South Africa Chapter

pathways to

deep decarbonization

2014 report

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SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
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Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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1.1 The national context for deep decarbonization and sustainable development

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The African Climate Change Response White Paper (DEA 2011) states, "South Africa is committed to contributing its fair share to global GHG mitigation efforts in order to keep the temperature increase well below 2°C. With financial, technology, and capacity-building support, this level of effort will enable South Africa's GHG emissions to peak between 2020 and 2025 in a range with a lower limit of 398 $MtCO_2eq$ and upper limits of 583 $MtCO_2eq$ and 614 $MtCO_2eq$ for 2020 and 2025 respectively, plateau with a lower limit of 398 $MtCO_2eq$ and upper limit of 614 $MtCO_2eq$ for approximately a decade, and decline in absolute terms thereafter to a range with lower limit of 212 $MtCO_2eq$ and upper limit of 428 $MtCO_2eq$." This is referred to as the Peak Plateau Decline (PPD) benchmark trajectory.

South Africa has a modern urban economy, with an advanced service sector and a large energy-intensive industrial base, dependent on huge mineral resources. There are high levels of inequality and poverty, given that society is divided along spatial, economic, and social lines established in colonial and then Apartheid eras (South Africa, 2013a):

- The top decile of the population accounts for 58% of income while the bottom half accounts for less than 8% (World Bank 2013), resulting in one of the highest inequality levels of the world as indicated by a Gini coefficient of 0.69.
- 45% of the population lives under the upper-bound poverty level (R706 [66.36 US$] per month in 2009 prices).

Unemployment is also a major, related concern. The unemployment rate reaches 25.5% according to standard definitions (40% when including discouraged work seekers [Gumede, 2013]); this is the highest rate out of 40 emerging markets tracked by Bloomberg (Bloomberg, 2014).

These issues are acknowledged in key policy documents, namely the National Development Plan (NDP) and the New Growth Path (NGP), and they are highly relevant in economic policies related to GHG emissions mitigation. Social grants were extended to 14.8 m people in 2011, an increase from 3.8 m in 2001 (Gumede, 2013), but relying on grants is not sustainable and substantial socio-economic development is required to address poverty, inequality, and unemployment.

The population of South Africa was some 52m in 2011, is 60% urbanized, and grew 21% between the 1996-2011 censuses. South Africa will need to make provisions for the projected 8m new urban residents by 2030. Of 10m households, 3m remain without electricity connections.

The average GDP growth of 3.5% over the past decade has not been associated with a significant increase in employment. The NDP envisages an average GDP growth of 5.4% until 2030 (NPC, 2011), and the NGP states that GDP growth between 4-7% is necessary (South Africa, 2011a) to meet development objectives.

The shift in the twentieth century of the South African economy from primarily a rural, agricultural economy to an urban, industrial one was initially based on mining and then transitioned to energy-intensive minerals-based industrialization, with the energy supply primarily based on coal and imported crude oil.

The structure of the economy has evolved from a tertiary sector accounting for 57% of total GDP in 1984 to 70% today. There are important linkages between the tertiary sector and the minerals-based components of the primary and secondary sectors, and the economy relies on the primary and secondary sectors for much foreign direct investment and 60% of foreign exchange export earnings.

South Africa's recoverable coal reserves amount to approximately 49,000 Mt, giving the country the world's sixth-largest coal reserves (SACRM, 2013) and a reserve/production ratio of more than 200 years. Fluri (2009) estimates 548 GW of potential for concentrated solar power (CSP). Hageman (2013) estimates wind potential at 56 GW, 157 TWh p.a. There is a large regional hydro potential, greater than 40 GW.[1]

The NDP recognizes that the South African economy is highly energy and (mineral) resource-intensive but states: "a resource-intensive development path is unsustainable (NPC 2011)." This is at odds with parts of the Industrial Policy Action Plan 2013-2016 (South African Department of Trade and Industry, 2013), the Beneficiation Strategy in the NGP and the current Integrated Resource Plan (DOE, 2013), which all envisage strong growth in the resource-intensive sectors and labor absorbing industrialization (South Africa, 2011a).

1.2 GHG emissions: current levels, drivers, and past trends[2]

GHG emissions in 2010 were around 543 $MtCO_2eq$, 78% of which were from fossil fuel combustion, amounting to 10 t/cap. This high level is the combined result of an energy and electricity-intensive

1 This would require construction of regional transmission lines but projects are already under development and official planning (DOE 2013) includes Grand Inga in the Democratic Republic of Congo some 3000km from SA and other research reports indicate firm resource availability see IRENA 2013.

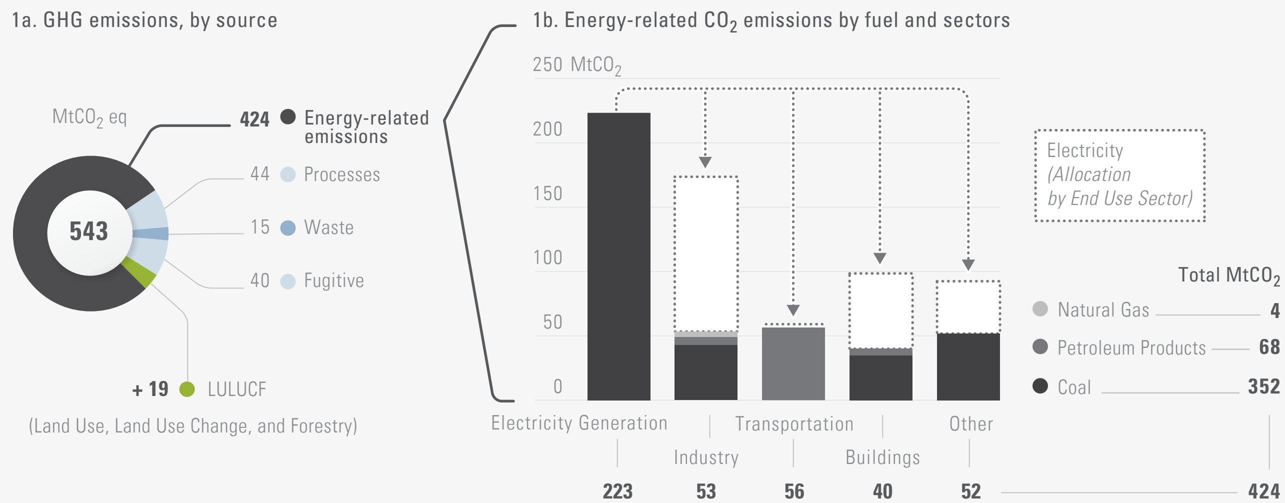
2 Most energy-related figures in this chapter, including energy GHG emissions, are estimated based on: (i) DOE 2006 statistics (DOE 2009) which are the latest available official statistics covering all energy sub-sectors and related time series from 1992-2006; (ii) Eskom statistics published in the Eskom annual report; and (iii) where public data is not available, estimates are made based on work by the Energy Research Centre (ERC) at the University of Cape Town (UCT) related to the SATIM energy and emissions model. see http://www.erc.uct.ac.za/Research/esystems-group-satim.htm

economy, since 95% of electricity is generated from coal and about 35% of liquid fuels are manufactured from coal (coal to liquids, CTL).

Of 250 Mt coal mined annually, 44% is for electricity generation, 28% exported, 18% for CTL, and 10% used directly. Of the 10% used directly, 65% is used in industry, 23% in households, and 12% in commerce (DOE, 2009).

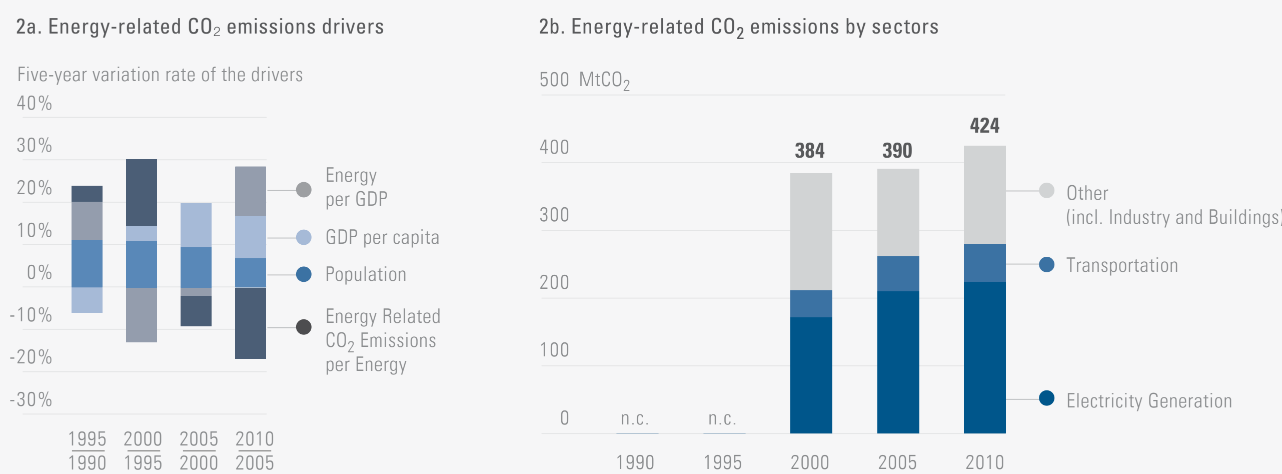
In 2010, industry, residences, and commercial buildings accounted for 60%, 20%, and 15% of electricity demand respectively. Electricity consumption grew steadily for decades until 2007

Figure 1. Decomposition of GHG and Energy CO_2 Emissions in 2010



Note: The "other" category includes both energy and process emissions of South Africa's unique coal to liquids plants.

Figure 2. Decomposition of historical energy-related CO_2 Emissions, 1990 to 2010



Note: Sector specific data for 1990 and 1995 were not available for this report. (South Africa did develop GHG inventories for the years 1990, 1994 and 2000. However, between them there are wide variations in methodologies and results and the 1990 and 1994 versions do not have sufficiently detailed supporting information to resolve the variations to derive sufficiently meaningful trends for DDDP purposes. The 2010 inventory has been released for comment in June 2014 and is therefore not final).

when a supply constraint, which is still at work, arose. Electricity prices have more than doubled in real terms and are set to double again by 2015. Two large coal-fired power stations totaling 9.6 GW, equivalent to some 25% of currently installed capacity, are under construction. More than 3 GW of low-carbon electricity generation, mainly utility scale wind, solar photovoltaic (PV), and concentrated solar (CSP), are also being contracted or under construction.

2 National deep decarbonization pathways

2.1 Illustrative deep decarbonization pathway

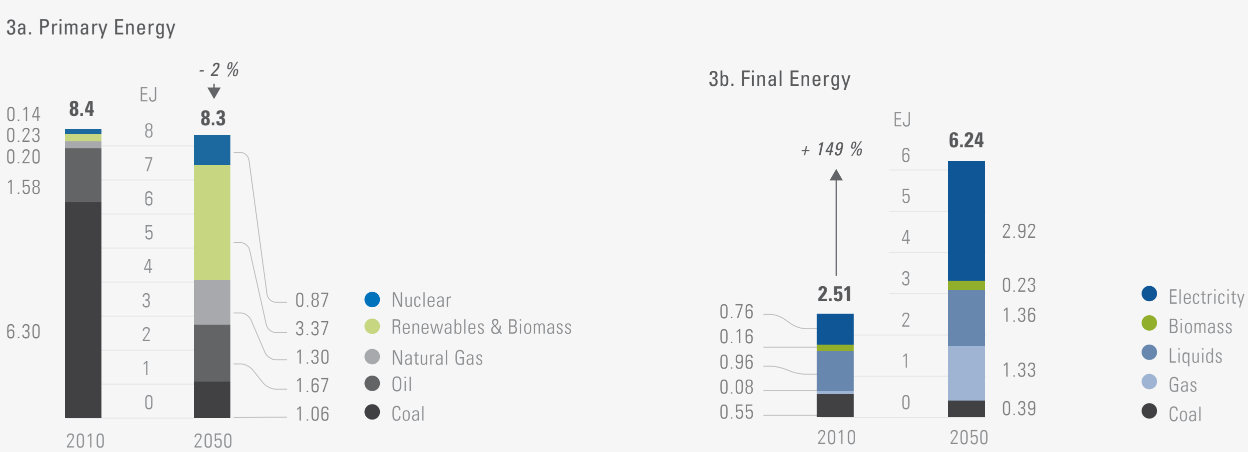
2.1.1 High-level characterization

The South African Illustrative DDP is based on an economy that prioritizes meeting socio-economic development needs in terms of adequate income levels and income distribution and providing energy services for South African residents, business, and industry. This is done while retaining the GDP structure of the economy and configuring an energy supply and end-use system that is consistent with the PPD. The

Table 1. Development Indicators and Energy Service Demand Drivers

	2010	2020	2030	2040	2050
Population [Millions]	50	58	67	69	70
GDP per capita [$/cap]	5,052	6,355	8,008	11,411	16,339
Electrification rate [%houses connected]	81%	90%	95%	97%	100%
Household income distribution [m residents]					
• Low Income (R0 - R19,200)	24	14	9	5	0
• Middle Income (R19,201 - R76,800)	15	32	39	34	27
• High Income (R76,801 and above)	11	12	19	29	44

Figure 3. Energy Pathways, by source



GDP structure is retained to provide products such as steel and cement crucial for development and to maintain the macro-economic stability provided by investments in and foreign exchange contributions of the minerals and industrial sectors. These assumptions are discussed in section 2.2.

In the illustrative scenario, the economy has average GDP growth of some 4%, which is consistent with the low end of the range of the NDP and NGP. Over 2010-2050, there is an improvement in income distribution, and by 2050 there are no households with "low incomes" (below R19,200 [around 1,800 US$]). Meaningful employment impacts could not be estimated.

Energy end-use demand per sector for the illustrative economy is used as input to the ERC's TIMES model of the South African energy system (SATIM)[3] using a cumulative energy emissions constraint over 2010-2050 of 14 $GtCO_2eq$. This is consistent with cumulative emissions of the median of the PPD trajectory, achieving the same cumulative emissions but a higher end level. A technically feasible energy system for the DDP is achieved with a 2050 level of energy emissions of 257 $MtCO_2eq$. There is a large increase in end-use energy required for the illustrative economy with a net decrease in primary energy over 2010-2050 and a significant decrease in primary energy per GDP.

3 For details of the SATIM modeling framework and methodology, see http://www.erc.uct.ac.za/Research/esystems-group-satim.htm.

Figure 5. Energy-related CO_2 Emissions Pathway, by Sector, 2010 to 2050

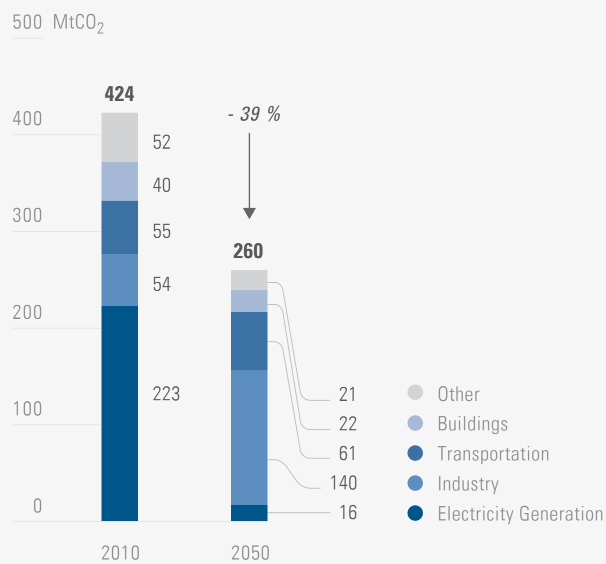
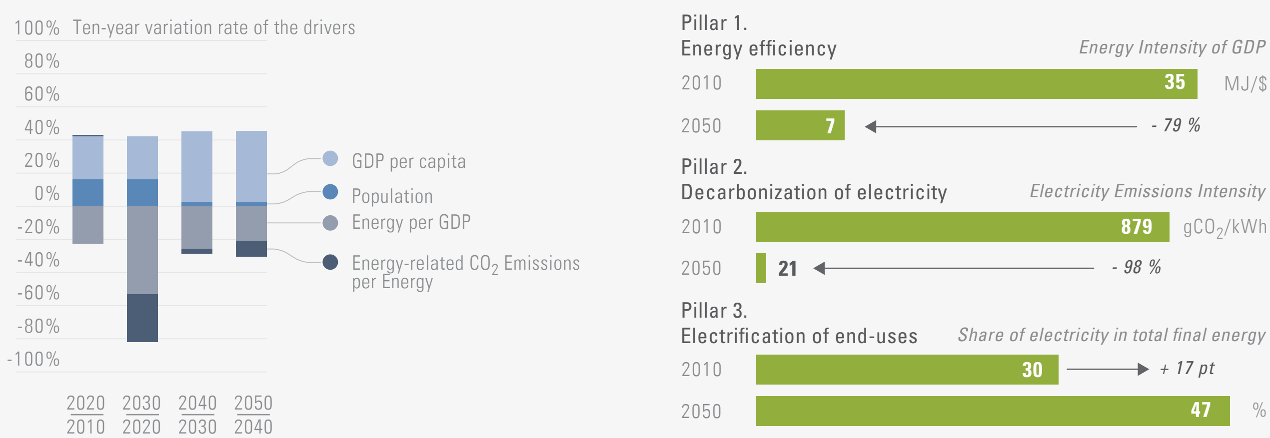


Figure 4. Energy-related CO_2 Emissions Drivers, 2010 to 2050

4a. Energy-related CO_2 emissions drivers

4b. The pillars of decarbonization



Electricity sector emissions reduce radically, emissions from buildings halve, and emissions from industry increase threefold. Transport emissions remain relatively constant. The "other" sector (in Figure 1), which is largely CTL, is phased out.

2.1.2 *Sectoral characterization*

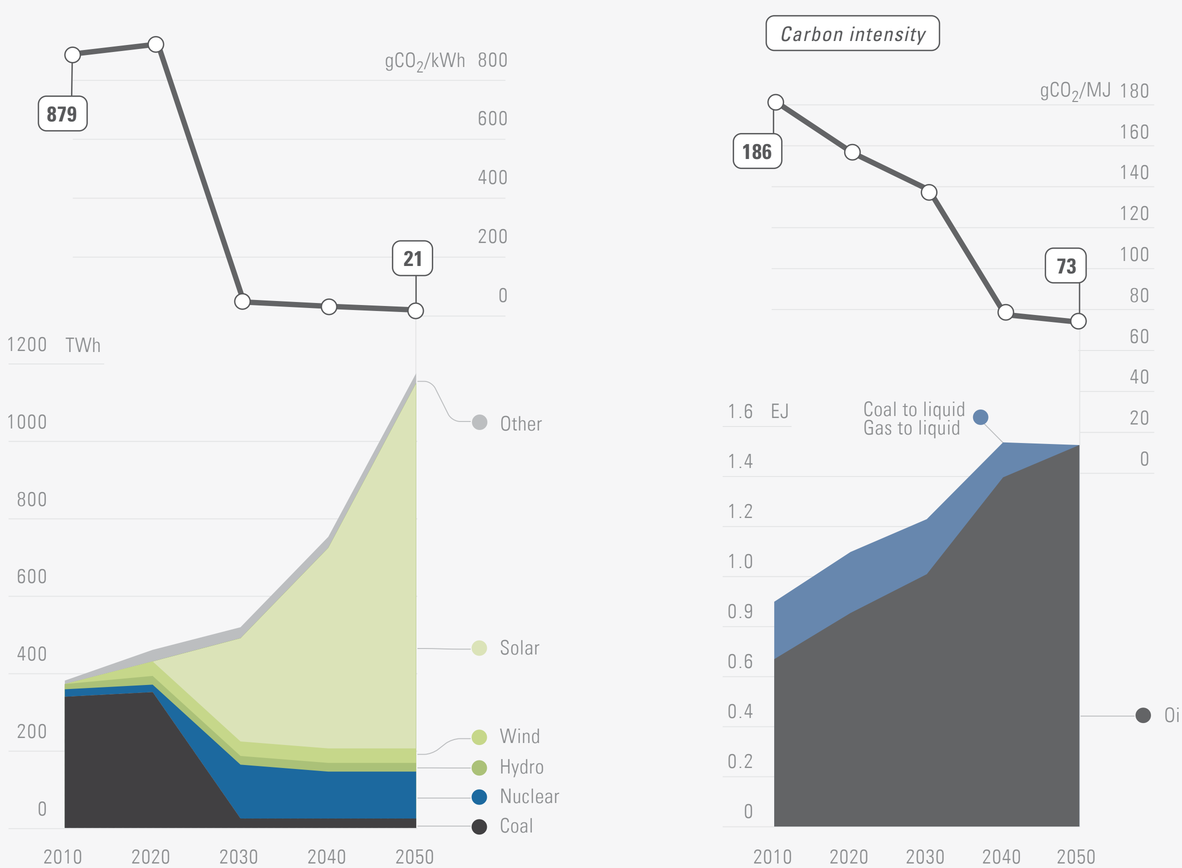
Electricity

Electricity generation increases threefold. Electricity generation emissions decrease from 880 g/kWh in 2010 to 20 g/kWh in 2050, mainly through the replacement of coal-fired generation with CSP with storage and construction of significant additional CSP, nuclear, and widespread rooftop PV. With South Africa's solar radiation resource, the extensive use of CSP with storage and PV across a wide geographic spread combined with some dispatchable generating assets provides a system with satisfactory loss-of-load probability.

Liquid fuels

Liquid fuels production emissions intensity is radically reduced through phasing out of CTL,

Figure 6. Energy Supply Pathways, by Resource



6a.Electricity

6b. Liquid Fuels

and by 2050 all liquid fuels are produced locally from crude oil.

Industry

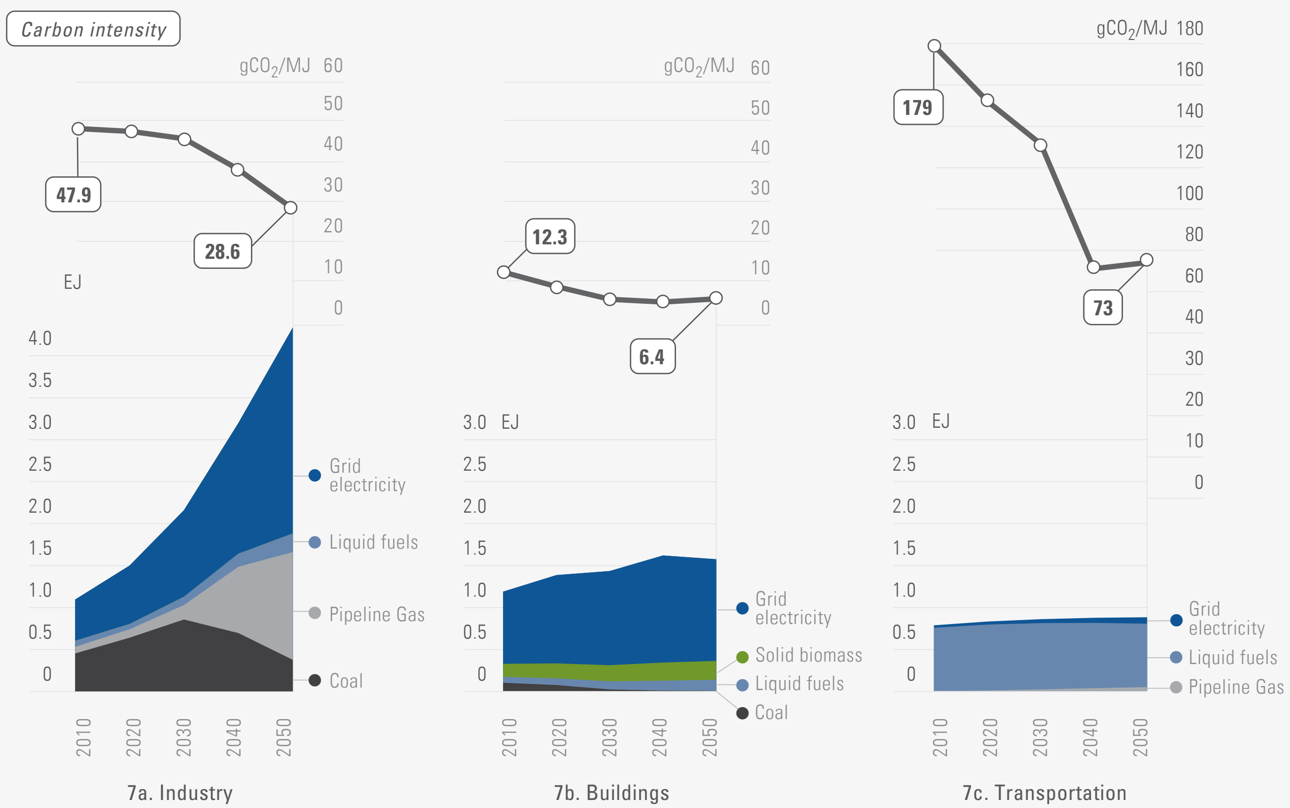
The industrial sector remains a constant proportional contribution to GDP, and it significantly expands at some 4% p.a. along with the rest of GDP, which leads to a significant increase in energy demand. Concurrent decreases in total emissions attributable to industry (i.e. direct and induced emissions) are achieved through fuel switching from coal to gas, improvements in efficiency of end-use technologies, and shifting to electricity for some thermal applications.

Transport

Passenger Transportation

Supply of significant additional passenger transport from 285 bn p-km to 509 bn p-km, a per capita increase from 5,724 km/cap to 7,233 km/cap, meets basic development objectives. Private vehicle transport increases from 2,669 km/cap to 3,861 km/cap and public transport from 3,055 km/cap to 3,327 km/cap. Public transport involves a significant shift from mini-bus taxi (MBT) to Bus-Rapid-Transit (BRT) and rail, which are far safer and more comfortable. The number of private vehicles doubles from 5m to 10m (9 people/vehicle to 6.5 people/vehicle).

Figure 7. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



Note: Carbon intensity shown in Figure 7 for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity or hydrogen production.

Passenger transportation achieves a large increase in supply combined with a small decrease (from 31 Mt - 29 $MtCO_2eq$, 2010-2050) in emissions through a combination of modal shift and vehicle efficiency improvements. The emissions intensity of private transport improves from 160 to 59 gCO_2/p-km.

The Illustrative DDP has a low 5% level of electric private vehicles, but by 2040 around 19% of Bus Rapid Transit (BRT) vehicles introduced are electric and 25% compressed natural gas (CNG)-powered, increasing to 50% by 2050.

Jet air transport emissions nearly double over the 2010-2050 period and remain largely un-mitigated as standard fossil fuels are used. There is no shift to high-speed inter-city rail.

Freight Transportation

More than 90% of freight is carried by heavy commercial vehicles (HCV) or rail in 2050 with export of minerals and beneficiated minerals accounting for 20%; thus heavy haulage dominates.

Freight transport demand derives from sectoral GDP growth and related transport requirements and increases from 292 bn t-km to 998 bn t-km (~240%) with an increase of 342 PJ to 492 PJ in energy and 24 Mt to 32 Mt in emissions. The large increase in transport supply combined with the proportionally smaller increase in emissions is achieved mainly through a combination of modal shift and vehicle efficiency improvements: a shift from HCV to rail and improvement in HCV fuel economy from 39.1 to 16.6 l/100km. All rail is electrified. Average freight emissions intensities improve from 83 to 32 tCO_2/t km.

If biomass is sustainably harvested and paraffin is replaced with biofuels, the liquid fuels and solid biomass components in figure 7b reduce to zero, and the South African building sector contributes a negligible amount to GHG emissions in 2050 because all other energy services are supplied with very low-carbon electricity.

Of some 10m households, 3m remain without electricity connections in 2010, but Tait and Winkler (2012) show that providing adequate electricity for poor households in the medium term will not contribute significantly to emissions associated with coal-fired electricity in comparison with the emissions from other sectors. South African climatic conditions allow for provision of adequate energy services with little energy on average (<1000kW p.a.) required for home space heating and cooling. 60% of water heating (currently largest single household energy component accounting for 50% of mid-income households) can be provided with solar water heaters and with very efficient lighting and electronic technologies that are already commercially available, cooking becomes the largest electricity energy service at around 5,000 kWh p.a. Thus, with adequate thermal performance, an additional 6m households could require only some 36 TWh p.a., less than 5% of total demand in 2010.

2.2 *Assumptions*

The central assumption used in formulating the Illustrative DDP for South African is that it is based on known resources and technologies currently deployed commercially although by 2050 industrial end-use technologies are assumed to improve significantly in efficiency beyond current available levels.

Availability and suitability of electricity generation technology and fuel and renewable energy resources

Achieving the required 14 $GtCO_2eq$ cumulative emissions, while maintaining a feasible energy supply to industry as per economic development assumptions requires early retirement of coal-fired electricity generation and deployment of low-carbon technologies to meet additional demand.

The specific configuration in the Illustrative DDP, with 80% CSP, is one of many very different but equivalently feasible configurations that could provide similar performance; South Africa has excellent low-carbon natural energy resources.

Industrial end-use technology: efficiency improvements and lower-carbon alternatives to coal

Generic assumptions were made regarding end-use technology per major sub-sector: steady rates of improvement in end-use technologies were implemented, as were rates for switching from coal to gas technologies, with limits for totals. This conservative approach has been taken in the absence of detailed plant and end-use technology inventories. The rates and limits are considered to be conservative. For example, improvements made in the iron and steel sector, which increases its production from 10 Mt p.a. to 47 Mt p.a. from 2010-2050, achieve an intensity of 0.83 $MtCO_2eq$/Mt by 2050. This is at the top end of the range of the international benchmark range of 0.47-0.84 tCO_2eq/t.

Switching from coal to gas is an essential component to decarbonize industry. Although South Africa does not currently have significant gas resources or the required capacity for gas importation, transmission, and distribution, it is assumed that it is technically feasible for this to be provided.

Transport vehicle efficiencies

Efficiencies across the range of small-medium passenger vehicles increase by between 50-60% from 2010-2050. Gasoline and diesel vehicles improve from 9.0 to 4.0 and 7.5 to 3.2 l/100km respectively, and diesel MBT improve from 11.3 to 5.5 l/100km. It is assumed that 5% passenger vehicle sales are EV's in 2050.

2.3 Alternative pathways and pathway robustness

The central assumption used in formulating the Illustrative DDP for South African is that it is based on known resources and technologies deployed at commercial scale.

Decarbonization of electricity generation

The electricity decarbonization relies heavily on CSP with storage. There is a more than adequate solar resource. CSP technology is already operating at scale (NREL 2014), and bids have been accepted by the South African government for supply of a Power Purchase Agreement for the Bokpoort 50 MW station with storage which is already under construction. Thus, from a technical point of view CSP should be a robust solution.

However, should CSP not prove to be viable, there are alternative configurations. A combination of wind generation, solar PV, and regional hydro could substitute all or at least most of the CSP and additional nuclear could make up the difference (See IRP 2010 documentation DOE 2013).

Industrial end-use technology: efficiency improvements and lower carbon alternatives to coal

As mentioned previously, assumptions are conservative and should not be a threat to robustness.

Transport: vehicle efficiency improvements

The 2050 vehicle efficiencies are robust. For example, average light vehicle efficiencies assumed in 2050, namely 4 and 3.2 l/100km for gasoline and diesel vehicles, are already available for individual commercial models available today. The 5% sales of EV's by 2050 is a conservative target and hence robust.

2.4 Alternative pathways and pathway robustness

Carbon Capture and Storage (CCS)

CCS has not been included because South Africa has not identified disposal sites despite the considerable efforts that have been devoted to their exploration. A government decision has been taken not to pursue ocean storage; geological storage is still being investigated and could provide additional reduction potentials, notably in the industrial sectors.

Industry

Four subsectors account for 85% of direct (non-electricity induced) emissions, namely iron and steel (28%), “other” (24%), mining and quarrying (19%), and chemical and petrochemical (14%). Cement and glass (6%) and paper and pulp (6%) raise this to 97% of emissions. Opportunities for significant deeper cuts that have been quantifiable, based on data and knowledge accessible in this phase of the DDPP project, mainly exist through improving emissions intensities in the iron and steel subsector and/or limiting production of the subsector to local requirements, which is viewed as an option in the DDPP approach.[4]

The DDP includes an iron and steel sector that increases production from 10-47 Mt from 2010-2050 with emissions of 39 $MtCO_2eq$ in 2050, i.e. 0.83 tCO_2eq/t. This can be compared with an international benchmark range of 0.47-0.84 tCO_2eq/t. Most of these emissions are coal and gas emissions associated with providing thermal end-use energy. Substituting the remaining coal with gas technology would achieve 0.73 tCO_2eq/t, i.e. a reduction of 4.7 $MtCO_2eq$. If intensity were decreased[5] from 0.73 $t/tCO_2eq/t$ to 0.47 $t/tCO_2eq/t$, further emissions reductions of some 12.2 $MtCO_2eq$ could be achieved, reducing emissions to 24 $MtCO_2eq$.

The iron and steel sector exports about a third of its production. If this remained similar for 2050 production and the sector was limited to providing for local demand, another approximately one-third of 24 $MtCO_2eq$, i.e. 8 Mt, could be saved.

The majority of South African energy intensive industrial plants were constructed in an era of very low electricity and coal prices and no GHG emissions constraints; it is therefore reasonable that substantial improvements in energy efficiencies and GHG emissions performance, similar to those in the iron and steel subsector, could be achieved, but the lack of readily available or accessible data for other subsectors has not allowed for meaningful estimations in this phase of the DDP project.

Transport

There is a low level of electrification of passenger transport in the Illustrative DDP, and only conventional fossil-based liquid fuels are considered, providing opportunities for significantly deeper cuts involving electric vehicles (EVs) and biofuels. The large contribution of kerosene combustion emissions for jet-transportation also provides a potential deep cut.

If 50% of EVs were introduced by 2050, approximately 80 PJ of gasoline + 35 PJ diesel p.a. would be saved, reducing emissions by 8 $MtCO_2eq$. If biofuels were introduced for 50% of the remaining light passenger vehicles, 14%, or 4 $MtCO_2eq$ would be saved. If biofuels

4 Insufficient data has been (readily/publically) accessible in this phase on other industrial subsectors to assess cuts deeper than the DDP. Improvements are probably possible in cement and glass and paper and pulp but their relatively small contribution made this too minor to consider in this phase.

5 These estimations are not based on actual South African iron and steel plant performance metrics but on estimations based on public energy consumption data and aggregate projections 35 years ahead and thus are indicative only.

were substituted for the jet-fuel, then roughly 6 Mt CO_2eq would be saved. These ballpark estimates of fuel and technology substitutions save 18 MtCO_2eq of the 29 MtCO_2eq of passenger emissions in 2050, or some 60% of passenger transport emissions.

Substituting 50% of the diesel used in freight transport with biofuels would save 11 MtCO_2eq.

2.5 Challenges, opportunities, and enabling conditions

CTL

CTL facilities are the core of the largest industrial complex and largest industrial company in South Africa. Phasing out or decarbonisation of CTL thus presents a significant challenge.

The electricity generation system

The early retirement of large coal-fired electricity generation plants departs radically from official plans (DOE, 2013) and requires the construction of considerably more costly CSP plants and a large expansion to the transmission network. It is unlikely that South Africa could cover such major costs without international assistance.

Industry: Improvements in efficiencies and switching to gas and electricity

Production capacities in 2050 are multiples of 2010 capacities, and so by 2050 most of the plant and equipment will be new and in theory should be able to be at the best end of international benchmarks' ranges. Industries involved in the majority of emissions, which are from large facilities, are typically owned and operated by multinationals who own and operate world-class facilities worldwide. The challenge would thus be to get these multinationals to invest in the best-emissions class facilities in South Africa.

If industry is to grow at a rate consistent with an economy that can support socio-economic development and make an appropriate contribution to achieving the PPD, regulations and incentives will have to be put in place to ensure that consistency with the PPD is maintained and that investment remains attractive when the trade-offs between cost and reducing emissions intensity are considered.

Transport

The challenge will be to develop and mobilize policy, strategic planning, finance, project implementation, and administration to realize the BRT and rail projects and to implement complimentary policies in road traffic management to achieve the modal shifts. This will require significant development of management and administrative capacity and sourcing of finance.

2.6 Near-term priorities

- Avoiding lock-in to large emissions intensive energy system assets with long economic lifetimes is crucial. Emissions from coal-fired electricity generation will take up emissions space required by other sectors and maintain a level of emissions in electricity that will cause induced emissions from other sectors to limit their potential to contribute to socio-economic development in a carbon-constrained world.
- The PPD policy as specified in the Climate Change Response White Paper (CCRWP) needs to be implemented. The CCRWP defines the PPD and elaborates how policies will be implemented to achieve the PPD.
- Fast tracking of the necessary capacity to develop and implement transport strategies and plans to build transport infrastructure and to regulate and incentivize modal shifts is necessary.

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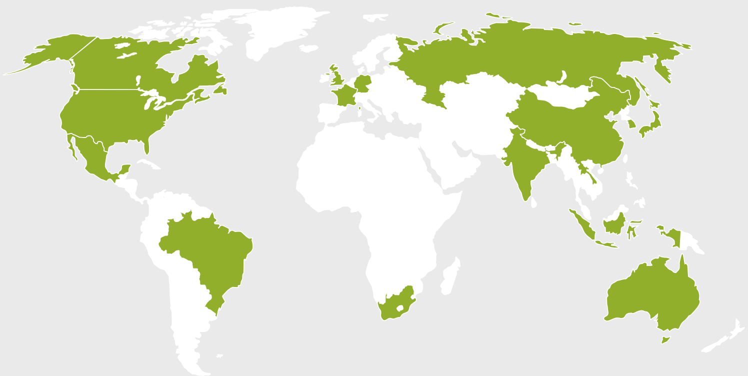

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