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SADC Futures of e-Mobility: EVs as Enablers of a New Energy Paradigm

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African perspectives
Global insights

SAIIA
SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

Executive summary

This report unpacks how Southern Africa could achieve preferable e-mobility futures by adopting electric vehicles (EVs) as enablers of a new energy paradigm. First, it discusses the backdrop to the shift towards the large-scale adoption of EVs worldwide. Second, a systemic innovation approach is taken to review the Southern African energy landscape, pointing out the current dilemmas facing utilities such as Eskom. Third, it identifies five systemic innovations in the SADC energy sector to enable a new energy paradigm and the adoption of preferable regional e-mobility futures. Throughout, the analysis considers the implications of the large-scale adoption of EVs for employment, the need for reskilling and rapid adaptation, and the broader impact on economic pathways and choices for policymakers, society and the business sector. Each systemic innovation also highlights the key seeds or pockets of the future in the present. The five systemic innovations point to suggested leverage points for policy action by stakeholders that would enable the e-mobility revolution to unlock Southern Africa's green, more resilient, sustainable and just future. The report concludes by advocating a Southern African Green New Deal and bold, hopeful futures to enable not only an e-mobility revolution but also a regional new energy paradigm.

Abbreviations & acronyms

BEV	battery electric vehicle
CSIR	Council for Scientific and Industrial Research
CSIR LC	CSIR's Least Cost Scenario
CO2	carbon dioxide
DSM	demand-side management
DSR	demand-side response
DRC	Democratic Republic of Congo
DEA	Department of Environmental Affairs
DEA_RD	DEA Rapid Decarbonisation Scenario
DERs	distributed energy resources
DSOs	distribution system operators
DTIC	Department of Trade, Industry and Competition
EV	electric vehicle
EW Chain	Energy Web Chain
EWF	Energy Web Foundation
ENTSOE	European Network of Transmission System Operators for Electricity
GHG	greenhouse gas
ICT	information and communications technology
ICE	internal combustion engine
IEA	International Energy Agency
IoT	Internet of Things
IRP	Integrated Resource Plan
LSEVs	low-speed EVs
NDP	National Development Plan
NEC	National Executive Committee
NDCs	Nationally Determined Contributions
PV	photovoltaic
PPP	public–private partnership
R&D	research and development
RE	renewable energy
REN21	Renewable Policy Network for the 21st Century

REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
RMI	Rocky Mountain Institute
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SOE	state-owned enterprise
SDG	Sustainable Development Goal
TSOs	transmission system operators
V2G	vehicle-to-grid
V2X	vehicle-to-anything
WTW	well-to-wheel
ZEV	zero-emission vehicle

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About SAIIA

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Cover image

Petrol station (Getty Images)

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CHAPTER 1

The SADC energy landscape

The global energy landscape has changed dramatically over the past 25 years, but there are potentially much larger and more rapid changes in store. Resources for the Future recently released a game-changing report[1] that compares 'apples with apples' through a unique methodology that provides an integrated analysis of the long-term energy projections of various governmental, intergovernmental and private organisations.[2] The report, entitled *Global Energy Outlook 2019: The Next Generation of Energy*, states that global energy consumption is poised to grow by over 20–30% through 2040 and beyond.[3] In the absence of ambitious climate change targets, this growth would largely be driven by the increased consumption of fossil fuels.

The outlook is framed by the rising energy consumption needs that are included in economic and population growth projections of the global 'East',[4] whereas consumption levels in the 'West'[5] are projected to remain largely fixed at current rates. Carbon dioxide (CO_2) emissions also continue to grow if policymakers fail to introduce changes in the energy mix or make use of new technologies that engineer greater energy efficiency in the long run. The comparative scenarios hold positive news for the renewable energy (RE) sector. The rapid growth in wind and solar power drives the expansion of RE but does not significantly displace the consumption of fossil fuels unless more robust climate policies are put in place.

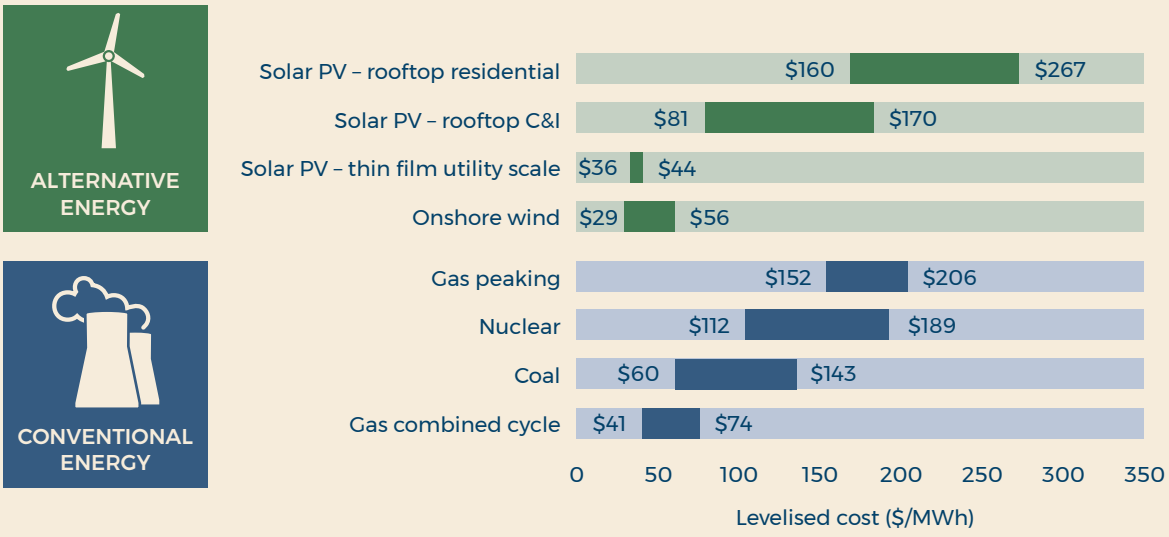
The role of electricity in all forms of energy consumption becomes increasingly prominent, especially where scenarios integrate the rapidly growing electric vehicle (EV) market into their parameters. While EVs have a significant role in the future of transportation, they are not the sole solution in reaching a zero-carbon economy. However, EVs might be the initial change that makes a difference, in that they offer a viable alternative in various forms of mobility in the face of a global decline in oil demand. This is, of course, exacerbated by the coronavirus pandemic. Large-scale adoption of EVs could radically change the energy landscape. More and more major cities and countries are adopting congestion restrictions to lower air and noise pollution. Urban designers are employing new tactics that include carless areas where only cycling, walking and forms of micromobility are allowed.

1 Richard Newell, Daniel Raimi and Gloria Aldana, *Global Energy Outlook 2019: The Next Generation of Energy* (Washington DC: Resources for the Future, 2019).
2 The outlook of 11 organisations/authors/institutions were considered in the preparation of the 2019 Global Energy Outlook. See Newell, Raimi and Aldana, *Global Energy Outlook 2019*.
3 Newell, et al, *Global Energy Outlook 2019*.
4 East meaning Africa, Asia-Pacific and the Middle East.
5 West meaning Europe, Eurasia and North, South and Central America.

The global energy outlook shifts significantly under ambitious climate policies. With these, the global economy not only becomes more energy efficient but there is also a 50% decline in global coal consumption relative to current levels.[6] Furthermore, global oil use falls by 20% and natural gas increases modestly, while nuclear energy grows by more than 50%.[7] Finally, the scenarios highlight that the renewable energy sector doubles and improves when carbon capture and storage technologies are deployed at scale by 2040.[8]

In its *Renewables 2019: The Global Status Report*,[9] the Renewable Policy Network for the 21st Century (REN21) finds that the renewable energy sector is rapidly moving ahead to achieve record levels of new installations and investments. It attributes this progress to years of active policy support and technological advances.

Figure 1 Levelised cost of energy analysis: Declining costs of alternative electricity technology generation



Source: Lazard, "Levelized Cost of Energy and Levelized Cost of Storage", November 8, 2018, https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/

This rapid growth, driven by the dramatic reduction in the cost of solar photovoltaics (PV) and wind-generated electricity, means that globally, renewables are now less expensive

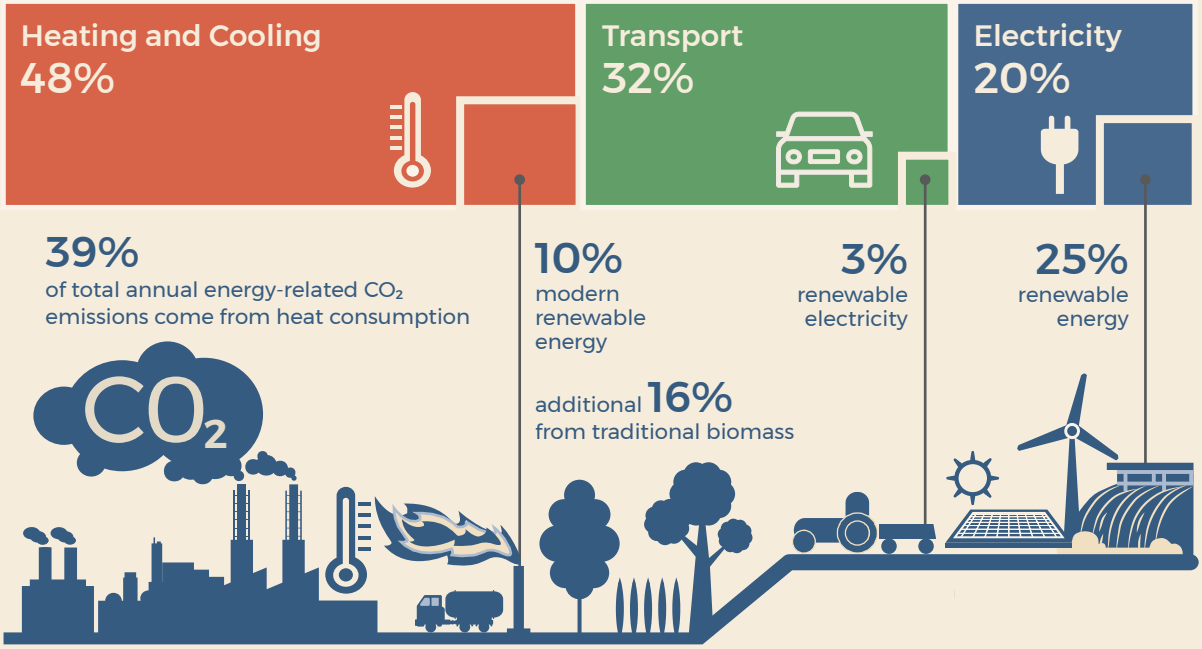
6 Newell, et al , *Global Energy Outlook 2019*.
7 Newell, et al , *Global Energy Outlook 2019*.
8 Newell, et al, *Global Energy Outlook 2019*.
9 REN21 is a multi-stakeholder network built on an international community of over 900 experts from governments, inter-governmental organisations, industry associations, non-governmental organisations, and science and academia. It grows from year to year and represents an increasing diversity of sectors. REN21 provides a platform for this wide-ranging community to exchange information and ideas, to learn from each other and to collectively build the renewable energy future. Renewable Policy Network for the 21st Century, *Renewables 2019: The Global Status Report* (REN21, May 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf .

than newly installed fossil and nuclear energy. This trend is accelerating, meaning that in coming years renewable energy will become even more affordable and the need to rely on fossil and nuclear energy generation methods will be significantly reduced.

REN21 cautions, however, that a switch in energy generation alone will not enable the world to reach its Paris Agreement commitments or Sustainable Development Goal 7 (SDG 7). SDG 7 commits the world to provide affordable, reliable, sustainable and modern energy for all. The heating and cooling industry, as well as the transport sector, will have to make a drastic shift towards renewable sources of energy for these ambitions to be realised. Figure 2 shows the contribution that heating/cooling, transport and energy generation makes to CO_2 emissions. Much work still needs to be done to shift the transport sector towards a renewable model that addresses the Paris Agreement requirements.

A 2018 report by Climate Transparency[10] paints a bleak picture regarding G20 members' reaching their Paris Agreement commitments. In sum, it finds that G20 countries roughly need to halve emissions by 2030, but adequate strategies to do so are still lacking. Alarmingly, in 15 of the G20 countries energy-related CO_2 emissions increased in 2017, and 82% of the G20's energy supply still comes from fossil fuels.

Figure 2 Renewable energy transition (final energy use by sector, 2015)



Source: Renewable Policy Network for the 21st Century, *Renewables 2019: The Global Status Report* (REN21, May 2019), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf

10 Climate Transparency, *Brown to Green: The G20 Transition to a Low-Carbon Economy* (Climate Transparency, 2018), https://www.climate-transparency.org/wp-content/uploads/2019/01/2018-BROWN-TO-GREEN-REPORT-FINAL.pdf.

It also found that the countries that need to do the most in transforming their power and transport sectors lack concrete actions towards developing such a strategy. G20 countries provided $147 billion in subsidies to the coal, oil and gas industries in 2016.[11]

The EV will thrive in an environment where energy is cheap and abundantly available. Global studies show that the oil industry should survive a decline in oil demand for internal combustion engine (ICE) cars by moving into petrochemicals and focusing attention on the ever-growing aviation industry. However, the future of the coal industry is far less certain. Futurists expect that the cost of energy generated from renewable sources will continue to fall, making electricity available to all. New technologies are also starting to overcome the storage challenge previously presented by wind and solar energy. Ever bigger and stronger batteries are being developed, allowing greater energy harvesting and applicability. This, in turn, makes the RE sector ever more competitive. RE has the added advantage of offering off-grid solutions, much like the cell phone provided a solution to connect people in far-flung rural areas without having to roll out landline infrastructure at a high cost.

The SADC energy baseline report of 2016 shows that the members of the Southern African Power Pool (SAPP)[12] use a diverse mix of energy sources to power the region. South Africa is the most significant contributor to the SAPP. However, its power utility, Eskom, relies primarily on coal-generated power production, and thus coal represents around 76% of all energy produced in the region.

The SADC energy baseline shows that three countries rely largely on coal-generated electricity: South Africa (86%), Botswana (82%) and Zimbabwe (63%). Hydropower is the second most significant contributor to SADC's energy mix, with four countries relying exclusively on hydropower: the Democratic Republic of Congo (DRC), Lesotho, Malawi and Zambia. Mozambique, Namibia, eSwatini and Tanzania have a significant hydro-generated electricity portion in their energy mix. Diesel, nuclear and combined-cycle gas turbines also contribute to SADC's available energy, but to a far lesser extent. Solar and wind-generated energy is only starting to take off in SADC member states.[13]

The SADC region has considerable potential to source almost all of its energy from renewable sources. Between solar, wind, hydro, biomass and geothermal electricity generation, the region could in the foreseeable future distance itself from all fossil and potentially nuclear energy generation. However, the coal industry in South Africa and Eskom have a near-monopoly on energy generation in the country and across the region.

South Africa has set itself a target of moving to a 30% renewable energy contribution to its energy mix by 2030 in its Integrated Resource Plan of 2019, and introduced the Renewable

11 Climate Transparency, *Brown to Green*.

12 The SAPP currently has 12 member states, which are the continental members of SADC: Angola, Botswana, the DRC, eSwatini, Lesotho, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe.

13 SADC, *SADC Energy Monitor: Baseline Study of the SADC Energy Sector* (Harare: Southern African Research and Documentation Centre, 2016).

Energy Independent Power Producers Procurement Programme (REIPPPP) in August 2011. The REIPPPP was initially deemed to be very successful, as it attracted diverse international and local investment and developers. Competition among them also resulted in rapid price reductions.[14]

By 2015 the programme was contributing around 15% of the national energy grid, and expectations were that the REIPPPP would grow. However, as then president Jacob Zuma sought to address South Africa's energy needs via a nuclear deal with Russia, the programme fell out of favour. It certainly made no sense for South Africa as a whole to abandon the REIPPPP given its early successes and the fact that the costs of RE were constantly falling. It did, however, make business sense for Eskom to abandon the REIPPPP, because the cheap electricity produced through the REIPPP was adversely affecting its revenue streams.[15] A study on the coal transition in South Africa found that Eskom's coal costs increased by 300% in real terms over the past 25 years, from ZAR[16] 42.79/ton ($6.95) in 1999 to ZAR 393/ton ($29.54) in 2017.[17] Jesse Burton of the Energy Resource Centre confirmed that 'new renewable energy capacity is now considerably cheaper than either the new Eskom coal-fired power plants that are currently under construction, such as Medupi or Kusile, or the privately-owned coal plants proposed in the Integrated Resource Plan (IRP 2018)'.[18]

Research done in 2017 provides a comprehensive capex comparison of the total system costs of energy generation for South Africa (see Table 1).[19]

After the removal of Zuma in 2018, President Cyril Ramaphosa reintroduced the REIPPP. However, it continues to face stiff opposition and criticism from labour unions, given fears that the RE sector could hurt jobs in Eskom and its supply chain. But the government also argues that the RE sector could become a significant contributor to job creation.[20]

The South African National Development Plan (NDP)[21] uses four different frameworks through which it considers economic and industrial development (Figure 3) in trying to address the quandary of growth and job creation. Although using natural gas as an energy source is preferable to burning coal, in essence, the investment in oil and gas exploration and production falls within the 'good for growth and not great for jobs' category.

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14 Anton Eberhard, Joel Kolker and James Leigland, *South Africa's Renewable Energy IPP Procurement Program: Success Factors and Lessons* (Washington DC: Public-Private Infrastructure Advisory Facility, May 2014).

15 John Oliphant, "Too Much Power in Eskom's Hands Undermines Potential of Green Energy", *BusinessDay*, November 24, 2016, https://www.businesslive.co.za/bd/opinion/2016-11-24-too-much-power-in-eskoms-hands-undermines-potential-of-green-energy/.

16 Currency code for the South African rand.

17 Jesse Burton, Tara Caetano and Bryce McCall, *Coal Transitions in South Africa: Understanding the Implications of a 2°C-compatible Coal Phase-Out for South Africa* (Cape Town: Energy Research Centre, 2018).

18 Admire Moyo, "Study Reaffirms Renewables Now Cheaper than Coal", ITWeb, September 13, 2018, https://www.itweb.co.za/content/JN1gP7O1gVJqjL6m.

19 Mark Sklar-Chik, "System Cost of Energy Generation Scenarios for South Africa: Understanding the Real Cost of Integrating Energy Generation Technologies" (Thesis, University of Stellenbosch, 2017).

20 Lameez Omarjee, "Radebe: Renewable IPPs to Create over 114 000 'Job Years'", *Fin24*, July 5, 2018, https://www.fin24.com/Economy/radebe-renewable-ipps-to-create-over-114-000-job-years-20180705.

21 South African Government, "National Development Plan 2030", https://www.gov.za/issues/national-development-plan-2030

TABLE 1 CAPEX COMPARISONS: SYSTEM COST OF ENERGY GENERATION FOR SOUTH AFRICA					
Type	**Capacity (MW)**	**Average CAPEX (R/kW)**	**CAPEX (Rands)**	**Lifespan**	**Interest (over loan term in Rands)**
Wind	14000	16 982.50	237 755 000 000.00	20	484 317 438 174.96
PV	17000	12 162.50	206 762 500 000.00	25	452 212 720 456.54
Existing coal	27430	34 916.00	0.00	60	0.00
New coal	9560	34 916.00	333 796 960 000.00	60	1 119 690 678 960.18
CCGT	4000	8 616.00	34 464 000 000.00	30	80 713 636 031.18
Existing OCGT	2175	5 676.50	0.00	30	0.00
New OCGT	5505	5 676.50	31 249 132 500.00	30	73 184 514 475.83
Existing pumped storage	1400	40 409.50	0.00	50	0.00
New pumped storage	1500	40 409.50	60 614 250 000.00	50	182 031 518 511.40
Hydro	2100	0.00	0.00	60	0.00
New hydro	1590	20 192.50	32 106 075 000.00	60	107 696 825 386.00
CSP	8000	46 979.12	375 832 957 778.28	30	880 189 315 303.97
Existing nuclear	1800	73 877.00	0.00	60	0.00
New nuclear	0	73 877.00	0.00	60	0.00
Total	**96060**		**1 312 580 875 278.28**		**3 380 036 647 300.05**

NOTE PV = photovoltaic
CCGT = combined cycle gas turbines;
OCGT = open cycle gas turbines
CSP = concentrating solar power

Source: Mark Sklar-Chik, "System Cost of Energy Generation Scenarios for South Africa: Understanding the Real Cost of Integrating Energy Generation Technologies" (Thesis, University of Stellenbosch, 2017)

Importantly, it would also not catalyse the transition to a Green Economy[22] or stay within the parameters of the Paris Agreement:[23]

> The Intergovernmental Panel on Climate Change has warned that all nations must stop burning fossil fuels by 2030 to avoid catastrophic warming. By 2027 climate change will be a fully-fledged reality, and Brulpadda will become a stranded asset. Further development of gas infrastructure is incompatible with the Paris agreement target.

22 See Republic of South Africa, Department of Environmental Affairs, "Green Economy for Sustainable Development", https://www.environment.gov.za/projectsprogrammes/greeneconomy; Council for Scientific and Industrial Research, "CSIR Creates a Guide for South Africa's Green Economy", https://www.csir.co.za/csir-creates-guide-south-africa%E2%80%99s-green-economy.

23 Janet Solomon, "Looking the Brulpadda in the Mouth", *Mail & Guardian*, March 1, 2019, https://mg.co.za/article/2019-03-01-00-looking-the-brulpadda-in-the-mouth.

Figure 3 Quandary of growth and job creation framework, NDP, 2010

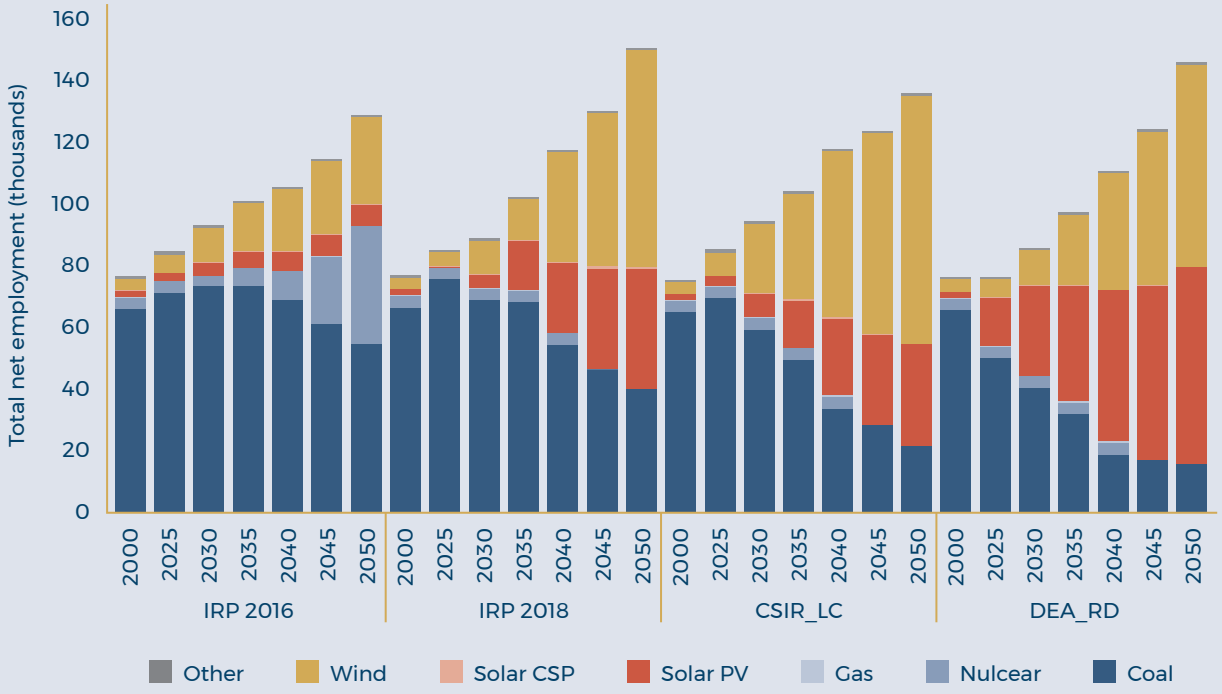
Source: National Planning Commission, "What the National Development Plan Proposes", https://www.politicsweb.co.za/documents/what-the-national-development-plan-proposes

Figure 3 highlights why the things that drive growth are not always the things that drive job creation, and conversely, why the things that are good for job creation are not always good for growth. As noted by the NDP Commission,[24]

> efforts should focus on growing exports and building the linkages between export earnings and job creation, which often occur in domestically focused small- and medium-sized firms, most often in the services sector. South Africa has to exploit its existing strengths to increase exports. This means using the country's advantages – its skills, technologies, firms, mineral wealth, underutilised labour and geography. If the economy is less competitive in one area, it will have to do better in others.

24 National Planning Commission, "What the National Development Plan Proposes", https://www.politicsweb.co.za/documents/what-the-national-development-plan-proposes.

Figure 4 Evolution of net employment in the power sector by different technologies (2020–2050)



Source: Ayodeji Okunlola et al. (eds), *Future Skills and Job Creation through Renewable Energy in South Africa* (Potsdam/Pretoria: Institute for Advanced Sustainability Studies and CSIR, 2019), https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/

A study[25] assessing the co-benefits of decarbonising the power sector in South Africa highlights the potential for skills and job creation through the development of RE. The report points to the following key statistics, as illustrated in Figure 4:

- by 2050 more than 150 000 new jobs (+17%) will have been created in the power sector in net terms (ie, including job losses in the coal sector) by the shift from IRP 2016[26] to IRP 2018;[27]
- up to 1.6 million additional jobs can be created economy-wide through the power sector transformation by 2050;
- across all scenarios, around 70% of new power-sector jobs associated with RE are categorised as highly skilled; and

25 Ayodeji Okunlola et al. (eds), *Future Skills and Job Creation through Renewable Energy in South Africa* (Potsdam/Pretoria: Institute for Advanced Sustainability Studies and CSIR, 2019), https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/.

26 Republic of South Africa, Department of Energy, "Integrated Resource Plan: Update Assumptions, Base Case Results and Observations Revision 1" (Department of Energy, Pretoria, 2016), http://www.energy.gov.za/IRP/2016/Draft-IRP-2016-Assumptions-Base-Case-and-Observations-Revision1.pdf.

27 Republic of South Africa, Department of Energy, "Request for Comments: Draft Integrated Resource Plan" (Department of Energy, Pretoria, 2018), http://www.energy.gov.za/IRP/irp-update-draft-report2018/IRP-Update-2018-Draft-for-Comments.pdf.

- jobs in the coal sector will decline by 35–40% between 2020 and 2050, with expected reductions in global demand and exports being the main driver behind this transformation.

Also, the report finds that 'South Africa can significantly boost employment by increasing the share of renewables'. If the government decides to increase RE in the energy mix, employment in the energy sector can be expected to grow by 40% from 2018 to 2030 (as seen in Figure 4), which equates to 580 000 job-years. In contrast, the president said in the 2019 State of the Nation Address that the private sector had committed to creating 155 000 new jobs in total over the following five years. This shows the potential for job creation in the RE sector. The Council for Scientific and Industrial Research's (CSIR) recommendation to the government is to follow the least-cost pathway, which estimates that job numbers could be doubled to more than 1.2 million job-years under their scenario.

An often mistaken perspective is that RE power generation jobs are only found in the services, construction and manufacturing sectors. In fact, they permeate almost all industries. This includes the mining sector. Although there are expected losses in coal mining, there will be a net increase in employment owing to more jobs in the energy sector and associated development minerals used for battery manufacturing. The co-benefit of the RE industry is that it has an economy-wide effect – by shifting from IRP 2016 to IRP 2018, an additional 1.3 million jobs could be created by 2050. The rapid decarbonisation pathway of the Department of Environmental Affairs (DEA) will have a similar impact on jobs, with the CSIR's least-cost pathway estimating an additional 300 000 economy-wide jobs.

In the combined scenarios of the CSIR's Least Cost Scenario (CSIR_LC) and the DEA's Rapid Decarbonisation Scenario (DEA_RD),[28] aggregated net employment in the electricity sector, solar PV and wind together account for more than 80% of total net employment in the electricity sector.

Figure 5 illustrates the transition from IRP 2016 to IRP 2018, pointing to a further 17% rise in new jobs in the power sector by 2050. This means an additional 150 000 (net) new jobs under the scenarios. In all the scenarios, higher shares of renewables lead to an increase in net employment figures. Also, if the government adopts the CSIR's least-cost pathway, it could enable the highest number of additional jobs in the energy sector by 2030, accounting for 94 000 new jobs (net). In contrast to the IRP 2018 scenario, the CSIR's scenario has an added benefit of the highest number of economy-wide additional jobs at 300 000. According to the report, 'the CSIR's least-cost pathway performs best in terms of economy-wide jobs at both the 2030 and 2050 horizons'.[29]

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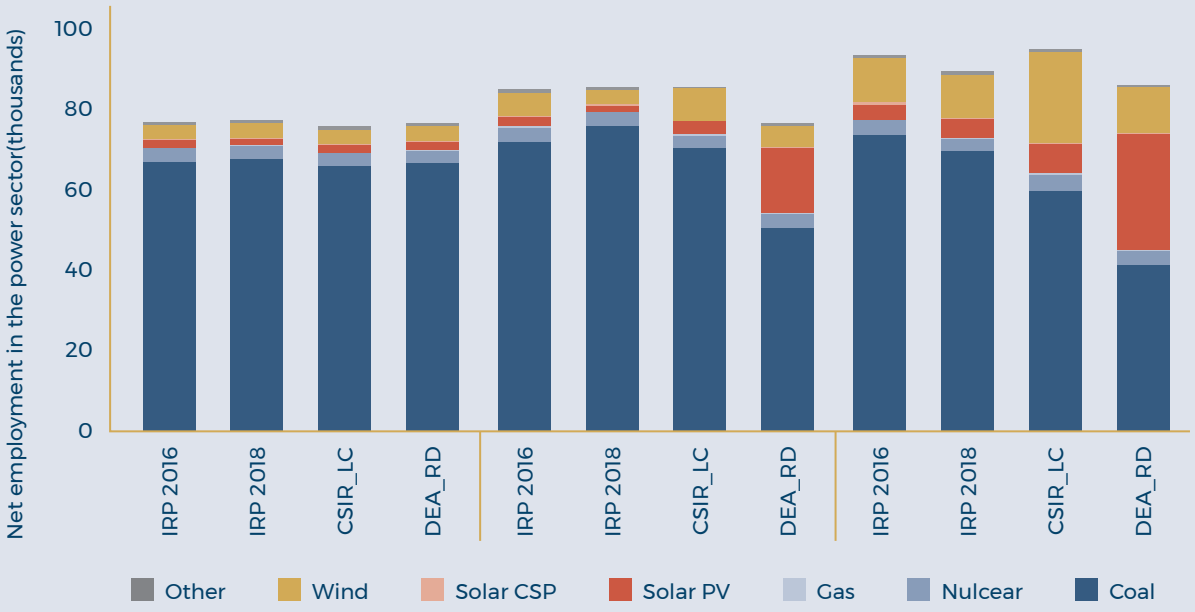
28 Four scenarios for the future development of the electricity sector in South Africa were analysed: Council for Scientific and Industrial Research Least Cost planning scenario (CSIR_LC); Department of Environmental Affairs Rapid Decarbonisation scenario (DEA_RD); Integrated Resource Plan 2016 (IRP 2016); and Integrated Resource Plan Policy Adjusted scenario 2018 (IRP 2018). See Ayodeji Okunlola et al. (eds), *Future Skills and Job Creation through Renewable Energy in South Africa* (Potsdam/Pretoria: Institute for Advanced Sustainability Studies and CSIR, 2019), https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/.

29 Okunlola et al., *Future Skills and Job Creation*.

Figure 5 Net employment in the power sector by different technologies by 2030



Source: Ayodeji Okunlola et al. (eds), *Future Skills and Job Creation through Renewable Energy in South Africa* (Potsdam/ Pretoria: Institute for Advanced Sustainability Studies and CSIR, 2019), https://www.cobenefits.info/resources/cobenefits-south-africa-jobs-skills/

The most substantial volume of jobs in the RE industry falls within the high-skilled labour bracket and will require workers who have an educational background of Grade 12 and above, but there is also space for other skill groupings. The overarching scenario paints a picture of the creation of around 70% new high-skilled (> Grade 12) jobs in the RE sector. The largest increases in the job creation scenarios rise to 76% in 2050 under the DEA's rapid decarbonisation pathway and the CSIR's least-cost pathway.

The report also describes the potential of the REIPPPP to contribute to significant localised job creation through RE deployment in South Africa. However, the enablement or constraint of the growth of the REIPPPP is linked to whether the government is willing to make continuous and long-term commitments to the deployment of RE.

A significant factor often overlooked is the localisation benefit requirements of the REIPPPP, which have resulted in the growth of manufacturing of essential RE technologies and associated components. For instance, the World Economic Forum estimates that the global battery market will be worth around $100 billion by 2025, which highlights the potential across the battery supply chain for job creation.

At the regional level, the SADC Industrialisation Strategy and Roadmap calls for increased use of RE sources and to aim for a (still very low) target of 10% of rural communities having

access to RE sources. The SAPP target of a 35% RE contribution by 2030 is similar to South Africa's target and reflects the country's important role in setting and reaching this target.[30] In the clearest indication yet of a shift in commitment to a just energy transition towards renewables, Ramaphosa said the following at the UN Climate Summit in 2019:[31]

> To ensure equity in the energy transition, we call upon you to champion initiatives that ensure not only that investment in renewable energy technologies is fast-tracked in developing countries, but that a large share of the value chain is located in these countries to support national development objectives. Africa is endowed with mineral resources critical to the production of renewable energy technologies. Therefore, consideration should be given to the establishment of a global regime for investment in relevant patent pools – technology buy-outs for the global common good.

The drive to introduce renewable and off-grid energy solutions in Southern Africa is motivated by the need to give access to energy to millions of households that still rely on biomass for heating and cooking. Reliable energy in rural communities to power clinics, schools and industrial jobs is critical for the region's development.

As the leading economy in SADC and its largest emitter, the South African government is setting the pace regarding the adoption of policies[32] towards a Green Economy. From a national perspective, South Africa's current position is that the introduction of EVs goes hand in hand with the roll-out of renewable energy. The Department of Trade, Industry and Competition (DTIC) believes that the benefit of zero-emission EVs (ZEVs) cannot be erased by simply charging them with electricity produced by coal, and therefore a just transition to clean and renewable energy justifies the transition to ZEVs. In a recent report,[33] there are indications that the government and industry are taking the necessary steps to adopt policies that will kick-start the production of EVs in South Africa, while also growing the market share of EVs locally. For example, policy suggestions that the National Association of Automobile Manufacturers of South Africa[34] is taking to government are:

- to reconsider reducing import duties in order to stimulate demand, with import duties to be 0% for a three-year period in order to kick-start demand;
- battery costs to be excluded from the ad valorem tax charged on motor vehicles, ie, if a car costs ZAR 250,000 ($16,930), and the battery is ZAR 50,000 ($3,386) of that, then government should only charge ad valorem on the ZAR 200,000 ($13,545); and

30 SADC, *SADC Energy Monitor: Baseline Study.*

31 Republic of South Africa, Department of International Relations and Cooperation, "Statement by H.E. President Cyril Ramaphosa of South Africa to the United Nations Secretary-General's Climate Summit", September 23, 2019, http://www.dirco.gov.za/docs/speeches/2019/cram0923.htm.

32 This report does not evaluate policy implications for the development of RE specifically to feed the increasing use of EVs in South Africa.

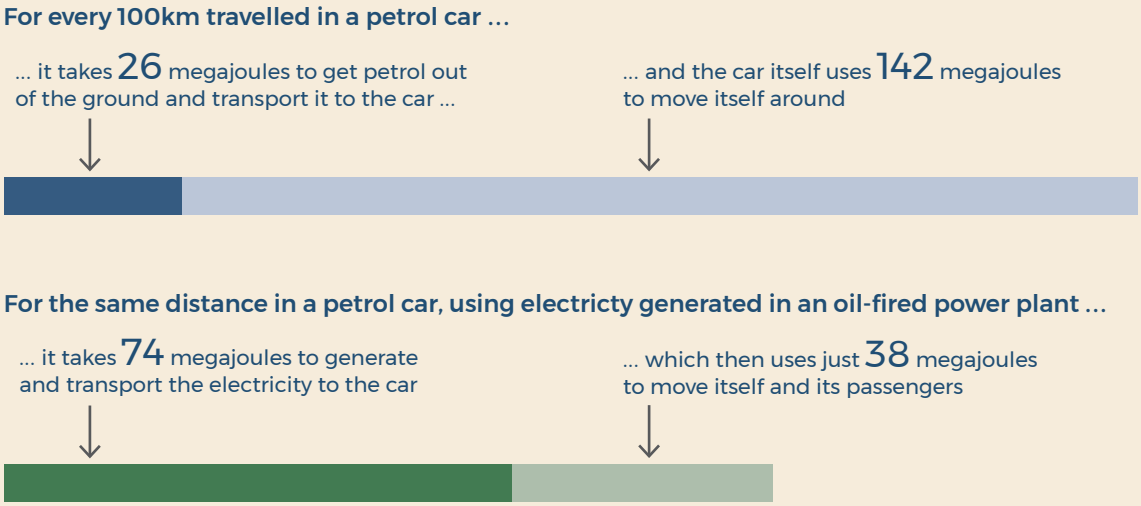
33 Gaylor Montmasson-Clair, Anthony Dane and Lesego Moshikaro, *Harnessing Electric Vehicles for Industrial Development in South Africa*, Report (Pretoria: Trade and Industrial Policy Strategies, 2020), https://tips.org.za/research-archive/sustainable-growth/green-economy/item/3876-harnessing-electric-vehicles-for-industrial-development-in-south-africa.

34 Irma Venter, "Auto Industry's EV Roadmap Aims to accelerate Sales and Production", *Engineering News*, October 9, 2020, https://www.engineeringnews.co.za/article/auto-industrys-ev-roadmap-aims-to-accelerate-sales-and-production-2020-10-09.

- it will not request a VAT reduction, as government is currently under pressure owing to the COVID-19 crisis.

Although ZEVs are the end goal, it does not mean that the transition to EVs can only begin when RE can be supplied at source manufacturing and generation level. This might be preferable, but reduced air, noise and water pollution would significantly benefit the general public, as well as underscore South Africa's commitment to lowering its carbon footprint in line with its commitments to the Paris Agreement. In fact, multiple studies have found that EVs are more efficient, and hence emit less GHGs and other emissions than cars powered solely by internal combustion engines.

Figure 6 EVs using electricity from coal-powered plants



Source: Seán Clarke, "How Green Are Electric Cars?", *The Guardian*, December 25, 2017, https://www.theguardian.com/football/ng-interactive/2017/dec/25/how-green-are-electric-cars

As demonstrated in Figure 6, an EU study based on expected performance in 2020 found that an EV using electricity generated solely by an oil-fired power station would use only two-thirds of the energy of an ICE car travelling the same distance.[35]

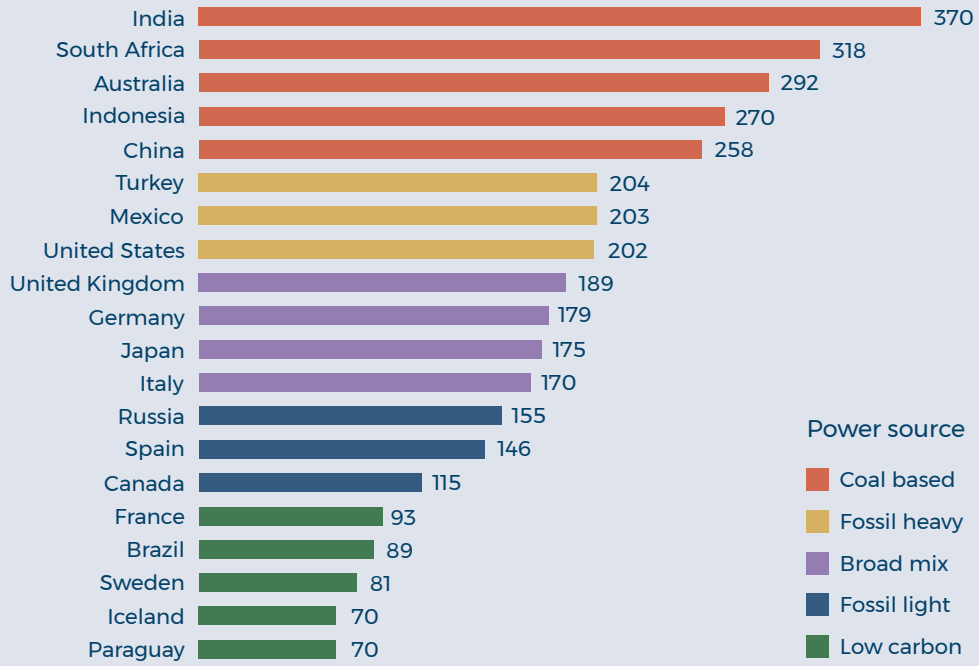
Since South Africa's energy supply for the foreseeable future will be coal-based, sceptics[36] argue that EVs will not dramatically reduce GHG emissions or assist in achieving the Paris Agreement targets or SDGs. However, the International Energy Agency's (IEA) *Global EV*

35 Seán Clarke, "How Green Are Electric Cars?", *The Guardian*, December 25, 2017, https://www.theguardian.com/football/ng-interactive/2017/dec/25/how-green-are-electric-cars.

36 Mark Matousek, "Electric Cars May Be the Future, but They're Still Critically Flawed in a Key Area", *Business Insider*, November 2019, https://www.businessinsider.com/building-electric-cars-how-much-pollution-versus-gas-powered-vehicles-2019-11?IR=T.

Outlook 2019[37] argues that EVs progressively lessen GHG emissions if the electricity mix is not carbon-intensive.

Figure 7 Electric cars' carbon emissions (gCO_2e/km)



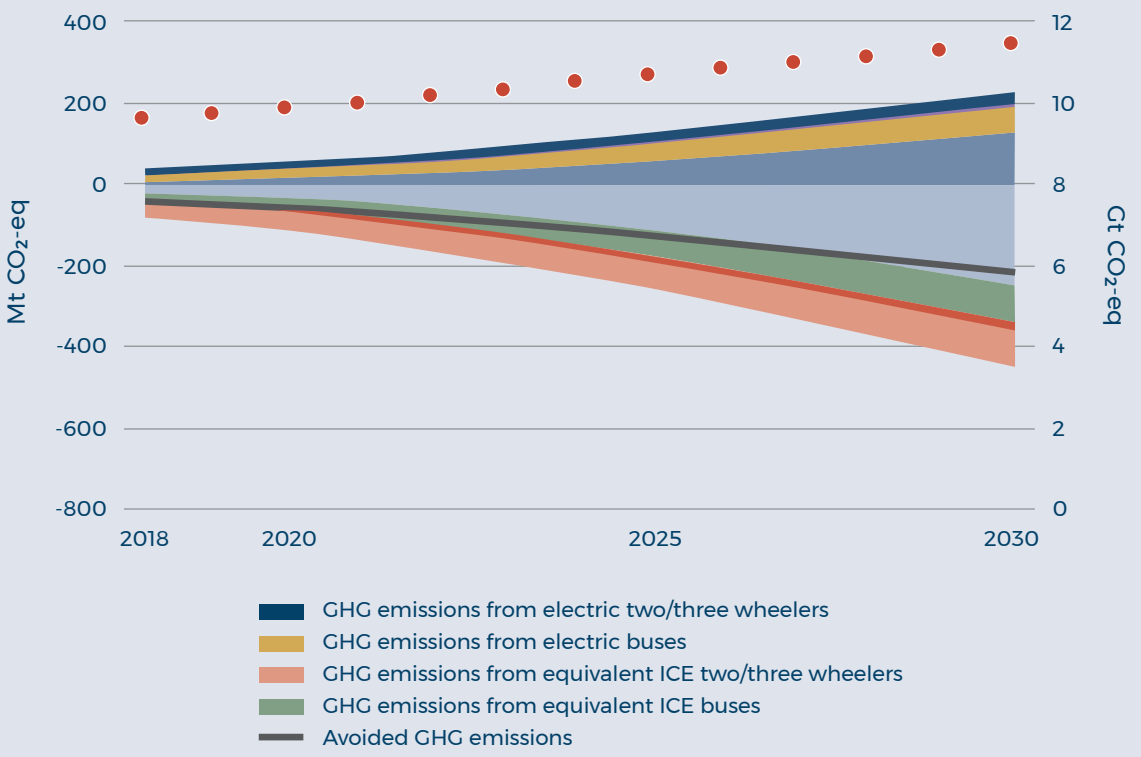
Note: Mt CO_2-eq = million tonnes of carbon-dioxide equivalent; Gt CO_2-eq = gigatons of CO_2 equivalent. Positive values are net emissions from the global EV fleet. Negative values are avoided emissions due to the global EV fleet, calculated as the difference between the emissions from an equivalent ICE fleet and the EV fleet. The WTW GHG emissions from the EV stock are determined in each country/region modelled as electricity consumption from the EVs times the carbon intensity of the power system from the IEA World Energy Outlook for the New Policies Scenario and its Sustainable Development Scenario for the EV30@30 Scenario. The WTW GHG emissions for the equivalent ICE fleet are those that would have been emitted if the EV fleet was instead powered by ICE vehicles with diesel and gasoline shares and fuel economies representative of each country/region in each year.

Source: Shrink that Footprint, *Shades of Green: Electric Cars' Carbon Emissions Around the Globe*, http://shrinkthatfootprint.com/electric-car-emissions

Calculating the well-to-wheel (WTW) GHG emissions of an EV fleet shows that WTW emissions from a global average EV are lower than that of a global average ICE vehicle powered by fossil fuels. Figure 8 points to the New Policies Scenario, where GHG emissions by the generation of energy for an EV fleet are projected at roughly 230 Mt CO_2-eq in 2030. This nearly doubles (450 Mt CO_2-eq in 2030) in the case of an ICE powertrain vehicle fleet.

37 International Energy Agency, *Global EV Outlook 2019: Scaling Up the Transition to Electric Mobility*, (Paris: IEA, May 2019), https://www.iea.org/publications/reports/globalevoutlook2019/, accessed 10 September 2019.

Figure 8 EV GHG emissions – New Policies Scenario



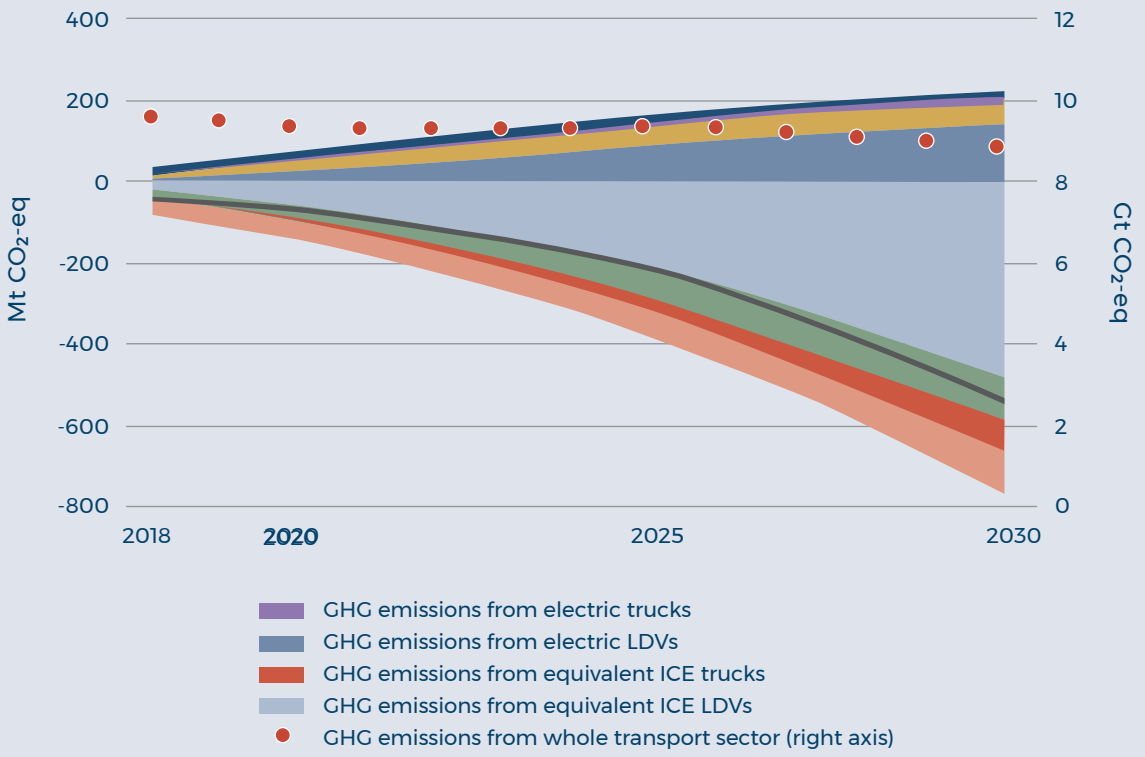
Source: IEA analysis developed with the IEA Mobility Model; carbon intensities from International Energy Agency, *World Energy Outlook 2018* (Paris: IEA, May 2019), https://www.iea.org/reports/world-energy-outlook-2018

However, does the adoption of EVs, even with a carbon-intensive energy mix, allow for a gradual transition to lower emissions? An even better scenario emerges when adopting the IEA's Sustainable Development Scenario, or the EV30@30 Scenario (Figure 9), where there is an accelerated deployment of EVs coupled with a trajectory for decarbonising power generation. In this scenario, the increase in EV uptake stabilises emissions at 230 Mt CO_2-eq in 2030, while there is a sharp rise in what an equivalent ICE vehicle fleet would emit – about 770 Mt CO_2-eq in 2030.

As the growth in sales of EVs rises, it is vital to rapidly decarbonise power generation, according to the envisioned EV30@30 Scenario, because it simultaneously limits the increase of GHG emissions. In these comparisons, EVs reduce WTW GHG emissions by half from an equivalent ICE fleet in 2030, offsetting 220 Mt CO_2-eq in the New Policies Scenario and 540 Mt CO_2-eq in the EV30@30 Scenario.

These comparisons of the IEA scenarios highlight the need to not only increase the net benefits of EVs to reduce GHG emissions but also focus on minimising emissions throughout the entire value chain, ie, the complete life cycle of EVs compared with other

Figure 9 EV GHG emissions: EV30@30 Scenario

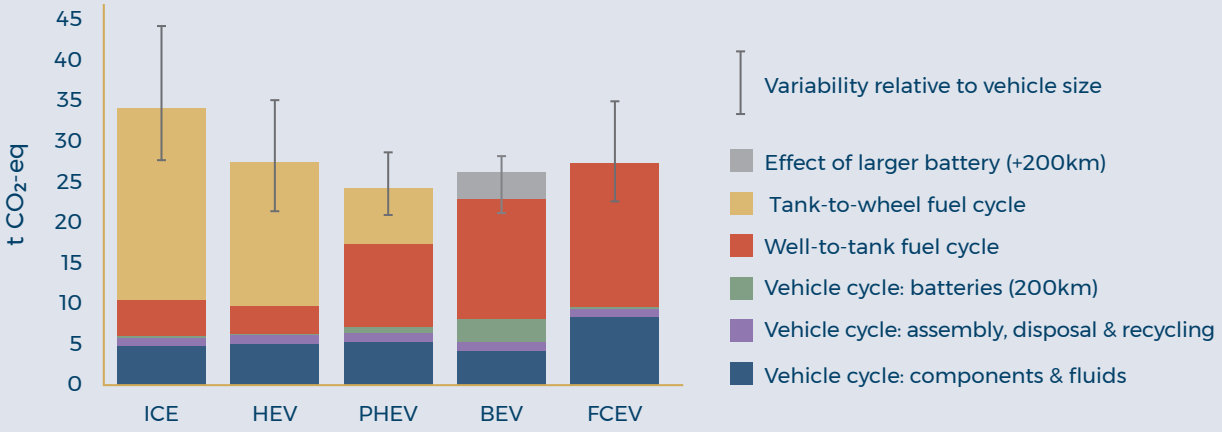


Source: IEA analysis developed with the IEA Mobility Model; carbon intensities from IEA, *World Energy Outlook 2018* (Paris: IEA, May 2019), https://www.iea.org/reports/world-energy-outlook-2018

options. These include the development of new mining and energy plants or battery and automotive manufacturing facilities.

It therefore stands to reason that the most significant potential reduction in GHG emissions over the vehicle lifecycle of EVs is the decarbonisation of power generation systems. If South Africa does not adopt the appropriate carbon intensity generation mix, it will not fully benefit from the contribution of EVs to lower GHG emissions, unless charging infrastructure is predominantly supplied by renewable energy sources. However, if South and Southern Africa decide to decarbonise their electricity generation mix rapidly, they will have a significant advantage in attracting EV investment benefits for battery electric vehicles (BEVs) and plug-in hybrid EVs over other powertrain technologies. Because the SADC region predominantly relies on coal for electricity production, transitioning towards a lower carbon generation mix is essential to deliver GHG savings from the electrification of road transport. The fact that the fuel cycle is the largest component of lifecycle GHG emissions (Figure 10) of all powertrains underlines the argument for EVs, hydrogen fuel cell EVs and hybrid EVs.

Figure 10 Comparative lifecycle GHG emissions of a mid-size global average car by powertrain



Source: IEA, *Global EV Outlook 2019: Scaling Up the Transition to Electric Mobility* (Paris: IEA, May 2019), https://www.iea.org/publications/reports/globalevoutlook2019/

Looking at the South African policy environment, the DTIC acknowledges that the current market share of EVs in South Africa is minimal (approximately 876 vehicles). Nonetheless, the potential exponential growth in the market would contribute meaningfully towards accomplishing GHG reduction targets.[38] This is the case despite the fact that the energy grid is largely driven by fossil fuels. The current pressure on the grid means that EVs that are charged via renewable solar sources may in the future play an important role in providing back-up power to households and the grid.

In conclusion, EVs fall within the 'good for jobs and growth' category and sidesteps the short-termism of the heavy industrial complex, associated with the oil and gas industries, which is a business-as-usual perspective. Introducing EVs powers South Africa and other SADC members into an alternative and sustainable transition with bold, hopeful and preferable futures.

The e-mobility revolution promises labour-intensive manufacturing with mid-skill service sectors, a greater variety of exports and significant process outsourcing among SADC members. The EV landscape thus provides the opportunity to co-create a unique Southern African 'Green New Deal' that could lead to a flourishing regionally integrated community.

38 Republic of South Africa, Department of Transport, *Green Transport Strategy for South Africa: (2018–2050)*, https://www.transport.gov.za/documents/11623/89294/Green_Transport_Strategy_2018_2050_onlineversion.pdf/71e19f1d-259e-4c55-9b27-30db418f105a.

CHAPTER 2

Co-creating systemic innovations in the energy sector

The world's largest EV manufacturer, BYD,[39] claims that 'the world is on the cusp of a permanent shift to electric mobility'.[40] Although many experts are sceptical of the imminent demise of ICE vehicles, the question is whether South and Southern Africa will be left behind by the rest of the world, or whether they will embrace the impending electric mobility revolution. Will SADC muster the courage to reinvent the whole industrial regional value chain fed by its oil and coal dependency to create conditions for a just e-mobility transition? Can SADC develop a home-grown, unique 'Green New Deal' that re-imagines the climate crisis and uses the critical challenges embedded in the EV debate as leverage points to enable systemic change and innovation?

Irrespective of which policy position governments and private sector decide to take, the global landscape will be affected by the e-mobility revolution. In this context, it is crucial to recognise the large-scale movement and evolution of the digital into the physical.[41] Apart from spurring mobility through electrical means, foresight practitioners also foresee the integration and merger of the digital and the physical world, ie, an even more integrated future.[42] This revolution means a movement away from mere physical products to digitally integrated services in the physical world.

By being proactive SADC countries can avoid the inevitability of the 'business as usual' scenario, and of becoming a dumping ground for old ICE technology. They can also avoid becoming the owners of non/low-value resources such as coal, which might become redundant[43] or prohibited[44] in South Africa and the global market in the future.

39 BYD is an EV manufacturer based in China and listed on the Hong Kong and Shenzhen Stock Exchanges. See BYD, "About BYD", http://www.byd.com/en/CompanyIntro.html.

40 Matthew Campbell and Tian Ying, "The World's Biggest Electric Vehicle Company Looks Nothing Like Tesla", *Bloomberg Businessweek*, April 16, 2019, https://www.bloomberg.com/news/features/2019-04-16/the-world-s-biggest-electric-vehicle-company-looks-nothing-like-tesla.

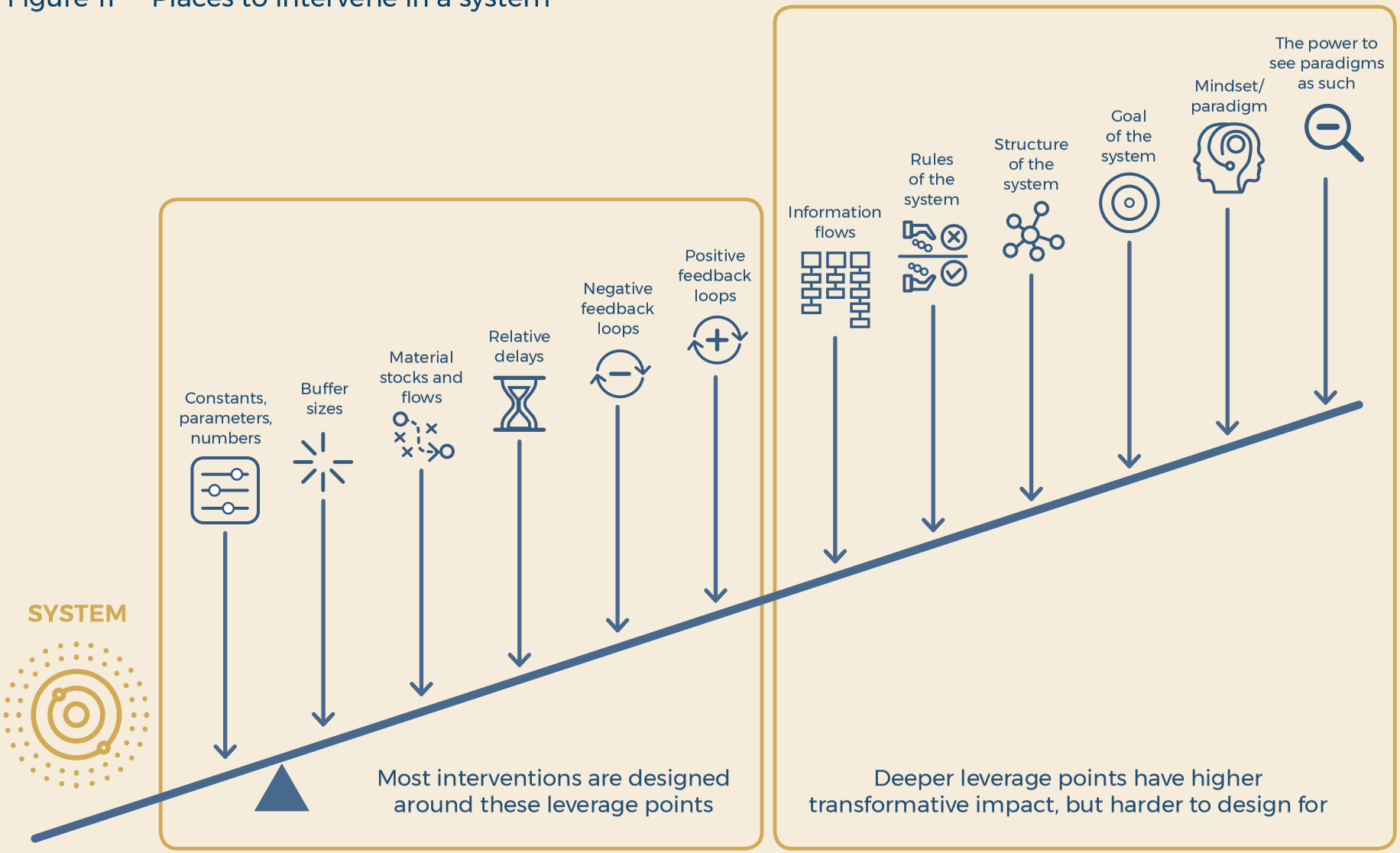
41 See Appendix A for the grid that points to the shift from the physical services orientated to the digitalisation of the physical, and the evolution of the digital/physical environment.

42 Justin Small, "The Future Is Integrated", *Medium* (blog), June 21, 2018, https://medium.com/@JustinKSmall/the-future-is-integrated-93ac46c70bb3, site accessed 21 October 2019.

43 Damian Carrington, "Global 'Collapse' in Number of New Coal-Fired Power Plants", *The Guardian*, March 28, 2019, https://www.theguardian.com/environment/2019/mar/28/global-collapse-in-number-of-new-coal-fired-power-plants.

44 The "Deadly Air" case (alleging thousands of deaths and tens of thousands chronic illnesses) between NGOs and government currently before the Pretoria High Court might become a landmark case against the government and the president owing to high levels of air pollution linked to open-cast coal mines and coal-fired power stations in the Highveld.

Figure 11 Places to intervene in a system



Source: Corina Angheloiu, "IPCC: A Site for Innovation In Its Own Right?", Medium (blog), October 18, 2018, https://medium.com/the-shape-of-things-to-come/ipcc-a-site-for-innovation-in-its-own-right-4a321e5b6d22

A recent analysis of EV adoption[45] and transitions shows that it is essential that critical decision makers, policymakers and stakeholders identify those leverage points that would ensure the achievement of preferable futures for the impending e-mobility revolution in South Africa and SADC. Leverage points are '[the] places within a complex system … where a small shift in one thing can produce big changes in everything'.[46] What will it take to transition from a business-as-usual mindset to alternative, co-created, preferable futures? When developing complexity-informed policies, it is critical to know where to intervene as systems grow, adapt or change. According to systems change specialist Donella Meadows, there are 12 strategic places to intervene in complex social, political, economic and environmental systems.[47]

The effectiveness of the interventions can be viewed on a scale from weak to strong. Strong interventions have the potential to create broad, durable improvements and therefore increase the resilience and sustainability of the entire ecosystem. Weaker interventions are helpful but do not necessarily create systemic change in a way that radically re-imagines and transforms the underlying structure, power dynamics and paradigms of the entire ecosystem. Weak interventions normally consider the individual capacity of actors and use predictive measures to arrive at an envisioned system. However, leveraging systemic change comes to life when system change agents start changing the information flows, rules and structure of systems, by transforming the way leadership and power are conceived and acted upon. As soon as the information flows, rules, structure and goals of the systems are critically transformed, change actors can engage with more profound leverage points that have a higher transformative impact.

Systemic innovation in the context of EVs thus means that all possible leverage points should be critically explored from a systems innovation mindset to co-create strong interventions with high transformative impact that enable resilient and sustainable systemic change. In assessing the appropriateness of interventions, it is important to consider the challenges inherent in system innovation relative to other traditional approaches. These are juxtaposed with the traditional policy rationales for intervention in the case of market or structural systems failures (see Table 2).

45 Loren McDonald, "15 Shifts: How The Transition to Electric Vehicles Will Transform Industries, Jobs and the Environment", *EV Adoption* (blog), January 1, 2019, https://evadoption.com/15-shifts-how-the-transition-to-electric-vehicles-will-transform-industries-jobs-and-the-environment/.

46 Donella Meadows, "Leverage Points: Places to Intervene in a System", *Solutions* 1, no. 1 (January 2010).

47 Meadows, "Leverage Points".

TABLE 2 DIFFERENT KINDS OF FAILURES AND POLICY RATIONALES IN ANALYTICAL APPROACHES: NEO-CLASSICAL, INNOVATION SYSTEMS AND SYSTEM INNOVATION

Market failures (Neo-Classical)	Structural system failures (Innovation Systems)	Transformation system failures (System Innovation)
Too little investment in research and development (R&D), because of the public good character of knowledge (and leakage) and uncertainty about outcomes (which hinders cost–benefit calculation).	Infrastructural failure: Limited investment in physical infrastructure because of risks (large-scale investments and long-time horizons) and low return on investment.	Directionality failure: Transformation process will be hindered by: • lack of a shared vision regarding goal and direction; and/or • ineffective collective coordination of distributed agents involved in shaping systemic change.
Negative externalities: Private actors do not take negative consequences into account if they can externalise costs.	Institutional failures: Problems in formal institutions (laws, property rights, regulations) create uncertainty that hinders investment and innovation. Informal institutions (norms, values, attitudes, trust, risk-taking) may also hinder innovation.	Demand articulation failure: The exploration of new user patterns and opening up of new markets will be hindered by: • insufficient spaces and opportunities to learn about user needs; • absence of orientating signals from public demand (eg, public procurement); and/or • lack of demand¬-articulation capabilities.
Over-exploitation of commons, leading to over-use of public resources in the absence of regulations.	Interaction or network failure: Very strong cooperation may lead to lock-in and inward-looking behaviour. Too-limited interaction hinders knowledge exchange and interactive learning.	Policy coordination failure: Transformation will be hindered by: • lack of multi-level policy coordination (national, regional, global); • lack of horizontal coordination between innovation policies and sectoral policies (eg, transport, energy, agriculture); and/or • lack of vertical coordination (between ministries and implementation agencies)
	Capabilities failure: Lack of appropriate competencies prevents access to new knowledge and inability to adapt and compete.	Demand articulation failure: The exploration of new user patterns and opening up of new markets will be hindered by: • insufficient spaces and opportunities to learn about user needs; • absence of orientating signals from public demand (eg, public procurement); and/or • lack of demand-articulation capabilities.

Source: OECD, *Draft Synthesis Report on System Innovation, DSTI/STP/TIP*, December 3, 2014, https://one.oecd.org/document/DSTI/STP/TIP(2014)12/en/pdf, adapted from M Weber and H Rohracher, "Legitimizing Research, Technology and Innovation Policies for Transformative Change: Combining Insights from Innovation Systems and Multi-Level Perspective in a Comprehensive 'Failures' Framework", *Research Policy* 41 (2012): 1037–1047

The challenges inherent to system innovation frame the context in which system innovation policy interventions are undertaken. It is important to recognise that system innovation is difficult to direct and manage because it is an uncertain, open and complex process where the state, and government more specifically, is neither all-powerful nor all-knowing. The

process itself involves multiple groups of which government is but one and entails co-creation or co-evolution among a variety of system elements. It is dependent on firms and businesses (for knowledge, innovation, taxes, jobs and resources) and on wider civil society support (for legitimacy and consent).[48] Nonetheless, providing systems-wide steerage and direction is critical and as, noted by the Organisation for Economic Co-operation and Development, the likelihood of successful system innovation 'increases when the policymakers at the top of decision-making hierarchies (in government, firms as well as intellectual and opinion leaders in civil society) adopt it *first*'.[49] In government this highlights the importance of central coordinators (like the President's Office and other key planning offices in government such as Treasury). It also flags the importance of vertical coordination between government departments and at various levels, ie, international, national, sub-national and local. There is an arsenal of policy instruments to support system innovation. Table 3 defines some of these.

TABLE 3 POSSIBLE POLICY INSTRUMENTS FOR SYSTEM INNOVATION

Type	Description
Transfer of authority and organisational redesign	The transfer of authority for decision-making to other parts of government or outside government has significant potential to affect the efficiency and effectiveness of policy. It creates opportunities to enhance innovation without necessarily increasing the burden on the state and varies from total ownership to arm's length coordination or advice on a voluntary basis. (Examples of these include establishment of new organisations, mergers or transfer of ownership [privatisation].) It is a powerful tool to break down concentration of systemic power, to locate responsibility and improve accountability and to provide checks and balances.
Policy intelligence	These range from mapping interdependencies and gathering detailed case studies and reliable statistics, to using strategic foresight to detect impulses for change and identify vulnerabilities, sharing information and experiences internationally, supporting policy learning, and effecting ongoing monitoring and evaluation to improve impact. All of these require significant resource allocations by policymakers.
Socio-economic visions and strategies	The use of visions to provide a long-term framework has many uses. On the one hand, it coordinates action and helps to identify barriers to progress (for example, regulations or outdated technologies). On the other hand, the purpose of a vision may be not only to direct the allocation of resources but also to enable an environment to test various policy paths. Finally, an ambitious, well-articulated and differentiated forward-looking future vision whose objectives are also adaptive and framed within co-decision-making approaches (eg, public–private partnerships [PPPs]) creates the scope to move beyond current paradigms and current leaders. This avoids the trap of constantly being in catch-up mode or stuck in a political dead-end.
Funding for R&D and innovation	This requires carefully directing funding during the transition to both reduce uncertainty and assist in crucial decision-making processes. Apart from conventional R&D funding, it is also important to dedicate resources towards understanding the social drivers and social implications (such as job creation/losses) of system innovation interventions.

48 OECD, *Draft Synthesis Report on System Innovation, DSTI/STP/TIP*, December 3, 2014, https://one.oecd.org/document/DSTI/STP/TIP(2014)12/en/pdf.

49 OECD, *Draft Synthesis Report*, 45.

Funding for infrastructure	PPP is critical here, and in at least two areas during the early transition phase it is important to consider the implications of infrastructure decisions. First, delineating the role of government and consulting widely and deeply to ensure that investment decisions have the largest multiplier effect is critical. Apart from consulting with experts, the business sector has a critical and central role. Second, the timing of interventions is critical given that early interventions might accelerate a transition, but also run the risk of locking in a particular trajectory. Hence interventions that keep alternative options open are preferable to those that early on channel decision-making towards a narrow trajectory. There is a risk here, as certainty is a key dimension of locking in private sector support, but attention should be given to the overall design and learning from international experience. Once a dominant design emerges it is easier to crowd in private sector support. Throughout this process it is important to be open to private sector inputs.
Skills provision	Based on historical international experience there is generally a critical skills shortage at the emergence point of a new technology or industry, requiring special policy actions to ensure that the demand for skills can be met rapidly enough to support the take-off of the sector. This is often only possible in the initial phase through imported labour, and policymakers have a critical role to ensure that this type of mobility is possible. At the same time it requires significant flexibility and responsiveness of the education system to ensure that it is open to industrial demands, and aware of and positioned to respond to global industry developments in a variety of sectors. Actively pursuing the internationalisation of education policies to support competitive innovation and learning is essential, as is the ability of the system to deliver short-term, ad hoc interventions to deliver relevant skills or to support on-the-job training.
Public procurement	Public procurement is an important policy tool to create or emulate 'lead markets'. Lead markets comprise 'early adopters, who tend to be technically proficient and are willing and able to pay price premia'.[a] This requires an exceptional technical competency in government and its procuring agencies to both assess and justify spending on goals that are not necessarily cost-effective. It is also important to avoid the negative dimensions of demand concentration through monopsony, especially considering its impact on the lack of specialisation and diversity – important dimensions of long-term resilience in any system. This implies a clear time-horizon and exit strategy, but also a clear understanding of latent demand, including demand for complementary products and services.
Standards, regulation and legislation	Standards are critical to creating new markets, reducing uncertainties and supporting the division of labour.
Legislation, regulation and institutional changes	Legislation is critical to address market and coordination failures that cannot be addressed through the price mechanism, or to regulate certain activities. It also has an important role in providing clarity about liability and hence apportioning of risk.
Support for networks and PPPs	This instrument has the role of ensuring participation by a specialist community, especially in the early phases of a transition where the incentive to cooperate, contribute or participate might still be low. The seeding of such networks until they develop their own dynamic is an important policy contribution.
Public consultation	The importance of public consultation as a policy tool in system design goes without saying. It is a key instrument to receive input on social demands and expectations of policies, to support the legitimacy of the transition and long-term framework and, finally, to create a public space for debate and discussion.

Innovation programmes	Innovation programmes are important piloting mechanisms or prototypes whose application in smaller parts of the system can be used to test the robustness of the system, its legitimacy and efficiency, or to establish new areas for innovation and learning. However, in this context it is also important to pay attention to the fact that the long-term success of the system is dependent on social change. Hence an understanding of social technologies (ie, technologies that are rooted in people's behaviour) is critical in assessing whether one can truly generalise from pilot studies and whether best practices in system innovation are transferable.

a OECD, *Draft Synthesis Report*, 51.

Source: OECD, *Draft Synthesis Report on System Innovation, DSTI/STP/TIP*, December 3, 2014, https://one.oecd.org/document/DSTI/STP/TIP(2014)12/en/pdf

In the context of the e-mobility revolution and SADC's road map towards EV adoption, there are various places to intervene in each of the sectors identified. A systems innovation perspective helps identify the possible leverage points[50] in policymaking that could be crucial catalytic interventions on the road towards developing a more sustainable, economically viable and technologically progressive region. At the same time, these interventions could also deal with the underlying causes of the current climate crisis, biodiversity collapse and pollution, and over-exploitation of resources.

50 A note of caution – the leverage points are not a recipe to find places to intervene, but should rather be seen as an invitation to think more broadly about the complex unfolding change process and underlying system change interventions.

CHAPTER 3

Systemic innovations towards a new energy paradigm

Build infrastructure that lowers the costs of acting

Automakers become energy companies; utilities adopt e-mobility battery-leasing models

When cars run on petrol or diesel, oil company ecosystems that focus on oil exploration are separate from those in refining/production and distribution. However, with electricity and batteries that fuel transport, the battery ecosystem production creates an overlap with a plethora of possible future commercial and residential battery storage systems. The same battery system that powers a car's electric motor may store clean energy, supplement the grid and power a home or business. This means that, almost by default, most automakers will enter the energy storage and vehicle-to-grid/home/building business.

Crucial policy instruments include fuel economy standards, zero-emission vehicle (ZEV) mandates and more ambitious public procurement programmes. Government could consider the creation of a ZEV mandate and action plan along with the Green Transport Strategy. This would create a reinforcing feedback loop where the green energy transition could increase low-income markets' ability to buy affordable and fit-for-purpose vehicles by investing in the manufacturing of low-speed EVs (LSEVs) under $3,000. New business models could follow shared-use or subscription models without purchasing. LSEV procurement programmes are essential instruments to kick-start demand for EVs and encourage automakers to increase the availability of EVs to all market segments and not only the middle class and the rich. A strategically orchestrated ZEV action plan with an accompanying procurement plan could also enable the initial roll-out of publicly accessible infrastructure.

With the electric mobility transition Eskom could attract crucial investment. If framed correctly, with a clear commitment to a much faster RE transition through the massive network of existing fuel stations along public roads[51] and connecting those to regional electricity distributors, investors might revisit the utility's potential. Eskom could also enter the transport industry by leasing batteries to customers. This will enable it to dictate bulk charging times, stabilise the grid, level the demand curve and become more energy efficient, resulting in lower tariffs. This will also lower the EV price through the cost of the battery and get rid of luxury tax. In addition, with the invention of solar tiles, panels,

51 Please see Appendix B, which points to the current road networks in comparison to existing transmission grid networks.

geysers and other new RE technologies, Eskom could enable home and business users to become RE generators, and so enhance the energy mix generation and distribution. This would mean that Eskom starts focusing on electric power transmission wheeling rather than generation, which in turn would enable third-party access and connectivity. These are crucial steps in laying the foundations for an e-mobility revolution in the SADC region.

The Fourth Industrial Revolution can change the role of utilities. Utilities should embrace the digital revolution in the energy industry. A McKinsey & Company report[52] on future digital utilities outlines how energy providers could benefit from various opportunities along the energy value chain (Figure 12).

Figure 12 The future digital utility value chain

Source: Adrian Booth, Niko Mohr and Peter Peters, "The Digital Utility: New Opportunities and Challenges", McKinsey & Company, May 12, 2016, https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-digital-utility-new-opportunities-and-challenges#

52 Adrian Booth, Niko Mohr and Peter Peters, "The Digital Utility: New Opportunities and Challenges", McKinsey & Company, May 12, 2016, https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-digital-utility-new-opportunities-and-challenges#.

A just e-volution (electric-mobility revolution) in the Southern African economy would change the traditional role of utility companies in the supply of energy. Utilities would transform into the 'new oil companies' that ensure the exploration of new technologies for electricity generation, infrastructure, distribution and, most importantly, regulation. At the same time, utilities would have to navigate the rise of automakers entering the energy space through EVs, power walls and associated EV technologies such as vehicle-to-anything (V2X) and vehicle-to-grid (V2G) applications. Automakers would either been seen as partners to utilities or competition, depending on the business model utilities use.

Seeds of the preferable just transition

- The African Alliance for Energy Productivity[53] seeks to double energy productivity by 2030 and become a leading energy productivity partner that connects decision makers, enables policymaking processes and ensures proactive information to tackle climate change and promote environmental sustainability.
- Eskom's crisis is already becoming its greatest strength by unbundling the state-owned enterprise (SOE) into three business units, transforming it into an electricity wheeling, coordinator, integrator and SADC regional infrastructure company, as per the recent announcement of investment in a massive battery project.[54]

Suggested leverage points for policy action

Governments could:

- convene a broad coalition of energy producers to build infrastructure, products and processes that lower the costs of maintaining and generating electricity for EVs, by re-imagining the roles of Eskom and automakers to collaborate as energy innovators, brokers and partners and not merely product or service suppliers;
- provide buffers to energy utilities to move from a centralised organisation to incorporate decentralised electric power transmission wheeling through third-party investments, PPPs and collaborations;
- build 'cognitive bandwidth' for unstructured time and funds to increase the use of new smart technology solutions to enable new products and services for partnerships in balancing the grid, integrating new variable and distributed resources, improving operating efficiency and reducing costs for all customers;
- educate consumers and government on the benefits of supporting domestic fuel sources (rather than imports of fossil fuels) and incentivise EV purchases by investing in PPPs to grow charging infrastructure and smart load management solutions;

53 AAEP, "About Us: AAEP", http://www.aaep.org.za/about-aaep/#ourstory.

54 "Eskom Is Working on a Massive New Battery Project – Here's What You Need to Know", *BusinessTech SA*, https://businesstech.co.za/news/energy/343147/eskom-is-working-on-a-massive-new-battery-project-heres-what-you-need-to-know/.

- engage National Treasury to invest in domestic energy generation (Eskom electricity, especially renewables) by encouraging the public to replace 1 million ICE vehicles with BEVs to improve the trade balance by $1 billion (the yearly foreign exchange outflow per ICE vehicle is about $1,000);
- build the capacity of Eskom and SADC utility companies to embrace their new role of 'energy cross-scale coordinators and integrators' with an 'OPEC-like' function to stabilise, secure and monitor regular supply; and improve efficiency and environmental sustainability in the regional energy market (these new services could include developing domestic bi-directional V2G, smart-charging technologies, thereby lowering the cost of electricity and SADC's dependence on coal-generated power);
- increase the size of the RE mix (currently at 30% by 2025) and the speed of achieving the REIPPPP targets by installing RE electricity substations/microgrids (solar) and introduce an incremental transition programme that replaces petrol pumps with e-mobility recharging stations;
- convene a diverse transdisciplinary working group to create a ZEV mandate;
- create diverse transdisciplinary partnerships to develop and execute an LSEV action plan along with the Green Transport Strategy; and
- create an LSEV watchdog that ensures accountability and equity in the ZEV transition by collecting data on the decisions of dominant actors and making it public.

Seek inclusion and enable weaker actors to influence decisions

Utilities partner with less powerful actors through EV-enabled demand-side response services

Eskom plays a crucial part in determining who has access to electricity. A high EV uptake with uncoordinated charging can pose a challenge for Eskom if this demand coincides with peak demand periods and pushes the peak demand beyond supply markers in the system. Clustering effects in the increased uptake of EVs can also lead to local overloading of distribution networks, resulting in the need to upgrade the distribution network. This can be avoided by decentralised generation – rooftop PV feed-in to the grid – if made attractive to home owners. This includes the replacement of transformers and reinforcement of lines. All of the above are costly and challenging exercises amid the power utility's current turmoil.

Controlled EV charging, on the other hand, enables access to a range of solutions for Eskom through the provision of demand-side response (DSR) services. The European Network of Transmission System Operators for Electricity (ENTSOE)[55] defines DSR as the load

55 Mark Norton et al., eds., "Demand Side Response Policy Paper" (European Network of Transmission System Operators for Electricity, Brussels, 2014), https://eepublicdownloads.entsoe.eu/clean-documents/Publications/Position%20papers%20and%20reports/140915_DSR_Policy_web.pdf.

demand that can actively be changed by a trigger. Demand-side management (DSM) is the utilisation of DSR for a purpose such as system security (ie, balancing and congestion) or system adequacy. The uptake of DSR should be wide-ranging and intensive if Southern Africa is to achieve decarbonisation in the energy transition. ENTSOE[56] also argues that DSR has numerous benefits:

- it creates value for consumers and society by rewarding consumers for changing their consumption behaviour, and therefore reduces the cost of energy;
- it provides flexibility to system operators, helping them to maintain the security of supply and system adequacy, and optimises the utilisation of infrastructure and investment in the grids; and
- it can be a competitive alternative to other power sources, thereby enhancing competition and improving the emission target for electricity markets.

A just e-volution includes EV-charging capacities that help utilities build their resilience through partnerships with IPPs. To enable a just energy transition, the Global EV Outlook Report 2019 outlines several solutions.[57]

- EVs can minimise impacts on the grid by shaping the electricity demand pattern through changes in the timing of charging events to low-demand periods.
- EVs have the potential to put energy into the power system when needed. The properties of EV batteries allow a speedy and precise response to control signals, as well as the ability to shift demand across more extended periods. These capabilities enable EVs to provide DSR services to the system across a wide range of timescales and to participate in electricity markets. This is a significant advantage EVs have compared with other sources of DSR.
- EV batteries can store energy that can be used for other purposes than powering the vehicle, thanks to the opportunities offered by V2G and similar technologies (for example, V2X). With V2X, EVs can discharge energy to buildings and, more generally, the power grid to maintain system stability. This feature can help to address challenges at a local level by preventing an overload of distribution grids, as well as at the main network level.

The Eskom advisory board should look into the e-mobility revolution's potential to help re-imagine the role of the utility. If Eskom refinanced its existing assets it could develop the necessary capacity to become a partner of recharging stations through a third-party organisation like Gridcars and other new e-mobility entrepreneurs. This shift from energy dominator to decentralised partnership-building will allow new opportunities, agility and job creation in the utility. Other options could include the manufacturing of innovative battery storage and RE supply technologies. A partnership with the likes of Tesla (for its

56 Norton et al., "Demand Side Response".
57 IEA, *Global EV Outlook 2019*.

powerpack systems) or Southern African start-ups that provide large-scale distributed battery storage for peak demand management would be ideal. Such systemic innovations would minimise load and capacity charges in municipalities to facilitate energy resilience and distribution stability.

These suggested energy innovations show how Eskom can start working with IPPs and build energy system resilience while also progressing with the REIPPPP. For instance, one of Tesla's inventions is its renewable microgrids, which offer turnkey energy solutions that combine RE and storage to provide communities with clean, resilient and affordable power.

Seeds of the preferable just transition

- The CSIR has suggested DSR services[58] as a solution to Eskom's significant energy planning risks. DSR becomes a critical approach to help Eskom delay some of its capacity investment through EVs that will predominantly charge at night and deploy slightly more solar PV energy during the day.
- Kaua'i Island Utility Cooperative, which dispatches solar energy, helps the island meet peak demand daily.
- Connecticut Municipal Electric Energy Cooperative reduced its load and capacity charges with a solar and Powerpack system.
- American Samoa replaced its diesel energy with Tesla's renewable microgrid,[59] which shows that RE microgrids are a cost-competitive option for energy supply in remote locations.
- Eskom launched its pilot solar-powered microgrid[60] at Wilhelmina Farm, Ficksburg. The microgrid demonstration plant, which was completed in November 2019, provides electricity to 14 households with 81 family members in the Wilhelmina community.

Suggested leverage points for policy action

- SADC member states should enable less-powerful RE actors to influence decisions on electricity demand and generation capacity, ie, build distributed energy resources (DERs). DERs are small-scale units of local generation connected to the grid at distribution level.
- SADC member states should provide the resources to build national policy frameworks for a target programme to retrofit existing buildings to a high-efficiency standard, promoting measures to inform consumers and fostering social tariffs or energy subsidies for low-income households.

58 CSIR Energy Centre, "Formal Comments on Integrated Resource Plan (IRP) 2018", October 25, 2018, http://researchspace.csir.co.za/dspace/bitstream/handle/10204/10492/Wright_Formal%20comments_slide.pdf?sequence=5&isAllowed=y.

59 Engerati Network, "The Tesla Microgrid – American Samoa Shows the Way", December 9, 2016, https://www.engerati.com/article/tesla-microgrid-%E2%80%93-american-samoa-shows-way.

60 "Eskom Launches Ground-Breaking Microgrid Pilot Plant", *Electricity+Control*, November 6, 2018, https://www.crown.co.za/latest-news/electricity-control-latest-news/8324-eskom-launches-ground-breaking-microgrid-pilot-plant.

- SADC member states and the SADC directorates of Industry Development and Trade and of Infrastructure and Services should build inclusive and open communication networks that agree on the roles and responsibilities of transmission system operators (TSOs) and distribution system operators (DSOs). They should organise data-handling procedures, ensure security of supply, configure market mechanisms, and define a common SADC energy transmission framework.
- ENTSOE[61] makes various policy recommendations to empower a successful transformation of the power system.
    - » Set clear roles and responsibilities of relevant parties to facilitate and enable the delivery of DSR and customer engagement. In particular, this requires significant collaboration between TSOs and DSOs.
    - » Develop a framework that optimises the use of DSR across multiple parties (eg, DSR sharing), facilitated by a future data-handling body (or bodies). This will ensure TSOs, DSOs, suppliers and other market participants are able to gather the data required to fulfil licence/regulatory/commercial obligations.
    - » Seek agreement between SADC countries on the security of supply needs from the networks and the development of network planning and operational standards to reflect a new network paradigm with DSR. This will entail defining and ensuring performance criteria for DSR.
    - » Pursue integration of DSR as a market participant on equitable and transparent terms with generation and storage rights. These DER services will require opening all markets to DSR on a non-discriminatory basis and creating generic 'DSR-friendly' products to allow markets to deliver appropriate price signals and incentives to develop DSR in the system.
    - » Adopt a common SADC energy framework for DSR with regional/national settings. These should set clear and consistent ground rules and roles for all relevant parties to deliver DSR while creating flexibility for pilot projects at a regional or national level.

Create enabling constraints, equalise access to information and data transparency by adding feedback loops

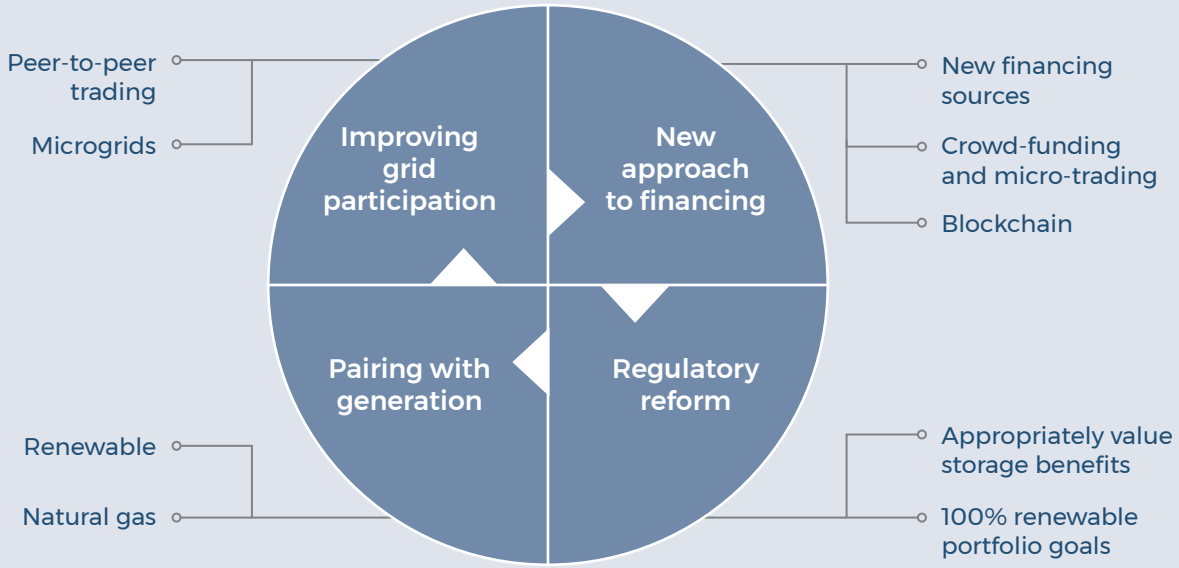
From electricity consumers to prosumers, peer-to-peer traders and micro-generators

Eskom's energy supply woes have triggered a shift by electricity users to alternative forms of energy. Those with the capital to do so have installed various sources of electricity in their homes or businesses to safeguard against load shedding. The large-scale adoption

61 "Eskom Launches Ground-Breaking".

of 'anything-but-Eskom' electricity in private homes or businesses has contributed to the utility's revenue losses. There has been a shift has to microgrids and prosumerism (customers who consume goods aimed at the professional market).[62] The delay in the provision of reliable electricity supply to consumers is a systemic leverage point and has become a core growth opportunity for the battery storage industry at the micro-level.

Figure 13 Next steps in battery energy storage



Source: Adeline Pang and Saghar Khodabakhsh, "Energy Storage: Opportunities, Key Trends and Market Drivers", White & Case LLP, October 18, 2018, https://www.whitecase.com/publications/insight/energy-storage-opportunities-key-trends-and-market-drivers?s=tesla

South Africans are becoming more energy-empowered because of the delay in the rate of systems change at the utility. This creates an opportunity to decentralise the energy grid and make the entire energy system more resilient. One way of doing this is to facilitate a shift to peer-to-peer trading among micro-generators. This approach is already evident in the UK's first blockchain-backed energy trade between housing blocks in London in April 2018.[63] Allowing this type of trading to take place on an open and transparent ledger may be a significant opportunity to provide battery services in exchange for a small flat fee or on a charge-per-use model. This would allow prosumers to connect to microgrids, which in turn could further Eskom's energy goals and address current woes by linking these microgrids with the national system. Such an approach would smooth out the peaks and

62 Adeline Pang and Saghar Khodabakhsh, "Energy Storage: Opportunities, Key Trends and Market Drivers", White & Case LLP, October 18, 2018, https://www.whitecase.com/publications/insight/energy-storage-opportunities-key-trends-and-market-drivers?s=tesla.

63 Pang and Khodabakhsh, "Energy Storage".

troughs in the energy generation-distribution system, and so build resilience in the utility's energy crisis and safeguard South Africa's too-big-to-fail SOE.

Seeds of the preferable just transition

- The ANC National Executive Committee's (NEC) position on an energy transition, opting for the lowest-cost option, is:[64]

  > The NEC agreed to develop a strategy on a just transition to a low-carbon path of development that takes into account the interests of workers, communities and broader society. This should include such new technologies as fuel cell applications which require platinum group metals (PGM) which South Africa has in abundance.

- Rwanda has launched the first African-made smartphone factory,[65] showing fellow African countries that it is possible to build a gigafactory linked to the global battery supply chain.

Suggested leverage points for policy action

- The South African government should incentivise Eskom to build decentralised recharging infrastructure that enables access and provides DSR services. These services could include V2G and V2X technologies that ensure energy systems' resilience and allow for new products that can be sold to electricity consumers at their homes.
- SADC member states should provide utilities with buffers that enable unstructured time and funds to increase research and innovation capabilities through broad coalitions of private, public and academic actors to grow domestic technological innovation and skills.
- SADC departments of energy should co-create feedback loops that collect data on the consequences of the e-mobility transition on the energy sector to ensure negatively affected stakeholders are included and accounted for, and that just and equitable actions are taken that allow for democratic feedback to disaffected economic sectors.
- SADC member states should introduce programmes that help utilities move from centralised generation to regional generation hubs with a regional electricity distribution system that function as decentralised affiliated hubs to Eskom. This will ensure broader access, local procurement and job creation, and systems network and grid resilience.[66]

64 Mark Swilling, "Wake Up, Everyone: ANC NEC's Energy Statement is a Real New Dawn for South Africa", *Daily Maverick*, October 4, 2019, https://www.dailymaverick.co.za/opinionista/2019-10-04-wake-up-everyone-anc-necs-energy-statement-is-a-real-new-dawn-for-south-africa/.

65 David Ochieng Mbewa, "President Kagame Launches First Smartphone Factory in Rwanda", *CGTN Africa*, October 7, 2019, https://africa.cgtn.com/2019/10/07/president-kagame-launches-first-smartphone-factory-in-rwanda/.

66 NREL, "Connecting Electric Vehicles to the Grid for Greater Infrastructure Resilience", April 20, 2017, https://www.nrel.gov/news/program/2017/connecting-electric-vehicles-to-the-grid-for-greater-infrastructure-resilience.html.

From centralised energy generation, transmission and distribution to dynamic localised DER networks

Historically, the energy relationship between the public and governments has been dominated by the state. However, new technologies such as blockchain[67] provide enormous opportunities to equalise access to energy information, income and resources, and thereby allow home users more control over how they consume energy. The main reason for this equalisation is that blockchain has the potential to tokenise renewable energy. The blockchain enables a distributed system, thus removing the middleman and allowing wind, solar and hydro producers to seamlessly connect with investors who are willing to pay upfront for the right to consume renewable energy.

The application of blockchain will accelerate the Internet of Things (IoT), increasing interconnectivity and enhancing smart technology integrations. By creating a more inclusive data ecosystem, blockchain technologies equalise information flows for more high-quality data to be exchanged freely between devices. This development should be welcomed as a critical opportunity for SADC states that seek integrated solutions that inherently increase transparency and equality towards a just energy transition. Energy experts point to several possible benefits of employing blockchain technology to solve pressing challenges in enabling a just energy transition:[68]

- blockchains provide privacy, enhance cybersecurity, and are a low-cost way of managing DER-focused transactions at the edge of the distribution grid;
- blockchains provide a more transparent and secure way of tracking energy flows than the status quo;
- blockchains enable small-scale and low-credit customers to participate in business models focused on DERs and RE; and
- blockchains are a key enabler of balancing and managing the grid from the bottom up versus today's top-down approach.

But how will this work practically in Southern Africa? SADC members will need to invest in DERs such as rooftop solar, demand response, and EVs. This will require setting up innovation labs that experiment along with governments, utilities and other stakeholders from across the globe to find new ways to regulate and manage the electricity grid.

67 A blockchain is essentially a distributed ledger that is hosted on the Internet and is a digital means of handling secure and trustworthy transactions between various parties. A transaction is an exchange of value that is then encoded as a digital exchange of information on a blockchain. The transactions can range from monetary transactions, such as the trading of bitcoins, to others like trading electricity.

68 Jesse Morris, "The Energy Web Foundation: Bringing Blockchain Technology to the Grid", Renewable Energy World, February 23, 2017, https://www.renewableenergyworld.com/2017/02/23/the-energy-web-foundation-bringing-blockchain-technology-to-the-grid/.

According to the Rocky Mountain Institute (RMI), these experiments currently face four main issues, regardless of geography:[69]

- controlling demand is difficult: customers are concerned about privacy and sometimes loathe to share data – let alone allow third parties to control DERs that they own;
- tracking energy flows is imperfect: energy markets and markets for energy attributes (eg, RE credits) can be expensive to run, can be subject to double spending, and can usually be accessed only via intermediaries;
- not everyone can participate in the grid's evolution: in developed economies, only large, sophisticated businesses are able to enter into off-site power purchase agreements for renewables, while in emerging economies, access to capital is a major barrier to accessing DERs and RE, even if these technologies are capable of generating cost savings; and
- putting customers and DERs first is challenging: the entire grid was originally designed from the top down, making it difficult to prioritise customers and DERs.

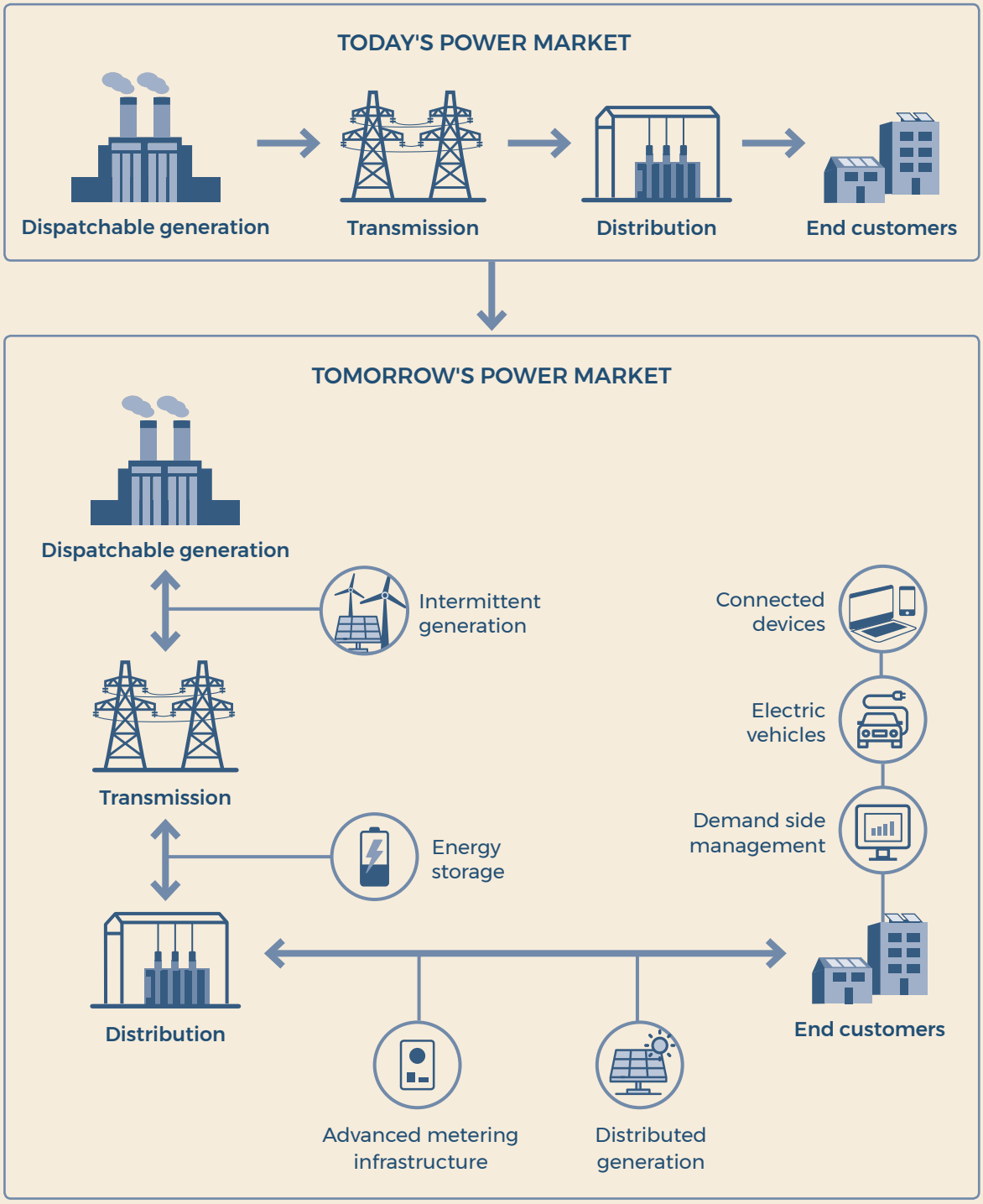
To enable the just e-volution there needs to be a shift away from centralised linear approaches of infrastructure design premised on supporting predictable, unidirectional power flows, by means of centralised generators through transmission and distribution systems, to passive customers. The DER approach is a more complete alternative owing to its combination of increased availability of granular data and communications. DERs in many ways are a reinvention of electricity networks and delivery. The use of DERs creates an equalised platform for interconnectivity – from power plants, DERs and consumers to aggregators – which ultimately becomes a transactive, resilient, efficient network.

All of this requires updated infrastructure, regulation, business models, technologies and markets. The just energy transition in SADC needs to take place without sacrificing the reliability and affordability of energy to customers.

The just e-volution plays a significant role in decentralising the energy system. The growing Southern African EV and charging infrastructure market allows operators and utilities to experiment with two-way communications, control and charging/discharging technologies such as V2G. Ultimately, a decentralised system, in conjunction with EVs and associated infrastructure, can act as flexible demand response that adjusts to load patterns assisted by energy storage for excess non-dispatchable generation. This is especially true for remote and rural locations where energy provision is best facilitated by decentralised sources in the form of microgrids or off-grid power options. In other cases, a mixed approach via the extension of the existing centralised grid infrastructure will be needed. Energy access could become both a driver and a beneficiary of the global decentralisation trend.

69 Jules Kortenhorst and Jon Creyts, "Energy Web Foundation Launches Pioneering Blockchain to Accelerate a Low-Carbon, Customer-centric Energy System", Rocky Mountain Institute, June 19, 2019, https://rmi.org/energy-web-foundation-launches-pioneering-blockchain-to-accelerate-a-low-carbon-customer-centric-energy-system/.

Figure 14 Decentralisation of the energy system



Source: Shayle Kann, "4 Trends Reshaping the Power Sector", Green Tech Media Research, August 22, 2017, https://www.greentechmedia.com/articles/read/four-trends-reshaping-the-power-sector

Seeds of the preferable just transition

- At Enel Foundation – Open Africa Power 2020, Power Futures Lab & MIRA[70] students can get holistic know-how on the electricity sector, enhancing their technical, regulatory and business skills to work in the private and public sector towards the electrification of Africa. This flagship training initiative is undertaken in partnership with the Graduate School of Business at the University of Cape Town.
- The US Department of Energy's Office of Science awarded a $1.05 million grant[71] to start-up IoT company BEM Controls for a blockchain project to create the 'Energy Internet'. This transactive energy platform will allow building owners to buy energy from distributed sources such as solar generators or wind farms. Energy utilities and grids will also participate in the platform.
- Bitcoin mining as a revenue-increasing mechanism for Eskom.[72]

Suggested leverage points for policy action

Adedayo Adebajo makes the following suggestions regarding the design of energy policy in a blockchain-led industrial revolution in Africa:[73]

- lease unused or available land in less congested areas and rooftops in areas associated with power supply projects;
- build micro-grids in areas where RE sources have advantages;
- prepare a token remuneration plan for leased spaces where a certain percentage of the generated energy in token value is transferred to a meter wallet to be used for free power supply;
- connect nearby shelters to the supply, with payments depending on usage (established via smart meters);
- based on demand in certain areas, increase microgrid production;
- give individual investors a chance to procure facilities to supply power to some areas to reduce monitoring efforts, thereby increasing returns from percentage-based energy profits and maintenance services;
- facilitate the construction of RE supply to the main grid in congested areas to reduce losses to resistance (actionable options include constructing new distribution grids

70 Enel Foundation, 'Open Africa Power 2020: Call for Applications", https://www.enelfoundation.org/news/a/2019/10/open-africa-power-2020--call-for-applications.

71 Ledger Insights, "US Department of Energy Makes Blockchain Grant", https://www.ledgerinsights.com/department-of-energy-blockchain-bem-comed/.

72 Carel de Jager, "Bitcoin Mining as a Revenue Increasing Mechanism for Eskom", *Medium*, blog, September 25, 2018, https://medium.com/@careldj/bitcoin-mining-as-a-revenue-increasing-mechanism-for-eskom-407cd134b648.

73 Adedayo Adebajo, "Blockchain Industrial Revolution in Africa", *Medium*, blog, February 24, 2019, https://medium.com/coinmonks/blockchain-industrial-revolution-in-africa-a624b908c613.

or transporting older grids to new locations to reduce the span of supply cables and resistance losses);

- focus on the use of smart meters to channel energy supply based on requirements in various locations;
- implement a blockchain voting system to reward energy enhancement projects using lightweight contracts, which will be monitored by end-users;
- install nodes in every facility and introduce incentives to enable forging,[74] which includes encouraging 24/7 power demand and keeping account with forging balance; and
- introduce a user damage control and remuneration programme. (This is a blockchain insurance programme for end-users that uses lightweight contracts to remunerate high-tariff payers for events such as blackouts and high/low voltage supply, which can cause damage to goods, houses and infrastructure. This is a step ahead for competitors. The remuneration is best issued in tokens for metered energy payments, which can also be sold to other customers.)

Organise alliances and change the rules of the system

From analogue carbon-based energy to digitalised low-carbon distributed electricity systems

Along with 4IR technologies such as blockchain, the just e-volution creates new ways for people to network around energy that ultimately change the rules of energy systems. The global non-profit organisation, Energy Web Foundation (EWF) – founded by RMI and Grid Singularity – is focused on capturing open-source blockchain infrastructure to serve as the standard industry platform for blockchain applications in the energy sector. The purpose is to accelerate the deployment of renewables and DERs.

The EWF community has organised more than 100 alliances, making it the world's largest energy blockchain ecosystem and a critical leverage point in the energy ecosystem. The growth of the Energy Web Chain (EW Chain) is a significant development, as it shows the global shift in alliances and lobby groups to change the rules of the energy system.

74 Forging (or minting) in cryptocurrencies is the creation of new blocks in blockchain based on the proof-of-stake (POS) algorithm with the opportunity to receive a reward in the form of new cryptocurrencies and commission fees. But forging is not the only technology for creating new blocks. An alternative is mining, which is based on the proof-of-work (POW) algorithm. Usually only one technology is used, but some cryptocurrencies use combinations of them. Different cryptocurrencies may have additional conditions for participation in forging. For example, only those amounts that have at least 1 440 confirmation blocks can join forging. See Coinstelegram, "What is Forging?", https://coinstelegram.com/2018/07/07/what-is-forging/. Thus, forging is an activity to make passive income with the use of blockchain. In POW environments the blockchain is secured by the miner by adding a new block to the blockchain, thereby making sure of its integrity. In the POS environment the activity is done by forging, where the user uses the balances to confirm transactions and add new blocks to the blockchain, providing the network with the security and resources needed. Apollo Wiki, "Forging", https://www.apollowiki.net/index.php?title=Forging.

According to RMI, the EW Chain is noteworthy for several reasons:[75]

- the EW Chain is a public blockchain, designed to foster innovation and interoperability while encouraging adoption;
- thanks to a blockchain approach known as proof-of-authority, the enterprise-grade EW Chain is energy efficient and highly scalable (two requisite qualities for an energy-sector blockchain); and
- unique among blockchains, the EW Chain's validator nodes that maintain copies of the blockchain database and agree on adding new blocks of transactions to the chain are respected energy companies (rather than the anonymous computer 'miners' common in other blockchains), a key design decision that should help the EW Chain gain favour among regulators and boost energy-sector confidence in the technology.

The EWF, along with affiliated companies, has identified and prioritised four blockchain application domains in the energy sector:[76]

- utility billing: any blockchain application where utilities and third parties use cryptographic identities to manage metering, customer settlement, advanced rate implementation or customer switching;
- certificates of origin: any blockchain application where RE generators and certificate buyers interact directly and use smart contracts to streamline the overall process through the automation of certificate issuance, tracking and retirement;
- demand response: any blockchain application where demand response aggregators (ie, utilities and third parties) use secure smart contracts to conduct aggregation, real-time measurement and verification, settlement, and trading for energy efficiency and demand response programmes; and
- transactive energy: any blockchain application where devices automatically respond to local conditions on the distribution grid in real-time, engaging in two-way price negotiation based on a combination of user preferences and grid needs.

These applications are recreating energy markets, facilitating security and robustness, lowering costs and ensuring integration. At the same time they are enabling increased collaborations among renewable generators and certificate buyers of varying sizes. Many of these benefits can be facilitated by smart contracts[77] that are directly issued to consumers and that radically simplify and lower the cost of certificates of origin. The shift from one-way utility–consumer relationships to peer-to-peer trading systems also improves the process

75 Douglas Miller and Claire Henly, "Blockchain Is Reimagining the Rules of the Game in the Energy Sector", RMI, August 28, 2017, https://rmi.org/blockchain-reimagining-rules-game-energy-sector/.

76 Miller and Henly, "Blockchain Is Reimagining".

77 RMI states that a smart contract is a string of code, shared between participants, that executes an action when a set of predetermined conditions are met – to streamline the overall process through the automation of certificate issuance, tracking and retirement.

of 'real-time settlement, eliminating the need for intermediaries and related process steps, lowering internal administration and auditing costs, and increasing confidence in the traceability of renewable energy generation'.[78]

The systemic innovation of blockchain technology applied to the energy system is a critical leverage point in the e-mobility revolution to shift the rules underlying the energy sector. The data immutability of blockchain-based systems enhances the leveraging capacity of the intervention. This is because data on distributed ledgers is difficult to tamper with owing to strong cryptography, the interdependent relationship between each block of data, and distributed consensus.[79] The use of smart contracts to create systemic innovations as a way to interact helps to eliminate risks such as double-counting practices. It automates certificates to retire when obsolete and executes retirement 'events' in real-time with full public transparency.

Blockchain in the energy sector thus creates an opportunity for global standardisation procedures across geographies. It establishes an appropriate platform for the buying and selling of electricity by enabling frictionless trade through certificates of origin in any location accessible to the Internet. The new platform would hasten the entry of renewable generators and buyers into the market by sidestepping institutional inertia and high utility transaction costs.

The rules of the energy sector change when the use of blockchain transforms an overly complicated and costly institutional design into elegant and efficient relationships, interactions and an interconnected whole. The traditional energy arrangement pointing to the schematic features of typical current certificates of origin system is depicted in Figure 15, and Figure 16 shows the EWF's schematic of a future blockchain-based certificates-of-origin system.

The EWF's work on blockchain solutions in the energy sector is a game changer that needs scaling up in its possible delivery of solutions to utility billing and demand response that would streamline and enhance their functioning.

Seeds of the preferable just transition

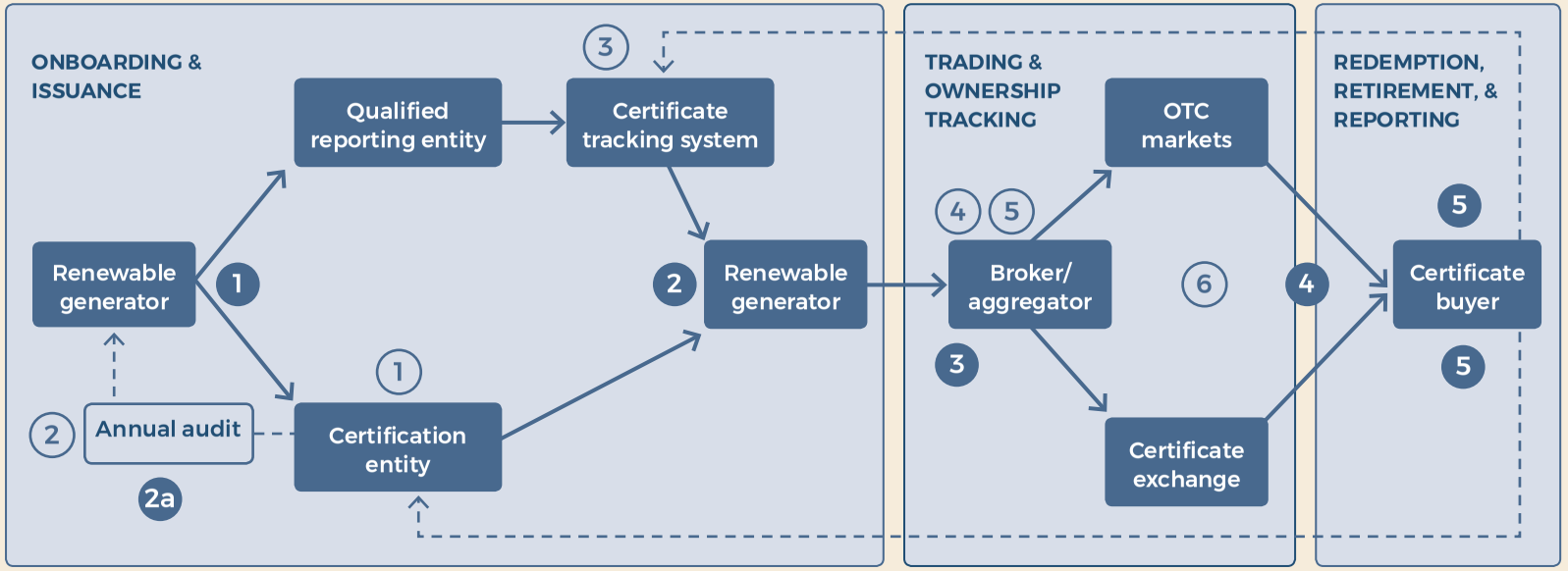
- The EWF's Brooklyn Microgrid Project,[80] where all transactions are managed and stored on blockchain, shows the usefulness and scalability of smart meter technology and blockchain software, with transactions easily made from neighbour to neighbour. This project is proving the concept that blockchain can create a local community market for renewable energy.

78 Miller and Henly, "Blockchain Is Reimagining".
79 Miller and Henly, "Blockchain Is Reimagining".
80 Jennifer Runyon, "How Smart Contracts (Could) Simplify Clean Energy Distribution", Renewable Energy World, May 15, 2017, https://www.renewableenergyworld.com/2017/05/15/how-smart-contracts-could-simplify-clean-energy-distribution/.

Figure 15 Schematic of a typical current certificates-of-origin system

CURRENT STATE

1. Generator produces electricity and passes data to certificate-creating entities
2. Certificate-creating entities verify validity of renewable generation and issue certificate
2a. Certification entity conducts annual audit on all certificate issuers
3. Brokers aggregate small certificates into larger blocks and source buyers. Note: many certificates are sold to purchasers by PPAs
4. Certificates are sold either on exchanges (ICE) or directly to purchaser in over-the-counter (OTC) deals
5. Load serving entity purchases and retires certificates



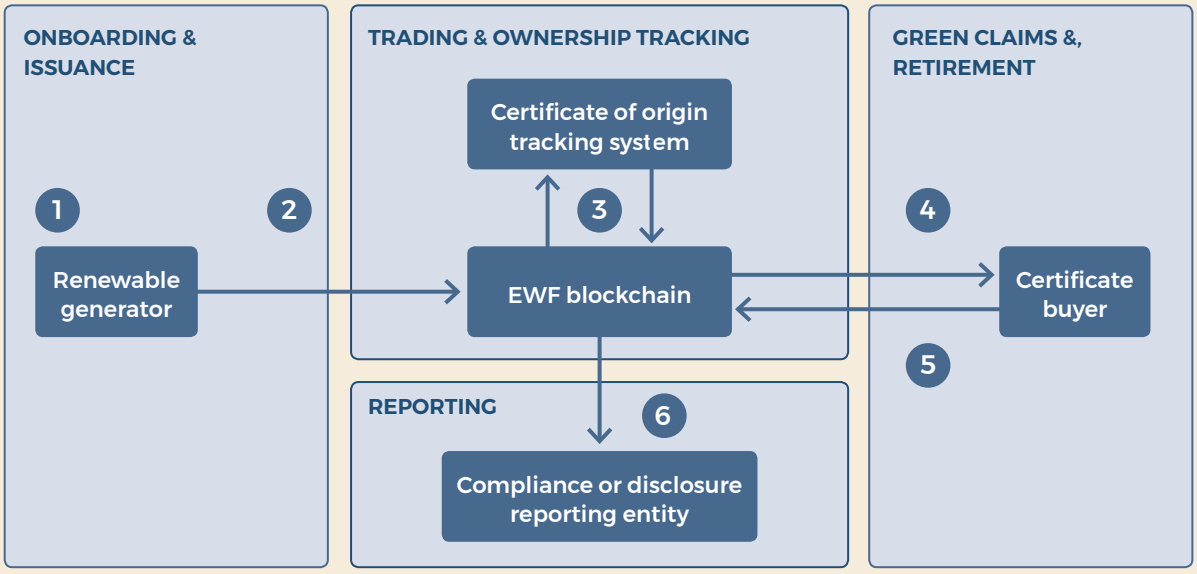
PAIN POINTS

1. Certification system required to verify generator is compliant
2. Audit to ensure against double counting of certificates
3. Tracking system to ensure compliance with policy mandates
4. Retail certificates too small to be transacted cost-effectively: need aggregation for block transactions
5. Opaque, shallow markets require brokerage to find counterpart
6. Exchange cost and post trade paperwork and overhead

Source: Energy Web Foundation (EWF), https://www.energyweb.org/; Rocky Mountain Institute (RMI), https://rmi.org/about/

Figure 16 EWF's schematic of a future blockchain-based certificates-of-origin system

1. Generation asset is permissioned to write data/modify blockchain after onboarding process
2. As each MWh generated, oracles or meters linked to generation assets automatically update blockchain with newly issued certificate
3. Changes in certificate (smart contract) ownership are tracked as an "event" on blockchain
4. Certificate buyers source certificate liquidity P2P through blockchain
5. When owner claims a certificate, smart contract makes its status change from active to retired; this is tracked as an "event"
6. Data about retired certificates and ownership is readily accessible for compliance and disclosure reporting entities



Source: EWF, https://www.energyweb.org/; RMI, https://rmi.org/about/

Suggested leverage points for policy action

- Organise SADC member energy alliances to call for investment in net-zero carbon emission energy generators, in line with the worldwide shift to investment in sustainable business practices, which include environmental, social and governance considerations.
- Invite the International Renewable Energy Agency to educate energy providers on how advances in RE and DERs offer lower rates and emission-free energy while delivering the same grid reliability services as new fossil fuel-fired power plants.
- The SADC directorates of Industry Development and Trade and Infrastructure and Services should build a SADC energy cooperative that seeks to transition to novel decarbonised grid solutions. This should be supported by utilities' deploying not only RE but also other so-called non-wires solutions (eg, energy storage, energy efficiency and demand response) to cost-effectively meet growing grid needs.

- The SADC Business Council should create a SADC member state affiliate programme with the EWF to build regionally formed affiliate taskforces focused on each application domain to test the value of blockchain within the domain. Where value is identified, it should form a foundation for commercial applications. Taskforces should unpack the challenges in existing systems, identify how blockchains can overcome those challenges, build a technical architecture for blockchain-based applications and, critically, accelerate the implementation of commercial projects in the real world.

Build or defend desirable institutions that embed fairness and enable the weak

Electrical and technical jobs replace many auto industry jobs

With rapid urbanisation comes urban electrification. A high demand for electricians and technically skilled jobs could be intertwined with information and communications technology (ICT) industries' latest skills geared at 'smart technologies', eg, smart homes and cities. The EV transition might generate large-scale employment for Fourth Industrial Revolution ICT software programmers, coupled with electricians/installers, vehicle/battery repairs and vehicle factory workers.

There are roughly 350 million households in the SADC region, which is a considerable number of homes, townhouses and apartments that will need EV charging stations and, in many cases, updated electrical systems. Therefore, the need for electricians, EV charging stations, battery storage and solar panel installers will become one of the most significant areas of job growth beginning in the next decade. Figure 17 demonstrates the required skills across the labour force and the estimated medium- to high-skilled occupations, according to the International Labour Organization.

Seeds of the preferable just transition

- AfterOil is an investment crowdfunding-based platform on blockchain aimed at meeting renewable energy needs beyond oil, coal and gas.
- South Africa's REIPPPP, for example, has attracted approximately $14 billion in private sector investment in 102 projects and created around 40 000 jobs.[81]

Suggested leverage points for policy action

- SADC member states' departments of higher education and training should strengthen their action planning for the skills development of unions and labour organisations. This should be integrated with key climate and environmental policies and regulations,

81 South African Government, "President Cyril Ramaphosa Concludes Financial Times Africa Summit Visit in London", October 14, 2019, https://www.gov.za/speeches/president-cyril-ramaphosa-concludes-financial-times-africa-summit-visit-london-14-oct-2019.

including Nationally Determined Contributions (NDCs), to ensure that skills needs are met and climate commitments implemented.

- The SADC Business Council should coordinate with SADC governments to develop skills policies and training measures for the private sector that take a longer-term and systematic approach to skills development in the context of EV transition.
- The Association of African Automotive Manufacturers should develop training and onboarding skills frameworks for auto industry workers to become electricians, technicians, repairers or ICT professionals, with jobs in EV repair, charging, battery storage and RE installers.

FIGURE 17 MAIN CORE SKILLS REQUIRED FOR GREEN JOBS, BY SKILL LEVEL OF OCCUPATION

Required across the labour force	Required in medium- to high-skilled occupations
• Environmental awareness and protection; willingness and capability to learn about sustainable development • Adaptability and transferability skills to enable workers to learn and apply the new technologies and processes required to green their jobs • Teamwork skills reflecting the need for organisations to work collectively on tackling their environmental footprint • Resilience to see through the changes required • Communication and negotiation skills to promote required changes to colleagues and customers • Entrepreneurial skills to seize the opportunities of low-carbon technologies and environmental mitigation and adaptation • Occupational safety and health (OSH)	• Analytical thinking (including risk and systems analysis) to interpret and understand the need for change and the measures required • Coordination, management and business skills that can encompass holistic and interdisciplinary approaches incorporating economic, social and ecological objectives • Innovation skills to identify opportunities and create new strategies to respond to green challenges • Marketing skills to promote greener products and services • Consulting skills to advise consumers about green solutions and to spread the use of green technologies • Networking, IT and language skills to perform in global markets • Strategic and leadership skills to enable policymakers and business executives to set the right incentives and create conditions conducive to cleaner production, cleaner transportation

Source: International Labour Organization, *Skills for Green Jobs*, Country Reports (Geneva: ILO, 2018), https://www.ilo.org/skills/projects/WCMS_707582/lang--en/index.htm

CHAPTER 4

Enabling a new energy paradigm shift

Change the paradigm from which the system arises

From climate crisis to climate emergency as a prominent feature of post-COVID-19 green recovery

A paradigm shift in Southern Africa would be when politicians stop talking about climate change and act in tandem with society to address the climate emergency. The Club of Rome has led the thought leadership on sustainable development since its influential *Limits to Growth report*[82] in 1972. Its most recent publication makes the call for '[n]ations [to] declare a Planetary Emergency'[83] and is supported by its Planetary Emergency Plan.

A fundamental shift in mindset is brought about through growing awareness in behaviour and critical reflection on ways of thinking. Complexity and systems thinking[84] hold the promise of fundamentally changing the way of thinking from which the current dominant systems arise. This new way of thinking, which embraces the inherent complexity of our world, engages with a relational worldview and recognises change as episodic rather than linear or static. Traditional understandings of the beliefs that guide behaviour assume the world to be controllable through rational and purposeful decision makers who act in each other's best interests. Complexity thinking provides a more complete alternative and offers a new way of thinking that can alter the paradigm from which the political economy of the current energy paradigm arise.

Experts point to the considerable influence that the invisible and qualitative characteristics shaping our society have on the political economy. The political economy is built on the measurement of visible constants, parameters and numbers such as inflation, interest rates and GDP. While these measures influence lives, a change in the petrol price and the introduction of a carbon tax will hardly shift consumer behaviour towards larger systemic issues such as addressing climate change. However, a change in what is measured through new complexity-informed approaches could enable a paradigm shift when it prompts a move from traditional monitoring and evaluation to re-evaluation.[85]

82 Donella H Meadows et al., *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* (New York: Universe Books, 1972).

83 Club of Rome, "Nations Should Declare a Planetary Emergency, Says Club of Rome", September 24, 2019, https://www.clubofrome.org/2019/09/24/nations-should-declare-a-planetary-emergency-says-club-of-rome/.

84 Jean Boulton, Peter Allen and Cliff Bowman, *Embracing Complexity: Strategic Perspectives for an Age of Turbulence* (Oxford: Oxford University Press, 2015).

85 Alternatives to traditional evaluation methodology have been developed, such as Revaluation. See Revaluation, https://www.revaluation.org.uk/.

Global shifts towards protectionism and populism have seen the world become increasingly self-absorbed. Complexity thinking invites one to use the future in new ways to anticipate and re-imagine relations and interconnections in systems. Complexity thinking encourages a questioning of paradigmatic assumptions about the political economy and the role of the e-mobility revolution against the backdrop of a new paradigmatic framework for social change and economic well-being. Complexity approaches also enable the conditions for systemic change and innovation that build behavioural awareness and new thinking.

The business-as-usual paradigm brought about a global economy enveloped in a 'triple crunch' even before the COVID-19 pandemic. The credit-fuelled financial crisis embedded in deep income inequalities; the unfettered extraction of resources; the climate emergency and unprecedented destruction of the environment and species extinction; and growing youth unemployment against the backdrop of a seismic shift in traditional industrial organisation and business practices are closing in from all sides. The interlocking nature of these threatening developments is creating a perfect storm, and echoes some of the conditions that gave rise to the Great Depression. It has also prompted a rethinking globally of the entire premise on which the global economy is organised. This has given rise to new economic models that take into account planetary boundaries when calculating externalities in traditional economic modelling,[86] as well as reconsidering the guiding rules of the multilateral system.[87] It is in this context that it is critical to reimagine the future against the backdrop of the myriad challenges facing Southern Africa. Hence an approach that embraces key tenets of a Green New Deal and that secures a more sustainable future for the region using foresight, futures thinking, and system innovation is proposed.

Seeds of the preferable just transition

- Cities worldwide are taking a stance on the climate change emergency[88] and leading the charge to ban ICE vehicles in cities, while also minimising the use of any vehicles within city centres.
- National governments, jurisdictions and local governments have declared the climate emergency a national emergency.[89]
- Broad coalitions for a Green New Deal have formed in the US[90] and Europe.[91]

86 Kate Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist* (White River Junction: Chelsea Green Publishing, 2017).

87 Kevin P Gallagher and Richard Kozul-Wright, *New Multilateralism for Shared Prosperity: Geneva Principles for a Global Green New Deal* (Boston: Global Development Policy Center and UNCTAD, 2019), http://www.bu.edu/gdp/files/2019/04/A-New-Multilateralism-GDPC_UNCTAD.pdf.

88 Fermin Koop, "These 30 Cities Are Leading the Way in Climate Action: Their Emissions Are Already Dropping", *ZME Science*, October 10, 2019, https://www.zmescience.com/science/cities-climate-change/.

89 Climate Emergency Declaration, "Climate Emergency Declarations in 1 143 Jurisdictions and Local Governments Cover 287 Million Citizens", December 4, 2020, https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/.

90 Green New Deal Coalition, "The Green New Deal", https://www.greennewdealforall.org/.

91 The Green New Deal for Europe, "A Blueprint for Europe's Just Transition", 2019, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

Suggested leverage points for policy action

- International partners such as the AU, in collaboration with the EU, should build greater transnational institutional capacity in SADC member states for increased autonomy over domestic monetary policy (interest rates and money supply) and fiscal policy (government spending and taxation).
- The South African government should set an example for other SADC member states by showing that economic growth is compatible with low-carbon and climate-resilient pathways, which will avoid lock-in to carbon-intensive infrastructure. This will allow SADC countries to implement and accelerate the reduction of GHG emissions with NDCs in line with the Paris Agreement.
- Philanthropic organisations should invest in just energy transitions in marginalised SADC communities by giving people an opportunity to escape poverty without fuelling global warming by helping to finance massive investment in climate change adaptation and renewable energy.
- The AU should support the free and unconstrained transfer of new energy technologies to developing countries.
- The AU should support transformation of the thinking and language used in climate change to become climate emergency focused.

Fostering a Southern African Green New Deal

From the Green New Deal to fostering seeds of good Southern African futures

A critical reflection on the current era has seen scientists agree that humans are now the most significant drivers of earth systems change.[92] This new geological era[93] is called the Anthropocene, or human era/epoch, because it outrivals geological forces and is marked by massive patterns of unsustainable human production, consumption and population growth that are materially reshaping the earth's landscape.[94] The Anthropocene points to a significant shift in humanity's impact on the planet on a global scale, with local and regional effects for the socio-ecological systems services on which humans depend.[95] Scholars agree that this distinct shift has occurred since the onset of the industrial era in the 19th century and can be distinguished particularly from the 1950s onwards.[96]

Humanity has to reflect on whether our world and the paradigms that are shaping us have kept pace with the changing planet. One could argue that Southern Africa is still living in

92 Paul J Crutzen, "The 'Anthropocene'", *Journal de Physique IV (Proceedings)* 12 (2002): 1–5.
93 Will Steffen et al., "The Anthropocene: From Global Change to Planetary Stewardship", *Ambio* 40, no. 7 (2011): 739–61.
94 Will Steffen et al., *Global Change and the Earth System: A Planet Under Pressure* (Berlin, New York: Springer, 2004).
95 Reinette Biggs, Maja Schlüter and Michael Schoon, *Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems* (Cambridge: Cambridge University Press, 2015).
96 Bruce Smith and Melinda Zeder, "The Onset of the Anthropocene", *Anthropocene*, vol. 4 (2013): 8–13.

an industrial revolution with 20th century lifestyles, even though the world has now entered a completely different era. The ways in which the people of Southern Africa acquire food, obtain energy, use water, travel, relate to wildlife, plan new infrastructure, organise human populations and make global decisions are still the same as in the previous century. This state of affairs may have been appropriate for a time of low human population, plentiful resources, a stable climate and abundant supplies of combustible fuels. However, the challenges of the Anthropocene demand a rethink, a questioning of established paradigms, and a new approach to the design of societies, ways of relating, cooperation, cultures and lifestyles.

There is a need for a transformative and strategic envisioning of alternative Southern African futures or paradigms that will facilitate regional coordination and integration. Africa has a strong storytelling tradition that is useful in voicing meta-narratives to offer way-finders in navigating the challenges that are facing SADC and its citizens. Pereira et al. highlight the importance of the African oral tradition and the role it plays in creating alternative bold stories to re-imagine the future to provide a decarbonised, creative and genuinely hopeful vision.[97]

Such visioning processes cater for the Southern African context and aim to draw on these vibrant African story-telling cultures to enable a radical departure from conventional scenario narratives that shape our deeply held myths and metaphors. Creating systemic innovation and leveraging the power to transcend paradigms means SADC will have to develop the capability of moving beyond fixed mindsets. It will have to embrace paradox and uncertainty by offering meaningful opportunities where people can let go of their preconceived truths, their political positions and their sense of otherness, and instead engage with those who may be very different from themselves.

Although EVs can catalyse the electric mobility revolution, the larger challenge is for the interchangeably connected Southern African nations to draw one another closer, transcend our current nation-state paradigms and work together on a common vision to secure the prosperity and welfare of our society. This might mean finding the boldness and courage to envision a hopeful story (vision) such as a Green New Deal for the SADC region; to cultivate and foster it as an initial step in a larger conversation that leads to brighter, bolder and hopeful emerging futures. A Southern African Green New Deal should speak for Africa and embrace Africa's values to enable alternative forms of organising, cooperation and collaboration that draw the preferable future we want closer to our current challenges.

Seeds of the preferable just transition

- The AU's vision[98] of '[a]n Integrated, Prosperous and Peaceful Africa, driven by its citizens and representing a dynamic force in the global arena'.

97 Laura M Pereira et al., "Using Futures Methods to Create Transformative Spaces: Visions of a Good Anthropocene in Southern Africa", *Ecology and Society* 23, no. 1 (2018).

98 AU, "About the African Union", https://au.int/en/overview.

- The SADC Vision 2050 and the SADC Regional Indicative Strategic Development Plan 2020–2030 were approved by SADC member states at the 40th SADC Summit on 17 August 2020.[99] They are meant to[100]

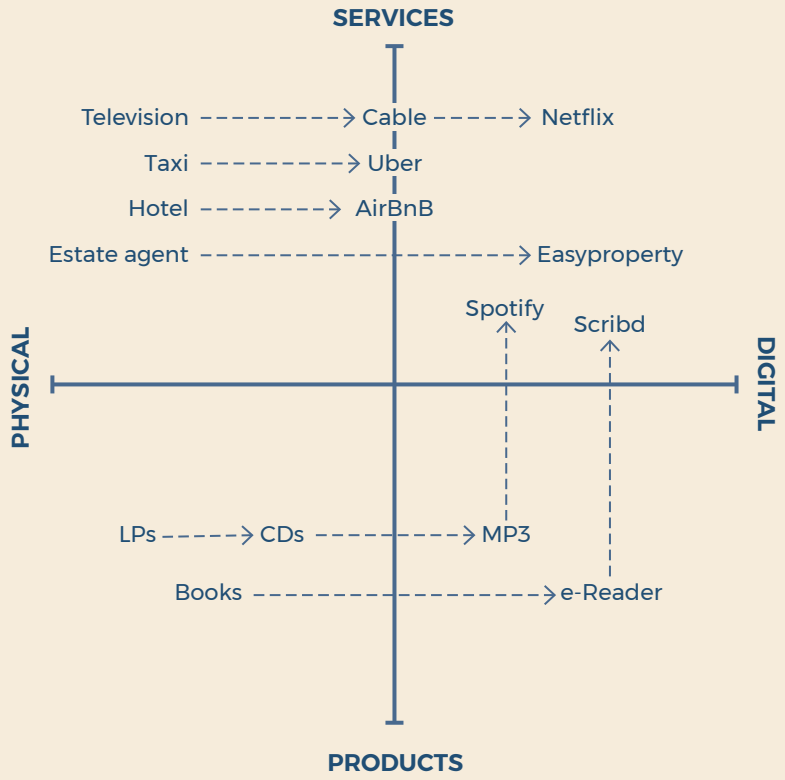
  > achieve development, peace and security, and economic growth, to alleviate poverty, enhance the standard and quality of life of the peoples of Southern Africa, and support the socially disadvantaged through regional integration, built on democratic principles and equitable and sustainable development.

99 SADC, "Communique of the 40th Ordinary Summit of the SADC Heads of State and Government", August 17, 2020, https://www.sadc.int/files/8115/9767/2537/Communique_of_the_40th_SADC_Summit_August_2020_-ENGLISH.pdf.

100 SADC, "Communique of the 40th".

A The evolution of digital/physical integration

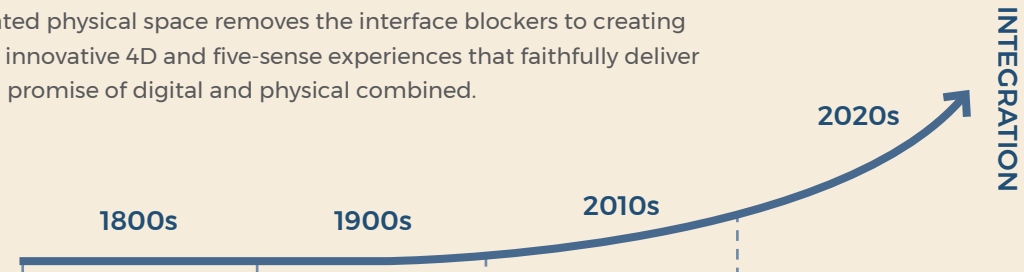
Figure A1 The digitalisation of physical services and products



Source: Justin Small, "The Future Is Integrated", *Medium* (blog), June 21, 2018, https://medium.com/@JustinKSmall/the-future-is-integrat ed-93ac46c70bb3

Figure A2 The evolution of digital/physical integration

Digitally integrated physical space removes the interface blockers to creating truly immersive innovative 4D and five-sense experiences that faithfully deliver the experiential promise of digital and physical combined.

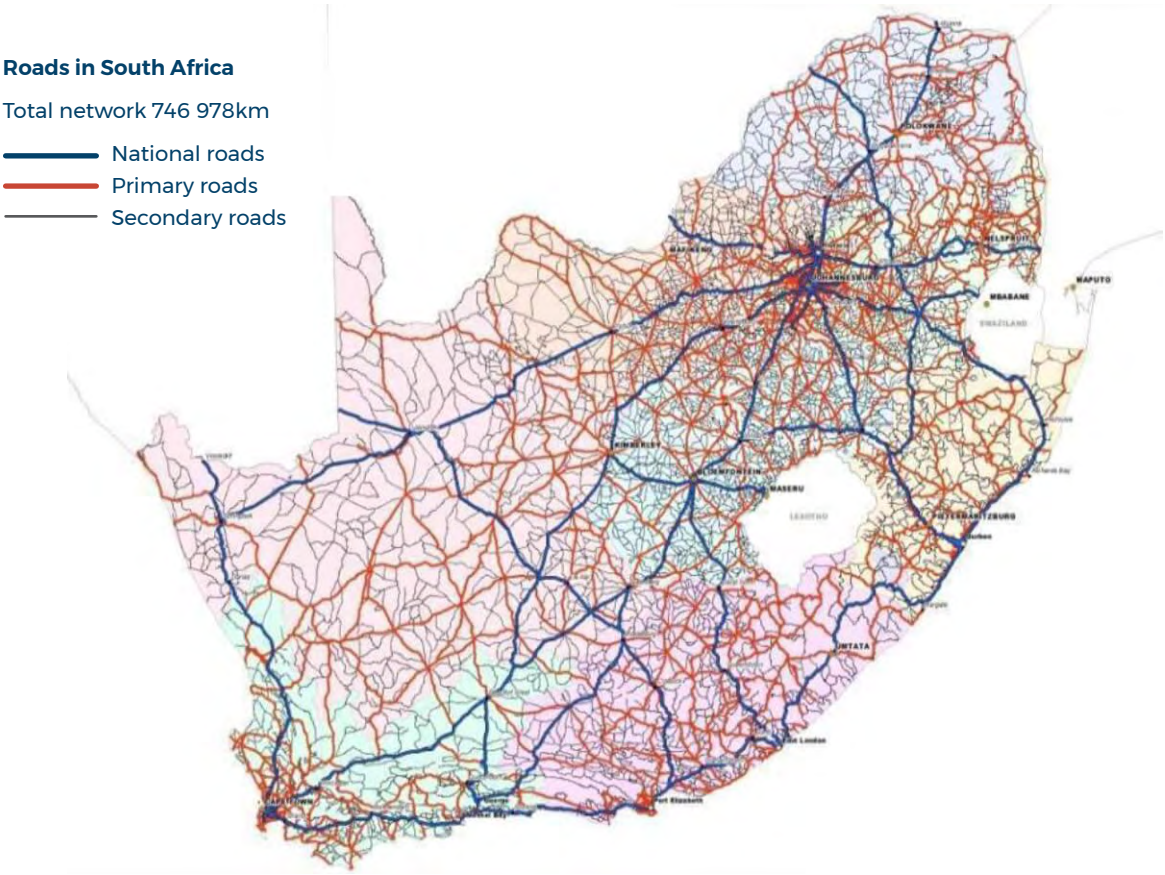


INTERACTIVE SPACE	SHOWROOM	SCREEN	AUGMENTED	INTEGRATED
INTERACTION	4D immersive	2D	3D	4D interactive
SENSE	Hear/see/touch/ smell/taste	Hear/see	Hear/see	Hear/see/touch/ smell/taste
TYPE	Physical	Digital	Augmented physical	Interactive physical
TECH	Store design	Internet/apps/ interactive screen	Oculus rift/ Google glass	Hologram/interactive 3D projection/ Haptic/Olfactory technology/Bio aurel & directional sound

Source: Small, "The Future Is Integrated"

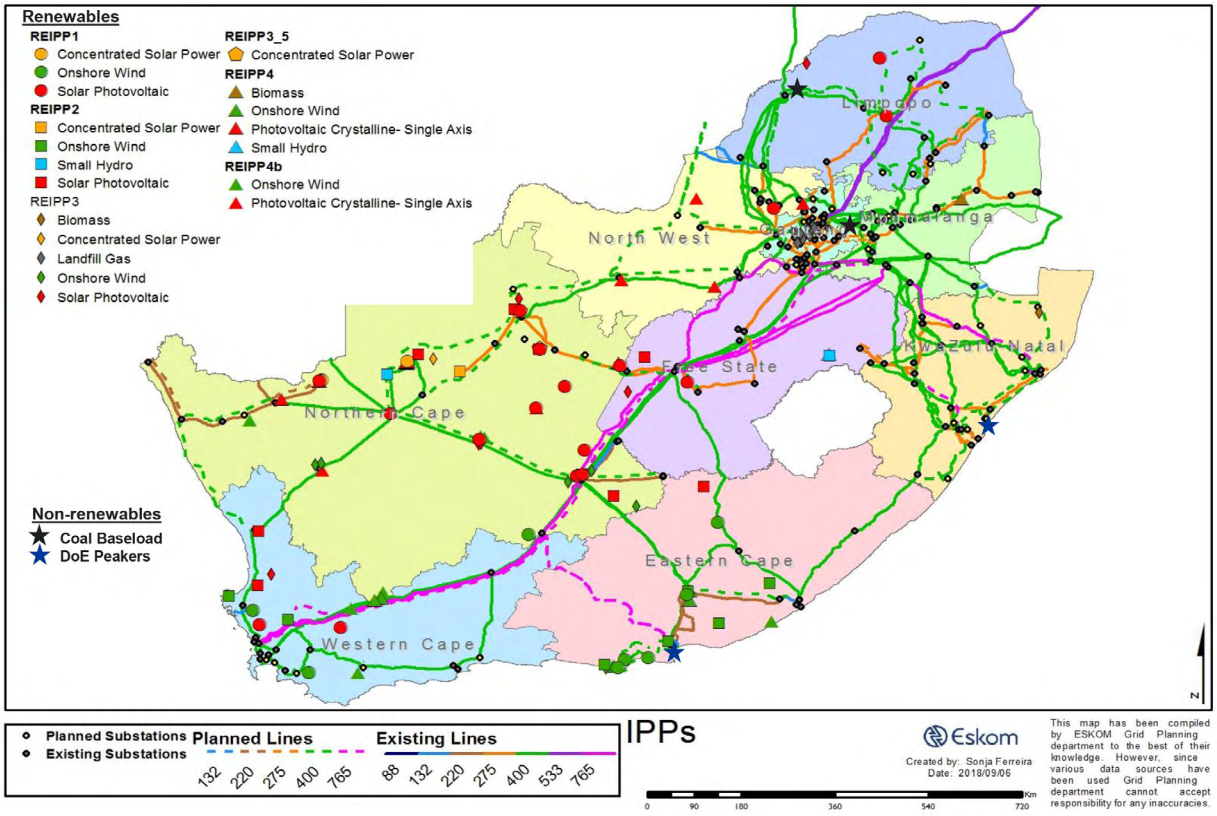
B Road vs transmission grid networks

Figure B1 South Africa's national, primary and secondary road networks



Source: South African National Roads Agency, "Arrive Alive", October 2016, https://www.arrivealive.co.za/The-South-African-National-Roads-Agency-LTD

Figure B2 South Africa's energy grid and IPPs



Source: Eskom, "Transmission Development Plan 2020–2029", October 2019, https://www.eskom.co.za/Whatweredoing/TransmissionDevelopmentPlan/Documents/TDP_2019_%20Public_Forum_Presentation_30_Oct2019_Final1.pdf

Figure B3 The Southern African Power Pool

Source: Global Energy Network Institute, "South African Power Network and Interconnections with Neighbouring Countries", http://www.geni.org/globalenergy/library/national_energy_grid/south-africa/southafricannationalelectricitygrid.shtml

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