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

SciencesPo

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2050 low-emission pathways: domestic benefits and methodological insights – Lessons from the DDPP

The DDPP Network
(see back cover for details)

The invitation for countries to communicate long-term pathways is a key provision of the Paris Agreement, specifically to support domestic measures and increase in ambition in the 5-year cycles. It is a key instrument for countries to build a concrete vision of the national low-emission transition, consistent with global climate goals but also widely shared by domestic stakeholders and explicitly articulated with domestic socio-economic priorities. The Deep Decarbonization Pathways Project (DDPP) actualizes the process for designing such long-term pathways that reflect national circumstances and gives proof of concept for how they can be useful to support domestic mitigation transformations. In this sense, the DDPP results illustrate the domestic benefits of designing long-term pathways, and shed light on key methodological insights to be used for this purpose.

KEY MESSAGES

The DDPP experience shows that designing long-term pathways can help:

1. **Build development pathways that are consistent with both national circumstances and global climate constraints**, by adopting collective benchmarks and an explicit representation of crucial variables that both drive emissions and measure important development metrics.
2. **Support the identification of country-specific actions towards low-emission futures**, by using a transparent and sectorally detailed common reporting template (the "dashboard") to structure a collective learning process through structured comparisons across different visions.
3. **Select the short-term actions needed to follow truly transformative pathways in the long term**, by adopting a "backcasting" approach which starts by defining a desirable future and works backwards to identify the policies and programs needed to reach that future from the present.
4. **Inform the regular revisions of domestic transformations in a context of uncertainties,** by developing several low-emission scenarios and making explicit the challenges, barriers, opportunities and enabling conditions associated to each of them, at different time horizons.
5. **Ensure that low-emission transformations are consistent with the satisfaction of domestic development priorities**, by using country-specific modeling tools to support the design of national scenarios, and in doing so provide scientific rigour to the articulation of emissions and development trajectories. A complementary approach to stakeholder engagement during the design of scenarios is needed to generate greater buy-in from a range of domestic stakeholders.
6. **Reveal the requirements from international cooperation to enable domestic transformations,** by providing an explicit vision of the physical, technical and economic dimensions of the domestic transformations that can then be aggregated to form a global picture emerging as a composite of national trends.

1. LONG-TERM PATHWAYS, A KEY INSTRUMENT FOR COUNTRY-DRIVEN, AMBITIOUS MITIGATION

The Paris Agreement (PA) defines a new paradigm for climate action framed by the self-selection of objectives, as reported in the Nationally Determined Contributions (NDCs), and of actions implemented by countries to follow them (Art 3 and Art 4.2). The Deep Decarbonization Pathways Project (DDPP) network is a global collaborative research initiative, designed to support this bottom-up approach of climate talks in its mitigation aspects through the study of national deep decarbonization pathways by in-country research teams from developed and developing countries.[1]

The follow-up of the mitigation part of NDCs is organized in a dynamic process in cycles, enabling an effective regular collective monitoring of measures adopted to meet NDC objectives. These cycles invite successive revisions of emission objectives every five years to progressively align national contributions with the requirements of the global climate goal (Art 3, 4.3, 4.9).[2]

A key condition for this process to effectively trigger action and ambition is to ensure that it enables practical domestic appreciation of challenges and opportunities brought by the low-emission transformation. To this aim, analytical work done at the country level needs to help identify potentials and options for emissions reductions that reflect the domestic vision of "equitable access to sustainable development and eradication of poverty" (preamble of the PA) and effectively capture the dynamic nexus between domestic development priorities and mitigation objectives. To support this process, the Paris Agreement invites Parties to "formulate and communicate long-term low greenhouse gas emission development strategies" (Art 4.19).

Such long-term pathways are country-led benchmarks that can establish a bridge between national medium term emissions, as considered in NDCs, and long-term domestic mitigation and development outcomes. Given their non-binding nature, the long-term pathways offer a space to conduct a wide consultation process with different groups of domestic stakeholders to develop an in-depth and detailed understanding of the mitigation transformation and build a sense of shared ownership around it. They can therefore provide the structure for an open discussion about development trajectories and the different options to domestic mitigation, stimulating the domestic creativity and catalyzing the production of country-led analyses. The knowledge produced during such process can eventually serve as input into both the domestic NDC revisions, and the collective assessments of the stocktaking dialogues.

1. Although recognizing adaptation as a key aspect of NDCs (Art 7), the expertise of the DDPP country research teams lies in mitigation, which will therefore be the focus of this paper.
2. Spencer, T. *et al.* (2015). Regular Review and Rounds of Collective Action and National Contributions the 2015 Climate Agreement: A Proposal, IDDRI-NCSC.

2. WHY AND HOW CAN LONG-TERM PATHWAYS BE CONCRETELY USEFUL TO COUNTRIES?

IDDRI's Policy Brief "Long-term low emissions development strategies and the Paris Agreement – Why, what and how?"[3] presents initial guiding principles about how the long-term strategies introduced by Article 4.19 should be implemented to be useful in the post-Paris context. In particular, they must be transparent, granular, structured and articulate short-term actions with long-term objectives; they should above all be seen as 'structured strategy exercises' rather than complex modelling exercises.

These methods were applied by country research teams from 16 countries in the first phase of the DDPP to develop national deep decarbonization pathways to 2050 consistent with the 2°C limit. The DDPP provides a proof of concept regarding how long-term strategies can be appropriated at the national level and become a real part of the domestic policy discussion.

IDDRI's Issue Brief "The impact of the Deep Decarbonization Pathways Project (DDPP) on domestic decision-making processes – Lessons from three countries"[4] shows how the DDPP studies have directly provided useful inputs in the domestic debates of three countries (Australia, Canada, France).

Based on these experiences and, more generally, on a cross-cutting look at the DDPP results and methods, we present here six key benefits that countries can expect from the development of long-term pathways.

3. Waisman, H. *et al.* (2016). Long-term low emissions development strategies and the Paris Agreement – Why, what and how?, IDDRI, *Policy Briefs* N°06/16. Available at: http://www.iddri.org/Publications/Long-term-low-emissions-development-strategies-and-the-Paris-Agreement-Why,what-and-how
4. Argyriou, M *et al.* (2016). The impact of the Deep Decarbonization Pathways Project (DDPP) on domestic decision-making processes – Lessons from three countries, IDDRI, *Issue Briefs* N°11/16. available at: http://www.iddri.org/Publications/he-impact-of-the-Deep-Decarbonization-Pathways-Project-(DDPP)-on-domestic-decision-making-processes-Lessons-from-three-countries

Figure 1. Energy-related CO_2 emissions per capita

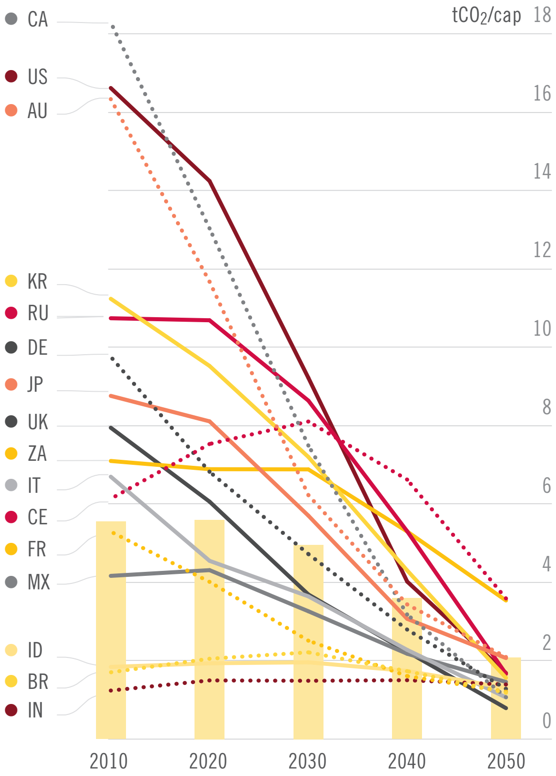


Figure 2. Growth rate of GDP per capita, 2010-2050

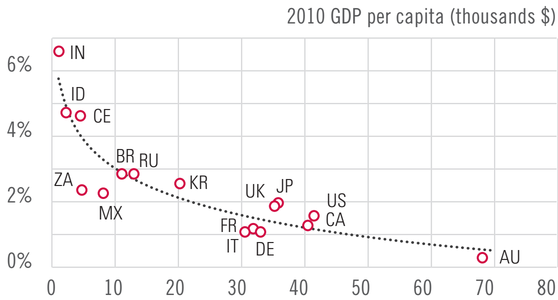
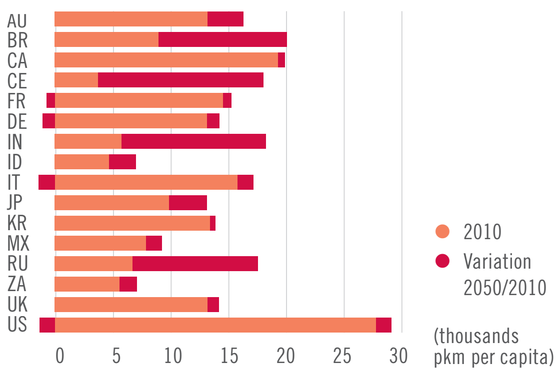


Figure 3. Passenger mobility



2.1. Building development pathways that are consistent with both national circumstances and global climate constraints

Results. The country scenarios of the DDPP reach, in aggregate for the 16 countries covered, emission trajectories in line with a 50% likelihood of being consistent with the 2°C limit.[5] The results for individual countries feature a variety of trajectories which provides a sort of recombined, *ex post* picture of the domestic visions of equitable contributions to the global effort (Figure 1). Three distinct types of per capita emissions profiles are obtained that correspond to the effect of a strong reduction in emissions per unit of GDP in all cases but with different country circumstances:

- Fast and profound declines with moderate GDP growth rates in developed economies (Australia, Canada, France, Germany, Italy, Japan, South Korea, United Kingdom, and USA, in our DDPP sample).
- Peak, plateau and decline trajectories in upper-middle-income economies (Brazil, China, Mexico, Russia, and South Africa).
- Moderate growth and stabilization of emissions in lower-middle-income economies (India and Indonesia).

These emission profiles are not predetermined results, but are *ex post* outcomes, resulting from the selection of set of actions adapted to each country context to simultaneously reach the decarbonization goal and the domestic development objectives.

Methodological lessons. Imposing targets on emissions for the definition of country-driven pathways would not be a relevant approach; indeed, whatever the metrics used (emissions per capita, emissions per unit of GDP or in any other indicator), this would fail to capture important differences across countries (like the technical potentials for decarbonization, the capabilities to implement mitigation actions, the existing economic structure and energy infrastructure, or the historical and cumulative emissions). However, country teams working independently on their national scenarios need some *ex ante* guidance regarding the requirements imposed by the

5. This assessment is based on an extrapolation of trajectories for countries and emission sources not covered , see extensive discussion in section 2.4 of the DDPP synthesis report (available at: http://deepdecarbonization.org/wp-content/uploads /2016/03/DDPP_2015_REPORT.pdf)

Figure 4. Energy intensity of GDP

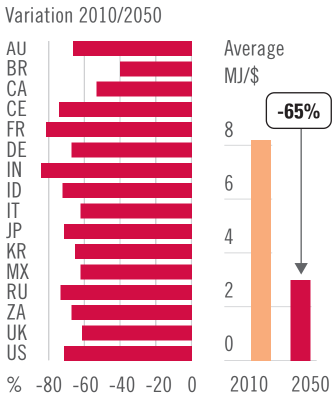


Figure 5. Carbon intensity of electricity

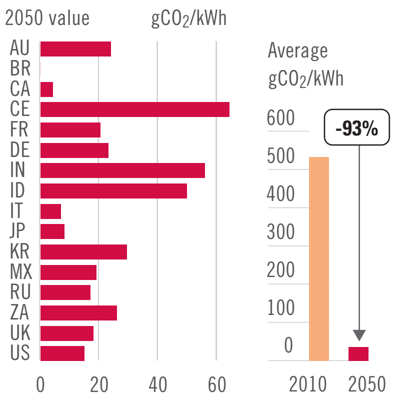
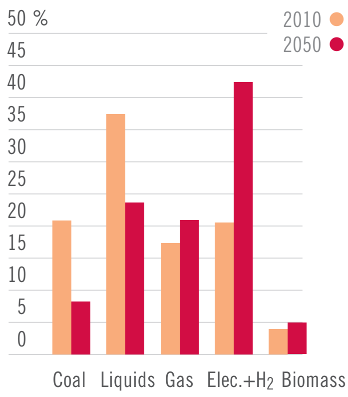


Figure 6. Final energy consumption



collective ambition in order to guarantee that the *ex post* composite of the country visions can be in line with the global constraints.

The choice made under the first phase of the DDPP was to use a set of collective benchmarks, in the form of a range of average per capita emissions in 2050[6] and sectoral performance indicators consistent with the 2°C limit for power generation, buildings, transport and industry.[7] These indicators, and notably the emission per capita benchmark, were selected as a pragmatic way to guide country teams working in countries lacking references for low-emission scenarios to 2050. But, in countries where pre-existing domestic or international debates had already produced country-specific official policy guidelines, country teams were free to use these alternative benchmarks of emission reductions to 2050 (e.g. the 'Factor 4' in France; the '80% or more reduction goal by 2050' as commonly used by G7 countries; or the '14 Gt carbon budget' in South Africa).

In all cases, the benchmarks were not used to set specific targets for the country scenarios, but to provide guidance in the elaboration of scenarios in a process where teams were explicit about their assumptions for crucial variables that both drive emissions and measure important development metrics (both aggregate indicators like average growth rates, and sectoral activity indicators like personal mobility measured by passenger-km per capita). The assumptions on emission drivers could be based on country-specific assumptions (based for example on expert-based judgments or local assessments) or international benchmarking to ground them on stylized facts, like the convergence of growth per capita (Figure 2) or the catch-up of personal mobility (Figure 3).

2.2. Supporting the identification of country-specific actions towards low-emission futures

Results. The DDPP emission pathways were not imposed *ex ante* but resulted from the autonomous selection by country research teams of country-specific actions at different time horizons. In all cases, a strong action on the three pillars of decarbonization in all sectors proved necessary to implement deep energy efficiency (Figure 4), profound decarbonization of electricity and fuels (Figure 5), and massive fuel switching in end-uses (Figure 6). But the strategies and technological options deployed to operationalize these transformations were chosen independently by each team to reflect the (technical, physical, socio-economic, etc.) specificities of each national context. This specificity of options, country by country, is illustrated by the heterogeneity of power generation mix options retained in an illustrative scenario for each country, which all implement strong decarbonization by 2050 but with very different combinations of solutions (Figure 7).

Methodological lessons. The design of DDPP scenarios started with an identification by each country team of the possible actions to implement concretely the three pillars of decarbonization in each sector. These strategies, reported into a "strategy matrix", were translated into a common reporting template (the "dashboard") that asked each team to report the evolution of key emission drivers resulting from these strategies, in a

6. We used as reference the International Energy Agency 2DS scenario, compatible with a 50% chance of staying within the 2°C limit, which translates to a global average of energy-related emissions of 1.7 tCO_2 per capita by 2050. We used 1.5-2 tCO_2/cap as the range for our collective benchmark.
7. Taken from the scenarios reviewed by Working Group III (WGIII) of the IPCC Fifth Assessment Report (see Table 5.1 of the 2014 report of the DDPP, available at: http://deepdecarbonization.org/wp-content/uploads/2015/06/DDPP_Digit.pdf)

Figure 7. Electricity generation mix in 2050

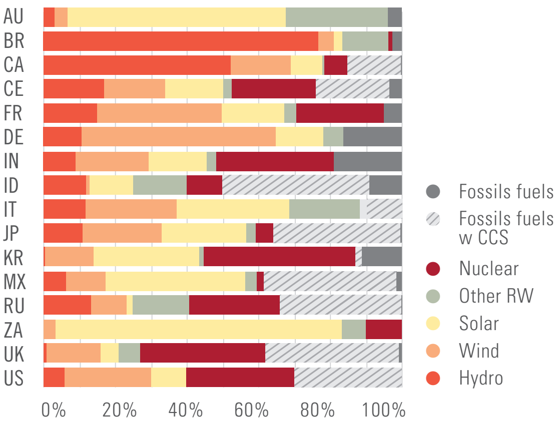
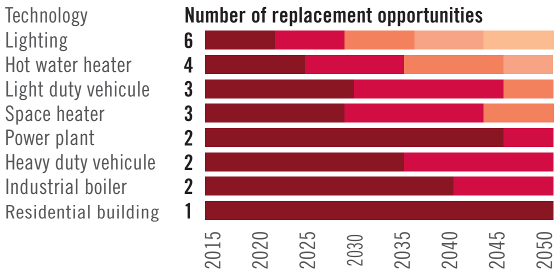


Figure 8. Equipment infrastructure: replacement opportunities between 2015 and 2050



transparent and sector-based detailed manner. This dashboard served as the basis for a collective learning process through structured comparisons supporting an iterative scenario design process. The first round of submitted scenarios was progressively revised *via* critical self-assessment by the country teams of their own assumptions, based on the benchmarking with assumptions adopted by other teams in different countries, domestic expert judgement, and/or literature references. The assumptions were not harmonized across countries since DDPP scenarios were built from autonomous choices by each country team, but the dashboard approach proved as an efficient and pragmatic way to support the progressive increase of ambition: revealing the drivers of emission trajectories in a transparent and sector-based detailed manner has proved instrumental to enable these comparisons, and foster ambition while ensuring domestic ownership and country specific choices.

2.3. Selecting the short-term actions needed to follow truly transformative pathways in the long-term

Results. For each country, the emission pathways should be assessed in the light of the objective set by the Paris Agreement, i.e. reaching global net zero (and possibly negative) emissions during the second half of the century. In such a framing, the question should primarily be about evaluating whether the transformations implemented domestically puts the domestic economy on the path towards very low emissions and builds the conditions for a development process without bad surprises in the long term. The steep decrease of the carbon intensity of GDP, from 2010 to 2050, in all DDPP scenarios (from 80% to 96% across the 16 countries) is reached without significant stranded assets, demonstrating the consistency of short-term actions considered in all country scenarios with the domestic requirements of long-term deep decarbonization. Several studies have used the sectoral granularity of DDPP scenarios to assess the compatibility between transformations triggered by current measures or envisaged in INDCs against the requirements of the long-term climate goal.[8, 9]

Methodological lessons. The scenarios are elaborated as "backcasts," a term for the process of defining a desirable future—very low emissions in 2050, on the path towards net-zero emissions during the second half of the century (see section 2.1)—and working backwards to identify the policies and programs needed to reach that future from the present. Country scenarios towards the long-term goal were built as clear and tangible blueprints for change, sector by sector and over time, for each country's physical infrastructure—such as power plants, passenger and commercial vehicle fleets, buildings and industrial equipment—with an explicit accounting of the stock rollover with different replacement opportunities given different equipment and infrastructure lifetimes (Figure 8). The consequences of short-term actions on the pathways towards the long-term objective are explicitly captured by adopting transparent representation of underlying physical transformations at a sufficient level of granularity to identify the potential risks of lock-ins in infrastructure dynamics potentially affecting later decarbonization potentials.

8. Spencer, T, Pierfederici, R. (2015). Beyond the numbers: Understanding the transformation induced by INDCs, Iddri, *Study* N°05/2015. Available at: http://www.iddri.org/Publications/Beyond-the-numbers-Understanding-the-transformation-induced-by-INDCs
9. Spencer, T, Pierfederici, R, Sartor, O, Berghmans, N. (2016). State of the Low-Carbon Energy Union: Assessing the EU's progress towards its 2030 and 2050 climate objectives, Iddri, *Study* N° 08/2016. Available at: http://www.iddri.org/Publications/State-of-the-Low-Carbon-Energy-Union-Assessing-the-EU-s-progress-towards-its-2030-and-2050-climate-objectives

2.4. Informing the regular revisions of domestic transformations in a context of uncertainties

Results. The DDPP country research teams developed several pathways in each country, which are all consistent with ambitious long-term deep decarbonization but follow different routes. These pathways differ according to the main uncertainties affecting the nature of the domestic transformations according to the specificities of the country context. Beyond the availability, cost and scale of low-carbon technologies which play an important role in most cases, other key factors may relate to the international conditions (ex. the oil price in the Canada DDPP study, which drive export volumes[10]), the socio-economic drivers (e.g. skills profiles in the South African DDPP study), the appreciation of risk and social acceptability of certain technologies (e.g. carbon capture and storage in the Italian DDPP study), the articulation with other development objectives (e.g. climate-centric *vs* sustainable development in the Indian DDPP study) or the efficiency of an infrastructure program (e.g. the retrofitting of buildings in the French DDPP study). The multiplicity of these visions is suited to support sequential decision-making that builds upon learning and progressive arrival of information under strong uncertainty, short-term horizons and myopia, and to prioritize the policies that trigger ambitious emission reductions in the near term while inducing innovation and preserving options for accelerated action in the longer-term. This "adaptive management" approach is discussed more in depth in the French and German DDPP studies[11].

Methodological lessons. The DDPP approach to scenario design acknowledges the need to consider uncertainties, bifurcations, (bad or good) surprises and hence to depart from the standard optimization paradigm, in which pathways maximize an objective function with perfect knowledge about future trends. The DDPP adopts instead a multiple scenario approach, in which all scenarios for a given country would be framed by similar assumptions of the long-term outcomes, notably regarding emission trajectories, but would follow different pathways corresponding to different narratives of the transformations. To implement this approach to scenario design, the DDPP country scenarios are grounded on an identification of key potential variants in long-term trajectories through expert-based judgments, including a clear vision of the main uncertainties and bifurcations over time. This was done by starting upfront in the analysis from the decomposition of the transformations in the key sectors along the different pillars of decarbonization at different time horizons (see section 2.2), and identifying there the main challenges, barriers and enabling conditions associated to each of them.

10. All DDPP country reports are available at: http://deepdecarbonization.org/countries/

11. Mathy, S. *et al.* (2016). "Uncertainty management and the dynamic adjustment of deep decarbonization pathways", *Climate Policy* 16 (S1): S47–S62. http://dx.doi.org/10.1080/14693062.2016.1179618

2.5. Ensuring that low-emission transformations are consistent with the satisfaction of domestic development priorities

Results. The DDPP scenarios show that emission reductions can be done in a way that provides multiple economic and environmental benefits and opportunities for raising living standards. These include improved air quality (see case studies 15 and 16 of the online supplementary material of the DDPP Synthesis Report[12] on the example of China and India), enhanced energy security (case studies 17 and 18 on the example of Japan and India), addressing energy poverty (case studies 19, 20 and 21 on the example of UK, France and South Africa), improved employment, reduction in basic poverty and improved income distribution (case study 22 on the example of South Africa) and good macroeconomic performance (case studies 23 and 24 on the example of France and Brazil).

Methodological lessons. To inform the articulation between emission trends and socio-economic aspects in a country-specific manner, the common dashboard was expanded by each country team to include the key metrics measuring the most important development indicators in their country. Modelling assessments were used to inform these variables consistently with deep decarbonization trajectories of the energy system thanks to the common frame these models provide for energy and development dimensions. But the DDPP did not have any prerequisite in terms of modelling tools, the choice between different model paradigms (or the combination between them) being decided by each country team according to their relevance to inform the core domestic questions. The DDPP exercise is therefore primarily a "scenario design" exercise and not a "modelling exercise" in that it promotes the use of appropriate modelling tools to inform some aspects of the scenarios, but not as the primary channel through which storylines

12 http://deepdecarbonization.org/wp-content/uploads/2016/02/DDPP_SupplementaryMaterial.pdf

should be built.[13] Both a strength and a limitation of the DDPP approach is its focus on modeling as the key method to support scenario design. It provides scientific legitimacy and accuracy, but its orientation as an expert-based approach makes it challenging to communicate with stakeholders. A complementary approach is provided by the MAPS program, which combined research with mandated, facilitated stakeholder process that is better suited to generate greater up-front buy-in from a range of domestic stakeholders into long-term development pathways.[14]

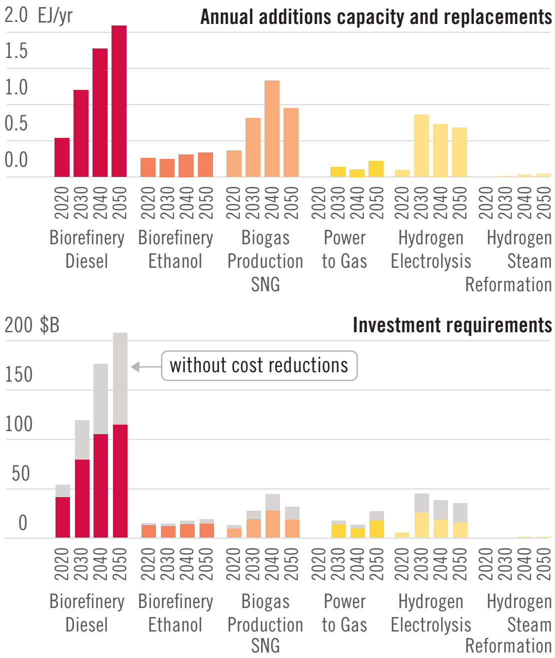
2.6. Revealing the requirements from international cooperation to enable domestic transformations

Results. The DDPP illustrates how to build a global vision of key global enabling conditions as a composite of national transformations. This mimics the process of aggregating the requirements of national transformations to inform global-scale dimensions that deserve collective attention.

First, global low-carbon investment flows for three key sectors (power generation, passenger transport and liquids production) have been distilled from the set of national DDPP scenarios. This evaluation gives low-carbon investment needs of around 1.2-1.3% of GDP in 2050 if global-scale cooperation on technologies driving costs down is assumed, and almost double in absence of such cooperation (see the example of decarbonized electricity generation in Figure 10). Such information is key for countries to have a clear view on the diffusion and cost of the low-carbon options they can consider in their domestic assumptions. This is also essential to provide clear indication of the global market potential emerging as a composite of domestic deployment prospects, which is key information to incentivize the scale-up of investments by technology developers, ultimately triggering a decrease of costs and hence facilitating the wide adoption by different countries.

Second, the reconstruction of global trends from national-scale DDPP scenarios in the case of carbon-intensive goods (iron & steel, and cement) shows how useful guidelines for the international

Figure 9. Additions and replacements, and investment for decarbonized fuel supply technologies



discussion can be derived from such assessment.[15] Notably, this study shows that the national DDPP scenarios are close to the technical limit benchmarks, which suggests that national DDPP projections are very optimistic. This implicitly requires global carbon pricing and/or significant scale-up of international research and development effort to develop low emissions technologies for these products. This points in turn to the need of coordinated (at least aligned) policies in these key sectors at the international scale. Another benefit of such analysis is that the production of DDPs in various countries provides scarce information for the private sector on the development of innovative technology markets, and facilitates virtuous alignment of anticipation by public and private stakeholders.

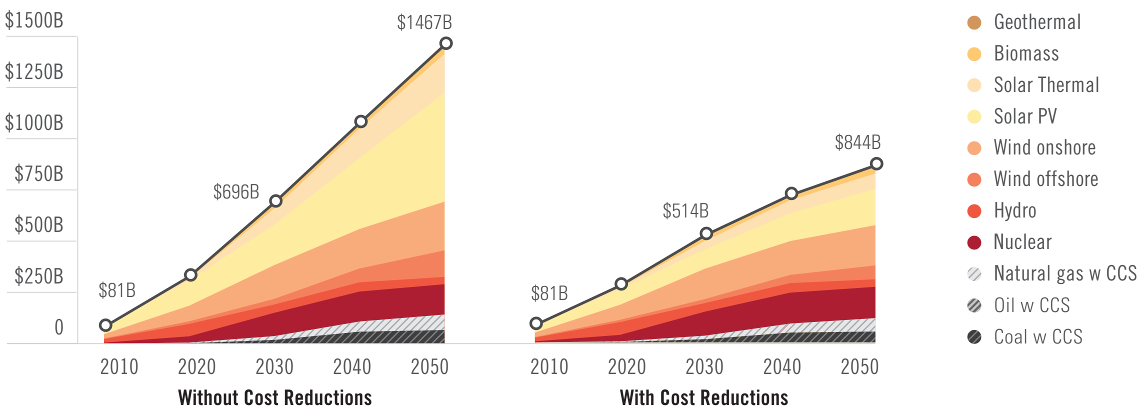
These examples show that domestic long-term pathways can be a unique opportunity for countries to identify and communicate the key global enabling conditions for their domestic transformations to be better aligned with the global climate goal. As such, they can be key inputs to discussions on international cooperation (on trade, investments, technologies notably) and sectoral roadmaps, which should be a core focus of the 2018

13. Pye, S., Bataille, C. (2016). “Improving deep decarbonization modelling capacity for developed and developing country contexts”, *Climate Policy* 16 (S1): S27–S46. doi:10.1080/14693062.2016.1173004.

14. see www.mapsprogramme.org. A synthesis of the MAPS approach and results is available in: Raubenheimer, S et al (2015). *Stories from the South: Exploring low carbon development pathways*. Edited by Stefan Raubenheimer. Cape Town, MAPS team (Mitigation Action Plans and Scenarios). A MOOC describing the MAPS experience can be found at: https://www.coursera.org/learn/climate-change-mitigation/home/welcome

15. Denis-Ryan *et al.* (2016). Managing carbon-intensive materials in a decarbonizing world without a global price on carbon, *Climate Policy* 16 (S1): S110–S128, http://dx.doi.org/10.1080/14693062.2016.1176008.

Figure 10. Decarbonized electricity generation, annual investment requirements with vs without technological learning



stocktaking dialogue. The concrete identification of means to scale-up cooperation on these dimensions could then be reflected by more optimistic assumptions in subsequent NDCs regarding global conditions affecting domestic mitigation potentials, and be a concrete way to operationalize ambition mechanisms within the 5-year cycle context.

Methodological lessons. The composite DDPP global picture could be built thanks to a common approach to national scenarios with physical accounting of capacity additions and equipment rollover in three key sectors (power generation, passenger transport and liquids production).[16] This enabled reconstructing the global trends as a summation of country annual capacity additions and replacements and to derive investment assessments by applying an exogenous assumption on costs (illustration on liquid fuel production in figure 9). The choice was made under DDPP phase 1 to adopt cost profiles given by a simple, one-factor learning curve in which one unit of a given type of capacity sees its cost decreasing in function of its global cumulative deployment (the sum of all installed capacity over time). The assumption that the cost decreases in function of the global deployment of capacities, with no distinction by country, captures the cooperative nature of technological deployment and progress, which is a core condition for deep decarbonization.

The study of energy-intensive materials based on DDPP scenarios mentioned above (see footnote 15) was permitted by a similar principle, i.e. the physical representation of the main drivers of the sectoral transformations in the country scenarios. Here, they correspond to the quantities of cement and iron & steel produced in each country scenarios, expressed in tons, which permitted to reveal explicitly the domestic assumptions regarding sectoral technical change and a meaningful comparison with global-scale benchmarks derived from the literature.

16. These sectors were chosen because they can be treated rather homogeneously in terms of technological deployment and costs. For other sectors like buildings and industry, the heterogeneity of infrastructure and hence of costs is such that more country-specific analysis will be relevant.

*** The DDPP Network consists of Country Research Teams, independent of their governments, in the following institutions:**

Secretariat: Institut du Développement Durable et des Relations Internationales (Iddri) – **Australia**: ClimateWorks Australia; Australian National University – **Brazil**: Instituto de Pós-Graduação e Pesquisa de Engenharia (COPPE), Universidade Federal do Rio de Janeiro (UFRJ) – **Canada**: Simon Fraser University; EnviroEconomics – **China**: Institute of Energy, Environment and Economy, Tsinghua University; National Center for Climate Change Strategy and International Cooperation (NCSC) – **France**: UMR GAEL-Edden, CNRS/INRA/Université de Grenoble; UMR CIRED, CNRS/Ponts ParisTech – **Germany**: Wuppertal Institute for Climate, Environment and Energy – **India**: Institute of Management of Ahmedhabad (IIMA); Faculty of Planning, CEPT University, Ahmedhabad – **Indonesia**: Center for Research on Energy Policy, Bandung Institute of Technology; Center for Climate Risk and Opportunity Management, Bogor Agricultural University – **Italy**: Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA); Fondazione Eni Enrico Mattei (FEEM) – **Japan**: National Institute for Environmental Studies (NIES); Mizuho Information & Research Institute, Inc. (MHIR); Institute for Global Environmental Strategies (IGES) – **Mexico**: Tempus Analytica – **Russia:** Russian Presidential Academy of National Economy and Public Administration (RANEPA); Higher School of Economics, National Research University, Moscow – **South Africa**: Energy Research Center (ERC), University of Cape Town – **South Korea:** SDSN Korea; KDI School of Public Policy and Management; Korea University; Green Technology Center Korea – **United Kingdom:** UCL Energy Institute, University College London – **United States of America:** Energy+Environmental Economics (E3); Sustainable Solutions Development Network (SDSN); Evolved Energy Research (EER).

Contact details for each of these research teams can be found at **http://deepdecarbonization.org/countries/**

Correspondence on this paper should be sent to Henri Waisman (IDDRI): **henri.waisman@iddri.org**