Review Article

Climate Change Policies of the Four Largest Global Emitters of Greenhouse Gases: Their Similarities, Differences and Way Forward

ABSTRACT

Aims: The impetus to combat intensifying climate change has prompted countries to make policies pertinent to climate change. With China, India, the United States and the European Union contributing to more than half of greenhouse gases emitted, their climate change policies are of concern particularly as signatories of the Paris Agreement.
Study design: This article critically reviews the climate change policies of the four largest emitters of greenhouse gases, particularly their similarities and differences.
Methodology: This review examined more than 85 literature including scholarly articles, official reports and policy documents published between 2010 and 2020, pertaining to climate change and energy policies, plans and programs of the four regions.
Results: This review shows that the policies address similar domains comprising efficiency in energy and resources utilization, development of cleaner and renewable energy, optimization of transport system and promotion of electric mobility. Land use, land-use change and forestry is more commonly addressed in policies of developing countries than the developed ones. Major differences of the policies are the emphasis where the United States and European Union focus more on clean transportation particularly hydrogen fuel, besides carbon market. The extents of making policy targets legally binding also differ. While retrospective technical verification of emission goals show that European Union was on track, situational validation against 2°C emission targets of the Paris Agreement shows incompatibility except India. There is a significant deficiency of adaptation policies compared to mitigation policies.
Conclusion: This review, thus, contributes to identifying shortcomings of current climate change policies and continuous improvement of the policies.

Keywords: Paris Agreement, plan, renewable energy, strategy, verification, mitigation

1. INTRODUCTION

With exponential increase of human population and the growing industrial and agricultural activities to support the growing population, the world is now coming to terms with global climate change. The trend of changing climate shows no sign of a reversal or a halt in the

near future as long as anthropogenic generation of greenhouse gases (GHGs) continues. The major GHGs are carbon dioxide, methane, nitrous oxides and fluorinated gases [1]. Carbon dioxide alone constituted slightly more than three quarters (76%) of the four GHGs emitted in 2010 with fossil fuel combustion and the industrial sector being the largest emitters of carbon dioxide followed by forestry and other land use to a much smaller extent [2]. In the same year, electricity and heat production was the largest emitter of GHGs, followed closely by agriculture, forestry and other land use collectively [2][3][4].

GHGs generally trap heat by absorbing the long wave radiation released from the Earth's surface which would otherwise partially radiate into the space, and releasing it later as heat. In a balanced state, this trapping of heat is crucial to the life processes on Earth by keeping temperature fluctuations in a narrow window [5][6]. Increasing GHGs in the troposphere disrupts the balance sheet, causing more heat to be trapped and resulting in rainfall variation, warming of land and sea surfaces, retreat of glaciers and rising sea level [7]. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has elucidated an average increase of global land and ocean temperature by 0.85°C from 1880 to 2012 and is confident of the occurrence of significant warming between 1983 and 2012 [2].

While global temperature variation has historically unfolded as cycles parallel to the rise and fall of atmospheric carbon dioxide, increasing human activities since the mid-20th century have disrupted the equilibrium and resulted in an upsurge of carbon dioxide [8]. This is manifested as unprecedented rate of warming in the past few decades. Increasing emission of GHGs due to intensifying human activities has always been regarded as a global issue. However, statistically, four regions account for more than half of the global GHGs emission, led by China contributing 30% of the carbon dioxide emission from fossil fuel combustion and industrial processes, followed by the United States (US) contributing 15%, the European Union (EU) chipping in 9% and India pitching in 7% [9]. In terms of production-based GHGs emission by country, as of 2017, China was the largest emitter of CO_2, releasing an estimated 9839 $MtCO_2$ while the US came in second with 5270 $MtCO_2$ emitted. India was ranked third at an estimated CO_2 emission of 2467 $MtCO_2$ and the Russian Federation fourth at approximately 1693 $MtCO_2$ [10]. Among members of the EU, Germany emerged as the top CO_2 emitter with about 799 $MtCO_2$ emitted in 2017 and France was at the second place with 356 $MtCO_2$ emitted [10]. Figure 1 shows the total CO_2 emitted by the four regions, with China charting a sharp increase from 2002 to 2013 and India gradually picking up while the US and EU showing steady and slightly downward trends [11].

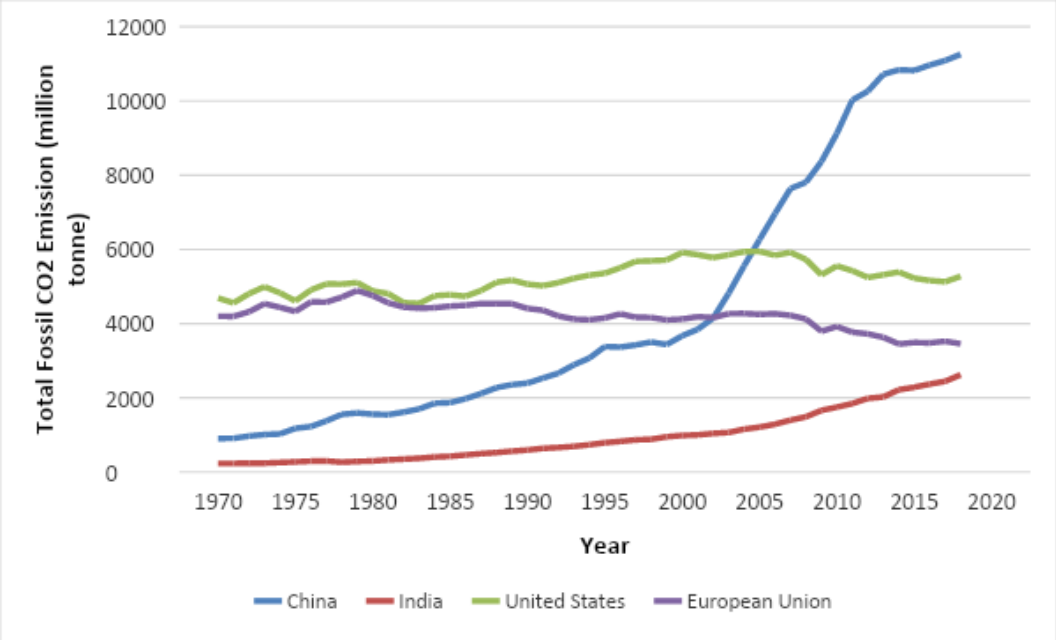

Figure 1. Total Fossil CO_2 Emission from the Four Largest CO_2 Emitting Regions [11]

With China being the most populous country in the world, it is unsurprising that China topped the chart of CO_2 emission. However, India as the second most populous country came as the third largest CO_2 emitter. It seems worthwhile to also examine CO_2 emission on the basis of population size. Translated to per capita CO_2 emission, the giant emitters mentioned above are nowhere in the top ten. The US falls to the eleventh with an emission rate of 16 tCO_2/person [10]. Despite the disparity in regional or national emissions of CO_2 and per capita emissions of CO_2 by country, it is believed that a top-down approach is necessary to drive climate change mitigation and adaptation [12]. While a bottom-up approach is not less important, such approach may have already been initiated locally by individuals or communities experiencing or likely to experience the impacts of climate change [13][14]. A top-down approach takes on a wider view of GHGs emissions at regional level and examines the regional or national policies in relation to climate change. This enables a comparison of how the regions or countries of interest have progressed in this respect and permits mutual learning and continuous improvement at the policy-making level [12]. As China, the US, the EU and India emit more than half of the global GHGs, it is particularly crucial to look into the climate change policies of the four entities. The EU has been considered an entity in tackling climate change due to its concerted effort in prioritizing climate change matters, driving energy-efficient and low carbon economy and endorsement of the 2030 climate and energy framework framing targets and policy objectives across all member nations from 2021 to 2030 [15].

The recent Paris Agreement aims to contain global average temperature rise within a 1.5°C margin and necessitates its signatories to plan and constantly report their efforts in mitigating global warming. While all the four major emitters of GHGs are signatories of the Agreement, the US intended to withdraw from the Agreement in November 2020 [16]. It is also of interest to examine how the Paris Agreement has influenced policy-making on climate change in the four entities and draw a comparison of the climate change policy of the US which plans to withdraw from the Agreement and those of the entities which shall stay with the Agreement. Policies pertaining to climate change commonly revolve around mitigation and adaptation

[17]. Mitigation involves the reduction of GHGs emission to alleviate global warming, hence providing a long-term solution to climate change. Adaptation, however, deals with responding and adjusting to the impacts of climate change without negating the impacts [18][19]. This review encompasses policies related to mitigating as well as adapting to climate change.

In addition, very few reviews have been conducted to compare climate change policies in the past decade. Rübbelke evaluated the effectiveness of international supports rendered in the formation of climate change policies by developing countries and provided recommendation for the supports but did not examine existing policies to identify the gaps [20] . In the EU, comparison of national adaptation strategies has been made among few member nations but this has not been extended beyond the EU as a whole [12]. Nordhaus probed the consequences of induced innovation in climate change policy which led to a series of studies in proposing the models of climate change policy and the framework in designing such policies [22]. Goulder and Stavins looked into the interactions between the state and federal climate change policies in the US and the challenges such interactions presented [23]. There are many similar studies which delve into national and regional implications of climate change policies but there are only few that put the policies through a systematic comparison to highlight the strength and weaknesses and promote mutual learning [24][25]. This review aims to fill in this gap by analyzing the climate change policies of the four major GHGs emitters. In doing so, it brings out the strengths and weaknesses of the policies as well as adds value by providing relevant recommendations for improvement.

2. METHODOLOGY

This review examined more than eighty-five official and scholarly reports and articles published mainly in the period of 2010 to 2020. The literature was sourced from major journal databases comprising the Web of Science, Scopus and ScienceDirect as well as government websites where the policy documents are publicly displayed. The search was conducted using the search engine of the databases with keywords such as climate change, policy, China, United States, European Union and India. Policies in this review consist of strategies, action plans, national plans, the actual policy documents as well as the executive orders of the United States. They do not include laws, regulations and other legal documents, even though legislation can be affected by national policies. The review does not include the nationally determined contributions (NDCs) of the countries which are fundamentally their intended actions in combating climate change as required by the Paris Agreement [26]. The policies deemed to be relevant to climate change are those explicitly addressing the reduction of GHGs and adaptation to the climate change through resilience building and increasing green cover.

3. RESULTS AND DISCUSSIONS

3.1. Climate Change Policies of China

China signed the Paris Agreement on the 22 April 2016 which came into effect on the 4 November 2016 [27]. Prior to signing the Paris Agreement, China has established its National Strategy for Climate Change Adaptation in 2013 aiming to increase resilience to and public awareness of climate change [28]. The strategy was framed by the National Development and Reform Commission (NDRC) and it focuses on forestry, infrastructural,

risk planning and meteorological management. The strategy puts forth an array of measures for water resource protection, soil erosion control, disaster monitoring and prevention via early detection and information technology at national and provincial levels, as well as coastal restoration [28]. The strategy also caters for agricultural sector with new farming practices through pest control and enhancing crop adaptability developed. The strategy sets climate targets using 2013 as baseline, which include 1) having 70% rural farmers trained in adaptive technology by 2020, 2) protecting more than 60% of natural wetlands and controlling desertification in more than 50% of area experiencing desertification [28]

In 2014, China rolled out the National Plan for Tackling Climate Change which includes comprehensive mitigation and adaptation strategies against climate change ranging from controlling the emissions of greenhouse gases and implementing pilot demonstration projects to improving regional response, forging international cooperation and capacity building [29]. The plan targets to reduce carbon emissions per unit GDP by 40-45% with reference to the 2005 levels. Furthermore, it targets to push the share of non-fossil fuels in the China's primary energy mix to 15% [29]. In the same year, the Energy Development Strategy Action Plan was published by the Central People's Government and it aligns with the target of the National Plan for Tackling Climate Change to reduce carbon emissions by proposing actions, particularly reducing per unit GDP energy consumption through the use of more efficient green energy [30]. The action plan also endeavors to limit the annual primary energy consumption at 4.8 billion tonnes of standard coal equivalent until 2020, with coal consumption kept below 4.2 billion tonnes annually till 2020. The action plan also echoes the national plan in increasing the share of non-fossil fuels and provides more specific targets for the share of various energy sources by 2020 [30].

The 13th Five-Year Plan of China introduced in 2016 sets the path of China's development from 2016 to 2020 and it features the peak targets for carbon emissions as well as energy and water consumption [31]. It also promulgates production of renewable energy and development of green infrastructure. While the previous plans are committed to the reduction of carbon emission and energy consumption, this plan sets clear targets of 18% and 15% reduction in carbon dioxide emissions and energy consumption respectively, per unit GDP by 2020 with 2015 levels as baseline [32][33]. It demonstrates the resolution of China as a signatory of the Paris agreement since 2016 to reduce the emissions of greenhouse gases. This plan, nonetheless, indicated relaxation of the limit of 4.8 tonnes of standard coal equivalent in annual primary energy consumption to 5 tonnes by 2020[31] [34]. This plan also highlights the increased usage of electric vehicles and expansion of forest coverage [31].

3.2. Climate Change Policies of the United States

The US expressed its intention to withdraw from the Paris Agreement in November 2020 under president Donald Trump. Besides, the US did not adopt the Kyoto Protocol aiming to reduce emissions of greenhouse gases particularly by industrialized nations [35]. However, the succession of US presidency by Joe Biden put the US back to the Paris Agreement on 19 February 2021, thus including the US as part of the combat against global climate change. The US has established policies related to climate change. The Executive Order 13423: Strengthening Federal Environmental, Energy and Transportation Management which came into existence in 2007 necessitates an environmentally sound and integrated approach in transportation and energy-related activities [36]. It promotes the production and use of renewable energy while pushing for 30% reduction of energy intensity by 2015 with the 2003 energy consumption as baseline. It also sets target for the use of non-fossil fuel in

the total fuel consumption of government fleets and the deployment of plug-in hybrid electric vehicles [36].

In 2014, the US passed the Executive Order 13677: Climate-Resilient International Development which prompts the incorporation of climate resilience into international projects where the relevant agencies are required to conduct risk assessments and, based on assessments, make necessary adjustments to the projects [37]. The Clean Air Act of the US has resulted in the inception of the Clean Power Plan aiming to reduce carbon emissions of the power sector by as much as 32% in 2030 with reference to the 2005 levels, which is equivalent to approximately 870 million tonnes [38]. The reduction is targeted particularly on fossil fuel-fired electric steam generators deployed mainly in coal- and oil-fired power plants, and natural gas-fired combined cycle generators. The plan also entails higher dependence on renewable energy, natural gas and nuclear power instead of coal, with renewables being the top priority [38]. To promote the energy efficiency and the use of renewables beneficial to the low-income groups, incentives are offered. The plan is foreseen to yield climate-related benefits of $20 billion due to its potential significant contribution to reducing pollution [39].

3.3. Climate Change Policies of the European Union

Climate change policy of the European Union is also closely tied to energy policies, as in the US. Similarly, despite being explicitly linked to climate change in their titles, the climate change policies in China also revolve around the reduction of carbon emissions through adjusting the energy mix. The European Energy Security of 2014 was an emergency response against the political crisis in Ukraine which could potentially disrupt energy imports, and part of the plan involved increasing dependence on alternative fuels and energy efficiency of the building and industrial sectors parallel to the 2030 energy and climate goals [40][41]. The same year also saw the inauguration of the 2030 framework for climate and energy policies targeting to reduce 40% GHGs emissions by 2030 in comparison to the emissions in 1990 [42]. Besides, it endeavors to increase the share of renewable energy in power generation to at least 27% and achieve energy saving of 27% by 2030. It also specifies the GHGs reduction targets for the EU Emission Trading System (ETS) and the non-EU ETS sectors, as well as the regulation of emission allowances in the EU ETS [42][43]. The EU ETS has a central role in the EU's policy against climate change focusing on reduction of GHGs emissions. It is the world's biggest carbon market and operates on a 'cap and trade' basis where cap refers to the upper limit of permissible greenhouse gases an installation in the system can emit [44]. The cap is progressively reduced as emission targets tighten. Companies can sell or buy the emission allowances depending on their surpluses or deficits of GHGs quota [44]. The framework ultimately aims to pool resources, connect networks and unite EU member states' capacity for affordable and sustainable energy [42].

In 2016, A European Strategy for Low-Emission Mobility was launched to decrease GHGs emissions in the transport sector by pushing for a better-defined regulatory framework as well as an optimized and more efficient transport system [45]. In addition, it promotes low-carbon technologies and development including infrastructure for electro-mobility [46] Subsequently, a Hydrogen Strategy for a Climate-neutral Europe was rolled out in 2020 to catalyze the use of hydrogen fuel produced from renewable sources [47].

3.4. Climate Change Policies of India

Similar to China, India has explicit climate change policies. The National Action Plan on Climate Change introduced in 2008 aims to balance India's development and the combat

against climate change through eight national missions, namely 1) National solar mission, 2) National mission on sustainable habitat, 3) National mission for a Green India, 4) National water mission, 5) National mission for sustainable agriculture, 6) National mission for enhanced energy efficiency, 7) National mission on strategic knowledge for climate change, and 8) National mission for sustaining the Himalayan ecosystem [48][49]. In the subsequent year, the Revised Operational Guidelines of the National Afforestation Program was launched to aiming to more effectively manage, transfer fund and build capacity for the project. Specifically, it calls for increased forest and tree cover, sustainable forest management and rehabilitation of degraded forests [50]. Also in 2009, the Indian government rolled out the National Policy on Biofuels to bolster the production bio-diesel (20% blend) and bio-ethanol from non-edible oil seeds and waste besides setting the per liter price of bioethanol at USD 0.35 [51]. The Policy necessitates an initial 5% blending of ethanol with petrol which was increased to 10% in October 2008. It provides incentives for, encourages research and development in, as well as regulates biofuels [51].

The National Mission for Electric Mobility Plan 2020 was introduced in 2012 to promote the production and use of hybrid and electric vehicles via multiples schemes and projects under the National Board for Electric Mobility and the National Council for Electric Mobility [52][53]. The National Agroforestry Policy came in 2014 to streamline agroforestry programs and schemes of various agencies under a more focused governance. It also serves to provide employment and income to rural communities particularly smallholder famers via agroforestry while driving the growth of agroforestry in a sustainable manner [54]. Akin to the other major GHGs emitters, the transport sector has been a critical area in India's fight against climate change. Following the Electric Mobility Plan, the National Urban Transport Policy launched in 2006 was revised in 2014 to propel greater improvements in urban transport services and infrastructure [55]. The revision calls for energy efficiency and the use of clean fuel besides lifestyle changes through the use of public transport, walking and cycling [55]. In the same year, the Auto Fuel Vision and Policy raised the bar for fuel and emissions standards [56][57]. The National Electricity Plan (Generation) was passed in 2012, addressing issues related to aged power plants, energy and resource efficiency while catalyzing technological improvements of power plants. The plan also drives the development and use of renewable energy [49].

In fact, the focus on renewable energy has been demonstrated in the Tariff Policy of 2006 which provides for renewable energy and cogeneration [58]. The policy obligates the government electricity regulatory bodies to purchase electricity generated by the renewables and spurs the solar power purchase by states to 3% by 2022. Furthermore, the policy sets the tariffs for non-conventional energy technologies to make them more competitive against the conventional ones [58]. The policy was amended in 2011 to include provisions for the state's purchase of solar power in line with the National Solar Mission strategy [59]. The Union Budget 2019-2020 was another manifestation of the intention of the Indian government to upscale incentivization for deployment of electric vehicles [60].

3.5. Similarities of the Climate Change Policies

Though named differently, the policies pertaining to climate change of the four largest emitters of GHGs are fundamentally similar in their approaches to reduce GHGs emissions via more efficient use of energy and resources, development of cleaner and renewable energy, optimization of transport system and boosting of the adoption of electric vehicles. Table 1 summarizes the policies while Table 2 shows the transportation goals of the nations.

Table 1 shows that transportation and energy are the most common areas addressed by the policies and all the nations have established policies related to these two dimensions [36][45][55]. Specifically, the countries are examining ways of optimizing the transport system and infrastructure to make transportation more efficient while facilitating a gradual shift from cars running on fossil fuels to electric and hybrid cars with lower GHGs emissions in their lifecycles [46][55]. With popularization of electric and hybrid cars, the infrastructure for operating and maintaining the cars will be further developed [53]. Where energy is concerned, it revolves around the common themes of energy efficiency, reducing dependence on fossil fuels and increasing dependence on non-fossil fuels and the renewables [26][31] [42]. The EU particularly is interested in hydrogen fuel, particularly renewable hydrogen in the long-term and low-carbon hydrogen in the short-term, which does not generate carbon dioxide during its combustion [47].

All the countries, except India, also stipulate economy-wide strategies without tying the GHGs reduction to a particular sector but to the economy in general such as reducing the GHGs emissions per unit of gross domestic product or setting emission reduction target for a group of sectors as in the case of the EU-ETS and the non-EU-ETS sectors (Table 1) [44][61]. In certain instances, economy-wide strategies only provide an overall GHGs reduction of a particular country against a baseline [61]. Land use, land-use change and forestry (LULUCF) is another common area addressed by the policies especially in the developing nations where there are needs to regulate land-use conversion to ensure sustainable development. The common facets under LULUCF include setting targets for or increasing tree covers, conservation areas as well as floral and faunal diversity [62]. China and EU have made provisions for industrial sector with the former focusing on curtailing GHGs from industrial units while establishing low-carbon industrial parks, and the latter regulates emissions from heavy industrial installations through the EU-ETS (Table 1) [29][44].

Commonalities have been observed among the energy targets of the nations, particularly in terms of the share of renewable energy in the energy mix. While China has more specific targets on the installed capacity for different types of renewable and cleaner energies, the general emphasis across the nations is to increase energy generated from non-fossil fuel sources. Besides, reducing energy intensity is common target of both China and the US. The EU also has a similar target on increasing energy efficiency.

3.6. Differences of the Climate Change Policies

The obvious differences between the climate change policies are the emphasis and the coverage. The policies of China, particularly the National Plan for Tackling Climate Change caters for GHGs reduction in other sectors such as building and tourism while its 13th Five-year Plan sets targets for shoreline protection [29][63]. The National Strategy for Climate Change Adaptation emphasizes adaptive technical training for rural farmers [28]. Policies of the US and the EU, however, place greater focus on the transportation and energy domains with EU emphasizing hydrogen fuel specifically and its carbon market through the ETS. In the Indian policies for energy, biofuel occupies an important place [64]. Developing countries like China and India put higher emphasis on LULUCF in their policies than the developed ones like the US and EU. The reason could be that developing countries contribute to most of the emissions from LULUCF [62].

Though addressing the same domains, the goals set under each domain may differ among nations. Taking transportation for instance (Table 2), China's targets seem to focus on CO_2 reduction for different modes of transportation as well as the utilization rate of public transport and transport sharing against a particular baseline year while the US tends to focus on the fuels for transportation with targets established to increase the use of renewable and cleaner fuels [29][36]. India does not have specific targets for transportation based on the policies reviewed though its National Mission for Electric Mobility Plan 2020 predicted a decrease in CO_2 intensity with the execution of its public transportation programs [52]. The EU has established specific targets under its legislation rather than policies. This also demonstrates the binding nature of the targets, hence the strategies to achieve the targets. For instance, under the Clean Sky (Council Regulation (EC) No. 71/2007 setting up the Clean Sky Joint Undertaking and No 558/2014 of 6 May 2014 establishing the Clear Sky 2 Joint Undertaking), the EU strives to achieve a 50% and 80% reduction in CO_2 and NOx emissions of air transportation respectively against the 2007 baseline, besides increasing the efficiency of aircraft fuel for CO_2 reduction [65]. The EU has also made provision for lower-carbon fuels through Fuel Quality (Directives 2009/30/EC and 2015/2013 amending Directive 98/70/EC as regards the specification of petrol, diesel and introducing a mechanism to monitor and reduce GHG emissions) [66]. Translating policies and targets into laws demonstrates the resolution of EU in reducing GHGs emissions. Back in 2008, the EU's 20-20-20 targets already came under the consideration for legislation. The 20-20-20 targets center on reducing at least 20% GHGs emissions of the EU by 2020 against the 1990 baseline, increasing renewable energy consumption to 20% and reducing primary energy use by 20% against the projected levels through enhanced energy efficiency [67]. The following year saw the passing of four laws collectively called the 'climate and energy package' which consist of Directive 2009/29/EC, Directive 2009/28/EC, Directive 2009/31/EC and Decision No. 406/2009/EC of the Parliament and the Council [67].

In terms of energy targets (Table 3), the EU has established a specific target for the installation of the hydrogen electrolyzer in line with its Hydrogen Strategy for a Climate-neutral Europe [47]. The targets of Indian policies reviewed seem to focus on infrastructural development particularly for solar power without stipulating the overall increase of the share for renewables it aims to achieve in its energy mix as well as the reduction of GHGs emissions from the energy sector. Few targets are action-focused for instance the mandates on smart meter installation, in comparison to targets of other countries which are quantitative [59]. Despite a lack of quantitative energy targets in the policies reviewed, India has established targets for renewable energy in its intended NDCs. Among the targets are increasing the installed capacities of wind power and solar power to 60 GW and 100 GW respectively by 2022. The intended targets have yet been converted into national policies to garner larger commitment [68].

Akin to its transportation targets, many of the EU's energy targets have been granted binding status through legislation. Under the 2020 Climate and Energy Package, the EU aims to reduce a minimal 50% of GHGs emissions through biofuels and bioliquids by 2020 with the levels of 2009 as baseline. The same law package also spells out a binding 20% reduction in primary energy consumption by 2020 [43][67]. Therefore, the targets that may appear in the policies of other nations will come under the EU legislation.

Table 1. Major Aspects Addressed by the Climate Change-Related Policies of the Four Largest GHGs Emitters

Country/ Region	Year – Climate Change-Related Policy	Transportation	Energy	Economy-wide	LULUCF	Industry	Buildings
China	2011 – 12th Five-year Plan for the Development of National Economy and Society (2011-2015)		•	•	•		
	2013 – The National Strategy for Climate Change Adaptation				•		
	2014 – National Plan for Tackling Climate Change 2014-2020	•	•	•	•	•	•
	2014 – Energy Development Strategy Action Plan		•				
	2016 – 13th Five-year Plan		•	•	•		
United States	2007 – Executive Order 13423: Strengthening Federal Environmental, Energy and Transportation Management	•	•				
	2014 – Executive Order 13677: Climate-Resilient International Development			•			
	2015 – Clean Power Plan		•				
European Union	2020 – A Hydrogen Strategy for a Climate-neutral Europe		•				
	2016 – A European Strategy for Low-Emission Mobility	•					
	2014 – 2030 Framework for Climate and Energy Policies		•	•		•	
	2014 – European Energy Security Strategy		•				
India	2006 – Tariff Policy 2006; amended in 2016		•				
	2008 – National Action Plan on Climate Change						
	2009 – Revised Operational Guidelines of the National Afforestation Program				•		
	2009 – National Policy on Biofuels		•				
	2012 – National Mission for Electric Mobility Plan 2020	•					
	2012 – National Electricity Plan (Generation); amended in 2016		•				
	2014 – National Agroforestry Policy				•		
	2014 – National Urban Transport Policy	•					
	2014 – Auto Fuel Vision and Policy 2025	•					
	2019 – Union Budget 2019-2020	•					

Table 2: Transportation Targets under the Climate Change-Related Policies

China		US		India	EU
Aspect	Target	Aspect	Target	Aspect/Target	Aspect/Target
Public Transport	30% ↑ (2020)	Lifecycle GHG reduction for renewable fuel production	20%↓	None stated in the policies reviewed	None stated in the policies reviewed
CO_2 emission of air freight	11% ↓ (2020; against 2010 baseline)	GHG emissions from agencies with more than 20 vehicles	4%↓ (2017) 15%↓ (2021) 30%↓ (2025)		

			Against 2014 baseline
CO_2 emission of waterway transportation	13% ↓ (2020; against 2010 baseline)	Hydrogen-fueled vehicles	100,0000 (2010) 2.5 million (2020)
CO_2 emission of railway transportation	15% ↓ (2020, against 2010 baseline)	Zero emission or plug-in hybrid agency passenger vehicles	20% (2020) 50% (2025)
CO_2 emission per unit passenger volume	5% ↓ (2020, against 2010 baseline)	Petroleum consumption in agency fleets	2%↓ (2020 against 2005) baseline
Sharing rate of public transportation	30% ↑ (2020, against 2014 baseline)	Non-petroleum fuel consumption in agency fleets	10%↑ annually by 2015 against 2005 baseline

Note: ↑ means increase; ↓ means decrease

Table 3: Energy Targets under the Climate Change-Related Policies

China		US		India		EU	
Aspect	Target	Aspect	Target	Aspect	Target	Aspect	Target
Energy consumption per unit GDP	3.4%↓ (2016, against 2015 baseline) 15%↓ (2020, against 2015 baseline)	CO_2 emission reductions from the utility sector	32%↓ (2030, against 2005 baseline)	Smart meters	Mandated (2017 and 2019 against 2016 baseline)	Share of renewable energy consumption	At least 27% by 2030
Installed capacity of conventional hydropower	350 million kilowatts (2020)	Energy intensity	3% annual ↓ or 30% total ↓ (2015, against 2003 baseline)	Off-grid applications	1000 MW (2017) 2000 MW (2022)	Installed capacity of renewable hydrogen electrolyzers	6 GW (2024) 40 GW (2030)
Non-fossil fuel in primary energy consumption	11.4%↑ (2015) 15%↑ (2020, against 2014 baseline)	Percent renewable energy from new renewable sources	50%	Solar thermal collector area	15mil m^2 (2017) 20mil m^2 (2022)	Energy efficiency against projections of future energy consumption	27%↑ (2030, against 2014 baseline)
Shale gas production	>30 billion m^3 (2020, against 2014 baseline)	Petroleum consumption in agency fleets with at least 20 vehicles	2% annual ↓ (2015, against 2005 baseline)	Solar lighting systems for rural areas	20 m by 2022		

Installed capacity of solar power generation	100 million kilowatts (2020)	Non-petroleum fuel consumption in agency fleets with at least 20 vehicles	10% annual ↑ (2015, against 2005 baseline)	Solar power	9000 MW grid-connected (2017) 800 MW off-grid solar power (2022)
Energy intensity of GDP	16%↓ (2015, against 2011 baseline)			Energy from Waste-to-Energy plants	Mandatory percentage (not specified)
Primary energy consumption	Capped at approx. 4.8 billion tons standard coal			Blending of biofuels (bio-diesel and bio-ethanol)	20%
Installed capacity of grid-connected wind power	200 million kilowatts (2020)				
Installed capacity of biomass power generation	50 million tons (2020)				
Geothermal energy	50 million tons of standard coal (2020)				

Note: ↑ means increase; ↓ means decrease

3.7. Implications and Limitations

Overall, the climate change policies reviewed are still skewed towards mitigation and most targets set focus on reducing CO_2 emissions of various sectors which are essentially mitigation strategies. While mitigation provides long-term solution to climate change, the impacts of climate change have unfolded and are foreseen to have increased severity [18]. Adaptation to climate change is also of importance since the global population is living with its impacts. However, the policies on adaptation seem to be constrained to LULUCF and agriculture with LULUCF largely focuses on increasing forest cover which is both mitigation and adaptation [69]. Rübbelke pointed out that adaptation policies did not receive sufficient attention until the mid-1990s. Even at present, countries still perceive the benefits of adaptation as excludable because adaptation impacts are often regional [70]. Such perception could hinder international incentives for efficient adaptation [20]. Therefore, national policies on adaptation and international transfer schemes supporting adaptation in developing countries are promulgated [20].

This review has a few inherent limitations. Due to the multitude of policies and programs which directly or indirectly address climate change, it reviews only the major pieces with explicit aspects of climate change. Though important to achieving the global warming target of the Paris Agreement, it does not review the NDCs which have not been turned into national policies. It does not probe the system vindication of the policies which deal with issues such as fairness, legitimacy and transparency [71]. This usually concerns the compatibility of the policies with political and social values, and calls for participatory approach in policy-making and target-setting. Participation could help filling in incomplete and uncertain information of climate governance [72] and the participants are usually stakeholders comprising the public, politicians, private companies and the regulators [73].

4. Conclusion

This review has examined the climate change policies of the four largest GHGs emitters in the world which cover the similarities and differences as well as the strengths and weaknesses. Their climate change policies are largely similar in addressing efficiency in energy and resource utilization, development of cleaner and renewable energy, increasing the environmental-friendliness of transport and transport system with transportation and energy most commonly emphasized. The policies, however are different in focus and coverage with the developing countries putting relatively higher emphasis on LULUCF than the US and the EU. The EU has incorporated certain policy targets into its legislation and is particularly interested in hydrogen fuel.

Decreasing reliance of developing countries on fossil fuels for power generation while pursuing energy efficiency and cleaner energy is paramount to climate change policies. The current climate change policies which are dominated by mitigation strategies should be partly balanced with adaptation strategies. This review advocates a participatory approach to policy-making, target-setting as well as policy evaluation to ensure fairness, legitimacy and transparency [74]. It also encourages review of the policy targets in line with the Paris Agreement besides effective governance and execution to achieve the targets. Further research can probe into developing criteria for effective evaluation of the policies as well as strategies to effectively and efficiently execute the policies and achieve their targets.

References

1. EPA (2017) Global greenhouse gas emission data. https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
2. IPCC (2013) Climate Change 2013: The Physical Science Basis. Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change
3. Tang K (2019) Climate change and paddy yield in Malaysia: A short communication. Glob J Civ Environ Eng 1:14–19
4. Tang KHD (2019) Impacts of Climate Change on Tropical Rainforests' Adaptive Capacity and Ecological Plasticity. Clim Chang Facts, Impacts Solut 1:1–5
5. Ramanathan V, Feng Y (2009) Air pollution, greenhouse gases and climate change: Global and regional perspectives. Atmos Environ 43:37–50 . https://doi.org/https://doi.org/10.1016/j.atmosenv.2008.09.063
6. Tang KHD (2020) Implications of Climate Change on Marine Biodiversity. Glob J Agric Soil Sci 1:1–6
7. Wild M, Gilgen H, Roesch A, Ohmura A, Long CN, Dutton EG, Forgan B, Kallis A, Russak V, Tsvetkov A (2005) From Dimming to Brightening: Decadal Changes in Solar Radiation at Earth's Surface. Science (80-) 308:847 LP – 850 . https://doi.org/10.1126/science.1103215
8. Lüthi D, Le Floch M, Bereiter B, Blunier T, Barnola J-M, Siegenthaler U, Raynaud D, Jouzel J, Fischer H, Kawamura K, Stocker TF (2008) High-resolution carbon dioxide concentration record 650,000–800,000 years before present. Nature 453:379–382 . https://doi.org/10.1038/nature06949
9. Boden TA, Marland G, Andres RJ (2017) National CO2 emissions from fossil-fuel burning, cement manufacture, and gas flaring: 1751-2014. Carbon Dioxide Inf Anal Center, Oak Ridge Natl Lab US Dep Energy
10. Global Carbon Atlas (2019) Territorial (MtCO2). http://www.globalcarbonatlas.org/en/CO2-emissions
11. Crippa M, Oreggioni G, Guizzardi D, Muntean M, Schaaf E, Lo Vullo E, Solazzo E, Monforti-Ferrario F, Olivier JGJ, Vignati E (2019) Fossil CO2 and GHG emissions of all world countries. Luxembg Publ Off Eur Union
12. Biesbroek GR, Swart RJ, Carter TR, Cowan C, Henrichs T, Mela H, Morecroft MD, Rey D (2010) Europe adapts to climate change: Comparing National Adaptation Strategies. Glob Environ Chang 20:440–450 . https://doi.org/https://doi.org/10.1016/j.gloenvcha.2010.03.005
13. Mickwitz P, Aix F, Beck S, Carss D, Ferrand N, Görg C, Jensen A, Kivimaa P, Kuhlicke C, Kuindersma W (2009) Climate policy integration, coherence and governance. irstea
14. Tang KHD (2021) The effects of climate change on occupational safety and health. Glob J Civ Environ Eng 3:1–10 . https://doi.org/10.36811/gjcee.2021.110008
15. European Council - Council of the European Union (2019) Tackling climate change in the EU. https://www.consilium.europa.eu/en/policies/climate-change/
16. United Nations Treaty Collection (2019) Chapter XXVII Environment 7.d Paris Agreement. https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en#EndDec
17. Tang KHD (2019) Are We Already in a Climate Crisis? Glob J Civ Environ Eng 1:25–32
18. Tang KHD (2019) Climate change in Malaysia: Trends, contributors, impacts,

mitigation and adaptations. Sci Total Environ 650:1858–1871 . https://doi.org/https://doi.org/10.1016/j.scitotenv.2018.09.316
19. Tang KHD (2021) Climate Change and Its Impacts on Mental Wellbeing. Glob Acad J Humanit Soc Sci 3:144–151
20. Rübbelke DTG (2011) International support of climate change policies in developing countries: Strategic, moral and fairness aspects. Ecol Econ 70:1470–1480 . https://doi.org/https://doi.org/10.1016/j.ecolecon.2011.03.007
21. Nordhaus WD (2002) Modeling induced innovation in climate-change policy. Technol Chang Environ 9:259–290
22. Hallegatte S, Lecocq F, De Perthuis C (2011) Designing climate change adaptation policies: An economic framework. The World Bank
23. Goulder LH, Stavins RN (2011) Challenges from State-Federal Interactions in US Climate Change Policy. Am Econ Rev 101:253–257 . https://doi.org/10.1257/aer.101.3.253
24. Corbera E, Hunsberger C, Vaddhanaphuti C (2017) Climate change policies, land grabbing and conflict: perspectives from Southeast Asia. Can J Dev Stud / Rev Can d'études du développement 38:297–304 . https://doi.org/10.1080/02255189.2017.1343413
25. Pietrapertosa F, Khokhlov V, Salvia M, Cosmi C (2018) Climate change adaptation policies and plans: A survey in 11 South East European countries. Renew Sustain Energy Rev 81:3041–3050 . https://doi.org/https://doi.org/10.1016/j.rser.2017.06.116
26. Bardhan R, Debnath R, Jana A (2019) Evolution of sustainable energy policies in India since 1947: A review. WIREs Energy Environ 8:e340 . https://doi.org/10.1002/wene.340
27. Hilton I, Kerr O (2017) The Paris Agreement: China's 'New Normal' role in international climate negotiations. Clim Policy 17:48–58 . https://doi.org/10.1080/14693062.2016.1228521
28. National Development and Reform Commission P.R.C. (2013) The National Strategy for Climate Change Adaptation. https://climate-laws.org/geographies/china/policies/the-national-strategy-for-climate-change-adaptation
29. National Development and Reform Commission P.R.C. (2014) National Plan for Tackling Climate Change (2014-2020). https://policy.asiapacificenergy.org/sites/default/files/国家应对气候变化规划 (2014-2020年.pdf
30. State Council of the People's Republic of China (2014) Energy Development Strategic Action Plan (2014–2020)
31. Gosens J, Kåberger T, Wang Y (2017) China's next renewable energy revolution: goals and mechanisms in the 13th Five Year Plan for energy. Energy Sci Eng 5:141–155 . https://doi.org/10.1002/ese3.161
32. Meng M, Niu D, Shang W (2012) CO2 emissions and economic development: China's 12th five-year plan. Energy Policy 42:468–475 . https://doi.org/https://doi.org/10.1016/j.enpol.2011.12.013
33. Sun W, Meng M, He Y, Chang H (2016) CO2 emissions from China's power industry: Scenarios and policies for 13th Five-Year Plan. Energies 9: . https://doi.org/10.3390/en9100825
34. Yu X, Qu H (2013) The role of China's renewable powers against climate change during the 12th Five-Year and until 2020. Renew Sustain Energy Rev 22:401–409 . https://doi.org/https://doi.org/10.1016/j.rser.2013.02.008
35. Dai H-C, Zhang H-B, Wang W-T (2017) The impacts of U.S. withdrawal from the

Paris Agreement on the carbon emission space and mitigation cost of China, EU, and Japan under the constraints of the global carbon emission space. Adv Clim Chang Res 8:226–234 . https://doi.org/https://doi.org/10.1016/j.accre.2017.09.003
36. The White House (2007) Executive Order 13423—Strengthening Federal Environmental, Energy, and Transportation Management. In: Fed. Regist. https://storage.googleapis.com/cclow-staging/ylohk1d66h4bwnlvrozfk0h0mzt2?GoogleAccessId=laws-and-pathways-staging%40soy-truth-247515.iam.gserviceaccount.com&Expires=1604047820&Signature=Amjqysn%2Fl04RHhhEoAj%2Bb99%2BiPd%2BK8W9lfJc%2BoQluSOJ%2Bwwq4mk4j%2B
37. The White House (2014) Executive Order 13677—Climate-Resilient International Development. In: Fed. Regist. https://storage.googleapis.com/cclow-staging/56i7wxebk232ftxagd5q19ppjvlb?GoogleAccessId=laws-and-pathways-staging%40soy-truth-247515.iam.gserviceaccount.com&Expires=1604046836&Signature=cB3y60FbLQ51AFVv0p1P2GE00SiV7WOsU4GD0ZZ9T12lxD%2BFS7GNFZ5f5rdTuqB1Mz
38. Bushnell JB, Holland SP, Hughes JE, Knittel CR (2017) Strategic Policy Choice in State-Level Regulation: The EPA's Clean Power Plan. Am Econ J Econ Policy 9:57–90 . https://doi.org/10.1257/pol.20150237
39. Hogan WW (2015) Electricity Markets and the Clean Power Plan. Electr J 28:9–32 . https://doi.org/https://doi.org/10.1016/j.tej.2015.09.017
40. Jonsson DK, Johansson B, Månsson A, Nilsson LJ, Nilsson M, Sonnsjö H (2015) Energy security matters in the EU Energy Roadmap. Energy Strateg Rev 6:48–56 . https://doi.org/https://doi.org/10.1016/j.esr.2015.03.002
41. Goldthau A, Sitter N (2015) Soft power with a hard edge: EU policy tools and energy security. Rev Int Polit Econ 22:941–965 . https://doi.org/10.1080/09692290.2015.1008547
42. Helm D (2014) The European framework for energy and climate policies. Energy Policy 64:29–35 . https://doi.org/https://doi.org/10.1016/j.enpol.2013.05.063
43. Skjærseth JB (2016) Linking EU climate and energy policies: policy-making, implementation and reform. Int Environ Agreements Polit Law Econ 16:509–523 . https://doi.org/10.1007/s10784-014-9262-5
44. European Commission (2020) EU Emissions Trading System (EU ETS)
45. Emberger G (2017) Low carbon transport strategy in Europe: A critical review. Int J Sustain Transp 11:31–35 . https://doi.org/10.1080/15568318.2015.1106246
46. Faure Schuyer A (2016) E-mobility: European Energy and Transport Policies at cross-roads The challenge of infrastructure deployment. France
47. van Renssen S (2020) The hydrogen solution? Nat Clim Chang 10:799–801 . https://doi.org/10.1038/s41558-020-0891-0
48. Pandve HT (2009) India's National Action Plan on Climate Change. Indian J Occup Environ Med 13:17–19 . https://doi.org/10.4103/0019-5278.50718
49. Tiewsoh LS, Jirásek J, Sivek M (2019) Electricity generation in India: Present state, future outlook and policy implications. Energies 12:1–14 . https://doi.org/10.3390/en12071361
50. Joshi AK, Pant P, Kumar P, Giriraj A, Joshi PK (2011) National Forest Policy in India: Critique of Targets and Implementation. Small-scale For 10:83–96 . https://doi.org/10.1007/s11842-010-9133-z
51. Das S (2020) The National Policy of biofuels of India – A perspective. Energy Policy 143:111595 . https://doi.org/https://doi.org/10.1016/j.enpol.2020.111595
52. Government of India (2012) National Electric Mobility Action Plan 2020
53. Srikanth R (2018) Role of electric mobility in a sustainable, and energy-secure future for India. Curr Sci 114:732–739

54. Singh VP, Sinha RB, Nayak D, Neufeldt H, Noordwijk M Van, Rizvi J (2016) The national agroforestry policy of India: experiential learning in development and delivery phases. WorldagroforestryOrg 3:26
55. Airy A, Chandiramani J (2019) Urban transport policy in India: a review. Int J Public Sect Perform Manag 5:399–414 . https://doi.org/10.1504/IJPSPM.2019.101057
56. Sharma S, Jain S, Goel A, Mahtt R, Kumar A, Datt D, Kundu S, Aggarwal P, Sharma P (2014) Advancement of Fuel Quality and Vehicle Emissions Norms to Improve Urban Air Quality in India. New Delhi
57. Rastogi A, Rajan A V, Mukherjee M (2018) A review of vehicular pollution and control measures in India. In: Advances in Health and Environment Safety. Springer, pp 237–245
58. Thapar S, Sharma S, Verma A (2018) Key determinants of wind energy growth in India: Analysis of policy and non-policy factors. Energy Policy 122:622–638 . https://doi.org/https://doi.org/10.1016/j.enpol.2018.08.004
59. Chandel SS, Shrivastva R, Sharma V, Ramasamy P (2016) Overview of the initiatives in renewable energy sector under the national action plan on climate change in India. Renew Sustain Energy Rev 54:866–873 . https://doi.org/https://doi.org/10.1016/j.rser.2015.10.057
60. Mukherjee S (2020) Inter-governmental Fiscal Transfers in the Presence of Revenue Uncertainty: The Case of Goods and Services Tax (GST) in India. J Dev Policy Pract 5:74–102 . https://doi.org/10.1177/2455133320909927
61. Sandén BA, Azar C (2005) Near-term technology policies for long-term climate targets—economy wide versus technology specific approaches. Energy Policy 33:1557–1576 . https://doi.org/https://doi.org/10.1016/j.enpol.2004.01.012
62. Khatun K (2012) Reform or reversal: implications of the Common Agricultural Policy (CAP) on land use, land use change, and forestry (LULUCF) in developing countries. Conserv Lett 5:99–106 . https://doi.org/10.1111/j.1755-263X.2011.00214.x
63. Sun Q, Li M, Ma C, Chen X, Xie X, Yu C-P (2016) Seasonal and spatial variations of PPCP occurrence, removal and mass loading in three wastewater treatment plants located in different urbanization areas in Xiamen, China. Environ Pollut 208:371–381 . https://doi.org/https://doi.org/10.1016/j.envpol.2015.10.003
64. Pohit S, Biswas PK, Ashra S (2011) Incentive structure of India's biofuel programs: status, shortcomings and implications. Biofuels 2:389–403 . https://doi.org/10.4155/bfs.11.19
65. Fleig A, Schmidt NM, Tosun J (2017) Legislative Dynamics of Mitigation and Adaptation Framework Policies in the EU. Eur Policy Anal 3:101–124 . https://doi.org/10.1002/epa2.1002
66. Crippa M, Janssens-Maenhout G, Dentener F, Guizzardi D, Sindelarova K, Muntean M, Van Dingenen R, Granier C (2015) Forty years of improvements in European air quality: the role of EU policy--industry interplay. Atmos Chem Phys Discuss 15:
67. Peña JI, Rodríguez R (2019) Are EU's Climate and Energy Package 20-20-20 targets achievable and compatible? Evidence from the impact of renewables on electricity prices. Energy 183:477–486 . https://doi.org/https://doi.org/10.1016/j.energy.2019.06.138
68. Vishwanathan SS, Garg A (2020) Energy system transformation to meet NDC, 2° C, and well below 2° C targets for India. Clim Change 1–15
69. Tang KHD, Yap P-S (2020) A Systematic Review of Slash-and-Burn Agriculture as an Obstacle to Future-Proofing Climate Change. Proc Int Conf Clim Chang 4: . https://doi.org/10.17501/2513258X.2020.4101
70. Barrett S (2008) Climate treaties and the imperative of enforcement. Oxford Rev Econ Policy 24:239–258 . https://doi.org/10.1093/oxrep/grn015

71. Fischer F (1995) Evaluating public policy. Nelson-Hall Publishers, Chicago, USA
72. Pielke RA (2004) What future for the policy sciences? Policy Sci 37:209–225 . https://doi.org/10.1007/s11077-005-6181-x
73. Vedung E (2017) Public policy and program evaluation. Routledge
74. Tang KHD (2020) Hydroelectric dams and power demand in Malaysia: A planning perspective. J Clean Prod 252:119795 . https://doi.org/https://doi.org/10.1016/j.jclepro.2019.119795