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Carbon taxes and the attainment of emissions reductions targets in South Africa

A critical stocktaking of recent analyses and policies[1]

Martin Gustafsson[2]

Abstract

Attaining emission reduction targets in the South African context largely means implementing the country's 2019 Carbon Tax Act, which would cover around 86% of all emissions when fully phased in. The paper aims to provide a critical review of key analyses and policies behind these targets and the likelihood of attaining them. It does this by answering three questions. Firstly, can South Africa's contribution to global targets be considered fair? Viewed broadly, the current arrangement of national targets is unfair insofar as developing countries are expected to curtail emissions at an early stage of development, in ways developed countries did not. Moreover, national targets set in line with the 2015 Paris Agreement as they currently stand are an injustice to future generations, as they are clearly insufficient if the average surface temperature increase is to be kept within two degrees Celsius. Targets need to become more ambitious. South Africa's targets are relatively unambitious, and rely in part on the argument that exceptional skills constraints slow down mitigation efforts. Secondly, how do South Africa's mitigation strategies, and specifically its carbon tax, compare internationally? South Africa's carbon tax rests on a number of modelling exercises, and has been considered exemplary by global organisations for its comprehensiveness and relative simplicity. Thirdly, how likely is it that South Africa will reach its emissions targets? Modelling indicates this is possible if the carbon tax is implemented as envisaged, and that targets can be achieved without any significant loss of income or jobs. In fact, the tax provides opportunities for a net creation of jobs, and new government revenue streams which could be used to tackle the country's serious income inequalities. There are, however, some risks. The first two years since the tax was promulgated suggest that more transparency and advocacy are needed. Moreover, an official trajectory for the tax rate in future years, as it is phased in, seems necessary to facilitate planning and investments in the public and private sectors.[3]

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EXTENDED SUMMARY

This paper partially addresses what seemed to be a gap. There appeared to be no well-referenced, comprehensive and critical review of the various policy documents and analyses relating to South Africa's emission reductions, in a format which would be accessible to academics, educators and journalists who are not specialists in this area. Such a review seemed necessary given how difficult it can be to interpret existing policies and underlying analyses. There are three key reasons for this. One is the technical nature of much of the literature. A second is that there are certain inconsistencies between the various documents, which can be difficult to explain. Thirdly, policy documents may downplay or avoid certain issues which might either be unpopular with voters or might compromise the country's position in international negotiations.

The paper addresses the gap only partially insofar as it focusses on sources relating to the mitigation of greenhouse gas emissions. What it does not focus on is a closely related but largely separate policy area: adaptation to climate change.

Though the paper is aimed at providing an understanding of South Africa's policies, it reviews both South African and international documents, as these comprise a critical backdrop to the South African policies.

The paper is guided by three over-arching questions, dealing with: (1) the fairness of the burden of emission reductions carried by each country; (2) the nature of South Africa's carbon tax, introduced in 2019; and (3) what South Africa's emission reductions plans might mean for ordinary South Africans. The questions in full are given and briefly answered at the end of this summary.

After an introduction in section 1, which explains the rationale behind the structure of the paper, section 2 discusses relevant parts of **the 2014 assessment reports of the Intergovernmental Panel on Climate Change (IPCC)**. These voluminous reports, produced every seven years, are an indispensable source, drawing from the expertise of hundreds of natural scientists, economists, philosophers, and others. They deal with divergences of interpretation in a structured and transparent manner. The IPCC notion of two types of necessary 'decoupling' is important and useful. Consumption needs to be decoupled from emissions. It is necessary to reduce the emissions associated with the products and food consumed. At the same time, and far more controversially, human well-being needs to be decoupled from consumption. Put differently, those who consume most should consume less, and this does not have to compromise their levels of happiness. Given the almost universal political emphasis on economic growth, even in countries where a sizeable percentage of the population already enjoys high levels of consumption, it should not come as a surprise that this second form of decoupling receives scant attention in mainstream political debates.

It would be good if there were better warnings over a potential source of confusion. It is well-known that the 2015 Paris Agreement targets a minimum permissible increase in the average global surface temperature, specifically no more than 2.0 degrees Celsius by 2100, and preferably no more than 1.5 degrees. These targets, in turn, rest on desirable levels of concentration of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, with non-CO_2 gases converted to CO_2-equivalent measures. While there is little confusion around the concentration levels of just CO_2 in the atmosphere, authoritative versions of the broader CO_2-*equivalent* concentration level can differ. Yet it is the latter which is most important from a policy perspective. The IPCC uses the indicator consistently, but other organisations,

such as the European Environment Agency, put forward statistics which are not consistent, to a considerable degree, with what the IPCC uses, due to differing definitions of the non-CO_2 part. Clearly, indicator values need to be treated with caution.

Section 3 **uses international data and the IPCC concepts to produce a simple schema that can inform a discussion around a fair division of the responsibility to limit emissions**. The very large responsibility of the 43 so-called Annex I countries, high-emitting countries which are on the whole developed and rich, is clear. These countries account for 60% of all anthropocentric (human-induced) greenhouse gas emissions occurring before 2010, yet in 2020 they accounted for just 17% of the world's population. Moreover, the total emissions embodied in what was consumed by Annex I countries increased by 5% between 1990 and 2020, though 1990 is commonly considered a point at which it had become clear that emissions posed a grave danger to future human development. The more commonly used, and easier to derive, trend for territorial, or production-based, emissions was a downward one in Annex I countries during this period, but this was because these countries essentially 'outsourced' more emissions-intensive manufacturing to other countries, such as China. The schema represents how per capita emissions and per capita income might have to change, for Annex I and non-Annex I countries, up to 2100, if the equity and development goals put forward by the IPCC were to be realised. It is clear that as Annex I annual emissions as a share of global emissions decline, what will become increasingly important is the responsibility of these countries to facilitate, through technology sharing and financing, transitions to low-emission economies in non-Annex I countries.

The role of strategies to limit population growth as part of the mitigation of emissions is a sensitive one, and is seldom dealt with, not even within the IPCC's voluminous reports. The arguments made by proponents of a stronger focus on population are discussed, as is China's argument that its one-child policy ought to be considered in part a contributor to its international mitigation commitments.

Section 4 explains **what a carbon tax is meant to achieve**. Such a tax is increasingly seen as an optimal centrepiece of a country's mitigation strategy. The alternative policy, also aimed at attaching a price to emissions, is an emissions trading system (ETS). While a carbon tax fixes the price, with a view to achieving a certain level of emission reduction, an ETS fixes the emission reduction, and allows the price to be determined through, for instance, an auctioning process. A key advantage with a carbon tax is that government revenue is assured, which can facilitate reductions in other taxes, possibly to reduce historical income inequalities, and investment in new technologies.

Section 5 discusses **the extent to which carbon taxes have been implemented across the world**. A 2020 World Bank update on the pricing of emissions identifies just 61 initiatives, of which 23 are national carbon tax initiatives. Five of the 23 are in developing countries: South Africa, and four in Latin America. The more developed Annex I countries, which mostly began implementing new policies over a decade ago, have used both ETSs and carbon taxes, sometimes in combination within the same country. China has prioritised regional and national ETSs, rather than carbon taxes. The United States and Russia are conspicuous for their absence of national emissions pricing policies, though in the case of 13 of the 50 states in the United States, such policies are found.

Section 6 shifts the attention to **South Africa-focussed analyses**. In section 6.1, **South Africa's latest greenhouse gas inventory** is examined with a view to understanding what the new 2019 Carbon Tax Act encompasses. The scope of the act is around 86% of the country's emissions, making the coverage of the South African tax particularly wide. The 14% not covered would be difficult to tax, for instance emissions from livestock in the agricultural sector. The national electricity supplier Eskom accounts for almost half of the 86%, with Sasol accounting for a further 13%. These two companies would thus be responsible for 61% of the carbon tax paid. The remaining 39% would be paid by, in particular, oil refineries, and steel and cement producers. Around 12% of the tax would be paid by owners of petrol- and diesel-driven vehicles, though here the tax would be levied ‘upstream’, on oil refineries.

Section 6.1 also discusses two types of breakdowns not required in the greenhouse gas inventories of countries, but which are nonetheless interesting. The annually updated ‘global carbon budget’ reports reveal that a production-based emissions accounting process results in total emissions which are 43% higher for South Africa than those obtained through a consumption-based approach. This difference is the fourth-largest in the world, and reflects the degree to which South Africa exports commodities and products which embody high emissions. Using a production-based approach, South Africa is the twelfth-largest emitter in the world. Using a consumption-based approach, South Africa remains a particularly high emitter, though the country drops to position 18. The global Carbon Disclosure Project’s collection and analysis of emissions data submitted by South African companies is also examined.

Section 6.2 discusses **an influential modelling exercise focussing on economically optimal shifts to ‘cleaner’ technologies in South Africa**, such as renewable energy and more nuclear energy. The analysis, from 2014, has some limitations, such as a projected economic growth trajectory which is almost certainly too steep, and an assumption that all shifts to new technologies occur before 2030, and not beyond that point. Yet the analysis is informative, both methodologically, and in terms of what is projected up to 2030. Nuclear energy is put forward as the most cost-effective alternative to coal-based energy. Yet it is envisaged that renewables would generate around three times as much energy as nuclear. This is due to social and environmental concerns relating to nuclear energy. Within the renewables category, wind energy emerges as more cost-effective than solar, and thus solar is expected to generate only around half of the energy generated by wind. The literature on the comparison of costs across the nuclear and renewables options points to considerable uncertainties, which are not reflected in the 2014 modelling. How these uncertainties play themselves out in the South African context warrants closer attention.

Section 6.3 discusses the **modelling of the effects of a carbon tax**, drawing mainly from a 2009 World Bank study, focussing on South Africa, which has been influential in shaping the country’s carbon tax. This modelling aims to do something rather different to the 2014 work discussed above. Here costs across different energy technologies are not a driver, but instead the reaction of producers to changes in the price of electricity and petrol. The World Bank’s modelling does not use pre-determined economic growth trajectories. The modelling is simply aimed at establishing what the carbon tax on a tonne of emissions would have to be to reduce emissions by 15%. The finding is that the tax would have to be R96 a tonne, at 2003 price levels. This tax would constitute 9% of all tax revenue. Without an explicitly pro-poor ‘recycling’ of this revenue when cuts in other taxes occur, the poor would experience the largest decline in income, of 1.0%. It seems clear that pro-poor recycling would be necessary, and that with this element, the poor would not be left worse off on average. This is a vital finding. A carbon tax does not have to leave vulnerable South Africans worse off than before. In fact, it could help to advance income equality. Importantly, the required carbon tax rate rises faster than the desired emission reduction, as higher levels of reduction mean costlier adjustments in the economy. What this implies is that a tax rate that is half of the R96 would reduce emissions by *more* than half of 15%.

Section 7 focusses on **South Africa's policies**, beginning with, in section 7.1, the country's **international commitments to reduce emissions**. South Africa's commitments are particularly non-committal in the sense they consist of wide future ranges of emissions, as opposed to the specific targets seen in many other countries. For instance, the commitment for 2030 is a level of emissions that is between 20% higher and 20% lower than the historical 2010 level. Such a wide range means little. The commitment for 2050 is between 12% and 56% below recent levels. In line with the Paris Agreement, each country must set targets based on its own assessment of what a fair distribution of the burden of mitigation across the world is. South Africa worked together with India, China and Brazil in a modelling exercise where ultimately each country's experts could draw their own conclusions. Country experts tended to use an approach that produced a more generous future 'carbon budget' for their country. For instance, the modelling of the South African experts resulted in more of the fixed global budget being allocated to South Africa, and less to India, compared to what the Indian experts arrived at. A key and interesting assumption used by the South African experts to arrive at a relatively generous allowance for South Africa was that the country's low level of human capital implies more time is needed for a shift to a low-carbon economy. South Africa's educational quality levels are indeed exceptionally low for a middle income country.

The least ambitious commitments made by South Africa within its range of targets are within the country's carbon budget to 2050 calculated by local experts.

There has been little in the way of an independent evaluation of how fair the carbon budgets countries have estimated for themselves are. The UN is expected to release an in-depth evaluation only in 2023, in line with the Paris Agreement. Some independent research groups have however released evaluations. Prominent among these is the Carbon Action Tracker (CAT). South Africa's current commitments in the CAT system fall into the 'insufficient' category. This is also, however, the classification assigned to the great majority of the world's countries. This is not encouraging.

A curiosity is a commitment announced by the South African president in 2009, and repeated in the current 2019 to 2024 five-year plan of the government, to reduce emissions by 42% by the year 2024. This impossible target is completely out of line with the country's official commitments to the UN.

Section 7.2 examines **South Africa's overall strategy to reduce emissions**, focussing in part on a strategy released in 2020, and paying special attention to how the lives of ordinary citizens might be affected. The termination of around a third of coal-fired power generation by 2030 would bring large health benefits to communities, especially in Mpumalanga Province, where pollution from power stations can result in 20% of deaths being premature. South Africans with solar panels at home will be able to feed energy into the national grid, and be paid for doing so. Wind farms will change the landscape in parts of the country. A new form of 'loadshedding', caused by weather conditions such as wind-free days, could become a reality. The shift to renewable energy will create pressure on training institutions and incentives for young students to respond to the demands for new skills, and the creation of new jobs. The carbon tax is likely to become a major political discussion point, with those who stand to lose from the shift away from fossil fuels resisting increases in the tax.

Cities could become darker at night as smart lighting, which goes on only when it is needed, becomes the norm. Government plans to provide five million poorer households with solar-heated water systems between 2020 and 2030, in part to reduce future electricity demand for this purpose. Public transport will improve, and its use by the middle class increase. This will reduce road traffic, as will government's 'road-to-rail' programme focussing on moving freight from trucks on roads to the rail network. It is envisaged that 50% of South Africans will be separating their domestic waste by 2023. This can reduce methane emissions from organic waste, while recycling materials such as glass reduces the emissions associated with producing these materials from scratch.

Nuclear energy is complicated. While government still argues that a major expansion in nuclear is necessary, original initiatives were put on hold due to corruption scandals. The plans that exist point to five sites along the coasts of the Northern Cape, Western Cape and Eastern Cape which have been earmarked for new nuclear power stations.

Section 7.3 discusses **the 2019 Carbon Tax Act** in some detail. The details are complex but logical. Carbon dioxide, methane and nitrous oxide are covered by the tax, as are fuel combustion, fugitive emissions and emissions from industrial processes. Emitting firms will have to declare, for instance, the mass of the fuels they combust, from a list of 74 fuels, including various types of coal, which in turn translates to carbon dioxide-equivalent emissions and finally the tax to be paid. Initial steps taken to implement the tax have not been very clear. In 2020, a carbon tax was introduced as a tax revenue line in the Treasury's accounts, but in that year it accounted for just 0.05% of all tax revenue, with the actual amount being lower than expected. The tax per tonne of emissions came to around R20, after various allowances were taken into account. If the R96 tax rate mentioned above is inflated to 2020 price levels, the finding is that a tax rate of R232 would be necessary to bring about a 15% reduction in emissions. Clearly, the mechanisms in the Act to gradually increase the tax rate need to take effect.

Section 8 provides a conclusion that answers three key questions, drawing from the analysis of the previous sections. The questions in full, and brief summaries of the responses, are as follows.

The first question: ***Do South Africa's existing commitments to reduce greenhouse gas emissions represent an equitable sharing of this responsibility across the countries of the world?*** There can be no truly fair sharing of this responsibility insofar as rich Annex I countries have exceeded what can be considered a fair right to emit, and reversing historical emissions is technologically not possible. But the 2015 Paris Agreement outlines a process countries have accepted as sufficiently fair, and South Africa has abided by this process and presented commitments based on a burden sharing model that South Africa developed and believes to be fair. South Africa's argument that low levels of skills should be taken into account when the responsibility to mitigate is shared across countries, could be criticised by other countries as unfair in the future. The abovementioned CAT assessment, which finds the commitments of the great majority of countries, including South Africa, to be insufficient, suggests high costs could be paid by future generations. It is also noteworthy that the countries that do enjoy a positive rating by CAT are all developing countries. None are Annex I countries. Developed countries appear not be taking the lead as they should.

The second question: ***How does South Africa's carbon tax compare to similar taxes in other countries, and what might this mean for its effectiveness, taking into consideration that carbon taxes are commonly part of a broader package of emission reduction policies?*** South Africa's 2019 Carbon Tax Act reflects a tax which has been considered exemplary by bodies such as the World Bank. It is especially wide in its scope, covering around 85% of the country's greenhouse gas emissions, and is efficient in the sense that it targets emitters, such as the power utility Eskom, and not upstream entities such as coal mines. The considerable analytical work on carbon taxes, in South Africa and beyond, suggests that a well-designed carbon tax with a wide scope is efficient insofar as it minimises the economic costs of bringing about the necessary shifts in, for instance, power generation.

The third question: ***Is it possible, in part through its carbon tax, for South Africa to attain its emission reduction targets?*** The answer is yes, and the economic costs of this are probably lower than many would imagine. Indeed, the required adjustments present interesting opportunities, such as a net creation of jobs. At least five rigorous studies point to the impact on income being small. Revenue from the tax, estimated by one study at 9% of overall government revenue, would make it relatively easy to assist households, in particular poorer ones, experiencing the brunt of the adjustment costs. The job creation prospects seem good, with one study estimating an additional 300,000 jobs. This is in part due to the more labour-intensive nature of power from renewable sources. Obviously, if attaining emission reduction targets is possible economically, it is more likely to be possible politically. But there is much work to be done. For instance, an official position on how the rate of the carbon tax will evolve over time, from the current very low 0.05% of total tax revenue, to a required level of around 9% of total revenue by around 2045, is needed.

Contents

1 Introduction

This paper partially addresses what seemed to be a gap. There appeared to be no well-referenced, comprehensive and critical review of the various policy documents and analyses relating to South Africa's emissions reductions, in a format which would be accessible to academics, educators[4] and journalists who are not specialists in this area. Such a review seemed necessary given how difficult it can be to interpret existing policies and underlying analyses. There are three key reasons for this. One is the technical nature of much of the literature. A second is that there are certain inconsistencies between the various documents, which can be difficult to explain. Thirdly, policy documents may downplay or avoid certain issues which might either be unpopular with voters or might compromise the country's position in international negotiations.

The paper addresses the aforementioned gap only partially insofar as it focusses on the mitigation of greenhouse gas emissions. What it does not focus on is a closely related but largely separate policy area: adaptation to climate change.

The review is critical insofar as it brings to the fore contradictions across policies and analyses, and attempts to explain these. What is important, but beyond the scope of this paper, are critiques focussing on the need to view climate policies as an integral part of an effort to change unjust international and national economic systems. The paper does, however, deal with the link between curbing emissions and reducing income inequalities, as this *is* an integral part of the existing policies.

The paper is guided by three over-arching questions:

1. Do South Africa's existing commitments to reduce greenhouse gas emissions represent an equitable sharing of this responsibility across the countries of the world?

2. How does South Africa's carbon tax compare to similar taxes in other countries, and what might this mean for its effectiveness, taking into consideration that carbon taxes are commonly part of a broader package of emission reduction policies?

3. Is it possible, in part through its carbon tax, for South Africa to attain its emission reduction targets?

The paper is structured in terms of the types of original sources, or texts, discussed. Are the sources international or South African, policies or analyses, dealing with emission reductions in general or a carbon tax? This seemed the optimal way of organising a paper dealing a considerable variety of sources. The three questions guide the entire paper, but final responses to them are presented in the conclusion, section 8.

Sections 2 to 5 deal with texts that are not specific to South Africa, yet important for understanding the three questions. Section 2 discusses relevant parts of the latest major report of the Intergovernmental Panel on Climate Change (IPCC). Section 3 uses international data and the IPCC concepts to illustrate notions of fairness for use in the rest of the paper. Section 4 provides a short introduction to the theory of carbon taxes, and section 5 discusses how common these taxes are around the world.

[4] An appendix outlines where in the school curriculum topics relating to the climate change are covered.

Sections 6 and 7 focus on South African texts, with section 6 focussing on publicly available analyses and section 7 on South Africa's policies. Section 6 is divided into three sub-sections dealing with: South Africa's greenhouse gas inventory; the modelling of emission reductions in general; and the modelling of a South African carbon tax. Section 7 is also divided into three sub-sections, dealing with: South Africa's commitments to reduce emissions; national policies on how to achieve this; and a special focus on one particularly important policy: the 2019 Carbon Tax Act.

2 Background from the IPCC

The IPCC, a part of the United Nations system, has been releasing, every seven years, what are widely considered the most authoritative summaries of what is currently known about the science of climate change, and the effectiveness of mitigation efforts. The most recent set of three reports, known collectively as the Fifth Assessment Report, was released in 2014, and the next is expected in 2021. What makes these reports authoritative is that the IPCC brings together large numbers of scientists and academics, experienced in fields as diverse as marine biology and philosophy, and employs an established method when dealing with a divergence of interpretations, which includes being explicit about how much divergence there is.

While the 2014 reports do not provide an in-depth description of carbon taxes, they are a useful point of departure as they position carbon taxes within the broader topic of climate change. The 2014 report dealing with mitigation efforts, 1,500 pages in length and involving almost 500 scientists, including four South Africans[5], defines carbon taxes as follows[6]:

> Carbon tax: A levy on the carbon content of fossil fuels. Because virtually all of the carbon in fossil fuels is ultimately emitted as carbon dioxide (CO_2), a carbon tax is equivalent to an emission tax on CO_2 emissions.

The report explains that carbon taxes are necessary as, by raising the price of emissions-intensive fuels, they shift investments towards 'clean' or low-emissions energy, and encourage investment in more energy-efficient buildings, vehicles, and so on. Carbon taxes are not the only policy instrument available to slow down climate change, but they are among the most prominent. Carbon taxes have been on the policy agenda for long, and such taxes or some 'functionally equivalent policy instrument' are considered essential[7]. Emissions trading systems (ETSs), whereby emitters pay for tradeable permits giving them the right to emit, have a more or less equivalent effect. However, carbon taxes are considered, at least in theory, more cost-effective than ETSs[8]. In practice, though, emissions trading has been more widely adopted, in part due to pressure from lobby groups.

Apart from carbon taxes and emissions trading, other complementary policies include: energy efficiency standards; caps on the emissions of specific emitters, such as power plants; removing subsidies which encourage emissions; promoting technological innovation through R&D[9] funding and government procurement rules; education drives aimed at changing consumption and behaviour; and protecting forests and promoting afforestation[10].

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5 Enoch Liphoto, David Dewar, Harald Winkler and Andrew Marquard.
6 Intergovernmental Panel on Climate Change, 2014: 1255.
7 Intergovernmental Panel on Climate Change, 2014: 1053.
8 Intergovernmental Panel on Climate Change, 2014: 1167.
9 Research and development.
10 Intergovernmental Panel on Climate Change, 2014: 26-29.

No-one has developed a detailed 'recipe' for an optimal carbon tax rate, or for an optimal combination of a carbon tax and other policies. Importantly, there is a distinction between what is optimal in theory, which essentially assumes that a government is able to impose policies with no resistance, and what is optimal given the institutional and political dynamics of each country. Ideally, there would be a carbon tax rate, or price, agreed upon by all countries. This would help avoiding complex trade measures, such as tariffs, aimed at compensating for different carbon tax regimes in different countries. Any country would want to protect itself against cheap imports from another country, where this arose as a result of a lower carbon tax in the other country. A risk associated with *not* attaching a price to emissions is that this could result in retaliation from other countries, which might impose restrictions on imports from the country.

Modelling and actual practices in a few countries, such as Sweden, suggest to the IPCC that a carbon tax of between 100 and 165 USD per tonne of CO_2 is implementable and necessary, if levels of CO_2-equivalent (CO_2eq) atmospheric concentrations are to be kept within the necessary limits by the year 2100. Specifically, this assumes a limit, in 2100, of 480 parts per million (ppm) of CO_2 plus six other greenhouse gases and some other atmospheric elements[11]. In arriving at the 480, the impact the non-CO_2 elements on temperature increases has been translated to CO_2-equivalent terms[12]. A 480 CO_2eq level in 2100 is associated with an average temperature increase, relative to the 1850-1900 period, of 1.8 degrees Celsius. A 530 level is associated with 2.1 degrees, 580 with 2.3 degrees, and so on[13]. The milestone Paris Agreement, adopted in 2015, commits countries to limit increases to[14]:

> … well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

To compare, the temperature increase between what is referred to as the 'pre-industrial' 1850 to 1900 period to around 2000 was an increase of 0.6 degrees[15]. By 2020, the increase had become over 0.8 degrees[16]. Thus, a limit of 1.5 degrees means no more than an additional 0.7 degrees beyond 2020.

It is worth noting what these measures actually mean, in part given that climate change denialists typically cast doubt on their accuracy and meaning. The definition is the average temperature two metres above the surface of the earth, be this land or ocean, counting all times of the day and night. As there is not a system of thermometers placed, say, one kilometre apart two metres above the earth's surface, scientists must extrapolate from the various measurement systems in existence, which include thousands of land-based stations, some in existence since the 1700s, and data fed by ships and buoys at sea[17].

CO_2-equivalent atmospheric concentrations can be confusing, as what is counted among the non-CO_2 elements may differ across different analyses[18]. The 480 limit referred to above is

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11 Methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

12 Intergovernmental Panel on Climate Change, 2014: 557-559, 1159.

13 Intergovernmental Panel on Climate Change, 2014: 431.

14 United Nations, 2015.

15 Intergovernmental Panel on Climate Change, 2014: 50.

16 Intergovernmental Panel on Climate Change, 2013: 180.

17 Intergovernmental Panel on Climate Change, 2013: 187-201.

18 Intergovernmental Panel on Climate Change, 2013: 1257.

inclusive of all elements generally considered[19]. Unfortunately, historical reporting on the various permutations of this indicator is not good, and differences across prominent reporting systems are not easy to interpret. Between 1970 and 2010, the indicator moved from 322 to 426, according to the European Environment Agency (EEA)[20]. According to a source used by the IPCC, the indicator moved from 351 to 443[21]. The difference between the two 2010 values, 426 and 443, is obviously large, given the 2100 maximum of 480. There is, as might be expected, high consistency across sources of just the CO_2 part of this: 408 ppm in 2018 in both sources referred to here. However, the IPCCs targets are expressed, for logical reasons, in terms of CO_2-*equivalent* parts per million. Confusion around this indicator is obviously not good, but is possible given the lack of standardisation.

The IPCC report underlines the importance of ensuring that the immense structural changes necessary to avoid catastrophic climate change within the next hundred years promote, and are seen to promote, greater equity *within* each country. Carbon taxes are well-suited for this as the additional revenue they generate can be used to invest in the least advantaged.

The IPCC mitigation report of 2014 devotes two chapters[22] to clarifying concepts such as equity and development, with much of the emphasis being on an equitable distribution of the burden of mitigation across countries. But much of the emphasis also falls on how countries can develop and combat poverty, while at the same time dealing with climate change.

'Burden sharing', or a fair distribution of the responsibility for reducing emissions, is a hugely complex and politically charged topic. Among many factors to consider, is the historical point at which countries, at least those with the highest levels of development, could reasonably be expected to have begun the process of reducing emissions, because the link between emissions and climate change had become sufficiently understood. One year often used for this is 1990[23]. Beyond this point, the science was very clear that emissions could lead to catastrophic climate change.

'Effort sharing' models attempt to determine how different categories of countries can feasibly reduce their emissions in future years. The IPCC seems to support models which take into account the costs of reducing emissions for different countries, the rationale being that globally the cost of mitigation should be minimised[24]. A part of the rationale is that countries where emission reductions are more costly should pay for emission reductions in countries where this is less costly.

The 2014 mitigation report provides regional emission 'entitlements' emerging from a wide range of effort sharing models. Surprisingly, what is not discussed are country-specific entitlements, though such entitlements would clearly be of interest to the authorities and the population of each country. As will be explained in section 7.1, few authoritative national entitlement calculations exist.

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[19] Intergovernmental Panel on Climate Change, 2013: 430.

[20] https://www.eea.europa.eu/data-and-maps/indicators/atmospheric-greenhouse-gas-concentrations-6/assessment-1, accessed December 2020.

[21] See Intergovernmental Panel on Climate Change (2013: 149) and background spreadsheets of Meinshausen *et al* (2011).

[22] Chapters 3 and 4 of Intergovernmental Panel on Climate Change (2014).

[23] Intergovernmental Panel on Climate Change, 2014: 217.

[24] Intergovernmental Panel on Climate Change, 2014: 457.

In envisaging pathways towards lower emissions, the IPCC report refers to two critical forms of 'decoupling'. Firstly, consumption needs to be decoupled from emissions. The emissions behind the products that people consume need to be reduced. There is a key distinction between each country's consumption-based emissions, and its production-based, or territorial, emissions. The latter takes into account the emissions produced in a country, while the former takes into account the emissions behind the consumption occurring in a country. Rich countries which import many of the 'dirty' products they consume, such as steel, have consumption-based emissions which can be considerably higher than their production-based emissions. Decoupling consumption from emissions is about reducing the emissions behind all products consumed, whether they are produced locally or imported[25].

The second form of decoupling required is more controversial. Human well-being needs to be decoupled from consumption and economic growth. Climate change has been accelerated by the fact that a minority have over-consumed. They have consumed more – in terms of their houses, vehicles, consumables produced locally and imported, and international travel – than what was needed to maintain a reasonably good level of well-being. At the same time, many have been left without basic necessities[26]:

> … the spread of consumerism means that a large share of goods and services produced are 'luxuries' that only the wealthy can afford, while the poor are unable to afford even basic goods and services

Achieving well-being with fewer assets, less travel, and more modest food consumption is obviously a deeply philosophical matter which many people accustomed to high levels of consumption would oppose. Critically, avoiding catastrophic temperature rises and climate change is *technically* feasible, according to the IPCC report. The largest uncertainty relates to whether countries and global organisations can *politically* navigate a pathway to the desired goal, which in part is a matter of limiting consumption[27].

3 Arguments on a fair global distribution of mitigation efforts

The terms 'burden sharing', 'effort sharing' and 'entitlements', introduced in section 2, all relate to determining a fair global distribution of the obligation to reduce greenhouse gas emissions. The IPCC materials confirm how hugely complex a matter this, given uncertainties in the physical science, the difficulty of predicting the future, differing views of human history, differing views on the ethics of responsibility, and so on.

What is attempted here is an exposition of the key parts of the debate, using a relatively simple schema. Figure 1 brings together emissions, timelines, income and global inequality using real data, but in a manner which is purely educational, and not practical in a policy sense. Key issues the schema leaves out, for the sake of simplicity, are acknowledged below.

The timeline extends to 2100, as that is the horizon commonly used today, and the horizon of the Paris Agreement. The start of the timeline considered is a matter of much debate. The year 1990 is used here as a point at which the science of climate change had become clear and irrefutable. Any emissions of greenhouse gases beyond this point would have occurred with full knowledge of the damage this would cause. Countries, especially those which had already reached a high level of development, could be expected to introduce efforts to reduce emissions at this point. The average per capita emissions of Annex I and non-Annex I

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[25] Intergovernmental Panel on Climate Change, 2014: 288.
[26] Intergovernmental Panel on Climate Change, 2014: 304.
[27] Intergovernmental Panel on Climate Change, 2014: 292.

countries are shown. Annex I countries are 43 relatively developed and high-emitting countries defined in the 1990s within the United Nations system for the purposes of combatting climate change. This group includes Russia and Turkey, though within the Annex I group, these are countries with relatively low standards of living. The Annex I countries, though only accounting for 17% of the world's population in 2020, were responsible for around 60% of all historical greenhouse gas emissions prior to 2010[28]. Average per capita income in these countries was 29,918 USD in 1990, using 2017 purchasing power USD. This increased to 46,433 by 2020[29], just before the COVID-19 pandemic. The width of each red circle in the graph is proportional to per capita income. The standard of living in these countries thus improved by 55% in just 30 years, after it had become clear that emissions were causing climate change. However, over these 30 years, emissions per capita *declined*, for two key reasons. One is that these countries found ways of 'decoupling' consumption, or income, and emissions: they found ways of producing the same things with lower emissions. The other key reason is that these countries increasingly imported products associated with high emissions, in particular from China. They thus, in a sense, exported or outsourced their emissions to less developed countries. The emissions trajectory indicated by the red dotted line reflects a territory-based calculation. Only emissions occurring inside a country are captured. A *consumption*-based calculation produces somewhat different figures. Roughly, in 1990 consumption-based emissions for Annex I countries were 1% higher than territorial emissions[30]. By 2020, that figure had become around 8%[31]. If the consumption-based trend for Figure 1 were used, there would still be a decline in per capita emissions for 1990 to 2020, but the decline would be smaller. Specifically, instead of an 15% decline for 1990 to 2020, there would be a 9% decline.

Non-Annex I countries, accounting for 83% of the world's population, are represented by the black circles and black dotted lines. These countries saw a large increase in per capita income, but off a very low base, meaning that in 2020 these countries still displayed a standard of living less than a quarter of that in Annex I countries. These countries also saw their emissions per capita rise. Some of this would be the result of the fact that they were increasingly producing products for export to Annex I countries involving relatively high levels of emissions.

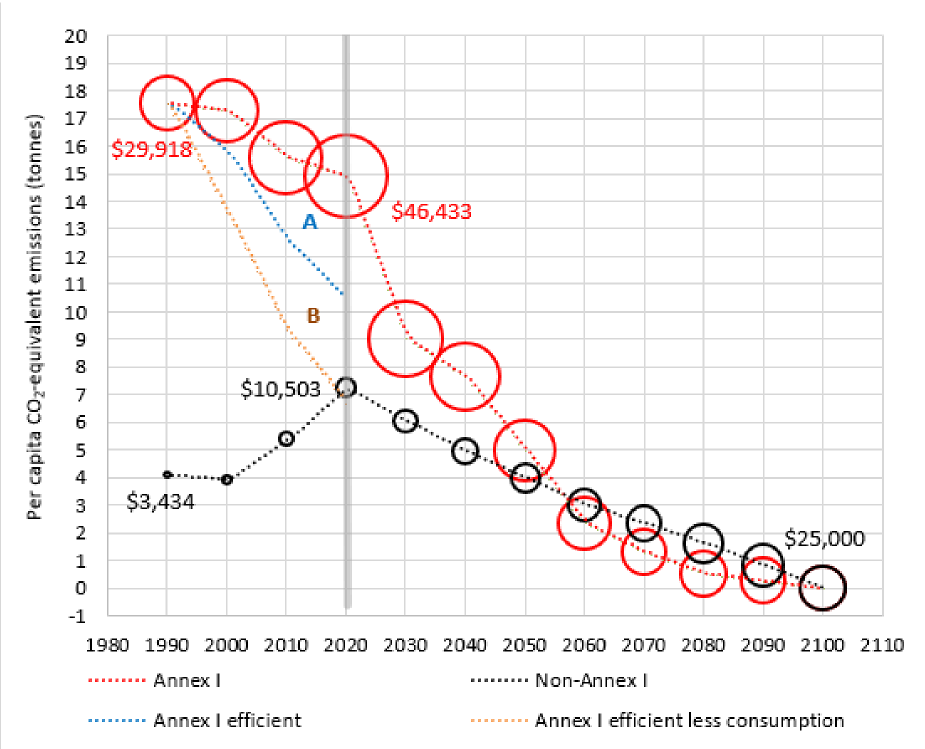
[28] Intergovernmental Panel on Climate Change, 2014: 43.

[29] The variable 'GDP per capita, PPP (constant 2017 international $)', from the World Bank's World Development Indicators (WDI). For the sake of simplicity, 2019 values were used for 2020, to exclude the income effects of the 2020 pandemic.

[30] Intergovernmental Panel on Climate Change, 2014: 46.

[31] Data accompanying Friedlingstein *et al* (2020). Those data cover only CO_2, so it was assumed that the CO_2eq trend would be equal to the CO_2 trend, in terms of percentage increases.

Figure 1: A schema for understanding burden sharing



Note: The width of each bubble is proportional to income per capita measured in 2017 USD with purchasing power parity.

The areas A and B in Figure 1 reflect emission reductions Annex I countries should arguably have achieved. The blue dotted line represents the emissions per capita Annex I countries could have achieved, if all these countries had decoupled emissions and income as successfully as the most successful 50% of countries among Annex I countries. To illustrate, Poland succeeded in reducing the tonnes of greenhouse gases per $10,000 of per capita income by 0.2 a year between 1990 and 2020. At the other extreme, Canada saw virtually no decline in its emissions per $10,000 of income. If countries such as Canada had been more like countries such as Poland, the blue dotted line could have been achieved.

Achieving the brown dotted line would be a more controversial matter for Annex I citizens. But morally, there are strong arguments supporting this. The brown dotted line reflects what would have occurred had Annex I countries been better at decoupling emissions from consumption *and* at the same time decided not to allow per capita income to increase beyond 1990 levels. As explained in the IPCC reports, the second kind of decoupling required is the decoupling of consumption and well-being. Had Annex I countries decided to settle for the $29,918 income of 1990, reflecting what was already a remarkably high standard of living in the global context, while also decoupling emissions and consumption more successfully, emissions per capita would have reached roughly those of *non*-Annex I countries by 2020. In terms of combatting climate change, and achieving trust and cooperation between countries, the world would have been better off.

This point had not been reached by 2020. Yet it is a point which needs to be reached in the coming decades, it can easily be argued, in the interests of sustainability and equity. The section of Figure 1 to the right of 2020 illustrates how this could occur. Both Annex I and non-Annex I countries would see their emissions per capita decline continuously, reaching zero by 2100. Roughly, this follows a global budget for emissions put forward by the IPCC which should not be exceeded if dangerous temperature increases beyond 2.0 degrees are to be avoided. For non-Annex I countries to achieve the necessary declines in emissions, while incomes were *increasing*, considerable technical assistance would be required from Annex I countries, which have the resources and the moral obligation to invest in technology innovation and to assist non-Annex I countries in the process. In fact, financial transfers to non-Annex I countries would be one factor behind the decline in per capita consumption in Annex I countries. The ultimate aim, according to Figure 1, is a convergence of per capita income by 2100, at some level between the current Annex I average and the current non-Annex I average. In Figure 1, this has been set at US$25,000 per capita.

It is important to note that the share of total emissions produced by Annex I countries has dropped, from 55% of the total in 1990 – around 21 gigatonnes[32] of a global total of 37 – to 30% in 2020 – 20 of 66 gigatonnes. This reflects the large increase in emissions from non-Annex I countries. The reduction of emissions in Annex I countries, while obviously important, is becoming less significant as a solution over time. This underscores the importance of the other key responsibility of Annex I countries: using their additional resources and know-how to develop low-emissions technologies, and financing in part of their implementation across the globe.

One key issue not taken into consideration in the above discussion is population growth. Unfortunately, the topic is also seldom comprehensively addressed in the climate change literature and policies. A 2007 article in an academic journal run jointly by the Royal Statistical Society of the United Kingdom and the American Statistical Association argued that all countries should pay more attention to 'national population strategies' aimed at substantially reducing populations. For instance, it is argued that the United Kingdom should aim to achieve a population of 17 to 27 million[33] – in 2020 the country's population was 67 million. The implication, assuming no coercive policies, is that a majority of adults would voluntarily agree to have no children. The UK-based group, Population Matters[34], whose patrons include Sir David Attenborough, consistently promotes radical declines in the population of all countries. China has argued that its one-child policy, in many senses a coercive strategy, represents a major contributor to climate change mitigation, given that without this policy the country's population would have been 400 million higher[35]. Analysts have quantified the impacts of the policy on China's emissions and found the mitigation effects to indeed be large[36].

A few researchers have examined why population has not featured more prominently in the literature around climate change. Some have argued that the 1994 United Nations conference on population in Cairo, and how the debates at that conference unfolded, represent a turning point after which population was downplayed in the global policy agendas[37]. It has been argued that religious and cultural opposition to even non-coercive family planning has resulted in missed opportunities to empower women and at the same time to limit population growth[38].

In Figure 1, what is not shown is that the population of Annex I countries grew by 14% between 1990 and 2020, which essentially cancels out the 15% decline in per capita emissions over this period, from the point of view of *total* emissions. If the consumption-

[32] A gigatonne is 1,000,000,000 (a billion) metric tonnes.
[33] Desvaux, 2007.
[34] https://populationmatters.org.
[35] Li Xing, 2009.
[36] Stauverman *et al*, 2018.
[37] Hodgson and Watkins, 1997.
[38] Campbell and Bedford, 2009.

based decline in emissions per capita was just 9%, as indicated above, then total emissions in what was consumed *increased* by 5% between 1990 and 2020 in Annex I countries. This strengthens the arguments that Annex I countries should have more actively pursued the two types of decoupling. Population growth in non-Annex I countries is far greater between 1990 and 2020, at 55%. The world's population is expected to increase from just under 8 billion in 2020 to around 11 billion in 2100[39]. This obviously introduces an additional difficulty not reflected in Figure 1. Emissions per capita would need to be decline even faster, to compensate for the fact that there are more people consuming emissions-inducing products.

Population growth, the 'exporting' of emissions from rich countries to developing countries, and the need for financial flows between countries to deal with both mitigation and adaptation to climate change, are key issues not covered in the basic Figure 1 schema. Another is that poorly understood dynamics in the natural environment could suddenly change the need for mitigation and adaptation in ways which are not commonly anticipated. One risk which may have been under-estimated is the release of large quantities of underground methane into the atmosphere as permafrost melts in places such as Russia and Canada[40]. More optimistically, technological solutions focussing on carbon capture and storage (CCS), for instance in the form of the removal of carbon dioxide from the atmosphere and its storage underground, could remove some of the pressure to reduce emissions.

To conclude, a problem with the Figure 1 schema, and with nearly all burden-sharing proposals, is that they focus on inequalities *between* countries. A 2015 paper co-authored by Thomas Piketty approaches the problem from the perspective of inequalities across individuals. Chancel and Piketty (2015) propose that elites in developing countries who have experienced rising incomes, along the lines of the Annex I average in Figure 1, and who are high emitters, share as much responsibility as citizens in Annex I countries to reduce their consumption levels and contribute financially towards schemes that facilitate mitigation and adaptation. To illustrate the problem, it is estimated that the world's top 10% of individual emitters are responsible for 45% of all emissions[41]. In calculating this, consumption-based emissions of countries are used. Of the 800 million or so individuals represented by the 10%, around two-thirds live in rich countries, but a third do not. For example, 2% of the top 10% of emitters are South Africans, 1% are Indian and 10% of the top 10% are Chinese. These figures translate to 16 million South Africans, 8 million Indians and 80 million Chinese. The 16 million figure for South Africa, which roughly encompasses the entire middle class defined very broadly, seems high. Yet given the very carbon-intensive nature of the South African economy, and specifically power generation, a relatively high figure should be expected. Chancel and Piketty argue that all these relatively well-off people, no matter where they are, share similar responsibilities.

4 An overview of the theory of carbon taxes

Taxes are primarily a means for governments to raise revenue in order to fund public services. Income taxes and value-added taxes (VAT) clearly fulfil this function. However, taxes can also play the role of encouraging or dissuading certain practices. For instance, excise taxes imposed on the manufacturing of alcoholic beverages and cigarettes are intended to raise the prices of these products for consumers, and hence reduce their

39 United Nations, 2019.
40 Holmes *et al*, 2015.
41 Chancel and Piketty, 2015: 10.

consumption. They are Pigovian taxes insofar as they attempt to force consumers to pay for hidden costs, such as the increased need for healthcare.

A tax on pollution, such as the emission of greenhouse gases, is a Pigovian tax. In theory the amount of the tax corresponds to the cost of the damage caused by the pollution.

A carbon tax is one of two key market-based approaches to curbing emissions, the other being an emissions trading system (ETS). Both are market-based as they intend influencing behaviour through prices, as opposed to measures such as prohibitions on emissions, or the setting of specific quotas of permitted emissions by specific companies. The desired behaviour changes include more investment in clean energy by companies and investors, and a reduced reliance among consumers on 'dirty' energy, for instance through greater use of public transport, and more energy-efficient devices in the home.

In an emissions trading system, government sets the total amount of emissions allowed, and allows the price of permits to emit, which are auctioned, to fluctuate. A carbon tax is essentially the opposite. Here the government sets the price of each unit of emissions, and then lets the total amount of emissions fluctuate.

Superficially, an ETS may seem preferable as it aims explicitly at curbing emissions to a particular level. However, there are drawbacks with this approach. For example, it requires the establishment of new institutions, specifically institutions that auction out permits to emit. A carbon tax, on the other hand, can be implemented through the existing tax authority, taxing companies which would already be paying other taxes, such as company tax. But more importantly, in many economies a few companies are responsible for a large proportion of total emissions. This facilitates collusion between emitters in the auctioning process, with the aim of lowering the price of the permits. Emitters would have to reduce their emissions, in line with the permits they bought, but they are also likely to raise the prices of what they sell, for instance electricity, even beyond what is required to cover the cost of the tax, in order to maintain historical levels of revenue. Low permit prices could leave government with limited revenue to deal with the social problems associated with, for instance, higher electricity costs. Carbon taxes would also raise the price of electricity, but government is assured of its revenues, which could be used to subsidise, for instance, electricity consumption in poor households.

While ETSs originally seemed the optimal approach, from around 2007 carbon taxes have increasingly been favoured, as their advantages became clear[42]. This has led to better analysis of how best to design a carbon tax. A key design matter is what tax to attach to, say, every metric tonne of carbon dioxide emitted. The enormous economic effect of a properly implemented carbon tax points to a need for a phased introduction, specifically by allowing the amount of the tax to rise gradually. It is extremely difficult to calculate the cost of the damage of climate change. Insofar as climate change threatens the very existence of human life, the costs are arguably infinite. Moreover, there is uncertainty over the exact speed at which climate change will change the conditions for human societies in future.

The preferred method for setting the level of a carbon tax is the abatement target approach[43]. This involves taking an emission reduction target, and a predictive model of the economy, generally what is known as a computable general equilibrium (CGE) model, and then selecting the tax rate which produces the desired abatement, or reduction in emissions.

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[42] World Bank, 2017: 27.
[43] World Bank, 2017: 92.

Currently, there is no readily available technology that allows us to measure actual emissions, in the sense of for instance some device inside the smokestacks of coal-fired power stations measuring what passes through the smokestack. What has been recorded across most industries for many years, is the amount of fuel used, for instance the tonnes of coal used per month at a power station. Carbon taxes must thus currently tax the fuel used, as opposed to actual emissions. This means using emissions factors, or the amount of emissions produced by burning, say, a particular type of coal, and allowing the tax to vary in line with the emissions factor, so that the end result is approximately what a tax on a tonne of carbon dioxide would be. There are some risks with this approach. A power station could effectively reduce its taxes by ensuring that no fuel is wasted, where in the past some fuel may have been left unused. The tax might thus result in slightly higher emissions by the power station initially. A power producer could try to evade taxes by under-reporting on the coal which is combusted. This could create the need for a new official inspection system. Clearly, a power station that introduced carbon capture and storage (CCS), where emissions are converted to a material which can be buried, would need to receive tax credits for this.

Fortunately, fossil fuels tend to be difficult to extract. If coal which could be burnt to provide heat was easily extractable from people's gardens, implementing a carbon tax would be very difficult. However, the mining and combusting of coal and other fossil fuels is mostly limited to a few companies. This facilitates the implementation of the tax. A special case is the non-stationary combustion of petrol and diesel in vehicles. This is typically done by millions of people in a country. The solution here is to implement upstream taxation of fuel refineries, who would pay the tax on behalf of ordinary citizens, even if the refinery is not combusting the fuel.

The ideal would be a carbon tax set at the same rate, and implemented according to the same rules, across the entire world. However, this is generally not seen to be feasible from a political perspective. This means that carbon taxes must come with trade tariffs that aim to compensate for different tax regimes in different countries, at the border. The theory around how to do this is still at an early stage.

Finally, how the revenue from a carbon tax is utilised is crucial. What may be considered ideal is a revenue neutral approach. This means the new revenue generated by the carbon tax leads to equivalent reductions with respect to other taxes. It is easy to see that this might be politically necessary. For example, reducing income taxes in a manner that at least partially compensates for the additional costs households must endure with respect to, say, electricity, would make the carbon tax more acceptable. However, there may also be a good argument for a transformational use of revenue, where perhaps total revenue is increased to allow for state investment in renewable energy. A revenue neutral approach could be transformational if the new tax is used as an opportunity to reduce historical inequalities, by reducing the relative tax burden on the poor.

5 Carbon taxes in practice around the world

Since 2014, the World Bank has released an annual *State and trends of carbon pricing* report, which seems the best available source for a recent stocktaking of carbon taxes, ETSs and related initiatives, essentially any initiative that attaches a price to units of emissions.

The 2020 update report identifies just 31 ETSs and 30 carbon tax systems in existence around the world. Some are national, and some sub-national. Of the carbon taxes, 23 are national. The 61 initiatives govern around 22% of global emissions. However, the ability of these initiatives to impact on that 22% is often weak, because prices are so low. It is estimated that the average global carbon price is just 1 USD, while the World Bank has estimated that by 2020 this price should be between 40 and 80 USD for the impact required by the Paris Agreement to be felt[44].

Annex I countries feature a strong presence of both ETSs and carbon taxes, with the two mechanisms co-existing in some countries. The largest of any initiative is easily the European Union Emissions Trading System (EU ETS), established in 2005 and governing around 5% of the world's emissions. The price per tonne of CO_2eq emitted within the EU system is 19 USD. A notable gap is the United States, which has no national initiative at all, though 13 of the 50 states do[45]. Russia has no national or sub-national initiatives.

With the exception of China, developing countries have pursued carbon taxes, and not ETSs. By 2020, five developing countries had introduced a carbon tax: four Latin American countries – Mexico, Colombia, Chile and Argentina – and South Africa. South Africa's carbon tax is particularly broad in terms of what it covers. It is said to cover 85% of the country's emissions. The only other carbon taxes which get close to this are Singapore's, at 80%, and Japan's, at 65%[46]. Moreover, South Africa's and Chile's carbon taxes are said to come closest to taxing actual emissions, because taxpayers are emitters, and not more upstream entities, such as coal mines[47]. It could be argued that South Africa emerges as the 'poster child' of carbon taxes in developing countries in a 2017 World Bank guide for policymakers[48]. South Africa's planning and consultation processes for arriving at a tax receive considerable attention in this guide.

China has no carbon taxes, according to the 2020 report, though three provinces[49] and five major cities have introduced ETSs, mostly around 2013. China plans to launch a national ETS in 2021.

Strikingly, India is not mentioned in the 2020 World Bank update, though in an earlier 2017 report, the World Bank decided to consider India's tax on coal a carbon tax[50]. Some googling makes it clear that this coal tax still exists. Why the World Bank decided not to count the tax among the world's 61 initiatives in 2020, is not clear.

Prices attached to emissions are clearly lower in developing countries. Among the five developing countries listed above, amounts range from 1 to 8 USD, with South Africa said to be at 8 USD. The second-highest price, of 6 dollars, is seen in Argentina[51]. However, South Africa's relatively high price, among developing countries, is considered deceptive insofar as it does not take into account extensive exemptions[52]. In developed countries, carbon tax rates per tonne of emissions, are higher, roughly in the range of Ireland's 28 dollars to Sweden's 119 dollars.

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44 World Bank, 2020: 7-8, 11.

45 World Bank, 2020: 25, 40. Ten north-eastern states participate in the Regional Greenhouse Gas Initiative (RGGI), California has had a carbon tax since 2012, while Washington state and Virginia have non-tax initiatives.

46 World Bank, 2020: 45.

47 World Bank, 2017: 15.

48 World Bank, 2017.

49 Guangdong, Hubei and Fujian.

50 World Bank, 2017: 27.

51 World Bank, 2020: 25.

52 World Bank, 2017: 90.

Turning to the use of revenue derived from carbon taxes and ETSs, it is estimated that around 20% of global revenue essentially compensates for reductions in other taxes. The remaining 80% is thus directed towards increasing total revenue, though not by a large margin, given how low prices currently are. About half of this 80% is being used to invest in adjustments to cleaner energy[53].

International collaboration is noted as being poor in the 2020 update report. It has been estimated that were international collaboration extensive enough on, for instance, prices, this could reduce the economic cost of cutting emissions by a half[54]. Clearly, the complexities of international agreements, or the lack of such agreements, are costly.

6 Existing South Africa-focussed analyses

6.1 Accounting for emissions

South Africa's 2019 greenhouse gas inventory

An important and recurring monitoring exercise in South Africa is the compilation of an inventory of greenhouse gas emissions in a year. The earliest South African inventory is for 1990, and the most recently published inventory covers the years 2000 to 2015. South Africa[55], like other countries, is required through its UNFCCC[56] commitments to produce inventories, following methods of the IPCC first published in 1996, and updated in 2006. The IPCC manuals allow for different approaches, depending on the data availability, data quality and analytical capacity of the country. The manuals place considerable emphasis on making uncertainties and margins of error explicit in the national inventory. The national inventories produced within the UNFCCC system are all production-based, or territorial. How production-based and consumption-based emission totals differ, a matter introduced in section 3 above, is discussed further within this section.

South Africa's most recent inventory, a 296-page report published in 2019 by the Department of Environmental Affairs (DEA), is comprehensive yet relatively easy to follow. Emissions statistics are provided in a variety of formats. Figure 2 provides a format not found in the report, using figures from the inventory. Here the aim is to reflect emissions as categorised by the 2019 Carbon Tax Act. The three categories on the horizontal axis are used by the Act, as are the three gases shown in the legend. Nitrous oxide (N_2O) contains no carbon, meaning that strictly speaking the scope of South Africa's 'carbon tax' extends beyond carbon. Emissions reflected in Figure 2 come to 466,122 Gg of CO_2eq, or gigagrams of carbon dioxide-equivalent emissions, in 2015. To convert gigagrams to metric tonnes, the other measure commonly used in this context, Gg should be multiplied by 1000. In this instance, that would produce 466,122,000 tonnes of CO_2eq. Total gross emissions in South Africa in 2015 was 540,854 Gg CO_2eq, meaning Figure 2, and thus the Act, cover 86% of all emissions. This means 74,732 Gg CO_2eq would not be covered by the Act. This includes the following: around 28,000 corresponding to what is essentially livestock burping methane on farms; around 21,000 for nitrous oxide released during fertiliser usage; around 20,000, mostly methane, emitted from waste disposal[57]; and around 6,000 in the form of the release

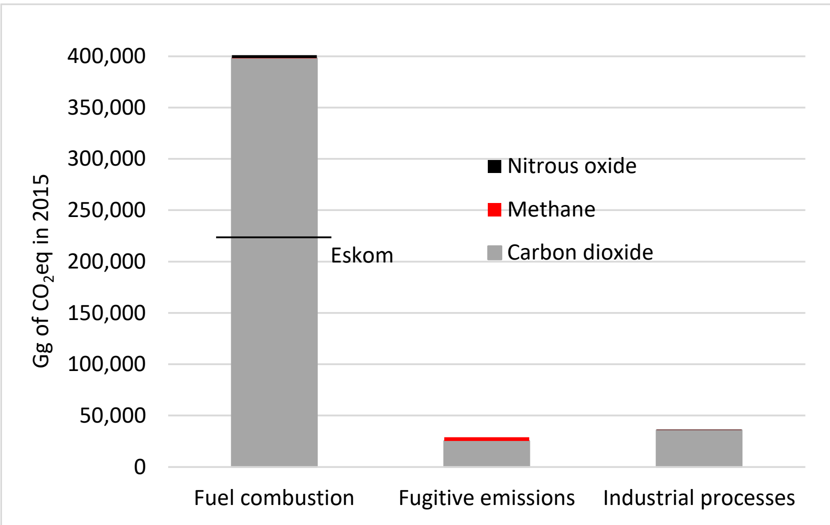
53 World Bank, 2020: 20.
54 World Bank, 2020: 87.
55 Department of Environmental Affairs, 2019.
56 United Nations Framework Convention on Climate Change. The UNFCCC is an international treaty, in existence since 1992.
57 One small waste category, 'waste incineration', amounting to around 350 CO_2eq emissions a year, is taxable within the Act.

through industrial processes of gases other than the three shown in Figure 2. The 14% of emissions not covered by the Act are not unimportant, but in some ways they do not lend themselves to a tax. For instance, taxing livestock emissions would require setting up new data collection systems involving thousands of additional taxpayers, in a context where the taxpayer can do little to reduce the emissions.

Mention was made of the *gross* emissions in 2015, amounting to 540,854 Gg CO_2eq. *Net* emissions would be 512,383, which takes into account land use change. Net is 5% lower than gross in the case of 2015 because analysis of land use data suggests that CO_2 was extracted from the atmosphere. Specifically, land covered by forest increased, and forests absorb CO_2 when they grow.

Figure 2 illustrates how large carbon dioxide emitted through fuel combustion is – this accounts for 85% of all emissions covered in the graph. And within CO_2 from fuel combustion Eskom, the national electricity supplier, accounts for 56%. Within that, 99.3% is the combustion of coal by Eskom. The remaining 0.7% is mostly accounted for by four Eskom gas-fired power stations, and some transport by Eskom vehicles[58]. Eskom would clearly be a major taxpayer in terms of the Act.

Figure 2: Gross emissions using Carbon Tax Act breakdowns



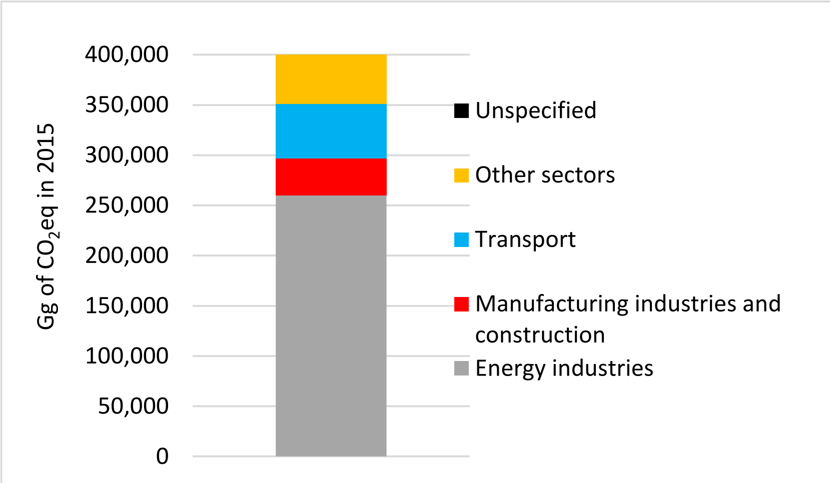
Source: Calculated from Department of Environmental Affairs (2019).

Sources beyond the inventory confirm the very large role of Eskom in South Africa's emissions. Eskom generates around 95% of the country's electricity. Around 20% of this goes to households, around 37% to mining, and the remainder to other industries[59].

If the fuel combustion column in Figure 2 is broken down by IPCC activities, figures from the inventory can be used to produce Figure 3 below. 'Energy industries' in Figure 3 exceeds 'Eskom' in Figure 2 by 17% due to, for instance, a few non-Eskom power plants run by municipalities, and fuel combustion within the petroleum industry.

[58] Eskom, 2020.
[59] Deloitte, 2017: 20, 25.

Figure 3: Fuel combustion broken down by IPCC main activity



Source: As for Figure 2.

The second column in Figure 2, fugitive emissions, is emissions which are largely unintended, and includes emissions from underground fires in disused coalmines, which can continue for years. The third column, industrial processes, reflects emissions resulting largely from metal industries, not with respect to fuel combustion, but with respect to chemical processes employed in, for instance, the production of steel, which release large amounts of carbon dioxide. The third column also covers non-combustion emissions in cement production. All these categories lend themselves to a carbon tax, in part because they imply dealing with relatively few, and large taxpayers. However, this assumes one thing is done. Transport emissions are from vehicles, including vehicles owned by households. In this group, there are clearly millions of emitters. To deal with transport, the carbon tax would need to be paid by refineries supplying the petrol or diesel, which would then pass on the higher price to owners of vehicles.

Where would South Africa's emissions be located on the earlier Figure 1? South Africa's 2000 per capita emissions figure would be 9.4 CO_2-equivalent tonnes. This would make South Africa's value over twice that seen in non-Annex I countries, yet around half of the average for rich Annex I countries.

Breakdowns not included in the official inventory

Two breakdowns are not required in the national inventories, according to the IPCC manuals, but they greatly assist in understanding a country's emissions: emissions associated with the products people in a country *consume*; and what individual companies emit.

As mentioned previously, national inventories use a production-based approach. Consumption-based emissions accounting is even more complex to realise, though the results are readily understandable. Two things make consumption-based accounting difficult. First, this needs to occur for the world as a whole, given how inter-connected national economies are. For instance, steel produced in South Africa and exported to China, to produce a vehicle which is then exported to Italy, should result in the original emissions occurring in South Africa being attached to the consumer in Italy. To produce estimates that deal with these types of complexities, global trade data must be used. Secondly, it is necessary to know how the different sectors *within* each country interact with each other. For instance, it can be important to know whether the manufacturing of steel in South Africa uses energy generated at the steel plant, or off the power grid, as this can influence the emissions associated with the manufactured steel. Many countries, including South Africa, produce input-output, or IO, tables which reflect how sectors feed into each other[60]. The most comprehensive consumption-based emissions statistics per country available are those published annually, since 2013, through the journal *Earth System Science Data*, the most recent article being 'Global carbon budget 2020'[61]. Unfortunately, they cover just carbon dioxide, which in CO_2-equivalent terms accounts for 76% of greenhouse gas emissions globally[62] and 85% in South Africa[63]. They cover 118 countries, including South Africa, accounting for 97% of territorial (or production-based) emissions worldwide.

The Figure 4 map below illustrates the extent to which the production-based national statistics exceed the consumption-based ones. Both national values are from 'Global carbon budget 2020'. South Africa's excess, at 43%, is the fourth-highest in the world, after three small oil-producing countries: Qatar; Bahrain; and Trinidad and Tobago. Carbon dioxide emissions occurring in South Africa are 43% higher than the emissions embodied in what South Africans consume. This would largely be due to large volumes of exports of goods associated with high emissions, though what South Africa imports also influences the statistic. Importantly, the consumption-based figure still leaves South Africa as a high emitter. Using production-based emissions, South Africa is the world's 12th largest emitter. Using consumption-based emissions, it is ranked 18th. In per capita terms, South Africa is ranked position 26 using a production-based approach, and position 51 using a consumption-based approach, where the total number of countries with the available data for both rankings is 117.

The global total, whether a production- or consumption-based approach is used, remains the same. The difference is that the total is differently apportioned across countries. The map illustrates how Asia is a major exporter of emissions-embodied products, while the rest of the world is largely a net importer of emissions. In general, large exporters of oil, such as Nigeria, or manufactured products, such as China, are exporters of emissions. The reason why so many African countries, and even Saudi Arabia, are net *importers* of emissions would be that these countries have weak manufacturing sectors, and would thus have to import many manufactured goods.

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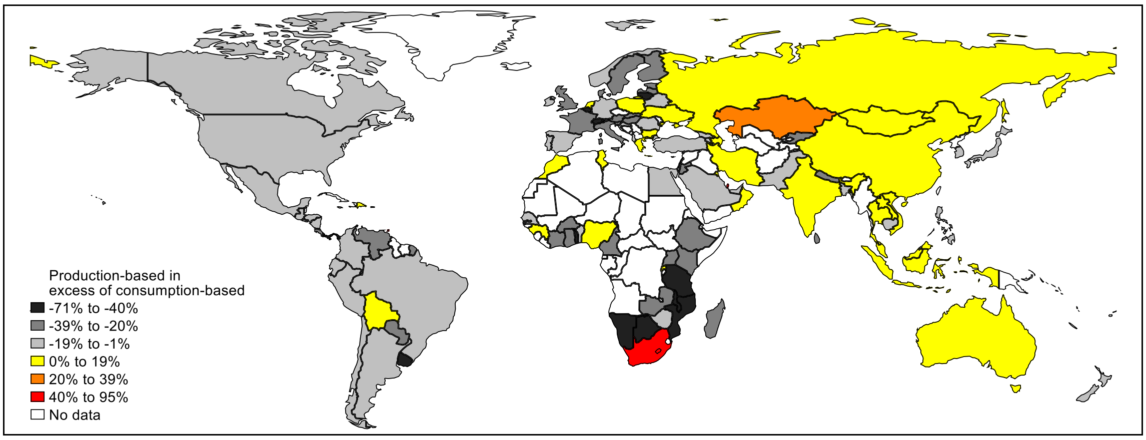
60 Statistics South Africa, 2017/

61 Friedlingstein *et al*, 2020. The national statistics are in an Excel file accompanying the article.

62 Intergovernmental Panel on Climate Change, 2014: 354.

63 This 85% is based on a territorial calculation.

Figure 4: Excess of production-based over consumption-based



Source: Friedlingstein et al*, 2020.*

The dataset used for the map has few details explaining the underlying factors. However, it can be assumed much of the explanation for South Africa's high statistic would lie in the exporting of mining-derived products associated with high-energy extraction and processing. South Africa's IO tables point to 33% of exports, in terms of monetary value, being from the mining sector[64], and as pointed out above, mining consumes around 37% of electricity generated by Eskom.

Turning to breakdowns by company, data on this is becoming increasingly available as pressure mounts on companies to disclose their emissions. Given that Eskom is responsible for 49% of all of South Africa's CO_2 emissions, it makes sense for the national inventory to pay special attention to Eskom. However, emissions for other companies are not provided in the inventory.

A key global initiative is CDP, originally derived from 'Carbon Disclosure Project', though its scope extends beyond carbon dioxide. This initiative involves the promotion of standard reporting practices, and the collection of data from hundreds of the world's largest companies. The data includes information on the kind of independent auditing of emissions employed by each company. No global report since 2013 seems to be have been produced by CDP, though in more recent years many regional and country reports have been produced, including a 2017 report for South Africa. The 2013 global report[65] provides emissions statistics for around 400 of the world's 500 largest companies, considered the 'Global 500'[66] group. The 400 would be the companies agreeing to compile and disclose their emissions. They account for 7% of global greenhouse gas emissions[67]. In global position 14 in terms of 'scope 1' emissions, meaning emissions the company controls fully, is South Africa's Sasol, which is also ranked fourth among the energy companies, after (from largest emitter) Gazprom of Russia, Exxon Mobil of the United States, and Royal Dutch Shell of the Netherlands. Eskom is not in the Global 500 group. What is striking about Sasol is that its emissions exceed by far what would be expected, given the size of the company. To

64 The three categories 'Coal; lignite', 'Metal ores' and 'Other mining; quarrying' from the IO tables in Statistics South Africa (2017) considered.

65 PwC, 2013.

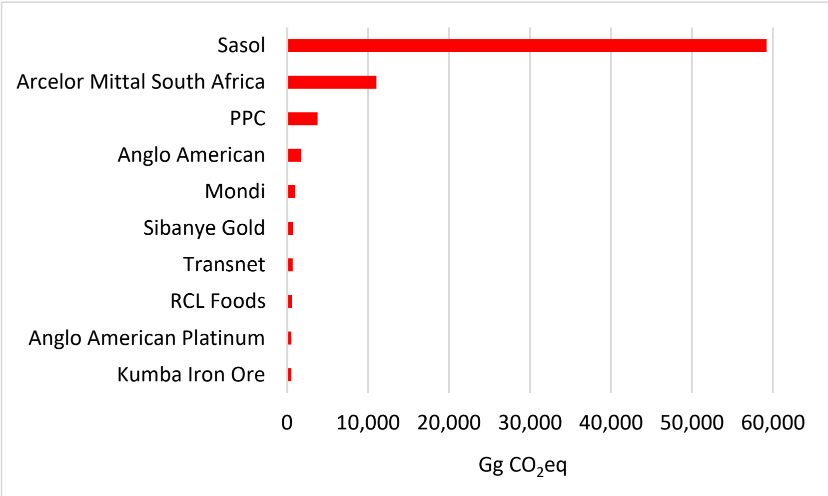
66 These are the 500 companies with the largest market capitalisation on the FTSE.

67 3,600,000 Gg CO_2eq divided by 53,526,302.

illustrate, Royal Dutch Shell has very similar emissions, yet is 30 times the size of Sasol in terms of revenue[68].

The scope for the 2017 CDP report for South Africa[69] is 115 countries, being the JSE[70] 100 plus an additional 15 companies. Of the JSE 100, 29 did not provide data, one being Eskom, though it should be noted that in 2020 Eskom did publish its first comprehensive emissions report ever, which provides emissions totals in line with what can be seen in the DEA inventory report[71]. Eskom seems to be the only company with considerable emissions among the 29 non-reporting companies in the CDP report. Figure 5 below reflects the ten companies with reported data whose emissions came to 500 Gg CO_2eq or more. Had Eskom been included, its emissions would have been around three times as high as those of Sasol. Clearly, beyond Eskom, Sasol predominates as an emitter, accounting for 74% of the emissions illustrated in the graph. Sasol accounts for 11% of gross national emissions, while the other nine companies shown in Figure 5 together account for 4% of emissions.

Figure 5: South African company greenhouse gas emissions 2017



Source: PwC, 2017.

6.2 Modelling emissions reduction mechanisms in general

The 2014 Mitigation report

The 152-page *Mitigation report*, published by the Department of Environmental Affairs (DEA) in 2014 and funded by GIZ, the German international development agency, seems to represent the most ambitious and influential analysis of how South Africa could achieve major reductions in its emissions in the period up to 2050. For instance, it is a key input into the 2020 emissions reduction strategy of the Department of Environmental Affairs[72]. The 2014 report, produced by an international firm, Camco Clean Energy, lacks the clarity of the IPCC assessment reports, so the reader needs to work through it carefully[73]. The Excel files

68 Subsequent to 2013, Sasol has been overtaken by other companies in terms of size, and is now no longer within the Global 500 group.

69 PwC, 2017.

70 Johannesburg Stock Exchange.

71 EcoMetrix Africa, 2020.

72 Department of Environmental Affairs, 2020: 7.

73 The two-page executive summary is unclear in many places, and in the report as a whole the meaning of specific statistics could have been clearer.

used for the modelling do not seem to be publicly available online, but almost 500 additional pages of technical appendices are[74].

Viewed against South Africa's official emission reductions targets (section 7.1 below), the report is at face value not encouraging, at least not beyond 2030. The most optimistic scenario sees emissions in 2030 being slightly below both 2010 and 2020 levels, for instance 8% below the 2020 level. This would be in line with South Africa's international commitments. However, the decline expected after 2035 in these commitments is not reflected in the most optimistic scenario with maximum mitigation efforts. In fact, in this scenario emissions are expected to *increase* by around 40% between 2035 and 2050[75]. This is striking, and could have been discussed better in the report, especially considering that the commitments in question were clear when the report was produced[76].

A careful reading of the report reveals that two unlikely assumptions drive the large post-2035 increases in emissions. One is the fact that shifts to cleaner energy beyond 2030, other than what was planned before around 2010, are not envisaged, because the 2010 Integrated Resource Plan of the Department of Energy has a time horizon of 2030, and did not specify shifts beyond 2030[77]. Clearly, the assumption of no shifts beyond 2030 is unrealistic. Secondly, continuous and relatively high economic growth to 2050, of around 4.3% a year, is assumed, using projections by the National Treasury. While many would argue this is desirable and some may argue possible, there are two reasons why such growth is unlikely. One is that Treasury's projections have nearly always been considerably higher than the economic growth actually seen in recent years. For instance, between 2005 and 2020, Treasury forecasts of two years into the future exceeded actual growth by, on average, 2.1 percentage points[78]. The other is that the growth assumed in the report would take income per capita in South Africa in 2050 to levels seen in developed countries in around 2000, specifically around USD 34,000 in 2017 purchasing power terms (see earlier Figure 1)[79]. Pressure to decouple income from well-being – a matter discussed in section 3 – is likely to work politically against the realisation of such a high per capita income in South Africa, even if such a level of income were technically possible[80].

Some rough calculations which assumed, firstly, that the shift to cleaner energy beyond 2030 would be as fast as before 2030 and, secondly, that South Africa's per capita income would not rise above USD 25,000 – the rough estimate of a ceiling arrived at through Figure 1 – suggest that substantial declines in emissions beyond 2035, of the kind envisaged in South Africa's commitments, would be possible. Even per capita income of USD 25,000 by 2050 is ambitious in the sense that taking Treasury growth estimates and subtracting the aforementioned 2.1 gap, would produce a per capita income figure of only USD 18,000 in 2050.

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74 https://www.environment.gov.za/documents/research#climate_change

75 Department of Environmental Affairs, 2014: 88, 91.

76 The commitments are in fact described in the report (Department of Environmental Affairs, 2014: 3).

77 Department of Environmental Affairs, 2014: 90.

78 Analysis of National Treasury *Budget Review* documents. If one excludes 2020 and hence the pandemic from the analysis, Treasury's over-estimate is reduced to 1.6 percentage points for 2005 to 2019.

79 The per capita income projections referred to here take into account population change, using population projections for South Africa published by the UN.

80 The mitigation report does consider an alternative 'low-growth scenario', but this is just 0.4 percentage points below the reference scenario, and only a few statistics relating to this alternative scenario are presented.

The report's findings in relation to the impact of mitigation efforts on jobs and total income are encouraging. Adoption of the full set of mitigation measures results in a net addition of jobs. Ten years into the future, 300,000 additional jobs would exist[81], relative to a situation where no new mitigation measures were implemented. An additional 300,000 jobs translate to 1.8% of the total labour force. The additional jobs would be concentrated in the agricultural, forestry and waste sectors, according to the report. There would be better management of landfill sites, and even extraction of energy from such sites. There would be more planting and management of trees, in plantations but also in urban areas, and there would be more labour-intensive manure management in livestock farming. Shifts to wind and solar power generation are said to result in a net *loss* of jobs as the cleaner energy options are less labour-intensive than coal-fired power stations[82]. However, it appears as if a critical factor is not considered, namely the demand for labour as new energy infrastructure is built. A separate 2019 study by South Africa's Council for Scientific and Industrial Research (CSIR) estimates that just within the energy sector there would not be a net loss of jobs, but rather a steady increase in employment, with around 60,000 more jobs in 2050 than in 2020[83].

The modelling of the report essentially proceeds as follows. First, a business-as-usual model is used to develop likely future pathways in terms of, for instance, economic growth for the country and outputs and emissions across various sectors and sub-sectors. As is the case in much of the modelling of this kind, the economic damage brought about by climate change is not considered in the business-as-usual trajectory[84]. This trajectory thus assumes there is no climate change. The model takes into account mitigation initiatives already in government's planning pipeline. Then, additional ways of reducing emissions which would be technically implementable in South Africa were identified. The annual cost of each of these, relative to the emissions which would be avoided, was estimated. Within the annual cost, capital investments annualised over the lifespan of the installations are included. Scenarios were then created which prioritised the most cost-effective mitigation interventions, keeping in mind the physical limitations of each intervention. For example, there is a limited area of South Africa which lends itself to wind farms. Finally, prioritisations were adjusted in line with social needs. For instance, an intervention which would create more jobs would be additionally prioritised. The projections referred to previously are all from a scenario where the *maximum* possible degree of mitigation occurs, within the parameters of the model, parameters which include, as discussed previously, relatively high economic growth and no new shifts to clean energy beyond 2030.

What the modelling did not do is consider what policies would be needed, or possible, to bring about the interventions. There is hence no discussion of a carbon tax, though such a tax would clearly assist in, for instance, moving the economy away from coal-based energy. Moreover, political factors, such as pressure from trade unions for or against certain shifts in the economy, were not considered.

Given when the report was produced, it would obviously not have taken into account the COVID-19 pandemic. It has been estimated that globally emissions in 2020 were around 7% lower than in the previous year, an unprecedented decline. Much of this has been due to

[81] Department of Environmental Affairs, 2014: 88, 91.
[82] Many of these details are in the technical appendices.
[83] Council for Scientific and Industrial Research, 2019: 16.
[84] There is no 'damage function', as described in Intergovernmental Panel on Climate Change (2014: 1255).

lower emissions from the transport sector[85]. Some of these reductions would be sustained beyond the pandemic, for instance as virtual meetings become entrenched. These issues would need to be taken into account in future emissions and mitigation projections.

Fossil fuels, renewables and nuclear power in the 2014 report

Turning to matters of direct relevance for a South African carbon tax, a key question is the extent to which the dependency on fossil fuels in the generation of electrical power will be reduced. The share of electricity derived from fossil fuels is expected to decline from 88% in 2020[86] to 48% in 2050, but given the overall increase in electricity demand, electricity from fossil fuels would increase by around 55%. However, as was explained above, the mitigation report assumes virtually impossible economic growth rates. Perhaps what is more relevant than the increase in electricity from fossil fuels, is the absolute increase in electricity generated from renewable sources or by nuclear power stations. Electricity from renewable resources is expected to increase fifteen-fold between 2020 and 2050. By 2050, electricity output from renewables would be about 1.3 times what coal-based electricity was in 2020. And electricity output from nuclear would be around 0.4 times what coal-based electricity was in 2020. Adding 1.3 and 0.4 gives 1.7, meaning if coal-based electricity were completely abandoned, nuclear and renewables would, by 2050, be able to produce around 70% more electricity than what coal produced in 2020. Clearly, nuclear is expected to play an important role, but renewables are expected to play an even larger role. The figures provided here had to be extrapolated from figures provided in the 2014 report, as the report does not provide most of these figures explicitly. They are ballpark figures to provide a sense of the envisaged energy sector[87].

One reason why nuclear energy plays a large role in the forecasts, is that the report finds nuclear energy to be the lowest cost route towards reducing emissions. For instance, its cost is around two-thirds of that of onshore wind energy, which itself is a relatively low-cost mitigation route. However, nuclear energy is given a relatively low 'social and environmental' score[88], which probably explains why the projected use of nuclear energy is not higher.

There is uncertainty and heated debate over whether the economics of different sources of energy favours nuclear to the extent seen in the 2014 report. Moreover, nuclear energy is not just about economic costs, but about the extent to which society is willing to accept the risks associated with nuclear, in the light of disasters such as Chernobyl and Fukushima. On the economic side, it is extremely difficult to produce comparable cost factors that will allow for nuclear and renewables to be weighed up against each other. This is due to complexities on both sides. With respect to nuclear energy, in countries where the state largely controls the energy industry costs are easily hidden, for instance with respect to the risk of cost overruns. Cost overruns are very common with nuclear energy as delays are typically experienced in the construction phase. Whether technological innovations, for instance 'small modular reactors', smaller power stations which are faster to establish, will bring costs down substantially remains unclear. On the side of renewable energy, costs have been declining, but this decline has been slowing down, and there is uncertainty around future

85 McSweeney and Tandon, 2020.

86 The 2020 figure is from the International Energy Agency (IEA) online 'Data and statistics' portal. The 12% that is not based on fossil fuels includes 5% nuclear, 3% wind energy, 2% solar energy, and 2% hydro energy.

87 Figures calculated from IEA 2020 values, plus values reflected in Department of Environmental Affairs (2014: 15, 40, 47).

88 Department of Environmental Affairs, 2014: 125.

cost trajectories. A key drawback of renewable energy is its intermittency: energy is generated only when the wind blows, or when the sun shines. Predicting this intermittency can be difficult, and costs associated with storing energy remain high. Renewables work best with 'smart grids', grids that automatically take decisions around how to direct the flow of electricity, based on changing patterns of supply and demand[89].

Within the renewables category, it is clear that wind energy predominates in the scenarios of the 2014 report. Solar is expected to generate half the electricity that wind is expected to generate by 2050[90]. However, according to the CSIR report, solar energy would generate as much employment as wind energy, given the more labour-intensive nature of solar.

There seems to be little robust debate about mitigation pathways in South Africa, at least not in the documents available in the public domain. Halsey *et al* (2019), in a South African report also funded by a German development agency, argue that socio-economic effects and poverty reduction need to feature more prominently in the national policies, but do not provide much in the way of specificities. In some developed countries, there has been an emotive debate around the need for changes in diet, in particular away from red meat, as a means of not only reducing per capita emissions, but also advancing health[91]. Such debates would be relevant in South Africa, where for instance the consumption of red meat is high. To illustrate, South Africa's per capita consumption of bovine meat exceeds that of the European Union slightly, and is about 2.5 times the figure for Africa as a whole[92].

It has been argued that modelling work of the kind presented in the 2014 mitigation report ought to be communicated better to more people beyond South Africa's 'carbon elite'[93], the small group of people who understand the work. Such communication could help to bring about more debate, a greater awareness of the challenges, and wider acceptance of the need for action.

6.3 Modelling a carbon tax

One of several modelling exercises that informs South Africa's carbon tax is that of Devarajan *et al* (2009). This work, focussing on South Africa, but by a non-South African team of four analysts, is described in a 36-page World Bank report. Devarajan *et al* offer useful insights into what is found when the introduction of a carbon tax is modelled in the South African context. The report influenced the 2019 carbon tax in part through its consideration within National Treasury's 2010 *Reducing greenhouse gas emissions: The carbon tax option*. This 2010 Treasury discussion paper, and a follow-up paper in 2013, were instrumental in shaping the debates around a carbon tax in South Africa[94].

Devarajan *et al* use a computable general equilibrium (CGE) model, a common model for this type of analysis. A static CGE approach is adopted, meaning there are just two points in time: the country before the introduction of the tax, and the country with the new tax. In theory, the gap between the two points in time could be any number of years. They target a

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[89] Khatib and Difiglio, 2016. Wright *et al* (2019), mostly from the CSIR, argue that a least cost approach points to the need for no nuclear energy by 2050, with non-renewable energy being generated from the remaining coal-fired power stations.

[90] Department of Environmental Affairs, 2014: 40.

[91] Intergovernmental Panel on Climate Change (2020: 479) deals with the science of diet and emissions.

[92] Ritchie and Roser, 2017.

[93] Tyler and Gunfaus, 2016.

[94] National Treasury, 2010, 2013.

reduction of 15% in the CO_2eq emissions of the energy sector, a sector accounting for 92% of the emissions conceivably covered by a carbon tax[95]. Other sectors are considered in the model, but only the energy sector's emissions are considered, and gases other than CO_2 are ignored. The carbon tax is levied on the combustion of three fuels: coal, oil and gas, which account for 98% of emissions in the energy sector. The model breaks households down by income group. Essentially, a CGE model examines how producers react to changes in prices, for instance brought about by the imposition of a carbon tax, assuming certain 'elasticities of substitution', or the physical ability to change the mix of production inputs when prices change. International trade is not considered, but very basic revenue recycling, or reductions in taxes other than the carbon tax, is modelled.

Devarajan *et al* find that a carbon tax of R96 per tonne of CO_2eq emitted, at 2003 price levels, produces the desired 15% reduction in emissions. Revenue from the carbon tax comes to 9% of all tax revenue. If the emissions target is increased by a factor of around 1.7, from 15% to 25%, the carbon tax rate must increase by a factor of 2.5. In other words, it becomes more costly to reduce emissions, the higher the target. This is not surprising. Larger reductions mean turning increasingly to more costly mitigation options.

The model finds large reductions in steel production associated with the new tax, but growth in the hospitality, financial and agricultural sectors. Impacts on income are worst for the poor: while the average loss in household income associated with the introduction of the tax is 0.3%, it is around 1.0% for the poorest fifth of South Africans[96]. But this is because revenue recycling of a deliberately pro-poor nature is not modelled. The scope for this is obviously large. One comparison is interesting in this regard. Though the carbon tax would not *raise* government revenue by anything like 9% – the modelling keeps government tax revenues constant – *if* this were the case, the proposed basic income grant (BIG), which requires an increase of 12% in tax revenue[97], would become almost affordable.

Devarajan *et al* admit their findings under-estimate the benefits of the tax. For instance, environmental benefits other than emission reductions, such as cleaner air in places which currently have coal-fired power stations, and education and training opportunities brought about by new energy technologies, are not taken into account.

Devarajan *et al* implicitly take it as a given that carbon taxes are superior to emissions trading systems as a means to reducing emissions, if the aim is to promote equity and efficiency in the economy. The 2013 Treasury paper explains in some depth why this applies strongly in the case of South Africa. If government were to sell permits to emit, these would be bought by a very limited number of emitters, in particular Eskom, which could manipulate prices. The oligopolistic nature of the industries accounting for the bulk of emissions would make a dynamic emissions trading system unlikely[98].

Before Devarajan *et al*, the widely quoted *Long term mitigation scenarios* (LTMS) report of the Department of Environmental Affairs and Tourism[99], modelled the impact of a carbon tax. The finding was that a carbon tax could eliminate three-quarters of South Africa's above-target emissions in 2050, with the economic impacts being slightly pro-poor. This study assumed that much of the revenue from the tax would go towards subsidising

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95 429,907 from Department of Environmental Affairs (2019: xi) over the 466,122 covered by Figure 2 above.

96 Devarajan *et al*, 2009: 15.

97 African National Congress, 2020: 5.

98 National Treasury, 2013: 9.

99 This department became the DEA and the separate Department of Tourism in 2009.

renewable energy[100]. Alton *et al* (2012) and Van Heerden *et al* (2016), each a team of largely South African researchers, present modelling that confirms the workability of a carbon tax in the South African context. However, Van Heerden *et al* warn that planned exemptions and allowances with respect to the carbon tax, aimed at protecting certain industries, could be excessive if the desired emission reductions are to be achieved. They also argue that exemptions may not be the most efficient route. For instance, revenue recycling in the form of a reduction in the value-added tax could be better for the steel industry, than exemptions carrying the same cost.

7 South Africa's carbon tax and the underlying mitigation strategies

7.1 South Africa's international commitments to reducing emissions

Existing targets and how they are set

Virtually all countries in the world, and all countries which are members of the United Nations, are signatories of the United Nations Framework Convention on Climate Change (UNFCCC). South Africa ratified the convention in 1997. In line with the Paris Agreement of 2015, an agreement within the UNFCCC system, countries are required to be guided by their own 'nationally determined contribution' (NDC), a set of targets for reducing greenhouse gas emissions. The NDC that currently applies to South Africa is one submitted in 2016 to the UNFCCC by the Department of Environmental Affairs[101]. This is a short 11-page document.

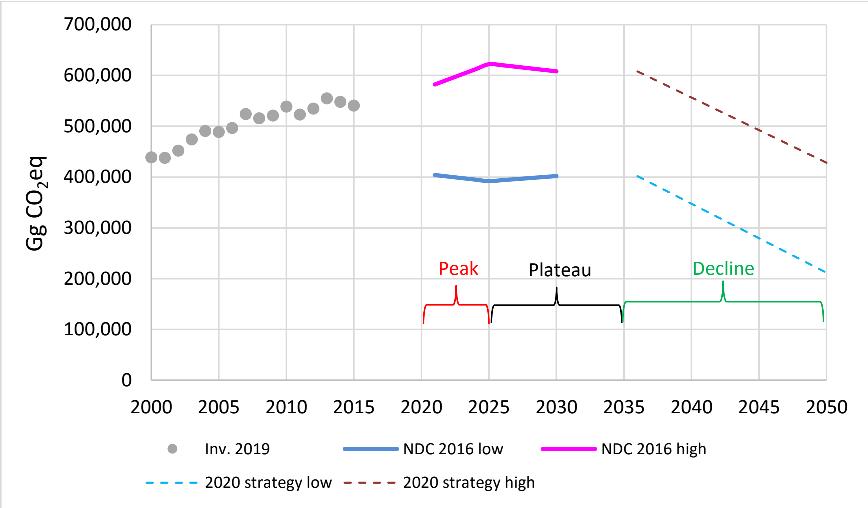
Importantly, the Paris Agreement includes no consequences for non-attainment of targets. Instead, it pays attention to transparency of information on emissions, and on social and international pressure on governments. Implicitly, the agreement relies on 'naming and shaming' countries which fail to take action[102].

A 'national communication' is a separate report each country is expected to submit to the UNFCCC, describing measures taken to reduce emissions and vulnerabilities to climate change. South Africa submitted national communications in 2003, 2011 and 2018. South Africa's 2018 national communication is a lengthy 370-page document[103].

South Africa's targets in its 2016 NDC, and some targets from outside that document, are reflected in Figure 6 below. There are historical annual figures available up to 2015. These point to annual CO_2-equivalent emissions rising from around 440,000 gigagrams ($GgCO_2e$) in 2000 to 540,000 gigagrams in 2015. This equals 540 million tonnes in 2015, or around 10 tonnes per annum per capita. Just carbon dioxide emissions would come to around 80% of total CO_2-equivalent emissions[104]. The 2016 NDC refers to a higher and a lower limit to the intended emissions in the years 2021 to 2030. These are reflected in Figure 6. The NDC also refers to a three-stage evolution consisting of a peak, a plateau and then a decline. The envisaged periods for these stages are also shown in the graph. Figures for the post-2035 period of decline are not given in the NDC (but are given in a 2020 strategy, discussed below). Moreover, the figures and stages do not tally very well. In particular, the lower plateau is lower than the historical trend, suggesting a decline *before* the plateau stage.

[100] Department of Environmental Affairs and Tourism, 2007: 20.
[101] Department of Environmental Affairs, 2015.
[102] Tingley and Tomz, 2020.
[103] Department of Environmental Affairs, 2018.
[104] Department of Environmental Affairs, 2011: 31.

Figure 6: South Africa's nationally determined contribution (NDC)



Sources: The vertical axis represents gigagrams of carbon dioxide-equivalent emissions – four non-CO_2 gases are considered – with land use taken into account. 'Inv. 2019' values are historical estimates published in the 2019 national inventory report (Department of Environmental Affairs, 2019). The 2021 to 2030 range of targets uses five-year total figures published in the 2016 NDC.

How do the targets in Figure 6 compare to regional targets put forward by the IPCC? There are no authoritative lists of desirable targets *per country* based on commonly used effort-sharing models[105]. However, the 2014 mitigation report of the IPCC does present targets per world region, using averages across scenarios from 32 models developed by various institutions, where the IPCC considers these models useful[106]. For the Middle East and Africa region, the 2014 report presents a peak in annual emissions being reached by 2020, and with the 2030 emissions being about 8% lower than those of 2010[107]. The comparable figures for rich countries are a peak in 2010 and a 32% reduction for 2010 to 2030. This assumes a global concentration of CO_2eq parts per million by 2100 of between 430 and 530, in other words roughly the 1.5 to 2.0 degrees Celsius limit. The 'NDC 2016 low' figures in Figure 6, which point to a 2010 to 2030 reduction of 20%, represent a contribution that is easily in excess of, and therefore better than, the IPCC's Middle East and Africa figures. On the other hand, 'NDC 2016 high' in Figure 6, pointing to a 20% *increase* for 2010 to 2030, is clearly not in line with the IPCC's trajectories.

NDC's are required to state why a country believes its intended contribution is fair and ambitious. South Africa's 2016 NDC argues that its contribution complies as 'South African experts' have established that a fair carbon budget for South Africa would exceed both of the two peak and plateau trajectories shown in Figure 6[108]. By implication, the commitments of the NDC are even more ambitious than what the experts have considered fair. South Africa is doing even more than it should.

Some searching leads to the technical background report that informs the NDC, produced by the Energy Research Centre at the University of Cape Town. That report points to a fair carbon budget for South Africa, in terms of the *total cumulative amount* during 2000 to

[105] Van den Berg *et al* (2019) describe systematically the methods one may wish to use for such an undertaking.

[106] Intergovernmental Panel on Climate Change, 2014: 1308.

[107] Intergovernmental Panel on Climate Change, 2014: 436.

[108] Department of Environmental Affairs, 2015: 8.

2049, being between 28 and 32 gigatonnes of CO_2-equivalent emissions ($GtCO_2eq$)[109]. Adding up the area in Figure 6 under the higher levels ('NDC 2016 high' and '2020 strategy high') produces a total of around 28 $GtCO_2eq$ for 2000 to 2049. Strictly speaking then, the least ambitious level of commitment in the NDC exactly matches what the experts considered the lowest likely emissions in a fair scenario. Thus, the least ambitious commitment is fair, or even bit unfair to South Africa.

How the estimates for the experts' fair contribution came about is illustrative how very sensitive such estimates are to the methodology used. An important 2011 report[110] reflects joint work by analysts from South Africa, India, China and Brazil, the South African researchers being those behind the 28 to 32 $GtCO_2eq$ range referred to above[111]. Each country's researchers employed a specific set of equity and sustainable development criteria in dividing up the global budget. Researchers from a specific country tended to employ an approach which produced a larger, or more lenient, carbon budget for their country. The contrast between the Indian and South African models is particularly striking. The Indian model provides a 2000 to 2049 budget for South Africa which is 71% lower than the budget the South African model produces for South Africa. And the South African model provides a budget for India which is 31% lower than the budget the Indian model produces for India[112]. The relatively lenient budget for South Africa, using the South African model, and appearing in the 2011 report, is the budget used in South Africa's 2016 NDC.

The key factor explaining why the Indian and South African models arrive at such different emissions budgets for South Africa, is that the South African model uses the human development index (HDI) of the UNDP[113] to predict that limited human capital will limit the speed with which South Africa will be able to mitigate its emissions[114]:

> We have assumed that in addition to wealth, broader human development is also an indicator of mitigation capability. We have used the UNDP's Human Development Index as an indicator of development on account of its wide acceptance, and applied this as a corrective factor to the GDP-based capacity indicator.

South Africa's HDI values, like the performance of South Africa's schools in the international testing systems, are exceptionally low for a middle income country. Within the 2011 report, South Africa's model is the only one of the four which uses a measure of human capital, and some searching suggests South Africa may be the only country which has approached its mitigation scenarios in this manner. The exact reasoning behind South Africa's use of a human capability indicator does not seem to have been made explicit, but it is not difficult to deduce. The increasing availability of good data on the quality of human capital, driven largely by the expansion of international testing programmes focussing on schools, has facilitated new models of economic growth. These models have brought to the fore what was previously not really appreciated: foundational language and numeracy skills in the population matter enormously for economic development, and school participation levels are often a poor indicator of these skills[115]. A rationale for a relatively slow emissions mitigation trajectory for South Africa could comprise the following two arguments. Firstly, a broad public understanding of the need for mitigation is necessary, especially considering

[109] Energy Research Centre, 2015. To illustrate, 28 $GtCO_2eq$ would be 28,000,000 $GgCO_2eq$.
[110] Winkler *et al*, 2011.
[111] Winkler, Letete and Marquard, 2013.
[112] Winkler *et al*, 2011: 16.
[113] United Nations Development Programme.
[114] Winkler *et al*, 2011: 80.
[115] Hanushek and Woessman, 2015: 20.

the democratic governance system. Secondly, the skills required to adopt new technologies need to be sufficiently widespread, given that not all such adoption occurs in a centralised manner, for instance through technological innovation in large power plants. Some of the adoption needs to occur in a more de-centralised manner, for instance in the case of solar energy generated in households and firms.

While the assumption that average levels of human capability in the population facilitate mitigation of emissions seems intuitively correct, there is little theoretical or empirical work on this, in particular in developing country contexts[116].

It is worth noting that the key reason why South Africa's HDI value for 2000, which is the one used for the emissions budget, was below the world average, was not educational weaknesses, but low life expectancy. This reflected two things. Firstly, HIV/AIDS had a devastating impact on life expectancy at the time. Secondly, education was measured using adult literacy rates and enrolments, both of which were and remain relatively high in the case of South Africa. Had education been measured using what are today widely used, and rather accurate, international test score results, South Africa's education levels would have emerged as being well below the world average[117]. Published adult literacy rates are not a good basis for comparing countries as they remain largely based on responses in household surveys to questions on whether the respondent considers himself or herself literate. Between 2000 and 2020, South Africa's HDI ranking barely changed, though life expectancy improved considerably[118]. To conclude, it can be argued that South Africa's human capital is indeed low, and perhaps this should be considered in calculating a fair mitigation contribution, but there are today better measures of human capital than the HDI. Above all, there are other measures which are better at capturing a key factor which could limit the country's capability to bring about mitigation, namely low levels of skills in the population[119].

That researchers from country X would tend to produce a partitioning of the global emissions budget which is generous for country X, is perhaps not surprising. Not only might researchers be more sympathetic to the constraints faced by their home country, even a researcher attempting to avoid a sympathy bias is likely to be accustomed to modelling issues pertinent to the home country, and this on its own to could lead to the patterns discussed above.

As the 2011 report makes clear, all the scenarios for the sharing of the burden of mitigation represent compromises on the part of developing countries, and are not truly fair. They are not truly fair if the standard is used that all people have in the past had an equal right to emit. Using this standard results in Annex I countries all having exceeded their historical carbon budgets, and developing countries mostly still enjoying some remaining right to emit in future[120]. This implies that the only truly fair distribution of the burden would be for developed countries to remove from the atmosphere a large portion of their past emissions.

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116 Bano *et al* (2018), which uses Pakistan data, is one of the very few studies which could be found.

117 Van der Berg, Gustafsson and Malindi, 2020; Pritchett, 2019. According to an Excel file accompanying UNESCO (2020), South Africa's human capability as reflected in internationally comparable test scores is considerably below that of China and Brazil, but also India.

118 UNDP, 2002: 149-152; UNDP, 2020: 343-346. While South Africa's 2000 HDI value is considerably worse than those of China and Brazil, it is considerably better than India's value. India would have 'benefitted' from this fact in the South African modelling, meaning the relatively low carbon budget allocated to India by the South African model would be driven by factors other than human capability.

119 See for instance the comparison in Liu and Fraumeni (2020).

120 Winkler *et al*, 2011: 9.

Currently, the technology for such a reversal does not exist, nor does it seem likely that the required technology would exist in the foreseeable future.

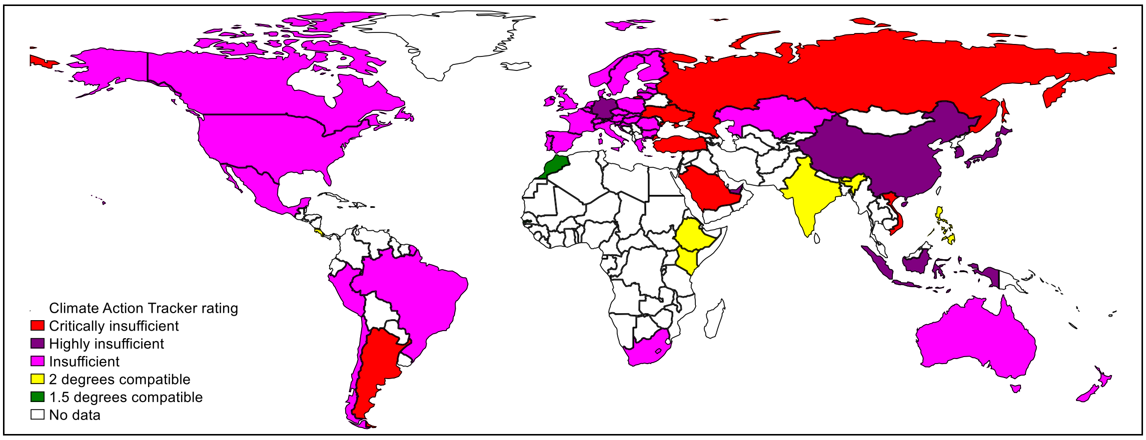
The adequacy and fairness of the targets

The 2016 NDC acknowledges that alternative emissions budgets calculated for South Africa are substantially lower than those calculated by the South African experts[121]. The obvious question is whether there is some process assessing whether, firstly, the NDCs from across the world add up to feasible global emissions pathways to 2100 and, secondly, whether there are countries which are clearly contributing less than their fair share of emissions mitigation, according to their NDCs. Article 14 of the Paris Agreement requires the world to take stock of commitments and actual mitigation efforts in 2023, and thereafter every five years. Moreover, in 2015 the UNFCCC released an initial assessment of the adequacy of NDCs existing at that point. That assessment concluded that the existing commitments, including commitments from developing countries described as conditional on external funding, produced global emissions totals for 2025 and 2030 which were higher than what was needed. Specifically, a decline in per capita emissions, but an increase in total emissions, between 1990 and 2030, was found. Thus, population growth was expected to play an important role. The trajectory to 2030 was found to be compatible with no more than a two degree warming by 2100 only if extremely ambitious cuts occurred beyond 2030[122].

A few research institutes have conducted assessments which, unlike the UNFCCC assessments so far, make judgements that are country-specific. One such initiative that stands out is Climate Action Tracker (CAT)[123]. CAT applies a variety of effort sharing models and then ranks a country's commitments along a six-level scale ranging, from 'Critically insufficient' to 'role model'. This information is updated at least annually per country. Ratings as they stood at the end of 2020 are illustrated in Figure 7 below. South Africa was the only country, among 35, which had not one but two ratings, given the rather different NDC levels shown in Figure 6[124]. The two ratings were 'Highly insufficient' and '2 degrees compatible'. The rating between these levels is 'Insufficient', and this is South Africa's rating in the map. Assuming a rating of 'Insufficient', there are 13 countries with a worse rating than South Africa, and 8 countries with a better rating. Viewed in this manner, South Africa emerges as a fairly typical country, but typical is 'insufficient'. The overall situation is thus not an encouraging one.

[121] Department of Environmental Affairs, 2015: 10.
[122] UNFCCC, 2015, 2016 2021.
[123] https://climateactiontracker.org.
[124] The European Union is counted as one of the 35.

Figure 7: Climate Action Tracker ratings of NDCs



Note: The countries CAT focusses on are said to represent around 70% of the world's population and 80% of emissions. The map reflects ratings as they stood at the end of 2020. EU is treated as one country in the map, except where CAT had a specific rating for an EU country, as in the case of Germany.
Source: Climate Action Tracker website (climateactiontracker.org), accessed February 2021.

The UNFCCC makes the NDCs of all countries easily accessible[125], allowing for some basic comparisons across countries. A look at a few other NDCs confirms that South Africa's is rather non-committal and unclear. For example, Brazil's NDC commits to a 2025 level of greenhouse gas emissions which would be 37% below the 2005 baseline level, the figure for 2030 being 43%. A relatively favourable commitment according to Figure 7 does not necessarily mean a reduction in emissions. India's NDC says that emissions per dollar of GDP will be 34% lower in 2030 than in 2005. However, if GDP growth of 5% a year is assumed for the years leading to 2030, which would be in line with growth experienced in 2005 to 2019, then India's economy would be so large in 2030 that the 34% reduction would translate to total emissions in 2030 which were 2.8 times *higher* than those in 2005.

The 2015 Paris Agreement added a third key document which countries should submit to the UNFCCC, apart from the two already discussed above, these being the 'national communication', whose role is largely to communicate a greenhouse gas emissions inventory, and the 'nationally determined commitment' (NDC). The additional document is a 'long-term low greenhouse gas emission development strategy'. South Africa submitted its first such strategy in 2020, and was one of just eight non-Annex I countries to do so by early 2021. This strategy includes targets beyond 2030 not included in the NDC: a targeted range of total CO_2eq emissions in 2050, of 212,000 Gt to 428,000 Gt[126]. This is reflected in Figure 6 above. These levels are 56% and 12% below the 2005 level respectively (2005 is used as the base year here as that is the base year used in the NDCs of several other countries). Had these 2050 targets been included in South Africa's 2016 NDC, the NDC may have been rated more favourably by CAT.

There is a South African target not mentioned above which has found its way into South Africa's 2019 to 2024 five-year plan, released in 2020, and which must have been included erroneously. That target refers to a '42% reduction in total GHG emissions by 2024'[127]. The baseline year for this is not specified, but whatever the baseline, it would be an extremely ambitious target probably unparalleled across the world, and not at all in line with South

[125] Page titled 'NDC registry (interim)' at https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx.
[126] Department of Environmental Affairs, 2020: 20.
[127] Department of Planning, Monitoring and Evaluation, 2020: 159.

Africa's NDC or the DEA strategy. The 42% reduction target appears to have originated in a 2009 media release by President Zuma[128] from shortly before the 2009 Copenhagen climate change conference. The 42% reduction is repeated in the 2011 White Paper on the national climate change response[129], but then did not re-appear in any major plan until the five-year plan released in 2020. Even when it was first announced, the 42% reduction commitment was controversial. It has been described as in conflict with the negotiation strategy South Africa had agreed upon with other African countries[130].

7.2 Policies on emission reduction mechanisms in general

The point of departure for this section is two documents submitted to the UNFCCC. First, the 2018 'national communication' is considered. This document includes 67 pages devoted to mitigation strategies. Secondly, the 88-page *South Africa's low-emission development strategy 2050*, released by the Department of Environmental Affairs and submitted to the UNFCCC, in terms of the Paris Agreement, is considered. There is considerable detail in these documents. However, much of the detail is references to other plans emanating from several government departments. There is less detail on synergy across plans, accomplishments to date, and financial and other risks. The approach taken in this section is to view the contents of the two documents, or their gaps, in terms of what this might mean for the experiences of ordinary South Africans.

By 2030, a third of coal-fired power generation existing in 2020 would be 'decommissioned' and ended[131]. Moreover, even where power stations continue functioning, on average 10% of emissions would not escape into the atmosphere, due to sequestration, or carbon capture and storage[132]. Many living in the vicinity of stations should notice an improvement in the quality of air, and their health. To illustrate the existing problem, around 20% of deaths around Mpumalanga's coal-fired power stations are deaths occurring earlier than normal because of pollution emitted by these stations[133].

'Embedded generation' of electricity is expected to become widespread. This occurs when households are paid, or receive a credit, for feeding power into the grid, from for instance solar panels. This will change the way people think about their electricity charges.

The growth in power generated from renewable resources, particularly wind and solar, will change the landscape in certain parts of the country. In particular, energy from wind is expected to generate up to 16 gigawatts (GW) of power by 2030, against 39 GW generated from all sources in 2020. Embedded generation is expected to reach 2 GW[134]. South Africans have become accustomed to 'loadshedding', resulting from unexpectedly low power generation at coal-fired stations. If interruptions remain in future, these are increasingly likely to be the result of the weather, for instance periods of little wind. To enable the shifts in electricity generation, many new jobs will be created in areas where there has been little training in the past, such as solar energy. Training institutions will have to widen their offerings to accommodate the new demand.

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[128] Page titled 'President JG Zuma to attend Climate Change talks in Copenhagen' and dated 6 December 2009, at https://www.gov.za/president-jg-zuma-attend-climate-change-talks-copenhagen (accessed January 2021).
[129] Government Notice 757 of 2011.
[130] Nhamo, 2012.
[131] Department of Environmental Affairs, 2020: 23.
[132] Department of Environmental Affairs, 2018: 251.
[133] Gray, 2019.
[134] Department of Environmental Affairs, 2020: 23-25.

The carbon tax will become a well-known and widely discussed policy matter. In particular, how revenue from the tax is used to advance equity is likely to be hotly debated. Firms and workers whose futures look uncertain as the carbon tax increases and shifts to different energy sources occur, are likely to want to keep the tax as low as possible.

As electricity prices rise, there will be strong incentives to find ways of reducing demand. Government hopes to reduce the demand for off-the-grid electricity of public buildings by 50% by 2030. More movement-sensitive lighting would be one way of achieving this. Such lighting is likely to become more common in open spaces too, meaning urban areas could become darker than they currently are at night[135]. While government schemes providing solar water heating to disadvantaged households which have never enjoyed water heating at home previously will not reduce emissions directly, it will prevent electricity from being used for this purpose in future. Government plans to add solar water heating to five million homes in poorer communities between 2020 and 2030. Home appliances are expected to become more efficient, using 30% less electricity than is currently the case by 2030. Households will be under pressure to purchase more efficient appliances, in particular as electricity prices rise. Labelling of the energy efficiency of appliances will become more prominent.

Public transport is expected to be improved, through for instance better ticketing systems, to encourage a shift away from private vehicles. By implication, the middle class is expected to use public transport to a greater degree. Where private vehicles are used, these will increasingly be electric or driven by biofuels. Filling stations will look different. For instance, many will have electric charging stations. There will be fewer trucks on the road as the 'road-to-rail' shift takes effect to lower the emissions associated with freight.

From an emissions perspective, two shifts are important when it comes to waste. On the one hand, organic waste easily leads to methane emissions. This can be avoided by composting. Secondly, if materials such as glass and plastic are recycled, and not left in a landfill, the emissions associated with producing new glass and plastic can be avoided. Better management of waste requires waste to be separated. It is envisaged that by 2023, 50% of households would be separating their waste. This can require additional work by households, and assumes the introduction of some form of penalty where waste is not separated[136].

The 2020 plan emphasises 'leading by example'[137]. Leaders in government, business and religious organisations will be encouraged to lower their own environmental footprints and to advocate for environmentally responsible behaviour. Politicians and business leaders could find using public transport a way of enhancing their status and support.

One matter that receives curiously little attention in the 2020 plan is nuclear power, despite the apparent need for nuclear power to grow considerably – the projections discussed in section 6.2 see nuclear being as large as 40% of current coal-generated power by 2050. This lack of detail needs to be understood against the controversies and corruption surrounding the nuclear sector in recent years. Projections published by government in 2007 envisaged nine new nuclear power stations by 2040[138]. The 2010 Integrated Resource Plan (IRP)[139] of the Department of Energy refers to nuclear power stations producing as much as 10 GW of

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135 Department of Environmental Affairs, 2020: xi, 24, 27.
136 Department of Environmental Affairs, 2020: 38.
137 Department of Environmental Affairs, 2020: 28.
138 Department of Environmental Affairs and Tourism, 2007: 7.
139 Department of Energy, 2010: 10.

power by 2020 – this would be around 25% of current coal-generated power and five times the generating capacity of the existing Koeberg nuclear power station. In 2014, it was announced that a deal had been concluded with Rosatom of Russia to build nuclear power stations capable of producing 10 GW of power. However, this was controversial and resulted in the resignation of the minister of finance due to the lack of transparency around the deal, and the apparently elevated cost of around one trillion Rand[140]. The 2014 mitigations report suggests the cost should be around a quarter of this for the period up to 2050, but it is difficult to say whether definitions of cost are comparable[141]. A 2016 response by the Department of Energy to Parliament reveals the locations for five new nuclear power plants, all on the coasts of the Western Cape, Northern Cape and Eastern Cape[142]. In 2017, a South African court ruled the Rosatom deal to be unconstitutional, and government consequently withdrew from it. The 2019 IRP of the Department of Energy indicates that the expansion of nuclear energy in South Africa will occur, but that planning for it must yet begin in earnest[143].

7.3 The 2019 Carbon Tax Act

As already explained in section 6.1, dealing with South Africa's greenhouse gas inventory, the 2019 Carbon Tax Act[144] covers taxation across three major greenhouse gases – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – and three sectors, or activities: fuel combustion; fugitive emissions; and industrial processes. What exactly these categories entail was discussed to some extent in the earlier section. The scope of the Act is around 86% of all gross emissions of the country. Clearly, the Act has the potential to make a very large impact on South Africa's emissions.

According to the Act, the tax is paid by anyone who 'conducts an activity in the Republic resulting in greenhouse gas emissions above the threshold'. This translates into international aviation and international maritime transport[145] being excluded. The thresholds, which vary by IPCC-defined activity, are relatively high for many industries where emissions could be low. For instance, a hypothetical textile factory which used diesel-driven generators would need to exceed 10,000 kW of electricity consumption to be subject to the tax. This level of electricity consumption would be achieved if around 100,000 sewing machines were operating at once. But this is very hypothetical, as the carbon tax can be levied 'upstream' on refineries, even if they are not burning the fuel, so indirectly even households with a petrol-driven car will pay the carbon tax[146].

Where emissions are likely to be high, such as a mine or a cement factory, there is no threshold, meaning all emitters would be subject to the tax. The focus is on targeting large emitters, though the structure of the Act would make it easy to broaden the tax base in future to cover smaller emitters too.

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140 Weiss and Rumer, 2019: 11.

141 R106 and 2,052,714 from Department of Environmental Affairs (2014: 106, 114) used.

142 Department of Energy, 2016. Dunefontein, Bantamsklip and Schulpfontein in the Western Cape; Thyspunt in the Eastern Cape; and Brazil in the Northern Cape.

143 Department of Energy, 2019: 47.

144 Act 15 of 2019.

145 The wording in the Act is 'international aviation and maritime transport', so it seems unclear whether the domestic maritime transport would be included. Domestic maritime transport would be extremely limited in the case of South Africa.

146 This type of upstream taxation is not explicitly covered by the Act, though as will be explained below, such taxation is already occurring under the label of a 'carbon tax'.

How the Act calculates the tax payable is described in detail in Appendix 2, using the hypothetical example of a coal-fired power station. There are three distinct steps involved. Firstly, the emissions associated with the burning of one tonne of a specific fuel are found. The Act provides tables for 74 different fuels, the values in these tables being universal and determined by the IPCC. If an emitter burns more than one type of fuel, emissions factors per tonne for each fuel burnt are found.

Secondly, the allowances that might reduce the tax liability of the emitter are calculated. These allowances facilitate various government goals. One is the gradual phasing in of the tax, and hence the avoidance of undesirable shocks in the economy, through large allowances in the initial years. Moreover, allowances apply if an emitter exports goods or services to other countries with a lower carbon tax. The competitiveness of the local producer is thus protected. Allowances also apply if the emitter invests in technological innovation or ‘offsets’ its own emissions by investing in emission reductions in, for instance, the surrounding community. In the example of the power station, total allowances are estimated to come to 76%, meaning only 24% of the initially calculated tax would be paid. By far the largest allowance relates to the phasing in the of the tax.

Thirdly, the tax payable is calculated. The tonnes of fuel burnt in a year are multiplied by the relevant emissions factors to produce tonnes of carbon dioxide-equivalent emissions, and this is then multiplied by the tax in Rand applied to each tonne of emissions. The Act sets the latter at R120, and specifies it should increase with inflation. The allowances already discussed are applied. Two further reductions in the tax are also calculated. If the emitter practices carbon sequestration, or carbon capture and storage (CCS), whereby carbon is for instance buried underground after the emissions have occurred, the emitter would not be taxed for the emissions. Sequestration is not yet implemented in South Africa, and has been successful in very few countries, but the Act clearly anticipates this in future. Lastly, tax on the burning of petrol and diesel is removed if the tax has already been paid upstream, on behalf of the emitter, by a refinery.

To provide an idea of how small the tax in the initial years would be, it is estimated that it would raise the price of electricity by just 4%.

Treasury’s *Budget Review* reports since 2019 provide key details on the implementation of the Act. Implementation started in June 2019. The tax rate has increased in line with the Act, reaching R134 from January 2021[147].

Treasury’s reports suggest that actual revenue from the tax has been lower than anticipated. While ‘carbon tax’ has featured as a new line in the tax revenue tables since 2019, actual revenue appears for the first time for 2020/21, and this was R630m, against an expected R1.75bn[148]. Some of the shortfall would be due to the pandemic, but the pandemic would not explain all of it. The actual amount of R630m comes to just 0.05% of all tax revenue. To compare, if the carbon tax were fully implemented in 2021, in other words if R134 were collected per tonne of emissions, within the tax’s scope of 85% of all emissions, then revenue from the carbon tax would come to around 3.7% of all tax revenue[149].

[147] 2021 *Budget Review,* p. 50.
[148] 2021 *Budget Review*, p. 211.
[149] 2021/22 tax revenue expected before the pandemic was used.

It appears as if the carbon tax revenue that exists currently is virtually all from new carbon taxes on petrol and diesel[150]. By 2021 the applicable rate had reached 8 cents per litre of petrol and 9 cents per litre of diesel[151]. This translates into a carbon tax, or Rands per tonne of CO_2eq, of R19 and R24 for petrol and diesel respectively. Reporting on the implementation of the Act has been criticised as lacking in transparency. In particular, it has been argued that it should be made clear that large emitters, such as Eskom, will effectively pay no new carbon tax until 2023, when Phase 2 of the implementation of the Act begins[152].

8 Conclusion

The conclusion is organised according to the three questions posed in the introduction. The first question was as follows:

Do South Africa's existing commitments to reduce greenhouse gas emissions represent an equitable sharing of this responsibility across the countries of the world?

It is often argued that an ideal and truly equitable approach would be to allocate everyone who has lived since the start of the industrial revolution an equal 'carbon budget', or amount of permissible emissions, such that global warming would be kept within a reasonable limit, for instance the 1.5 degrees Celsius increase set in the 2015 Paris Agreement. Using this logic, the general pattern is that developed countries have already exceeded their budgets and that developing countries have not used up all their budget yet. Rich countries arguably have a duty to remove emissions from the atmosphere, to a point where they reach their budgets. Thereafter, they should emit no more. Unfortunately, the technology for this does not exist, and is probably unlikely to exist in the foreseeable future. Thus, a truly fair solution is not possible. Developing countries will not be in a position to access their fair share of the global emissions budget, because much of this has already been used up by developed countries.

What aggravates the unfairness, is that since the point at which the effect of greenhouse gases on climate became indisputable, arguably around 1990, developed countries have not done enough to reduce their emissions, which today are around twice as high as in developing countries, in per capita terms. While emissions per capita in rich countries have declined a bit, the total emissions embodied in what people in rich countries consume have increased by around 5% between 1990 and 2020. This is explained by two factors: more importing of goods with a high carbon footprint from developing countries, and growth in the population. These two factors are not dealt with explicitly in the Paris Agreement, though arguably they should be.

Due to growth in emissions in developing countries, which cover 83% of the world's population, the contribution to global annual emissions by rich countries, the so-called 'Annex I' group of countries, has dropped to 30%. This underscores the importance of slowing down the growth in emissions in developing countries, which in part must be facilitated through financing, by developed countries, of emission reduction initiatives in developing countries. This is made very clear in the Paris Agreement. South Africa is likely to

[150] The ratio of the carbon tax rate to the general fuel levy rate for 2020/21 on p. 49 of the 2021 *Budget Review,* at 53, is very close to the ratio of *expected* revenue from the carbon tax to revenue from the fuel levy on p. 211, giving 48. Of course, the fact that *actual* revenue from the carbon tax in 2020/21 is so much lower than expected suggests that there were collection problems which were not experienced with respect to the general fuel levy.

[151] 2021 *Budget Review*, p. 49.

[152] De Wet and Daniel, 2020.

require considerable support insofar as the country's emissions, in per capita terms, are fairly high for a developing country, meaning extensive shifts to cleaner production and power generation technologies will be necessary.

It could be argued that the United Nations should calculate an emissions budget for every country in the world, and that each country should be obliged not to exceed its budget. This would not be fair in the sense that developed countries have already exceeded their budgets. But at least in theory, an arrangement with a degree of fairness, which would include obligations by Annex I countries to assist other countries, is conceivable. However, the United Nations has not been able to translate this theory into reality, given technical complexities and, above all, political disagreements. As an alternative, the Paris Agreement allows countries to make their own global calculations of a fair sharing of the burden of mitigation, and then to set their national targets in accordance with this. Obviously, this makes the risk that the global budget will be exceeded a virtual certainty, but there is some fairness in terms of the process followed.

South Africa worked together with Brazil, China and India in the analytical exercise. While the work was collaborative, with countries learning from each other, the intention was that each team of country experts would produce its own model. Key details of this modelling work have been published. South Africa's experts decided to use a measure of human capability in their modelling, the assumption being that the lower this is, the more generous the national carbon budget should be, because human capability is important for realising a reduction in emissions. This approach strongly favours South Africa, whose measures of human capital are low, according to various international indicators. The fairness of this approach could be questioned by other countries. Exactly how human capability affects the capacity to reduce emissions, and how this capability is measured, are important questions for all countries. There has been little research on this to date.

South Africa's international commitments are in line with the work of the South African experts.

Not much has been done to assess the fairness of existing national commitments, and the degree to which the sum of all these commitments exceed the global limit that must be respected to avoid catastrophic climate change. The Paris Agreement requires the UN to conduct such an assessment only in 2023. The Climate Action Tracker research group has undertaken a relatively comprehensive modelling exercise, using the existing national commitments. Their finding for South Africa is that its commitments are 'insufficient', but this is also the finding for most other countries. Only eight countries have favourable ratings, including Morocco, India, Philippines, Ethiopia and Kenya. Notably, no major developed country is rated any better than 'insufficient'. Clearly, if most countries are insufficient or worse, this is not fair to future generations. And fairness across countries will have to be achieved by more ambitious targets and actions across the great majority of countries, and in particular developed countries, which at the very least need to set an example[153].

The second question reads as follows:

[153] The response to the first question draws mainly from sections 3 and 7.1.

How does South Africa's carbon tax compare to similar taxes in other countries, and what might this mean for its effectiveness, taking into consideration that carbon taxes are commonly part of a broader package of emission reduction policies?

South Africa's carbon tax is considered exemplary. When the legislation behind it was passed, in 2019, knowledge about how to optimally design a carbon tax had come a long way. In particular, the benefits of a carbon tax, as opposed to the alternative market-based mechanism, an emissions trading system (ETS), had become clear. This explains why developing countries, which have only recently begun focussing on emission reduction, have relied on carbon taxes, with one big exception: China, which has focussed mainly on ETSs. Yet few developing countries have reached the point where they have legislated a carbon tax policy. Apart from South Africa, there were just four other countries, all major Latin American economies. Apart from being among the earliest adopters of a carbon tax, at least among developing countries, South Africa's tax has a particularly wide scope. It covers around 85% of all greenhouse gas emissions. This reflects an efficient approach to reducing emissions, in other words an approach which will minimise adjustment costs. A carbon tax with a wide scope is easily more efficient than a complex patchwork of different policies. Moreover, South Africa's tax is particularly good at targeting firms which emit, such as Eskom, as opposed to more upstream entities, such as coal mines. This too enhances the efficiency of the tax. A system of allowances in the 2019 Carbon Tax Act makes it possible to start with a low tax burden, and then to increase it gradually, something which is necessary to facilitate adjustments in the economy.

While the scope of South Africa's carbon tax means there would be less reliance on other mitigation strategies, other complementary policies are envisaged. This has been communicated to the UNFCCC. For example, a 'road-to-rail' initiative will improve the rail network and shift freight from trucks to rail. More forest coverage is envisaged. Standards to make buildings more energy efficient are planned. However, these complementary policies seem for now mostly official intentions. They need to be incorporated into the country's plans and budgets to a greater extent.

One difficult area is nuclear energy. While a considerable expansion in nuclear is still seen as necessary, by government but also by key analysts, major initiatives were halted as a result of corruption. This means nuclear expansion is significantly behind schedule[154].

The third question reads as follows:

Is it possible, in part through its carbon tax, for South Africa to attain its emission reduction targets?

The answer is yes, and despite the enormous shifts that would be necessary in South Africa's economy and society, the economic costs are surprisingly low. Indeed, the process offers new opportunities for tackling South Africa's social ills of poverty and inequality. This is not wishful thinking, but based on the findings of at least five rigorous studies conducted by various analysts[155], South African and foreign, in the last decade or so. To illustrate, a World Bank study focussing on South Africa, which admits to under-stating the benefits of a carbon tax, finds that reducing emissions by 15% through the tax, while holding government revenue constant, would reduce the average income of South Africans by 0.3%. The poor

[154] The response to the second question draws mainly from sections 5 and 7.2.

[155] The 2014 mitigations report discussed in section 6.2 and the four studies that explicitly include a carbon tax discussed in section 6.3.

would be affected most: for the poorest one-fifth of South Africans the loss would come to 1.0%. These are small effects, and subsidies to the poor to facilitate the transition could be dealt with by increasing total government revenue a bit, which would not be difficult given that the carbon tax would generate revenue equalling around 9% of total revenue. In fact, the revenue from the carbon tax introduces new opportunities to *reduce* income inequalities.

With regard to jobs, the evidence is also encouraging. The 2014 'mitigations report' finds a net addition of 300,000 jobs to the labour market within ten years as a result of emission reductions, mostly in the agricultural, forestry and waste sectors. A separate Council for Scientific and Industrial Research (CSIR) study expects jobs in just the energy sector to rise by 60,000 between now and 2050, given the labour-intensiveness of setting up and running renewable energy facilities.

An important next step for South Africa would be to establish an official expected trajectory of carbon tax rates going forward. This does not seem to exist yet, at least not in the public domain. This would be necessary to facilitate planning by government and the private sector. There are several possible trajectories, depending on the extent to which emission cuts are delayed or brought forward. The key parameters are as follows. In 2021, the carbon tax rate was R134 per tonne of CO_2-equivalent emissions. At this rate, the tax should account for 3.7% of total government revenue. However, currently this figure stands at a tiny 0.05%, as large exemptions and a process of phasing in currently apply. Revenue from the tax would have to reach 9% of all revenue for an emission reduction of 15% to be achieved. A reduction of 15%, relative to current emissions, is envisaged by around 2035, at the earliest, and around 2045, at the latest. Moving from 0.05% of total revenue currently to 9% of total revenue in 2045 implies an increase of 0.4 percentage points a year, assuming a linear trajectory. This is rough, but it provides a sense of the magnitudes. What is also assumed is that other policies would have equivalent impacts on the 15% of emissions not covered by the tax, largely in the agricultural and waste sectors.

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Appendix 1: Climate change in the South African grades 10 to 12 curriculum

The following details are from the Curriculum and Policy Statement (CAPS) documents of the Department of Basic Education.

	Grade 10	*Grade 11*	*Grade 12*
Geography	'Heating of the atmosphere', 'greenhouse effect' and 'global warming'.	'Desertification', 'resources and sustainability', and 'energy sources'.	
Economics		'Globalisation' and 'environmental deterioration', and options for sustainable development.	'Environmental sustainability' and the role of international agreements.
Life sciences		'Human impact on the environment', 'current crises for human survival' and 'problems to be solved within the next generation'. Also 'the sixth extinction'.	
Agricultural sciences	'Long-term weather predictions' and 'agricultural adaptation measures'.		
History			'Environmental movements'.
Religious studies		The relationship between religions and the environment, also the 'greenhouse effect'.	
Life orientation	'Social and environmental responsibility'.	'Climate change' introduced.	

Appendix 2: How the Carbon Tax Act calculates the tax payable

The next three tables are intended to demonstrate the workings of the Act. For demonstration purposes, the taxpayer is the Arnot power station in Mpumalanga Province, a medium-sized coal-fired station within Eskom. In reality, the taxpayer would not be this power station, but Eskom as a whole. However, zooming in on one power station makes the numbers a bit easier to grasp.

Table 1 uses only figures from the Act, and would thus apply to any power station using sub-butiminous coal, the most commonly used coal in Eskom's power plants[156]. The aim of Table 1 is to produce the bottom line value, the emissions associated with the combustion of one tonne of the fuel, in this case sub-butiminous coal. This is known as an emissions factor. Numbers in bold are from tables appended to the Act. Non-bold numbers are all derived from the bold numbers. The global warming potential (GWP) values reflect by how much a kilogram of, say, methane (CH_4) must be inflated to reflect the global warming potential of CO_2. Clearly, a kilogram of methane is considered to do 23 times as much harm as a kilogram

[156] Department of Environmental Affairs, 2019: 84.

of carbon dioxide. The kilograms of each greenhouse gas typically emitted in producing one terajoule (TJ) of energy appear in the second line of Table 1[157]. One terajoule is 278 megawatt hours of electricity. Each value in line 1 is multiplied by the value in line 2 to produce the CO_2-equivalent kilograms of each gas. The total kilograms of emissions in CO_2eq terms produced when a terajoule of energy is produced using sub-bituminous coal, is 96,567. The terajoules of energy produced by a tonne of sub-bituminous coal is 0.0192. Multiplying 96,567 by 0.0192 produces 1,854 kg of CO_2eq emissions produced by one tonne of sub-bituminous coal. Why would burning one tonne of coal produce more than a tonne of emissions? This is because carbon from the coal would combine with oxygen from the atmosphere to produce CO_2.

The values in bold in Table 1 are not specific to South Africa and can be found in the IPCC documents[158].

What does the calorific value of 0.0192 mean? It translates into around 2.5 kg of coal being used to produce 14 kWh of electricity, this being roughly the average daily household consumption in Cape Town[159]. The average household indirectly combusts 2.5 kg of electricity a day. It should be emphasised that this average hides vast inequalities in electricity use across the households of this city, or any South African city.

Table 1: Calculation of CO_2eq per tonne of fuel

	CO_2	CH_4	N_2O	All gases
Global warming potential (GWP)	**1**	**23**	**296**	
kg per TJ (sub-bituminous coal)	**96,100**	**1.0**	**1.5**	
Above two multiplied	96,100	23	444	96,567
Bituminous coal calorific value (CV) in TJ / tonne				**0.0192**
CO_2eq emissions in kg of 1 tonne of sub-bituminous coal				1,854

The values in the second line of Table 1, and the CV value, all change if the focus switches to another fuel. The relevant table in the Act lists 74 different fuels. A taxpayer can of course be liable for taxes with respect to more than one fuel.

An important part of the Act is a set of tax 'allowances' designed largely to diminish the initial impact of the tax, and allow for gradual increases as allowances are reduced. In the fuel combustion category, there are five types of allowances, which are reflected in the first five rows of Table 2. The values for the five allowances can differ in line with 168 different 'activities'. The activity reflected in Table 2 is 'electricity and heat production'. Section 7 of the Act reduces the tax payable by 60%. Though it is not made explicit in the Act, this basic allowance is what gives government room to scale up revenues from the tax, through the reduction of this large allowance. The basic allowance ranges from 100% for farming and residential, meaning no tax is paid, to 0% for 'cement production' and 'iron and steel production', suggesting that these industries would immediately be liable to pay the full tax, in the absence of other allowances. There would be no phase-in for these industries in other words.

[157] Figures for the general category 'Other bituminous coal' in the Act were used.

[158] Intergovernmental Panel on Climate Change, 2006a: 8.5; Intergovernmental Panel on Climate Change, 2006b: 1.18, 2.16; Intergovernmental Panel on Climate Change, 2001: 47.

[159] Calculated from Table 1 of Sustainable Energy Africa (2015).

Section 10 of the Act introduces a 'trade exposure allowance', which can go as high as 10%. It would apply, for instance, in the case of a power generator which exported power to another country which did not have a carbon tax. This allowance is assumed to be zero for the Arnot power station. Section 11 allowances are applied if a taxpayer can prove a performance gain in the form of a recent reduction in emissions, presumably arising out of some innovation. It is assumed to be 1.0% in the case of Arnot, and can never be higher than 5%. According to section 12 of the Act, an allowance of 10% applies if the taxpayer participates in 'the carbon budget system', or some scheme where annual maximum emissions limits apply. Arnot is given 10% here. Power station reports on the Eskom website do display limits in terms of the maximum tonnes of coal which may be combusted in one month[160]. According to these reports, actual fuel combustion always falls within these limits. Section 13 specifies that an emitter 'must' invest in offsets, in line with rules set by 'the Minister', who in the case of the Carbon Tax Act is always the minister of finance. Offsets could take the form of projects financed by Arnot and aimed at reducing emissions in the surrounding communities. It was assumed that the full 10% would apply. The sum of the five allowances is 76% – the carbon tax calculated for Arnot would be discounted by 76%.

Table 2: Allowances in the Carbon Tax Act

Category of allowance	Allowance
Section 7 basic allowance	60%
Section 10 trade exposure allowance (max. is 10%)	0%
Section 11 performance allowance (max. is 5%)	1.0%
Section 12 carbon budget participation (max. is 5%)	5%
Section 13 offsets allowance (max. is 10%)	10%
Sum of the above	76%
Maximum allowance for power plants	90%

Table 3 calculates the carbon tax to be paid by Arnot. The formula, and its symbols, are as reflected in the Act. The emissions at Arnot associated with the combustion of sub-bituminous coal would be the 1,854 of Table 1 multiplied by six million tonnes of coal used in 2019 – the latter is roughly what is obtained if the 'monthly emissions report' of Arnot for the twelve months of 2019 is examined. The result would be 11,124,518 tonnes of CO_2eq emissions. The small difference between this figure and the slightly higher figure seen in Table 3 is due to the fact that two other fuels were taken into account. One is 'heavy fuel oil', used in coal-fired boilers to stabilise flames and manage combustion, producing 188,215 tonnes of emissions[161]. The other is diesel in 'mobile combustion', meaning vehicles such as trucks. This produces an estimated 4,288 CO_2eq of emissions[162]. These other fuels required calculations similar to those used for coal. Sequestrated emissions in the Act are a reference to carbon capture and storage (CCS), whereby emissions are captured after combustion but before entering the atmosphere, and then compressed and stored somewhere, usually underground. CCS is not practiced in South Africa, and has been successfully implemented in very few countries. The Act is clearly anticipating CCS as a future possibility in South Africa. Allowances of 76% are from Table 2. Emissions from petrol or diesel are entered as 'D' in Table 3, even after having been dealt with under 'E'. This is to allow for an adjustment which completely removes the tax on petrol and diesel, as the carbon tax on these fuels is administered elsewhere, specifically on the manufacturers of the fuels. Taxing the same fuel

[160] The 'monthly emissions reports' for Arnot can be found at https://www.eskom.co.za/Whatweredoing/AirQuality/Pages/ArnotEmissions.aspx.

[161] The Arnot emissions reports were used to arrive at an estimate of 60,000 tonnes of heavy fuel oil a year.

[162] Based on Eskom (2020).

twice is thus avoided. The tax per tonne of CO_2eq emissions was set at R120 in 2019. The Act specifies that above-inflation increases to this tax rate should occur annually, beyond 2019. The bottom line is that the tax payable by Arnot would be around R325 million, obtained using the formula in the last row of Table 3.

Table 3 deals only with the activity of fuel combustion. Strictly speaking, Arnot would also have to declare emissions within the activity 'fugitive emissions', as power stations do have such emissions, though they only come to around 0.02% of overall emissions[163].

Table 3: Annual carbon tax for a medium-sized power station

E: Total emissions in tonnes	11,317,022
S: Sequestrated emissions	0
C: Allowances	76%
D: Petrol and diesel related greenhouse gas emissions	4,288
M: Sum of sections 7, 12, 13 allowances	75%
R: Tax per tonne of emissions in Rand	120
Tax in Rand <{([E - S) × (1 - C)] – [D × (1 - M)]}> × R	325,664,410

Using the relationship between tonnes of emissions and energy generated discussed previously, the tax seen in Table 3 implies an increase in Eskom's price of one kWh of electricity from 103 cents to 107 cents, or a 4% increase[164]. Moreover, dividing the tax payable in Table 3 by the total emissions gives R28 per tonne of emissions. This is what the R120 becomes after the various reductions.

[163] Eskom, 2020: 2.
[164] Eskom, 2019: 4.