MILES

Modelling and Informing Low Emission Strategies

SEPTEMBER 2017

INSIDE NDCs: NATIONAL STRATEGIES IN THE LIGHT OF THE PARIS AGREEMENT

Insights from 7 countries and regions

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IDDRI

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Contact information

Roberta Pierfederici, IDDRI, roberta.pierfederici@iddri.org
Henri Waisman, IDDRI, henri.waisman@iddri.org

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The MILES Project

MILES is a 3-year research project (2014-2017) that brings together partners from the US, Japan, Europe, China, India and Brazil to elaborate transparent narratives for low-emission development strategies at the national and global levels in order to inform the international negotiations on climate and national climate policies.

The project involved in-country teams developing low-carbon transition pathways in line with their national context, as well as global modelling to assess the collective impact of climate action. These efforts considered both the 2030 horizon of the Intended Nationally Determined Contributions (INDCs) and the longer-term perspective of contributing to the elaboration of pathways at a 2050 horizon.

The project featured two main work streams.

On the one hand, it focused on the **design of national low-carbon narratives in participating countries, through the development of new models and improvement of existing tools**.

On the other hand, it fostered **the dialogue between national and global model-based analyses**. This dialogue is crucial as a common understanding of viable mitigation pathways is required to make the bottom-up architecture of the Paris Agreement work towards the long-term targets.

The timing of the MILES project and diversity of participants give its findings a unique perspective for informing key Paris Agreement outcomes such as the 2018 Facilitative Dialogue, Global Stocktake, updating of NDCs and preparation of long-term Low Emission Development Strategies Strategies (LEDS). The project began while the negotiation of the Agreement and preparation of the INDCs was still underway. And it has continued through to 2017, as countries and stakeholders have been considering how these Paris-mandated Agreement outputs will work in practice.

The MILES project outputs therefore provide a useful starting point, both for countries themselves and for subsequent projects focused on the realisation of the Paris Agreement vision.

This study collects the new low-carbon pathways developed by in-country research teams in the project, taking into account the socio-economic specificities of each country and trying to address some of the development issues associated with the decarbonization process.

BRAZIL Economic and social impacts of a low emission development strategy

Emilio Lèbre La Rovere, William Wills, Carolina Grottera, Cláudio Gesteira, CentroClima/COPPE/UFRJ

Brazilian NDC is quite ambitious targeting a 43% reduction of absolute GHG emissions level in 2030 compared to 2005. The development of new deep decarbonization scenarios for Brazil, beyond 2030 up to the middle of the century is key to design revised and more ambitious strategies that would keep the country's GHG emission pathway in line with the Paris agreement goal of keeping global warming well below 2ºC, ideally below 1.5ºC. This study carried out a comparative analysis of two 2050 scenarios for Brazil: a Reference Case with full implementation of the NDC up to 2030 but without further increase in ambition (Government Plan Scenario – GPS) and a Low Emission Development Strategy compatible with the 1.5ºC target (New Brazil 1.5ºC).

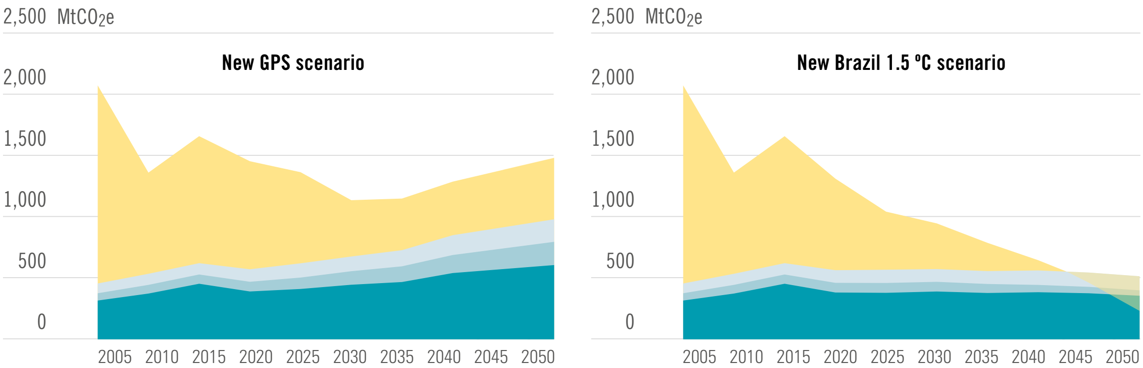
Brazil is currently experiencing one of the most serious recessions in its history as GDP fell 7.5% in the last three years. In 2017, Brazilian GDP is projected to increase only between 0.2 – 0.5%, near stagnation, and by the end of February 2017 the unemployment rate reached 12.6% attaining 12.9 million workers. A major rearrangement of the economy is required to resume economic growth, what is projected only by 2020. With this new trend in mind, we have updated and significantly lowered the pre-crisis projections of high economic growth made by the government and used to design the iNDC. In GPS, the new GDP annual average growth rate assumed for the 2015-2050 period is now 2.8% per year, just slightly higher than the last 35-years average. At this pace, Brazilian GDP per capita would reach the current level of Argentina, Hungary and Poland in 2030, and of Portugal and the Czech Republic in 2050.

According to the Emissions Gap Report (EGR), for a 1.5ºC target global emissions should be limited to 8 $GtCO_2e$ in 2050 (50% probability), in a world with average GHG emissions per capita of 0.82 tons of CO_2e. As Brazilian population will reach 226 million people in 2050, hence in the New Brazil 1.5ºC scenario Brazilian GHG emissions were limited at 186 $MtCO_2e$ in 2050 to stay below the world per capita average and its cumulative GHG emissions from 2010-2050 are made consistent with this 1.5ºC global GHG emissions pathway.

With the same initial GDP growth assumption as in the GPS, to achieve such a deep decarbonization in the simulation of New Brazil 1.5ºC scenario we have added extensive additional mitigation measures (high-efficiency biomass production and use, green electricity generation, electric vehicles, and modal shifts towards railways and waterways in the transportation sector) along with a carbon tax.

In the new GPS, despite significant GDP and GDP per capita growth, emissions per capita are more than halved from 2005 to 2030, and Brazilian NDC targets up to 2030 would be met. However, as no additional mitigation policies are put in place from 2030 on, total GHG emissions would resume growth and reach 1.48 Mt CO_2e in 2050. In the New Brazil 1.5ºC scenario additional mit-

Figure 1. GHG emissions per source from 2010-2050, GPS and New Brazil 1.5 ºC scenario



New GPS scenario

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Energy	317	374	454	391	412	446	468	542	575	607
Waste	60	71	76	79	93	111	128	148	169	190
IPPU	80	91	93	102	117	120	132	162	173	184
AFOLU	1,621	828	1,039	884	745	461	422	438	470	502
Total	**2,077**	**1,364**	**1,662**	**1,457**	**1,367**	**1,138**	**1,152**	**1,290**	**1,387**	**1,484**

New Brazil 1.5 ºC scenario

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Energy	317	374	454	383	380	391	379	385	376	356
Waste	60	71	76	79	81	79	74	60	52	44
IPPU	80	91	93	104	109	104	106	119	117	115
AFOLU	1,621	828	1,039	749	475	374	231	84	-114	-331
Total	**2,077**	**1,364**	**1,662**	**1,315**	**1,044**	**948**	**789**	**647**	**432**	**185**

igation measures are required to bring down Brazilian GHG emissions, reaching in 2050 a level 87% lower than in the GPS (0.185 against 1.48 $GtCO_2e$, see **Figure 1**).
The most important finding of this analysis is that a LEDS such as the New Brazil 1.5ºC scenario does not necessarily have significant negative economic and social implications for Brazil, if implemented through appropriate policies. As a result of the carbon tax, total GDP was slightly reduced in 2030 (-2.0%, from 2.75 trillion 2015 US$ to 2.69 trillion 2015 US$) and in 2050 (-3.8%, from 4.72 to 4.54 trillion 2015 US$) in the New Brazil 1.5 ºC scenario compared to the new GPS. However, the policy of using carbon tax revenues to decrease labour charges has allowed an increase of job creation, helping to keep employment level (see **Figure 2**). Household income has only slightly decreased if compared to the new GPS. The absolute growth from current levels is very significant on both scenarios allowing for considerably improving energy and food security. Social development gains were secured and the public policy targeted at a slow reduction in inequalities set in the GPS scenario was strengthened by the very ambitious mitigation level achieved (see **Figure 3**).

Figure 2. Full time jobs

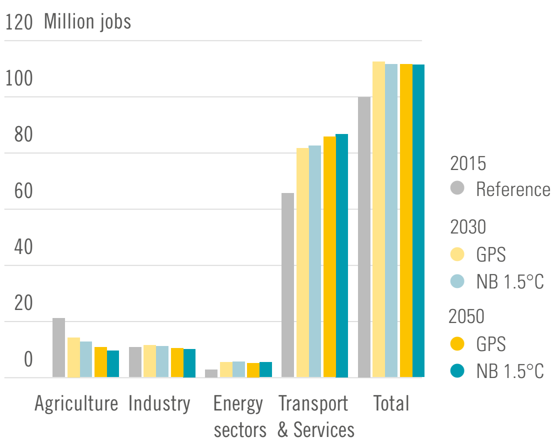
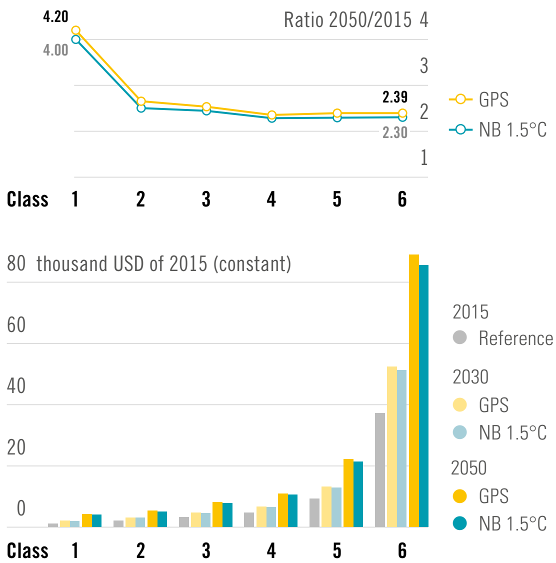


Figure 3. Household income, per income class, in GPS and New Brazil 1.5ºC Scenario



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CHINA Addressing non-CO_2 greenhouse gases in long-term climate strategy

***Fei TENG, Xin WANG,** Institute of Energy, Environment and Economy, Tsinghua University*

China announced its 2020 and 2030 emissions reduction pledges in 2009 and 2015, respectively, which have demonstrated leadership and built momentum for the international climate negotiations. However, China's 2020 and 2030 emissions reduction pledges address only energy-related carbon dioxide (CO_2) emissions. There is no quantified target for non-CO_2 greenhouse gas (NCGG) reduction even though China's NCGGs contributed 2 billion metric tons of CO_2 equivalent in 2012, representing 16.84% of China's overall greenhouse gas (GHG) emissions (excluding land use change and forestry) and approximately 10.55% of the 18.95 billion metric tons of global NCGG emissions. These percentages make it clear that reducing NCGG emissions should be an essential component of China's long-term low-emissions strategy, which is currently under development.

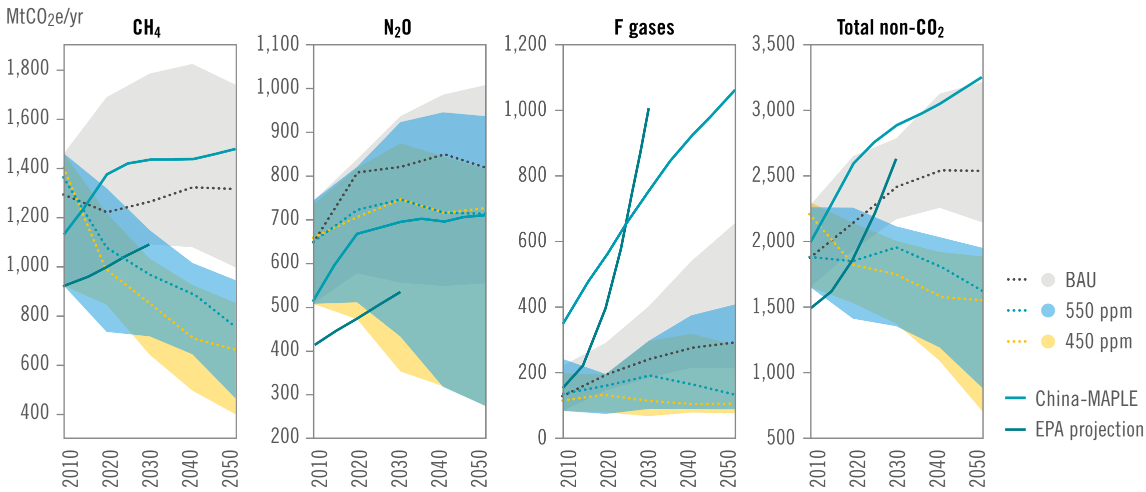
Growing awareness of the benefits of multi-gas mitigation strategies includes studies revealing that a multi-gas mitigation strategy encompassing both CO_2 and NCGG mitigation options is more cost effective and flexible than an approach focused only on CO_2. Furthermore, the significant co-benefits of mitigating NCGG emissions are also highlighted. However, there are still research and policy gaps in advancing NCGGs in China's long-term strategy, especially future projections of NCGG emissions.

Various baseline scenarios developed by different modeling teams have been collected in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). **Figure 1** shows the uncertainty of China's NCGG baseline scenarios. Compared with the range of China's CO_2 baselines from the same model portfolio, the range of NCGG baselines is much wider, with a maximum variance of more than 53.00% in 2030 and more than 74.87% in 2050. By contrast, the maximum variance of CO_2 baselines is only 37.03% and 50.88% in 2030 and 2050, respectively.

Figure 1 | Future NCGG emissions trajectories from IPCC AR5 scenario database. The bands indicate the 20th to 80th percentile for baseline scenarios (blue), scenarios consistent with 450 parts per million (ppm) (grey) and scenarios consistent with 550 ppm (pink) collected in IPCC AR5 scenario database respectively. The dashed lines indicate median values, the blue solid lines indicate U.S. EPA estimates, the red solid lines indicate BaU scenarios estimates in China-MAPLE ,and linear interpolation was used to generate a consecutive time-series estimates.

A challenge is associated with China's capacity to model NCGG mitigation scenarios. Although Chinese modeling teams have participated in international modeling comparison efforts, China's analysis of NCGG mitigation

Figure 1. Future NCGG emissions trajectories from IPCC AR5 scenario database



The bands indicate the 20th to 80th percentile for baseline scenarios (grey), scenarios consistent with 450 parts per million (ppm) (yellow) and scenarios consistent with 550 ppm (pink) collected in IPCC AR5 scenario database respectively. The dashed lines indicate median values, the dark red solid lines indicate U.S. EPA estimates, the red solid lines indicate BaU scenarios estimates in China-MAPLE ,and linear interpolation was used to generate a consecutive time-series estimates.

scenarios is still very limited. This analysis is essential as a basis for sound NCGG mitigation target-setting in China's long-term strategy. In MILES project, China team developed NCGG scenarios presented in **Figure 1**. In this scenario, the total amount of NCCG is 1970.35 $MtCO_2e$, among which CH_4, N_2O and F-gases contribute 57.4%, 26.3% and 16.3% respectively. The NCCG emission in the REF scenario increase markedly towards 2030, reaching 2881.25 $MtCO_2e$, and 3200 $MtCO_2e$ in 2050.

The portfolio of mitigation scenarios for CH_4 represents absolute future reduction potential compared to 2010 levels; however, the reduction rate is still quite uncertain. For N_2O emissions, there is less mitigation potential than for CH_4, with an early peak achievable between 2030 and 2040. For F-gases, a stabilization goal may be more appropriate rather than peaking or absolute reduction. Most of the mitigation potential for F-gases will be low-hanging fruit but will make a limited contribution to the target of reducing global temperature rise by more than 2 °C.

China's early actions to reduce NCGGs align with the country's socio-economic development plans, including supporting the 2016 Kigali Amendment to phase down HFCs emissions. The government also recently announced agricultural CH_4 and N_2O emissions elements for inclusion in NDCs for 2030. However, these are single-gas mitigation policies. A systematic, integrated policy agenda for mitigating NCGGs emissions is needed. To effectively integrate concrete, comprehensive NCGG targets into China's long-term climate strategies by 2020, efforts are needed to strengthen data accuracy and emission monitoring, and conduct research on cost-effective mitigation options and future scenarios that can provide a solid basis for policy decisions. Overcoming the barriers described here will open a path for including NCGGs in China's long-term climate strategy and for development of concrete follow-up actions.

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EUROPEAN UNION Climate policies, NDC and low-carbon pathways

Leonidas Paroussos, Panagiotis Fragkos, Pantelis Capros, *National Technical University of Athens-Institute of Communication and Computer Systems [ICCS]*

The policy brief is based on the journal article published in Energy Policy in 2017 entitled "Energy system impacts and policy implications of the European INDC and low-carbon pathway to 2050" and in the MILES report entitled "A model-based analysis of the European INDC". The research leading to the results has also been partly funded by the European Commission DGENER under the framework contract for "*Long-range energy modelling for the period up to 2050*" and DG CLIMA under the "*Service contract on development and application of EU economy-wide climate change mitigation modelling capacity (all greenhouse gas emissions and removals)*"

The EU has been an early mover in the global climate policy landscape and has ratified the Paris Agreement with its NDC target to reduce GHG emissions by 40% in 2030 from 1990 levels. In the last 20 years, the EU has been decoupling GHG emissions from economic growth with the carbon intensity of GDP declining by about 45% over 1990-2015. The ambitious and transparent EU energy and climate policy framework has led to a rapid expansion of RES in electricity generation, while energy demand has stabilized in 1995-2015. In parallel, GHG emissions have declined by 20% in the period 1990-2015 and the EU as a whole is on track to achieve its 2020 emission reduction targets.

In this context, the European INDC implies acceleration of current climate policy efforts especially in the period after 2020. The 40% GHG reduction target by 2030 (as proposed by the EU INDC) is found to be consistent with the global objective of limiting temperature increase to 2oC if comparable action is also taken around the world. Implementation of the INDC leads to a cost-efficient pathway to achieve the EU's long-term objective of at least 80% reduction in domestic GHG emissions by 2050. Recently, the European Commission presented the "Clean Energy for all Europeans", commonly referred to as the "winter package", a package of measures to keep the EU competitive as the clean energy transition is changing global energy markets. The EU puts in legislation its NDC commitments to the Paris Agreement and the proposed policies and legislation are aligned with EU NDC targets and the 2030 climate policy framework objectives agreed by the European Council regarding GHG emissions reduction, renewable energy and energy efficiency.

Important carbon abatement options

The model-based analysis of the EU INDC is based on PRIMES modelling results and shows that the most important options to decarbonise the EU energy system include:

- Energy efficiency improvements in all sectors of the economy
- High deployment of RES, with RES share in gross final energy demand increasing to 27% in 2030
- Decarbonisation of power generation mainly driven by wind power and solar PV
- Electrification of the transport sector especially after 2030
- Fuel switching in final energy mix towards electricity and natural gas

High RES expansion is driven by significant cost reduction due to accelerated technical progress. For the period beyond 2030, transport decarbonization requires large-scale deployment of electric cars and increased use of advanced biofuels in non-electrified transport modes. The role of electricity is central in the EU's low-carbon transition; the electrification of final energy demand (both in stationary and transport uses) complemented with decarbonised power supply has a critical role for the cost-efficient energy system decarbonization by 2050.

In the INDC context, the power generation sector is projected to undergo a profound restructuring towards the dominance of variable renewables, with the share of solar PV and wind power in power generation increasing from 12% in 2015 to 29% in 2030 and 45% in 2050. In parallel, gas-fired capacities have a strategic role for balancing and reserve to complement expansion of intermittent RES. In the longer term, the massive penetration of variable RES in

Figure 1. Decarbonisation options for the EU energy system

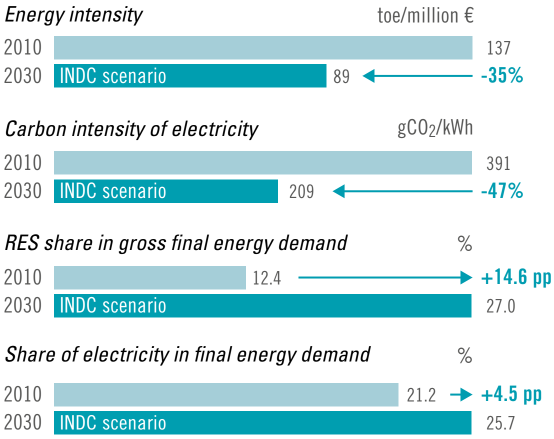
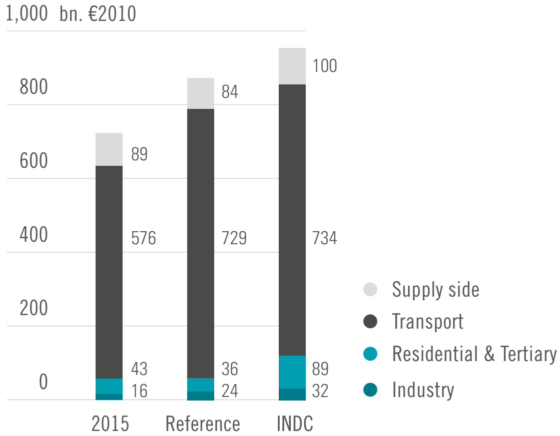


Figure 2. EU energy system investements



the electricity system is supported by the development of small-scale batteries, chemical energy storage (via power-to-gas technologies) and hydro pumping. CCS technologies penetrate after 2035, but their share remains limited at about 13%, as the INDC scenario considers the current difficulties for licensing CO_2 storage sites, acceptability issues and scarcity of storage sites. The large majority of CCS plants use gas (and not coal) due to the ramping flexibility of gas-fired power plants and the possibility of maintaining CHP without CO_2 emissions.

Impacts of the energy system restructuring

The restructuring of the EU energy system implies significant changes in the energy mix away from Reference scenario trends and has impacts on the production and employment in all economic sectors. A rapid change in energy sector investment patterns occurs within the INDC context; upfront investment expenditures increase by 20% from 2015 levels and by 10% from Reference levels in 2030, while the cost of energy purchases declines following implementation of energy saving measures. The EU INDC target implies particularly high challenges for the buildings sector, as investment expenditure have to more than double in 2015-2030 period, due to extensive investments for improving thermal integrity of the building stock and refurbishment of buildings. The energy-related costs for households and firms shift to CAPEX, away from OPEX, which can be a challenge for low income classes.

On the other hand, the low-carbon transition has clear positive implications for security of energy supply, air quality and human health. The energy efficiency gains, together with the shift towards variable RES, reduce the need for imported oil (for transport) and natural gas (for power generation) and lead to a large decline in the EU energy import bill. The CGE analysis performed with GEM-E3 shows that the INDC has relatively limited impacts on the EU GDP, as higher production costs that compress domestic consumption counterbalance the positive effect from increased investment and reduced fossil fuel imports. Favourable financing conditions combined with technology progress for low-carbon options can benefit the EU's economic activity in the medium and long term.

The model-based analysis of the European INDC and its legislative policy package supports the feasibility, technically and economically, of the INDC targets for 2030 and the long-term transition to a low-carbon economy with limited economic impacts. In order to meet the targets, concrete bottom-up policy measures are identified in each sector and are combined with market based mechanisms including the ETS reform; increased ETS carbon prices are difficult to trigger sufficient clean energy investment in transport and in buildings when acting alone. The main challenges towards the EU low-carbon transition are the removal of non-market barriers to enable cost-efficient decision-making of energy agents, the high financing requirements and the coordination of different actors to achieve decarbonization of power supply and road transport. The EU INDC and the 2030 Energy and Climate policy framework can facilitate the effective market coordination between individual consumers, technology developers, policy makers and infrastructure builders towards the cost-efficient low-carbon transition of the European economy.

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INDIA Policy implications of a low-carbon growth

Saritha S. Vishwanathan, Amit Garg, Indian Institute of Management Ahmedabad (IIMA)

To understand the complex dynamics and interactions of energy system and major economic sectors in India in lieu of changing climate, a reference, intended nationally determined contributions (NDC) and 2 °C compatible scenarios have been developed.

The main targets for NDC scenario include: 1) overall emission intensity reduction of its GDP by 33-35% from 2005 level during 2005-2030, and 2) achieving 40% of electric generation capacity from non-fossil fuels by 2030 (INDC, 2015). The range of the carbon budget for a 2 °C scenario for India has been estimated to be between 80-130 bt-CO_2 during 2011-2050 (Shukla et al., 2015; Tavoni et al, 2014).

India's emissions in the NDC scenario decline from the reference scenario levels in all sectors from 2020 and beyond. Total carbon dioxide emissions are projected to decline by about 20% in the NDC and 46% in the 2 °C scenario compared to BAU in 2050. The cumulative CO_2 emissions during 2011-2050 are projected to be 165 bt-CO_2, 147 bt-CO_2, and 123 bt-CO_2 under BAU, NDC and 2 °C scenario respectively (**Figure 1**). By 2030, power sector is responsible for 72% of CO_2 reductions in the NDC scenario, with the industrial sector contributing to about 15% of overall CO_2 abatement effort. The reduction increase under 2 °C are mainly due to demand reduction and addition of carbon capture and storage (CCS) in power and industrial sector. After 2030, the transport sector also starts decarbonizing driven by shifts towards public transportation, higher vehicular emission standards and electrification of passenger vehicles.

In the power sector coal remains the major fuel, constituting 73% of the total fuel mix in 2010 reduced to 32% in 2050 under BAU conditions, 24% in 2050 in INDC and less than 21% for 2 °C. Path dependency, resource availability, matured industrial base and improved technical competence constitute some of the major factors responsible for the reduction. While the share of gas increases from 12% in 2010 to about 38% in 2050. The share of renewables (solar, wind, biomass) increased from 3% in 2010 to 22% in 2050 under refer-

Figure 1. Total CO_2 emissions under BAU, NDC and 2°C scenarios

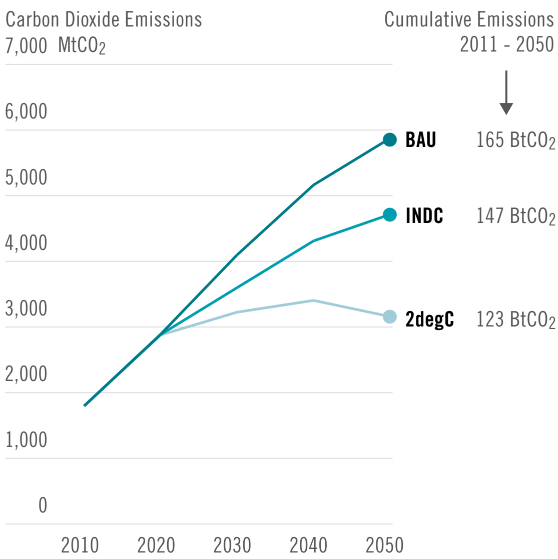


Figure 2. Installed Capacity under BAU, NDC and 2°C scenarios

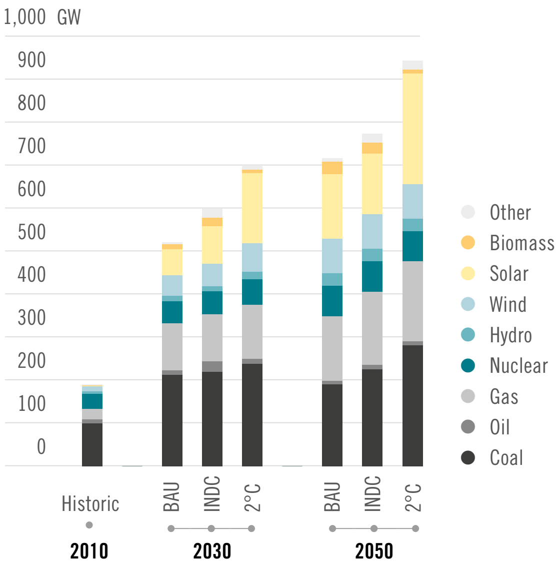
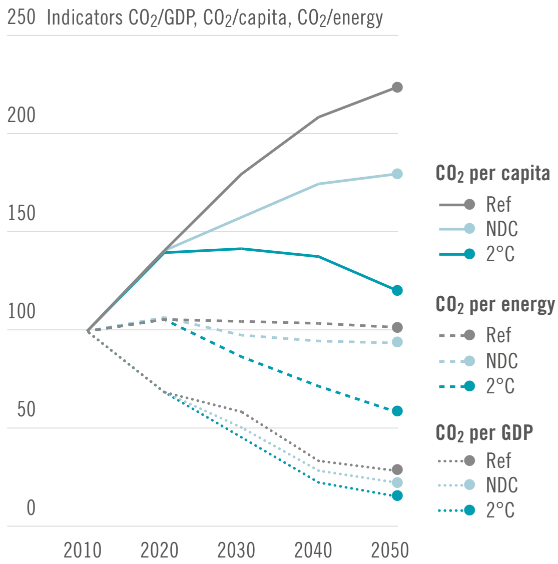


Figure 3. Indicators over time under reference, NDC and 2°C scenarios



ence scenario, whereas the share increases to 32%, and 36% in INDC, and 2 °C scenarios respectively (**Figure 2**). While retrofitting existing coal option seems to have very attractive returns and negative carbon prices, it also requires that a majority of the old inefficient coal power plants are capable of being retrofitted. A sizable amount of coal capacity need to be phased out for flexibility upgrades given that 52 GW of coal capacity will be older than 35 years by 2027. CCS will become a critical technology to mitigate emissions mitigation as coal continues to remain the dominant fuel. The MAC curves for 2 °C show that CCS will be picked up at US$ 40-60/t CO_2 for gas and at US$60-100 for coal power plants. Additionally, CCS in industries that are located within 180-200 km from the selected storage localities can be feasible at US$ 40-70/t CO_2.

Emission intensity of GDP declines by more than 49% in the NDC scenario, assuming India strictly adheres to realising renewable generation capacity (40%) by 2030 compared to 2005 levels. The CO_2 per capita decreases by 20% in NDC and almost 50% in 2 °C when compared to reference scenario in 2050. The energy intensity of carbon decreases by 10% in NDC scenario and by 40% in 2 °C scenario in 2050 when compared to reference scenario (**Figure 3**).

To decouple CO_2 emissions from economic growth and energy basket, it is crucial to adopt deep decarbonization measures such as increase in renewable generation capacity, deployment of CCS and demand reduction through energy efficiency, dematerialization, recycling, reuse, and behaviour and lifestyle changes. Reliability and uncertainty in adopting technologies such as CCS due to lack of field experiments and feasibility data remains a challenge. Concerning lifestyle changes, adopting the measures implemented in the scenarios will be difficult with rising incomes and aspirations, in addition to policy thrust for more infrastructures and indigenous industrialization through 'Make in India' policy. In order to realize the low carbon targets, India needs to not only transform urban infrastructure but also cultivate the younger generation to adopt low-carbon consumption lifestyle.

This policy brief is based on forthcoming journal paper titled "India in 2 deg C and well below 2 deg C worlds - Opportunities and challenges" which is under review in Carbon Management Journal.

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INDONESIA Deep decarbonization for the AFOLU sector and food sovereignty

Rizaldi Boer[1,2], Gito Sugih Immanuel[1], Lukitawati Anggraeni[1,3], Anter Parulian[1], Irsal Las[4], Muhammad Ardiansyah[1,5], Ruandha Agung Sugardiman[6], and Belinda Margono[6]
[1] Center for Climate Risk and Opportunity Management, Bogor Agricultural University
[2] Faculty of Mathematics and Natural Sciences, Bogor Agricultural University
[3] Faculty of Economic and Management, Bogor Agricultural University
[4] Indonesian Agency for Agriculture Research and Development, Ministry of Agriculture
[5] Faculty of Agriculture, Bogor Agricultural University
[6] Directorate General for Climate Change, Ministry of Environment and Forestry

In the National determined contribution (NDC), the Government of Indonesia (GoI) includes an unconditional target to reduce carbon emissions by 29% in 2030 against a business-as-usual level (BaU), a conditional target at 38% under international support. **Figure 1** presents the 2030 emission structure in these three scenarios. The Agriculture, Forestry and Other Land-Use (AFOLU) sector is key since it is expected to contribute to about 60% of the target while energy sector covers about 30%).

The key question is whether the ambitious emission reduction target for AFOLU can be consistent with the key targets of the master plan of agriculture development (2015-2045), notably the achievement of food sovereignty through an increased production of main food crops, mainly rice, maize, soybean, sugar, and meat. This poses a challenge since this strategy may require more land for food production and hence may be in contradiction with the emission objective. In the NDC, food self-sufficiency is assumed only for rice and maize and the production target is reached only for palm oil and wood, requiring then increased reliance on food import for many commodities.

An alternative scenario to NDC has been developed under the MILES project, in order to assess the feasibility of reaching emission reductions consistent with NDC, while achieving food sovereignty by reducing

Figure 1. Projection of GHG emission to 2030 under the BAU and mitigation scenarios

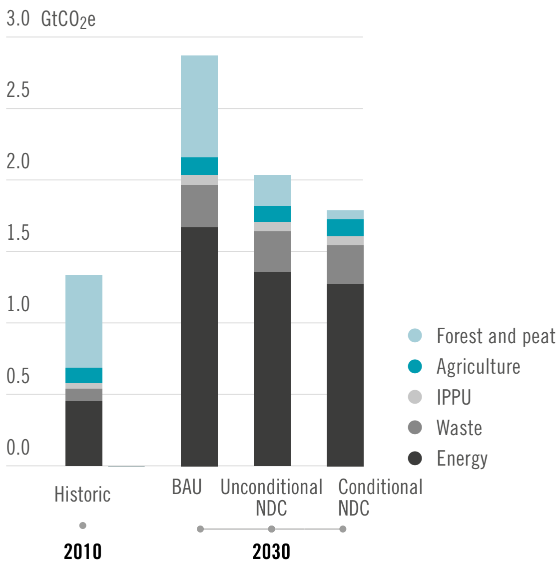
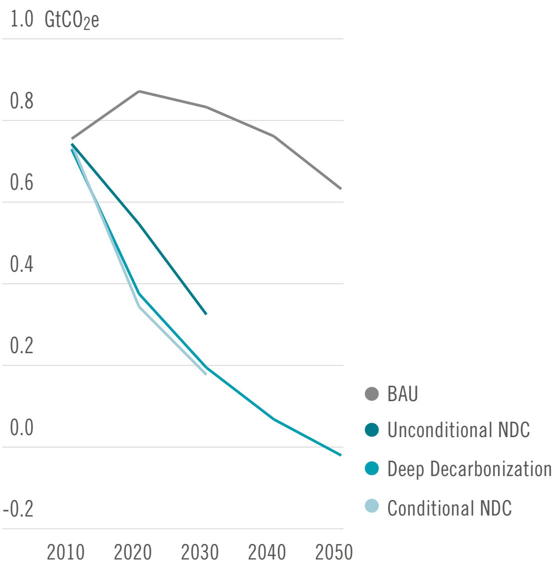


Figure 2. Net emission of BAU and mitigation scenarios of the NDC and DD



reliance on food import, particularly maize, sugar and horticultures. All the scenarios adopt the same demographic and economic assumptions: the annual population growth rate is about 1.1% up to 2020, and then declines to 0.6% until 2050; and the GDP per capita rises at an annual average rate of 4.8% throughout the 2010-2050 periods, consistently with development needs.

The alternative deep decarbonization (DD) scenario of the AFOLU features two major differences compared to the conditional NDC scenario. On the one hand, crop productivity and cropping intensity are assumed to grow faster under DD (but remain lower than the attainable yield) and higher mitigation intervention (reforestation/afforestation, improvement of water management in peatland and peat restoration) are considered. On the other hand, the dependency on food import is significantly lower through notably an increase of land demand triggering an increase of cumulative deforestation, from 4.75 million ha under over 2011-2030 in conditional NDC to about 6.5 million ha under the DD. As a result of these opposite trends, emissions are very similar in the conditional NDC and DD scenarios until 2030 and the DD scenario is consistent with continued reduction of emissions to reach net negative emissions by 2050 (**Figure 2**). The unconditional NDC, conditional NDC and DD require, respectively, about 618, 997 and 895 million USD additional investments for the mitigation action, compared to the business-as-usual scenario.

Over 2011-2030, the main difference between the conditional NDC and the DD scenarios, which are close on emissions, lies in production levels for different agricultural products.

For vegetables, fruits, sugar and other cereal (maize), the DD scenario allows a significant decrease of importation needs, compared to the fast increase under NDC, with important economic benefits. For example, government spent about 800 million US$ per year in 2010 to 2,300 million US$ in 2030 for importing sugar, but under DD it will decrease to about 532 million US$.

For other food crops, i.e. rice and cassava, which already feature surpluses under NDC, the level of this surplus is significantly increased under DD allowing a rise of 2030 exportation revenues compared to NDC, from 9.7 billion $ to 13.4 billion $ for rice, from 5 to 12 Billion US$ for cassava.

For some other industrial crops, i.e. rubber, cacao, tea and coffee, which also feature surpluses, export earnings increase from 10 billion US$ under NDC to about 23 billion US$ under DD.

For palm oil, export revenues under DD amount to about 50 billion US$ but are lower than under business-as-usual given limitations on production (about a division by 2 in 2050). This limitations are implemented to preserve expansion opportunities for other crops, avoid the risk of deforestation and allowing the domestic demand for biofuel of the NDC target to be met.

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MEXICO Electric power generation scenarios in the context of the Paris Agreement

Daniel Buira, Jordi Tovilla, Tempus Analitica

TEMPUS ANALITICA

Mexico´s "Clean Generation" goals are not aligned with the Paris Agreement since they increase Natural Gas use in power generation, driving up sector CO_2 emissions to 2050.

The electricity sector´s "Clean Generation" targets to 2024, 2030 and 2050 form the core of Mexico´s NDC but are not sufficient to achieve the Paris Agreement or Mexico´s Climate Change Law commitments. Planned 2050 power sector emissions will be greater than today´s, taking up over half the permitted national emissions for that year (see **Figure 1**) and exceeding those required by the "Sustained Mitigation" deep decarbonization scenario (compatible with 2°C), by a factor of seven (**Figure 2**).

A high-renewable alternative can provide a stable grid, and will have lower cost than official plans if meaningful international carbon prices take hold.

This study shows, by means of hourly dispatch curves, how the "Sustained Mitigation" scenario can provide a reliable grid while increasing renewable generation far faster than official plans. This scenario still relies on material Natural Gas capacity for balancing, although with far lower dispatch than the official scenario. Although under basic cost assumptions this yields a higher unit cost of dispatched energy, a carbon price aligned with

Figure 1. Reduction of CO_2 emission required by law

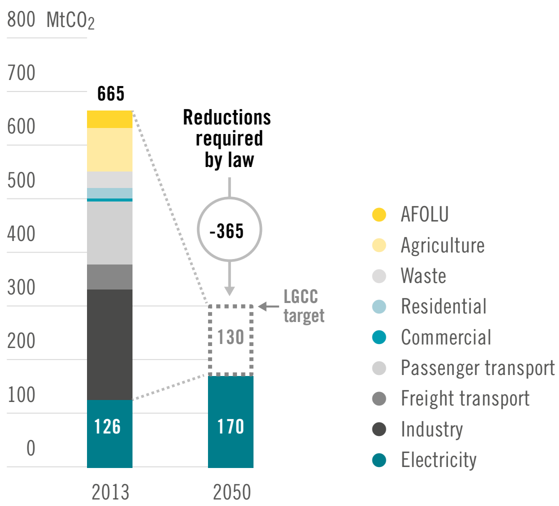
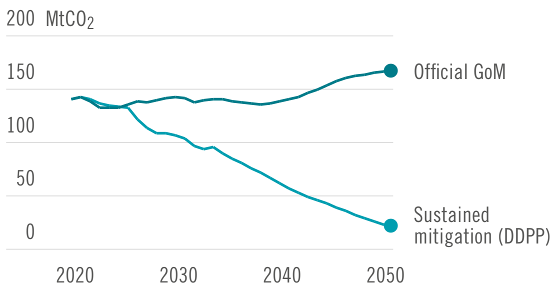


Figure 2. Net emission of Official GoM and sustained mitigation (DDPP) scenarios



the recent High Commission on Carbon Pricing report (chaired by Stiglitz and Stern) would reverse this, making the "Sustained Mitigation" scenario more economically viable than the official plan.

Investments made over the next few years may be decisive, because Natural Gas assets can lock-in emissions and make Paris achievement less likely.

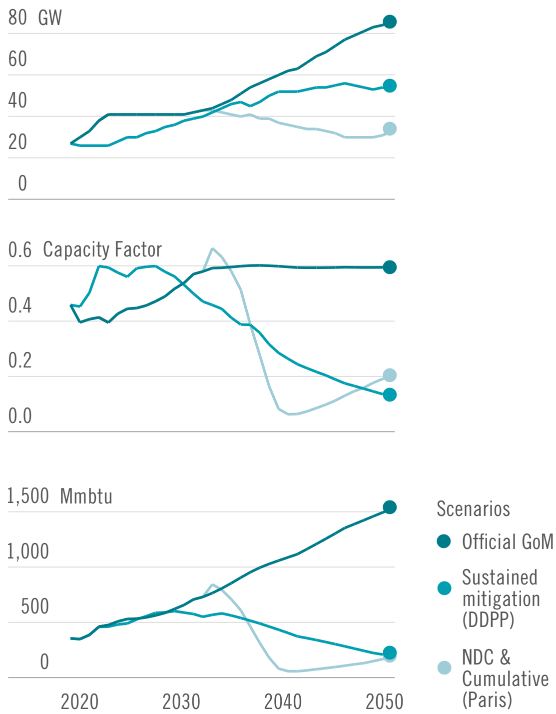
Mexico is currently in the midst of a gas investment boom, which makes sense in the context of official plans. However, the demand for gas-fired power will become significantly lower if Mexico choses to follow policies that are more closely aligned with its commitments, particularly post 2030. If this range of scenarios does not inform investment over the short/medium term, excessive capacity may lead to gas asset underutilization, or emissions lock-in.

Figure 3 illustrates this by comparing capacity installed, capacity factor, and total energy required from gas generation in three scenarios. The official scenario ensures a continuous capacity factor over time through steady growth of capacity and demand. The "Sustained Mitigation" scenario reduces gas investment from now, allowing for a managed reduction in dispatch and the gradual transfer from power to capacity business models. The "NDC & Cumulative (Paris)" scenario follows the official NDC plan until 2030 and then increases ambition to meet cumulative emissions compatible with the Paris Agreement. This leads to a rapid drop in gas power generation post 2030. Achieving such a sudden change will need firm policies, while economic and institutional resistance could lead to significant lock-in and thus missed targets.

Moderating investment in gas capacity over the coming years will thus protect investors as well as increase the likelihood of Mexico delivering on its climate goals.

This study shows the challenges faced by NDC scenarios in achieving long-term climate goals. For Mexico´s electricity sector, dedicated implementation of current NDCs until 2030 as planned may well obstruct eventual compliance with the Paris Agreement. Policy changes are needed before the update timeframes of the NDC and other instruments as currently envisioned, to prevent

Figure 3. Capacity installed, capacity factor, and total energy required from gas generation in three scenarios



emissions lock-in. Mexico should pursue the high-renewables "Sustained Mitigation" scenario from before 2020, and adjust existing 2018-2023 gas build plans accordingly.

Policymakers are advised to use the 2018-2020 period to re-visit energy and climate change plans. Deep decarbonization analyses, the IPCC 1.5°C report, the Facilitative Dialogue, and a host of other inputs should provide information to ensure that the next iteration of plans drive sustained long-term decarbonization across all sectors with well-defined pathways through to 2050. Stock modeling approaches such as that of the EnergyPATHWAYS open-source model used in this study can continue to provide analytical tools and insights for this task.

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UNITED STATES

Energy system restructuring for deep decarbonization

Gokul Iyer, Catherine Ledna, Leon Clarke, James Edmonds, Haewon McJeon,
Pacific Northwest National Laboratory (PNNL)

The United States has set targets to reduce economy-wide greenhouse gas (GHG) emissions in the range of 17% below 2005 levels by 2020, and 26–28% below 2005 levels by 2025. Both of these targets put the United States on a path towards 80% or greater reductions below 2005 levels by 2050. In particular, the U.S. NDC lies on a straight-line path from the 2020 goal toward the 80% target (**Figure 1**).

A key question for decision-makers is the extent to which the NDC would facilitate deeper reductions in the future and the challenges involved in the transition toward a low-carbon economy. We use a state-level model of the U.S. energy system embedded within a global integrated assessment model (GCAM) to compare the rates of energy system transitions through 2025 required to achieve the NDC with rates required to achieve the long-term U.S. deep decarbonization goal of 80% reductions by 2050.

The energy system formulation in GCAM comprises of detailed representations of extractions of depletable primary resources such as coal, natural gas, oil and uranium along with renewable sources such as bioenergy, hydro, solar and wind at regional levels. GCAM also includes representations of the processes that transform these resources to final energy carriers which are ultimately used to deliver goods and services demanded by end users in buildings, transportation and industrial sectors. The version of the model used in the present analysis breaks the energy and economy components of the U.S. into 50 states and the District of Colombia in addition to modeling the simultaneous interactions with 31 other geopolitical regions outside of the U.S.

We model two scenarios: *Reference* and *NDC to Deep Decarbonization*. The *Reference* scenario presents a counterfactual pathway in which no new mitigation policies

Figure 1. The U.S. NDC and 2050 deep decarbonization target

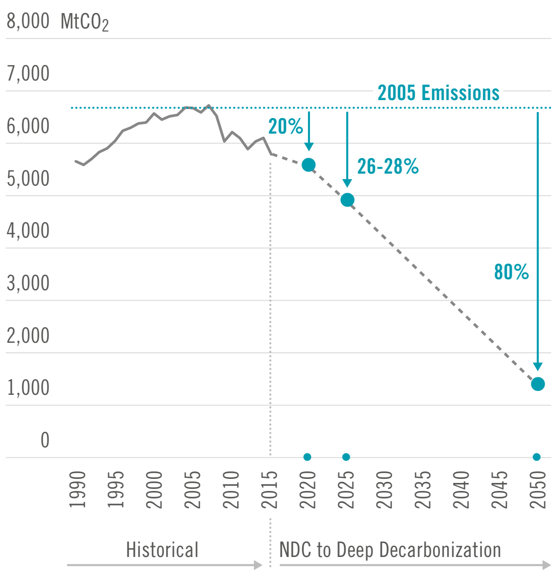
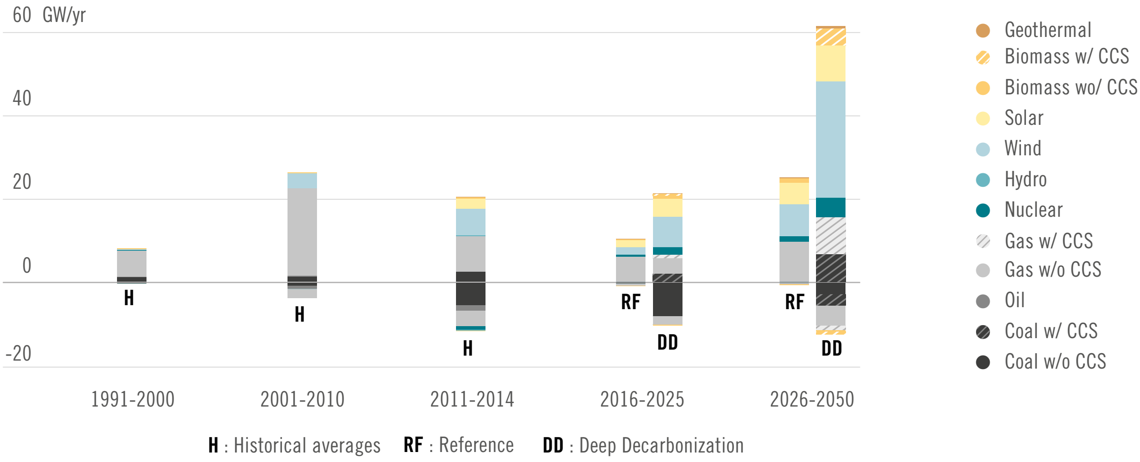


Figure 2. Capacity additions and pre-mature retirements of fossil-fuel based capacity in electricity generation



Historical averages are from the U.S. Energy Information Administration (U.S. Energy Information Administration 2016)

are put in place excepting for a moratorium on coal power. The *NDC to Deep Decarbonization* scenario presents a straight-line emissions reduction pathway, meeting the U.S. NDC in 2025 and leading to 80% emissions reductions relative to 2005 levels by 2050. Both scenarios assume limited deployment of bioenergy consistent with the U.S. Department of Energy's Billion Ton Study (U.S. Department of Energy 2011). Using GCAM, we compute the rates of capacity additions, capital investments and pre-mature retirements of fossil-fuel based capacity in the electricity generation sector, a pivotally important sector in most assessments of U.S. emissions mitigation, implied by the NDC. We then compare these rates with rates required to achieve the long-term U.S. deep decarbonization goal of 80% reductions by 2050 to draw insights about the scale of challenges involved in achieving the 80% deep decarbonization target.

Our results suggest that although the U.S. NDC lies on a straight-line path toward deep decarbonization, the energy system transitions required to reach 80% are non-linear, and increase dramatically in the period following the NDC (**Figure 2**). Rates of capacity additions and capital investments in electricity generation beyond 2025 are more than three times the rates during the next decade. This implies that achieving the 80% target will require a strengthening of policies, infrastructure and institutions beyond what exists today and what is expected to be put in place to achieve the 2025 NDC.

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Notes

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IDDRI

Institut du développement durable et des relations internationales
27, rue Saint-Guillaume
75337 Paris cedex 07 France

WWW.IDDRI.ORG