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Article

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Review

BRICS and the Race to Net-Zero Emissions by 2050: Is COVID-19 a Barrier or an Opportunity?

Lazarus Chapungu *, Godwell Nhamo, David Chikodzi and Malebajoa Anicia Maoela

Exxaro Chair in Climate and Sustainability Transitions, University of South Africa, Preller St, Muckleneuk, Pretoria 0002, South Africa

* Correspondence: tchapul@unisa.ac.za

Abstract: The emerging economies of Brazil, Russia, India, China and South Africa (BRICS) have significant influence on the global economic and environmental trajectories. They have carbon intensive economic systems, which contribute significantly to total global greenhouse gas (GHG) emissions, leading to climate change. However, BRICS have joined the race to net-zero emissions by 2050 in the quest for a climate neutral and sustainable global economy. The journey, however, is not without challenges and opportunities. The proliferation of the coronavirus disease 2019 (COVID-19) had mixed reactions from scientists regarding its implications on net-zero trajectories. While statistical data show a correlation between COVID-19 and a decrease in total emissions, it is envisaged that COVID-19 compromised the efforts to develop carbon neutral economies. Hence, there is still need for more scientific examination of COVID-19's impact on net-zero ambitions, especially in the emerging economies. This study focuses on India and South Africa's trajectories. Statistical analysis of secondary data from authentic interactive web-based dashboards for COVID-19 data repositories, namely Our World in Data and Climate Action Tracker was performed in conjunction with the document analysis approach following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology. Some of the COVID-19 challenges as indicated by the results of the study include curtailing the technology transfer staircase in the energy sector, retaliatory emissions for recovery and resource diversion. The opportunities presented by COVID-19 in the quest for carbon neutrality include behavioural changes in investment, production and consumption patterns with a focus on low carbon options. Governments and stakeholders need to focus on addressing the barriers whilst riding on the opportunities presented by the pandemic to achieve net-zero emissions by 2050.

Keywords: BRICS; climate change; COVID-19; GHGs; India; net-zero emissions; South Africa

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1. Introduction

Climate change is one of the most adverse contemporary challenges faced by humanity [1] and there is scientific consensus that the problem is driven by the emissions of greenhouse gases (GHGs) into the atmosphere [2–4]. The emission of GHGs and the consequent increase in their concentration in the atmosphere since 1900, breed catastrophic and irreversible changes in the climate system, including frequent and extreme weather events [5]. Average global temperatures are projected to increase beyond 3.5 °C if the current emission trajectories perpetuate under the business-as-usual model [6]. In view of the devastations associated with this temperature rise, the need to decarbonise global economies cannot be overemphasized. In 2015, at the United Nations Framework Convention on Climate Change (UNFCCC) Paris Conference, commitments to reduce GHGs emissions were made by parties. If fully implemented, the commitments will limit temperature increase to 2.7 °C by 2100, which is still calamitous to humanity [1]. To achieve carbon

neutrality and avoid climate change related catastrophism, the world is required to do more [7].

Brazil, Russia, India, China and South Africa (BRICS) are among the countries with the greatest contribution of emissions into the atmosphere. Their emissions have been increasing consistently over the past decades [8]. However, following the 2015 Paris agreement and the 26th conference of parties (COP 26) in 2021, the BRICS committed to contribute to the reduction in emissions and have joined the race to net-zero by 2050.

As countries were grappling with the modalities of pursuing the net-zero emission trajectories, in 2020 COVID-19 pandemic took centre stage, spreading quickly across the world, killing millions of people and bringing economies to a halt [9,10]. Consequently, attention to macro-economic and environmental challenges was diverted to the pandemic. COVID-19 dictated the implementation of a slew of aggressive strategies to combat the pandemic, including stringent lockdowns, mask wearing and social distancing [11–13]. These measures disrupted economic, social and physical activities across the world. The lockdowns meant partial or full-scale temporary closure of GHGs-emitting industries, including other important components along their value chains. While a slew of COVID-19-driven negative consequences were observed, Naderipour et al. [14] submitted that there was a notable improvement in the quality of air due to reduced emissions of GHGs, principally CO_2, as a consequence of the lockdown and other restrictive measures. For example, emissions from the transport sector were reduced as intercity travel was suspended. The work-from-home policy meant individuals who drove to work had their carbon footprint reduced [15,16].

Ray et al [17], stated that much had been studied with regards to the impact of COVID-19 related activities on carbon monoxide, but there is still a paucity of detailed studies on the effects on CO_2 emissions. However, Khan et al. [18] observed a considerable decrease in carbon emissions in the US, India, Italy, Spain and Brazil among other high CO_2 emitters. Similarly, Lamb et al. [19] indicated that there was a decrease in global carbon emissions in 2020 and this coincided with the period of COVID-19 induced lockdowns, which saw several polluting industries reduce their carbon footprint. Le Quéré et al. [20] found a 17% decrease in daily CO_2 emissions between 2019 and 2020 comparing emissions that occurred from January to April of both years.

Various scientific studies also confirmed that the emissions of GHGs generally decreased during the COVID-19 period following the implementation of lockdown measures which reduced the intensity of carbon emitting activities [12,20,21]. In view of the current global call and commitment towards the net-zero emissions trajectory, any decrease in GHGs emissions is applaudable and the drivers of such a decrease require scrutiny to enhance and entrench the perpetuity of the low carbon trajectory. However, with COVID-19, some scholars aver that its impact on emissions is temporary and may have variously affected the pathways towards net-zero emissions by 2050 [10,22–24]. Given the significance of the BRICS countries in the GHGs emissions-climate change matrix, as well as their prominent trends and the dynamics of the COVID-19 pandemic, an analysis of the impact of COVID-19 on their net-zero trajectories is worthy of scientific attention. It is in view of this need for scientific attention that this study examines India and South Africa's net-zero emissions trajectories in the context of COVID-19, with a focus on whether the pandemic enhanced or derailed their pathways towards net-zero emissions by 2050.

2. Literature Review

2.1. Climate Change and the Global Net-Zero Trajectory

Global agreements such as the Kyoto Protocol, Paris Agreement and the Glasgow Pact have so far not deterred the increase in global warming that leads to increasing surface temperatures [7]. The temperatures continue to increase as emissions of GHGs, principally carbon dioxide (CO_2), continue to increase. Carbon dioxide has exceeded a record

high stage, posing a deluge of climate-induced challenges and fast-tracking global warming [25]. In recent years, the impacts of climate change have become more intense and devastating, with billions of dollars being lost in the form of infrastructural damage and loss of life annually [26]. In response to the GHGs-emissions-driven catastrophic climatic vagaries and the projected consequences related to the changing climate, the world's major economies, as well as developing countries, including the BRICS have pledged to cut their GHGs emissions to achieve net-zero emissions by around the mid-21st century. China, which is one of the leading emitters, aims to achieve carbon neutrality by 2060 and reach its carbon emissions peak before 2030 [7,27]. The US has indicated its commitment through a return to the Paris Agreement, pledging to drive their economy towards a net-zero trajectory [28]. Europe, on the other hand, has the ambition to become the first region to achieve net-zero emissions by 2050 [27].

To achieve carbon neutrality and stabilise the fast warming globe, as well as mitigate the related impacts, the net-zero emission pledges must be backed by ambitious actions [7]. In general, the 1.5 °C limit is the tipping point beyond which the risk of phenomena associated with climate change, such as extreme droughts, wildfires and floods, will exponentially increase [29]. Thus, the need for ambitious actions to avoid going beyond the tipping point cannot be overemphasised. In the face of these catastrophes and in the interest of achieving sustainable development, all countries must be tied down to the objective of achieving net-zero emissions. Net-zero emissions imply a negative carbon economy, which involves a focus on carbon capture rather than emission [30].

Emissions reduction has been the key preoccupation for climate-concerned policymakers even during the ravaging COVID-19 pandemic. Some governments have actually tied climate net-zero goals to COVID-19 bailout packages [7]. The biggest challenge now is figuring out how to achieve net-zero emissions in the face of other pressing issues such as COVID-19. Does COVID-19 impose further burdens, or can it enhance the pathway to net-zero? The most notable pathway towards a net-zero trajectory is the recruitment of renewable energy sources and replacement of fossil fuels. Carbon neutrality can only be achieved through investment into renewable energy [31].

2.2. The COVID-19 Pandemic and Global Emissions

The COVID-19 outbreak was declared a global pandemic by the World Health Organisation on the 11 March 2020 [17]. The virus spread rapidly across the national borders resulting in 81.5 million cases by December 2020 in 223 countries [32]. Suddenly, the pandemic plunged the globe into a season of "industry silence" owing to a cocktail of measures put in place to combat its proliferation [33]. The rate at which the virus was spreading necessitated the implementation of some aggressive strategies that included social distancing, face mask wearing and stringent lockdowns that saw people working remotely from home [34,35]. The COVID-19 induced lockdowns precipitated complete and partial economic shutdowns characterised by low industrial production, quiet cities, low traffic volume and low social and physical activity [17]. The immediate effect of this scenario was that 30% of the world's population was disproportionately suddenly affected [36] and 80% of businesses were plunged into disarray [9,37], leading to a worldwide economic recession. The energy sector was not spared as oil prices suddenly dropped steeply [34].

The proliferation of COVID-19 and the subsequent restrictive measures and lockdowns led to a temporary period of improved environmental quality, specifically air quality due to a significant reduction in the emissions of GHGs into the atmosphere [14]. The strict procedures associated with lockdowns and temporary shutdowns during COVID-19 restricted movements of masses domestically, and individuals internationally and directly affected the transport sector, with a significant cut in energy demands [34,38]. The lockdown measures instituted across the world transformed operational modalities at workplaces and lifestyles [39]. Energy consumption patterns were altered due to the changes in lifestyles and work modalities, with most individuals turning to e-working, e-

schooling and e-shopping [39]. There was a decline in energy demand but electric power gained prominence due to increased use from home in online education and entertainment, among several other lockdown related uses [17]. There were also COVID-19 related disturbances on the energy equilibrium market which was indicated by price fluctuations [34].

Several studies have indicated that the COVID-19 pandemic has reduced the pace of economic growth and production activities, resulting in the drop in energy demand [9,10,40,41]. This affected the deployment of renewable energy technologies [34]. The estimated drop in energy demand was 3.8% during the first wave of the pandemic, 6% during the second wave towards the end of 2020 [42]. At global scale, the decline in energy demand precipitated a financial crisis of a magnitude six to eight times greater than the one experienced in 2008 [42]. It is predicted that the blow to the energy sector as a consequence of COVID-19 is set to be the largest in the past seven decades [17,34]. While the energy demand drop appears simple and small, the spill-over ramifications are detrimental to the demand and supply balance [43].

Despite the energy demand challenges posed by COVID-19, [44] argue that this is an opportunity for countries to develop and institute strategies to reduce GHGs emissions and achieve the net-zero ambitions by 2050. The COVID-19 period presents the perfect time to examine non-lockdown measures strategies implementation to cut the burgeoning trend of global CO_2 emissions and deal with the climate change phenomenon in the long run [44]. From this argument, it can be said that COVID-19 provided an opportunity for countries to realise that they can reduce their carbon footprint and improve environmental quality if there is a cut in the levels of fossil fuel use. With further examination of the available options that contributed to the decline in emissions during the pandemic period, the pathway towards net-zero emissions by 2050 becomes feasible. However, knowledge about the influence of the non-lockdown measures implemented during the COVID-19 period on GHGs emissions and improved environmental quality is still limited. In the absence of such knowledge and consequently lack of action, there is a high likelihood of GHGs emissions bouncing back to the pre-COVID-19 trends [20] or even worse, due to the compensatory propensity of companies.

2.3. The BRICS GHG Emissions and COVID-19

The BRICS countries contribute significantly to the net global emissions of GHGs [1]. However, the block has made significant efforts to prioritise climate action, using its position in the G20 to shove the grouping to implement deep rooted reforms on climate change related issues [45]. Several futuristic commitments have been proposed to try and reduce the rate of GHGs emissions. The bloc has a reaffirmed position to cooperate to fight against climate change based on the principles of equity and "common but differentiated responsibilities and respective capabilities" [46]. Given this background, each country has determined its emissions trajectories, anchored on national priorities and abilities. However, the advent of COVID-19 has, in one way or another disrupted the planned pathways and altered the emission patterns. For all the BRICS countries but Brazil, there has been a general decrease in emissions during the COVID-19 period. China, the most populated country in the world is a major player in the climate change matrix. It is the greatest importer of energy and impacts greatly on decarbonisation efforts. Its emissions increased significantly by 230% between 1990 and 2012 and over the same period, its share of global GHGs emissions rose to 22.44% from 9.48% [26]. The Chinese energy sector only, contributed about 19.98% of the total global emissions of GHGs in 2012 [26].

Russia operates a carbon intensive economy with huge exports of fossil fuels, especially natural gas [1]. However, its emissions decreased by 18% between 1990 and 2012 while its global carbon share was reduced to 4.73% from 9.18% over the same period [47]. The most significant driver of emissions in Russia is energy production and use. In comparison with the energy sector, the contribution of agriculture, industry and waste does

not contribute significantly to the total emissions. For example, the three sectors contributed about 0.54% of total world GHG emissions in 2012 [26]. The emergence of COVID-19 changed the emissions trajectory in the short term, but the nature of policy response may have long-term repercussions on the mid-century net-zero emissions trajectory. In 2020, during the peak of the COVID-19 pandemic CO_2 emissions amounted to 1.48 billion metric tons and this was a marked decrease compared to the 2019 emissions [47].

India is one of the world's most populated countries and has an economy growing faster than the other BRICS countries [1]. India's absolute emissions have increased over time and are regarded as contributing significantly to the net global emissions into the atmosphere. However, the capita emissions of India are very low. It imports huge amounts of energy. Its emissions increased by 140.18% between 1990 and 2012 and its share of GHGs emissions at the global scale have doubled [1]. Agriculture is an important contributor to the total emissions in India, having increased by 31.08% between 1990 and 2012 [26]. The sector has contributed about 1.52% of the global net emissions in the same period. Industry and waste sectors contributed 0.53% of the total global emissions of GHGs between 1990 and 2012. The proliferation of the COVID-19 pandemic across India invited nationwide lockdowns that resulted in restricted air, surface and water transportation as well as reduced industrial activity [48]. This directly and indirectly interrupted the existing emission dynamics and projected emission pathways. India's emissions fell by 15% in March 2020 and is predicted to have dropped further by 30% in April of the same year [49]).

Brazil is also regarded as an important player in the global climate change matrix. However, its emission trajectories are different from the other BRICS countries in that, its land use, land-use change and forestry (LULUCF) sector contributes significantly to the net GHGs emissions [1] compared with the other sectors. However, Brazil has made great strides in dealing with emissions from LULUCF during the 1990–2012 period although its net emissions increased by 13.48% during the same period. The energy and agriculture sectors also contribute to the net emissions quite significantly. For example, between 1990 and 2012, the emissions from these sectors increased by 120.65%, contributing 1.09% of the global emissions [26]. Industry and waste together contributed 0.22% of the emissions in 2012. Brazil had a unique emissions trend during the COVID-19 pandemic, with a 9.5 percent increase whilst the globe experienced a 7% decrease [50]. Per capita emissions also increased due to deforestation and low occupancy rate in the aviation sector [51]. However, some sectors, such as the aviation sector, experienced a decrease of about 63% due to COVID-19 related lockdowns. Approximately 4.7 million metric tons of emissions were abated in the aviation sector in 2020 [51].

South Africa is one of the main global contributors to GHG emissions through its energy system which is dominated by coal use. In 2018, it was the world's 14th greatest emitter [52]. In 2012, it released about 464 million metric tons of emissions. Between 1990 and 2012, the country's emissions increased by 44% [53]. However, the current electricity plan aims a major shift towards the use of gas and renewable energy sources. While coal would be relied on for a few more coming decades, no new plants are on the cards after 2030 and most of their capacity is to be closed by 2050 [52]. South Africa's net-zero emissions trajectory is based on a "peak, plateau and decline" strategy which entails an increase in emissions between 2020 and 2025, and stable emissions for about a decade followed by a decline in absolute terms [54]. This trajectory has already been interrupted by the proliferation of the COVID-19 pandemic. The pandemic saw a significant decrease in carbon emissions due to lockdown measures which resulted in reduced transport emissions and industrial activities [55].

3. Materials and Methods

3.1. Study Areas

The study covers two of the BRICS countries, India and South Africa. The BRICS countries have seen an increase in popularity as developing markets sharing substantial common characteristics including less developed but fast growing economies, burgeoning populations, influential governments, and the inclination towards embracing global markets [56]. What is of interest is that both India and South Africa have more than 70% of their electricity grid supplies from coal. Figure 1 shows the location of the study countries.

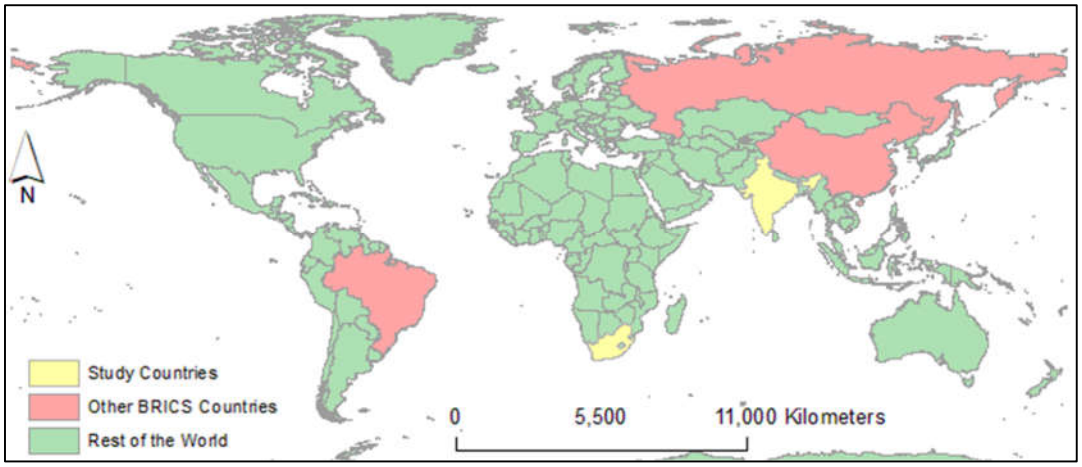

Figure 1. Study Countries.

India is located in the northern hemisphere between 8°4′ N and 37°6′ N and 68°7′ E to 97°25′ E. It is the seventh largest country by size in the world, covering about 3.3 million spare kilometres (km²). The country is characterised by a fast-growing population with a resultant high carbon footprint. It has high absolute emissions, making it one of the most carbon emitting countries in the world. However, the per capita emissions are generally low. The International Energy Agency [57] postulated that India is the third largest producer and importer of coal as well as the third largest importer of oil. About 71% of its electricity is generated from coal. The country is regarded as an energy intensive economy. However, per capita energy consumption (ton of oil equivalent) is below the world average, standing at 0.64 against the world average of 1.90 and OECD's per capita consumption of 4.19. India's electricity consumption per capita (760) is lower than the global average (2972). About 25% of the population has no access to electricity whilst more than 6 million people depend on biomass [58]).

India strongly depends on energy imports and over time, the imports have been increasing. This makes it sensitive to fluctuations in the global energy markets. The development of low carbon energy sources could benefit India in reducing energy access gap and increasing energy security [1]. India is committed to climate action and has pledged to contribute towards the net-zero trajectory. It has substantial strategies focused on increasing the share of renewables in its energy matrix. The country was hit by the COVID-19 pandemic, resulting in the implementation of various lockdown measures which contributed to the 2019–2020 decline in carbon emissions. It remains veiled in obscurity whether the pandemic presents a barrier or an opportunity for the country to be grounded on a decarbonisation trajectory.

South Africa is located in the southern most parts of Africa with a long coastline distending for about 3000 km. It stretches from 22° S to 35° S latitude and from 17° E to 33° E longitude, covering a surface area of 1,219,602 km² [59]. The country is the world's 14th highest emitter of GHGs in the world and the highest emitter of carbon dioxide in Africa relying on coal to power more than 80% of its energy requirements [60]. In 2019, South Africa released 471.6 million metric tons of carbon into the atmosphere. Its reliance on coal

influences its environmental policies, allowing coal fired power plants 10 times more nitrogen oxide emissions than China and Japan. Generally, the policies and climate action are not consistent with the dictates of the Paris Agreement's 1.5 °C temperature limit [26]. However, with moderate improvements, South Africa can achieve this target. With the current policies, the emissions trajectory for 2030 would decrease by approximately 5–6% below 2010 levels [59]. The country was hit by the COVID-19 pandemic resulting in the death of about 99,970 people by the 29 March 2022 [61].

3.2. Data Compilation

3.2.1. Document Analysis Protocol and Screening

The document analysis approach was used as one of the key strategies of inquiry in this study. It included a systematic literature review approach in which the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used for screening [62] as shown in Figure 2. The PRISMA methodology was adopted owing to its comprehensiveness and wider applicability. The PRISMA has been used in various studies across disciplines [62–65]. The protocol comprised search terms, databases and literature selection criteria. The study used word schemes such as: COVID-19 AND "net-zero by 2050" OR "net-zero by 2050", Net-zero emissions AND "COVID-19 in South Africa", as well as Net-zero emissions AND "COVID-19 in India". Six major e-databases (Scopus, Web of Science, PubMed, ScienceDirect, JSTOR and ERIC) were initially considered to achieve a multidisciplinary scope of the literature on the impact of COVID-19 on the net-zero trajectories of South Africa and India. However, only three (Scopus, ScienceDirect and Web of Science) were successfully used due to access challenges, and were considered sufficient given that some previous reviews considered even less than three databases [63,66]. The terms used in the search process were examined in the study text, titles, keywords or abstract in journals in the period between 2015 and 2022.

The literature was screened using the PRISMA as shown in Figure 2. The approach sets out steps followed in carrying out a review that generates trustworthy data.

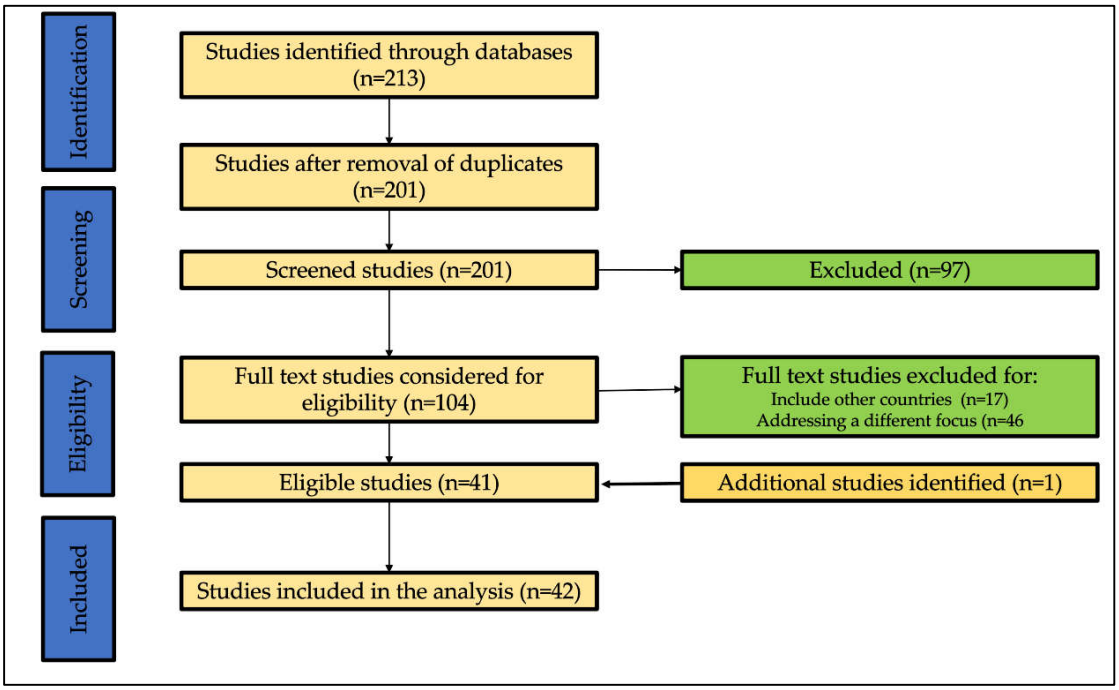

Figure 2. The PRISMA process adopted in screening literature for analysis.

The PRISMA methodology was adopted owing to its comprehensiveness and wider applicability. It has been used in various studies across disciplines [62,67,68].

The terms used in the search process were examined in the study titles, abstract and keywords in the period between 2020 and 2022. The study used the following word schemes and Boolean operators for searching in the Scopus database:

TITLE-ABS-KEY ((COVID-19) AND (net-zero emissions OR GHGs OR CO_2 OR Methan OR Nitrogen Oxide) AND (South Africa OR India OR BRICS))

The searched literature initially yielded 213 studies from which editorials, conference proceedings, reviews and overlapping studies were removed. After this stage, 201 studies were left. The remaining 201 studies were subjected to further screening, matching with the literature selection criteria. A total of 97 research articles were screened out at this stage, leaving the analysis with 104 research articles. The residual 104 studies were subjected to thorough analysis, looking at the abstract, full text and conclusion content. At this stage, 63 studies were removed for not addressing the focus of the research and including other countries in the analysis, leaving 41 eligible studies. Another research paper was identified at this stage and added to give a total of 42 research articles that were considered for the synthesis and analysis.

3.2.2. Data Sources and Analysis

Variable data on carbon emissions, COVID-19 restrictions, and low carbon technologies were obtained from interactive digital platforms namely: Our World in Data (www.ourworldindata.org) (accessed on 16 June 2022) and Climate Action tracker (www.climateactiontracker.org) (accessed on 16 June 2022).

The variable data were subjected to statistical analysis to ascertain the trends and dynamics. The stringency index was also determined based on the Oxford Government Response Tracker (OxCGRT) methodology. The stringency index data is found at https://ourworldindata.org/metrics-explained-covid19-stringency-index (accessed on 16 June 2022). The index uses nine metrics as follows: "School closures, workplace closures, cancellation of public events, restriction on public gatherings, closure of public transport, Stay-at-home requirements, public information campaigns, restrictions on internal movements and international travel controls" [69]. The index is calculated as the mean score of the nine metrics. A higher score indicates a stricter response. Equation (1) shows how the index is calculated:

$$index = \frac{1}{k}\sum_{j=1}^{k} I_j \quad (1)$$

where k is the number of component indicators in an *index* and Ij is the sub-index score for an individual indicator. The presentation and discussion of the key findings will now be presented in the following section.

4. Results

4.1. GHGs Emissions and COVID-19 Interruptions

Results show that both South Africa and India have joined the race to net-zero emissions by 2050 as indicated in their national plans and commitments to the existing global pacts such as the Paris Agreement. India has pledged to reduce its emissions by 33–35% by the year 2030, compared to 2005 levels whilst South Africa has pledged to reduce its emissions intensity from 2030 going forward. Since the late 1800s, GHG emissions for both countries have been increasing (Figure 3). The increase has largely been driven by the use of fossil fuels, principally coal, in the energy sector. However, the increasing trend for both countries was periodically interrupted by phases of decline associated with global crises, including the 1973 oil crisis, 1979 oil crisis, 1997 Asian financial crisis and the 2008/09 global financial crisis. With the advent of COVID-19 by the end of 2019, a decrease in GHGs emissions in both countries is observed.

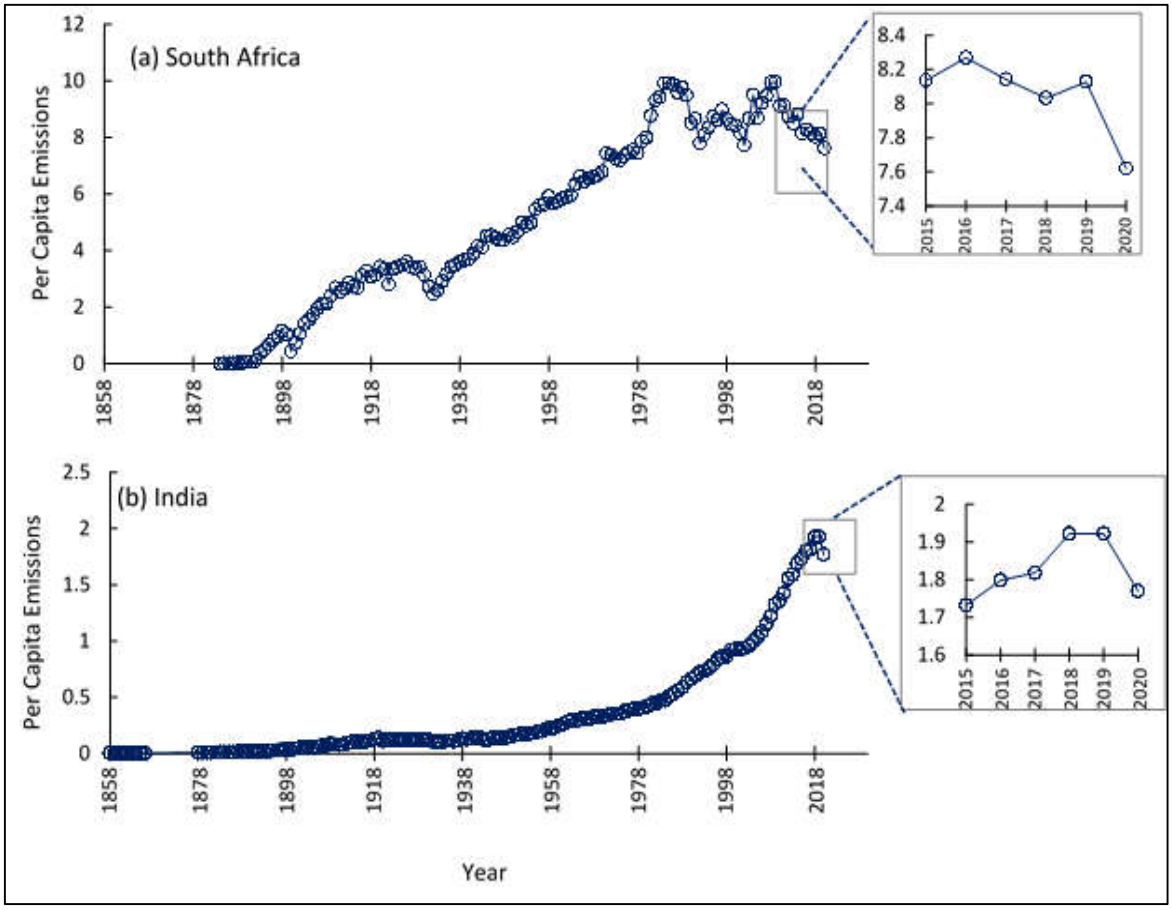

Figure 3. Per capita GHG emissions for South Africa (**a**) and India (**b**) showing a COVID-19 related decrease from 2019 to 2020.

As shown in Figure 3, there is a sharp decline in GHGs emissions in both South Africa and India in 2020, coinciding with the period of COVID-19. For South Africa in particular, a sharp decline can be observed since 2016, due to the faltering economy. The decline got steeper in 2019–-2020 as a result of COVID-19 related lockdowns and industrial slowdowns. GHGs emissions for India also declined in 2020 as a result of COVID-19 related lockdowns. The declines are attributed to the stringency of lockdown measures as depicted by the level, type and length of periods of confinement or operational restrictions [67]. However, it is worth noting that the average per capita emissions do not reflect spatial differences in emissions. For example, it was observed that Indian cities showed different responses with regards to lockdown measures; Delhi, Hyderabad, Kolkata and Mumbai experienced varied carbon emission rates per annum. For Delhi, GHGs emission differences between 2019 and 2020 were estimated at −8.6 to−177 g C m−2 yr−1, while in Mumbai, the emissions over the same period actually increased to 95.7 g C m−2 yr−1. Between 2016 and 2019, Indian cities had different carbon emissions trajectories, but the year 2020 saw a general decline in emissions at national level.

The GHGs emissions profiles for both countries since the emergence of COVID-19 reflects a relationship between operational restrictions, depicted by the stringency index, and the amount of emissions emitted per capita. South Africa's average stringency index during the period was higher than 50% (Figure 4), depicting a tightened operational environment where companies were literally shut down, movement was restricted and traffic was reduced. This consequently resulted in low emissions along the production value chains. For India, during the 2020–2021 period, the average stringency index ranged between 50% and 100% (Figure 3), indicating that industries were almost shut down with limited production and emissions occurring during this period.

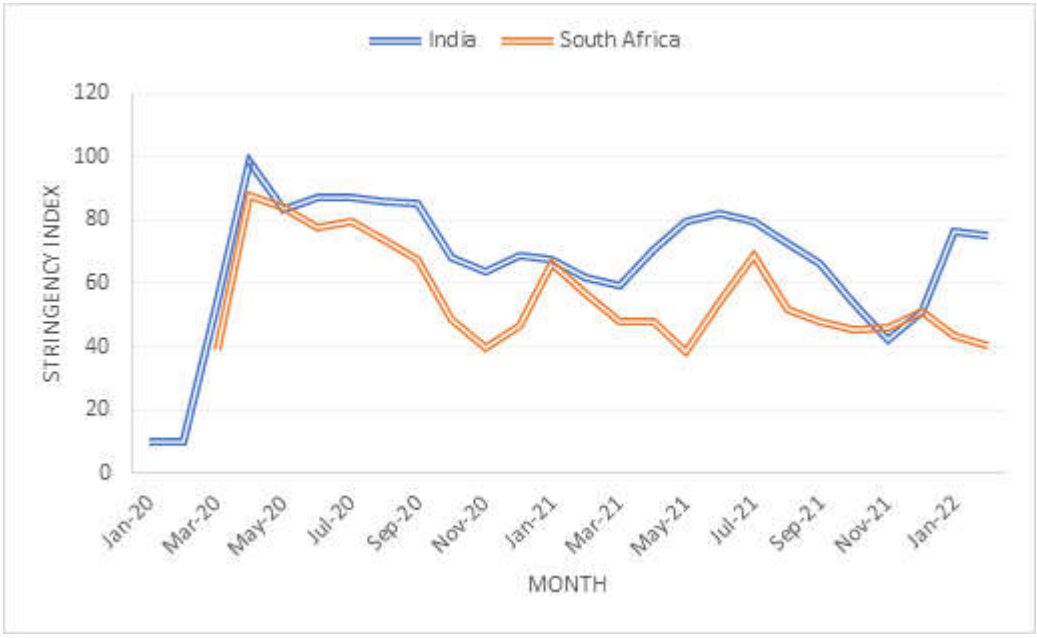

Figure 4. Monthly COVID 19 related restrictions stringency indices for South Africa and India.

As shown in Figure 4, in May 2020, during the first COVID-19 wave, the level of stringency was high for both countries. India reached 100 percent stringency at that point, meaning that schools were closed, people were working from home, all systems of industrial production were halted and various activities were on hold, reducing production based emissions. For India, the stringency remained above 60 until October 2021. This had implications on both production and consumption-based emissions. Although stringency for South Africa was lower than that of India, it remained above 40 percent until January 2022, with implications on emissions of GHGs. A stringency index more than 40% for South Africa was associated with a near shutdown of production processes as employees were not permitted to go to work except for those regarded as providing essential services. This introduced the working-from-home narrative, which reduced emissions from the transport sector and related entities.

It was also observed that the COVID-19 induced work-from-home culture contributed significantly to the reduction in transport-related emissions (Figure 5). Residential emissions remained lower than other sectors, but they picked during periods of hard lockdown as shown in Figure 5.

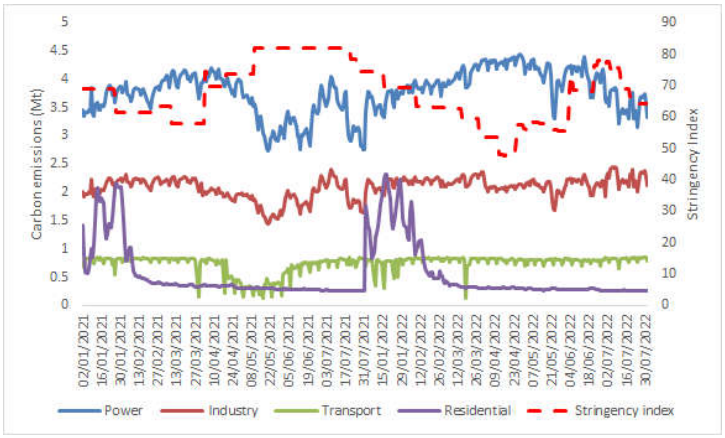

Figure 5. Sector-specific daily carbon emissions. The dotted red line shows the stringency index. The left vertical axis shows the carbon emissions while the right vertical axis represents stringency index.

Figure 6 shows that an increase in the stringency index was associated with a decrease in power/energy-induced emissions. The same applies to industry-based emissions although the rate of change in industrial emissions was low. The COVID-19 pandemic introduced restrictions which largely controlled emissions intensity for India. The work-from-home culture was also introduced, contributing to the reduction in transport related emissions. Figure 6 shows the relationship between stringency index and CO_2 emissions in India.

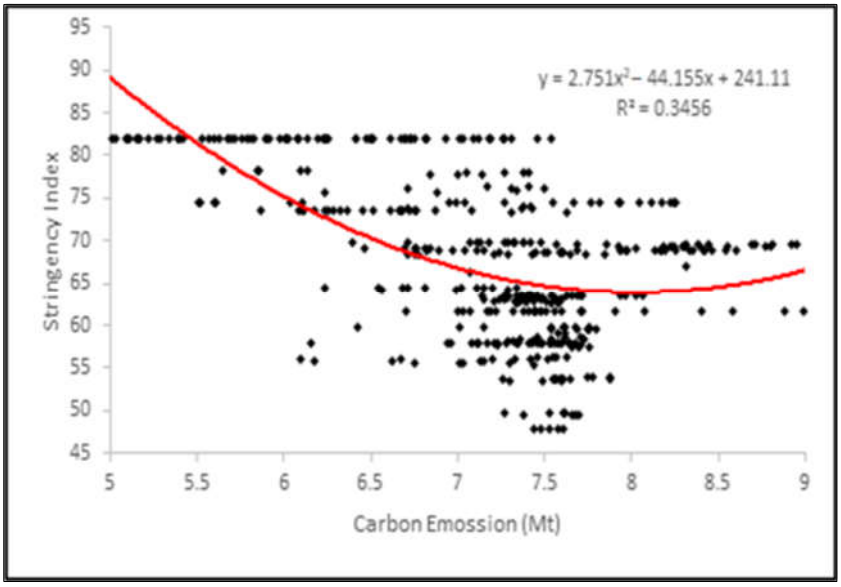

Figure 6. The relationship between stringency index and Co2 emissions in India.

The 2019–2021 emissions profiles for India and South Africa due the COVID-19 restrictive measures and related spill-over effects are inclined to the net-zero emission ambitions. What the world wants is a decline in emissions and this is what COVID-19 has offered, albeit under difficult circumstances. To that extent, COVID-19 presents an opportunity for the two countries, and the world at large to learn and adjust to low-emitting behaviours.

4.2. Behavioural Changes Induced by COVID-19

Several behavioural changes with the potential to instigate a low emissions trajectory towards 2050 have been reported in literature, as a result of the COVID-19 pandemic. Figure 7 shows how COVID-19 induced behavioural change is linked to the net-zero emissions by 2050 pathway in both India and South Africa.

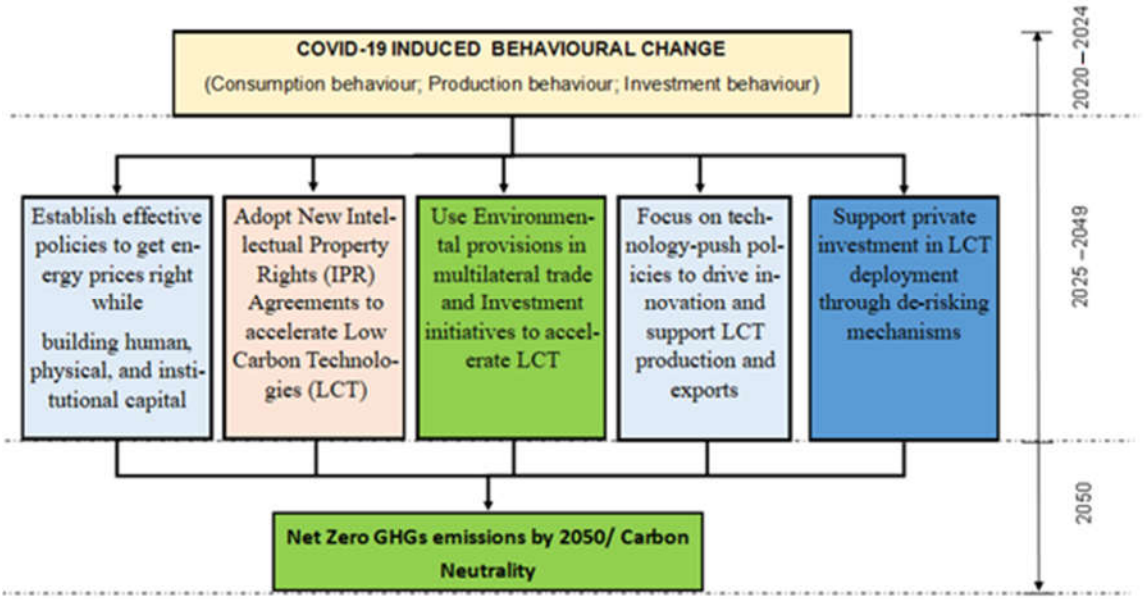

Figure 7. The COVID-19 induced behaviour changes enabling the net-zero emissions by 2050 pathways for India and South Africa. Source, Authors, Data from secondary data sources.

As shown in Figure 7, COVID-19 has changed the consumption, production and investment at individual, household, institutional, and cooperative levels, as well as at national level [68,70]. The behaviours have become more inclined to the net-zero emissions pathways. For example, several companies, institutions and educational facilities in India and South Africa have been investing in online facilities to conduct business. COVID-19 has proven that it is possible to host international conferences and do business online with minimal carbon footprint by using virtual platforms. About 88% of small and medium enterprises (SMEs) in South Africa have indicated their need to move to digital platforms [71] . The Indian e-commerce is projected to grow by 84% due to COVID-19 [72] . A shift to online business has cut the carbon footprint associated with air travel, road transport, and energy use, among other carbon intensive activities, providing an opportunity for countries to pursue the net zero emissions ambitions.

Although there is no scientific evidence linking climate change to the COVID-19 pandemic, scientists acknowledge that pandemics can worsen the vulnerability of societies and economies to climate-change-related phenomena [73–76] such as heat waves, cyclones, floods and droughts, among others. Whilst South Africa's post COVID-19 recovery strategies have been regarded as being carbon intensive, efforts are underway to pursue policies and investments that are carbon neutral. There has been a keen drive towards the adoption of new intellectual property rights agreements to accelerate low carbon technologies in both India and South Africa.

4.3. COVID-19 Induced Barriers to the Net-Zero Pathway

The impact of the COVID-19 pandemic on India and South Africa's net-zero emissions trajectory remains veiled in obscurity. However, restrictions implemented during the peak of the COVID-19 pandemic contributed to a decrease in carbon emissions in both countries, with South Africa's per capita emissions reducing to approximately 6.95 tons per annum from around 8.1 in 2019. India on the other hand had a reduction from approximately 1.93 to about 1.75. If such a trajectory is to be maintained, the 2050 net-zero targets would be easily achieved. However, in view of the effects of the lockdown measures on economic productivity, this trajectory is unsustainable and practically impossible.

It emerged from this study that COVID-19 presented several challenges to the net-zero emissions by 2050 targets in both India and South Africa. Table 1 shows the number

of studies that have mentioned the specific challenges posed by COVID-19 on net-zero efforts or low carbon development.

Table 1. Selected studies highlighting challenges posed by COVID-19 on net-zero by 2050 emissions.

Challenge/barrier	Example studies	Number of studies in This analysis
Inhibit the implementation of low carbon technologies	[12,23,74]	22
Create emission appetite	[22,40,77–80]	8
Inhibit technology transfer	[12,80–84]	40
Reduced the pace of adoption of renewable energy technologies	[9,33,34,76,85]	39
Reduced information flow on renewable energy and net-zero trajectories.	[24,86]	6
Affected net-zero emissions related policy monitoring and implementation.	[23,40,87]	4

As shown in Table 1, several challenges have been mentioned by studies showing that COVID-19 has impeded the implementation of net-zero policies and strategies in South Africa and India. This includes challenges such as the inhibition of the implementation of low carbon technologies. It has emerged that low carbon technologies are at risk because of the pandemic. This is a result of a shift in government focus to provide funding or a conducive environment for their adoption. India and South Africa have experienced enormous economic and social challenges. In India, for example, COVID-19-induced lockdown implemented in March 2020 coincided with the peak of the harvesting period of Rabi crops in the north-west, resulting in massive losses to farmers [80]. This also affected the whole agricultural value chain including the transport systems. Demand and supply chains in the manufacturing sector were disrupted. About 12 million Indians were pushed into poverty, 122 million lost their jobs in April 2020 and 80% of the people in urban centres experienced a decline in their earnings whilst mental illness amongst 16,500 people was reported to be aggravated by COVID-19 related socio-economic pressures [88]. In South Africa, about 8700 cases of domestic and gender-based violence were reported between 26 March 2020 and 3 April 2020 [89]. This was postulated to have been aggravated by the COVID-19 pandemic. The economy contracted by 7% and approximately 1.5 million jobs were lost at the instigation of COVID-19 [89]. Poverty and social inequalities were further exacerbated by the pandemic [90].

The above-mentioned COVID-19 induced problems resulting in a shift in government priorities. India and South Africa were preoccupied with instituting strict containment measures to abate the proliferation of COVID-19. In addition, more resources and attention were directed towards the health crisis. Another priority area was the adoption of support policies and strategies to minimise job losses, restore incomes, support value chains and re-energise production capacity. The two BRICS countries focused on addressing the immediate alarming challenges posed by the pandemic at the expense of focusing on the net-zero emissions trajectory. Consequently, investment in low carbon initiatives was affected and the implementation of net-zero strategies was almost abandoned. Even international financiers such as the International Monetary Fund (IMF) funded COVID-19 interventions to the tune of billions. For example, South Africa received USD4.3 billion from the IMF to address the socio-economic impacts of COVID-19. Public expenditure primacies and budgets in both India and South Africa have been re-organised, with priority having been given to COVID-19 related interventions and the associated economic recovery exertions. Most of the economic recovery strategies are averse to the net-zero emissions path.

Technology transfer is a strategy seen as key to the achievement of the net-zero emissions target by 2050 [91,92]. Failure by developing countries to facilitate the transfer of low carbon technologies is the greatest barrier to the achievement of net-zero emissions by 2050. Stern efforts are being made in South Africa and India to adopt new renewable energy and low carbon technologies in preparation for the 2050 net-zero pathway. However, COVID-19 has imposed barriers which are threatening the existing commitments and set targets. It emerged in this study that COVID-19 curtailed the technology transfer staircase in both countries as shown in Figure 8.

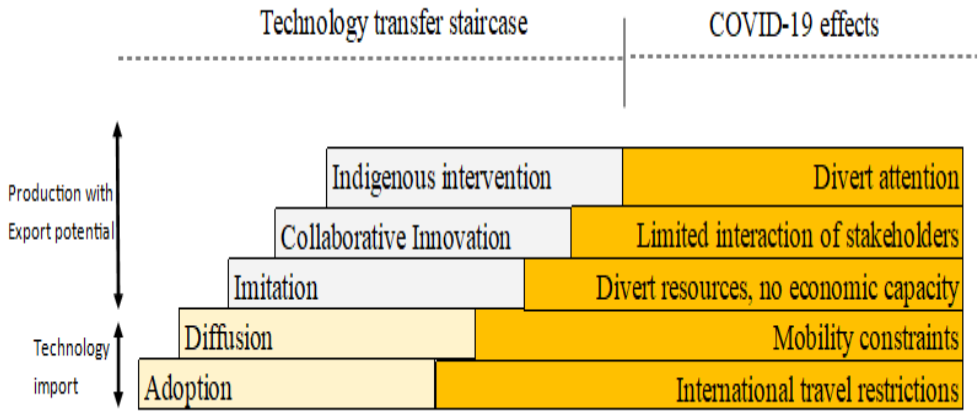

Figure 8. Barriers imposed by COVID-19 on the technology transfer staircase.

As shown in Figure 8, technology transfer occurs in phases, starting from the adoption phase, diffusion phase, imitation phase, collaborative innovation phase and lastly the indigenous intervention phase. At every stage of the transfer staircase, COVID-19 has imposed some challenges. These include restriction of travel, mobility constraints, resource diversion, limited physical interaction of stakeholders and diversion of attention of governments and entrepreneurs.

In agreement with [93], it is noted in this study that the race to net-zero emissions by 2050 requires a rapid shift towards low carbon economies. Radical new innovations in addition to incremental modifications of the existing technologies are critical. Calvino et al. [94] have observed that young and small organisations have the dexterity to drive radical innovation more than the older ones. However, Bell et al. [95] observed that young and small organisations have a high likelihood of being severely affected by COVID-19 compared to incumbent and larger firms due to lack of access to capital to bust transitory shocks. South Africa has witnessed closure of nearly 1000 industries due to COVID-19. India had about 43% of SMEs closing shop. Along the process, COVID-19 desiccated the new and small firms with potential to introduce and propagate clean technologies that would contribute to the larger pool of renewable energy technologies available in the country, contributing towards a cleaner environment that drives the Paris Agreement goal for carbon neutrality by 2050. Table 2 shows the number of industries whose operations have been affected by COVID-19, leading to complete shutdown.

Table 2. South Africa's industries whose closure was partly or fully instigated by the COVID-19 Pandemic.

Industry	Number liquidated January-June 2021	Number liquidated June 2020	Number liquidated May 2021	Number liquidated June 2021	Percentage of new/small firms
Agriculture	9	0	2	0	67.8
Mining	5	1	1	2	93
Manufacturing	44	9	9	5	88.3
Electricity, gas and water	6	1	0	2	94.5
Construction	36	4	7	3	98
Trade, catering and accommodation	217	28	42	30	86.5
Transport, storage, communication	25	2	7	3	90.1
Financing, insurance, real estate	322	32	59	44	77.8
Community, social, personal services	72	7	14	14	92
Unclassified	261	50	50	29	98.8
Total	997	134	191	132	88.68

Source: Authors, data from Arndt [89].

Table 2 shows that several South African industries have been affected by COVID-19 directly and indirectly, leading to their closure and loss of employment, among other spill-over effects. A total of 997 have been recorded between January and June 2021. Most of the companies are small and young and could not handle the challenges imposed by the lockdown policy. As indicated in Table 2, about 88.68 percent of the total closed or incapacitated companies were either new or operating at a small scale. In the context of net-zero emissions by 2050, such losses have a bearing on the long-term climate goals given the catalytic role played by these companies in technology adoption.

It has emerged that COVID-19 has aggravated South Africa's electricity public utility Eskom's financial insolvency, contributing to the delays in expanding renewable energy capacity. There has been progress towards renegotiating electricity prices for renewable energy projects already connected to the grid but COVID-19 has been regarded a contributing factor to the delays in establishing a sustainable strategy for renewable energy inclusion in the system. COVID-19 has created an insatiable appetite for economic rebound characterised by massive emissions through the use of fossil fuels. There is likelihood of a higher-than-expected economic rebound in the post-COVID-19 period as companies try to recover from the periodic slumber driven by the pandemic. The South African Reserve Bank predicted a 4.6% recovery of the GDP [96]. The Climate Action Tracker (CAT) predicts that by 2030, GHGs emissions for South Africa will be approximately 31-61 MtCO2e higher than the earlier projections due to the rebound effect. A deluge of high-carbon strategies are lined up as recovery measures within a 12-month timeframe. For example, there is deliberate promotion of mining operations without emphasis on low carbon operations. To date, only 4% of the recovery spending has been channelled towards low-carbon measures. The response is contrary to the domestic and international calls for low-carbon economic recovery and dampens progress towards the net-zero by 2050 ambitions.

5. Conclusions

The proliferation of the COVID-19 ignited sector-wide consequences punctuated by loss of human life, economic crises, energy demand decrease, job losses and various other social, economic and cultural vices. However, empirical studies have shown that there was an improvement in environmental quality, marked by a decrease in the amount of GHG emissions into the atmosphere. Clearly, COVID-19 brought both challenges and opportunities. Out of a slew of negative ramifications of the pandemic on all facets of life, nature's thrust to re-establish its climatic balance was realised. This study examined India

and South Africa's pathways towards the 2050 net-zero trajectory in the context of the COVID-19 pandemic. It has emerged that the pandemic has presented both opportunities and barriers towards the achievement of low carbon economies for both countries. The barriers include the creation of an environment which makes it difficult to disseminate the net-zero message to communities, curtailing the technology transfer staircase, reducing energy options, among other barriers. In view of these barriers, the drop in emissions is regarded as a temporary dip, a common feature of historical global crises that have instigated a short-term decline in emissions but eventually re-emerge and follow the usual trend leading to the warming of the globe.

On the other hand, COVID-19 also presented some opportunities in the form of changes in investment behaviour, consumption behaviour, production behaviour and re-emphasising the pivotal role of the environment for sustainable health systems. Such changes are deemed important ingredients for a net-zero emissions trajectory. Following an extraordinary decline in global energy demand and lack of support for fossil fuel production facilities, investors are turning their focus towards renewable energy with unprecedented level of determination and enthusiasm with the ultimate goal of achieving carbon neutrality or net-zero emissions by 2050. The attitude at all levels (Policymakers, industries and communities) is gradually shifting towards low carbon technologies and phasing out of polluting entities. Consequently, green energy investment has increased since pre-COVID-19 times. Following this trajectory, production can be restored to normalcy through the establishment and expansion of green energy-based production units, creating spill over opportunities such as employment, and environmental sustainability, among others. Riding on COVID-19 recovery efforts, economies need to take advantage of the key renewable energy initiatives to support clean energy transition whilst also creating suitable conditions for stronger economies with more responsive and robust health systems with the dexterity to withstand global health crises.

Given the above, it is up to the concerned players and the world at large to focus on the barriers or to exploit the availed opportunities to further the net-zero by 2050 agenda. It is important to underscore the observation that the COVID-19 pandemic has sent a signal to the business-as- usual practices, indicating the significance of re-thinking and re-establishing economy wide values and norms hinged on systemic sustainability considerations. A change in norms, values and perceptions has potential to drive the impetus to design transformational and ambitious policy instruments and strategies that contribute to net-zero by 2050. The policies and strategies will be strategically situated to take advantage of post COVID-19 low carbon opportunities.

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