Mapping sectors for high employment and low carbon growth in South Africa

by

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Abstract

South Africa is facing an unemployment crisis, with an unemployment rate of 43.2% by the expanded definition in quarter 1 of 2021. At the same time, the threats of climate change are becoming ever more evident and the world is under increasing pressure to lower its carbon emissions. The distributional effects of a lower carbon growth pathway will be an important part of the overall transition to a lower carbon economy, in South Africa and elsewhere. Previously, sectors have been characterised according to either their employment or carbon intensity, but have not been mapped based on both measures. This dissertation fills this gap by mapping sectors for a prospective high employment and low carbon growth pathway in South Africa. This is done by constructing a two-by-two typology to explicitly map sectors / subsectors by both their employment multiplier rank and carbon intensity. This mapping lays the basis for providing an understanding of the implications of three policy measures across different sectors. The three policy measures discussed – a wage subsidy, carbon tax and phase out of fossil fuel subsidies – have the potential to jointly help shift the growth pathway of South Africa to higher employment and lower emissions. On the one hand, a wage subsidy applied to all sectors would provide larger benefits for more employment intensive sectors and so incentivise growth therein. On the other hand, the phasing out of fossil fuel subsidies and a more punitive carbon tax would place more financial pressure on relatively capital and carbon intensive sectors. Overall, the focus of this dissertation is to support a 'Just Transition' to a new growth pathway characterised by high employment and low carbon.

Plagiarism Declaration

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List of Abbreviations and Acronyms

APAP - Agricultural Policy Action Plan
CRDP – Climate-Resilient Development Pathway
CTLF - 'Clothing', 'Textiles', 'Leather' and 'Footwear'
CSP - concentrated solar power
DEFF[1] – Department of Environment, Foresty and Fisheries
DMRE - Department of Mineral Resources and Energy
DOE[2] – Department of Energy
DTI - Department of Trade and Industry
G7 - Group of Seven
G20 – Group of Twenty
GBCSA – Green Building Council South Africa
GDP – Gross Domestic Product
GFC – Global Financial Crisis
GHG – Greenhouse gas
GTS - Green Transport Strategy
GW – Gigawatt
ICT - information and communications technology
IDC - Industrial Development Corporation
IO – Input-Output

[1] Renamed the Department of Forestry, Fisheries and the Environment (DFFE) on the 1 April 2021.
[2] the Department of Mineral Resources and the Department of Energy merged into a new Department of Mineral Resources and Energy (DMRE) on 29 May 2019.

IRENA – International Renewable Energy Agency
IRP2019 – Integrated Resource Plan 2019
IPAP - Industrial Policy Action Plan
IPCC – Intergovernmental Panel on Climate Change
ISIC - International Standard Industrial Classification
JTT – Just Transition Transaction
NEMA - National Environment Management Act
NEP – National Electrification Plan
NDC – Nationally Determined Contribution
NDP – National Development Programme
NECSA – Nuclear Energy Corporation of South Africa
OECD - Organisation for Economic Cooperation and Development
OWE - Offshore Wind Energy
PAMs – Policies and Measures
PGMs – Platinum Group Metals
PV - Photovoltaic
RE – Renewable Energy
RMI4P – Risk Mitigation Independent Power Producer Procurement Programme
RSA – Republic of South Africa
SAM – Social Accounting Matrix
SA LEDS - South Africa's Low Emission Development Strategy
SASID – South African Standardised Industry Database
SATIM-eSAGE - South African energy and economic linked model
SAWEA – South African Wind Energy Association
SETs – Sectoral Emission Targets
SIC – Standard Industrial Classification
SJRPs - Sector Jobs Resilience Plans
SNA - System of National Accounts
SU – Supply-Use
StatsSA – Statistics South Africa
TIPS - Trade & Industrial Policy Strategies
TVET - Technical and Vocational Education and Training
UCT – University of Cape Town
UN – United Nations
UNDESA – UN Department of Economic and Social Affairs
UN SDG – UN Sustainable Development Goal
TWh – Terawatt-hour

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1. Introduction

South Africa's growth pathway has been characterised by both low employment and high emissions. The country's history of apartheid has resulted in numerous socioeconomic challenges, including unemployment, poverty, and inequality. At the same time South Africa has unsustainably high carbon emissions as a result of its dependency on coal based energy (Black & Hasson, 2016). This legacy of coal dependence is largely due to South Africa's industrial economy having been built off the back of access to cheap coal and electricity (Burton, Marquard & McCall, 2019). This reliance began in the 1970s when the state supported infrastructure investments in coal mines, coal-fired power plants, and the conversion of coal to liquid fuels. Thereafter, state-owned enterprises for electricity and transport, and the South African economic growth policy at the time, endorsed this coal dependency as it supported their own interests regarding the conversion of coal to liquid fuels (Burton, Marquard & McCall, 2019).

The growth pathway since South Africa's democratic transition in 1994 is characterised by extreme levels of unemployment, poverty, and large inequalities. Compared to other middle income countries, South Africa's official unemployment rate is exceptionally high at 32.6% in the first quarter of 2021[3] (StatsSA, 2021). When expanding the definition of 'unemployed' to include discouraged workers, this metric increases to 43.2%, and when looking specifically at those aged 15-34, the unemployment rate is 46.3% (StatsSA, 2021). This is in the context of an economy with a high greenhouse gas (GHG) emissions profile, due to an energy economy dependent on coal (Winkler & Marquard, 2009). In this sense the economy and its distorted growth pathway is ticking all the 'wrong' boxes. Moreover, certain market and policy inefficiencies have meant that the state has been unable to make significant progress in tackling many of the baleful legacies of apartheid.

With the country having an overall aim towards net-zero carbon emissions by mid-century (IPCC, 2018), the increasingly capital- and energy-intensive structure of the economy are problematic (Burton, Marquard & McCall, 2019). In order to move to a more sustainable growth pathway that ticks the metaphorical 'right' boxes, changes are necessary to promote employment and a reduced GHG emissions profile (Burton, Marquard & McCall, 2019). In the 2019 State of the Nation address, President Cyril Ramaphosa acknowledged that the first task of government would be to 'accelerate inclusive economic growth and create jobs'. He accepted that the 'levels of growth that we need to make significant gains in job creation will not be possible without massive new investment' (Lawrence,

[3] The highest since the Quarterly Labour Force Survey (QLFS), conducted by the Department of Statistics South Africa (StatsSA), began in 2008.

2020). Following on from this, Burton et al. (2019) emphasize that South Africa's unemployment challenge needs to be considered as part of the 'broader economic agenda' which addresses energy constraints, dependence on coal, deindustrialisation, low growth in employment intensive sectors, and an overall lack of innovation and expansion in established (and new) sectors. Therefore, creating an environment that could enable a shift in South Africa's growth pathway - to one that is increasingly higher in employment and lower in carbon emissions. To explore such shifts, employment and carbon intensity across different sectors needs to be fully understood.

(i) The need to map sectors by both employment intensity and carbon intensity

Employment intensity in South Africa varies sector by sector (Tregenna, 2015), and so too does the carbon intensity of sectors (Reeler, 2021). Combining employment and carbon intensity metrics for each sector would enable one to attain an overview of how various sectors and subsectors represent different combinations of employment intensity and carbon intensity levels. If the aim is to have employment intensive and low emissions growth, South Africa would want to implement policies that might lead to faster growth in the sectors that are characterised by high employment and low carbon intensities. At the same time, sectors that are characterised by low employment and / or high carbon intensity need to be induced to alter their processes in order to lower their carbon intensity and maximise employment. By identifying the employment and carbon emissions profile of sectors / subsectors, policymakers can better understand the implications of industrial and energy policy on the South African economy and its growth pathway.

The structure of the economy needs to move away from its present state of capital intensive and energy intensive distorted growth that has limited the expansion of employment, to one that instead promotes high employment and low carbon emissions (Winkler & Marquard, 2009). South Africa cannot simply target one or the other, but needs to integrate both into policy. Thus, by combined analysis of employment intensity and carbon intensity, this dissertation will characterise sectors / subsectors of the economy according to both their employment and emissions profile. This allows for analysis of the implications of policy across different sectors / subsectors of the economy.

A 'Just Transition' is important to introduce here, as it ties together the employment and carbon intensity concerns of growth in South Africa. It thus serves as a useful starting point regarding the transition from a capital and energy intensive economy to an inclusive, employment intensive, and lower emissions 'green' economy. However, the concept of a 'Just Transition' in South Africa does not explicitly characterise sectors / subsectors by linking both their employment and emissions intensities - this dissertation will thus work towards filling in this gap.

(ii) Research question and objectives

This dissertation addresses the following research question: Which sectors / subsectors have opportunities for high employment and low emissions growth in South Africa, and what are some policy measures that could realise this potential? The objective here is to identify the sectors and subsectors in the South African economy that will enable both increased employment absorption, as well as a shift in South Africa's emissions trajectory towards a lower carbon intensity. This research question is hypothesis generating, and the findings will be used to discuss the implications of certain policy measures across sectors / subsectors - based on their emissions and employment profile.

In terms of the broader context, this dissertation seeks to contribute to theory by looking at sectors in a new way. Looking at a sector solely as a function of its employment or carbon emissions is useful, but putting both of these measures together provides something more. This is especially fitting in the broader context of a 'Just Transition', that focuses on both these aspects of certain sectors and subsectors.

(iii) Outline of the dissertation

The structure of this dissertation proceeds as follows: Having introduced the topic and the need to map sectors by both employment intensity and carbon intensity, Chapter 1 then states the research question and objectives. Chapter 2 outlines the problem statement, explores theoretical frameworks, and reviews the relevant literature. Chapter 3 presents the mapping methodology, as well as the adjustments I used in order to work with the data and draw out appropriate findings. Using published and unpublished sources alongside data from StatsSA, this dissertation identifies sectors that fall into various categories of employment and carbon intensity. The findings of the mapping process are then discussed in Chapter 4. Chapter 5 explores the research question by using the findings to analyse policy measures that could realise the potential for a new growth pathway, and the implications across various sectors / subsectors. This is achieved by making use of their employment and emissions profile from Chapter 3, and is in the overall context of shifting towards a higher employing and lower emissions growth pathway. Chapter 6 concludes and briefly presents the limitations and further research directions.

2. Literature review

This Chapter outlines the problem statement and explores various theoretical frameworks regarding shifting the growth pathway of South Africa. It then locates the dissertation in previous studies on employment intensity and carbon intensity, and explains how this dissertation builds on them to work towards a response to the problem statement. This entails a broad framing of the solution space that reviews the literature on various relevant policy domains, including industrial policy, climate energy policy, and the literature on a 'Just Transition'.

(i) Problem Statement: Why does South Africa's growth pathway need to shift?

South Africa is not only facing the international challenge of climate change, but also a multitude of country specific socioeconomic challenges (including vast levels of unemployment) which act as a constraint to dynamic growth (Tregenna, 2008). The unemployment rate has steadily worsened since 2008 (StatsSA, 2021), pointing towards the importance of firms in sectors with higher employment intensities. Thus, a sectoral analysis of employment intensity is valuable, and so too are policies aimed at employment creation and economic growth (Tregenna, 2015).

According to Tregenna (2015), the sector with the highest employment multiplier is that of 'Other producers', which has a multiplier over twenty times as high as the sector with the lowest ('Coke and refined petroleum products'). The large difference between these sectors is evidence that for South Africa, a sectoral analysis of employment intensity is not only important but also needs to be managed with attention to detail. At the same time as decreasing unemployment, employment creation results in higher domestic demand, as well as relief from negative externalities associated with high levels of unemployment. In other words, employment creation in itself can promote growth in a country (Tregenna, 2008).

For sustainable growth, the country needs to start off by having a reliable and efficient energy sector. At the same time, policymakers are beginning to realize that the future of South Africa's growth will be carbon constrained, meaning that the country's minerals-energy complex (Fine & Rustomjee, 1996) will have to be altered (Winkler & Marquard, 2009). So far, mitigation principles focus on energy efficiency in the short run, moving South Africa's fuel mix away from coal dependence in the medium run, and altering the economic structure in the long run (Winkler & Marquard, 2009) to less energy intensive and emissions intensive sectors (Winkler, 2018).

In order to significantly reduce carbon emissions under the Paris Agreement on Climate Change (which South Africa has committed to), the country needs to not only phase out fossil fuels as an energy source, but also redirect residual capital and labour to lower emitting sectors. There is thus an opportunity to look towards energy sources and productive sectors of the economy that not only have lower carbon intensities but also have higher employment intensities – shifting the growth pathway of South Africa to one that is characterised by high employment and low carbon.

South Africa's emissions will have to start declining, with an overarching target of net-zero carbon emissions by 2050. To this end, the Integrated Resource Plan 2019 (IRP2019) states that over 35 Gigawatts (GW) of the currently operating 42 GW of coal based energy capacity needs to be decommissioned by 2050 (Climate Action Tracker, 2021). However, energy demand for growth still need to be met, and thus the IRP2019 gives guidance as to how the South African electricity supply will evolve (RSA, 2020). In itself, the IRP2019 is a position statement that acts as a means for the Government to promote renewable energy (RE) and other low carbon technologies in the overall diversification of country's electricity generation mix (RSA, 2020). But the IRP2019 document has no further indications as to which specific sectors will support South Africa's progress towards reaching net-zero emissions by 2050, alongside explicitly taking into account the country's overarching socioeconomic context.

Unsustainably high unemployment levels and a carbon constrained future, mean that there is an explicit need to shift South Africa's growth pathway to lower carbon emissions. Moving away from fossil fuels and meeting the energy demands of the country using cleaner sources of energy – i.e., shifting away from coal based energy – is a start at creating a lower carbon economy. At the same time, a sectoral analysis of employment intensity and policies aimed at employment creation and economic growth (Tregenna, 2015) are key to shift the growth pathway of the country to higher employment levels. Having established the need for these shifts, the following section considers possible enabling theoretical frameworks.

(ii) Theoretical Frameworks: Enabling a shift of South Africa's growth pathway

There is no single theory as to how best a developing country such as South Africa should tackle climate change at the same time as their various socioeconomic challenges (such as unemployment). Is one more important than the other? Should they be targeted separately or together? In general, growth would be required to stimulate employment, and a proposition by Altieri et al. (2015) starts to pick up the narrative of faster growth in particular sectors. In other words, stimulating growth in sectors with low carbon emissions that require higher levels of employment. This can be achieved by pursuing faster growth in these specific 'desirable' sectors, and implementing policies that incentivise changes within high emitting and / or low employing sectors. Thus, enabling a shift in the characteristics of South Africa's growth pathway. I will draw on literature that comes from both the climate change side of the argument as well as the employment side.

Globally, socioeconomic and climate concerns are being taken seriously, with the UN including in its SDGs the following (The United Nations Department of Economic and Social Affairs, (UNDESA), 2015):

- Goal 1 – 'end poverty in all its forms everywhere',
- Goal 10 – 'reduce inequality within and among countries',
- Goal 13 – 'take urgent action to combat climate change and its impacts'.

In 2018, the International Panel for Climate Change (IPCC) published their research regarding a 1.5°C global warming pathway (IPCC, 2018), and gives evidence that tackling climate change will bring synergies with some of the SDGs. These include SDG 3 (health), 7 (clean energy), 11 (cities and communities), 12 (responsible consumption and production), and 14 (oceans). However, if not managed carefully, efforts to follow a 1.5°C pathway will have potential trade-offs for SDGs 1 (poverty), 2 (hunger), 6 (water) and 7 (energy access). This essentially means that by tackling Goal 13, the country could threaten both Goals 1 and 10. A 'Climate-Resilient Development Pathway' (CRDP) is therefore important, defined as 'trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transitions and transformations while reducing the threat of climate change through ambitious mitigation, adaptation and climate resilience' (IPCC, 2018).

According to (Winkler, 2018), SDGs 1, 10 and 13 are inexplicitly linked and should be solved together. Climate related increases in the frequency and severity of extreme weather events have more destructive effects on the wellbeing and livelihoods of people in poorer communities (Lawrence, 2020). Some of these climate-change related effects include increasing temperatures and increased intensity and instances of heatwaves, droughts, water shortages, floods, food insecurity, damage to infrastructure, and spread of diseases (RSA, 2020). These changes increase the vulnerability of poorer communities, and so climate change is considered a threat to South Africa and its socioeconomic advancement. However, contributing its fair share to emission reductions will also come with financial burdens, pressure to slow down growth, and thus various socioeconomic challenges (RSA, 2020). Any agenda to reduce emissions, needs to simultaneously have poverty and inequality reducing characteristics (Winkler, 2018). This includes providing employment opportunities in the economy, particularly for low skilled workers.

This narrative follows the theory of 'green' growth, whereby economic growth remains a priority in order to alleviate poverty, alongside the exploration and utilisation of synergies between this growth and the protection of the environment (Pegels, 2014). These 'synergies' would mean looking towards sectors / subsectors of the economy that provide scope for growth that does not put unnecessary pressure on the environment. In other words, decoupling economic growth from unsustainable levels of resource use. However, the distributional impacts need to be considered in the South African socioeconomic context in order to ensure this 'green' growth does not exacerbate unemployment, poverty, and inequality. This means the pursuit of a CRDP that is able to achieve carbon emissions reductions in conjunction with reducing unemployment levels to support poverty eradication and inequality reduction (IPCC, 2018).

At the same time, the employment literature proposes that direct employment potential should not be the only criterion in selecting sectors to prioritize in an economy. Tregenna (2015) argues that the artificial promotion of employment potential could in some cases undermine aggregate employment growth. While employment absorption is objectively important in South Africa, a certain sector might be labour absorbing but also be a dead end for growth as global demand declines and / or lower cost producers take over the majority share of that demand (Tregenna, 2015). Industrial policy thus needs to take a range of criteria into account when prioritising sectors for growth, with employment intensity being only one of them (Tregenna, 2010). This is especially important when considering sectors that may not be directly employment intensive, but are necessary for other reasons that create growth and indirectly promote employment (Tregenna, 2010).

There is no easy solution to the question of employment intensive growth, but when considering the various productive divisions of the economy, employment intensity should be looked at (Tregenna, 2015). However, this needs to be in the context of other sector attributes and the wider country specific context, which means taking into account the challenges that the particular economy is facing. Confronting climate change and the accompanying need to reduce GHG emissions is one of these challenges, and is becoming increasingly more important.

Winkler (2018) reasons that it is imperative that growth follows innovative pathways that are able to adapt as the country context changes over time. Low emission pathways to achieve increased employment in South Africa will require 'adaptive management'. This means viewing growth through the lens of both carbon emission reduction and increased employment. Thereafter, using this framework to engage in interdisciplinary research and having a flexible policy space to meet the evolving challenges (Winkler, 2018).

As the evidence above illustrated, both the climate side and the employment side advocate for bringing challenges together, and engaging with them simultaneously instead of looking at each challenge in a silo. In Chapter 2.iii and 2.iv, I will look at which sectors the literature identifies as either employment intensive or low carbon, these are then brought together in Chapter 2.v with a discussion on what a 'Just Transition' would look like.

(iii) Previous studies on employment intensity and carbon intensity

Previous studies have analysed sectors either based on their employment intensity or their carbon intensity. However, these characteristics are both important when looking at the future for growth of particular sectors – not just one or the other in isolation. As of yet, there is no literature that uses both the employment intensity and carbon intensity of sectors in order to explore a shift in South Africa's growth pathway. This dissertation will thus map the employment intensity and carbon intensity of sectors / subsectors to identify those that have opportunities for high employment and low emissions growth in South Africa.

It is important to note here that the size of each sector in relation to its employment intensity and carbon intensity measures is not explicitly considered. Sectors with low intensities may actually be large emitters purely as a result of their size, and vice versa. The consideration of sector size thus represents an area for future research. Moreover, the informal sector is not covered by the scope of this dissertation, but plays an important role in creating livelihoods for many of the South African population. In the future, if reliable carbon emission and employment metrics can be obtained for the informal sector, it could be brought into the analysis. The future also brings with it the 'fourth industrial revolution', various trends in automation, and the transition to energy sources that have lower carbon emissions (such as renewable energy). This will impact sectors going forward, and so with this analysis being a static one, the results would inevitably change over time.

Studies identifying sectors with high employment intensities

Relevant research point towards certain sectors and subsectors in the South African economy that represent opportunities for employment intensive growth. These include various service and manufacturing sectors, and are opportunities for South Africa to shift its growth pathway to that of higher growth alongside employment creation. This dissertation relies specifically on various work by Fiona Tregenna (2008, 2010, 2015), as her analyses are of a sectoral nature and thus useful in what this dissertation is working towards doing.

To increase optimal growth and employment opportunities, it is imperative for capital investments to be directed towards labour absorbing over labour displacing sectors. Tregenna (2008) notes here that this may result in a trade-off between sectors that are highly productive and technologically driven (such as certain subsectors of manufacturing), and those that are instead more directly labour absorbing. The main example of the latter are service sectors, which may be more employment intensive but have lower capabilities for capital-intensifying factor substitution, technological progress, and overall growth. Looking at employment, service sectors frequently have a higher employment intensity than manufacturing (Tregenna, 2008).

Nevertheless, manufacturing subsectors are more important as a source of demand for services, than the other way around. In addition, manufacturing is critical for low skilled employment (Tregenna, 2008), as well as driving growth through its many forward linkages (growth of manufacturing leads to the growth of other sectors that use its output as an input) and backward linkages (growth of manufacturing leading to growth of the sectors that supply its inputs) to other sectors in the economy (Bell et al., 2018). Strong manufacturing backward linkages are particularly important as a source of demand for the economy, including services sectors. This suggests that a decline in manufacturing could negatively affect future growth (Tregenna, 2008).

Looking specifically at the manufacturing subsectors – Black, Craig & Dunne (2016) use the following classifications:

- **'Ultra-labour intensive'** – 'Clothing', 'Footwear', 'Furniture', 'Leather products', 'Other manufacturing industries' and 'Wood and wood products'.
- **'Labour intensive':** 'Textiles', 'Plastic products', 'Metal Products', 'Printing and publishing', 'Machinery', and 'Electrical machinery'.
- **'Intermediate capital intensive'** – 'Glass and glass products', 'Other non-metallic mineral products', 'Tobacco products', 'Other transport equipment', 'Motor vehicles and parts', 'Rubber products' and 'Food'.

- **'Capital intensive'** – 'Chemical products', 'Iron and steel basic industries', 'Paper and paper products' 'Beverages' and 'Non-ferrous metals'.

Growth-generating properties that can be attributed to certain subsectors in manufacturing include not only strong linkages with the rest of the economy, but also learning by doing, increasing returns to scale, and the potential for technological progress (Tregenna, 2008). At the same time, services are still imperative to growth, with service subsectors (such as the capital intensive information and communications technology (ICT) sector) being technologically progressive and having large economic growth-supporting potential. However, for South Africa, the trend has been to lower value, lower productivity services, including those classified as 'Other business services' (for example, security and cleaning services) and 'Retail'. Thus, it is argued that the increase of services as a percentage of Gross Domestic Product (GDP) (60% in 1994 to 68% in 2016) has not been a positive component of the economy's structural transformation (Bell et al., 2018), indicating the need for a shift towards services that promote employment opportunities through various direct and indirect mechanisms.

According to research by Tregenna (2015), the 'Other producers' subsector has the largest employment intensity. However, there is inherent difficulty in understanding this subsector as it broadly includes employment in services 'not elsewhere classified (n.e.c.)'. No further detailed information is available on the activities accounting for most of the employment – apart from a few minor specific activities, such as those performed by laundries and dry-cleaning, hairdressing and other beauty treatments and funeral services. Thereafter, the sectors that follow include a mix of manufacturing, agriculture, and services sectors[4].

The same research revealed that sectors with the lowest employment intensity are all subsectors of heavy manufacturing (Tregenna, 2015), namely: 'Coke and refined petroleum products', 'Electricity, gas, and steam', 'Coal mining', 'Water supply', and 'Basic chemicals'. Looking at the service subsectors, 'Finance and insurance' has the lowest employment intensity. Despite financial services having grown in value added, it has not grown employment and its growth has not been associated with higher levels of savings and investment in the real economy – including productive capacity and infrastructure (Bell et al., 2018).

[4] 'Clothing', 'Catering and accommodation', 'Textiles', 'Agriculture', 'Furniture', 'Leather', 'Furniture', 'Wood and wood products', 'Wholesale and retail trade', 'Footwear', 'Food', 'Motor vehicles, parts & accessories', 'Machinery and equipment', 'Building construction' and 'Metal products excluding machinery', and 'Civil engineering and other construction'.

South Africa’s economy has continued to be focused on resource based sectors, and has deindustrialised at the same rate as the advanced Group of Seven (G7) economies – prematurely for its developing context. Bell et al. (2018) describes South Africa’s poor industrial performance as ‘striking when considered against its peers’ (other middle income countries). Instead of growth in diversified manufacturing and increasing shares of world manufacturing value added, South Africa has instead experienced increasing import penetration of intermediate inputs. A prime example is in the underdeveloped automotive industry, which despite being a major exporter is also a significant importer of automotive components. In 2015, the local content in South African assembled vehicles was 38.7% (Bell et al., 2018). Consequently, despite the increase in value of vehicle assembly activities from R75 billion in manufacturing sales in 2012 to R137 billion in 2015, this so called ‘success’ was supplemented by an increase in the automotive component imports by R44 billion (Bell et al., 2018).

It is not only manufacturing that can provide these opportunities, as service sector investment will also be necessary in order to create employment opportunities and improve the overall employment intensity of the economy (Mkhize, 2019). However, sectors are inherently linked to each other with forward and backward linkages across the entire economy, including the manufacturing and service sectors (Arndt et al., 2013). With a changing structure and employment already shifting away from the primary sector towards the tertiary sector, the focus should not be solely on sectors that enable productive capacity such as manufacturing, but also the service sectors that support manufacturing and assist in improving employment intensity. These include the ‘Finance’, ‘Business services’, ‘Transport’, and ‘Utilities’ sectors (Mkhize, 2019).

In the context of South African deindustrialization, services have seen a growth in economic importance (Bell et al., 2018), but a lot of this growth has been in low value traditional services. For example, the value added in financial services has grown, but has not seen growth in employment. In addition, there has been a sustained loss of manufacturing capabilities across the economy that has meant a knock on affect in other parts of the economy, including a reduction of high-value services. Furthermore, the commodities boom and subsequent exchange rate appreciation, led to the weakening of non-commodity diversified services (Bell et al., 2018). Manufacturing drives investment in technology and has an important ‘symbiotic relationship’ with services that are high in value (Bell et al., 2018). Thus, in order for industrialisation and employment opportunities to be promoted in the service sectors, services related to manufacturing, engineering, and design will need to play an important role.

The literature above not only identified specific sectors with high employment intensities, but also indicated the importance of a range of other manufacturing and service sectors. These may not have relatively high employment intensities, but are nonetheless important in their economic linkages and the support they provide to the economy and its ability to create employment opportunities.

Studies identifying sectors with lower emissions intensities

According to the various carbon intensities of industrial activities and their relative products, calculated by Arndt et al. (2013) and Reeler (2021), coal is the most carbon intensive product in the economy. Electricity generation and distribution have high carbon intensities, along with oil, gas, petroleum products, and natural water distribution (which in South Africa is characterised by large infrastructure investments). Trade industries and support services, as well as non-metallic manufactured products are also relatively carbon intensive. Many of the carbon intensive non-energy sectors and products are in heavy industry[5] including:

- Sectors – 'Basic iron and steel, casting of metals', 'Nuclear fuel, basic chemicals', 'Basic precious and non-ferrous metals' and 'Non-metallic minerals'.
- Products – 'Non-metallic minerals', 'Metal products, and 'Other mining'.

Notably, the products above are produced by sectors that in general use more primary fuels and transformed energy than other sectors. Take for example the 'Non-metallic minerals' sector, which uses coal to produce clay bricks, and the vast quantities of electricity used in aluminium smelters (Arndt et al., 2013). Heavy industry and its products are often seen as 'hard-to-abate' sectors due to their characteristically carbon intensive processes. In addition, these industries are interlinked, for example, metal products are produced using mining inputs and thus the carbon intensity of metal products must include the carbon from the upstream mining process. On the other hand, services tend to be less carbon intensive – the lowest being 'Financial services'. Services hardly use primary fuels in their direct activities, and their intermediate inputs also contain less carbon (Arndt et al., 2013).

Sectors and products that have relatively low carbon intensities[6] (Reeler, 2021) are important for a low carbon economy, but as previously clarified, firstly a reliable and low carbon energy sector needs to be developed. The electricity sector requires a rapid phase out of coal based energy, with South

[5] Note here the intersection with low employment intensive sectors – indicating heavy industry is a problem area on both sides.

[6] 'Finance', 'Insurance and pension funding', 'Government', 'Forestry', 'Hotels and restaurants', 'Post and telecommunication', 'Engines, turbines', 'Medical appliances, 'Ships and boats', 'Other transport equipment', 'Tobacco products', 'Bearings, gears', 'Lifting equipment' 'Manufactured products n.e.c.', 'General machinery', 'Special machinery', and 'Food n.e.c.'

Africa’s Low Emission Development Strategy (SA LEDS) envisioning this by 2050 (RSA, 2020). McCall et al. (2019) and Bischof-Niemz & Creamer (2019) have examined the implementation of a least cost scenario for South Africa’s electricity sector. The findings indicate that RE will supply the energy sector in the cheapest and most reliable way in the carbon constrained future. This will primarily come from wind, solar PV, and flexible power generators (e.g., gas, CSP, hydro, biogas, demand response, batteries, fuel cells), with no new coal or nuclear power plants. This would then result in an increased demand for the necessary infrastructure and thus downstream industries such as ‘Civil engineering and other construction’, ‘Machinery & equipment’, and ‘Metal products excluding machinery’.

Efforts to decouple carbon emissions from electricity generation is integral and with South Africa’s ageing coal power fleet being slowly decommissioned over the next 30 years, there is scope for RE technologies to fill this electricity generation gap. Rae & Erfort (2020) present the case of using offshore wind technology as a clean electricity generation alternative, enabling power security and decarbonization opportunities. The study identified the following regions for offshore wind development: Richards Bay, KwaDukuza, Durban, and Struis Bay. It looked at four scenarios in order to estimate the potential offshore wind energy (OWE) that could be generated to meet South Africa’s annual electricity demand (297.8 TWh in 2018). The scenarios indicated that OWE has significant potential in the power security and decarbonization of the South African economy (Rae & Erfort, 2020) – just one example of how electricity generation can be decoupled from carbon emissions.

Due to the mineral intensive nature of low emission energy and transportation systems, the transition to a RE supply provides an important opportunity for the South African mining sector (Maennling & Toledano, 2019). At the same time, mining companies will have to power their operations with RE, operate electric vehicle truck fleets and integrate recycling in their value chains in order to sell low carbon premium minerals (at present mining is a relatively carbon intensive industry). Mineral beneficiation has been identified in the South African ‘Industrial Policy Action Plan’ (IPAP), put together by the Department of Trade and Industry (DTI, 2018), as key in order for South Africa to play a role in the global hydrogen economy and energy storage space. This would mean a focus on the Platinum Group Metals (PGMs) and manganese in particular, which fall under the sector ‘Mining of metal ores’, as an important input for fuel cells and energy storage technology development. The developing fuel cell industry will also support energy efficiency and carbon reductions in the South African economy (DTI, 2018).

However, the mining sector also faces a number of barriers to growth including local opposition and problems in obtaining a 'license to operate' in many communities (Maennling & Toledano, 2019). The uncertainties and restrictions of the third mining charter has resulted in many international mining companies pulling their operations out of South Africa (Seccombe, 2018), and an overall lack of capacity has been revealed by the Department of Mineral Resources and Energy (DMRE) - evidenced by a huge backlog in mining applications and transparency issues that are deterring investment (Stoddard, 2021). Nonetheless, with a stable regulatory environment, increased transparency in the mining industry, and the power of new low carbon technologies, a major opportunity exists to unlock the potential of mining in South Africa on a greener basis (Goodman, Rajagopaul & Cassim, 2019).

It is also important to consider how the push for energy efficiency and low carbon facilitating technologies will affect the South African economy by sector. The International Renewable Energy Agency (IRENA, 2020) defines energy efficiency as 'efficiency measures deployed in end use sectors (industry, buildings and transport) and investments needed for building renovations and structural changes (excluding a modal shift in transport).' In particular, this will have an effect on the 'Building construction' and 'Civil engineering and other construction' sectors with an increasing demand for the building, repair, or retrofitting of buildings to be rated 'green' by the Green Building Council South Africa (GBCSA). Other industries in the manufacturing and service sector will see increasing demand for the necessary inputs – these include building materials such as metals and wood, machinery, equipment, and services.

In 2013, transaction margins (moving products from factory to market) made up 7.1% of the carbon intensity of South Africa's final demand (Arndt et al., 2013). There is thus an opportunity for the transport sector and its associated subsectors to move towards lower carbon solutions such as electric vehicles (EVs), more fuel efficient vehicles, and advanced biofuel use for aviation and shipping (IRENA, 2020). In 2018, the Green Transport Strategy (GTS) to 2050 was launched, providing strategies for the transport sector to reduce GHG emissions (RSA, 2020). Carrying out the various measures would stimulate demand in some of the downstream industries and products that have already been identified as low carbon by Arndt et al. (2013) and Reeler (2021)[7].

[7] Including, 'Engines, turbines', 'Other transport equipment', 'Bearings, gears', 'Lifting equipment' 'Manufactured products n.e.c.', 'General machinery', and 'Special machinery'.

The literature above identified sectors and products that have relatively high or low carbon intensities (Reeler, 2021). However, for a low carbon economy there are other prerequisites such as a reliable and low carbon energy sector, resulting in an increased demand for the necessary infrastructure and thus downstream industries. Additionally, the mineral-intensive nature of low emission energy and transportation systems provides an opportunity for the South African mining sector. This indicates that sectors with low carbon intensities are not the only ones that are important in the transition to a low carbon economy, but so too are various sectors that support and provide materials for a lower carbon economy.

(iv) Policy

Various policy domains are relevant to this dissertation, and are reviewed in turn.

Industrial policy literature

After 1994, in the context of trade liberalisation in South Africa, manufacturing has become increasingly capital intensive and its share of GDP has declined from 24% in 1990 to 13% in 2014, with significant associated employment losses (Black, Craig & Dunne, 2016). More employment intensive downstream sectors were further restrained by import parity pricing caused by a lack of upstream competition, as well as a failure to develop the skilled industrial workforce that was required (Black, Craig & Dunne, 2016). This is not to say that industrial policy has done nothing in terms of intervening, with sectoral involvement in both the intermediate capital intensive automotive sector and the employment intensive garment sectors. However, the reality is that heavy industries have grown and light manufacturing has shrunk. Part of the reason is as a result of the historic bias towards heavy industry, such as in the form of cheaper energy prices (Black, Craig & Dunne, 2016). Two of the problems with this growth pathway are: (1) the carbon intensive nature of heavy industry with it making up a large part of South Africa's minerals-energy complex (Fine & Rustomjee, 1996), and (2) the lack of labour absorption in these industries.

South African industrial policy has tried to promote growth in higher value added manufacturing, employment intensive activities, and smaller firms - but at the same time has continued to support larger scale, capital intensive firms and sectors (Black, Craig & Dunne, 2016). In order to move the South African growth pathway towards being labour absorbing in nature, the economy's comparative advantage will need to be shifted away from capital intensive products (artificially induced by low energy prices and other policy measures) and towards labour absorbing products. Thus, industrial policy requires a tilting of the playing field towards labour demanding economic activities – in particular, those that make use of low skilled workers (Black, Craig & Dunne, 2016). Incentives will need to work towards increasingly subsidising labour and training as opposed to capital investment, electricity, and infrastructure.

This would entail the introduction of a policy such as an employment or wage subsidy. Wage subsidies can be structured in multiple different ways, and can be broader or more specific as a policy tool. The purpose is ultimately to increase employment by the having the government provide payments to workers through their employers. A wage subsidy in South Africa may only be able to have a relatively small impact as a percentage of the total unemployment (Burns, Edwards & Pauw, 2013). This is not only due to South Africa's particularly high unemployment levels, but also because a wage subsidy would be found in the formal labour market, from which many people are essentially excluded (Burns, Edwards & Pauw, 2013). Nonetheless, a wage subsidy would still serve an important purpose in order to subsidize employment for firms in the context of a country with large and unsustainable employment levels.

According to Black & Hasson (2016), there are certain positive externalities that come with an industrial policy that takes into account employment intensity of certain sectors and subsectors. These serve as motivation for public policy support for employment creation in South Africa (including the promotion of employment intensive production). These externalities include the development of skills that would then have broader economic benefits, creating a reduced dependence on public and private support that would be needed to sustain employees should they be unemployed. Additionally, the positive contribution of employee's income to aggregate demand, income taxes paid to the state as a result of earnings, and the positive effects of lower unemployment on social stability and cohesion (Tregenna, 2015).

Moreover, there would be indirect employment (through backward and forward linkages) in the rest of the economy as a result of a production increases in certain sectors and subsectors. However, employment intensity is not the only important factor to take into account from a policy perspective. Some sectors or subsectors may not directly be employment intensive but rather contribute to the economy in other important ways such as the balance of payments, revenue contributions to the fiscus, and technological progress. This is important for the overall context of employment and growth – thus, sector prioritization for industrial policy support needs to take into account employment intensity as well as country context and other sectoral attributes (Tregenna, 2015).

Looking at the IPAP (DTI, 2018), government policy has tried to move away from mining and resource extraction towards a ‘manufacturing, value adding and job creating economy’ (Black, Craig & Dunne, 2016). Resource based economies are affected by commodity price volatility – as evidenced by South Africa’s fluctuating mineral export prices. However, the reality is still that of mineral wealth in the country, and so policy makers are rightly concerned with adding more value to these resources through beneficiation (Black, Craig & Dunne, 2016). Policy measures encourage these processes, despite the relative capital- and energy-intensive nature of the metal processing sector. The IPAP (DTI, 2018) identified mineral beneficiation as one of the necessary sectors for the industrialisation agenda during the period 2018/19-2020/21.

In 2017, the mining sector’s percentage contribution to GDP dropped to 5.1%, purportedly due to ‘subdued commodity prices and policy and regulatory uncertainty’ (DTI, 2018). The result has been the suspension of various projects, decommissioning of certain assets, and largescale job losses – affecting the sustainability of not only the sector itself but also upstream and downstream industries and supporting services. However, South Africa is home to over 80% of the world’s platinum reserves and three of the largest platinum mining companies are found in the country. According to the IPAP (DTI, 2018), platinum mines provide direct employment to 136,000 people and support 325,000 indirect jobs. In addition, PGMs are the second largest source of export revenue in South Africa – meaning that there is a strong policy interest to support this industry (DTI, 2018). In 2016, the Industrial Development Corporation (IDC) launched a lead group consisting of mining houses, local engineering, manufacturing companies, and technology providers to work with government in creating and implementing a roadmap for PGM beneficiation (with the special focus being on fuel cells, but also looking at other options). In addition, opportunities are emerging for other South African mineral resources (vanadium, nickel, and manganese) with an increase in the use of mineral beneficiation-linked energy storage solutions that use these mineral resources (DTI, 2018).

This means that mining and mining-related manufacturing activities require support from services such as finance, transport, logistics, and quality assurance. These services are important for the industrialisation trajectory of South Africa as they are some of the highest value added divisions of the mining supply chain, can catalyse investment in skills development and technology transfer, and can support growth in other sectors of the economy, including manufacturing (Bell et al., 2018).

Having an industrial policy that promotes capital intensive sectors (stimulating the demand for mineral resource) and relying on employment being generated in other protected sectors is possible. Another scenario could be where industrial policy targets leading sectors that generate the export expansion needed to finance growth and support the protected sectors that provide the employment required. However, in South Africa it is essential that industrial policy is also targeted towards supporting more employment intensive and inclusive growth. It is important to note that South Africa cannot suddenly outcompete China in employment intensive manufacturing, and should not support unsustainable sectors (Black, Craig & Dunne, 2016). However, in order to decrease the unemployment rate, industrial policy will have to consider how to make certain employment intensive manufacturing industries more competitive, by decreasing their high input costs and providing support and incentives for growth.

By 2007, industrial policy had become more sector oriented and tried to stimulate diversified non-resource based industries and more employment intensive sectors and subsectors. This policy direction was made known in a series of Industrial Policy Action Plans, such as the most recent IPAP 2018/2019-2021/22 (DTI, 2018). Financing measures were introduced - for example, the 'Manufacturing Competitiveness Enhancement Programme' (MCEP). Tariff policy has become more targeted in order to try and decrease the high input prices of manufacturing, and opportunities for further localisation of government procurement have been investigated – see for example the 2012 Preferential Procurement Policy Framework Act. But despite the various policy statements to develop downstream manufacturing industries and diversify away from heavy industry, the effects that were desired have not been achieved (Black, Craig & Dunne, 2016). In order to explain this point in more detail, Bell et al. (2018) looks at three relatively labour absorbing industries – 'Metals, Machinery and Equipment', 'Automotive Vehicles and Components', and 'Agriculture and Agro-processing'.

In sum, South Africa clearly has a low output in terms of employment intensive manufacturing, with manufactured exports being concentrated in capital-intensive and intermediate capital-intensive sectors. The top five exports are non-ferrous metals, vehicles and parts, iron ore, coal and steel – a very different composition when looking at comparative countries such as Malaysia, Mexico, Thailand, Tunisia and Turkey (at least two of their top five export products are from the ultra-labour intensive or labour intensive categories). The decline in labour intensive manufacturing accounts for a large part of the overall decline in manufacturing employment, additionally this decline has been remarkably rapid. The largest contributor has been textiles and clothing sectors, with their share of manufacturing output declining from 7.6% in 1990 to 1.8% in 2010 (Black, Craig & Dunne, 2016).

Due to the costs and barriers associated with policy change, and shifting the overall growth pathway of the economy (Tregenna, 2015), it is important to be able to analyse the implications that various policy measures may have across sectors of the economy. Policy design and implementation needs to be an iterative process that is coordinated with the overall South African policy space as discussed above (Bell et al., 2018), as well as the current features of the sectors in the economy. Mapping the carbon intensity and employment intensity of sectors is thus a useful starting point to be able to do this kind of planning and analysis.

Energy and climate policy literature

The energy generation and use characteristics of an economy and its sectors will be based on past policies, only transforming if future policies enable it to (Tregenna, 2008). Policy thus needs to be flexible to change, so as to be able to specifically target the reduction of GHG emissions in different scenarios. Although, as Winkler (2018) emphasizes, policy is not a panacea and needs to be understood in the overall context of interconnected and complex systems. It is thus important to pilot, demonstrate, and replicate specific instruments – learning from the associated successes and failures and adapting as lessons are learnt.

In order to reduce South Africa's historical dependence on fossil fuels for energy generation, government has committed to 'peak, plateau and reduce' GHG emissions (RSA, 2020). They have also earmarked RE generation as not only an alternative low carbon energy source, but also a way to achieve more localisation of components, job creation, and develop industrial competitiveness (DTI, 2018). In order to do this, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) was introduced in 2012 – with the aim to develop the RE sector in South Africa by way of a competitive bidding process.

Some of the policy tools that have been investigated include (RSA, 2020):

- **Carbon Tax** – Based on the 'polluter pays principle' and effective as of 1 June 2019, set at R120 per tonne of CO2 equivalent. However, tax exemptions for up to 95% of emissions during the first phase until 2022 are in place (*Carbon Tax Act, No. 15 of 2019,* 2019), effectively rendering the tax ineffective as of yet (Climate Action Tracker, 2021). The tax structure will be revised post-2021 to align with the proposed mandatory carbon budget and in 2022 payments will be made (RSA, 2020). There is still scepticism as to whether or not the tax will be large enough to have a measurable effect on carbon emissions. This is according to Climate Transparency's 2019 'Brown to Green' Report, which concludes that coverage and pricing of CO2 emissions is insufficient in Group of Twenty (G20)[8] countries, with 70% of CO2

[8] The G20 an intergovernmental forum that consists of 19 countries and the European Union.

emissions unpriced or priced insufficiently. In particular, South Africa has one of the highest carbon pricing gaps which sits at 89% (Climate Transparency, 2019).

- **Sectoral Emissions Targets (SETs)** – Quantitative GHG emission targets for sectors / subsectors over a certain period of time. Government departments will develop and implement Policies and Measures (PAMs) to make sure that emissions from within a specific sector / subsector remain within its SET limits. It is understood that the SETs will be released later in 2021 (RSA, 2020).
- **Carbon Budgets** - A maximum volume of emissions that individual entities can emit over three rolling five year periods (for certain activities). Exceeding the budget allocation would result in a penalty to that individual entity, in this instance South African companies. Carbon budgets are currently implemented through voluntary pollution prevention plans under the National Environment Management Act (NEMA). The Climate Change Bill, to be reintroduced to Parliament in 2021, would provide a legal basis for carbon budgets (they were included in the Bill in 2019). With this, companies could plan ahead as they would have a clearer idea of their mitigation requirements now and in the future (RSA, 2020).
- **Phasing out of inefficient fossil fuel subsidies/incentives** – South Africa provides the third highest fossil fuel subsidy[9] per unit of GDP in the G20 (Climate Transparency, 2019). However, as a member of the G20, South Africa has indicated willingness to 'identify and minimise their harmful impacts' at the same time as taking into account the socioeconomic context of the country (Climate Transparency, 2019). Here, an opportunity exists for the sharing of experience and joint learning among G20 members - the next step in pinpointing inefficient fossil subsidies within the South African economy and phasing them out relatively rapidly where needs be.

All the policy measures above work in different ways, but ultimately the aim is for them to complement each other in lowering the carbon intensity of the economy and total GHG emissions. According to Hepburn et al. (2020), the Covid-19 pandemic has demonstrated that governments do have the capability to intervene decisively when the emergency is immediate and clear, and there is enough public support. At the same time, as result of 'lockdown' as a policy response, many countries' experienced cleaner air, uncongested roads, and a returning of some animals and plants to urban

[9] 'These include significant state support for new coal-fired power plants, subsidies for new privately owned coal plants, public finance directed at coal mining and direct state involvement in coal extraction, as well as regulated prices for liquid fuels that protect the conversion of coal to liquid fuels' (Burton, Marquand. & McCall, 2019).

areas (Hepburn et al., 2020). This brings up the question of whether post-Covid-19 South Africa can 'build back better'.

Many countries have thus targeted certain sectors and / or clean energy technologies in their various 'green' recovery packages. Hepburn et al. (2020) used this, as well as finance proposed or authorized after the Global Financial Crisis (GFC), to look at what kind of stimulus packages have been shown to deliver the largest impact at shifting emission trajectories towards 'net-zero'. The recommendations that emerged and would apply for South Africa (aimed specifically at economic and climate goals) included:

- Investing in clean physical infrastructure
- Investing in efficiency retrofits in buildings
- Investing in education and training - addressing unemployment from Covid-19 and structural unemployment from the transition to a lower carbon economy
- Investing in natural capital to ensure ecosystem resilience and regeneration
- Rural support spending

The appropriate policies and stimulus packages differ by country context, but the evidence suggests that the long run multipliers of climate positive policies have been high - reflective of strong returns on government investment spending (Hepburn et al., 2020). In addition, recovery packages that 'seek synergies between climate and economic goals' have been shown to have higher potential for increasing national wealth, enhancing productive human, social, physical, intangible, and natural capital.

However, initial proposals by the South African government for post-Covid-19 economic recovery indicated the intention to focus on carbon intensive investments such as the gas sector (in the draft Mining and Energy Recovery), instead of prioritising a 'green' (Climate Action Tracker, 2021). This is despite evidence that investments in low carbon technologies would enable opportunities for localisation of value chains, reductions in air pollution, and job creation. As an example, a 'green' recovery could include having a requirement of low carbon technologies in new infrastructure investment (Climate Action Tracker, 2021). Additionally, Climate Action Tracker evaluates South Africa's Updated Nationally Determined Contribution (NDC)[10] as 'insufficient', meaning that a more

[10] As of October 2018, 177 countries had submitted their first NDCs, demonstrating near universal participation in mitigation for both developed and developing countries (Winkler, 2018), despite the fact that developing countries have contributed less to the problem. NDCs set out a countries goals relating to temperature, mitigation, adaptation, and finance – including compulsory reviews. South Africa updated NDC September 2021.

ambitious emissions reduction target for 2030 is recommended (this is currently rated as ‘nearly sufficient’).

Climate Action Tracker (2021) has recognized the opportunity to further increase RE capacity by 2030 and beyond, by stopping the planned commissioning of 1.5 GW of new coal based energy capacity, fully phasing out coal based energy generation by 2040, and avoiding investing in natural gas. However, the uncertainty around Eskom’s financial condition is a factor that has delayed the progress on RE extension. The government has introduced an initial refinancing initiative to reduce the contribution of grid connected RE projects to the wholesale electricity price, while a long awaited bid round for RE projects has recently been launched – indicative of some progress, albeit slow (Climate Action Tracker, 2021).

Literature on a ‘Just Transition’ to move away from high unemployment and emissions

According to the Climate Justice Alliance’ webpage (Climate Justice Alliance, 2017),

> a *‘Just Transition is a vision-led, unifying and place-based set of principles, processes, and practices that build economic and political power to shift from an extractive economy to a regenerative economy. This means approaching production and consumption cycles holistically and waste-free. The transition itself must be just and equitable; redressing past harms and creating new relationships of power for the future through reparations. If the process of transition is not just, the outcome will never be. Just Transition describes both where we are going and how we get there.’*

This is relevant to emphasize here, as the conclusions of this dissertation will in part inform a ‘Just Transition’. By mapping sectors for employment intensive and low carbon growth in South Africa, I am essentially looking at what a new growth pathway that is in line with the ultimate definition of a ‘Just Transition’ would look like, as well as policy measures and the implications for sectors / subsectors based on their employment and emissions profile.

Climate change experts at the University of Cape Town (UCT) were recently involved in a case study to identify what a ‘Just Transition’ might look like in a South African context (Winkler, Keen & Marquard, 2020). This Just Transition Transaction (JTT) would look towards solving the electricity supply crisis through transitioning towards RE generation and creating jobs at the same time. According to this case study, electricity demand could be met with the use of 3000 square kilometres of solar PV cells – equating to 0.25% of the country’s land mass. Adding in wind power, RE is the logical choice for South Africa’s power generation future.

For this transition to be 'Just' nobody must be left behind, meaning that the JTT would work as a mechanism that both mobilises blended finance to fund the phase out of coal based energy and increase in RE generation, as well as ensuring that the livelihoods of the communities and the employment of the workers affected are protected (Winkler, Keen & Marquard, 2020). The JTT outlines a faster and more extensive phase out of coal based energy than the IRP2019, seen as essential to attract the international climate finance necessary – around US$11 billion. This money would go towards:

- An accelerated phase out of coal based energy;
- Assisting Eskom remain solvent as it decarbonises ($4 billion from concessional loans); and
- Supporting the communities and workers affected by the shift away from coal based energy.

For a developing country such as South Africa, with urgent need for investment in growth and socioeconomic advancements, financing the transition is imperative. In a case study (Forrest, 2020), Winkler discusses the example of a reskilling programme in Mpumalanga. This would mean that workers who lose jobs in coal based energy value chains (including coal-fired power stations and coal mines) would be able to take advantage of another opportunity to earn a livelihood. Another example mentioned was supporting regional growth and socioeconomic plans by the provincial government or specific districts (Forrest, 2020). On the whole, transitioning to RE has the potential to drive industrialisation while simultaneously localising the technology value chain – thus, encouraging local job creation and community infrastructure ownership (Winkler, Keen & Marquard, 2020).

According to Trade & Industrial Policy Strategies (TIPS), 'Just Transition' discussions are primarily focused on the coal based energy value chain – in particular, coal based energy generation and the associated 'Coal mining' sector. In South Africa, the majority of coal-related operations are found in Mpumalanga, specifically in eMalahleni (formerly Witbank) and Gert Sibande (Nkonyane et al., Mar 24, 2021). However, a more exhaustive narrative that explicitly provides the mapped employment and emissions intensity of sectors / subsectors in the wider South African economy has not been completed. The provision of this kind of information could bring the country one step further in enabling progress across all the sectors and subsectors of the economy (in all geographies).

So far, research for the development of Sector Jobs Resilience Plans (SJRPs) was conducted by TIPS for the Department of Environment, Forestry and Fisheries (DEFF) and Trade and Industry (TIPS, 2020). The SJRPs are meant to help protect vulnerable groups that stand to lose their jobs as a result of climate change impacts. These impacts could be from the physical effects of climate change or as a result of the transition to alternative sources of energy (such as RE). The proposals for the SJRPs are conveyed as a suite of documents, including 'SJRP Toolbox: Summary for policy makers' (Makgetla et al., 2020) as well as proposals for five value chains that are likely to be affected – namely: Coal, metals, petroleum-based transport, agriculture, and tourism.

A 'Just Transition', alongside TIPS and the SJRPs, provides valuable support for sectors of the South African economy. However, there is no explicit characterisation of sectors / subsectors by both their employment and emissions intensities. Thus, this kind of mapping would be significant in order to give further guidance to a wider range of sectors. Therefore, allowing for the analysis of policy measures and the implications on various sectors / subsectors.

Chapter 2 concretizes the problem statement and discusses the theoretical framework with regards to enabling a shift of South Africa's growth pathway. The chapter then reviews previous studies pertaining to employment and carbon intensities, in order to firstly identify sectors with high employment intensities and secondly sectors with low carbon intensities. In response to the problem statement, a broad framing of the solution space follows. This provides an introduction to the literature on relevant industrial and energy climate policy, as well as the literature on a 'Just Transition'. Using this as a basis, Chapter 3 will present the mapping methodology.

3. Data and methodology

In this Chapter, I first sketch out the research design, the data that I have made use of, the relevant adjustments in order to work with the data and draw out appropriate findings, as well as the methods taken in order to map data between the employment and carbon intensity models used. All data in the form of appendices A to F can be found as online supplementary information on Zivahub at DOI: 10.25375/uct.15043164.

(i) Research design

In order to analyse the overarching research question (see Chapter 1.ii), an important step is to map sectors and subsectors in order to categorize where the opportunities for high employment and low carbon growth in South Africa can be found. In order to do this, the employment intensity as well as the carbon intensity of sectors will both be used. Similar to the method used by Hepburn et al. (2020), I will use a table in order to sort sectors into the following four quadrants:

A) low carbon intensity / high employment intensity

B) high carbon intensity / high employment intensity

C) low carbon intensity / low employment intensity

D) high carbon intensity / low employment intensity

Figure 1: Typology using both employment intensity and carbon intensity

Source: Author's own analysis

	Low employment intensity	**High employment intensity**
Low carbon intensity	C) low carbon intensity / low employment intensity	A) low carbon intensity / high employment intensity
High carbon intensity	D) high carbon intensity / low employment intensity	B) high carbon intensity / high employment intensity

This enables the formation of a two-by-two typology (see Figure 1 above). According to the prior discussion of the literature, faster growth in the top-right quadrant (A) would be in the interest of the

South African economy and the country's new growth pathway. This would constitute a move towards 'clean-and-inclusive sectors' that foster 'green' and employment intensive growth, enabling a 'Just Transition' (as previously defined). Once the typology has been filled, the principal sectors in each category can be identified, and discussed further. Thereafter, the implications of certain policy measures across sectors / subsectors can be analysed.

(ii) Employment multipliers as a measure for employment intensity

The employment intensity of an industry is an indicator of the extent to which that industry requires labour for its outputs to be processed. It is reasonable to expect that the employment intensity across sectors and subsectors in the South African economy will vary based on the characteristics of the industry and its outputs. Employment multipliers are one method of measuring employment intensity, but are specifically advantageous because they take into account indirect employment absorption (Tregenna, 2015). This means that employment multipliers include the degree that activities in a sector are linked to other sectors of the economy, and the degree to which these other sectors are themselves employment intensive (or not).

This is important because a particular subsector (let us call it x) may have a low direct employment intensity, but if x uses outputs from other employment intensive subsectors (y and z) for its inputs, then x's employment multiplier should be larger due to the indirect effect that occurs. This means that an expansion in x's output would have a larger impact on employment than the direct measure indicates. This is because there would also be an increase in the demand for outputs from subsectors y and z (as x's inputs), resulting in increased employment due to the employment intensive nature of y and z (indirect effect). Employment multipliers in fact go a lot broader and look at the inputs for y and z (and so on until we are down to the raw materials), thus creating a more accurate measure as opposed to simply looking at the direct employment effect (Tregenna, 2015). However, at the same time, employment multipliers do not take into account where the job creation would lie in terms of skill level, which is important as unemployed people in South Africa are generally low skilled workers (Tregenna, 2015).

Nevertheless, if there is a composition change in one particular sector due to a policy intervention for example, we can gauge how this will affect the labour demand over the entire economy (i.e., how the economy in aggregate would respond in terms of employment). In other words, employment multipliers allow us to determine what the total employment effect throughout the economy would be if the final output were to change in one specific sector. In order to do this, the direct effect in the sector specified is taken alongside the indirect effect of backward (where the inputs come from) and forward (where the outputs are used) linkages between various sectors in the economy. This means that employment multipliers take into account how a particular sector would use outputs from other sectors as their inputs, and those further sectors would use outputs from other sectors in their inputs (and so on).

In order to calculate these employment multipliers, data is used from the Input-Output (IO) table or the Social Accounting Matrix (SAM) for South Africa. Essentially, combining sectoral direct employment intensities with the Leontief inverse (computed from an IO table or SAM, showing the strength of a sector's backward linkages). Backward linkages describe how a sector purchases its goods, products, or supplies from different sectors in the economy - as inputs. The Leontief inverse works here as it is a matrix that shows the strength of these backward linkages between sectors (Tregenna, 2015). Thus, we are able to show the intensity of each sectors' backward linkages to other sectors in the economy. This is in terms of what would be required from other sectors if an extra unit in a specific sector were to be produced (where the output of those other sectors are inputs for that specific sector).

Tregenna (2010) uses South African employment data from Quantec's South African Standardised Industry Database (SASID) (Quantec) in order to calculate the multipliers at the most detailed level of disaggregation for which the data is available (46 sectors)[11]. Tregenna (2010) gives numerical values and / or rankings for the employment intensity of these 46 sectors using various measures, including employment multipliers which will used as the employment intensity measure in this dissertation. Each of the 46 sectors above have a corresponding employment multiplier rank (the explicit employment multiplier values were not obtainable). This means that using the rank is the most accurate option. Thereafter, each sector is mapped according to its Standard Industrial Classification (SIC) division code (Fifth Edition). The 46 sectors are somewhat aggregated, meaning that some will have more than one SIC code (as can be seen in Table 1). I have assigned SIC codes by using 'Appendix A: List of subsectors and what they include' (Tregenna, 2010) and the manual for the SIC of All Economic Activities (Fifth Edition) (StatsSA, 1993). Interested readers can find details in the online

11 *Agriculture; Coal mining; Gold mining; Other mining; Food; Beverages; Tobacco; Textiles; Clothing; Leather; Footwear; Wood & wood products; Paper & paper products; Printing, publishing & recorded media; Coke & refined petroleum products; Basic chemicals; Other chemicals & man-made fibres; Rubber products; Plastic products; Glass & glass products; Non-metallic minerals; Basic iron & steel; Basic non-ferrous metals; Metal products excluding machinery; Machinery & equipment; Electrical machinery & apparatus; TV, radio & communication equipment; Professional & scientific equipment; Motor vehicles, parts & accessories; Other transport equipment; Furniture; Other manufacturing; Electricity, gas & steam; Water supply; Building construction; Civil engineering & other construction; Wholesale & retail trade; Catering & accommodation services; Transport & storage; Communication; Finance & insurance; Business services; Medical, dental & veterinary services; Other private services; Other producers; General government.*

supplementary information that is provided, as well as in the online manual for the SIC codes (see References for the link).

Table 1: Employment intensity by sector, categorised by SIC code and ranked from highest labour employment multiplier to lowest employment multiplier.

Source: SIC mapping author's work, using data and rankings from Tregenna (2010)

Sector	SIC code (edition 5)
Other producers	99
Clothing	313, 314, 315
Catering & accommodation services	64
Textiles	311, 312
Agriculture	11, 12, 13
Furniture	391
Leather	316
Wood & wood products	321, 322
Wholesale & retail trade	61, 62, 63
Footwear	317
Food	301, 302, 303
Motor vehicles, parts & accessories	381, 382, 383
Machinery & equipment	356, 357, 358, 359
Building construction	502
Metal products excluding machinery	354, 355
Civil engineering & other construction	501, 503, 504, 505
Printing, publishing & recorded media	324, 325, 326
Business services	831(8311, 8312, 8319), 832, 84, 85, 86, 87, 88
Beverages	305
Professional & scientific equipment	374, 375, 376
Paper & paper products	323
TV, radio & communication equipment	371, 372, 373
General government	91
Electrical machinery & apparatus	36
Rubber products	337
Glass & glass products	341
Tobacco	306
Medical, dental & veterinary services	93
Gold mining	23
Other private services	92, 94, 95, 96
Non-metallic minerals	342
Other transport equipment	384, 385, 386, 387
Other chemicals & man-made fibres	335, 336
Plastic products	338
Transport & storage	71, 72, 73, 74
Other manufacturing	392, 393, 395
Basic iron & steel	351, 353

Basic chemicals	334
Communication	75
Basic non-ferrous metals	352
Other mining	221 (2211, 2212), 24, 25
Coke & refined petroleum products	331, 332, 333
Water supply	420
Finance & insurance	81, 82
Electricity, gas & steam	411, 412, 413
Coal mining	21

(iii) Carbon intensity of sectors

Using the results of Reeler (2021), the carbon intensity of sectors in the South African economy can be ascertained. Reeler's (2021) paper made extensive use of the national Supply-Use (SU) and the South African Energy Accounts in order to map sectors and products by their emissions intensity. The main difficulty found was that the energy balances were disaggregated further than the SU tables, thus the final carbon intensity values were calculated for the more general sectors found in the SU tables. This required some assumptions so as to aggregate similar activity / product classes in the energy balances. The result was a sectoral mapping on the basis of the system of national accounts, which is essentially a mapping of energy consumption to GDP. I will thus use the sectors in the SU tables, of which there are 63, and their associated carbon intensities calculated by Reeler (2021).

Similar to Tregenna in 3.ii, Reeler (2021) has used IO / multiplier analysis to calculate the carbon intensity measures of various sectors. Each sector requires inputs from other sectors in the economy, in the form if goods, products, or supplies. This means that the production of one extra unit in a specific sector would also require other sectors to increase their outputs (where the output of those other sectors are inputs for that specific sector). Most production processes emit very little carbon emissions directly, and so these indirect effects through interindustry backward linkages are important in the energy sector in order to assign carbon emission intensities correctly.

Carbon intensities (tonnes of CO2e per thousand Rand expenditure) are available for 2005, 2010 and 2015 – both for 63 sectors and 105 aggregate products (Reeler, 2021). This is useful as I can look at not only the sector and the associated products' carbon intensity, but I also have an idea of how industries and products may have experienced a reduction in carbon intensity over 10 years, as GDP has grown and emissions have remained relatively stable. Similarly, to the process in 3.ii of this Chapter, the 63 sectors often consist of more than one SIC code (as can be seen in Table 2). I use the definitions of the sectors that were applied to the work done by Reeler (2021) and the manual for the

SIC of All Economic Activities (Fifth Edition) (StatsSA, 1993). Interested readers can find details in Reeler (2021), as well as in the online manual for the SIC codes (see References for the link).

Table 2: Carbon intensity (tCO2e/R'000) by sector, categorised by SIC code and ranked from lowest carbon intensity to highest carbon intensity in 2015.

Source: SIC mapping author's work, using data from Reeler (2021) and StatsSA (2015) Appendix B

Sector	2015 (tCO2e/R'000)	SU classification (Stats SA, 2015) - SIC 5th edn
Activities auxiliary to financial intermediation	0.0022	83
Insurance and pension funding	0.0070	82
Financial intermediation	0.0099	81
Government	0.0153	91
Forestry	0.0194	12
Non-observed, informal, non-profit, households	0.0217	0100, 0200, 0900
Hotels and restaurants	0.0246	64
Post and telecommunication	0.0266	75
Radio, television, communication equipment and apparatus	0.0283	371, 372, 373
Retail trade	0.0290	62
Sewerage and refuse disposal	0.0290	94
Medical, precision, optical instruments, watches and clocks	0.0300	374, 375, 376
Beverages and tobacco	0.0312	305, 306
Mining of coal and lignite	0.0332	21
Wholesale trade, commission trade	0.0337	61
Activities of membership organisations	0.0337	95
Other transport equipment	0.0340	384, 385, 386, 387
Health and social work	0.0343	93
Research and experimental development	0.0344	87
Footwear	0.0362	317
Education	0.0364	92
Tanning and dressing of leather	0.0382	316
Sale, maintenance, repair of motor vehicles	0.0388	63
Motor vehicles, trailers, parts	0.0423	381, 382, 383
Recreational, cultural and sporting activities	0.0425	96
Food	0.0432	301, 302, 303, 304
Other activities	0.0433	99
Machinery and equipment	0.0436	356, 357, 358, 359
Furniture	0.0446	391
Manufacturing n.e.c, recycling	0.0449	392, 393, 395
Sawmilling, planing of wood, cork, straw	0.0452	321, 322
Publishing, printing, recorded media	0.0457	324, 325, 326
Renting of machinery and equipment	0.0467	85
Knitted, crouched fabrics, wearing apparel, fur articles	0.0473	313, 314, 315
Construction	0.0530	501, 502, 503, 504, 505
Real estate activities	0.0530	84
Other mining and quarrying	0.0537	25, 2212

Land transport, transport via pipelines	0.0542	71
Auxiliary transport	0.0571	74
Agriculture	0.0578	11
Fishing	0.0615	13
Fabricated metal products	0.0658	354, 355
Electrical machinery and apparatus	0.0662	36
Collection, purification and distribution of water	0.0672	42
Other business activities	0.0698	88
Plastic	0.0718	338
Spinning, weaving and finishing of textiles	0.0727	311, 312
Mining of metal ores	0.0789	24
Rubber	0.0792	337
Computer and related activities	0.0792	86
Air transport	0.0809	73
Other chemical products, man-made fibres	0.0827	335, 336
Water transport	0.0833	72
Mining of gold and uranium ore	0.0865	23
Glass	0.0927	341
Paper	0.1156	323
Non-metallic minerals	0.1186	342
Basic precious and non-ferrous metals	0.1346	352
Nuclear fuel, basic chemicals	0.1493	333, 334
Basic iron and steel, casting of metals	0.1630	351, 353
Gas sector	0.2071	2211
Coke oven, petroleum refineries	0.7470	331, 332
Electricity, gas, steam and hot water supply	0.9260	411, 412, 413

In terms of sector definitions, Reeler (2021) does not include as detailed an appendix as Tregenna (2010), but provides information on how the process was carried out, which I could then replicate (Table 2). In using the SU data (reported in his Appendix C), Reeler (2021) had to deal with the activity descriptions not being aligned. This was because estimates of value added by industry in the System of National Accounts (SNA) is classified according to the SIC Fifth Edition (based on the third revision of the International Standard Industrial Classification (ISIC) of all Economic Activities). For the purposes of the study, Reeler (2021) had to work with the industries as specified in the SU tables, so was required to find the correspondences between the SU industries and the SIC codes. In order to work out the equivalences, the Statistics South Africa Annual Reports were made use of, which detail the SIC classes aggregated into each of the reporting classes for the SU tables (StatsSA, 2015) – see Appendix B in online supplementary.

A final note is that industries by themselves do not have a final demand - they are intermediate consumers so they use inputs in the manufacture of final products consumed by households or exported (Arndt et al., 2013). Thus, the carbon intensity of certain products of industry is also provided by Reeler (2021). The product carbon intensity is not captured in the industry carbon intensity, and so it is important to check that the carbon intensity of an industry and its products do not differ significantly. The only substantial case is for the 'Mining of coal and lignite' sector, which is a relatively low emitter when looking at the industry carbon intensity (0.0332 tCO2e/R'000). But the product of this industry (coal in particular) yields a much higher carbon intensity (3.3202 tCO2e/R'000). Thus, it is important that the carbon intensity of the product is considered in Chapter 4 after the typology is filled in. I will also need to make explicit use of the carbon intensity of certain products for varying SIC codes and the reconciliations made in Chapter 3.v.

(iv) Mapping sectors

In order to map sectors using the two measures above, I use the SIC codes (broken up into divisions, groups, classes, and subclasses) as well as the descriptions of each in the SIC manual (StatsSA, 1993). In order for this process to be valid, I have demonstrated for both employment multiplier ranks and carbon intensities that certain activities map to certain SIC codes, and are thus materially the same. On the employment side, Tregenna (2010) has provided the definition for each sector she has given an employment multiplier rank - see Appendix A. On the carbon intensity side, Reeler (2021) has used the Statistics South Africa Annual Reports to map SU industries (column number and SU tables description) with SIC codes. The SIC codes are not explicitly given in Reeler (2021) but the SU table column number is given, so the sector and its associated carbon intensity can be assigned a SIC code and thus the linked SIC definition – see Appendix B for SU to SIC conversion (StatsSA, 2015), and Statistics South Africa (1993) for full SIC definitions and online SI to follow the calculations in Excel.

Thus, if a sector from the employment side has the same SIC code as a sector from the carbon intensity side, they are materially the same – meaning that I can map sectors from the employment multiplier rank to their respective carbon intensity. Thus, ending up with each sector having both an employment multiplier ranking as well as a carbon intensity value (the carbon intensity of sectors is further disaggregated, so in multiple cases the specific sector from the employment multiplier side will have more than one carbon intensity value, and vice versa – see Chapter 3.vi).

From there, the sectors (with their respective SIC codes) will be sorted into the four quadrants as specified in Table 1 (A, B, C, and D), using the thresholds in Table 3 (see below). The threshold for the employment side has been taken as the multiplier rank midpoint – so the sectors from 1 to 23 would be in either A or B, and 24 to 46 would be in C or D. The carbon intensity threshold has been chosen as the median rounded to two decimal places (0.04545 rounded to 0.05), so sectors below would either fall in A or C, and sectors above in B or D. The analytical process has been undertaken as follows:

1. List the SAM industry categories along with their employment multiplier rank, then categorize each with a SIC code (demonstrating the activities align). List from highest to lowest on a separate excel spreadsheet.
2. List the 64 sectors used in the SU tables with the associated carbon intensity values, then categorize each with a SIC code (demonstrating the activities align). Rank from lowest to highest on a separate excel spreadsheet, i.e., from low carbon intensity to high carbon intensity.
3. Review alignment of SIC codes and show calculations and assumptions used in order to resolve the differing disaggregation of the data.
4. Take the measures from the initial unranked spreadsheets and map the sectors, so for each there is both an employment multiplier rank and a carbon intensity.
5. List the sectors in order of high emission / low carbon intensity down to low emission / high carbon intensity (take into consideration the carbon intensity of the industry products for any inconsistencies e.g., ‘Coal mining’ sector which has a low industry carbon intensity but a high product carbon intensity).
6. Sort into the four quadrants as defined in Figure 1 (A, B, C and D), using thresholds in Table 3 (below).
7. Present the findings (Chapter 4) and thereafter engage in further discussion using these findings (Chapter 5).

Table 3: Initial thresholds used to sort sectors into their respective categories

Source: Author’s own analysis

A: employment multiplier rank 1-23	A: carbon intensity below 0.05 tCO2e/R'000
B: employment multiplier rank 1-23	B: carbon intensity above 0.05 tCO2e/R'000
C: employment multiplier rank 24-46	C: carbon intensity below 0.05 tCO2e/R'000
D: employment multiplier rank 24-46	D: carbon intensity above 0.05 tCO2e/R'000

(v) Addressing challenges in the data

Differing years for data

The datasets used are from different years, specifically the employment multiplier ranks use data from 2010 and the carbon intensities are from 2015. I do have the carbon intensities for 2010, but a lot changed in many sectors in this regard. However, between 2010 and 2015, industry employment shares have remained relatively constant – this was established by using SASID (Quantec) data from 2010 and 2015 for formal and informal employment in industry (Appendix D). On average, comparing 2010 and 2015, the number of people employed in industry as a proportion of the total differed by 0.0246 (using the average of the absolute value of the differences – see Appendix D). Therefore, the assumption that industry employment shares have remained relatively constant is valid. Thus, I will use the 2010 employment multiplier ranks as a placeholder for the 2015 equivalents.

Some varying SIC codes at first glance, and reconciliation

An initial review of the SIC codes for the employment multiplier ranks and the carbon intensities was conducted (step 3 in Chapter 3.iv) in order to determine the inconsistencies that need to be dealt with. A few issues emerge which will be explained below, as well as what is done to resolve them. The main limitation here was that the employment multiplier ranks were not always sufficiently disaggregated. On the employment intensity rank side, average direct employment (000s) values (SATIM–eSAGE, 2012) will be used to calculate each sector's direct employment (000s) as a proportion of the average for the sectors that were grouped together. This gives a proportion that can 'adjust' the rank of the disaggregated sectors. On the carbon intensity side, income shares (StatsSA, 2018) will be used when looking at electricity and gas, to obtain disaggregated carbon intensity values for each. In other cases, I will aggregate sectors with similar carbon / employment intensities, and in cases such as 'Tobacco' and 'Beverages' I consider the carbon intensity of the sector products to give more information.

1 'Agriculture', 'Foresty', and Fishing'

The sector 'Agriculture' in Tregenna (2010) adds 'Forestry' and 'Fishing' (giving us a single employment multiplier rank). Whereas on the emissions side the carbon intensities are disaggregated into each of the three sectors (Reeler, 2021) with SIC codes 11, 12, 13 - each having its own carbon intensity. Looking at each sector, 'Forestry' has a carbon intensity of 0.0194 tCO_2e/R'000, 'Fishing' has a carbon intensity of 0.0615 tCO_2e/R'000 and 'Agriculture' of 0.0578 tCO_2e/R'000 – which materially differ ('materially differ' is defined here as having carbon intensities that places sectors in different quadrants in the typology). Thus, it would be best to have three different carbon intensities mapped to three different employment multiplier ranks. But as the sectors cannot be separated using raw

SASID (Quantec) data, I have used the 2012 South African energy (SATIM) and economic (eSAGE) linked model (eSAGE-SATIM), which can be found in Appendix E (SATIM–eSAGE, 2012). This model gives direct employment numbers for industry in 2012, clearly showing that direct creation of jobs differs significantly between 'Agriculture', 'Forestry' and 'Fishing' (see Table 4).

The average direct employment (000s) for these three sectors is 231.33 - corresponding to the rank of 5. The logic follows that with a combined rank of 5, individual ranks will be higher or lower than 5 based on the sectoral direct employment being above or below the average direct employment. I thus calculate each sector's direct employment (000s) as a proportion of the average for the three sectors – giving me a proportion that I can use to 'adjust' the rank of the disaggregated sectors.

Table 4: 'Adjusted' employment multiplier rank for 'Agriculture', 'Forestry, and 'Fishing'

Source: Direct employment from SATIM-eSAGE (2012) and calculations author's own analysis (SATIM-eSAGE, 2012)

Sector	**'Agriculture'**	**'Forestry'**	**'Fishing'**
eSAGE-SATIM employment (000s)	643.46	34.99	15.55
Current aggregated rank	5	5	5
Expected to be higher or lower than rank 5	higher (i.e., smaller than 5)	lower (i.e., bigger than 5)	lower (i.e., bigger than 5)
Proportion	$643.46 / 231.33 = 2.8$	$34.99 / 231.33 = 0.2$	$15.55 / 231.33 = 0.1$
Resulting 'adjusted' rank	$5 - (5/46) / 2.8 = \mathbf{5}$	$5 + (5/46) / 0.2 = \mathbf{6}$	$5 + (5/46) / 0.1 = \mathbf{7}$

The calculations in Table 4 above mean that I end up with following three mapping points:

- **'Agriculture -** carbon intensity of 0.0578 tCO2e/R'000 and employment multiplier rank of 5
- **'Forestry' -** carbon intensity of 0.0194 tCO2e/R'000 and employment multiplier rank of 6
- **'Fishing-** carbon intensity of 0.0615 tCO2e/R'000 and employment multiplier rank of 7

2 'Electricity' and 'Gas'

The sector titled 'Electricity, gas & steam' (Tregenna, 2010) is defined as the 'Production, collection and distribution of electricity; generation; distribution of purchased electric energy only; generation and / or distribution for own use; manufacture of gas; distribution of gaseous fuels through mains; steam and hot water supply' needs to be mapped to the sector 'Electricity, gas & hot water', as defined by (Reeler, 2021). 'Electricity, gas, steam and hot water supply' needs to be disaggregated on both sides into its three components. However, looking at the SU tables (StatsSA, 2015) as well as employment data from SASID (Quantec), the raw data – see Appendices C and D – is formatted in a way that inherently groups them together. However, having 'Electricity' as a single sector is necessary in order to look at the carbon intensity and employment multiplier of Eskom in particular. I therefore look towards the carbon intensities of the products (Reeler, 2021) to make it possible to disaggregate this sector into the necessary components. I will first make some clarificatory points and then explain the process.

'Steam and hot water supply' (includes the production, collection and distribution of steam and hot water for heating, power, and other purposes) (StatsSA, 1993) is not a significant part of this sector grouping (StatsSA, 2018). The industry as a whole in South Africa is small enough that I will assume that the subsector consists of only 'Electricity and gas'.

Natural gas is classified as its own category for the carbon intensities ('Gas sector') and under 'Other mining' for the employment multiplier rank. The 'Gas sector' here is different to the gas found in 'Electricity, gas, steam and hot water supply'. This 'Gas sector'[12] (natural) is introduced in order to disaggregate the primary fossil fuels. This means that natural gas does not form part of the 'Other mining products' group in the SU tables, as all the electricity industry's expenditure on 'Other mining products' became attributed to gas turbines (Reeler, 2021). It is also noteworthy to add that most of the gas consumption is endogenous, meaning it does not rely on household consumption. Therefore, 'Gas' in the 'Electricity and gas' sector, namely the 'manufacture of gas; distribution of gaseous fuels through mains' (excluding natural gas), is a relatively small subsector. In terms of income and employment, the supply of gas does not make up a large part of the 'Electricity and gas' grouping overall – roughly 6% share of income and 1% share of employment in 2016 (StatsSA, 2018).

Looking at the data given (Reeler, 2021), I have an industry carbon intensity and two product carbon intensities for 2015 (tCO2e/R'000), namely:

(1) Electricity (generation) and gas (products of SIC 411, 412) with a carbon intensity of 0.5027 tCO2e/R'000
(2) Electricity distribution (product of SIC 411) with a carbon intensity of 0.8840 tCO2e/R'000
(3) Electricity, gas, steam and hot water supply with a carbon intensity of 0.9260.

[12] Defined as 'manufacture of gaseous fuels in gasworks. The production of gas by the carbonation of coal or by mixing manufactured gas with natural gas or petroleum or other gases. The distribution of gaseous fuels through a system of mains to household, industrial, commercial, or other users' (StatsSA, 1993).

Generation emissions are attributed to both electricity generation and distribution, as transmission losses are not tracked sufficiently in the SU tables (Reeler, 2021). This means that I can essentially use the carbon intensity for (2) Electricity distribution (0.8840 tCO2e/R'000) as the carbon intensity for the electricity subsector overall. It also means that ascertaining the carbon intensity for the gas subsector is possible by removing the electricity component from the electricity and gas carbon intensity. Using the income shares of electricity and gas (StatsSA, 2018), I can obtain exact percentages for the year 2016:

- $Electricity\ =\ R201\,316\ /\ (R201\,316\ +\ R11\,946)\ *\ 100\ =\ 94.4\%$
- $Gas\ =\ R11\,946\ /\ (R201\,316\ +\ R11\,946)\ *\ 100\ =\ 5.6\%$

Therefore, taking the carbon intensity of electricity to be 0.8840, I have that:

$$carbon\ intensity\ for\ gas\ = 0.056(0.5027 + 0.9260)$$
$$\therefore \boldsymbol{carbon\ intensity\ gas =\ 0.08}$$

I can then use the labour shares for 2016 (StatsSA, 2018) in order to split up electricity and gas, thus obtaining two different employment multiplier rankings:

- $Electricity\ =\ 46\,287\ /\ \ (46\,287\ +\ 423) *\ 100\ \ = 99.1\%$
- $Gas\ =\ 423\ /\ (46\,287\ +\ 423) *\ 100\ \ = 0.9\%$

Current aggregated rank is 45, with labour share electricity = 0.991 & labour share gas = 0.009. Therefore,

$Adjusted\ rank\ electricity\ subsector\ (expected\ to\ be\ smaller\ than\ 45\ ie.more\ employment\ )$

$$= 45 - \left(\frac{45}{46}\right) * 0.991 = \mathbf{44}$$

$Adjusted\ rank\ for\ the\ gas\ subsector\ (expected\ to\ be\ larger\ than\ 45\ ie.less\ employment\ intensive)$

$$=\ 4 + \left(\frac{45}{46}\right) * 0.009 = \mathbf{45}$$

3 'Mining and metal ores', 'Gas sector (natural)', and ''Other mining and quarrying

The employment multipliers for 'Other mining' (Tregenna, 2010) are defined by the 'Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying; mining of iron ore; mining of non-ferrous metal ores, except gold and uranium; stone quarrying, clay and sand-pits; mining of precious and semi-precious stones, except diamonds;

asbestos; other minerals and materials n.e.c.; service activities incidental to mining of minerals' (SIC code 221 (2221 & 2212), 24 and 25). However, on the emissions side this is split into three groupings which materially differ in value – namely:

(1) 'Mining of metal ores' (SIC 24) with a carbon intensity of 0.0789 $tCO_2e/R'000$
(2) 'Gas sector' (SIC 2211 i.e., natural gas) with a carbon intensity of 0.2071 $tCO_2e/R'000$
(3) 'Other mining and quarrying' (SIC 2212 and 25) with a carbon intensity of 0.0537 $tCO_2e/R'000$.

Looking back to the employment side, the energy-economic linked model in Appendix E (SATIM–eSAGE, 2012) makes it clear that direct jobs created by each sector differ. 'Mining of metal ores' created the most direct jobs and the 'Gas sector' (natural) created the least (despite being the most carbon intensive). It would therefore be most accurate to have three separate mapping points for these sectors. But as natural gas ('Gas sector') cannot be separated using raw SASID (Quantec) data, I will use the energy-economic linked model mentioned above (see Appendix E and Table 5 below).

The average direct employment (000s) for these three sectors is 68.86 - corresponding to the rank of 41. The logic follows that with a combined rank of 41, individual ranks will be higher or lower than 41 based on the sectoral direct employment being above or below the average direct employment. I thus calculate each sector's direct employment (000s) as a proportion of the average for the three sectors – giving me a proportion that I can use to 'adjust' the rank of the disaggregated sectors.

Table 5: 'Adjusted' employment multiplier rank for 'Mining of metal ores', 'Gas sector' and 'Other mining and quarrying' (SATIM-eSAGE, 2012)

Source: Direct employment from SATIM-eSAGE (2012) and calculations author's own analysis

Sector	**'Mining of metal ores'**	**'Gas sector' (natural)**	**'Other mining and quarrying'**
eSAGE-SATIM employment (000s)	155.32	2.42	48.82
Current aggregated rank	41	41	41
Expected to be higher or lower than rank 41	higher (i.e., smaller than 41)	lower (i.e., bigger than 41)	lower (i.e., bigger than 41)
Proportion	$155.32 / 68.86 = 2.3$	$42.42 / 68.86 = 0.04$	$48.82 / 68.86 = 0.71$

Resulting 'adjusted' rank	$41 - (41/46) / 2.3 = \mathbf{40}$	$41 + (41/46) / 0.04 = \mathbf{66}$	$41 + (41/46) / 0.71 = \mathbf{42}$

The calculations in Table 5 above mean that I end up with following three mapping points:

- **'Mining and metal ores' –** carbon intensity of 0.0789 tCO2e/R'000 and employment multiplier rank of 40
- **'Gas sector' (natural) -** carbon intensity of 0.2071 tCO2e/R'000 and employment multiplier rank of 47[13]
- **'Other mining and quarrying' -** carbon intensity of 0.0537 tCO2e/R'000 and employment multiplier rank of 42

4 'Tobacco' and 'Beverages'

The sectors 'Tobacco' (SIC 306) and 'Beverages' (SIC 305) have separate employment multiplier rank values (Tregenna, 2010), but on the emissions side they are grouped together and thus have one value for their combined carbon intensity (Reeler, 2021). I thus map both the employment multiplier rankings of 'Tobacco' (20) and 'Beverages' (19) with the single carbon intensity level of 'Beverages and tobacco' (0.0312 tCO2e/R'000). This is credible as looking at the carbon intensity of industry products (Reeler, 2021), the carbon intensity of 'Tobacco products' is 0.0087 tCO2e/R'000, 'Alcohol, beverages' is 0.0118 tCO2e/R'000, and 'Soft drinks' is 0.0212 tCO2e/R'000. These do not differ by huge amounts, so I have left these sectors grouped together in terms of their carbon intensity, although note that the industry product of the 'Tobacco' sector has a lower carbon intensity compared to 'Beverages'.

5 'Basic chemicals' and 'Coke and refined petroleum products'

The employment multiplier rank for 'Coke & refined petroleum products', which is defined by Tregenna (2010) as the 'Manufacture of coke oven products; petroleum refineries/synthesisers; processing of nuclear fuel' (SIC codes 331, 332, 333), is separated from the rank solely for 'Basic chemicals' (SIC 334). Whereas Reeler (2021) groups 'Nuclear fuels' (SIC 333) together with 'Basic chemicals' (SIC 334) under one carbon intensity (0.1493 tCO2e/R'000). I then have a separate carbon intensity for the sector 'Coke oven, petroleum refineries' (SIC 331 and 332, with a carbon intensity of 0.747 tCO2e/R'000). As of yet there are few opportunities to decarbonise the chemical production process and despite global efforts, there have been no significant reductions that are expected in the

[13] This would rank the 'Gas sector' in last place in terms of employment multipliers i.e., I create a new ranking of 47 for this sector.

short to medium term. This means that it is an important sector to look at on its own, thus I need to split up 'Basic chemicals' and 'Nuclear fuels' on the carbon intensity side. Ultimately I want the chemical industry to have a standalone employment multiplier rank and carbon intensity, as this is where Sasol's coal to liquid fuels processes sit. This coal to liquid fuels process is associated with significant CO_2 emissions from the gasification process and the generation of process heat and electricity inputs (Höök et al., 2014).

According to the 2019 South African Energy Sector Report (DOE, 2019), in 2016 energy supply was dominated by coal, followed by crude oil with 14% and renewables with 11%. Both natural gas and nuclear only contributed 3% each to the total primary supply during the same period. This is the first indicator that the 'Nuclear fuels' sector is quite small in comparison with the 'Basic chemicals' sector. The second is looking at the relatively small employment numbers for the 'Nuclear fuels' sector – in 2017/2018, the South African Nuclear Energy Corporation of South Africa (NECSA) employed 1,962 people (Nesca, 2018). Therefore, in order to map these sectors as accurately as possible, I take out the 'Nuclear fuels' sector on both measures, as its contribution is minor. For the mapping, I thus have two points – one for 'Basic chemicals', and the other for 'Coke and refined petroleum products'.

6 'Construction'

The 'Construction sector' (SIC 501-505) has a single carbon intensity (Reeler, 2021), however on the employment multiplier side (Tregenna, 2010) the sector is split into 'Civil engineering & other construction' (SIC 501, 503-505) and 'Building construction' (SIC 502). I therefore map both the employment multiplier rank values of 'Civil engineering & other construction' (rank 16) and 'Building construction' (rank 14) with the single carbon intensity of 'Construction'. Thus, one carbon intensity of 0.053 $tCO_2e/R'000$ is mapped to two different employment multiplier rankings.

7 'Wholesale & retail trade'

'Wholesale & retail trade' is defined by Tregenna (2010) as 'Wholesale trade and commission trade, except of motor vehicles and motorcycles; retail trade, except of motor vehicles and motorcycles; repair of personal and household goods; sale, maintenance and repair of motor vehicles and motorcycles; retail trade in automotive fuel' (SIC 61, 62 and 63). However, Reeler (2021) splits this sector up into three parts with their own associated carbon intensity – 'Wholesale trade, commission trade' (0.0337 $tCO_2e/R'000$), 'Retail trade' (0.029 $tCO_2e/R'000$), and 'Sale, maintenance, repair of motor vehicles' (0.0388 $tCO_2e/R'000$). Since the carbon intensities do not differ materially here, I am using the single employment multiplier ranking for ‘Wholesale & retail trade’, and mapping it with the average of the three associated carbon intensities– 0.0338 tCO2e/R'000.

8 ‘Transport and storage’

‘Transport and storage’ on the employment multiplier side (Tregenna, 2010) is defined as SIC 71-74[14]. On the other hand, Reeler (2021) breaks this definition up into four separate sectors with their own associated carbon intensity– ‘Land transport, transport via pipelines’ (0.0542 tCO2e/R'000), ‘Water transport’ (0.0833 tCO2e/R'000), ‘Air transport’ (0.0809 tCO2e/R'000), and ‘Auxiliary transport’ (0.0571 tCO2e/R'000). I therefore group the single employment multiplier rank for ‘Transport and storage’ with the four associated carbon intensities, obtaining an average of 0.0689 tCO2e/R'000. However, it is important to note that both the sectors ‘Water Transport’ and ‘Air Transport’ are higher emitters than the other sectors that form part of the ‘Transport and storage’ mapped point.

9 ‘Finance and insurance’

The sector grouping ‘Finance and insurance’ (SIC 81 and 82) has a single employment multiplier rank and is defined as ‘Monetary intermediation; central banking; other financial intermediation n.e.c.; lease financing; other credit granting; other financial intermediation n.e.c.; life insurance; pension funding; medical aid funding; other insurance n.e.c.’ (Tregenna, 2010). However, it is split into two sectors on the emissions side (Reeler, 2021) – ‘Insurance and pension funding’ (SIC 81 with a carbon intensity of 0.007 tCO2e/R'000) and ‘Financial Intermediation’ (SIC 82 with a carbon intensity of 0.0099 tCO2e/R'000) - and thus has two separate carbon intensities. Since the carbon intensities do not differ materially, I will map the ‘Finance and insurance’ employment multiplier rank with both these sectors and their associated carbon intensities, obtaining an average of 0.0085 tCO2e/R'000.

10 ‘Business services’

‘Business services’ is defined by Tregenna (2010) as SIC 83-88[15]. However, on the emissions side this sector is split into six separate groups (Reeler, 2021) – ‘Activities auxiliary to financial intermediation’

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[14] ‘Railway transport; other land transport; other scheduled passenger land transport; other non-scheduled passenger land transport; freight transport by road; transport via pipelines; sea and coastal water transport; inland water transport; air transport; cargo handling; storage and warehousing; other supporting transport activities; travel agency and related activities; activities of other transport agencies’

[15] Administration of financial markets; security dealing activities; activities auxiliary to financial intermediation n.e.c.; activities auxiliary to insurance and pension funding; real estate activities with own or rented property; renting of land transport equipment; renting of water transport equipment; renting of air transport equipment; renting of agricultural machinery and equipment; renting of construction and civil engineering machinery and equipment; renting of office machinery and equipment (including computers); renting of other machinery and equipment n.e.c.; renting of personal and household goods n.e.c.; hardware consultancy; software consultancy and supply; data processing; data base activities; maintenance and repair of office, accounting and computing machinery; other computer related activities; research and experimental development on natural sciences and engineering; research and experimental development on social sciences and humanities; legal activities; accounting, book-keeping and auditing activities; tax consultancy; marketing research and public opinion polling; business and management consultancy activities; architectural and engineering activities and related technical consultancy; technical testing and analysis; advertising; labour recruitment and provision of personnel; investigation and security activities; building and industrial plant cleaning activities; photographic activities; packaging activities; other business activities n.e.c.’

(SIC 83 with a carbon intensity of 0.0022 tCO2e/R'000), 'Real estate activities' (SIC 84 with a carbon intensity of 0.053 tCO2e/R'000), 'Renting of machinery and equipment' (SIC 85 with a carbon intensity of 0.0467 tCO2e/R'000), 'Computer and related activities' (SIC 86 with a carbon intensity of 0.0792 tCO2e/R'000), 'Research and experimental development' (SIC 87 with a carbon intensity of 0.0344 tCO2e/R'000), and 'Other business activities' (SIC 89 with a carbon intensity of 0.0698 tCO2e/R'000). However, I cannot average them in this case as they materially differ. I therefore map the single employment multiplier rank of 18 for 'Business services' with the six associated carbon intensities.

11. *'Other private services'*

'Other private services' is defined by Tregenna (2010) as SIC 92, 94-96[16]. On the other hand, Reeler (2021) splits this up into four separate groups – 'Education' (SIC 92), 'Sewerage and refuse disposal' (SIC 94), 'Activities of membership organisations' (SIC 95), and 'Recreational, cultural and sporting activities' (SIC 96). Since the carbon intensities do not differ materially, I will map the single employment multiplier rank for 'Other private services' with the four associated carbon intensities, obtaining an average value of 0.0354 tCO2e/R'000.

Chapter 3 has outlined the mapping methodology in detail, and thus enabled the mapping of sectors based on their employment multiplier rank and carbon intensities. The findings from the quantitative mapping process are presented in Chapter 4, with further detail in Appendix F and other relevant data in Appendices A-E, found as online supplementary information on Zivahub at DOI: 10.25375/uct.15043164.

[16] 'Education; sewage and refuse disposal, sanitation and similar activities; activities of business and employers' organisations; activities of professional organisations; activities of trade unions; activities of religious organisations; activities of political organisations; activities of other membership organisations n.e.c.; motion picture and video production and distribution; motion picture projection; radio and television activities; dramatic arts, music and other arts activities; other entertainment activities n.e.c.; news agency activities; library and archives activities; museum activities and preservation of historical sites and buildings; botanical and zoological gardens and nature reserve activities; sporting activities; other recreational activities'.

4. Mapping of sectors by employment and carbon intensity measures

Chapter 4 applies the employment multiplier rank and carbon intensity measure, giving Figure 2, a graphical representation of the results of the full mapping methodology in Chapter 3. This allows for the categorization of sectors / subsectors into quadrants based on their relative employment and carbon characteristics. I discuss the findings from this process and thereafter, I bring attention to the impending transition away from coal based energy and thus the 'Coal mining' sector, which will bring growth opportunities in other sectors (such as the RE sector).

In order for the graph (Figure 2 in Chapter 3.i) to feed into the original typology (Figure 1), the carbon intensity values have to be functionally manipulated. This is because most fall in the 0 to 0.05 tCO2e/R'000 range, with only two points being closer to 1 in value. In other words, carbon emissions are highly concentrated in a few activities. This squeezes the majority of the points into an extremely narrow band, making graphic analysis impractical. The log function has thus been applied to the carbon intensities, and then the absolute values taken (positive values which represent the magnitude) - thus distributing the points sufficiently for analysis. I will now call this the carbon intensity measure. The functional transformation applied means that a higher value of the carbon intensity measure represents a lower carbon intensity. I then reorganise the employment multiplier ranks in ascending order from smallest to largest.

The thresholds then need to be adjusted, so that lines can be drawn on the graph – indicative of the quadrant split in the typology. This includes reversing the employment multiplier rank (i.e., 1 becomes 46), as well as applying the absolute value of the log function to the carbon intensity threshold (0.05 becomes 1.3) – see Table 6 below.

Table 6: Thresholds after functional transformation - used to sort sectors into their respective categories.

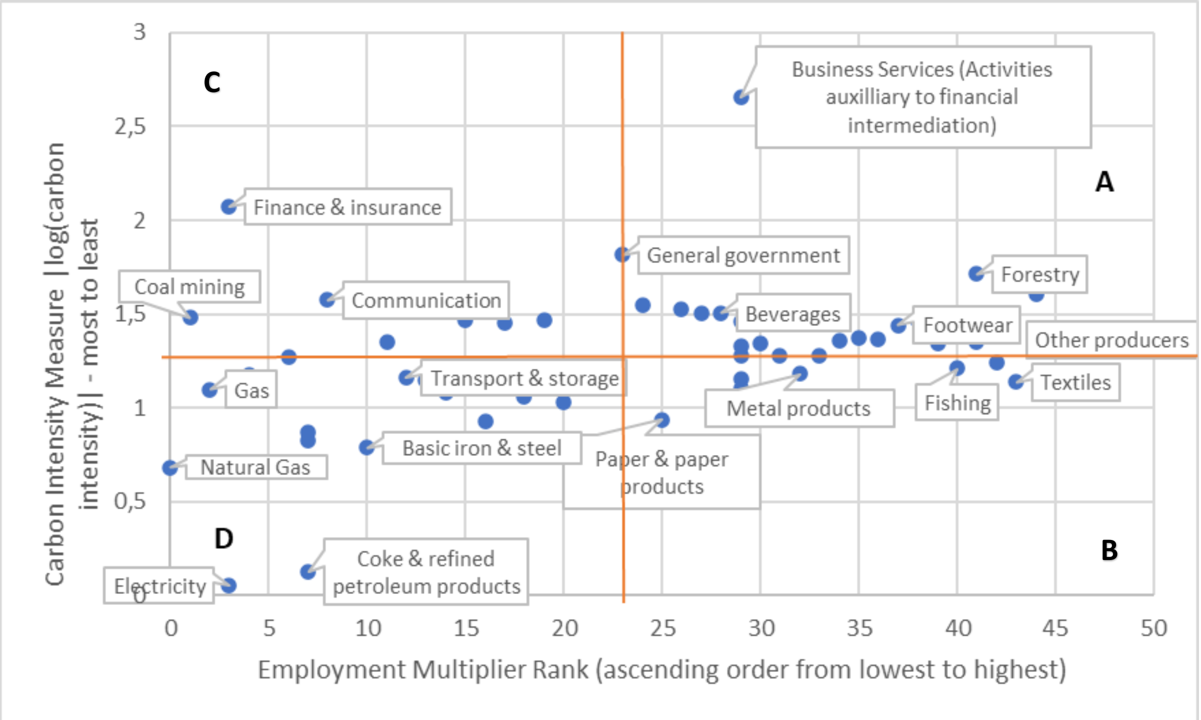
Source: Author's own analysis

A: employment multiplier rank 24-46	A: carbon intensity measure above 1.3
B: employment multiplier rank 24-46	B: carbon intensity measure below 1.3
C: employment multiplier rank 1-23	C: carbon intensity measure above 1.3
D: employment multiplier rank 1-23	D: carbon intensity measure below 1.3

I now have a graphic (Figure 2) that accurately uses the data and fits the specifications for the typology, where moving up and to the right would mean a higher employment multiplier rank and a higher carbon intensity measure (lower carbon intensity).

Figure 2: Mapping of employment multiplier rank against carbon intensity of sectors

Source: Author's own analysis

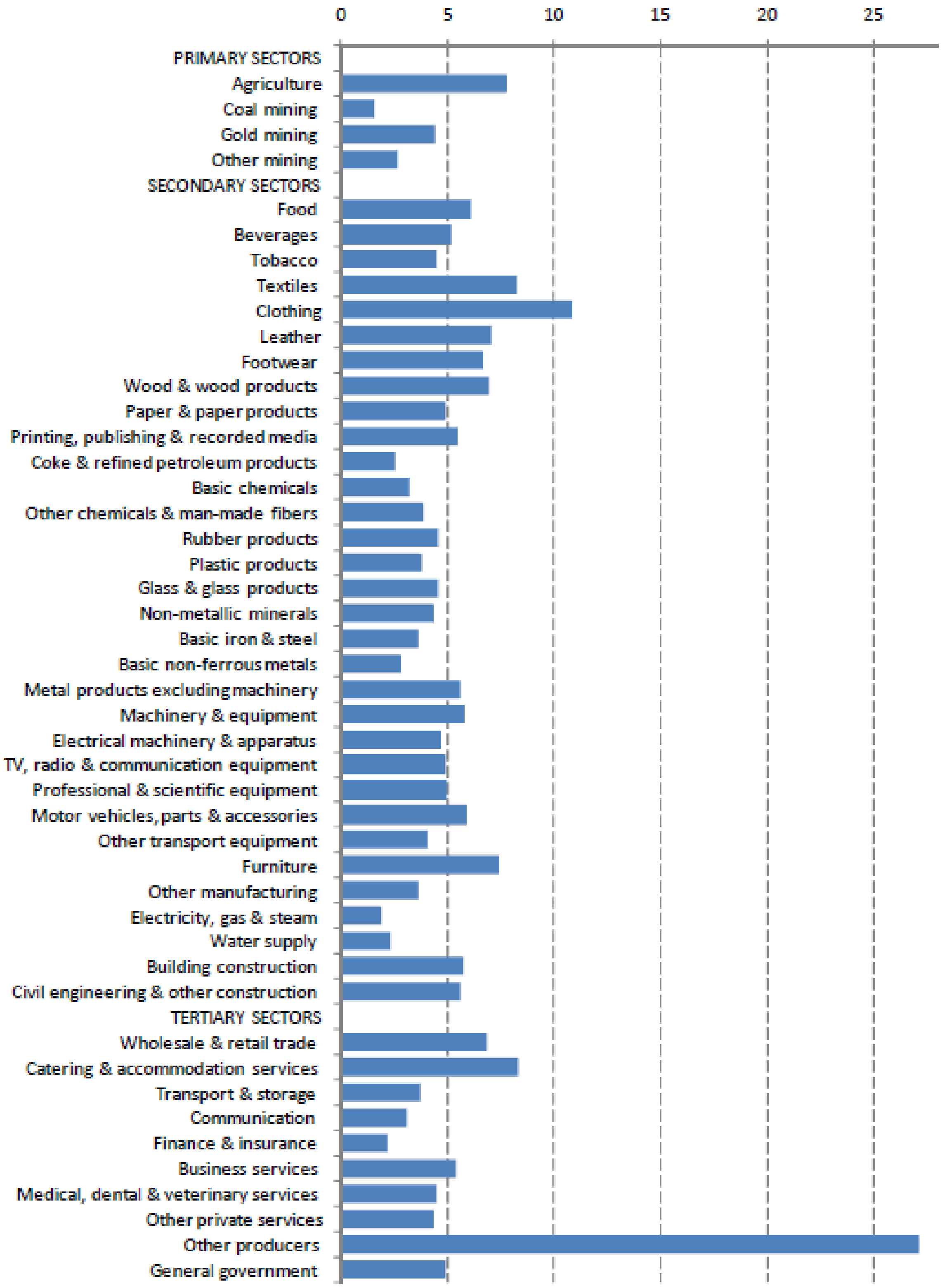


As can be seen from the mapping in Figure 2 above, the sectors fall into four different categories based on their combined employment multiplier rank and carbon intensity measure. However, it is important to note here that the lack of a clear-cut trend is due to the ordinal nature of the employment multiplier rank. The underlying data behind the employment multiplier ranks was unavailable from the author, leaving little option but to present the mapping process graphically, as shown in Figure 2. However, it is still clear that in general the sectors / subsectors with a higher employment multiplier rank also have a lower carbon intensity.

This is evident as sectors found in quadrant B may be classified as having relatively high carbon intensities, but none of them are as high as those in sector D. This is also seen in Chapter 2.iii, with the intersection of high carbon and low employment characteristics of heavy industry. In sector B, 'Paper & paper products' has the highest carbon intensity (0.1156 tCO_2e/R'000), with the rest of the mapped points sitting *just* above the threshold (below the functionally transformed threshold) of being classified as having relatively low carbon intensities. This means that the sectors / subsectors in quadrant B that are significantly high employers are still important to a high employment and low carbon growth pathway. In order to identify whether these sectors do provide significant employment, I use Figure 3 below (Tregenna, 2010) to get more of an idea of the magnitude and scale of the differences between the various employment multipliers.

Figure 3: Employment multipliers by sector

Source: Tregenna (2010)



Using Appendix F, which goes through the mapping processes described in Chapter 3, I can fill in the original skeleton typology (see Figure 1 in Chapter 3.i). The result can be seen in the form of Figure 4 (below), which takes the sectors / subsectors and places them in their respective quadrant based on their employment multiplier rank and carbon intensity measure (using the thresholds in Table 6). Note here that Figure 4 lists sectors in order of employment multiplier rank – quadrants A and B are listed from most employment intensive to least, and quadrant D and C lists from least employment intensive to most .

Figure 4: Filled in typology (Figure 1) using both employment rank and carbon intensity measure of sectors / subsectors

Source: Author's own analysis

Low carbon intensity	**C. Coal mining (21); Finance & insurance (81, 82); Post & telecommunication (75); Manufacturing n.e.c, recycling (392, 393, 395); Other transport equipment (384-387); Other private services (92, 94-96); Health (med, dent, vet) & social work (93)**	**A. Other producers/activities (99); Clothing (313, 314, 315); Catering and accommodation (64); Forestry (12); Furniture (391); Leather (316); Wood and wood products (321, 322); Wholesale and retail trade (61, 62, 63); Footwear (317); Food (301-304); Motor vehicles, parts & accessories (381-383); Machinery & equipment (356-359); Printing, publishing & recorded media (324-326); Business Services (83, 85, 87), Beverages (305); Tobacco (306); Professional & scientific equipment (374-376); TV, radio & communication equipment (371-373); General government (91)**
High carbon intensity	**D. Gas sector (natural) (2211); Gas (412); Electricity (411); Collection, purification & distribution of water (42); Coke & refined petroleum products inc. nuclear fuel (331-333); Mining of metal ores (24); Other mining & quarrying (221, 25); Basic precious & non-ferrous metals (352); Basic chemicals (334); Basic iron & steel (351, 353); Transport & storage (71-74); Plastic products (338); Other chemicals & man-made fibres (335, 336); Non-metallic minerals (342); Gold mining (23); Glass & glass products (341); Rubber products (337); Electrical machinery & apparatus (24)**	**B. Textiles (311, 312); Agriculture(11); Fishing (13); Building construction (502); Metal products excluding machinery (354, 355); Civil engineering & other construction (501, 503-505); Business services (84, 86, 88); Paper & paper products (323)**
	Low employment	**High employment**

Figures 2, 3 and Figure 4 allow for some findings to be extracted:

(i) Quadrant D (low employment multiplier and high carbon intensity)

- 'Gas sector' (natural gas) and 'Gas' ('manufacture of gas; distribution of gaseous fuels through mains') are both carbon intensive subsectors, as well as the being the two least employment intensive in the South African economy.
- 'Electricity'- electricity generation and distribution have high carbon emission intensities as well as being ranked second to last in terms of employment multiplier.
- 'Collection, purification & distribution of water' - natural water and water distribution has a high carbon intensity due to South Africa's artificially interconnected water catchment and

management system – 'with pumped storage, large pipelines and high infrastructural investment' (Reeler, 2021).

- 'Coke and refined petroleum products', 'Mining of metal ores', 'Other mining & quarrying', and 'Basic precious and non-ferrous metals'.
- 'Basic chemicals' – it is important here to look at the significance of Sasol's synthetic fuels in terms of emissions. These fuels are located in (and make up the majority of) the subsector 'Basic Chemicals (334)'. Due to the large emissions associated with these fuels, 'Basic Chemicals' has a high carbon intensity and is thus found in quadrant D. However, the subsector 'Basic Chemicals' consists of not only 'Manufacture of basic chemicals, except fertilizers and nitrogen compounds' (3341), but also 'Manufacture of fertilizers and nitrogen compounds' (3342) and 'Manufacture of plastics in primary form and of synthetic rubber (3343). At present, the latter two subsectors are also high carbon emitters.
- 'Basic iron and steel', 'Transport & storage', 'Plastic products; ''Other chemicals & man-made fibres'; 'Non-metallic minerals'; 'Gold mining'; 'Glass & glass products'; 'Rubber products'; and 'Electrical machinery & apparatus' make up the other sectors found in this quadrant.

(ii) Quadrant A (high employment multiplier and low carbon intensity)

- 'Other producers/activities' – this is a broad sector so further research would need to be conducted to ascertain where the opportunities lie. But as Figure 3 shows, this sector has a significantly larger employment multiplier than any other sector / subsector – indicative of the importance 'Other producers/activities' plays for the shift towards a new growth pathway.
- 'Clothing', 'Leather', 'Footwear', 'Catering and accommodation', 'Forestry', Furniture', 'Wood and other wood products', 'Food', 'Motor vehicles, parts & accessories', 'Printing, publishing & recorded media', 'Business services (SIC 83, 85, 87)', 'Beverages', 'Tobacco', 'Professional & scientific equipment', TV, radio & communication equipment', and 'General government'. 'Clothing' in particular has an important role to play for a high employment growth pathway due to its relatively high employment multipliers (see Figure 3).
- These sectors are all found in quadrant A, where faster growth would be important for a high employment and low carbon growth pathway.

(iii) Quadrant B (high employment multiplier and high carbon intensity)

- 'Textiles', 'Agriculture', 'Fishing', 'Building construction', 'Metal products excluding machinery', 'Civil engineering and other construction', 'Business services (SIC 84, 86, 88)', and

‘Paper & paper products’ are the sectors that are found in quadrant B. This means that they have higher employment multipliers but also have relatively high carbon intensities.

- Many of these sectors only *just* fall into quadrant B and not A, and are thus not as high in carbon intensity compared to the sectors in quadrant D. This means that the employment in these sectors is still significant for the South African economy and its new growth pathway – especially the ‘Textiles’, ‘Agriculture’ and ‘Fishing’ sectors (see Figure 3).

(iv) Quadrant C (low employment multiplier and low carbon intensity)

- ‘Finance and insurance’, ‘Post and telecommunication’, ‘Manufacturing n.e.c., recycling’, ‘Other transport equipment’, ‘Other private services’, ‘Health and social work’ are the sectors that are found in quadrant C. This means that they may have low carbon intensities but are not relatively employment intensive. This means that on their own they will not be able to move the South African economy onto a high employment and low carbon growth pathway, and so preference should go towards supporting faster growth in sectors / subsectors found in quadrant A.

- The ‘Coal mining’ sector is ranked last in terms of employment multiplier, but ‘Coal mining’ is found in quadrant C rather than quadrant D (indicating that the sector is not relatively carbon intensive). However, it is important to note that coal is the most carbon intensive product in the South African economy – with a carbon intensity in 2015 of 3.2 tCO2e/R'000 (Reeler, 2021).

It is important to also take into account that based on the SA LEDS, fossil fuels will be phased out as far as possible by 2050) (RSA, 2020). The output of coal based energy will decline to only 7 GW in 2050, mainly from the presently ‘under construction’ Kusile and Medupi (Lo, 2020). This is not only due to the SA LEDS and South Africa’s IRP2019 policy, but also as a result of an increasing unwillingness by global finance to provide capital for coal-fired power stations, with more and more financial institutions blacklisting coal investments from their portfolios and lending decisions. For example, the Finance in Common Summit (Finance in Common, 2020) was held in November 2020 in order to bring together the entire finance community in support of common actions in terms of both climate and the United Nations Sustainable Development Goals (UN SDGs). Locally, Nedbank has decided to stop funding the construction of new coal-fired power plants (Nedbank, 2019), which extends to thermal coal-related activities outside of South Africa as well as restrictions on total financing for oil mining companies, thermal coal-related infrastructure, and thermal coal-related trade - ‘to less than 1% of its Group Total Advances, reducing to 0.5% by 2030’ (Nedbank, 2019).

As stated in Chapter 2.i, it is important to consider how the energy demand is going to be met. This means there is a requirement to invest into alternative sources of low carbon energy, as energy is needed to enable a country's growth and thus the ability to provide employment in the first place. In order to do this the country will need to invest in RE infrastructure projects, which would at the same time create employment opportunities in the RE sector (Chinyavanhu, 2021) and other sectors (depending on the extent to which local content and skills are used). The RE sector has proven to provide significant employment opportunities in emerging economies, for example, distributed RE access has accounted for about 95,000 formal jobs in India and 10,000 in Kenya (Chinyavanhu, 2021). This means that government RE infrastructure investment, even towards small projects such as mini grids, could contribute significantly to an 'economic revival'. Not only could RE provide a more reliable energy sector and employment opportunities, but could also increase investor confidence and so attract both private investment and international finance (Chinyavanhu, 2021).

As of yet, South Africa as a major fossil fuel producer has failed to substantially transition toward RE sources, such as wind and solar power, that are cleaner, cheaper, and more abundant (Lawrence, 2020). This is despite the huge benefits to the South African economy if a more rapid transformation to RE sources was rolled out. According to Lawrence (2020), these include:

- **Consistent power supply:** Over 90% of electricity is generated from coal by the state-owned enterprise, Eskom (RSA, 2020) - an unreliable fossil fuel-based power supply. Additionally, in South Africa there are large inequalities in access to energy services (Winkler, 2018), thus a rapid transition will represent an opportunity for a more consistent power supply, especially in rural areas that lack infrastructure.
- **Reduce pollution and health concerns:** Reducing the pollution associated with coal based energy - which has severe negative consequences for local and regional health (Lawrence, 2020).
- **Using endowments:** Taking advantage of South Africa's clean energy capabilities (such as wind and solar energy) - over 2500 Terawatt-hours (TWh) of wind generating potential, a concentrated solar power (CSP) potential of over 4000 TWh, and a solar photovoltaic (PV) potential of over 3000 TWh (Lawrence, 2020).
- **Reducing dependency on resources:** The opportunity to gradually start reversing the 'resource curse'[17] that mining has brought with it (Humphreys, Sachs & Stiglitz, 2007).

17 When countries with an abundance of natural resources (such as coal in this case) underperform in terms of their economic growth and development outcomes. This is as a result of focusing productive capacity (labour and capital) on a resource dependent sector and failing

Furthermore, allowing for a valuation of the rand that is not based off commodity prices and so creating more competitive local markets[18] (Bell et al., 2018).

- **Moving away from a stagnating coal power sector:** The coal based energy sector has increasingly represented a stagnating sector for South Africa. This result is slowing economic growth, as capital and labour are still to a large extent targeted towards the 'Coal mining' sector (Lawrence, 2020). This has meant a lack of progress in other sectors (or other sources of energy) that have the potential to bring about employment opportunities and economic growth.

With this shift away from coal base energy, the labour and capital presently invested into coal-related activities will need to be gradually redeployed to sectors that will help South Africa move towards an employment intensive and low carbon growth pathway. Figure 4 points towards certain lower carbon sectors and subsectors that would be better at absorbing the labour and capital, enabling the economy as a whole to start aligning with a new growth pathway. Policy thus becomes important as a tool used to drive certain changes. Sectors will be influenced differently by various policy measures, which then affects levels of employment and investment in the economy (Winkler & Marquard, 2009). Some sectors will be incentivised to adapt by decreasing their carbon intensity, others may become more competitive in the economy (if they receive certain subsidies), and others will have liabilities placed on them that will threaten their future. This means that support will be needed for redeployment and reskilling of workers (Bell et al., 2018).

Chapter 4 applied the employment multiplier rank and carbon intensity measure in order to provide a graphical representation of the results. This allowed for the categorization of sectors / subsectors as either falling into quadrant A, B, C or D - based on their relative employment and carbon characteristics. This is graphically illustrated by the original typology (Figure 1), which becomes Figure 4 once filled in. Thereafter, Figures 2, 3 and Figure 4 allow for the extraction of some findings pertaining to each quadrant. Thereafter, I discussed the transition away from coal based energy and thus the 'Coal mining' sector, and the potential for growth and employment opportunities in the RE sector. Next, this dissertation examines the implications of policy measures across the various sectors / subsectors found in these quadrants.

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to make investments into other sectors. The resource curse is complex and is characterised by three processes (*Escaping The Resource Curse*. 2007). (1) "Dutch Disease", when the currency appreciates due to revenues from the natural resource, having a negative effect on the competitiveness of other industries; (2) The disruptive effects of fluctuating commodity prices ; and (3) The effect on political conditions.

[18] In time of commodity booms, the rand becomes overvalued and the incentive is to instead import from international markets (Bell et al., 2018).

5. Policy measures and implications

Having filled in the typology (Chapter 4. Figure 4), I can now start looking at the main research question stated in Chapter 1: Which sectors / subsectors have opportunities for high employment and low emissions growth in South Africa, and what are some policy measures that could realise this potential?

There are a number of possible policy measures, of which I will be discussing the following: the phasing out of fossil fuel subsidies, a carbon tax, and a wage subsidy. This is certainly not an exhaustive policy discussion, but will highlight some of the various effects that policy may have in the sectors / subsectors found in the typology. These policies thus serve as three examples of possible measures and what the implications would look like across the various quadrants and the sectors therein.

Thereafter, I will engage with some of the recommended 'adjustment support measures' for transitioning to a low carbon economy, and look at the implications for the various quadrants. These 'adjustment support measures' are distinct from policy measures as they look at enabling characteristics to smooth the transition to a low carbon economy, as opposed to government policies that are regulated by law.

(i) Approach to policy measures discussion

Firstly, I will outline the three policy measures mentioned above and discuss the general economy wide implications of these policies. Secondly, I will be using the typology and specific sectors / subsectors within quadrants A, B, C and D in order to sketch out how the various policy measures will affect the quadrants and the sectors / subsectors therein. This is instead of targeting policy towards specific sectors / subsectors (either to decrease carbon emissions or stimulate employment opportunities), as sectors are very diverse and tailoring policy to a specific sector is simply not realistic. This is particularly the case in South Africa where there is a limited governmental capacity to manage regulation. One point to note before looking at the research question, is that in any given sector, small firms tend to be more labour intensive than larger firms (Tregenna, 2015), so a more rapid entry of smaller firms in the 'desirable' sectors would be beneficial.

From 2000 to 2015, the carbon intensity of the economy (tonnes CO2 equivalent / R1000) had decreased by 18.7% and the energy intensity of the economy (tonnes oil equivalent (toe) of energy / R1000) had decreased by 12.4% (RSA, 2020). The LEDS (RSA, 2020) attributes this to the growth in less energy intensive services and financial sectors, together with the decline of heavy industry and mining during this period. But at the same time, unemployment has been increasing This means that policy measures need to consider keeping the economy's carbon intensity moving in the same direction but at a faster pace, whilst reversing the direction that the unemployment trend is moving. I thus examine the following policy measures and the anticipated economy wide outcomes: The phasing out of fossil fuel subsidies, a carbon tax, and a wage subsidy.

Phasing out of fossil fuel subsidies

South Africa's reliance on fossil fuels for energy has historically been driven by the support provided for the production and use of fossil fuels (Burton et al., 2018) – in particular, coal based energy and the conversion of coal into liquid fuels. These subsidies encourage the extraction and overconsumption of under-priced fossil fuels, and undermine the competitiveness of other sources of energy - such as renewable energy (RSA, 2020). Additionally, fossil fuel subsidies act as a negative price on carbon, and so removing this distortion would allow for greater efficiencies in the economy. Previous advantages have of course put certain sectors at a competitive advantage, so removing the subsidies would need to be followed by measures for large consumers of previously subsidized fossil fuels (found in quadrant B and D) – such as a carbon tax.

Inefficient fossil fuels energy subsidies in SA can divert finance from other priority sectors such as education, health, and infrastructure (RSA, 2020). So, removing fossil fuel subsidies could provide an opportunity to ensure a progressive distribution of state funds towards sustainable growth (RSA, 2020). The lesson here is that future regulation in the energy space needs to be careful to not create distortions, such as in the case of these subsidies for fossil fuels. Inefficient subsidies limit the competitiveness of industries that do not benefit from the subsidy, and slow down efforts towards transformation in the sectors involved (RSA, 2020).

Removing the support provided for the production and use of fossil fuels would be the first step required in order to 'level out the playing field'. Firms that are found in the sectors / subsectors that fall in quadrant B and D would feel this policy measure the most, specifically those granted large subsidies in the past – namely, Eskom ('Electricity') and Sasol ('Basic Chemicals') (Burton et al., 2018). On the other hand, sectors that do not rely on energy subsidies and are relatively less carbon intensive (namely the sectors / subsectors in quadrants A and C), will not incur any direct costs or benefits from this measure. However, the electricity and fuel that they do use would still come at a higher cost if the 'Electricity' and 'Basic Chemicals' sectors maintain their fossil fuel use and pass the costs on via price increases. However, with the increasing availability and acceptance of other cheaper sources of energy, such as renewables, it is likely that over time the economy would transition towards alternative cleaner energy sources so as to avoid the higher prices of fossil fuels.

Carbon tax

Another policy instrument is taxing externalities in the form of a tax on carbon emissions. In the case of a carbon tax, a higher price on carbon would act as a financial incentive for firms throughout the economy to integrate cleaner processes, energy efficiency measures, and 'green' innovation. This would be more so the case for higher emitting sectors in quadrants B and D.

As of yet, the South African carbon tax of R120 per ton of CO2 emissions (launched in June 2019 and increasing with inflation) has not had measurable effects throughout the economy (Climate Transparency, 2019). South Africa has one of the highest carbon pricing gaps (Climate Transparency, 2019), with the country's carbon tax being 89% lower than the Organisation for Economic Cooperation and Development (OECD) countries' benchmark to achieve the Paris Climate Agreement (Climate Transparency, 2019). The pricing of CO2 emissions needs to be sufficiently high to actually induce changes, but at the same time a carbon tax can threaten the competitiveness of firms within higher emitting sectors. These firms may use other methods to avoid having to directly pay the tax, this includes increasing their prices (where possible) so the tax is simply passed onto consumers, lowering the wages paid, retrenching workers, decreasing labour hours, or as a last resort downsizing or shutting down the firm. This would be adverse for employment goals and the broader South African socioeconomic context.

A carbon tax might be able to reduce the carbon emissions of the economy to a certain extent, but it certainly will not enable the reduction of South Africa's high unemployment levels. However, the tax revenues could be recycled back into the economy to meet this end, analogous to propositions by Winkler (2017) on reducing energy poverty through carbon tax revenues in South Africa. Part of the tax revenues could be filtered back into a wage subsidy (discussed below).

A wage subsidy

Taking into account the context of high levels of unemployment in South Africa, the South African Wind Energy Association (SAWEA) suggests that the transition to a lower carbon economy will have employment implications that are 'highly complex, dynamic and politicised' (SAWEA, 2018). Coal is used not only by the 'Electricity' sector but also in refineries, in industry, and it is sold internationally (Merven et al., 2019). The coal value chain is thus embedded within the South African economic context, and the contraction of the 'Coal mining' sector in the transition to a low carbon economy will have ripple effects throughout various sectors and subsectors, potentially increasing unemployment levels. Considering the already high levels of unemployment in the country, a wage subsidy could support employment throughout the entire economy.

A wage subsidy would act as an incentive to expand production and thus increase growth in relatively employment intensive sectors (quadrant A and C). As the cost of labour becomes cheaper, these firms can expand with less financial burden as their core operating costs are being subsidized. It is important to note here that despite technology and productivity being important for competitiveness, subsidising and encouraging premature automation would not be in the best interest for an economy with such high unemployment numbers, such as South Africa. In other words, policy does not want to encourage 'too soon' or 'too much' when it comes to technological advancement and automation.

The structure of a wage subsidy would not be a targeted or too specific one, but would rather act as a general subsidy to all firms (more employment intensive firms would derive more benefit). In terms of the financing of a wage subsidy, some of the money that was previously allocated to fossil fuel subsidies, as well as carbon tax revenues, could be redirected towards wage subsidies. In this way a wage subsidy could act as a supporting mechanism for firms to expand operations using their present ratio of labour to capital. The subsidy would also support the establishment and growth of relatively employment intensive industries (important for coal-producing regions).

(ii) Implications of policies

For the phasing out of fossil fuel subsidies and / or a carbon tax, as discussed above, it seems inevitable that firms in carbon intensive sectors may have to slow their growth or even go out of business. This would result in unemployment – but adding a wage subsidy, or other form of labour focused policy, could act as a counter measure to increased unemployment. A concrete example of this unemployment is the inevitable phasing out of coal based energy and the loss of jobs that will result. This means that there is an urgent need to reskill and redirect these workers towards other suitable sectors of the economy. I will take various sectors from quadrants A, B, C and D in order to look at how the policies discussed above would theoretically play out (both on the employment side and on the carbon emissions side).

Relatively employment intensive sectors

'Agriculture' (B), 'Fishing' (B), and 'Forestry' (A) – Despite their contribution to GDP being relatively small, these sectors are a key provider of rural employment and export earnings (RSA, 2020). Their employment multiplier is 53% higher compared to the next highest sector, 'Textiles' (Tregenna, 2015). A wage subsidy would thus benefit these sectors by essentially decreasing the cost of labour and thus the overall operating costs of firms in these sectors. However, at the same time, the removal of fossil fuel subsidies and / or a carbon tax policy could mean that the cost of energy would increase over time – a liability to these sectors, albeit small.

This means that for the firms in quadrant A (the 'Forestry' sector in this cluster), a wage subsidy would most likely have a larger effect than the potential increase in energy prices. According to the IPAP (DTI, 2018), the 'Forestry', timber, pulp, paper and 'Furniture' sectors have the potential to create jobs and growth in marginalised areas in South Africa. In addition, these sectors are important as 'sustainable future sectors incorporating bio-refinery and transformative technologies' (DTI, 2018).

'Agriculture' and 'Fishing' are both higher emitters than 'Forestry', but both these sectors only just fall into quadrant B instead of A (with carbon intensity values of approximately 0.06 tCO_2e/R'000). A wage subsidy would have a larger effect than the increased cost of energy (in particular liquid fuel). Additionally, DEFF's low emission development strategy (RSA, 2020) includes the draft Climate Change Adaptation and Mitigation Plan for the South African Agricultural and Forestry sectors, the Conservation Agriculture Policy, and the Agroforestry Strategic Framework for South Africa. Taking DEFF's low emission development strategy alongside the employment intensive nature of 'Agriculture', 'Forestry' and 'Fishing', means increased growth in these sectors could help shift South Africa towards a growth pathway that is increasingly characterised by high employment and low carbon.

'Clothing' (A), 'Textiles' (B), 'Leather' (A) and 'Footwear' (A) – Apart from the agricultural sectors above, these form part of the manufacturing subsectors that are relatively employment intensive. However, the results of South Africa's multi-stakeholder initiatives in these sectors have not yielded the intended results, and have left these light manufacturing subsectors unable to compete effectively (Morris & Levy, 2016). Since then, there have been improvements in these manufacturing subsectors – largely as a result of the conditional support under the Clothing and Textile Competitiveness Programme. However, strong pressure is still felt as a result of cheaper and / or illegal imports (DTI, 2018). With increased investment opportunities, the 'Clothing', 'Textiles', 'Leather' and 'Footwear'

(CTLF) sectors can create sustainable employment and sectoral growth in the manufacturing sector (DTI, 2018). A wage subsidy could thus be a start towards achieving meaningful growth in these sectors

The DTI has used the CTPT programme in order to incentivise growth in these sectors - a ‘market neutral’ programme that is subdivided into the Production Incentive Programme and the Competitiveness Improvement Programme. Looking at the policies chosen for this discussion, increased costs of electricity and fuel (as a result of the removal of fossil fuel subsidies and / or a higher carbon tax) could act as a small disincentive to faster growth. But on the other hand, wage subsidies would encourage increased growth in these employment intensive manufacturing subsectors. Due to the relatively employment intensive nature of these sectors, it is expected that a wage subsidy would go over and above any increased operating costs from increased energy prices. Therefore, increased growth in these manufacturing subsectors could play an important role in shifting South Africa’s growth pathway to one that is increasingly characterised by high employment and low carbon growth.

‘Machinery and equipment’ (A), ‘Wood and wood products’ (A), ‘Building construction’ (B), ‘Metal products excluding machinery’ (B), and ‘Civil engineering and other construction’ (B) - These are all sectors that have relatively high employment intensities, and will be important considering the infrastructure improvements that South Africa requires to boost the economic attractiveness of the region (Burton, Marquard & McCall, 2019). This includes ports, railways, water supply and power infrastructure, and industrial capacity. The 2021 Budget Speech in parliament outlined that the government has set aside R791.2 billion for this infrastructure investment drive (South African National Treasury, 2021). This will aid the potential for increased growth in the related sectors / subsectors listed above, as well as creating various employment opportunities (Burton, Marquard & McCall, 2019).

Increased costs of electricity and fuel (as a result of the removal of fossil fuel subsidies and / or a higher carbon tax), could be a small financial liability for these sectors (in particular those in quadrant B). Being important for infrastructural growth means that it is vital that these sectors / subsectors are not threatened by these policies, however a wage subsidy would work in the opposite direction and support these relatively employment intensive sectors. This would be especially advantageous for the two sectors that are found in quadrant A and are the most employment intensive in this particular cluster – namely ‘Machinery and equipment’ and ‘Wood and wood products’. With the latter being an ‘ultra-labour intensive’ sectors (Black, Craig & Dunne, 2016), indicative of the potential this sector has in South Africa’s high employment and low carbon growth pathway.

According to the IPAP (DTI, 2018), the wood processing sector (which is comprised of board manufacturers and manufacturers of wood-based products) has seen significant investments in advanced wood-processing technologies. However, there is still scope for investments in the sawmilling industry – an employment intensive industry that is an important contributor to the rural economy. More investment in research and technology would improve the industry processing recovery rate (49% per log needs to be increased to at least 55%) and lead to the production of more advanced products such as cross-laminated timber (DTI, 2018). A wage subsidy could provide financial support to this end.

Additionally, with energy efficiency measures in industry, buildings and transport being supported by independent organisations such as IRENA (2020) – particularly for building, repair, or retrofitting of buildings to be rated 'green' by the GBCSA. Therefore, it is expected that over time there will be an increase of investments going towards building renovations and structural changes, which will increase demand in these sectors – particularly the relatively employment intensive 'Building construction' and 'Civil engineering and other construction' sectors. These sectors are located in quadrant B, but with a carbon intensity measure of 0.053 tCO_2e/R'000 they only just fall into quadrant B and not quadrant A. Thus, the financial liability created by the removal of fossil fuel subsidies and / or implementation of a carbon tax would be relatively small, whereas a wage subsidy would be significant and incentivise increased growth in these sectors.

'Food' (A), 'Beverages' (A), and 'Tobacco' (A) – The South African government has identified agro-processing as an important driver of inclusive growth in South African economy, particularly due to its relatively large direct and indirect job creation potential (DTI, 2018). Agro-processing is the biggest subsector in manufacturing and over the past 15 years has seen significant growth in employment and sales. Approximately one million job opportunities have been identified in agro-processing and its upstream sector ('Agriculture'). Commitment to agro-processing has been reiterated by the National Development Plan (NDP); IPAP; the Agricultural Policy Action Plan (APAP); Operation Phakisa for Agriculture, Land Reform and Rural Development (2016); and the Presidential 9-Point Plan (Revitalisation of the Agriculture and Agro-processing Value Chains) (DTI, 2018).

According to the IPAP (DTI, 2018), over the past 10 years agro-processing in particular has made a significant contribution to GDP. South Africa is a net exporter of agro-processing production, with the main contributors towards this positive trade balance being fresh fruits (citrus, grapes, apples, maize, and other processed products like wine, fruit juice, nuts and refined sugar). Whereas the main contributors to South African imports are rice, poultry, wheat, alcohol spirits, palm oil and soy oil cake (DTI, 2018) – i.e., 'staple foods'. With South Africa's local food demand increasing (largely as a result of population growth), there should be more support for competitive local production of these 'staple foods'. In particular, strategic alliances and partnerships between larger and smaller local producers are important so as to increase the penetration to the local markets (DTI, 2018). In addition, to increase exports there would need to be investment in processing facilities, new machinery and technology, and product development in order to meet various exporting quality, safety and certification requirements – especially in rural areas (DTI, 2018).

Due to the relatively high employment multiplier rank and low carbon intensity of these sectors (all found in quadrant A), it would be expected that the only policy here that would significantly impact these sectors / subsectors would be the introduction of a wage subsidy.

Relatively carbon intensive sectors

'Gas sector (natural)' (D) - This sector plays a small roll in South Africa's primary energy supply (3% of total primary energy supply in 2016) with domestic production by PetroSA amounting to 18% of this (DOE, 2019). The rest is imported by Sasol Gas from Mozambique's Temane and Pande gas fields, and supplied to Sasol and other industrial and commercial customers. The Gas Utilisation Master Plan has been under development for a number of years, and will provide more clarity as to the intended role that gas will play in South Africa's future energy mix (RSA, 2020). It is becoming increasingly apparent that there is an ambitious plan for natural gas in the future, as the Gas Amendment Bill was approved by Cabinet in February 2021 for submission to Parliament (Swilling, 2021). This document essentially highlights a baseload gas strategy for South Africa, and so far the Risk Mitigation Independent Power Producer Procurement Programme (RMI4P) has indeed favoured gas producers and thus non-lowest cost energy (eight successful bidders, of which three were to be the controversial powerships[19]) (Swilling, 2021).

However, the removal of fossil fuel subsidies and / or the implementation of a carbon tax could undermine justification for these plans. These policies would mean that the presently small South African natural gas sector incurs a large carbon tax liability, and pays more for their energy usage. This would create a disincentive for expanding local production or importing more natural gas. Furthermore, the contentious powerships would also undergo this tax and it would mean that the cost of the power produced by them would in theory be higher. Additionally, the sector is not relatively

[19] A powership is essentially a floating power plant – liquified natural gas (LNG) to power.

employment intensive (ranked last in the measure used by this dissertation), meaning it would not receive significant wage subsidies. This is the case despite taking into account the local content and labour requirements agreed on by the powerships (Yelland, 2021). Thus, the policies chosen could slow growth in this sector.

'Gas' (D), 'Electricity' (D) – A removal of fossil fuel subsidies and a carbon tax would place a large financial burden on both the 'Gas' and the 'Electricity' sectors due to their high carbon intensities. The Department of Energy (DOE) used a scenario planning approach in their 2016 Integrated Energy Plan (IEP) to project energy demand, and a scenario that excluded shale gas is the one that resulted in the greatest number of jobs in the electricity sector (SAWEA, 2018). Looking at the international viewpoint on gas, the IPCC holds that in order to reduce the carbon emissions intensity of the economy whilst maintaining dynamic economic growth, there are certain implications for the South African power sector (RSA, 2020). In order to meet climate change goals by 2050, power cannot be primarily generated from coal, oil, or gas without carbon capture. So, the growth prospects for the 'Gas' sector seem less than hopeful even before considering the removal of a fossil fuel subsidy and a carbon tax burden. Furthermore, a wage subsidy would not meaningfully impact this sector as it has a relatively low employment multiplier.

Looking at the 'Electricity' sector in isolation, made up of three subsectors (generation, transmission, and distribution) which are dominated by Eskom, coal-fired power stations are important for South Africa's power generation capacity (DOE, 2019). According to the IEP, solar had the highest potential for job creation, followed by nuclear and wind, with natural gas and coal making smaller contributions (SAWEA, 2018). In 2018, coal-fired power stations made up 83% of the maximum generating capacity mix, with 5% by gas turbines, 4% nuclear, and 6% from pump storage (DOE, 2019). A removal of fossil fuel subsidies and / or a higher carbon tax would thus place pressure on the 'Electricity' sector, which relies heavily on coal, with electricity generation contributing approximately 42% to gross national emission (RSA, 2020).

However, as discussed in Chapter 2, the IRP2019 has outlined the decommissioning of 12,600 MW of Eskom's coal generation capacity by 2030 (increasing to 34,400 MW by 2050) (RSA, 2020). This essentially leaves the 'Electricity' sector no choice but to transition away from coal based energy. This could entail moving towards alternative sources such as gas, nuclear energy, or renewable energy. With the removal of fossil fuel subsidies and the implementation of a carbon tax, there would be pressure to make sure the alternative sources of energy are as low carbon as possible. As it stands, the ‘Electricity’ sector ranked forth lowest in its employment multiplier, meaning that a wage subsidy would not significantly impact this sector.

Mining: ‘Other mining and quarrying (D)’, ‘Mining of metal ores (D)’, ‘Basic precious and non-ferrous metals (D)’, ‘Basic iron and steel (D)’, ‘Basic chemicals (D)’, ‘Non-metallic minerals’ (D) – The mining sector is relatively carbon intensive - found in quadrant D. This sector is a main consumer of the country’s energy supply (DOE, 2019), meaning that removing fossil fuel subsidies and / or implementing a higher carbon tax would place a large financial burden on the various mining sectors and subsectors. South Africa is rich in mineral resources such as gold, coal, iron ore, manganese, chrome, platinum, and diamonds as well as being a major producer of non-ferrous metals and stainless steel. Minerals thus represent an important source of export revenue for the country (RSA, 2020), and in 2016 the industrial sector utilised 52% of the final energy supplied, broken up as follows (DOE, 2019):

- ‘Basic iron and steel’ - 18% of the energy used in the industrial sector,
- ‘Basic chemicals’ - 14%,
- ‘Mining of metal ores’, ‘Other mining and quarrying’ - 10%,
- ‘Basic precious and non-ferrous metals’ – 8%,
- ‘Non-metallic minerals – 5%,
- and the remaining subsectors had energy consumptions of 2% or less.

However, these sectors make up a large part of the South African economy and in aggregate create a considerable amount of employment (despite individually having relatively low employment multipliers). As discussed in Chapter 2, mineral beneficiation has been identified in the IPAP (DTI, 2018) as key in order for South Africa to play a role in the global hydrogen economy and energy storage space. A major opportunity exists to unlock the potential of mining in South Africa, but this would require a stable regulatory environment, increased transparency in the mining industry, and the power of new low-carbon processing technologies (Goodman, Rajagopaul & Cassim, 2019). A wage subsidy on its own would not significantly impact these relatively low employment intensive sectors/ subsectors, so other policy tools could be considered here.

As discussed previously, it is also important that mining and mining-related manufacturing activities are provided support from services such as finance, transport, logistics and quality assurance. In addition, these services are important for the industrialisation trajectory of South Africa as they are some of the highest value added divisions of the mining supply chain, can catalyse investment in skills development and technology transfer, and can support growth in other sectors of the economy, including manufacturing (Bell et al., 2018).

Table 7: Illustrative summary of the implications of policy measures for various sectors, using a scale from 1 to 5 based on the estimated size of the effect

Source: Author's own analysis

Sectors and respective quadrant	**Phasing out of fossil fuel subsidies**	**Carbon tax**	**Wage subsidy**	**Estimated overall policy effect**
Agriculture' (B), 'Fishing' (B), and 'Forestry' (A)	Employment: ▬ Carbon emissions: ▬	Employment: ▬ Carbon emissions: ▬	Employment: (4) ↑ Carbon emissions: ▬	Employment: (4) ↑ Carbon emissions: ▬
'Clothing' (A), 'Textiles' (B), 'Leather' (A) and 'Footwear' (A)	Employment: ▬ Carbon emissions: ▬	Employment: ▬ Carbon emissions: ▬	Employment: ↑ (5) Carbon emissions: ▬	Employment: ↑ (5) Carbon emissions ▬
'Machinery and equipment' (A), 'Wood and wood products' (A), 'Building construction' (B), 'Metal products excluding machinery' (B), and 'Civil engineering and other construction' (B)	Employment: ▬ Carbon emissions: ▬	Employment: ▬ Carbon emissions: ▬	Employment: ↑ (2) Carbon emissions: ▬	Employment: ↑ (2) Carbon emissions: ▬
'Food' (A), 'Beverages' (A), and 'Tobacco' (A)	Employment: ▬ Carbon emissions: ▬	Employment: ▬ Carbon emissions: ▬	Employment: ↑ (3) Carbon emissions: ▬	Employment: ↑ (3) Carbon emissions ▬
'Gas sector (natural)' (D)	Employment: ↓ Carbon emissions: ↓ (4)	Employment: ↓ Carbon emissions: ↓ (4)	Employment: ▬ Carbon emissions: ▬	Employment: ↓ Carbon emissions: ↓ (4)
'Gas' (D)	Employment: ↓ Carbon emissions: (3) ↓	Employment: ↓ Carbon emissions: (3) ↓	Employment: ▬ Carbon emissions: ▬	Employment: ↓ Carbon emissions: (3) ↓
'Electricity' (D)	Employment: ↓ Carbon emissions: ↓ (5)	Employment: ↓ Carbon emissions: ↓ (5)	Employment: ▬ Carbon emissions: ▬	Employment: ↓ Carbon emissions: ↓ (5)

Mining - Other mining and quarrying (D)', 'Mining of metal ores (D)', 'Basic precious and non-ferrous metals (D)', 'Basic iron and steel (D)', 'Basic chemicals (D)', 'Non-metallic minerals' (D)	Employment: ↓ Carbon emissions: ↓ (2)	Employment: ↓ Carbon emissions: ↓ (2)	Employment: ▬ Carbon emissions: ▬	Employment: ↓ Carbon emissions: ↓ (2)

In order to depict the impact of the chosen policies more clearly, I have constructed Table 7 above so as to be able to assemble some overarching comparative findings. Table 7 indicates that the phasing out of fossil fuel subsidies and / or the introduction of a higher carbon tax will largely impact firms in quadrant D, with the magnitude of this effect increasing as the carbon intensity of the firm increases. In other words, the financial liability would steadily increase as the analysis moves from firms with the lowest carbon intensity in quadrant B ('Building construction' and 'Civil engineering and other construction') to the highest carbon intensity in quadrant D ('Electricity').

As previously discussed, the carbon intensities in quadrant B are in general lower than in quadrant D, so the financial liability would be insignificant for the majority of the sectors in quadrant B ('Paper and paper products' being an exception). It is expected that the larger the policy burden, the larger the pressure placed on the respective firms to slow their growth and thus decrease employment. In addition, firms in quadrant D are not relatively employment intensive and so a wage subsidy would not make a significant difference. It is difficult to say to what extent this decline in employment would occur, so visually I have indicated a downward trend for employment.

On the other hand, the implementation of a wage subsidy would incentivise firms that are relatively labour intensive to grow at a faster rate, overall increasing employment. The higher the employment multiplier of a firm, the larger the subsidy and thus the larger the support to increase growth. In other words, firms that are found in quadrant A would in general see larger inducement to faster growth – in particular the first four clusters of sectors in Table 7.

The typology constructed in this dissertation thus becomes a useful tool to analyse the implication of various policies across sectors / subsectors of the economy (based on both their employment multiplier rank and carbon intensity).

(iii) Further 'adjustment support measures' for the transition to a low carbon economy

The 'adjustment support measures' discussed below are distinct from policy measures as they are enabling characteristics that South Africa *could* pursue - in other words the extent to which measures may or may not be utilized cannot be fully predicted. The country as a whole, and specifically regions that rely on the coal value chain, need to build their resilience in the face of the impending transition to a low carbon economy. Burton, Marquard & McCall (2019) consider various features and 'adjustment support measures' (as opposed to structured government policies that are regulated by law) that have been highlighted as important in a country's transition away from coal based energy.

The SA LEDS (RSA, 2020) fully recognizes that the prediction of how markets and sectors / subsectors of the economy will evolve in the future is unlikely to be accurate. However, 'failing to plan is planning to fail', and so engaging with these measures is recommended to ensure a power sector transition that does not threaten South Africa's overall growth pathway. This is especially important for various firms in quadrant D, where some sectors may see slowing growth (and therefore unemployment) as the economy shifts to a new growth pathway. Looking at the 'adjustment support measures' (Burton, Marquard & McCall, 2019) that are important in the transition to a low carbon economy, allows for a sense of how various sectors in the typology may be effected. Additionally, the country can plan for a shift towards a high employment and low carbon growth pathway. These 'adjustment support measures' include:

Related diversification: Expanding industries and economic activities that are already established in regions and do not depend on 'Coal mining' or sectors / subsectors in quadrant D of the typology - specifically growth in firms found in quadrants A and B of the typology. This would include leveraging existing transmission infrastructure and expertise (Burton, Marquard & McCall, 2019), and engaging in worker transition schemes for employees - either redeployment or retraining (Winkler, Keen & Marquard, 2020). For the latter, the opportunity then exists for workplace support schemes where unemployed youth can be trained simultaneously. Additionally, local innovation is important, and could include residential rooftop solar PV ownership with feed-in tariffs (Burton, Marquard & McCall, 2019).

Smart specialisation: The growth of new sectors / subsectors that would have a competitive advantage in a region. Historically in coal dependent regions, strengths have seen to be in 'existing power, rail or port infrastructure, land availability, cultural and industrial heritage, skills of the local workforce, existing industries with growth potential' (Burton, Marquard & McCall, 2019). The aim would be to create opportunities in relatively employment intensive sectors / subsectors (found in quadrant A and B) so as to maximise employment opportunities.

According to Burton, Marquand & McCall (2019), for regions that rely on the coal value chain, this could include renewable energy assembly and manufacturing (leveraging the skilled workforce), other manufacturing (Mpumalanga has close links to markets, good transport links, and an experienced industrial workforce), alongside agriculture and agro-processing (high potential arable land in Mpumalanga and access to increased water as coal plants are retired). This fits in with the findings from this dissertation, which indicated that certain subsectors of manufacturing and agriculture are important for employment intensive growth in South Africa.

Strengthening of local entrepreneurial networks: Creating linkages between higher education and entrepreneurs, local companies, and training colleges (Burton, Marquard & McCall, 2019). This is especially important in the case of Technical and Vocational Education and Training (TVET) colleges (DTI, 2018), that provide many of the productive skills for quadrant A sectors / subsectors - required for the economy and its high employment and low carbon growth pathway.

Improvement of local infrastructure: This would boost the overall economic context and increase the productivity and potential for increased growth opportunities in sectors / subsectors found in quadrant A of the typology, as well as increasing linkages with other economic activities in the country (Burton, Marquard & McCall, 2019). Additionally, as discussed in Chapter 2, Hepburn et al. (2020) recommends directing finance towards clean physical infrastructure and in efficiency retrofits in buildings (with respect to a Covid-19 stimulus package). This would create opportunities in some of the sectors / subsectors that are identified in this dissertation as important for shifting the South African economy to a high employment and low carbon growth pathway – namely, 'Machinery and equipment' (A), 'Wood and wood products' (A), 'Building construction' (B), 'Metal products excluding machinery' (B), and 'Civil engineering and other construction' (B).

'Soft attractiveness factors': Supporting investment, as well as ensuring there are enough opportunities to limit the outflow of those with skills and capital (Burton, Marquard & McCall, 2019) – notably in sectors / subsectors in quadrant A. This would also include investing in education and training, alongside rural support spending (Hepburn et al., 2020). The rationale is that communities that rely heavily on industries vulnerable to a transition to a low carbon economy are frequently small mining and farming towns in more rural parts of South Africa (SAWEA, 2018).

Innovation or energy transition projects: It is often the case that regions linked to the energy sector want to retain this 'local identity', and would technically have the infrastructure capacity to do this (Burton, Marquard & McCall, 2019). These types of projects are imperative for a low carbon economy, and for a 'Just Transition' would include activities in the RE industry (Winkler, Keen & Marquard, 2020).

Chapter 5 worked towards answering the research question by discussing the impacts of three policy measures (phasing out fossil fuel subsidies, a carbon tax, and a wage subsidy) on various clusters of sectors / subsectors. These policies serve as three examples of possible regulation and the potential implications across the quadrants. Thereafter, I engaged with some of the recommended 'adjustment support measures' in shifting away from coal based energy. These enabling characteristics that South Africa *could* pursue in the transition to a lower carbon economy are useful to discuss in order to start looking at how sectors in various quadrants of the typology *could* be affected by these 'adjustment support measures'. Drawing on the findings from both Chapter 4 and 5, Chapter 6 concludes the dissertation, offering an answer to the research question in its entirety.

6. Conclusion

South Africa requires an urgent shift away from its current growth pathway that is characterised by high levels of unemployment and a carbon intensive economy. Shifting growth towards high employment and low carbon growth can lead to a more inclusive and sustainable economy. Trying to reduce GHG emissions whilst considering increasing employment is often seen as a zero-sum game. However, these objectives can and should be pursued together using the relevant policy and additional 'adjustment support measures' (as defined in Chapter 5.iii). This dissertation analyses this subject by mapping the necessary sectors for high employment and low carbon growth in South Africa, and investigating three enabling policy measures. These include the phasing out of fossil fuel subsidies, carbon tax, and wage a subsidy. Based on the typology quadrant in which sectors / subsectors are classified, I am able to discuss the implications of these policy measures. This is followed by a brief analysis of the impact of the recommended 'adjustment support measures' in shifting the economy away from coal based energy.

(i) Answering the research question

The 'Just Transition' to a low carbon economy is a vital consideration for South Africa's growth pathway in the context of climate change. This dissertation has explored the research question: Which sectors / subsectors have opportunities for high employment and low emissions growth in South Africa, and what are some policy measures that could realise this potential? Given the hypotheses generated by the mapping methodology of Chapter 3, I am able respond to this question. Firstly, Chapter 4 ascertains the sectors / subsectors where an increase in growth will be important to significantly shift the growth pathway of the country. Secondly, Chapter 5 uses the typology as a tool to analyse the implications of policy measures across sectors / subsectors.

The objectives of high employment and low carbon growth have each been individually explored in Chapter 2, with Chapters 3 to 5 then building on this existing research, exploring growth characterised by both high employment and low carbon. This dissertation mapped sectors / subsectors by their employment multiplier rank and the carbon emissions intensity, presenting initial results in Chapter 4. These findings enabled the classification of sectors / subsectors by their respective employment and carbon characteristics - indicating the importance of faster growth in the sectors / subsectors found in quadrant A (alongside some in quadrant B). Furthermore, industries in the other quadrants are still important in the overall economic context and thus may need 'adjustment support measures' to smooth the 'Just Transition' to a lower carbon economy. This is especially apparent for various firms in quadrant D, where some sectors may see slowing growth as the economy shifts to a new growth pathway.

A more specific response to the research question can be seen in Chapter 4. Figure 4, identified in particular as opportunities for high employment and low carbon growth in South Africa the following sectors / subsectors (SIC codes in brackets) (quadrant A): Other producers/activities (99); Clothing (313, 314, 315); Catering and accommodation (64); Forestry (12); Furniture (391); Leather (316); Wood and wood products (321, 322); Wholesale and retail trade (61, 62, 63); Footwear (317); Food (301-304); Motor vehicles, parts & accessories (381-383); Machinery & equipment (356-359); Printing, publishing & recorded media (324-326); Business Services (83, 85, 87), Beverages (305); Tobacco (306); Professional & scientific equipment (374-376); TV, radio & communication equipment (371-373); General government (91). Alongside Textiles (311, 312); Agriculture(11); and Fishing (13) found in quadrant B.

The typology constructed in this dissertation thus becomes a useful tool to analyse the implication of various policies across sectors / subsectors of the economy (based on both their employment multiplier rank and carbon intensity). The comparative findings from the analysis in Chapter 5 indicate that the phasing out of fossil fuel subsidies and / or the introduction of a higher carbon tax will largely impact firms in quadrant D, with the magnitude of this effect increasing as the carbon intensity of the firm increases. Firms that are higher emitters would thus feel these policy measures the most. Specifically, those granted large fossil fuel subsidies in the past, namely, Eskom ('Electricity') and Sasol ('Basic Chemicals'). Furthermore, firms in quadrant D are not relatively employment intensive and so a wage subsidy would not make a significant difference.

On the other hand, the implementation of a wage subsidy would incentivise firms that are relatively labour intensive to grow at a faster rate, increasing overall employment. Firms that are found in quadrant A would in general see larger inducement to faster growth – in particular the first four clusters of sectors in Table 7 (found in Chapter 5.ii). Additionally, these firms have relatively low carbon intensities, meaning that the direct effects of the phasing out of fossil fuel subsidies and / or the introduction of a higher carbon tax will be insignificant.

While the policies explored above can be important levers, policy is not a panacea and there are bound to be various unexpected externalities and policy implementation adjustment costs. South Africa will need to consider a variety of 'adjustment support measures' for transitioning to a lower carbon economy, and analysis needs to span across all the sectors / subsectors of the economy in order to enable a shift in the country's growth pathway. It is important to consider all the quadrants in Chapter 4. Figure 4, because value chains, jobs, and livelihoods rely on firms situated in these quadrants. In particular, sectors / subsectors in quadrant D will need these 'adjustment support measures' in order to soften the transition to a low carbon economy (that could see their growth trajectory slowing). This is especially apparent in the context of a 'Just Transition', and the workers and communities that rely on jobs found in quadrant D.

(ii) Constraints and limitations

A key limitation to this dissertation is the large degree of variability from firm to firm when looking at an employment multiplier for any one sector (Tregenna, 2015). This limitation would apply to the carbon intensity too. Factors such as firm size, firm location, product characteristics, and management choices would affect the individual firm's employment and carbon intensity. In this sense any sectoral analysis has limitations as to how much detail can be provided pertaining to sectors and subsectors. The empirical findings in this dissertation provide useful information, by linking the employment multiplier and carbon intensity of the sectors / subsectors in the South African economy, and grouping them by these characteristics.

The methodology chosen for this thesis (Chapter 3) is generally appropriate to investigate the research question. However, there are limitations in all methods, including the ones used here. An important limitation found in the process of research lies in the different sectoral definitions and the lack of disaggregation of the employment and the carbon emissions data. The dissertation made some simplifying assumptions to deal with this limitation. Overall, the limitations in both the disaggregation of data and availability of numerical employment multipliers reduce the accuracy of the sectoral mapping process.

There are also broader limitations in terms of what the results show and how they can be used. Due to the static nature of this research, the results are a snapshot of the present picture. But in the future, things are bound to change with the 'fourth industrial revolution', various automation trends, and plans to transition to lower emission energy sources. For example, under a renewable energy dominated scenario, would the electricity sector still have a low employment intensity. A dynamic analysis of employment and carbon intensities would be able to capture this type of information, and so results would be more useful going into the future.

(iii) Future research directions

In order to accurately map the employment and carbon intensities of various sectors / subsectors, further disaggregation of data would be valuable. For example, electricity, gas, and steam are grouped as one sector but ultimately they need to each have separate measures, and thus separate raw data. Electricity and gas are both high emitting sectors and need to be looked at individually, not grouped together. Each sector / subsector has its own characteristics, stakeholders, and operating environments. It makes sense then that they should be kept separate when measuring carbon emissions and employment intensities. This would mean that the mapping process could go ahead without having to make assumptions on how to disaggregate the various measures. In addition, actual employment intensity measures would mean that ordinal ranking measures would not need to be used.

Similarly, disaggregating and understanding 'Other producers / activities' is important because this sector contains the highest employment opportunities. Thereafter, the informal sector is also an important area for future research, as well as the changing context of the 'fourth industrial revolution', trends in automation, and the transition to low emission energy sources. This would greatly impact on sectors going forward, and means that a more dynamic approach is needed in general, as the employment and carbon emission characteristics of sectors change over time.

Another aspect to consider in future research, would be the current size of each sector in conjunction with the sector's relative carbon / employment intensity measure. An engagement with size as well as intensity could yield interesting results as a sector / subsector may have a very low carbon emission per unit of output, but at the same time be emitting much more carbon emissions than another more carbon intense sector. At the same time, a low employment intensity sector may create more employment than a high employment intensity sector because it is much larger in size.

Another important aspect to consider for future research would be the skills levels associated with each sector. A dynamic mapping of each sector in terms of sector size, skill levels associated, alongside the carbon / employment intensity measures could yield some interesting and useful results going into the future and considering a 'Just Transition'.

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