

Pathways to zero emissions

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To keep global warming below 2 °C, countries need long-term strategies for low-emission development. Without these, immediate emissions reductions may lock-in high-emitting infrastructure, hamper collaboration and make climate goals unachievable.

In the 2015 Paris Agreement, countries committed to balancing greenhouse gas emissions and removals in the second half of this century. Put simply, governments recognize that in order to limit temperature increases to well below 2 °C above pre-industrial levels, they must achieve net-zero emissions.

The global policy discussion often fails to acknowledge the complexity and scale of emission reductions required to meet this objective. In order to stay within a carbon budget that would provide a chance to limit warming to 2 °C, average energy-related emissions of greenhouse gases need to fall from some 6.4 tons of CO₂ per capita emitted today¹, to around 1.7 tons of CO₂ in 2050, and to zero by 2070^{2–4}. However, if the world's gross domestic product (GDP) continues to grow at rates observed over the past ten years, the world economy will increase two- to threefold by 2050. Emissions per unit of world GDP would then need to fall by a factor of seven to eleven. Staying within 1.5 °C will require net-zero emissions as early as 2050, that is, within less than the lifetime of a new power plant built today.

Low-cost solutions can make it more difficult or even impossible to achieve net-zero emissions.

Fortunately, the Paris Agreement⁵ introduces a policy instrument to encourage every country to undertake an analysis and a public discussion of how to decarbonize its energy system and reduce non-energy greenhouse gas emissions: in Article 4.19 countries resolved to “formulate and communicate long-term low greenhouse gas emission development strategies” by 2020.

Here we argue that such low-emission development strategies are key for avoiding lock-in to an energy system that would not allow full decarbonization in the

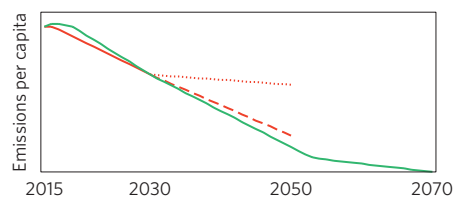


Figure 1 | Illustration of the long-term low-emission development strategies consistent with limiting warming to 2 °C and short-term INDCs. A long-term low-emission development strategy (green line) achieves net-zero emissions by 2070. A short-term INDC (red solid line) might achieve the same 2030 target, but instead of preparing long-term emission reductions as commonly projected (red dashed line), short-term strategies that are not based on long-term pathways will lead to lock-in (red dotted line).

long term. In our view, low-emission development strategies are an essential tool for problem solving, long-term energy planning and international collaboration. Our analysis builds on lessons from the Deep Decarbonization Pathways Project, a collaborative effort across 16 national research teams to prepare long-term pathways for reducing emissions consistent with limiting the rise in the global average temperature to less than 2 °C (refs 4,6,7).

The need for long-term strategies

Before the advent of low-emission development strategies, global climate policy had focused exclusively on the period 2025 to 2030 for the implementation of emissions cuts, with the intended nationally determined contributions (INDCs) that were collected in the run up to the Paris Agreement to be finalized as nationally determined contributions by 2020. However, short-term strategies not embedded in long-term pathways may encourage governments to adopt low-cost solutions that can make it more difficult or even impossible to achieve net-zero emissions within the timeframe of 2050 to 2070.

As an illustration of the problem, two distinct pathways for reducing 2030 emissions per capita by one-third relative to 2015 (as suggested by the emission ranges presented in the Emission Gap Report⁸) lead to very different long-term outcomes (Fig. 1). In the first strategy, low-cost steps are taken by replacing coal-fired power plants with natural gas plants and increasing the fuel efficiency of conventional automobiles with internal combustion engines. This approach, followed by many INDCs, may deliver the one-third reduction needed by 2030. However, the country will then be locked into continued emissions from gas-fired power plants and conventional vehicles, with poor prospects for rapid progress to net-zero emissions by 2070 or earlier.

Alternatively, a different strategy compatible with long-term emission reductions would be to replace coal-fired plants with zero-carbon power generation, and conventional vehicles with all-electric vehicles or other technologies that produce zero tailpipe emissions. This transformation might initially be more expensive and slower than the first strategy, but it would put the country firmly on the path to net-zero emissions. Indeed, the shift to electric vehicles might have little effect on national emissions in the early years, as the power system will still largely be fossil fuel based, but it will lead to sharp emission reductions in the long term as power generation shifts to zero-carbon primary energy.

Therefore, both to design and to assess the INDCs, it is critical to evaluate whether a potential INDC pathway to 2030 will support deep emission reductions after 2030, or whether it might instead lock the country into continued relatively high emissions after 2030. Current analyses of INDCs do not make this distinction; instead they tend to mechanically extrapolate headline emission reductions to 2050. As many countries prioritize low-cost solutions in their INDCs, such extrapolations probably overstate the long-term emission reductions implicit in the current round of INDCs. Moreover,

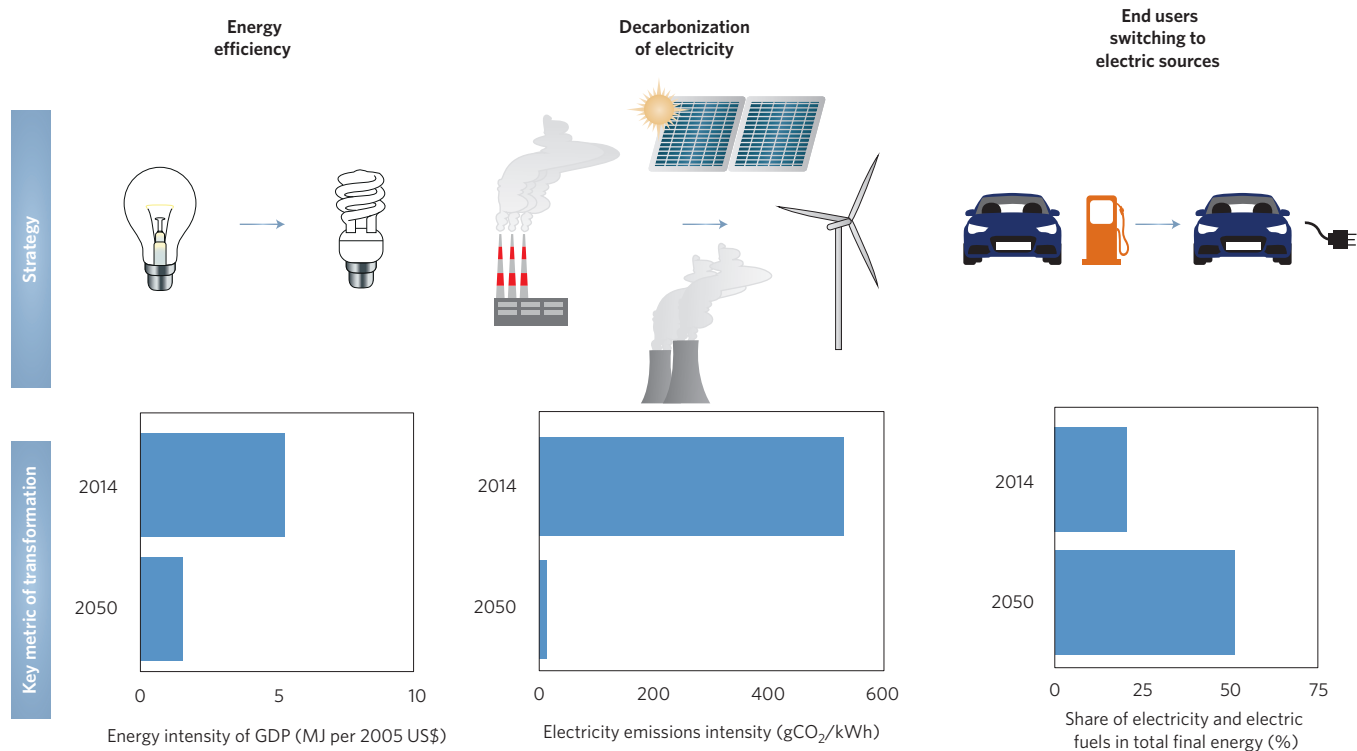


Figure 2 | The three pillars of decarbonization. Low-emission development strategies need to address three key areas related to the energy system: energy efficiency; electricity generation without carbon emissions; and end users switching from carbon reliance to electric sources (top row). Key metrics include energy intensity per GDP, emissions intensity per unit of electricity and share of electricity in final fuels (bottom row; illustrated for the case of the United States). Figure adapted with permission from refs 10 & 11.

today's INDCs are not only too short term, but they also do not reach the levels of emission reductions required by 2030^{8,9}.

Deep decarbonization

Sixteen national pathways were developed by the Deep Decarbonization Pathways Project's national teams to demonstrate that low-emission economic development consistent with 2 °C is feasible. The pathways vary by country, in terms of technology choices, investments and policies that are reflective of national circumstances and choices. Yet they all are underpinned by the same three key pillars of decarbonizing energy systems¹⁰: high levels of energy efficiency; near complete decarbonization of power generation; and the substitution of end-use equipment (such as vehicles or heating) to electricity where feasible, but otherwise to lower-emission fuels (Fig. 2).

Current energy technologies can sustain the upper limit of the carbon budget for 2 °C (as defined by the Intergovernmental Panel on Climate Change), but they will need significant improvements in performance in order to do so at low cost⁴. Transparent low-emission development strategies provide technology benchmarks with set timeframes for implementation,

for example, for minimum penetration rates of vehicles with zero tailpipe emissions and for the carbon intensity of newly constructed power plants. These benchmarks will mobilize and direct public and private resources to accelerate the development and diffusion of low-emission energy technologies.

Low-emission development strategies can become a dynamic ratchet mechanism for ambition, rigor and operational effectiveness.

The Deep Decarbonization Pathways Project shows how low-emission development strategies can also provide insights into the financial costs of decarbonization. For the US, net costs are estimated to peak at around 1% of GDP per year during the 2030s¹¹. For low-income countries, low-emission development strategies will spell out the long-term support required — in terms of financing and technology access — to make low-emission development and net-zero emissions possible.

A method for problem solving

The analyses from the Deep Decarbonization Pathways Project underscore the depth of the energy transformations required in each country. Success will require unprecedented problem solving and a societal consensus on how to achieve deep decarbonization. Transparent low-emission development strategies provide a framework for engaging key stakeholders, such as governments, businesses, civil societies and the scientific community, to review, pose questions and suggest improvements. This process may lower the cost, improve the feasibility, and increase the buy-in of moving towards net-zero emissions in the country. Low-emission development strategies demonstrate how countries can improve their overall well-being and they invite countries to decide how to compensate losers from deep decarbonization, such as coal miners. Indeed, California has used such a process to build broad support for its commitment to reduce greenhouse gas emissions to 40% below 1990 levels by 2030; and 80% below 1990 levels by 2050^{12,13}. France and Germany, too, have engaged in structured dialogues on decarbonization¹⁴.

Low-emission development strategies are also an important method for building trust between countries and for fostering

international collaboration. A transparent and rigorous low-emission development strategy will demonstrate a country's seriousness to achieve net-zero emissions and will allow others to assess the adequacy of the country's short-term climate policies. In this way low-emission development strategies will build trust among countries that decarbonization has begun, which in turn can spur greater domestic action. As the world learns how to undertake deep decarbonization, low-emission development strategies can become a dynamic ratchet mechanism for ambition, rigor and operational effectiveness of national climate strategies.

Nest short-term actions in pathways

The nationally determined contributions need to be nested in a low-emission development strategy. This will require careful modelling⁷ and three structural shifts for today's INDCs. First, to achieve net-zero emissions from energy use, every nationally determined contribution should address all three pillars of decarbonizing the energy system. Greater analytical work is needed on how to reduce emissions from land-use change.

Second, the nationally determined contributions should spell out policies to promote the development and diffusion of improved low-emission technologies. Finally, nationally determined contributions must guide and coordinate policies across a broad range of sectors that traditionally do not coordinate closely, such as electricity and transportation; or urban planning and building codes.

Opportunities for early action

Even before the Paris climate meeting, many heads of state had already committed to prepare low-emission development strategies consistent with a global warming limit of 2 °C, as stated, for example in the US–China Presidential statement¹⁵ and an informal statement by 44 heads of state at the UN¹⁶. A growing number of cities and provincial governments are also committing to put forward low-emission development strategies.

The 2016 Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), in



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Marrakesh, Morocco, provides the next important opportunity for building a shared understanding of how to design and implement low-emission development strategies. The Government of Morocco, the World Business Council for Sustainable Development, Local Governments for Sustainability, and the Sustainable Development Solutions Network will co-host a Low-Emissions Solutions Conference to bring together technical experts from all UNFCCC parties, including scientists and business leaders, to explore the practicalities of achieving net-zero emissions in the second half of the century.

In the summer of 2017, at the G20 in Germany every member country should present a preliminary national low-emission development strategy. Subsequently, other countries, too, should consider how their INDCs needs to be revised. The process of finalizing low-emission development strategies and revising national contributions must then be completed by 2020, as agreed in the Paris Agreement. □

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