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Achieving Carbon Neutrality: US and India Weigh Policy Options

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Abstract

The paper takes a critical look at the US and India positions on achieving carbon neutrality as per their commitment to the *Paris Agreement* on Climate Change. These are based on the climate change policies of the leaders of the two countries, President Joe Biden, and Prime Minister Narendra Modi, at the COP 26 summit held in Glasgow, Scotland in November 2021. Policy tools to achieve carbon neutrality such as cap and trade and carbon tax (both market-based approaches), regulations (command and control approach) and other economic incentives such as tax credits and subsidies are examined. Based on various empirical research published in the literature regarding the two countries, an assessment is made regarding the use of these tools to achieve the goals of efficiency, equity, liberty, and sustainability in the two countries. Carbon taxation at the national level is currently missing in both countries and has the potential to be a revenue source of climate finance. The US needs to assert its leadership among the OECD donor countries to provide climate finance to developing countries and direct more of such finance for adaptation to climate change among developing countries. Low Carbon Technology (LCT) transfer through trade is low among both countries and there is a need to accelerate this process. Innovations that are occurring in both countries presently in nuclear power, hydrogen power and other clean energy such as solar, hydroelectric, geothermal and biomass can provide a great fillip to early achievement of net zero emissions. International cooperation and partnership between the US and India are growing in pursuing nuclear and solar as clean fuels. However, stepped up co-innovation in clean energy between the two countries holds great dividends to achieve carbon neutrality in both countries.

Keywords: Carbon neutrality, climate policy tools, climate finance, technology transfer, innovation, international cooperation and partnerships

Introduction

Since 1992 countries of the world are collectively engaged to slow down global warming. Climate change threatens humanity with all kinds of environmental

catastrophes such as sea level rise, droughts and floods, desertification and species loss that reduces biodiversity in nature. But it is not clear from the most recent concluded year 2021 that efforts to thwart consequences of global warming have been working.

The foreign minister of Tuvalu, a Pacific Island nation, gave his speech to the United Nation's Conference on Climate Change held in Glasgow in November 2021 standing knee deep in seawater in order to show how the low lying country was at the front line of climate change (Colin, 2021). Several other island countries are also at high risk for sea level rise. It has been observed that sea level rise has already encroached lands on many of the islands. High tides and frequent storms continue to place local homes and property at risk. Recent research indicates that on average sea levels have been increasing by 3.4 millimeters (0.13 inches) per year. (Albert et al, 2016). The Standardized Precipitation Evapotranspiration Index (SPEI) Global Monitoring, a real time global monitor, reported that the world is facing unprecedented levels of drought and that no continent had been spared except Antarctica. Drought affected large areas in the United States, Brazil and Madagascar in 2021 (Tebor, 2021). At the same time, heavy rains and floods occurred in several countries around the world. These included various countries such as Germany, France, Bosnia, Herzegovina, Turkey, China, India, Afghanistan, Pakistan, Sri Lanka, Guatemala, Mexico, the United States, Nigeria, Somalia, Australia, and New Zealand (Bir, 2021). Desertification affected 45 percent of the African continent in 2021 (UN, 2021). Also, researchers at the Natural History Museum in UK released a report in October 2021 which stated that globally biodiversity intactness index stood at 75 percent. The biodiversity intactness index represents the proportion of the original number of species in an area that remain and their abundance. Scientists have set 90 percent as the safe limit in order to maintain ecological processes such as pollination and nutrient cycling that is vital to the survival of humanity (Ashworth, 2021).

Economic Impact

An IPCC Special Report for policy makers released in 2018 notes that risks to global aggregated economic growth due to climate change impacts are projected to be lower at 1.5°C than at 2°C by the end of this century. Excluded from these costs are the costs of mitigation, adaptation investments and the benefits of adaptation. The largest impacts due to climate change should global warming increase from 1.5°C to 2°C would be for countries in the tropics and Southern Hemisphere subtropics. A great proportion of people both so exposed and susceptible to poverty are in Africa and Asia. Global warming risks across energy, food, and water sectors could overlap spatially and temporally. This would create new and exacerbating current hazards, exposures, and vulnerabilities that could affect increasing numbers of people and regions adversely (IPCC, 2018).

Christian Aid, a charity organization, reported that based on its research, climate emergency cost the world nearly $200 billion in 2021 (Democracynow, 2021). Swiss Re, an insurance company, has provided a macroeconomic forecast that climate change could potentially cost the world economies $23 trillion by 2050 in annual global economic output if governments fail to act decisively on the climate (Flavelle, 2021). This amount represents about 18 percent of the world's Gross Domestic Output (GDP).

The first report in 1990 of the Intergovernmental Panel on Climate Change (IPCC) held that emissions resulting from human activities are increasing the atmospheric concentrations of the greenhouse gases (GHG), resulting on average in an additional warming of the Earth's surface. The terms carbon emissions and greenhouse gases are used interchangeably in the literature.

In the three decades since the IPCC report was made public, governments have collectively pledged to slow global warming. But despite intense lobbying by activists, political leaders and diplomats, the world still faces the perils of climate change.

By terms of the Kyoto Protocol negotiated in 2005 and the Paris Agreement negotiated in 2015, a large number of countries agreed to reduce greenhouse gas emissions. However, the amount of carbon dioxide in the atmosphere keeps rising, and as a result the Earth is being warmed up at an alarming rate. Scientists have warned of dire consequences if the warming continues unabated. Table 1 shows carbon emissions of the top twelve emitter countries in the world and the progress made or lack thereof in the decade since 2010. Table 2 shows per capita emissions for the same 12 select countries.

Table 1: Carbon Dioxide Emissions by Select Country, 2010 and 2020 (Source: https://www.statista.com/statistics/270499/co2-emissions-in-selected-countries/)

Country	Yr-2010 (Million metric tons)	Yr-2020 (Million metric tons)
China	8617	10668
US	5676	4713
India	1678	2442
Russia	1613	1577
Japan	1215	1031
Iran	570	745
Germany	833	644
Saudi Arabia	518	626
South Korea	596	598
Indonesia	452	590
Canada	559	536
Brazil	440	467
South Africa	467	452
Turkey	314	393

Table 2: Per Capita Carbon Dioxide Emissions by select country, 2010 and 2020 (Estimated per capita emissions based on population figures for 2010 and 2020 for selected countries from the Population Council)

Country	Yr-2010 (metric tons/capita)	Yr-2020 (metric tons/capita)
China	6.44	7.56
US	18.35	14.30
India	1.36	1.77
Russia	11.29	10.94
Japan	9.49	8.19
Iran	7.73	8.87
Germany	10.19	7.74
Saudi Arabia	18.85	17.98
South Korea	24.28	23.20
Indonesia	1.87	2.16
Canada	16.44	14.10
Brazil	2.25	2.20

South Africa	9.12	7.62
Turkey	4.34	4.66

International Legal Framework

Clearly trying to impact climate change to reduce global warming requires tremendous cooperation from all countries of the world. Over the last 35 years, international negotiations have resulted in four landmark agreements. These include the *Montreal Protocol in 1987, the UN Framework Convention on Climate Change (UNFCCC) in 1992, the Kyoto Protocol in 2005 and the Paris Agreement in 2015* (Maizland, 2021).

The *Montreal Protocol* does not tackle climate change directly. It requires countries to stop producing substances that damage the ozone layer, such as chlorofluorocarbons (CFCs). The protocol which has been ratified by all countries has served to virtually eliminate ozone-depleting substances. The Kigali Amendment to the *Montreal Protocol* agreed to by all parties in 2016 requires further those countries also reduce their production of hydrofluorocarbons (HFCs), powerful greenhouse gases that contribute to climate change.

The *UN Framework Convention on Climate Change (UNFCCC)* has been ratified by 197 countries and is the first accord to address climate change. The medium chosen to address the issue is an annual forum, known as the Conference of the Parties, or COP for short. The international discussions that followed to stabilize the concentration of greenhouse gases in the atmosphere resulted in the *Kyoto Protocol* and the *Paris Agreement*.

The *Kyoto Protocol* was adopted in 1997 by various countries and entered into force in 2005. This was the first legally binding climate treaty. Developed countries were required to reduce emissions by an average of 5 percent below 1990 levels, and a system to monitor countries' progress was also established. The treaty did not compel developing countries to act. Included among them were China and India which are major carbon emitters The United States became a signatory in 1998. The country never ratified it however, and later withdrew its signature from the agreement.

The *Paris Agreement* is considered the most significant global climate agreement. It requires all countries to set emissions-reduction pledges. Governments set targets, known as nationally determined contributions (NDCs), with the goals of preventing the global average temperature from rising 2°C (3.6°F) above preindustrial levels and pursuing efforts to keep it below 1.5°C (2.7°F). The key idea is to achieve global net-zero emissions, where the amount of greenhouse gases emitted equals, the amount removed from the atmosphere, in the second half of the century. This is also known as being **climate neutral** or **carbon neutral**. The US became a signatory to the agreement in April 2016 under President Obama, withdrew from the Paris Agreement on November 4, 2020 under President Trump and rejoined as a signatory on February 19, 2021 under President Biden(McGrath, 2020; NPR, 2021). This flip flop shows that domestic politics play a significant role in shaping a country's commitment to abide by the terms of the *International Paris Agreement.*

As per the Global Stock Take (GST) process of the Paris Agreement, every five years, countries assess their progress toward implementing the agreement. Countries are allowed to set their own targets, and there are no compelling enforcement mechanisms to ensure that the targets are being met. The first of the GST process started in 2021 and is set to conclude in 2023.

Numerous countries have made new pledges during the recent UN climate conference known as COP26 held in Glasgow, Scotland in November 2021. The US has pledged to decrease carbon emissions by 50 percent by 2030, India by 22 percent and China by 25

percent over the same period. The US plans to achieve full carbon neutrality by 2050, China by 2060 and India by 2070. Still, skeptics remain concerned that these pledges are not ambitious enough.

As mentioned earlier, carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. To achieve net zero emissions, all worldwide greenhouse gas (GHG) emissions will have to be counterbalanced by carbon sequestration. In the following sections, we review the most recent climate change policies of the United States of America and India to achieve carbon neutrality by the latter half of the twenty first century and examine some of the economic tools available to achieve the same. A longitudinal view of climate change policies under various administrations in the two countries since the Kyoto protocol was signed in 1997 can be found in Table 3. What can be inferred from the Table is that climate change policy changed drastically in the US when the country withdrew from the Paris Agreement. It is also clear that in India there has been growing awareness of its global responsibility as it previously regarded climate change primarily as a problem of developed countries. It has also increased its commitment to be part of the solution to the problem of climate change.

Table 3: Longitudinal Climate Change Policy of US and India since the Kyoto Protocol of 1997

Leader of Country	Climate Change Policy	Source
USA		
President William Clinton (1992-2000)	The Clinton Administration launched the Climate Change Technology Initiative to spur the development of clean energy technologies to reduce greenhouse gas emissions that lead to global warming while saving money and creating jobs.	https://clintonwhitehouse5.archives.gov/WH/Accomplishments/eightyears-08.html The Clinton Presidency: Protecting our Environment and Public Health
President George W. Bush (2001-2008)	President Bush stated that his plan would prevent the release of 500 million metric tons of greenhouse gases, which is about the equivalent of 70 million cars from the road. This target would achieve this goal by providing tax credits to businesses that use renewable energy sources.	https://en.wikipedia.org/wiki/Climate_change_policy_of_the_George_W._Bush_administration Climate Change Policy of the Bush Administration.
President Barack Obama (2009-2016)	The Climate Action Plan is an environmental plan that proposed a reduction in carbon dioxide emissions. It included preserving forests, encouraging the use of alternate fuels, and increased study of climate change.	https://en.wikipedia.org/wiki/Presidential_Climate_Action_Plan Presidential Climate Action Plan
President Donald Trump (2017-2020)	Programs to be eliminated included the radon program, grants to clean up industrial sites ("brownfields"), climate change research, and the Office of Environmental Justice. Trump's objectives include the lifting of regulations from various energy industries to boost domestic energy production. Withdrew the US from the Paris Agreement on June 1, 2017.	https://en.wikipedia.org/wiki/Environmental_policy_of_the_Donald_Trump_administration Environmental Policy of the Donald Trump Administration. https://en.wikipedia.org/wiki/United_States_withdrawal_from_the_Paris_Agreement United States withdrawal from the Paris Agreement
India		
PM Atal Bihari Vajpayee (1999-2004)	Increase the share of wind, solar and hydro power. Promote various energy efficiency measures in the industrial, commercial, governmental and domestic sectors. Increase forest cover and reduce energy intensity of GDP.	https://archivepmo.nic.in/abv/speech-details.php?nodeid=9066 Speech of Prime Minister Shri Atal Bihari Vajpayee At the High Level Segment of the Eighth Session of Conference of the Parties to the UN Framework Convention on Climate Change

PM Manmohan Singh (2004-2014)	Country is pursuing solar energy, urging energy efficiency, creating a sustainable habitat, conserving water, preserving the Himalayan ecosystem, creating a "green" India, creating sustainable agriculture and, finally, establishing what Singh called a "strategic knowledge platform for climate change."	https://www.nytimes.com/2008/07/01/business/worldbusiness/01rupee.html India Offers 8 Ideals on a Climate Change Policy, but Few Details

US Current Climate Change Policies

The US plans to be carbon neutral by 2050. On December 8, 2021, President Joe Biden has signed an executive order to make the federal government carbon-neutral by 2050, with a 65% reduction in planet-warming greenhouse gas emissions by 2030 and an all-electric fleet of cars and trucks five years later. The highlights of the plan include the following:

The United States federal government will use its full influence in scale and procurement power to be a prime example in preventing the climate crisis from further escalation. The US seeks to curtail emissions across federal operations, advance American clean energy industries and manufacturing, and create clean, healthy, and resilient communities. It hopes to manage the climate crisis in a manner that creates well-paying jobs, newer industries, and makes the country more economically emulous. It may be noted in context that there have been 13 bills or enabling legislations that have been approved by the US Congress since 1992 which are aimed at combatting various aspects of climate change (C2ES, 2022). They also support various aspects of the Biden plan.

The salient features of the new climate policy of President Biden is directed to achieve five ambitious goals (Whitehouse, 2021):

- 100 percent carbon pollution-free electricity (CFE) by 2030, at least half of which will be locally supplied clean energy to meet 24/7 demand.
- 100 percent zero-emission vehicle (ZEV) acquisitions by 2035, including 100 percent zero-emission light-duty vehicle acquisitions by 2027.
- Net-zero emissions from federal procurement no later than 2050, including a Buy Clean policy to promote use of construction materials with lower embodied emissions.
- A net-zero emissions building portfolio by 2045, including a 50 percent emissions reduction by 2032; and
- Net-zero emissions from overall federal operations by 2050, including a 65 percent emissions reduction by 2030.

The US federal government will also orient its procurement and operations efforts in line with the following principles and goals (Whitehouse, 2021):

- Achieving climate resilient infrastructure and operations.
- Building a climate- and sustainability-focused workforce.
- Advancing environmental justice and equity.
- Prioritizing the purchase of sustainable products, such as products without added perfluoroalkyl or polyfluoroalkyl substances (PFAS); and
- Accelerating progress through domestic and international partnerships.

India's Current Climate Change Policy

The national statement delivered by Prime Minister Modi at COP26 Summit in Glasgow highlighted the fact that India, which is working to uplift millions of people out of poverty accounts for 17 % of the world's population but bears responsibility for only 5 percent of the carbon emissions (MEA, 2021). India has been delivering in letter and spirit on the Paris Commitment. He also noted that India ranks fourth in the world in installed renewable energy capacity. The National Renewable Energy Laboratory (NREL) has shown that a 35 percent penetration of renewable energy can reduce carbon emissions by 25-45 percent (Tierney and Bird, 2020). It has been estimated that India's non-fossil fuel energy had increased by more than 25% in the previous 7 years, and it had reached 40% of India's energy mix. Among other notable achievements, India had more passengers travel by Indian Railways than the entire population of the world which is estimated currently

at 7,9 billion. This ultra large railway system hopes to achieve 'Net Zero' by 2030 which initiative alone could reduce carbon emissions by 60 million tonnes annually. Likewise, the massive LED bulb campaign could reduce carbon emissions by 40 million tonnes annually.

India had also worked to provide institutional solutions to provide a cooperative pathway with the world at the international level. It had initiated the International Solar Alliance to use solar power more effectively. It had also created a coalition for disaster resilient infrastructure for climate adaptation. This was both a sensitive as well as a vital initiative to save millions of lives.

The Government of India (GOI) pledged to do the following in the near future (MEA, 2021):

- take its non-fossil energy capacity to 500 GW by 2030.
- meet 50 percent of its energy requirements from renewable energy by 2030.
- reduce the total projected carbon emissions by one billion tonnes from now till 2030.
- reduce the carbon intensity of its economy by more than 45 percent by 2030.
- achieve the target of Net Zero by 2070.

The Prime Minister observed that the promises made till date regarding climate finance had proven to be hollow. There was a need to revise the world's ambitions on climate finance since the time of the *Paris Agreement* as the world's ambition on climate change had increased substantially. Transfer of climate finance and low-cost climate technologies had become more important than ever before. Developed countries need to provide climate finance of $1 trillion at the earliest. Alongside tracking the progress made in climate mitigation, it was also important to track climate finance. There were proper justice issues which required applying pressure on those countries that did not live up to their promises made on climate finance. Thus, India has signaled that emission cutting pledges from India and other developing nations would require finance from rich developed nations that have been historically large emitters.

Policy Options to Mitigate Climate Change

The US and India are the second and third largest respectively among the world's three biggest emitters of greenhouse gases in the world. In this section, we study various economic tools that are available to mitigate the problem of climate change. These public policy tools need to be applied in various countries bearing in mind that the world has over 194 countries at various stages of development. These countries could be classified as developed economies or developing economies or least developed economies, or alternately as high income, medium income, or low-income countries. So within each country, depending on the political set up, concerns and emphasis over efficiency, equity, liberty and sustainability in applying these economic tools of public policy to attain climate change goals will vary (Dolan & Goodman, 1995). The choice of economic tools thus could be influenced based on national priorities.

By studying the policy options available to both a developed nation such as the United States and a developing nation such as India, a critical evaluation of the options is also provided in this section and shows how these two democracies can learn from each other while pursuing prosperity for their respective countries and yet interact cooperatively to deal with the grim message of the COP26 climate crisis summit held in Glasgow, Scotland.

In the literature, various economic tools have been identified to deal with the problem of climate change (EPA, 2021-a; Harris et al., 2017; McKibbin & Wilcoxen, 2002; Prahu & Hofman, 2009). These include cap and trade, carbon tax, regulation, and economic policy

tools such as tax credits and subsidies. The first two represent market-based approaches, whereas the third is part of command and control (CAC) and the last one is part of larger economic policies to alter economic behavior. In terms of international cooperation among countries to achieve progress over climate change the *Paris Agreement* also incorporates sections on climate finance and technology transfer. All of these are discussed in this section of the paper.

Cap And Trade

The *Kyoto Protocol* established a carbon credit system. For countries that ratified it, a system was devised that placed national caps on GHG of developed nations. These countries were aligned as Annex B countries. Each developed country ratifying the *Kyoto Protocol* has been given an allotment and corresponding number of emission allowances known as Assigned Amount Units (AAUs). The target set for them is to reduce their emissions to well below 1990 levels and more than 5% by 2012. Emissions could be reduced by trading in emission allowances with countries that had surplus allowances. A country could also meet its target by buying carbon credits.

National and international bids to mitigate the growth in concentrations of GHG in the atmosphere have relied on a system of carbon credits and carbon markets. A carbon credit also referred to as a carbon offset is a credit for GHG emissions reduced or removed from the atmosphere by an emission reduction project. Governments, industry, or private individuals can use carbon credits to offset emissions generated elsewhere. Trading partners use GHG mitigation projects that generate credits to finance carbon reduction schemes (example renewable energy such as wind, solar, geothermal and biomass or reforestation) around the world. One carbon credit is equal to one metric ton of carbon dioxide, or in some markets, carbon dioxide equivalent gases. The transaction involving carbon credits is accomplished through international brokers, online retailers, and trading platforms. Utilizing a carbon credit means that there will be one less metric ton of carbon dioxide in the atmosphere than otherwise.

Recent data shows that the cap and trade for carbons is gaining traction worldwide. There has been swift and rapid growth of voluntary carbon.

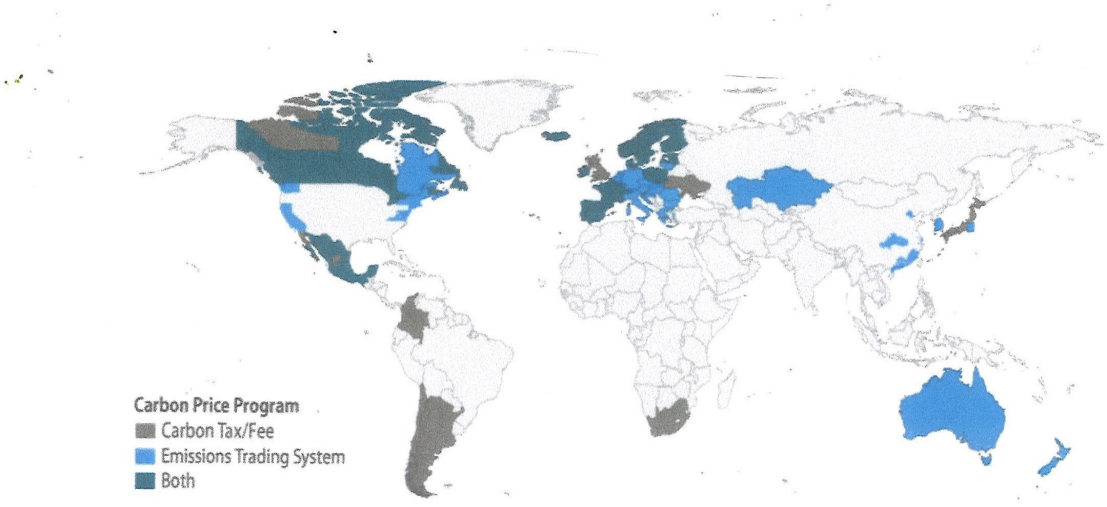

Figure 1: National and subnational carbon pricing programs (Source: CRS using data from World Bank, "Carbon Pricing Dashboard" as of November 1, 2020 https://carbonpricingdashboard.worldbank.org)

Voluntary carbon markets had hit an all-time market value of $6.7 Billion by August 2021. This was based on growing global network of 172 EM Respondents (13% increase from 2020 of 152), with traded credits from projects located in 80 countries. The gain in value of voluntary carbon markets in the first eight months of 2021 represented a near-60% increase in value from the 2020 year. Corporate net-zero ambitions and growing interest in carbon markets to achieve *Paris Agreement* climate goals contributed to this result. Companies and speculators were both purchasing credits and thus becoming a serious source of finance for green projects around the world (EcosystemMarketplace, 2021).

According to the State of the Voluntary Carbon Markets 2021 report by 31 August 2021, voluntary carbon markets had already posted $748.2M USD in sales for 239.3 million credits, each representing one ton of carbon dioxide equivalent, reflecting a 58% year-to-date jump in value (up from $472.9M), and growth in credit volume of 27% over 2020 performance (up from 188.2 million credits transacted) (EcosystemMarketplace, 2021).

Energy, consumer goods, and finance and insurance sectors were the most active in the market. The identified sectors face challenges in quickly cutting climate impacts both in direct as well as financed emissions. A large share of their emissions resulted from an infrastructure or technological base they could not quickly upgrade or resulted from parts of their supply chain or portfolio they had less influence over than direct operations. Thus, purchasing carbon offsets by companies provided the means to immediately reduce the net emissions footprint. It provided time for the companies to abate more costly and difficult-to-address emissions in the medium to longer term (EcosystemMarketplace, 2021).

The *Kyoto Protocol* provides for three mechanisms namely, Joint Implementation (JI), Clean Development Mechanism (CDM) and International Emissions Trading (IET) that enable countries, or operators in developed countries, to acquire greenhouse gas reduction credits.

India's has one of the fastest growing carbon markets in the world and has already generated approximately 30 million carbon credits, the second highest transacted volumes in the world. The pace of growth of the carbon trading market has been more rapid than even its information technology, biotechnology, and Business Process Outsourcing (BPO) sectors (Gautam, 2021). Earlier there was a question whether India would lose millions of carbon credits or emission reduction certificates (CERs) that it had earned by investing in low-carbon intensive technologies, such as switching to renewable energy and protecting forests. This had happened under an earlier climate agreement - the *Kyoto Protocol*. The Madrid COP 25 meeting had failed to finalize rules for a new global carbon market as part of the current *Paris Agreement* over a disagreement on double counting of credit, when both buyers and sellers claim the carbon credit. For instance, if a country or company sells the credit it has earned by building a solar park, the buyer offsets their carbon emissions in the credit they bought. According to critics, since the seller also counts the credit in its favor, the seller is not making meaningful emission reductions (BBC, 2019). However, the more recently concluded Glasgow COP26 meeting had finalized the rules of carbon trading after adopting compromise language to phase down coal instead of phase out coal. India thus will be able to sell more than a million carbon credits from previous years, and can also create a domestic market for carbon trading (The Hindu, 2021). India's gain through carbon trading is estimated at least $5 billion to $10 billion over a period of time. It is one of the largest beneficiaries of the total world carbon trade through the Clean Development Mechanism (CDM) claiming about 31 per cent of the total (Gautam, 2021).

Compliance markets are also used to achieve decarbonization in the United States although limitedly. The compliance carbon market is represented by the California Global

Solutions Act system and the Regional Greenhouse Gas Initiative in the northeastern states which include eleven states, namely Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey (withdrew in 2012, rejoined in 2020), New York, Rhode Island, Vermont, and Virginia (Estuaries, 2021), Compliance carbon markets are marketplaces through which regulated entities obtain and surrender emissions permits (allowances) or offsets in order to meet predetermined regulatory targets. It is a market for carbon offsets created by the need to comply with a regulatory act (Rainforests, 2014). In a Cap-and-Trade emissions reductions market, actors buy and sell carbon offsets to comply with the cap or limit imposed on their emissions.

Intercontinental Exchange (ICE) witnessed a record number of trades of carbon allowances in 2021, up almost 30% on the previous year (Twidale, 2022). Europe and parts of the United States, including California have set up emission trading systems (ETS), that place a price on carbon dioxide emissions as part of their efforts to cut greenhouse gas emissions to achieve climate targets. A total of 18.3 billion tons of carbon allowances traded in 2021 on the exchange, up from 14.3 billion in 2020. Of the total some 15.2 billion tons, were trades of EU Allowances, traded on Europe's ETS. In 2021, a record 2.4 billion California Carbon Allowances and 346 million tons of Regional Greenhouse Gas Initiative (RGGI) allowances traded on the exchange. These were up from 1.87 billion and 231.5 million allowances in 2020 respectively (Twidale, 2022).

The Global Financial Markets Association (GFMA) and the Boston Consulting Group (BCG) report finds that 80% of GHG emissions are not covered by regulated carbon pricing in compliance carbon markets. But within ETS coverage/compliance markets there is scope to expand not only within and across sectors by including more high-intensity emission sectors. These include energy and power as well as transportation, oil and gas industries (Pablo, 2021). Other large emitters are iron and steel production and processing companies, those who produce commodities such as cement, glass and ceramics and the paper and pulp industry (Gold Standard Help, 2015).

The compliance carbon market size was estimated at $261 billion in 2020. CCM is considered the more mature and larger of the two carbon offsets markets. CCMs are tools used by countries to meet their climate goals (Gold Standard Help, 2015). The compliance carbon market (CCM) and the voluntary carbon market (VCM) can be complementary to each other and both can play a significant role in decarbonizing the environment (Pablo, 2021).

Cap and Trade is considered an efficient method to deal with carbon emissions (Denny, 2018). However, concerns remain whether it is equitable and fair. In California, there is a view that distributing free allowances overcompensates firms for the cost of compliance, assuming any compensation is warranted. There should be no transfer of ownership to industry of the atmosphere at the expense of the public (Farber, 2011). Cap and Trade has also been considered efficient which minimizes waste and recognizes liberty and at the same time having favorable distributional effects on richer households at the expense of poorer households (Caney & Hepburn, 2011). In the United States, California's climate policies which relies on the Cap and Trade program has brought about a steady decline in the state's carbon dioxide pollution (EDF, 2007). So, there is reason to believe it supports sustainability of the environment.

Carbon Tax

A carbon tax is another market mechanism through which application carbon emissions can be reduced. It is the imposition of a fee directly on using fossil fuels (coal, oil, gas) as an energy source (C2ES, 2021). Potentially, a policy tool such as a carbon tax

can help reduce and eventually eliminate the use of fossil fuels which results in carbon emissions and climate change.

A carbon tax causes users (both businesses and consumers) of carbon fuels either to internalize the cost in production or in consumption and to pay for the climate damage caused by the release of carbon dioxide into the atmosphere. A high enough carbon tax would result in a monetary disincentive to use carbon fuels and create the necessary motivation to switch to non-carbon fuels and reduce carbon emissions.

Since the carbon content of every fossil fuel, from anthracite or lignite coal to heating oil and natural gas, is precisely known, the carbon tax thus is structured accordingly which implies higher taxes on coal than petroleum products, and much more than on natural gas (C2ES, 2021).

There is no carbon tax in the United States. There were Washington State Initiatives 732 in 2016 and1631 in 2018 for a carbon tax on the ballot both of which failed. Such an initiative in the state was defeated because it could impact on infrastructure, growth and employment prospects (Ballotpedia, 2018).

Between 2018 and 2020, several congresspeople and senators have sponsored various bills in Congress to have some form of federal carbon tax in the US. Such a federal tax could have various impacts on the US economy (Energy Policy, 2020). Although carbon taxes would increase revenues, the impact on net revenues would be to lower it, because payments of the carbon tax leave individuals and businesses with less income, and thus lower tax payments on that income. The Joint Committee on Taxation and the Congressional Budget Office refers to it as the "Income and Payroll Tax" Offset. A study by Urban – Brookings Tax Study Center of carbon tax proposals has estimated that the size of the offset could reduce government revenue by about 23 percent of the annual carbon tax revenue (Rosenberg et al., 2018).

A carbon tax also impacts energy prices directly. Since a carbon tax is based on the carbon content of various sources of energy i.e., on carbon-intensity of fuels, price impacts are most significant for energy produced with coal, then petroleum, then natural gas.

Emissions are also impacted by a carbon tax. A financial incentive causes emitters of greenhouse gases to shift to lower-carbon alternatives especially if doing so costs less than the tax. This results in lesser emissions. Via the price mechanism, the carbon tax encourages and accelerates low-carbon technological progress and larger investments in innovation.

Low income and middle-income households can be more adversely affected than wealthier households by what is seen as a regressive carbon tax. This is because these households spend a larger proportion of their total consumption on energy- intensive goods such as electricity, home heating fuels, and gasoline. Thus distributional impacts to lower income households can be more adverse than to wealthier households (Energy Policy, 2018).

A large-scale shift from high-carbon to low-carbon energy sources will have wide-ranging effects on the U.S. economy. A price on carbon is a necessary part of a low-cost climate change strategy because it encourages emissions reductions wherever and however, they can be achieved at the lowest cost.

A study shows that impacts of a carbon tax on near-term macroeconomic outcomes like gross domestic product (GDP) for the US are small and typically negative compared to a status quo policy (Energy Policy, 2018). GDP impacts are less than 0.5 percent per year and they could be positive or negative, depending on how the revenue is used i.e., whether revenue is used to reduce payroll taxes or income taxes or returned to eligible recipients without corrections to distortions in the economy. It is important to perfect the estimate of

macroeconomic impact by capturing the economic benefits of avoided regulations, reduced air pollution, and the technological progress stimulated by the tax.

Finally, there can be also variations in regional impacts of a carbon tax due to differing regional patterns in energy production and consumption (Energy Policy, 2020). Rural communities will experience larger energy cost increases as a proportion of income than urban residents. This is because the low population density in rural areas lends to a higher per capita energy demand for transport, heating, and cooling. Western and Northeastern regions of the country would fare well under a carbon tax than would the more carbon- and energy-intensive southern and Midwest parts of the country. However, carbon tax revenues can be used to mitigate such regional disparities.

It was recently reported that the Biden Administration supports a carbon tax of $20 per ton of carbon ahead of the COP 26 summit (Bloomberg, 2021) .

In India also there is currently no carbon tax at the national level. However, it had a clean energy cess on coal since 2010. The aim was not only to earmark revenues to fund research and innovative projects in clean energy but also to nudge consumers to greater use of cleaner fuels at the expense of coal via the price mechanism (ipleaders, 2021). Criticisms of the cess was that the earmarked revenues were not used to promote research and that it failed to distinguish between users of cheap polluting form of coal or clean coal and was thus not linked to the quantum of carbon emissions. The clean energy cess was eliminated the Government of India in 2017. Some states or city jurisdictions have also imposed taxes on their own to compensate for the negative externalities such as the green cess in Goa or the Eco tax imposed on vehicles entering Mussoorie city in Uttarakhand.

It has been argued that India as a very large emitter of GHG, should re-introduce a comprehensive carbon tax in order to: a) discourage the use of carbon emission intensive inputs and outputs; b) promote research of cleaner alternatives and support renewable energy projects with the carbon tax revenues which would result in sustainable alternatives that would in turn help Indian products meet international standards and also be exempt from cross border tariffs related to carbon emissions; and c) streamline implementation through seeking uniformity between federal and state measures (Sawhney, 2021).

Recent research by the Observer Research Foundation explored four scenarios of climate action for India using a systems dynamics model called the Energy Policy Simulator for India. Research tried to address the dilemma that exists for a developing country like India with its huge population size, low income, and employment levels whether strong climate action could compromise economic development and job creation. Among the four scenarios examined in this macroeconomic study was a net zero emission or a deep decarbonization scenario which included implementation of an economy wide carbon tax as a policy driver, among others. Surprisingly, the policy simulator found that deep decarbonization in the Indian economy could increase jobs and GDP and at the same time prevent millions of premature deaths due to harmful air pollution by 2050 relative to the reference scenario i.e., India's ongoing efforts in renewable energy (RE), energy efficiency, electric mobility, and cost-optimization of technologies in the electricity and transport sectors. The study concluded that massive investments would be needed in the power, industry, transport, and hydrogen sectors. Early policy signals could accelerate technology adoption by industries that benefited from decreasing technology costs (Agarwal et al., 2021).

A couple of studies exist about the distributional impact of carbon pricing in India. A carbon tax in India has been found to be mildly progressive with progressivity being higher in the rural sector as compared to the urban sector. The progressivity also varied

between different fuels. Carbon tax was more regressive for kerosene relative to electricity or liquefied petroleum gas in India (Rathore & Bansal, 2013).

Another distributional policy issue is the regressive nature of the tax that affects lower-income households more adversely than middle and high-income households, since a larger share of their incomes are spent on energy-intensive goods and services. The distributional and welfare concerns associated with a carbon tax are primarily determined by how the revenues are spent. If the carbon tax revenues are used for financing the fiscal deficit, the impact is likely to be more regressive. Another concern is that higher domestic prices will raise costs for local industries, making them less competitive in global markets. A revenue neutral approach is advocated in light of the political volatility and distributional concerns associated with the carbon tax, Revenue recycling could be a panacea for the distributional issues related to a carbon tax, If adopted, the revenues generated from the carbon tax could be earmarked and returned to society through spending the money on green initiatives or returning money back to firms and household in the form of dividends (Chandra, 2021).

The carbon tax has been proven environmentally efficient. An empirical analysis of the carbon tax in the energy industry in Europe showed that an increased tax rate curbed GHG production, which statistically significantly is affected by the consumption of fossil fuels (Hájek et al., 2019) . The study showed that by raising the carbon tax by one euro per tonne can cut annual per capita emissions by 11.58 kg (25.47 pounds).

The investigation of the distributional and equity aspect of a carbon tax has been investigated for Sweden (Andersson & Atkinson, 2020). The Swedish carbon tax on transport fuel was determined to be regressive between 1999-2012 when measured against annual income, but progressive when using lifetime income. An increase in regressivity was found to be highly correlated with a rise in income inequality. So, the distributional impact is also affected by the inequality in the distribution of income. Since a carbon tax should be applied to goods that typically are necessities like transport fuel, food, heating, and electricity for mitigation purpose, the tax is likely be regressive in high-income countries, especially in countries with a more unequal distribution of income. More recently the US Congressional Budget Office has used a method that allocates the carbon tax burden to households on the basis of their income rather than their consumption (Carloni & Dinan, 2021). Its estimates show that the burden on households in the lowest income quintile, measured as a percentage of income before transfers and taxes, would be twice as large as that imposed on households in the highest income quintile. However, the burden on households appears less regressive if measured as a percentage of income after transfers and taxes, largely because of the progressivity of the existing federal transfer and tax system.

From a conservative perspective a carbon tax could be good for liberty and spur innovation (Neeley & Collins, 2017). A carbon tax encourages bearing responsibility for creating a negative externality. Second, prices matter for better resource allocation and environmental mitigation so zero price for carbon emission should be avoided. A carbon tax would be a powerful signal to businesspeople and entrepreneurs to switch to cleaner and cheaper use of energy which could through ripple effect stoke decarbonization and help end energy poverty. Third, carbon tax revenues could be used to substitute for income or capital gains taxes. Such a tax swap would promote economic prosperity. And finally, a carbon tax reduces the risk of climate change without growing government.

Carbon taxes are also a good policy option to promote the goal of sustainability (UN, 2021). By applying a tax on greenhouse gases (GHG) emissions, they encourage businesses to invest in cleaner technology or switch to more efficient practices. Consumers too are

incentivized to invest in energy efficiency, alter lifestyle habits and switch to clean fuels. Further carbon tax revenues could be used to invest in sustainable development.

So overall, carbon taxes support efficiency, liberty, and sustainability although there are distributional and equity issues that need to be addressed.

Regulations

Current US Climate Change policy under President Biden is to squarely face the urgent threat of climate change and to propel the country toward a clean energy future. Towards this end, the US Environmental Protection Agency (EPA) is considering fresh regulations to address some of the nation's largest sources of both climate- and health-harming pollution, such as the transportation, oil and natural gas, and power sectors (EPA, 2017).

1. Currently being used in applications such as air conditioning, refrigeration, fire suppression, solvents, foam blowing agents, and aerosols are regarded as highly potent greenhouse gases with global warming potentials that are hundreds to thousands of times greater than carbon dioxide (CO_2). EPA regulation will phase down the U.S. production and consumption of HFCs by 85% over the next 15 years, as mandated by the American Innovation and Manufacturing (AIM) Act of 2020. A global phasedown of HFCs is expected to avoid up to 0.5°C of global warming by 2100.
2. New federal greenhouse gas emissions standards have been set for passenger cars and light trucks for Model Years (MY) 2023 through 2026. The new standards aiming to usher in clean car technology will result in $190 billion in net benefits to Americans and help reduce climate pollution, improve public health, and save drivers money at the pump. The new standards set on vehicle emissions are most stringent to be ever established for the light-duty vehicle sector. These scientific standards have been determined based on a rigorous assessment of current and future technologies. Over three billion tons of GHG emissions will be avoided through 2050 due to the new standards. Over the next three years, new standards will also be adopted for heavy duty trucks in MY 2027 and beyond. The new standards would apply to criteria pollutants and GHG and reduce emissions in highway transportation.
3. The EPA is ensuring that airplanes used in commercial transportation and large business jets are compliant with standards set by the United Nations' International Civil Aviation Organization.
4. EPA is also implementing the Renewable Fuels Standard Program which requires petroleum-based transportation fuel to be replaced by a certain volume of renewable fuel.
5. Among stationary sources, EPA is: i) proposing new standards for the oil and gas industry that would sharply reduce methane and other harmful air pollution from both new and existing sources in the industry; ii) looking to further reduce greenhouse gas pollution under the Clean Air Act from fossil fuel-fired power plants in the power sector which is by far the largest category of stationary sources of greenhouse gases in the United States; iii) developing meaningful reductions in carbon dioxide emissions from existing power plants; iv) establishing emission standards for greenhouse gas emissions from new, modified and reconstructed fossil fuel-fired utility boilers and natural gas-fired stationary combustion turbines; and v) updating New Source Performance Standards (NSPS) for new and modified landfills and guidelines for existing landfills to reduce emissions of methane-rich landfill gas.

6. Under the Greenhouse Gas reporting program of the EPA, information is gathered from large emission sources across a range of industry sectors, as well as suppliers of products that would emit greenhouse gases if released or combusted. Facilities that meet reporting thresholds must report greenhouse gas emissions to the program annually. Also, EPA collects detailed CO_2 emissions data and other information from power plants across the country as part of the Acid Rain Program (ARP), Cross State Air Pollution Rule CSAPR and CSAPR update programs.
7. Among Greenhouse Gas Endangerment and Cause or Contribute Findings, the EPA has issued final actions under different sections of the Clean Air Act, that motor vehicles and various classes of engines used in aircraft also constitute a threat to public health and welfare and contribute to climate change.

In India, the National Action Plan on Climate Change (NAPCC) has been promulgated to deal with climate change. Legislation has not been the primary avenue in India. It has adopted policies to reduce carbon emissions.

Emission standards have been set for the transportation and the power sector specifically coal thermal power plants.

Current automobile emission standards were set in 2014 by the Expert Committee and were to be implemented nation-wide by 2020. The foundation is laid out in the Expert Committee's *A*uto *Fuel Vision and Policy 2025* report. India had started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles by around 2000 and it rolled out in various stages. Currently it is in Stage VI of the implementation program. India's own emission regulations apply to two- and three-wheeled vehicles (Dieselnet, n.d.). Emission standards have been adopted for the following categories of new engines and/or vehicles: These apply to emissions and fuel economy of cars and light trucks, 2- and 3- wheel vehicles, heavy duty truck and bus engines, non-road (off roads) diesel engines and generator sets. There have been challenges in implementing the regulations and ensuring compliant vehicles. Some of these challenges have occurred due to jurisdictional issues, court challenges and prior exemption granted to specialty vehicle (taxis) manufacturers.

India's transportation sector accounts for 10 per cent of India's total greenhouse gas (GHG) emissions and road transportation contributes about 87 per cent of the total emissions in the sector (Paladugula et al., 2018).

With respect to the power industry, the Union Ministry of Environment, Forest and Climate Change (MoEF&CC) of the Government of India released the final list of the coal thermal power plants and their categorization in line with the ministry's April 2021 notification which revised the deadline for meeting emission norms (Aggarwal, 2021). The three groupings (drawn up by jointly by the Central and State Pollution Control Boards) of the 596 coal thermal power plants are i) Category A of plants located within a 10 km radius of the capital or any city with +1 million population; ii) Category B includes plants located within 10 km radius of critically polluted areas or non-attainment cities; and iii) Category C consisting of the remaining power plants. Category A and Category B coal thermal power plants (combinedly constituting 11 percent of the total plants) were to meet the emission norms set by the ministry in 2022 and 2023, respectively. However, indications are that about 78 percent of the plants in the country are not likely to be compliant till 2024.

Coal thermal power plants contribute to over half Sulphur dioxide (SO2) concentration, 30 per cent oxides of Nitrogen (NOx), 20 per cent particulate matter (PM) in the ambient air.

It has been estimated that India's coal-based power sector contributes to 2.4 per cent of global greenhouse gas (GHG) emissions, 33 percent of India's GHG emissions, and around 50 per cent of the country's fuel related emissions (CSEindia, 2022).

A regulatory approach or command and control approach is less likely to achieve the desired goals given problems of practical implementation and political realities. In a comparative study in the US it was found to achieve only 59 percent of the desired goal and cost twice as much as the carbon tax (Rossetti et al., 2018). So, it is less efficient.

To look at the distribution impacts of the regulatory approaches, it is important to look at the compliance costs, and monitoring, recordkeeping and reporting costs and compare it to monetized social benefits i.e., improved climate and co-health benefits. The cost and benefits could be distributed unequally regionally, occupationally and across various income classes of consumers given existing unequal income distribution (EPA, 2014-b; Super, 2010).

Several international guaranteed human rights are affected by climate change caused by carbon emissions. States (duty-bearers) may therefore be regarded as having affirmative obligation to take effective measures to prevent and redress the climate impacts. To the extent the regulatory approach is aimed at mitigating the adverse impacts of climate change and promoting adaptation to the climate crisis and upholding human rights, it could be regarded as promoting both liberty and sustainability (OHCHR, 2015). It has also been argued that more regulations and more government in order to curb carbon emissions is detrimental to liberty (Neeley, 2018). An alternate way to deal with carbon emissions could be through 1) cutting regulatory red tape for clean energy sources such as nuclear and hydro power which face millions and billions of permitting costs and 2) removing restrictions on energy competition by removing the "monopoly" feature of regulated utilities and protecting them with rate setting rather than allowing for more competition from clean energy sources such as solar and wind which have had falling costs to generate clean energy for the past two decades. These measures would imply less regulation and shrinking government resulting in more liberty.

Taxes and Subsidies

Tax credits or other types of tax incentives can be used to encourage business investment in GHG-reducing technologies, like renewable energy generation or carbon capture and sequestration. This leads to their early adoption. Without public support businesses are reluctant to invest in research of such technologies because they cannot capture all the benefits. Governments also use tax policies to incentivize consumers to buy electric vehicles and solar panels or invest in household energy efficiency improvements. A tax on gasoline is intended, for example, to curb its use in order to reduce greenhouse gas emissions (Ramseur et al., 2021).

Currently, the US federal government provides a 26% tax credit for renewable energy systems installed by homeowners through 2022, and 22% for 2023 (Pickrell, 2021). Biden has also proposed subsidies for farmers to retain carbon in the ground. Farming contributes about ten percent of the greenhouse gas emissions in the US (NPR, 2021).

India too is providing capital subsidies at 40 percent for capacities below 3 kWp and 20 percent for capacities between 3 kWp and 10 kWp for roof top installations of solar panels in the form of central financial assistance. Direct and indirect tax benefits such as sales tax, safeguard or anti-dumping duty inclusions, excise duty exemptions and custom duty exceptions have also been given by the government. Project developers benefit from income tax exemption on all earnings from a project in its first 10 years of operation. Solar energy producers can claim accelerated depreciation (AD) and claim 40% of the costs in

the first year itself. Domestic manufacturers who provide modules for rooftop solar PV systems are being supported through these measures (Energetica, 2021).

Some researchers have found that the energy investment tax credit is efficient, that is, reducing the price of energy-efficiency property would lead to additional investment (Hassett & Metcalf, 1995). Other researchers have found that the tax credits to recipients were instead more likely associated with windfall gains rather than with additional energy-efficiency investment(Dublin & Henson, 1988; Walsh, 1989).

Taxpayers that are homeowners tend to be higher income than taxpayers living in renter-occupied housing. Thus, energy tax investment tax credits targeted at homeowners would tend to benefit higher-income taxpayers. This is borne out in 2012 tax data, as residential energy-efficiency tax credits are claimed by middle- and upper-income taxpayers. So tax credits pose equity and fairness issues (Crandall-Hollick & Sherlock, 2012).

Distributional issues related to loss of common land and right to land use has come up at the large Charanka Solar Park developed by the Solar Park Group in Gujarat in India. The benefits of renewable energy development with less carbon emissions tend to accrue at regional and national level whilst local host communities bear the adverse consequences of land acquisition for the project. Within the host community the economically well-off members of the community were able to take advantage of the development opportunity while vulnerable sections suffered from the loss of use of land for grazing. The uneven distribution of benefits arising from the solar park development reinforced and deepened existing inequalities (Yenneti et al., 2016). Companies involved with producing renewable energy have tax exemptions. The Gujarat state government has also declared more benefits to residential, individual and commercial producers of solar energy in addition to the incentives provided by the central government (Business Line, 2020). The security deposit required to be given to Discoms for the Power Purchase Agreement (PPA) by the developers has been significantly reduced.

The US federal government provides tax credits to taxpayers that do carbon capture and storage (CCS), or use carbon dioxide and carbon oxide in accordance with rules laid out in Section 45Q of the Internal Revenue Code of 1986, as amended, and the Treasury Regulations thereunder (Rodgers & Brandon, 2021). The Bipartisan Budget Act of 2018 made a number of significant changes to Section 45Q that made these credits more attractive to investors. Among the changes, the Act: a) expanded Section 45Q to cover both carbon dioxide and carbon oxide; b) eliminated limits on the overall credits available in the market; c) lowered thresholds for the amount of carbon that would have to be captured in a given year for some types of taxpayers; d) clarified that credits would be available for 12 years from the time carbon capture equipment is placed in service offering greater certainty to investors; and e) enhanced the value of the tax credits.

Investors reacted positively to the changed rules making it likely that significant investment in CCS would occur in the future. Since tax credits directly lower the amount of tax one owes, one could surmise it is conducive to liberty. On the other hand, harmful government subsidies such as allowing people to build homes in coastal areas likely to be adversely impacted due to sea level rise caused by global warming limit liberty and grow the government in the future (Neeley, 2018). So, tax credits and subsidies have a mixed impact on liberty.

Economic incentives such as tax credits and subsidies applied to reduce greenhouse gas emissions to control for climate warming can help improve sustainability of the environment (EPA, 2021-c).

Climate Finance

The Convention, the Kyoto Protocol and the Paris Agreement all called for financial assistance to be provided by developed countries with more financial resources to developing nations that were less endowed and more vulnerable to climate change. This climate finance was expected to be about $100 billion per year drawn from local, national, or transnational financing and made available from public, private and alternative sources of financing. Such finance could be used by developing nations to support mitigation and adaptation actions they undertook to deal with climate change. However the developed countries did not resolve how this money would be raised among themselves and what share of it would be undertaken by each country (Rodgers & Brandon, 2021).

Speaking at the COP 26 Summit in Glasgow, the Prime Minister of India said (MEA, 2021):

> "We all know this truth that the promises made till date regarding climate finance have proved to be hollow. While we all are raising our ambitions on climate action, the world's ambitions on climate finance cannot remain the same as they were at the time of the Paris Agreement.
>
> Today, when India has resolved to move forward with a new commitment and a new energy, the transfer of climate finance and low-cost climate technologies have become more important. India expects developed countries to provide climate finance of $1 trillion at the earliest. Today, it is necessary that as we track the progress made in climate mitigation, we should also track climate finance. The proper justice would be that the countries which do not live up to their promises made on climate finance, pressure should be put on them."

Numerous countries from Fiji to the Philippines to Uganda and small island nations like Antigua, Barbados, Grenada, Kiribati, Marshall Islands and Tuvalu also referred to the broken promise on climate finance at the COP 26 Summit (Piper & James, 2021; UN, 2021). The Alliance of Small Island States (AOSIS) and the Least Developed Countries Group have also wanted to establish liability and compensation for loss and damage for vulnerable and developing countries.

Developed countries are offering developing countries climate finance more in terms of loans rather than outright grants. This is increasing the burden of developing countries who are already weighed down with past debts. This makes it difficult to grow their economies and eventually get out of debt. This practice is also inequitable as the problem of global climate change was a creation of developed countries primarily which went unabated for a period of 150 years. Climate finance is also offered for mitigation projects that directly reduce carbon emissions with a small trickle going for adaptation to climate change because loans for the latter will not be as easy to recover as for the former. This neglect of providing funds for people to adapt to climate change is impoverishing people in developing countries who suffer the consequences of floods, droughts, hurricanes, and other disasters due to climate change. Some developed countries are adding a climate component requirement to their former aid programs and calling it climate finance (Timperley, 2021). These actions of developed countries together with not meeting the pledged goal of $100 bn per year are unlikely to meet the 2015 Paris agreement goal of restricting global warming to "well below" 2 °C, if not 1.5 °C, above pre-industrial temperatures.

In 2018, the United States provided only about $6.6 billion of the world's climate finance funds. The total annual flow of US climate finance funds through all channels (bilateral and multilateral inflows and multilateral development banks outflows) is about $7.56 bn average between 2016 and 2018. About 70 percent of its funds were directed to

mitigation projects about 23 percent were devoted to adaptation and about 7 percent were cross cutting. The average per capita climate finance provided by the United States was $16.59 during the 2016-2018 period. The World Resources Institute estimated that based on an analysis of the gross national income, population size, and carbon emissions of OECD countries, as per fair share the United States should have contributed between 40 and 46 percent of the climate finance funds and provided between $28 bn to $32 bn. on the low end and between $40 bn to $46 bn on the high end instead of the $6.6 bn it did in 2018 (Thwaites & Bos, 2021). The amount of OECD Climate Finance funds reported on an annual basis from 2013 to 2018 ranges from $34.1bn to $54.7 bn which is way below the $100 bn that were pledged in the *Paris Agreement*. However, even this size of climate finance funds claimed by OECD as having been provided to developing countries is grossly exaggerated according to Oxfam and India (OECD, 2021). Oxfam says most of the money provided is loans and not grants, the Indian Ministry of Finance says the amount is grossly overstated and Antigua and Barbuda say the figures put out by OECD are highly inflated. President Biden has promised to double the US contribution from $5.7 bn to $11.4 bn by 2024 and $3 bn will be for adaptation to climate change (Dloughy, 2021; Vinopal, 2021). His pledge has been termed both political and inadequate. Without US leadership, it is unlikely that *the Paris Agreement* pledge of $100 bn a year will be achieved. Furthermore, the climate finance need is expected to grow to $ 200 bn a year by 2030 and even more by 2040 (OECD, 2021; Robins & Kyiakipoulou, 2022; Timperley, 2021).

Developing countries are unlikely to get to net zero emissions if the funds pledged to assist them are not forthcoming. If there are cosmetic changes to former aid funds now being provided as loans from the re-termed climate finance funds by developed countries, the world would be perpetually under a delusion of fighting climate change. This vicarious living by people in developed countries at the expense of poor people in developing countries, who are expected to bear the burden of halting climate change, is neither equitable nor sustainable.

Technology Transfer

Under the United Nations Framework Convention on Climate Change (UNFCCC), clean energy technology transfer is an important precondition for climate change mitigation and the transition to a low-carbon global economy (UNFCCC, 2022). This transfer occurs from developed to developing countries. It involves technology information, learning, enabling environments, capacity building and mechanisms for transfer to occur. This is necessary as clean energy technologies are costly and face barriers to adoption in developing countries.

Technology transfer is complicated and involves multiple different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations, and research/education institutions.

Low and zero carbon technology (LZC) is also the term given to low carbon technologies (also known as LCT) that emit low levels of CO2 emissions, or no net CO2 emissions(Brighton-hove, n.d.). The utilization of low carbon technologies is more effective within buildings with a highly energy efficient fabric after heat demand and loss have been minimized. Solar water heaters, solar photovoltaics, combined heat, and power (CHP), biomass power, air and ground source heat pumps, efficient gas boilers, carbon capture and storage (CCS) and wind turbines could be considered LCTs. There are other LCTs that could be used in aviation and maritime transport, steel industry, cement industry, chemicals industry, and construction as well as fuels like hydrogen and nuclear power (Brighton-Hove, n.d.).

Providers/donors of LCT transfers are from developed countries, for example, the US or any of the OECD countries; recipients are in developing countries like India. A LCT transfer process takes place across borders. The entities in the transfer process can be governments, NGOs, international agencies, or private sector companies. The LCT transfer processes involve both primary flows and dual flows. The primary flow is tangible technologies or intangible "know-how" transferred from developed countries to developing countries; the dual flow is the money that finances the technology transfer. For the primary flow that the source of LCT transfer is developed countries and the destinations are developing countries. However, the directions of the dual flows are less transparent. If developed countries fund the transfer process, money flows from developed to developing countries; if the transfer process is a part of an international trade transaction, money flows from developing countries to developed countries (Yang, 2009).

In 2020, the relative percent share of exports and imports of LCT products of overall exports and imports for the United States was 5.82 and 5.14 percent respectively, while the relative percent share of exports and imports of LCT products of overall exports and imports for India was 2.56 and 3.53 percent, respectively. The comparative advantage index for India for environmental goods stood at 0.56 in 2020 (value < 1 implying relative disadvantage) while for the United States it was 1.14 (value > 1 implying relative comparative advantage) (IMF, 2021).

At the COP 22 Marrakesh Summit in Morocco, Canada, Denmark, the European Union, Germany, Italy, Japan, Korea, Switzerland, and the United States pledged US$23 million to provide a major scale-up of the United Nations Framework Convention on Climate Change (UNFCCC) Climate Technology Centre and Network. This was to assist the Centre deliver tailored capacity building and technical assistance to developing countries across a broad range of mitigation and adaptation technology and policy sectors (Venkatesh, 2016). Between 2010 and 2015, the United States was a LCT innovator and held 18 percent share of all LCT patents world-wide according to PATSTAT. Also, Patentscope Data reveals that India was only second among developing countries with 0.54 percent of all LCT patents over the same period (Pigato, 2020). Thus, both India and the US have major roles to play in low carbon technologies transfer to combat climate change.

India and the US could increase technology transfer of low carbon and clean energy technologies in a variety of ways. These have been discussed by the bilateral Climate and Clean Energy Agenda 2030 Partnership (Lopes, 2021) and a policy paper of the Brookings Institution (Jones and Saran, 2015) that deals with an 'India exception' and India-US partnership on Climate Change. The salient points are stated below:

- US investment of between $50 billion and $100 billion over the next 10 years—in natural gas infrastructure, renewables and clean building technologies that will encourage India to adopt more efficient energy pathways during its industrialization.
- Assisting India with Green Technology in buildings so that new buildings in cities have low carbon emissions.
- Partnership to Advance Clean Energy (PACE), to accelerate low-carbon economic growth and deployment of clean industrial technologies, through sharing of knowledge and technology
- Setting up a US-India Green Transition Finance Initiative to mobilize investment for India to transition to renewable fuel technologies expected to cost $2.5 trillion. PACE mobilized $ 2.5 billion in private and public investment in clean energy

deployment in India. In 2016, both countries launched S7.9 million PACEsetter Funds to provide grants for innovations in clean energy solutions

- Providing finance and technology applications for decarbonizing end-use sectors thus reducing economy-wide net greenhouse gas emissions.

Innovation

There are opportunities and a need for Federal agencies in the US to provide financial and technical assistance for low-carbon innovation. The federal aid could be targeted for electric-vehicle (EVs)) manufacturing, energy storage innovations that would give the impetus for wider use of the intermittent renewable energy power sector, nuclear energy generation with small modular fission and fusion technologies, manufacture of blue hydrogen from natural gas, focusing on use of hydrogen fuel in the steel and cement industries, use of biofuels in aviation, trucking and shipping, carbon capture and storage (CCS) technologies and the development of better materials such as graphene to make batteries and solar cells (Pinner & Rogers, 2021). Investments in these innovations are likely to accelerate the pace at which the US will achieve net zero emissions. United States committed $114 billion in low carbon energy transition between 2020 and 2021 (BloombergNEF, 2022). The Biden Administration has proposed a 37 percent increase in Research, Development and Demonstration of clean energy in the 2022 budget (Gallagher & Anadon, 2021). An MIT startup has recently made waves with its electrochemical technology to suck up carbon dioxide from the atmosphere and other industrial sources and attracted investments from major backers of carbon capture and storage (CCS) (Bloomberg, 2022).

India invests a substantial amount in nuclear energy R&D to further its goal of indigenizing its nuclear program. India seeks to indigenize nuclear power plant materials and reactor technology by developing an Advanced Heavy Water Reactor that uses thorium as its main fuel. The government aims to more than triple its current nuclear power capacity to achieve 22.5 GW by 2031. India has also adopted stricter SO_2, NO_x, and $PM_{2.5}$ emission standards for power plants and this has led to an increase in renewable energy capacity away from coal plants. Renewable energy R&D investments have increased but remain tiny in the overall portfolio. Grid-related R&D investments in technologies have also increased substantially since 2009 (Zhang et al., 2021).

Electricity installation capacity and power generation at an aggregate level from various sources have increased over time in India. The share of clean energy (hydropower, nuclear, and renewable) has also increased over the last two decades. India is thus slowly shifting from fuel-based energy sources to non-fuel-based sources to meet peak demand. In India's energy portfolio, renewable energy rose to 3.6% in 2019 from 0.2% in 2000. By 2020, India had installed capacity of 37.5 GW for Wind Energy, 33.7 GW for Solar, 9.9 GW for Biomass and 4.7 GW for small hydropower (Sahoo, 2021).

Of these renewables, the role of biomass has been questioned in promoting carbon neutrality since burning biomass releases carbon emissions (DeCicco, 2016). More recent evidence suggests that as per net life cycle approach (LCA)), the potential of bioenergy is similar to other renewable energy sources in reducing emissions (Bird and Cherubini, 2013). A note on the Climate Portal at MIT shows that biofuels are a promising option that will not contribute to the greenhouse effect and climate change because the carbon dioxide (CO_2) they emit is recycled through the atmosphere (Prather and Krol, 2020). The Biomass Energy for Rural India (BERI project) conducted in Tumakuru (Tumkur) district of Karnataka covered 33 villages and was funded by UNDP and the Global Environment Facility (GEF) and co-financed by the Indo Canadian Environment Facility (ICEF) and both

the Governments of Karnataka State and Government of India. It aimed to develop and implement a bio-energy technology package to reduce GHG emissions to promote a sustainable and participatory approach in meeting rural energy needs. The project used biomass electrical generators, community biogas cooking systems, improved stoves and afforestation and reforestation. The annual target achieved by the BERI project for carbon savings was 26,761 tCO2 annually showing enormous potential for rural India (Ravindranath, 2011). India has 771 districts and 664,369 villages in the country. In more recent news, researchers in the US used microbes to make carbon neutral biofuel (NSF, 2021)

India has also provided financial support for clean energy startups that focus: on transport such as solar powered and electric powered vehicles; on energy efficiency such as micro-LED chips, electro-mechanical switches, smart home energy management and retrofit services; on energy renewables such as biofuels, solar and geothermal; on hydrogen; and, on energy storage like lithium extraction services and metal-hydrogen battery stationary storage (Bennett & Le Marois, 2021).

India is also developing co-innovation strategies for low carbon or green technologies with Japan and Switzerland (Sethi et al., 2021). Also several private and public entities in India have been active in setting up blue hydrogen and green hydrogen plants in 2021 (Business-Standard, 2022; Economic Times, 2021; Pekic, 2021).

Indo-US International Collaboration on Climate Change

There have been several landmark agreements between the United States and India as the two work together actively to achieve carbon neutrality or zero emissions as per their Nationally Determined Contributions (NDCs) which are at the heart of the Paris Agreement and reiterated last at the COP 26 summit in Glasgow. The cooperation agreements are conducive to the achievement of their respective long-term goals. The US NDC endeavors to reduce national carbon emissions by 50-52 percent by 2030 over 2005 levels and achieve carbon neutrality or net zero emissions by 2050 (Arosetegui, 2021). India will cut its carbon emission by one billion tons between 2021 and 2030 as per its NDC. This means that India has set an ambitious goal to cut its emissions by 22 per cent by 2030 and achieve net zero by 2070 (Narain, 2021).

In 2020, India and the USA extended their Memorandum of Understanding for cooperation on the Global Centre for Nuclear Energy Partnership (GCNEP) by another 10 years (world-nuclear-news, 2020). The Centre located in Bahadurgarh in Haryana officially opened in 2017. It supports international cooperation in nuclear energy applications. Under the 2020 MOU, the two countries cooperate on issues related to nuclear safety and security, research and development in nuclear science and technology, nuclear and other radioactive material security and collaborate on advanced future nuclear technology projects. The outcomes are expected to be shared internationally. However, the pursuit of nuclear energy as a clean fuel option to combat climate change has been criticized in the literature due to its excessive capital requirements and the issue of radioactive waste disposal which is currently deemed unsafe (Jordaan et al, 2019).

United States and India also launched the "India-US Climate and Clean Energy Agenda 2030 Partnership." in April 2021 (MEA, 2021). Both countries hope to reach their stated carbon emission reduction goals for 2030 through this partnership. Both mitigation as well as adaptation to climate change are addressed. They will jointly seek to: a) mobilize finance and speed clean energy deployment; b) demonstrate and scale innovative clean technologies needed to decarbonize sectors including industry, transportation, power, and buildings; and c) build capacity to measure, manage, and adapt to the risks of climate-

related impacts. The Partnership is expected to proceed along two main tracks: the Strategic Clean Energy Partnership and the Climate Action and Finance Mobilization Dialogue.

In November 2021, the US joined the inter-governmental treaty based International Solar Alliance (ISA) which India and France had initiated at COP 21 (Roche, 2021). This provides one more area of international cooperation for the rapid deployment of solar globally. This is particularly important for developing countries, The framework agreement of the ISA hopes to catalyze global energy transition through a solar led approach and its vision hopes that the approach will culminate with interconnected global grids. This has been launched as the Green Grids Initiative i.e. One Sun One World One Grid at the COP 26 Summit.

Conclusion

This research has documented the many harmful consequences of global warming and the efforts of various signatory countries to *the Paris Agreement* to halt greenhouse gas emissions. We have examined in depth the commitments of the two large democracies, the United States and India, made at COP 26 in Glasgow in November 2021. These two countries are the second and third largest carbon emitters in the world.

The timelines provided by the two countries to achieve zero carbon emissions or net zero emissions stretch from a period of 30 to 50 years hence. The United States plans to achieve net zero emissions by 2050 and India by 2070. Given that in democracies, there are periodic changes in governments which bring with it changes in policies, our attempt to analyze the situation is based on enunciated policies of the current governments of the United States and India. We note that there are considerable risks and uncertainties pertaining to the science, technologies, and public policies to deal with climate change over the exceptionally long run. Both countries have attempted to reduce the production of greenhouse gases sincerely and have outlined steps that they plan to take with respect to various industrial sectors, transport, power production, the grid system and carbon capture and storage that will help achieve the goal of zero emissions.

We examined the economic tools available to the two countries for achieving carbon neutrality through incentivizing various sectors of the economy. We also evaluated the market approach methods such as cap and trade and carbon taxes, the command-and-control approach such as regulations and other economic policy tools such as tax credits and subsidies based on four goals or standards of efficiency, equity (distribution effects), liberty and sustainability. These evaluations were based on the results of empirical studies undertaken in both countries and available in the literature. All the above approaches had a positive impact on sustainability since they positively affect the environment by slowing climate change. Subsidies had the potential to enhance liberty.

The cap-and-trade mechanism controlled for the emission levels whereas the pricing was uncertain. It could be efficient way to price carbon that also recognizes liberty but could have negative distributional impact for lower economic classes. It could also transfer public rights of the environment to private hands. Compliance Carbon Markets (CCMS) and Voluntary Carbon Markets (VCMs) are doing extremely well in the United States. India is also one of the largest beneficiaries of the total world carbon trade through the Clean Development Mechanism (CDM).

Carbon taxes may be efficient and obtain reductions in emissions levels through internalizing the cost of an environmental externality. The pricing is certain but there is uncertainty over emission levels. It could also be regressive on lower income levels. It could also impact fuel prices differently as the tax is based on carbon content or carbon

intensity of the fuels. It also has adverse distributional impacts on lower income households and rural communities due to its regressivity. Carbon taxes could hasten low carbon technological progress and spur innovation. However, both the United States and India do not employ carbon taxation at the national level at the present time. Concerns remain over the impact of carbon taxes on unemployment, income, and gross domestic output levels. Recent macroeconomic studies in both countries appear to show that these concerns may be exaggerated. There is *a prima facie* case for exploring a carbon tax to generate revenues that could be used for climate finance in both countries.

Regulations have been resorted to in both countries to limit carbon emissions especially in the power and transportation sectors. A regulatory approach may not be a very efficient method in controlling emissions due to practical implementation problems and the political realities in both countries. The cost and benefits of regulations could be distributed unequally regionally, occupationally and across various income classes of consumers given existing unequal income distributions. From a human rights perspective, the regulatory approach may enhance liberty but for many to whom big government and more regulations is an anathema, this approach to limit carbon emissions restricts liberty. Economic incentives such as tax credits and subsidies are an efficient method to get individuals and businesses to make the necessary investments in technologies that limit carbon emissions. These incentives are being offered in both the United States and India. The distributional impacts are that they are being claimed by middle- and high-income people and the low-income people get a smaller share of these incentives and may end up with fewer resources.

Climate finance is especially important to developing countries like India to achieve carbon neutrality. India is committed to making the necessary sacrifices to achieve zero emissions despite having an extremely low per capita carbon emission rate and a large percent of its population living at low-income levels. United States and other developed countries have not sufficiently contributed to the goal of $100 billion in climate finance funds annually for developing countries as per their undertaking in the *Paris Agreement.* The U.S. could exercise its leadership not only by contributing more for mitigation efforts but also by making more funds available for adaptation to climate change by developing countries.

Currently, both the United States and India, are not engaged sufficiently in the transfer of low carbon technologies. The trade of low carbon technology (LCT) goods as noted in their exports and imports remain low. There is a need to step up efforts to increase the volume of LCT goods in the trade flow with respect to each other and then other countries of the world.

Both countries are continuing to invest private and public sector funds in research and development to foster innovations in electrical vehicles (EVs), nuclear energy, energy storage cells, carbon capture and storage and alternative clean fuels such as biomass, wind, solar, hydrogen and other renewable fuels.

The two countries are making several collaborative and cooperative partnerships to work together for harnessing clean energy and reducing carbon emissions. Co-innovation partnerships between the United States and India could help hasten zero emissions or carbon neutrality in both countries.

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