

The Journey to Carbon Neutral: State of the Transition 2023



Paul Kenney April 22, 2024

Summary of Report Produced by Bill Gates and Breakthrough Energy

Introduction

Breakthrough Energy is a group founded by Bill Gates to accelerate innovation, sustainable energy and other technologies to reduce greenhouse gas emissions. In Q4 of last year, they produced a report State of the Transition 2023 - Accelerating the Clean Industrial Revolution. The report focuses on the Five Grand Challenges: Electricity, Manufacturing, Agriculture, Transportation, and Buildings. The report provides insights on the scale of change needed to move the world closer to the goal of being carbon neutral. While the scope of change needed is staggering, as Bill Gates noted in the forward of the report, he has become more optimistic:

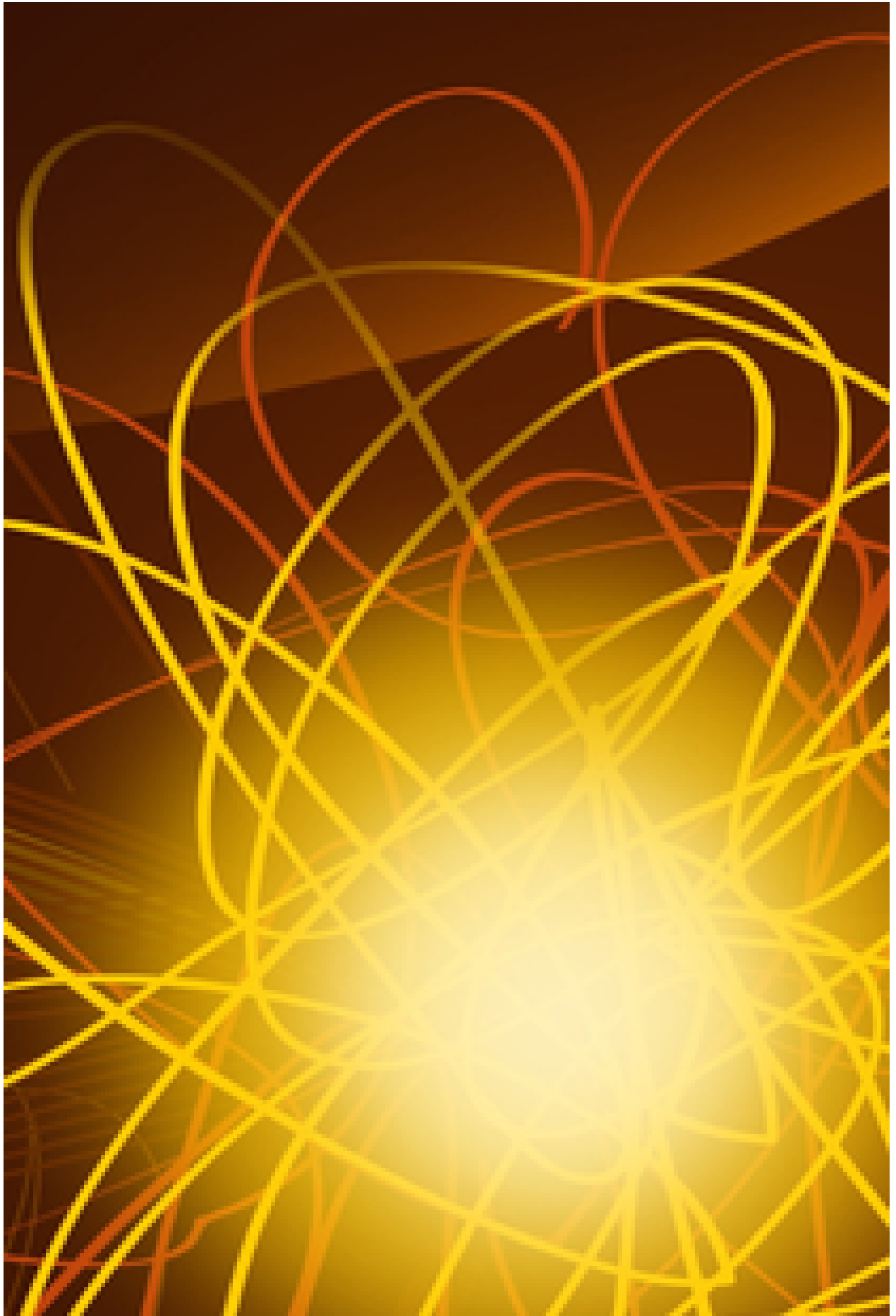
“For me, 2023 was a year of climate dissonance. On one hand, every week seemed to bring another once-in-century natural disaster - fires in Greece and Maui, deadly heat waves in India, a drought in Kenya, and the sky turning orange in New York - and still, the world pumped more greenhouse gasses (GHHs) into the

atmosphere than in any prior year. On the other hand, the year left me feeling more hopeful than at any point in my two decades of working to confront climate change. Why? One word: Innovation.”

He further goes on to say “The climate innovation landscape has changed completely. It’s not an exaggeration to say that we’re in the beginning stages of a Clean Industrial Revolution.”

In this paper we review each of the Five Grand Challenges and have pulled from the report facts pertaining to the scope of the challenge, where things stand today, the innovation taking place, and the breakthroughs needed in the future to reduce emissions.

Electricity – 29% of Global Emissions



The goal here is to “electrify everything,” which involves replacing fossil fuel sourced power plants with those sourced by renewable energy. Today there are 8,000 gigawatts of installed global electricity capacity in the world, and there is a need to build another 20,000 to 30,000 carbon-free gigawatts to reduce emissions elsewhere. Challenges here include:

- Existing electrical grid systems need to be modernized, as many are near the end of their economic life. The US grid is presently a bottleneck for reaching the goals of the Inflation Reduction Act.
- New grids need to be built to get the electricity from where the renewable energy is created to where it is needed - “there is no transition without transmission”. This is a policy problem, not a technology issue.
- Demand will continue to rise as developing countries use more electricity as they grow.
- To meet demand, renewables will need to expand at 3x their current deployment rate.
- The issue of intermittency associated with renewables (i.e., providing energy when the sun is not shining, or the wind is not blowing) needs to be addressed through a combination of storage and transmission solutions.

The good news with the electricity challenge is that there are near-term solutions and promising technologies on the horizon.

- The game changing breakthrough is the potential of nuclear fusion that could provide limitless clean energy, though when this technology will be ready at scale is still to be determined.
- Nuclear fission is the best understood zero carbon option today; new designs prevent the kinds of accidents people tend to associate with fission.
- Solar is now 10 times cheaper than it was in 2010.
- New designs for wind power, including floating offshore wind turbines, offer hope for greater deployment.
- Hydropower is the biggest source of renewable energy in the US, and geothermal is a meaningful opportunity.
- The key for increasing renewables is tied to batteries being able to store the energy for use when needed. Long-duration energy storage technologies (LDES) provide the ability to use hydrogen fuel cells to both store and move

energy to where it is needed. To make the impact needed, their costs need to come down. For this to happen, governments need to create policies that create the demand for LDES.

Manufacturing – 29% of Global Emissions

We need to improve how we build things to get to net zero. Within manufacturing, cement (the binding agent in concrete) and steel are responsible for 10% of GHG emissions. They are actually among the lowest emissions-intensive building materials, but the challenge is their volume. Concrete, for example, is the second most consumed material on the planet behind water. Steel and cement are not going to be replaced, so the opportunity lies with improvements to their manufacturing processes and finding substitutes where possible. Making progress is tied to:

- Incentivizing the use of clean steel and cement through public procurement, tax credits and other tools. Builders are reluctant to move to new technologies when their old way of doing things works well.
- Increasing the use of recycled steel, which is presently 24% of global steel production.

Progress is being made.

- There are start-ups focused on reducing CO₂ generated in the production of cement by using substitutes for limestone and through process changes that allow cement to be produced more efficiently using renewable electricity.
- Direct Reduced Iron (DRI) is a technique used to produce steel that has a lower carbon dioxide footprint than traditional methods. As green hydrogen becomes cheaper and more accessible, it can replace natural gas in the steel production process. This will result in a much lower carbon footprint.

As is the case with many solutions, there are some challenges and opportunities. A challenge with DRI is it can only be used on high grade ores without too many contaminants, and the cost of green hydrogen needs to fall for DRI to expand. On the opportunity front, substitutes for limestone used to make cement may lower costs.

Agriculture – 20% of Global Emissions

The demand for food will increase with population growth, heightening the need to find better ways to fertilize plants, raise livestock, conserve water, and reduce food

waste. Methane from cows and livestock is the dominant driver of agricultural emissions - by 2050, there could be an additional 500 million cows roaming the planet! Agriculture presents these challenges:

- The majority of emissions come from GHG other than CO₂. Methane is 28 times more potent than the equivalent CO₂, and nitrous oxide has 300 times the warming potential of CO₂.
- Food usage and production vary globally, so there isn't one solution. India has the largest cattle herd, Indonesia suffers from deforestation tied to palm oil, while in Brazil deforestation is tied to cattle farming. In the US, there are issues with the application of fertilizer and nitrous oxide emissions.
- Agriculture is most impacted by climate change and the vicious cycle it creates: lower yields lead to more fertilizer and deforestation, further raising emissions.
- By 2050, we will need an additional 500 million acres of crop land (almost the size of Argentina) to meet demand, creating pressure on deforestation.
- The use of nitrous oxide, a toxic byproduct of nitrogen fertilizers, is one of the world's most dominant ozone depleting substances.

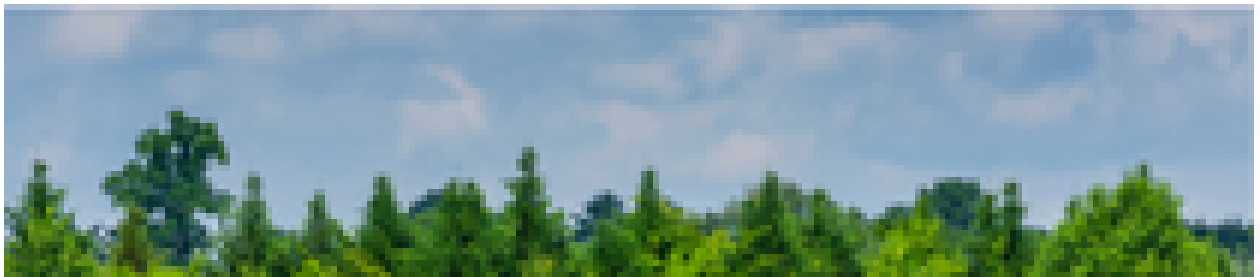
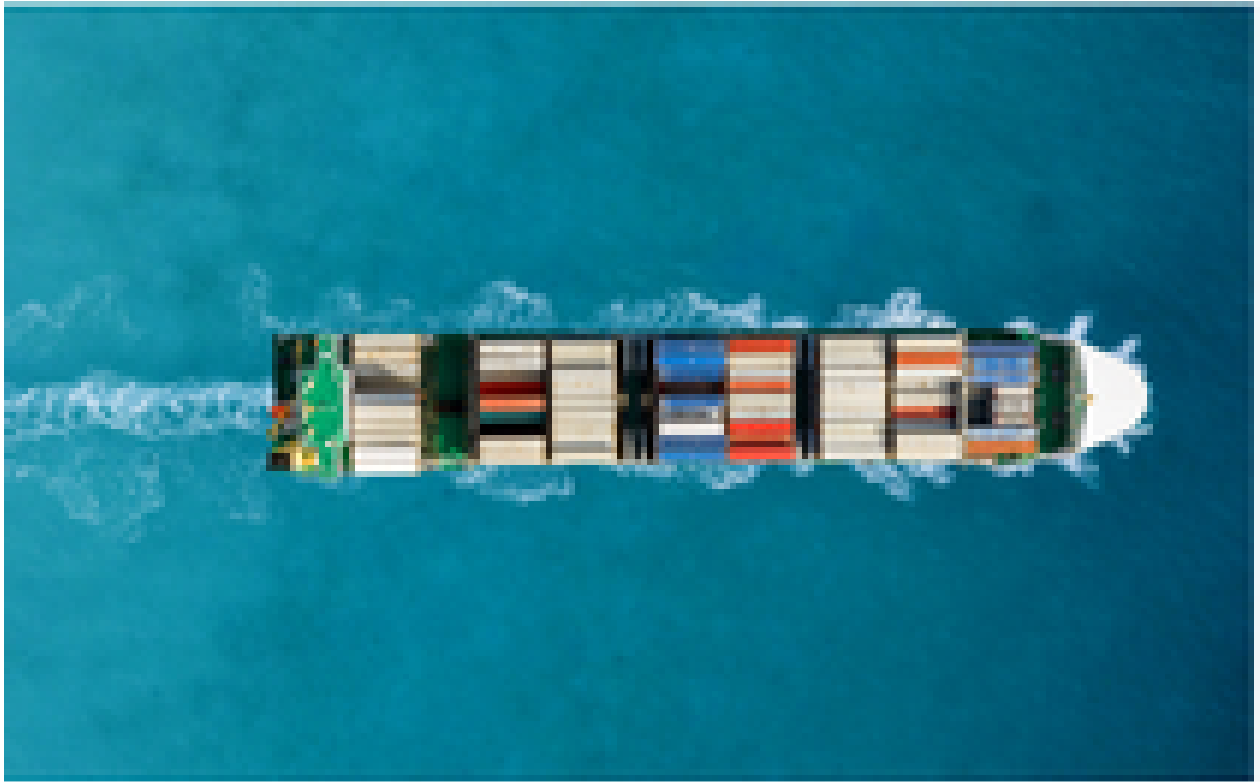
There is also a lot of innovation taking place in this space:

New companies have been founded to tackle the emissions released by the digestive processes of livestock, including feeds that reduce methane and vaccines that deliver antibodies to a cow's rumen to reduce methane.

- There have been advances in farming practices that keep carbon trapped in the soil, and in seeds that have traits that help improve their resistance to heat, pests, and disease.
- Synthetic fertilizers offer the potential to reduce the use of nitrogen, which is very inefficient with about 50% of what is applied being lost to the environment.
- China, Brazil, and India have increased their agricultural R&D spending (though, unfortunately, this has decreased in the U.S.).
- Significant reductions in emissions can be realized by making plant-based substitutes to meat more desirable to consumers. Plant-based meat alternatives comprise just 1% of the market today. The report noted start-ups working on developing substitutes to animal fat and dairy products like

cheese that improve the texture and flavor to make them appeal more to consumers.

Transportation – 15% of Global Emissions



Transportation is likely the Grand Challenge most people are familiar with given the press and familiarity surrounding electric vehicles, which under some projections reach 50% of the market by 2035. Concerns regarding the supply and location of lithium (40% in China) and cobalt (50% Democratic Republic of Congo) deposits are well known, which prompted excitement when a major lithium deposit was found in California. That said, the engineering and economics behind EV's have largely been solved. EV challenges are tied to the charging infrastructure, battery safety and supply chain stability. The biggest hurdle is finding a solution for ships, planes and heavy-duty trucks which are problematic given their weight and the distance they travel.

The answer to this transportation challenge is finding alternative fuel sources, but right now the costs are too high. Per the report, "the science and economics of creating carbonless liquid fuel just aren't mature yet. And it's going to take huge investment, historic innovation, and major policy changes to get there."

Gas is shelf stable, cheap and energy dense, easy to transport. By comparison, the report states the best lithium-ion batteries contain 35 times less energy pound-for-pound when compared to gas, so they won't solve the problems for ships, planes and trucks.

There is innovation taking place, but there is no breakthrough on the horizon.

- Biofuels made from plants, crops, and waste have been around for a while, but some emit more CO₂ than gas due to fertilizer or clearing land for crops.
- Lipid rich algae grown in ponds offers some hope of being an alternative fuel source.
- Electrofuels or e-fuels are an alternative using carbon capture technology and clean hydrogen, but sustainable aviation fuel using this process is three to five times more expensive than regular jet fuel according to an analysis by the Rhodium Group.

Over the next three decades, a trillion dollars will need to be invested to help the fuel industry scale and reduce its green premium. This is just for commercial airplanes and doesn't include fuel for ships and trucks.

Buildings – 7% of Global Emissions

Buildings waste a lot of energy as most are not energy efficient - the average building in New York City is 90 years old. While there are challenges, technology exists to make meaningful improvement as the green premium here is lower than in other areas. On the challenge side:

- Cooling demand is rising rapidly. The expectation is for 5 billion A/C units globally by 2050, with an installed base of 40% of that total today. 90% of U.S. homes have A/C installed today, while in India the total is just 12%.
- Furnaces and water heaters are powered by oil, natural gas or propane, so the solution is not tied to the electric grid.
- As much as 40% of heated or cooled air leaks out of buildings.
- Buildings make up 7% of emissions, but 40% of CO2 emissions.

The good news is the technology to decarbonize heating and cooling exists today:

- Heat pumps run on electricity which can be generated by renewable fuels, making them more environmentally friendly than furnaces which run on fossil fuels.
- In addition to heat pumps, smart controls, energy efficient A/C, and double and triple-glazed windows offer meaningful efficiency gains.

The issues facing buildings are largely behavioral. For example, if the renter of an apartment complex or commercial building pays the electric bills, the landlord has little incentive to incur the costs to retrofit the building to make it more energy efficient. Similarly, consumers are not taking full advantage of the new technologies as they frequently do not purchase the most fuel efficient A/C units available. Public policy will play a key role in improving the carbon footprint of buildings.

Summary and Closing Thoughts

The State of the Transition 2023 by Breakthrough Energy provides insights into both the challenges and opportunities associated with the Five Grand Challenges. Each of the five areas is a different story:

- **Electricity (29%)** is less about technology and more about scale and public policy. The amount of renewable energy capacity needed to electrify everything will require a threefold increase relative to today. Public policy will be key in building a grid that can meet this need. As stated in the report, there is no transition without transmission.
- **Manufacturing (29%)** on a comparison basis is relatively straightforward: it is about cement and steel and finding ways to produce them with less emissions. Improving public sector procurement of more green options is needed.

- **Agriculture (20%)** is leaning heavily on technology to address the issues tied to methane gas from livestock, nitrogen-based fertilizers, and developing crops with greater resistance to the challenges tied to climate change.
- **Transportation (15%)** has made progress on electric vehicles, but perhaps the greatest transition challenge is tied to finding a clean energy source for planes, ships and trucks.
- **Buildings (7%)** offer the potential for meaningful gains as the technology to make buildings much more energy efficient is available today. The challenge here is one of incentives highlighting the need for government policy to entice property owners to invest in this space.

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