

IEEE PES Kolkata DLP Lecture
10 December 2022

Advancing Technology Solutions to Climate Change

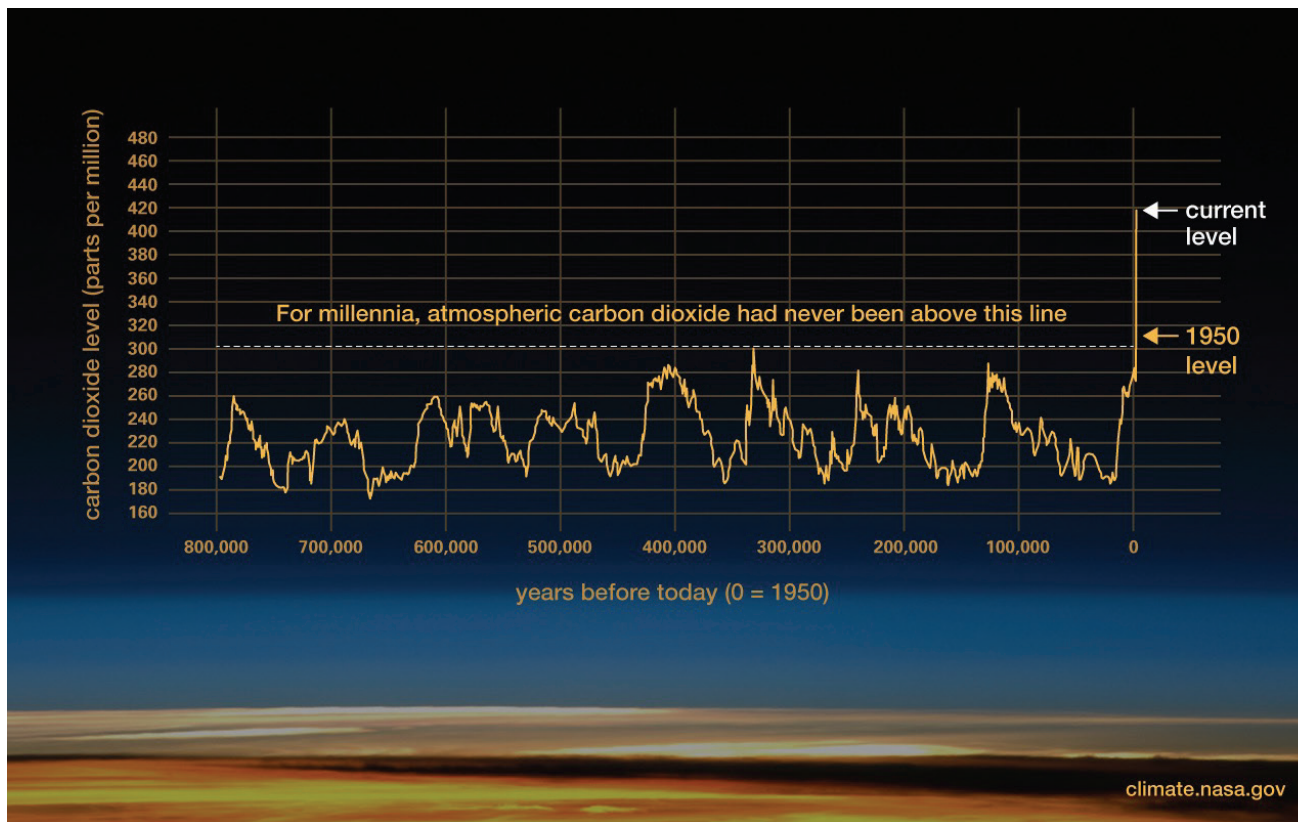


Prof. Saifur Rahman
2022 IEEE
President-elect

**Director, Virginia
Tech Advanced
Research Inst., USA**

Carbonization is Causing Climate Change

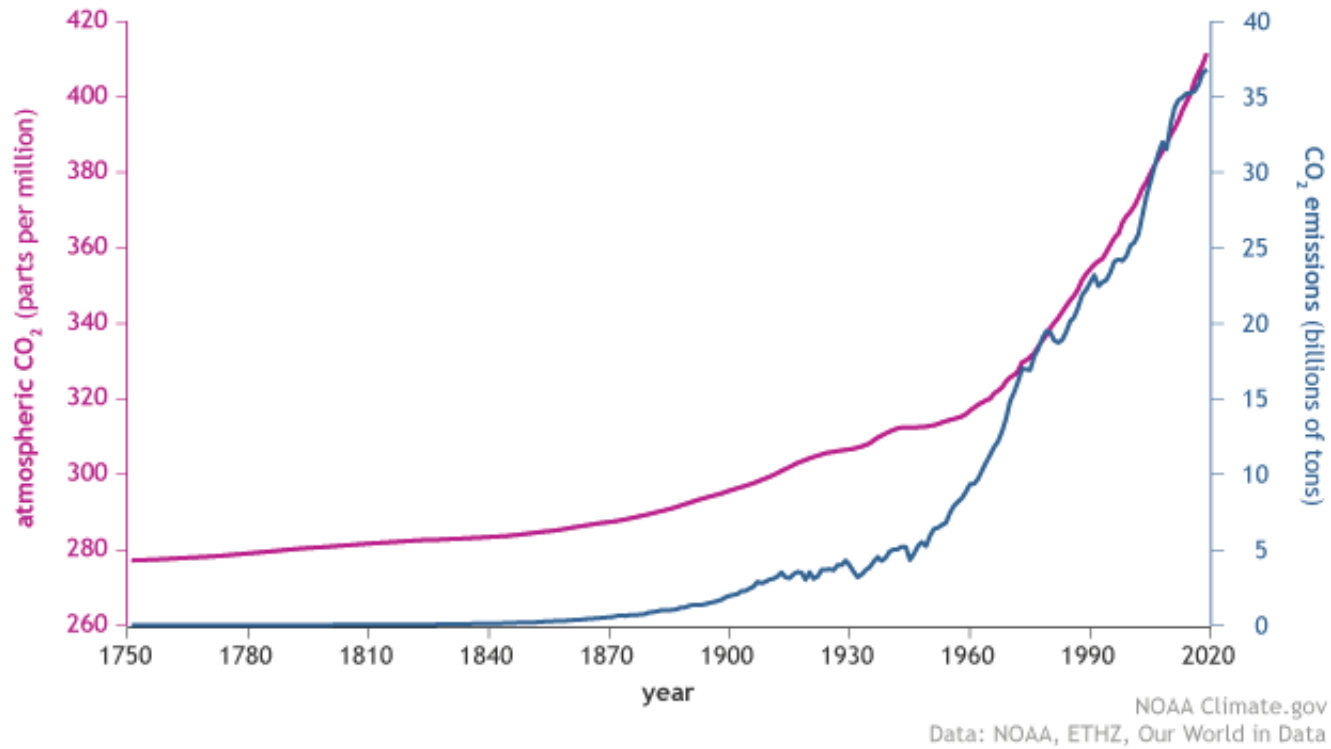
What is Carbonization ?



Source: NASA

https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/

CO₂ in the atmosphere and annual emissions (1750-2019)



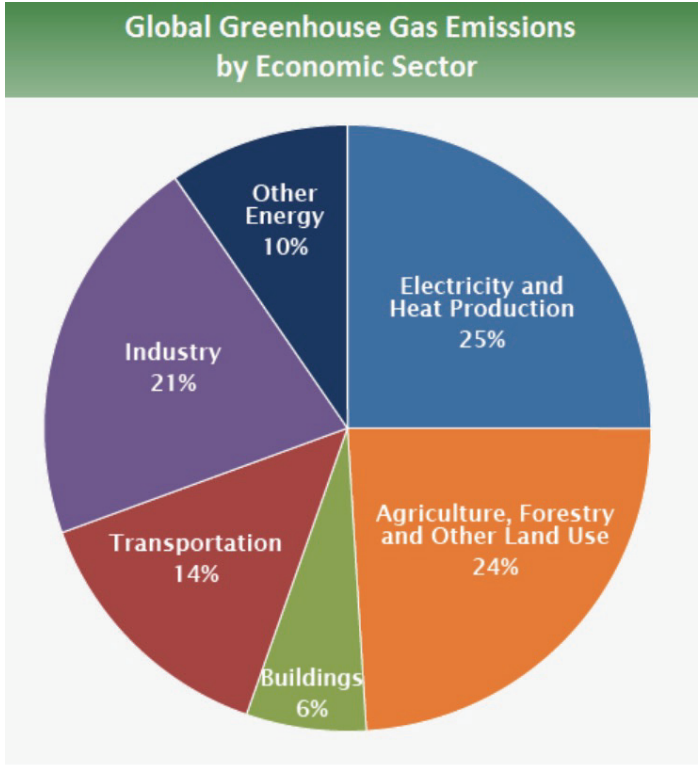
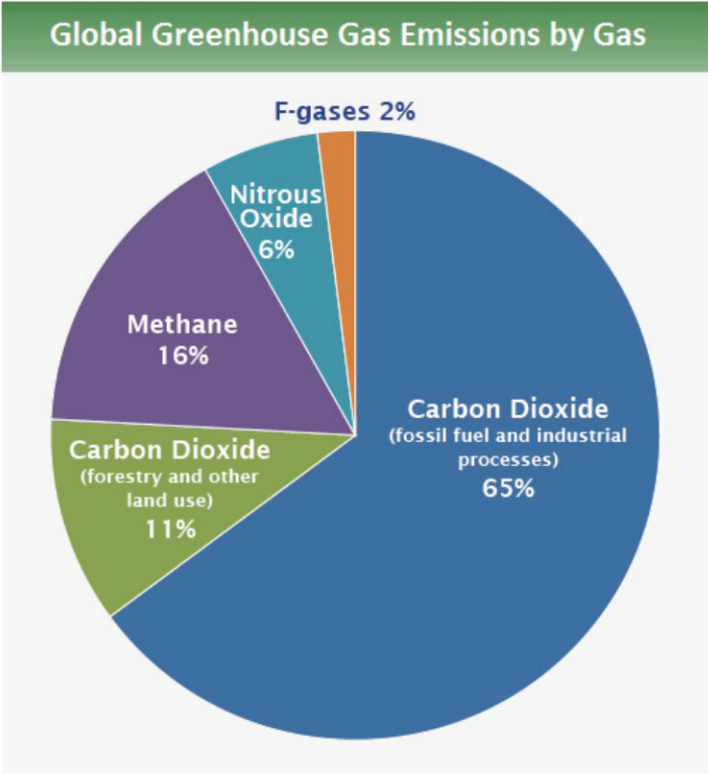
Source: State of the Planet

<https://news.climate.columbia.edu/2021/02/25/carbon-dioxide-cause-global-warming/>

Global CO₂ Emissions Due to Fossil Fuels in 2021

Coal	15.3 billion tons
Nat. Gas	7.5 billion tons
Oil	10.7 billion tons

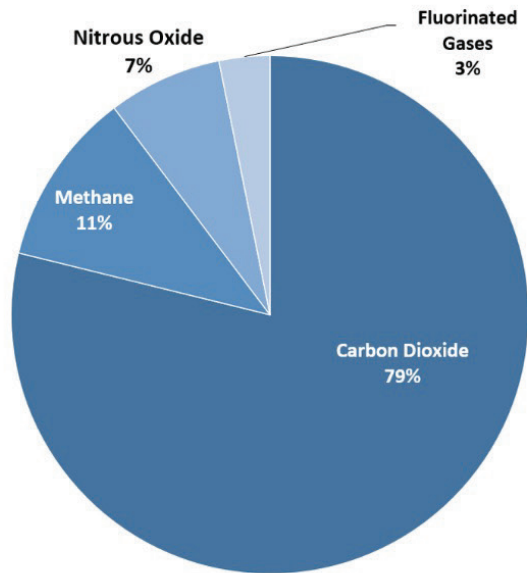
Source: IEA Global Energy Review: CO₂ Emissions in 2021
<https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2>



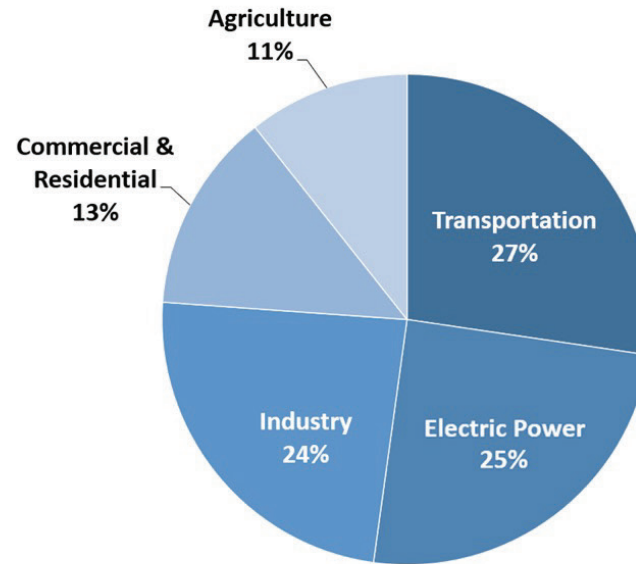
Source: [IPCC \(2014\)](https://www.ipcc.org/)

<https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

Overview of U.S. Greenhouse Gas Emissions in 2020



Sources of U.S. Greenhouse Gas Emissions in 2020



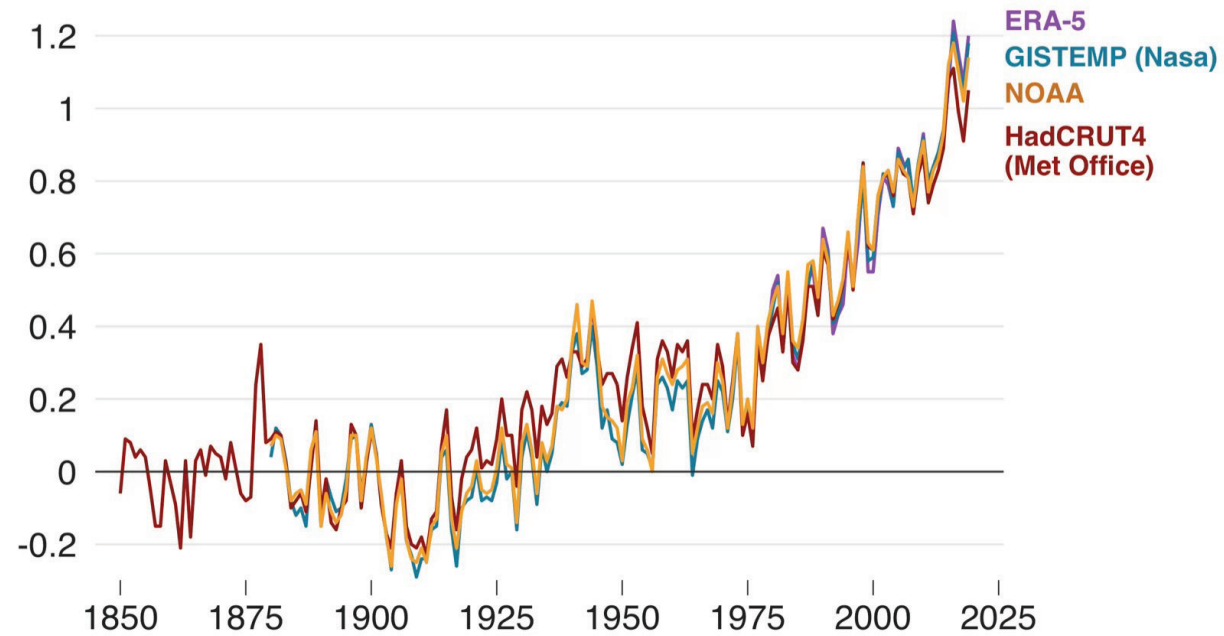
Note: All emission estimates from the [Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020](https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks)

<https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>

Impacts of Carbonization

Temperature rise since 1850

Global mean temperature change from pre-industrial levels, °C



Source: Met Office

BBC

Source: <https://www.bbc.com/news/science-environment-51111176>

Temperature rise of 1.5 – 2.0 °C = Point of No Return



Source: Craig Dearden-Phillips: Don't be a polar bear
<https://www.thirdsector.co.uk/craig-dearden-phillips-dont-polar-bear/management/article/1488091>

Climate Change Hits
Poor and the Rich Alike

Florida, China and Africa





Hurricane Isabel struck the Mid-Atlantic region of USA between Sept. 18-19, 2003.

Flooding in Pakistan – August 2022



Source: <https://www.npr.org/sections/pictureshow/2022/08/30/1119979965/pakistan-floods-monsoon-climate>



Source: <https://www.nytimes.com/2022/09/07/briefing/climate-change-heat-waves-us-europe.html>



China





Hurricane Sandy

New York, New Jersey 2012



Droughts in 2022



Dry river bed in **Italy** (Po River) due to worst drought in 70 years, June 2022

<https://idsb.tmgrup.com.tr/ly/uploads/images/2022/07/08/217454.jpg>

The Jialing Riverbed at the confluence with the Yangtze River is exposed due to drought on August 18, 2022 in Chongqing, **China**.



<https://image.cnbcfm.com/>

Wildfires in the US



July 2021 - The Dixie fire burned close to a million acres in **California's** Lassen county over three months and became the first fire to cross the Sierra Nevada. Photograph: Noah Berger/AP

Peaks glowing with thousands of spot fires on June 13, 2022 in Flagstaff, **Arizona**.
Schumacher/The Republic



Wildfires in Europe - Summer of 2022



Southwestern France, July 17, 2022



Central Portugal, July 13, 2022



Brandenburg, Germany, August 2022



Greece, July 2022



Northern Spain, June 2022



Central Italy, July 2022

“The number of wildfires in 2022 in the EU have nearly quadrupled the 15-year average”

[Source: CNN according to Copernicus, EU Earth observation program](#)

Siberia: Wildfires in June 2020 and June 2021



The Greenpeace Russia team has documented forest fires in the Krasnoyarsk region.
JULIA PETRENKO / GREENPEACE



In this June 16, 2021 photo, firefighters work at the scene of forest fire near Andreyevsky village outside Tyumen, western Siberia, Russia. -
Copyright AP Photo/Maksim Slutsky, File

2008 China Snowstorm



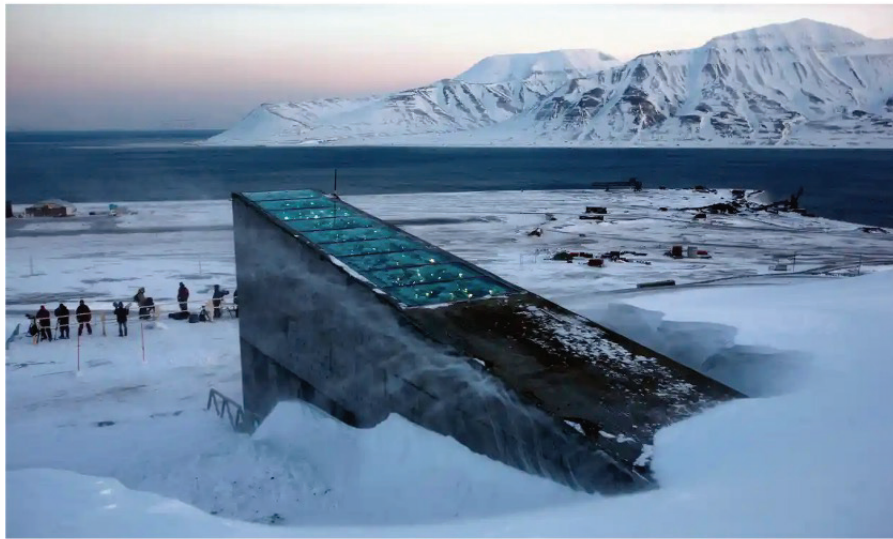
Glacier Comparison Mer de Glace in France, 2012



The Global Seed Vault in Svalbard, Norway

Arctic stronghold of world's seeds flooded after permafrost melts

No seeds were lost but the ability of the rock vault to provide failsafe protection against all disasters is now threatened by climate change



The Svalbard 'doomsday' seed vault was built to protect millions of food crops from climate change, wars and natural disasters. Photograph: John Mcconnico/AP

Source: [The Guardian, May2017](#)



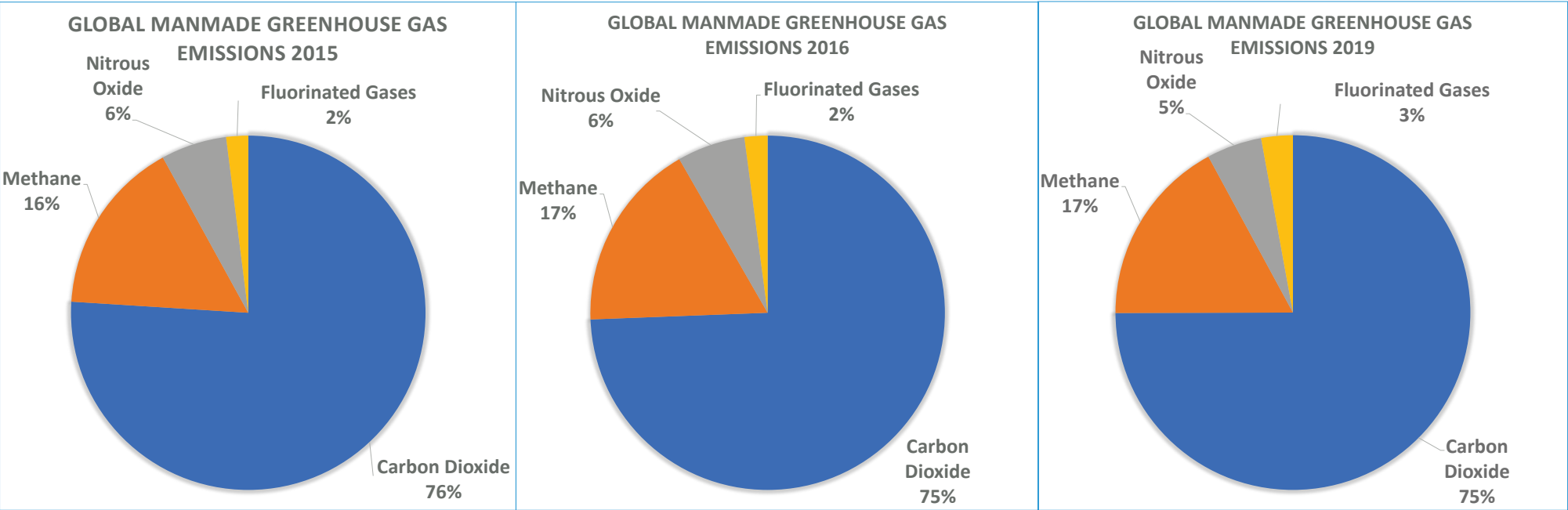
Entrance to the Svalbard Global Seed Vault (SGSV), on the island of Spitsbergen, Norway. HEIKO JUNGE/AFP/GETTY IMAGES



[Svalbard Global Seed Vault Protects...](#)
[nationalgeographic.com](#)

Global Anthropogenic Greenhouse Gas Emissions by Gas 2015, 2016 & 2019

Fluorinated Gases include: HFC, PFC and SF6

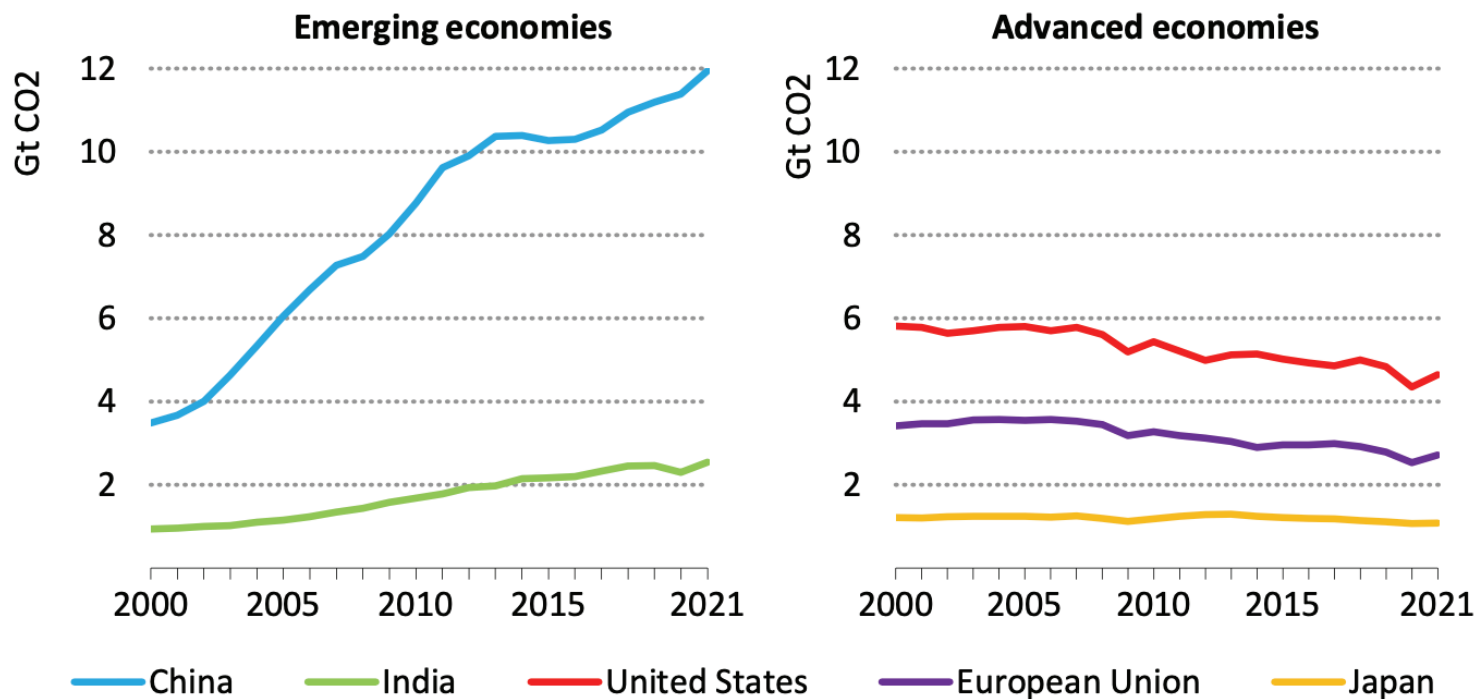


Source: <https://www.c2es.org/content/international-emissions/>

Source: <https://ourworldindata.org/greenhouse-gas-emissions#annual-greenhouse-gas-emissions-how-much-do-we-emit-each-year>

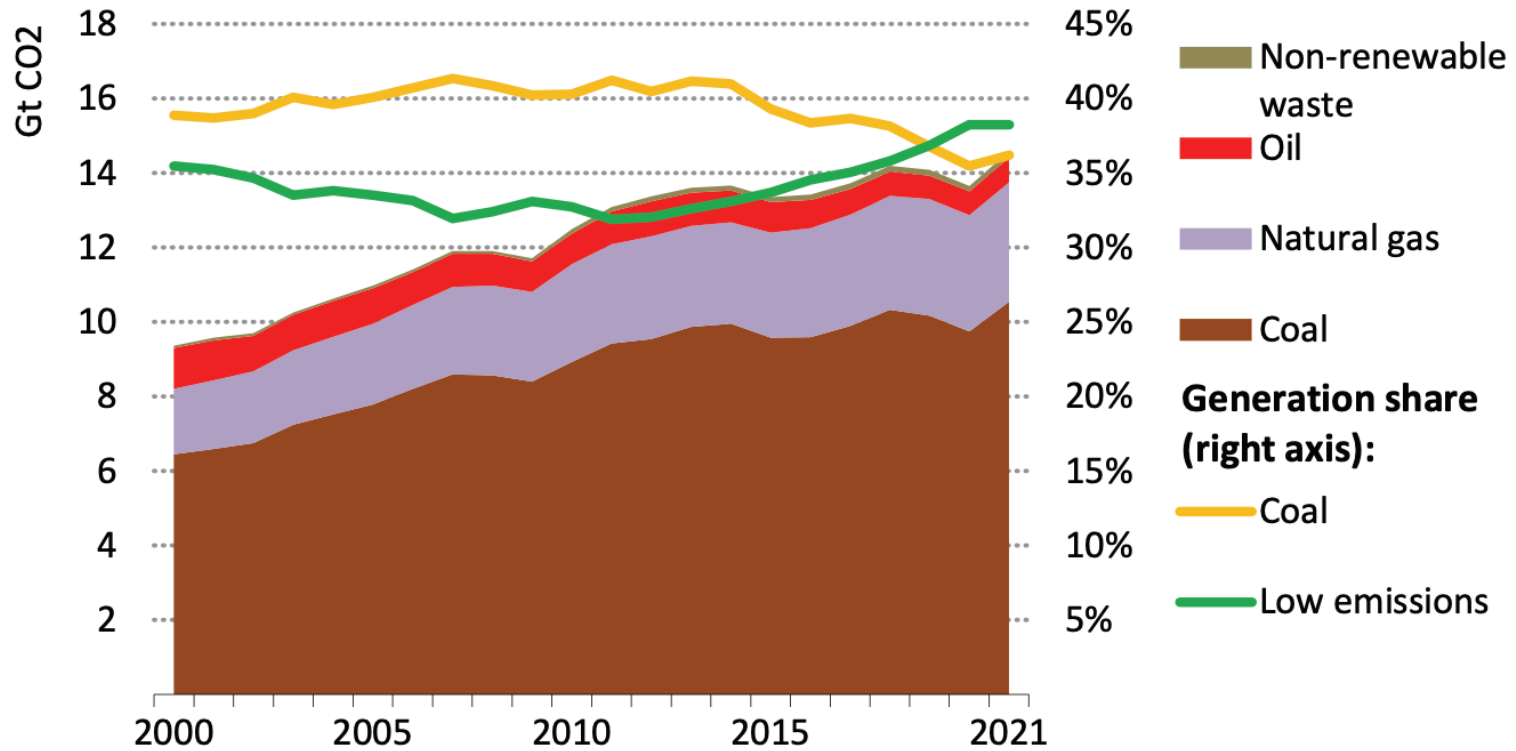
Source: UNEP Emissions Gap Report 2020 <https://www.unep.org/emissions-gap-report-2020>

CO2 emissions in selected emerging and advanced economies, 2000-2021



IEA. All rights reserved.

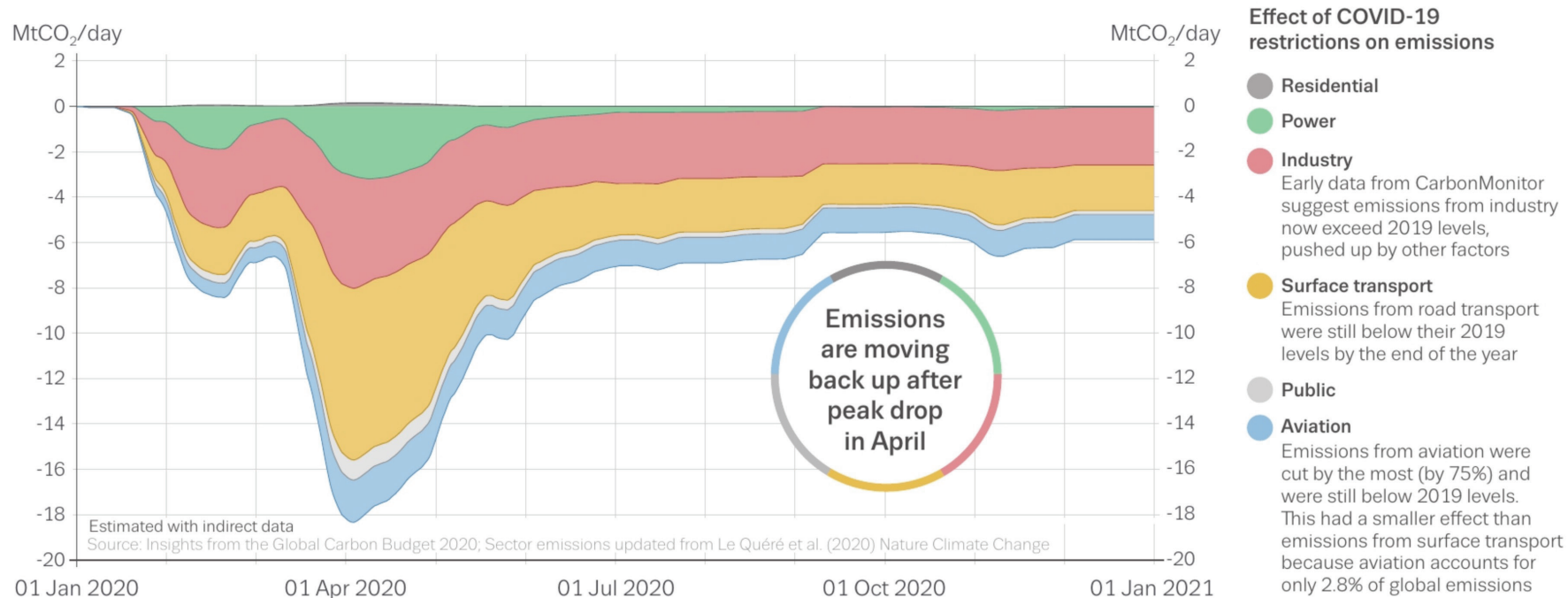
CO2 emissions from electricity and heat production by fuel, and share by fuel, 2000-2021



IEA. All rights reserved.

Source: IEA Global Energy Review: CO2 Emissions in 2021
<https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2>

Emissions from road transport cause the largest share of the global 2020 decrease

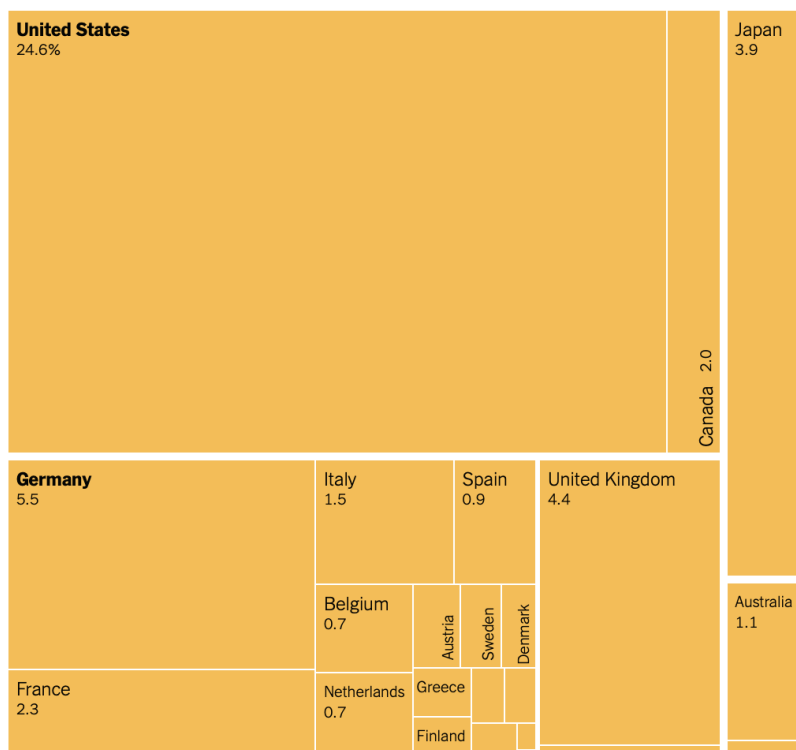


Copyright: Produced by the Global Carbon Project based on Friedlingstein et al. Earth System Science Data (2020).
Written and edited by Corinne Le Quéré (UEA) with the Global Carbon Budget team. Graphics by Nigel Hawtin.
Infographic funded by the European Commission VERIFY (776810) and 4C (821003).

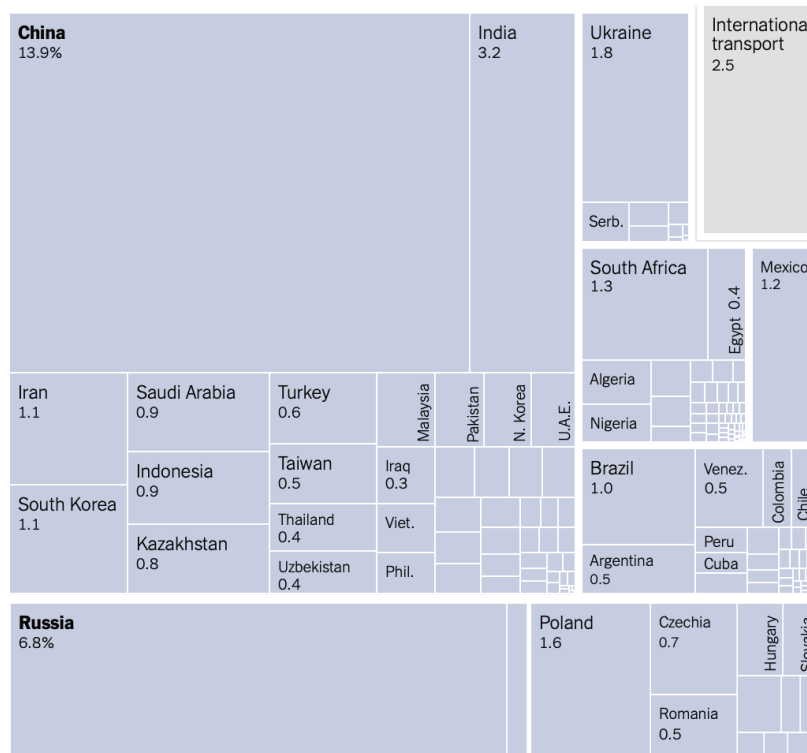


Who Has The Most Historical Responsibility for Climate Change

23 rich, developed countries are responsible for half of all historical CO₂ emissions.



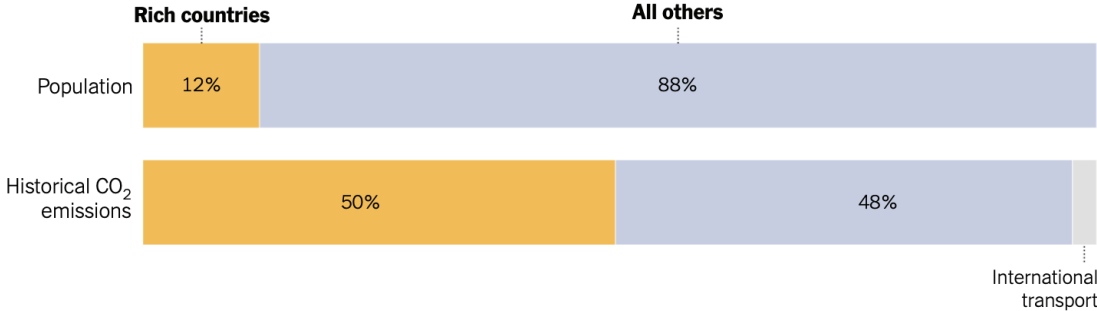
More than 150 countries are responsible for the other half.



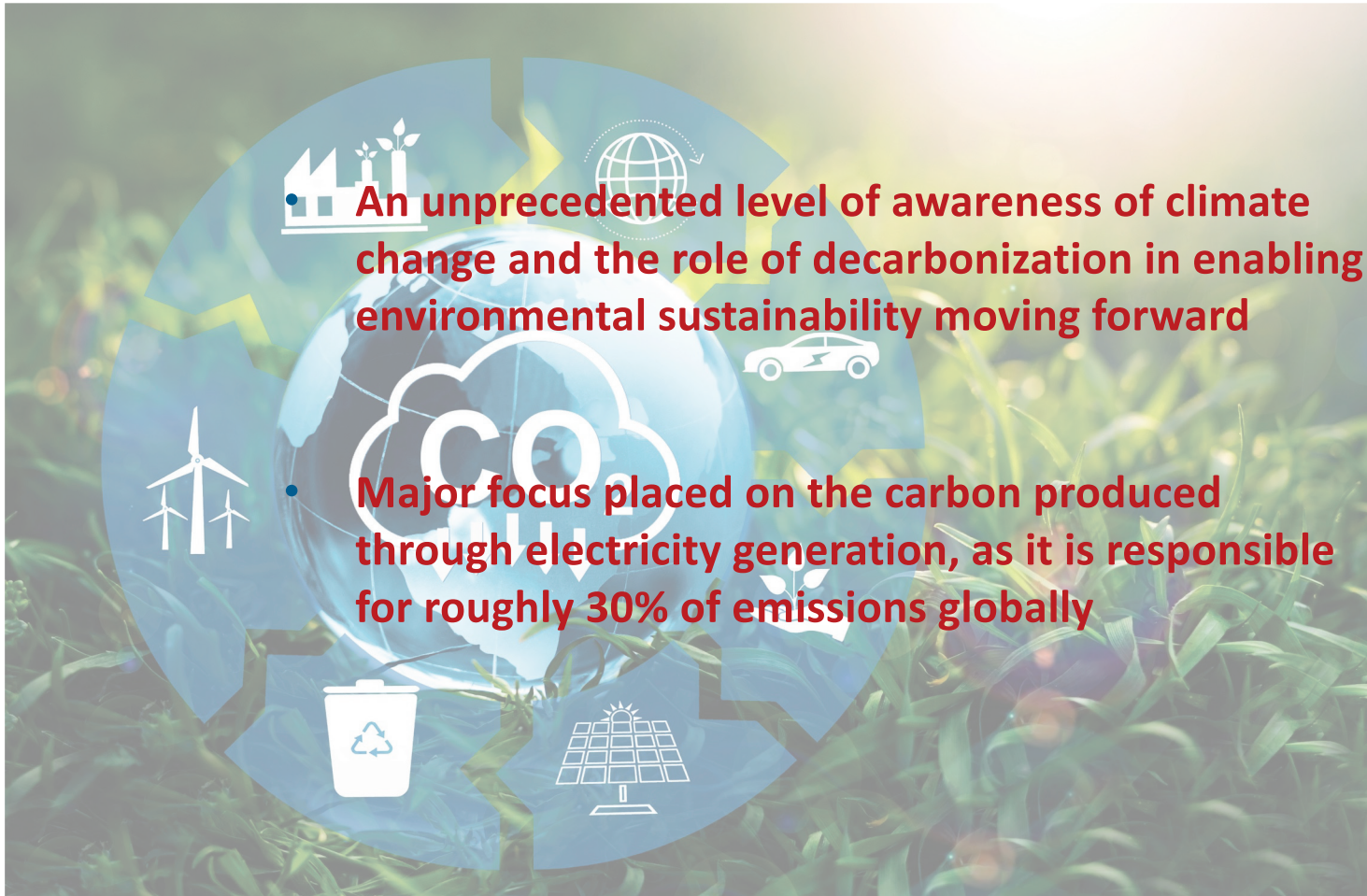
Source: The New York Times article "Who Has The Most Historical Responsibility for Climate Change?" by [Nadja Popovich](#) and [Brad Plumer](#), Nov. 12, 2021 (<https://www.nytimes.com/interactive/2021/11/12/climate/cop26-emissions-compensation.html>)

Who Has The Most Historical Responsibility for Climate Change

Rich countries, including the United States, Canada, Japan and much of western Europe, account for just 12 percent of the global population today but are responsible for 50 percent of all the planet-warming greenhouse gases released from fossil fuels and industry over the past 170 years.



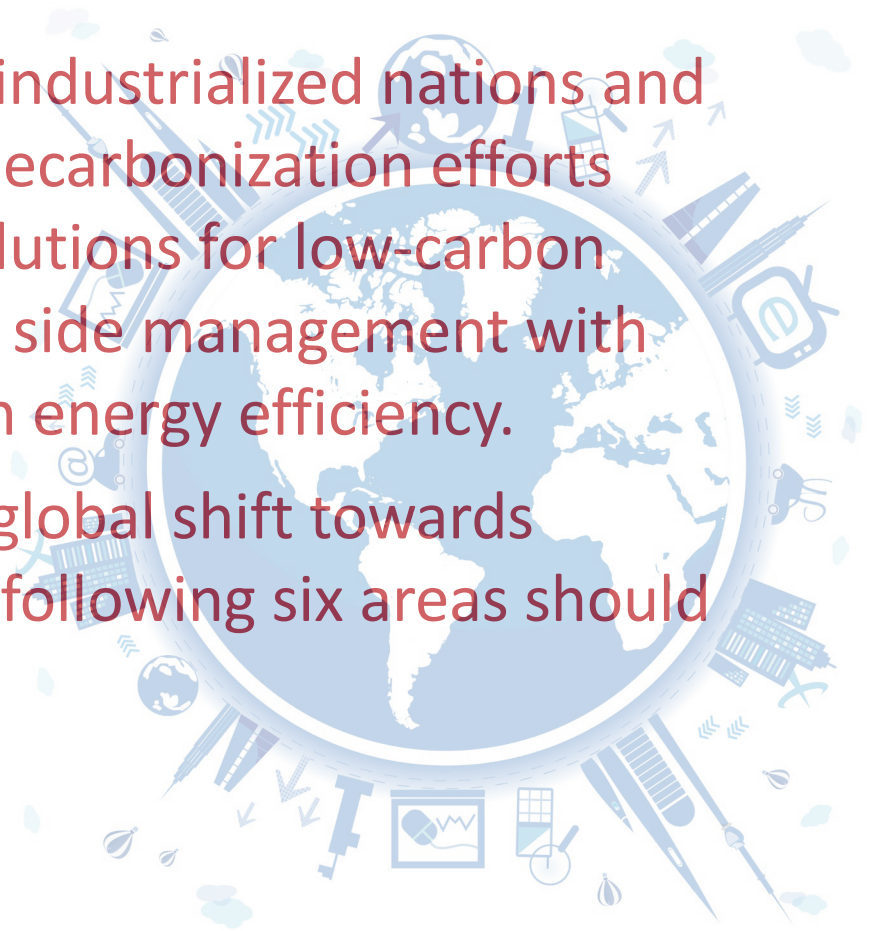
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- **An unprecedented level of awareness of climate change and the role of decarbonization in enabling environmental sustainability moving forward**

- **Major focus placed on the carbon produced through electricity generation, as it is responsible for roughly 30% of emissions globally**

- Navigating the tension between industrialized nations and emerging economies for global decarbonization efforts requires a diverse portfolio of solutions for low-carbon generation, storage and demand side management with advanced technology focusing on energy efficiency.
- To more efficiently facilitate the global shift towards renewable energy adoption, the following six areas should be our priority.



Reduce Carbon Emissions from Electricity Production



Reduce Carbon Emissions

1. Use less electricity, energy efficiency
2. Use low carbon fossil fuel power plants
3. Use H₂ & other storage technologies
4. Promote more renewables
5. Accept some nuclear
6. Promote cross-border power transfer

Customers Controlling Buildings Optimized for Savings

Measured energy savings across deployments

20% HVAC Energy Savings

25% Lighting Energy Savings

Occupant satisfaction: spaces controlled by a building automation systems are more comfortable due to more consistent temperature profiles and healthier air quality through consistent monitoring of environmental factors (CO₂ levels, PM 2.5).



Energy Efficiency Applications

Consider light bulbs

- Provide more energy efficient applications and tools globally
- The amount of electricity required to run an LED light bulb is less than 15% of what is needed to run an incandescent light bulb producing the same amount of light
- Providing developing nations with lightbulbs that are more energy efficient can ensure that energy consumption and carbon emissions are being reduced requiring lesser investments in power generation, transmission & distribution



Highly Efficient Fossil-fuel Power Plants

Carbon Capture and Storage

- Combined Cycle Gas/Steam Power Plant
- Ultra-supercritical steam power plant

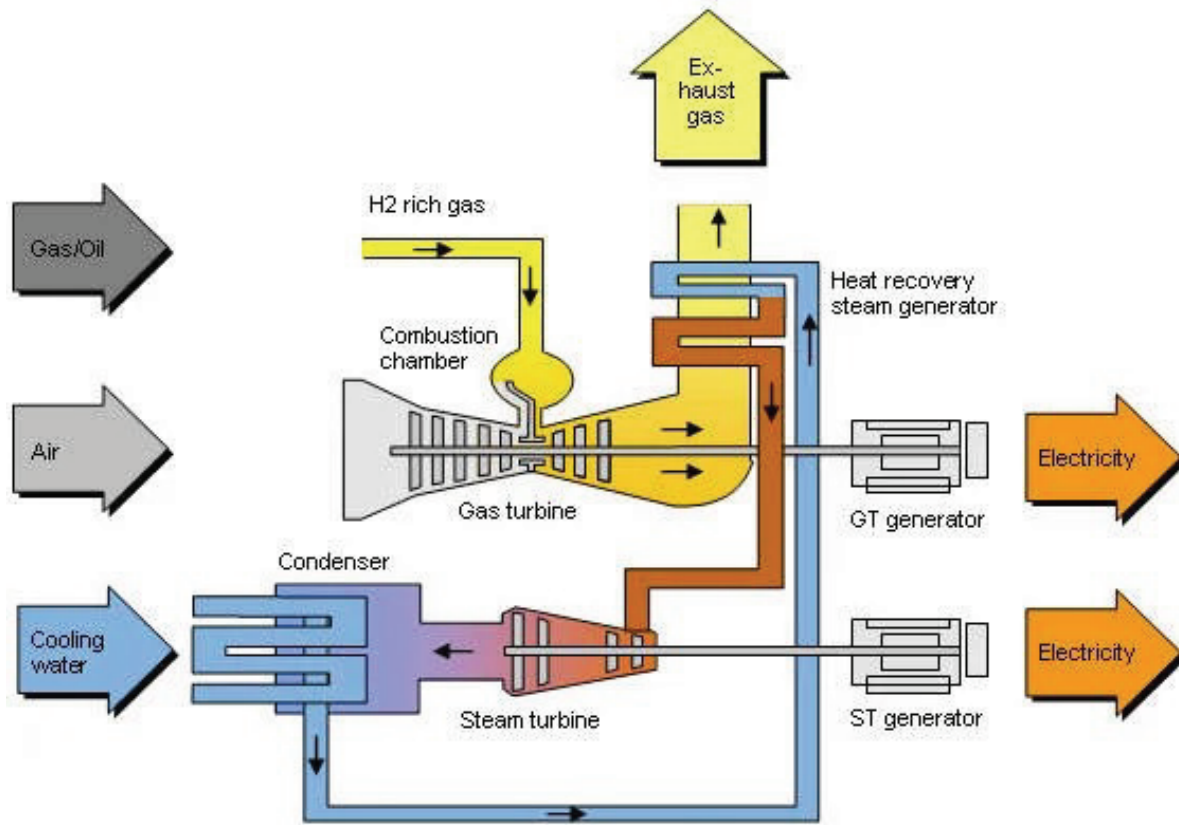
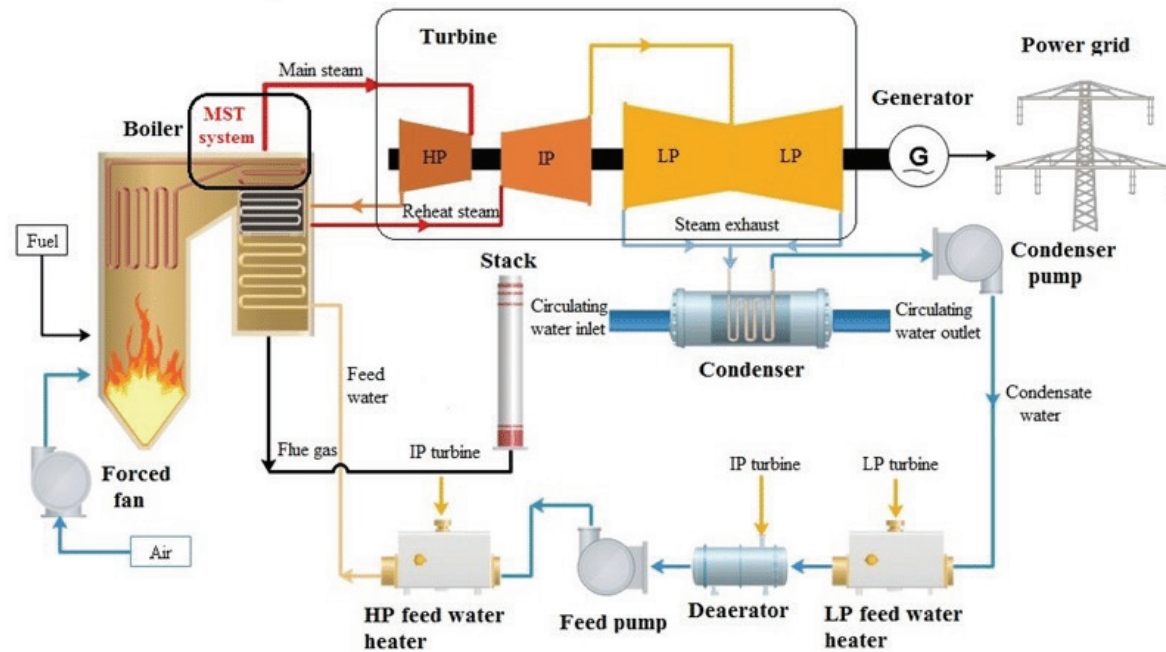


Image courtesy of: <http://www.powergeneration.siemens.com>

Simplified layout of a 1000 MW coal-fired ultra-supercritical power plant.



Source: https://www.researchgate.net/publication/343169041_An_Efficient_Robust_Predictive_Control_of_Main_Steam_Temperature_of_Coal-Fired_Power_Plant

Eemshaven ultra-supercritical steam power plant, The Netherlands



Power Plant: Two units rated 800MW each

Efficiency: 46.2%

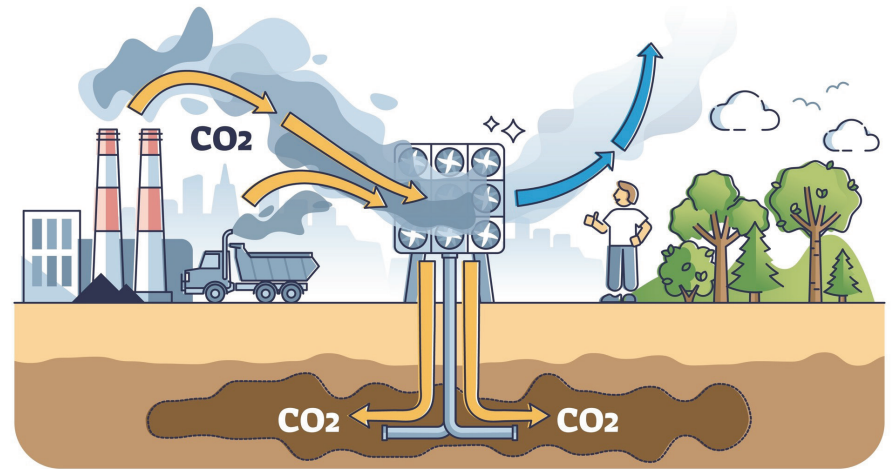
Temp: 609 deg C

Steam Turbine: Siemens SST5-6000

Built: 2014

Carbon Capture & Storage Systems (CCS)

- Can help ensure that emissions created during the energy generation phase will not be emitted into the atmosphere
- These technologies have the potential to significantly reduce carbon emissions in energy systems across the board



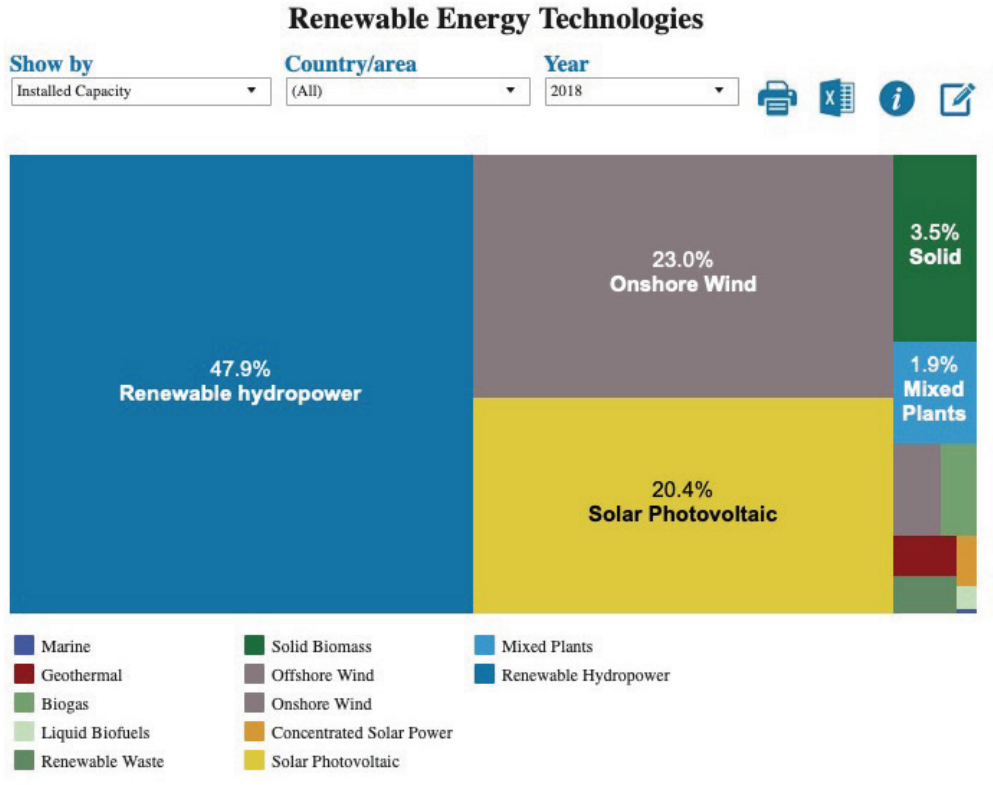
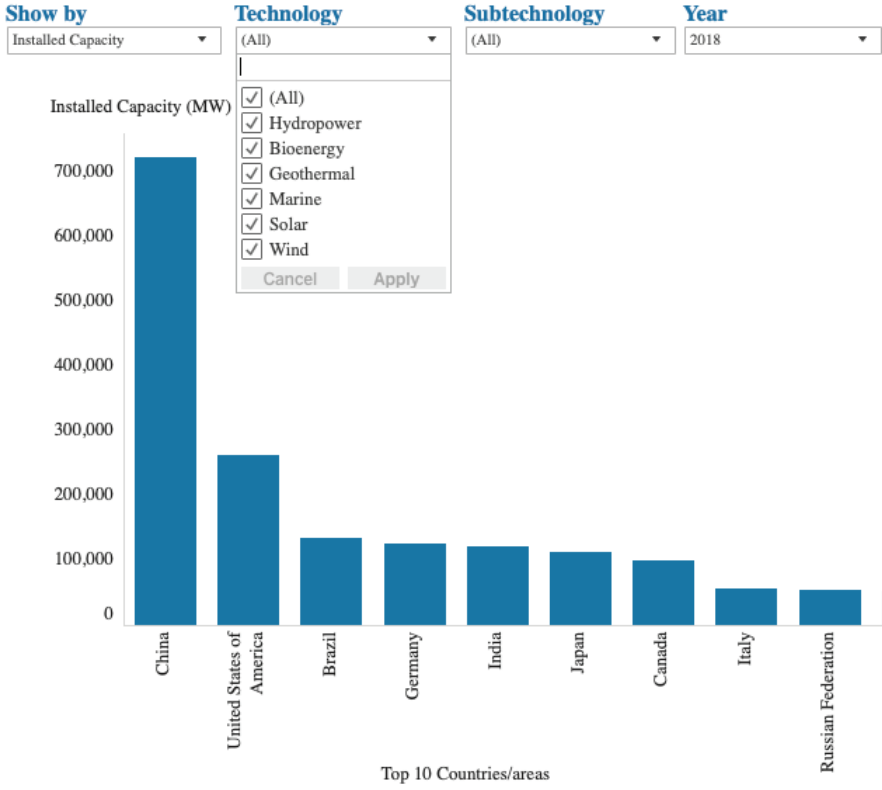
Renewable Energy Integration

Build more strategically from the start

- Focus on where energy is needed most, via three core components:
 - Energy generation
 - Transmission
 - Distribution



Total Installed Renewable Energy Capacity Top Ten Countries (2018)



Source: International Renewable Energy Agency IRENA
<https://www.irena.org/Statistics/>

Hydrogen and Storage Solutions

Optimize renewable energy solutions being integrated into energy grids

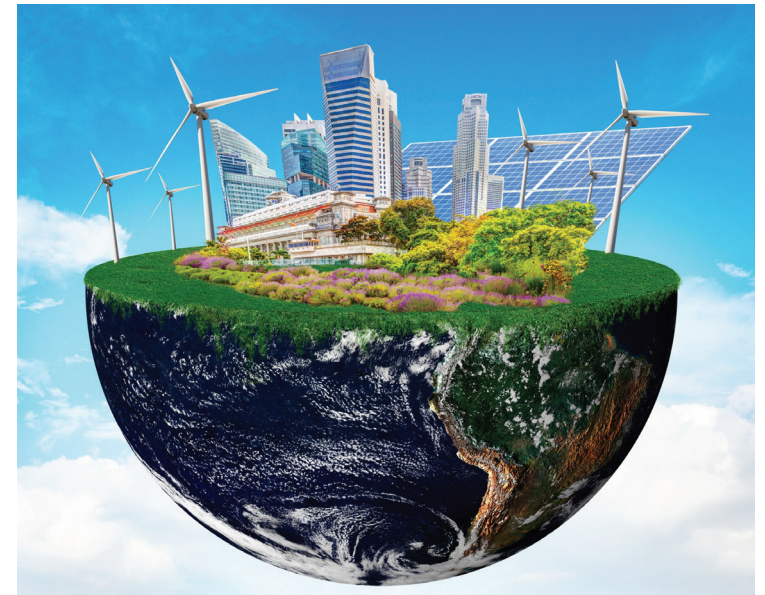


- Low-carbon hydrogen will help emerging economies to meet climate goals in and of itself
 - Provide for diverse energy portfolios
 - Improving resilience
 - Lowering costs
- Storage solutions serve as optimizers for other renewable energy solutions
 - Ensure that electricity generated during off-peak hours does not go to waste

Cross-Border Energy Transfer

We all are impacted by climate change

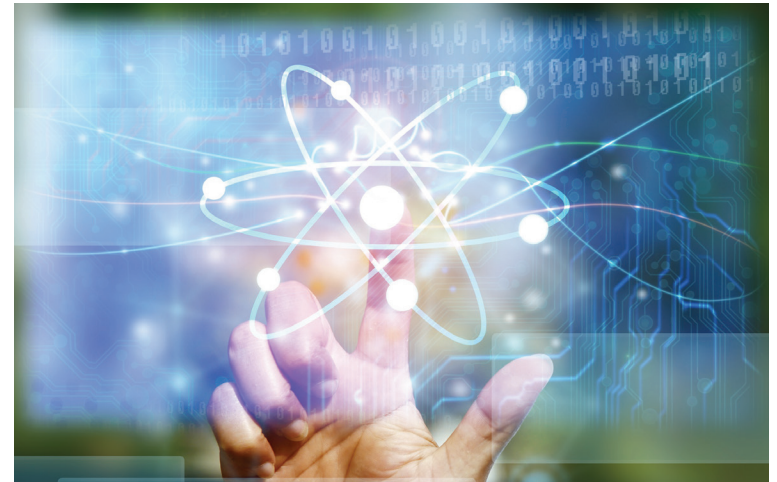
- As we are in this fight together, our solutions should be collaborative to secure better outcomes for all countries, regardless of location
- The International Energy Agency (IEA) has identified three main modes of cross-border energy integration:
 - Bilateral
 - Multilateral
 - Unified



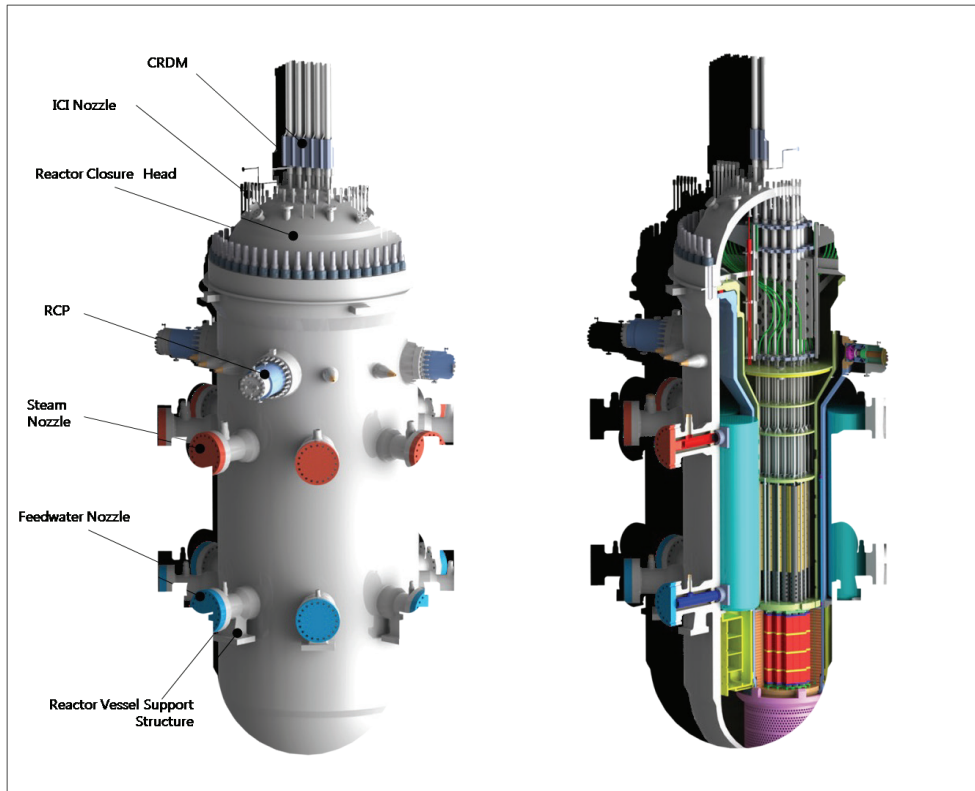
Advanced Nuclear Technologies

Diverse solutions to address climate change

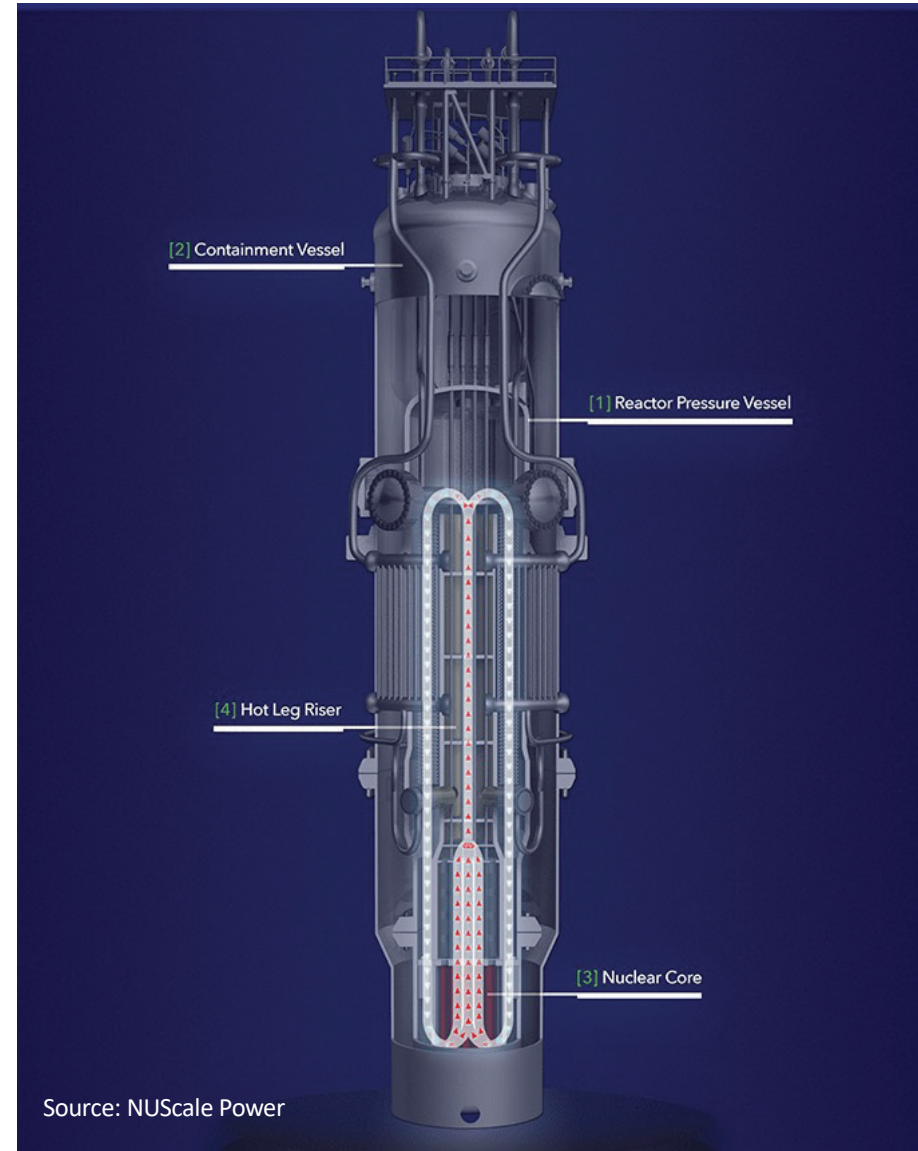
- Advanced nuclear technologies, such as small modular reactors (SMRs), can play a role
 - Smaller and can be built more quickly than more traditional nuclear reactors
- Ramping up the development of SMRs can help to produce energy when and where needed
- This energy could be integrated into existing power grids
 - helping to provide improved resiliency while simultaneously reducing emissions



Small Modular Reactors (SMR)



20m tall, 2.7m dia. 590 tons LWR
4.95% enrichment 50 – 60 MWe



US Chief Climate Negotiator Senator John Kerry at COP27



Our Plan for a Clean Energy Future

Our Goals



2050
Net Zero
GHG Emissions

2030
50%
Reduction

Our Progress



2020
52%
Reduction¹

2017
36%
Reduction

2007
GHG Emission
Baseline

<https://www.southerncompany.com/clean-energy/net-zero.html>

So, What is the bottom line?

- Efforts in the electric power sector by replacing fossil fuel with renewables and nuclear will help
- But if emission from the transportation sector continues to rise, the power sector contributions will not be enough
- Large scale Electric Vehicle deployment will help, but question remains – how will the EV be powered



IEEE Work on Climate Change

Connect efforts to mitigate the impact of climate change

- IEEE Climate Change Collection (ICCC)
 - Collection of climate change-related articles from IEEEXplore
 - Open for access before COP27 (06-18 Nov 2022)
- [IEEE Climate Change Website](https://climate-change.ieee.org)
 - <https://climate-change.ieee.org>; live since 24 October 2022
- IEEE Personal Carbon Contribution (IPCC) App
 - Tool for individuals to compute their contributions to carbon emissions emanating from their daily activities like electricity usage, travel, recreation, etc.
 - Under development

IEEE Climate Change Website

<https://climate-change.ieee.org>



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Climate
Change

IEEE: Enabling Innovation and Technology Solutions

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RESOURCES FROM IEEE

As the world's largest organization of technical professionals, IEEE has both the opportunity and the responsibility to assist in organizing the response of engineers, scientists, and technical professionals across the world to address the causes, mitigate the impact, and adapt to climate change.

IEEE's scholarly publications, conference proceedings, technical standards, and other materials help foster the exchange of technical knowledge and information for the critical climate issues that our planet faces today.

[View the IEEE Climate Change Collection in IEEE Xplore®](#)

THANK YOU!

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