

THE LONG-TERM STRATEGY OF THE UNITED STATES

Pathways to Net-Zero Greenhouse
Gas Emissions by 2050

Quick Review of What We Know about Climate Change and Weather

- Everywhere gets hotter
 - The poles get hotter and get there faster
- Dry places, on average get drier
 - Hotter makes you drier, even with the same rainfall
- Wet places, on average, get more extreme rain events and flooding, but not necessarily more total rain.
- Most extreme weather gets more extreme (tornados still an open ?)
 - Heat waves are potentially the most deadly
 - Hurricanes and typhoons reach new areas and cause more damage
 - Even cold waves become more extreme, at least for a while.

Quick Review of What We Know about Climate Change and the Ocean

- More CO₂ in the atmosphere makes the ocean more acidic (lowers the pH)
 - This makes it harder to mineralize shells
 - It has other effects we do not fully understand
- Warmer water kills some coral, which affects large ecosystems.
- Warmer water and lower pH change the ecosystem generally.
- Warming increases sea level rise
 - This will be meters over the long-term
 - The short-term rate is uncertain
 - Sea level rise takes decades to centuries to equilibrate, so we will likely see 2 meters by 2300.

Temperature Uncertainty

- Temperature sensitivity to increases in CO₂.
- There is 412 ppm of CO₂ in the atmosphere
- If that stays constant, what is the final equilibrium temperature and when do we reach it?
 - What about 450 ppm, where we are headed?
 - What about 500 ppm?
- How fast do things cool if we remove CO₂ from the atmosphere, given the amount of CO₂ dissolved in the ocean and the thermal inertia of the ocean?

Weather Uncertainty

- All the changes in weather events are tied to temperature changes, but we do not know how much they increase for each increase in temperature.
- Since temperature is also uncertain, it makes predictions much more uncertain as we reach extremes.

Technological Uncertainty

- Will technology fix climate change in the future, so we do not have to make expensive and difficult choices now?
- An efficient way to remove CO₂ from the atmosphere?
 - What if the tech isn't developed?
- Geoengineering – particles in the upper atmosphere to block the sun and thus cause some cooling?
 - The predictability of the effect goes down and the chances of unacceptable side effects goes up with increases in temperature.

Tipping Points

- There are tipping points, events that accelerate climate change and make it very difficult to control.
- The most important one we know about is melting permafrost.
 - This releases CO₂ and methane.
 - Once it starts, it takes a long time to stop.
- There is a huge amount of methane ice (methane clathrate) in deep water, stabilized by high pressure and cold water.
 - This could be released if the deep-water warms, progressively releasing methane as the warmth goes deeper.
- The actual climate, rather than models, is both nonlinear and incompletely understood.
 - There may be other tipping points that either change warming rates or fundamentally change weather patterns, such as causing the monsoon to fail in India, leading to massive famine.
- Hitting a tipping point means potentially losing control of climate change.

Looking at the Strategic Plan

- What will the US need to do to decarbonize?
- What has to happen in each sector?
 - Residential
 - Business
 - Industry
 - Transportation
 - Agriculture
- What will this cost politically and economically to accomplish in different timeframes?
 - Is 2050 easy or hard?
 - Is 2050 too late?