Emission pathway modeling to analyze national ambition levels of decarbonization

The Deep Decarbonization Pathways Project (DDPP) is a knowledge network comprising 15 Country Research Teams and several Partner Organizations which develop and share methods, assumptions, and findings related to deep decarbonization. It analyzes the technical decarbonization potential, exploring options for deep decarbonization, but also better taking into account existing infrastructure stocks. It shows the possibility to reduce total CO_2-energy emissions by 45% by 2050, with bottom-up analyses by 15 Country Research Teams.

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Introduction

According to the fifth assessment of IPCC [1], global GHG emissions levels in 2020, based on the Cancun Pledges, are not consistent with cost-effective, long-term mitigation trajectories that limit the temperature change to 2 °C relative to pre-industrial levels. Meeting this goal would require further substantial reductions beyond 2020. The Deep Decarbonization Pathways Project (DDPP) analyses the technical decarbonization potential, exploring options for even deeper decarbonization, but also better taking into account existing infrastructure stocks [2]. The DDPP is a knowledge network comprising 15 Country Research Teams (Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, United Kingdom, United States) and several Partner Organizations which develop and share methods, assumptions, and findings related to deep decarbonization.

DDPP aims to draw some lessons for the international negotiations leading up to the 21st Conference of the Parties (COP 21) of the UN Framework Convention on Climate Change (UNFCCC), based on emission pathway modeling analyses.

The 15 DDPs developed by the Country Research Teams share three common pillars of deep decarbonization of national energy systems: energy efficiency and conservation, low-carbon electricity, and fuel switching. Within the three pillars that are common to all countries, individual DDPs show a wide variety of different approaches based on national circumstances. Differentiating national circumstances include socio-economic conditions, the availability of renewable energy resources, and national preferences regarding the development of renewable energy, CCS, and other technologies.

Current estimates of DDPs show the possibility of achieving deep absolute emissions reductions by 2050. Total CO_2-energy emissions from the 15 preliminary

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DDPs reach a level of 12.3 Gt by 2050, down from 22.3 Gt in 2010. This represents a 45% decrease of total CO_2-energy emissions over the period, and a 56% and 88% reduction in emissions per capita and carbon intensity of GDP, respectively.

Economic growth and energy demand

All 15 DDPs assume continued—and for some countries rapid—economic growth by 2050. Assumed GDP growth rates are especially strong in today's middle-income economies, which start from lower levels of GDP per capita than high-income countries today, and therefore have room for catch-up growth. As a result of sustained economic growth, all 15 DDPs anticipate higher levels of GDP per capita in 2050 than South Korea today.

Across the 15 DDPs, average energy consumption per capita converges to two metric tons of oil equivalent (toe) by 2050. It declines in absolute terms in high-income countries, where energy efficiency improvements outweigh population and GDP growth. In middle-income countries, on the other hand, energy consumption increases in absolute terms as a result of improved energy access and rapid GDP growth, in part driven by energy-intensive industries. However, this increase is lower than it would otherwise be because of improvements in energy efficiency.

Energy efficiency and CO_2 intensity

All 15 DDPs achieve a large decrease in CO_2 intensity of GDP (t-CO_2 emitted per $ GDP) by 2050 compared to 2010: 88% on average. This is the result of the combined effects of: (1) a decrease in the final energy intensity of GDP (toe consumed per $ GDP) and (2) a decrease in the CO_2 intensity of energy (t-CO_2 emitted per toe of final energy consumed). On average, the energy intensity of GDP decreases by 70% between 2010 and 2050, and the CO_2 intensity of energy decreases by 60%.

The relative importance of these two elements in the DDPs changes over time (Figure 1). Reducing energy intensity of GDP is more important in the early phase, while reductions in the CO_2 intensity of final energy consumption play a larger role in the long term. The dynamics in Figure 1 are driven, in part, by the effects of electrification. All Country Research Teams use decarbonization of electricity supply and electrification of energy end uses as a strategy for deep decarbonization, to different extents. In the short run, electrification has only a small effect on the CO_2 intensity of energy, since electricity generation is still rather carbon-intensive. Though electrification plays a big role in the decrease of the CO_2 intensity of energy over the longer term as electricity supply is decarbonized. These kinds of sequencing challenges, and their implications for cumulative CO_2 emissions, will be further explored in the next phases of the DDPP.

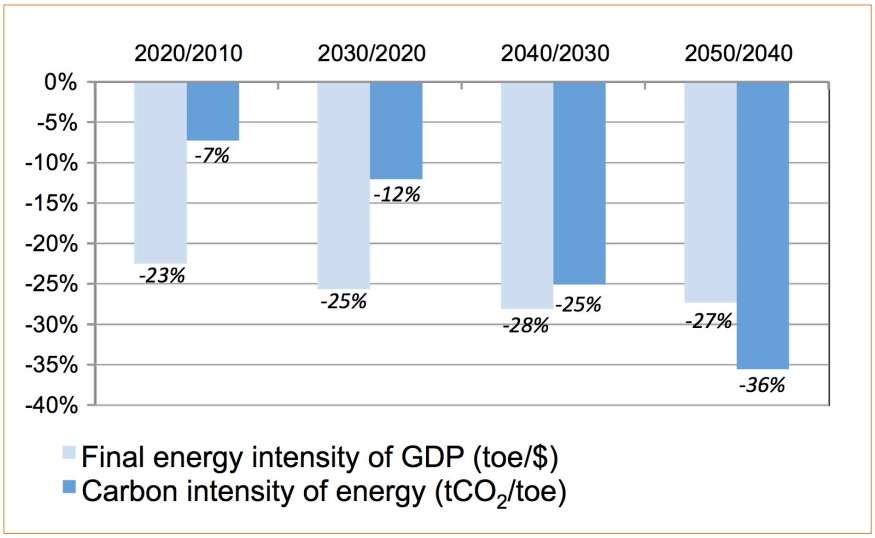

FIGURE 1 Decadal percent change in energy/GDP and CO_2/energy for the 15 DDPs, 2010 to 2050
Source: [2]

Power generation: switch to low-carbon electricity

Electrification and decarbonization of electricity play a central role in all 15 DDPs. Electricity has a much larger role in energy supplies. The share of electricity in final energy consumption almost doubles from 2010-2050, rising from 19% to 35%. Power generation is almost completely decarbonized in all countries. On average, the CO_2 intensity of power production is reduced by 94%, from 617 g-CO_2 per kilowatt-hour (kWh) in 2010 to 34 g-CO_2 per kWh by 2050.

To reach such a low level of carbon intensity, power needs to be generated almost exclusively from zero- or low-carbon sources in all countries: renewable energy, nuclear power, or fossil fuels with CCS. Across countries, the DDPs achieve the deep decarbonization of power generation through a diverse mix of low-carbon energy sources because countries have different potential for renewable energy, geological storage capacity for CCS, and social preferences and degrees of public support for nuclear power and CCS (Figure 2). For example, the DDP developed by the Indian team decarbonizes power generation using primarily renewable energy and nuclear power, but not CCS, because the scale of the potential for geological carbon sequestration in India is still uncertain. At the other end of the spectrum, the DDPs developed by the Canadian, Chinese, Indonesian, Japan, Mexican, Russian, UK, and US teams project a significant share of coal and gas-fired power generation with CCS by 2050. It is noted that some country teams have also developed scenarios with both a low and a high share of CCS. By 2050, almost all electricity in all 15 DDPs is expected to be generated from zero- and low-carbon sources.

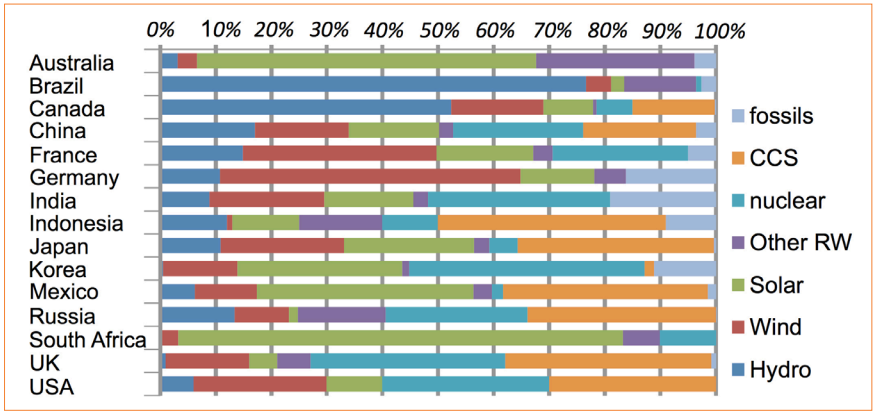

FIGURE 2 Characterization of electricity production in 2050
Source: [2]

Steps toward deep decarbonization

As the DDPP and many other analyses make clear, staying within 2 °C will require deep transformations of energy and production systems, industry, agriculture, land use, and other dimensions of human development. It will require profound changes in the prevailing socio-economic development frameworks. Many of the technologies that will need to underpin these transformations are available, but many others are not ready for large-scale deployment. Making critical low-carbon technologies commercially available and affordable, enabling countries to pursue long-term transformations, will require long-term international cooperation and trust.

Deep decarbonization of the world's energy systems requires the deployment of new low-carbon technologies to transform energy production and consumption patterns. This in turn will require accelerated research, development, demonstration, and diffusion (RDD&D) of these emission-reducing technologies to make them reliable, cost-competitive, and widely available in every country.

One of the important areas of RDD&D is energy storage and grid management. Recent sharp declines in the cost of solar photovoltaic modules, and more gradual declines in price of wind turbines, have reduced the direct costs of electricity from time-varying renewable energy resources to levels comparable to that from other fuels in many countries. The

cost of solar and wind energy, per se, is therefore no longer a substantial impediment. The main challenge remains the intermittency of these energy sources and therefore their inability to provide reliable power on a desired schedule.

Another important issue is to link national strategies with local ones. Lots of local efforts to reduce CO_2 emissions have been made in many cities world-wide. For example, Tokyo metropolitan government set a target to reduce CO_2 emissions by 25% by 2020 compared to the 2000 level. It also has a target to reduce final energy consumption by 20% by 2020, compared to the 2000 level. It has conducted climate change actions such as a cap-and-trade program for large facilities, requesting carbon reduction reporting and reducing tax for small- and medium-size facilities, sending energy saving advisers and delivering environmental education for the residential sector, providing subsidy for electric vehicles and plug-in hybrid vehicles. The total CO_2 emissions from facilities covered by the cap-and-trade program dropped by 22% from the base year (between 2002 and 2007 depending on the previous efforts by the facilities) to 2012. Such kind of local governmental efforts are also crucial to reduce CO_2 emissions from the end-use side.

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[1] IPCC, 5th Assessment Report: Mitigation, 2014, available at http://www.ipcc.ch/report/ar5/wg3/.

[2] Pathways to deep decarbonization – 2014 report, Sustainable Development Network (SDSN) and Institute for Sustainable Development and International Relations (IDDRI), September 2014, available at deepdecarbonization.org.