Perceptions of Carbon Capture and Storage as a CO_2 emissions reduction technology in South Africa

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A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management in Energy Leadership

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ABSTRACT

This research aimed to establish the perceptions of role-players in South Africa of the Carbon Capture and Storage (CCS) technology. The CCS technology aims to capture CO_2 emissions and prevent them from entering the atmosphere. The technology was mandated by Cabinet in 2012. The two role-players chosen for this study are the CO_2 emitting Industry and Policy Influencers. The introduction of a new technology presents challenges, especially in its full adoption by those intended to use it. CCS was identified by government as a CO_2 reduction technology, but has not been enforced on industry, it has merely been suggested as one of the climate change mitigation options, according to the National Development Plan 2030. Technology alone is not always a factor in its adoption, concerns of regulation, investment, safety and environment always arise. It is therefore of interest to ascertain if the mentioned role-players have the same or a differing understanding and regard for CCS. An aligned perspective is necessary so that each role-player may know its individual contribution to CCS development in South Africa.

The study followed a quantitative approach using an electronic platform to reach respondents. The respondents received identical statements and were only differentiated by their sector of employment. The results were analysed using the Fisher's exact test, suitable for small samples. Statistical significance was determined using p values as evidence against the null hypothesis.

Key findings include a sizeable portion of respondents who neither agreed nor disagreed with posed statements. The role-player with the most overall neutral responses was Industry. Policy Influencers seemed to be more confident of their responses. The role-players produced more similar than differing responses. Industry respondents showed a noticeable gap (neutral) in the general knowledge of the CCS technology, compared to the policy influencers' confidence in the general knowledge of the technology. Both industry and policy influencer are convinced that regulation and cost are potential barriers to the development of the technology in South Africa. Both industry and industry showed neutrality in the notion that CCS will lead to unintended consequences. The key message is that further stakeholder engagement is required between the two role-players, as both the Industry and Policy Influencers are in agreement of what could impede the development of CCS in South Africa.

KEY WORDS

- South Africa
- Perceptions
- Barrier to new technology
- CO_2 emissions reduction
- Carbon Capture and Storage

DECLARATION

I, ____Gcobisa Melamane_______________, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in ……………… at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Gcobisa Melamane Signature: gmelamane

Signed at ………………Douglasdale……………………………………

On the ……………………18……….. day of …November……………… 2021…..

DEDICATION

This report is dedicated to my parents Mr Thobile Melamane and Mrs Nonzukiso Melamane, for making education necessary and attainable. My aunt Ms Nomawethu Danster for inspiring education in me and my aunt Ms Phindiwe Melamane for being a disciplinarian and instilling order in all of us.

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LIST OF ACRONYMS

Acronyms	Full text
CFCs	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon Dioxide
GHG	Greenhouse gases
H_2O	Water
HFCs and HCFCs	Hydrofluorocarbons and Hydrochlorofluorocarbons
IEA	International Energy Agency
INDC	Intended National Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
MoA	Memorandum of Agreement
MoU	Memorandum of Understanding
Mt CO_{2eq}	Metric tons of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
N_2	Nitrogen
N_2O	Nitrous oxide
NO_x	Oxides of Nitrogen
NDP	National Development Plan
SCFD	Standard Cubic Feet/Day
SIA	Social Impact Assessment
SO_x	Oxides of Sulphur
UCG	Underground Coal Gasification

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

The research aimed to establish the manner in which CO_2 emitting industries and policy influencers perceive Carbon Capture and Storage (CCS) as a CO_2 emissions reduction technology, while relating factors that will have an impact on industry to adopt or reject the technology.

1.2 Context of the study

Carbon dioxide (CO_2) emissions and subsequent contribution to climate change are externalities arising from an increased use of fossil fuels. Concerted efforts by both the private and public sectors of business are required to mitigate the rising concern over climate change. Therefore, mitigation efforts require an introduction of strategies that may or may not be perceived as beneficial or practical due to their novelty to CO_2 emitting industry. South African economic activities such as mining, manufacturing and services are heavily reliant on fossil fuels in order to operate, with two major end-user energy carriers being electricity and liquid fuels. South Africa's energy supply is dominated by coal, which provides 65.7% of primary energy, supplemented by 21.6% of crude oil and 2.8% of gas, (Energypedia, 2020). As a result, the nation produces 93% of its electricity from coal, making it one of the world's 15 biggest CO_2 emitters. The emissions produced by combustion of fossil fuels include, but are not limited to CO_2, SO_x, NO_x, and CO_2 emissions in particular contribute to global climate change. Other big contributors of CO_2 emissions include steel and cement production. Climate mitigation strategies thus need to be deployed because:

- Climate change has adverse effects on weather patterns leading to catastrophic events.
- International treaties on climate change, such as the Paris Agreements, are 'pleading' with the world to reduce CO_2 emission to stall the rise of the average global temperature to significant levels below 2°C.
- To reduce the emission of greenhouse gases (GHG) into the atmosphere, South Africa, with the rest of the world, needs to implement the recommendations of the Paris agreement and other national policies. Adherence means moving away from fossil fuels, or at least using fossil fuels in a manner that emits less GHG of which CO_2 is part thereof.

- Coal, a fossil fuel that emits CO_2, is the dominant primary energy carrier within South African electricity generation.
- Coal mining is a significant foreign exchange earner; the sector provides employment for many South Africans, and contributes to the building of the economy. An abrupt ceasing of the use of coal would therefore have a negative socio-economic outcome, while affecting the export process.

Therefore, in order for South Africa to continue the use of fossil fuels in its energy transition journey and still ensure that the process does not disadvantage the South African population in terms of accessibility, supply, employment, security, business and sustainability, the country has to employ technologies to reduce the CO_2 emissions until a just energy transition is achieved.

Energy transition is not a short process, but is unique and prolonged. Therefore, examining historical precedents should give insight into how this transition might unfold in the future. The quickest sector-specific energy transition recorded is thirty years. However, full energy transformations have taken much longer, affecting both industries and utilities, (Fouquet, 2016) therefore, in the meantime humans will have to be responsible with fossil fuel use, and reduce CO_2 emissions using technologies that may not have been used in the country before. Notwithstanding environmental concerns, particularly climate change, the transition from fossil fuels to renewable and nuclear energies is also driven by the finiteness of fossil fuels.

Therefore, novel technologies such as CCS have been proposed as mitigation technologies and recommended by the NDP 2030, (South African Government, 2012). However, such technologies are not easily understood due to their novelty, thus creating a drawn-out process in their deployment. There may also be a reluctance in adopting such said technology due to a lack of understanding of the technical aspects, associated benefits, and financial burdens incurred by its deployment.

There are many CCS stakeholders in South Africa, which include but are not limited to the CO_2 emitting industry, relevant government policy influencers and society. Apart from an in-house study conducted by the South African National Energy Development

Institute (SANEDI), (Cohen, Lewis, & Matoti, 2019), publications on how these relevant stakeholders perceive CCS in the South African context is limited, especially regarding the two role-player groupings chosen for this study: Industry and Policy Influencers. An understanding of general CCS as a technology, the potential barriers and perceived unintended consequence from both the CO_2 emitting industry and relevant government policy influencers is required to establish synergy in future consultation and collaboration.

1.3 Research problem

Concerted efforts have been initiated to bring CCS to life in South Africa. The efforts include collaborations, steering committees, advisory committees, memoranda of understanding and consultations with relevant stakeholders. The two role-players in this study have been part of these efforts, however, the perception of CCS has not been amplified enough to establish a common or differing understanding and interpretation of this CO_2 technology by these two role-players.

The growing concern to ameliorate global climate change by reduction of CO_2 emissions has driven the South African government to seek mitigation technologies such as CCS. The National Development Plan (NDP) 2030 has cited CCS as one of the technologies that could achieve CO_2 emission reduction. The NDP further states that it will promote the research and development of CCS and other coal cleaning technologies, as South Africa is still heavily dependent on coal usage, thus giving legitimacy to the investigation of CCS, (The Republic of South Africa, 2012). Subsequently, the South African government's Long Term Mitigation Scenario plan identified CCS as an option in CO_2 reduction, (DIRCO, 2012). The development was adopted by the then Department of Environmental Affairs. CCS was also listed as one of the eight near-term priority flagship programmes in the National Climate Change Response White Paper, 2011.

At inception, challenges of deploying CCS in South Africa were similar to those elsewhere in the world, including the need for an early start, how to address CCS costs, what regulatory framework will be acceptable, and building human capital in this comparatively new industry, (Beck, Garrettb, Havercroftc, Wagner, & Zakkour, 2011).

However, the problems persist currently with gaps in information, which create potential barriers that may present themselves during the lifespan of the CCS technology.

CCS is a novel technology in South Africa, such that its deployment may depend on how related stakeholders such as industry and policy influencers perceive it. This study investigates the CO_2 emitting industry and relevant government policy influencers on their general CCS understanding of the technology and seeks to establish whether there are similar or differing interpretations on potential barriers such as policy, regulation, costs and unintended consequences to the deployment of CCS.

1.4 Research objectives

1.4.1 *To establish the perception of CO_2 emitting industry and policy influencer on CCS as a CO_2 emissions reduction technology in South Africa*

a) The general understanding of CCS
b) The potential barriers to CCS in South Africa
c) The potential unintended consequences of CCS in South Africa

1.5 Significance of the study

The significance of the study is to establish perceptions of role-players on a new technology (CCS) that is being introduced to the CO_2 emitting sector in South Africa. With the introductions of most new technologies, there is usually resistance to, reluctance and concerns about the proposed introduction. The study proposes that the introduction of new technologies will give rise to different views as to what the technology is and why it is necessary, which will, in turn, give rise to concerns of regulation or lack thereof, costs, and unintended consequences. New technologies often require capital to implement, leading to questions on how this capital will be acquired, and who will be the responsible party to acquire the said capital. These questions need be understood before adoption occurs.

Part of the running of a successful organisation is the technological innovation that is normal, safe and fully planned. To expand, one needs to update their resources and processes continually. Yet no matter how wonderful your new technology is, it will be absolutely pointless until people adopt it.(Memory, 2020). Many factors influence the adoption rate of technology including the characteristics of an innovation and various cultural, sociological, organisational, and psychological variables. Knowing the adoption rate in any given situation includes examining factors that can promote adoption and those that can serve as barriers to adoption, (Darrell & Martin, 2002).

Technology on its own is not always the only factor in the solution of a problem. International experience has shown that industry, stakeholders and political factors are significant elements of any endeavour. With the rising climate change concerns, governments have adopted strategies to reduce GHG by proposing several novel technologies. In the case of this study, CCS is one of those technologies put forward in the NDP 2030. However, the buy-in from all relevant stakeholders should be acquired for the technology to be adopted.

As a study in China has indicated, in the instance of policy makers, there should be strength in the propaganda of carbon reduction, which will in turn encourage CO_2 emitters to reduce their output. While there seems to be an understanding of the policy maker's role, the CO_2 emitting industry may need policy subsidies to invest in CCS, (Zhao & Liu, 2019). Therefore, this study aims to investigate if the South Africa role-players are aware of their expectations of each other. Are they able to ascertain each role-player's perception of CCS and factors that may impede the adoption of the technology? The study will focus on collating individual interpretation, regard and understanding of CCS and present it in a way that will paint a picture of concerns, similarities and differences to establish similar or differing perceptions.

This study focuses on two role-players, namely the CO_2 emitting industry and policy makerss responsible for the regulatory imposition of climate change initiatives. These two role-players have been chosen for this study based on their current CCS involvement, which includes collaboration, Memoranda of Understanding (MoU's), Memoranda of Agreement (MoA's) and consultations with the CCS implementing agency. Another contributing factor to the selection of these two particular role-players is ease of communication as the researcher has an established rapport with the potential respondents. In addition, due to the limited time available for the research, the use of electronic means to interview respondents was deemed convenient opposed to interviewing the remainder of the stakeholders in person, most of whom have limited access to internet hardware and connection. The choice to use web-based survey management is supported by (Greenlaw & Brown-Welty, 2009) as it produces higher response rates when administered to an educated population with computer access. The total cost per response is significantly less onerous than paper-based administration and effort.

The perceptions of the two role-players have the potential to contribute positively or negatively in the deployment of CCS, thus contributing to the success or failure of the technology. At this stage the gap in the literature does not indicate if industry and policy influencers have the same regard, interpretation and understanding about CCS in the South Africa context. This study will address gaps in the literature about the perception and subsequent unified response to the adoption of CCS.

The contribution made by this study will assist in adding knowledge to the two role-players and streamline milestones to reach the same goal of the deployment of CCS. Each role-player will have a better knowledge of how the other role-player perceives CCS technology, its deployment and related regulations.

Below are some of the reasons why CCS is considered to be one of the technologies that will assist South Africa in moving away from fossil fuels:

- The South African energy sector is going through an energy transition. It is employing the 4D's = Decarbonisation, Decentralisation, Digitalisation Deregulation (or Democratisation).
- There is global climate change, characterised by events such as changing weather patterns and melting ice caps (thermal expansion of water).
- Emissions from fossil fuels such as gas, oil and coal are major contributors to the changing climate and coal is a major source of primary energy in South Africa.
- There is a global drive to mitigate climate change by stalling the change in temperature to below 2°C.

- The effects of global warming have also been felt by South Africa, yet the country is continuing to contribute to CO_2 emissions and should comply with global agreements by reducing CO_2 emission.
- If South Africa were to leap to greener options, that is, Renewable Energy, the following will be affected:
    - security of supply (baseload requirements to power the country) because the current green technologies are unable to fulfil this requirement;
    - unskilled job loss (coal mining, petroleum jobs would be lost, with no opportunities for those employees to move to and work on the new technology).
- Industry and policy influencers must contribute effectively to the formulation of related policy, regulation and other relevant standards that will be required in order to deploy CCS in South Africa.

1.6 Delimitations of the study

Included:

i. General information of South African industry as pertaining to CO_2 emissions
ii. General information of South African policy influencers as pertaining to CO_2 emissions
iii. General information about CCS as a CO_2 emissions reduction technology
iv. Data collected on only two role-players of CCS (industry and policy influencers)
v. Data collected from related multiple CO_2 emitting industries
vi. Data collected from related multiple government policy influencers
vii. Information on global and South African energy developments
viii. Anything additional that evolves from the research undertaken
ix. Limitations placed by sample and population

Excluded:

i. An investigation on all CCS stakeholders
i. Focus on business and/or technical performance of each role-player
ii. Conclusion based on the ideal perception

1.7 Definition of terms

- **Climate Change Mitigation**

  Mitigation is a human intervention aimed at reducing greenhouse gas sources or increasing the sinks of greenhouse gases, (IPCC, 2014)

- **CO_2 emissions**

  CO_2 is the gas that is generated in the combustion process of fossil fuels, (Pereira, 2008)

- **Decarbonisation**

  Decarbonisation is the reduction of carbon in primary energy carriers over a period. It is an increase in low carbon content/emission energy carriers as compared with the reduced use of fuels with high carbon content, (Greencoast, 2019).

- **Decentralisation**

  Decentralisation is the relocation of authority from central to provincial and local government; to move away from a single administrative centre to other locations, (World Bank, 2001).

- **Deregulation**

  Deregulation is the reduction or elimination of the control of government in a particular industry so as to create competition within that industry, (Kenton, 2019).

- **Digitalisation**

  Digitalisation that is leveraged for the purpose of improving business, (Burkett, 2017).

- **Digitisation**

  The process whereby information is converted from physical (analogue) to digital format, (Burkett, 2017)

- **Energy Transition**

  Implementing a variety of measures that focus on energy efficiency and the use of sustainable energy sources to decarbonise economies and achieve effective reductions in greenhouse gas emissions and sustainable development, (Neofytou, Nikas, & Doukas, 2020)

- **Fossil fuels**

  Coal, crude oil, and natural gas are all considered fossil fuels because they were formed from the fossilised, buried remnants of plants and animals that lived millions of years ago. Fossil fuels have a high carbon content because of their origins, (Denchak, 2018)

- **Global Climate Change**

  Climate change is characterised by three major components – global warming, changes in patterns of precipitation and increased frequency of extreme weather. Global warming is a result of growing greenhouse gas concentrations. Atmospheric CO_2 levels currently have risen from 280ppm pre-industrial to 400ppm currently. It also includes the increase of the global mean surface temperature by about 1ºC above the pre-industrial pre-induced levels, (Ruszkiewicz, et al., 2019)

- **Industry**

  An industry is a community of related businesses, based on their primary business activities. There are hundreds of classifications of industry in modern economies, usually clustered into larger groups called sectors. Different companies are typically categorised into a sector based on their main revenue sources, (Will Kenton, 2019). For the purpose of this study, the focus will be Sasol, Eskom, PPC, Anglo America, and any other similar industry.

- **Just Transition**

  Just Transition is a structure created by the movement of trade unions to embrace a variety of common (social) measures that are needed to protect employment and the livelihoods of workers as the economies are transitioning towards sustainable development, that includes the avoidance of climate change effects and the protection of biodiversity, (McCauley & Heffron, 2018)

- **Perspective**

  Perspective is described as an understanding of how various aspects of a topic interact with one another and with the larger picture, a point of view or a subjective assessment of relative importance. It is the capacity to interpret items in relation to one another or in terms of relative value, (Embree, 2007)

- **Policy Influencers**

  Policy formulation, adoption, and implementation are complicated and dynamic processes that require input and participation from a wide range of stakeholders, or 'policy-influencers', where policy development refers to the process by which government decision-influencers become aware of new ideas or issues that need to be addressed, (Campbell, Olstad, Spence, Storey, & Nykiforuk, 2020). For the purpose of this study, the focus will be on grouping policy stakeholders (influencers and makers) that are directly affiliated with the government either by being a state owned entity, a government ministry and/or wholly owned by the government. The institutions are namely; the Department of Mineral Resources and Energy (DMRE), Department of Environment, Forestry and Fisheries (DEFF), Council for Geoscience (CGS), Council for Scientific and Industrial Research (CSIR), South African Bureau of Standards (SABS), government financial institutions, Local Government and any other related institution.

- **Primary Energy**

  Primary energy is the energy embodied in natural resources before undergoing any transformations or human-made conversions. Examples of primary energy resources include coal, crude oil, sunshine, wind, flowing rivers, uranium and vegetation, (Kydes, 2015)

1.8 Assumptions

- The respondents in the study are representative of the majority of the two role-players chosen for this study.
- The respondents to the study are truthful in their perspectives.
- Information and data collected have no limitations – which all information and data collected from participants is credible and referenced material is not biased and/or manipulated.
- The research outcomes will have an influence on the progression of CCS development in South Africa, or the lack thereof.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

2.1.1 *Theoretical Framework*

An externality is a societal expense imposed by a corporation's behaviour. A power plant, for example, can emit mercury but fail to pay for the cost of pollution to the people who live near the plant. The health impacts of corporate activities, the unsustainability of production systems, the promotion of goods that contribute to environmental harm, and economic policies that perpetuate high levels of poverty due to successful lobbying by the business sector can all be analysed in these imposed expenses. Companies have no incentive to avoid externalities, which is a concern. Any expense a corporation incurs has an effect on its earnings. As a result, in a competition economy, companies are more likely to choose practices that lower such costs. They have little incentive to cut expenses that are carried by others. Businesses may find it lucrative to participate in activities that enable them to avoid incurring such costs, (Biglan, 2009)

The problem that CO_2 emitting industries face is that it has been established that externalities pose a risk to the environment and companies are being compelled to adopt strategies to reduce the negative impacts thereof. The South African private and public sector have adopted many technologies to reduce their carbon footprint and one of the technologies that has been suggested to be effective in CO_2 emissions reduction is CCS, but the issue is CCS has never been deployed in South Africa, and has little demonstrable deployment around the world. It thus becomes a new technology to the South African industries.

New technology can increase the quality, performance and protection of life; however, in certain environments, the implementation of new technology may be a sensitive process and may pose new threats and unexpected hazards. New technology may be new in conceptual terms or new in contextual terms. Conceptually, modern technology is innovative or truly modern, created, or invented only recently, whereas contextually, the technology is established but new in a particular environment, (Mytton, et al., 2010). In the case of CCS, it is conceptually a fairly new technology globally as there are no set standards on how the technology should be deployed. It is both conceptually and contextually new in South Africa as the technology has never been deployed in the country.

There are perceived benefits to CCS such as pollution control, climate change mitigation, energy security and energy transition. There are also disadvantages such as the perceived risk to health and environment, safety and the economic cost of CCS. The project assumes the developer will take care of the CCS installation for 20/30/50 years and if it is, so to speak, "stable" in all manner of ways, then the state will take care of it. Yet, in the case of long-term CO_2 storage, chemical processes with some degree of unpredictability and their impact, in particular on the area from about 1000 to 1200m underground, are not known, (Riesch, Oltra, Lis, Upham, & Pol, 2013) page.

The research has identified one of Porter's five forces to determine the attractiveness of new business, and in this case, new technology: The Threat of New Entrant force. (Pringle & Huisman, 2011), describes force as “new industry entrants bring new resources and a desire to capture market share, which puts pressure on prices, costs and the investment levels required to compete”, (p. 39) . Another aspect to this force is the flow of capital. The institutional arguments concerning capital flows in and out of industries indicate the degree that political, legal and regulatory institutions do not provide investors with an opportunity to minimise the risks of capital or asset losses, as emerging markets have sluggish capital movements unlike developed economies, (Narayanan & Fahey, 2005)

A decade of international research has consistently shown that CCS is not a commonly recognised or understood technology for the public. Even though respondents have judged that self-knowledge of CCS is good, factual cross-checks have shown that people overestimate their own knowledge of CCS, although this varies in scope across countries, (Riesch, Oltra, Lis, Upham, & Pol, 2013). The provision of CCS information is known to affect opinion, often (although not always) negatively. For this reason, this study aims to ascertain the perceptions of CCS in South Africa because it is possible that even those who may be entrusted with deploying the technology may have gaps in what could advance or impede CCS development in the country.

The perceptions on which this study focuses are the general understanding of CCS as a technology, where role-players 'background knowledge of the technology is investigated. The study further seeks to ascertain that the role-players 'response in relation to barriers to CCS will converge or diverge from the notion that:

- companies do not want to carry the cost borne by someone else;
- there is little incentive to do anything about externalities;
- new technology has entry barriers and what those barriers are perceived to be;
- to establish perceived factors may promote or impede the development of the technology; and
- there are perceived unintended consequences.

This study will also provide background on how CCS came to be recognised as one of the technologies that the country should invest in concerning climate change. This study will also elaborate on the causes of climate change, what the CCS technology is as well as policy, regulatory practices in relation to CCS, globally.

2.1.2 *Factors leading SA to CCS*

Climate change is defined as a change in the condition of the climate that can be detected (e.g., by statistical tests), by changes in the mean and/or variability of its properties over time, generally decades or more, (UNFCCC, 2011) . And, Global Warming is an accumulation of atmospheric GHG, which include Water Vapour (H_2O), Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Chlorofluorocarbons (CFCs), and Hydrofluorocarbons (HCFCs and HFCs). The growing presence of atmospheric GHG has a net effect of warming the Earth's surface and the atmosphere's lower levels. The result is an altered radiative balance in the atmosphere because of the absorption of the Earth's exiting heat radiation that is reradiated back to the surface, (UNFCCC, 2011). The UNFCCC asserts that a long time range is required to establish if individual instances such as heatwaves, droughts, mudslides et cetera are attributable to climate change.

The Paris Agreement's aim is to retain the global warming temperatures to levels significantly lower than 2ºC and engage efforts to the limit of 1.5ºC. State parties to the Agreement, such as South Africa, have to outline their Intended National Determined Contribution (INDC) that will outline the country's actions post 2020, (Rogelj, et al., 2016). South Africa as a part of the Agreement responded to their requirements and published the South African INDC in 2015.

The SA-INDC was developed to enable mitigation and adaptation, as well as climate change finance, technology and transparency arrangements. South Africa has outlined challenges as a developing country which faces climate change challenges and has prioritised the reduction of poverty and inequality. INDC priorities include finalising the National Adaptation Plan by 2020, the sectoral policy framework, building institutional capacity for climate change response planning by 2025/2030, developing an early warning system for climate change sectors by 2025/2030 and developing a framework for vulnerability assessment and adaptation needs by 2020, (Department of Environmental Affairs, 2015). The mitigation of CO_2 component of the INDC is outlined as a peak, plateau and decline of GHG emissions by 2025 (firm) and 2030 (indicative). The proposed range is 398 and 614 Mt CO_{2eq} as the benchmark against which the effectiveness of mitigation actions will be measured, (Department of Environmental Affairs, 2015).

The National Development Plan (NDP) 2030 has stated the perceived impacts of climate change marked by rising temperatures, rising sea levels and rainfall/drought variations. Therefore, the NDP has recognised that a short-term policy to ensure society and environment are protected from inevitable adverse effects of climate change, (Department of Environmental Affairs, 2015). A National Adaptation Strategy Plan was produced in 2017 with the vision to effect "t*ransition to a climate-resilient South Africa that will pursue a path of development driven by expectation, adaptation and recovery to a changing climate and environment in order to achieve our ambitions for progress"*, (Department of Environmental Affairs, 2017) (p.3). The NDP 2030 further states that "*cleaner coal technologies will be promoted by investment in R&D and technology transfer agreements, including the utilisation of ultra-supercritical coal-fired power plants, fluidised bed combustion, underground coal gasification (UCG), integrated combined cycle gasification and carbon capture and storage",* (South African Government, 2012).

The Africa Energy Outlook (Interanational Energy Agency, 2019) report gathered information on the growth of the South African population and the growth of other key indicators in relation to the country's Gross Domestic Product (GDP). The report states that over the past eight years (2010 – 2018), the population grew by 19.3% and other key growths include: GDP: 37%, electricity access: 18%, clean cooking: 31% and CO_2 emission: 33%. The primary energy demand in relation to GDP growth indicates that in the last eight years, coal has not seen a change, as it has accounted for approximately 100Mtoe per year; dependence on oil also remained the same over the eight years at approximately 50Mtoe, (Interanational Energy Agency, 2019).

As part of the energy mix, other sources include low-carbon and bio-energy dependence, which also emit CO_2, albeit at a lower rate than coal. The envisaged primary energy dependence will see a decrease in coal demand as well as a rise in oil demand and bio-energy by 2030, (IEA, 2019).

Energy transition in South Africa is outlined in the Integrated Resource Plan (IRP) 2019. The plan reports on the continuation of the use of coal in electricity generation, as the country has the resource in abundance. The IRP indicates an overall decrease of coal-fired electricity generation capacity from 72% in 2018 to 45% by 2030, the gap being taken up by renewable energies. However, the actual decrease in coal-fired capacity decreased only by ±13% (39,126MW to 33,847MW), (Department of Energy, 2019). A new 1500MW of coal-fired electricity is also scheduled to be procured by 2030, however, the new investment will be directed towards high efficiency. The plan also states that 6000MW and 14400MW of solar and wind power respectively will be commissioned by 2030. There will be support of gas infrastructure in the form of converting all diesel fired plants to gas. During the process of ensuring that energy transition is successful, a just transition process should be followed.

Climate change has disproportionately affected the poor. There is widespread poverty In South Africa that includes high population mobility, poor sanitation in informal settlement housing and the risk of waterborne disease and fires. These are human health-related risks that can be aggravated by climate change. The African continent is being affected by global failure to mitigate climate change; hence, South Africa has committed to its own carbon emission mitigation strategies in concert with the rest of the world, (South African Government, 2012).

The proposed just transition management is considering the following factors:

- public infrastructure investment;
- committing to a particular technology;
- Infrastructure to commit to an emission profile.

It is important that there is coordination of policies at all levels of government on long-term environmental and national mitigation goals. Therefore, the transitions will be a cross-cutting objective that will integrate into the plans of the South African government departments, (South African Government, 2012).

Therefore, this study refers to the NDP 2030 for suggested technologies that aim to reduce CO_2 emissions in the country. The NDP 2030 has committed to promote the research and development of CCS in the country, (South African Government, 2012) and SANEDI became the technical custodian of CCS before the project was moved to the CGS. In 2010, SANEDI's South African Centre for Carbon Capture and Storage (SACCCS) division commissioned the compilation of an Atlas, (Council for Geoscience, 2010), to explore the feasibility of potential storage sites for CCS in South Africa. The Atlas was endorsed by the then Minister of Energy Ms Dipuo Peters, and financially supported by government and industry namely, PetroSA, Eskom, Sasol and AngloAmerican. The Atlas explored the country's GHG emission and energy economy, geological conditions that would be required for CCS, aimed to provide information for decision making and also provided technical information to be utilised by specialists. Findings of the Atlas were that South Africa has potential storage sites required for CCS and that research efforts into the feasibility of CCS in the country should continue. What the Atlas was not commissioned for is to source opinions of role-players as a way of determining if CCS would be perceived favourable or not.

Thus, this report aims to source that information, as literature discussed below suggests that there may be a reluctance to adopt CCS based on environmental and economic factors.

The literature in this report will cover topics that have led to the suggestion that CCS is one of the technologies to mitigate climate change. The literature will also aims to highlight climate change progression and challenges and the efforts towards energy transition from high carbon content energy to renewable energy. In addition, this report describes what CCS is and how it has been deployed in some parts of the world. Most importantly, the report aims to identify literature that will assist in highlighting how CCS is perceived by role-players in other countries, thus contributing to the research question of the perception of CCS in South Africa.

2.2 Fossil fuels and CO_2 emissions

Fossil fuels have been supplying the world's primary energy for centuries and the use of fossil fuels will continue for decades to come. It is predicted that coal, petroleum and natural gas will continue to be bases of primary energy. Fossil fuels account for an estimated 82% share of primary energy providers globally, approximately the same amount that it was 25 years ago; therefore the arrival of renewable energy sources reduced fossil fuel consumption by only 7%, (Miller, 2015).

The major constituents in fossil fuels are hydrogen and carbon and they, upon combustion generate heat, and in the process release CO_2. Once the carbon is oxidised during fossil fuel combustion, CO_2 emissions can be measured by considering the CO_2 to carbon molecular weight ratio. Therefore, a lineal relationship between CO_2 emissions and fossil fuel combustion activities can be determined taking into account the amount of fuel used, its carbon factor, the oxidation degree and CO_2 to the energy ration, (Pereira, 2008).

Fossil fuel combustion and the manufacture of cement are contributors to the single largest net carbon flow between surface and atmosphere. It is therefore important that the global carbon cycle is understood and this emerges as the key element in advancing understanding and projections of climate change, (Gurney, et al., 2009).

There are stationary emitting sources known as point sources, that is, industrial facilities that have emissions exiting through a stack or exhaust. There are areas and non-point sources; these are stationary sources that do not get accounted for in inventories such as residential and commercial activities and they represent diffuse emissions. There are also airport sources; these are emissions that are associated with airport locations and represent the take-off/landing cycle, taxiing and other aircraft activities. In terms of quantifying and accounting for CO_2 emissions, direct monitoring from stationary sources is the most reliable, (Gurney, et al., 2009).

It is to be noted though that the IPCC does offer guidelines for GHG inventories, namely *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, which describe methodology for calculating national inventories of anthropogenic greenhouse gas emissions by sources and removals by sinks. The guidelines were subsequently refined to the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* The guidelines address how to choose which methods to use and how to use key category analysis to help you make that decision. Where key categories are described as inventory categories that are prioritized within the national inventory system, either individually or as a group because their estimates have a significant impact on a country's total inventory of greenhouse gases in terms of absolute level, trend, or level of uncertainty in emissions or removals, (IPCC, 2019)

Scholars claim that during the Han dynasty, commencing around 206 BC, China first started burning coal for heat, cooking, and smelting steel, (Stanway, 2011). Coal use in ancient China allowed the country to grow into an advanced economy and society. Inhabitants of Britain were one of the first to use coal as far back as the thirteenth century when they discovered ‘black rocks ’that could burn. Following the discovery, coal mining began and the 'black rock' was used in metal smelting, steam engine development, powered railway development, steamship and steam-electric power, (Hubbert, 1949). The coal discovery was made great when another great source of fossil fuel – petroleum and natural gas – was discovered a century ago. The fossil fuel was exploited and would be used in the internal combustion engine, airplanes, cars, and diesel-electric power, (Hubbert, 1949).

2.2.1 *Carbon tax in South Africa*

Carbon tax is a charge imposed on enterprises and companies that pollute the climate by emitting large amounts of carbon. The most common offenders are industries that rely on fuel use and power generation. It has been on the table as a draft bill from Parliament since 2015. As promised by the Minister of Finance in the 2019 Budget, the President had signed into law the Carbon Tax Act No 15 of 2019, which took effect on June 1, 2019. The Act was published in the Gazette on May 23, 2019. (Gazette No. 42483), alongside the Customs and Excise Amendment Act No. 13 of 2019 (Gazette No. 42480). The Carbon Tax Act ensures that major emitters follow the polluter-pays principle and that enterprises and consumers factor in negative external costs (externalities) when making future production, consumption, and investment choices. Over the next decade and beyond, businesses will be rewarded for embracing cleaner technologies, (IEA, 2020).

The Carbon tax applies to entities in the country that operate emissions-generating facilities with a total installed capacity equal to or more than the carbon tax threshold. Carbon tax applies to the CO_2 equivalent of greenhouse gas emissions as defined in the Carbon Tax Act of 2019. The emissions that are subject to carbon tax are calculated using either the Department of Environment, Forestry and Fisheries' (DEFF) approved reporting technique or the Carbon Tax Act of 2019's stipulated formulas. The carbon tax rate in the first phase is R120 per ton of CO_2 equivalent emissions. This rate will rise every year by inflation plus 2% until 2022, then by inflation every year after that. Significant industry-specific tax-free emissions allowances ranging from 60% to 95% will result in a modest nett carbon tax rate of R6 to R48 per ton of CO_2 equivalent emissions, giving current emitters time to transition to cleaner technologies through investments in energy efficiency, renewables, and other low-carbon measures, (SARS, 2021).

Before the second phase, after at least three years of implementation, a review of the tax's impact will be done, taking into consideration the progress made in reducing GHG emissions in accordance with the country’s Nationally Determined Contributions Commitments. After any appropriate budget announcements by the Minister of Finance, any modifications to rates and tax-free thresholds under the carbon tax will follow, and will be subject to the standard transparent and consultative processes for all tax legislation, (IEA, 2020).

2.3 Carbon Capture and Storage (CCS)

Continued utilisation of fossil fuel as the main source of energy will remain for the coming years and CCS is one of the technologies that can alleviate atmospheric CO_2 levels, (Pires, Martins, Alvim-Ferraz, & Simões, 2011). CCS is a technology involving the capture of CO_2 at a fixed point through the absorption, adsorption and/or separation by membranes and cryogenic separation of such power plants and cement processing. The captured gas is compressed into a supercritical fluid and transported by pipeline or ship. The supercritical fluid is deposited in a geological, oceanic or mineralised system, (Pires, Martins, Alvim-Ferraz, & Simões, 2011).

CCS has the potential of lowering future world emissions from energy by 20%, however, it is not without challenges. The separation of CO_2 from flue gas as a step in CCS consumes the most energy and results in high costs. CO_2 separation, if scaled up, has the potential of consuming 25 - 40% of fuel energy of a power plant, thus increasing it up to 70% more of extra cost in capture and storage, (Haszeldine, 2009). However, the parasitic load of CCS can be reduced by renewable energies. In addition, the overall concerns regarding CCS, technological, economic, and environmental and safety problems are still to be solved. There needs to be efficiency in CO_2 capture, process cost needs to be reduced and verification of environmental sustainability of CO_2 storage is required, (Pires, Martins, Alvim-Ferraz, & Simões, 2011).

Attention given to alternate uses for the captured CO_2 is also increasing. The overall process is known as carbon capture and utilisation (CCU). CCU enables emissions reduction and delivers useful product and energy system flexibility. CO_2 is then able to be reclassified from unwanted by-product to a resource for subsequent processing, (Quarton & Samsatli, 2019). CO_2 captured from a CCU process can be used as feedstock for industrial purposes or converted into synthetic fuels. Hydrogen is an integral part of the energy-based CCU pathways (i.e. Fischer-Tropsch synthesis).

Therefore, CCU has the potential to be used as an incentive to carbon capture by forming a marketable product from CO_2, (Quarton & Samsatli, 2019).

The subsurface is the largest carbon reserve on Earth, where coals, tar, gas-rich shales, and carbonate rocks contain the vast majority of the global carbon. For hundreds of millions of years, geological accumulation of CO_2 has been a natural cycle in the upper crust of the Earth, (Benson & Cook, 2005). Geological formations suitable for storing CO_2 through numerous physical and chemical trapping mechanisms must have the required capacity and injectivity, must contain CO_2 and prevent its horizontal movement and/or straight up leakage to other layers, shallow drinking groundwater, soil and/or atmosphere, (Bachu, 2007).

One of the more technically advanced solutions available is the geological disposal of CO_2, or the injection and recovery of vast quantities of CO_2 into the subsurface deep saline aquifers, natural hydrocarbon reservoirs or unmineable coal-seams. A variety of studies aimed at understanding the behaviour and long-term fate of CO_2 when deposited in geological formations have been carried out, (Baines & Worden, 2005).

2.4 CCS in Operation

2.4.1 *SASK Power – Boundary Dam, Canada*

The world's first commercial coal-fired power station fitted with the technology of CCS was opened by SaskPower in Canada in October 2014, with the expectation that the facility would create global opportunities for the state-owned utility of Saskatchewan, (McCarthy, 2014).

In the autumn of 2000, a re-commissioning of a CO_2 extraction pilot plant adjoining to SaskPower's Boundary Dam (BDPS) power station took place, and operations were able to process 500,000 SCFD of flue gases and capture up to 4 tonnes of CO_2 per day. This facility is used to test and demonstrate the possibility of various technologies to capture CO_2, (Wilson, et al., 2014).

This pilot plant has given those who have invested interest in the plant the ability to assess the functioning and dependability of proprietary CO_2 solvent extraction technologies and to acquire the much-needed engineering data that can be utilised to build commercially available CO_2 absorption units. A succession of tests were performed with a monoethanolamine (MEA) based solvent (i.e., Fluor's Econamine FG^{SM} technology) over a reasonably long test period, (Wilson, et al., 2014).

The SaskPower Boundary Dam's Integrated Carbon Capture and Storage (ICCS) project represents a major step towards the global adoption of Shell Cansolv's post-combustion CO_2 capture technology. The technology uses regenerable amines to absorb both SO_2 and CO_2 to avoid direct waste, (Stéphenne, 2014).

At full capacity SaskPower's ICCS Demonstration Project collects more than one million tonnes of CO_2 annually, representing a 90% CO_2 capture rate for the 139 MW coal-fired plant. The subsequent emissions of CO_2 are compressed and conveyed through pipelines to Cenovus Energy, which is using the Enhanced Oil Recovery (EOR) CO_2 activities in the Weyburn oil field. Meanwhile, all the sulphur dioxide (SO_2) in the flue gas is recovered and used as a valuable by-product for the making of sulphuric acid and thereafter sold, (Stéphenne, 2014).

2.4.2 *The Snøhvit CCS project, Norway*

The Snøhvit CCS project, which began in 2008, is part of the development of the Snhvit gas resource in the Barents Sea. The CO_2 is extracted from the gas at Melkya, an onshore gas processing plant, and then transferred to a subsea injection template through a 150-kilometer conduit. Almost 5Mt of CO2 had been pumped into the subsurface by the end of 2017. At first, CO_2 was pumped into the Tuben Formation, a saline aquifer beneath the gas-bearing St Formation. However, a slow rise in pressure was seen over the first three years after injection, owing to geological constraints that limited access to the accessible pore space. As a result, in 2011, the decision was made to undertake a well intervention, resulting in a modified injection plan with CO2 injected into the St Formation aquifer, (Ringrose, 2018).

Statoil, the carbon efficient producers of oil and gas, which has subsequently changed its name to Equinor revealed in early 2010 that they had discovered that the Snøhvit injection site had less storage capacity than projected. Drilling new holes and/or fracturing the formation are now being used to expand Snøhvit's capacity. A monitoring program has also been established to explore CO_2 subterranean behaviour, (MIT, 2016).

The Snøhvit CO_2 operation provides a unique data collection as well as inspiration for CO2 injection data analysis and connection of injection pressure data with reservoir models. Snøhvit's CO_2 injection time series observations have provided important insights into aquifer dynamics. The Snøhvit case also demonstrates that aquifers and abandoned gas fields aren't the only options for CO_2 storage and sequestration; a satellite segment at an active gas field can also be a viable option, (Bohloli, et al., 2018)

2.4.3 *In Salah CCS project, Algeria*

The Krechba CO_2 Storage facility in Salah, Algeria was one of the first carbon capture and storage projects (CCS). Since its inception in 2004, more than 3.8 Mt of CO_2 has been stored underground until it’s decommission in 2011. The CO_2 in the produced natural gas is taken out and re-injected into a deep saline reservoir. Three wells penetrate the Carboniferous sandstone strata, which is down-dip from the gas-producing horizon. The CO_2 is in supercritical phase because the reservoir temperature is around 90 °C and the reservoir pressure is around 180 bar (the critical point for CO_2 is 31.1 °C and 73.9 bar). Due to its large size and diverse and extensive portfolio of monitoring methods, including satellite InSAR data that allows monitoring of ground deformations and, as a result, the rock mechanical response due to subsurface CO_2 injection, the CO_2 storage project in In Salah is a one-of-a-kind project, (Bjørnarå, Bohloli, & Park, 2018)

The In Salah CO2 Storage project was a very instructive demonstration project, and the data gained has been researched and reported widely in the scientific literature. Even so, the following are some crucial general lessons acquired from this project: The Field Development Plan and ordinary field operations should include monitoring, normal oilfield procedures and practices, plus surface monitoring methods derived from standard geotechnical and environmental monitoring standards, make up the majority of the monitoring technologies to be installed at any CO_2 storage site. Satellite InSAR data has been particularly useful in determining the geomechanical reaction to CO_2 injection, but it must be combined with high-quality reservoir and overburden data and models. The storage monitoring programme should be developed to meet site-specific leakage hazards identified during the selection process, but it should also be flexible enough to be adjusted during the operational phase. A critical leakage risk that must be carefully handled is legacy wellbore integrity. A complete set of baseline data, including the overburden, must be acquired, modelled, and integrated in order to assess long-term storage integrity. The evolution of CO_2 plumes is not uniform, necessitating high-resolution data for reservoir characterisation and modelling, (Ringrose P. S., 2018).

2.5 General Perceptions of CCS

Two contextual factors are helping to promote CCS acceptance. Firstly, climate change should be recognised as an issue; and secondly, substantial CO_2 reduction should be recognised as the only solution to the problem. An understanding of climate change and the related need for proactive action may be a precondition for stakeholders to embrace and endorse CCS and other climate mitigation options, (Chrysostomidis, et al., 2013).

While CCS has already been proven technologically feasible, power generating companies seem reluctant to embrace CCS technology actively. Based on the scale of CCS projects, CCS is far from satisfying the 2 ºC target, as the CO_2 capture rate is nearly 100 times lower than the minimum demanded by 2050. This disparity in perceptions and actualities may be attributed to the unsatisfactory diffusion of CCS technology, (Zhao & Liu, 2019). New technology's contribution to economic development can only be understood as and when the new technology is widely diffused and used. Diffusion itself results from a series of individual decisions to start using the new technology, decisions that are mostly the result of a contrast between the unknown advantages of the new innovation and the unknown costs of implementing it, (Hall & Khan, 2003).

An increasing number of onshore CCS demonstration projects were started some ten years ago. EU and governments in many nations, including the Netherlands, have been promoting the implementation of CCS. Shell - the owner of the onshore CCS demonstration project in Barendrecht, the Netherlands - began to educate the Municipal Government and communicate to the local public early on. It soon became clear that there was strong opposition from local politicians and that residents had several concerns about the operation, protection, and public health risks. Local governments stated their opposition to the project officially, while the national government agreed that the project was secure and would proceed, thus resulting in the delay of the project for approximately two years, (Brunsting, de Best-Waldhober, Feenstraa, & Mikunda, 2011).

Recently, the cost of CCS has been described as a major obstacle to its adoption, but other possible obstacles also hinder its broader implementation. There are many non-technical obstacles, including the lack of market frameworks and incentives, less efficient frameworks for penalising major sources of CO_2 emissions, insufficient regulatory structure for transport and storage (inland and offshore) and public knowledge and perception. Within a non-regulated market the cost of extracting CO_2 prevents advancement. About location and storage site capacity, the key considerations to consider include accumulated carbon storage ability, release and consumption levels, source-to-storage relation, and storage time-scale climate impacts, (Budinis, Krevor, Dowell, Brandon, & Hawkes, 2018).

Costs associated with CCS have been described as the major obstacle preventing this technology from being widely adopted. It is difficult to quantify real CCS costs and to articulate them consistently. This is due largely to the lack of empirical evidence (currently, only two full-scale CCS plants are in operation in the power sector). There is also difficulty in selecting the baseline when comparing different CCS plants. A variety of currencies and currency base years in the literature published, cost differences due to unavailability of transport and storage facilities, and a variety of procedures, operating conditions and capture procedures, are cited to be contributors to the cost of CCS, (Budinis, Krevor, Dowell, Brandon, & Hawkes, 2018).

In some countries, including China, the regulatory system has not yet made explicit provisions about how to implement CCS projects (including demonstrations) and the implementation of the institutional framework is also weak. Thus, there are no established guidelines for sanctioning, controlling, handling, environmental standards, allocation of liability in the event of a leakage accident for CCS projects, (Zheng, Dongjie, Linwei, West, & Weidou, 2011). Full and fair regulatory frameworks, guidelines, structures, and processes are of great importance for CCS's sustainable growth. Yet their development could take too long to wait for the CCS demonstration projects in China. Meanwhile, the danger of leakage and other risks such as human, health and contamination of groundwater still exist during and after the process of CCS projects, (Zheng, Dongjie, Linwei, West, & Weidou, 2011).

Although CCS has already proved technically feasible, power companies seem reluctant to actively adopt CCS technology. Nevertheless, companies are opposed to latent CCS risks, including high costs and technology uncertainties, market immaturity and incentives, and political propellant weakness. It is unlikely that companies will lose their self-interest and adopt CCS on their own initiative if there is a lack of regulation. The government, meanwhile, is the most powerful regulator, whose intervention plays a critical role in the decision on low-carbon output by the companies. It is key for governments to investigate how CCS can be promoted effectively within power enterprises, (Zhao & Liu, 2019).

2.6 CCS Policy

Communication among stakeholders is a particularly important field when formulating timely policy support and overcoming obstacles associated with large-scale implementation and demonstration of CCS technologies. Several researchers have explored the views of business experts and policy makers in the European Union, the United States of America and Australia, (Liang & Reiner, 2013). Governments have been paying close attention to CCS and promulgating various policy strategies to propel development of CCS. Governments and businesses, as can be seen, play crucial roles in the process of implementation of CCS technology, with each group engaging with each other to try to optimise its own benefit under different conditions.

Considering the interactions between governments and businesses, strategic interactions are the effective means of researching their shared strategic decision-making, (Zhao & Liu, 2019).

A study conducted in China, (Zhao & Liu, 2019) found that the government will need to strengthen the campaign of energy efficiency and carbon reduction, which not only encourages coal-fired power plants to understand the importance of low-carbon growth, but also stresses the superiority of CCS technology for society as a whole. Moreover, when it comes to policy, the departments concerned need to strengthen the legislation in this area for the power generation sector and formulate low carbon output requirements. At the same time, the supervisory efficiency of the government on the production model of coal-fired power enterprises should be reinforced, (Zhao & Liu, 2019).

Other findings in China regarding industry and government participation in the evolution of CCS indicate that, because of the high cost of deployment and the low price of carbon trading, investment in CCS is supported mainly by the policy subsidies, which also place a high burden on the government, thus weakening the enthusiasm of government regulation, (Zhao & Liu, 2019).

2.7 Barriers to CCS Deployment

At all levels, politicians are influential stakeholders in the CCS debate. Their support for the technology as a whole and for specific regional or local-level projects is critical to success, while opposition can be very problematic. Politicians, as policy makers, set the regulations under which the CCS must operate and can accordingly facilitate or impede its progress, (Chrysostomidis, et al., 2013). However, there are also many opposing CCS development around the world. One argument against CCS is that it is used to continue building polluting coal-fired power plants as a "free ride ticket", (Zheng, Dongjie, Linwei, West, & Weidou, 2011).

In addition, CCS is an immature technology with only four large-scale, integrated commercially active projects around the world as well as some looming uncertainties such as deployment costs and long-term liability distribution. Opponents argue that

CCS is not and will not be ready in time to contribute significantly to climate change mitigation, so money invested in CCS is money taken from renewable energy and development of energy efficiency. Such claims contributed to the failures of several CCS projects worldwide, (Zheng, Dongjie, Linwei, West, & Weidou, 2011).

The *European Technology Platform for Zero Emission Fossil Fuel Power Plants* members provided extensive data that was organised into three Working groups for purpose of cost forecasting. The cost basis was European and reported in Euros (at the time $1.387 = €1). The Working Group on Storage's original goal was to gather comparable cost data from published studies, align it with the group's agreed-upon assumptions, and provide the results as a cost range. However, existing literature does not readily lend itself to storage cost comparisons, either due to a lack of data on CAPEX and OPEX or due to the wide variety of assumptions made, (IEAGHG, 2011).

The (IEAGHG, 2011) report documented cost estimates ranging from €1-7/tonne CO_2 stored for the cheapest option (onshore depleted oil and gas fields with re-usable wells) to €6-20/tonne CO_2 stored for the most expensive option (offshore Saline Aquifers). Within each example, the uncertainty ranges are primarily derived from the natural fluctuation of storage candidates (i.e. reservoir capacity and injectivity). Due to their smaller scale, the necessity for more comprehensive study work, and greater monitoring costs; demonstration projects will be more expensive than commercial-phase CCS.

Another challenge to fruitful negotiation is that specific policy or technological options are central to the discussion, not stakeholder perspectives. This is because it is impossible to classify perspectives as 'right' or 'wrong' – they are just lenses through which people see reality. Attacking the perspective of a stakeholder group will not lead to a useful discussion and ultimately leads to an impasse, (Brunsting, de Best-Waldhober, Feenstraa, & Mikunda, 2011).

As mentioned previously, CCS costs have been identified as the main obstacle to its wider adoption. There is no market at the moment for CCS, and this is mainly because the CCS plant will always be more expensive (in terms of capital and operating costs) compared with the same plant sans CCS. In addition, a further concern is the public investment in CCS would cut the renewable alternatives budget. The CCS costs may also be expressed as carbon costs ($/t$CO_2$), which may refer to prevented, captured or decomposed CO_2. The cost of CO_2 avoided includes the capture, transport and storage steps, and thus represents the entire CCS chain. At the same time, it depends heavily on the baseline used for comparison, which may or may not be the same plant type as the ‘CCS’, (Budinis, Krevor, Dowell, Brandon, & Hawkes, 2018).

2.8 Unintended potential consequences of CCS

The IEA CCS Roadmap actions for a CCS regulatory framework development builds on existing domestic regulatory frameworks in recommending review and adaptation of existing regulatory frameworks to govern CCS demonstration projects, and in assessing whether comprehensive CCS regulatory frameworks are needed for large-scale CCS deployment. The IEA CCS Model Regulatory Framework also guides the review of regulatory regimes related to the international and domestic contexts. It emphasises that jurisdictions should consider how regulatory issues resulting from CCS operations can be resolved by amending current regulatory structures to cover certain aspects of the CCS chain, and whether introducing a regulatory regime for CCS might result in unintended consequences or interactions with existing legislation, (Beck, Garrettb, Havercroftc, Wagner, & Zakkour, 2011).

In line with CCS research, considerable concern is expressed in focus groups on the identification of risks and the prevalence of uncertainty, with participants mentioning unintended consequences such as the creation of earthquakes or hazardous seabed changes. Focus group members in the United Kingdom (UK) also recognise CCS 'technological ’complexity and further identify the likelihood of long chains of unintended consequences. Besides concerns about the intrinsic nature of CCS, this means that there are questions about 'in action' implementation, the untested essence of the system and where that could lead, (Lock, Smallman, Lee, & Rydin, 2014).

Coal-fired power generation in Australia currently provides much of the stability of the grid, but it also results in a relatively high rate of emissions of CO_2 in Australia. The proportion of Australia's coal-based power generation has decreased in recent years as a response to the need to reduce emissions, while the proportion of intermittent wind and solar power has increased, resulting in the unintended but inevitable consequence of a less secure grid. High-efficiency low-emission (HELE) coal-fired generation would be preferable to current largely critical or sub-critical coal-fired generation to provide lower stability of the emission grid. If used alone, however, HELE coal-fired generation would still produce emissions per megawatt hour above the emission standards for power stations, (Cook, 2017).

Another growing concerning regarding CCS is the Social Impact Assessment (SIA), defined by the International Association for Impact Assessment (IAIA) as "*the process of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of the planned interventions (policies, programs, plans, projects) and any processes of social change invoked by those interventions*", (Mabon, Kita, & Xue, 2017). The capacity for infrastructure projects to have effects in neighbouring communities has long been recognised, but the emergence of terms such as SIA and 'social license to operate' – that is, an informal agreement focused on ongoing approval and general acceptance by society of an operator carrying out their activities in the local region – is comparatively recent, (Mabon, Kita, & Xue, 2017).

2.9 Conclusion of Literature Review

An externality is an expense imposed on society by the behaviour of corporates, where this behaviour poses risk to said society. Corporates do not have incentive to avoid the externality, especially because it will be more of a cost that affects the bottom line. Therefore, corporates continue to let the expense of externalities be carried by someone else. Thus, the government suggested the adoption technologies to combat negative impacts that externalities have on societies. In South Africa, an increase and an accumulation of CO_2 emissions have compelled the government to put forward technologies to reduce CO_2 emission with technologies such as CCS. CCS is a new technology in the sense that it has never been deployed in South Africa and it may thus not be perceived in the same way by those entrusted with its deployment.

Factors leading South Africa to invest in CCS research and deployment include the Paris Agreement, to which South Africa is a party, which aims at retaining the global warming temperatures to significantly lower than 2ºC. As such, South Africa has formulated a response to the Agreement – the INDC that outlines the country's actions post 2020. The INDC has been developed to enable mitigation and adaptation to climate change. South Africa also has the NDP 2030 to assist in recognising short-term policies that will ensure societal and environmental protection from adverse impacts of climate change. The NDP 2030 suggests CCS as a novel mitigation technology in CO_2 emissions reduction.

CCS is a technology that involves CO_2 captured at point source, compressed, transported and deposited in a suitable geological formation, to avoid upward migration. CCs has the potential to reduce CO_2 emissions by approximately 20%. SaskPower opened the world's first commercial coal-fired power station fitted with CCS in 2014. At full capacity, the plant can collect over one million tonnes of CO_2 per year, which represents a 90% capture rate.

CCS acceptance is promoted by concerns relating to climate change and that CO_2 emissions reduction is recognised as the only solution to the climate change problem. Perceptions of CCS show that power-generating companies are still reluctant to embrace CCS even though it has been proven to be technologically feasible. Some of the reasons include that CCS will not satisfy the 2^0C target. Other stakeholders have concerns over operation, protection and health risks. In recent times the cost has been described as the major obstacle to CCS adoption.

Government and business play a crucial role in CCS implementation. Each group engaging each other to try optimising their own benefit under different conditions. When it comes to policy, relevant departments need to strengthen the legislative work in legislative work in the power generation sector. Especially formulation of low carbon output requirements. In addition, because of the high cost of deployment and the low price of carbon trading, the investment in CCS is supported mainly by the policy subsidies, which will also bring a high burden on the government, thus weakening the enthusiasm of government regulation.

Most obstacles relating to CCS are non-technical, such as market framework and incentives. Costs have also been identified as a major obstacle due to the difficulty in quantifying the real CCS cost and consistent articulation of the costs. Barriers to CCS include the notion that CCS is just there for the continuation of coal mining and coal fired power stations. In addition, that CCS is an immature technology therefore presenting uncertainties, and that money invested in CCS takes away money that should have gone to renewable energy. Unintended consequences such as creation of earthquakes and disturbances to the seabed as posed by stakeholders need to be taken into consideration.

CHAPTER 3. RESEARCH METHODOLOGY

The three objectives of this study: general understanding of CCS, potential barriers and unintended consequences, required a quantitative approach in the form of a survey where participants were presented with a questionnaire that was uploaded on a web-based platform. The approach assisted the researcher to quantify the perceptions of role-players on CCS. Questions were generic, literature-based statements with answers presented in a Likert Scale that determined the degree of agreement or disagreement. Data were analysed through statistical analysis that was descriptive of the relationship between the variable in the population and also provided a summary of data.

The research approach of the study was quantitative. The approach is appropriate because it enabled the researcher to quantify the problem statement by developing numerical data that can be used to establish similar or varying perceptions of CCS. Most quantitative work, in general, appears to be confirmatory and deductive, nevertheless, there are other quantitative researches which can also be categorised as exploratory, (Atieno, 2009), as is the case with this study, where the researcher aimed to ascertain how CCS was viewed by the two role-players.

3.1 Research approach

For this analysis, a statistical approach was used. The researcher wanted to quantify the perspectives of respondents by posing identical questions to two groups of CCS role-players. The research chose specifically themed statements to capture these perspectives, so as to avoid open-ended responses. Each objective had sub statements that summarised the general perspective of that particular objective. The approach ensured that no additional information was provided by the respondents outside of the research statement. This approach avoided being side-tracked by information that did not pertain to the topic at hand.

3.2 Research design

The research followed a survey design, where there were generic statements posed to each group of CCS role-players to scale their responses (i.e., Likert Scale). For a collection of statements, respondents determined their degree of agreement or disagreement on a symmetric agreement-disagreeable scale. Therefore, the intensity of each perception was captured for a given statement relating to the objective statement. The ordinal scale was used thus allowing the researcher to establish the order of values and not be concerned about the difference of each value.

3.3 Data collection methods

Data were collected in form of electronic questionnaires. The question for each group had three sub-questions as indicated in Section 1.4 above. Each sub-statement was further divided into smaller statements to provide context to the main sub-objective thus providing a general perception to the main statement. The questionnaire is presented in **Appendix A.**

The survey gathered information from each group of individuals to generalise the findings for wider populations. A vital source of data and perspective was provided by the type of survey proposed.

3.4 Population and sample

As described in Section 1.5, the focus of the question was on two groups described as role-players in CCS in the country, namely:

- Industry; and
- Policy influencer.

Below is a description of each group.

Population

> **Industry:** An industry is a community of related businesses, based on their primary business activities. There are hundreds of classifications of industry in modern economies, usually clustered into larger groups called sectors. Different companies are typically categorised into a sector based on their main revenue sources, (Will Kenton, 2019). In the case of this research, industry comprised individuals in mining, energy and CO_2 emitting companies such as Eskom, Sasol, PPC, Samancor, South 32, SAPREF, Manganese Metal Company and Sibanye-Stillwater.

Policy Influencer: Policy formulation, adoption, and implementation are complicated and dynamic processes that require input and participation from a wide range of stakeholders, or 'policy-influencers', where policy development refers to the process by which government decision-influencers become aware of new ideas or issues that need to be addressed, (Campbell, Olstad, Spence, Storey, & Nykiforuk, 2020). In the case of this research policy influencers were those individuals in government ministries and related state-owned entities such as Department of Mineral Resources and Energy, Department of Environment, Forestry & Fisheries, SANEDI, CSIR, CGS, SABS, Universities, DBSA, National Treasury, KZN provincial government.

3.4.1 *Sample and sampling method*

Table 1 Profile of Industry respondents

Industry respondents	**Number of respondents**
• Eskom • Sasol • PPC • Samancor • South 32 • SAPREF • Manganese Metal Company and • Sibanye-Stillwater.	20

Table 2 Profile of Policy Influencer respondents

Policy Influencer: Manager and Officer (or equivalent role players)	Number of respondents
• Department of Mineral Resources and Energy • Department of Environment, Forestry & Fisheries • SANEDI • CSIR • CGS • SABS • Universities • DBSA • National Treasury • KZN provincial government.	25

3.5 The research instrument

The instrument was a web-based platform (Qualtrics) for web-based surveys to be developed and distributed. It can be used on any device, which is connected to the Internet. The survey instrument was one that is supported by the University of Witwatersrand. Section 3.2 explains the type of design the research followed (i.e., Likert scale), this form of scale is supported by Qualitrics. The choice to use a web-based platform was because of its advantages, such as, it saves time, the ability to reach a wider population, ease of completion by participants and rapid access to participants. Some of the disadvantages may have include limited internet access for participants and technical troubles for users, (Albrecht & Jones, 2009). **Appendix A** illustrates contents of the questionnaire that was sent to participants.

3.6 Procedure for data collection

Data were gathered by using a list of contacts, obtained by the researcher, of those who have been involved in CCS activities in the country. Some respondents were suggested to the researcher. The link to the survey was sent directly to the respondents in the form of electronic mail containing a link to the survey.

3.7 Data analysis and interpretation

Data analysis and interpretation were through statistical analysis. The researcher applied the Fisher's exact test: "*G*Power 3: A flexible statistical power analysis program for social, behavioural, and biomedical sciences".* The analysis programme is used on computer platforms, (Faul, Erdfelder, Lang, & Buchner, 2007). The analysis programme was chosen based on its suitability for small sample sizes and graphic options. P values were used for statistical significance as evidence against the null hypothesis, which is a popular arithmetic theory that states that no statistical association or meaning exists between two sets of observed data and measured phenomena in a collection of single, observed variables, (Haldar, 2013).

3.8 Limitations of the study

It is to be noted that perceptions cannot be directly measured, hence the method by which a survey is used. Results obtained will be indicative of the general population, (Stacey, 2012). Due to the time constraints to complete the report, not all desired respondents were reached and not all desired respondents responded, thus affecting the sample size. A statistical tool to analyse small samples such as the Fischer's exact test was found to be the suitable tool for such a small size of respondents. The researcher had to use available data at the time of the deadline.

3.9 Validity and reliability

Information acquired was used as presented by the source (i.e., the respondent on the proposed platform) and was presented as is without alteration, as it is assumed in Section 1.9 that information is assumed that the respondents to the study are truthful of their perspectives.

3.9.1 *External validity (generalisability) OR transferability*

The study's generalisability is present but limited. The CCS technology is a new and unique technology in the country in that it has not yet been deployed and therefore finding of this study may not easily apply to other technologies. However, because the NDP 2030, (South African Government, 2012) has cited other technologies alongside CCS that may be able to reduce CO_2 emissions such as UCG, findings of this study may be applicable. To maximise generalisability, the research survey questions may be applied to other novel technologies that the government and industry may want to explore.

3.9.2 *Internal validity or Credibility*

The researcher aimed to meet internal validity by making sure that the content of the survey was identical for all participants, and that the content of the questions covered only information related to the CCS technology.

3.9.3 *Reliability OR dependability*

The researcher aimed to meet the reliability of the research by ensuring that the process of surveying respondents was sufficiently detailed to allow other researchers to repeat the work, should they wish to.

3.9.4 *Objectivity OR confirmability*

The researcher was indifferent to the subject matter as the deployment or lack thereof of the CCS technology does not rely on the findings and recommendations of this research. The research was conducted to obtain an indication of perspectives and to add to literature relating to the CCS technology in South Africa.

3.10 Ethical considerations

Over and above following the ethical guidelines of the University of the Witwatersrand, the researcher sought for informed consent from participants by requesting permission to include their responses in the research, and that the potential participant should do so at his/her free will, since participating in this research was not compulsory. The researcher ensured that participants were aware that there would be no harm encountered by participating in the survey. Confidentially and anonymity were maintained, as the researcher seeks to find information based on the professional understanding of the subject matter and not that of individual personal opinion. All of the above information was made clear to participants prior to their participating in the survey, giving them a choice to proceed or not.

CHAPTER 4. PRESENTATION & DISCUSSION OF RESULTS

The data offers an opportunity to look at a number of areas. However, for the purpose of this research the focus will be on three themes, namely:

- *Neutral responses* – those that did not know or were neutral to the interrogation;
- *Identification of differences* - comparison of the opinions of respondents who differed in their response to the interrogation;
- *Identification of similarities* - indication of the opinions of respondents who agreed in their response to the interrogation.

The results have been presented in two formats: graphical and tabular presentations, as well as text to describe each table. The sequence focuses on each of the three objectives as presented in Section 1.4.1. a), b), and c). Each objective has a list of sub-statements (see Appendix A). The presented data will be described and analysed.

A discussion has been presented at the end of each objective's section, where focus is on the above-mentioned themes in the order of neutral response from industry, neutral responses from policy influencer, identified differences between industry and policy influencer and identified similarities between industry and policy influencer.

4.1 Results pertaining to Objective 1 - The general understanding of CCS

4.1.1 *Objective 1 - Graphical presentation of results*

a. ***Overall results of objective Section 1.4.1 a)***

Figure 1 gives a presentation of raw data in graphical form from the Industry's responses to the general understanding of CCS statements

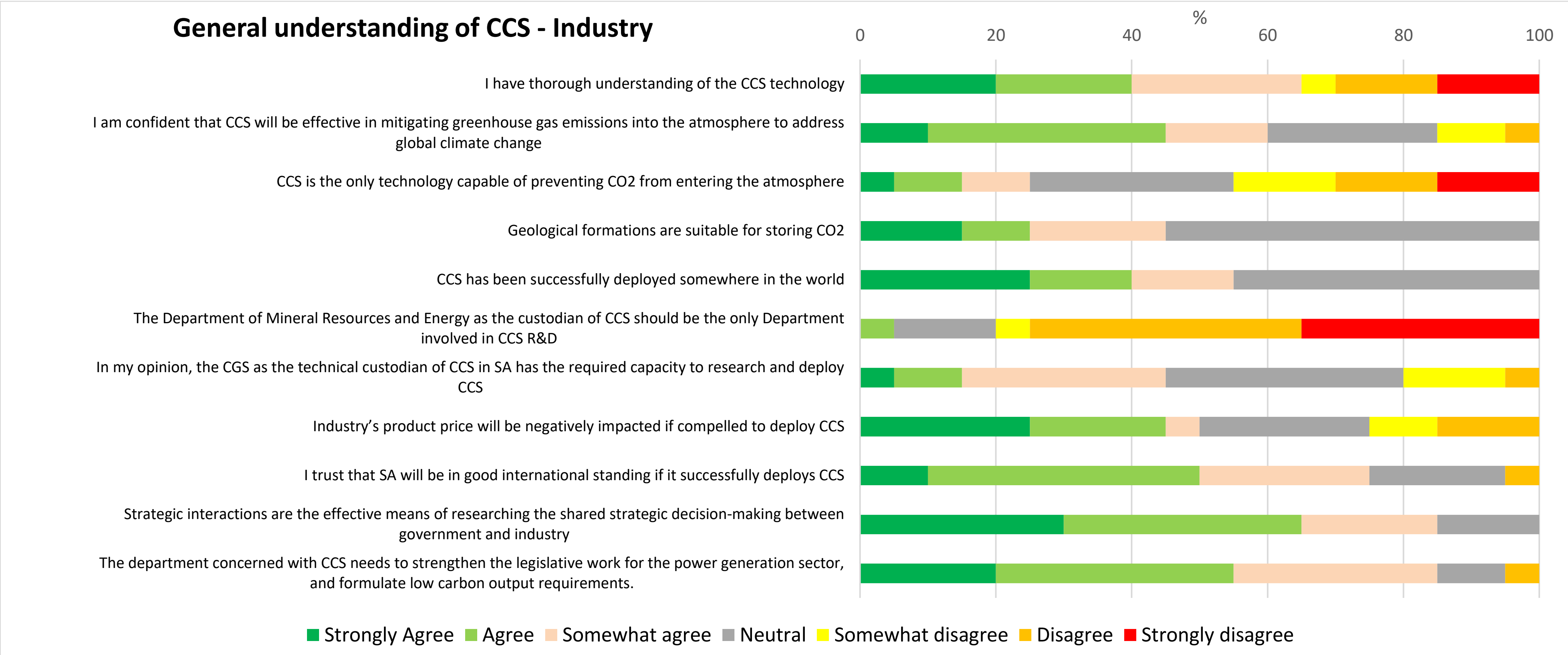


Figure 1 Objective 1 General understanding of CCS technology

Figure 2 gives a presentation of raw data in graphical form from the Policy Influencer's responses to the general understanding of CCS statements

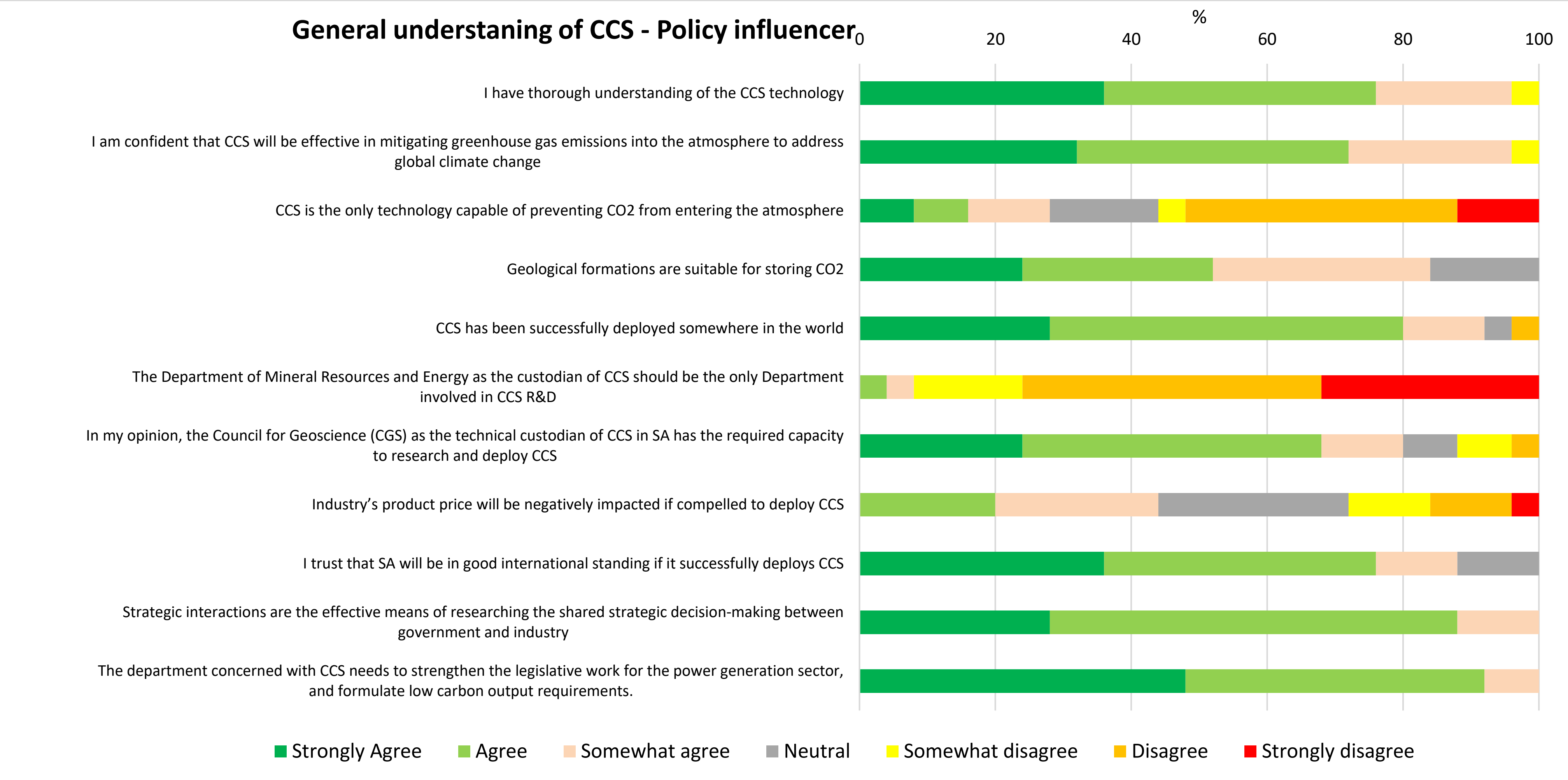


Figure 2 Objective 1 General understanding of CCS technology - Policy Influencer grouping

b. ***Presentation of the neutral responses from Industry (grey colour)***

Figure 3 gives a graphical presentation of neutral responses in ascending order from Industry to the general understanding of CCS statements

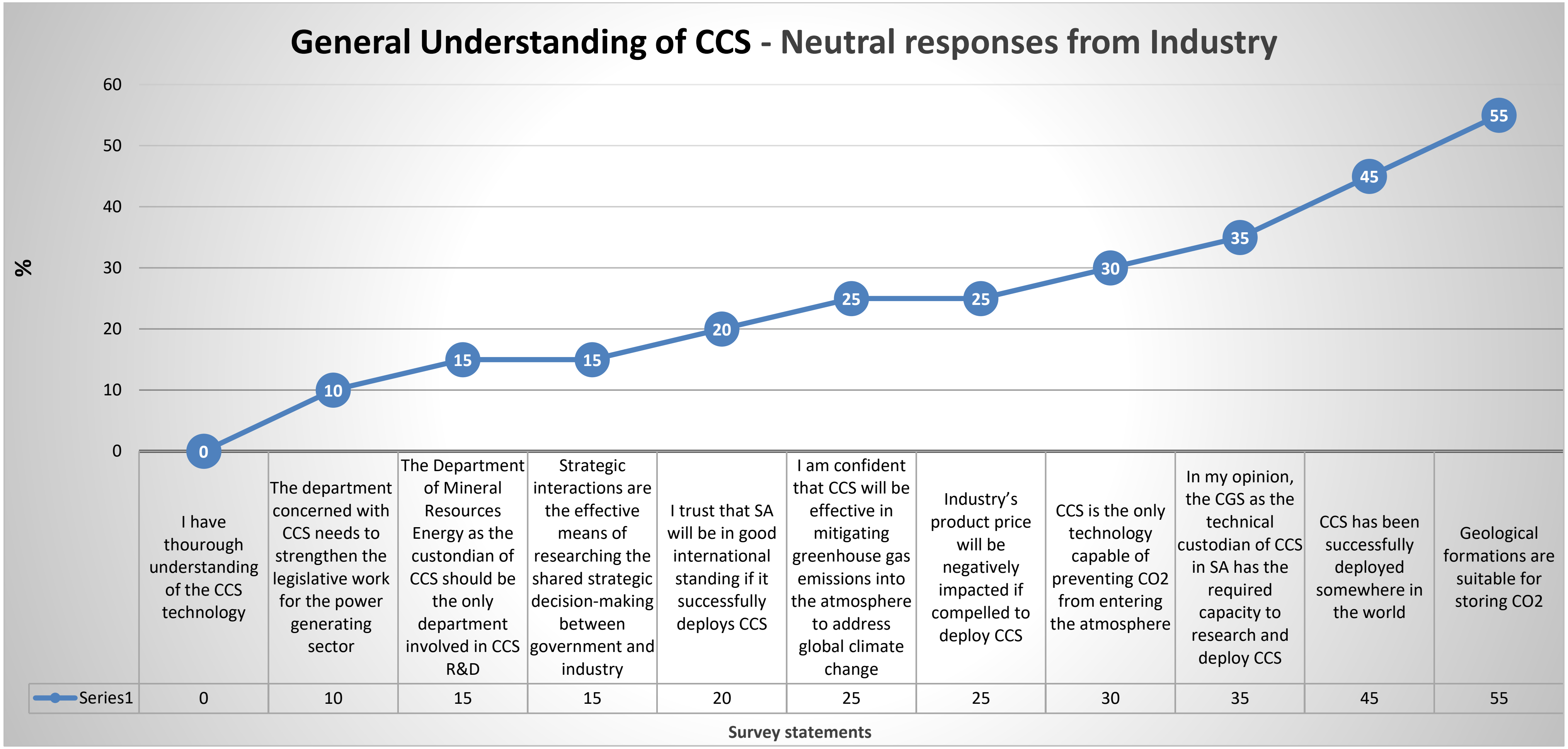


Figure 3 Objective 1 - Presentation of neutral responses from Industry grouping

Figure 4 gives a graphical presentation of neutral responses in ascending order from Policy Influencer to the general understanding of CCS statements

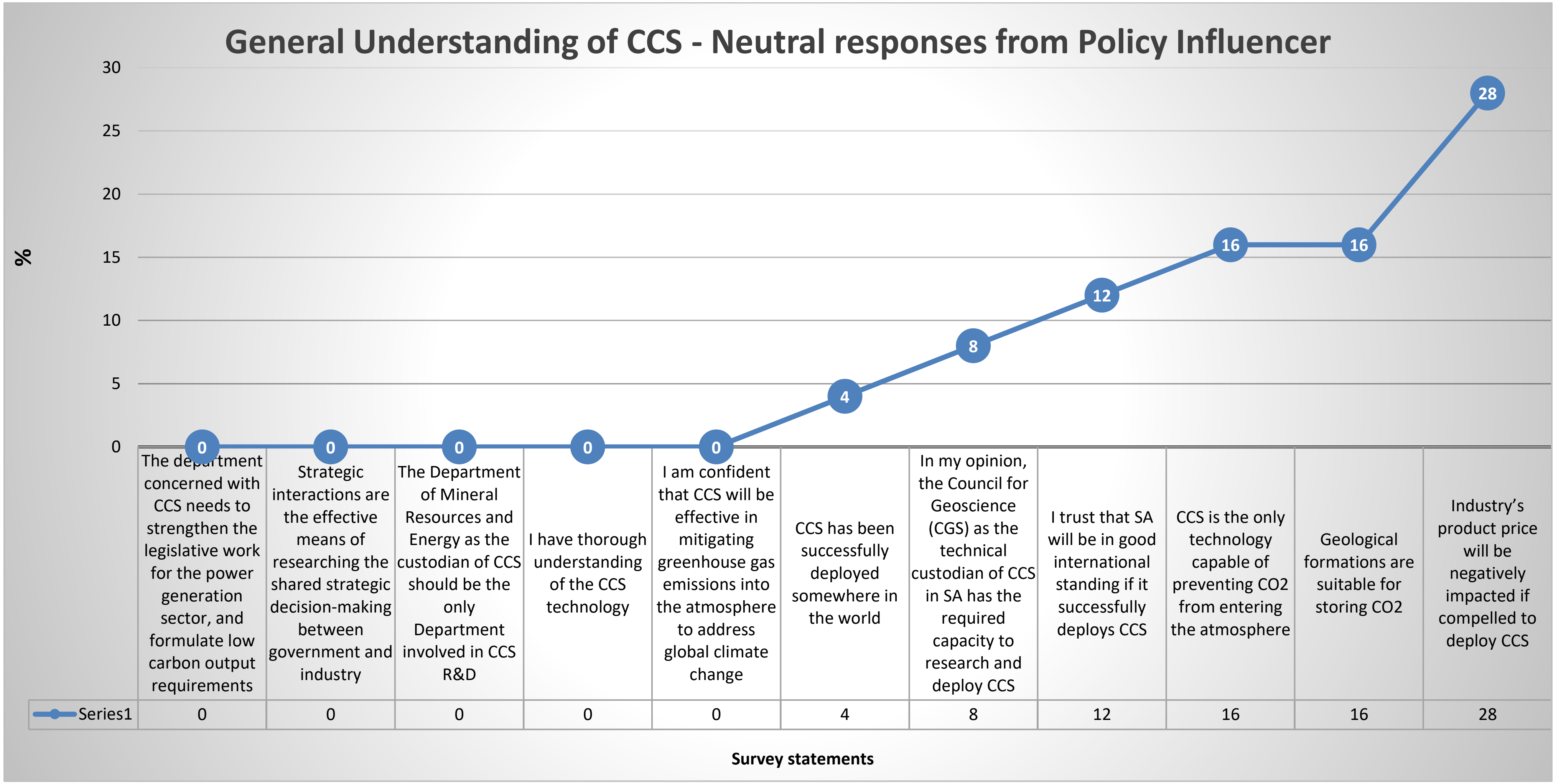


Figure 4 Objective 1 - Presentation of neutral responses from Policy Influencer grouping

c. *Differences*

The tables below are grouped according to their p-value, where a p-value <u>less</u> than 0.05 ($\leq$ 0.05) is statistically significant as it presents evidence against the null hypothesis which states '*that there is no difference between certain characteristics of a population*'

Table 3 Objective 1 - Statistical significance - presentation of p values for the Industry and Policy Influencer groupings

Characteristic	p-value for between-group test
I have thorough understanding of the CCS technology	0,015
I am confident that CCS will be effective in mitigating greenhouse gas emissions into the atmosphere to address global climate change	0,0061
Geological formations are suitable for storing CO2	0,01
CCS has been successfully deployed somewhere in the world	0,0054
In my opinion, the Council for Geoscience (CGS) as the technical custodian of CCS in SA has the required capacity to research and deploy CCS	0,027

Figure 5 gives a graphical presentation of the statements that had significant differences in responses between Industry and Policy Influencer

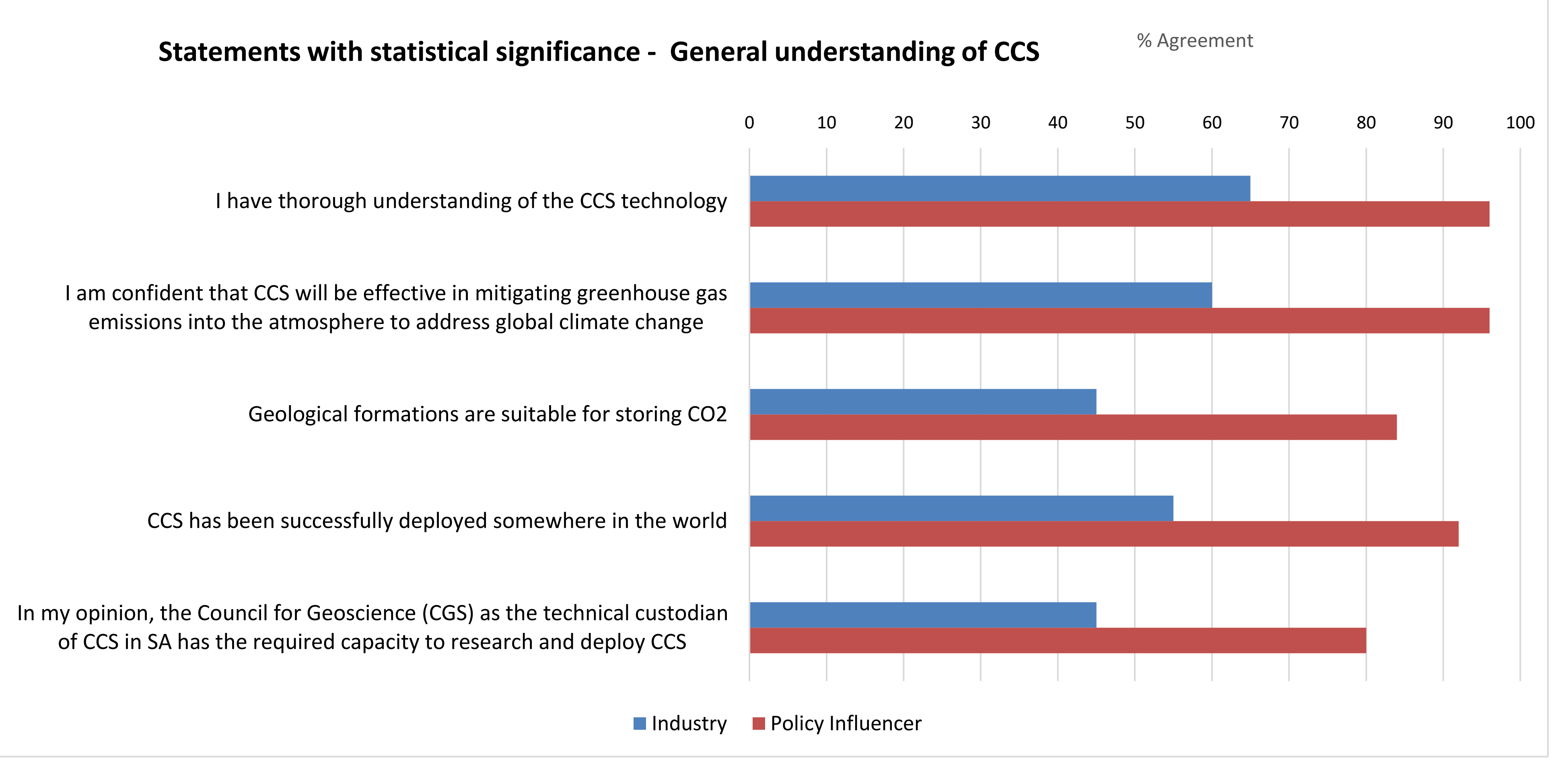


Figure 5 Objective 1 - Difference between Industry and Policy Influencer responses

d. ***Similarities***

The tables below are grouped according to their p-value, where a p-value <u>more</u> than 0.05 (≥ 0.05) is not statistically significant as it presents evidence for the null hypothesis which states '*that there is no difference between certain characteristics of a population*'

Table 4 Objective 1 - Statistical insignificance - presentation of p values for the Industry and Policy Influencer groupings

Characteristic	p-value for between-group test
CCS is the only technology capable of preventing CO2 from entering the atmosphere	>0.99
The Department of Mineral Resources and Energy as the custodian of CCS should be the only Department involved in CCS research and development	>0.99
Industry's product price will be negatively impacted if compelled to deploy CCS	0,77
I trust that SA will be in good international standing if it successfully deploys CCS	0,43
Strategic interactions are the effective means of researching the shared strategic decision-making between government and industry	0,08
The department concerned with CCS needs to strengthen the legislative work for the power generation sector, and formulate low carbon output requirements.	0,08

Figure 6 gives a graphical presentation of the statements that had insignificant differences in responses between Industry and Policy Influencer

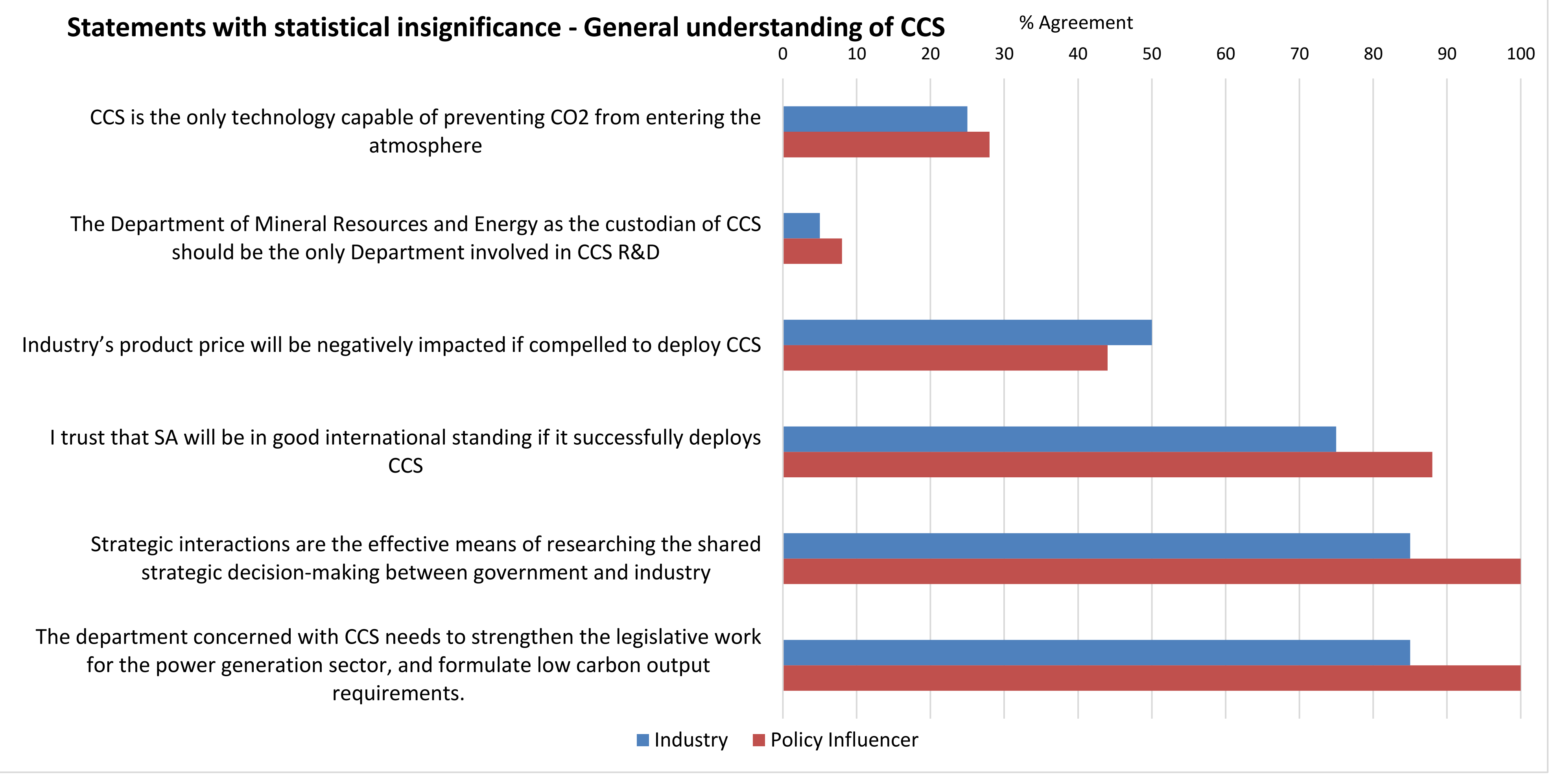


Figure 6 Objective 1 - Similarities between Industry and Policy Influencer responses

4.1.2 *Description of Industry grouping data*

Data description – Industry

Figure 1

Figure 1 gives a presentation of raw data in graphical form from the Industry's responses to the general understanding of CCS statements.

- It can be noted that out of the 11 question, 10 have an indication of a grey colouring – neutral (not supporting or helping either side in a conflict). It could also indicate respondents 'limited knowledge on the statement at hand. Analysis of the neutral responses is discussed in the sections below.
- The overall sentiment is that the respondent mostly agrees with his/her understanding of the CCS technology – notwithstanding the gaps identified by grey areas.

Analysis of neutral data – Industry

Figure 3

Figure 3 gives a graphical presentation of neutral responses in ascending order from Industry to the general understanding of CCS statements.

- Over half (55%) of respondents had no knowledge if geological formations are suitable for CO_2 storage.
- Almost half of the respondents (45%) had no knowledge of a successfully deployed CCS operation.
- 35% respondents are neutral about CGS being capable of researching and deploying the technology.
  - o This ascertains the perspective of the respondents of the decision taken by the DMRE to move the CCS project to the CGS
- 30% of respondents are neutral on whether CCS is capable of preventing CO_2 from entering the atmosphere.
- It also important to note the following reservations based on the sample that;
  - o Persons responding to the survey may not specialize in geology and may have limited knowledge in geological formations
  - o Persons responding may work for companies that specialize in geology and may have knowledge in geological formations

4.1.3 *Description of Policy Influencer grouping data*

Data description – Policy Influencer

Figure 2

- Visual observation of Figure 2 indicates that policy influencers have lesser neutral responses compared to their industry counterparts.
- The general sentiment indicates that policy influencers are in agreement with most of the statements posed to them.

Analysis of neutral data – Policy Influencer

Figure 4

- Indicates that the question with the most neutral response (28%) pertains to the product price being negatively impacted should CCS be enforced.
- The Policy Influencer grouping is quite confident of their responses as they have less neutral responses.
- It also important to note the following reservations based on the sample that;
  - Persons from research institutions may have better understanding of CCS
  - Because of the limitations noted in Section 3.8, government officials and persons from research institutions have been sampled as one group

4.1.4 *Description of differences in general understanding of CCS*

Table 3 and Figure 5

- A greater proportion of Policy Influencers (96%) claimed to have an understanding of CCS technology compared to Industry (65%) ($p=0.015$).
- A greater proportion of Policy Influencers (96%) agreed that CCS will be effective in mitigating greenhouse gas emissions into the atmosphere to address global climate change compared to Industry (60%) ($p=0.0061$).
- A greater proportion of Policy Influencers (84%) agreed that geological formations are suitable for storing CO_2 compared to Industry (45%) ($p=0.010$).
- A greater proportion of Policy Influencers (92%) agreed that CCS has been deployed successfully somewhere in the world compared to Industry (55%) ($p=0.0054$).

- A greater proportion of Policy Influencers (80%) agreed that the CGS as the technical custodian of CCS in SA has the required capacity to research and deploy CCS compared to Industry (45%) (p=0.027).

4.1.5 *Description of similarities in general understanding of CCS*

Table 4 and Figure 6

- A similar but small portion of Industry (25%) and Policy Influencer (28%) agree with the notion that CCS is the only technology that is capable of preventing CO_2 from entering the atmosphere (p=>0.99).
- A similar but small portion of Industry (5%) and Policy Influencer (8%) agree that the DMRE should be the only department involved in CCS (p=>0.99).
- A similar portion of Industry (50%) and Policy Influencer (44%) agree that product prices will be negatively impacted if industry is compelled to deploy CCS (p=0.77).
- A similar but large portion of Industry (75%) and Policy Influencer (88%) agree that South Africa will be in good international standing if it successfully deploys CCS (p=0.43).
- A similar but large portion of Industry (85%) and Policy Influencer (100%) agree that strategic interactions are the effective means of researching the shared strategic decision-making between government and industry (p=0.08).
- A similar but large portion of Industry (85%) and Policy Influencer (100%) agree that the department concerned with CCS needs to strengthen the legislative work for the power generation sector, and to formulate low carbon output requirements. (p=0.08).

4.1.6 *Discussion on General Understanding of CCS*

Over half of Industry respondents (55%) are neutral about geological formations being suitable for storing CO_2 and 35% are neutral about the Council for Geoscience's capability to research and deploy CCS. This may be an indication of the industry's lack of knowledge on CCS and its custodians. At inception of CCS in South Africa an Atlas compilation was commissioned to explore the feasibility of potential storage sites. The Atlas was compiled by CGS and endorsed by the then Minister of Energy, supported by industry organisations such as PetroSA, Sasol, Eskom and AngloAmerican, (Council for Geoscience, 2010). It was therefore not expected that some of these institutions would be neutral to CGS's capabilities.

Policy Influencer respondents have lesser neutral responses, which may indicate a higher confidence in their knowledge of CCS. The highest neutral response (28%) is in relation to negative impact product price, which is almost similar to industry's response (25%) to the same statement.

Differences between the two groups is that Policy Influencer respondents are more confident of their knowledge of CCS and confident that it will be effective in mitigating greenhouse gas emissions into the atmosphere. It is however noted that opponents to CCS argue that CCS is not and will not be ready in time to contribute significantly to climate change mitigation, (Zheng, Dongjie, Linwei, West, & Weidou, 2011). Also the two groups differ in their opinion of geological formation being suitable for CO_2 storage, less than half (45%) of industry respondents agree with the suitability of geological formations. There are varieties of physical and chemical trapping mechanisms that demonstrate that geological formations are ideal for CCS and can prevent horizontal transfer to other layers, (Bachu, 2007).

Both groups have similar responses regarding CCS not being the only technology capable of preventing CO_2 from entering the atmosphere. This sentiment is supported by the NDP where other technologies such as underground gasification and utilisation of ultra-supercritical coal-fired power plants are suggested alongside CCS, (South African Government, 2012). Another highly similar response is the importance of strategic interactions being an effective means of researching shared strategic decision-making between government and industry, (Zhao & Liu, 2019).

It also important to note the following reservations based on the sample that; persons responding to the survey may not specialize in geology and may have limited knowledge in geological formations. Persons responding may work for companies that specialize in geology and may have knowledge in geological formations.

It also important to note the following reservations based on the sample that; persons from research institutions may have better understanding of CCS as opposed to their Industry counterparts. Because of the limitations noted in Section 3.8, government officials and persons from research institutions have been sampled as one group.

4.2 Results pertaining to Objective 2 - Potential barriers to CCS

4.2.1 *Objective 2 - Graphical presentation of results*

a. ***Overall results of objective Section 1.4.1 b)***

Figure 7 gives a presentation of raw data in graphical form from the Industry's responses to potential barriers to CCS statements

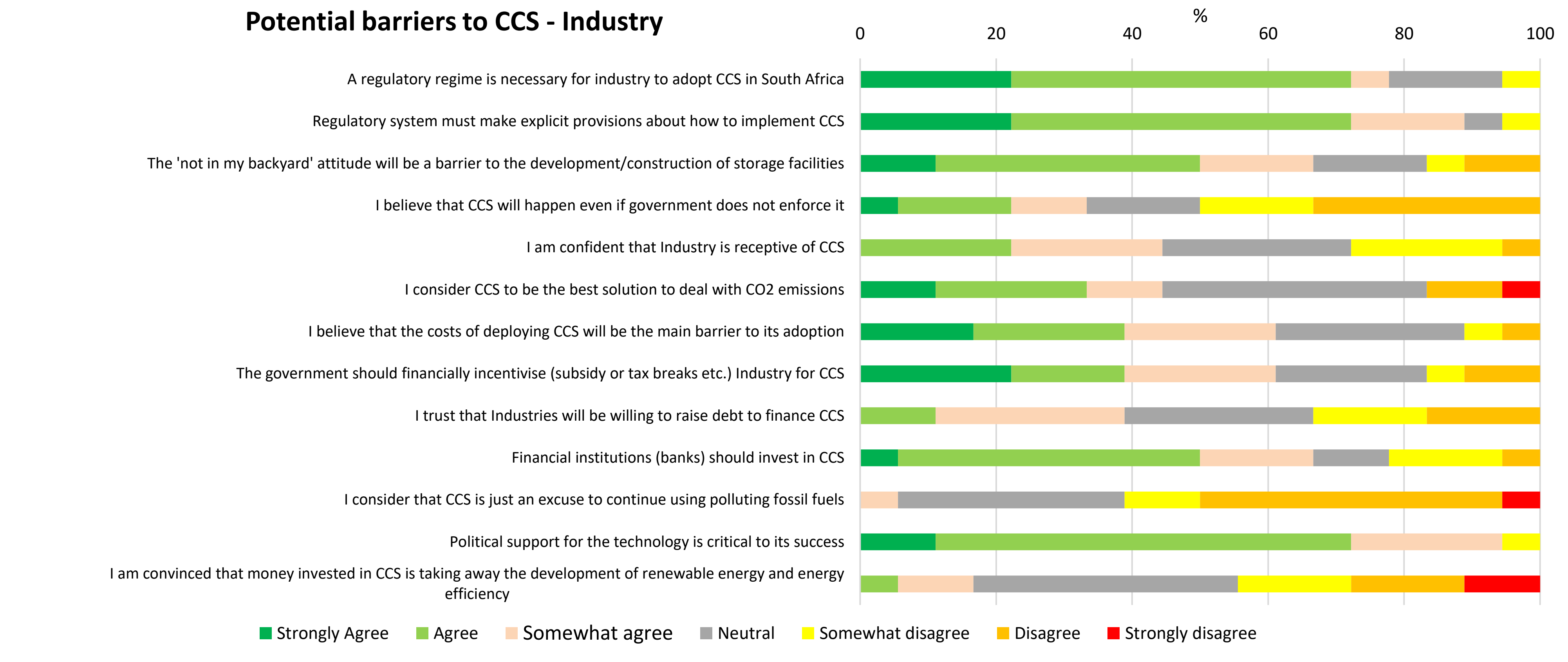


Figure 7 Objective 2 Potential barriers to CCS- Industry grouping: overall responses

Figure 8 gives a presentation of raw data in graphical form from the Policy Influencer's responses to potential barriers to CCS statements

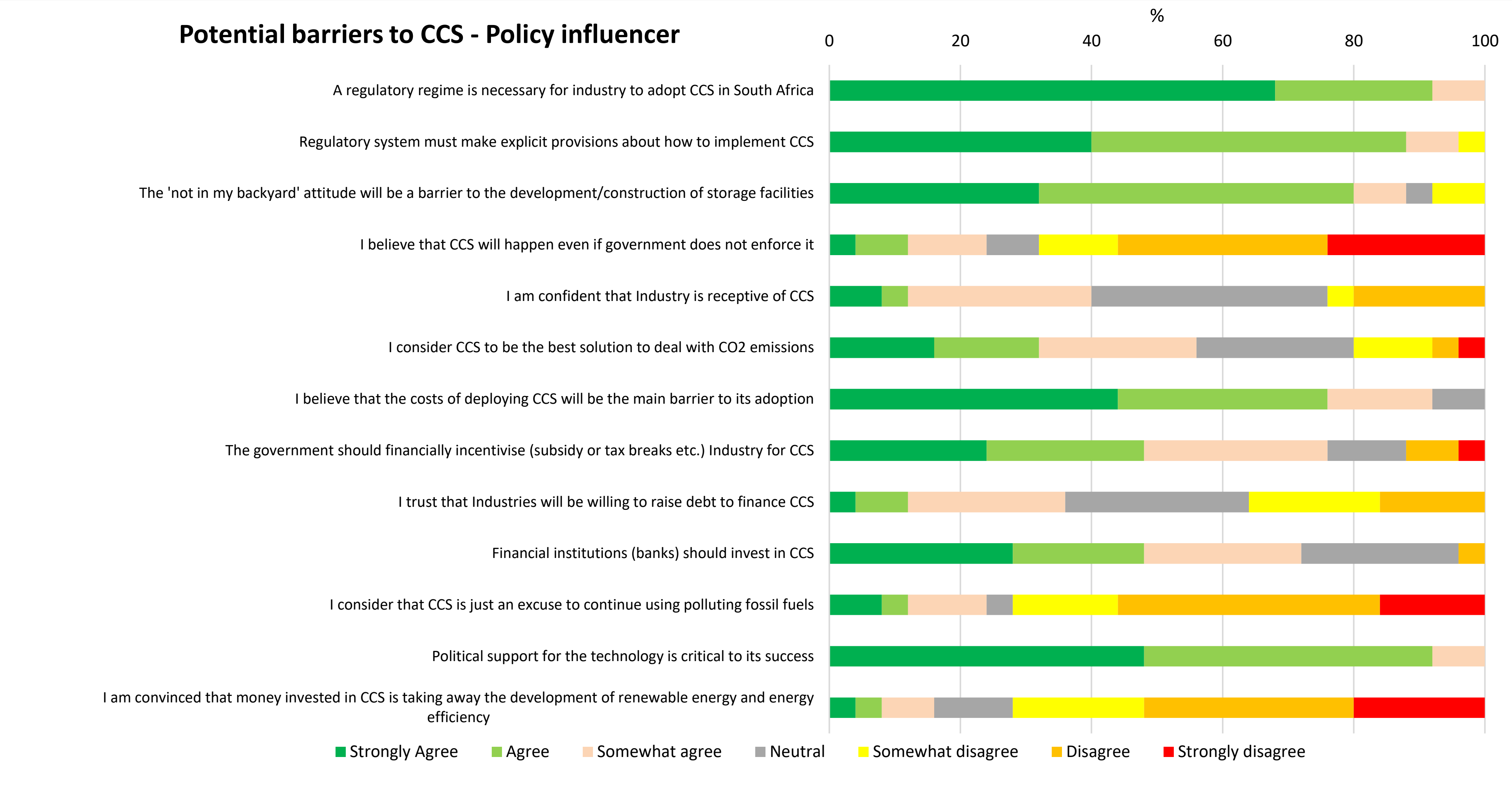
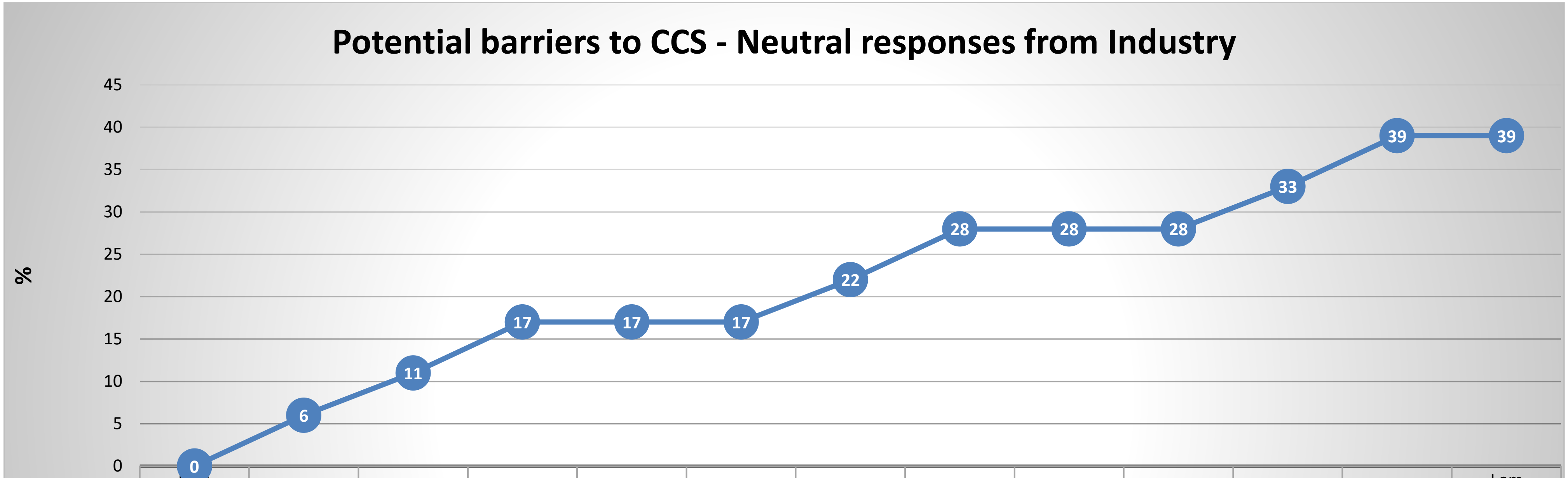


Figure 8 Objective 2 Potential barriers to CCS technology - Policy Influencer grouping: overall responses

b. ***Presentation of the neutral responses from Industry (grey colour)***

Figure 9 gives a graphical presentation of neutral responses in ascending order from Industry to potential barriers to CCS statement



	I am convinced that money invested in CCS is taking away the development of renewable energy and energy efficiency	Regulatory system must make explicit provisions about how to implement CCS	Financial institutions (banks) should invest in CCS	A regulatory regime is necessary for industry to adopt CCS in South Africa	The 'not in my backyard' attitude will be a barrier to the development /construction of storage facilities	I believe that CCS will happen even if government does not enforce it	The government should financially incentivise (subsidy or tax breaks etc.) Industry for CCS	I am confident that Industry is receptive of CCS	I trust that Industries will be willing to raise debt to finance CCS	I believe that the costs of deploying CCS will be the main barrier to its adoption	I consider that CCS is just an excuse to continue using polluting fossil fuels	I consider CCS to be the best solution to deal with CO2 emissions	I am convinced that money invested in CCS is taking away the development of renewable energy and energy efficiency
Series1	0	6	11	17	17	17	22	28	28	28	33	39	39

Figure 9 Objective 2 - Presentation of neutral responses from Industry grouping

Figure 10 gives a graphical presentation of neutral responses in ascending order from Policy Influencer to potential barriers to CCS statement

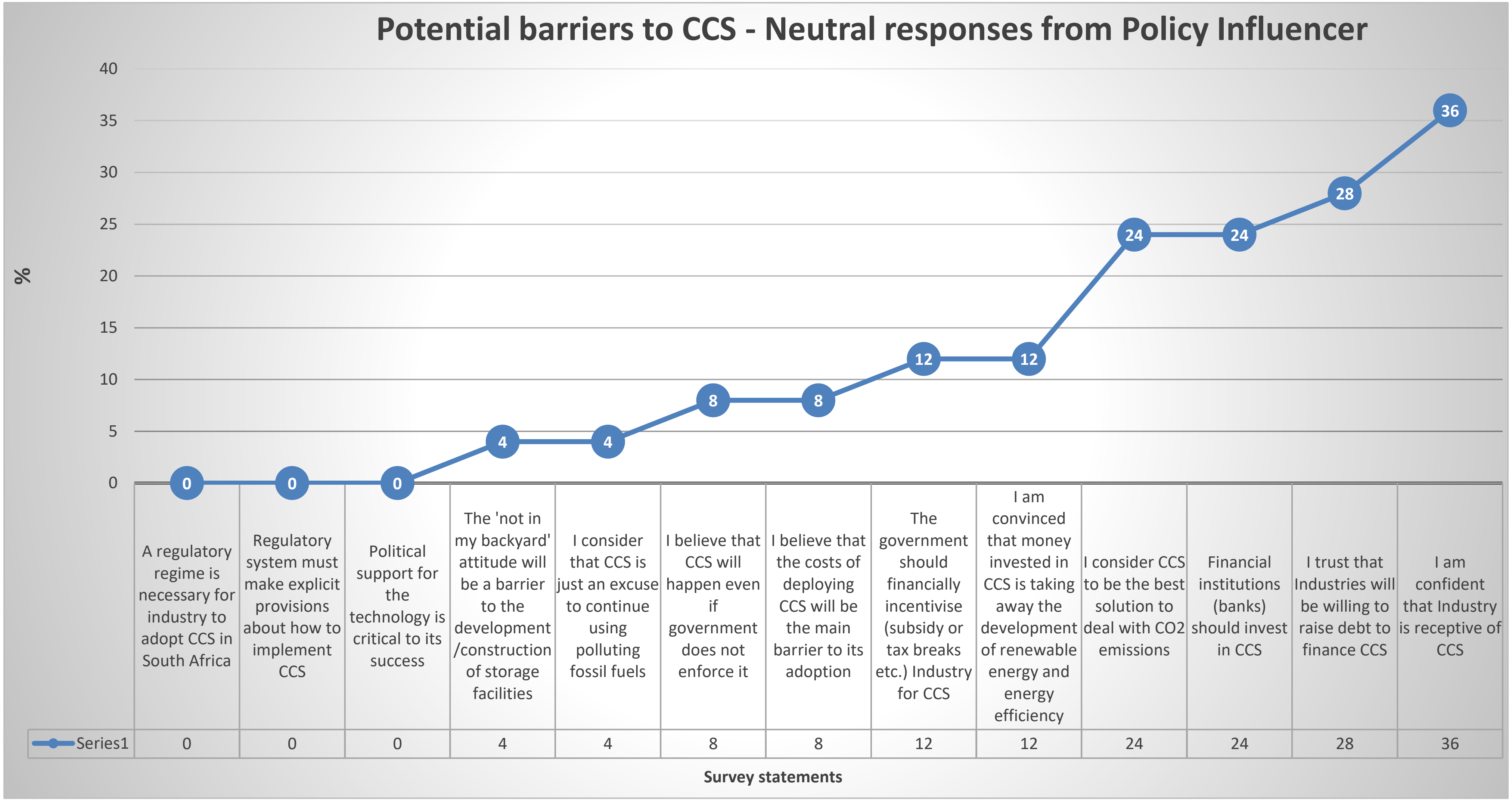


Figure 10 Objective 2 - Presentation of neutral responses from Policy Influencer grouping

c. ***Differences***

The tables below are grouped according to their p-value, where a p-value less than 0.05 (≤ 0.05) is statistically significant as it presents evidence against the null hypothesis which states '*that there is no difference between certain characteristics of a population*'

Table 5 Objective 2 - Statistical significance - presentation of p values for the Industry and Policy Influencer groupings

Characteristic	p-value for between-group test
A regulatory regime is necessary for industry to adopt CCS in South Africa	0,027
I believe that the costs of deploying CCS will be the main barrier to its adoption	0,023

Figure 11 gives a graphical presentation of the statements that had significant differences in responses between Industry and Policy Influencer

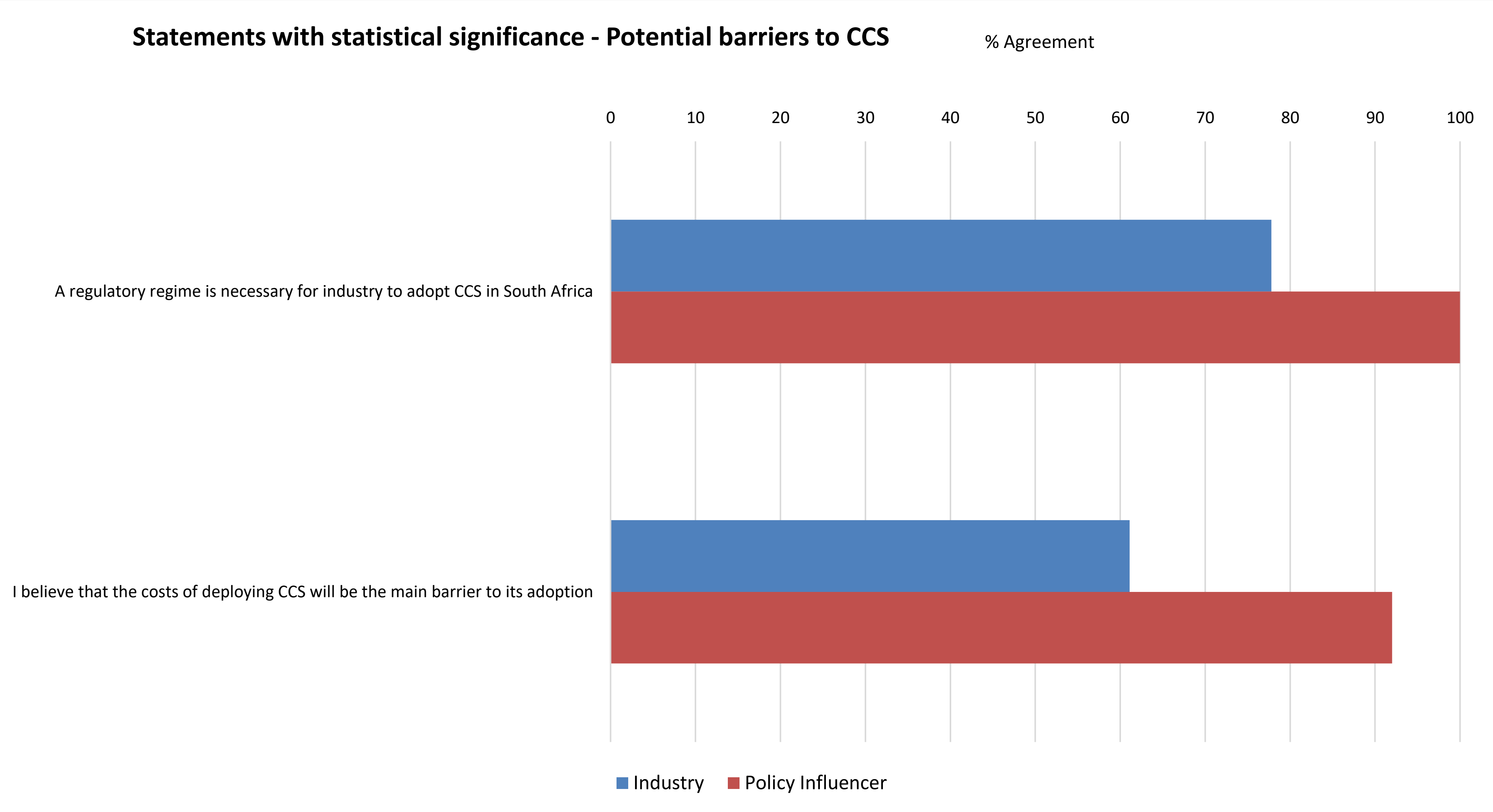


Figure 11 Objective 2 - Difference between Industry and Policy Influencer responses

d. ***Similarities***

The tables below are grouped according to their p-value, where a p-value more than 0.05 (≥ 0.05) is not statistically significant as it presents evidence for the null hypothesis which states '*that there is no difference between certain characteristics of a population*'

Table 6 Objective 2 - Statistical insignificance - presentation of p values for the Industry and Policy Influencer groupings

Characteristic	p-value for between-group test
Regulatory system must make explicit provisions about how to implement CCS	0,56
The 'not in my backyard' attitude will be a barrier to the development/construction of storage facilities	0,13
I believe that CCS will happen even if government does not enforce it	0,52
I am confident that Industry is receptive of CCS	>0,99
I consider CCS to be the best solution to deal with CO2 emissions	0,54
The government should financially incentivise (subsidy or tax breaks etc.) Industry for CCS	0,33
I trust that Industries will be willing to raise debt to finance CCS	>0,99
Financial institutions (banks) should invest in CCS	0,75
I consider that CCS is just an excuse to continue using polluting fossil fuels	0,21
Political support for the technology is critical to its success	0,42
I am convinced that money invested in CCS is taking away the development of renewable energy and energy efficiency	0,48

Figure 12 gives a graphical presentation of the statements that had insignificant differences in responses between Industry and Policy Influencer

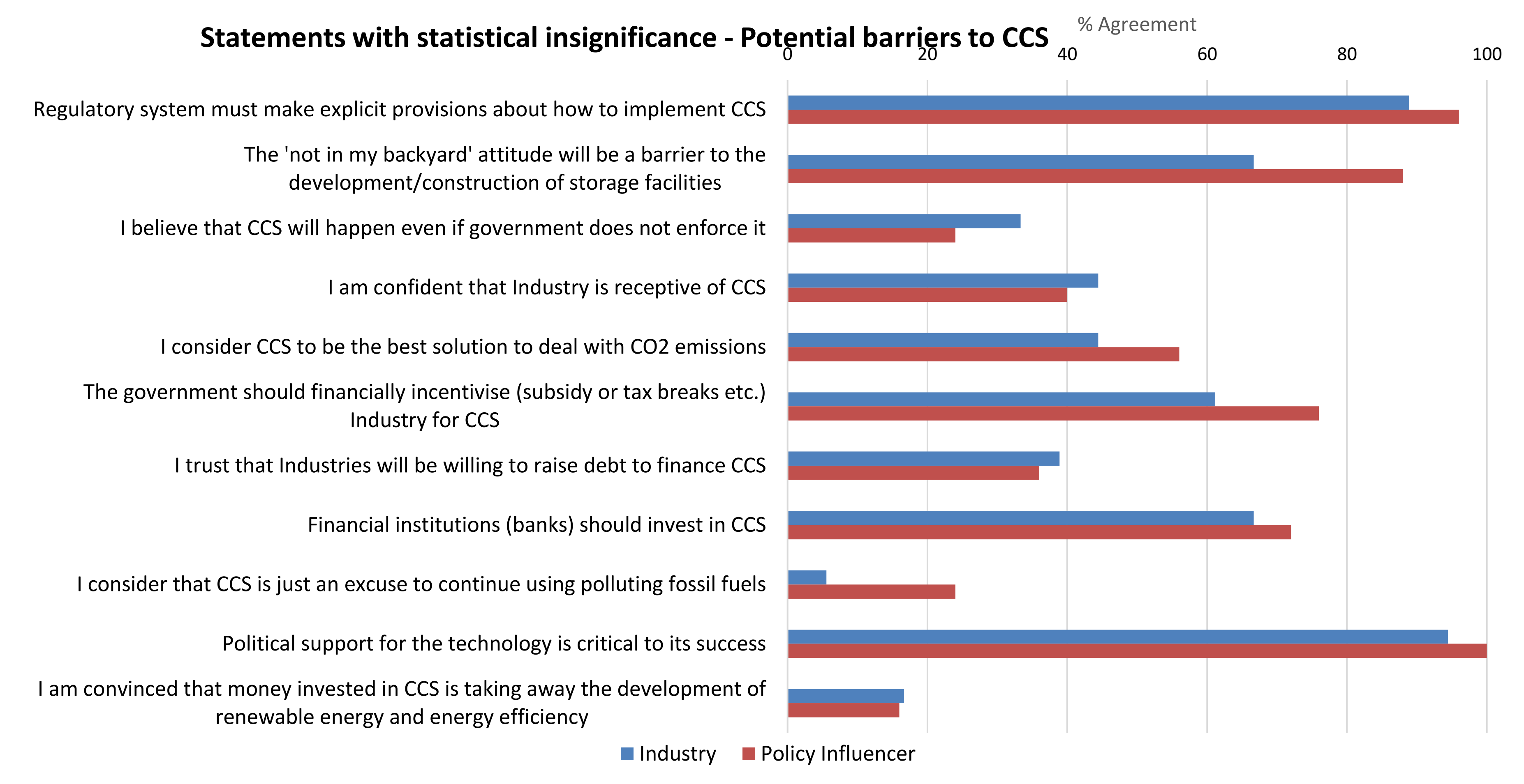


Figure 12 Objective 2 - Similarities between Industry and Policy Influencer responses

4.2.2 Description of Industry grouping data

Data description – Industry

Figure 7

Figure 7 gives a presentation of raw data in graphical form from the Industry's responses to potential barriers to CCS statements.

- It can be noted that out of the 13 questions, 12 have an indication of a grey colouring – neutral (not supporting or helping either side in a conflict). It could also indicate respondents 'limited knowledge on the statement at hand. Analysis of the neutral responses is discussed in the sections below.
- The overall sentiment is that the respondent mostly agree with the statements posed toward the potential barriers to CCS – notwithstanding the gaps identified by grey areas

Analysis of neutral data – Industry

Figure 9

Figure 9 gives a graphical presentation of neutral responses in ascending order from Industry to potential barriers to CCS statements.

- 39% of respondents were neutral to whether the money invested in CCS is taking away the development of renewable energy and energy efficiency, despite the fact that government has other mitigations option that are funded from different baskets (private and public sector). This may indicate a real concern on how CCS in accepted on not.
- A similar portion (39%) are non-committal to CCs being the best solution to deal with CO_2 emissions.
- 28% of respondents are neutral about their confidence in industry's reception of CCS, that industry is willing to raise debt to finance CCS and that the cost of deploying CCS with be the main barrier.
- A smaller portion of respondents – less than 22% are also neutral to the government giving financial incentives to industry for CCS that CCS will happen if the government does not enforce it and the remainder of the statements depicted in Figure 9.

4.2.3 *Description of Policy Influencer grouping data*

Data description – policy influencer

Figure 8

- Visual observation of Figure 8 indicates that policy influencers have lesser neutral responses compared to their industry counterparts: 9 neutral responses out of 13 statements.
- The general sentiment indicates that Policy Influencers are in agreement with most of the statements posed to them.

Analysis of neutral data – Policy Influencer

Figure 10

- Indicates that the question with the most (39%) pertains to Policy Influencers neutrality about their confidence on industry's receptiveness of CCS. This could perhaps be because the uncertainty relating to the technology is very high in terms of feasibility, cost and sustainability.
- A small portion of policy influencers (28% and 24%) are neutral in their trust of industry's willingness to raise debt to finance CCS and if financial institutions should invest in CCS.
- An even smaller portion – less than 12% - are neutral about government financial incentives towards CCS, that the costs of CCS will be the main barrier in CCS deployment, as well the remainder of the statements as depicted in Figure 10.

4.2.4 *Description of differences in potential barriers to CCS*

Table 5 and Figure 11

- A greater portion of Industry (78%) agreed that a regulatory regime is necessary for it to adopt CCS in the country compared to policy influencer (25%) ($p=0.027$).
- A greater proportion of Policy Influencers (92%) believe that the cost of deploying CCS will be the main barrier to CCS adoption compared to Industry (61%) ($p=0.023$).

4.2.5 *Description of similarities in general understanding of CCS*

Table 6 and Figure 12

- A similar but big portion of Industry (86%) and Policy Influencer (96%) agree that a regulatory system must make explicit provisions about how to implement CCS (p-0.56).
- A similar portion of Industry (67%) and Policy Influencer (88%) agree the ‘not in my backyard ’attitude will impede CCS efforts (p=0.13).
- A similar but small portion of Industry (33%) and Policy Influencer (24%) believe that CCS will go ahead even if not enforced (p=0.52).
- A similar portion of Industry (44%) and Policy Influencer (40%) are confident that industry is receptive of CCS (p=>0.99).
- Industry (44%) and Policy Influencer (56%) consider CCS to be the best solution to deal with CO_2 emissions (p=0.54).
- A similar but large portion of Industry (61%) and Policy Influencer (76%) agree that the government should financially incentivise industry for CCS (p=0.33).
- A similar but small portion of Industry (39%) and Policy Influencer (36%) trust that industries will be willing to raise debt to finance CCS (p=>0.99).
- A similar but large portion on Industry (67%) and Policy Influencer (72%) agree that financial institutions should invest in CCS (p=0.75).
- A small portion of Industry (6%) and Policy Influencer (24%) consider CCS as an excuse to continue using polluting fossil fuels (p=0.21).
- A large portion of Industry (94%) and Policy Influencer (100%) agree that political support for CCS is critical to its success (p=0.42).
- A large portion of Industry (67%) and Policy Influencer (80%) are convinced that money invested in CCS is taking away from the development of renewable energy and energy efficiency (p=0.48).

4.2.6 *Discussion*

Industry has expressed neutrality in money related statements such as industry raising debt to finance CCS, costs being the main barrier, receiving financial incentives from government and money invested in CCS is taking away from renewable energy and energy efficiency development. Industry may need policy subsidies in order to adopt CCS, (Zhao & Liu, 2019), however the technology is still at pilot stage in South Africa, under the technical custodianship of the CGS. It is therefore not know if the policy influencers will develop any kind of incentive to encourage CCS uptake by industry. This may be the reason why industry would express neutrality as the future of CCS in South Africa is not public knowledge at this point. The notion that CCS is not readily available to contribute to climate change mitigation, further creating confidence gaps in the technology, is the reason that those opposing the technology believe that money invested in CCS is taking money away from other mitigating technologies, (Zheng, Dongjie, Linwei, West, & Weidou, 2011).

Also, Industry's neutrality to whether CCS will happen even if the government does not enforce it, may indicate that Industry may think the government is unpredictable. Therefore, it is not easy to anticipate what the government may do going forward regarding CCS. Other efforts that may be required is for policy influencers to create reasons for why the investment in CCS needs to be made and to respond appropriately to status quo seekers, (Harper-Slabosz, McGregor, & Sunderhauf, 2012). What the government needs to take into account is that Industry may choose the most fitting mitigation efforts based on their operations and that CCS may not be the technology chosen for CO_2 emissions reduction

The Policy Influencer grouping has expressed neutrality about their confidence in industry's receptiveness towards CCS, willingness to raise debt to finance CCS, the government's financial incentive towards CCS and costs being the main barrier. However, it is to be noted that the percentages are much lower. Policy Influencer seems to be more confident on their agreement and disagreement responses and leave very little doubt on where they stand regarding CCS. It is however to be noted that in some parts of the world, the support of policy incentives is viewed as an action that will place a high burden on the government, (Zhao & Liu, 2019).

Out of the 13 statements posed to Industry and Policy Influencer, only two statements indicated that they differ greatly. The first differing statement is that of a regulatory regime being necessary for industry to adopt CCS in South Africa, where 78% of Industry are in agreement with this statement and a low 25% from Policy Influencers. Industry may be justified in their need for a regulatory regime because capital flows within industries indicate that political, legal and regulatory institutions do not provide investors with an opportunity to minimise the risks of capital or asset losses, as emerging markets have sluggish capital movements unlike developed economies, (Narayanan & Fahey, 2005). In a surprising twist, a higher percentage (92%) of Policy Influencers believe that CCS cost will be the main barrier; this is surprisingly higher than the 61% of Industry's respondents.

Out of the 13 statements in this section, Industry and Policy Influencer shared 11 statements that had similar responses as per Table 6. Among the statements that stand out include that a regulatory system must make explicit provisions about how to implement CCS. Absence of these explicit provisions has led to absence of established guidelines in sanctioning, controlling, handling, environmental standards and allocation of liability, (Zheng, Dongjie, Linwei, West, & Weidou, 2011).

Both Industry and Policy Influencer agree that money invested in CCS is taking away from renewable energy and energy efficiency development. Both groups agree that CCS will not proceed if not enforced by government, and that they do not trust that industry will be willing to raise debt to finance CCS. Other statements that may have impeding outcomes to CCS include: agreement that the 'not in my backyard 'attitude will be a barrier, Those opposing CCS also share these sentiments and such claims have contributed to failures of several CCS projects worldwide, (Zheng, Dongjie, Linwei, West, & Weidou, 2011). In addition, the government has made other explicit plans outside of CCS (i.e. new 1500MW coal-fired electricity scheduled to be procured by 2030), but the focus of this coal-fired electricity will be on efficiency, (Department of Energy, 2019), therefore dispelling the notion money is being diverted from other programmes to CCS.

4.3 Results pertaining to Objective 3 – Unintended consequences of CCS

4.3.1 *Objective 3 - Graphical presentation of results*

a. ***Overall results of objective Section 1.4.1 c)***

Figure 13 gives a presentation of raw data in graphical form from the Industry's responses to the unintended consequences of CCS statements

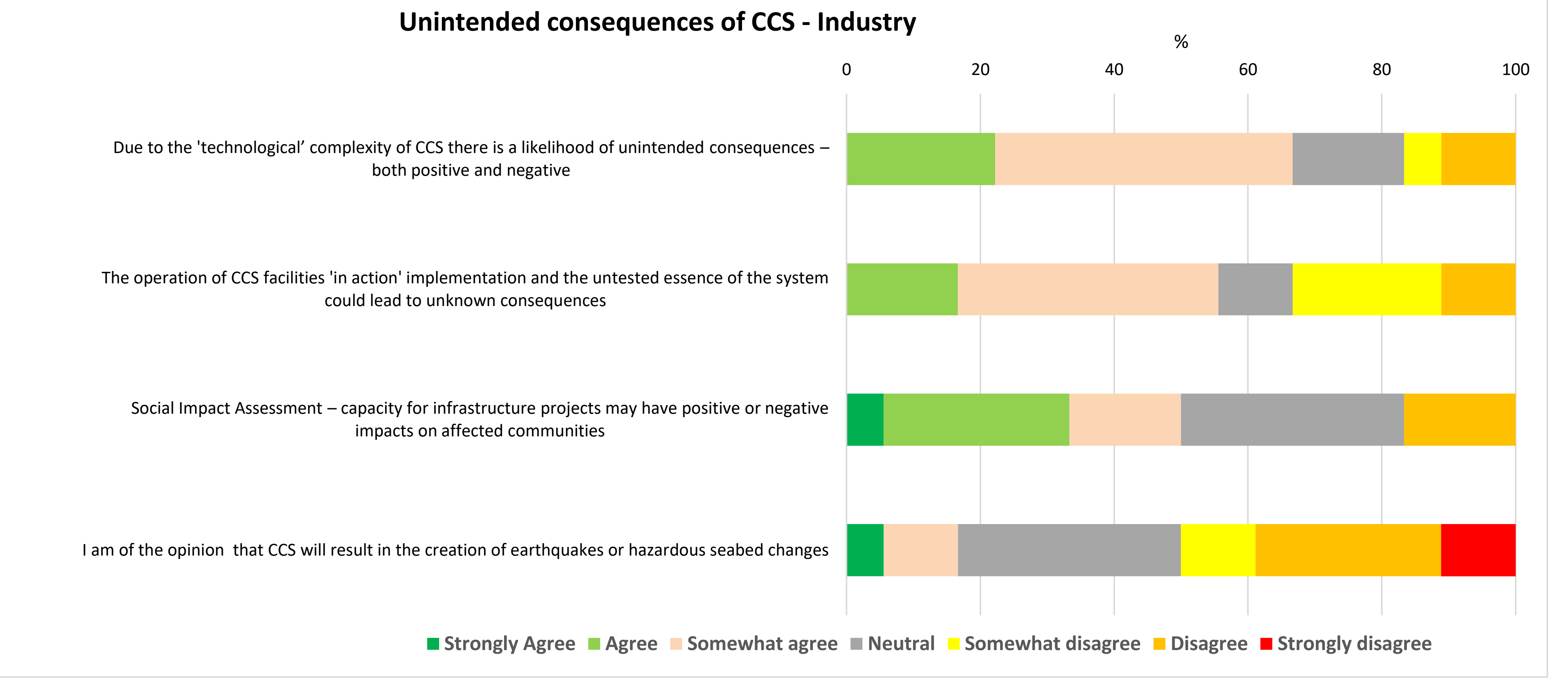


Figure 13 Objective 3 - Industry grouping: overall responses – unintended consequences of CCS

Figure 14 gives a presentation of raw data in graphical form from the Policy Influencer’s responses to the unintended consequences of CCS statements

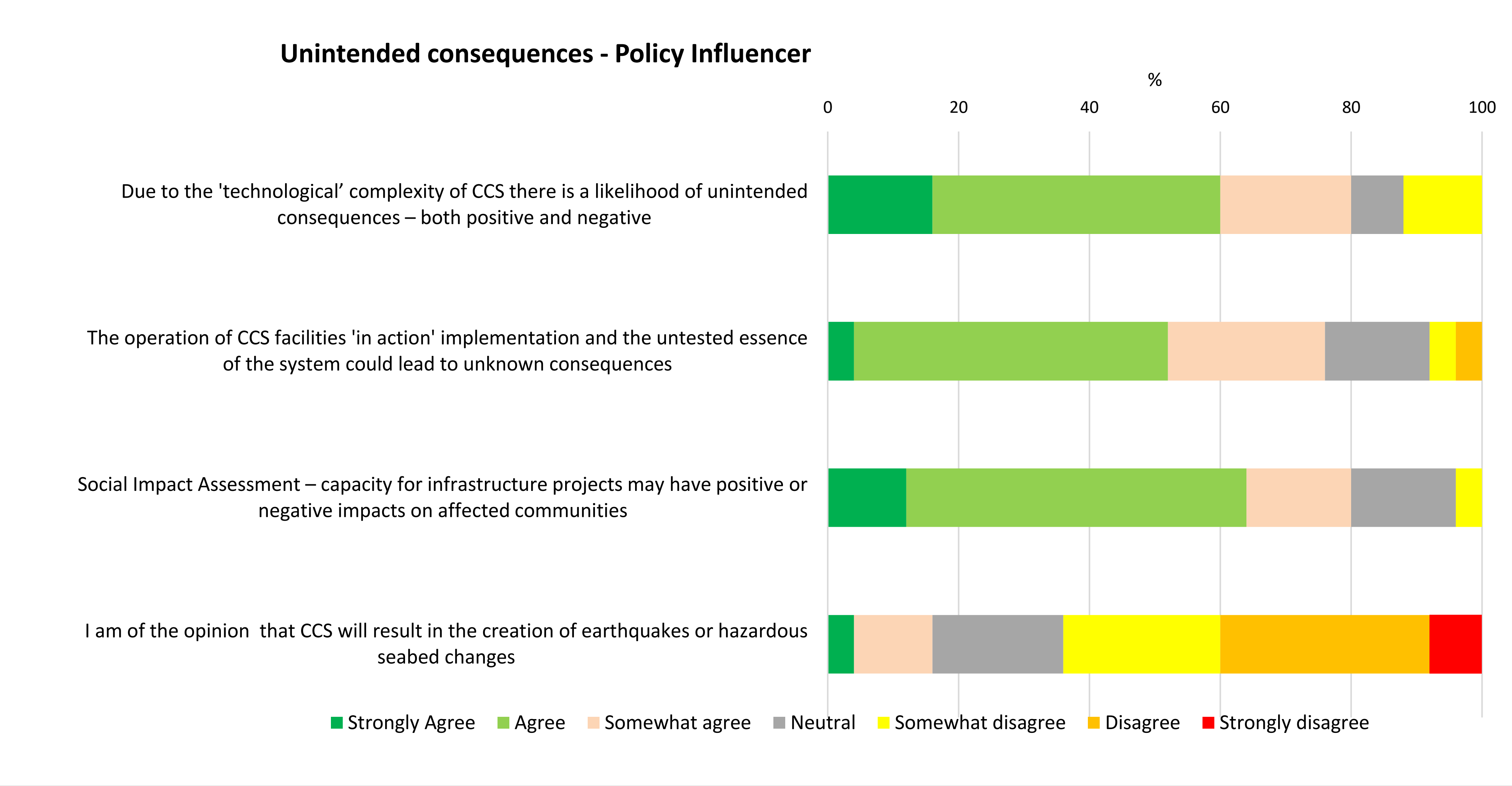
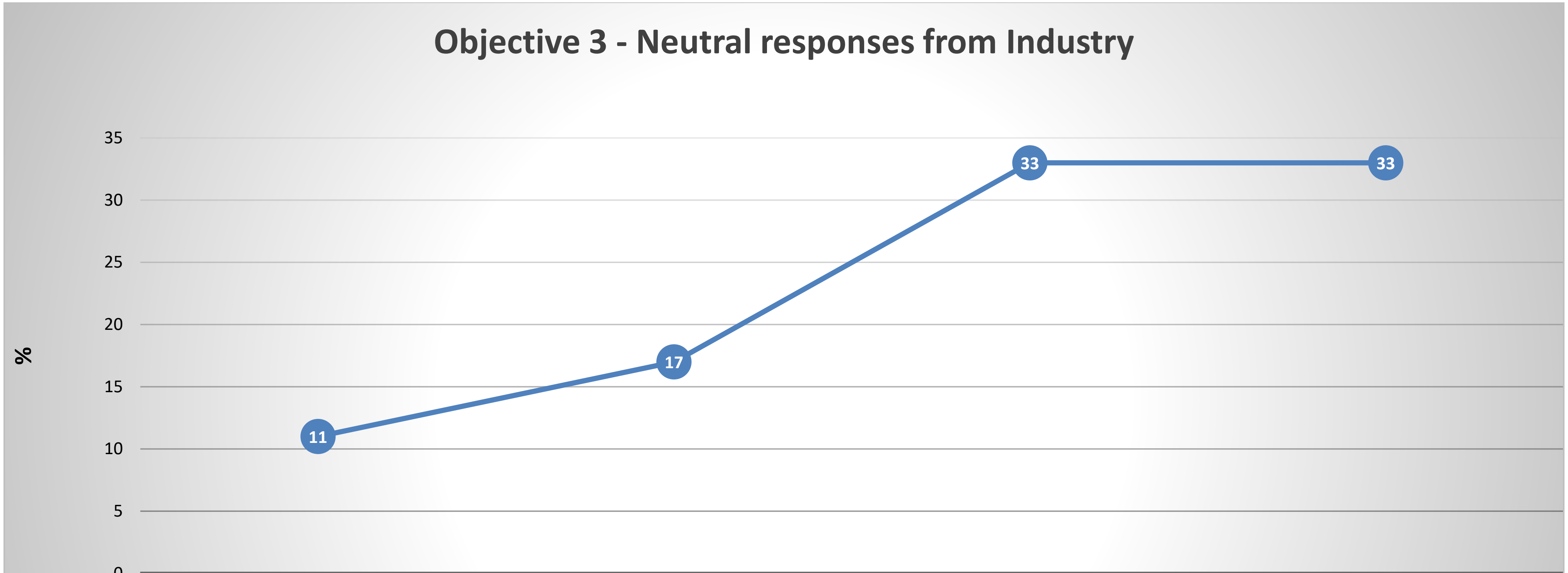


Figure 14 Objective 3 - Policy Influencer grouping: overall responses – unintended consequences of CCS

b. ***Presentation of the neutral responses from Industry (grey colour)***

Figure 15 gives a graphical presentation of neutral responses in ascending order from Industry to unintended consequences of CCS



	Due to the 'technological' complexity of CCS there is a likelihood of unintended consequences – both positive and negative	The operation of CCS facilities 'in action' implementation and the untested essence of the system could lead to unknown consequences	Social Impact Assessment – capacity for infrastructure projects may have positive or negative impacts on affected communities	I am of the opinion that CCS will result in the creation of earthquakes or hazardous seabed changes
Series1	11	17	33	33

Figure 15 Objective 3 - Presentation of neutral responses from Industry grouping

Figure 16 gives a graphical presentation of neutral responses in ascending order from Policy Influencer to the general understanding of CCS statements

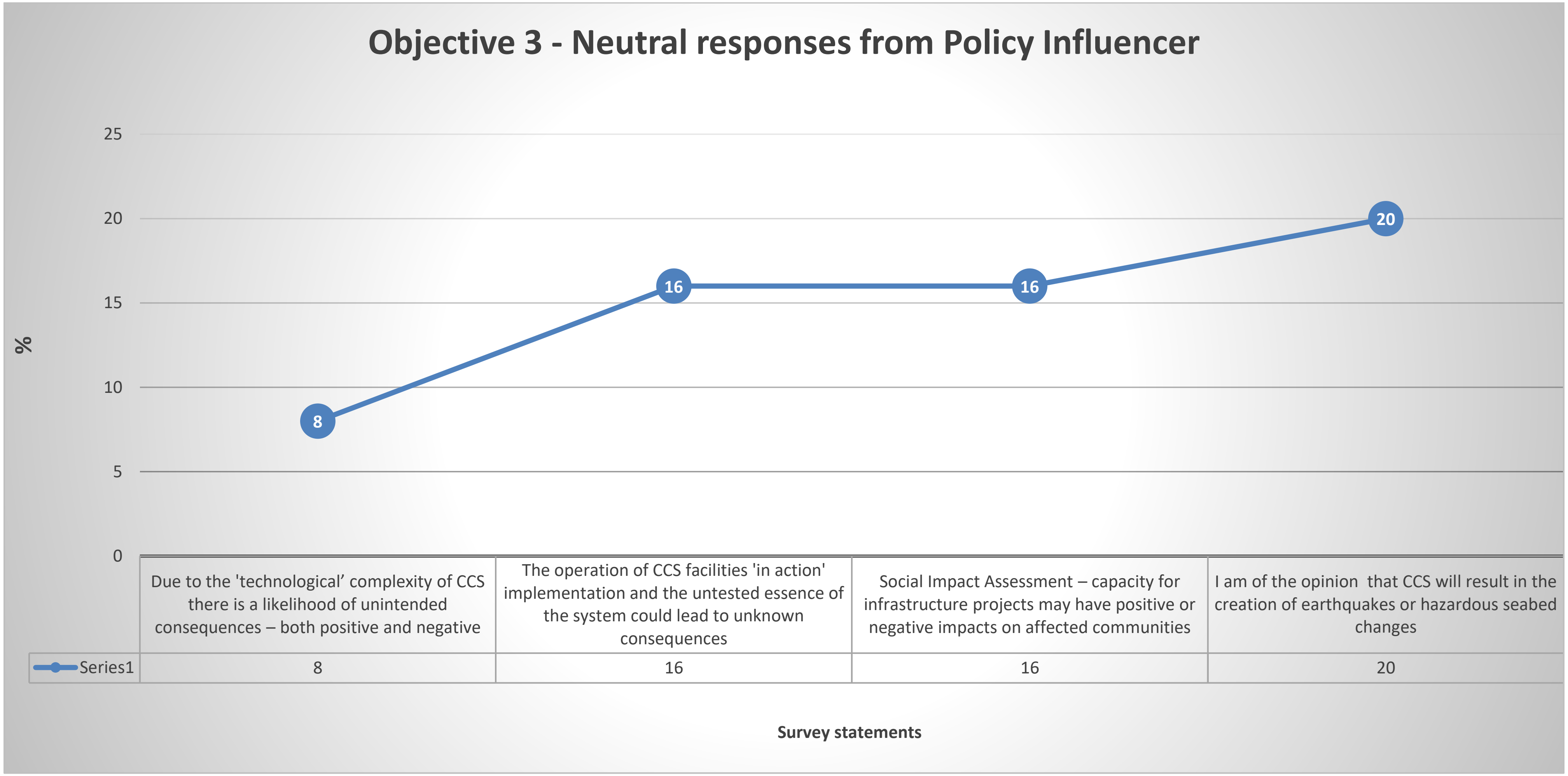


Figure 16 Objective 3 - Presentation of neutral responses from Policy Influencer grouping

c. *Similarities*

The tables below are grouped according to their p-value, where a p-value <u>more</u> than 0.05 (≥ 0.05) is not statistically significant as it presents evidence for the null hypothesis which states '*that there is no difference between certain characteristics of a population*'

Table 7 Objective 3 - Statistical insignificance - presentation of p values for the Industry and Policy Influencer groupings

Characteristic	p-value for between-group test
Due to the 'technological' complexity of CCS there is a likelihood of unintended consequences – both positive and negative	0,48
The operation of CCS facilities 'in action' implementation and the untested essence of the system could lead to unknown consequences	0,20
Social Impact Assessment – capacity for infrastructure projects may have positive or negative impacts on affected communities	0,052
I am of the opinion that CCS will result in the creation of earthquakes or hazardous seabed changes	>0,99

Figure 12 gives a graphical presentation of the statements that had insignificant differences in responses between Industry and Policy Influencer

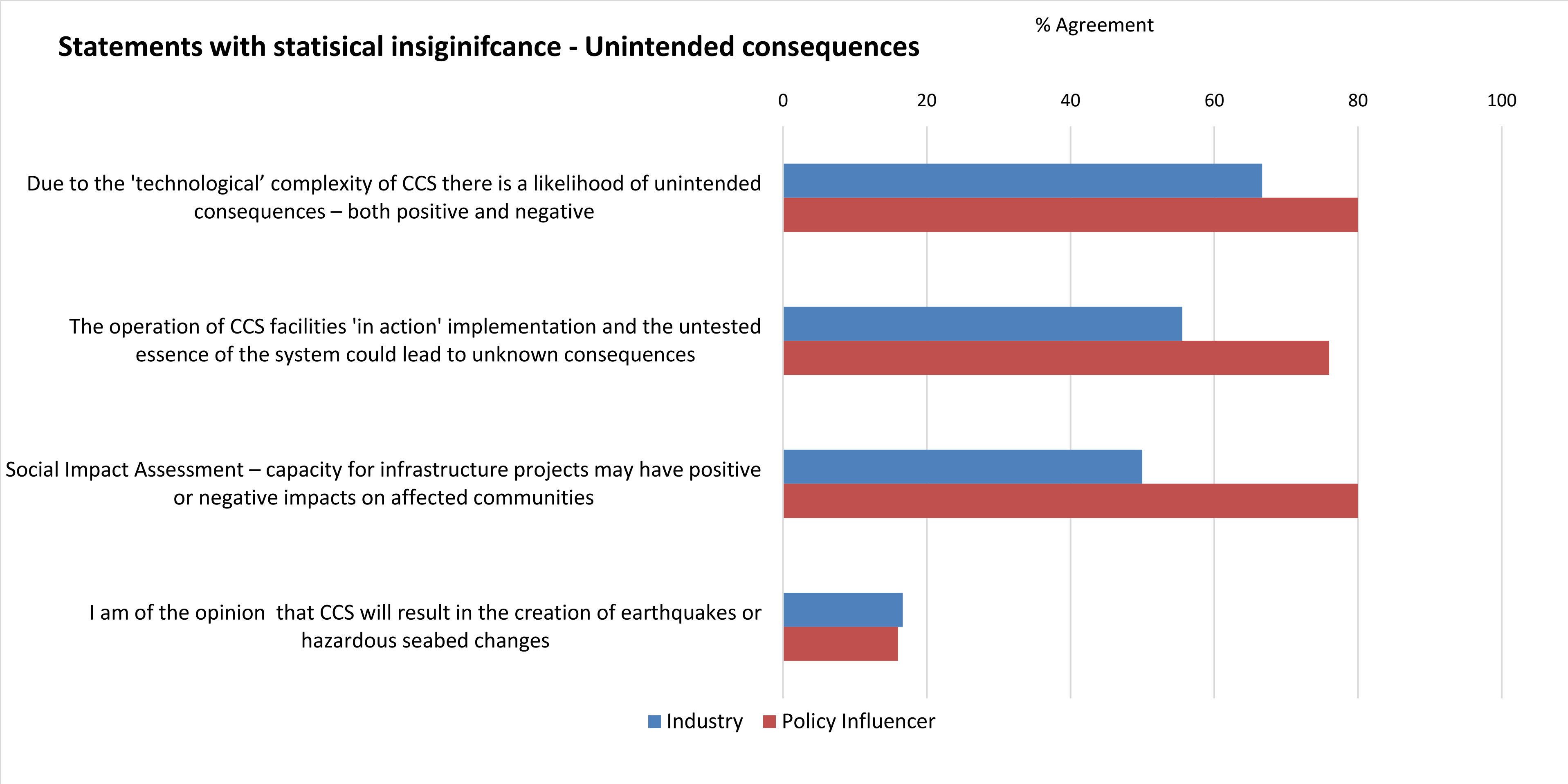


Figure 17 Objective 3 - Similarities between Industry and Policy Influencer responses

4.3.2 *Description of Industry grouping data*

Data description – industry

Figure 13

Figure 13 gives a presentation of raw data in graphical form from the Industry's responses to unintended consequences of CCS statement.

- It can be noted that all of the four statements have an indication of a grey colouring – neutral (not supporting or helping either side in a conflict). It could also indicate respondents 'limited knowledge on the statement at hand. Analysis of the neutral responses is discussed in the sections below.
- The overall sentiment is that the respondents are divided in their agreement/disagreement on unintended consequences to CCS.

Analysis of neutral data – Industry

Figure 15

Figure 15 gives a graphical presentation of neutral responses in ascending order from Industry to the unintended consequences of CCS statements.

- Only (33%) of respondents had a neutral response to CCS creating earthquakes or hazardous seabed changes, and that social impact assessment projects may have positive or negative impacts on affected communities.
- A smaller portion of respondents (17% and 11%) are neutral that the implementation of CCS could have unknown consequences and that the complexity of CCS could lead to positive or negative consequences, respectively.

4.3.3 *Description of Policy Influencer grouping data*

Data description – Policy Influencer

Figure 14

- Visual observation of Figure 14 indicates that policy influencers have 3 neutral responses out of the 4 statements.
- The general sentiment indicates that policy influencers are in agreement with most of the statements posed to them.

Analysis of neutral data – Policy Influencer

Figure 16

- Indicates that the question with the most neutral response (20%) pertains to CCS creating earthquakes or hazardous seabed changes, and social impact assessment.
- Less than 16% of respondents are neutral about the remainder of the statements posed to them in Figure 16.

4.3.4 *Description of similarities in unintended consequences of CCS*

Table 7 and Figure 17

- A similar but large portion of Industry (67%) and Policy Influencer (80%) agree that the complexity of CCS could lead to both positive and negative unintended consequences (p=0.48).
- A similar portion of Industry (56%) and Policy Influencer (76%) agree that the in action implementation of CCS could lead to unknown consequences (p=0.20).
- A differing portion of Industry (50%) and Policy Influencer (80%) agree that social impact assessment may have positive or negative impacts on affected communities (p=0.052).
- A similar but small portion of Industry (17%) and Policy Influencer (16%) are of the opinion that CCS will result in the creation of earthquakes or hazardous seabed changes (p=>0.99).

4.3.5 *Discussion*

The largest portion of neutral response (33%) from Industry is the belief that CCS will result in earthquakes and hazardous seabed changes. This is fairly a significant portion to not have a definite assertion on CCS. The Policy Influencer also has a neutral response (28%) to the same statement. This sentiment is shared by other stakeholders in other countries towards their own CCS initiatives, (Lock, Smallman, Lee, & Rydin, 2014). All four statements in this section received neutral responses from both groups: there are concerns about the intrinsic nature of CCS; there are also questions about 'in action' implementation; the untested essence of the system; and where that could lead, (Lock, Smallman, Lee, & Rydin, 2014).

The groups had no differing statements. In addition, all four statements received similar responses from both groups. The two groups just like any other stakeholder are not quite confident of the positive outcome from CCS, there is an element of uncertainty, as mentioned above, and the untested nature of CCS means no one knows other outcomes of CCS beside preventing CO_2 from entering the atmosphere.

CHAPTER 5. RECOMMENDATIONS

5.1 Objective 1 General understanding of CCS recommendations

- DMRE and CGS should speed up research on utilisation of CO_2 to give options to other forms of mitigation and inform the stakeholders accordingly. This is to give assurance that subsurface storage of CO_2 is not the only option being explored.
- Those tasked with investigating the feasibility of CCS in South Africa within the CO_2 emitting industry may need to be equipped with further information on the suitability of geological formations.
- Literature indicates that CCS is not commonly recognised and understood by public, which may refer to the general population. However, the study targeted specific organisations that may be eligible for CCS and the identified gaps in responses from Industry indicate that extra effort should be put into informing the concerned individuals with further information on CCS.
- Geology is a specialised field that may not be easily understood by those not in the field. Thus, it would be a reasonable expectation that some respondents may not understand its suitability for CCS. Therefore, an introductory or basic understanding of the geology may need to be introduced to the Industry counterparts.

5.2 Objective 2 Potential barriers to CCS recommendations

- Industry should determine a clear position on whether policy incentives will be welcomed in order for it to adopt CCS.
- It is recommended that the government affiliated organisation start making plans and publishing on whether there will be any policy incentives directly linked to CCS adoption by industry.
- At commercial stages of CCS, political, legal and regulatory institutions should provide investors with opportunities to minimise risk of capital and/or asset losses as SA has a developing economy. Further engagement will be required to identify opportunities beneficial to industry.
- If a large portion both industry and policy influencer believe that CCS investment is taking away from renewable energy and energy efficiency development, explicit communication and information sharing of the energy

related budget should be shared publicly to give reassurance that no other areas of DMRE's mandate is being compromised by CCS investment.

- Since industry and f agree that financial institutions should invest in CCS – a further investigation should be conducted to determine if financial institutions have an appetite for CCS.
- The challenge facing the CCS in SA is that there needs to be an awareness of the latest developments in their field, which might not always be publically available. Furthermore the field requires a multidisciplinary approach, including engineers, scientists and geologist. Managing such a multidisciplinary group may also be difficult to manage productively
- The investigation should also include trade-offs between the cost of CCS vs Carbon Tax imposition.

5.3 Objective 3 Potential unintended consequences of CCS recommendations

- CCS stakeholders in South Africa should seek out geological information of currently active CCS information, such as, SASK Power Boundary Dam. It would be of interest to prove that for the duration of the project there has not been any hazardous geological activity.

CHAPTER 6. CONCLUSION

There needs to be continued stakeholder engagement in order for CCS to be widely accepted. What this report has shown is that there are still gaps regarding CCS in South Africa, and they need to be filled so as to minimise any opposition to the technology.

CCS is generally understood better by the policy influencer much more than their Industry counterparts. Most notably is the need for geological information as way for Industry to better understand why geological formations are suitable for CCS and more models and demonstration of the technology. The Policy Influencer grouping agreed with most statements that were in favour of CCS indicating that the technology has their full support.

Both the Industry and Policy Influencer groupings were united in their regard for the most prevalent potential barriers to CCS, which mainly consist of lack of a regulatory regime, the high cost of deploying CCS and lack of political support. In a developing country like South Africa. These three statements, if not addressed, could mean that CCS will never see the light of day. Once again industry could benefit from further information sessions relating to investment and cost of CCS, and table their concerns to relevant responsible government entities. This is so that when policy and regulation on CCS are concluded, every stakeholder has a positive outcome.

Industry and Policy Influencer share the same sentiments about the potential unintended consequences. There was no difference in how they perceived the unintended consequences.

Overall this study highlighted where there is a gap in information and where extra effort needs to be made so that respondents are confident of their opinion on CCS. Even though the focus was on neutral responses, differences and similarities, there is still much more that can be analysed from the data presented in this report. One can determine the levels of agreements or disagreements on each role-player, other comparisons such as the differences and similarities between agreements or disagreements. Below is a summary of findings that stood out for the researcher.

Table 8 Summary of findings

	Industry	Policy Influencer
General understanding of CCS	Industry has a noticeable gap in knowledge of CCS.	The policy influencers seems to have better knowledge of general understanding of CCS and viewed it most favourably.
Potential barriers to CCS	Over 60% of industry respondents are convinced that regulations and cost are potential barriers.	Over 92% of policy influencer respondents are convinced that regulations and cost are potential barriers – however there is a great difference in number when compared with industry.
Unintended consequences of CCS	Industry has a big gap (neutral) on the consequences of CCS leading to earthquakes and hazardous seabed changes.	Policy influencers has gaps (neutral) considering in all statements of the 3rd objective. Further information sharing may close the gaps.

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Appendix A

Research Objectives

1. **To establish the perception of CO2 emitting industry and policy influencer on CCS as a CO2 emissions reduction technology**

a) The general understanding of CCS
b) The potential barriers to CCS in South Africa
c) The potential unintended consequences of CCS in South Africa

Good day

My name is Gcobisa Melamane and I am a student studying towards a Masters of Management: Energy Leadership degree at the University of the Witwatersrand (Wits Business School). I invite you to kindly participate in completing an anonymous survey as part of my research study titled ***"Perceptions of Carbon Capture and Storage (CCS) as a CO_2 emissions reduction technology in South Africa."***

The purpose of this questionnaire is to obtain information pertaining to perceptions of the two role players of CCS in the country, namely industry and policy influencers.

The online survey takes approximately 10-15 minutes to complete. Confidentiality and anonymity of participant's is maintained as the survey does not ask for any identifiable information like names, personal details or place of employment. Participation is entirely voluntary. By completing the survey, you indicate that you voluntarily participate in this research. If you have any concerns, please contact me using contact details provided below. The research is for academic purpose only.

Gcobisa Melamane (Ms)
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The survey are answered on Likert Scale i.e.

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Participant Profile

a) Sector of employment
    - Government/State Owned Entity i.e. DMRE, CSIR etc.
    - CO2 Emitting Industry i.e. Eskom. Sasol, PPC etc.

b) Level of employment
    - Managerial / Director / Decision Influencer
    - Technical / Officer / Consultant

Survey Statements broken into 3 sections – as per research objective above

Objective 1. General understanding of CCS

1. I have thorough understanding of the CCS technology
2. I am confident that CCS will be effective in mitigating greenhouse gas emissions into the atmosphere to address global climate change
3. CCS is the only technology capable of preventing CO_2 from entering the atmosphere
4. Geological formations are suitable for storing CO_2.
5. CCS has been successfully deployed somewhere in the world.
6. The Department of Mineral Resources and Energy as the custodian of CCS should be the only Department involved in CCS research and development
7. In my opinion, the CGS as the technical custodian of CCS in SA has the required capacity to research and deploy CCS
8. Industry's product price will be negatively impacted if compelled to deploy CCS
9. I trust that SA will be in good international standing if it successfully deploys CCS
10. Strategic interactions are the effective means of researching the shared strategic decision-making between government and industry
11. The department concerned with CCS needs to strengthen the legislative work for the power generation sector, and formulate low carbon output requirements.

Objective 2. The potential barriers to CCS

1. A regulatory regime is necessary for industry to adopt CCS in South Africa
2. Regulatory system must make explicit provisions about how to implement CCS

3. The *not in my backyard* attitude will be a barrier to development/construction of storage facilities
4. I believe that CCS will happen even if government does not enforce it
5. I am confident that Industry is receptive of CCS
6. I consider CCS to be the best solution to deal with CO_2 emissions
7. I believe that the costs of deploying CCS will be the main barrier to its adoption
8. The government should financially incentivise (subsidy or tax breaks et al) Industry for CCS
9. I trust that Industries will be willing to raise debt to finance CCS
10. Financial institutions (banks) should invest in CCS
11. I consider that CCS is just an excuse to continue using polluting fossil fuels
12. Political support for the technology is critical to its success
13. I am convinced that money invested in CCS is taking away the development of renewable energy and energy efficiency

Objective 3. The potential unintended consequences of CCS in South Africa

Unintended Consequence *(sometimes unanticipated consequences or unforeseen consequences) are outcomes of a purposeful action that are not intended or foreseen)*

1. Due to the 'technological' complexity of CCS there is a likelihood of unintended consequences – both positive and negative
2. The operation of CCS facilities 'in action' implementation and the untested essence of the system could lead to unknown consequences
3. Social Impact Assessment – capacity for infrastructure projects may have positive or negative impacts on affected communities
4. I am of the opinion that CCS will result in the creation of earthquakes or hazardous seabed changes.