the last 60 years would estimate 5.40 in 2050. In 2050, increasing farm technology will likely still be able to overcome and adapt to climate change. But the rate of linear increase has been so consistent for so long that I don't think we will be able to exceed it by much."

Downward Pressures

(i.e., factors that would lead to *lower* yields)

- **Climate change**: Climate change effects can limit the extent to which technological development will improve yields. Not all climate change effects will be negative,

however (e.g., CO2 fertilization effect). While overall net negative, climate change will not be catastrophic in 2050, according to most Superforecasters.

> On the one hand, global warming-caused heat stress, crop diseases, drought, flooding, erosion, pests, and unpredictable weather (climate weirding) will reduce output per hectare. On the other hand, CO2 fertilization, warmer climates, and longer growing seasons will benefit some crops in some regions of the world. Agricultural regions near the equator will be devastated while the Global North will see some modest gains in agricultural productivity. This forecast is my guess about how these countervailing trends will balance out in the end. We should see increased productivity of C3 (rice) and C4 crops (wheat, maize) in a high emissions scenario before the full negative effects of climate change start kicking in."

> The likelihood of catastrophic climate impacts in the 30-year timeframe is not as high, so I don't think we'll see much of a deviation from the recent trend. I could see technological improvements drive a faster pace, but also some headwinds from climate change."

- **Outlier events**: Because this question focuses on yields in a single year, much like the 2023 question, it is susceptible to outlier events in that year.

> Given that this is another one of those 'point-in-time' forecasts, it's still possible for some unexpected shock that happens to throw off the numbers for 2050 such that they're significantly different from 2048 and 2049. And at this point, I think that any shock that could occur is more likely to result in a Bin A resolution than a Bin E resolution."

Q5: ASSUMING THAT THE EARTH'S GLOBAL AVERAGE SURFACE TEMPERATURE INCREASES BY 7°C IN 2100 AS COMPARED TO 1880, WHAT WILL BE THE YIELD OF CEREALS PER HECTARE IN THE WORLD IN 2100, ACCORDING TO THE FOOD AND AGRICULTURE ORGANIZATION (FAO)?

A Less than 2.00 tonnes	12%
B Between 2.00 tonnes and 5.00 tonnes, inclusive	23%
C More than 5.00 tonnes but less than 8.00 tonnes	51%
D Between 8.00 tonnes and 11.00 tonnes, inclusive	12%
E More than 11.00 tonnes	2%

Resolution Criteria: Measurements of global average surface temperature have increased since the 1880. The outcome will be determined using data as reported by the FAO. In 2020, the yield of cereals per hectare was 4.07 tonnes.

- In a scenario envisioning a global average surface temperature increase of 7°C in 2100 above the 1880 levels, the Superforecasters still expect a **trendline level of yields** (**55% probability**) with **35% probability for downside risk** (5.00 tonnes per hectare or lower). Accounting for this forecast is, in part, the calculus behind the FAO yield figure: The land in use in 2100, while undoubtedly smaller in area, may have been made at least as productive as it is today.

"The development of heat-tolerant grain varieties, automation, and precision farming become only more essential/critical if humanity is to cope with a 7°C increase in temperature on top of population growth. The alternative is increasing levels of food scarcity, starvation, and civil unrest."

"Given sea level rise impacts, there will likely be less money and fewer resources available for research and more devoted towards relocation, and many more wars/mass refugee movements as a result. There also might be a population collapse as a result of disruption, which actually might increase yields if production is focused in the most hospitable areas, so really a very wide range of outcomes here."

"At 7°C, there probably won't be much land left to cultivate, but I imagine our technology will be such that what we still have is extremely productive."

"Such a change may rather increase yields. I think that in such conditions, there would be further shift from extensive to intensive farming. It would be much harder for individual farmers or smaller companies whose yields are lower as they have less capital and use less mechanization to maintain production in unfavorable conditions. Low-yield areas will be abandoned while new areas for farming will use much more capital and newest technologies as land there will be acquired by huge farming conglomerates which will bring yields up to speed."

- On the other hand, **conflict is likely to increase** under such conditions, and not all Superforecasters are convinced global cooperation will improve.

"There's no question climate change will have a strong negative impact on crop yields under this scenario. Then there's the likely human response to the decline in crop yields. I think a society that allowed a 7°C warmer planet to happen in the first place isn't going to be one that engages in responsible, sustainable, and efficient farming practices. Nor will it be one that assists the most vulnerable populations."

"Human conflict is likely to be much more extreme, but whether a major war will be playing out in 2100 is impossible to accurately forecast. Whether the rising temperatures will be accompanied by a global breakdown in order and civilized society or helps unify us around a common threat is also an unknown. The global and national responses to Covid, including polarization along political lines, however, suggest current lack of cooperation is likely to continue."

Q6: WHAT WILL BE THE FAO FOOD PRICE INDEX VALUE FOR 2023?

A Less than 110.0	3%
B Between 110.0 and 130.0, inclusive	28%
C More than 130.0 but less than 150.0	43%
D Between 150.0 and 170.0, inclusive	21%
E More than 170.0	5%

Resolution Criteria: The outcome will be determined using data as reported by the FAO. For 2021, the real Food Price Index was 125.1.

Base Rate

- The **index average has been around 100**, although it has exhibited some short-term volatility, including its current level of 125.1 for 2021 on an annual basis. The Superforecasters expect it to remain elevated in 2023 but moderate somewhat from its recent highs.

> We are currently in Bin D, uncharted territory, which is the highest it's ever been in the 60-year history of the index. Furthermore, the monthly numbers are coming down. I don't see things getting much worse, and I don't see us sitting above 150 for prolonged periods."

> While world food prices will moderate in real terms for 2023, they will still remain elevated relative to the decades-long trend. That said, the index is bouncy, and a new war, a deadlier Covid variant, a new flu pandemic, unrest in China, a worsening situation in Ukraine, a run of bad weather (whether climate related or not) are factors that each could send the index soaring again —or rather keep it up where it is. Whereas smooth geopolitical/pandemic sailing, paired with the dynamic where high pricing drives increased crop yields and increases in arable land, could swing the index back to the A Bin—as it traditionally reverted to after spikes."

Upward Pressures

(i.e., factors that would keep food prices *high*)

- **Effects of the war in Ukraine**: The war in Ukraine has reduced the global wheat crop and has led to increased cost of natural gas, which affects fertilizer and fuel costs. As

the Superforecasters as a group do not expect the situation to be resolved prior to 2023, geopolitical factors will continue to exert upward pressures on food prices.

"The cost and availability of natural gas will likely rise through the winter, as will instability in Europe. Reaching Bin A would require two consecutive years of drops that near the limits of the recent historical record. In 2009, the price dropped ~25, but there were never back-to-back years like that. Supply shortages will continue to keep prices high. Bin E is unlikely, but the situation is already fragile so an expansion of the war or serious unrest in major food producing regions of the world make me hesitant to completely discount another jump."

"The resumption of grain export from Ukraine happened faster than I expected. On the other hand, I expect natural gas prices to stay elevated into 2023, as a knock-on effect of the current disruptions. This is because even if gas flows increase in 2023, I expect storages to be very low as Europe draws down during winter (the severity of which is one factor here). High gas prices will bleed into fertilizer pricing, which will likely lower yields or be passed on to consumers and thus exert upward pressure on food prices."

- **New shocks**: Adverse weather conditions, or indeed any new shocks to the system, would keep the price index level above the historical norm.

"As long as there isn't a new disruption in the next 12-18 months, the FAO index should begin to decrease. Will it go all the way back below 100 like it was in 2020? Probably not. However, I think it's more likely that it goes down below 100 than it goes up over 170."

Downward Pressures

(i.e., factors that would *reduce* food prices in this timeframe)

- **Reversion to the mean**: Many Superforecasters expect a reversion to the mean has started as the existing risks are becoming priced in.

"The index value has shot up due to Covid and now Russia's invasion of Ukraine and subsequent supply chain shocks. However, I think the shocks have now happened, and the global food system is adapting, and this explains the slow but steady fall in the last three months."

- **Recession**: A recession, now increasingly expected in late 2022-2023, would have a cooling effect on prices, including prices of fertilizer and fuel, leading to a drop in the food price index.

// The main driver of the food price index in 2023 will be the price of fuel and energy sources, which will probably fall due to global recession or at least slowdown in economy. It will probably not get to sub-50 USD per barrel levels, which would guarantee sub-110 food price index, but if oil falls to 60-80 USD, food price index level of 110-130 is possible."

// Cereals price is the most highly correlated with the total index. Although wheat and other grains have come down in the last couple months, there is still plenty of risk from Ukraine. A recession in 2023 might bring down prices, but food prices are very inelastic. A new normal might be in the 120-140 range that we saw from 2011 to 2014."

- **Possible end of active hostilities in Ukraine**: Some of the effects of the war in Ukraine are smaller than might appear at first glance, but a resolution of the crisis could be a downward pressure on food prices.

// Lion's share of world's cereals production is consumed locally in countries of origin and only 17% is traded internationally. Of those 17%, roughly 10% has been originating in Ukraine. So, a loss of entire Ukrainian export would result in loss of 1.7%-2% of world's demand. And ups and downs of 2% in cereals production due to various reasons are not something unusual, and the world is generally prepared for it keeping stock-to-use ratio at 30% levels."

// If the Ukraine situation is resolved, there might very well be a glut next year."

Q7: WHAT WILL BE THE FAO FOOD PRICE INDEX VALUE FOR 2050?

A Less than 80.0	6%
B Between 80.0 and 115.0, inclusive	35%
C More than 115.0 but less than 150.0	37%
D Between 150.0 and 185.0, inclusive	17%
E More than 185.0	5%

Resolution Criteria: The outcome will be determined using data as reported by the FAO. For 2021, the real Food Price Index was 125.1.

Base Rate

- The **index average has been around 100**, although it has exhibited some short-term volatility. The Superforecasters are almost evenly split between two answer options: "Between 80.0 and 115.0, inclusive" (which includes the historic base rate; 35% probability) and "More than 115.0 but less than 150.0" (which includes current level; 37% probability), with a 22% probability in total for upside risks (i.e., higher food prices).

> While there was a long period of stability between 1990 and 2003, the trend since then has been higher. There have been no years below 80 since 2005, and no years below 90 since 2006. Nine of the past 15 years have been above 100. While I believe we will continue to see cycles of both increase and decrease, I think the general trend during this period will keep the index above 100, with occasional peaks above 180 due to higher energy prices, extreme weather events, general inflation in the short term, and conflicts leading to reduced supply."

> I'm guessing the higher post-2007 prices will persist and even modestly increase by 2050. My underlying assumptions driving that forecast are: (1) crop yield efficiencies will continue to be driven by industrial agriculture in countries with enough political stability and underlying infrastructure to sustain them; (2) while this has the potential to exert downward pressure on pricing, the consolidation also means food prices will remain more vulnerable than in decades past to storms, flooding, and heatwaves, as well as supply chain issues and spikes in transportation costs; (3) there will also likely be 20-30% more people on the earth by 2050, which will exert upward pressure on (real) pricing both by increasing demand for food and because it may impact the cost and availability of land. That said, the food price index is bouncy, and even if the trendline suggests a certain value is likely, that 2050 could be an anomalous year."

Upward Pressures

(i.e., factors that would keep food prices *high*)

- **Climate change effects**: Some of the climate change effects will be felt by 2050, and can lead to higher levels of the food price index.

"There will be some climate change impacts by 2050: increased drought, hotter temperatures, some sea level rise, and maybe more severe storms. Vulnerable crops like corn might already start to shift north. I don't think 100 is the base to which prices will return; there's probably a general upward trend. Prices are more volatile than yield, and can jump around quite a bit. Energy and fertilizer prices will also likely increase, which will also drive the FPI up."

"There is no question that climate change will impact food prices in 2050. Warming past 2C by 2050 (the likely scenario) will devastate agriculture in the world's most fertile regions not simply because drought will become more common but also because farming will become an increasingly unpredictable enterprise thanks to weird weather ('climate weirding'). Climate weirding and failed harvests will wreak havoc on food prices."

- **Lag in technology**: Technological development will need to keep pace with climate change and growing world population. Any lag will put an upward pressure on food prices.

"New acreage is less likely due to climate change. Labor-saving machines may continue to improve, albeit more slowly. Fertilizers will likely become more expensive but not likely better. Purpose designed crops are one vector that may continue to improve over the next 30 years. It thus will likely be a race between the changing climate and bioengineers' ability to redesign crops to meet new climate realities. Human inertia to change will likely slow down the acceptance of new crops or new versions of existing crops. Thus, there will likely be a lag, which forces the food index upward over a period of time. If bioengineering is very successful and new crops are accepted by the public quickly, the Food Price Index could moderate in spite of climate changes and reduced arable crop land. Public acceptance may be the wildcard, however, if there is continued resistance to GMO foods."

"Vegetable oils is the component I worry about because of their dependence on bees. These oils may become more expensive if the number of pollinators is reduced due to climate change. Dairy and meat may also still be struggling in 28 years. They can be selectively bred to survive climate changes, but it will take longer to do so. I think those prices could still be high in 28 years."

- **Lack of international cooperation**: Continued trend toward deglobalization is another risk.

> The current global food situation is likely to increase protectionism and prioritize local food security. Agriculture is already highly protectionist in the developed world."

Downward Pressures

(i.e., factors that would *reduce* food prices in this timeframe)

- **Technological development**: Adaptation and mitigation will be crucial to keep food prices from soaring in the face of increasing climate change effects, including less predictable growing seasons. Electric or hydrogen-powered vehicles would also help by reducing the cost of transport.

> I generally expect prices to decline after the current spike and revert to long-term trends. In the long term, prices are a function of growing demand (including both population growth and growing meat consumption), improvements in technology (a countervailing effect to the one before), and cost of supply (which climate change will generally increase). For my forecast I am also assuming that many projections underestimate future technological innovation and behavioral change, which are inherently poorly represented in economic models (aka computable general equilibrium). Factors that probably bias these upward include potential growth in lab-grown meat and a behavioral shift toward less meat-intensive diets."

> Transportation costs may decrease by 2050 if the land component is optimized through electric and/or hydrogen-powered vehicles."

- **Population growth**: While increased global population would mean increased demand for food, it could also mean gains in productivity.

> A few people mention population growth as a driver for increased food demand and higher prices. The counterpoint to this is that more people makes for a more productive civilization through progress in technology, infrastructure, etc."

- **Cyclical nature of agriculture**: The Superforecasters also point out the cyclical nature of agriculture and the effect of outlier events on single-year outcomes as a source of uncertainty.

"In the long term, factors that would push index higher, like climate change, more mouths to feed, water shortages, potential political, economic, and cultural stresses, will be offset by improvements in technology and development; therefore, status quo seems most probable. However, agriculture, if treated as part of the economy where various kinds of food are just commodities, is cyclical, so it is hard to predict in which point of the cycle 2050 will fall. Options A, D, and E seem as outliers for me which can happen due to extraordinary circumstances in that particular year but would not be representative or typical for, say, the 2045-2055 period."

Q8: ASSUMING THAT THE EARTH'S GLOBAL AVERAGE SURFACE TEMPERATURE INCREASES BY 7°C IN 2100 AS COMPARED TO 1880, WHAT WILL BE THE FAO FOOD PRICE INDEX VALUE FOR 2100?

A Less than 80.0	16%
B Between 80.0 and 120.0, inclusive	20%
C More than 120.0 but less than 170.0	30%
D Between 170.0 and 230.0, inclusive	22%
E More than 230.0	12%

Resolution Criteria: The outcome will be determined using data as reported by the FAO. For 2021, the real Food Price Index was 125.1.

- In a scenario envisioning a global average surface temperature increase of 7°C in 2100 above the 1880 levels, the Superforecasters expect the FAO Food Price Index to be **above 120.0** (64% probability in total).

"For a 7°C increase to have happened, unless it was caused by a one-time event, adaptations would have been underway for decades. Food scarcity would exist, but global population may have already suffered significant culling. Moving north does not necessarily mean finding fertile land. Tundra is fragile. Technology may have solved some of the problems, and if energy is abundant and cheap, much food may be grown indoors, but not likely on a scale to feed the world. The time scale is long enough and the temperature shift radical enough that I forecast this with a low degree of confidence."

"This is worse than the worst-case RCP 8.5 scenario. Even if yields for grains don't fall much because the planted land moves to Canada and Siberia, total food production will probably be lower. There's no way to overcome warmed oceans. Hardest-hit areas will be in the tropics and their ability to adapt is not great without support. Changes in trade policy, diet, and land use will lag behind. Population growth will probably have stopped under those conditions. If the food production system is under extreme stress, chances are prices will be higher."

"It's important to keep in mind that climate science generally omits complex interactions between risks, so numbers cited are likely to be underestimates considering climate change will exert negative effect through multiple pathways. Also, scaling these non-linearly for 7°C and factoring in inelasticity of food demand suggests very high prices."

- On the other hand, **the pace, and timing, of the temperature change** will play a major role here: If the bulk of temperature increase happened prior to 2100 and unfolded somewhat gradually, humanity would have started **adaptations** in earnest and global **population would have decreased** by 2100.

"While humans would adapt to a 7-degree Celsius rise, the transitional period, when the temperature was still rising rapidly, would be rocky. Such a fast-changing landscape, paired with the increasingly global nature of the food supply chain, would likely lead to significant periods of disruption."

"I am not saying it is going to be a bed of roses, but perhaps it will also not be an apocalypse."

HEAT

Q9: HOW MANY HEAT-RELATED DEATHS WILL THERE BE IN THE WORLD IN 2023?

A Less than 250,000	2%
B Between 250,000 and 300,000, inclusive	24%
C More than 300,000 but less than 350,000	55%
D Between 350,000 and 400,000, inclusive	16%
E More than 400,000	3%

Resolution Criteria: The outcome will be determined using data reported by Global Burden of Disease. There were 307,846 heat-related deaths in 2019.

Base Rate

- The trend in heat-related deaths worldwide has been **up since 1990**, and shows signs of **acceleration**, according to the Superforecasters. Annual heat-related death figure hasn't been below 350,000 (upper boundary of Bin C) since 2011.

"It is clear that humanity can be successful in adapting to climate change in some ways. For example, nations should have the tools in the coming years to reduce the death toll resulting from stronger and more frequent storms and flooding, and perhaps from the spread of zoonotic diseases. Humanity will have a lot more trouble dealing with other climate impacts. Heat is one such impact. The upward trend of heat deaths since 1990 has been inexorable. This is likely to continue. We haven't seen deaths drop to less than 250,000 since 2011. Bin A is very unlikely. Outlier years on the low side have happened before (2008 and 2011), though."

"The data since 1990 strongly suggests a combination of two things: The trend is accelerating, and the variance in the data is increasing."

Upward Pressures

(i.e., factors that would lead to *more* heat-related deaths)

- **Increased global temperatures**: The Superforecasters expect global temperatures to continue to rise; even though this effect will be more pronounced in the year and decades to come, rising temperatures already create stress for many global systems.

> "The average world temperature and absolute world population have both increased since 2019 (the last year for which data was available) and I expect both to continue to increase until 2023 and beyond."

- **Population growth**: Global population continues to not only grow but also age. Health, age, and poverty are pre-existing conditions increasing one's risk of death from heat.

> "The growing and ageing population combined with rising temperatures suggest that the upward rate would continue."

- **Improvements in data collection**: Better data collection in lower-income countries, which bear the brunt of heat- and climate-related risks, could lead to a higher number of reported deaths in this category.

> "There is a chance that data collection improves in the hardest hit places, in which case the numbers will show an increase, beyond what the linear (or quadratic) trends would predict."

- **Outlier events**: Because this forecast focuses on a single year, a significant heat wave, grid failure, or unrest could lead to an elevated number of heat-related deaths next year.

> "The rather obvious fact is that older, poorer adults with health issues bear the brunt of this dangerous trend. A catastrophic failure of a major electrical grid in the midst of a summer heat wave could result in a drastic number of deaths in the US—one of the countries not expected to have a major impact on the global numbers."

Downward Pressures

(i.e., factors that would lead to *fewer* heat-related deaths)

- **Adaptation and mitigation**: There is already some evidence of successful adaptation and mitigation measures limiting the number of climate-related deaths in many parts of the world. Some Superforecasters argue, for instance, that the number of heat-related deaths in 2022 has so far been lower than could be expected.

> Heat waves this year have not seen as many deaths as expected. A main reason seems to be better adaptation, including public agencies becoming better at warnings and messaging, though there is more to be desired in terms of disaster preparedness."

> There is a general upward trend in temperature as well as variation in temperature. On the other hand, more heat waves and greater awareness of heat waves will accelerate efforts to mitigate deaths."

- **Year-to-year variation** in the global trend: While an outlier event (as described above) could increase the number of heat-related deaths next year, cooler temperatures, below the trend, could have an opposite effect.

> Climate shows a lot of variation from year to year. 2022 looks like a hot year, but 2023 could be relatively cooler, without negating any of the current long-term effects of climate warming."

- **Poor reporting in high-risk countries**: Business-as-usual scenario in data collection and reporting may lead to a lower reported number of deaths, particularly in poorer countries that also tend to be at greater risk from heat waves.

> While I don't doubt that plenty of people are dying because of high temperatures, and that the number of people dying from high temperatures is increasing, as temperatures and populations increase faster than mitigating measure are, when heat waves hit megacities in underdeveloped countries, it's at best a very rough guesstimate as to how many people are dying as a result of the heat."

> Other than following the trend line and maximum yearly variance, my forecast accounts for the following uncertainties: 1. Inaccuracy of reporting, particularly in developing countries in SE Asia and Africa, where the majority of deaths occur. 2. Unrest leading to more vulnerable people, but also possibly less reporting of actual heat-related deaths ."

Q10: HOW MANY HEAT-RELATED DEATHS WILL THERE BE IN THE WORLD IN 2050?

A Fewer than 300,000	3%
B Between 300,000 and 400,000 inclusive	20%
C More than 400,000 but fewer than 500,000	33%
D Between 500,000 and 600,000 inclusive	27%
E More than 600,000	17%

Resolution Criteria: The outcome will be determined using data reported by Global Burden of Disease. There were 307,846 heat-related deaths in 2019.

Base Rate

- By taking the historical data and projecting the trendline out to 2050, the Superforecasters arrive at an outcome on the border between answer options B and C as a starting point in their forecast. They assign a **33% probability** the decadal average of annual heat-related deaths in the world from 2041 to 2050 will be **more than 400,000 but fewer than 500,000** (answer option C) and a 20% probability it will be 300,000-400,00 (answer option B).

"Base rates here may be of limited value for obvious reasons. Heat deaths will be higher in 2050 than in 2020. The pattern is clear. The big question is the rate of increase. Linear progression suggests we'll be right on the line between B and C. Is that justified? With an indication that humanity is learning to adapt, a range of 300,000 to 400,000 is still possible. On the other hand, once we reach critical tipping points (e.g., wet bulb temperatures), deaths from heat will begin to rise exponentially. When regions of the Earth that used to support civilization become too hot to live in, we will have reached the limit of adaptation."

"The trend has been upwards since 1990, and it looks quite linear, with a potential tendency to grow faster. When looking at the resolution site, it's up from 200,000 to 300,000 in 30 years, and it's a fair bet to assume that this will continue. 20-30 more years out from now into to 2040-2050, something around 400,000 is the absolute minimum to expect."

"On the one hand, increasing temperatures strongly suggest increasing heat-related deaths. Runaway climate change effects could worsen this. On the other hand, mitigations may help reduce the number of deaths even if temperatures continue to rise. Some math: Extrapolating a linear trend from 1990 onwards suggests an estimate in the 370,000 range. Extrapolating a linear

trend from the 2010-2019 data suggests an estimate in the 440,000 range. Extrapolating a quadratic trend from 1990 onwards gives an estimate above 500,000 (but below 600,000). This suggests that, on balance, our estimates should be concentrated in the B-D range with some allowance for answer option E due to possible runaway effects, and answer option A due to possible mitigations and precautions."

Upward Pressures

(i.e., factors that would lead to *more* heat-related deaths)

- **Rising global temperatures**: While the world can adapt to rising temperatures over time, this increase creates a risk, and sudden spikes in the temperature are particularly dangerous.

"Consistently hot weather is probably less dangerous than a sudden hot spell in an area that's not used to it. So, if climate change causes an area to gradually get hotter over a few decades, with no sudden spikes, humans adapt well. Climate change is much more dangerous if it leads to more sudden spikes of heat in areas that don't expect them. Needless to say, less affluent areas likely will suffer more."

"Increased heat waves, in number and severity, are here to stay during this time frame, and likely beyond. Increased temperatures and growing urbanization are two big factors in this decade's numbers growing over past decades."

- **Population growth** and urbanization: The Superforecasters expect 2041-2050 to be a decade that still has a growing population with relatively high poverty rates. Rapid urbanization is a risk factor here.

"Urbanization (urban heat island [UHI] effect) is an issue as cities are hotter than the countryside and less likely to have the informal 'checking on a neighbor' system. Urbanization is projected to increase from ~55% now to ~68% by 2050."

"It strikes me that global population increase through 2050 and a continuing shift to urbanization are all but guaranteed to offset any improvements in functionalities, so I would conclude that climate impacts will not be decreasing. All of this leads me to thinking that the key to annual heat-related deaths will come down to effective urban adaptations and the increasing implementation of heat mitigation strategies. Moving entire populations out of regions or subcontinents simply is not a viable solution and a failure to adapt is not really an option."

- **Global inequalities**: More affluent countries are likely to fare much better in 2041-2050 thanks to technological development and adaptations; the same may still be unaffordable to lower-income countries (LIC) for economic or governance reasons.

"The solutions to preventing heat deaths aren't new, we already have them: shelter, air conditioning, and easily accessible water. None of these solutions are likely to be any more affordable than they are now for the poorest countries."

"Status quo per capita is 372,000. However, migration to cities and the urban heat island effect will increase this. Adaptation is possible in this time period. For instance, after the 2003 EU heatwave, simple measures were taken that reduced future mortality. Even though 2022 was hotter than 2003, there were a lot fewer deaths. However, adaptation is unlikely to happen in LIC in this time frame due to governance issues."

- **Interaction among climate risks**: The Superforecasters do not expect heat-related deaths to grow exponentially in 2041-2050, but reserve a 17% probability this number will exceed 600,000 due to the possibility the currently understudied interaction among climate change effects will lead to a tipping point.

"Some models suggest annual deaths' increase by a factor of 3 without adaptation, and 1.4 with a very hypothetical adaptation. However, these numbers are probably underestimates, as the models include no interactions among the climate change effects and the data doesn't cover all countries (notably excluding Southwest Asia, Central America, and Africa). In general, the interaction between hazards is a 'missing link' in the climate literature because most studies focus on one hazard or risk factor at a time. Possible interactions include: 1. Heat and humidity. 2. Heat and timing. 3. Heatwaves and heat. 4. Heat and drought. 5. Heat and other weather hazards. 6. Heat and societal preparedness."

"Whatever the deaths are now, I'm forecasting things will be marginally worse, in terms of deaths as a percentage of the population, in 2041-2050, but not exponentially worse. There's definitely a chance, though, that if temperatures rise more and faster than predicted and a tipping point is reached in some countries, overloading health systems and the limits of the human body, that it could get exponentially—or at least significantly—worse."

Downward Pressures

(i.e., factors that would lead to *fewer* heat-related deaths)

- **Adaptation and mitigation**: The Superforecasters expect adaptation and mitigation efforts to continue in the coming decades, which should help prevent a sharp increase in average heat-related deaths.

> I think that climate change will kill many people, but I'm just not very convinced that there will be a meaningful increase to the heat-related death rate specifically. It's a pretty tractable case for adaptation (e.g., depopulating super-hot regions, changing norms/regulations regarding outdoor physical labor, better buildings and cooling), whereas I think a lot of the second- and third-order impacts of climate change (e.g., war, famine, zoonotic spillover pandemics) will be the major killers, and potentially much less tractable."

> My conclusion is that as the world population begins to appreciate that the climate is going to continue to heat, adaptation to those to those changes will accelerate, and while heat deaths while continue to rise, the rate at which they rise will be lower."

- **Poverty reduction**: Reduction of poverty due to either international cooperation or growing wealth in some parts of the world would also help contain heat-related deaths in this period.

> A decline in mortality risk per a unit of temperature is to be expected as societies become richer and some adaptation to climate change begins to take place."

Q11: ASSUMING THAT THE EARTH'S GLOBAL AVERAGE SURFACE TEMPERATURE INCREASES BY 7°C IN 2100 AS COMPARED TO 1880, WHAT WILL BE THE DECADAL AVERAGE OF ANNUAL HEAT-RELATED DEATHS IN THE WORLD FROM 2091 TO 2100?

A Fewer than 350,000	5%
B Between 350,000 and 500,000, inclusive	3%
C More than 500,000 but fewer than 800,000	10%
D Between 800,000 and 1.2 million, inclusive	24%
E More than 1.2 million	58%

Resolution Criteria: The outcome will be determined using data reported by Global Burden of Disease. There were 307,846 heat-related deaths in 2019.

- Unlike in the case of deaths caused by floods and drought in this scenario (see the relevant sections below), the Superforecasters see a 7°C increase in global average surface temperature in 2100 above the 1880 level as a **major risk for heat-related annual deaths**. Adaptation in this scenario will be at its limit, the number of conflicts will rise, and there is little reason to feel optimistic about the quality of governance and international cooperation in a world that is 7°C warmer on average. The Superforecasters see a 58% probability more than 1.2 million heat-related deaths will on average be recorded annually in the last decade of the century.

"Adaption obviously works well, to a certain degree. But for an increase of 7 degrees Celsius,I would consider the ability to adapt becoming overstretched."

"This scenario would certainly involve revolutions, wars (especially over water and food or possible farmland), and migration on an unprecedented level."

"Going to 7C, considering the non-linearities of the climate system, could mean large increases in mortality. Numbers lower than Bin E would require very substantial adaptation measures (and for the world to get lucky and be on the lower end of some of these estimates), which are possible, but decision-makers have yet to start walking the walk. While capacity to handle heat will rise, it will be unevenly distributed. Given that societies are on track to continued economic and political inequality, adaptation is likely to be limited."

"If we're talking a rise of 7 degrees Celsius, that suggests a collective global failure of epic proportions. Nothing about that scenario would give me faith that, having failed to curb emissions, the better part of the world would somehow succeed in aiding the least fortunate to

adapt. The speed with which such a rise would occur would also make adaptation exceptionally difficult."

- On the other hand, if this rapid increase in surface temperatures led to a drastic decrease of global population, and if the bulk of it happened before 2091, the decadal average of annual heat-related deaths could come in at a lower number.

"The increase would be too fast (1 degree every 15 years) for the global economy to adapt and for humans to migrate to safer areas. On the other hand, it could reduce heat deaths because the population is so much smaller."

"The only chance I see of B-C-D bin resolution in this scenario would be if the timing of the warming was such that the bulk of the temperature rise and its effects were experienced prior to the last decade of the century—so that when 2091-2100 came, most of those who were able to adapt had already adapted and those that couldn't had already perished."

FLOODS

Q12: HOW MANY DEATHS WILL BE CAUSED BY FLOODS IN THE WORLD IN 2023, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 3,000	11%
B Between 3,000 and 10,000, inclusive	71%
C More than 10,000 but fewer than 30,000	14%
D Between 30,000 and 100,000, inclusive	3%
E More than 100,000	1%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 6,179 deaths caused by floods.

Base Rate

- Annual deaths attributed to floods in the past 20 years have been **relatively low**. The closest it came to breaching 10,000 (upper boundary of answer option B) was in 2013 with 9,819 deaths. The trend in 2010-2020 has been down (i.e., fewer recorded deaths caused by floods), and the average deaths per year caused by floods over the last five years of data (i.e., 2016-2020) were about 4,400, based on the Superforecasters' calculations.

"Annual deaths caused by floods during the past 20 years (2001-2020) have been low and more stable than ever. There were no years with more than 10,000 deaths in this period. Annual deaths during the previous two 20-year periods (1961-1980 and 1981-2000) veered from very low deaths (fewer than 3,000) to high deaths (10,000-30,000). Years of catastrophic deaths (30,000-100,000) also occurred three times during this 40-year period. Modern society is better equipped to handle flood disasters than before. That accounts for the low and stable numbers during the period 2001-2020."

"Trend was actually down in 2010-2020. Even though climate change will likely continue to result in an increase of the frequency and severity of flooding worldwide, I don't see it as a risk like I do heat waves."

Upward Pressures

(i.e., factors that would lead to *more* deaths caused by floods)

- **Increased number of catastrophic events**: In 2021, a total of 432 catastrophic events were recorded, which is above the average of 357 annual catastrophic events for 2001-2020. Floods dominated these events, with 223 occurrences, up from an average of 163 annual flood occurrences recorded across the 2001-2020 period. Increased number of events can exert an upward pressure on the outcome, particularly in the case of **flash floods**, which are sudden and harder to predict.

> Flash floods often catch residents by surprise, which causes the most deaths when it comes to flooding."

> Flash flooding is the main killer here. The predicted increase in hurricanes in 2023 could increase the deaths associated with flooding."

- **Population growth**: Although the timeframe of this question is very short, population growth, particularly in flood zones, may lead to a higher number of deaths—but this is more likely to play out in the medium to long term and will have only a limited effect for 2023.

> The more frequent low numbers (bin A) for previous 20-year periods can be attributed to the lower global population then. Perhaps, too, there were fewer people who lived in flood zones. Evidently, there has been a 24% increase in people living in flood zones, to 80 million since 2000."

- **Single-year volatility**: The outcome can be skewed by a single, high-impact event.

> All it takes is for a single massive event, like the Vargas tragedy in Venezuela in 1999 that resulted in 10,000-30,000 deaths, to skew the result for the year."

Downward Pressures

(i.e., factors that would lead to *fewer* deaths caused by floods)

- **Better forecasting and early warning systems**: Although the world already has more flooding—and greater population—than 20 years ago, the number of deaths caused by

floods did not rise accordingly in this period. The Superforecasters attribute this outcome to better weather forecasting and dissemination of early warning systems, a factor which is going to play a role in 2023 outcomes as well.

// While flooding has increased over the years, deaths aren't going up at the same rate. Improved early warning systems is the big reason this number isn't likely to explode in 2023, even if the increase in hurricanes comes true."

// Despite climate-change-induced increasing rainfall and severe weather, the number of people killed by flooding annually around the world is unlikely to reach the very high numbers of earlier years. The reasons are better weather prediction, better governmental planning, and rescue capability, and better mass communication and warning."

- **Stringency of the resolution criteria**: Because the resolution source counts only deaths caused directly by floods, and does not include those caused in the aftermath, the Superforecasters see only an 18% probability the 2023 outcome will be above the base rate.

// Given the low numbers, the Our World in Data source seems to be just counting deaths that were directly related to flooding, rather than the peripheral deaths that floods leave in their wake, namely due to poor sanitation, crop failure, and displacement. If the resolution criteria included those other deaths, I'd feel much differently about this question."

// Downstream events such as starvation and disease are not included."

- **Lack of significant climate change effects** in this timeframe.

// Changes are unlikely to be significant in 2023."

Q13: HOW MANY DEATHS WILL BE CAUSED BY FLOODS IN THE WORLD IN 2050, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 5,000	10%
B Between 5,000 and 20,000, inclusive	65%
C More than 20,000 but fewer than 100,000	19%
D Between 100,000 and 400,000, inclusive	5%
E More than 400,000	1%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 6,179 deaths caused by floods.

Base Rate

- The decadal average deaths attributed to floods in the past 20 years have been **relatively low** and the **trend** since a high in 2000 has been **down** (i.e., fewer recorded deaths caused by floods).

"Focusing on the decadal annual averages since 1969 (reflecting data starting in 1960), the highest decadal annual average was for the ten years ending in 2000 (with 9,925 deaths), following some higher values in 1998-1999. Since then, the averages have dropped steadily, despite (presumably) tracking and attribution only getting better."

"Yes, climate change is accelerating, and the decade in question will likely see more frequent and extreme floods than that during 1960-2019. Meanwhile, the type of event(s) that would kick us up into Bin C or higher have not occurred since 1959. Clearly, it would be naive to say that they won't happen anymore, but after 60 years without one, I'm fairly comfortable assigning a pretty low probability (11%) to that type of event (or multiple events summing to that level) occurring in the decade in question here."

Upward Pressures

(i.e., factors that would lead to *more* deaths caused by floods)

- **Climate change effects**: The Superforecasters expect climate change effects to become more pronounced in this period, leading to greater volatility.

"I'm predicting more extreme weather in this timeframe. I also expect more international cooperation and improved detection systems. But even these two things could be overwhelmed by the unexpected events (mudslides), human fallibility (failed dams), and a possible deluge of extreme weather."

"The speed at which flash floods happen makes it difficult to get warnings out in time. Some 85% of flood deaths are flash flood deaths."

"The extreme weather has already hit us, and will likely hit us harder, and in unforeseen ways, in the future."

- **Population growth**: Population pressures and increasing urbanization mean more people are likely to move into flood zones, which in turn increases the risk of higher deaths from catastrophic events. Human factor can play a role too if people in danger zones choose to ignore early warnings.

"More people are moving into flood zones worldwide, which should increase the risk of truly catastrophic death tolls. Globally, there has been a 24% increase in people living in flood zones, to 80 million since 2000. That trend of people moving into flood zones is not likely to reverse given the growing populations in urban centers, and the likely need to house millions of climate refugees in the coming decades."

"In short-term and immediate flood risk situations, it's very hard for individuals to evaluate their risks, and this is one reason you see so many clips of governors pleading with their people to get on the road early and so few do."

"Increasing population is likely to lead to more people living in flood zone areas in poorer countries, although attribution of these deaths may still be to other causes, e.g., famine, storms, etc."

- **Global Inequality**: This has been the most cited factor among those limiting global ability to adapt to climate risks. Limited technological development is another such risk.

"In less developed countries, many people lack the short-term transportation options or the long-term economic flexibility to get out of the way."

"The decadal average hasn't been lower than 5,000 since the 1960s, when there were fewer floods and fewer people; I don't think our warning or transportation systems will be so much better by the 2040s that I'd expect us to fall below that level on that account."

Downward Pressures

(i.e., factors that would lead to *fewer* deaths caused by floods)

- **Adaptation**: Historically, humanity's adaptation to climate risks has been remarkable. It is unlikely to stop in this period.

"Let's not downplay the possibility of successful adaptation to new climate conditions. After all, we're seeing greater climate impacts now, yet deaths from flooding are both low and stable compared to previous decades."

"Technology is making it easier to make better flood assessments and this should result in even more effective global mitigation efforts by 2050. Continuing to improve forecasting and disaster response should keep deaths from flood events in check even as the world's population increases."

"Increased flooding should be more than outweighed by the increase in warning systems. This has been the historical trend."

- **Stringency of the resolution criteria**: Only deaths caused directly by flooding are included in the resolution criteria. This has led the Superforecasters as a group to assign a 75% probability in total that the decadal average of deaths caused by floods in 2041-2050 will remain within the historical base rate.

"The bulk of the dire problems caused by flooding are problems once-removed from the flood itself, and therefore not counted in this resolution criteria. If a family starved to death two months after the flood, because their crops were ruined, or 10 percent of a village died of cholera because of unsanitary water related to the flood, I don't think this would show up in the data. Do I think floods in some regions of the world will get worse because of climate change? Absolutely. But I'm not convinced that will show up that much in this data."

"All in all, I see flooding more as a threat multiplier and driver of migration and other risks (starvation, disease, conflict, food availability)."

Q14: ASSUMING THAT THE EARTH'S GLOBAL AVERAGE SURFACE TEMPERATURE INCREASES BY 7°C IN 2100 AS COMPARED TO 1880, WHAT WILL BE THE DECADAL AVERAGE OF ANNUAL DEATHS CAUSED BY FLOODS IN THE WORLD FROM 2091 TO 2100, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 5,000	10%
B Between 5,000 and 20,000, inclusive	65%
C More than 20,000 but fewer than 100,000	19%
D Between 100,000 and 400,000, inclusive	5%
E More than 400,000	1%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 6,179 deaths caused by floods.

- In a scenario envisioning a 7°C increase in the Earth's global average surface temperature in 2100 above the 1880 levels, the Superforecasters have a **wide distribution across the outcomes**, with 61% in total for 10,000 to about 125,000 deaths recorded as a decadal average at the end of the century.

"The increase would be too fast (1 degree every 15 years) for the global economy to adapt and for humans to migrate to safer areas, leading to starvation, failure of governance and health care systems, etc. It could reduce flood deaths because the population is so much smaller. Or it could increase flood deaths due to inability to migrate, failures of warning systems, mitigation measures, etc."

"While I think floods in some regions of the world will get worse because of climate change, I'm not convinced that the dire impacts of said flooding (famine, disease, displacement, increased poverty) will show up that much in the resolution-source data. Even with the 7°C rise, I still think this will be the case to some degree. Especially with better meteorological forecasting, the aftermath of flooding is often—though, to be sure, not always—more lethal than the flood itself, particularly in developing nations. That said, the pace of change matters; the more rapid the rise in temperature, the greater the likelihood that meteorologists and the general public will be caught by surprise by unprecedented storms and storm surges that bring flooding with it. People can and will adapt to higher temperatures, but not overnight. And a 7°C rise over the next 78 years implies enormous change in a short period of time."

- On the other hand, if this increase in temperatures is anticipated, **technological development will help mitigate the toll** brought by floods to an extent.

> By the time we get to the year 2090, humans have figured out how to prevent massive amounts of deaths by flood (as defined by OWiD)."

> I've got to factor in innovation and natural progression. The massive flooding won't start suddenly in the year 2100—there will be an increase in the trend. And, presumably, humans would start to sort away from those zones where possible. Although, as has been mentioned, it's not always possible or easy to do that because of being locked into an area economically, etc."

> To what extent might technology play a role in slowing sea-level rise caused by global warming? Flooding infrastructure is already being implemented in places like New Orleans, Venice, and The Netherlands. Barriers or dams around Greenland's ice sheets and glaciers could also be cost effective and helpful to low-lying developing countries."

STORMS

Q15: HOW MANY DEATHS WILL BE CAUSED BY STORMS IN THE WORLD IN 2023, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 1,000	5%
B Between 1,000 and 4,000, inclusive	60%
C More than 4,000 but fewer than 20,000	25%
D Between 20,000 and 80,000, inclusive	5%
E More than 80,000	5%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 1,723 deaths caused by storms.

Base Rate

- Because the forecast of storm deaths in 2023 focuses on a single year, it is highly susceptible to the impact of outlier events—major storms that can cause a significant number of casualties. According to the Superforecasters, such events typically occur every 20 years, resulting in a spike in deaths. Recent data shows a fairly **consistent pattern of deaths** between 1,000 and 4,000. Furthermore, over the past 50 years, the rate of deaths over 4,000 has been declining. The Superforecasters expect 2023 to be mainly in line with the overall trend (**60% probability** for OWiD reporting **1,000-4,000 deaths caused by storms** next year), but keep a 25% probability for "more than 4,000 but less than 20,000" deaths in case of an outlier event. Climate change is not likely to be a major driver in 2023.

Upward Pressures

(i.e., factors that would lead to *more* deaths caused by storms)

- One Superforecaster points out years with catastrophic numbers of deaths (>100,000 in 1900-2020), although not a base-case scenario, are **not becoming increasingly**

rare. One reason for the above is that the most vulnerable populations to storm surges are still vulnerable.

"It is no coincidence that these are also some of the poorest countries who are least able to adapt to the increasing ferocity of storms. Topping the list are Myanmar, Bangladesh, Philippines, Vietnam, Haiti, Honduras, and Nicaragua. I would also add the islands of Oceania and Africa."

- Compounding this, the populations of those vulnerable areas tend to have **lower trust in authorities** and institutions, which limits the effectiveness of early warning and mitigation. Furthermore, the information used to calculate the base rate may be flawed: It is possible that some of the countries with greater vulnerability to storms weren't collecting or reporting data effectively during earlier years. **With improved data collection and reporting methods**, the number of known deaths may be higher.

Downward Pressures

(i.e., factors that would lead to *fewer* deaths caused by storms)

- **Better forecasting and early warning systems**: The following factors tend to benefit richer countries first, but poorer areas have seen some improvement as well through international cooperation and relief efforts: a.Better weather forecasting; b. Early warning systems; and c. Dissemination of communication technologies.

"Weather prediction has improved a lot in the last 50 years. At the time of cyclone Bhola in Bangladesh [in 1970], the forecast was missing. Pakistan didn't have their own weather forecasting satellite. Some limited data was shared by the US. Now such weather information is commercially available. Also, warning broadcasting to affected areas has improved manifold due to television and mobile phones."

"Most years from 1960 onward fall within 1,000-4,000 range. There are a few outlier years, 1970 being the most significant. Earlier detection than in past years and more international cooperation in relief efforts are two reasons why I'm not dipping too far into the higher ranges, even though it's predicted to be a heavy flooding season in the most at-risk populations of the subcontinent, plus Myanmar."

- **Stringency of the resolution criteria**: The Superforecasters also note that there are some limitations to the data OWiD reports for this metric: It counts only those deaths that were directly related to storms, rather than the peripheral deaths that storms and storm-related flooding leave in their wake, namely due to poor sanitation, crop failure, and displacement. As such, we may be underestimating the impact of storms if we only rely on this metric.

"Modern technology has given regions in the path of storms more hours/days to prepare than in times past—which could lessen the immediate impact of the storm in terms of human deaths, while doing little to mitigate many of the factors that make the aftermath of storms so dangerous."

Q16: WHAT WILL BE THE DECADAL AVERAGE OF ANNUAL DEATHS CAUSED BY STORMS IN THE WORLD FROM 2041 TO 2050, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 5,000	25%
B Between 5,000 and 20,000, inclusive	57%
C More than 20,000 but fewer than 80,000	15%
D Between 80,000 and 300,000, inclusive	2%
E More than 300,000	1%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 1,723 deaths caused by storms.

Base Rate

- The Superforecasters see a **57% probability the average annual number of deaths caused by storms in this period will be 5,000-20,000**, and a 25% probability it will be below 5,000.

"While I do expect 'fewer than 5,000' will become the norm in the first half of this century because nations are dealing better with the threat of storm surges, and that is where the trend is headed, a single catastrophic 100,000+ event can bring up the decadal average from, say, 2,000 to 12,000. The countries most at risk are Myanmar, Bangladesh, Philippines, Vietnam, Haiti, Honduras, Nicaragua, and Mozambique."

Upward Pressures

(i.e., factors that would lead to *more* deaths caused by storms)

- Historical base rates may play less of a role here as climate change affects weather patterns and **multiple risks start to interact**. This may lead to storms moving to **new regions** that may not have appropriate warning systems.

"Although climate change is going make storms and deadly storm surges stronger, more frequent, and more destructive, rich and developing nations can learn to adapt so as to ensure mortality rates remain low. Humans can learn to adapt very effectively to this kind of natural disaster. On the other hand, the poorest nations will remain as vulnerable as they were in the

1970s-2000s unless they receive assistance from rich countries to build up climate resilience. The actions and rhetoric of rich countries do not inspire confidence that this will happen."

"Better forecasting and warning systems are effective if there is enough time, viable routes to safe places, the means to get there, and a population willing to follow orders. Projections for 2050 place most of southern Vietnam under water at high tide, most of Alexandria, Bangkok, and Basra. These are not wealthy areas where people will just move to their summer homes."

"A key factor is how communities respond, in terms of preparedness and resilience. Preparedness requires both prediction capability (which is improving) as well as communication and level of institutional trust, the latter of which is likely to be severely lacking in many parts of the world."

Downward Pressures

(i.e., factors that would lead to *fewer* deaths caused by storms)

- The focus on the decadal average for 2041-2050 makes the second forecast in this group **less susceptible to single-year outlier events**.

"There will probably be outlier years between now and 2040 (and between now and 2050), but I don't think there will be enough outlier years that they pull the average up over 20,000."

- **Better forecasting and early warning systems**: The Superforecasters see a very low probability (3% in total) that deaths caused by storms in the period under investigation will reach catastrophic level of 80,000 or higher. However, here, too, second-order effects, such as the increase in disease, famine, and poverty that might follow in the months and years after a storm, likely won't be captured in the available metrics.

"The factors driving this include better forecasting, early warning, better infrastructure, improving search and rescue technology, etc. All of these factors are going to continue getting better over the coming decades, even in the face of mounting climate change."

DROUGHT

Q17: WHAT WILL BE THE DECADAL AVERAGE OF ANNUAL DEATHS CAUSED BY DROUGHT IN THE WORLD FROM 2041 TO 2050, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 5,000	52%
B Between 5,000 and 40,000, inclusive	26%
C More than 40,000 but fewer than 200,000	13%
D Between 200,000 and 800,000, inclusive	6%
E More than 800,000	3%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 45 deaths caused by drought.

- The Superforecasters see a **52% probability** that be the decadal average of annual deaths caused by drought in the world from 2041 to 2050 will remain **below 5,000**. Such deaths in the recent years have been **relatively low**, in part due to i**mprovements in technology and logistics** enabling international aid, and in part due to the difficulty of attributing deaths directly to drought in the data.

"Similar to floods, droughts are dangerous as multipliers for other mortality risks, which are not measured here, particularly through migration, food insecurity, and broader ecosystem impacts (e.g., forest fire risks). Mortality associated with drought is highly dependent on pre-existing vulnerabilities, such as poverty, age, and socio-economic disadvantages more generally."

"It will be easier for the developed world to episodically provide emergency food and water to the developing world than to accommodate refugees fleeing drought-stricken areas. As a result, I expect the recent reported trend, in which deaths from drought have been minimal, to continue. Over the past decade (2011-2020), seven of the 10 years recorded no drought deaths, and only double digits on the others for a decadal average of 17 per year. So, unless the reporting standard changes, I don't see any of the upper bins as probable."

"To experience events which would fall in 5,000-20,000 range or greater, you would have to go back to the early 1980s. I feel the ability of the international community to respond to humanitarian crises will prevent us from seeing such events again."

- Some Superforecasters argue, however, that historical **base rates may be of limited value given the timeframe** and the increasing impacts of climate change. They see therefore a potential for some increase in deaths caused by drought (26% probability the average deaths will reach 5,000-40,000 per year).

"Droughts have killed 650,000 since 1970. The 50-year average comes out to 13,000 per year. Though the trend has been downwards over time, we've seen the decadal average shift back up this decade. Like with storm surges and floods, we should see deaths for most years remain low but punctuated by years of extremely high deaths, thus bringing the decadal average up. The climate conditions for the 2040s will be vastly different. Single-year catastrophes are likely to return."

"The world has gotten better at providing basic necessities to affected populations. However, climate change is straining the marginal areas of the planet. With 'dry areas getting drier,' some marginal lands will no longer be productive. Therefore, the pressure on regional populations will intensify. The average number of deaths since 1990 has been less than 800/year. Global population is expected to increase through 2050, but at an ever-decreasing rate. Africa will be the fastest growing region but also one affected by climate change, putting more people in harm's way."

- A more **extreme scenario**:

"Clearly, the world has learned to reduce the impact of drought using communications, air transport, and ample stock of basic food stuffs. Rolling forward 20 years, will this trend continue? Obviously, most forecasters believe it will. But what if we have crop failures across a wide swath of the planet? Who comes to the rescue if Russia fails, or if the US heartland has a 'dust bowl' year?"

- Yet, most Superforecasters believe the **impact of climate change will be moderate** in this timeframe, with greater effects expected after 2050.

"The effects of climate change will undoubtedly be more apparent (and potentially devastating) by the end of this period. Wealthy countries will remain well-positioned to mitigate the most extreme impacts, albeit in potentially less-comfortable circumstances than at present. However, poorer and less developed countries have potential to experience catastrophic loss of life, depending on the location, severity, and duration of a drought. That said, I think the potential for catastrophic impacts is higher during the latter half of this century."

// The most extreme climate impacts are out longer than 20-30 years, so I would expect a slight increase with global warming over this time period, but not a dramatic one."

- Wealthier countries will be able to adapt faster, including through international trade and relocation away from vulnerable areas. **Climate change will exacerbate the already existing vulnerabilities**, especially in poorer regions of the world. Areas prone to conflict may be hit particularly hard .

// Developed countries and regions such as the US and Europe will have droughts but should have almost no deaths from it unless the political and economic situation severely deteriorates. Wealthy countries can shift resources from one region to another and buy food on the international market. Embargoes and conflict zones can upend this calculation, however. Even in poor countries, basic food supplies can often be distributed if there are no military conflicts where food becomes a tool of power."

// In areas where the worst droughts are likely to happen, those effects are already being felt, and in the next 5-10 years, populations will shift to wetter areas from those regions where possible. Of course, there are the poor who will not be able to migrate, but I'm not sure they will have survived another 20 years without finding some way to mitigate their situation. Besides, wealthy countries may decide it is easier to truck in water or build desalinators than to take in hordes of refugees."

// Nowadays, drought as a weather condition is not enough to cause large-scale deaths, as basic humanitarian aid will be delivered if images of dying people start to emerge on the internet, and it will happen quite fast. The problem is if drought happens in conflict zone or in failed state as it happened in Somalia in 2010."

- Furthermore, there are projections that **population growth**, which could place greater strain on scarce resources, is **slowing**, which may also mitigate the impacts of drought and resulting food shortages. Therefore, even though droughts can be expected to become longer and more severe, due to adaptation, but also due to the stringency of data (that such deaths must be directly caused by drought, discounting any second-order effects in the metric), the Superforecasters expect an increase in the average deaths caused by drought, but say it will not be an exponential one in this period.

Q18: ASSUMING THAT THE EARTH'S GLOBAL AVERAGE SURFACE TEMPERATURE INCREASES BY 7°C IN 2100 AS COMPARED TO 1880, WHAT WILL BE THE DECADAL AVERAGE OF ANNUAL DEATHS CAUSED BY DROUGHT IN THE WORLD FROM 2091 TO 2100, ACCORDING TO OUR WORLD IN DATA (OWID)?

A Fewer than 10,000	32%
B Between 10,000 and 50,000, inclusive	25%
C More than 50,000 but fewer than 250,000	22%
D Between 250,000 and 1,250,000, inclusive	14%
E More than 1,250,000	7%

Resolution Criteria: The outcome will be determined using data as reported by the OWiD. For 2020, there were 45 deaths caused by drought.

- This question is predicated on a **failure to limit surface temperature increases**. If the Earth's global average surface temperature increases by **4°C/7°F** in 2100 as compared to 1880, the Superforecasters expect this rise to be gradual, giving the world population time to adapt.

"As drought increases over time, there will be several mitigation processes. Rich cities will move to desalination, which will become increasing cheap. Poor cities will move to migration, which will decrease the population. Drought in poor areas is likely to occur far before 2091 in any reasonable climate scenario."

- Even this increase in global temperatures would suggest, as one Superforecaster writes, that "global governance over the course of the century had been poor, suggesting, in turn, that efforts to mitigate the impacts of climate change in developing nations had also been poor."

"While 7 degrees F will certainly affect quality of life and livability of the planet, I think that will have started happening at 4 and 5 degrees, which gives time for mass relocation and advanced developments. Clearly, things will have to change, whether we start treating water as a valuable commodity like oil and have pipelines and tankers carrying to more desertified areas, or desalination plants are all the rage. People won't remain in a crisis situation for decade after decade."

// The adaptations to climate change will be well embedded by 2091. Unfortunately, that is likely to mean many lives claimed by drought, but it's likely to occur before the end of the century."

- If the Earth's global average surface temperature increases by **7°C** in 2100 as compared to 1880, the Superforecasters see a 32% probability the decadal average of annual deaths caused by drought will be fewer than 10,000, a 25% probability it will be 10,000-50,000, and a **43% probability in total it will exceed 50,000**.

// Do I think a 7°C rise in temperature is likely to lead to millions of deaths from drought, particularly in the developed world, whether or not someone is standing there with a clipboard to record them? Given all that I've read about the likely impacts of a 7°C rise, absolutely. And I also still think that many of those deaths wouldn't be reflected in the OWiD numbers. As with floods, many of the impacts of drought in the developed world will be once or twice removed from the inciting incident."

// I think about 5-6°C is the tipping point for the human civilization. Migration, droughts, storms, etc., will greatly impact the way we live. The rate of change is important here because if the major portion of the temperature change is before, say, 2070, most of the adapting to it will be done before 2091. World population will greatly reduce even before 2090. If the change is back-loaded—say, most temperature change happens between 2070 to 2100—then adapting will be still ongoing in decade 2091-2100, and deaths could be much higher during that period. Assuming the likely scenario is linear increase in temperature, the major portion of the droughts, migration, depopulation will probably happen during 2060-2090, then continued at the slower rate in 2090s."

// Necessity is the mother of invention: To survive past 2050 and the predicted peak of global population and widespread drought conditions, adaptations will have to have been made well prior to 2091-2100."

FUTURE OF THE AMAZON BIOME

Q19: WHAT PERCENTAGE OF THE CURRENT AMAZON BIOME WILL TRANSITION TO SAVANNAH OR GRASSLAND AS OF 2100?

A Less than 10.0%	9%
B Between 10.0% and 20.0%, inclusive	21%
C More than 20.0% but less than 30.0%	29%
D Between 30.0% and 40.0%, inclusive	23%
E More than 40.0%	18%

Resolution Criteria: There are concerns that the Amazon rainforest biome will see dramatic changes in the 21st century.

Current Modeling

- The status quo **trend would lead to 30-40%** (answer option D). The Superforecasters point out that in a worst-case scenario in which carbon emissions aren't curtailed and temperatures rise by about 4.7 degrees Celsius by 2100, modelers predict that only about 36% South American forest will be considered stable. The likely rise in the temperature and the rate of intentional deforestation will play a role, however, in whether this outcome would occur.

"How likely is that kind of warming? The latest IPCC report says 2.4-3.5C. Other modelers estimate 1.5-3.5C. Climate Action Tracker's 'Policies and action' scenario is 2.5-2.9C (represents current policies). On balance, I would put my central guesstimate at 2.5C, but my full uncertainty range would be quite large. My current thinking is that the 99% distribution could be something like 1.4-5.5C. This uncertainty distribution is very dependent on the climate sensitivity (which is far from settled) for a given amount of GHG concentrations, and tipping points in, e.g., permafrost melting, Atlantic circulation, and the carbon cycle (including forest carbon) and associated feedbacks."

Upward Pressures

(i.e., factors that would lead to *greater* transition of the Amazon biome to savannah or grassland by 2100)

- **Human factors**: Political climate, population growth and urbanization, as well as lifestyle and dietary choices of local and global consumers will determine the rate of deforestation.

"While the impact might be global, the decisions will be made locally. The anti-environmental movement in Brazil has long roots going to the 1980s. This movement is partly a development perspective and partly a backlash against the international community. Thus, the ability to moderate is severely limited."

"I don't think the two main threats to the Amazon biome, man and warming, are equal, but a feedback loop makes that more complex. Man is more likely to make a more permanent clearing of the Amazon. Once land is claimed from the biome, by roads and farms, it's less likely to revert to the biome. A bimodal distribution of forecasts may be sensible if you don't know where the politics of Brazil will go in the next few decades. I'm shading toward this: forces less favorable to maintaining the biome will at least be competitive in the next few decades. For a tipping point caused by man, there doesn't have to be another 78 years of such rule. In only five years of such rule, there has been about 17% of the Amazon destroyed. How many more five-year periods of such rule can the Amazon bear before there is a tipping point?"

"The most common reason for deforestation is to create grazeable land for livestock. Brazil uses 80% of its deforested land in the Amazon for raising cattle. Worldwide, we destroy over 6 million acres of land to raise cattle. Deforestation also makes space for people to live. In many cases, people cut forests down for urban development. With these areas free, cities can expand housing, highways, and commercial space, contributing to strong local economies. As of April 2020, there are 7.8 billion people on Earth. Because of our booming population, usable land is becoming more and more scarce. Deforestation, furthermore, creates jobs and tax revenues: logging jobs and potential mining jobs created by clearing forest, and new farming jobs in the area. These new jobs and commercial ventures also lead to increased tax revenues to fund social services and other government ventures."

"Experience to-date on the transition to plant-based foods or away from beef is a very difficult journey. Food is politics, security, and the agribusiness is very powerful. Add in consumer behavior, the right to choose what I want to eat, and there are more negative feedback forces and

loops than positive. Governments would lead on this topic, but government transitioning farmers and farms is very difficult."

- **Environmental tipping points**: Climate change-related effects are another source of concern, and here potential tipping points create a high degree of uncertainty.

"The loss of resilience will only increase as time goes by, so that the 'tipping point' will eventually be reached and the rainforest will begin to convert to savannah. Since it is 75+ years to 2100, the amount converted will probably be in the upper answer options."

"There are human factors that enhance the transitioning process. Increased land use leads to fragmentation of the forests. That leads to reduced resilience and reduced rainfall in the centers of the remaining patches. These local climate changes can 'cascade' and possibly transform the landscape in a very short time. Forests could convert into grasslands and/or an open-canopy, degraded state and that likelihood increases when fragmentation and human settlement in the region is high."

"As far as I can tell, all the answer options are possible for the reasons forecasters have provided throughout: We don't know exactly how much of the rainforest humans are going to cut down, we don't know what the impact of climate change will be, and we don't know where the tipping points are for a much larger collapse. The loss between 1970 and now was about 20%. Just projecting that rate would get us 30.19% by 2100. But it's hard to know if we should instead expect a higher rate of deforestation than over the past 52 years, because of climate change and the possibility of hitting tipping points where a large-scale transition to savannah occurs even in regions which humans haven't cleared, or instead a lower rate, because as Brazil gets richer, it will be more willing to forego the economic benefits of cutting down trees."

Downward Pressures

(i.e., factors that would lead to *lower* transition of the current Amazon biome to savannah or grassland by 2100)

- **Mitigation efforts**: The Superforecasters would expect less of the Amazon biome to transition to savannah or grassland by 2100 if we start seeing evidence of a shift in the political climate away from deforestation or greater international cooperation in this area. That said, the Superforecasters largely expect mitigation efforts to remain limited.

"Political factors (i.e., who is in office in Brazil and their policies) can have a significant impact up to a point. However, this is mitigated by two factors: 1) Slash-and-burn farming rapidly uses up the soil and the farmers move on. These areas then tend to recover; and 2) political parties go in cycles, so over the next 80 years, we can expect policies to swing between protection and destruction."

"International pressure has, at times, been successful in reducing deforestation. Starting in 2009, deforestation was reduced but the trend has reversed. 2022 is starting out as the worst six months of deforestation for the Brazilian Amazon since 2008. Better governance will help, but there is no easy path forward."

"Brazil's initial pledge in Paris included some forest restoration (actually 120,000 sq.km). This was eventually changed in Brazil's later Paris Agreement plan (i.e., NDC), but nevertheless this shows that restoration is within the Overton window and remains a possibility, should we see political change in Brazil."

"International support for avoided deforestation or reforestation is another mechanism. There's been a long-running effort to establish a system of ecosystem payments that incentivize forest communities to keep forests intact (e.g., the so-called REDD). More recently, the climate agreement in the aviation sector (known as CORSIA) is generally reliant on offsets to achieve its targets and could hypothetically constitute demand for forest credits. There was also a long period in which Norway engaged with Brazil to help it—financially—with reducing deforestation. I'd say it's likely that, should a more cooperative government be elected in Brazil, similar partnerships will emerge."

- Future trends in **meat and soy consumption**: Lower demand for Brazil's meat and soy exports would take away one incentive for converting the Amazon to farmland.

"The major cause of Amazon destruction is growing soy, feed, and grazing of beef for export. I agree that climate change could affect the composition of the Amazon. For me, this question also hinges on major meat-eating regions such as China and Europe changing their consumer eating habits. The growth of meat substitutes is still a single-digit share of market. An increased awareness, however, could shift the demand needle just enough to reduce the land destruction and facilitate regrowth. But getting farmers to re-wild their land needs government interventions."

COST OF SOLAR ENERGY

Q20: WHAT WILL BE THE MIDPOINT FOR UNSUBSIDIZED SOLAR PHOTOVOLTAIC LEVELIZED COST OF ENERGY (LCOE) IN 2023, ACCORDING TO LAZARD?

A Less than $31.00	3%
B Between $31.00 and $33.00, inclusive	19%
C More than $33.00 but less than $35.00	39%
D Between $35.00 and $37.00, inclusive	29%
E More than $37.00	10%

Resolution Criteria: In its 2021 analysis (Version 15.0), Lazard reported a range of $30/MWh to $41/MWh, with a midpoint of $35.50.

Base Rate

- The historical trend has been toward **cost declines** associated with cumulative deployment.

> If the current trend of LCOE continues, the mean LCOE value in 2023 should be between $34 to $34.5."

> The trajectory is likely to either flatten ($35.50 for 2022 and 2023) or continue to decline at the same pace as 2020/2021 ($34.50 for 2022 and $33.50 for 2023). A steeper decline, to as low as $28.50, is much more likely than an increase to over $37.00."

Upward Pressures

(i.e., factors that would lead to *higher* LCOE)

- **Higher associated costs**: Increased component/material costs, cost of labor, and cost of capital of capital due to higher interest rates are some of the factors that, especially in combination with supply chain issues, could drive LCOE higher.

"Upward cost dynamics are: Supply chain shortages and disruptions, general inflationary pressures, increased cost of capital investment related to interest rates, increased demand exceeding supply driving up prices."

"In the time between 2021 and 2023, I anticipate only incremental change in technology and costs. Inflation is likely to impact installation costs harder than material costs, which are based on long-term material contracts. Assuming installation and transport are more than 3/4 the project cost in some regions, prices could increase with the cost of labor at 5-10% in the time of this question."

"The resolution source provided sensitivity analysis where we can see midpoint if cost of debt has increased to 9% or 10%, resulting in 39 USD and 43 USD respectively. I am pretty sure that cost of debt due to rate hikes has increased at least by 2%, which is in answer option E territory."

"The days of dramatic declines in cost of solar energy may be over, at least for now. Polysilicon and component costs and supply chain issues are ongoing and not expected to fully resolve until mid- to late 2023. Labor costs for installation, sales, marketing, and overhead are also increasing. Given the above, I'm assuming flat to slightly higher pricing in 2023 in comparison to the 2021 figures. I see more indicators of escalation than reduction. However, a potential recession could soften demand enough to affect prices next year."

- **Supply chain issues and trade barriers**: Supply chain issues, tariffs, and trade barriers are other examples of upward pressures on LCOE. A particular risk would also be a China/Taiwan conflict, although the likelihood of this happening in 2023 is low, according to the Superforecasters.

"Due to global turmoil (both economic and political), I expect higher LCOE."

"Risk factors include instability between China, Taiwan, and Japan. If this leads to war or even China capturing small islands and shoals, it could interrupt global supply."

- **Increased demand for photovoltaics** (PV): Increased demand, particularly in the fact of supply constraints, could also lead to higher costs in the short term.

"First, electric car sales have risen sharply. This may increase the demand for PVs because of the need to charge the cars and the desire to do it ecologically. California accounts for nearly half of all new electric car sales and has a climate (political and natural) that favors solar energy. Those who buy electric cars are also making a major foray into green energy. This could drive up

demand and thus cost, especially while there are supply chain issues. Second, fuel prices are currently declining, but the winter is likely to be very difficult for Europe due to issues related to Russian supplies of oil and gas. This could lead to accelerating the move to photovoltaics, thus driving up the global cost due to increased demand."

Downward Pressures

(i.e., factors that would lead to *lower* LCOE)

- **Technological advancement**: Many Superforecasters expect technological progress (learning by doing) and increased deployment, with current higher costs of materials in fact accelerating the pace of development.

> The future will hold a wide variety of innovative sustainability methods. I predict the techniques that will sustain humanity into future will become widely available."

> There is a tension between rising costs due to cost of capital and decreasing costs due to improvements in technology. High costs have salience at present, but development marches on, and in some cases, the cost of materials is leading to accelerated development work, which I think might most benefit the utility-scale part of the market in 2023."

- **Economies of scale and production capacity in China**: China's production capacity, coupled with the economies of scale, is another key factor that will exert a downward pressure on LCOE.

> Project size is growing increasingly large over time, which should bring down deployment costs due to economies of scale."

> China's inflation rate in June was 2.5% compared to 9.1% in the US. This will help keep the cost of installation and maintenance low. The US Inflation Reduction Act will lead to a massive increase of utility-scale PV projects, but 16 months is a short time to go from concept to financing approvals and completion. For this reason, I don't see it as a significant factor in 2023, but it will be in future years. Germany and other European countries are likely to boost PV utility-scale projects in an effort to decouple from Russian energy dependence. Like the US, these efforts will have a significant long-term impact, but 2023 is very near term."

"The midpoint has fallen every year and my instinct is that will continue, however slowly. Growing economies of scale will continue to grow this year and next and the technology will continue year-on-year improvements."

- **Increase in investment**: Finally, green transition is expected to bring more investment in solar energy in the West, while China continues to prioritize this sector domestically, which may have some impact in 2023 and greater impact beyond.

"Due to the Russian invasion of Ukraine, the EU will be investing in alternative energy sources and they would be wise to include the low cost of solar energy as a main new energy supply source."

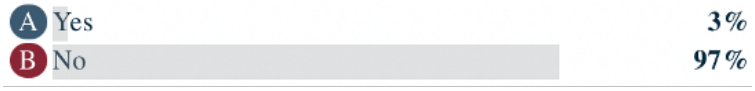
"Share of deployment in China means that inflation may not be as much of a concern as it is in many Western countries. Beijing has also shown solar to be an industry of interest, and will likely continue to prioritize deployment."

"Increased tensions between China/Taiwan/US, global supply chain issues, general inflation, and the gas crisis in Europe driven by the war in Ukraine will force efforts to shift to green energy. If the agreement between Schumer and Manchin is enacted basically in its current form, it will increase investment in solar energy, which should drive down LCOE in the long run."

EXTINCTION

Q21: WILL CLIMATE CHANGE BE A CAUSE OF HUMAN EXTINCTION BY 2100?

Q22: WILL CLIMATE CHANGE BE A CAUSE OF HUMAN EXTINCTION BY 2300?



- The Superforecasters see a very low risk that climate change be a cause of human extinction by either 2100 or 2300. The Superforecasters assign a 1% probability on aggregate that climate change will be a necessary, but not necessarily sufficient, cause of human extinction by 2100. Forecasts on this question ranged primarily between 0 and 1%, with just one Superforecaster entering a higher forecast of 10%. The median decimal forecast for those forecasting between 0-1% is **0.00055%**. The aggregate forecast for 2300 is 3%. Of 26 Superforecasters active on this question, 21 made forecasts between 0-1% and median decimal forecast for those is **0.05%**. Of the five Superforecasters who forecast above 1%, four gave forecasts between 2-5% and one gave a forecast of 55%.

Key Drivers behind the Consensus Forecast

- The Superforecasters see total extinction as a high bar, as **each of the relevant risks carries only a very small probability**.

"Although climate change will exacerbate almost any crisis, and although climate change could increase the likelihood of extinction-level events, extinction is a Boolean event, and I think it is unlikely that climate change will be a necessary precondition. Extinction is a very high bar."

"If one were to try to get a handle on the total risk resulting from climate's many indirect impacts, it could go something like this. If the probabilities of extinction by nuclear war, engineered pandemics, AI, nanotech, natural risks (volcanoes, asteroids), and unknown unknowns for 2100 are respectively 1/1,000, 1/1,000, 1/100, 1/1,000, 1/10,000 and 1/1,000, and if climate change is a necessary condition in 10%, 10%, 1%, 10%, 30%, 5% of all such scenarios respectively, assuming independence, that would suggest a total risk of 0.048% (~1/2000)."

"Will there be wars fought over, or that can be said to be a direct result of, climate change? A nuclear war? A war that leads to the weaponization of Artificial General Intelligence? Depending on how such a war developed, it might suffice to resolve the question. Or will the ravages of climate change become so bad that a non-anthropogenic risk (asteroid, supervolcano, etc.) that wouldn't otherwise lead to our extinction does so—in a way that suffices to resolve this question? These are the issues the team should consider. But even considering them, the risk in this time frame is close to zero. Don't get me wrong, I do believe that we're going through a particularly dangerous period in human existence. But even if we've vastly underestimated the risks of climate change, and find that the models were wrong, and the most dire predictions, at the very tail end of the probability curve, come to pass, I struggle to envision a scenario where the entire human race is rendered extinct by these dates."

- The Superforecasters cite **adaptability** of humans as a species. Humans live in a wide range of climates, each with their respective challenges. Even if a major catastrophe drastically reduces global population, some people will find a way to survive and adapt. Furthermore, by 2100, we will likely be a multi-planet species, some Superforecasters argue.

"Maybe I'm too optimistic, but I do see the human race addressing climate change via (a) transition to clean energy, (b) innovation, and possibly (c) geo-engineering and/or carbon capture. We aren't addressing it as fast as we should, but we will get there, suffering more than necessary on the way. Complete extinction, as in every last human is dead, is exceedingly unlikely. Even in the most dire circumstances, I envision 50-100,000 people surviving via extraordinary measures for at least a considerable period of time."

"I think any scenario causing human extinction is very unlikely; climate change may have profound effects on how we live, but there is very low probability it causes human extinction. Engineered pathogen? Massive nuclear war as climate change causes a scarcity of food? Are

there major feedback/feed-forward loops in the climate that we don't yet know about/understand that would make the planet uninhabitable? Even then, human ingenuity would probably manage some sort of existence."

"Climate change has a good chance to make us miserable, and cause deaths, for the reasons I mentioned above. But it will not cause extinction to a species that's resilient and clever enough to find solutions."

"I can easily see that many of the disasters described by my colleagues could lead to the collapse of civilization. But not to total human extinction. By 2100 we will likely be a multi-planet species."

- Variability of climate conditions across the globe also means humanity will have, at least temporarily, **more hospitable areas to flock to**, which will give humans time to adapt. Furthermore, current climate modeling offers some cause for optimism with regard to extinction.

"Change is not the same everywhere. Therefore, risks are not spread evenly. Rate of change and duration count. This varies by location. Yes, there will be dead zones in the oceans where there is not enough oxygen for marine life and plants. But there are a number of mitigation things humans can do to survive. Rich nations and people will be able to afford those. Could the rich live in a dystopia where they never go outside, grow food inside, have enough energy and live their lives in some metaverse headset or even 3D cave simulations? Maybe."

"In climate model simulations, it requires substantial warming (more than 6 degrees Celsius) to create zones deadly to endothermic mammals and birds over substantial areas. That is not likely to happen even by the year 2300 in the most likely carbon emissions scenarios. With 3 degrees Celsius of global warming, which current research indicates is the most likely future, most of the world's terrestrial biosphere will avoid crossing the 35 degrees Celsius wet-bulb limit for significant periods of time."

Risks to the Consensus Forecast

(i.e., factors that would make the Superforecasters change their forecast)

- The risk is not zero, however, according to many Superforecasters. Among the scenarios they considered, **conflict in its various forms** represents a prominent risk, including nuclear risk, risks from AI or biological weapons, or a Götterdämmerung

scenario where a faction on the losing side in a conflict decides to take humanity down with them through malevolent use of the abovementioned weapons.

"Leading contenders are genetically engineered pathogens and AI risk. Nuclear war is unlikely to lead to extinction, even with the possibility of nuclear winter. While neither AI or engineered pathogens would be directly caused by climate change, the rapid warming of the planet will increase resource scarcity and fuel conflict. This is likely to lead to more malevolent uses of technology."

"As humanity becomes equipped with ever more dangerous means of destroying itself (e.g., biological and AI weapons, including DIY variants), the risks that climate-induced disasters will precipitate extinction-level conflict increase."

"I assume climate will be a necessary condition in a relatively large share of extinction scenarios (5-30%). I tend to agree with William MacAskill that most of the existential risk comes from conflict (he says 90%). Climate change is a threat multiplier, so we'd expect a non-negligible role in conflict."

- "Tipping cascade," or a cascade of adverse climate effects, is another scenario the Superforecasters are concerned about.

"Just because what life that existed on earth some 55 million years ago was able to adapt over thousands or hundreds of thousands or millions of years doesn't mean we'll be able to in the next few hundred without decimating our species. IPCC models deal with probabilities, not certainties. They could be wrong, or it could just be that the temperature in 2300 falls on the far upper tail of the probability curve."

"Humans are able to survive in a wide range of climates, and there are a lot of us spread across the globe. The only two possible scenarios I am aware of where climate change can cause human extinction are: (1) An ecological collapse cascade: Due to climate change some ecosystems collapse, and this causes a cascade that causes basically all/most ecosystems that we are dependent on for our survival to collapse. Due to the speed of the change, life is not able to evolve fast enough to adapt to the new conditions. (2) Hothouse Earth/Venus effect: During global warming, we hit a series of positive feedback effects (like methane released by the melting of Siberian permafrost), and this outweighs the negative feedback effects like increased vegetation growth, leading to a runaway warming scenario where Earth becomes uninhabitable (like Venus) to humans (and probably all life except maybe very simple forms)."

"Climate projections don't generally account for reinforcing feedbacks such as the melting of Arctic permafrost and, perhaps more significantly, the thawing of methane clathrates in the ocean. Both of these could release very large amounts of greenhouse gases into the atmosphere, theoretically causing a runaway greenhouse effect leading to much higher temperatures and perhaps pushing Earth beyond habitability. Note that the science is very murky on such feedbacks."

"All life is interconnected. Humans depend upon biodiversity for food, medicine, clean air and water, pest control and so much more. Technological advancement should be able to keep pace with incremental changes, but perhaps less so with too many large overlapping catastrophes."

"The combined impact of direct and secondary effects of climate change, including resource wars, zoonotic diseases, wet bulb temperatures, aridification, food loss, water scarcity, infertility, etc., could wipe us out. All of these factors would come into play in a 4C-5C warmer world. A 5C warmer world is quite plausible even under a 'moderate' emissions scenario (RCP 4.5) thanks to positive feedbacks such as ice-albedo, carbon sinks becoming carbon emitters, methane release, and global dimming, although the timing is unclear. Ill-conceived geoengineering (e.g., stratospheric sulfate aerosol injection) done out of desperation would make the problem worse. Passing 5C by 2100 or so means we'll pass the threshold for entering a mass extinction event comparable to the Big Five extinction events. In the past, few animal species larger than a rabbit survived these events. While extinction in this scenario is likely to play out over the course of many centuries, can we be confident that it won't happen within two?"

- **Reduced resilience** followed by the above, AI, or non-anthropogenic catastrophe is another way through which climate change could be a necessary, but not necessarily sufficient, cause of human extinction. Climate change could reduce our capacity to respond to the event.

"Using Toby Ord's 'anatomy of extinction risk' framework, climate change could: (1) be pre-condition for the origin, (2) amplify the catastrophe, (3) diminish our resilience. The most obvious effect to me is (1), but (3) could be more important as climate change will affect our access to water, food, and energy, cause mass migration, erode institutions, and conceivably trigger social chaos on a global scale. Total climate risk is a lot higher from considering resilience in addition to the more common arguments around climate as a pre-condition. It also shows that climate change could be a part of risks that are otherwise non-anthropogenic (like volcanic eruptions or asteroid impacts)."

- In sum, the Superforecasters see **climate change as a cause of extinction very unlikely**. **Societal collapse**, however, **is another matter**, and is the chief reason they cite to be mindful of such tail risks as described in section above.

"Though this forecast is very low, I believe climate change is one of the greatest challenges, or the greatest, of the next 80 years, and if not solved, it will radically decrease our quality of life."

"I do think we should be investing enormous amounts of time and money into preventing the worst-case climate-change scenarios from occurring. And I think we should be extraordinarily mindful of the tail ends of the probability curve when it comes to potential consequences of pumping unprecedented levels of greenhouse gasses into the atmosphere."

GOOD JUDGMENT

From groundbreaking theory to powerhouse practice

In 2011, IARPA—the US intelligence community's equivalent to DARPA—launched a massive competition to identify cutting-edge methods to forecast geopolitical events. Four years, 500 questions, and over a million forecasts later, the Good Judgment Project (GJP)—led by Philip Tetlock and Barbara Mellers at the University of Pennsylvania—emerged as the undisputed victor in the tournament. GJP's forecasts were so accurate that they even outperformed intelligence analysts with access to classified data.

Good Judgment Inc is now making this winning approach to harnessing the wisdom of the crowd available for commercial use. Our clients benefit from the externally validated forecasting methodology that made the Good Judgment Project so successful.

Today, Good Judgment's professional Superforecasters deliver unparalleled accuracy on forecasting questions across the political, economic and social spectrum. And, we train others to apply this evidence-based methodology within their own teams.

100 Park Avenue, 16th floor
New York NY 10017

https://goodjudgment.com