Deep Decarbonization – From Technological Pathways to Societal Transformation

Final synthesis report on the results of a project funded by BMUB and implemented by DIE in cooperation with UN-SDSN

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Contents

Abbreviations

BMUB	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
C	Celsius
CCS	carbon capture and storage
CO_2	carbon dioxide
COP	Conference of the Parties of UNFCCC
DDPP	Deep Decarbonization Pathways Project
DIW	Deutsches Institut für Wirtschaftsforschung
EnBW	Energie Baden-Württemberg AG
EJ	Exa Joule
ERC	Energy Research Center
ETS	emissions trading scheme
EU	European Union
FiT	feed-in tariff
GDP	gross domestic product
GHG	greenhouse gas
Gt	Giga ton
IDDRI	Institute for Sustainable Development and International Relations
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
INDC	Intended Nationally Determined Contributions
MEC	minerals-energy complex
Mt	Mega ton
NCSC	National Climate Change Strategy Research and International Cooperation Center
PV	photovoltaic
R&D	research and development
REFIT	Renewable Energy Feed-in Tariff
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
RWE	Rheinisch-Westfälisches Elektrizitätswerk AG
SDSN	Sustainable Development solutions Network
SSA	sub-Saharan Africa
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WBCSD	World Business Council on Sustainable Development

1 Introduction

This report presents the results of the project 'The Political Economy of Deep Decarbonization Pathways – Country Studies of Drivers and Constraints' (hereinafter referred to as the 'Project'), which was funded by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The project was implemented by the German Development Institute (DIE) between mid-2014 and end-2015 in close cooperation with the global Deep Decarbonization Pathways Project (DDPP) under the auspices of the Sustainable Development Solutions Network (SDSN) of the United Nations.

This report is structured along the following lines: Chapter 2 places the Project in the overall context of global climate policy and the required transition towards low-carbon development. Chapter 3 elaborates on the approach, methodology and results of the global DDPP and the complementary objectives and deliverables of the Project itself. Chapter 4 puts forward the specific results of the various component studies of the Project while the final chapter 5 draws key conclusions and offers recommendations in a comparative perspective.

This report presents the substantive results achieved in the Project. It does not address administrative and financial issues of implementation, which are covered by other reporting instruments. While clearly focusing on the results of the Project itself, in a few instances the report also draws on complementary research largely undertaken within the DIE.

2 Background: Climate change and development

The decarbonization of economic development – for long relegated to a subject of scientific analysis and debate – has now been firmly placed on the global policy agenda. The final declaration of the 2015 G-7 Summit unequivocally calls for the *"decarbonization of the global economy over the course of this century"* (G7 Germany 2015, 15). Likewise, following protracted negotiations resulting in more circumscribed language, the Paris Agreement concluded at COP-21 includes an aspirational goal of reaching a *"global peaking of greenhouse gas emissions as soon as possible ... so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"* (UNFCCC 2015, 22).

In purely technical terms, the carbon emissions of a country are a function of the level of economic activity (as conventionally measured by GDP) on the one hand, and the structural composition and efficiency of generating and consuming energy on the other hand. In other words: Decarbonization can be achieved by (a) reducing economic output, (b) reducing the carbon intensity of energy production and/or (c) enhancing the efficiency of energy use – ranging from buildings infrastructure to industrial processes and final consumption patterns.

However, pushing decarbonization is anything but a purely technical issue. In reality, it is among the most complex and challenging policy goals conceivable involving thorny questions and trade-offs related to costs, benefits, technological and behavioral change, distribution and fairness at both national and global levels. It has taken considerable time to fully grasp the magnitude of the task at hand. Initially, global climate protection was couched almost exclusively in terms of environmental policy before being considered in a second phase as a multi-dimensional challenge of systemic transformation towards low-carbon development paths. Only more recently has it been placed in a broader perspective of calling not just for technological innovation but for fundamental *"social, normative and cultural innovations"* (Messner 2015, 261).

In essence, the required transformative change towards low-carbon development trajectories calls for bold policy interventions ready to anticipate and manage desirable long-term pathways. More specifically, this entails (for a detailed elaboration see Lütkenhorst / Altenburg / Pegels / Vidican 2014):

- Acting under an exceedingly high level of uncertainty as the behavior of complex climate systems cannot be fully predicted and is subject to yet unknown patterns of resilience and irreversible tipping points;

- Dealing with pervasive market failures that go beyond mere externalities and call for a well calibrated policy mix of regulatory instruments, standards and market-based incentives;

- Actively disrupting old pathways that have proven to be unsustainable, for example through incentivizing divestment from so-called stranded assets ('unburnable carbon');

- Creating new pathways through adopting R&D policies that combine clear, long-term directionality (Mazzucato 2013) with competitive elements in creating new markets;

- Building confidence for business players that the policies pursued will be 'locked-in' and not be subject to erratic changes thus allowing long-term investment decisions to be taken.

Obviously, these are policy characteristics and conditions that even at national level constitute formidable tasks. In addition, they are amplified by climate and sustainability policies posing quintessentially a collective action problem, which requires a global consensus to be effective. Such a global consensus has remained elusive for decades and was now reached through the Paris Agreement.

While several factors have converged to make the Agreement possible, this was significantly helped by the fact that some of the major CO_2 emitting countries are now directly experiencing the climate and health consequences of increased emissions - be it in terms of the unprecedented drought in parts of the USA or the emissions generated by coal-based power plants and heating, massively rising traffic and industrial production in the major urban agglomerations of China and India. What we can observe is thus a partial country-level internalization of what is normally considered as global externalities. At the same time, from a political economy perspective, the legitimation and stability of political power are becoming closely intertwined with delivering not just growth and jobs but also decent living conditions.

It is this mounting domestic pressure on governments that in the case of some key players has contributed to a growing sense of urgency.

The Paris Agreement represents a historic achievement that should not be easily dismissed – as some commentators have done - as being the lowest common denominator and lacking enforcement mechanisms for implementation. The Agreement is a major global milestone and provides a platform for further efforts to build upon. It contains quantified global warming targets (committing to 2C and striving for 1.5C), broad principles of burden sharing that put developed countries in the lead but also hold developing countries responsible, clear expectations to scale up climate funding as well as agreed mechanisms to track and monitor progress achieved, even starting before the Agreement enters into force in 2020.

Against this backdrop, it is critically important to demonstrate that reaching the emission targets postulated in the Paris Agreement is both technologically feasible and politically doable – and that ambitious emission targets can indeed be reconciled with growing populations and economies. This is the key objective of the global DDPP and the Project itself as will be elaborated in the following chapter.

3 The Project and its context

3.1 The global DDPP[1]

Within the overall framework of the UN-SDSN, the DDPP was launched in the fall of 2013 and formally kicked off at an inception workshop in mid-October in Seoul. The project covers 16 countries[2], which between them account for close to three quarters (74 per cent) of energy-related global carbon dioxide emissions. It is coordinated by a joint secretariat of SDSN and the Paris-based Institute for Sustainable Development and International Relations (IDDRI). The German Development Institute is among a select number of partner organizations contributing to DDPP.[3]

DDPP has delivered quantitative modeling exercises for 16 national pathways demonstrating that under certain technological assumptions (see below) these economies can be radically decarbonized while at the same time meeting key national socio-economic development objectives. Implementing such deep decarbonization cuts would go a long way in achieving the global 2C target. However, in and of itself this would not be sufficient, as the cuts do not reflect the development trajectories of the many, mostly developing countries outside DDPP coverage. This explains the

[1] This section draws on information provided in DDPP 2015 and http://www.deepdecarbonization.org

[2] The countries covered include Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, the United Kingdom, and the United States.

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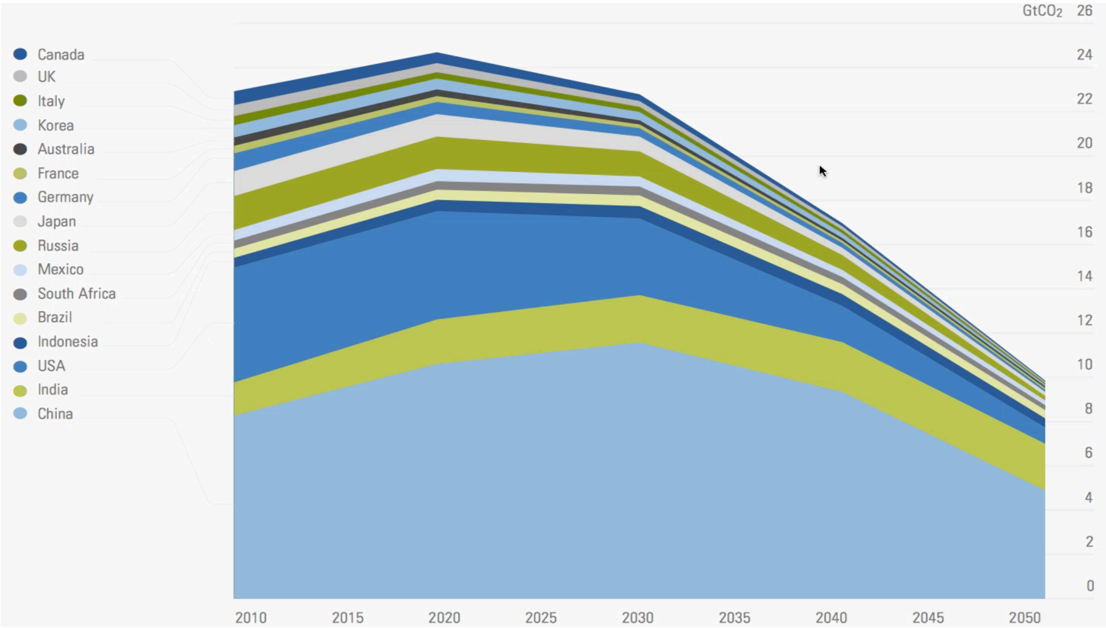
[3] The other partner organizations are the International Energy Agency (IEA), the International Institute for Applied Systems Analysis (IIASA) and the World Business Council on Sustainable Development (WBCSD).

cautious claim that *"DDPP cumulative emissions are not inconsistent with the 2° C limit"* (DDPP 2015, 6).

The country scenarios are exceedingly ambitious and assume an average emission level as low as 2.1 t CO_2 per capita by 2050 across the 16 countries covered. This has to be seen against a current world average of approximately 4.9 t per capita (with for example 17 t for the USA and around 7 t for China as well as the EU as a whole; 2014 figures from http://www.globalcarbonatlas.org). As can be seen from Figure 1, total country-level emissions would peak between 2020 and 2030 and by 2050, would reach around 50 per cent or even less of their 2010 levels.

Figure 1: Emissions trajectories for energy CO_2, 2010-2050

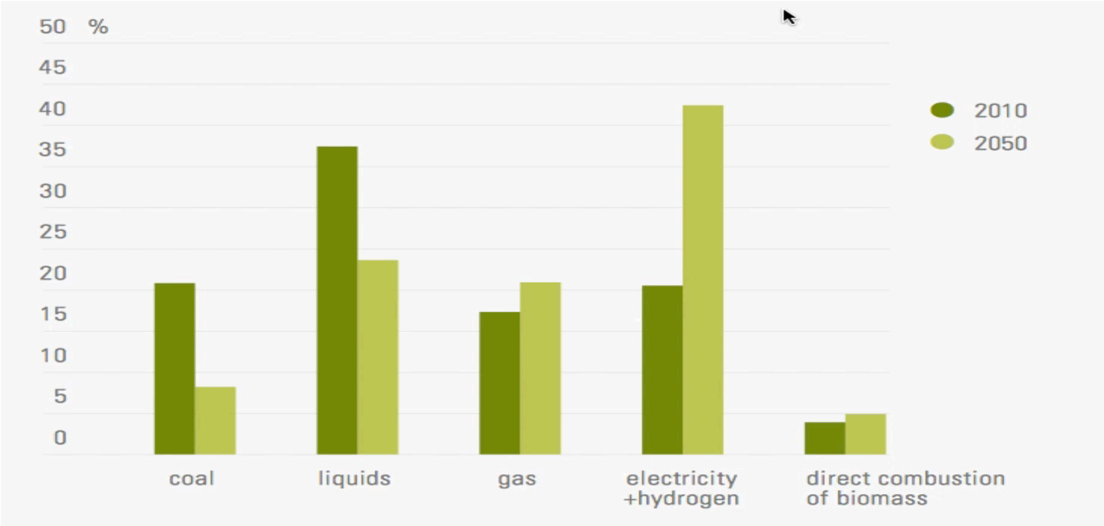


Source: DDPP 2015, 4

All pathways assume a largely decarbonized electricity generation (with an average reduction of the carbon intensity of electricity of 93 per cent by 2050). This presupposes a fast transition towards renewables coupled with nuclear power and a complete operation of the remaining fossil fuel generation under carbon capture and storage (CCS) technologies. Figure 2 demonstrates the massive shift away from coal and the transition towards decarbonized electricity and hydrogen.

The decarbonization scenarios are considered to be economically affordable. Factoring in technological learning effects as well as resulting energy savings, the net investment costs for the energy sector are calculated to be around 1 per cent of GDP. Thus *"the economic story of energy sector decarbonization is primarily one of investment displacement, in which investment in the energy sector transitions away from fossil fuel extraction as demand decreases, and towards low-carbon technologies"* (DDPP 2015, 10).

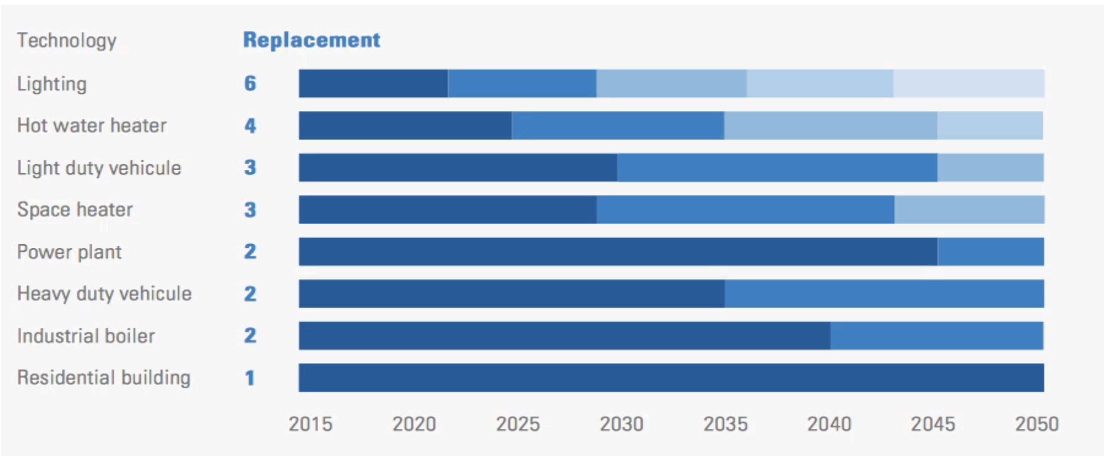
Figure 2: Share of different fuel types in final energy consumption, 2010-2050



Source: DDPP 2015, 7

Without any doubt, the DDPP modeling exercises constitute an impressive consolidated research effort and as such serve a number of important purposes. They drive home the point that only highest levels of ambition and determination can result in the emission cuts required under the remaining global carbon budget. They further demonstrate the extent of interlinkages between different productive sectors, related physical infrastructures and prevailing technology options thus emphasizing systemic coordination requirements. Also, they establish a basis for additional countries to consider deep decarbonization in their planning exercises and for the international community to understand financial and capacity-building support requirements. Perhaps most important of all, they establish the case for long-term technology roadmaps and for spelling out the long-term implications of current policy decisions, which often necessitates a frontloading of tough choices if early emission peaks are to be achieved and carbon lock-in effects to be avoided. The replacement cycles of various types of investments (as shown in Figure 3) illustrate this point.

Figure 3: Typical lifetimes of selected energy technologies and infrastructure



Source: DDPP 2015, 14

At the same time, such quantitative simulations suffer from inherent limitations that need to be recognized. They can only be as valid as their assumptions are. Concerning the technological options, the DDPP scenarios were built *"using technologies that are commercially available or expected to be in the time frame of the analysis"* (DDPP 2015, 6). However, some of the technologies factored in are still subject to controversial debates and it seems that fairly optimistic outlooks were taken. CCS is a case in point. While the scenarios assume all remaining fossil fuel based power to be generated under CCS conditions, presently this bridging technology remains subject to high investment and operating costs, relatively low fuel efficiency, lack of sufficient experience in upscaling, significant environmental and carbon leakage risks and considerable opposition from various groups of stakeholders. This is not to say that the technology can and will not be further developed yet the concerted international effort necessary to establish CCS as a viable and accepted technology has so far not been undertaken.

Moreover, the modeling exercises by their very nature remain silent on the political feasibility and societal acceptance of the fundamental transformations ahead. Who are the winners and the losers? Where must the strongest resistance be expected? Which transformative alliances can be built to push change? Which are the unavoidable trade-offs and where can synergies be reaped in terms of co-benefits?

3.2 The DIE Project

The DIE Project was designed to complement the global DDPP exercise and bring into focus exactly the type of political feasibility questions raised above. A number of country and regional studies serve to identify the major barriers to deep decarbonization pathways and possible solutions to overcome such barriers thus providing potential role models for country-level action.

By doing so, they contribute to embedding the quantitative modeling results into a political and institutional context from which realistic transformational strategies for decarbonization can depart. In each case, this calls for a stock-taking of green growth and low-carbon trajectories pursued so far, coupled with an assessment of likely development paths going forward. The intention is to contribute to gradually building up a pool of national narratives demonstrating how complex interactions between various groups of stakeholders and institutions (in the public, business, academic and civil society sectors), the innovation system, the regulatory framework and the financial sector ultimately define the success or failure of green transformation processes. The leading research question thus was why in many cases technologically feasible scenarios of deep decarbonization are being blocked by countervailing societal forces or alternatively, how they are being translated into socially and politically accepted solutions.

Specifically, the Project has generated six component studies, which can be grouped into three categories:

(1) Direct contributions to the global DDPP

Through funding support to the global DDPP, the Project has provided the financial basis for conducting the final modeling work and preparing the two country reports on China and South Africa. This has resulted in the following two outputs:

- Teng, et al. (2015), Pathways to deep decarbonization in China, SDSN-IDDRI
http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_CHN.pdf
- Altieri et al. (2015), Pathways to deep decarbonization in South Africa, SDSN-IDDRI
http://deepdecarbonization.org/wp-content/uploads/2015/09/DDPP_ZAF.pdf

(2) Country studies of the political economy of transformation towards deep decarbonization

Two country studies were prepared in conjunction with the modeling work for the same countries, China and South Africa, resulting in the following two outputs:

- NCSC (2015), A political economy analysis on China's approach to deep decarbonization (unpublished)
- Baker / Burton / Godinho / Trollip (2015), The political economy of decarbonization: Exploring the dynamics of South Africa's electricity sector, Cape Town: Energy Research Center (ERC), University of Cape Town
http://deepdecarbonization.org/wp-content/uploads/2015/11/DDPP-Political-Economy-261115-FINAL-for-printing.pdf

In addition, the Project delivered a study on the German case, which is widely considered as a possible benchmark for a policy-driven energy transition of a mature industrial economy:

- Kemfert / Opitz / Trabe / Handrich, (2015), Deep decarbonization in Germany: A macro-analysis of economic and political challenges of the 'Energiewende' (energy transition), DIW Berlin: Politikberatung kompact 93
http://diw-econ.de/en/publications/studies/diw-berlin-policy-advice-compact-93/

(3) Regional study sub-Saharan Africa

Beyond the country coverage of the global DDPP and with a view to exploring the options for low-income countries to avoid carbon lock-in trajectories, a study on sub-Saharan Africa was undertaken:

- Hogarth / Haywood / Whitley (2015), Low-carbon development in sub-Saharan Africa. 20 cross-sector transitions, London: Overseas Development Institute
http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9878.pdf

4 Key results of component studies[4]

4.1 Modeling of deep decarbonization pathways

The key features of the two country pathways elaborated under the Project are briefly summarized below. They demonstrate both a basic degree of commonality of methodology but also the specificity of approaches selected and their alignment with a broader set of development objectives and individual historic and social conditions.

4.1.1 China

The China deep decarbonizaton pathway departs from a number of national long-term development parameters, which essentially include the continued need for economic growth, the elimination of poverty (with 13 per cent of the population still in absolute poverty according to the World Bank definition), the technological upgrading and diversification of the economy, the strong trend towards further urbanization and a very moderate population growth.

Against this backdrop, the basic decarbonization narrative emphasizes both the climate change risks that require ambitious carbon emission control as well as the more localized pollution and public health effects, which have begun to threaten the ruling elite's political legitimacy: *"Air quality has become the number one cause of social instability in China"* (Teng et al. 2015, 7). In general, the narrative relies heavily on a co-benefits perspective that presents investments into low-carbon technologies and infrastructure as a critically important driver of future economic growth and competitiveness. Indeed, a proactive policy push towards greening the economy is portrayed as a precondition for *"avoiding the middle-income trap"* (Teng et al. 2015, 26).

The key elements of the central decarbonization scenario for 2050 – which assumes an emission level peak around 2030 - are synoptically presented in Figure 4. They include:

- Further significant growth of primary energy consumption (by 76 per cent) coupled with a shift away from coal, a strong reliance on coal with CCS (which would be roughly equal to non-CCS coal use), a massive expansion of renewable sources of energy (accounting for more than 30 per cent of the total) and a significant build-up of nuclear energy capacities;

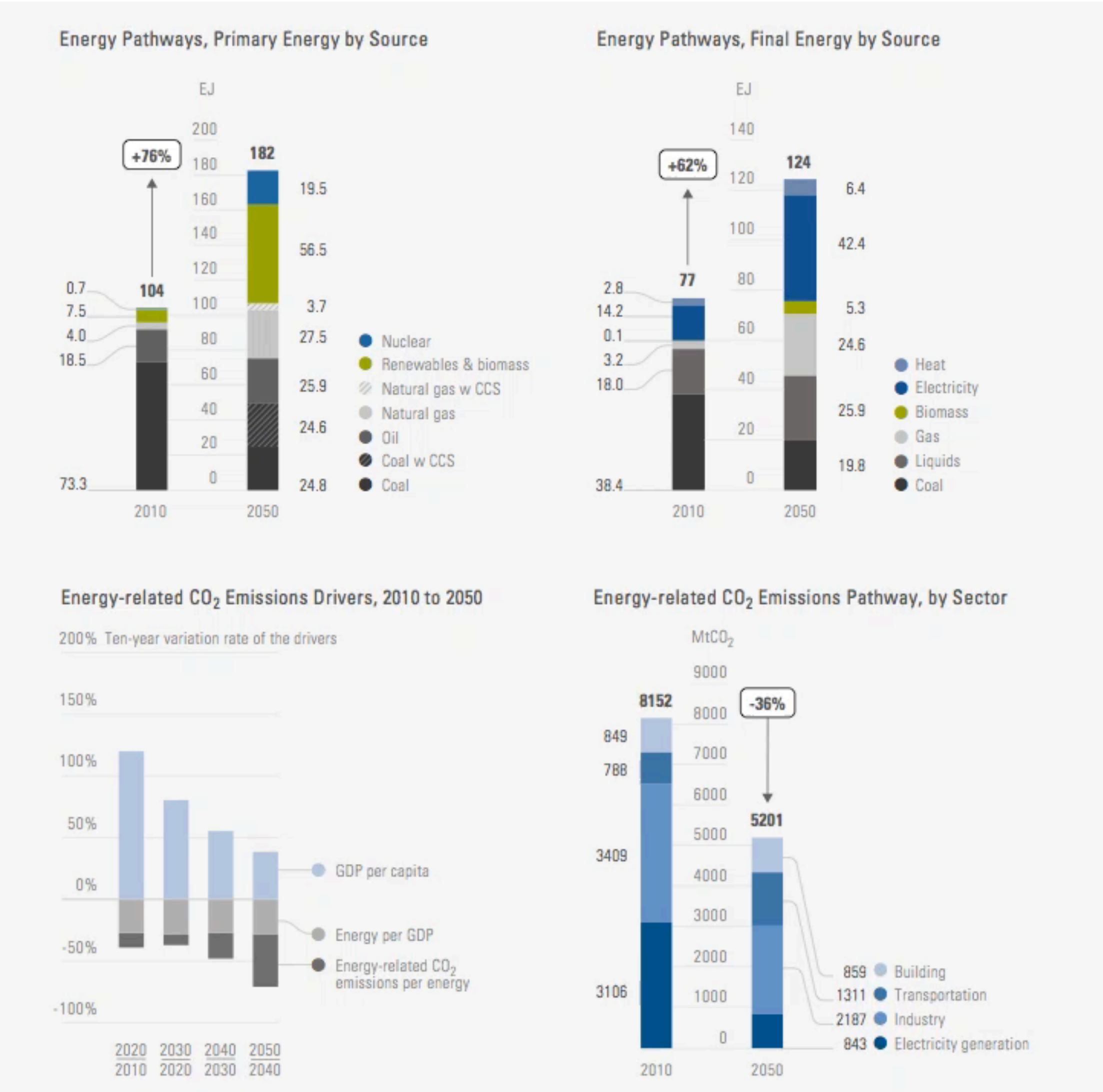
- A sharp rise in the share of (decarbonized) electricity in final energy consumption, from 18 per cent in 2010 to 34 per cent in 2050;

- A reduction of energy-related CO_2 emissions by more than one third, largely accounted for by electricity generation and industry whereas the CO_2 emissions generated by transport are projected to further grow;

[4] This sections draws on the analyses and findings contained in the various component studies as listed on the previous page.

- In terms of the key emission drivers, a high yet diminishing importance of GDP per capita (in accordance with the 'new normal' concept), which is being compensated for by the growing impact of a progressively decarbonizing energy generation system.

Figure 4: Deep decarbonization pathway China – key features



Source: Teng et al. 2015, 32.

While the scenario presupposes a widespread application of various CCS technologies after 2030 (accounting for one third of total decarbonization), the country report devotes high attention to discussing the related prospects and uncertainties and is quite explicit about the risks of failure. On the one hand, it is assumed that as of 2050, CCS will reduce emissions by 2.7 Gt CO_2 per year. On the other hand, the report points out that *"in light of uncertainties regarding storage potential, technology, policy, and cost, the more realistic storage capacity of CCUS will be around 1.5 Gt CO_2 per year" (Teng et al. 2015, 24).*

Likewise, the scenario depends on ambitious levels of electrification in passenger transport where it is assumed that by 2050 electrically powered vehicles and fuel cell vehicles would account for 60 per cent of the total passenger car stock.

Concerning some basic policy recommendations, the report argues for the gradual introduction of economy-wide systems for carbon emission control with increasing reliance on market-based pricing instruments. It is considered *"necessary to build a national carbon market during the 13th Five-Year Period, based on current carbon cap-and-trade pilots"* (Teng et al. 2015, 28).

4.1.2 South Africa

The South Africa country report is very deliberate in putting the decarbonization challenges distinctly in the broader context of the country's recent history and its full development agenda. To date, South Africa has remained a starkly divided country with levels of income and wealth inequality far outside the normal range observed in other countries, developed and developing alike. Most of the features characterizing the economy can be traced back to an enclave-type, capital-intensive mining and mineral-processing industry in early industrialization stages that has led to low labour incomes, persistent patterns of poverty, high unemployment, lack of skills upgrading and diversification, and highly dualistic structures. In essence, South Africa combines the status of an upper middle-income country with structural deficiencies more typical of low-income, resource-dependent economies.

The resulting pressure on meeting hard-core economic objectives (above all in terms of creating sufficient employment opportunities for a growing population) drives the decarbonization scenarios: *"Lower poverty and inequality are goals that cannot be sacrificed to lower emissions"* (Altieri et al. 2015, 41).

The key elements of South Africa's decarbonization scenario[5] for 2050 are synoptically presented in Figure 5. They include:

- A slight reduction in primary energy consumption, which however is accompanied by a heavy increase (72 per cent) in final energy consumption. This unusual coincidence can be explained by the high amount of electricity in the final energy mix already in 2010 and the inefficient conversion of primary (mostly coal) energy to electricity, while in 2050 electricity will be almost exclusively generated from renewable sources of energy;

- A radical shift away from coal as a primary energy source, from 73 per cent in 2010 to 25 per cent in 2050, and a transition to renewable sources of energy, which are assumed to rise from negligible levels in 2010 to a share of almost 50 per cent;

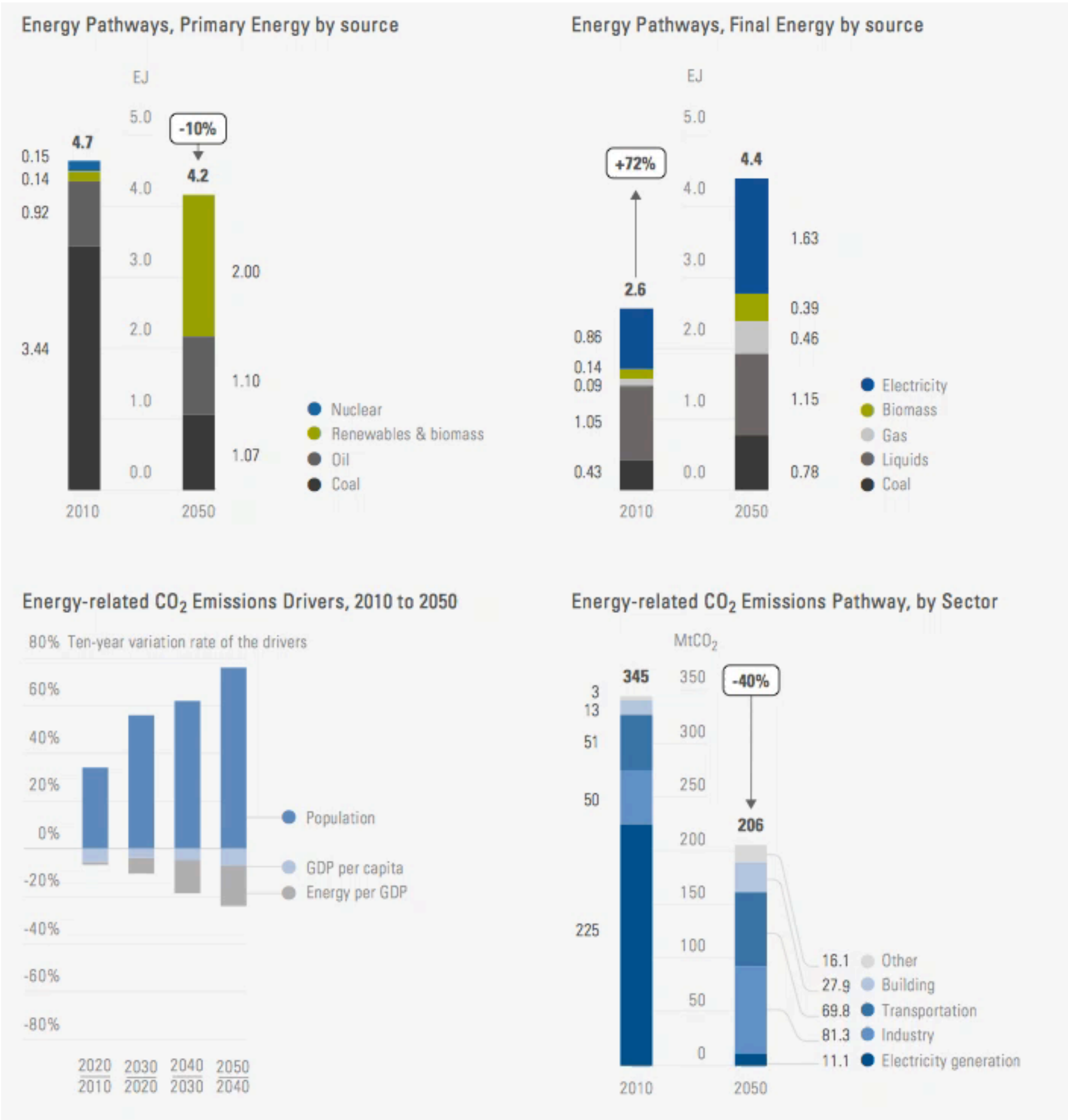
- No reliance on nuclear energy (assuming no new nuclear investments and the last nuclear power plant retiring in 2044) and no reliance on CCS, which *"is*

[5] The country report presents two different scenarios referred to as 'economic structure scenario' and 'high skills scenario'. Figure 5 is based on the 'economic structure scenario'.

not considered feasible for South Africa as the coal mines are located far from potential storage sites, and the current costs, as well as forecasted costs, are incredibly high" (Altieri et al. 2015, 30);

- Population growth as the key driving force for future energy-related CO_2 emissions, which in total are expected to be reduced by 40 per cent and would be largely accounted for by industry and transportation requirements.

Figure 5: Deep decarbonization pathway South Africa – key features



Source: Altieri et al. 2015, 48.

The annual investment costs to achieve a deeply decarbonized energy system are calculated to reach close to US-$ 20bn around 2030 and, in some years, would be in the order of 15 per cent of total investment. This is considered to exceed by far the economy's domestic capacity and would imply a partial reliance on internationally available climate funds.

Finally, the country report concedes a remaining dilemma in that *"the answer of how to achieve mitigation and development goals remains elusive, as unemployment rates remain unacceptably high in 2050 in both scenarios. Development and climate are both complex problems in themselves, and we offer no easy solutions for addressing them in tandem ... More understanding based on in-depth and country-led research is needed to really meet the challenges of zero poverty and zero emissions"* (Altieri et al. 2015, 4).

4.1.3 Differences and commonalities

It is stating the obvious that the decarbonization challenges of China and South Africa must respond to national economic and political characteristics and, as a result, are quite different:

- This begins with the sheer scale of total energy requirements, which in China surpass those of South Africa by a factor of approximately 30, both in 2010 and in the projections for 2050.

- Also, the main driving forces of energy-related CO_2 emissions are principally different; population growth is considered to be the key factor in South Africa while for China it is the assumed growth in GDP per capita.

- The two scenarios are built on divergent technology asssumptions. Specifically, this relates to two important factors: nuclear energy on the one hand and the use of CCS on the other hand. For 2050, the China modeling exercise expects a share of more than 10 per cent of nuclear energy in primary energy consumption while for South Africa no nuclear energy use at all is foreseen. Concerning CCS, in the case of China half of the remaining coal consumption in 2050 is forecast to take place under CCS application whereas the South African scenario does not envisage any CCS use.

At the same time, there are noteworthy commonalities. First, this is true for the massive energy-efficiency gains built into the models (energy-intensity of GDP is expected to be halved in South Africa and to even decrease by three quarters in China). Second, it applies to the strong push towards scaling up a whole spectrum of renewable sources of energy (expected to account in 2050 for half of total primary energy in South Africa and for one third in China). Third, the ambitious assumptions related to the electrification of passenger vehicles characterize both country scenarios.

Arguably the most important feature in both scenarios is the rapidly diminishing role of coal in the energy mix. Weaning economies off coal raises complex issues related to energy technologies, changing grid management requirements and the economics of a fuel switch towards renewables. Above all, it implies a fundamental challenge to established political power constellations. This is a key aspect of the political economy studies of Germany and South Africa presented in the following chapter.

4.2 Political economy of low-carbon transformation

4.2.1 Germany – Energy transition as a national project

The German energy transition ('Energiewende') is a long-term national transformation project of the first order, which has come to be acknowledged as a policy reference point for similar endeavors in many other countries. For this reason, the Project has also incorporated a review and assessment of the German experience.

Concerning its scale, its scope and its level of aspiration, the German energy transition is indeed unique. It represents the only case of a mature industrial economy seeking to achieve ambitious decarbonization targets (in terms of reduced CO_2 emissions and a radical shift towards renewable sources of energy) without recourse to nuclear energy. Immediately on the heels of the Fukushima disaster, the German government decided to completely close the nuclear option and phase out all remaining nuclear power plants by 2022.

It is noteworthy that – notwithstanding debates on various implementation shortcomings – to date the energy transition has consistently enjoyed exceedingly high levels of popular support, with approval ratings hovering around 80 per cent. Hence, it can legitimately be considered as a broadly supported national energy strategy that is in line with the generally high public backing of climate change and environmental policy objectives that has characterized Germany for many decades.

The emission-related and energy-related targets laid down in official policy documents are linked to those prevailing in the broader EU framework yet in many instances go even further. Table 1 summarizes the most important targets:

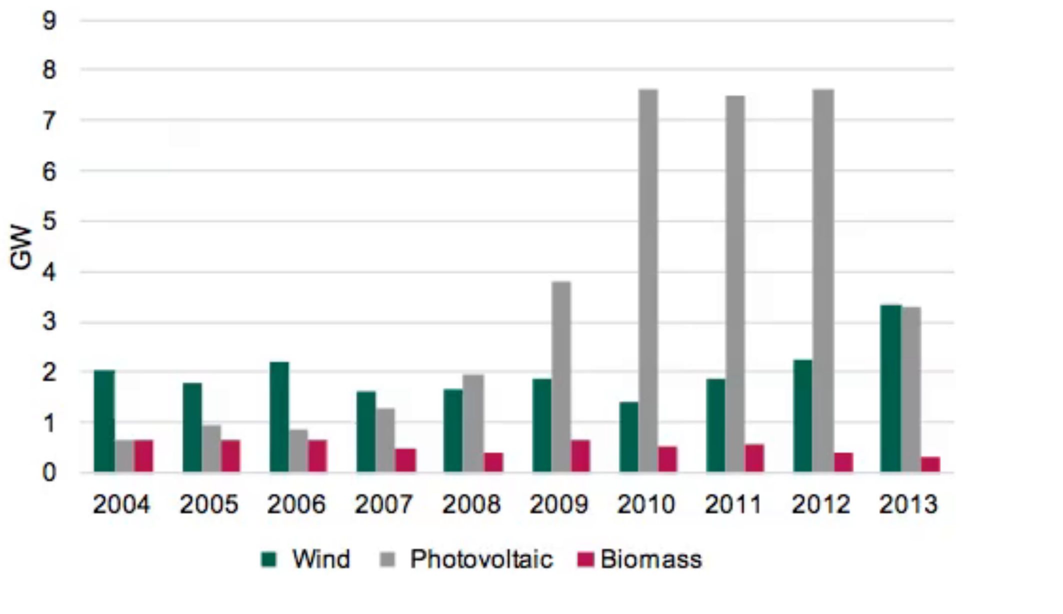
Table 1: German energy transition: Compilation of main long-term targets

	2013	2020	2030	2040	2050
GHG emissions (compared with 1990)	-22.6%	-40%	-55%	-70%	-80% - -95%
Renewable Energies					
Share in gross final energy consumption	12.0%	18%	30%	45%	60%
Share in gross electricity consumption	25.3%	35%	50%	65%	80%
Energy Efficiency					
Primary energy consumption (compared with 2008)	-4.0%	-20%			-50%
Energy productivity (final energy consumption)	0.26% p.a. (av. 2008-2013)	2.1% p.a.			
Gross electricity consumption (compared with 2008)	-3.3%	-10%			-25%
Thermal refurbishment of residential buildings	~1% p.a. (2012 value)	2% p.a.			
Final energy consumption of transport sector (compared with 2005)	1.0%	-10%			-40%

Source: Kemfert et al. 2015, 9.

While the renewable energy and energy-efficiency targets have stayed on course, question marks have emerged recently regarding the likelihood of the emissions targets being met (see below). Clearly, the rapidly rising contribution of renewables in Germany's energy mix is among the cornerstones of the energy transition. From just around 5 per cent fifteen years ago, the share of renewables in total electricity consumption has surged to 25 per cent in 2013. These dynamics were largely accounted for by wind and solar PV energy, as can be seen from Figure 6.

Figure 6: Germany: New capacities of renewable energy in the electricity sector by source



Source: Kemfert et al. 2015, 35.

The study clearly identifies the various policies adopted as the key driver of the remarkable expansion of renewables. Apart from a whole range of conventional promotional instruments (related e.g. to preferential financing and targeted R&D support), the introduction of feed-in tariffs (FiT) constituted the major policy innovation. By now, the FiT approach is well known and has been widely replicated in more than 100 countries across the world. However, when originally embodied in the Renewable Energy Act of 2000 (and in a precursor law in the early 1990s), it broke new ground. Its main features include:

- Guaranteed FiT levels for a 20 year period, with initially fixed amounts (for 5-12 years) subject to a degressive scale later on;
- Source-specific application in accordance with different technologies and deployment conditions
- Purchase guarantees for unlimited volumes of energy produced
- Grid priority in terms of connection ('feed-in') and transmission
- Burden sharing of additional costs by all electricity consumers

The staggering success of this policy is beyond any doubt. By providing long-term security to both investors and financing institutions, and by remaining open-ended in terms of technology choice, it has triggered the roll out and up-scaling of a whole range of renewables technologies. However, in the course of time the original FiT approach has become the victim of its own success by causing an excessive expansion of heavily subsidized solar PV deployment[6] – a development that has led to recent policy reforms as described below.

Before turning to some of the key political economy issues of the German energy transition, its heavy emphasis on economic co-benefits must be recognized. From the outset, the strategy was couched not only in terms of its positive climate impact but also as a forward-looking transformation that would create first-mover advantages for key sectors of German industry. Indeed, significant new employment opportunities were generated, export market shares increased, technological innovation stimulated and competitive positions improved – more so in the case of wind energy technologies than in the solar PV industry, which in recent years has been subject to aggressive import competition above all from Chinese equipment manufacturers (for details see Kemfert et al. 2015, chapter 5 and Pegels / Lütkenhorst 2015).

The rapid transformation of the electricity system towards renewable sources of energy has led to stark decreases in producer prices, which have thrown Germany's major, largely coal-dependent utilities (E.on, RWE, Vattenfall and EnBW) into deep crisis. The results have been huge operating losses and precipitous falls in stock prices. The ensuing depreciation of company values can be considered a prototypical case of 'stranded assets'. Following an initial phase of outright denial of the new realities, the corporations turned to defensive strategies demanding government funding for electricity capacity reserves (as a buffer against alleged fluctuations of renewable energy sources) and more recently, have embarked on fundamental corporate restructuring into separate divisions for 'old' and 'new' lines of business. What can be observed now, is thus a gradual and reluctant acceptance of a future business model that will have to radically depart from carbon-based revenue streams.

In addition to the economic and political implications of the changing energy mix, the German energy transition is faced with two typical industrial policy challenges: the distribution of costs to be borne as well as various dimension of policy alignment:

- *Distribution of incremental costs*. The incremental electricity costs originating from subsidized FiTs amount to approx. 18 per cent of total electricity costs, which translates into less than one per cent of average household income. However, the political economy is lopsided due to (1) generous exemptions for more than 2,000 companies; (2) private households bearing a disproportionately high share of costs; and (3) the impact of additional costs being regressive and thus perceived as unjust.

- *Policy alignment*. There is a growing need to ensure well aligned policies in various dimensions: (1) along the time axis with a view to maintaining policy stability despite changing government coalitions; (2) vertically between state, federal and local level decisions, as e.g. in the case of managing the expansion

[6] It is telling to note that in 2013 solar PV accounted for roughly 20 per cent of renewable energy capacity supported under the Renewable Energies Act, whereas it was responsible for more than 40 per cent of the related electricity price increases (Kemfert et al. 2015, 36).

of the transmission grid; (3) horizontally across different policy domains, such as energy, environment, technology, social protection and trade policies; and (4) between national and supra-national policy levels. The significance of the latter aspects lies mainly in the interaction between national energy markets and the EU-wide emissions trading system (ETS). The low CO_2 prices generated by ETS are favoring the use of lignite, which is known to be the top 'climate killer', and thus put Germany's long-term emission reduction targets into jeopardy.

The requirements for policy coherence, the unpredictability of market forces and technological learning curves, and the risks of creating policy-induced producer rents (and thus an innovation-hostile 'sweet subsidy' syndrome) call for a continuous process of stakeholder consultations, and policy monitoring and evaluation. This has taken place in Germany and has led to a whole series of reforming the FiT approach. Two major overhauls of the legal provisions were undertaken in 2012 (resulting in reduced FiT rates and the new concept of an expansion corridor linking further reductions to the speed of capacity expansion) and in 2014 when the piloting and gradual introduction of competitive tendering ('reverse auctioning') schemes was introduced.

The German energy transition is work in progress and will remain so for many years to come. In essence, the experience gained so far reveals the transformative power of a determined process of redesigning a country's entire energy system. Yet it also underlines the importance of being endued with effective and well-orchestrated institutional implementation capabilities and of being open to policy learning curves.

4.2.2 China – Strengthening policy coherence and implementation[7]

The political economy study on China – to be seen in conjunction with the China DDPP scenario as summarized in section 4.1.1 above – is set against the background of the country's far-reaching emission reduction goals. Most recently, these have been laid down in the 12th Five-Year Plan and various companion documents, the Joint US-China Presidential Statement on Climate Change of November 2014 and the Chinese Intended Nationally Determined Contributions (INDC) document submitted to UNFCCC in June 2015.

The study concentrates on questions related to policy coherence and policy coordination across a range of actors at different levels. In general, the need for capable and effective institutions for policy implementation is a key aspect in current debates in China. This applies in particular to plans to merge the country's seven ETS regional pilot schemes into a consolidated national ETS in the course of 2016. In this context, serious doubts are being raised as to whether the required institutional monitoring and enforcement preconditions are in place.

[7] The China political economy study (NCSC 2015, unpublished) has not been fully completed. Its analyses and conclusions are thus of a provisional nature. However, they do provide important pointers to the nature of policy challenges and shortcomings in the country's decarbonization strategy.

The study stresses that – in accordance with China's general economic policy principles – also the decarbonization policy approach relies heavily on top-down regulatory instruments. These are complemented by various incentive schemes (typically preferential access to subsidized financial support and tax breaks) as well as information and advisory policies aimed at promoting environmentally responsible behavior on the part of enterprises and consumers.

A wide range of national laws, regulations and administrative orders are in force seeking to govern both energy-efficiency and carbon emissions. However, they tend to be uniform in nature thus disregarding the varying marginal abatement costs of different sectors and enterprises. Similarly, they are formulated at national level and not broken down in terms of their regional and provincial implications. Also, the rigid imposition of quantitative emission ceilings fails to stimulate innovation and the adoption of best practice technologies that would often be able to exceed the mandatory emission reductions. As the regulatory instruments imply high administrative implementation costs, they are frequently confined to large and emission-intensive enterprises and do not cover the vast majority of smaller enterprises. Finally, they are often lacking the necessary detailed implementation rules and guidelines. In some cases, it is reported that local governments have even tried to meet emission reduction targets simply by cutting down production.

At the same time, the funds made available by the government for energy conservation and emission-reduction investments have remained underutilized due both to complex application procedures and to insufficient information at the level of enterprises. As the study underlines, information gaps indeed seem to be a major hindrance for effective decarbonization policies. This also negatively affects the incentives for enterprises to sign voluntary energy reduction contracts with the government. Such performance contracts are often perceived by businesses as causing additional costs without resulting in tangible benefits in terms of public recognition and ultimately, increased demand for their products. It would seem that the creation of public awareness of such voluntary schemes is still largely lacking.

The role of provincial and local governments deserves special attention as the gradually changing policy priorities at national level are not yet aligned with the political incentive and reward systems prevailing locally: *"In local economic development ... the contradiction between local economic growth and enterprise environmental protection is especially prominent"* (NCSC 2015, 24). Local governments have acted in a growth-maximizing mode for decades and now often refuse to exercise their power to penalize companies for excessive emissions or even shut them down. They are literally 'at the end of the line' and in danger of facing immediate popular unrest as long as economic income and employment interests of the population trump environmental concerns. This is exacerbated by a short-term perspective favoring immediate fiscal revenue gains over longer-term benefits, which are perceived as uncertain.

Moreover, there is a tendency for local governments to offer lower environmental standards to enterprises as an incentive to attract investment in what the study refers to as *"cutthroat competition"* (NCSC 2015, 28) among the various regions of the country.

In summary, the study argues that for China to be put on a sustained decarbonization pathway, the following issues need to be addressed:

- Strengthened incentives and simplified institutional arrangements and administrative procedures for promoting technological innovation, including through incubation schemes and the creation of networking platforms for enterprise cooperation;

- A more active role of the financial system that should lower the costs for innovative low-carbon technology through the provision of dedicated funding and support in de-risking long-term investments; and

- Most importantly, a general strengthening of policy-implementing institutions.

The study concludes by stating that the country's *"low carbon institutional arrangement determines whether China can realize (the) transformation to a deep decarbonization path"* (NCSC 2015, 36).

4.2.3 South Africa – Overcoming the dependence on coal

For South Africa, in an only slightly stylized perspective, decarbonization can almost be equated with moving away from the country's exceedingly strong dependence on coal as a source of energy – both for electricity generation and in terms of fueling the important mining and minerals industry. The challenge is further exacerbated by the fact that the country's energy sector in general, and coal in particular, are dominated by Eskom as a state-owned monopoly utility.

More specifically, the electricity sector accounts for almost half of South Africa's CO_2 emissions. Within the sector, it is coal-fired power plants that are responsible for 85 per cent of total capacity and as much as 92 per cent of generated electricity. Moreover, coal-based electricity in conjunction with coal-based liquid fuels (which is the domain of Sasol) as well as direct coal use have historically been the energy driver of the country's minerals-energy complex (MEC), i.e. mining, smelting and refining of various minerals, as well as the production of a wide range of metals. Indeed, most of Eskom's coal power plants are adjacent to the country's largest coalmines. The contribution of MEC to South Africa's economy – while gradually declining – is expected to remain dominant in the years to come. In light of these facts, *"any shift towards decarbonization of the electricity sector would significantly affect the coal sector and the South African economy more broadly" (Baker et al. 2015, 14).*

Appreciating the position of Eskom is key to understanding the political economy of South Africa's energy sector. Eskom is strongly vertically integrated and holds a monopoly in terms of electricity generation and transmission, while also controlling some 60 per cent of total distribution. The company's installed capacity amounts to 42 GW of which 36 GW are coal-based and the remainder spread over small capacities of gas, nuclear, hydro and wind (the latter almost negligible at just 100 MW). The customer structure of Eskom is strongly biased towards heavy industry, with the well-organized Energy Intensive Users Group alone accounting for 44 per cent of electricity purchases.

In recent years, Eskom has come under heavy criticism in connection with both the increasing incidence of load shedding (a new phenomenon for South Africa) and the company's financial situation. In early 2015, its financial crisis had become so severe that the company had to be bailed out with government funds. This precarious situation is likely to intensify given that the costs for two major new coal-based power plants (to be completed in 2022) are exploding, while their competitive position is being challenged by the rapidly declining prices of electricity produced from renewable sources.

In general, it can be expected that South Africa will remain coal-dependent for many years to come, not only due to the powerful vested interests of Eskom and its corporate and political allies in mining and industry, but also as the existing infrastructure has created a particularly strong path dependency. However, there are early signs of a gradual change originating from emerging renewable sources of energy and their increasingly favorable economics.

Renewables entered the picture in 2007 when South Africa launched a feed-in tariff scheme known as REFIT. A few years later in 2011, this was reinforced by the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP), which turned out to be a remarkable success story. Contributing factors were a strong regulatory framework, a positive response also from international renewable energy and technology suppliers as well as an effective and transparent bidding process. The latter has benefitted from significant competitive elements based on a reverse bidding approach, which has brought down the electricity prices of various renewables faster than expected. The study comes to the conclusion that *"REIPPPP has provided strong arguments in favour of an increased renewable energy allocation and is an important consideration for the decarbonisation of South Africa's electricity sector" (Baker et al. 2015, 29).*

Concerning the governance of energy and electricity policy in South Africa, the study identifies a high level of indecision as to where the main responsibility should reside and how the cooperation among relevant ministries and departments should be organized. Accordingly, numerous realignments of mandates have taken place over time and have resulted in a lack of strategic leadership and coherence. In turn, this has translated into weak institutional implementation capabilities and ultimately, an insufficient build up of technical knowledge on the part of both policy-makers and administrators.

The study points out that for the first time, there is an emerging potential for transformative alliances in favour of decarbonizing the country's energy system. The new renewable energy industries are getting organized into sector-specific business associations. While their advocacy and lobbying power as well as their access to political decision-makers are still in their infancy, clearly the new players are being recognized by vested interests. There are encouraging signs of broadening the foundation for renewables; in some instances, the new business associations have engaged successfully in negotiations with established players from heavy industry and independent coal producers.

Notwithstanding these gradual changes, the overall picture is still one in which *"those groups that we would expect to be pro-mitigation are fragmented and dispersed,* *whereas coalitions concerned with maintaining the status quo are well organized … this has been exacerbated by the country's fragile economic position" (Baker et al. 2015, 2).*

In the light of South Africa's apartheid history and the continued high inequality of incomes and assets, there is great concern that the necessary decarbonization process should be leading to a fair and socially inclusive transition. This implies attention to energy access for the poor and to the generation of local jobs by the new energy technologies. This policy priority is also visible in the manner in which renewable energy sources are being promoted. For instance, project bids are not assessed on price alone (with a 70 per cent weight) but also on criteria related to their development impact including specifically *"job creation, participation of historically disadvantaged individuals, protection of local content, rural development, community ownership, and skills development" (Baker et al. 2015, 28).* The local content thresholds have been raised in successive bidding rounds and manufacturing units for low-technology solar PV and wind technology components have been set up. However, their long-term viability in a scenario characterized by a small domestic market remains subject to debate.

In conclusion, the study sees the dominant position of Eskom being slowly eroded by emerging independent power producers, above all those from renewable energy sources that are rapidly gaining price competitiveness. Eskom's business model is now being fundamentally challenged and it may be just a question of time until South Africa's policy-makers adapt their priorities and take a more proactive stance pro decarbonization.

4.3 Sub-Saharan Africa: Avoiding early carbon lock-in

Most studies of decarbonization pathways tend to focus on those countries that account for the lion's share of carbon emissions and thus, by reducing their negative climate impact, can really make a global difference. As mentioned above (see section 3.1), this also applies to the global DDPP exercise, which concentrates on 16 countries responsible for 74 per cent of total CO_2 emissions. This obviously makes sense from a short-to medium-term impact perspective seeking to assess the potential implications of a sustainability transformation that is enacted now and can have tangible results in the next 10-15 years. In this spirit, this report so far has summarized the country-specific scenarios and possible transformation paths for Germany, China and South Africa.

At the same time, there is a flipside to this approach. The more than 70 low-income countries currently account for just 10 per cent of global CO_2 emissions (Nordhaus 2013, 253) yet it is now at the early latecomer stage of their industrialization process that key decisions on defining their development trajectory are being taken. With only incipient industrial capacities in place, low levels of motorized private transport, poorly developed transport infrastructure and a high population share without access to modern energy, the critical challenge for these countries going forward is not to decarbonize existing economic structures but rather to develop productive capacities, while avoiding the build-up of high-carbon economies relying on unsustainable technologies. Moreover, in view of recent massive discoveries of coal and oil reserves in sub-Saharan Africa (SSA), their commercial exploitation may be in conflict with a limited global carbon budget as derived from a global 2°C warming scenario. The question thus emerges how the legitimate economic development aspirations of low-income countries can be reconciled with global climate change boundaries and targets.

This is why the Project has deliberately included a special study on low-carbon development challenges in SSA with a view to identifying areas of critical importance for preventing a carbon lock-in. The study – while providing numerous specific country and regional examples of necessary policy action – is largely conceptual in nature and as such, opens up an innovative research perspective. The present section focuses on the conceptual framework developed without intending to summarize the rich findings of the entire study, which addresses seven sectors (agriculture, forestry, energy, transport, extractives, construction and manufacturing) and for each of these, reviews the key technologies and infrastructure as well as options for policy interventions.

The study acknowledges that in the case of low-income countries, there are strong reasons for adopting low-carbon technologies at an early stage but also valid concerns that need to be factored in (Table 2).

Table 2: Adopting low-carbon development strategies in low-income countries

Potential pros*	Potential cons*
Early acquisition of technological and managerial capabilities and skills related to sustainable technologies that will dominate in future	Overall scenario of tough trade-offs and exceedingly high opportunity costs (e.g. originating from critical investment needs in health, education, etc.)
Investment into future export potentials: access to stringently regulated markets in terms of carbon footprints and various sustainability labels that increasingly govern global value chains	Widespread poverty and high wealth aspirations of population put premium on growth objectives; widening access to energy valued higher than decarbonization
Access to dedicated green donor funds (bilaterally and in terms of global climate finance facilities)	High upfront investment costs coupled with back-loaded and often uncertain benefits; limited green donor funding available
Avoiding early lock-in of technologies that will decline and possibly be banned while new ones are rapidly phased in and becoming cost-effective	Awaiting impact of technological learning and cost curves to make new low-carbon technologies economically more attractive
Significant co-benefits (e.g. health benefits from clean air and water as well as resource efficiency) that are key for policy management	Lack of green awareness among private sector players focusing on quick profits

Note: * The table contains just a listing of relevant considerations on both sides. The arguments are *not* meant to be horizontally linked.

Source: Altenburg/Lütkenhorst 2015, 89.

Hence, in some cases trade-offs between climate, environmental and economic goals cannot be denied and should not be 'defined away'. Simply declaring growth, social and green development as being in harmony, will not suffice to get political buy-in in the countries concerned.

Based on country evidence across SSA, the study identifies 20 important low-carbon transitions. These are assessed against four criteria: the GHG reduction potential, the relevance for carbon lock-in risks, the contribution to productivity increases and the impact on poverty reduction. The resulting ranking (see Table 3) thus reflects elements from all three pillars of sustainability (economic, social and environmental) and can be used as a first pointer as to whether synergies or trade-offs prevail in the different cases.

Table 3: Multi-dimensional scoring of low-carbon transitions (high 15+, medium 10+, low 5+)

	Linked to high GHG emission source	**Avoids lock-in to GHG intensive activities**	**Increases productivity**	**Contributes to poverty reduction**	**TOTAL (out of 20)**
1. Reduce demand for agricultural land by intensifying production and reducing post-harvest waste	5	2	5	4	**16**
2. Reduce emissions from livestock	5	2	2	1	**10**
3. Diffuse climate-smart agriculture practices	3	2	3	2	**10**
4. Integrate rural land-use planning	5	3	3	4	**15**
5. Capture the value of forests' ecosystems services	4	3	2	2	**11**
6. Formalise the charcoal industry, and promote efficient charcoal kilns and biomass cook-stoves, and fuel switching	2	2	2	4	**10**
7. Generate on-grid electricity from renewable sources and prevent lock-in of coal power	4	5	5	4	**18**
8. Promote electricity access from off-grid and mini-grid systems in rural areas	1	4	4	5	**14**
9. Remove fossil fuel subsidies for consumption	5	5	4	3	**17**
10. Shift to a low-carbon automobile fleet and fuels	4	4	3	1	**12**
11. Implement higher density multi-use urban plans	3	4	4	4	**15**
12. Promote mass transportation systems	3	5	4	4	**16**
13. Strengthen the use of energy efficient processes and technologies in the extractives sector	3	3	2	1	**9**
14. Switch to lower carbon fuel sources and renewable energy in the extractives sector	3	3	2	1	**9**
15. Remove and avoid subsidies for fossil fuel production	4	5	3	1	**13**
16. Reduce emissions from construction materials and methods	3	4	2	1	**10**
17. Reduce emissions from buildings operations	4	4	3	1	**12**
18. Increase use of energy efficient processes and technologies and clean energy in heavy manufacturing	4	5	4	1	**14**
19. Increase use of energy efficient processes and technologies and clean energy in light manufacturing	2	4	5	4	**15**
20. Develop low-carbon products	2	5	4	3	**14**

Source: Hogarth et al. 2015, 74 (colour coding added).

This ranking exercise has resulted in the identification of seven high-impact transitions in areas ranging from agricultural production patterns to renewable energy, energy-efficiency, urban planning and mass transportation. For these, the study provides further analyses on the most appropriate policy tools to be applied in incentivizing transformative change. It also emphasizes the need to ensure highest-level political leadership and an early buy-in from the private sector, in particular from key business champions, who often dominate investments in low-income countries.

Capacity-building of government agencies in charge of policy implementation is considered even more crucial than in emerging economies (see sections 4.2.2 and 4.2.3 above for China and South Africa) and so is the build-up of the necessary skills and capabilities of agency staff. This assigns a critically important role to donor agencies and their development of targeted support programmes: *"To realise the 20 low-carbon transitions ... international financial and technical support will need to be scaled-up, and directed to all the sectors highlighted"* (Hogarth et al. 2015, 73).

5 A comparative perspective: Conclusions and recommendations

The Project presented in this report has proven to be both highly relevant and timely. Its timeliness originates from the close alignment with the COP-21 preparatory process, which has allowed the immediate insertion of key results into decision-making processes and policy documents at national level as well as into the COP-21 meeting itself. The project's relevance stems from a number of factors. These include: the combination of quantitative scenario-building with qualitative policy research; the strong evidence base derived from concrete country case studies; the involvement of researchers from national centers of excellence; and the broad coverage of countries at different levels of development ranging from a mature industrial economy (Germany) to poor countries in sub-Saharan Africa.

With its direct contribution to the global DDPP exercise, the Project has demonstrated and exemplified the intellectual power of quantitative modeling, which allows for the simulation of different decarbonization pathways based on varying assumptions. This can contribute to defining a realistic range of trajectories, establishing boundaries of what can be considered as technologically feasible and identifying relevant interlinkages between different sectors, such as in the case of industrial and infrastructural requirements. As such, these models can serve as a methodological point of departure for complex policy decisions.

In its three qualitative country studies (Germany, China, South Africa), the Project has probed into the political economy dynamics of low-carbon transformation. It is only through such rich case studies that the likelihood of transformative change can be established. Key drivers need to be contrasted with forces of resistance, institutional preconditions need to be taken into account - and not just the feasibility but more so, the social acceptance of new technologies needs to be realistically assessed.

Invariably, the strategic incorporation of the many co-benefits of decarbonization is a key element. Whether it is the health benefits accruing in severely polluted Chinese mega-cities; the broadened access to energy through renewable sources in South Africa or indeed in many countries of SSA; or the positive impact on employment, innovation and global competitiveness for new energy technologies in Germany – these are key arguments that can reinforce the support from powerful stakeholders (whether business associations, trade unions or civil society organizations) and eventually swing public opinion in favour of low-carbon development.

Another resounding theme in the various studies has been the urgency of shifting the energy mix away from the current dependence on coal. In a way, this harks back to a fairly conventional subject of industrial policy, namely the reality of structural change, which at times can be threatening and disruptive. This has happened to many sectors and regions over the course of industrialization. For instance, the Ruhr district in Germany is a prototypical case in which a heavy reliance on coal and steel industries was economically challenged in the 1960s and has led to structural unemployment and a gradual yet painful change towards various service sectors.

However, there is an important distinction to be made. While e.g. the competitive position of the German coal industry was being eroded by global market forces, the low-carbon transition is actively pushed by policy interventions. This has at least two implications. First, the induced structural change is proceeding at an exceedingly high pace thus causing significant adjustment costs. Second, with an industrial policy that is actively intervening, the resulting pressure on justifying the chosen development path is higher vis-à-vis the political constituency.

This shifts the emphasis from discussing technological trajectories (as important as they undoubtedly are) to choosing long-term 'policy paths' that remain consistent over time and stay the course. Indeed, the commercial viability of a new green technology (like in the case of large-scale offshore wind turbines) will depend on policy decisions taken far into the future. Obviously, such decisions cannot be guaranteed by governments currently in power. What a government can do however, is to create markets for green investments (for instance, through feed-in tariffs for renewable energy), which trigger learning effects and economies of scale – and in turn increase the pressure on future governments to continue on the same path. In technical terms, this can be referred to as enhancing the 'endogeneity' (Karp/Stevenson 2012) of future policies - a concept whose importance is underlined by the various studies under the Project.

Given the strong case for active pro-low-carbon policies in an environment of failing markets, it is no surprise that the studies stress the need for an effective organization of the policy process. This has essentially two dimensions. On the one hand, low-carbon policies have demanding requirements in terms of alignment and coherence between a broad range of responsible agencies; they involve thorny issues of energy, environment, competitiveness, trade and social policies and thus should be consistently coordinated by a high-level authority. On the other hand, well designed strategies must not suffer from insufficient implementation capabilities. The creation of competently staffed and well-resourced supporting institutions is key to success.

This also applies to dedicated capacities for effective monitoring and evaluation. By their very nature, low-carbon development policies enter new territory and often imply experimenting with innovative tools. This calls for regular progress assessments and the readiness to recalibrate policy measures that may not have reached the intended effects.

Finally, the conclusions reached in the Project provide signposts to shaping future research agendas. It is recommended to move into two directions.

Based on the robust methodology developed in the SSA study component, further country studies on avoiding an early carbon lock-in scenario would be essential. Such studies could be conducted in low-income countries in Africa, Asia and Latin America but also in the many second-tier emerging economies that mostly remain below the radar screen of research focusing on the 'usual suspects' among the high carbon emitters.

For countries that have gained valuable experience with various policy tools (such as feed-in tariffs, carbon taxes, emissions trading schemes, green standards, etc.), it would be important to open up an interactive research space in which their successful application as well as the shortcomings encountered would be subject to comparative assessments.

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