22 August 2018

Exploring The Potential of the Circular Economy between the Oil and Gas and Agricultural Sectors in Kazakhstan.

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Subject: ENVR S-599 Independent Research Capstone

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Submitted in partial fulfillment of the requirements for the Degree of Master of Liberal Arts in Sustainability

Harvard Extension School

Abstract

This research project is an attempt to assess the potential for instituting a circular economy between parts of Kazakhstan's oil and gas and agricultural sectors. This research project explores the opportunities to reduce two particularly hazardous wastes – associated petroleum gas (APG) and sulphur – produced by Kazakhstan's oil and gas industry, and to use those as an input for scaling up the wheat production in Kazakhstan, making both economic sectors more sustainable.

This objective was reached by: 1) exploring the current issues related to the linear 'extract-use-dispose' model used in the oil and gas sector in order to formulate an understanding of the benefits of embracing a circular economy mindset; 2) conceptualizing how a sustainable circular model would function between these two sectors; 3) estimating the sustainability impact of proposed ideas based on plausible assumptions; and 4) designing a roadmap to help enable the transition from the 'business as usual' to the 'to-be' situation.

Results indicate that implementation of the proposed circular ideas between two major economic sectors contributes to substantial reduction in CO_2 (-13.0%) and NO_X (-12.5%) emissions, therefore contributing to improving sustainability. Given that Kazakhstan will continue to develop its oil and gas industry in the medium future, recommendations have been made about how to improve the sustainability of both sectors through circular economy ideas. Therefore, the proposed solutions explored in this research project have the potential to contribute to economic, social, and environmental sustainable development in Kazakhstan. This research project is intended for Kazakhstani policymakers, business leaders, and the country's civil society to track their progress toward the objective of achieving sustainable economic development.

Acknowledgements

First and foremost, I would like to take this opportunity to express my gratitude to my research advisor, Dr. Richard Wetzler, for the continuous support of my independent research capstone throughout the course, for his dedicated involvement, encouragement, and immense expertise and knowledge. His aspiring guidance and direction have greatly assisted me in writing of this research project.

Besides my research advisor, I would like to thank our teaching assistant, Mr. Marshall Spriggs, not only for his tremendous academic support and insightful comments, but also for the challenging questions that incented me to consider my research from various perspectives.

I would like to extend thanks to all the experts, who have participated in the discussions, and have provided significant insight and expertise. Special mention goes to Prof. Alexander Van de Putte, Dr. Sadykov, Mr. Kussainov, and Mr. Shakenov for contributing to the work presented in this paper by sharing their informative views and feedback on a number of issues related to this research project.

Last but not the least, I would like to thank my family - my parents and my husband - for supporting me throughout writing this research project.

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CHAPTER I: INTRODUCTION

1.1 Outline of the research paper

1.1.1 Kazakhstan facing challenges from relying on oil and gas sector

Currently, Kazakhstan's economy is the largest in Central Asia, however it is considered as one of the world's least sustainable economies due to its heavy reliance on suboptimal and unsustainable extraction of natural resources (Central Asia Metals Plc, 2017). As numerous oil fields are being developed, an absence of the required infrastructure and practices to manage hazardous wastes produced results in severe environmental consequences arising from oil production and refining operations (Nurbekov & Van de Putte, 2014). In addition, Kazakhstan's agricultural industry, potentially the country's most productive economic sector, has been overlooked for decades, and as such, the country's potential in agriculture has not yet been realized (Fengler, Gill, Miller, & Chatzinikolau, 2017).

This research project explores potential circular economy opportunities between oil and gas and agricultural sectors, which might help to reduce certain types of waste in the oil and gas industry, while scaling up the production in the agricultural sector, thus making country's two major economic sectors more sustainable. According to the Ellen McArthur Foundation, the circular economy is: "restorative and regenerative by design, and aims to keep products, components and materials at their highest utility and value at all times, as opposed to the current "take, make, and dispose" extractive industrial model" (Webster, 2015). At first glance, these two industries might seem completely unrelated, however this research project develops a view of how a sustainable circular model could look between these sectors of the economy.

As such, given the national economy's reliance on natural resources, this research project also explores opportunities to capture additional value from continuing operations in the oil and gas sector, while reducing waste, and realizing country's agricultural potential by applying "reduce, reuse, and recycle" circular economy principles. Thus, the potential solutions investigated in this research will contribute not only to reducing negative externalities in one industry and achieving its potential in another, but also to becoming more sustainable overall. These will not be sufficient to completely offset the magnitude of the current challenges, however this project will assist in leveraging circular economy principles in order to realize sustainable benefits, thereby challenging complacency, and prompting further action.

1.1.2 Aims and objectives

This research project aims:

- To explore an existing sustainability challenge in regard to two critical issues associated with the linear 'extract-use-dispose' model in the oil and gas industry—the production of waste by-products associated petroleum gas (APG) and sulphur—based on collected data;
- To explore potential circular feedback loops between parts of the oil and gas and the agricultural sectors that would help to reduce certain types of waste in the oil and gas sector, while scaling up production in the agricultural sector, thus making the country's two major economic sectors more circular, and as such more sustainable;
- To design a roadmap to an envisaged circular system that would be aspirational in nature, as to what must be improved in order to achieve the best potential to meet the main "reduce, reuse, and recycle" objectives of the circular economy, while focusing on material and resource management on one hand, and transformation of the economy on the other. This roadmap can then be used by policymakers, business leaders, and members of country's civil society to track their progress toward the objective of achieving sustainable economic development.

1.1.3 Research Question

This research paper explores the environmental, economic, and social benefits of re-utilizing waste by-products of the oil and gas industry, APG and sulphur, thus reducing their impact on the environment. This leads to my research question of how Kazakhstan can reduce waste levels in the parts of the oil and gas sector, while realizing its agricultural potential in a more sustainable way by applying "reduce, reuse, and recycle" circular economy principles, thus making the country's two major economic sectors more sustainable.

1.2 Background

1.2.1 General background

Kazakhstan, officially the Republic of Kazakhstan, is located in Central Asia. With its 2,699,700 square km of land area, Kazakhstan is the 9th largest country in the world, but its population is one of the lowest globally (18.4 million people) (World Population Review, 2018). Economically, over the past 25 years Kazakhstan has transformed itself from a lower-income to upper-middle-income status country (Baigunakova, Gagelmann, & Lewandrowski, 2015). Currently, Kazakhstan's economy is the largest in Central Asia (Central Asia Metals Plc, 2017). According to Trading Economics (2017), Kazakhstan's GDP per capita, when adjusted by Purchasing Power Parity (PPP), has reached an all time high of $24,055.59 in 2017.

1.2.2 Commodities driven export economy

Kazakhstan is rich in natural resources, such as hydrocarbons and numerous types of minerals, and ranks 6th in the world for its reserves of natural resources (Central Asia Metals Plc, 2017). According to the BP *Statistical Review of World Energy* (2017), there are an estimated 25.6 billion tons of proven coal resources, 30 billion barrels of proven oil resources, and 1 trillion cubic meters of proven natural gas resources in Kazakhstan as of 2017. With a production level of 1.7 million barrels per day, Kazakhstan is considered the 2nd largest oil producer among the former Soviet Union countries after Russia, and the 17th largest in the world (Climatescope, 2017; Gordeyeva, 2017).

The Kazakhstan government puts considerable faith in three major oil deposits—Tengiz[1], Karachaganak[2], and Kashagan[3]—to boost its finances and accelerate the country's economic growth (Voloshin, 2018). According to Voloshin (2018), Kazakhstan's oil production had increased from 78 million to 86.2 million metric tons year-on-year, as of January 2018, and is projected to grow further. The oil and gas sector is central to Kazakhstan's GDP growth,

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[1] The Tengiz field is one of the ten largest oil and gas fields in the world, located in close proximity to the Caspian Sea. Its geological reserves are estimated to be at 9 billion barrels (US Energy Information Administration, 2015).

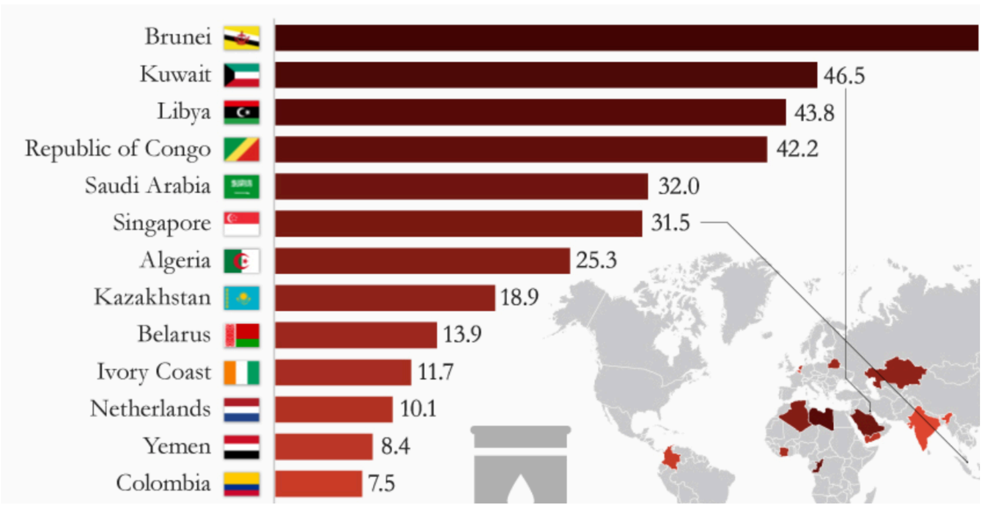
[2] The Karachaganak field is a major oil and gas field that holds 1.542 billion barrels of proven oil reserves (LUKOIL, n.d.).

[3] The Kashagan oilfield is the fifth largest oilfield in the world in terms of reserves, with recoverable reserves estimated at 13 billion barrels of crude oil (US Energy Information Administration, 2015).

accounting for approximately 60% of its total exports and more than 25% of GDP, and as such reflecting a considerable dependence of the national economy on the industry's revenues (see Figure 1.1) (The Observatory of Economic Complexity, 2018). As seen on Figure 1.1 that ranks countries by their dependence on oil exports as a percent of GDP, Kazakhstan comes 8th (McCarthy, 2018).

Although economic diversification is an officially proclaimed priority in the domestic agenda, it is projected that Kazakhstan's economy will continue to be oriented towards development of natural resources due to the country's massive natural resources endowment (Central Asia Metals Plc, 2017). According to projections by the Kazakhstani Ministry of Energy, oil and gas condensate production in 2020 will be 88 million tonnes (KazMunaiGas, 2017). While Kazakhstan's development strategy involves transforming its economic model towards a more value-added economy, oil extraction is not planned to be phased out in the near future, as oil presents a key source of national income and transforming the economy takes time (Central Asia Metals Plc, 2017; World Bank Group, 2018a). Nevertheless, it is important that on its way to economic diversification, Kazakhstan finds the right balance between these opposing forces, and achieves more inclusive development and sustainable growth.

Figure 1.1: Country Rankings by Dependence on Oil Exports as a % of GDP in 2018 (McCarthy, 2018).



1.2.3 Unrealized potential of Kazakhstani agriculture

Agriculture, on the other hand, presents one of the most potentially productive economic sectors for Kazakhstan, given that more than 80% of the country's land is suitable for agricultural production (Trading Economics, 2018). The country's geographic location and four climatic zones allow for the production of numerous types of crops and the breeding of many kinds of livestock. At times of growing demand for food products, with its 180 million hectares of pasture and more than 25 million hectares of land suitable for mechanization, Kazakhstan has enormous potential to become the world's major wheat exporter, dominate the livestock sector, as well as expand its horticulture potential (World Bank Group, 2018a). In addition to private land ownership and a flexible labor market, the country's agricultural sector also benefits from close proximity to major food-importing markets, such as Russia, China, India, and the Middle East (World Bank Group, 2018a).

Historically, Kazakhstan was the largest agricultural producer and grain exporter in the former Soviet Union as a result of Nikita Khrushchev's "Virgin Lands" program in early 1960s (Timofeychev, 2017). But as Timofeychev (2017) further reports, inefficient food production strategies and environmentally reckless practices have destroyed the fertile lands, and, as such, led to the collapse of the Kazakhstani agricultural sector. Upon gaining independence, Kazakhstan's role as a major food supplier to other former Soviet Union countries has been overlooked and, as such, the country's agricultural potential has not been realized (Fengler, Gill, Miller, & Chatzinikolau, 2017). It is now the least productive country among all global food producers, with less than half the average yields per hectare of countries such as Russia and Canada (Fengler, Gill, Miller, & Chatzinikolau, 2017).

The World Bank (2018a), in cooperation with the International Finance Corporation, has identified that the agricultural sector, and wheat production specifically, holds the most promise to meet Kazakhstan's development objectives. Following Russia's export cuts, over the last decade Kazakhstan became a crucial wheat supplier to the food markets of the Commonwealth of Independent States, the Gulf Arab countries, Iran, and other Middle East areas (Berlyne, 2012). Kazakhstan started exporting wheat to China in 2010, and since then China has emerged as an enormous importer of Kazakhstani food products (Berlyne, 2012). As Berlyne (2012) further notes, through China, Kazakhstan has started exporting wheat to South Korea and other Asian countries on the Pacific Rim. At the times of growing demand for food products, scaling up the food production could feed parts of the population of neighboring countries, and, as such, as one of the leading wheat producers, Kazakhstan can substantially benefit by entering the neighboring markets, but only if its export competitiveness can be improved (Fengler, Gill, Miller, & Chatzinikolau, 2017).

Agriculture forms the main economic activity in the rural communities of Kazakhstan, as one in four workers rely on the agricultural sector for employment (Syzdykov, Aitmamber, & Dautov, 2015). Although the Kazakhstani agricultural sector has long underperformed, it still remains at the heart of the national culture and presents a realistic opportunity for economic growth. In accordance with "Kazakhstan–2030" development strategy, at least $20 billion of the governmental budget is allocated to the national agricultural sector in order for it to become a global food producing and exporting power (Syzdykov, Aitmamber, & Dautov, 2015).

1.3 Existing sustainability challenge

1.3.1 Dependence on revenues from oil and gas sector counters sustainability

Kazakhstan's heavy dependence on the revenues from the export of primary commodities raises a question as to what extent the country's development model is susceptible to sustainability challenges. The World Commission on Environment and Development defines sustainability as follows: "A process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony, and enhance both current and future potential to meet human needs and aspirations" (Buchs & Blanchard, 2013). According to the "Five Capitals" framework, sustainability is about balancing, maintaining, and growing all five capitals of sustainability simultaneously: natural capital, human capital, manufactured capital, financial capital, and social capital (Porritt, 2005; Van de Putte, Kelimbetov, & Holder, 2017).

Kazakhstan is considered the 14th largest emitter of greenhouse gases (GHG) in the world, with total annual emissions of 231.9 MtCO2e in 2016 (Heckman, 2016; World Bank, 2018B). According to the World Bank (2018b), 82% of Kazakhstan's total GHG emissions are produced by the energy sector, 9.6% by the agricultural sector, and 6.4% by industrial processes. Emissions intensity of GDP[4] in Kazakhstan is among the top ten in the world,

[4] The total amount of energy-related CO2 emissions required to generate one unit of GDP (Baigunakova, Gagelmann, & Lewandrowski, 2015).

reaching 0.56 kg CO2 per $1,000 GDP in 2016 (Baigunakova, Gagelmann, & Lewandrowski, 2015; World Bank, 2018b).

The 2018 Environmental Performance Index (EPI), produced by the Yale Center for Environmental Law & Policy, assesses the policies of 180 nations on 24 performance indicators across numerous categories ranging from environmental health to ecosystem vitality (EPI, 2018). It analyzes whether countries are meeting internationally established environmental standards. Top of the eco-chart is Switzerland, followed by France and Denmark (EPI, 2018). Kazakhstan places 101st, with an EPI score of 54.56 (EPI, 2018).

Table 1.1 compares Kazakhstan with a select set of countries on six indicators that might illustrate the level of sustainability in regard to the economy's dependence on natural resources. In comparison to the other countries, Kazakhstan performs poorly on most of the indicators used. As Table 1.1 shows, Kazakhstani economy's heavy reliance on natural resources is done in suboptimal and unsustainable way, as followed by Russia, Norway, Canada, and China. Although Kazakhstan's total CO2 emissions are lower than China's and Russia's, Kazakhstan's CO2 emissions per capita and CO2 emissions per GDP are higher than for these countries.

Table 1.1: Economic Indicators by Country in Regard to Sustainability, 2016 (The Global Economy, 2018).

	Unit	Canada	China	Kazakhstan	Norway	Russia
CO_2 total emissions	kt	675,919	10,432,751	231,920	43,456	1,661,899
CO_2 per capita emissions	ton CO2/cap	18.62	7.45	12.88	8.28	11.54
CO_2 per GDP emissions	ton/$1000	0.43	0.52	0.56	0.13	0.47
Income from natural resources	percent of GDP	1.01	1.13	15.04	5.81	11.46
Oil revenue	percent of GDP	0.25	0.26	10.05	3.84	7.01
Natural gas revenue	percent of GDP	0	0.03	0.88	1.9	2.7

Moreover, there is limited value added in Kazakhstan's oil and gas industry. Kazakhstan primarily exports crude oil and does not upgrade this oil into finished products, at least not to a large degree. Table 1.2 compares Kazakhstan with the same set of countries on their dependence on the export of crude oil. According to Table 1.2, out of these five countries, Kazakhstan's economy is the most dependent on crude oil exports.

Kazakhstan's economic stability might be threatened by this reliance on a single sector. Research by Hausmann et al. (2007) shows that Kazakhstan may seem to be stuck in a "low product" trap, as it is exporting products that are not high-value and sophisticated. As Hausmann et al. (2007) suggest, one option for the country to upgrade economically is to increase or improve a product that it has already been exporting: crude oil and metallurgical products. Exporting crude oil and gas has served the country very well before, but this is no longer the case for variety of reasons. Hausmann and co-authors (2007) argue that by focusing on what it has been exporting so far, it is unlikely that Kazakhstan will reduce its reliance on natural resources, precluding diversification to high-value products. Oil prices and oil revenue might fluctuate widely, thus in order to reduce the effects of such instability, it is imperative to develop value-capturing sources of revenue (Hausmann et al., 2007). If additional value could be captured, both the oil and gas sector and agricultural industries could then become more sustainable, as this will help to reduce negative externalities in one industry and achieve its potential in another.

Table 1.2: Top 5 Exports by Country, 2016 (The Observatory of Economic Complexity, 2018).

Country	**Top exports**				
	1	**2**	**3**	**4**	**5**
Canada	Cars	Crude Petroleum (11% of total exports)	Vehicle Parts	Refined Petroleum	Lumber
2016 Value	$48.9B	$39.6B	$10.5B	$8.34B	$7.79B
China	Computers	Broadcasting Equipment	Telephones	Integrated Circuits	Office Machine Parts
2016 Value	$173B	$160B	$109B	$64.6B	$42.8B
Kazakhstan	Crude Petroleum (40% of total exports)	Refined Copper	Petroleum Gas	Radioactive Chemicals	Ferroalloys
2016 Value	$13.2B	$2.24B	$1.92B	$1.87B	$1.5B
Norway	Crude Petroleum (24% of total exports)	Petroleum Gas	Non-fillet Fresh Fish	Refined Petroleum	Raw Aluminium
2016 Value	$22.7B	$21.6B	$5.24B	$3.23B	$2.59B
Russia	Crude Petroleum (28% of total exports)	Refined Petroleum	Petroleum Gas	Coal Briquettes	Raw Aluminium
2016 Value	$75.7B	$43.1B	$16B	$10.4B	$6.08B

1.3.2 APG and sulphur present important challenges associated with linear economy in the oil and gas sector in Kazakhstan

Carbon Limits (2013) projects that oil production in Kazakhstan will reach 2.5 million barrels per day in 2020. While Kazakhstan has extensive plans for exploration and development of its oil fields, the country is currently unable to employ proper techniques in managing oil and gas exploration waste, at least not to a large degree (Nurbekov & Van de Putte, 2014). This results in severe environmental consequences arising from petroleum production and refining operations (Nurbekov & Van de Putte, 2014). Most of the industrial companies in Kazakhstan use outdated technology or equipment with a considerable degree of wear (Baigunakova, Gagelmann, & Lewandrowski, 2015). This research project explores two important challenges associated with waste in the oil and gas sector—associated petroleum gas (APG) and sulphur.

Flaring and venting of associated petroleum gas (APG), which is produced during the extraction of crude oil, is one of the principal environmental challenges for the oil industry (Nurbekov & Van de Putte, 2014). APG is released into the atmosphere through the combustion process when reaching the surface, via a process called *flaring*, or through direct *venting* when released without being burned (Aniefiok & Udo, 2013). APG releases numerous toxic and hazardous emissions, including methane, sulphur dioxide, and carbon dioxide, which destroy natural habitats and damage human health, including, but not limited to, upper respiratory tract irritation, asthma, and cardiovascular effects (Haugland et al., 2013; Heikkinen, 2017). Nurbekov and Van de Putte (2014) state that Kazakhstan is one of the countries that is currently unable to exploit the production of natural gas in an economically and environmentally viable way due to limited technical resources, and unfavorable economic conditions with a low market value for gas combined with a lack of political will, economic incentives, and social responsibility on the part of major oil companies. As such, the country continues to release significant amounts of APG into the atmosphere (Nurbekov & Van de Putte, 2014).

The second most important environmental challenge in the local oil and gas sector is that oil contains high levels of corrosive sulphur (Kalb et al., 2002). As such, significant excess quantities of sulphur, with no social or commercial benefits, are currently being produced alongside petroleum and natural gas production at oil fields in Kazakhstan (Kalb et al., 2002).

Approximately 10 million tons of by-product sulphur has piled up in open deposits from oil produced at Tengiz field in 2005 alone (see Appendix B) (Rumer, 2005). As airborne particulate, this sulphur by-product contributes to the formation of acid rain as well as soil and surface water acidification, thereby polluting susceptible local aquatic and terrestrial ecosystems (Botkin & Keller, 2014). Sulphur is an important air pollutant, and exposure to sulphur dioxide can cause irritation of mucous membranes, decreases in lung functions, variable effects on tracheal and bronchial organs, etc. (Botkin & Keller, 2014). Presently, much of the sulphur is disposed of as waste, but as the volume of sulphur residue increases with rapidly expanding oil and gas production, this practice will reach a threshold, and, as a result, lead to air, water, and soil contamination (Kalb et al., 2002).

1.4 Potential of Circular Economy

Kazakhstan ratified the Paris Agreement in November 2016, thereby committing itself to the fulfillment of the proposed target of an economy-wide 15% reduction of GHG emissions from 1990 emissions levels by 2030 as its first Nationally Determined Contribution (NDC) (World Bank, 2018b). Also, to meet its obligations under the Kyoto Protocol, Kazakhstan has agreed to reduce carbon emissions by 15% by 2020 and by 25% by 2050 compared to its 1992 level (Baigunakova, Gagelmann, & Lewandrowski, 2015).

Despite ongoing advancements, the main working model in Kazakhstan has remained largely unchanged, as it was—and still is—characterized by the traditional linear economic model of 'extract-use-dispose' (Nugumanova, Frey, Yemelina, & Yugay, 2017). There is no 'circular thinking' embedded in business practices or in the legislative framework of the country (Nugumanova, Frey, Yemelina, & Yugay, 2017). It is imperative that Kazakhstan puts in place an appropriate policy framework and practices, and attempts to catch-up with the international standards agreed under the Paris Agreement and Kyoto Protocol.

There are ways to move from a traditional linear economy to a circular economy. The circular economy has aspects of sustainability that will help Kazakhstan's economy to achieve more inclusive growth and sustainable development. Arcadis Design and Consultancy group analysts led by Vos et al. (2015) argue that in a circular economy: "growth and prosperity are decoupled from natural resource consumption and ecosystem degradation. By refraining from throwing away used products, components and materials, instead re-routing them into the right value chains, we can create a society with a healthy economy, inspired on and in balance with nature".

In order to explore potential circular feedback loops between these two sectors, this research proposes two circular economy approaches. Transition to a circular economy would require the oil and gas sector to abandon its linear use of materials, by separating their waste in ways that allows it to be brought back into the materials cycle.

1.4.1 Converting APG into ultraclean transportation fuel as a circular idea

Numerous tools are available to utilize the gas from flares. As one of the circularity ideas, this research paper investigates the possibility of capturing APG and turning it into ultraclean transportation fuels - gas to liquids (mini-GtL) - to be used along the entire logistics value chain of wheat production in the agricultural sector[5] (see Figure 3.2) (Haugland et al., 2013). Mini-GtL is a technology that has recently emerged that can convert APG into liquid fuels (largely synthetic diesel) through the process known as "Fischer-Tropsch" (see Appendix A).

This would help to make the transportation and operations of the agricultural industry more sustainable, as well as increase the value of finite gas resources by reducing toxic emissions and monetizing previously wasted flare gas resources. Minimizing GHG emissions, and producing an ultraclean diesel fuel is a way to handle gas sources over a wide span of impurities with new and innovative techniques.

As natural gas presents an abundant, multipurpose, and affordable resource, converting APG into value-added ultraclean diesel via using mini-GtL presents both economically and environmentally feasible solution. Mini-GtL may play a critical role in terms of minimizing the carbon footprint, reducing GHG emissions, energy provision, and creating new markets for the use of such gases.

1.4.2 By-product sulphur presents an important nutrient for wheat growth

In addition, this research project explores the sustainability impact of a second circular economy idea on the agricultural sector: the possibility of utilizing sulphur from oil and gas open-air deposits at Tengiz oilfield as an important crop nutrient in agricultural production. According to the Sulphur Institute (2018), alongside nitrogen, phosphorus, and potassium,

[5] The proposed circular idea does not focus on the profitability of the transport sector, but rather on making wheat and sulphur transport more sustainable by using diesel from APG instead of diesel from crude petroleum.

sulphur is one of the critical plant nutrients that may result in higher crop yields and more nutritious foods.[6] Applying sulphur over arable land might thus result in increased food production in portions of agricultural sector, while simultaneously reducing the negative environmental and health effects of open-air sulphur deposits in Kazakhstan. Given that Kazakhstan has one of the smaller populations in the world (18.4 million people), at a time of growing demand for food products, scaling up the food production could feed large parts of the populations of neighboring China, former Soviet Union countries, Central Asia, and the Middle East (World Population Review, 2018). China, with an average annual consumption of 100 million tonnes of wheat, and with whom Kazakhstan shares a 1,783-km border, is one of the most promising food markets (Berlyne, 2012).

[6] In order to avoid sulfide toxicity, careful soil monitoring needs to be implemented. Based on the results, sulphur fertilization may need to be adjusted.

CHAPTER II: METHODOLOGY

2.1 Research philosophy

Before conducting any research project, it is essential to identify the research philosophy (Miller & Salkind, 2002). The research methodology in this paper applies the principle of triangulation, a concept used to describe how the use of multiple methods, approaches, and sources of evidence will help the researcher to "zero in" on the findings (Singleton & Straits, 1999). Triangulation in this research occurs through such activities as combining multiple methods of research approaches, and using multiple complimentary information channels.

According to Gill and Johnson (1991), the theoretical approach of researchers in social sciences involves two different philosophical paradigms: positivism and phenomenology. The positivist perspective focuses on laws and causal explanations, while phenomenology approach attempts to understand a phenomenon in context-specific settings (Easterby-Smith et al., 2002). As the focus of this research paper is primarily exploratory in nature, the research methodology involves the following methods: inductive, largely qualitative phenomenological approach-based research complimented with quantitative data collection and data analysis (Miller & Salkind, 2002).

The phenomenological approach is widely used in social sciences research, particularly in an exploratory, theory-building context (Eisenhardt, 1989). "The aim of phenomenological qualitative research is to deal with meanings and experiences, and to capture as closely as possible the way in which the phenomenon is experienced within the context in which the experience takes place" (Davidsen, 2013; Giorgi & Giorgi, 2003). This research project attempts to facilitate comprehension of the phenomenon within the real-life context, as such to understand and explain what is happening, rather than search for causality or particular laws.

In this particular case, the phenomenological approach is used due to the lack of *a priori* theory (Gill & Johnson, 1991), and a desire to produce knowledge of practical relevance, as well as to generate an incrementally more powerful theory on the basis of various theoretical concepts. Unlike positivism, where the research method uses the hypothetical deductive approach, phenomenology generates ideas and theory through induction from data (Miller &

Salkind, 2002). This research project falls under the phenomenology approach, where the theory will be developed through an explanatory method (Miller & Salkind, 2002).

2.2 Research strategy

This capstone project attempts to test whether the proposed 'to-be' situation is more sustainable than the 'business as usual' situation, by exploring and contrasting environmental and social impacts alongside assessing potential economic effects.

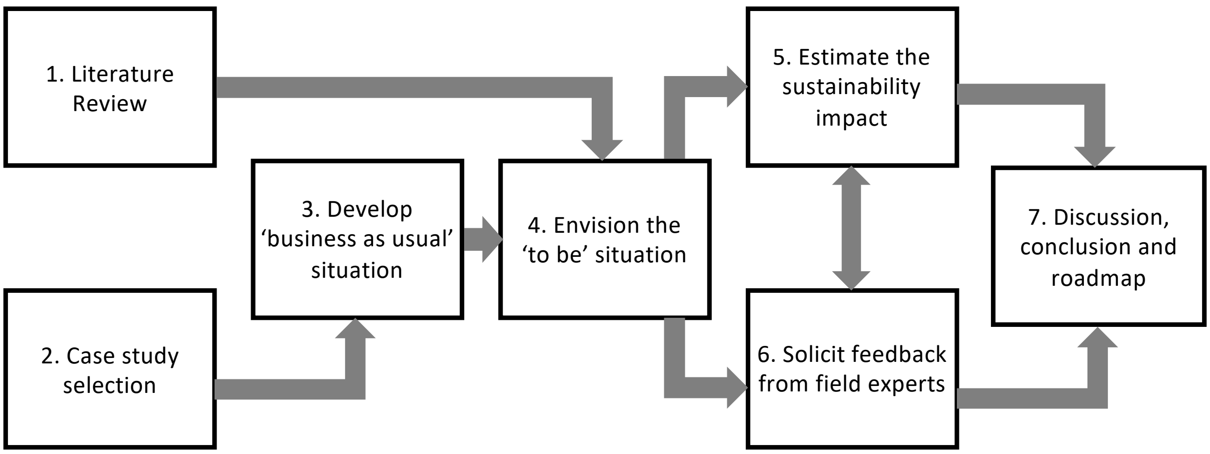
Firstly, a 'business as usual' situation and existing sustainability challenge is illustrated based on the collected data. Based on the "Kazakhstan-2030" strategy, a 'business as usual' situation model is built, projecting the configuration of the system 12 years into the future (Akorda, 2018). Then a 'to-be' scenario is developed that is aspirational in nature, which shows how the system could evolve if we implement the proposed circular economy commitments. The applied method assists in achieving a better understanding of the current and future consumption and use of resources, to measure the climate-changing impacts of current unsustainable practices, to quantify waste diverted from landfills within the perspectives of circular economy, and to identify potential cost savings and new revenue streams. The end product is a roadmap to 2030 to help Kazakhstan, not only reduce negative externalities in one industry and achieve its potential in another, but also to allow both industries become more circular, and thus more sustainable. To explore circular feedback loops between two sectors, this research method focuses on two possible circular economy approaches: 1) APG to ultraclean diesel fuel, and 2) sulphur as a key nutrient for wheat production.

One of the tools this research project applies is the Circular Economy Toolkit (CET), a circular sustainability toolkit developed by the Centre for Industrial Sustainability at Cambridge University's Institute for Manufacturing (Circular Economy Toolkit, 2018). CET is freely available online. CET comprises 33 trinary-based questions, applies lifecycle thinking, and also assesses the associated business opportunity, such as financial viability and market growth potential (Circular Economy Toolkit, 2018).

2.3 Research process

The research uses a 7-phase inductive, primarily qualitative, research process with the objective to explore the potential of the circular economy between the oil and gas and the agricultural sectors in Kazakhstan.

Figure 2.1: 7-Phase Inductive Research Process.



Phase 1: Literature review on the circular economy: The objective of the literature review is to formulate an understanding of the benefits of embracing a circular economy mindset in Kazakhstan, and to conceptually assess the potential of the circular economy between parts of the oil and gas and agricultural sectors in Kazakhstan.

Phase 2: Select case studies: Two case studies have been selected within the oil and gas sector to explore circular economy benefits with the agricultural sector in Kazakhstan. The first case study is to convert APG, which is otherwise flared or vented in Kazakhstan, into ultraclean transportation fuel to be used along the entire value chain of wheat production, one of the key agricultural crops in Kazakhstan. The second case study is to use sulphur, a by-product of the oil and gas development from the Tengiz field, as a crucial nutrient to improve wheat crop yields. Both case studies leverage circular economy concepts because what is considered waste in one sector is used as an input in another sector, thus potentially contributing to sustainable development.

Phase 3: Develop the 'business as usual' situation: After mapping the logistics value chain for wheat production in Kazakhstan, the 'business as usual' situation will estimate the CO_2 emissions over the entire logistics value chain of wheat production, starting from 2017 to 2030. The year 2030 is selected because it aligns with Kazakhstan's official strategy for development to become one of the most diversified and competitive nations in the world (Akorda, 2018). Initially envisioned in 1997, the "Kazakhstan-2030" strategy is regularly updated, and the development of an export-oriented agricultural sector increasingly features prominently among Kazakhstan's ambitions (Akorda, 2018).

Phase 4: Envision the 'to-be' situation: The 'to-be' case, on the other hand, shows where circular economy flows between parts of the oil and gas and agricultural sectors in Kazakhstan can be explored. The focus of the research involves turning two particularly harmful wastes from the oil and gas sector, APG and sulphur, into an input to scale the production of wheat in Kazakhstan. Here, a systems thinking map is developed to show some of the positive circular flows between these two sectors. Systems thinking was originally developed by Forrester in 1961 to show the non-linear relationships that may exist within a system's constituent parts, and is a powerful visualization tool (Forrester, 1961).

Phase 5: Estimate the sustainability impact: During this phase of the research, the sustainability impact of circular economy concepts between parts of the oil and gas sector and wheat production is explored and measured, both qualitatively and quantitatively across the entire logistics value chain of wheat production. It is expected that a significant reduction of CO_2 emissions can be realized by replacing diesel fuels from oil with ultraclean diesel fuels from APG, and by using sulphur, a waste by-product from oil production, as a key nutrient for wheat crop production. The quantitative sustainability impact is estimated over the period until 2030. In addition, the circularity of the proposed solution is estimated using the CET (see Section 3.4).

Phase 6: Solicit feedback from field experts: As mentioned, triangulation of multiple sources of evidence is important to ensure the validity of the findings. During Phase 6, selected conversations are held with experts from the agricultural and energy sectors, as well as with experts from the Ministry of Agriculture and the Ministry of National Economy. Their feedback is important in testing whether the research findings are realistic.

Phase 7: Discussion, conclusions, and roadmap: During the discussion part of the process, the advantages and disadvantages of embracing a circular economy mindset as a medium-term strategy are explored, while Kazakhstan and the rest of the world navigate the sustainable energy transition. Finally, a roadmap is developed to help enable the transition from the 'business as usual' to the 'to-be' situation. It is, however, not a long-term strategy for Kazakhstan's agricultural sector, say beyond 2040, because natural resources are finite, and they are the main source of global climate change, and contribute to air and soil pollution.

2.4 Data collection

Although the above-described tools provide an overview of the degree of circularity and an overview on the impact of the proposed system, they do not cover many essential aspects about how to achieve this. In addition, they do not provide operational or practical guidance for industrial practitioners. Therefore, several additional methods are used during the qualitative phenomenological approach as a means of collecting primary data, including gathering data from primary sources through conversations. An "insider" perspective on this subject is collected from local experts from the national oil and gas company "KazMunaiGas", Ministry of Energy, and Ministry of Agriculture. However, as Kazakhstan lacks experience in applying circular economy principles, it is important to explore the research topic from the perspectives of foreign industries that have successfully applied this concept. Therefore, conversations are held with foreign experts, who are able to provide a deeper understanding of this subject. The qualitative research method complimented with gathering data from primary sources is regarded as an appropriate approach as it effectively brings to the fore the ideas and experiences of the individuals, and as such could challenge normative assumptions (Creswell & Creswell, 2018). Adding a personal interpretive dimension to the phenomenological research would enable the research project to be used as the basis for practical theory (Creswell & Creswell, 2018).

The secondary data are collected from already printed or publicly available sources:

- Databases (e.g., The World Bank);
- Research reports carried out by research institutions (e.g., The Observatory of Economic Complexity);
- Published government and company reports.

2.5 Limitations

The flexibility of the phenomenological research approach could be a potential limitation, as it allows adding a personal interpretive dimension to the research (Miller & Salkind, 2002). This implies that the researcher should be able to "bracket his own preconceived ideas of the phenomenon and understand it through the voices of informants" (Miller & Salkind, 2002). Nevertheless, applying the triangulation of multiple sources of evidence helps to ensure the validity of the findings. Thus, assumptions were tested and backed up through conducting calculations, and the feedback from field experts helped to verify that the research findings are realistic and valid. As such, the method applied provides a solid basis for reliable results.

Furthermore, as Kazakhstan's government has legally binding international commitments on economy-wide climate change goals, such as Paris Agreement and Kyoto Protocol, it would be sensible for the projected 'to-be' situation to include the minimum expected policy and technology assumptions necessary to meet current and future obligations. This leads to another limitation: it is impossible to account for all the possible transformational changes and changes in technology that might significantly alter the trajectory of the future system. Thus, due to the fact that this research project is conducted at a master's level, and has restricted scope, there is not enough time in order to explore wide range of scenarios. As such, the projections are quantified based on the existing business practices, and social, technological, and policy norms.

Finally, the assumptions made for conducting calculations have been collected from credible sources and verified by the field experts. As such, the data used in the calculations is based on plausible assumptions. Thus, final estimations represent realistic rather than arbitrary results. However, the results may be not as valid as the results achieved using other data collection and analysis methods, which allow the researcher to examine the topic in a more comprehensive way. It is important to note that although the data gathered in the assessment is fact-based, there is a room for estimation error.

CHAPTER III: FINDINGS

3.1 Introduction

This section puts the methodology in Chapter II into action. First, the 'business as usual' situation is presented towards 2030 and in line with the "Kazakhstan-2030" strategy. The next section discusses the envisioned 'to-be' situation, where the two circular economy ideas between parts of the oil and gas and wheat production sectors in Kazakhstan are explored. The final section estimates the sustainability impact of circular economy ideas, both qualitatively and quantitatively across the entire logistics value chain of wheat production in Kazakhstan. Selected field experts are consulted to test whether the findings are realistic.

3.2 The 'business as usual' situation

As discussed in Section 1.2.3, the potential for growth in the agricultural sector in Kazakhstan is very large (Trading Economics, 2018). Especially the growing of wheat has enormous potential. In 2017 Kazakhstani wheat production totaled 14.8 million MT[7], a slight decline from 2016 (Lyddon, 2016). The reasons for this slight decline are two-fold: 1) foreign entities are not allowed to own land in Kazakhstan, and 2) until recently, Dostyk, the only rail border crossing between Kazakhstan-China, had reached full capacity. Dostyk is located in a narrow mountain pass and has limited or no capacity expansion potential. In 2016, wheat exports amounted to 7.4 million MT, mainly to Russia, Iran and China (US Department of Agriculture, 2018).

These two limitations have now been largely addressed. Starting in January 2019, foreign entities will be allowed to invest in Kazakhstan's agricultural sector through Special Purpose Vehicles (SPVs) registered with the Astana International Financial Centre.[8] A second rail border crossing was opened in 2017 in Khorgos on Kazakhstan's southeastern border (Khorgos Gateway, 2018). Currently the largest dry port in the world, the Khorgos Gateway provides an alternative export route for Kazakh wheat and other products to China. Figure 3.1 shows the Central Asia region and the location of the Dostyk and Khorgos rail crossings.

[7] Tonne or metric ton (MT) equals 1,000 kg.
[8] Astana International Financial Centre (2018), also known as AIFC, is Kazakhstan's financial hub for capital markets and the finance industry.

Figure 3.1. Regional Map of Kazakhstan.

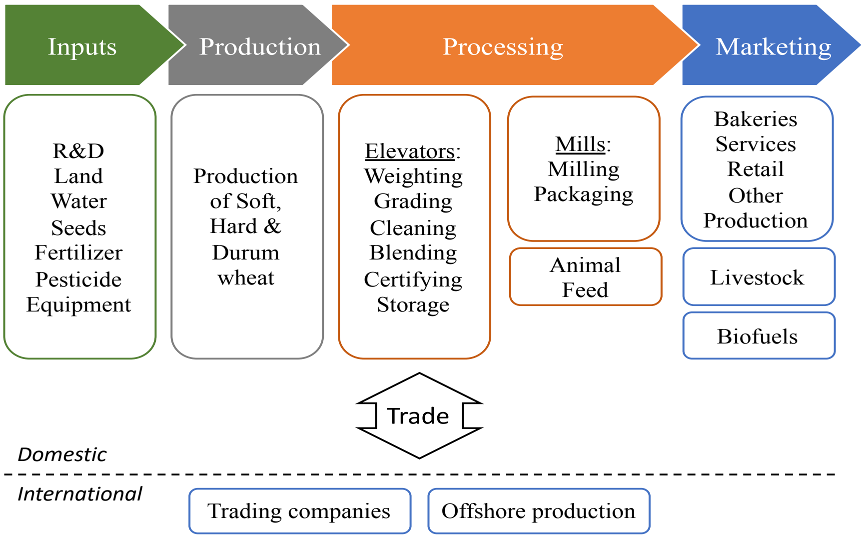
With these challenges addressed, there is no reason why Kazakhstan should not be able to scale its production of wheat in line with its "Kazakhstan-2030" strategy. Although developed before the Paris Agreement came into effect, it is believed that scaling agricultural production in Kazakhstan will help the country reach its sustainability commitments. Wheat production in Kazakhstan is concentrated in the north of the country (Akmola and Kostanay regions) along the Russian border, where population density is low, water availability for irrigation is high, and the soil and climate are ideal for growing crops such as wheat, barley, rice, and corn. This part of the country has enormous potential to increase production of wheat and other agricultural crops. For example, according to the Kazakh Ministry of National Economy (2018), wheat crop yields in this part of the country range between 12 and 14.5 t/ha,[9] whereas in western Kazakhstan is between 7 and 9 t/ha. For this project's analysis, an average wheat yield of 13 t/ha (2 harvests per year) will be used,[10] which is in line with global averages (Strutt & Parker, 2013).

The wheat production value chain is organized around inputs, production, processing, and the marketing of flour. Unprocessed wheat is traded both domestically and abroad (Figure 3.2). For the analysis of this paper, inbound logistics (transporting inputs to the land), production (the use of agricultural machinery to grow and harvest the crops), and outbound logistics (transporting harvested wheat to Kokshetau, from where it is transported via rail for export to

[9] Tonnes per hectare equals 100 grams per square meter.
[10] Note that crop yields could vary significantly from year to year because of weather events.

China via the Khorgos dry port) are considered. It is in these areas where the most important sustainability gains can be made between parts of the oil and gas sector and wheat production based on circular economy principles.

Figure 3.2. The Wheat Value Chain (Duke University, n.d.).



Kazakhstan wants to increase wheat production from the current (2017) 14.8 million MT per year to almost 17.4 million MT by 2030. Most of the production is destined for exports to China, which is expected to grow from the current (2017) 1.6 million MT per year to 4.6 million MT per year by 2030 (World Integrated Trade Solution, 2018). China is a net food importer and can easily absorb this increase in supply from Kazakhstan. Domestic consumption is also expected to increase in line with population growth and rising income levels, from the current (2017) 6.9 million MT to 7.7 million MT by 2030. Assuming a constant yield of 13 t/ha, this implies that Kazakhstan will need to increase the size of land for wheat production from the current (2017) 1.15 million hectares to 1.34 million hectares by 2030 if it is to meet planned levels. This is summarized in Table 3.1.

Table 3.1. Wheat Production in Kazakhstan to 2030.

	2017	**2018**	**2030**
Wheat production (million MT)	14.8	14.0	17.4
Yield (t/ha)	13.0	13.0	13.0
Land used (million ha)	1.14	1.08	1.34
Export to China (million MT)	1.6	2.0	4.6
Domestic consumption (million MT)	6.9	6.9	7.7

According to the Sulphur Institute (2018), sulphur is one of the four major plant nutrients, which helps to improve yields and contribute to more nutritious foods. To avoid sulphur deficiency due to leaching, soils in Akmola and Kostanay regions need to be supplied with sulphur (Agriculture and Horticulture Development Board (AHDB), 2014).[11] Sulphur for the agricultural sector is currently imported from Turkmenistan and Russia. Sulphur imports from Turkmenistan are designated for southern Kazakhstan, while Russia supplies northern Kazakhstan, primarily due to its proximity (Trading Economics, 2018b). Sulphur from Russia arrives in Kazakhstan in the northwestern city of Uralsk. From there it is transported by diesel trucks to Kostanay via Aktobe, a 1,252 km[12] trip (Figure 3.3).

Figure 3.3. Wheat Production in Kazakhstan: The 'Business as Usual' Situation.

Sulphur fertilization, in a mix with other nutrients, has shown to improve winter wheat yields by 7.7% to 45.5% (Jarvin et al., 2008). Sulphur fertilization also helps reduce the formation of acrylamide, a processing contaminant that can form during the cooking and processing of wheat (AHDB, 2014). To avoid sulphur deficiency, the AHDB (2014) recommends applying 50 kg of SO_3/ha or 20 kg of S/ha. Given the wheat production objectives, between 22,769 MT in 2017 and almost 27,000 MT of sulphur will need to be imported from Russia in 2030. Based on these volumes, the distance between Uralsk and the wheat production area, and a 25 MT load factor, between 911 truckloads in 2017 and 1,071 truckloads in 2030 of sulphur will

[11] The AHDB has no stake in sulphur profits. Instead its objectives are increased wheat production in Kazakhstan. Therefore, if potential sulphur overuse would be observed, the AHDB will likely revised its recommendation.
[12] Note that 1 kilometer = 0.62 US miles.

be needed. Assuming a diesel fuel economy of 40 l/100 km,[13] between 91 (2017) and 107 (2030) million liters[14] of diesel will be needed to transport sulphur to Kostanay, where it will be prepared for sulphur fertilization.

Based on the Dutch TLNplanner, it is possible to calculate the CO_2 and NO_X emissions of a Euro V[15] emissions compliant truck (TLN Planner, n.d.). Another source of useful information about emissions from heavy-duty trucks is the International Council on Clean Transportation (ICCT, 2016). Euro V compliant heavy-duty trucks are expected to emit 930 g/km of CO_2 and 4.6 g/km of NO_X respectively when using diesel fuel refined from petroleum. This translates into 2,141 MT (2017) and 2,495 MT (2030) of CO_2 and into 10.5 MT (2017) and 12.3 MT (2030) of NO_X emissions, respectively.

Wheat farms in Kazakhstan tend to be very large, and controlled traffic farming[16] (CTF) is used to minimize soil compaction. CTF allows for a 23% reduction in diesel fuel consumption (Gasso, et al., 2014). In Kazakhstan, an average of 36 l/ha of diesel is used per harvest, or a total of 83 million liters in 2017 and a projected 96 million liters by 2030. Based on these projections, wheat production contributes 1,906 MT (2017) and 2,242 MT (2030) of CO_2 and 9.4 MT (2017) and 11.1 MT (2030) of NO_X emissions, respectively. These GHG emissions are in line with what Sorenson et al. (2014) found in a large-scale study of energy inputs and GHG emissions of tillage systems.

Harvested wheat is transported by road trucks to a large distribution centre located in Kokshetau, from where it is transported via rail to Khorgos Dry Port and on to China. In this paper, only the sustainable challenges and solutions of transportation to Kokshetau are considered (Figure 3.3). The average distance to transport wheat to the distribution centre in Kokshetau is 195 km, and given the large volume of wheat, 64,000 (2017) and 184,365 (2030) 25 MT truckloads are needed for the two annual harvests. This translates into 23,213 MT (2017) and 66,869 MT (2030) of CO_2 and into 115 MT (2017) and 331 MT (2030) of NO_X emissions, respectively. The summary of the emissions results of the ‘business as usual’

[13] Or 0.047 US miles per gallon (mpg).
[14] Note that 1 liter = 0.264 US gallons.
[15] European emission standards were introduced in 1991 for cars and commercial vehicles. Euro V compliant trucks, the second most stringent emission standard currently in place in the EU, are being phased in in Kazakhstan.
[16] Controlled Traffic Farming refers to a farming management approach used to limit the soil compaction caused by the heavy agricultural machinery, which involves separation of crops and wheels (CTF Europe, 2013).

situation is provided in Table 3.2 below. See Appendix C for detailed calculations of the 'business as usual' situation.

Table 3.2. Summary of Emissions, 'Business as Usual' Situation

All results in MT	**2017**	**2018**	**2030**
Sulphur transport, CO_2	2,121	2,006	2,495
Sulphur transport, NO_X	10.5	9.9	12.3
Wheat production, CO_2	1,906	1,803	2,242
Wheat production, NO_X	9.4	8.9	11.1
Wheat transport, CO_2	23,213	29,016	66,869
Wheat transport, NO_X	115	144	331
Total CO_2 emissions	27,240	32,825	71,605
Total NO_X emissions	135	162	354

3.3 The 'to-be' situation

In the "to-be" situation, the objective is to make wheat production more sustainable along its entire logistics value chain by leveraging circular economy principles. The oil and gas sector generates a lot of waste, some of which could be turned into an input along the value chain of wheat production. The 'to-be' situation explores two such ideas. See Appendix D for detailed calculations of the 'to-be' situation.

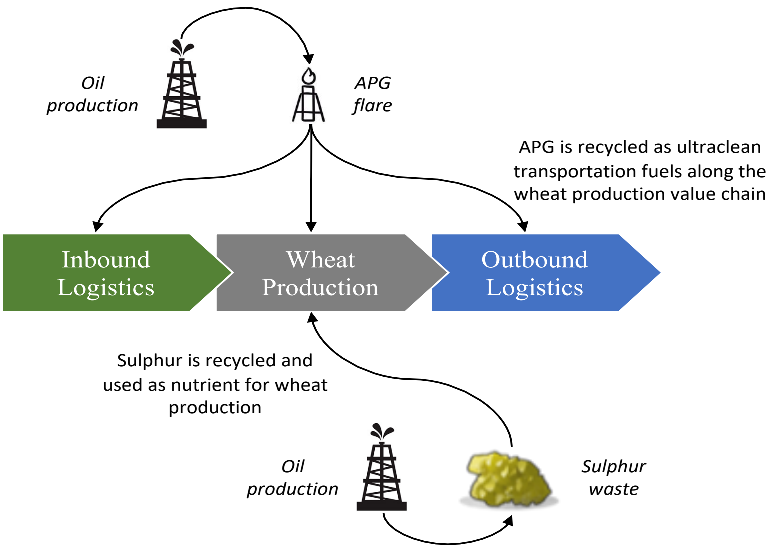
The first circular economy idea is to use domestic sulphur instead of importing sulphur from neighboring Russia. The Tengiz supergiant oil field generates about 4,500 tons of sulphur as a by-product of oil production (Hydrocarbons Technology, 2018). This sulphur is stored in open-air blocks. In large quantities, sulphur can have serious health effects on both humans and animals, including vascular damage in veins of the brain and the heart (Lenntech, 2018). In addition, these large sulphur piles lead to soil acidification and groundwater contamination (Environmental Regulatory Service, 1996). Instead of storing sulphur in large open-air blocks, it could be transported to Kostanay for use in sulphur fertilization.

The second circular economy idea is to convert APG into ultraclean diesel for transportation along the wheat production value chain. APG, a waste by-product from oil production, is often flared, which contributes significantly to global climate change. Instead, APG can be converted into ultraclean diesel using the gas-to-liquids (GtL) process. When using GtL diesel fuel, instead of diesel derived from petroleum, there are several benefits:

1. A waste by-product of petroleum production is no longer flared, thereby reducing CO_2 emissions by 13 g per cubic meter of natural gas that is converted into GtL diesel fuel (Pieprzyk & Hilje, 2015).
2. Use of GtL diesel fuel reduces CO_2 emissions by 5% (Hassaneen, et al., 2012) and NO_X emissions by 14.8% (Bassiony et al., 2016). Particulate matter (PM) is also dramatically reduced, further contributing to cleaner and healthier air.

Appendix B shows the extent of APG flaring and open-air sulphur deposits from the Tengiz oil field, located near Beneu at the Caspian Sea, which are the yellow stockpiles at the top-left of the picture. Figure 3.4 shows a simplified system thinking diagram illustrating the circular flows between parts of the oil and gas sector and wheat production.

Figure 3.4. Simplified System Thinking Diagram Showing Circular Flows between Parts of the Oil and Gas Sector and Wheat Production.



In the 'to-be' situation, instead of importing sulphur from Russia via Uralsk, it would be recovered from the open-air blocks at the Tengiz field and transported to Kostanay for sulphur fertilization for wheat production. The distance between Beneu and Kostanay is 1,527 km versus 1,252 km between Uralsk and Kostanay. Sulphur from the Tengiz field would have to be hauled over a longer distance of 275 km (Figure 3.5).

Figure 3.5. Wheat Production in Kazakhstan: The 'To-Be' Situation'

Given the wheat production objectives, which are the same as in the 'business as usual' situation, between 22,769 MT in 2017 and almost 27,000 MT in 2030 of sulphur would need to be transported. Based on these volumes, the distance between Beneu and the wheat production area, and a 25 MT load factor, between 911 truckloads in 2017 and 1,071 truckloads in 2030 of sulphur are needed (same number of truckloads as in the 'business as usual' situation).

Euro V compliant heavy-duty trucks are expected to emit 884 g/km of CO_2 and 3.9 g/km of NO_X when using diesel fuel converted from APG via the GtL process. This translates into 2,587 MT (2017) and 2,447 MT (2030) of CO_2 and into 12.8 MT (2017) and 12.1 MT (2030) of NO_X emissions, respectively. During the early years (2018 and 2019), diesel fuel refined from petroleum would be used, which has higher CO_2 and NO_X emissions, because the CompactGtL technology to convert APG into ultraclean diesel will become operational only at the start of 2020.

Given the amount of land that needs to be used to grow wheat, a total of 83 million liters in 2017 and 96 million liters by 2030 of diesel fuel would be required. Based on these projections, wheat production contributes 1,906 MT (2017) and 2,129 MT (2030) of CO_2 and 9.4 MT (2017) and 8.9 MT (2030) of NO_X emissions, respectively.

Harvested wheat is transported by road trucks to a large distribution center located in Kokshetau, and from there it is transported via rail to Khorgos Dry Port and to China. The average distance to transport wheat to the distribution center in Kokshetau is 195 km, and given the large volume of wheat, 64,000 (2017) and 184,365 (2030), 25 MT truckloads are needed for the two annual harvests. This translates into 23,213 MT (2017) and 63,526 MT (2030) of CO_2 produced and into 115 MT (2017) and 282 MT (2030) of NO_X emissions, respectively.

In addition to using cleaner transportation and wheat production fuels, there are important CO_2 abatement benefits from converting APG into diesel, instead of flaring it. As mentioned above, flared APG contributes to global climate change in an important way. For every cubic meter of APG converted into diesel, 13 g of CO_2 does not enter the atmosphere for a total of 8,934 MT of CO_2 abatement in 2030. Given that NO_X abatement from reduced flaring because of GtL conversion is negligible, it has not been estimated. The summary of the emissions results of the 'business as usual' situation is provided in Table 3.3 below.

Table 3.3. Summary of Emissions, 'To-Be' Situation

All results in MT	**2017**	**2018**	**2030**
Sulphur transport, CO_2	2,587	2,447	2,890
Sulphur transport, NO_X	12.8	12.1	12.8
Wheat production, CO_2	1,906	1,803	2,129
Wheat production, NO_X	9.4	8.9	7.1
Wheat transport, CO_2	23,213	29,016	63,526
Wheat transport, NO_X	115	144	282
CO_2 abatement, GtL conversion	0	0	8,934
NO_X abatement, GtL conversion	N/A	N/A	N/A
Total CO_2 emissions	27,705	33,266	59,612
Total NO_X emissions	137	165	304

3.4 The sustainability impact

The sustainability impact has focused on the areas where material sustainability gains are expected to be realized. Table 3.4 contrasts the key assumptions used in the 'business as usual' situation versus the 'to-be' situation.

Table 3.4. Contrasting the 'Business as Usual' and the 'To-Be' Situation.

		'Business as usual'	'To-be'
	Production in 2030	17.4 million MT	17.4 million MT
	Export to China in 2030	4.6 million MT	4.6 million MT
	Domestic use in 2030	7.7 million MT	7.7 million MT
Inbound logistics			
	Seeds source	Produced locally	Produced locally
	Water source	Available locally	Available locally
	Sulphur source and truckloads in 2030	Imported from Russia via Uralsk. 1,071 truckloads	Recovered from Tengiz sulphur waste piles
	Sulphur quantity in 2030	26,780 MT	26,780 MT
	Sulphur transport to agricultural land	Uralsk/Aktobe: 475 km Aktobe/Kostanay: 777 km Total: 1,252 km	Beneu/Aktobe: 750 km Aktobe/Kostanay: 777 km Total: 1,527 km
	Diesel fuel	Refined from crude oil	Recovered from APG
	CO_2 emissions (g/km)	930	884 (starting 2020)
	NO_X emissions (g/km)	4.6	3.9 (starting 2020)
Wheat production			
	Land used in 2030 (million ha)	1.34	1.34
	CO_2 emissions (g/ha)	1,674	1,590 (starting 2020)
	NO_X emissions (g/ha)	8.3	7.1 (starting 2020)
Outbound logistics			
	Wheat transport	195 km	195 km
	Truckloads in 2030	184,365	184,365
CO_2 abatement, GtL conversion			
	Bcm of APG needed in 2030	N/A	0.33
	CO_2 abatement (g/cubic meter)	N/A	27
	Total CO_2 abatement in 2030	N/A	8,934 MT

The results are largely positive, but unanticipated to some degree. Considering only CO_2 and NO_X emissions, it seems that recovering sulphur from the Tengiz field and transporting it to Kostanay does not make sense due to the longer distance (+22.0%) and that the benefits (CO_2: -5.0%, and NO_X: -14.8%) of using diesel derived from APG instead of from petroleum are not large enough to offset the longer distance.

However, this reasoning has an important flaw, because converting APG into diesel, instead of flaring it, abates CO_2 emissions in an important way. This indirect effect from turning waste into an input into the wheat production value chain is not included in the sulphur transport CO_2 reductions, but as a separate CO_2 abatement calculation. In addition, using sulphur for soil fertilization reduces the environmental and health impacts in a potentially material way. Given that these benefits are difficult to calculate they have not been estimated, but they should not be ignored.

However, the benefits from using GtL diesel fuels in both wheat production and wheat transportation (outbound logistics) are quite significant. Cumulative CO_2 emissions covering the 2018-2030 period are reduced by 4.3% for wheat production and by 4.5% for wheat transport. Alternatively, cumulative NO_X emissions during the same period are reduced by 12.7% for wheat production and by 13.4% for wheat transport. Finally, the potential cumulative CO_2 abatement (2018-2030), from capturing APG and converting it into ultraclean transportation fuels, is significant and amounts to 61,367 MT.

Overall, covering inbound logistics, wheat production, outbound logistics and abatement, cumulative CO_2 emissions are reduced by 13.0% from 650,595 to 566,058 MT, while cumulative NO_X emissions are reduced by 12.5% from 3,218 to 2,817 MT. The sustainability benefits, estimated as cumulative CO_2 and NO_X, are summarized in Table 3.5 below. The calculation sheets are presented in Appendix C and D respectively.

Table 3.5. Sustainability Benefits of the 'business as usual' versus the 'to-be' Situation: Cumulative Results of CO_2 and NO_X, 2018-2030.

All results in MT	**'Business as usual'**	**'To-be' situation**	**Difference (MT)**	**Difference**
Sulphur transport, CO_2	28,915	33,747	4,832	+16.7%
Sulphur transport, NO_X	143	152	9	+6.4%
Wheat production, CO_2	25,982	24,863	1,119	-4.3%
Wheat production, NO_X	129	112	16	-12.7%
Wheat transport, CO_2	595,698	568,815	26,883	-4.5%
Wheat transport, NO_X	2,946	2,553	394	-13.4%
CO_2 abatement, GtL conversion	0	-61,367	-61,367	N/A
NO_X abatement, GtL conversion	N/A	N/A	N/A	N/A
Total CO_2 emissions	650,595	566,058	-84,537	-13.0%
Total NO_X emissions	3,218	2,817	-401	-12.5%

During conversations with experts from Agromash, an agricultural machinery manufacturer in Kazakhstan, it was confirmed that the objectives are achievable and that the assumptions and results are realistic. These are all key stakeholders and involving them early on would improve the chances of implementing these circular economy solutions.

As discussed in Section 2.3, the Centre for Industrial Sustainability at Cambridge University's Institute for Manufacturing developed the Circular Economy Toolkit (CET). The CET has been designed for manufacturers, retailers, distributors, consumers, and purchasers, and thus can be applied to the two circular economy examples explored in this project. CET comprises 33 trinary-based questions, applies lifecycle thinking, and also assesses the associated business opportunity, such as financial viability and market growth potential (Circular Economy Toolkit, 2018). Table 3.6 summarizes the overall findings from applying the CET.

a) Recover sulphur, a by-product from the Tengiz oil field, and use it as a fertilizer:

- Design, manufacture, and distribute: Medium-High. Sulphur, a waste by-product of the Tengiz could be recovered for crop fertilization. In addition, sulphur could be distributed more efficiently to where it is used. For example, the use of rail instead of truck transport would reduce diesel consumption, but not sulphur consumption.
- Usage: Medium. Proper sulphur fertilization practices (e.g., the timely application of sulphur during the plant growth phase) could reduce the quantity of sulphur needed per hectare of land.
- Maintain/Repair: Low-Medium. Proper soil maintenance could reduce the quantity of sulphur needed per hectare of land.
- Reuse: Low. Once used on the land for fertilization, sulphur cannot be recovered for reuse.
- Refurbish/Remanufacture: Low. Once used on the land for fertilization, sulphur cannot be refurbished/remanufactured anymore.
- Recycle: Low. Once used on the land for fertilization, sulphur cannot be recovered for recycling.

b) Capture APG, a by-product from oil production, and convert it into ultraclean transportation fuels using the Mini-GtL technology:

- Design, manufacture, and distribute: Medium. Use of more advanced mini-GtL technology in the future has the potential to improve the APG/diesel conversion yield.
- Usage: Medium. Adoption of more fuel-efficient trucks and agricultural machinery will reduce diesel consumption, and CO_2 and NO_X emissions.
- Maintain/Repair: Medium. Timely and preventative maintenance of trucks and agricultural machinery will reduce consumption.
- Reuse/Redistribute: Low. Once used as a fuel for transport and wheat production, diesel cannot be recovered for reuse.
- Refurbish/Remanufacture: Low. Once used as a fuel for transport and wheat production, diesel cannot be refurbished/remanufactured anymore.
- Recycle: Low. Once used as a fuel for transport and wheat production, diesel cannot be recovered for recycling.

Table 3.6. Applying the Circular Economy Toolkit.

Area	**Sulphur**	**APG**
Design, manufacture and distribute	**Medium - High**	**Medium**
Usage	**Medium**	**Medium – High**
Maintain/Repair	**Low – Medium**	**Medium**
Reuse/Redistribute	**Low**	**Low**
Refurbish/Remanufacture	**Low**	**Low**
Recycle	**Low**	**Low**
SUMMARY	**Medium**	**Medium**

The CET conclusions may seem counter-intuitive. After all, the circular economy is about reducing, reusing, and recycling waste. Both circular economy examples used in this paper reduce, reuse, and recycle waste, but they do not do that during the wheat production, and sulphur and wheat transportation process. Instead, the sulphur by-product from oil production is reused, reduced, and recycled as a crop fertilizer. Similarly, APG is reused, reduced, and recycled as ultraclean transportation fuel. This is consistent with the objectives of this project, and capture circular economy benefits between parts of the oil and gas industry and wheat production.

CHAPTER IV: DISCUSSION

4.1 Discussion

The method applied in Chapter III has assisted in achieving a better understanding of the consumption and use of resources, and in estimating the sustainability impact of exploring circular ideas between parts of the oil and gas sector and wheat production in Kazakhstan. Based on the findings, it is evident that the proposed ideas are more circular than the existing situation, and as such the proposed 'to-be' situation is more sustainable than the 'business as usual' situation. The findings demonstrate that important reductions of CO_2 (-13.0%) and NO_X (-12.5%) emissions can be realized by replacing diesel fuels from petroleum with ultraclean diesel fuel from APG, and by using the sulphur by-product from crude oil production as a key nutrient for wheat production.

According to Schaltegger and Ludeke-Freund (2012), "A business case for sustainability intends and realizes economic success through an intelligent design of voluntary environmental and social management." Therefore, the findings from this project demonstrate that there is a strong business case to engage a wide range of stakeholders to implement the proposed circular ideas between the country's two major economic sectors.

4.1.1 The five capitals and sustainability

As a result, the proposed circular ideas entirely dovetail with the "Five Capitals" framework offered by Jonathon Porritt (2005). The objective of sustainable development is to balance, maintain, and grow all five capital stocks simultaneously (Porritt, 2005; Van de Putte, Kelimbetov, & Holder, 2017):

Natural capital. Circular ideas proposed in this research paper contribute to sustainability leveraging natural capital by utilizing otherwise wasted natural resources. Sulphur deposits and APG emissions from intensive oil extraction and refining activities across the country have detrimental effects on human health and environment, and the possibility of using them as inputs in the agricultural value chain is proved to demonstrate significant results. Prof. Van de Putte (personal communication, July 30, 2018) states "countries which have a large endowment of natural resources should develop the endowment in an economic and environmentally sustainable way". He further adds that this is not the same as rent seeking, as countries should leverage their natural endowment, and use it to create sustainable competitive advantage (Prof. Van de Putte, personal communication, July 30, 2018).

Firstly, capturing and processing APG, which is otherwise flared or vented, will be used to provide affordable, environmentally-cleaner feedstock for ultraclean diesel to be used for transport and wheat production along the entire logistics value chain within Kazakhstan's agricultural sector, thereby reducing the need to use diesel from fossil fuels. Diesel trucks currently used in Kazakhstan's agricultural industry can accommodate APG diesel without any modifications, allowing for a quick switchover with no additional infrastructure investment required; thereby become the cleanest transportation mode in the country (Carbon Limits, 2013). Mini-GtL technology produces a clear liquid, which can run existing diesel engines, dramatically reducing hazardous pollutants associated with conventional petroleum diesel (Carbon Limits, 2013).

Diesel from natural gas is cleaner than conventional petroleum diesel fuel due to a cleaner, more environmentally friendly feedstock, and lower emissions are a result (e.g., lower CO_2, NO_x, and particulate matter) (Botkin & Keller, 2014). Therefore, there are four major benefits of capturing and processing APG into ultraclean, high-quality diesel: 1) the APG feedstock is cleaner and less polluting than petroleum feedstock, resulting in cleaner diesel fuel; 2) the fuel produced from mini-GtL is colorless and odorless, as they do not contain sulphur, nitrogen, and various aromatics that are present in petroleum; 3) hazardous waste is diverted as opposed to being released into the environment, and; 4) the proposed circular system captures and extracts commercial value out of otherwise wasted resources, making it economical to tap vast natural gas reserves.

Secondly, sulphur, which previously had no social and limited commercial value, will be used as an important crop nutrient for growing wheat. As mentioned, applying sulphur as a soil nutrient results in higher crop yields (The Sulphur Institute, 2018). Protein production and its quality, where sulphur plays a major role in supporting nitrogen in biological processes, are particularly important in wheat production for the greater volume and higher quality crop yields (Potash Development Association, 2017). As Mr. Shakenov (personal communication, July 18, 2018) notes, "in terms of its investment approach, Kazakhstan needs to diversify its investment portfolio in order to strengthen the sectors which are not related to oil and gas, and agriculture presents a perfect opportunity."

Therefore, the proposed circular ideas help to reduce the amount of waste, diverting waste from the oil fields, by converting them into feedstock to be used in the agricultural sector.

Not only does this help to make the transportation and operations of the agricultural industry more sustainable, but it also increases the value of finite gas and sulphur resources by reusing, and as such monetizing, previously wasted resources. Hence, the findings illustrate how utilization of a 'waste' from one industry as an 'input' in other industry can help maintain or increase the natural capital stock. These concepts are aligned with circular economy's "reduce, reuse, and recycle" principles.

Human Capital. Furthermore, the circularity ideas proposed in this paper contribute to sustainability by enhancing the human capital stock by creating additional and highly skilled jobs, thus leveraging the knowledge economy. For instance, converting APG into ultraclean diesel will require skills in building and operating mini-GtL technology. Therefore, employees will acquire skills and knowledge that will help to manage hazardous wastes produced from oil production and refining operations. This, in turn, leads to greater efficiency, thus enhancing the manufactured capital stock. Moreover, the farmers in Kazakhstan will practice utilizing sulphur as an important soil nutrient, as well as learn to "reduce the use of fertilizers and other chemicals" to produce wheat. As Dr. Sadykov (personal communication, July 28, 2018) notes, "it is important for the country to transform itself into a knowledge-based economy[17], where knowledge is a key driver of economic growth and productivity."

Social capital. Social capital is improved by creating better conditions for people as a result of diverting and capturing waste, thus reducing its impact on the environment. The solutions particularly address the needs of the local communities living in the oil and gas production regions, people with respiratory problems or weak immune systems, children, senior citizens, pregnant women, and other vulnerable groups. These people depend the most on clean air and clean groundwater, and are among the most vulnerable to increased exposure of pollutants.

Dr. Sadykov (personal communication, July 28, 2018) also notes that as industries are increasingly held responsible for social and environmental impacts along their value chain operations, one of the most important drivers of a given business case is the reduction of legal, political, societal, and environmental risks. National regulations are discouraging gas

[17] P. Drucker introduces the term "knowledge-based economy" in his *The Age of Discontinuity*, which refers to the economy, where knowledge is a valuable tool to enable a sustainable economy (Anderton, 2008).

flaring in oil fields and collecting sulphur as open-air deposits. Therefore, there is a strong financial incentive for oil and gas producers to implement gas capturing systems to collect and process gas from their oil production and refining operations, as well as use the vast amounts of the by-product sulphur.

In addition, application of the proposed circular ideas increases societal awareness of environmental issues, promotes wider application of the "reduce, reuse, and recycle" circular economy principles, helps people to better understand the consumption and use of resources, as well as the climate-changing impacts of current unsustainable practices. Moreover, it helps in identifying discrepancies in the current system, and might assist in directing future actions and policies in natural resource-rich countries, including Kazakhstan. It is also anticipated that circular economy concepts will be more readily applied to other sectors in Kazakhstan's economy and throughout Central Asia, as the research project is shared with a broad group of stakeholders.

Manufactured capital. Manufactured capital is enhanced given that new and advanced technologies will be acquired by the oil and gas sector in order to utilize natural gas in an economically and environmentally viable way. As noted by Prof. Van de Putte (personal communication, July 30, 2018), to make long-lasting use of natural resources, Kazakhstan should adopt innovative technologies and processes to make the extraction and use of natural resources more sustainable. Mini-GtL units can provide an outlet for APG that in other cases would have been flared, as well as produce high quality, saleable diesel fuels from natural gas that would otherwise be too expensive to process. Mini-GtL plants can be assembled onsite, from prefabricated modules to collect APG in remote areas, which is particularly useful in cases where no gas processing plant is located nearby and where the extracted natural gas would have been otherwise flared. Mini-GtL technology presents an economical solution for the production of high-quality, ultraclean transportation fuels.

Financial Capital. Given the positive economic multiplier of this project, financial capital will be enhanced as well. Applying circular economy ideas has the potential to increase GDP growth by 0.5 to 1.2% in Europe over the next 30 years (McKinsey & Company, 2015). In natural resource intensive economies such as Kazakhstan, this increase could be twice as large (McKinsey & Company, 2015). Circular economy ideas also contribute to the diversification of the economy. Furthermore, applying "reduce, reuse, and recycle" circularity principles between two major industries could result in significant cost savings with regard to responsible production approaches, and the development of new revenue streams. Moreover, it helps in scaling up wheat production in the agricultural sector, as such contributing towards increased food exports. Mr. Kussainov (personal communication, July 25, 2018) argues that Kazakhstan has a unique geo-strategic location given that it is situated at the center of Eurasia, providing convenient access to China, Russia, Europe, and the Middle East. China, for example, is a net food importer and needs high quality food, and Kazakhstan is uniquely located and has the agricultural potential to feed people in neighboring countries. Mr. Shakenov (personal communication, July 18, 2018) further adds that redirecting the purpose of operations to meet environmental, economic, and social needs could provide new areas of business development and opportunities, as a focus on sustainability encourages thinking in multiple dimensions. This unlocks the capability of both the agricultural and oil and gas industries to innovate, thus encouraging further national economic growth.

As such, capturing and processing both APG and sulphur allows Kazakhstan's economy to capture and benefit from the value-added diversification potential, generate significant economic benefits, create additional employment opportunities, increase the country's exports, and help achieve socio-economic sustainable development. Therefore, this project is helping to contribute to all the dimensions of the **triple bottom line** – the nexus of social, environmental, and financial performance measures.

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study explores the sustainability benefits between the oil and gas and agricultural sectors, and is important because they represent two major national economic sectors. The oil and gas industry is one of the largest contributors to the country's economic growth, while agriculture can potentially become another major contributor to the local economic growth, and also helps Kazakhstan to diversify its economy.

Moreover, this research project is unique given that circular economy ideas have not yet been widely applied in Kazakhstan, nor between the oil and gas and agricultural sectors, specifically. Although the circular economy has enormous potential for the sustainable development of the country, it is a new and practically unexplored concept in Kazakhstan.

The purpose of this research project was to explore the opportunities to reduce certain types of waste in the oil and gas industry, while scaling up wheat production, and making the country's agricultural sector more sustainable. This research project has explored how circular thinking could be incorporated between Kazakhstan's oil and gas sector and wheat production. As both agricultural and the oil and gas industries are big contributors across all dimensions of the value chain to global climate change, the research carried out in this project provides a valuable input about how to reduce the climate impact in both sectors by applying circular economy ideas. The goal has been reached through collecting the data, analyzing the industries, making assumptions, conducting a number of calculations, contrasting the 'business as usual' and the 'to-be' situation, as well as applying Cambridge University's Circular Economy Toolkit (CET), and developing a roadmap about how to achieve the 'to-be' situation. It was found that applying the proposed circular economy ideas between two major economic sectors contributed to substantial reductions in CO_2 (-13.0%) and NO_X (-12.5%) emissions, thus helping improve the country's sustainability.

However, clearly these will not be sufficient to completely offset the magnitude of the current unsustainable development challenges related to Kazakhstan's reliance on natural resources. The proposed combination of several circular feedback loops has the best potential to meet the main objectives of the circular economy concept, and to reuse, reduce, and recycle waste between parts of the oil and gas sector and agricultural sectors in Kazakhstan. In order to achieve the estimated results (that were demonstrated in Chapter III), it is essential for the country to increase its efforts in achieving sustainability, while diversifying from the oil and gas sector, and strengthening other economic sectors. Thus, this research project assists in illuminating pressing system failures within the nation's oil and gas sector, thereby challenging complacency and prompting further action. Moreover, the potential solutions explored in this research project might contribute to fostering commercial, social, and environmental sustainable development in Kazakhstan.

5.2 Roadmap

Applying sustainability contexts within Kazakhstan is currently in its adoption/early expansion stage. This research suggests that in order to have a functioning sustainability culture, Kazakhstan needs to accelerate progress in applying sustainable practices in order to capture additional value from wasted resources within its major economic sectors. State initiatives, such as a "National Strategy for Sustainable Development" and "Kazakhstan-2030" strategy play a significant role in improving the nation's sustainability ecosystem. The government should promote sustainability practices across the country by setting targets and proving tangible incentives. As such, the roadmap to 2030 to capture proposed circular opportunities could look as follows:

- Given that oil presents a key source of national income and is not going to be phased out in the near future, the government should provide all means and encourage effective utilization of APG and sulphur waste by-products produced by the oil and gas sector. As Prof. Van de Putte (personal communication, July 30, 2018) notes: "Kazakhstan needs to become a full value chain solution provider, capture high valued added from the oil and gas sector, and explore ways to make the sector more sustainable".
- It is important to understand that the proposed circular economy ideas create value for all stakeholders involved, including shareholders of the oil and gas and agricultural companies, employees in both sectors, participants in the associated supply chains, local communities, etc. Michael Porter introduced the concept of "shared value," arguing that companies can generate economic value by addressing social problems that overlap with their business (Porter & Kramer, 2011). Different groups in the

government, civil society, industry, and public sector have an important role in supporting the proposed circular model. Therefore, there is a need for a shared understanding of the challenges and opportunities as a foundation for further improvement. An open dialogue and efficient cooperation between different groups should be initiated and maintained at the local, regional, national, and international levels.

- It is essential to conduct a sustainability footprint[18] analysis with regard to APG emissions and sulphur production in order to understand how operations, processes, and policies in the petroleum industry impact the environment and local communities (e.g., collect APG venting statistics). There are various tools to measure the corporate sustainability footprint, including but not limited to: corporate greenhouse gas reporting guidelines, process mapping, life-cycle analysis, and activity inventory in the value chain (Farver, 2013). The results should be reported to representative institutions related to oil and gas production (e.g., Ministry of Energy and/or Ministry of Environmental Protection) and competent environmental agencies (e.g., United Nations Environment Programme).
- A strong legal framework should be developed and maintained to assist in implementing proposed circular ideas to avoid the possible legal evasion and manipulation of the provision of data. This includes: 1) clearly articulating consequences of APG flaring and venting in the Subsoil Use Law and the Ecology Code of Kazakhstan; and 2) regular monitoring and inspection of oil production fields conducted by competent agents to ensure compliance with required standards.
- Companies in the oil and gas sector should conduct business in a transparent way, and regularly report/publish their performance level in general relative to the expectations and mandate (i.e., reporting actual APG flares versus planned APG flares). Industry operations should be monitored and audited by more than one internationally recognized auditing company.
- Ideally, oil and gas companies should be obliged to utilize 'zero APG flaring and venting' technology to ensure complete avoidance of APG emissions. But due to the high costs of such equipment, it is suggested to employ technologies and methods to capture and process released APG emissions, as opposed to simply releasing it into the atmosphere.

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[18] From a corporate perspective, a sustainability footprint refers to "the complete inventory of company's activities, products, and services, and their impact on the environment and society" (Farver, 2013).

- The government should provide technical and financial support to oil and gas companies in acquiring mini-GtL technology to capture and process APG.
- The government should ensure that ultraclean diesel produced by mini-GtL plants is used along the entire logistics value chain in the national agricultural sector.
- The government should provide incentives for companies in the agricultural sector to actively utilize sulphur as a nutrient for wheat production.
- Public-private partnerships should be initiated between Kazakhstan's agricultural sector and foreign food importers (e.g., China) to increase wheat exports abroad.
- The government should undertake an extended communication and educational campaign to increase awareness among all participants in the associated value chains of both sectors. This will inform the participants about their role in the proposed circular model, explain which sustainable processes are involved, what is the legal framework, etc.
- It is crucial to undertake an extended educational campaign to raise awareness among the general public about sustainability. Such measures will help to change the public's behavioral model in relation to resources, energy, and food consumption. Education should be a priority area given that a sustainability ecosystem can only be achieved and sustained by a well-trained and educated population with proper skills.

The circular ideas proposed in this research project are not intended to be an ultimate solution to sustainability, but rather an interim strategy, as natural resources are finite, and present the main source of air and soil pollution in Kazakhstan. In essence, it would help the country to gain some time on the route to sustainability: reducing negative externalities in one industry and achieving its potential in another. This would also allow both industries to become more circular, and thus more sustainable.

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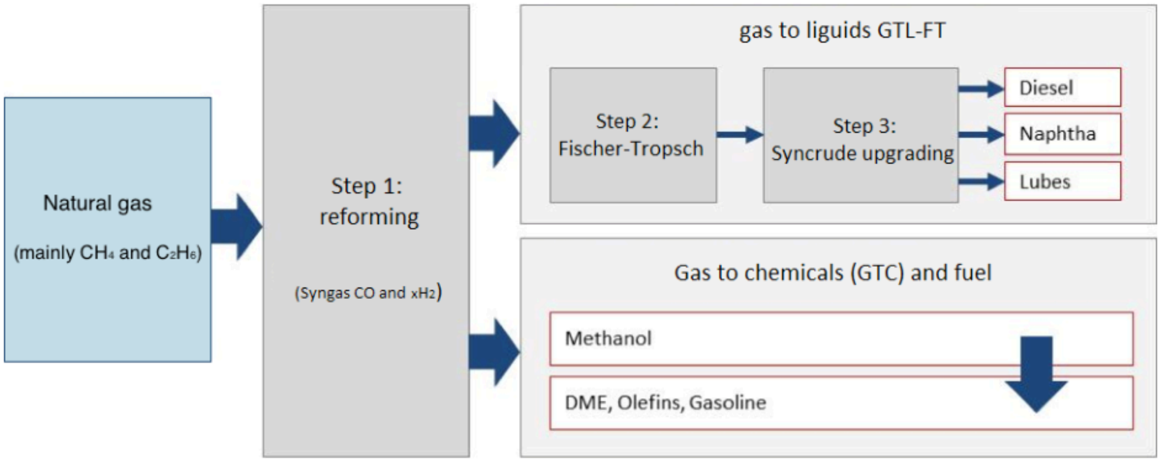
APPENDICES

Appendix A: The Fischer-Tropsch Process

Figure 1: Typical Conversion Routes for GtL Technologies (Carbon Limits, 2013).

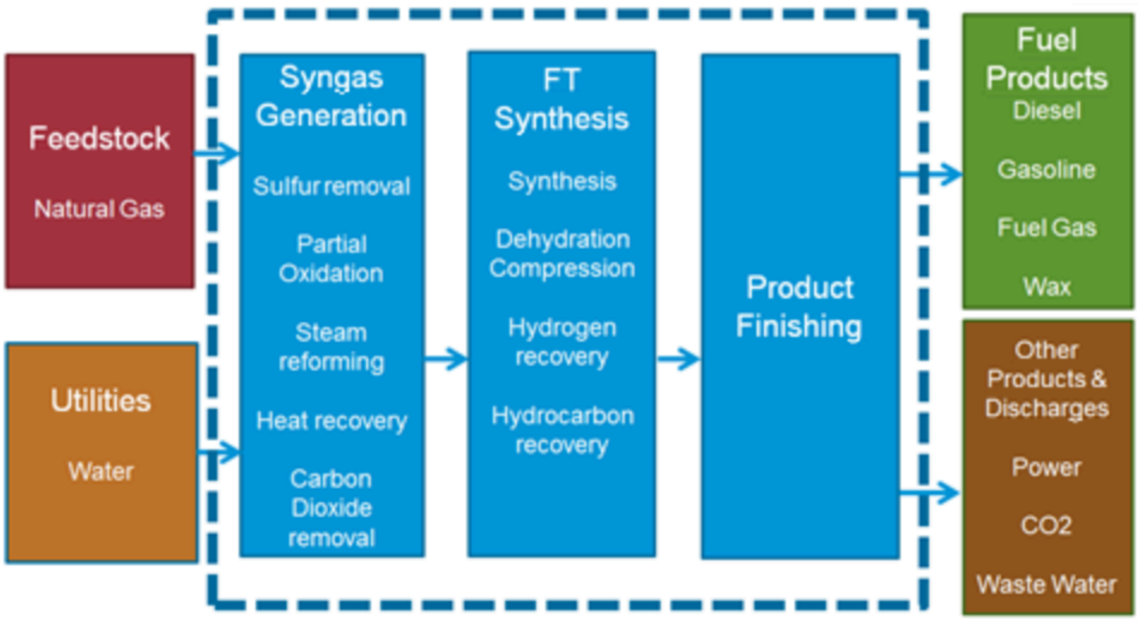


In the period between 2013 and 2015, considerable investments were poured into developing GtL technology as a result of cheap natural gas prices (driven by US shale gas exploration) versus record-high crude oil prices (Nichols, n.d.). As such, investors were attracted by the possibility of producing greater volumes of clean transportation fuel from cheap feedstock (Nichols, n.d.). However, Nichols (n.d.) argues that as soon as crude oil prices started falling, many large-scale commercial GtL projects lost their price competitiveness, and as such became unviable. Thus, as commercial-scale plants became no longer economical, the GtL market started developing smaller-scale and modular units – mini-GtL plants (Hamilton, 2008). Not only do mini-GtL plants require significantly lower capital costs as opposed to large-scale GtL plants, they can be rapidly constructed onsite from already pre-assembled materials, and this also allows the processing of natural gas in remote areas (Hamilton, 2008). Mini-GtL technology is relevant to this study, as it can provide an outlet for APG that else is flared or vented, in order to produce ultraclean diesel fuel from environmentally friendly natural gas that would otherwise be too expensive to process.

A gas to liquids mini-GtL technology goes through several steps to convert natural gas into end product (i.e., ultraclean diesel) (US Energy Information Administration, 2014). The most common GtL technique to turn natural gas to a liquid fuel is through Fischer-Tropsch synthesis (US Energy Information Administration, 2014).

In the first stage, natural gas is converted into a mixture of hydrogen, carbon dioxide, and carbon monoxide (i.e., synthesis gas regeneration) (US Energy Information Administration, 2014). Secondly, impurities, such as sulphur, water, and carbon dioxide are removed, to prevent catalyst contamination (US Energy Information Administration, 2014). The Fischer-Tropsch synthesis then combines hydrogen with carbon monoxide to form upgraded liquid hydrocarbons (Nichols, n.d.). Finally, these liquid products are processed using different refining technologies into high-quality liquid fuels (Hamilton, 2008).

Figure 2: Fischer-Tropsch Process Components (US Energy Information Administration, 2014).



Appendix B: The Tengiz Field

Figure 1. The Tengiz Field (Sicim, n.d.)

Appendix C: The ‘business as usual’ Situation Calculations

Business as Usual Situation	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Wheat production (million MT)	14.0	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	16.7	17.1	17.4
Yield, 2 harvests per year (MT/ha)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Land used (million ha)	1.08	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.24	1.26	1.29	1.31	1.34
Export to China (million MT)	2.0	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.1	4.3	4.6
Domestic consumption (million MT)	6.9	6.9	7.0	7.0	7.1	7.2	7.3	7.3	7.4	7.5	7.5	7.6	7.7
Sulphur Transport													
Sulphur fertilizer needed (kg/ha)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Sulphur quantity needed annually (MT)	21,538	21,538	21,969	22,409	22,857	23,314	23,780	24,256	24,741	25,236	25,740	26,255	26,780
Capacity per truck (MT)	25	25	25	25	25	25	25	25	25	25	25	25	25
Truckloads needed	862	862	879	896	914	933	951	970	990	1,009	1,030	1,050	1,071
Distance - one way (km)	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252	1,252
Diesel consumption (l/100 km)	40	40	40	40	40	40	40	40	40	40	40	40	40
Total volume of diesel (million l)	86	86	88	90	92	93	95	97	99	101	103	105	107
CO_2 emissions g/km	930	930	930	930	930	930	930	930	930	930	930	930	930
Total CO_2 emissions (MT)	2,006	2,006	2,046	2,087	2,129	2,172	2,215	2,259	2,305	2,351	2,398	2,446	2,495
NOx emissions (g/km)	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Total NOx emissions (MT)	9.9	9.9	10.1	10.3	10.5	10.7	11.0	11.2	11.4	11.6	11.9	12.1	12.3
Wheat Production													
Diesel consumption, 2 harvests (l/ha)	72	72	72	72	72	72	72	72	72	72	72	72	72
Total volume of diesel consumed (million l)	78	78	79	81	82	84	86	87	89	91	93	95	96
CO_2 emissions (g/ha)	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674	1,674
Total CO_2 emissions (MT)	1,803	1,803	1,839	1,876	1,913	1,951	1,990	2,030	2,071	2,112	2,154	2,198	2,242
NOx emissions (g/ha)	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Total NOx emissions (MT)	8.92	8.92	9.10	9.28	9.46	9.65	9.85	10.04	10.24	10.45	10.66	10.87	11.09
Wheat Transport													
Distance, export - one way	195	195	195	195	195	195	195	195	195	195	195	195	195
Truckloads needed	80,000	80,000	88,440	97,076	105,913	114,955	124,206	133,671	143,355	153,261	163,395	173,761	184,365
Total volume of diesel, export (million l)	1,248	1,248	1,380	1,514	1,652	1,793	1,938	2,085	2,236	2,391	2,549	2,711	2,876
Total CO_2 emissions, export (MT)	29,016	29,016	32,077	35,210	38,415	41,694	45,050	48,483	51,995	55,588	59,263	63,023	66,869
Total NOx emissions, export (MT)	144	144	159	174	190	206	223	240	257	275	293	312	331
GRAND TOTAL CO_2 (MT)	**32,825**	**32,825**	**35,962**	**39,173**	**42,457**	**45,817**	**49,255**	**52,772**	**56,370**	**60,051**	**63,815**	**67,666**	**71,605**
GRAND TOTAL NOx (MT)	**162**	**162**	**178**	**194**	**210**	**227**	**244**	**261**	**279**	**297**	**316**	**335**	**354**

Appendix D: The 'to-be' Situation Calculations

To-be Situation	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Wheat production (million MT)	14.0	14.0	14.3	14.6	14.9	15.2	15.5	15.8	16.1	16.4	16.7	17.1	17.4
Yield, 2 harvests per year (MT/ha)	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Land used (million ha)	1.08	1.08	1.10	1.12	1.14	1.17	1.19	1.21	1.24	1.26	1.29	1.31	1.34
Export to China (million MT)	2.0	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.1	4.3	4.6
Domestic consumption (million MT)	6.9	6.9	7.0	7.0	7.1	7.2	7.3	7.3	7.4	7.5	7.5	7.6	7.7
Sulphur Transport													
Sulphur fertilizer needed (kg/ha)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Sulphur quantity needed annually (MT)	21,538	21,538	21,969	22,409	22,857	23,314	23,780	24,256	24,741	25,236	25,740	26,255	26,780
Capacity per truck (MT)	25	25	25	25	25	25	25	25	25	25	25	25	25
Truckloads needed	862	862	879	896	914	933	951	970	990	1,009	1,030	1,050	1,071
Distance - one way (km)	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527	1,527
Diesel consumption (l/100 km)	40	40	40	40	40	40	40	40	40	40	40	40	40
Total volume of diesel (million l)	105	105	107	109	112	114	116	119	121	123	126	128	131
CO_2 emissions g/km	930	930	884	884	884	884	884	884	884	884	884	884	884
Total CO_2 emissions (MT)	2,447	2,447	2,371	2,419	2,467	2,516	2,567	2,618	2,670	2,724	2,778	2,834	2,890
NOx emissions (g/km)	4.6	4.6	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Total NOx emissions (MT)	12.1	12.1	10.5	10.7	10.9	11.2	11.4	11.6	11.8	12.1	12.3	12.6	12.8
Wheat Production													
Diesel consumption, 2 harvests (l/ha)	72	72	72	72	72	72	72	72	72	72	72	72	72
Total volume of diesel consumed (million l)	78	78	79	81	82	84	86	87	89	91	93	95	96
CO_2 emissions (g/ha)	1,674	1,674	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590	1,590
Total CO_2 emissions (MT)	1,803	1,803	1,747	1,782	1,817	1,854	1,891	1,929	1,967	2,007	2,047	2,088	2,129
NOx emissions (g/ha)	8.3	8.3	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Total NOx emissions (kg)	8.9	8.9	7.7	7.9	8.1	8.2	8.4	8.6	8.7	8.9	9.1	9.3	9.4
Wheat Transport													
Distance, export - one way	195	195	195	195	195	195	195	195	195	195	195	195	195
Truckloads needed	80,000	80,000	88,440	97,076	105,913	114,955	124,206	133,671	143,355	153,261	163,395	173,761	184,365
Total volume of diesel, export (million l)	1,248	1,248	1,380	1,514	1,652	1,793	1,938	2,085	2,236	2,391	2,549	2,711	2,876
Total CO_2 emissions, export (MT)	29,016	29,016	30,473	33,449	36,494	39,610	42,797	46,058	49,395	52,808	56,300	59,872	63,526
Total NOx emissions, export (MT)	144	144	135	148	162	176	190	204	219	234	250	266	282
CO_2 abatement from GtL conversion													
Total diesel consumption (million l)	1,431	1,431	1,566	1,705	1,846	1,991	2,139	2,291	2,446	2,605	2,767	2,933	3,103
Barrels of diesel (million)			9.9	10.7	11.6	12.5	13.5	14.4	15.4	16.4	17.4	18.5	19.5
Bcm of APG needed			0.17	0.18	0.20	0.21	0.23	0.24	0.26	0.28	0.30	0.31	0.33
CO_2 abatement (g/cm)			17	18	19	20	21	22	23	24	25	26	27
Total CO_2 abatement (MT)			2,839	3,271	3,740	4,246	4,790	5,374	5,999	6,666	7,377	8,132	8,934
GRAND TOTAL CO_2 (MT)	**33,266**	**33,266**	**31,753**	**34,378**	**37,038**	**39,734**	**42,464**	**45,231**	**48,034**	**50,873**	**53,748**	**56,661**	**59,612**
GRAND TOTAL NOx (MT)	**165**	**165**	**153**	**167**	**181**	**195**	**210**	**224**	**240**	**255**	**271**	**287**	**304**