Title: The need for national deep decarbonization pathways (DDPs) for effective climate policy

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Title: The role for national deep decarbonization pathways in implementing the Paris Agreement

Authors: Chris Bataille[1], Henri Waisman[2], Michel Colombier[2], Laura Segafredo[3], Jim Williams[3], Frank Jotzo [4]

[1]l'Institut du Développement Durable et des Relations Internationales/ The Institute For Sustainable Development and International Relations (IDDRI), 41 rue du Four, 75006 Paris, France; corresponding author e-mail: cbataill@gmail.com, +01-778-386-5242,

[2]l'Institut du Développement Durable et des Relations Internationales (IDDRI), Paris, emails: henri.waisman@iddri.org, michel.colombier@iddri.org

[3] Sustainable Development Solutions Network (SDSN), 314 Low Library, Columbia University, 535 W 116th Street, New York, NY, 10027, USA, emails: laura.segafredo@unsdsn.org, jim@ethree.com

[4] Australian National University, Crawford School of Public Policy, Canberra ACT 0200 Australia, email: frank.jotzo@anu.edu.au

Abstract:

Restraining global average temperatures to +2°C from pre-industrial levels will likely require halving global energy system emissions by 2050, and decarbonization by 2100 (IPCC 2014). In the nationally orientated climate policy framework codified under the Paris Agreement, each nation must decide the scale and method of their emissions reduction contribution while remaining consistent with the global carbon budget.

This policy process will require engagement amongst a wide range of stakeholders who have very different visions for the physical implementation of deep decarbonization. The Deep Decarbonization Pathways Project (DDPP) has developed a methodology, building on the energy, climate, and economics literatures, to structure these debates based on the following principles: i) country scale analysis to capture specific physical, economic, and political circumstances to maximize policy relevence, ii) a long-term perspective to harmonize short-term decisions with the long term objective, and iii) detailed sectoral analysis with transparent representation of emissions drivers through a common accounting framework. These principles are operationalized in the definition of Deep Decarbonization Pathways (DDPs), which involve

technically detailed, sector by sector maps of each country's decarbonization transition, backcasting feasible pathways from 2050 end points.

This paper shows how the current 16 DDPP country teams, covering 74% of global energy system emissions, used this method to collectively restrain emissions to a level consistent with +2°C while maintaining development aspirations and reflecting national circumstances, mainly through efficiency, decarbonization of energy carriers (e.g. electricity), and switching to these carriers. The cross-cutting analysis of country scenarios reveals important enabling conditions for the transformation, pertaining to technology R&D, investment, trade and global and national policies.

Policy relevence:

In the nationally based global climate policy framework codified in the Paris Agreement, the purpose of the DDPP and DDPs is to provide a common method by which global and national governments, business, civil society, and researchers in each country can communicate, compare and debate amongst differing concrete visions for deep decarbonization, in order to underpin the necessary societal and political consensus to design and implement short run policy packages consistent with long term global decarbonization.

Acknowledgements:

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Keywords: decarbonization, decarbonisation, pathways, climate policy, DDP

Title

The need for national deep decarbonization pathways (DDPs) for effective climate policy

1 Introduction

1.1 What are DDPs, and what is the DDPP?

The current international consensus on climate change policy is that deep greenhouse gas (GHG) emission reductions are necessary to limit the anthropogenic increase in global mean surface temperature to less than 2°C relative to preindustrial levels, and that for this to occur, substantial emissions reductions will be needed over coming decades, and eventually full decarbonization of the world economy.[1] This is consistent with IPCC (2014) findings that to ensure a better than even chance of remaining below a 2°C temperature rise, global annual emissions will need to be reduced 42-57% by 2050 (relative to 2010), and 73-107% by 2100.

During 2015, most national governments submitted Intended Nationally Determined Contributions (INDCs), as part of the process towards a new global climate agreement under the United Nations Framework Convention on Climate Change. These INDCs for the most part focus on emissions goals 2025 or 2030. They thus give a sense of the short-term transformation, but do not provide a clear vision of the profound transformation of energy systems that would be required by mid-century to maintain the 2°C limit.

What is needed to inform the debates that must be had in each nation is a set of detailed decarbonization trajectories for each sector of the economy. These need to describe a sequence of sectoral changes in physical infrastructure, deployment of technologies (e.g. energy efficient and low carbon vehicles, buildings, power plants, industrial boilers), investment, consumption

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[1] Exemplified by the Leaders' Declaration at the June 2015 G7 Summit (available at https://sustainabledevelopment.un.org/content/documents/7320LEADERS%20STATEMENT_FINAL_CLEAN.pdf [Accessed 20.10.15]) or the September 2015 US-China Joint Presidential Statement on Climate Change (available at https://www.whitehouse.gov/the-press-office/2015/09/25/us-china-joint-presidential-statement-climate-change [Accessed 20.10.15])

patterns, based on available and anticipated technologies. We call such a trajectory a Deep Decarbonization Pathway, or "DDP". DDPs are exploratory and iterative in nature, not prescriptive, and are meant to serve as a way to structure debates around different visions of the national transitions.

Construction of a DDP begins by considering the ambition necessary in 2050 to meet global climate goals, and assesses the necessary action needed from today out to 2050. There are three key components for a DDP: 1) It needs to be national-scale, with sectoral disaggregation to take into account national priorities, circumstances, and be relevant for policy. 2) It needs to have a long enough time scope to capture the necessary changes for decarbonization. Finally, 3) it needs to be transparent to be useful for stakeholders and policymakers.

The Deep Decarbonization Pathways Project is a collaborative global research initiative, convened by the Institute for Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN), that operationalizes the development of DDPs in order to demonstrate how individual countries can establish and use DDPs to understand how they can reduce emissions consistent with the 2°C limit.[2] As of late 2015, the DDPP comprised of sixteen country research teams from industrialized and emerging economies covering 74% of global energy related CO_2 emissions.[3] The teams explicitly do not represent the positions of their national governments, but are all engaged in their domestic policy debates. Each team has developed a set of national DDPs to explore what is physically required to achieve deep decarbonization in their own country's economy, while taking into account socio-economic conditions, development priorities, existing infrastructure, natural resource endowments, and other relevant factors. Depending on national analytical capabilities, some teams have explored investment costs, policy frameworks and investment needs.

1.2 The structure of this paper

Section 2 shows how the DDPP method evolved from the energy and climate policy literatures. Section 3 summarises the innovative approaches, messages and lessons learnt from the current

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[2] Further information on the DDPP initiative, the 2015 Global Synthesis Report, and country level reports can be found at www.deepdecarbonization.org

[3] Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, the United Kingdom, and the United States

process. Section 4 discusses the utility of country DDPs from a climate policy perspective. Section 5 concludes.

2 Background and motivation for the DDPP

2.1 The decoupling of GDP and energy, and its impacts on energy modelling

The history of energy modelling illustrates the changing requirements for analysis, leading to the approach described in this paper.

Prior to the 1970s, energy use grew roughly linearly with GDP in most developed countries. Energy policy was almost exclusively focussed on growing supply securely and governance of natural monopolies at the supply and retail level. Energy modelling was focussed on forecasting short term demand, the need for new capacity (oil supply, refineries, electricity, transmission grids), and optimal operation of facilities and infrastructure. Short term effects were typically analyzed with econometric methods, relevant for analysis of marginal variations around stable trends, while long-run interactions between oil markets and economic growth were explored using models focused on exhaustible resources *à la* Hotelling (1931) (see Krautkraemer (1998) for a review).

Fundamental change came in the early 1970s, when the oil shocks illustrated the limitations of the previous energy models, requiring new approaches to analyze energy demand in support of the development of institutions, tools and policies to mitigate the impact of oil prices on economies. It became clear that energy demand could not be derived solely from an elastic relationship to growth, but that instead technology, behaviour and economic structure were crucial elements to understand energy dynamics. In a survey of the lessons learnt from the analysis of oil shocks (Hamilton, 2008) argues that modeling exercises can better reproduce the observed magnitude of the economic effect of oil price variations if they account for market imperfections (Rotemberg and Woodford, 1996), limits in the substitution between capital and energy (Finn, 2000), capital stock renewal inertia (Atkeson and Kehoe, 1999), idle production capacity (Bresnahan and Ramey,1993), or differentiated levels of unemployment (Davis and Haltiwanger,2001).

The oil shocks also led to the development of detailed energy statistics that allowed development of a new generation of “bottom-up” tools. These tools use detailed energy and economic data to describe the energy supply and demand system physically (Bertrand and Lapillone 1990). They allow transparent and explicit sectoral and technology modelling to explore efficiency, fuel switching (Capros, Karadeloglou, Mentzas, and Valette 1989), development of alternative fuels, physical changes in economic structure, and effect of lifestyles on energy use. This allowed the development of normative “backcasting” approaches suitable to address environmental externalities not included in the market price (e.g. project Externe (2006)), by stating a policy goal at a future date (e.g. local air emissions below a certain level, reductions of oil imports) and analyzing the effectiveness of policy to meet these objectives under scenario conditions.

If economic results are required, however (e.g. GDP, employment, economic structure, trade), then “hybrid” models are needed, ones that encompass the macroeconomic completeness and microeconomic realism of standard economic top down models and the technological explicitness of bottom-up models (Hourcade, Jaccard, Bataille and Ghersi 2006). Today, bottom-up and hybrid top-down models are the work horses of the energy modelling world (see XXX in this issue).

2.2 Energy policy as a social, not just expert debate: the need for integrated and transparent approach

The issues inherent in the 1970s oil shock brought the greater public into the energy policy debate. It became accepted that energy policy interacts with economic, social and environmental policy, and energy policy experts are therefore expected to respond to decision makers and civil society’s appetite for a broader view than just energy availability and costs. This means that the analysis of energy must be articulated with key development metrics (e.g. energy security, competitiveness, local pollution, employment, access to basic services, urbanization), especially in the context of developing countries, where development predominates political priorities (see XXX in this issue; Kok, Metz, Verhagen, and VanRooijen , 2008; Shukla, Dhar, and Mahapatra, 2008; Shukla and Chaturverdi, 2013; and Winkler, Boyd, Gunfaus and Raubenheimer, 2015).

As a result of the socialisation of energy policy any significant change must be approached as a political process that needs political leadership, but also ownership, participation and stakeholder debate to assess options. Bottom up sectoral approaches are generally more amenable than economic models for engagement in stakeholder debates because they makes policy options "visible and tangible", and debatable at the non-expert level. They allow exploration of non-predictive "what if" scenarios describing different stakeholder visions of how to respond to energy issues.An example of this approach to inform and structure stakeholder discussions is the use and development of a "dashboard" in the 2012-13 French energy debate (ADEME 2012; Mathy, Fink and Bibas (2015)) . It was used as an interface to reveal the underlying assumptions of transition scenarios, described with different modelling tools and hence different levels of granularity.

2.3 What tools to assess the deep decarbonization transformation?

The emergence of climate change as a headline issue of public and policy concern at the end of the 1980's led to a need for long term approaches and consideration of a more radical energy system transformation. Following an early emphasis on differentiated responsibilities between developed and developing countries that prompted an unproductive debate on burden sharing that has arguably hobbled global climate policy (Ringius, Torvanger, and Underdal, 2002; Najam, Saleemul and Sokona, 2003), it is now recognized that all countries need to act, according to their respective capabilities. This has been formalized in bottom up, voluntary, national low-carbon strategies (Intended Nationally Determined Contributions or INDCs). Country-specific development needs, however they are defined, are explicitly part of the discussion on decarbonization [Fay, Hallegatte, Vogt-Schilb, Rozenberg, Narloch, and Kerr, 2015; Shukla et al (2008, 2012)]. Furthermore, it is clear that meeting the internationally-agreed 2°C limit will require all economies to reach close to zero GHG emissions by the second half of century (IPCC 2014).

These changes in the nature of the climate policy debate have important consequences for the methodological approaches applied to inform this process. Earlier research efforts were focused on partial decarbonization, in analytical frameworks of marginal change. But when full decarbonization is considered, "walking up the marginal abatement cost curve" is no longer the correct framework because what is appropriate at the bottom of the cost range is not appropriate at the top. Incrementally constructed pathways can also lead to lock-in of infrastructure and assets incompatible with longer term near zero carbon economy, and unsatisfactory alignment with development priorities (as per Henry (1974)).

A solution to the conundrum is 'backcasting' to an attractor like complete decarbonization. This approach inherently puts the required future situation at the centre and allows exploration of the sequence of policy options that can achieve the desired target (Fay et al, 2015). Key to this renewed approach has been the use of global Integrated Assessment Models (IAMs) in a "backcasting" mode. Global models, however, can fall short in providing detailed bases for analysis of the feasibility and needs of deep decarbonization at the national, regional and sectoral level. Providing tangible pathways to deep decarbonization that can help societies identify suitable policy is the goal of the DDPP.

2.5 Summary of the DDP process and Research questions

The DDPP starts from the need for each country to envisage the conditions for decarbonization by the second half of this century. Under this new paradigm, the purpose of DDPs is to support domestic policymakers in the definition of a strategic vision, identification and implementation of short term actions consistent with long run decarbonization, and establishment of an institutional framework to monitor the results and adapt decisions in a flexible manner.

Given these objectives, the DDPP aims to inform two research questions:

- How can national economies transition to a low-carbon future compatible with the 2°C limit? This means exploring: i) the feasibility and conditions for sector by sector deep decarbonization by mid-century, through attractor and backcasting approaches (instead of the burden sharing approach); ii) the interplay between decarbonization and socio-economic dimensions that are relevant to national contexts; and iii) the areas for international cooperation required to enable the national transformation (technology development and access, finance, carbon markets, alignment of policies etc.).
- How to support a substantive policy framework for the decarbonization objective? This means: i) elaborating a policy vision compatible with both the domestic socio economic development perspective and international conditions; ii) supporting a collective "adequacy" assessment to be used to benchmark existing and proposed domestic actions;

and iii) identifying the policies that make the transformation robust (i.e. suited to very different economic or technological environments, at the domestic and international level) and resilient (i.e. that swiftly recover their balance in the event of crises, accidents or acute instability); see XXX this issue for more discussion.

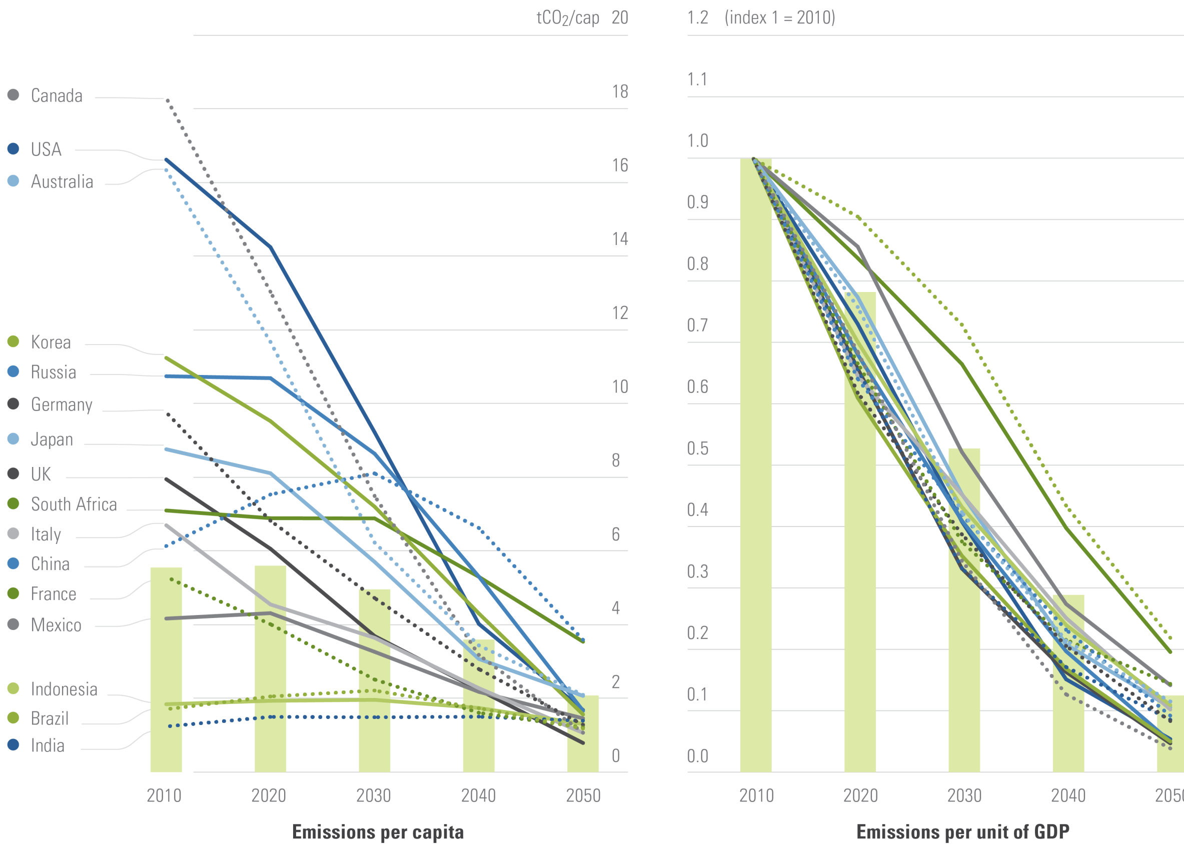
3 What are the contributions of DDPP to the scientific approach of the low-carbon transformation?

3.1 How does the global climate constraint frame the national transformations?

The DDPP considers the question of emission reductions in a bottom-up approach by which each country research team defines its emission trajectories independently of any ex-ante allocation rule. In order to ensure consistency with the amount of emission reductions required to maintain the 2°C limit, the DDPP consortium defined a "downward attractor" to provide a benchmark for global average emissions in order for the analysis to be consistent with the 2°C limit. We used as reference the IEA (2014) 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 tonnes CO_2 per capita by 2050 (Figure 1).[4] This value is used as a benchmark to guide the exploration of country-level DDPs; it is explicitly **not** used as a single target because this would fail to capture important differences across countries (e.g. peak, plateau and decline development needs (e.g. XXX in this issue); export of GHG intense commodities like steel and cement (e.g. XXX in this issue).

[4] The IEA 2DS reaches 15 Gt of global energy-related CO_2 emissions by 2050 and we assume a global population of 9 billion by 2050, in line with the medium fertility projection of the UN Population Division).

Figure 1 – GHG per capita and per unit GDP for the DDPP countries



Source: DDPP (2015).

In addition to average per capita emissions in 2050, the teams also used sectoral performance indicators to guide their DDPs. We used the scenarios reviewed by the IPCC AR5 WG3 to define sectoral performance indicators for power generation, buildings, transport, and industry consistent with the 2°C limit (Table 1).

Table 1 Range and median value of sectoral performance indicators in the IPCC 2°C scenarios

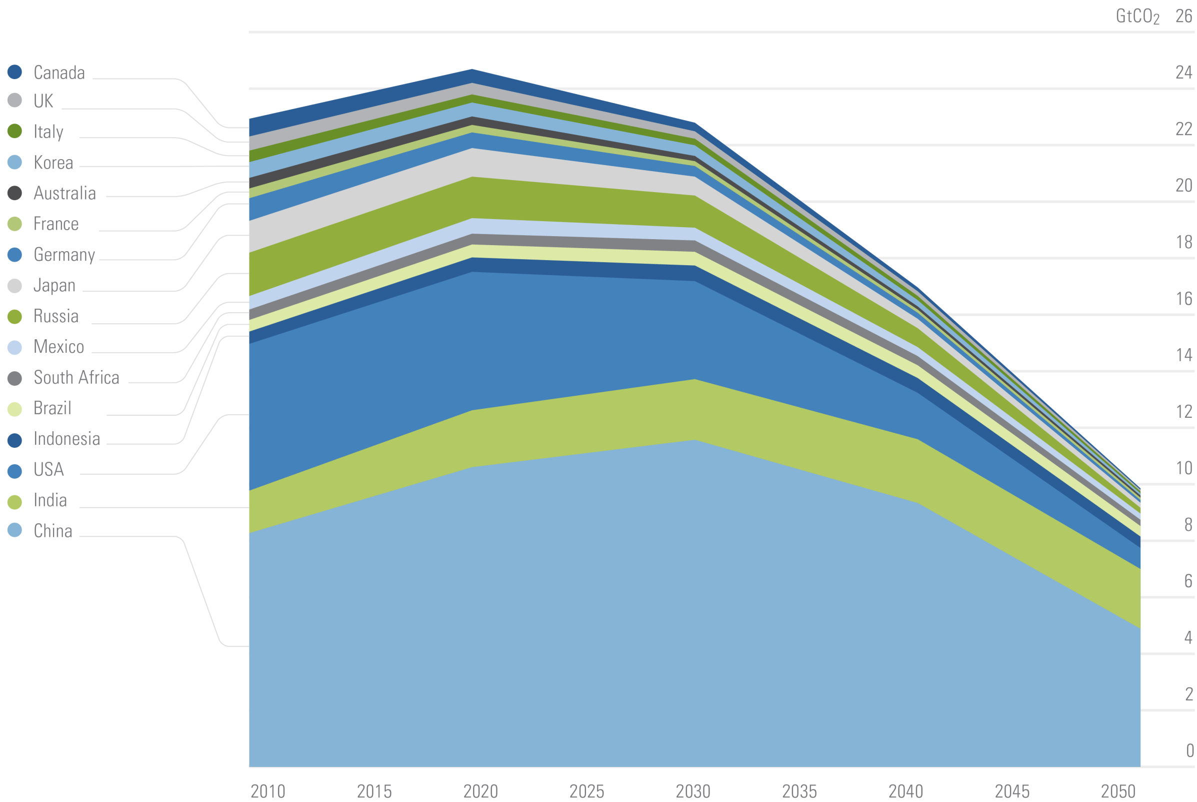
Sector	Sub-sector / Region	Indicator	Benchmark in 2050 Median value	Benchmark in 2050 Range
Electricity generation	_	gCO_2/kWh, note: net negative (biomass with CCS) was not used in the DDPP	20	-30 – 50
Transport	Passenger transport	(GJ/person kilometre, index 1=2010 value)	0.75	0.58 – 0.78
	Freight transport	(GJ/tonne-kilometre, index 1=2010 value)	0.65	0.45 – 0.9
	Total Transport	(tCO_2/GJ, index 1=2010 value)	0.7	0.6 – 0.85
Industry	Cement	tCO_2/ton	_	0.24 – 0.39
	Iron and steel		_	0.47 – 0.84
	Paper		_	0.16 – 0.20

It must be restated that these sectoral benchmarks are not used to set specific targets for the country scenarios, but to provide guidance in the iterative process where the teams are explicit about their assumptions for crucial emission trajectory drivers and compare them to the literature benchmark values. This comparison process is made possible by adoption of a common accounting framework (referred to as the "dashboard) which tracks carbon, energy, infrastructure stocks, and investment costs at the sector and subsector level, capturing the physical changes required to reduce emissions and providing a basis for aggregation and comparison across countries.

3.2 What emission profiles for different countries?

Under the DDPP, each country defines its emission trajectory as a function of its own assessment of realistic deep decarbonization. This flexible approach lead to an 80-90% decrease in the energy related emissions intensity of GDP for all countries; however, very different rates and timing of absolute emissions reductions occur between groups of countries (Figure 2). This heterogeneity reflects different rates of economic growth 2010-2050, initial per capita incomes, rhythms of capital stock renewal and deployment, and initial physical energy-related infrastructure that define the potential for deployment of low-carbon options.

Figure 2 – Total cumulative emission for the DDPP countries



Source: DDPP 2015

3.3 What physical changes occur?

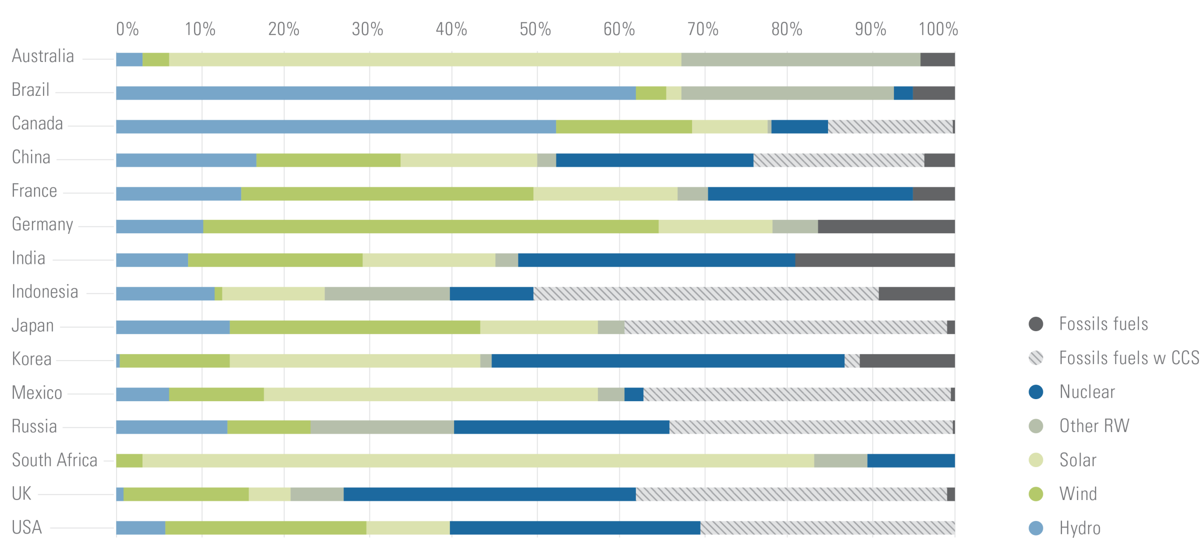
Cross-cutting analysis of national DDP scenarios indicates that ambitious mitigation requires simultaneous strong action on "three pillars" of energy system transformation: energy efficiency and conservation; decarbonization of energy carriers like electricity, biofuels and hydrogen; and fuel switching of energy end uses to decarbonized energy carriers like electricity.

Because of the interactive effects between the pillars (e.g. using low carbon electricity to electrify vehicles), all the national scenarios consistently show that deep decarbonization cannot be achieved if any of the pillars are absent or implemented at insufficient scale. On average across 16 DDP studies, the energy intensity of the economy reduces by 65% from 2010 to 2050; carbon intensity of electricity supply decreases by 93%; and the share of electricity in final more than doubles to over 40% (DDPP 2015).

While the use of efficiency, decarbonization of energy carriers and fuel switching to these carriers is consistent, the national DDPs are very different in terms of technologies and sequences of actions. This reflects the specifics of each country regarding the initial nature of infrastructure, building stock and speed of development, societal preferences (e.g. the acceptability of nuclear power), geographic specifics (e.g. amount of renewable resources available, spread-out vs. dense, hot vs. cold climate, geologic sequestration is available or not) and economic factors (e.g. production structures and trade).

An illustration of the pronounced differences in national approaches to achieving similar overall emissions outcomes is the composition of electricity supply (Figure 3). All DDP studies project a fully or nearly fully decarbonized electricity supply system at 2050, typically with significant increases in total electricity generated on account of electrification of activities that currently use fossil fuels directly, such as road transport, heating and industrial processes. Some countries rely exclusively on renewable energy for electricity in their core scenarios, while others project a substantial role for nuclear power and/or fossil fuel combustion with carbon capture and storage. The differences are due to different physical and economic characteristics, as well as judgements about societal acceptability of different technologies.

Figure 4 – 2050 Electricity generation mix by country



Source: DDPP (2014).

3.4 What uncertainties?

The DDPP has involved the construction of multiple decarbonization pathways in each of the 16 countries analyzed. These variants have been defined independently by each team according to the uncertainties affecting their national contexts, like the domestic potential for a low-carbon resources (e.g. renewables, CO_2 storage capacity), the international context (e.g. international fossil fuel markets, availability and cost of a specific technology), the structural evolution of the domestic economy (e.g. the evolution of skills and role of fossil-intensive sectors, industrialization trends), or the articulation of different political strategies (e.g. sustainable development goals, targeted policies to control energy demand).

Overall, energy-related CO_2 emissions were reduced by 48% to 58% below current levels by 2050, despite projected growing population and GDP (+17% population, and a more than tripling of GDP by 2050 across the 16 countries). The deep decarbonization transformation is robust to the main uncertainties specific to each national context. This analysis of country-specific factors and uncertainties, considering not only technical aspects but also structural and socio-economic dimensions, is a core contribution of the DDPP to the literature on climate mitigation,.

3.5 Is mitigation compatible with domestic socio-economic aspirations?

A core purpose of the DDPP is to investigate the interplay between decarbonization and domestic socio-economic priorities. On the one hand, in all the DDPs, economic growth and development were not constrained by carbon concerns, but rather the energy system was designed to provide all the energy services needed to meet national objectives, including expanded access to energy in developing countries. Economies continue to transport passengers and ship freight, provide similar or better housing and public amenities, and support high levels of industrial and commercial activity. This is ensured by an explicit representation, in the common dashboard used by all teams, of activity levels associated with crucial energy services in physical quantities (e.g. square meters of residential and commercial building space, passenger-km, ton-kilometers, industrial production).

In addition, each team had the opportunity to define the most sensitive socio-economic questions posed by decarbonization in their country, and designed their scenarios to explicitly meet these national priorities. Selected conclusions reached in the DDPP analysis include:

- It is possible to simultaneously improve income distribution, alleviate poverty, and reduce unemployment and transition to a low carbon economy, as demonstrated in the South African DDP (see XXX in this issue). This conclusion is reached via analysis that explicitly disaggregated labour markets by skill level and households by income category, and measures the effect of the deep decarbonization transformation on each of them.
- Reducing fossil fuel demand and developing domestic renewables capacity can increase the energy security of energy-importing countries, as seen for example in the Italy, Indian or Japan DDPs (see XXX in this issue). This is demonstrated via explicit representation of trade flows, in physical quantities and money values, associated with the evolution of the national economy.
- The reduction of uncontrolled fossil fuel emissions has significant public health benefits, as seen in the Chinese and Indian DDPs, since fossil fuel combustion is the major source of air pollution. This is demonstrated by coupling energy models with air pollution assessment frameworks. For example, in the Chinese DDP, deep decarbonization resulted in reductions of 42-79% of primary air pollutants (e.g., SO_2, NO_x, $PM_{2.5}$, VOCs, and NH_3), sufficient to allow major cities to meet air quality standards.
- The aggressive energy efficiency required under deep decarbonization is a way to improve access to energy and address energy poverty. This is demonstrated in the UK analysis, thanks to an explicit disaggregation of households according to their energy efficiency standards.
- The implementation of energy efficiency in residential buildings and personal transport under deep decarbonization can lower the net energy costs for households. This is demonstrated in the Australian DDPs where fuel and capital costs in these activities are explicitly captured.

3.6 What are the investment requirements and what are the costs?

The scale of infrastructure required to support the deep decarbonization transition is indicated by cumulative technology deployment over time, represented in physical quantities in the DDPs. Deep decarbonization is essentially the process of improving infrastructure and equipment over time by replacing inefficient and carbon-intensive technologies with efficient and low-carbon technologies that provide the same (or better) energy services. At the global scale, this will require the deployment of vast amounts of new equipment based on clean technologies ranging from LED lighting to electric heat pumps, from hydrogen production to solar electricity generation.

Assessment of the investments needed to support this deployment of low-carbon infrastructure is done by developing technology cost learning curves consistent with these market demands to derive investment requirements in the DDPs. Applying historically based assumptions about technological learning to key low-carbon technologies for power generation, fuel production, and transportation shows dramatic reductions in the cost of these technologies can be expected at the scale of production required, relative to the cost without learning.

Those savings illustrate how international cooperation in developing markets for low-carbon technologies can reduce costs for all countries relative to a go-it-alone approach, while providing large markets for technology providers and large incentives for further innovation. This represents a different approach to investment compared to the conventional studies, which essentially derive investment needs as a minimization of aggregated costs. Here, instead, the investments are assessed ex-post to the definition of the scenarios. These investments needs are calculated in three key sectors – electric power generation, alternative fuel vehicles, and decarbonized fuel production.

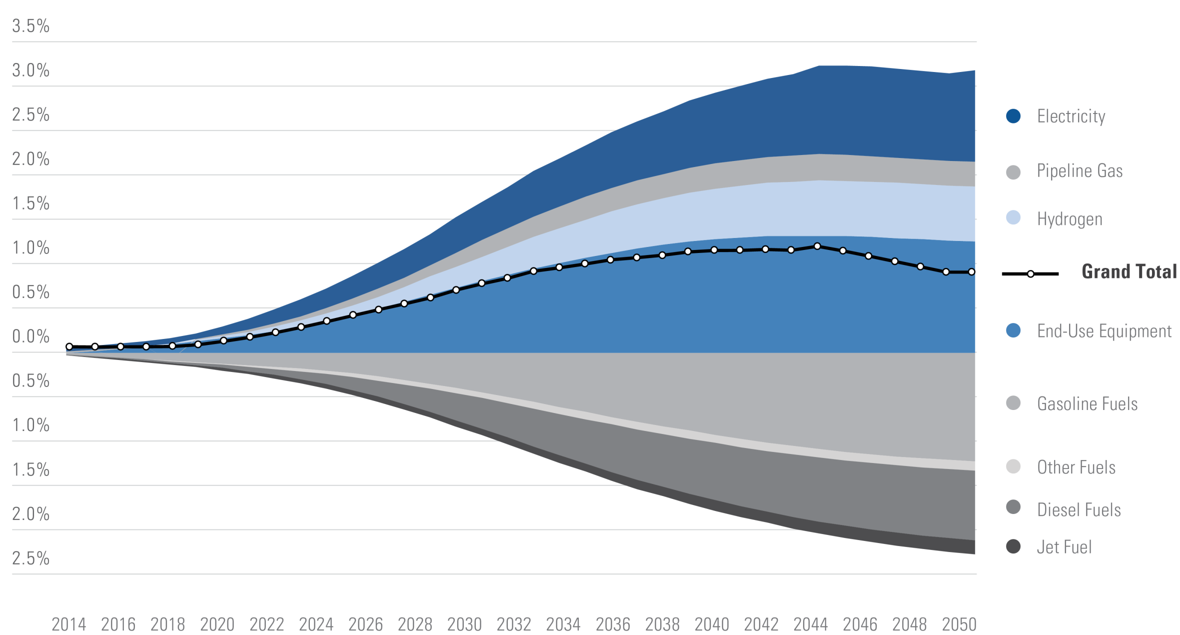
Energy investment under deep decarbonization does not represent a large increase over energy investment required in the absence of climate policy, but a transition from fossil fuel to low carbon technologies. The gross investment requirement for low carbon technologies in the DDPs constitute 1-2% of GDP for the DDPP countries, or an increase of 6-7% of total investment in these economies, on average about 1.2% GDP (Table 2).

Under deep decarbonization, the scale of investment in low carbon technologies will be orders of magnitude higher than current levels, creating major economic opportunities for forward-looking countries and businesses (Table 2), provided there is sufficient certainty in climate policy. Policies may be required to aid firms and consumers with the higher up front capital costs of decarbonization technologies. This however is compensated through lower ongoing energy costs, in particular savings for avoided expenditure on fossil fuels. This is illustrated in DDP modelling analysis for the United States, in which the net cost of supplying and using energy for a deeply decarbonized scenario in 2050 rises by less than 1% over the period from 2014 to 2050. Significant increases in the costs of end-use equipment and electricity supply, as well as supply of hydrogen and gas, are mostly offset though large savings for gasoline, diesel and jet fuel (Figure 4).

Table 2. Annual investment in key low carbon technologies and their share of GDP for DDPP countries ($2015 billion USD).

		2020	**2030**	**2040**	**2050**
Annual investments in the 16 DDPP scenarios ($)	Low-carbon power generation	270	514	701	844
	Low-carbon fuel production	57	117	124	127
	Low-carbon transport vehicles (passenger+freight)	157	333	626	911
	Total (Billion US $)	484	963	1452	1882
Annual investment in low-carbon technologies as % of GDP		0.8%	1.2%	1.3%	1.3%

Figure 5 – Net fuel expenditures compared BAU in the US DDPP



Source: DDPP (2015).

Household energy costs may also fall as a result of efficiency gains even if supply costs per unit of energy rise. DDP analysis for Australia projects the costs of privately used energy and transport per household falls by 13% from 2012 to 2050 under a scenario of deep decarbonization (DDPP 2015). Meanwhile income per household is projected to increase by 55%, so energy affordability increases greatly even while the energy and transport system is restructured with substantial investments to replace high-carbon with zero-emissions infrastructure and equipment.

3.7 Global harmonization of the country DDPs through ex-post analysis

Global supply and demand trade balance of fossil fuels and biofuels was not attempted in this first phase of the DDPP, and remains as an open question. XXX in this issue assess the fossil fuel trade balance based on the country DDPs, and show how even small changes in demand and production in larger regions could make significant changes to global trade flows, with significant consequences for exporters.

In related fashion, the country and global impacts of production and trade in GHG intense commodities was not directly addressed in this phase of the DDPP. Production of iron and steel and cement, essential in a decarbonized world, implies some regions could have higher emissions directly associated with these commodities. XXX in this issue demonstrate that production of these commodities using today's least emissions intense technologies could use up 20% of the global budget in a low-carbon global economy by 2050.

4 Discussion: What DDPs contribute to good climate policy practice

A key feature of the DDPP approach to DDPs is that it combines a rigorous accounting framework that is common across the country teams with scenarios that are developed autonomously by the teams ("the dashboard", as introduced in section 3.1). Making explicit the content of the deep decarbonization transition under this explicit framework has major benefits for climate policy discussion and negotiations.

First, DDPs fill a gap in the climate policy dialogue by providing a more concrete understanding of what is required for countries to reduce emissions consistent with the 2°C limit. DDPs provide an explicit plan for deep decarbonization actions by sector and over time, as a crucial condition to stay within carbon budgets. The operational lifetimes of much of the infrastructure and equipment that drive CO_2 emissions – power plants, buildings, industrial boilers, heavy duty vehicles – are long compared to the time remaining between now and mid-century. DDPs support current policy and investment decisions by making the long-term emissions consequences of these decisions explicit. DDPs can help avoid "dead end" investments that lead to incremental emissions reductions in the short term, but are not compatible with deep decarbonization in the long term.

Second, DDPs and the process of producing them allow policy makers and the public to concretely envision the path to decarbonization and to catalyze a mutual learning process, structured around a positive vision. They make the multi-decadal transition tangible, and clarifies what policies and markets must accomplish over that time. Experiences with outreach to decision-makers in politics, industry and civil society in countries for which DDPs were produced have shown that the emphasis on technological possibilities makes for a forward-looking discussion of options that encourages stakeholders to focus on the opportunities inherent in technological change and transformation of existing systems. This is in contrast to debates based around traditional economic analyses and their tendency to frame stakeholder discussions on cost minimization which is often equated with minimal departure from the status quo.

Third, DDPs can provide a framework to coordinate policy formation and investment across jurisdictions, sectors, and levels of government. By providing a transparent and concrete understanding of what a low carbon transition entails – scope and timing of infrastructure changes, technology options, investment requirements, RD&D needs, market potential – DDPs can help align public and private sector interests and expectations.

Fourth, DDPs provide a framework for understanding how deep decarbonization can work in harmony with other sustainable development priorities. Scenarios are defined in the context of socio-economic pathways compatible with development and prosperity. Having DDPs as a public point of reference can help countries ensure that the energy transformation and other decarbonization measures (e.g. land use) also support long-term goals such as energy access, employment opportunities, environmental protection, and public health.

Fifth, DDPs could increase trust in the international climate policy process. DDPs represent a transparent approach to understanding the long-term policy challenges, technology needs, and cost structures of deep decarbonization in different countries. This can do much to change the tenor of the international climate discourse, and place greater focus on opportunity-seeking and collective problem-solving. Much of the analysis informing past negotiations has been of a "black box" nature. DDPs, in contrast, are about putting "cards on the table," making long-term national aspirations and the underlying assumptions that inform them clear to other countries. An open approach of this kind can help to identify areas for policy cooperation, joint technology RD&D, market development and transformation, trade, and mutual assistance.

Finally, undertaking national DDP exercises will be essential for increasing the ambition of future national commitments to reduce their GHG emissions. By describing the full extent of the transformation required over a longer time frame, DDPs provide a context for understanding the ambition of current INDCs focussed on 2025 and 2030, and the further measures that deep decarbonization will entail.

5 Conclusion

The sixteen national analyses in the Deep Decarbonization Pathways project have demonstrated how deep decarbonization is technically and financial possible in a set of countries representing 74% of global energy system emissions, based on an innovative approach to the 2°C limit. The combined DDP pathways in the DDPP project potentially cut the Gordian knot of burden sharing that has bedeviled climate negotiations, and offer an approach to deep decarbonization that complements the INDCs, directly supporting the post Durban process.

The DDPP has also raised a host of fruitful research questions to be addressed in the next phase of the project under the twofold objective of increasing the robustness and relevance of the analysis, and helping catalyze the national discussions amongst policymakers and stakeholders that are necessary to establish policy to eventually decarbonise the global economy.

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