QATAR UNIVERSITY

COLLEGE OF ENGINEERING

TOWARDS QATAR NATIONAL VISION 2030: A DYNAMIC MODEL FOR SUSTAINABLE POLICY DEVELOPMENT

BY

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ABSTRACT

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Title: Sustainable Policies Development Towards Qatar Vision 2030

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Nowadays, most of the policies implemented are having a sustainability touch within them. To guide a policymaker essential tool like planning is required. For planning, it is necessary to address sustainable development goals (SDGs) to make a policy operative for the long term. Integrating modeling techniques with SDGs can help an organization or a country to make effective sustainability decisions. Qatar, as a country, is working towards the 2030 vision, in which Qatar aims to achieve the best and impressive results in the sector of economics and social human growth. At the same time, Qatar also aims for continuous development towards sustainability. The following thesis will be related to sustainable development goals with the integration of simulation software, VENSIM, to model and analyze different policies that Qatar can implement to hit the target of the 2030 vision by using a system dynamic approach. The research was carried out by generating different scenarios and comparing by altering the impact factors. It was deducted that a reduction in net migration by 50% will be beneficial, whereas a reduction of 25% on fuel export will reduce the annual CO_2 emission and opens the door for opportunities to diversify and sustain the economy. Another recommended policy is the utilization of energy production facilities based on biomass as a fuel. And lastly, a policy to shift energy production from oil and gas to renewable sources such as solar power will heavily reduce CO_2 emissions in Qatar.

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CHAPTER 1: INTRODUCTION

1.1 Background

From an environmental and economic perspective, a country needs to have simple knowledge regarding 17 SDGs and an enormous amount of analyzed data to sustain. The analyzed data assists the executives of the country in building a strategy that will help in the development of an established vision. Alongside this, the analyzed data also provides an emphasis on how different sectors of the country are progressing. Likewise, Qatar as a developing nation has an established vision and aims to achieve it by 2030 (Qatar Vision 2030, 2020). Through this vision, Qatar aims to withstand its environment by minimizing its environmental pollution, shifting its economical earnings which come from oil and gas to tourism and education, while providing top-level medical facilities to the people of Qatar.

The 2030 sustainable development agenda set by member states of the United Nations provides a perfect guide towards prosperity and peace on earth and the population existing within the earth. The agenda incorporates 17 SDGs which focus on integrated policies, improving the health and environment sector, preservation and limited use of resources, economic growth, and providing substantive support with an improves education culture. Concurrently, 17 SDGs strategies also work towards eliminating poverty & hunger, and gender inequality. (Department of Economic and Social Affairs, 2015)

The affordable and clean energy, SDG 7, promotes the desire for sustainable energy development, SED (Transforming our world: the 2030 Agenda for Sustainable Development. , 2015). Since the enforcement of SDG 7, sustainable energy development has been a vital share of sustainable development and international policy objective. To measure the progress of SED, it is essential to develop comprehensive and robust indicators (Gunnarsdottir, 2020). This set of progress measuring indicators will assist and promote policymakers to establish strategies which in result will mitigate environmental pollutants while approaching sustainable energy production. The significance of SED will be acknowledged once there will be a downward trend seen in injurious environmental pollutants and their respective health impacts (World Energy Council. World Energy Assessment: Energy and the Challenge of Sustainability, 2000).

The responsibility of the scientific community in reaching and understanding the SDG is very important, regardless of what the mental model considers. Encouragement towards research on sustainability and the instruments helps to achieve sustainability. These steps escalate and implement policies working on the protection of the environment, and sustaining an economic environment. The policies related to equity in sustainable development are still unable to prevent society from excess usage of limited fossil fuels (Walter Leal Filho, 2018).

The applications associated with SDGs modeling is massive. The modeling creates collaborations of different SDGs which can trigger conflicting results at times (Weitz, 2017). To explore these conflicts and overcome those, Pradhan (2017) had analyzed different SDG interactions identifying synergies and tradeoffs using data from 227 countries. To back this hypothesis, Heleen (2019) proposed the idea of using integrated assessment models for analyzing the collaborations/connections among different SDGs. This gives evidence of the contribution made by modeling incoherence and policy logic.

Similarly, progresses related to environmental aspects was coupled with industrial innovation and increasing energy access, while inequality and employment were still critical issues to be resolved (Nicolai, 2016).

The GCC nations continue to see booming rates of population, energy consumption, and economic growth (El-Katiri, 2014). Previously, it has been very advantageous for foreign companies to develop and establish businesses within the GCC region due to low energy prices, this resulted in an improved economy as well as a boom in energy demand (Bhutto, 2014). In the previous decade (2000-2010) the energy consumption by the GCC region went up by 74% (Ebinger, 2011) while from 2004-14 the annual energy consumption by the region rose to an average rate of 6.8% compared to the global average which was 1.8% (Alarenan & Gasim, 2019). However, the carbon dioxide emission by GCC nations in 2012 accounted for four times the world's average per capita (Al-Maamary, 2017). The dependency on gas and oil has been increasing which will result in affecting their economies as well as the exports (Al-Maamary, 2017). This upwards and increasing demand in the energy sector motivates the researchers to look forward to technologies with lower carbon emissions and at the same time sustain the development of an organization.

To seek more into different sources of carbon emissions, Nuri and Murat (2020) studied emission released from construction industries where they highlighted the major release of carbon from the construction supply chain process. Five countries were focused and the supplier associated with them were taken under consideration. Supplier's activities were decomposed ranging from energy use, transportation, and service provided, each activity was studied for the amount of carbon being emitted through the supply chain process. Later within the research, it was proposed that such countries shall implement strict policies when it comes to the selection of green suppliers. A similar study was conducted on industrial activities and activities linked to sustainable manufacturing, the results concluded that manufacturing sector were inefficient in copping up with eco-system whereas, industrial sector was labeled as 100% efficient (Gokhan Eglimez, 2013)

1.2 Research Objectives and Organization of the Thesis

The research was conducted for the following objectives:

1. To understand what national vision 2030 states and to understand its objectives.
2. Collect and Analyze past data for Qatar.
3. Validate and simulate the conceptual model in VENSIM.
4. Simulate net migration impact factor scenarios ranging from 25 to 100.
5. Simulate energy production impact factor scenario ranging from 25 to 100.
6. Simulation of scenario with net migration impact factor 25 and export impact factor of 25 in model 1. Model 2, simulation of net migration, export, energy production, and energy use all having an impact factor of 25.
7. Recommend if changing net migration impact factor to 25 will help Qatar to reduce its carbon emission as well as maintain its economy.

The thesis has been structured in a way that chapter 1 gives a brief introduction to what sustainable development goals are and the importance of sustaining the environment by shifting the economy to a knowledge-based economy. In chapter 2, past data were analyzed to capture and understand where Qatar is standing now and what sort of specific scenarios can be generated and modeled in VENSIM. Chapter 3 will highlight the problem statement of this thesis, describing the framework adopted within this thesis starting from problem definition, data collection, and its sources, building of the conceptual model, and validating the model. In the last chapter, chapter 4 will simulate different scenarios based on impact factor analysis and summarize the findings of this thesis and highlight some recommendations to help Qatar in reducing their emissions and sustaining the environment and economy.

CHAPTER 2: LITERATURE REVIEW

2.1 Sustaining by Change of Oil and Gas Economy to Knowledge-Based

The terminology ‘knowledge-based economy’ has been adopted and used in different concepts and contexts, where the meaning of the terminology was not altered within the academic research (Strożek, 2014). The terminology used in different forms depending on the addressing content such as, in some cases, it has been labeled as a knowledge-based economy, knowledge-based society, digital economy, knowledge society, network economy, new economy, intangible economy, and information economy. Drucker (2016) argues the coming society is considered to be a knowledge society and this hypothesis is backed by evidence that was collected in over 30 years. According to him, knowledge workers are going to be the most dominant group in the workforce and knowledge will be the essential resource. Besides, he describes three features of a knowledge-based economy: (1) borderless (i.e. travel and movement of knowledge will be much smoother when compared to money movement), (2) upward mobility (i.e. development of locals in the society will be easy and development of one can be achieved through formal education system), and (3) probability for success as well as a failure (i.e. knowledge is important but promoting and taking advantage of knowledge alone is not feasible and neither successful).

According to the Oxford Dictionary (2020), a knowledge-based economy is defined as an economic growth based on accessing the data and information, quantity, and quality of information available, rather than economic growth based on production.

In the development of the knowledge economy, six major aspects must be considered: information, human capital, innovation, education, employment, and communications technology (ICT). During the studying period of all these major aspects and while implementing these aspects towards shifting of economy, several challenges were faced. Those challenges were mainly related to human capital, where the employment rate of females was quite low even after getting educated and secondly, under the education sector the type and level of research being performed were not up to the satisfactory level.

Human capital is said to be the locomotive of human growth to acquire high-quality employees' human skills are obligatory (Becker. G, 2014). Knowledge workers can be used by individuals or firms to increase their efficiency (Guellec, 1996) (Vinding., 2006). Michie (2003) was able to correlate innovation with human capital positively within the firms in the UK. While Lopez (2012) was also able to correlate innovation capacity and human capital positively after using surveys from Spanish manufacturing and service firms as data (Siedschlag I, 2008).

ICT plays a vital role in enhancing the innovation performance of the firm. Jovanovic (2015) and Gretton (2003) claims that ICT has established a requisite platform for market development, innovation, and productivity improvement. There are three major components which ICT plays in innovation are: (a) information component: composed of elements such as the collection of data, generation of information, processing of the information generated, and communication of improved quality information (Polder M, 2010); (b) technology component: the integration and automation of business behaviors, product and/or process innovation (Spiezia, 2011); (c) learning component: the learning capacities of employees can be augmented through internet search engines and ICT-based courses (Corso, 2003).

This issue was further explored by Khalifa (2015), where it was investigated that if the organizational innovations, investment in ICT and human capital have any direct consequence on Tunisian firm’s innovation performance, also investigated that if any complementary effect is produced when grouping investment in these three pillars which establishes an innovative and efficient production system. Upon investigation, it was found investment in the knowledge economy does affect the firm's innovation level directly. Moreover, evidence collected shows good support between an organization leading with innovations and its ICT understandability and also between ICT usage and Human capital. However, the lack of evidence between organizational innovation and human capital was one of the drawbacks.

Wiseman (2014) presented an argument that in Arabian Gulf national education systems are essential for the transition to or development of a knowledge economy in general. They ascertained two major challenges: (a) the structural and functional challenge of establishing a mass education system based on knowledge economy; and (b) cultural and circumstantial challenge associating with Arabian Gulf traditions, norms, and expectations with institutionalized ideas of knowledge economies. Moreover, issues regarding ICT and the local and international populations in the Gulf were highlighted.

Ryan (2016) took the opportunity to calculate the performance of neighboring countries Qatar and UAE based on their accomplishments towards tuning into knowledge-based economies. The framework they use is built on the four pillars of ICT; innovation, education, regime, and economy. The results show UAE positions somewhat above-median position of 19 comparator countries, while Qatar positions slightly below the median. Furthermore, they also argue about the need for research culture while also enhancing the incentives that shall attract a high level of researchers and top quality of talented workers.

Ceptureanu (2014) argues, according to economic factors, in the Romanian context, the idea of the knowledge economy is more familiar to state-owned companies rather than private companies and it is best applied in the industry and service sector.

The last 4 years have proved more mature companies are making progress at an increasing rate while about age very young and young companies were able to recognize this transition to the knowledge economy as an opportunity. Khalifa (2015) has also shown evidence that supports that Tunisia has been in progress of becoming a knowledge-based economy. This transformation was possible due to three main developments such as 1. Formation and implementation of free trade zone, and signing of different free trade agreements. 2. Structural Adjustment Program in 1986, liberalization of the economy through institutional innovations which played an important role in changing the economy to a knowledge-based economy.

2.2 Sustaining in Construction Development

Nuri and Murat (2014) have been studying the effect of the social, environmental, and economical sectors on construction sustainability. The study has been titled a triple bottom, where the 3 sectors have been analyzed and how they impact building construction, operation, and disposal phases. Their finding revealed that electricity usage has more environmental impact, while construction activities are highly correlated with the impact of social and economic sectors. Optimizing the use or utilizing a different technique to generate electricity will help to sustain the construction sector as well as the design of pavement will also support sustainability (Kucukvar, Noori, Egilmez, & Tatari, 2014). This is a hot topic for countries which are heavily developing their infrastructure and at the same time trying to reduce environmental footprint (Onat, Kucukvar, & Tatari, 2014; Kucukvar & Omer Tatari, 2013)

Focusing on a single sector at a time will lead to a misunderstanding of the situation and ultimately a wrong decision will be made. For example, focus on the environment sector only will misguide the decision-maker to compromise with the economy and social variables, whereas if the impact of all the 3 is considered simultaneously the decision made will be much effective. A similar ideology was addressed in two different papers by different authors, one by Murat and Egilmez (2014) and second by Kucukvar and Gumus (2014).

The availability of the different construction materials and eco-efficiency towards the environment was studied by Murat and Omer (2012). Murat and Omer applied decision technique tools to draw the conclusion and to rank different construction materials concerning their environmental footprint and later the study was summed up by highlighting different gaps where improvement can be achieved. This research was practically studied later in the US by Murat and Omer (2012). Furthermore, building a green commercial building and how to achieve their efficiency which is highly linked to the supply chain of construction and commercial building was studied by Gokhan and Omer in two different papers (Gokhan, 2017; Omer Tatari, 2011)

2.3 Sustainability in Food Manufacturing

Due to the increasing population growth, one of the highly impacted sectors is food manufacturing. As the past studies indicate that food manufacturing is one of the global issues concerning the environment, a study carried out by Gokhan and Murat (2014) where decision technique such as data envelope analysis was coupled with life cycle assessment of food manufacturing industry and later sensitivity analysis was carried on different environmental factors. It was deducted that the manufacturing sector impacts heavily around 80% on water, energy, fishery, land, and carbon footprint. From sensitivity analysis, it was found that land footprint is the most sensitive environmental factor when it comes to the food manufacturing process.

Looking further into food manufacturing, sustainability with regards to food consumption was also taken under consideration by Galal and Murat (2020) and from an environmental point of view, it was observed that CO and SO_x were the main contributors when it comes to food consumption. The findings stated that 13.7% of the food and beverage are labeled as a high contributor, where the bakery is at the top.

Moving on to the supply chain in the food manufacturing sector, a study by Murat and Hamidreza (2015) revealed that 90% of carbon emission is a result of upstream stream supply chain process where utilization of energy is approximately around 50%. Turkish based research also states that 56.5% of carbon emission have resulted from the supply chain sector (Kucukvar, Egilmezb, Onat, & Samadid, 2015)

2.4 Sustainable Transportation

Transportation is another factor that heavily contributes to carbon emissions, and is directly correlated to population growth. As the population grows the demand for energy increases due to one of the factors know as transportation. The amount of fuel been burned to run vehicles is directly proportional to carbon footprint (Onat, Kucukvar, & Tatari, 2016). To control carbon footprint research on carbon reduction in transportation has become one of the hot topics (Onat, Noori, & Kucukvar, 2017). One of the alternatives to burning fuel for transportation is the adaptation of electric vehicles. Assessment research was carried out by Nuri (2020) and Murat (2016)on the sustainability of electric vehicles and the hybrid vehicle in Qatar. The study proposed that hybrid vehicle must take over 81% of the traditional fuel engine to achieve the targeted reduction in carbon emissions (Onat, Kucukvar, & Tatari, 2014)

The amount of carbon emission-related changing infrastructure when it comes to the change of traditional transportation to hybrid transportation in the US has been studied by Nuri and Serkan (2016). In the research, they generated two different policies one using the existing infrastructure for charging electric vehicles and the second building up infrastructure based on solar energy consumption.

To assess more on electric vehicle and its sustainability, a detailed article was published on the material footprint related to the electric vehicle where it was stated that 65% of the material footprint in the electric vehicle industry comes from battery manufacturing plant (Sena, Onat, Kucukvar, & Tatari, 2019). A similar water footprint study was performed on the electric vehicle in 2018 Onat, Kucukvar, & Tatari (2018) and Kucukvar, Onat, & Haider (2018). Carbon and water footprint plays an important factor when it comes to energy generation, therefore when design a national electrical energy production grid different production scenarios must be considered (Shaikh, Kucukvar, & Onat, 2017).

2.5 Fossil Fuels Exhaustion and Impressive Returns in Renewable Energy (RE)

Fossil fuels are limited. It is believed we approximately have 50 years of natural gas and oil remaining to be extracted, this estimate is made at the current rate of production. Furthermore, the statistics also prove coal production is not going to extinct until 115 years from now (BP, 2019). Thus, applying cost-friendly and alternative means of energy must be brought into action.

The process of extracting fuel from untouched reserves is financially and geologically quite challenging. Nevertheless, the more important concern is whether or not a country must search for new fossil fuel reserves. To bring down global warming below 2 degrees Celsius, the world needs to amend even stricter laws to limit the emission of carbon, which is about 70-80% of untapped fossil fuels (Glen., n.d.). It is said if the current level of investments in infrastructures where carbon emission is vital, is continued then it would cost around 6.74 trillion dollars throughout the next decade for establishing “unburnable” reserves (Ritchie, 2017). By using these investments for RE development, ROI (return on investment) can be huge and at the same time producing cleaner and greener as well (Dudley, 2019) (Giannetti, 2020). The major downside of RE production is the massive installation expenses and instant ROI, which make energy generation through fossil fuels high feasible. However, according to Brockway (2019) ROI coming from fossil fuel will gradually decline in the coming times while the ROI coming from RE resources will surpass fossil fuel resources.

Also, Qatar has recently established its very first dairy farm mainly for milk production. Initially, Qatar started its dairy farm with 4,000 cows and having a plan already set for expansion which will count also 10,000 cows. So, a total of 14,000 cows will be utilized for dairy production. Having said that each cow will produce around 50 to 60 kg of dung every day on average, this leads to a total generation of 840 tons of dung every day. The waste generated by be utilized for energy production using the concept of biomass production facility and the dried out dung from these facility can be served as top quality fertizer. Using biomass facility Qatar's dairy farm can impact in reducing annual CO_2 emission and at the same time moving towards self-sustaining farms (Bakshi, 2017).

2.6 Effects Changing Climate

GCC nations are extremely susceptible to the unfavorable effect of air pollution and climate change. Facing the result of fossil fuel dependence, which is pollution and climate change, GCC nations also face environmental discomforts such as loss of biodiversity, desertification, coastal and marine areas facing water pollution, and water scarcity (Bhutto, 2014).

Pal (2015) believes by 210 cities in the Arabian Gulf region with less mitigating air pollution and climate change might turn uninhabitable.

The climate change caused by human activities in the Gulf region is about 88% which is mainly related to continuous production and consumption of energy (Al-

Maamary, 2017). A detailed study was also carried out to understand energy-climate-manufacture nexus (Kucukvar, Cansev, Egilmez, Onat, & Samadi, 2016).

The necessity to adapt and work on the energy generation sector and its efficiency is becoming highly important day by day. Now here, RE plays a promising role in decreasing carbon footprint and greenhouse gas emissions, they also promise many positive implications alongside life-saving makeover.

Renewable resources can support socio-economic benefits through GCC nations. If the target of RE deployment is achieved by 2030, around 354 million barrels of oil consumptions can be saved subsequently carbon emission will shrink by 136 million tons (Irena, 2019). Until now, GCC nations have set some feasible and achievable RE targets, which says, by 2025, Oman and Bahrain seek to attain 10% and 5% of electricity generation through renewable resources, respectively. While Qatar aims to attain 200-500 MW of solar energy generation. By 2030, Saudi Arabia and Kuwait desire to attain 30% and 15% of the generation of electricity through renewable resources, respectively. UAE, on the other side, is determined to achieve its goal of meeting energy demand from renewable resources up to 44% by 2050 (Irena, 2019). Table 4 tells the targets set by GCC nations to attain energy efficiency (Irena, 2019). The entire reimbursement of RE deployment within the GCC region is accounted to be the US $40-76 billion in discounted fuel-saving, this amount is equal to two million barrels of oil. Lastly, RE adoption by 2039 can mitigate water usage for generation power up to 17%. Broad RE market will also help to create 220,500+ jobs.

2.7 System Thinking Approach, Life Cycle Assessment, Sustainability Assessment and Applications

System thinking is a powerful tool that is utilized to demonstrate and understand a wicked problem. System thinking identifies all the different aspects related to different sectors within the organization. Using this tool the interrelations and links between variables within one sector or links between different sectors within the organization are highlighted and these links guide to understand the causes of dynamics within the system using feedback loops (Akhtar, 2018).

Some of the applications of system thinking in real-world has been highlighted below;

Table 1: Application of System Thinking

Author(s)	Year	Application
Lutz E Schlange	(1995)	An application of systems thinking and metagame analysis to nuclear energy policy issues
Roger Stewart, Joyce Fortune	(1995)	Application of systems thinking to the identification, avoidance and prevention of risk
Gemma J. M. Reada, Paul M. Salmonb	(2015)	systems thinking design toolkit to improve situation awareness and safety at road intersections
Nuri C. Onat, Murat Kucukvar, Omer Tatari	(2015)	Integration of system dynamics approach toward deeping and broadening the life cycle sustainability assessment framework
David Collste, Matteo	(2017)	Policy coherence to achieve the SDGs

Author(s)	Year	Application
Pedercini		
Nuri Cihat Onat, Murat Kucukvar, Anthony Halog, and Scott Cloutier	(2017)	Systems Thinking for Life Cycle Sustainability Assessment: A Review of Recent Developments, Applications, and Future Perspectives
Ximei Liua, Ming Zengb	(2017)	Renewable energy investment risk evaluation model based on system dynamics
Shoaib Akhtara, Sajid Hussain Awanc, Shaheryar Naveedd	(2018)	A comparative study of the application of systems thinking in achieving organizational effectiveness in Malaysian and Pakistani banks
Chien Liang Lin, Chao Fu Chien	(2019)	Systems thinking in a gas explosion accident
Eirini Grammatiki Pagoni	(2019)	A system dynamics model for the assessment of national public–private partnership programmes
Adeeb Kutty, Galal Abdella, Murat	(2020)	A system thinking approach for harmonizing smart and sustainable city initiatives with United Nations sustainable development goals

Author(s)	Year	Application
Kucukvar, Nuri Onat, Melih Bulu		
Adam Hulme, Scott McLean	(2021)	Systems thinking-based risk assessment methods applied to sports performance
Sharon Newnam, Natassia Goode	(2021)	Systems-thinking in action: Results from implementation and evaluation of the patient handling injuries review of systems Toolkit

Another useful tool that can be combined with system thinking is life cycle assessment (LCA). Using LCA a complete breakdown of a product's life cycle can be analyzed and from there environmental, economic, and social issues can be noted down easily. These issues can be addressed using system thinking to find out the root causes and how to mitigate the disturbance. Below is a table that summarizes different LCA research held by different authors under different sectors.

Table 2: LCA Past Applications

Author(s)	Year	Application
Omer Tatari, Munir Nazzal,	(2012)	Comparative sustainability assessment of warm-mix asphalts: A thermodynamic based hybrid

Author(s)	Year	Application
Murat Kucukvar		life cycle analysis
Yong Shin Parka, Gokhan Egilmez, Murat Kucukvar	(2015)	A Novel Life Cycle-based Principal Component Analysis Framework for Eco-efficiency Analysis: Case of the United States Manufacturing and Transportation Nexus
Yang Zhao, Nuri Onat, Murat Kucukvar, Omer Tatari	(2016)	Carbon and energy footprints of electric delivery trucks: A hybrid multi-regional input-output life cycle assessment.
Gumus Egilmez; Serkan Gumus, Murat Kucukvar, Omer Tatari	(2016)	A fuzzy data envelopment analysis framework for dealing with uncertainty impacts of input–output life cycle assessment models on eco-efficiency assessment.
Yong Shin Park, Gokhan Egilmez, Murat Kucukvar	(2016)	Emergy and end-point impact assessment of agricultural and food production in the United States: A supply chain-linked Ecologically-based Life Cycle Assessment
Serkan Gumus, Murat Kucukvar, Omer Tataria	(2016)	Intuitionistic fuzzy multi-criteria decision making framework based on life cycle environmental, economic and social impacts: The case of U.S. wind energy
Burak Sen, Murat	(2020)	Life cycle sustainability assessment of

Author(s)	Year	Application
Kucukvar, Nuri Onat, Omer Tatari		autonomous heavy-duty trucks

Now after analyzing the LCA and know the root causes through systemic thinking, many researchers perform sustainability assessments where they test different policies on the variables responsible for the cause of disturbance or deviations within an eco-efficient system. Once the suitability assessment has been carried out it makes the decision-maker more confident towards the proposed policies and how to achieve sustainability in different sectors such as environment, economic, and social. Below is a table listing some publications where sustainability assessment was performed on different sectors to preserve and sustain them.

Table 3: Sustainability Assessment Research Articles

Author(s)	Year	Application
Gokhan Egilmez, Murat Kucukvar, Omer Tatari, and M Khurrum S Bhutta	(2014)	Supply chain sustainability assessment of the US food manufacturing sectors: A life cycle-based frontier approach
Murat	(2014)	Sustainability assessment of U.S. final

Author(s)	Year	Application
Kucukvar, Gokhan Egilmez, Omer Tataria		consumption and investments: triple-bottom-line input–output analysis
Murat Kucukvar, Mehdi Noori, Omer Tatatri	(2014)	Economic Input-Output Based Sustainability Analysis of Onshore and Offshore Wind Energy Systems
Gokhan Egilmeza' Serkan Gumus, Murat Kucukvar	(2015)	Environmental sustainability benchmarking of the U.S. and Canada metropoles: An expert judgment-based multi-criteria decision making approach
Murat Yalçıntaş, Melih Bulu, Murat Kucukvar, Hamidreza Samadi	(2015)	A framework for sustainable urban water management through demand and supply forecasting: The case of Istanbul
Gokhan Egilmez, Murat Kucukvar, Yong Shin Park	(2015)	Supply chain-linked sustainability assessment of the U.S. manufacturing: An ecosystem perspective
Serkan Gumus, Gokhan	(2016)	Integrating expert weighting and multi-criteria decision making into eco-efficiency analysis:

Author(s)	Year	Application
Egilmez, Murat Kucukvar, Yong Shin Park		the case of US manufacturing
Kevin Mackie, Murat Kucukvar, Omer Tatari, Ahmed Elgamal	(2016)	Sustainability Metrics for Performance-Based Seismic Bridge Response
Nuri Onat, Murat Kucukvar, Nour Aboushaqrah, Rateb Jabbar	(2019)	How sustainable is electric mobility? A comprehensive sustainability assessment approach for the case of Qatar
Murat Kucukvar; Galal Abdella; Nuri Onat	(2020)	A frontier-based managerial approach for relative sustainability performance assessment of the world's airports

CHAPTER 3: DATA ANALYSIS

3.1 Data Collection

The collection of information and data comprises different sources: analysis of relevant documentation such as reports.

The data necessary to analyze the process to generate useful information was gathered mainly from 4 sources. These sources are the Ministry of Development Planning and Statistics (Planning and Statistics Authority, 2020), World Bank yearly reports (The World Bank, 2018), Organization of the Petroleum Exporting Countries (OPEC, 2018), and Data Warehouse of CIA World Factbook Report (CIA, 2019).

3.2 Economic Development

One of the essential parts of the Qatar National Vision 2030 is economic development. This part plays an important role in progress for a better lifestyle of the local population in Qatar and at the same time opens the door for upcoming opportunities. Qatar's ability to maintain and proceed for a balance between a knowledge-based economy and an oil-based economy is highly dependent on achieving sustainable economic development goals. Working towards economic development and achieving the economic sustainability goal will lead Qatar on a path where they can shift their dependency from the oil and gas sector to a diversified economy and sustain the business environment. To better understand this objective, we shall look at the following economical parameters and understand how Qatar's economy is developing in the past 10 years and is close to be a knowledge-based economy that helps to diversify the economy.

Parameters looked over in this section are as follows:

1. GDP growth rate.
2. Type of exports, imports, and destinations exports and imports.

3. Inflation rate and GDP purchasing power.
4. Industrial production growth.

3.2.1 GDP Growth Rate

The Gross Domestic Product (GDP) in Qatar expanded 2.5 % on average between the years of 2000 to 2018 (see figure 1). This growth mainly was contributed to the hydrocarbon sector which expanded rapidly with huge production of liquefied natural gas (LNG) from the massive offshore North Field. However, within this period from 2000 to 2018, there was a decline noted in Qatar's GDP from 2012 to 2017 due to oil and natural gas prices, which when down in this period. As result, Qatar experienced its first economic deficit in 2016 even though there was an increase of a 2% growth rate. Qatar has an average economic growth rate between the years 2008 to 2017. But this growth model is not sustainable as it is highly linked to the oil and gas world price. Qatar did not diversify its economy in the past 10 years from hydrocarbon industries.

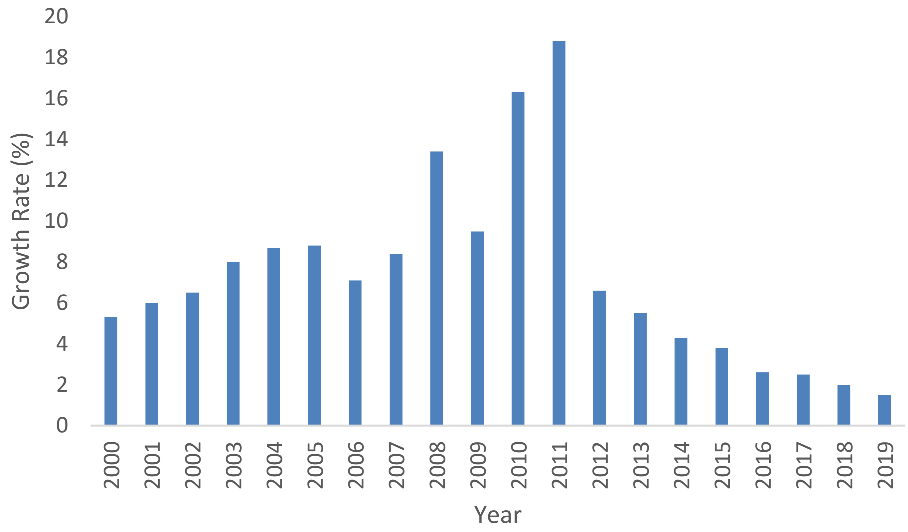


Figure 1. GDP movement of Qatar

3.2.2 Continents/Destinations Exports and Imports

The main export category for Qatar is the oil and gas sector, within this sector approximately 57% of total mineral product exports are LNG and 29% of the total mineral product being exports are crude oil. Moving back to 2016 statistics, and export worth of 55.7 billion USD were recorded for Qatar. This huge export ranked Qatar as the 45th largest exporter of the world. To classify the export percentage, 23.2% of the export results from crude petroleum products, and 53.3% from petroleum gas products. Looking at the past trend of export for Qatar, a dip of -12.5% was noticed in Qatar's export category, 108 billion USD in 2011 to 55.7 billion USD in 2016. The main reason drawn for this dip is a slum in oil and natural gas prices worldwide.

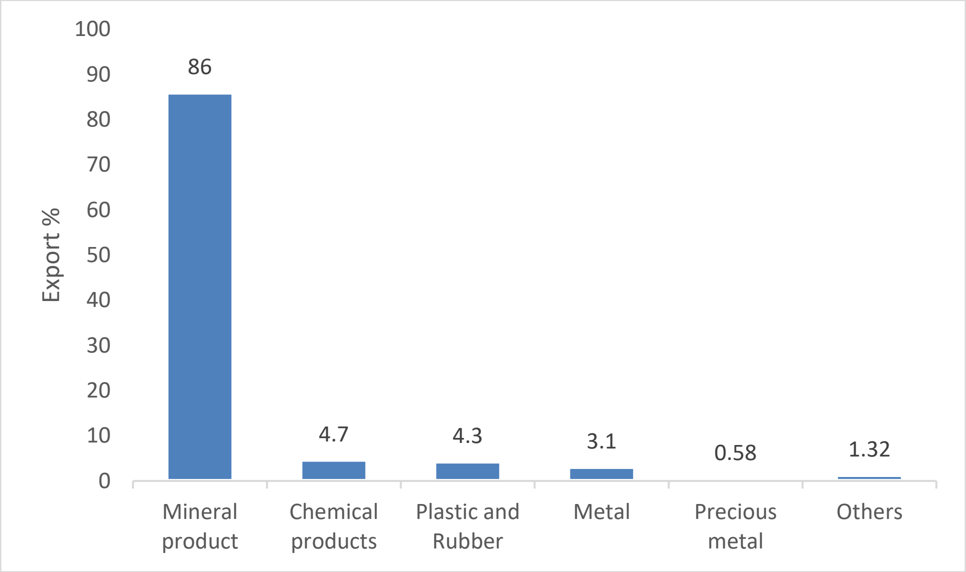


Figure 2. Qatar's export category

To detail out the import categories, in 2018, Qatar’s main imports are 22% transport equipment and parts, 27% machinery and mechanical appliances and parts, 9.3% base metals and articles, and 9.7% electrical machinery and equipment and parts. In 2016, Qatar’s import was worth 32.3 billion USD, which ranked Qatar as the 59th largest importer of the world. Considering the past five years' duration, an annual increment has been observed in the import of Qatar which is labeled as 15.2% and having a worth of 15.5 billion USD in 2011 to 32.2 billion USD in 2016 (see figure 3 and figure 4).

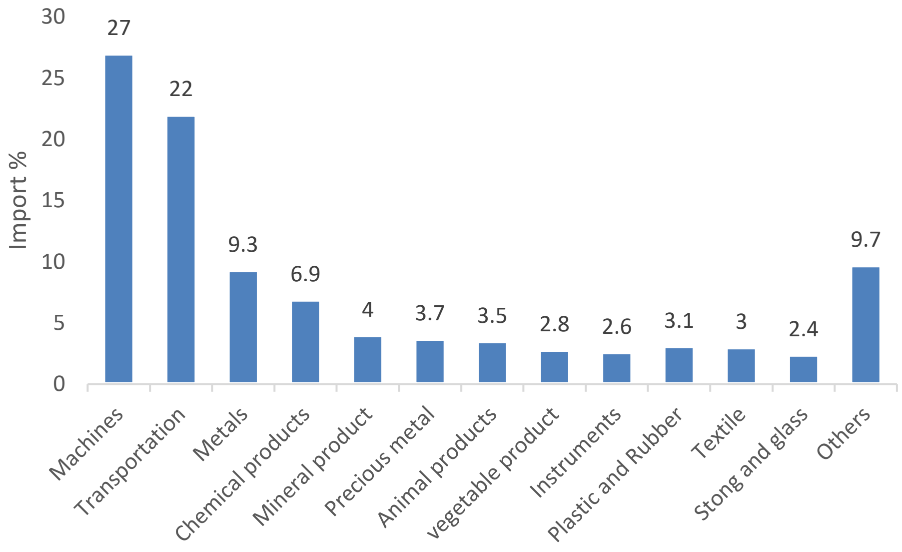


Figure 3. Qatar's import category

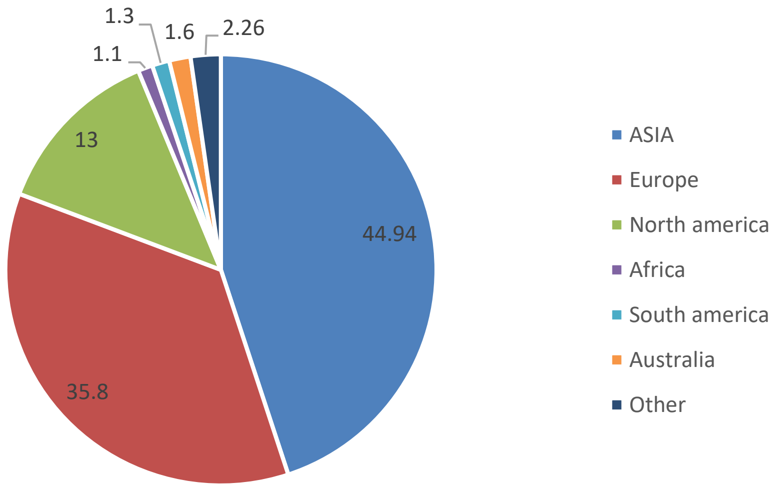


Figure 4. Imports to Qatar from different continents

In 2016 the top export destinations of Qatar were Japan 17.8 billion USD, South Korea 17.5 billion USD, India 13 billion USD, China 8 billion USD, and Singapore 5.2 billion USD (see figure 5). Asia considers as the biggest continent for Qatari export which accounts for more than 75.42% of Qatari export (see figure 6). While the top import origins of Qatar are the United States 13.12 billion USD, the United Arab Emirates 9.91 billion USD, China 9.82 billion USD, France 8.15 billion USD, and the United Kingdom 8.25 billion USD (see figure 7).

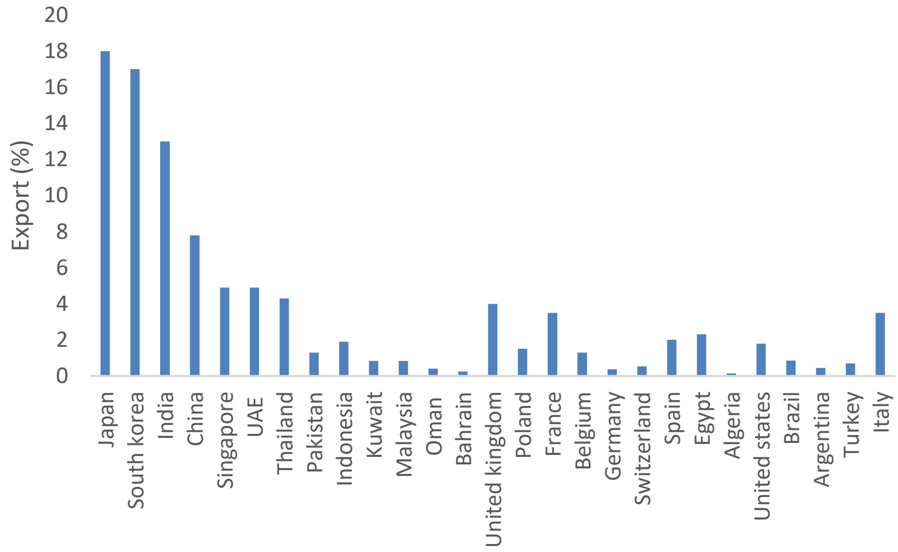


Figure 5. Percentage of export in different countries

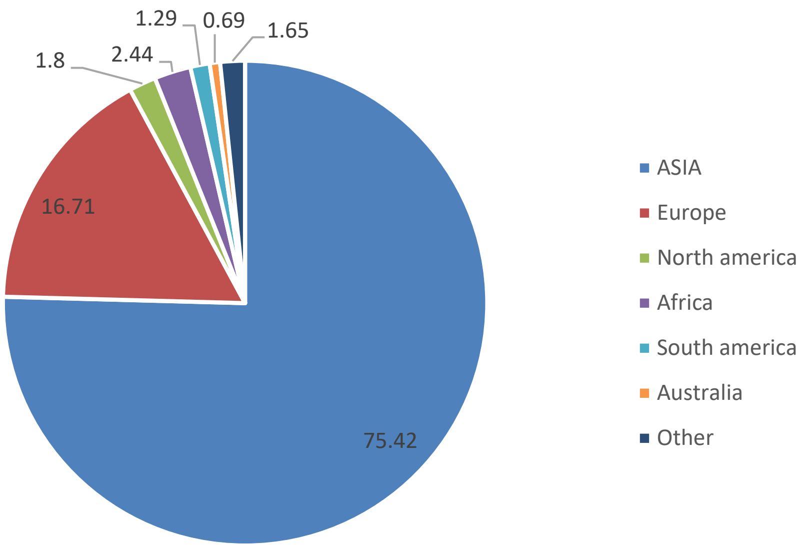


Figure 6: Export of Qatari products to different continents

Main import partners are the United States with an import percentage of 11%, United Arab Emirates 9.8%, China 9.5%, Germany 6.7%, and Japan 6.2%. Others include Saudi Arabia, Italy, India, the United Kingdom, and Switzerland (see figure 7). As of 2016, Qatar had a positive trend in its trade balance of 23.4 billion USD in net exports as compared to its trade trend back in 1995, where they still have a positive trend but much lower than of 2016, around 804 million USD.

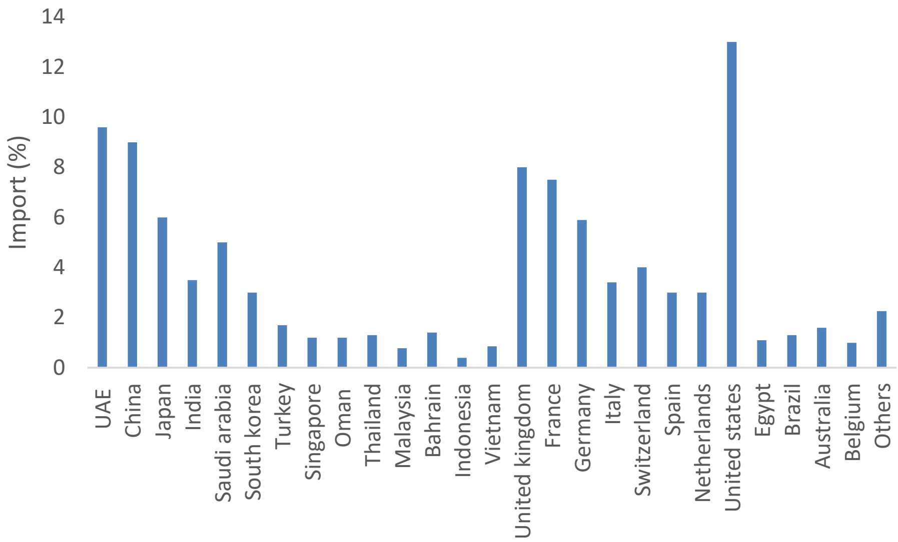


Figure 7. Importers to Qatar

To summarize, Qatar still relatively diversifies in import categories and partners. The diversification policy shows how resilient the country was during the ongoing GCC crisis where UAE one of the top importer to Qatar join the blockade of air and sea. However, from the import perspective, Qatar needs to change in economic model to catch up with the contrary vision 2030 where it needs to gradually reduce its dependence on hydrocarbon industries in the next 10 years.

3.2.3 Inflation Rate

The main elements of the consumer price index (CPI) which defines the inflation rate in Qatar are purchasing power of energy such as fuel and electricity with real state rents (21.9%), usage of transportation and communication facilities (14.6%), entertainment and cultural activities (12.7%), food and beverages (12.58%).

CPI also includes daily local needs to live such as textiles, and furniture (7.7%), hotels and restaurants (6.1 percent), telecommunication (5.9 percent), schooling (5.75 percent), various services (5.7 percent), and footwear (5.1 percent). The average inflation recorded for Qatar from 2005 to 2018 is around 2.76% (see figure 8). Within this period a high-end peak of 16.59% was observed in 2008 and a lower peak of -4.96 in 2009. An average of 2.76% in the past 12 years is considered very well comparing with rapid growth in country GDP (see figure 10) while at the same time mainlining acceptable living conditions for Qatari society.

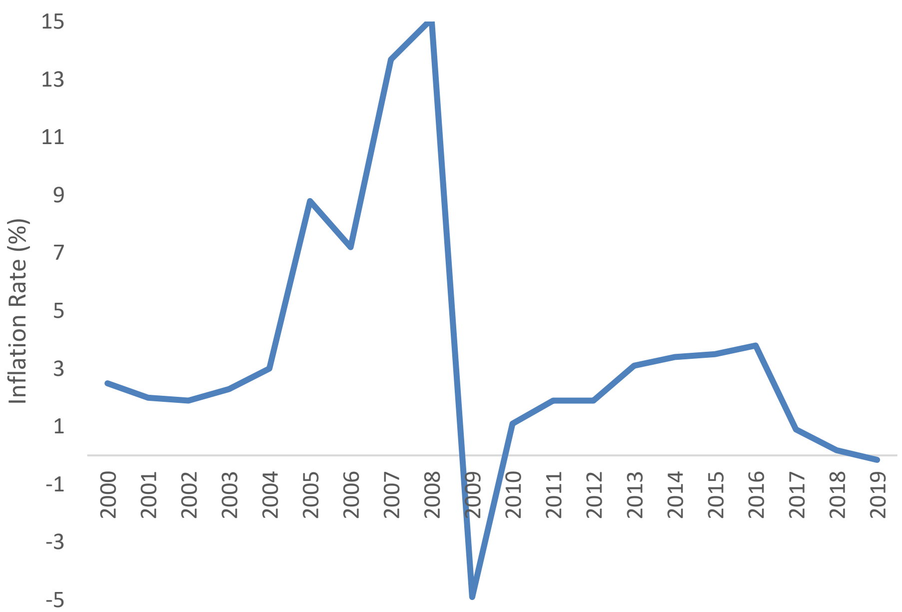


Figure 8. Inflation rate data representation

3.2.4 GDP Purchasing Power

The Gross Domestic Product (GDP) per capita PPP (figure 9) is computed by dividing the country's GDP over the number of people within Qatar (population) and adjusted by purchasing power parity. Qatar is considered in World as one of the leading nations in economic prosperity for its citizens. Higher the GDP per capita PPP help to increase the social and political stability for the Qatari community and achieving one of the pillars of QNV2030 for human development.

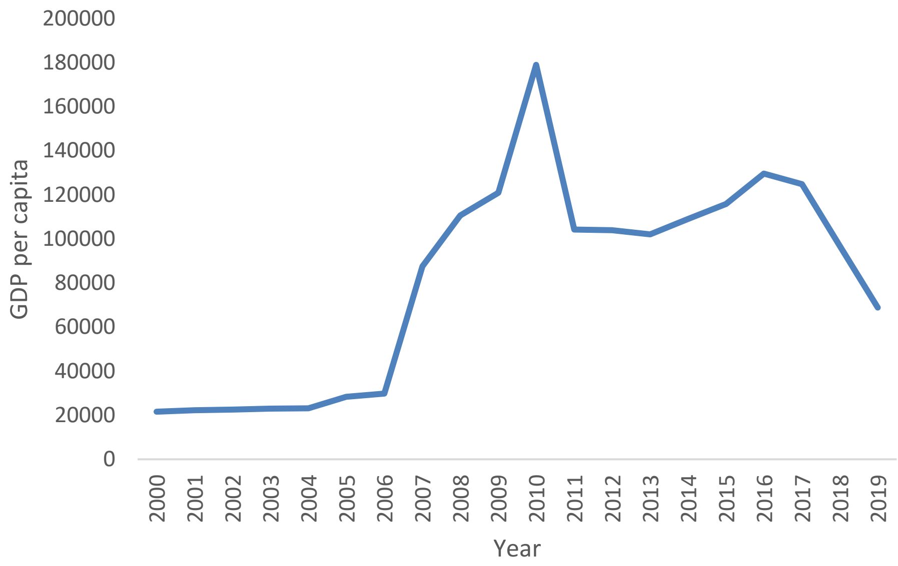


Figure 9. GDP per capita, purchasing power parity (PPP)

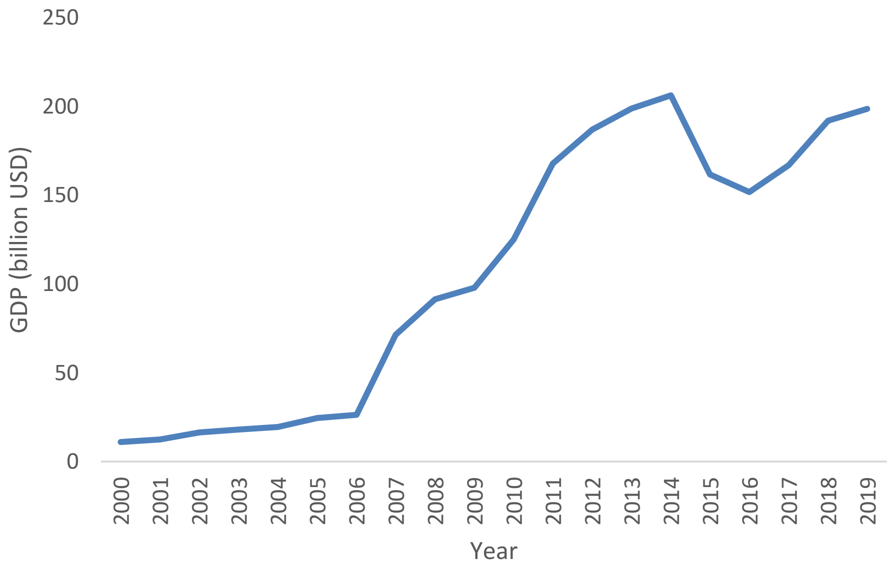


Figure 10. Purchasing power representation of GDP

3.2.5 Industrial production growth

The industrial growth parameter is a measure of output generated from the different business sectors within the country. For Qatar, the major sector plays an important role in the graph of industrial growth in the mining industry. The term mining has been used in general which define extraction and exploration of fossil fuels, this sector is represented by 83.6% of total production. 15.2% accounts for manufacturing industries such as the cement industry, 10.4% is linked production facilities of chemical and its derivatives, 1.6% for basic metals such as aluminum. Lastly, 0.7% corresponds to energy production (electricity production, steam production, gas production) and 0.5% to waste management and sewerage. In 2017, the Industrial production growth index had its first shrinkage in the last 20 years by -7 percent (see figure 11) due to historical oil and gas price and to Qatar commitment to OPEC cuts of over 45000 barrels of oil per day to help to raise the global oil price. This model certainly does not help to achieve Qatar vision 2030 and nor Qatar is on the right path.

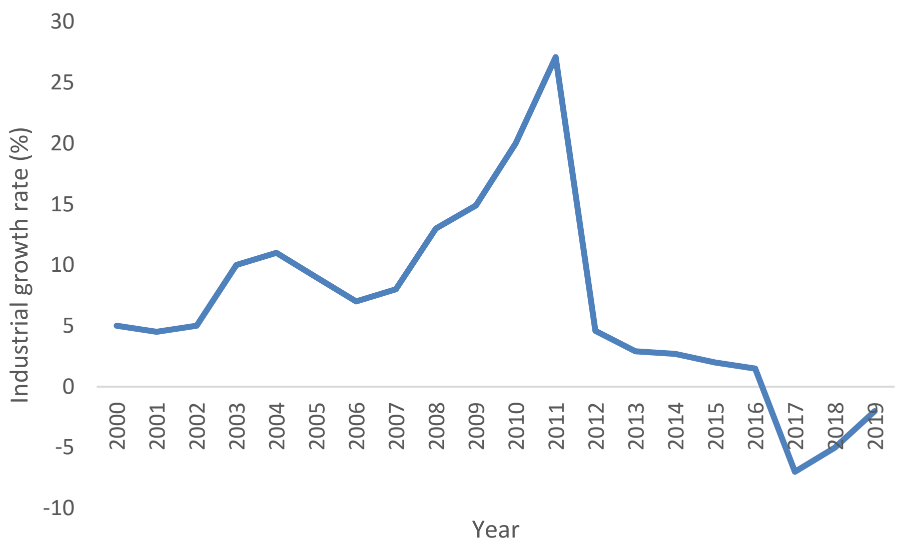


Figure 11. Industrial production growth (%)

3.3 Environment Development

Through vision 2030, Qatar aims for protecting and preserving its environmental elements like air, land, and water. To achieve this, Qatar has planned to work on a comprehensive legal system that helps in protecting these elements, and at the same time enhances public awareness and knowledge towards changing the environment. Implementing these steps will lead to a sophisticated system that can respond quickly by notifying any change or diversity from the main objective of environmental sustainability development. On a parallel side organization motivation to adopt environmental technologies has been boosted mainly by the research on the concept of renewable resources. Regional cooperation also has a high impact on achieving the objective of a sustainable environment and encouraged regional cooperation will help to mitigate all the negative environmental effects which resulted from development activities. This idealogy aims for proactive actions by mitigating the negative impacts and highlighting the important regional role in measuring the impact of climate change.

Parameters looked over in this section are as follows:

1. Total CO_2 emission.
2. Methane emission.
3. A comparison between CO_2 emission vs CH_4 emission.
4. Comparing emissions due to electricity and heat production vs emission due to transportation.

3.3.1 Total CO_2 Emissions

Looking over the past historical data for CO_2 emission in Qatar (see figure 12), there was an increasing trend observed. Dividing the graph into 3 parts based on the rate of increase in emission, from 2000 till 2005, 2006 till 2011, and 2012 onwards. In the first part, the rate of increase was comparatively higher than the second part of the graph but less when compared to the last section of the graph. In the last part of the graph, a drop in CO_2 emission was noted, the main reason for this drop is the oil crises. When oil prices went down, Qatar based refinery reduced their production to a certain limit but this drop-in graph did not go through half of the previous one, because still another major contributor to CO_2 emission, manufacturing industries, were dominating at that point, the high rate of release is an indication that Qatar’s production was increased to compensate the loss due to oil crises. Predicting the graph, it is clear that Qatar has been successful in controlling CO_2 emission as the rate of emission is constant over time, but now Qatar must look forward to reducing the emission either by new strategic planning for their production and manufacturing industries to maintain theirs on the growing economy or by introducing new technologies in the industry with less CO_2 emission.

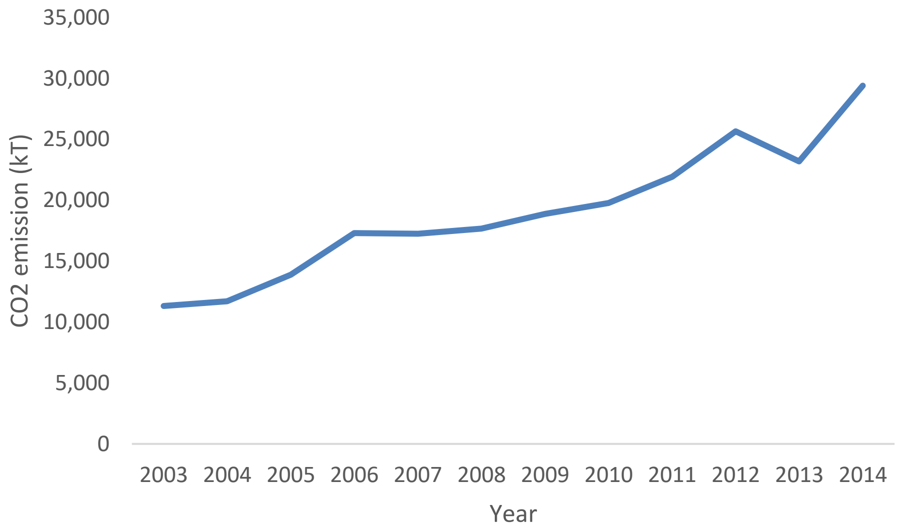


Figure 12. CO_2 emission in kT

3.3.2 Methane Emission

One of the major gas linked to emissions of greenhouse gas is methane. There are multiple sources for the emission of methane, the most common source is oil and gas industries, followed by emissions from livestock, agricultural activities, and the decaying process of organic waste in filling up landfills within the country.

At the start of the 21st-century, methane emission was around 13 kt/year and later it boosted up to 43 kT/year (see figure 13). A gradual increase was a result of the developing economy as natural gas and oil extraction process are at their peak. But, after 2010 a stability within the graph is observed and it could be expected that this stability will last long and can also follow a decreasing trend. One of the reasons explaining this stability is, Qatar is now aware of the value associated with methane and how methane can be recycled with the processing system. There is a huge market for petrochemical products and some of these products methane is used as raw material, for example instead of venting off unused methane into the atmosphere it could be connected to the petrochemical industry for the production of methanol which is having a demanding market at the moment. Moreover, methane is also used as a fuel for the furnaces and as a medium for the regeneration of molecular sieve dryers. These applications and usage of methane had help Qatar to reduce methane emission.

A great deal of research still needs to understand how different tools can be developed to detect, measure, and control methane emissions from different sectors as stated earlier, and bring down the trend from 40 kT/year. It is also important to improve our understanding and brief of our locals with the changing climate impact which results from methane emissions.

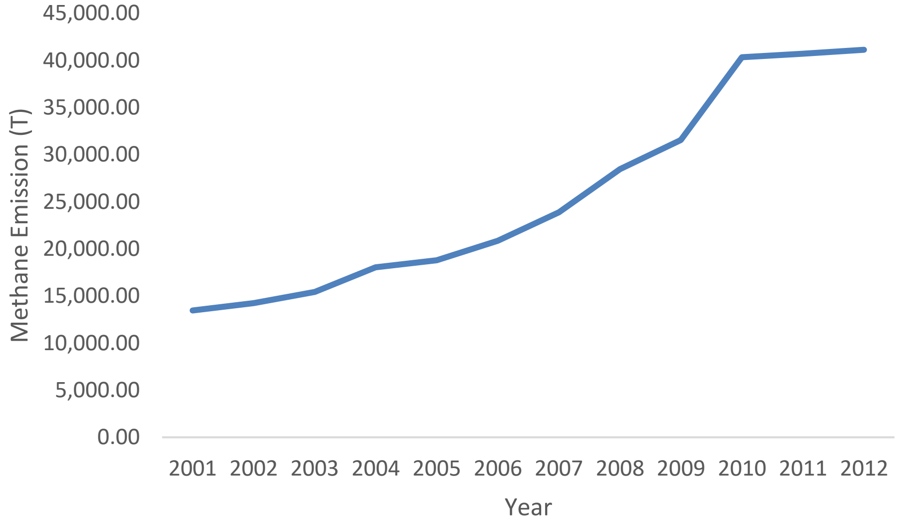


Figure 13. Methane emission

3.3.3 Emission Due to Liquid Consumption vs Emission Due to Gas Consumption

From the pie chart (see figure 14) it is clear that emission due to gas consumption is much higher than emission due to liquid (crude oil) consumption. This is justified as Qatar's main business is run on natural gas production and its downstream products. The oil produced by Qatar is around 850 barrels per day whereas for gas production it is around 18 billion ft3 as reported by the ministry of Qatar.

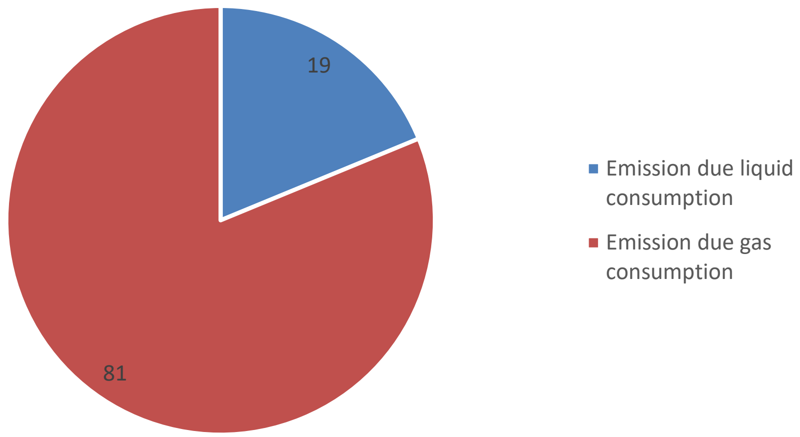


Figure 14: Emission comparison due to different type of fuel consumption

3.3.4 Emission Due to Electricity and Heat Production vs Emission Due to Transportation

Emission due to electricity production and emission due to transportation is almost 1/4 (see figure 15). To answer this comparison, it is obvious that gas used by Qatar to produce electricity and heat is far less, due to less population size, than the fuel required in transportation purposes or usage of fuel in manufacturing industrial equipment. Secondly, the gas used by Qatar is much cleaner in terms of emissions.

Therefore, from the pie chart, we can conclude that emission due to transportation is 4 times higher than emission due to electricity and heat production.

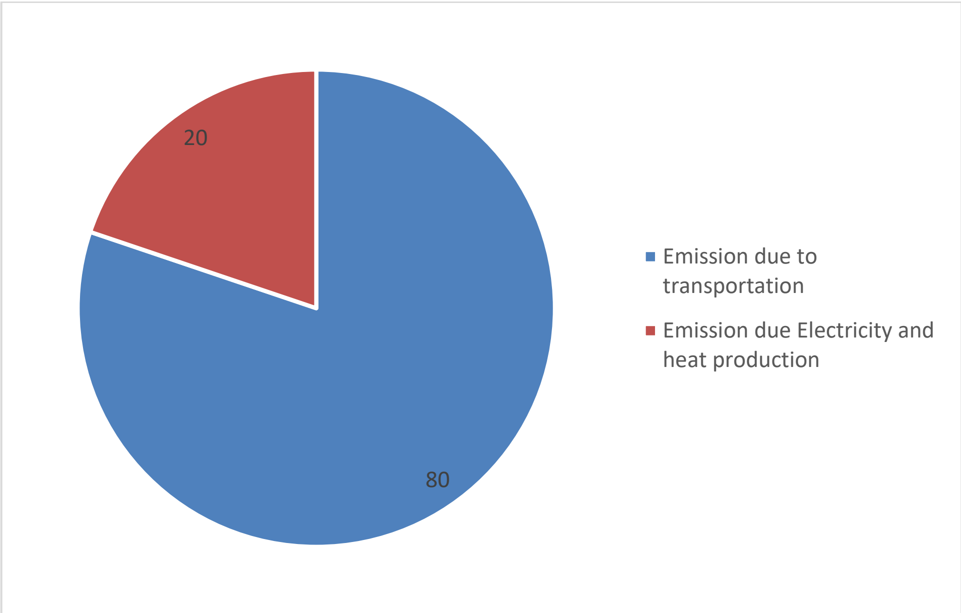


Figure 15. Emission due to electricity production vs emission due to transportation

3.3.5 Total CO_2 Emission vs CH4 Emission

In the pie chart, the emission of CO_2 vs CH4 (see figure 16) is almost the same except 5% difference which arises due to the high research area and implementation of the carbon capture sector in Qatar. One of the examples to support this CO_2 emission is, QAFAC (Qatar Fuel Additives Company) is reutilizing CO_2 within their process to reduce carbon capture.

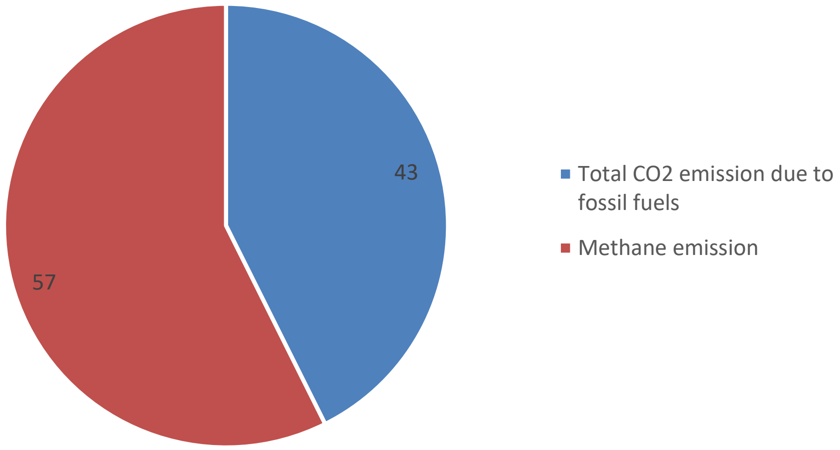


Figure 16. Methane emission vs CO_2 emission

3.4 Social and Human Development

This sector aims for the development of the local community and the persisting educational system. As a part of Qatar's national vision 2030, the local community is aimed to have strong bonds between families, this strong bond will support the factor of taking care of other family members and at the same time having a strong and right ideology on religious and human values. With the help of this objective, the designed system will protect and serve the locals with their civil rights, ensure a stable and sustained lifestyle, values of local in their developing society, and healthy enjoyable life.

Moving towards the educational system, the objective is to develop an effective self-sustaining system accountable for the operation of research development by granting research funds, filling the gap between industrial development and the education system, working and leading international research organizations, and being able to shift the economy to knowledge-based economy.

Designing an integrated health care system that works on offering high-quality health care services through private and governmental organizations and complying with the health development policies related to Qatar national vision 2030.

The result of social and human development objectives will be a skilled, knowledgeable, and healthy national workforce. Parameters looked over in this section are as follows:

1. Literacy and Population.

2. Unemployment (%).

The first graph (see figure 17) represents how the population growth rate changed within Qatar since the start of the 21st century. There is a lot of dynamic fluctuation in the population of Qatar, but this fluctuation is also under increasing trend. If we compare the trend with our CO_2 emission, the movement of the graph is similar and thus we can also conclude that CO_2 emission is linked to our population size. This statement can be validated as more people in a city will require more transportation and more human activities will result in CO_2 emission. Talking about the population graph, the factors which affect this graph are birth, death, and migration (number of people entering the country subtracted by the number of people leaving the country). Following the pattern, the population started to increase from 2000 till 2009, afterward it boosted up by a higher rate of increment this was mainly due to more people coming into the country for jobs as, at that point, oil business were at their peak to make money. So, migration was at an extremely positive sign which resulted in a higher population growth rate till 2013. From 2013 onwards, there was a drop in oil prices, to maintain the country’s economy and profit margin of the company many people were outsourced by local subcontracting companies. This outsourcing affected our migration heavily, at this point migration was close to 0, meaning more people were leaving the city than coming into the country. This decrease in oil prices turned out to be beneficial for Qatar as the population growth rate was reduced and Qatar can compete for its vision for 2030, which states controlling the population growth in terms of ex-pats entering the system and at the same time the economy is well stable but outsourcing local subcontracting companies.

The graph below population and literacy rate (see figure 18) is an indication of the literacy percentage within the corresponding population, for example, if the population at a certain time is 100 and the literacy rate is 10% which means 10 people out of 100 are educated and remaining 90 people are not. To generalize through the entire years up to 2010 50% of the population in Qatar were marked as literate people, who can read and write. From 2008 till 2010 the literacy rate reported was too high, almost 90% on average of the population was considered to be literate population. However, there was a slower rate of increment in literacy rate after 2010, as the outsourcing had taken place and many of the ex-pats moved out of the country, thereby decreasing the population growth rate as well as a decrease in literacy rate.

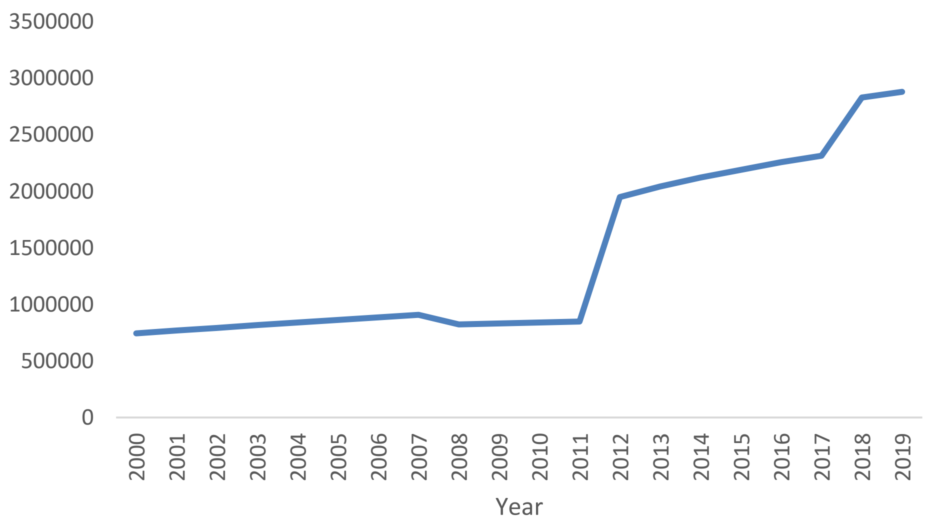


Figure 17. Population curve for Qatar

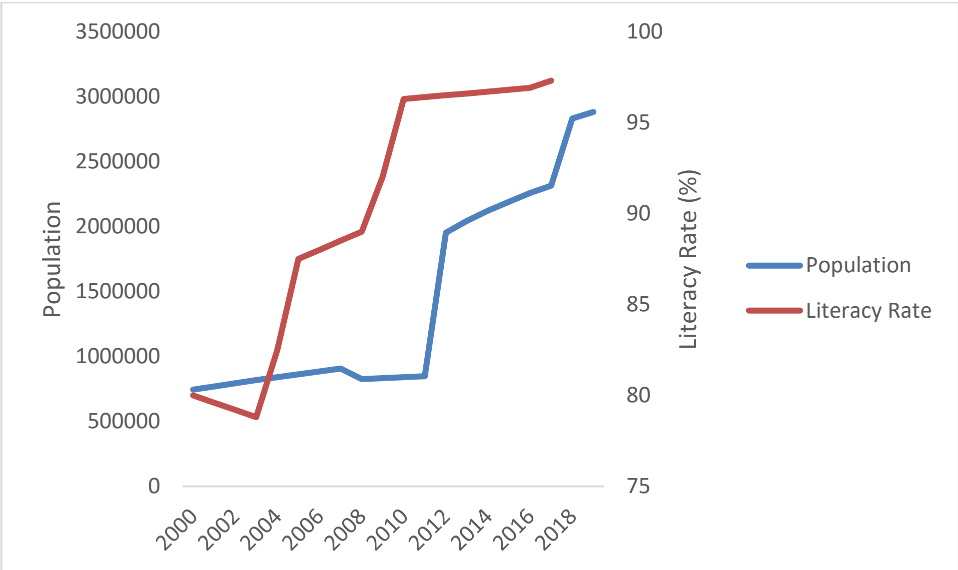


Figure 18. Population and Literacy Rate

At the start when the population was small, the majority of the people were ready to work, the labor force was high in number. But the number of people in the labor force went down after 2013 mainly due to reasons of ex-pats moving out of the country and to sustain their national population more birth took place, which is not considered as a part of the labor force.

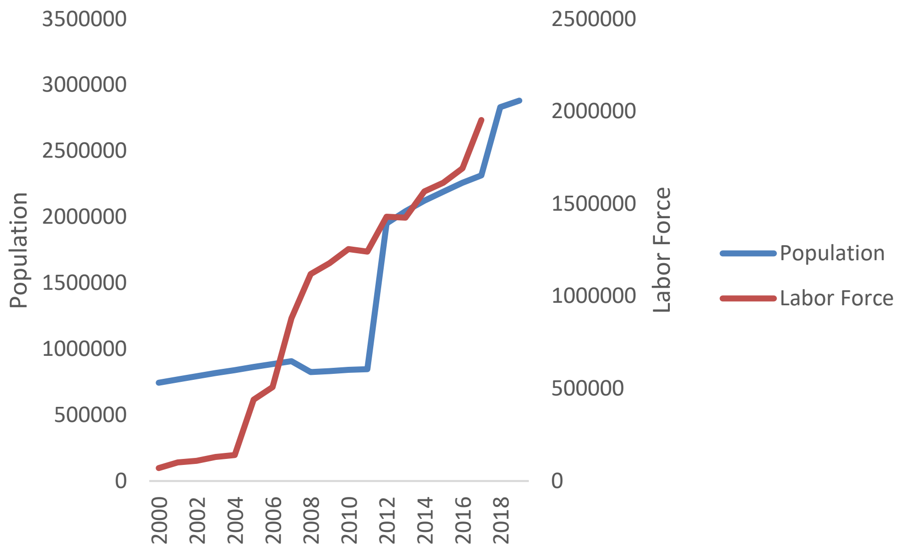


Figure 19. Population and Labor force

This graph below (see figure 20) is related to the unemployment rate of locals. Before 2008, the unemployment rate was quite high around 3% of the local population, but after introducing Qatar vision 2030, the unemployment factor went down straight to 0.5% of the local population. The reason for this drop (improvement) is that Qatar is focusing more on its local development and, as a result, they have hired many locals into developing programs. A developing program will hire a local from high school and will develop him/her for a certain targeted position after the completion of his higher degree. In this way, Qatar can achieve its vision of 2030 where it sates low local unemployment rate and more dependency on local to run the organization than on ex-pats.

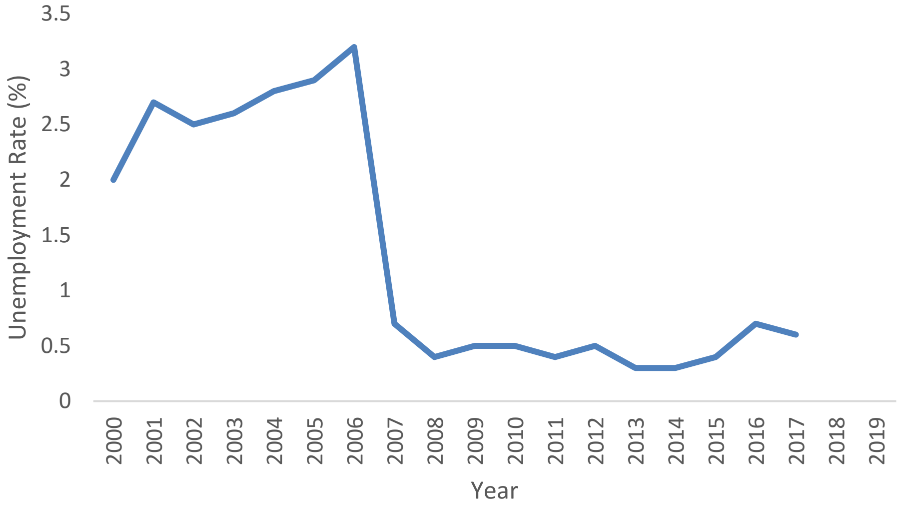


Figure 20. Unemployment curve of Qatar

CHAPTER 4: METHODS

Different research techniques and VENSIM software were used to conduct a brief simulation analysis on how Qatar can move towards sustaining its environment for Qatar vision 2030. A conceptual causal model was prepared linking different sectors such as environment, economy, social, and health. Based on the conceptual model different data were collected representing different variables in each sector. After data collection, the conceptual causal loop was altered based on the data availability and then validation of the model was performed using the historical data validation technique. But before validating the model an additional step was performed, regression analysis. Regression analysis is a statistics tool that helps to find out the correlation between different variables. Based on regression analysis, the stock-flow model was simulated in VENSIM and resulting curves were analyzed. The impact factor analysis technique was used to observe how Qatar can reduce its CO_2 emission based on altering impact factors for different variables in different sectors. After completion of simulation results were summarized and different policies were recommended at the end of this thesis. Figure 21, represents a complete framework performed in this thesis.

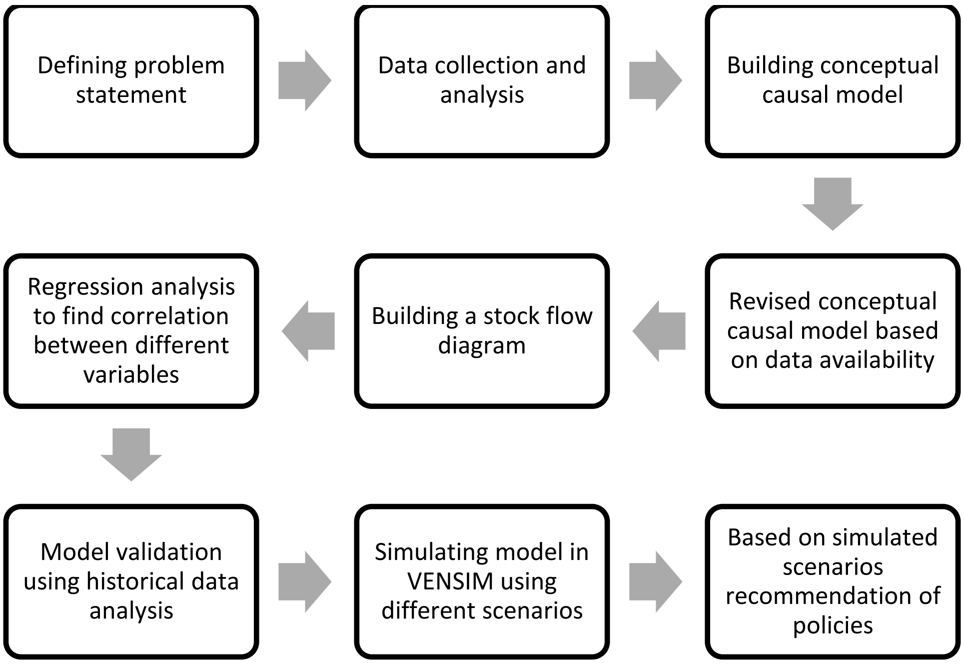


Figure 21: Research method flow chart

4.1 Causal Loop

Causal loop diagram (also written as CLD) is a tool widely used for defining and representing the structure of feedback systems. Causality plays an important role in describing a wicked problem, predicting how a specific variable will be performing, decision-making, and explaining the influence of one variable on other variables. This important role play has classified CLD as a fundamental notion in science. As discussed earlier within this context, that using CLD major problems can be addressed and their root cause can be identified, as well as variables causal effect and the effects of interventions, are easily traced. This structure of identifying the root cause and interventions is known as causal inference.

A simple causal loop diagram includes 4 basic elements

1. Variables,
2. links between different identified variables,

3. the type of correlation between variables, usually represented by a + or – sign,
4. and the type of the loop which will explain the behavior of the loop, either balancing or reinforcing.

In CLD, different variables are oriented and linked in such a way that the effect of each variable on other variables is easily observed. The concept associated with CLD helps the researcher with the following key points (Sterman, 2000)

1. Having a glance and understanding all the causes of dynamics.
2. Identifying important feedback loop and how the loops are affected in general either negatively or positively.
3. Generate a theoretical mode linking variables with all the causes and effects for groups or individuals.

Talking about the types of loops, there are two types of loops balancing loop and reinforcing loop. A reinforcing loop works by encouraging a similar trend as recorded for the initial state variable (Sterman, 2000). Whereas, a balancing loop will try to balance feedback to maintain a certain level. Generally speaking, a balancing loop will bridge the gap between the actual and desired variable's output by taking some actions, but in a reinforcing loop the output of the initial variable is amplified, either growth is shown or a decline.

4.2 System Dynamics

System Dynamics Society (2020) is a computer-based tool mainly used to analyze different policies and respective designs. The key factor of system dynamics which makes it one of the powerful tools is, its application on dynamic problem-solving. The dynamic problem can range from one sector to another, for example, problems arising in financial departments, concerns related to the environment, managerial issues, or ecological systems, all can be addressed as system dynamic application as long as the system is well defined using feedback loops, proper interaction between variables, and interaction between different subsystems. The main idea to grab over here is how the structure of the system must be designed to monitor a policy, as the whole analysis resulting in system dynamic approach depends on the structure of the system, variables involved in that system, and the link between those variables and between subsystems.

The steps taken to use the system dynamic tool begins first by identifying and describing the problem. Based on the problem definition modeling stages are mapped and a theoretical model is prepared which will be simulated later on. The second step is the mathematical formulation of the theoretical model. System dynamics has been proven with the flexibility of using nonlinear, integral, or first-order equations. After completion of formulation, the model is simulated using discrete intervals of time. Based on these simulations, predictions are performed which helps a police maker to design and implement policies.

Besides system dynamics, simulation can model different scenarios that can be compared, as well as what-if analysis, can be performed over soft variables, and at the same time sensitivity analysis can be conducted. The focus for system dynamics varies from discrete event analysis for individual variables to observing certain behavior patterns of the model being simulated.

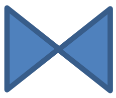
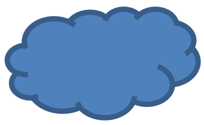
Nuri (2014) states some of the ideas and elements involved in the structuring and organizing framework for system dynamics. These elements are the boundary of the close system, different feedback loops, stocks, flow rates, goals, different conditions recorded from simulation, and desired actions planned based on simulation.

4.3 Stock Flow Diagram

Stocks and flows are considered as the basic building blocks of system dynamics models. A level or accumulating or declining variable with time is considered as stock, and flow of values from one point to another on time base are called as flow-rate. The stock-flow diagram consists of different elements such as stock, flow, rate, cloud, and link (see table 1).

Table 4. Elements of the stock-flow diagram

Name	Symbol	Description
Stock		• Accumulation over a certain period. The stock can either be bulk up or deplete it all depends on the flow in and out of the stock. • Stock can be formulated as inflow – outflow for each period. • Values of stock are manipulated with time, meaning at a certain time a stock will have a certain value. • Example: population value at a certain period.
Flow		• A variable that changes stock over time. Inflow, flow

Name	Symbol	Description
		accumulating in a stock. Outflow, flow declining the value of a stock. • Flows typically are measured over a certain interval of time • Example: number of death over a period (either month or year)
Flow Rate		• Variable expressed as per unit time. • Example: Revenue is calculated over time mainly year which is $/year.
Cloud		Cloud represents either: • Source of the flow, for outside of the model • Sink of the flow, flow getting declined into the system
Link		• Used to mark out the relation between stock or flow to flow diagram and their dependency

4.4 Model Generation

4.4.1 Causal Loop Model Generation

Based on the availability of the data the initial conceptual causal model was altered and the resulting causal model incorporated 4 different sectors (refer to figure 22). The four different sectors were the economic sector, the educational sector, the social sector, and the environmental sector. Each sector compromises different variables that are linked within the sectors and as well as to the variables in other sectors. Such as GDP in the economic sector is highly affected by the population of the country, therefore, there is an arrow coming out from the population variable and connecting to GDP.

Once the causal model was prepared stock-flow diagram was generated (as shown in figure 23). This stock-flow model was simulated in VENSIM software mainly for two purposes, firstly, to validate the model and secondly, to draw out results by performing an impact factor analysis technique.

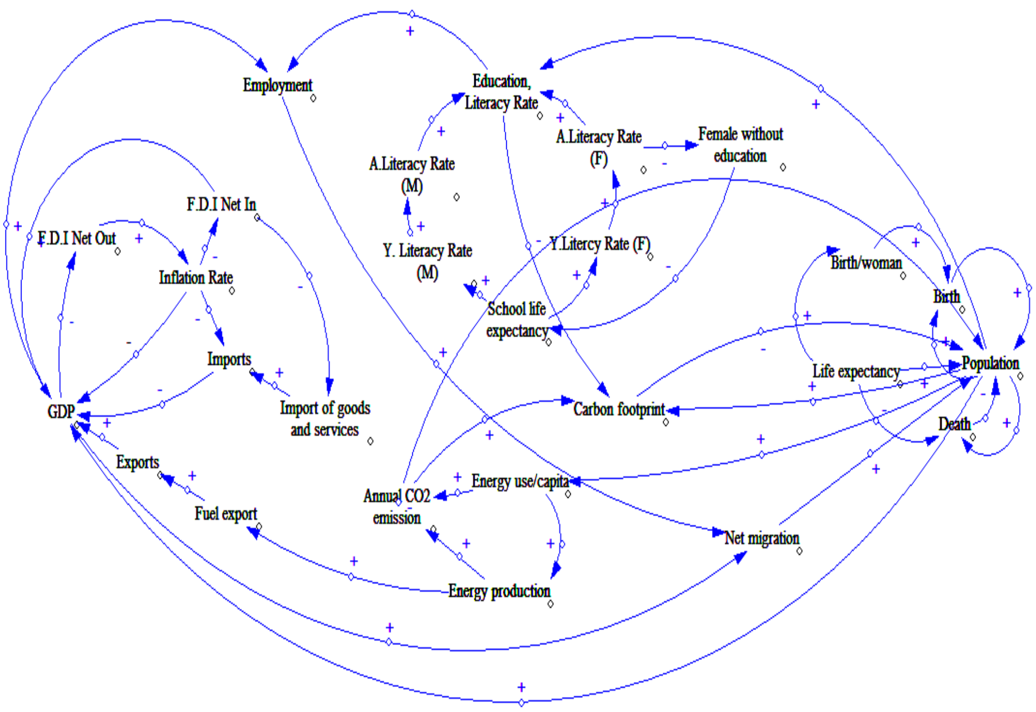


Figure 22. Conceptual causal loop model

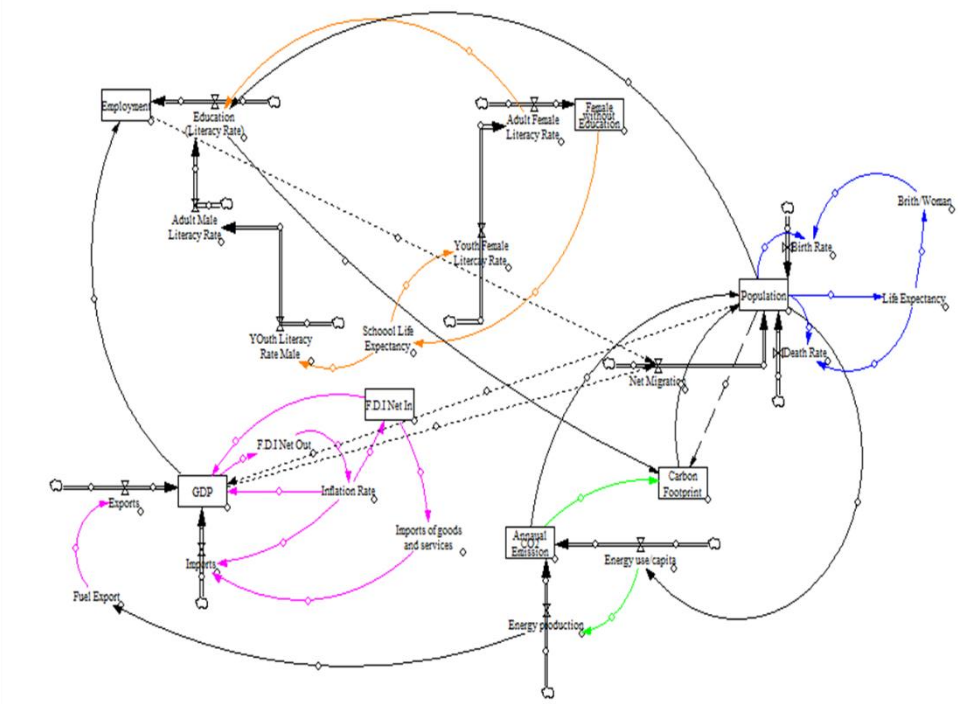


Figure 23. Stock flow diagram for the conceptual causal loop

4.4.2 Variable Description and Differentiation of Reinforcing and Balancing loops

In this part of the thesis, all the associated CLD variables are described concerning their units (see table 2).

The second part of this section will be discussing different identified loops in CLD and their respective polarity. If there exists a positive correlation between 2 variables, then those variables are said to have a positive polarity. For example: In our CLD, an increase in birth rate will increase the population variable, therefore the birth rate is said to have a positive polarity with the population. Similarly, if there exists a negative correlation then those variables are said to have a negative polarity. For example, an increase in the number of death rates will decrease the population variable, therefore the death rate is said to have a negative polarity with the population variable (Onat, Kucukvar, & Tatari, Integration of system dynamics approach toward deeping and broadening the life cycle sustainability assessment framework: a case for electric vehicles, 2015).

The reinforcing loop is defined as a loop in which one variable tends to increase or decrease another variable and when the loop is closed on the initial variable there is the same effect of increase or decrease on that variable.

A balancing loop is defined as a loop in which one variable tends to decrease or increase another variable and when the loop is closed on the initial variable there is an opposite effect either increase or decrease on that variable. Balancing the loop try to avoid the variation in the loop (Carolina Kelly, 2019)(see table 3).

Table 5: Variable Descriptions

Output Variable	Units	Description
Population	People	The total number of people inhabiting a country counted in 1000s.
Birth rate	People/year	The number of children being born in Qatar counted in 1000s
Death rate	People/year	Number of children + adult who is no more alive in Qatar counted in 1000s
Birth/woman	Children/woman	The average number of children a woman delivers in Qatar
Life expectancy	Years	The average age of local living in Qatar
Net migration	People	Number of people entering the country subtracted by the number of people living in the country, counted in 1000s
Carbon footprint	Tons/person	CO_2 equivalent emissions resulted from a person's activities. Mainly set of greenhouse gas emissions
Annual CO_2 emission	Tons/person	Amount of yearly CO_2 emission as a result of available industries
Energy use/capita	Kilo watt-	The energy in form of oil, gas, or

Output Variable	Units	Description
	hour/person	electricity being consumed by individuals in Qatar
Energy production	Tetra watt-hour	Amount of electricity, oil, gas, or another form of energy produced by Qatari industries
GDP	Billion USD	Gross domestic product accounts for terms like consumption, government expenditure, investments, and net export
F.D.I net out	Billion USD	Foreign direct investment, an investment in a form of ownership in business outside the country
Inflation rate	Percentage	Changes in the level of prices for goods and services being bought by individuals living in Qatar
Imports	Billion USD	Bring in goods and services into Qatar
F.D.I net in	Billion USD	Foreign direct investment, an investment in a form of ownership in business inside side the country
Imports of goods and services	Billion USD	Bring in goods and services into Qatar, such as consumable items, automobile, electronic industry, and so on
Fuel export	Billion USD	Amount of oil and gas being exported to different destination converted into the worth of USD
Export	Billion USD	Sending out goods and services from Qatar
Employment	People	Number of people holding jobs in Qatar
Literacy rate	Percentage of population	Number of people completed their college
Adult male literacy	People	Total number of males who completed high school, age ranging from 15 onwards
Adult female literacy	People	Total number of females who completed high school, age ranging from 15 onwards
Youth male literacy	People	Total number of males who completed secondary school, age ranging from 7 to 15
Youth female literacy	People	Total number of females who completed secondary school, age ranging from 7 to 15
Female without education	People	Total number of females who left schooling before even completion of secondary level
School life expectancy	Years	An average level a local will try to achieve in his life

A. Loops related to population variable

1. Population→(+)Birth→(+)Population
2. Population→(+)Death→(-)Population
3. Population→(+)Carbon footprint→(-)Population
4. Population→(+)Education→(+)Literacy Rate→(-)Carbon footprint→(-)Population
5. Population→(+)GDP→(+)Net migration→(+)Population
6. Population→(+)Energy use/capita→(+)Annual CO_2 emission→(-)Population
7. Population→(+)GDP→(+)Employment→(+)Net migration→(+)Population
8. Population→(+)Education→(+)Literacy Rate→(+)Employment→(+)Net migration→(+)Population
9. Population→(+)Energy use/capita→(+)Annual CO_2 emission→(+)Carbon footprint→(-)Population
10. Population→(+)Energy use/capita→(+)Energy production→(+)Annual CO_2 emission→(-)Population
11. Population→(+)Energy use/capita→(+)Energy production→(+)Annual CO_2 emission→(+)Carbon footprint→(-) Population
12. Population→(+)Energy use/capita→(+)Energy production→(+)Fuel export→(+)Exports→(+)GDP→(+)Net migration→(+)Population
13. Population→(+)Energy use/capita→(+)Energy production→(+)Fuel export→(+)Exports→(+)GDP→(+)Employment→(+)Net

migration→(+)Population

B. Loops related to GDP variable

1. GDP→(+)Net Migration→(+)Population→(+)GDP
2. GDP→(-)F.D.I Net Out→(+)Inflation Rate→(-)GDP
3. GDP→(-)F.D.I Net Out→(+)Inflation Rate→(+)Imports→(-)GDP
4. GDP→(-)F.D.I Net Out→(+)Inflation Rate→(-)F.D.I Net In→(+)GDP
5. GDP→(+)Employment→(+)Net Migration→(+)Population→(+)GDP
6. GDP→(-)F.D.I Net Out→(+)Inflation Rate→(-)F.D.I Net In→(-)Imports of goods and services-→(-)Imports→(-)GDP
7. GDP→(+)Net Migration→(+)Population→(+)Energy use/capita→(+)Energy production→(+)Fuel Export→(+)Exports→(+)GDP
8. GDP→(+)Employment→(+)Net Migration→(+)Population→(+)Energy use/capita→(+)Energy production→(+)Fuel Export→(+)Exports→(+)GDP

C. Loops related to Carbon footprint

1. Carbon Footprint→(-)Population→(+)Carbon Footprint
2. Carbon Footprint→(-)Population→(+)Education (Literacy Rate)→(-)Carbon Footprint
3. Carbon Footprint→(-)Population→(+)Energy use/capita→(+)Annual CO_2 Emission→(+)Carbon Footprint
4. Carbon Footprint→(-)Population→(+)Energy use/capita→(+)Energy production→(+)Annual CO_2 Emission→(+)Carbon Footprint

D. Loops related to Literacy rate

1. Education (Literacy Rate)→(-)Carbon Footprint→(-

)Population→(+)Education (Literacy Rate)

2. Education (Literacy Rate)→(+)Employment→(+)Net Migration→(+)Population→(+)Education Literacy Rate)

Table 6: List of Balancing and Reinforcing loops

Loop #	Balancing / Reinforcing	Corresponding CLD Loop
A.1	Reinforcing	Social loop
A.2	Balancing	Social loop
A.3	Balancing	Social loop
A.4	Reinforcing	Social loop
A.5	Reinforcing	Social loop
A.6	Balancing	Social loop
A.7	Reinforcing	Social loop
A.8	Reinforcing	Social loop
A.9	Balancing	Social loop
A.10	Balancing	Social loop
A.11	Balancing	Social loop
A.12	Reinforcing	Social loop
A.13	Reinforcing	Social loop
B.1	Reinforcing	Economy loop
B.2	Reinforcing	Economy loop
B.3	Reinforcing	Economy loop
B.4	Reinforcing	Economy loop
B.5	Reinforcing	Economy loop
B.6	Reinforcing	Economy loop
B.7	Reinforcing	Economy loop
B.8	Reinforcing	Economy loop
C.1	Balancing	Environment loop
C.2	Reinforcing	Environment loop
C.3	Balancing	Environment loop
C.4	Balancing	Environment loop
D.1	Reinforcing	Education loop
D.2	Reinforcing	Education loop

4.5 Model Formulation and Regression Analysis

In this section, the mathematical relation between all the variables and between different loops has been formulated using the regression analysis technique. First, different variables were identified and their correlation with other variables was taken under consideration. Using those correlations and regression tools in the excel output variable was formulated based on all other input variables (see table 4).

Table 7: Mathematical formulation of CLD

Output Variable	Corresponding CLD loop	Mathematical Formulation
Population	Social loop	61.68*birth rate+150.27*death rate+4.66*net migration+0*annual CO_2 emission+0*carbon footprint
Birth rate	Social loop	0.015*Population+35.26*"Brith/Woman"-81
Death rate	Social loop	1.64*life expectancy-0.00072*population-125.7
Birth/woman	Social loop	-0.23*life expectancy+20.43
Life expectancy	Social loop	0.0012*population+76.72
Net migration	Social loop	0.0083*gdp-0.00122*emploment+364
Carbon footprint	Environment loop	-1127.85*"education (literacy rate)"+88.41*population-51868.6+0*annual CO_2 emission
Annual CO_2 emission	Environment loop	18248.5*energy production-89.32*"energy use/capita"+5.0716e+07
Energy use/capita	Environment loop	-67.67*population+381786
Energy production	Environment loop	-0.0198*"energy use/capita"+5882.08
GDP	Economy loop	0.12*population+0.97*exports-0.92*imports+5.52*"F.D.I net in"+2.35*inflation rate-195.22
F.D.I net out	Economy loop	0.022*gdp+1.11
Inflation rate	Economy loop	0.25*"F.D.I net out"+0.95
Imports	Economy loop	1.1*imports of goods and services-0.25*inflation rate+3.3
F.D.I net in	Economy loop	-0.13*inflation rate+2.43
Imports of goods and services	Economy loop	-3.21*"F.D.I net in"+50.77
Fuel export	Economy loop	0.00025*energy production+21.47
Export	Economy loop	4.91*fuel export-7.71
Employment	Education loop	-290.24*gdp+3674.85*"education (literacy rate)"-18990
Literacy rate	Education loop	0.48-0.025*population-0.12*adult female

Output Variable	Corresponding CLD loop	Mathematical Formulation
		literacy rate+1.8*adult male literacy rate
Adult male literacy rate	Education loop	-104.36+2.04*youth literacy rate male
Adult female literacy rate	Education loop	-187.6+2.85*youth female literacy rate
Youth male literacy rate	Education loop	79.2+1.17*school life expectancy
Youth female literacy rate	Education loop	74.34+1.68*school life expectancy
Female without education	Education loop	12.52-0.12*adult female literacy rate
School life expectancy	Education loop	12.77-0.055*female without education

4.6 Model Validation

Model validation was performed using the technique known as historical data validation. Data for the past 10 years was collected; regression analysis was performed on the data to know the correlation between different variables. Those correlations were then considered as one of the inputs to VENSIM software and the stock-flow diagram was simulated using those correlations.

Each loop was validated on separate bases, meaning for social loop, population stock-flow diagram was considered and all the variables affecting population was considered (see figure 24. population stock flow diagram. The initial period was set as 2009 and the model was simulated for each year starting from 2010. The generated outputs for the population were recorded and then were compared to historical data for the population (see table 8). Later a graph was prepared to summarize all the findings related to validation of the social stock-flow loop (refer to figure 25).

4.6.1 Population Causal Loop

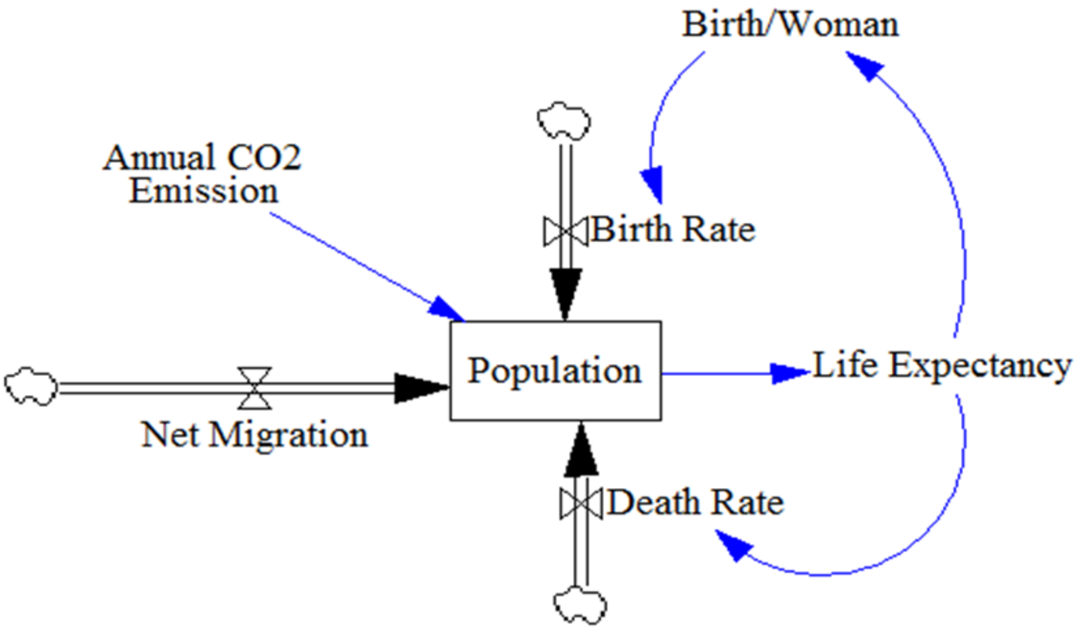


Figure 24. Population stock flow diagram

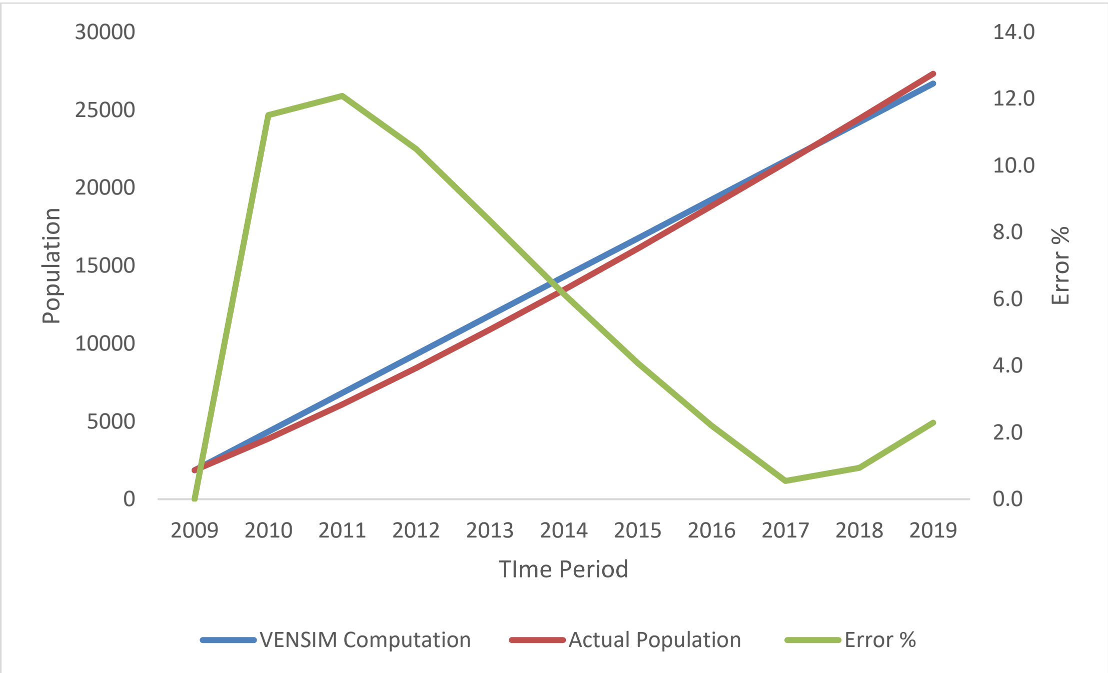


Figure 25. Plot representing the error associated with population loop

Table 8. The error associated between population data and data generated by VENSIM

Year	Actual Population (1000)	Vensim data generation for Population (1000)	Error %
2009	1857	1857	0.0
2010	3893	4341	11.5
2011	6089	6825	12.1
2012	8425	9309	10.5
2013	10885	11793	8.3
2014	13450	14277	6.1
2015	16105	16761	4.1
2016	18829	19245	2.2
2017	21611	21729	0.5
2018	24443	24213	0.9
2019	27324	26697	2.3

4.6.2 Economic Causal Loop

Similar to the social loop, model validation was also performed for an economic causal loop. All the variables affected GDP were presented in this causal loop (see figure 26). Similarly generating results as done for the social loop, the results were recorded in a table containing historical data for GDP and the percentage error associated between computation GDP and actual GDP value for each year (refer to table 9). 3 curves were prepared to summarize the actual GDP, computed GDP, and the error between the two values (see figure 27).

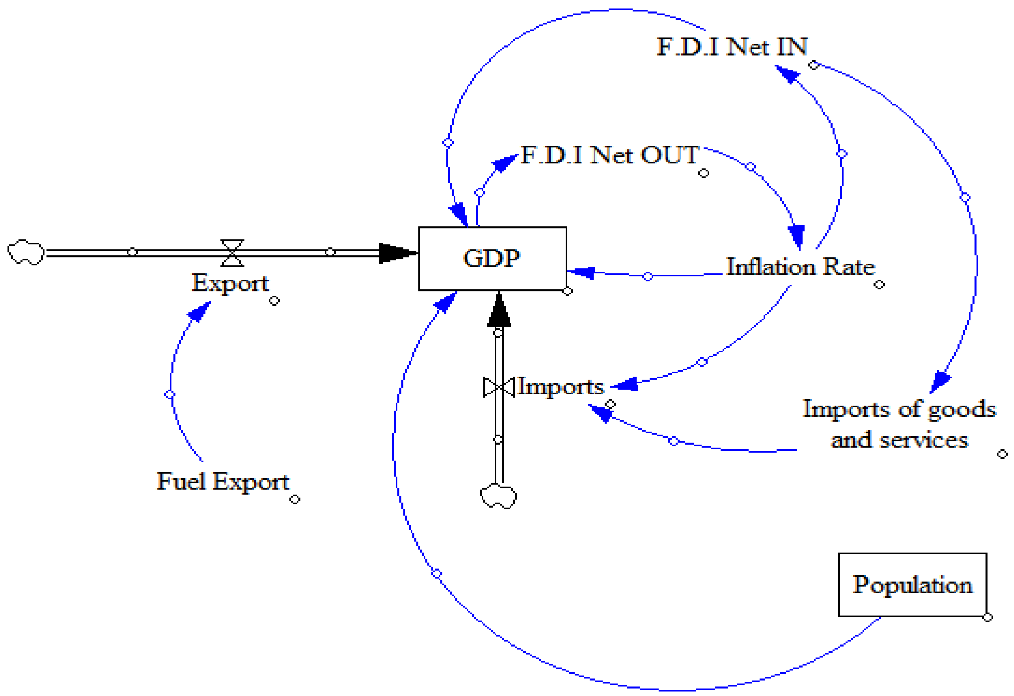


Figure 26. Economic stock flow diagram

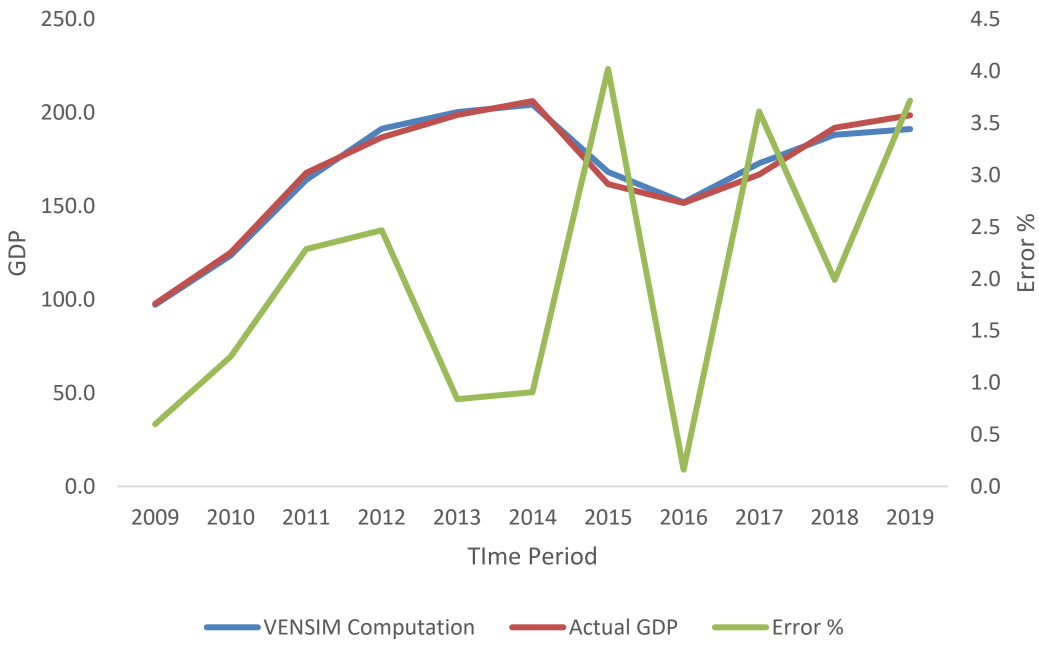


Figure 27. Plot representing the error associated with economic loop

Table 9. The error associated between GDP data and data generated by VENSIM

Year	GDP (Billion USD)	GDP Computation Using Vensim (Billion USD)	Error %
2009	97.8	97.2	0.6
2010	125.1	123.6	1.2
2011	167.8	163.9	2.3
2012	186.8	191.4	2.5
2013	198.7	200.4	0.8
2014	206.2	204.4	0.9
2015	161.7	168.2	4.0
2016	151.7	152.0	0.2
2017	166.9	173.0	3.6
2018	192.0	188.2	2.0
2019	198.6	191.2	3.7

4.6.3 Education Causal Loop

For the educational loop, all the variables affecting the literacy rate were presented in this causal loop (see figure 28). Similarly generating results as done for social loop, the results were recorded in a table containing historical data for literacy rate and the percentage error associated between computational literacy rate and the actual literacy rate for each year (refer to table 4). 3 curves were prepared to summarize the actual literacy rate, computed literacy rate, and the error between the two values (see figure 29).

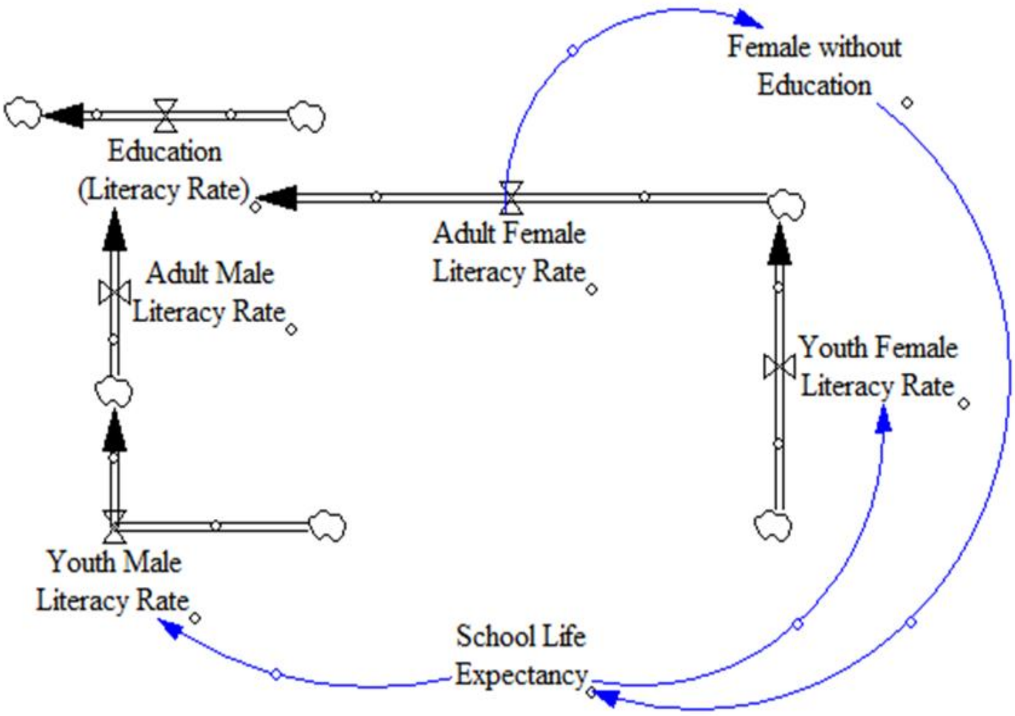


Figure 28. Education stock flow diagram

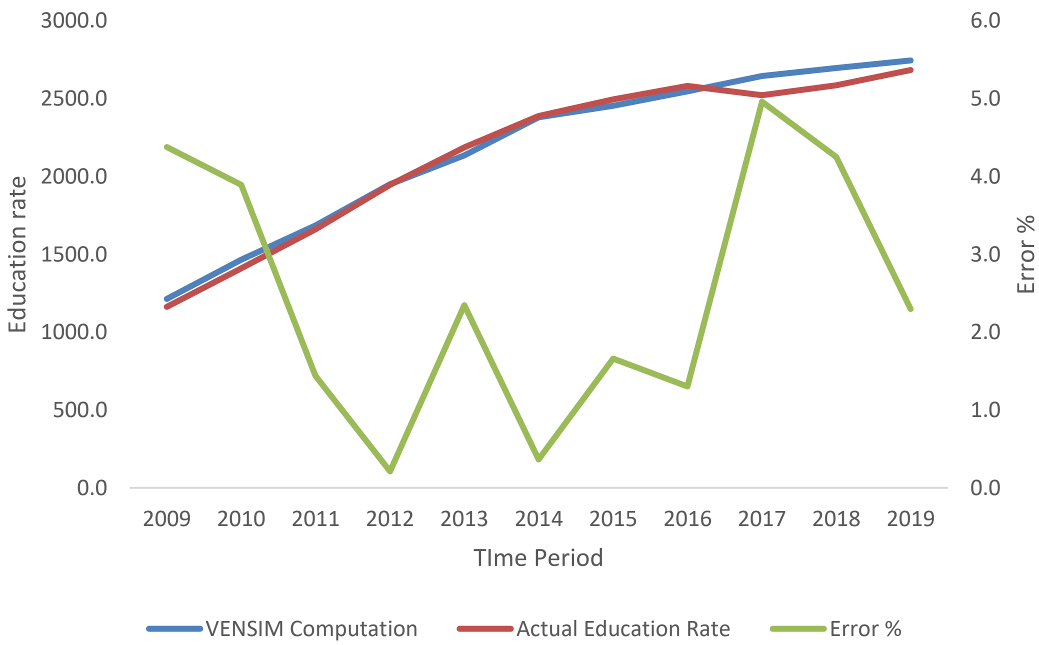


Figure 29. Plot representing the error associated with education loop

Table 10. The error associated between education data and data generated by VENSIM

Year	Education Rate (1000)	Education Rate Computation Using Vensim (1000)	Error %
2009	1162.6	1213.5	4.4
2010	1410.7	1465.6	3.9
2011	1661.0	1684.9	1.4
2012	1945.5	1949.6	0.2
2013	2187.8	2136.4	2.3
2014	2388.2	2379.6	0.4
2015	2494.8	2453.4	1.7
2016	2581.0	2547.4	1.3
2017	2521.1	2646.2	5.0
2018	2586.4	2696.3	4.2
2019	2683.6	2745.2	2.3

4.6.4 Environmental Causal Loop

For the environmental loop, all the variables affecting carbon footprint were presented in this causal loop (see figure 30). Similarly generating results as done for social loop, the results were recorded in a table containing historical data for carbon footprint and the percentage error associated between computational carbon footprint and actual carbon footprint for each year (refer to table 5). Three curves were prepared to summarize the actual carbon footprint, computed carbon footprint, and the error between the two values (see figure 31).

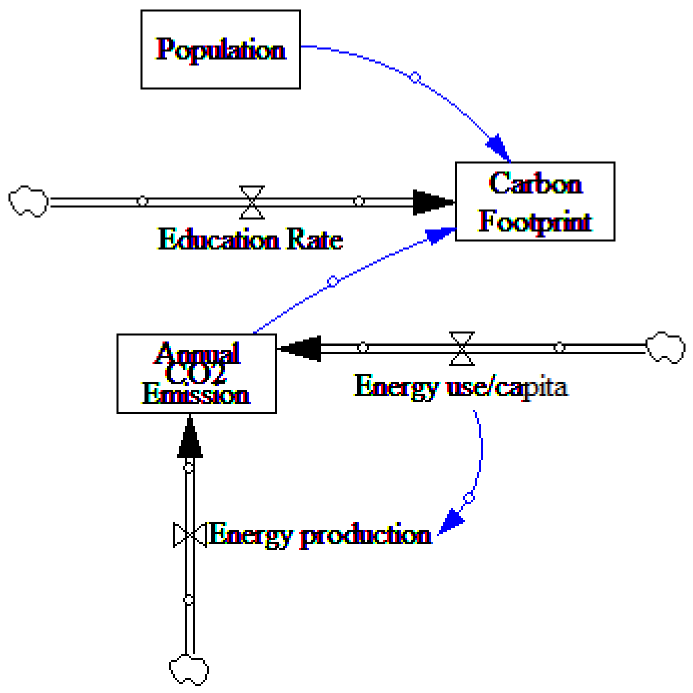


Figure 30. Environmental stock flow diagram

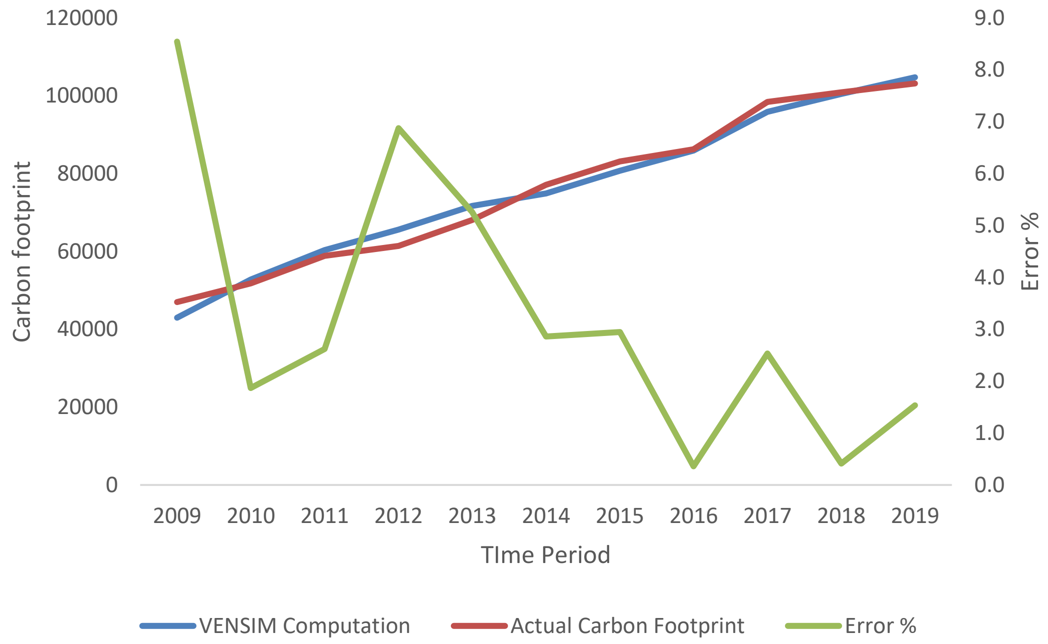


Figure 31. Plot representing the error associated with environmental loop

Table 11. The error associated between environmental data and data generated by VENSIM

Year	Carbon Footprint (Kt)	Carbon Footprint Computation Using Vensim (Kt)	Error %
2009	46984	42970	8.5
2010	51782	52748	1.9
2011	58828	60369	2.6
2012	61389	65609	6.9
2013	68074	71654	5.3
2014	77136	74929	2.9
2015	83149	80700	2.9
2016	86228	85918	0.4
2017	98392	95899	2.5
2018	100891	100475	0.4
2019	103155	104735	1.5

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Base Model Analysis

In this section, the prepared stock flow diagram and conceptual CLD is being simulated. To differentiate this model from the other upcoming models later in section 4.2, this model has been labeled as the base model. The base model refers to the terminology where prepared stock flow and CLD is simulated without any impact factor analysis.

Below is a representation of the forecasted population in Qatar for the next 10 years starting from 2019 till 2030 (see figure 32). The graph follows an exponential curve making it clear that the population growth will increase rapidly as time elapses. Based on the exponential curve for population growth, it can be predicted easily that energy consumption within the country will be having a rapid growth with a similar curve as of population (see figure 36), and at the same time, the increase in energy consumption will promote a higher release of CO_2 into the atmosphere (see figure 40).

One of the reasons for this rapid population growth can be net migration within the country (see figure 33). The terminology of net migration can be withdrawn after subtracting the number of people entering the country – the number of people exiting the country.

Another reason for the increase in population can be linked to the opening of job opportunities and hence increasing employment within the country (see figure 34). Therefore, a high employment rate will affect the net migration rate directly and positively.

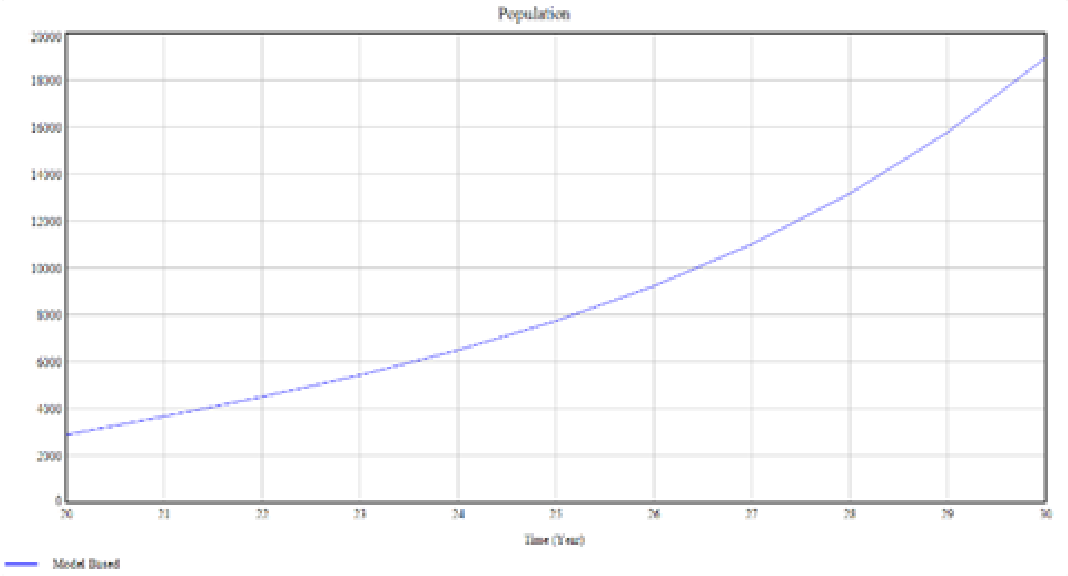


Figure 32. Base model population results

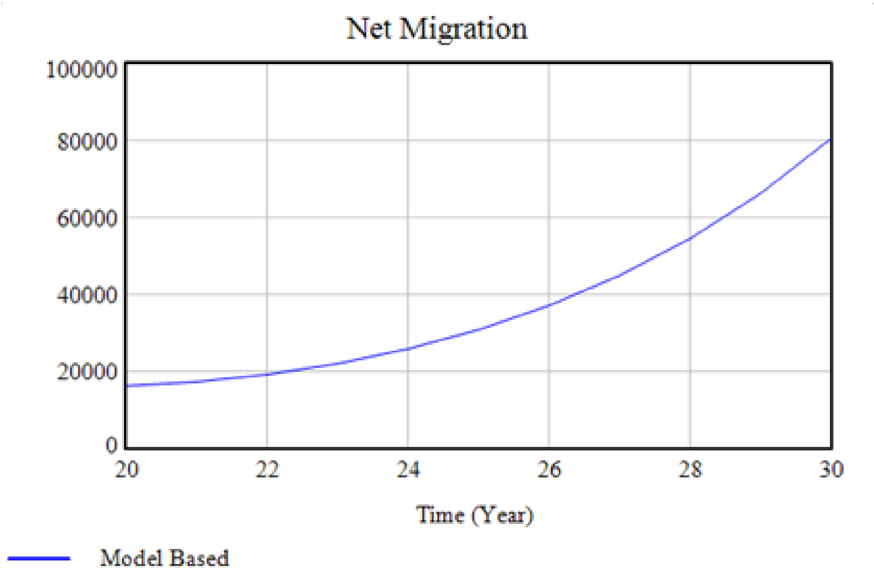


Figure 33. Base model net migration results

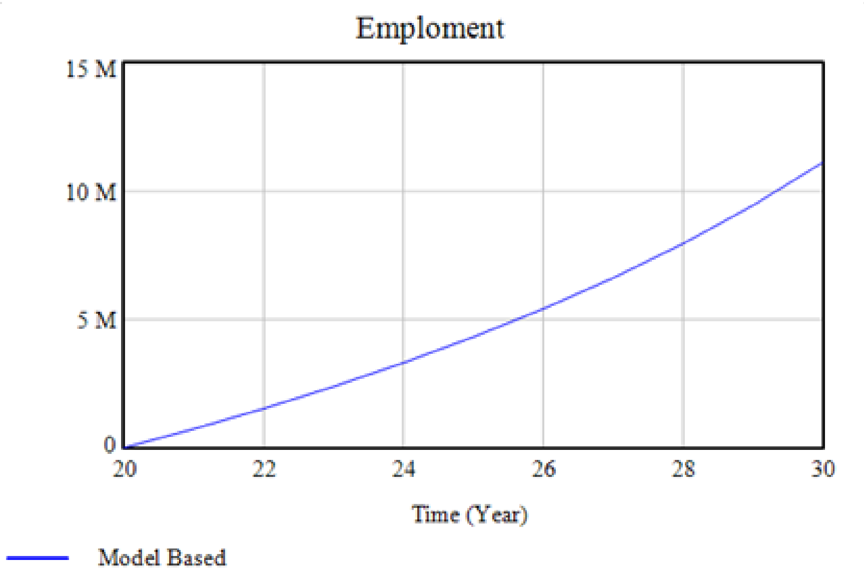


Figure 34. Base model employment results

By the passage of time, the model predicts a positive trend in literacy rate, the number of people getting educated (see figure 35). As shown earlier in the thesis that the literacy rate depends on multiple factors such as adult literacy rate, youth literacy rate, and most importantly number of females who leave the education system and spends the rest of their lives as uneducated. Positive rapid growth in population trends can explain the positive curve of literacy rate. As the number of people within the country increases either migrating or born locally, the chances of those people classified as educated or getting education increase and thus, education goes positively in parallel with the population.

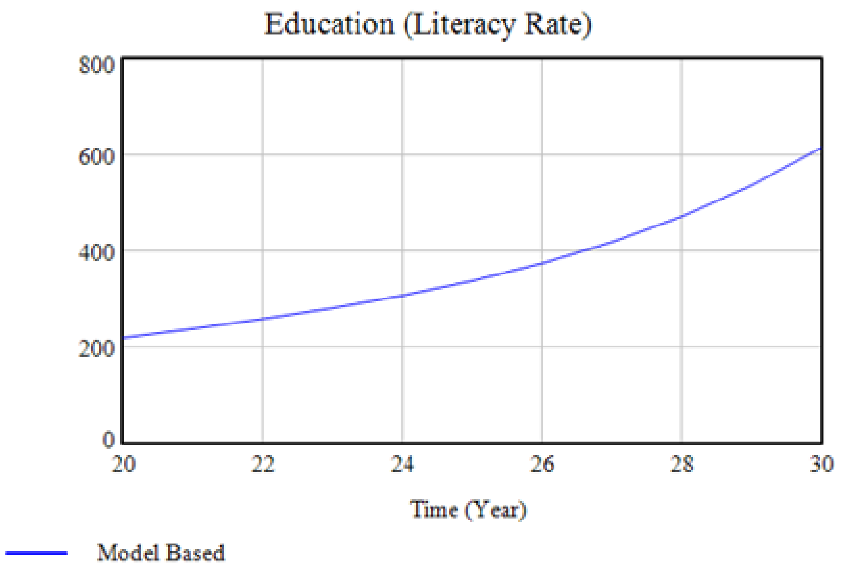


Figure 35. Base model Literacy rate results

Due to the increase in oil and gas export, the energy production shows an increment, as well as the total revenue for the country, will increase (see figure 36, figure 37, and figure 38). The increase in total revenue for the country will result in a higher value for the GDP.

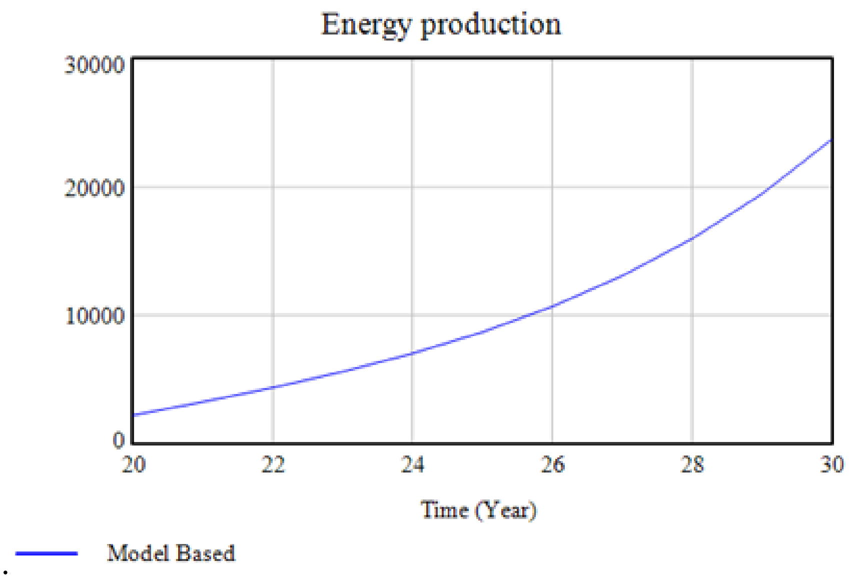


Figure 36. Base model energy production (oil & gas) results

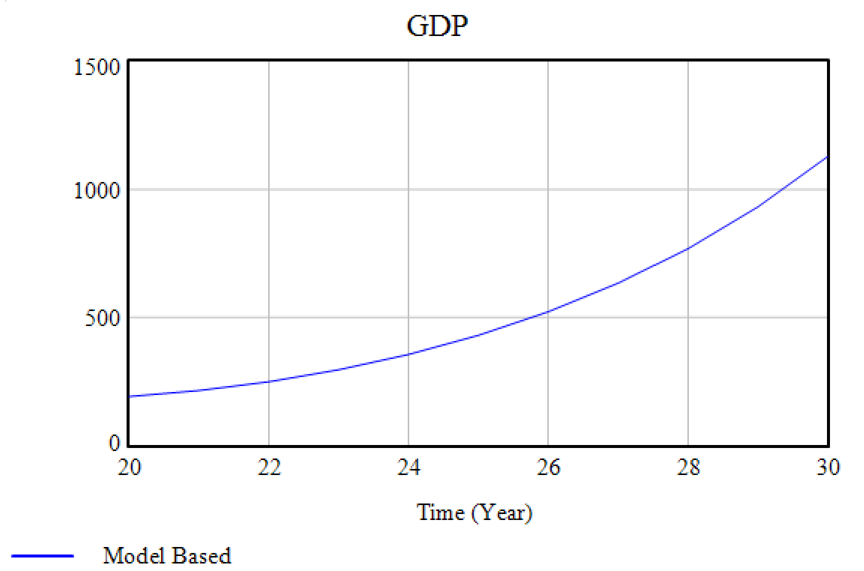


Figure 37. Base model GDP results

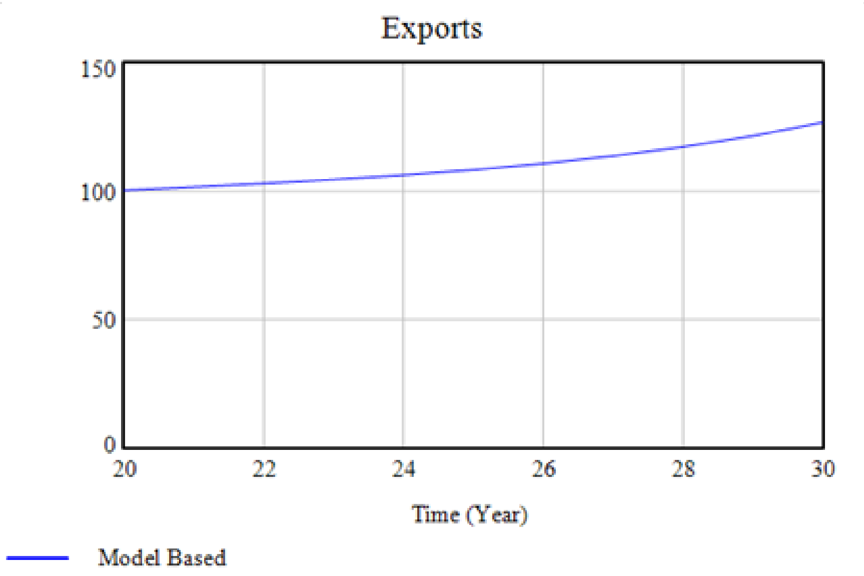


Figure 38. Base model export results

The increase in annual CO_2 emission and carbon footprint (see figure 39 and figure 40) can be explained by two main factors. For annual CO_2 emission, the huge demand for fuel export can justify the increase in annual CO_2 emission. The demand for oil increases the production which increases the amount of CO_2 being released into the atmosphere. Whereas, the increase in population is linked to an upwards trend in carbon footprint.

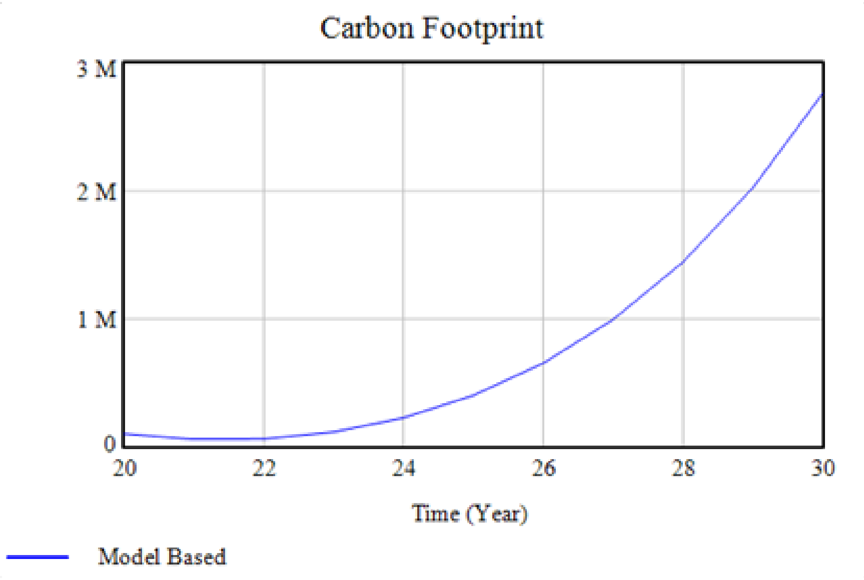


Figure 39. Base model carbon footprint results

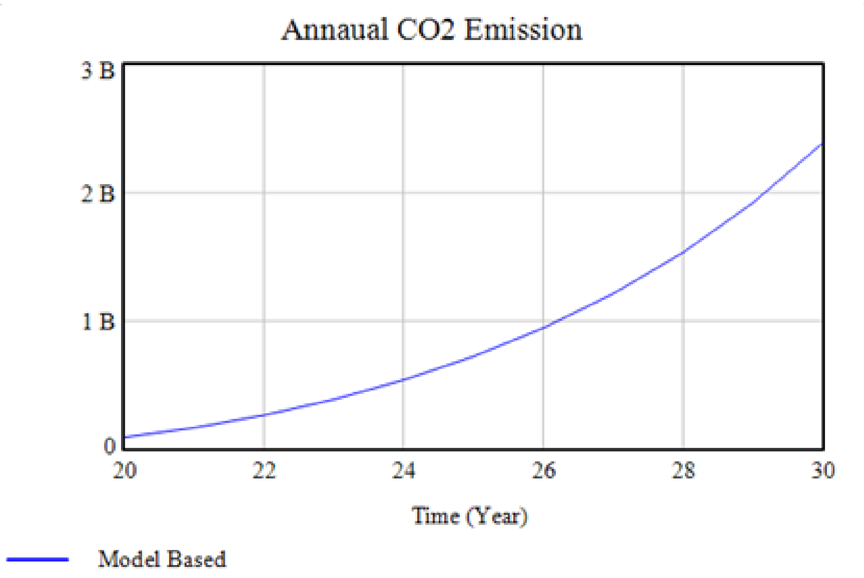


Figure 40. Base model annual CO_2 results

5.2 Impact Factor Analysis

5.2.1 Net Migration Impact factor

Changing the impact factor for net migration from 25 to 100, which is the base model. Net migration impact factor of 25 means, the equation is drawn from the base model in section 4.1 for net migration is multiplied by 25%, as the equation in the base model is considered to be 100%. To elaborate more, the net migration impact factor of 25 means that net migration values in that specific simulation run will be operating and giving input to the population at 75% lower value compared to base mode net migration values. Similarly, net migration impact factor 50 and 75 means that net migration values being input to the population variable will be 50% lower and 25% lower compared to the base model, respectively. The following observations were made. The rate of growth for the population will be at its lowest when an impact factor of 25 is applied on net migration and the rate will increase with an increase in impact factor (see figure 41). A similar trend to the population has been observed in birth rate and death rate (see figure 43 and figure 44), the curve for death rate can be made less stepper by improvising and enhancing the medical services in Qatar. The reason for not applying a zero impact factor on net migration is because Qatar is a developing country, applying an impact factor of zero means not allowing immigrants to enter Qatar. This implication will affect Qatar's development and future where collaboration with the outside world is necessary.

Net migration shows a positive linear trend with all the selected variables (see figure 42). A reduction in impact factor for net migration to 25 will help Qatar to control and reduce its annual carbon emission as well as carbon footprint as the population growth curve is less stepper compared to impact factor of 100 (see figure 47 and figure 48), but this impact factor will also lead to a significant reduction in Qatar's GDP (see figure 49) as one of the reason will be less demand of energy consumption within the country (see figure 50). GDP incorporates terminologies like consumption, investment, government spending, and net export. Due to lower population growth, local consumptions and local investments will also be reduced, and this has a major and direct effect on GDP. Therefore, GDP growth will be the highest when the impact factor for net migration is targeted to be 100%, but this 100 comes with a cost which is a higher rate of polluting the environment by emitting more CO_2 due to an increase in energy production and carbon footprint.

Observing education variable while performing impact factor analysis on net migration it was concluded that the relationship between education and net migration is directly proportional and positively correlated, which means the higher the impact factor, the more literacy rate will be shown by Qatar as a country (see figure 46). To justify this sort of trend, let us consider collaborating with the outer world by having a higher employment rate (see figure 45) and welcoming more educated people and at the same time, this will positively influence the education culture in Qatar. To change Qatar's economy from the oil and gas sector to a knowledge-based economy, an impact factor of 100 is preferred for net migration. But as discussed earlier increasing this impact factor will have a direct consequence on the environmental sector in Qatar. So, it is much preferred to have a tradeoff between the education sector and the environmental sector by compromising the impact factors for net migration to a certain extend, around 50.

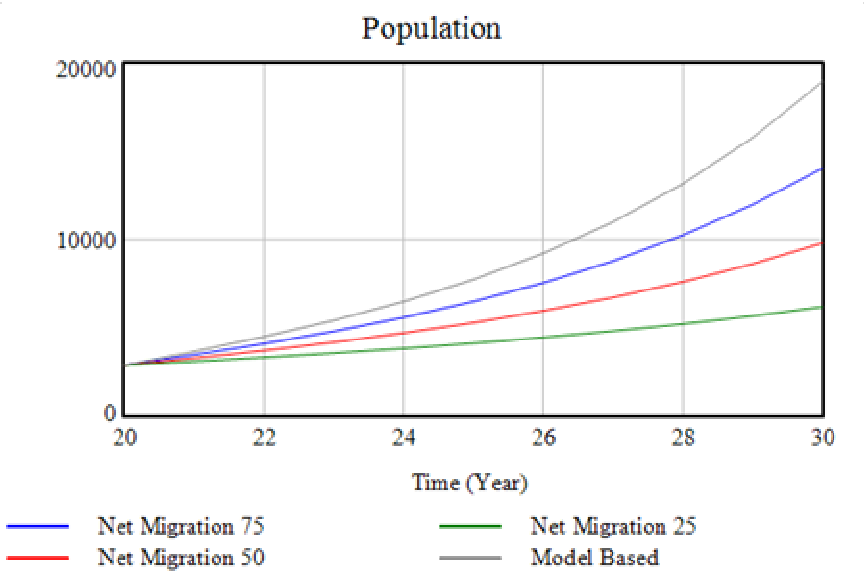


Figure 41. net migration impact factor analysis on population

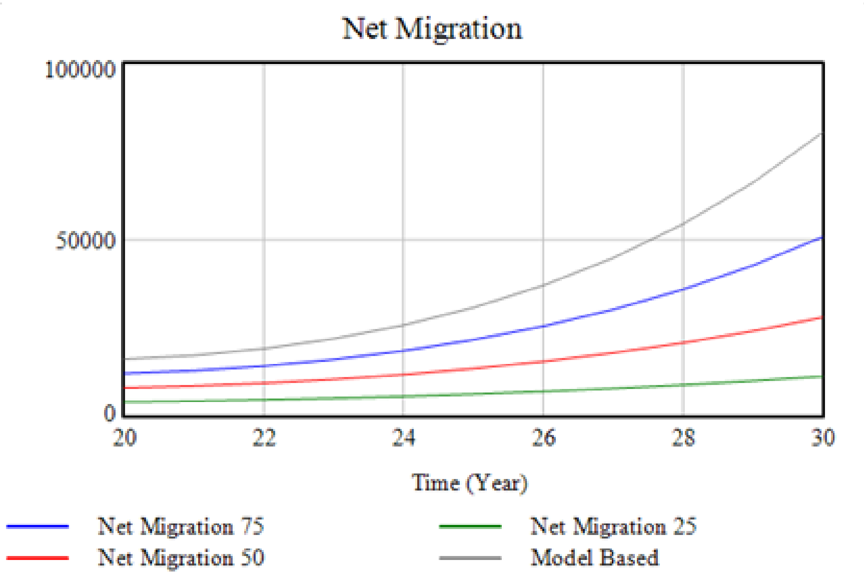


Figure 42. Net migration impact factor analysis on net migration

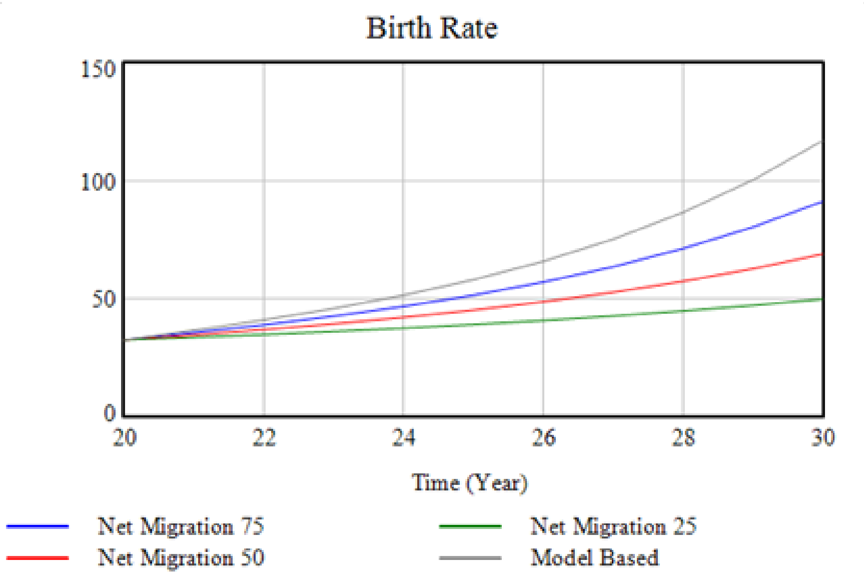


Figure 43. Net migration impact factor analysis on the birth rate

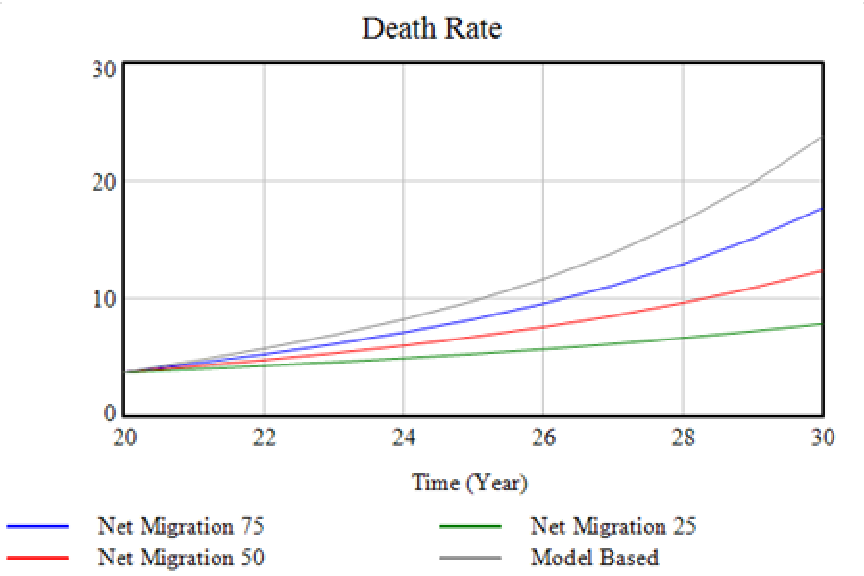


Figure 44. Net migration impact factor analysis on the death rate

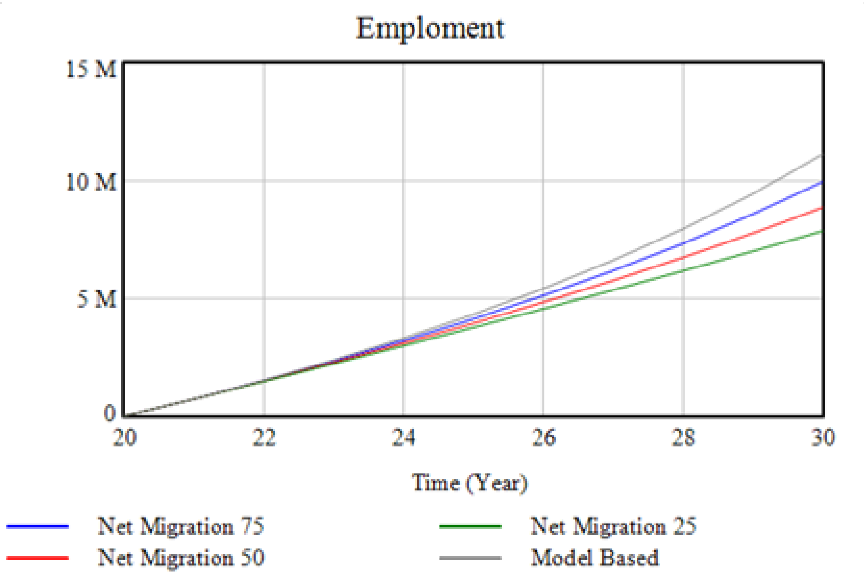


Figure 45. Net migration impact factor analysis on employment

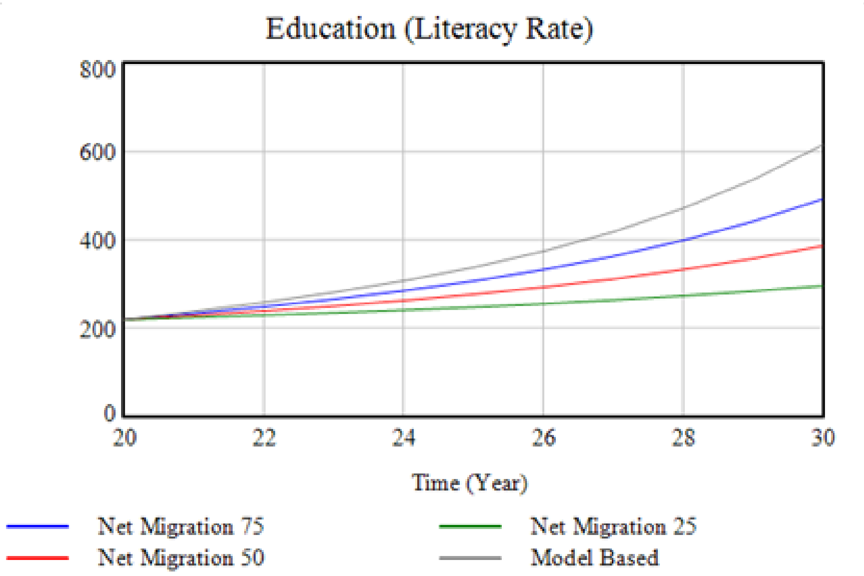


Figure 46. Net migration impact factor analysis on literacy rate

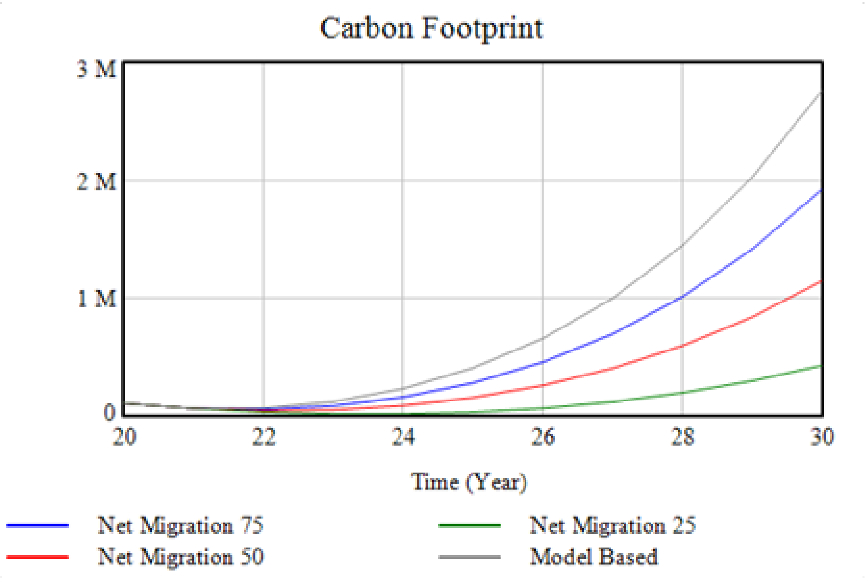


Figure 47. Net migration impact factor analysis on the carbon footprint

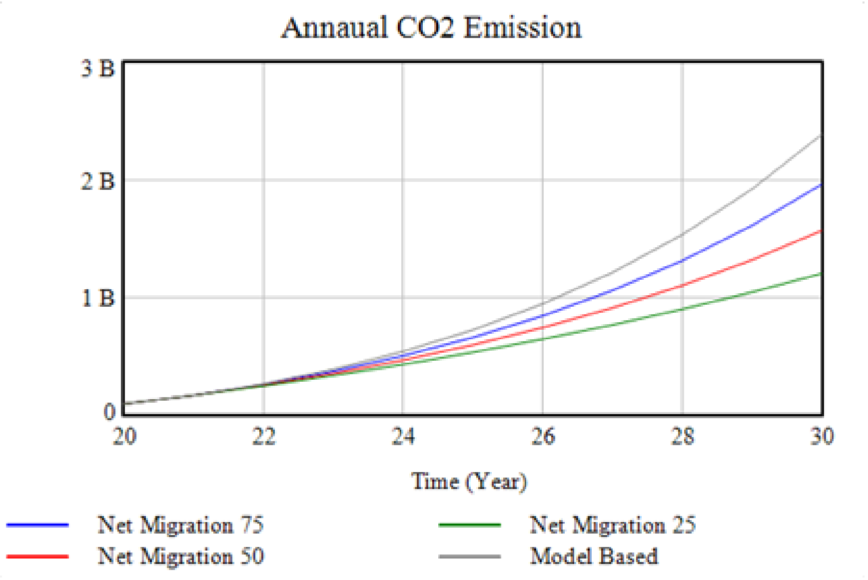


Figure 48. Net migration impact factor analysis on annual CO_2

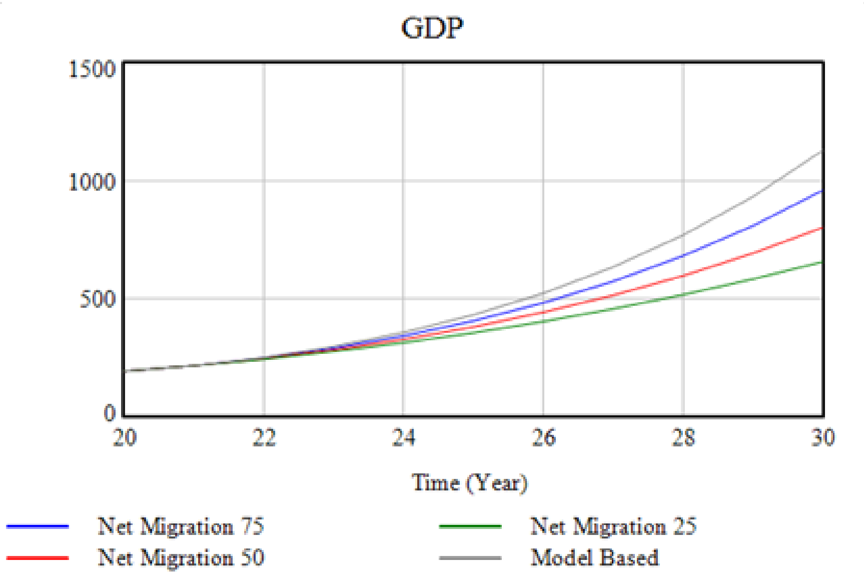


Figure 49 Net migration impact factor analysis on GDP

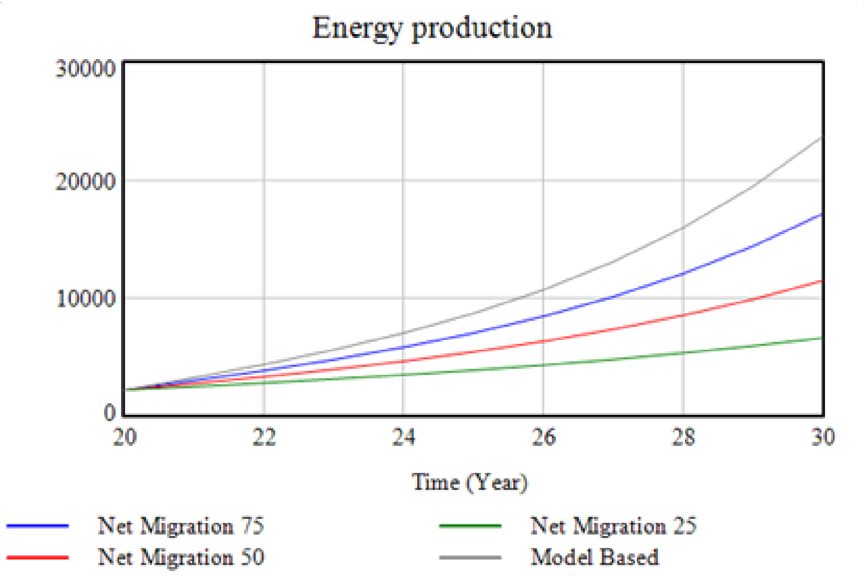


Figure 50. Net migration impact factor analysis on energy production

5.2.2 Energy Production Impact Factor

Ranging the impact factor from 25 to 100 for energy production means the equation drawn from the base model in section 4.1 for energy production is multiplied by 25% up to 100%. Multiplying impact factor means if the base model equation is considered to be 100%, at 25% impact factor the entire equation of energy production from the base model will be multiplied by 0.25 and the equation will generate outputs which are 75% lower in impact than compared to outputs of energy production in the base model. To elaborate more, the net migration impact factor of 50 indicates that energy production values in that specific simulation run will be 50% lower as compared to base model values. Similarly, energy production impact factor 75 means that energy production values being input to the annual CO_2 emission variable will have a 75% impact on that variable when compared to the base model.

Different outputs generated from each variable were recorded and graphed as shown in figures below. For example; when changing the impact factor of energy production to 25, how the fuel export curve will perform is recorded and on the same graph, the fuel export curve for an impact factor of 50 and 75 is also recorded (see figure 52). Later, all these graphs are analyzed and different policies are recommended towards the end of the thesis.

The first observation that can be drawn is the unaffected GDP curve (see figure 51). It has been noted the change in energy production does not have a significant impact on GDP, but the fuel export curve shows a direct variation with the change in energy production (see figure 52). The variation shown by fuel export is not that impactful on GDP, due to which GDP curve is not having any signs of variation by the change in impact factor for energy production.

A noticeable reduction in annual CO_2 emission is recorded (see figure 53) when the impact factor for energy production has been reduced to 25. This is mainly due to lower production of oil which results in lower energy consumption and hence lowers the burning of fossil fuels. To make a classification at this point, it has been stated that annual CO_2 emission is linked to total CO_2 emission corresponding to the production industry, manufacturing industry, and population's activities. Whereas, the carbon footprint is directly linked to the population's activities, which is why the change in impact factor for energy production shown direct variations in annual CO_2 emissions but does not account for any changes in the carbon footprint curve (see figure 54).

Similarly, there is no relation direct or indirect noted between energy production and population (see figure 55) when the energy production impact factor is altered. But the shift of curve will be more noticeable when the population curve is altered, this changes will result in changing energy consumption which will lead to a minor change in energy production.

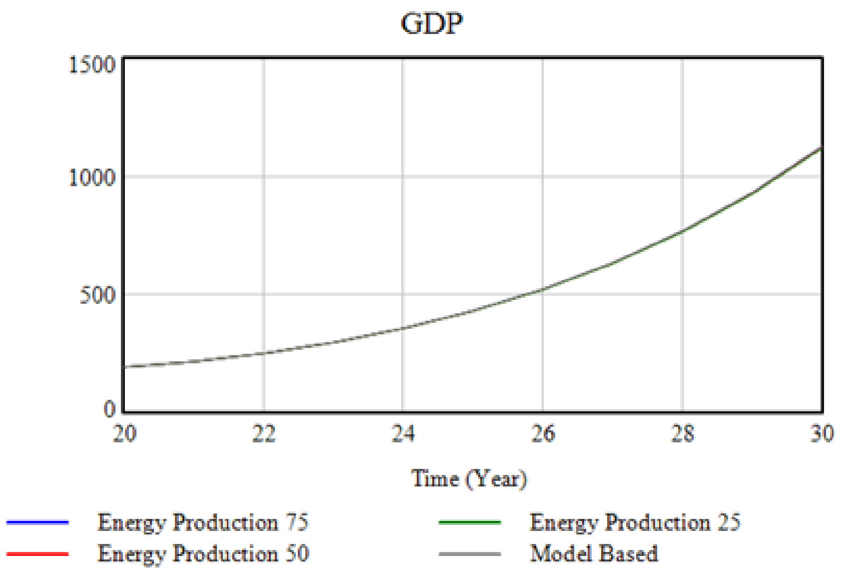


Figure 51. Energy production impact factor analysis on GDP

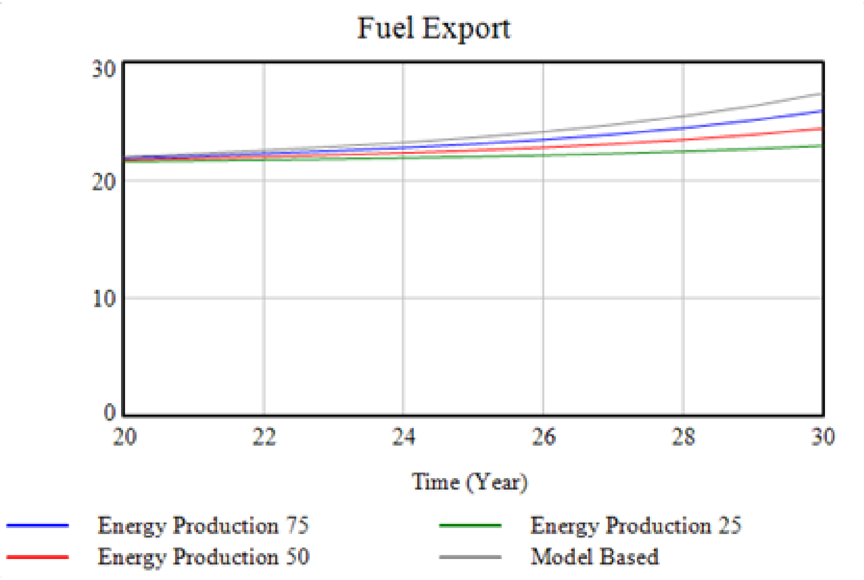


Figure 52. Energy production impact factor analysis on fuel export

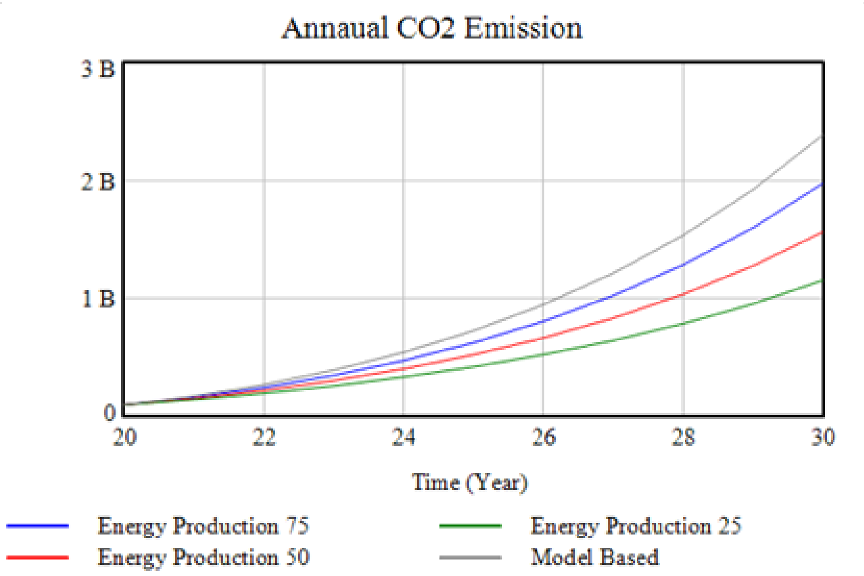


Figure 53. Energy production impact factor analysis on annual CO_2 emission

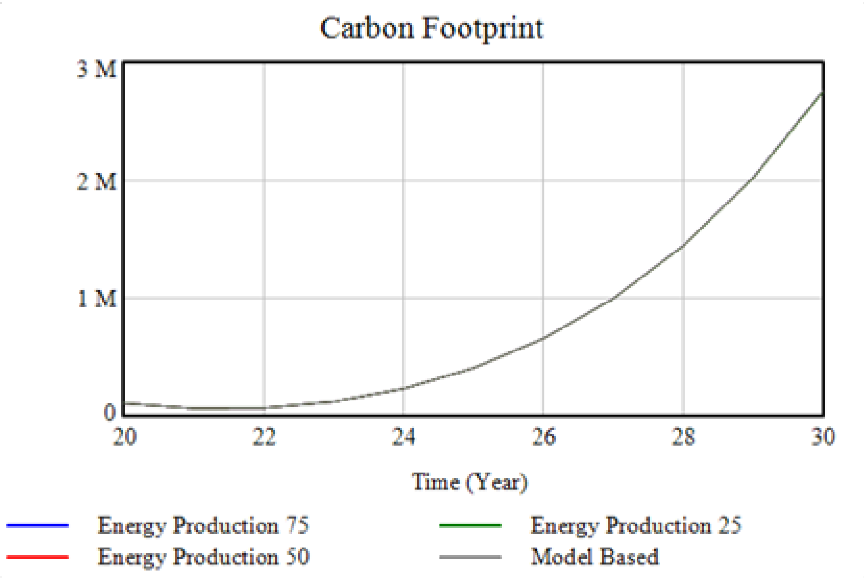


Figure 54. Energy production impact factor analysis on carbon footprint

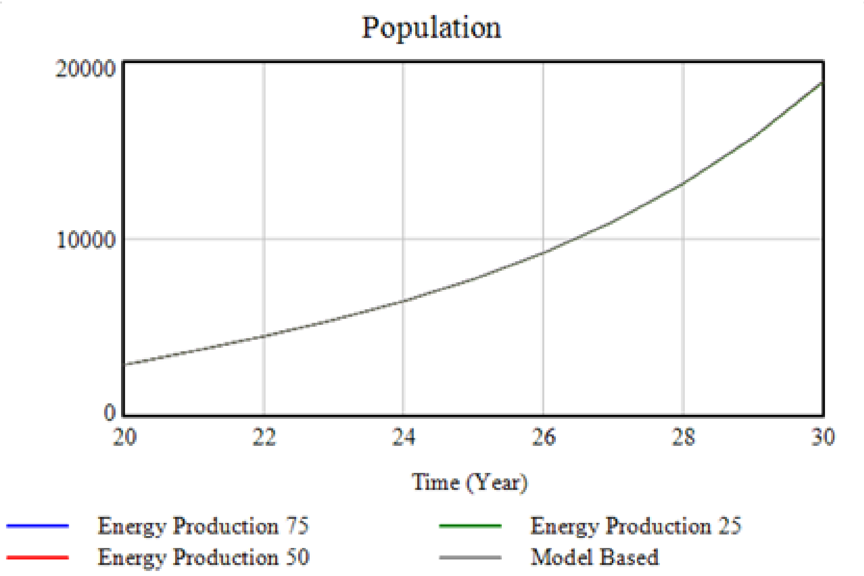


Figure 55. Energy production impact factor analysis on population

5.2.3 Export Impact Factor

To know more about how the GDP can influence the curve for annual CO_2 emission and Carbon footprint and to have a better conclusion towards the controlling of CO_2 emissions, the impact factor related to export was altered in a range from 25 to 100 (see figure 56). It has been observed that an increase in export will result in a positive increase in GDP (see figure 57), as stated earlier GDP is directly linked to net export. But due to this increase annual CO_2 emission and carbon footprint also shows an increment (see figure 58 and figure 60), which can be deducted as following, increasing export will require increasing energy production and this will lead to annual CO_2 increment. Whereas, an increase in export will increase net migration (see figure 59), and thus, the carbon footprint will show a positive upwards trend by every increase in impact factor for export. A tradeoff is required to optimize the economy of Qatar and at the same time to not increase CO_2 emission due to an increase in the country's economy, GDP.

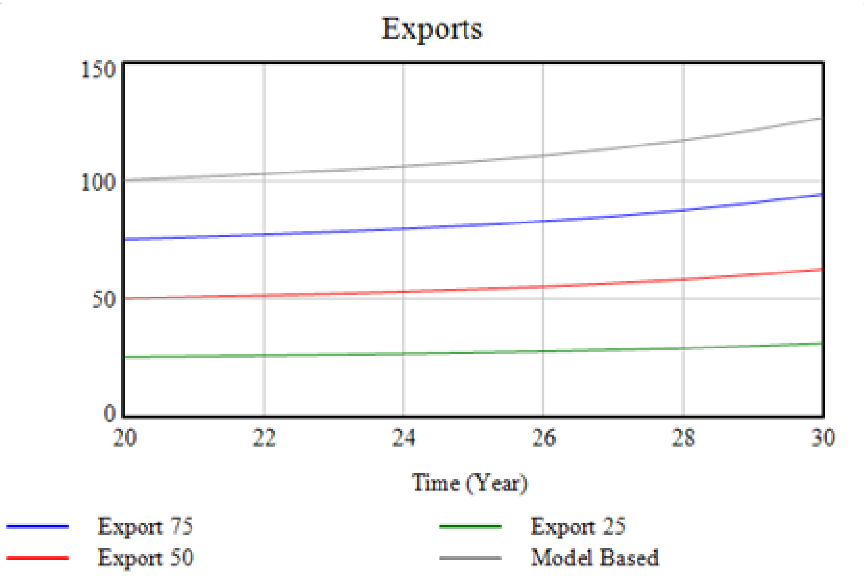


Figure 56. Export impact factor curve

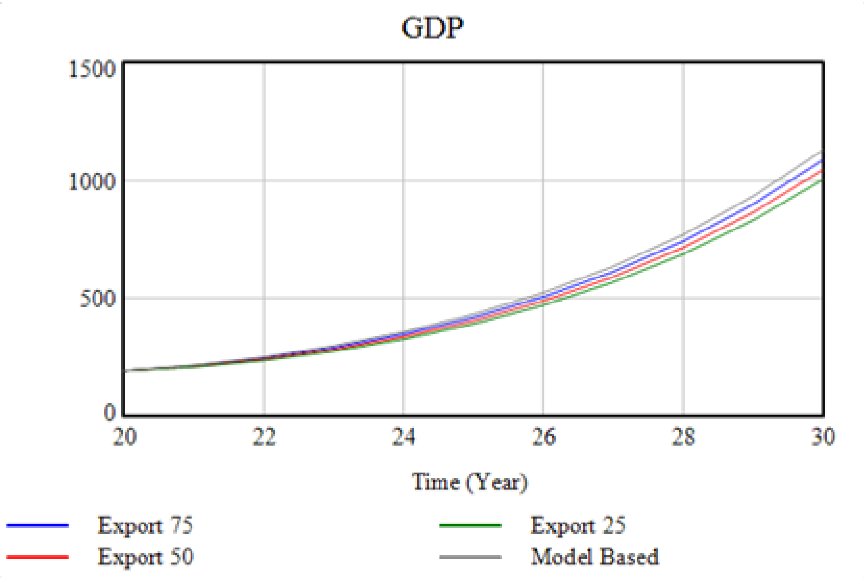


Figure 57. Export impact factor analysis on GDP

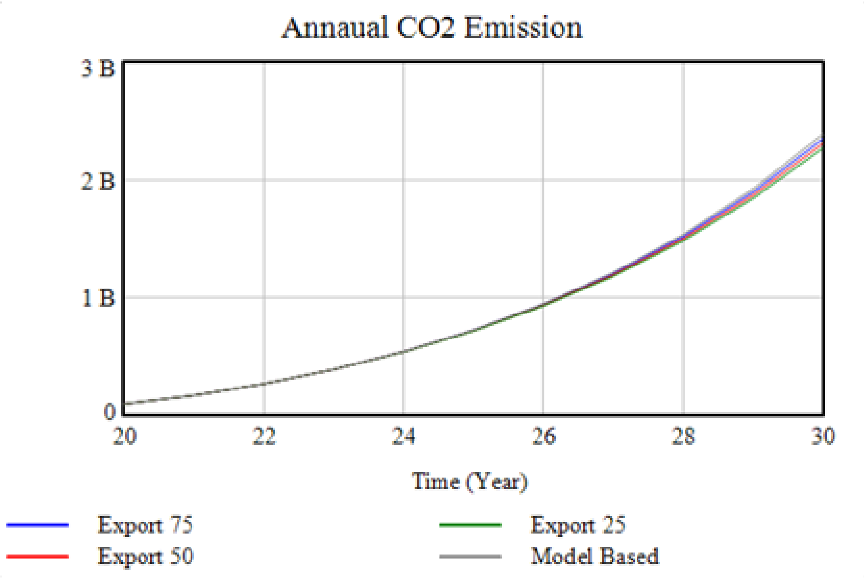


Figure 58. Export impact factor analysis on annual CO_2 emission

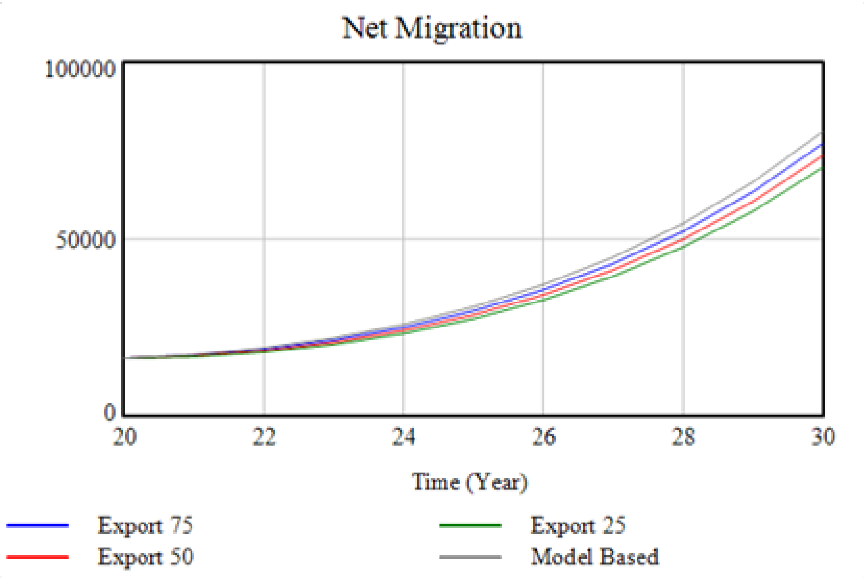


Figure 59. Export impact factor analysis on net migration

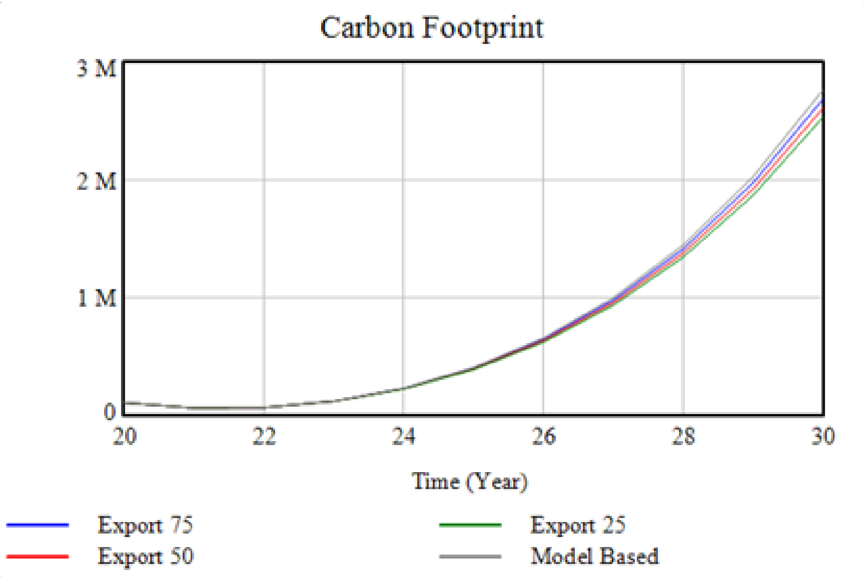


Figure 60. Export impact factor analysis on the carbon footprint

5.2.4 Changing Impact Factor to 25 and Generating Different Model for Comparison

Two models have been prepared which are as follows,

1. Model 1 – changing impact factor for net migration and export to 25

2. Model 2 – changing impact factor for net migration, export, energy production, and energy use per capita all to 25

After preparing these two models, both are compared with the base model and conclusion towards the education sector, environment sector, economic sector, and population sector is withdrawn.

Comparing model 1 and model 2 with the base model, the population curve has not shown as a difference between model 1 and model 2 (see figure 61), this is because the population has a direct and positive correlation with net migration and in both the models net migration was kept at an impact factor of 25 (see figure 62). Moving towards employment and education rate, the education rate has a slight decline when compared to the base model (see figure 63) whereas, employment shows no effect compared to model 1 and model 2 with the base model (see figure 64). The reason for the slight decline is due to the reduction of impact factor for net migration, as discussed earlier the relation between net migration and education is considered to be direct and positive.

Looking at GDP a downwards trend has been observed for both model 1 and model 2 when compared to the base model (see figure 65). This downwards trend is a result of a reduction in exports (see figure 66), as the impact factor for the export is reduced to 25 in both the models.

Similarly, due to reduction in export impact factor and reduction in energy production (see figure 69) has resulted in lower annual CO_2 emissions (see figure 68) and lower carbon footprint (see figure 67). Carbon footprint shows no difference when compared between model 1 and model 2 because carbon footprint is related to emissions due to population activities where annual CO_2 is related to emission due to production and manufacturing industries. That is why annual CO_2 emission curve is different in model 1 than model 2, due to the fact of reducing the impact factor for energy production in model 2.

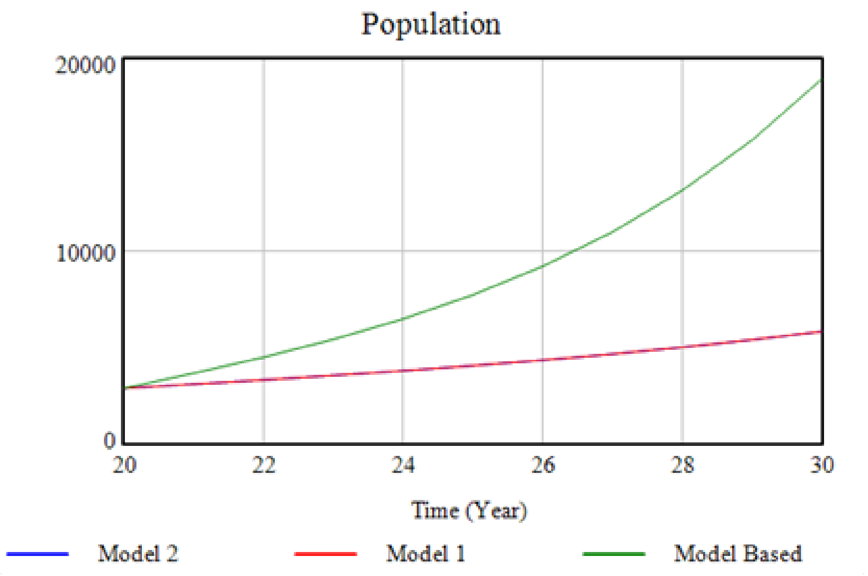


Figure 61. Comparison of the population curve in model 1 and model 2

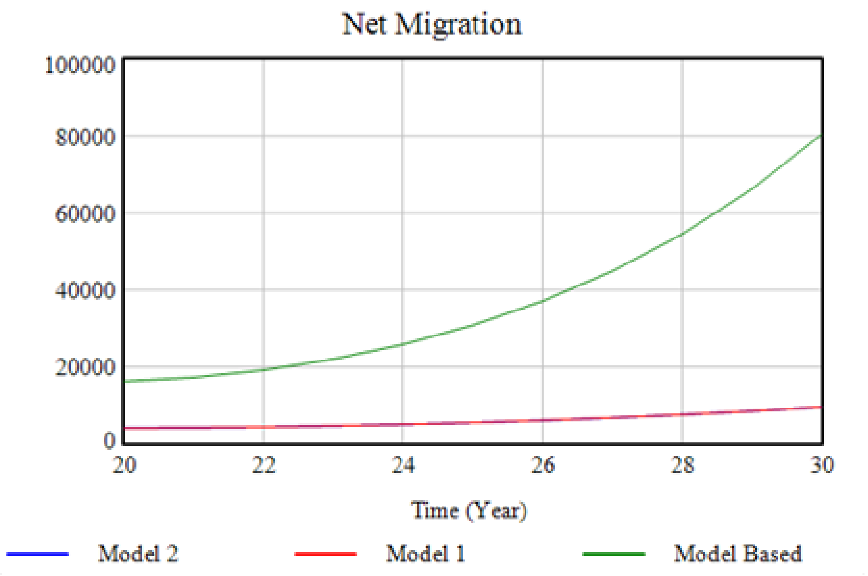


Figure 62. Comparison of net migration curve in model 1 and model 2

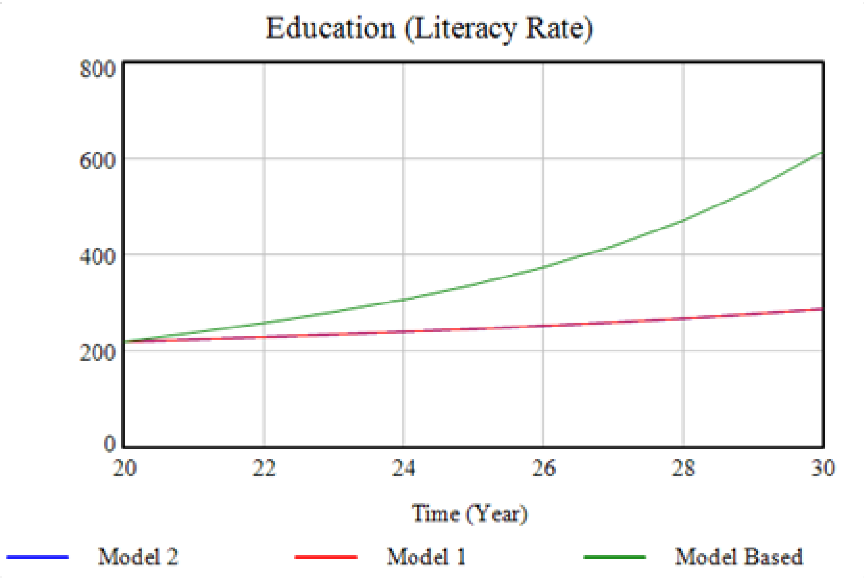


Figure 63.Comparision of literacy curve in model 1 and model 2

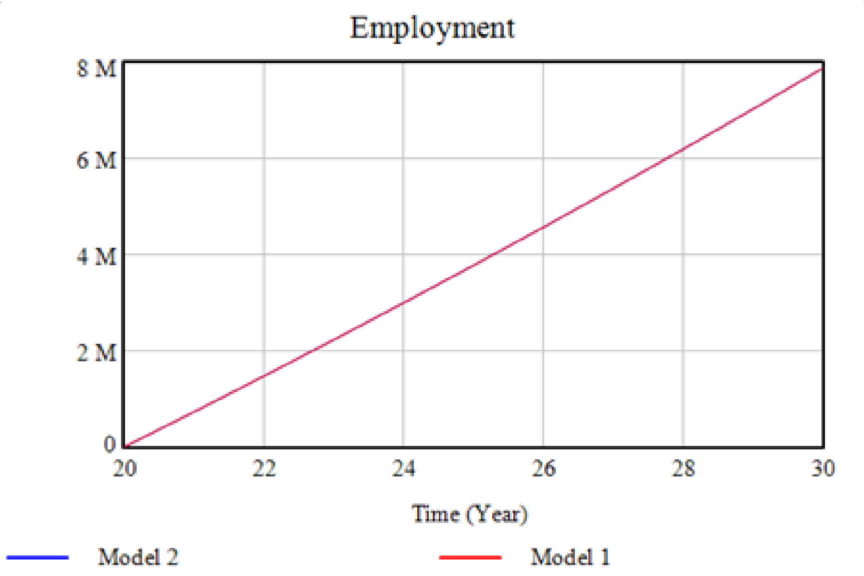


Figure 64. Comparison of employment curve in model 1 and model 2

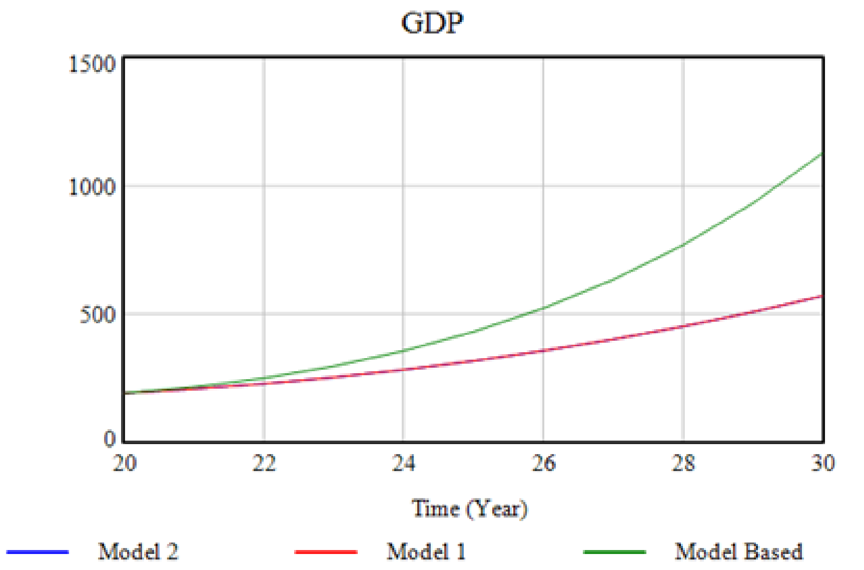


Figure 65. Comparison of GDP curve in model 1 and model 2

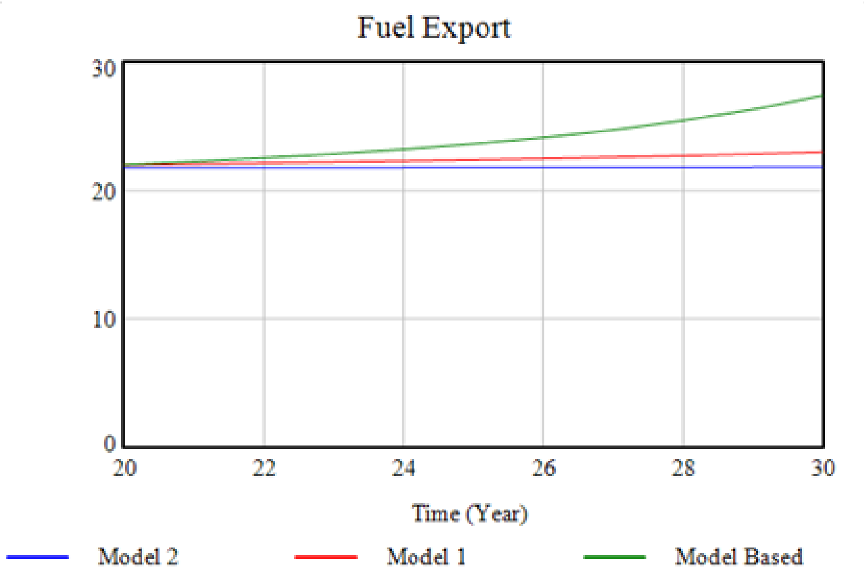


Figure 66. Comparison of fuel export curve in model 1 and model 2

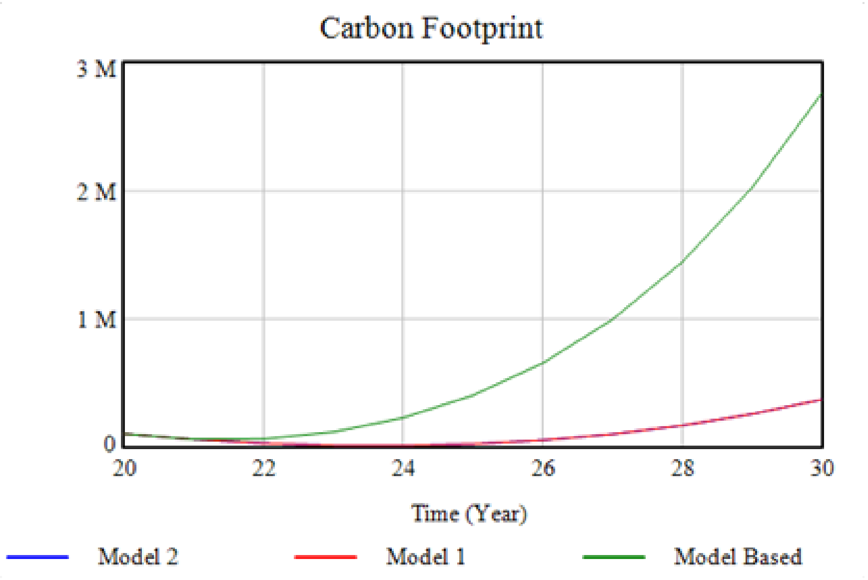


Figure 67. Comparison of carbon footprint curve in model 1 and model 2

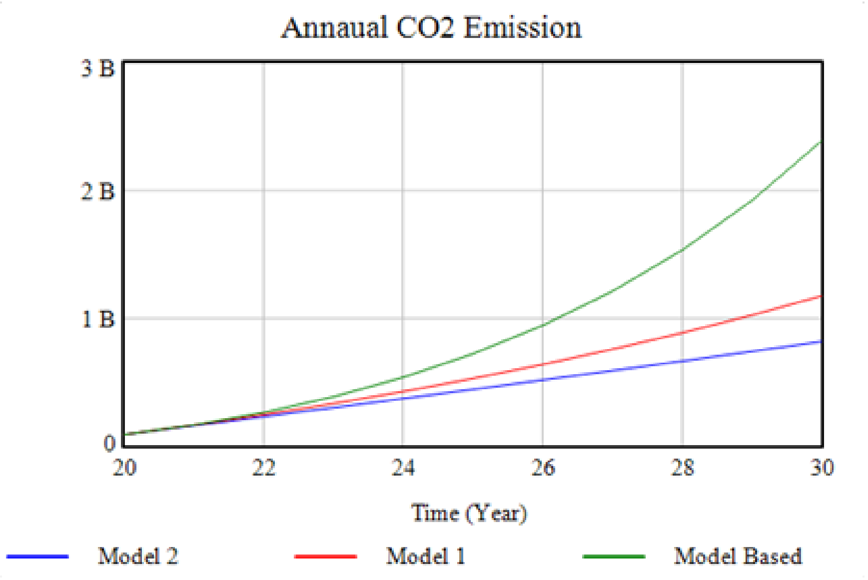


Figure 68. Comparison of annual CO_2 emission curve in model 1 and model 2

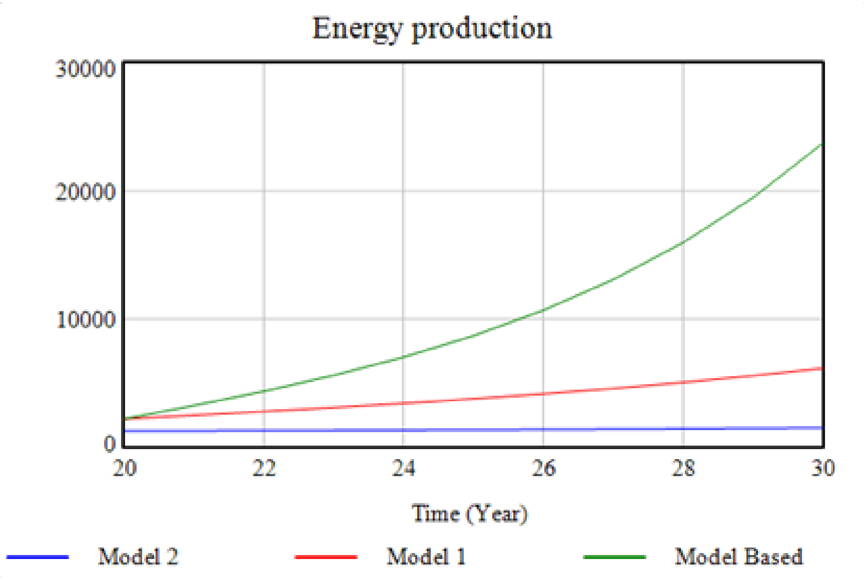


Figure 69. Comparison of energy production curve in model 1 and model 2

5.3 Discussion

Taking other variables under consideration, such as birth rate and death rate have a negligible effect on the population as the time slot for the model is too short, 10 years in total from 2019 till 2030. The population graph shows a high and positive correlation with net migration, changes in the impact factor of net migration result directly in population changes which further have an impact on GDP, carbon footprint, and so on.

Moving to the Environment sector, energy production has a negligible effect on carbon footprint and a significant effect on the amount of annual CO_2 released because carbon footprint is linked to each individual's activity whereas annual CO_2 release is the sum of CO_2 released by production and manufacturing industries for exporting and energy consumption within the country.

An increase in the fuel export and export sector due to an increase in energy production will have a direct and linear effect on the GDP of the country. So, to increase the GDP for the country and the increase in the export sector is well promising. But it has been observed that an increase in the export sector due to an increase in energy production will also lead to an increment in annual CO_2 emission. Thus, a tradeoff is recommended to increase Qatar's GDP and at the same time not to increase annual CO_2 emission to an intolerable level.

Two models were generated and in both, some similarities or unaffected variables were noted. The carbon footprint performed the same way in model 1 as in model 2. Annual CO_2 emission showed a higher reduction in model 2 comparing to model 1.

The education sector was not considered to be manipulated as one of the objectives for Qatar towards vision 2030 is to improve education and build a knowledge-based economy. Talking the other way around, the education sector is not affected by a change in the economy, environment, and/or population sector. Therefore, the education sector has been classified as independent of other sectors.

CHAPTER 6: CONCLUSION AND POLICY RECOMMENDATIONS

6.1 Conclusion

To summarize, a brief study and analysis were conducted on Qatar as a country and its progress towards Qatar National Vision 2030. The study started with a first basic understanding of 17 SDGs followed by categorizing and differentiating sectors to be studied such as the educational sector, economical sector, social sector, and the environmental sector. After understanding the different associated sectors and the importance of 17 SDGs the research was carried forward by performing a detailed data analysis on the previous historical data, out of which different snapshots were captured. The analysis gave a brief idea of how Qatar has been performing in different sectors for the past few years. The sectors targeted were ranging from the economic sector, the environmental sector, the education sector, and the social sector. The major findings were Qatar has a high import percentage of around 22% in the transportation sector, followed by 27% in mechanical machinery and its applications. This import was recorded to have a rise from 804 million USD in 1995 to 23.4 billion USD in 2016, approximately the expenses in imports have increased by 22.6 billion USD. Counting on the revenue, the export numbers also have showed a similar increment. The total revenue collected from Japan was around 17.8 billion USD, followed by South Korea 17.5 billion USD, and 13 billion USD from India. The major sector was the exportation of mineral products, which was classified as 57% liquefied natural gas, and 29% crude oil export. More under the economic sector, GDP variable was focused, which showed a growth of 2.5 % per year. At this point, the growth of GDP mainly depends on Qatari hydrocarbon industries and their export strategies. Moving on to the environmental sector, carbon emission was the main highlighted variable in this thesis. Different sources of CO_2 emissions were discussed as well as different types of emissions such as a comparison between CO_2 emission and methane emission was conducted which clearly showed that CO_2 emissions are much higher than methane emissions. In the social sector, there were a couple of variables taken under consideration such as population growth curve, employment rate, and literacy rate. As Qatar is planning to move towards a knowledge-based economy, the literacy rate variable can give a good indication of how Qatar can plan its policies and the actions that need to be changed or revised.

After completion of the data analysis, a conceptual causal model was prepared to consist of different variables and linkages between them. The conceptual model then was revised based on the data availability and the resulting stock-flow diagram was validated and simulated in VENSIM software. To conduct simulation, the impact factor analysis technique was used, where the first impact factor of net migration was changed from 25 % to 100 % and it was concluded that at 25% a positive impact was shown on CO_2 emissions of the country but simultaneously a lower GDP graph was also observed. Impact factor analysis was also conducted on export variable and the results are drawn were as follows at 25% CO_2 emissions will be lower, but this comes with a drawback of lower GDP of the country. Furthermore, two different models were generated and compared to the base model, model 1 – changing impact factor for net migration and export to 25%, and model 2 – changing impact factor for net migration, export, energy production, and energy use per capita, all to 25%. Based on this comparison it was concluded that a tradeoff between net migration and export level will be having promising results which will turn out to minimize the CO_2 emissions to a certain level helping Qatar to achieve the 2030 vision and at the same time without compromising much towards Qatar GDP growth rate.

6.2 Policy Recommendations

One of the main objectives of this study was to shortlist different policies that were generated using conceptual CLD and later these policies were simulated in VENSIM software to have a better understanding of how different variables in CLD interact with each other. After performing several simulations the following policies were concluded:

1. The implementation of renewable energy for energy production helps to overcome the harsh and opposing effects of greenhouse gas emission and consequently, helps in limiting climate change. The most feasible technologies that Qatar can adopt are through utilizing solar and wind. The development of solar power plants and having thermal energy storage facilities can boost up the use of renewable sources for energy production, as the solar plant can be easily connected to the electrical grid in Qatar. A

study was carried out by Mehdi, Murat, and Omer (2013) where they examined the production of energy and the amount of carbon emission while using wind turbines in the US. Therefore, even considering solar-based energy production, the amount of carbon emission that will be associated with it has to be taken into consideration. And different scenarios must be analyzed for carbon emission where solar energy production is coupled with different forms of energy production facilities.

2. Use of biomass production plants for energy generation. Cow dungs produced by cattle farms can be used for clean energy production as well as for the production of 'A' grade fertilizers. Hence, reducing energy consumption from burring foil fuels to a significant level.

3. The use of algae absorbent technology can be taken into consideration. Abdul Hai (2021) had investigated the process where the cultivation of algae takes place by absorbing CO_2 from the flue gas and the cultivated algae are responsible for biomass production. The research was taken to next level by Murat and Omer (2011), where they studied algae utilization in coal power plants and achieving sustainable energy. Thinking of Qatar and the amount of emissions from oil and gas industries, usage of algae will help in the reduction of CO_2 emissions and simultaneously enhance the production of biomass. Biomass production from different sources, from the oil and gas industry, and dairy farming can help Qatar to build upon self-sustaining energy production with a reduction in annual CO_2 emissions.

4. Reducing net migration to 50% will help in a better tradeoff between Qatar's economic growth and enough control over environmental pollutions. Implying to reduce net migration by 50% corresponds to a reduction of annual CO_2 emission by 34.3% at the end of 2030, and at the same time reduction in GDP to 801 billion USD from 1128 billion USD. But if the net migration was reduced to 25% instead of 50%

the resulting annual CO_2 emission and carbon footprint will be reduced by 49.6% and 84.66% respectively, besides, the GDP will be facing a drastic drop to 656 billion USD comparing to 801 billion USD if 50 impact factor for net migration is considered.

5. Manipulating the export quantity by reducing it to 25% will also help in less environmental emissions, but this reduction will have a high impact on reducing Qatar's GDP. As noted, this reduction of 25% in export will cause a bigger drop in GDP by the end of 2030. Considering the impact factor analysis the change between GDP impact factor 75 and GDP impact factor 25 is not that significant, 1087 billion USD and 1003 billion USD respectively. But this change of GDP from 75 to 25 will affect and a significant drop in annual CO_2 emission is observed, $2.35 * 10^9$ tone and $2.27 * 10^9$ tone respectively. Therefore, an impact factor of 25 is recommended when the export variable is taken into consideration.

6. A good balance between net migration and export reduction shows promising results, in which environmental pollution has been controlled as well as country GDP also shows a growth rate but lower when compared to other scenarios. If the base model is run based on an impact factor of 50 for net migration, 25 impact factor for export and energy production, the amount of annual CO_2 emission will be reduced by 64.3%, followed by 62.6 % reduction in carbon footprint, and a tolerable reduction in GDP corresponding to 37.8%.

7. The use of electric transportation can help Qatar in achieving a huge drop in carbon footprint. To enhance the efficiency of transportation, electric vehicles are coupled with diesel engines known as a hybrid vehicle. Nuri and Murat (2015) studied the implementation of hybrid vehicles in 25 states in the US and at the same time, they compare the efficiency of a hybrid vehicle to a solo electric vehicle. The study concluded that hybrid vehicle was found to more efficient than electric vehicle

and secondly, use of the electric vehicle will help to reduce carbon footprint by reducing energy consumption by 25%.

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