A TECHNICAL APPROACH TO SAUDI ARABIA CRUDE OIL SUPPLY FORECAST AND POTENTIAL SUBSTITUTES

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ABSTRACT

A TECHNICAL APPROACH TO SAUDI ARABIA CRUDE OIL SUPPLY FORECAST AND POTENTIAL SUBSTITUTES

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In this master thesis, crude oil production forecast of Saudi Arabia and its potential substitutes are investigated. Reservoir and production behavior of 12 giant fields and the other fields' production as a function of total production is estimated. Four different scenarios are suggested for crude oil production forecast while five potential substitutes can be classified as top substitutes.

The first part of the study shows that Saudi Arabia has produced more than 150 billion bbl crude oil so far and has another 208.7 billion bbl recoverable reserves to be produced. However, crude oil production would decrease to 6 MMbpd as 2044 since the mature oil fields as Ghawar and Abqaiq are close to depletion and some subfields as Ain Dar/Shedgum and Uthmaniyah is expected to deplete in 20 years. On the other hand, investments in oil exploration to discovery of new fields and development of the existing fields could provide consistent production above 15 MMbpd until 2040 with an expenditure around $96.35 billion.

In the second part, it is concluded that although Saudi Arabia has always been the major crude oil exporter, Iraq could be a perfect substitute if regional peace is constituted. Even so, the country is the second option considering the major export destinations of the Kingdom. The neighbor, UAE, is the third option for the crude importers after Saudi Arabia and Iraq. Moreover, Iran has still the opportunity to redeem its share in crude oil market to be a potential substitute if sanctions are lifted. The other potential substitute Russia needs new trade routes as Kanal Istanbul and Arctic Route or expanding pipeline capacity to canalize Asia markets. Other crude oil producers need more severe actions.

Keywords: Saudi Arabia, crude oil, production forecast, Middle East, energy politics

ÖZ

TEKNİK METODLAR İLE SUUDİ ARABİSTAN PETROL ARZI TAHMINI VE SUUD PETROLÜNÜN ALTERNATİFLERİ

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Bu yüksek lisans tezinde, Suudi Arabistan'ın ham petrol üretim tahmini ve potansiyel ikameleri incelendi. 12 dev petrol sahasının rezervuar ve üretim davranışları çıkartıldı ve diğer sahalar bu sahaların fonksiyonu olarak analiz edildi. Toplamda dört ana ham petrol üretim senaryosu üzerinden analiz yapılıp, beş ana ikame oluşturuldu.

İlk kısma göre, Suudi Arabistan şu zamana kadar 150 milyar varil petrol üretmiş olup, halen 208,7 milyar varil üretilebilir ham petrol rezervine sahip. Fakat, ham petrol üretimi Ghawar ve Abqaiq gibi olgun sahaların tükenmeye yakın olması sebebiyle üretimin 2044 senesine kadar 6 milyon varil gün miktarına kadar düşmesi bekleniyor. Ek olarak, Ghawar'ın bölümlerinden Ain Dar/Shedgum ve Uthmaniyah sahalarının da 20 sene içerisinde tükenmesi bekleniyor. Öte yandan, petrol rezervleri araması ve saha geliştirme metotlarına gerekli yatırım yapılırsa üretimin 2023 ile 2040 senesi arasında 15 milyon varil günden daha fazla olması bekleniyor. Toplam yatırım miktarı ise yaklaşık olarak 96,35 milyar dolar.

İkinci kısımda, Suudi Arabistan'ın dünyanın en büyük petrol ihracatçısı olmasına rağmen, Irak'ın bölgesel huzur sağlandığı takdirde mükemmele yakın bir alternatif olacağı ortaya çıktı. Bölgesel huzurun olmadığı senaryoda bile, Suud Petrolünü ithal eden ülkeler için en güçlü ikinci seçenek. Komşuları, Birleşik Arap Emirlikleri ise Suudi Arabistan ve Irak'ın ardından en güçlü üçüncü opsiyon. Ek olarak, İran da

yaptırımları kalkması ve ihracının eski haline dönmesi durumunda oldukça güçlü bir ikame olacak. Son olarak, Rusya'nın ise Kanal İstanbul ve Arktik Ticaret Hattı veya petrol taşıma kapasitesinin artırılması gibi alternatiflerle Asya marketindeki payını artırması lazım. Diğer üreticiler için ise henüz çok yol var.

Anahtar Kelimeler: Suudi Arabistan, ham petrol, üretim tahmini, Orta Doğu, enerji politikaları

To my family

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Finally, my deepest thanks belong to my family who always believed in me. Especially my sister Ezgi Aslanoğlu, mother Kadriye Aslanoğlu and father Ahmet Oğuz Aslanoğlu. They always stand whenever I needed.

I am sure it will not be enough to say that I am thankful to everyone who helped me throughout all these years to develop this thesis. I am hoping that this thesis will be the first step of something great.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

ap	Annual production
API	American Petroleum Institute
Bbl	Barrels
BMI	Business Monitor International
Bpd	Barrels per day
Cp	Cumulative production
CSIS	Center for Strategic and International Studies
d	Annual decline
D	Depletion rate
Dp	Daily production
EIA	Energy Information Administration
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GW	Giga-Watts
JODI	Joint Organisation Data Initiative
IFP	French Institute of Petroleum
IPO	The initial public offering
Km	Kilometers
MIT	Massachusetts Institute of Technology
Mbpd	Thousand barrels per day
MMbbl	Million barrels
MMbpd	Million barrels per day
OECD	The Organisation for Economic Co-operation and Development
OEEC	The Organisation for European Economic Cooperation
OOIP	Original oil in place
OPEC	Organization of the Petroleum Exporting Countries
ORB	OPEC Reference Basket

RRI	Risk/Reward Index
RRR	Remaining recoverable reserves
SPE	Society of Petroleum Engineers
SoCal	Saudi Arabia and Standard Oil Company of California
UAE	The United Arab Emirates
URR	Ultimate recoverable reserves
US	The United States
WTI	West Texas Intermediate

LIST OF SYMBOLS

SYMBOLS

C	Carbon
F	Fahrenheit
H	Hydrogen

CHAPTER 1

INTRODUCTION

Increasing energy demand following the 19th century's industrial revolution has been a naked truth of human history. Higher energy demand had caused increasing energy supply. Following that, this energy revolution had led to economic growth. The world's economy has enormously grown in the past few decades. Extraction volume of fossil fuels was the driven parameter of this development. As most of the energy consumed has been generated from fossil fuels in recent decades, humanity will remain in need of fossil fuels in the following years. Oil can be defined as the black blood that runs through the veins of the modern global energy system (Höök, 2008).

This fact makes crude oil the world's most traded commodity globally. Crude oil had been at the center of politics throughout the 20th century. Even the transformation through renewable energy sources are currently growing, crude oil is still the major energy source and is also expected to be so in the future (BP, 2019). On the other hand, the future of the crude oil market is a controversial issue due to the uncertainty in technical problems in oil fields also global politics and economics. For the foreseeable future, the crude oil production forecast is necessary to analyze the oil market accurately.

As of the end of 2017, there are only five countries which control more than 100 billion barrels (bbl) of oil equivalent of conventional oil reserves. These are Venezuela (302.8 billion bbl), Saudi Arabia (266.3 billion bbl), Iran (155.6 billion bbl), Iraq (147.2 billion bbl) and Kuwait (101.5 billion bbl) and followed by the United Arab Emirates (UAE) with 97.8 billion bbl of oil. While none of these countries ever produced more than 5 million barrels per day (MMbpd) during the last three decades, Saudi Arabia is consistently producing more than 7 MMbpd since 1991 (OPEC, 2019c). The kingdom has always been market balancer to prevent shortages. For example, Saudi Arabia increased its crude oil production from 5.4 MMbpd to 8.5 MMbpd in only 90 days during the Gulf War.

Most forecast reports consider existing econometrics data; although that approach neglects the scientific facts on reservoir conditions and upstream developments, this study aims to provide a technical approach to world's biggest crude oil exporter Saudi Arabia's crude oil assets and oil exports scenarios with the potential substitutes in the market.

The objective of this thesis is to analyze the world's most important crude oil producer and exporter Saudi Arabia's oil reserves and production behavior to enlighten the future of the Saudi Aramco, after that to the world oil market. For this purpose, Saudi Arabia's existing crude oil reserves and production scenarios for the following years evaluated, then the other major crude oil producers were compared for their replacement possibility of Saudi Arabian crude oil to its export destinations. The thesis starts with a brief introduction and literature survey, respectively as the first two chapters. The crude oil market is briefly introduced in chapter three. Then, chapter four gives details about the oil production of Saudi Arabia, its fields and export destinations. In the fifth chapter, the problem and thesis motivation are stated. Chapter six shows the methodology while analyzing the fields and substitutes. While chapter seven shows the results and discussions according to these analysis methods, the last part, chapter eight is the conclusions section.

While other countries can be more transparent about production and condition of the fields, it was observed that, due to the secrecy of Saudi Arabia oil fields, there was rarely transparent production or reservoir information about the oil fields of the kingdom. The primary struggle before analyzing the field was to gather actual production and reservoir data. However, as solving a puzzle, putting pieces together, production and reservoir data of fields could be gathered.

CHAPTER 2

LITERATURE SURVEY

The literature survey for this thesis was conducted on four main categories. These are;

1. Data gatherings by using the studies examining Saudi Arabia's fields as a whole,
2. Better investigation of the fields by using evaluation reports of each field,
3. Reservoir and production evaluation methods to use in this study,
4. Saudi Arabia's export destinations and competitors.

Center for Strategic and International Studies (CSIS) report was presented by Baqi and Saleri (2004) which the presentation shares the most transparent data ever for Saudi Arabia oil fields. This study emphasizes the principles of Saudi Aramco and focuses on the role of the company in the crude oil market. The publication mentions the share of the kingdom on global oil reserves, number of fields, seismic crew, rig and locations of the exploration wells in Saudi Arabia with official numbers. Also, the possible addition of unexplored wells and the growth of oil in initially in place trend is shown. The significant contribution of this report is the total depletion and annual depletion rates for major fields. The study is especially helpful for the forecast of mature fields. The king of oil fields, Ghawar Field, is investigated in subparts. Also, it is suggested that Saudi Aramco is a cost-effective oil supplier and predicted for sustained production levels of 10 MMbpd, 12 MMbpd or even to 15 MMbpd, well beyond 2054 which I think it is not that easy upon my study unless fields are not developed.

Literature survey and analysis of field behavior from the past production data were used to analyze Saudi Arabia oil fields with detail. Simmons (2005) defines Saudi

Arabia’s oil reserves as a miracle and an economical gift to the world. He analyzes the Society of Petroleum Engineers (SPE) papers written by technical experts. Also, adds that easy oil era is over. He mentions that Saudi Arabia’s great oilfields are mature and some of the fields are coming to end of their economic life, but oilfield technology provides a chance to increase in total producible reserves. The study is deep in information for each oil field which is helpful while gathering data.

Powers (2012) conducted another evaluation of the oil industry. He focuses on big players of the oil industry as the United States (US), Venezuela and the star of the crude oil market, Saudi Arabia. The study covers the reservoir assessment of the Saudi Arabian oil fields together with nearly 100 reservoir engineers. He mentions the goals of Saudi Aramco then emphasizes on each major field. Reservoir properties such as Original Oil in Place (OOIP) and recovery factors are estimated by using relatively reliable methods.

Also, the country reports by the international constitutions as Energy Information Administration (EIA, 2017) and Fitch Solutions (2018) considers econometric tools rather than the engineering forecast methods. Other studies conducted by Jud (2016) and Hart (2008) are detailed researches but results and methodology not reliable. Therefore, such analysis and forecasts are not taken into consideration.

Two volumetric simulations (2D) of the initial and remaining reserves in Ghawar was determined by Mearns (2007). Two different scenarios for each section of Ghawar is estimated. The technical approach of the author provides realistic results for the field. Staniford (2007) studies Ghawar Field by analyzing the oil saturation of each section. Then the reservoir was modeled in the study which was led to realistic results by using engineering techniques.

Other researchers as Al-Somali et al. (2009), Aleklett et al. (2010), Ali et al. (1981), Sadiq and Zaidi (1985), Saleri et al. (2006) and Xia et al. (2014) gave some minor past production or information about the investigated fields. They are highly considered in the production forecast.

Arps (1945) first suggested the idea of production decline curve analysis. The study shows that every oil fields production peaks and starts to decline exponentially, harmonically or with another trend.

Campbell (2013) summarizes the oil production forecast of a field with basic steps. The most vital is to reach past production through reliable sources. The sources are mentioned in the first part of the literature survey. The past production analysis covers cumulative production, the amount left to produce, percentage depleted and the depletion rate. Second is to use of Hubbert Linearization (Maggio & Cacciola, 2009) to understand future behavior. After that, the ultimate recoverable reserves (URR) of the field is calculated. Also, the undiscovered fields and consumption in the country are estimated. Campbell suggests the most proper guideline for the crude oil production forecasts.

Höök (2008) studied more than 300 giant oil fields to determine their typical production behavior. Production parameters, such as decline, depletion rate and timeline of first oil, build up, peak and decline are stated in the research. This study enlightens the research for future production of undiscovered oil fields of Saudi Arabia.

Energy Intelligence (2007) mentions the major traded crude oil types and their key characteristics which helps to the first categorization of other produced major crude oils.

Joint Organisation Data Initiative (JODI, 2019) provides monthly crude oil production data to categorize the substitutes. Also, export, import and direct use of crude oil data are provided by JODI. The Observatory of Economic Complexity of Massachusetts Institute of Technology (MIT, 2019) is one of the most helpful resources for export destinations. The resource provides reliable data about crude oil trade market. All the possible substitutes' crude oil export destinations and Saudi Arabia's target markets' import points are taken from this source. Also, the crude oil export of Iran is updated as the latest quarter of 2018, by Tanker trackers (2018).

Fitch Solutions Business Monitor International (BMI)'s Upstream Oil and Gas Risk/Reward Index (RRI) is a key parameter to evaluate potential substitutes to whether if the country is feasible to invest in upstream according to; oil reserves, discovery rate, hydrocarbon production and growth, state asset ownership, competitive landscape, Infrastructure integrity, royalties, income tax, license type, bureaucratic environment, legal environment risk, economic and political risk index, operational risk index (Fitch Solutions, 2018).

To summarize, Campbell (2013) suggests the oil field analysis to draw a forecast by using the previous production data. In this thesis, it is deepened by using this method to each major field. Simmons (2005) investigates the Saudi Arabian oil fields very detailed. He enlightens the readers and my objective while writing this thesis was to move along the way that Simmons opened and improve his legacy and complete the "Saudi Puzzle" by finding the missing pieces.

While most of the studies focus on one field, the country analysis was superficial, not that deep. The major difference of this thesis from the other studies analyzed was to evaluate each field as in separate way and gather them all to project the future of Saudi Arabian crude oil supply forecast.

CHAPTER 3

CRUDE OIL MARKET

Petroleum, as an almost infinite series of mixtures of differing hydrocarbons in their natural state, exhibits a wide range of physical characteristics. These characteristics have a strong influence on classifying crude oil types (Seba, 2016).

Oil formation needs a complete petroleum system with the necessary elements and processes. Some geological components and processes are necessary to generate and store hydrocarbons. These are; a mature source rock, migration pathway, reservoir rock, trap, and seal. Also processes as generation, migration, and accumulation are necessary to occur with the proper timing. If these elements are placed in the proper timeline, oil can generate (Al-Hajeri et al., 2010).

Source rock is the rock that forms oil. If the organic matter rich rock is heated and pressurized sufficiently, the oil will be generated.

The reservoir rock is where oil is mitigated from a source rock, the final destination of the hydrocarbons where they are finally located. A reservoir rock should have sufficient porosity and permeability to store and transmit the fluids.

Trap formation is a configuration of rocks suitable for containing hydrocarbons and sealed by a relatively impermeable formation through which hydrocarbons will not migrate since the reservoir rock is the last place for oil migration. Seal rock is an important component of the trap which provides a tight and impermeable layer to prevent further mitigation from reservoir rock (Schlumberger, 2019).

Figure 3.1 shows the ideal timing of a petroleum system. The proper timeline starts with the source-rock deposition. Then it is followed by deposition of reservoir rock, seal rock and overburden rock. Overburden effects system for a longer period. If elements are supported by the process with proper time order, petroleum system can be formed. The process is generation, migration and accumulation. Also, after these actions, reservoir rock needs to be preserved for a long time (Al-Hajeri et al., 2010).

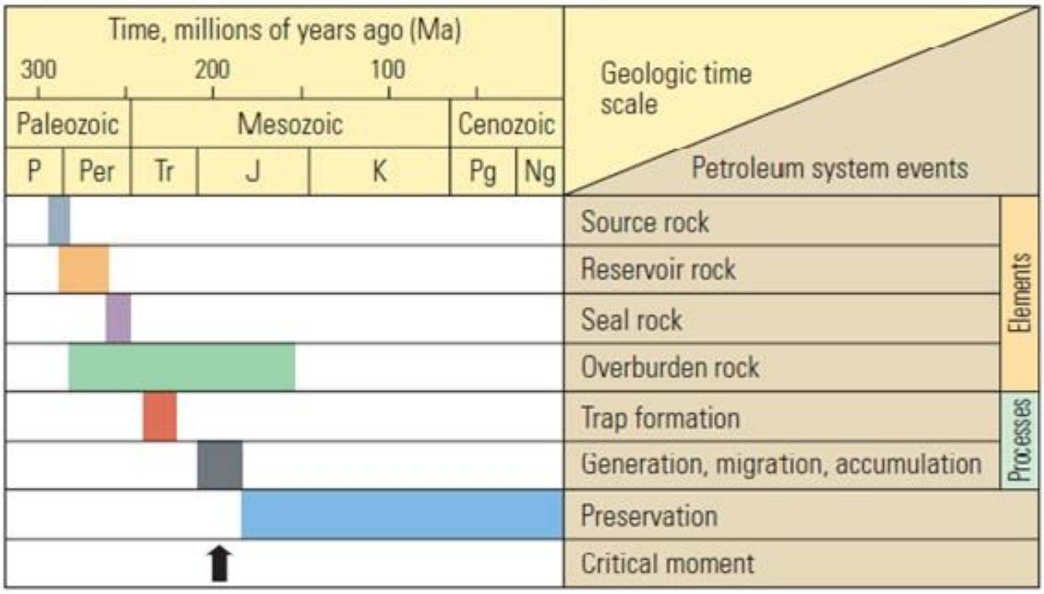

Figure 3.1. Petroleum System Timeline (Al-Hajeri et al., 2010)

Reserves are classified according to their production probabilities. There are three different scenarios about reserves. These are proven, probable and possible reserves.

Proven reserves: If reserve shows 90% probability to produce and reasonable certainty is seen with deterministic methods, it is called proven reserve.

Probable reserves: If probabilistic methods show at least 50% probability of recoverable reserve, in other word if engineering methods suggest more likely to produce than not to be recoverable, it is called probable reserves.

Possible Reserves: While possible reserves are unproven if geological analysis suggests that reserves are less likely to be recoverable than probable reserves (SPE, 2001).

3.1 Crude Oil

Crude oil is mostly known as petroleum, a wide-ranging term that includes many substances and forms of liquids (Höök, 2008). However, the term crude oil differs from petroleum. It excludes unconventional oil as shale oil, tar sands, bitumen and the refined petroleum liquids derived from any type of oil.

Unconventional Oil: The oil that cannot be produced, transported or refined using traditional techniques. They require new, highly energy intensive production techniques. Unconventional oil cannot be recovered through pumping in their natural state from an ordinary production without being heated or diluted. Extra heavy oil, oil sands and oil shale can be classified as unconventional oil (Deborah, 2012). Heavy oil is considered as crude oil even though its properties are close to tar sands and bitumen.

Also, Figure 3.2 shows, conventional crude oil is the most valuable fossil product compared to coal, extra-heavy oil, heavy oil, natural gas liquids, local natural gas and remote natural gas.

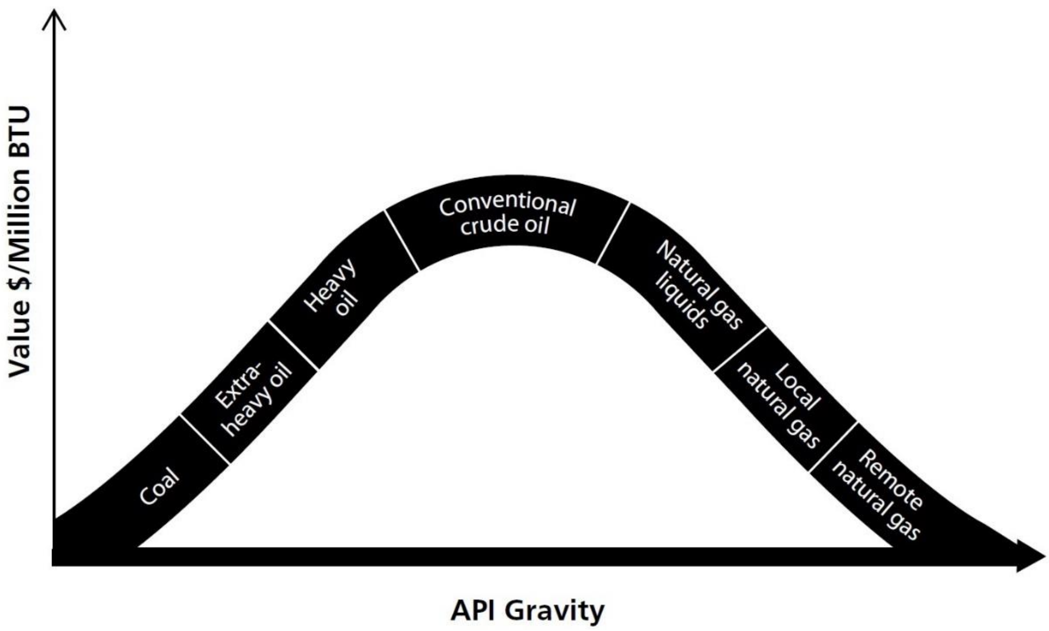

Figure 3.2. Hydrocarbon Value Hierarchy (Deborah, 2012)

As of the end of 2019, the total proven crude oil reserve of the world was 1.49 trillion bbl which is enough for humanity for at least 53 years with current crude oil demand unless there is no reservoir development or discovery happen. Figure 3.3 illustrates that, while the Middle East contains more than half of the total reserves, Middle East and Latin America, two continents together hold more than three-quarters of the crude oil reserves.

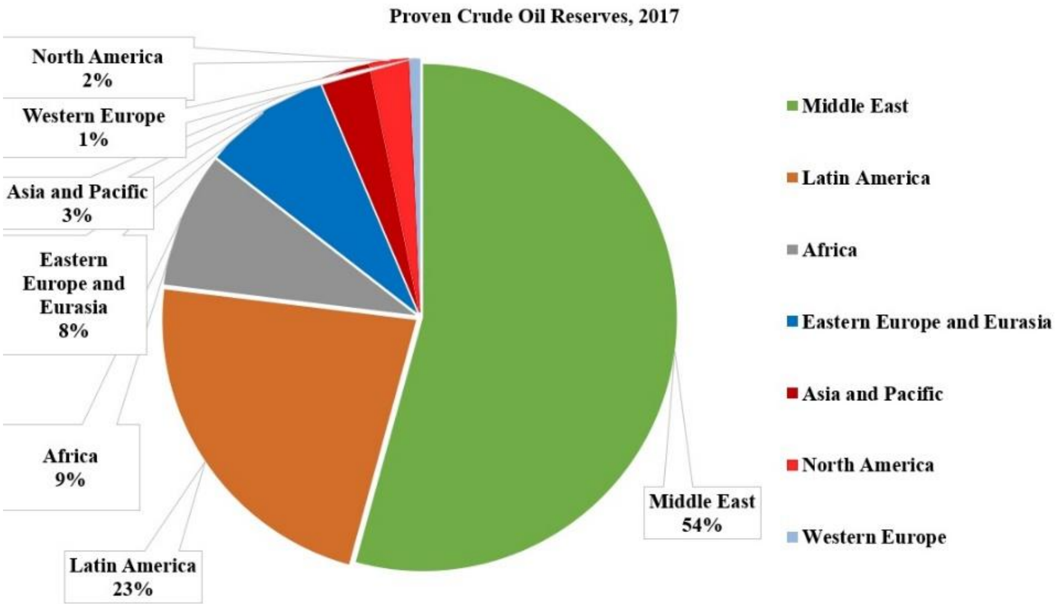

Figure 3.3. Proven Crude Oil Reserves by Region (OPEC, 2019c)

Table *3.1* shows the proven crude oil reserves by country. While Venezuela holds most of the reserves, five Middle East countries; Saudi Arabia, Iran, Iraq, Kuwait, and the UAE follow the country. Russia, Libya, Nigeria, and the US completes the top ten. Kazakhstan, China, Qatar, Brazil, Algeria, Angola, Ecuador, Azerbaijan, Mexico, Norway, Oman and Sudan are the other countries with more than 5 billion bbl reserves. Also, Canada is listed in some rankings as the third country with crude oil reserves with a total of 170 billion bbl. But if tar sands (already out of this comparison due to differences between crude oil types explained in this section) are excluded total conventional crude oil reserve is less than 5 billion bbl.

Table 3.1. *Proven Crude Oil Reserves, end of 2017* (OPEC, 2019c)

Country	*Proven Oil Reserves (MMbbl)*	Country	*Proven Oil Reserves (MMbbl)*
Venezuela	302,809	China	25,627
Saudi Arabia	266,260	Qatar	25,244
Iran	155,600	Brazil	12,634
Iraq	147,223	Algeria	12,200
Kuwait	101,500	Angola	8,384
UAE	97,800	Ecuador	8,273
Russia	80,000	Azerbaijan	7,000
Libya	48,363	Mexico	6,537
Nigeria	37,453	Norway	6,376
US	32,773	Oman	5,373
Kazakhstan	30,000	Sudan	5,000

According to Rystad Energy's reports (Figure 3.4), the record for the lowest global discovery of conventional volume was broken in 2017. It is announced that less than seven billion bbl of oil were discovered which is the lowest discovery ever since the 1940s. Also, resources per discovered field were around 100 MMbbl, while it was 150 MMbbl per discovered field in 2012. However, in 2018, total discovery amount surged again to 9.4 billion bbl (Rystad Energy, 2017, 2018).

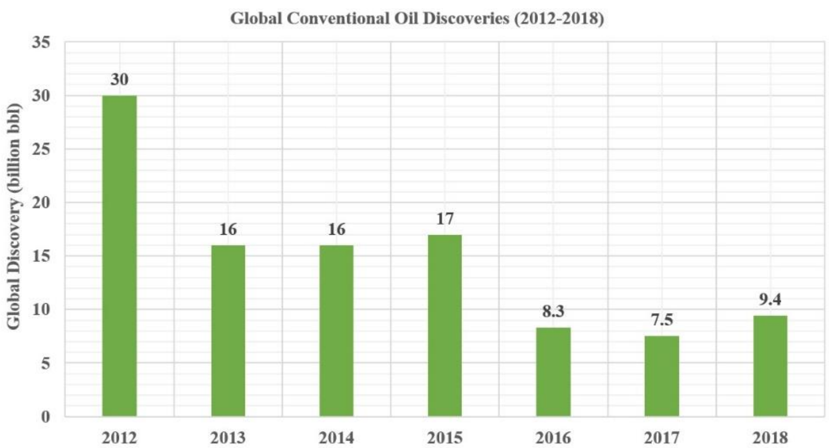

Figure 3.4. Global Conventional Oil Discoveries (Rystad Energy, 2017, 2018)

Also, the crude oil market has been suffering from the decreasing crude oil prices. The prices had been fluctuating during recent years. OPEC made some production adjustments to balance the decreasing crude oil prices. Figure 3.5 shows the OPEC Reference Basket (ORB) prices between March 2014 and February 2019. As of 1 May 2019, ORB is $72.00/bbl.

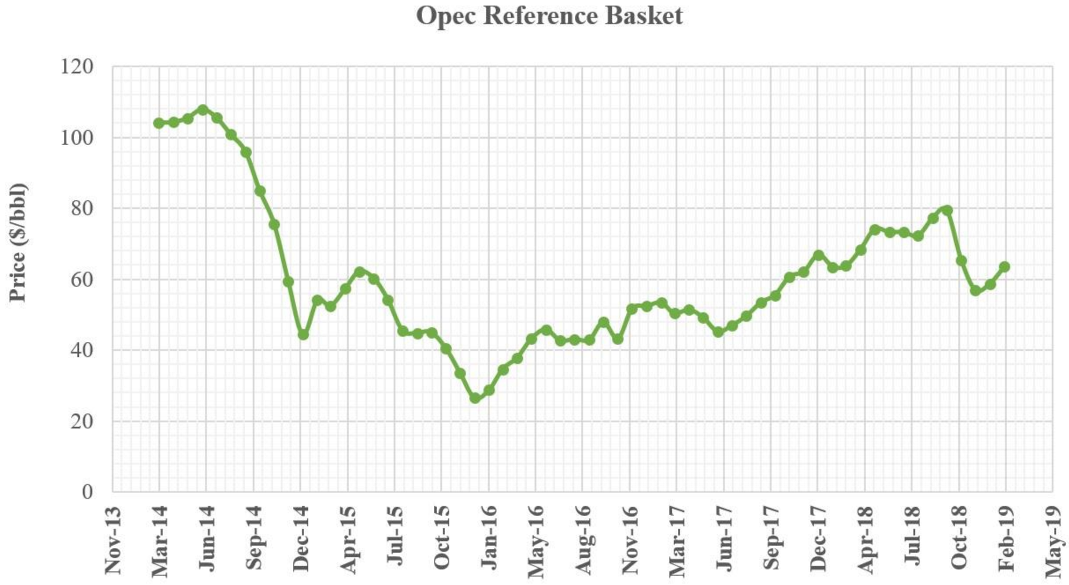

Figure 3.5. ORB Prices Mar 2014- Feb 2019 (OPEC, 2019b)

Table *3.2* shows the crude oil producers with higher than 500 Mbpd rate. As of May 2019, the US was the leading crude oil supplier with 12.20 MMbpd. Russia and Saudi Arabia were following the US with 10.60 MMbpd and 9.69 MMbpd productions respectively.

Table 3.2. *Crude Oil Production, May 2019* (JODI, 2019; OPEC, 2019a)

Country	*Crude Oil Production (MMbpd)*	*Country*	*Crude Oil Production (MMbpd)*
US	12,200	Kazakhstan	1,356
Russia	10,598	Libya	1,174
Saudi Arabia	9,690	UK	1,033
Iraq	4,724	Algeria	1,029
China	3,906	Oman	1,000
Canada	3,496	Colombia	852
UAE	3,061	Venezuela	741
Kuwait	2,710	Indonesia	704
Brazil	2,607	India	684
Iran	2,370	Egypt	631
Nigeria	1,733	Malaysia	617
Mexico	1,709	Qatar	615
Angola	1,471	Azerbaijan	599
Norway	1,403	Ecuador	529

There are different types of crude oils in the world oil market with different characteristics. Fundamentals vary for each parameter of the crude oil.

Crude oil can be mainly classified commercially according to different kind of properties as density (API Gravity) and sourness (sulfur content).

API Gravity is the most common way to describe oil quality which depends on the density of the oil. The American Petroleum Institute (API) defines the gravity number according to the equation below. API gravity is calculated in 60^{o} F. Length of hydrocarbons makes the difference in density. Also, as the H/C ratio decreases, density increases.

$$^{o}\text{API} = \frac{141.5}{\text{specific gravity}} - 131.5 \qquad [4.1.]$$

Sourness can be defined as the concentration of sulfur content. As Table *4.3* shows, total sulfur content less than 0.5 percent in mass, between 0.5% and 1.0% and more than 1.0% are called sweet, medium sour and sour respectively.

Table 3.3. *Crude Oil Classification* (Speight, 2011)

Crude Oil Type	*API Gravity (°)*	*Crude Oil Type*	*Sulfur (%)*
Condensate	>50	Sweet	<0.5
Light Crude Oil	35-50	Medium Sour	0.5-1.0
Medium	26-35	Sour	>1.0
Heavy Oil	10-26		

While different crude oils as light, medium or heavy oil can be used for different purposes according to industrial needs, in the most basic term it can be said that oil quality is proportional to API gravity, while inversely proportional to sulfur content. Although there are various factors affecting crude oil price and quality, the focus is basically on the API gravity and sulfur content.

Table *4.4* shows some of the major crude oil from 161 different blends traded internationally (Energy Intelligence Group, 2007). Also, the crude oil properties and the prices as of 1 May 2019.

Table 3.4. *Major Traded Crude Oil Types* (Energy Intelligence Group, 2007; OPEC, 2019a)

Crude Oil (Country)	*API Gravity (°)*	*Sulfur (%)*	*Price ($/bbl)*
Arab Light (Saudi Arabia)	34.0	1.78	70.78
Basrah Light (Iraq)	33.7	1.95	69.77
Bonny Light (Nigeria)	35.4	0.14	72.24
Brent Blend (UK)	38.3	0.37	71.15
Dubai (UAE)	31.0	2.00	70.93
Es Sider (Libya)	37.0	0.27	70.25
Girassol (Angola)	32.0	0.34	72.95
Iran Heavy (Iran)	30.2	1.77	67.86
Isthmus (Mexico)	33.4	1.25	70.34
Kuwait Export (Kuwait)	32.4	2.55	71.20
Marine (Qatar)	36.2	1.60	63.60
Merey (Venezuela)	15.0	2.70	58.95
Murban (UAE)	40.4	0.79	71.51
Oriente (Ecuador)	24.8	1.02	67.61
Rabi Light (Gabon)	34.6	0.06	70.40
Urals (Russia)	32.0	1.30	71.90
WTI (US)	39.6	0.24	63.87

Figure 3.6 shows the API Gravity and sulfur content of these major crude oil distribution. As going to the right API density decreases, while the sulfur content decreases as moving to the bottom.

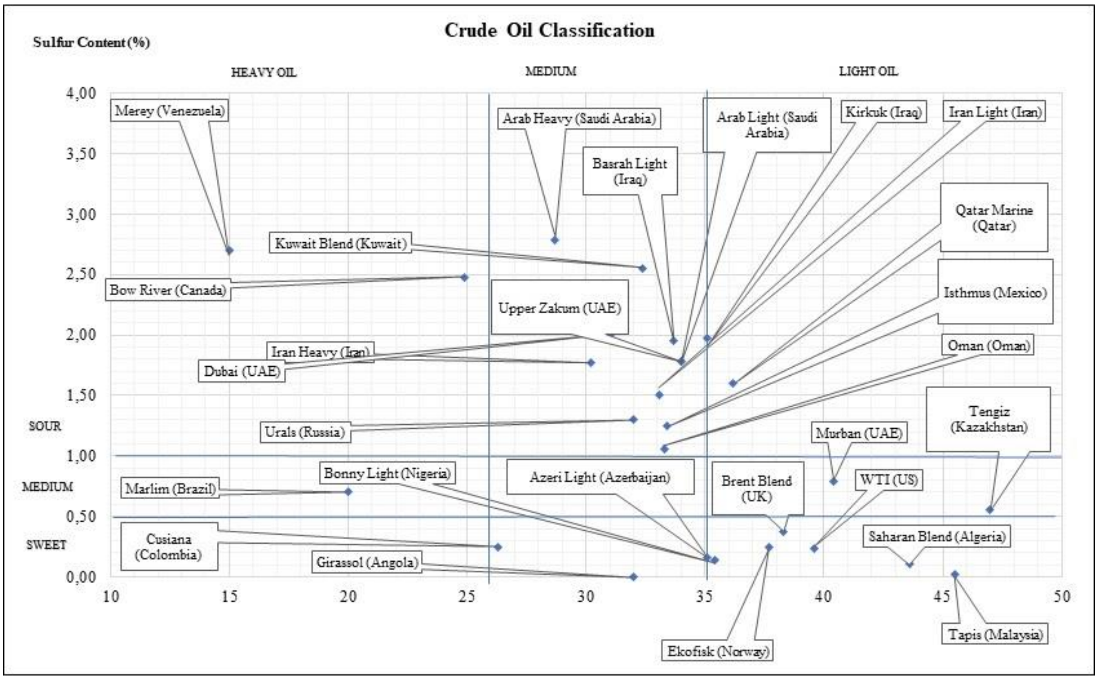

Figure 3.6. Classification of Some Major Crude Oils

The most significant crude oils in the trade market are West Texas Intermediate (WTI), Brent Basket and Dubai. While the two benchmark crude oils; Brent Blend and WTI are classified as sweet light oil, the other benchmark crude oil, Dubai, is classified as medium sour.

WTI crude is traded in New York Mercantile Exchange (NYMEX)'s oil futures contract. Its API gravity is around 39.6^{o} with 0.24% sulfur content. Also, WTI is refined easily because of its high quality. Brent Blend is another benchmark crude oil. Combination of 38 different oil fields in the North Sea forms the benchmark crude oil. Its API gravity is 38.3^{o} and contains 0.37% sulfur. These properties make Brent Blend sweet light crude oil. Its future market is based at the International Petroleum Exchange (IPE) in London. Dubai is the primary reference for crude oil delivered to Asian refineries from the Middle East Gulf. Dubai Crude Oil is medium sour with 31^{o} API gravity and 2% sulfur content (Platts, 2016).

Also, OPEC uses ORB to follow market prices. Although it is not physically traded, the basket is used for the monitoring of world oil market conditions. ORB consists of

15 different crude oils from different properties. If components are to be classified in terms of density and sourness, Saharan Blend (Algeria), Es Sider (Libya), Bonny Light (Nigeria), Qatar Marine (Qatar) and Murban (UAE) are sweet light, Girassol (Angola), Djeno (Congo), Zafiro (Equatorial Guinea) and Rabi Light (Gabon) are sweet medium, Iran Heavy (Iran), Basrah Light (Iraq), Kuwait Export (Kuwait) and Arabian Light (Saudi Arabia) are medium sour, Oriente (Ecuador) medium sour heavy and Merey (Venezuela) is sour heavy crude. Also, ORB averages 32.7^{o} API Gravity and 1.77 % sulfur content.

3.2 Organizations

There are some organizations which influence the oil supply and demand dynamics. Organisation for Economic Co-Operation and Development (OECD) is the major organization which holds the highest crude oil demand as an organization. OPEC is the petroleum exporting organization, in which Saudi Arabia can be referred to as their de-facto leader. Also, the Cooperation Council for the Arab States of the Gulf (GCC) is a cooperation of Gulf Countries for the union of the region in external politics

3.2.1 The Organisation for Economic Co-operation and Development

OECD was first founded in 1948 with the name of "The Organisation for European Economic Cooperation" (OEEC). The major purpose was the reconstruction of the region with the Marshall Plan which was financed by the US after devastating World War II. OECD was officially established on 30 September 1961 with the signing of the OECD Convention between OEEC members, Canada, and the US on 14 December 1960 (OECD, 2018). Therefore, the organization moved to the global stage. Also, the members contained 58.98 % of the global crude oil import at the end of 2017. The members are the US, UK, Canada, Denmark, Iceland, Norway, Turkey, Spain, Portugal, France, Ireland, Belgium, Germany, Greece, Sweden, Switzerland, Austria, Luxemburg, Netherlands, Italy, Japan, Finland, Australia, New Zealand, Mexico, Czech Republic, Hungary, Korea, Poland, Slovak Republic, Chile, Slovenia, Israel, Estonia and Latvia in time order.

3.2.2 The Organization of Petroleum Exporting Countries

OPEC was founded in 1960 by five major oil-producing countries; Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. The purpose of this inter-governmental organization was to coordinate a unified petroleum policy.

Other members are; Libya (1962), The United Arab Emirates (UAE) (1967), Algeria (1967), Nigeria (1971), Gabon (1975), Angola (2007) and Equatorial Guinea (2017) and Congo (2018). Now the organization consists of 13 members.

The OPEC Statute stipulates that "any country with a substantial net export of crude petroleum, which has fundamentally similar interests to those of Member Countries, may become a Full Member of the Organization, if accepted by a majority of three-fourths of Full Members, including the concurring votes of all Founder Members". OPEC's share in supply has been more than 40% since 1993 which has a huge impact on oil prices.

3.2.3 The Cooperation Council for the Arab States of the Gulf

GCC was established on May 25, 1981, with the cooperation of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE. Members hold 62% of the crude oil reserves of the Middle East and 33% of the global crude oil reserves. Saudi Arabia influences the economic growth of other GCC countries. As of the end of 2017, Saudi Arabia accounts for 53.7% of GCC crude oil reserves, 46.77 % of the GCC's GDP and 57.5 % of the total production. Additionally, the GCC Secretariat and the headquarters are based in Riyadh, Saudi Arabia which shows that Saudi Arabia is the de-facto leader of the Council (Martini et al., 2016).

CHAPTER 4

SAUDI ARABIA

Saudi Arabia is in the Arab Peninsula, the Middle East. GDP at market prices is $639.6 billion while the population of 32.9 million at the end of 2017 (World Bank, 2019). Additionally, Saudi Arabia is located near the Strait of Hormuz, the world's busiest chokepoint and Bab el Mandeb, the fifth busiest chokepoint. The Strait connects the Persian Gulf with the Gulf of Oman and the Arabian Sea. The total flow through the Strait of Hurmuz was 19.1 MMbpd as the end of 2017. The strait accounted for about 30% of all seaborne-traded crude oil and other liquids since 2010. Another regional chokepoint is Bab el Mandeb which links the Gulf of Aden and the Red Sea. This waterway is a strategic link between the Mediterranean Sea and the Indian Ocean. An estimated 4.8 MMbpd of crude oil and refined petroleum products flowed through this waterway in 2017 towards Europe, the US, and Asia. As the end of 2017 total world maritime oil trade was around 59 MMbpd, while these two chokepoints hold around 40 % of the global maritime oil trade (Berument et al., 2018).

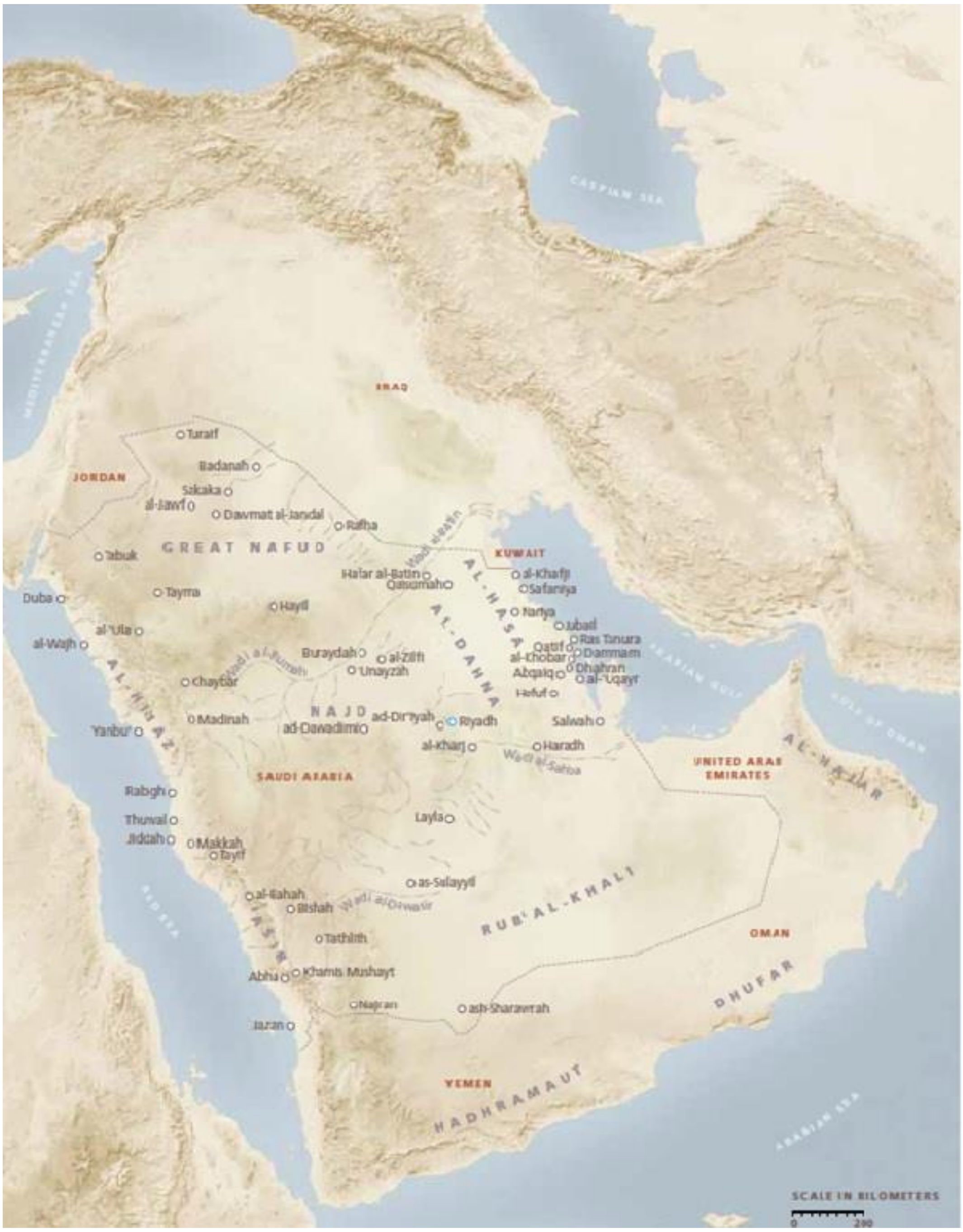

Figure 4.1. Saudi Arabia Map (McMurray, 2011)

As of May 2019, total crude oil production of Saudi Arabia was 9.69 MMbpd. The kingdom contains the worldwide 21.9% of the proven reserves with 266 billion bbl (OPEC, 2019c). Saudi Arabia's economy remains heavily dependent on petroleum exports which were accounted for 69.01% of the total import value at the end of 2017. The total value of petroleum exports was 85% of the total export value before 2013, but the Kingdom's oil revenue dramatically decreased to 69% as crude oil prices have decreased since mid-2014.

As illustrated in Figure 4.2, Saudi Arabia continuously produced more than 10.85 % of the worldwide, 27.68 % OPEC and 37.30 % the Middle East crude oil production since 1993. Also, Saudi Arabia is one of the three countries with more than 5 MMbpd crude oil production in the last three decades. Russia and the US make up the top three.

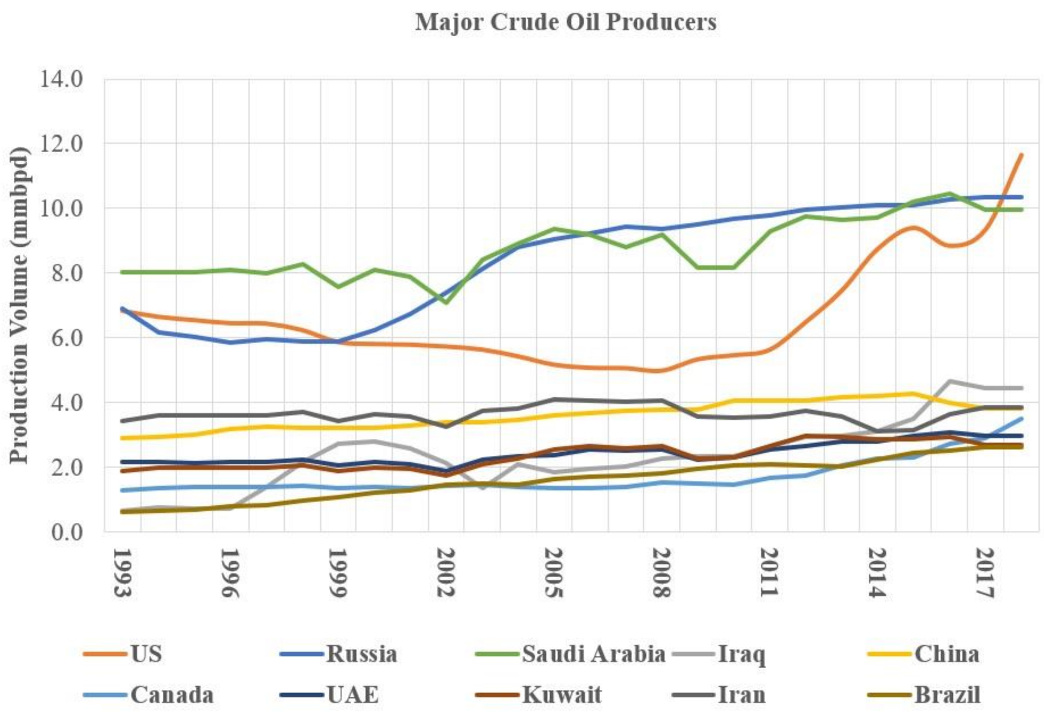

Figure 4.2. World Crude Oil Production, 1993-2017 (OPEC, 2019c)

Also, Figure 4.3 shows the production consistency of Saudi Arabia over the last 50 years. The kingdom protected its production share in recent three decades in the world, the Middle East and OPEC. As the end of 2017, 13 % of the crude oil supplied to the world was produced by Saudi Arabia.

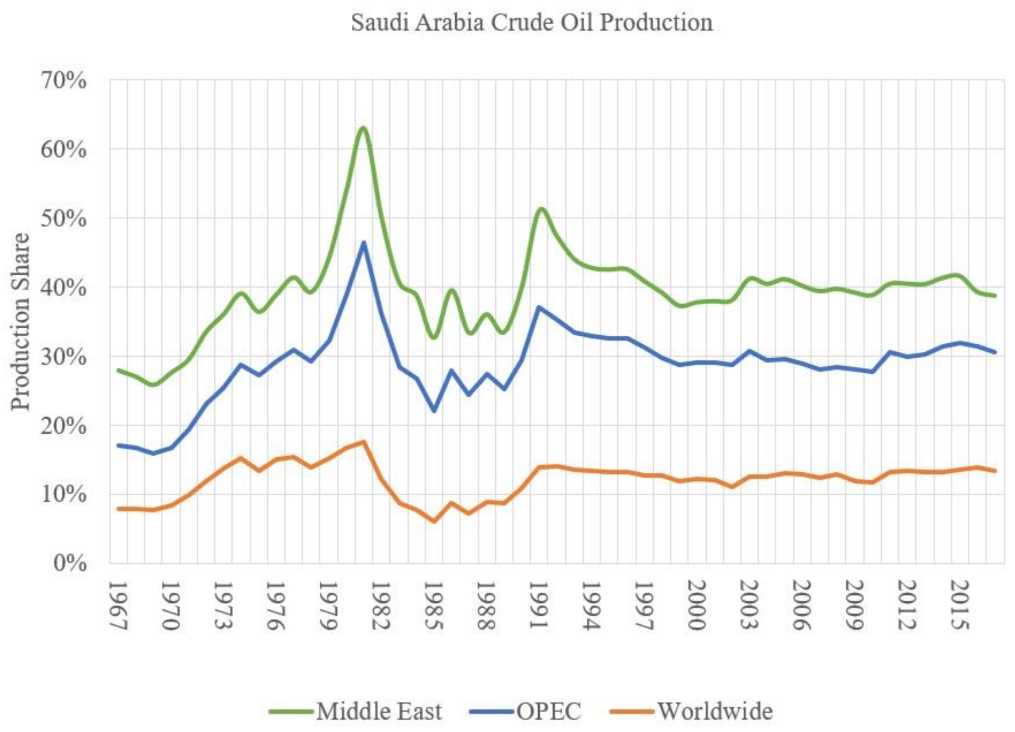

Figure 4.3. Saudi Arabia Crude Oil Production Share, 1967-2017 (OPEC, 2019c)

4.1 Saudi Aramco

Saudi Aramco is the national company of the kingdom. The company holds the licenses in the country and directs all the upstream activities. Saudi Aramco was first founded by the name of California Arabian Standard Oil Company (CASOC) with the agreement between Saudi Arabia and Standard Oil Company of California (SoCal). The company was first founded in Delaware on November 8, 1933. In 1934, Schuyler B. Henry and J.W Soak completed their survey and structural contour map of the Dammam Dome, the location of first oil discovery (Saudi Aramco, 2017). In 1934, the geologist Dick Kerr who is also a pilot took aerial photos of the region. In 1935, first well was drilled in Dhahran, Dammam Dome. In 1936, Texas Company acquired 50% interest in SoCal's concession (Both Texas Company and SoCal is part of Chevron now). In 1937, major oil fields including Ghawar, Abqaiq, and Qatif were discovered by the chief geologist Max Steineke. In 1938, the first commercial well (Well No.7, Figure 4.4) was discovered in Dammam. The well proved the existence of oil in the region and a new era started. Production was 1,500 bpd. Also, in 1939, commercial quantities of oil were found in 161 kilometers (km) northwest of Dhahran. The importance of this well was the final target which so deep that it was 3,050 meters (Saudi Aramco, 2017).

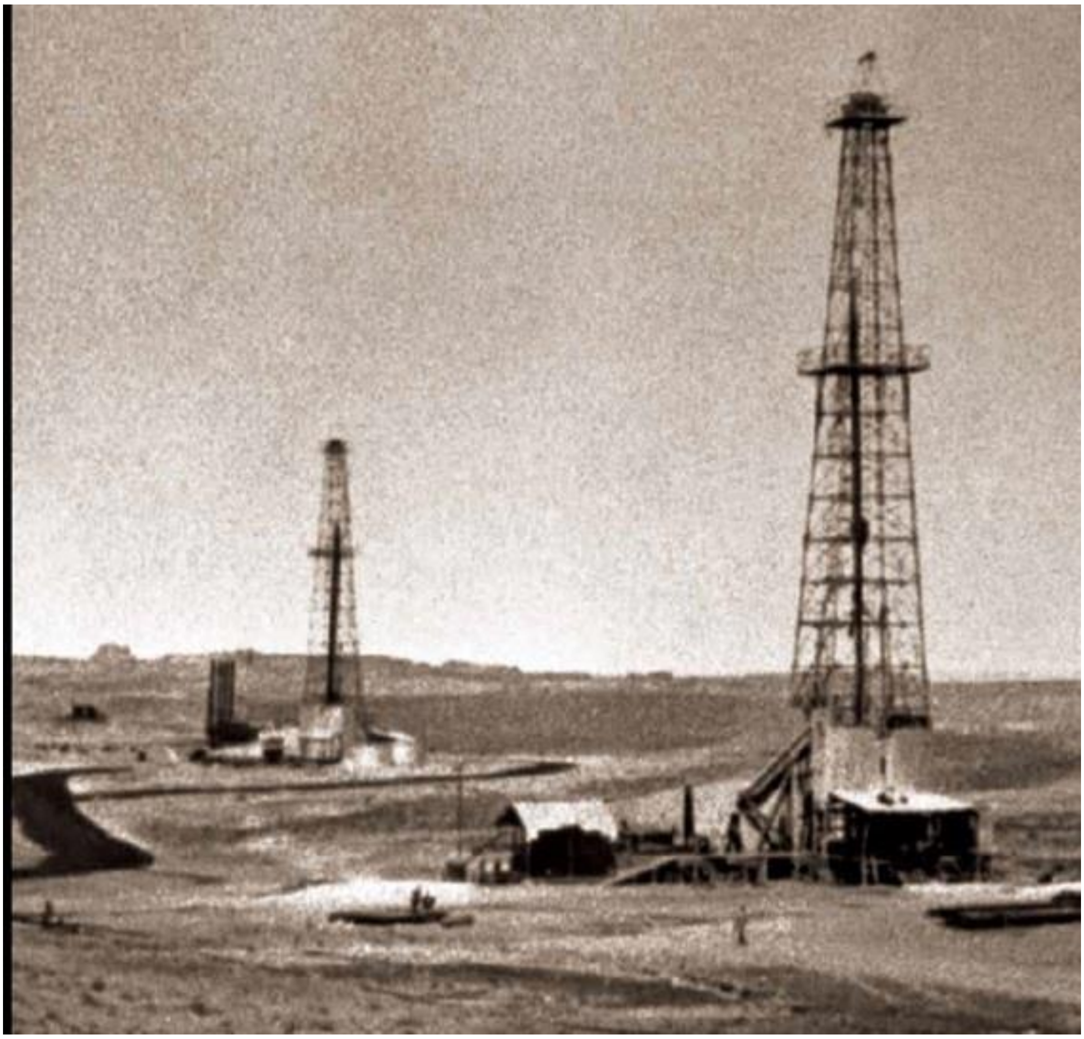

Figure 4.4. Dammam Well No.1 (Left), Well No.7 (Right) (McMurray, 2011)

In 1941, Abqaiq Field was discovered with the successful drilling operation of Abqaiq Well No#1. The flow rates were an indication of a major new oil field. The first refinery opened in Ras Tanura had a capacity of 3,000 bpd but then it was closed due to World War II. In 1944, the company's name changed to Arabian American Oil Company (Aramco), while average production rate was 20,000 bpd. In 1946, the Arab Industrial Development Department was established to contribute to the local economy. In 1947, Ras Tanura Refinery completed the first year of operations with 50,000 bpd capacity. In 1948, Exxon purchased 30 % of Aramco and Mobil purchased 10% (Yergin, 1990). Later, oil production hit 500,000 bpd in 1949.

With the discovery of the Safaniya and Ghawar; total recoverable reserves of the country have increased dramatically to 50 billion bbl. In May 1954, oil production exceeded one MMbpd and this production became consistent with the year 1958. Foundation of OPEC was a milestone for the kingdom in 1960. During 1973-1980 the Saudi Arabian government increased its stake slowly until the company is fully owned by Saudi Arabia. Finally, in 1988 the company's name changed to Saudi Aramco (Saudi Aramco, 2017).

During the 1990s, the company's proven crude oil reserves volume hit 260 billion bbl. Also, Saudi Aramco provided the supply deficit in the world oil market by increasing total production to 8.5 MMbpd from 5.4 MMbpd only in 90 days. This action helped the world crude oil market to stay stable.

So far approximately 151.36 billion bbl crude oil is produced from Saudi Arabia oil fields according to the study conducted in the thesis.

4.2 Oil Fields

Until the mid-1980s, there were 47 oil fields discovered. Currently, the number has increased to 92 oil fields including sub-areas. Figure 4.5 shows these oil fields in the map of Saudi Arabia, while the major fields to be evaluated in the following parts of the thesis are labeled green. Major oil fields have been producing for long years. There has not been a significant discovery over decades. The latest production added was Nuayyim in 2009 with 100 Mbpd which is not that much compared to other fields even though the field could be considered as a giant field (The term is defined as URR > 0.5 billion bbl and production > 100 mbpd (Robelius, 2007)). The nearest major discovery before that was Shaybah which was discovered in 1968.

The history of oil exploration in Saudi Arabia has followed a pattern seen in many other key oil basins of the world. Suggestion offers that all known petroleum basin contains oilfields of various sizes with a predictable hierarchy. All-important oil basins have a King, one or two queens, up to 10 Lords and hundreds of peasants" (small fields). Saudi Arabia's oil discoveries are classic examples of a "Royal Family" which was first suggested by the French Institute of Petroleum (IFP).

The King: Ghawar

The Queen: Abqaiq

The 2nd Queen: Safaniya

The Lords: Abu Sa'fah, Berri, Khurais, Khursaniyah, Manifa, Marjan, Shaybah, Qatif and Zuluf (Simmons, 2005) Table *4.1* shows the major properties of these oil fields. Abqaiq is the oldest discovered field amongst these fields. The king of oilfields Ghawar, Qatif and Safaniya followed that discovery.

Eight of these twelve fields are in the world's largest 20 oil fields in terms of URR (Robelius, 2007).

Table 4.1. *Saudi Arabia Major Oil Fields*

Field	*Discovery*	*Production*	*Location*	*Crude Type*	*Grade (°API)*	*Sulfur (%)*
Ghawar	1948	1951	Onshore	Light	34	1.90
Abqaiq	1941	1946	Onshore	Extra Light	36	1.32
Safaniya	1951	1957	Offshore	Heavy	27	2.97
Abu Sa'fah	1963	1968	Offshore	Heavy	29	2.00
Berri	1964	1967	Offshore	Light	38	1.17
Khurais	1957	1970	Onshore	Light	35	1.74
Khursaniyah	1956	1960	Onshore	Light	35	2.38
Marjan	1967	1974	Offshore	Medium	31	13.00
Manifa	1957	1964	Offshore	Heavy	29	3.00
Shaybah	1968	1998	Onshore	Extra Light	42	0.70
Qatif	1947	1951	Onshore	Light	38	1.59
Zuluf	1965	1973	Offshore	Medium	35	1.65

The Royal Family contributed to 96.34% of total crude oil production of Saudi Arabia, while the remaining 3.66% was from other 75 fields. Therefore, the production of these fields "Others" is evaluated as a function of these 12 fields. The examined fields are introduced in the order of "Royal Family" and the lords in the alphabetical order.

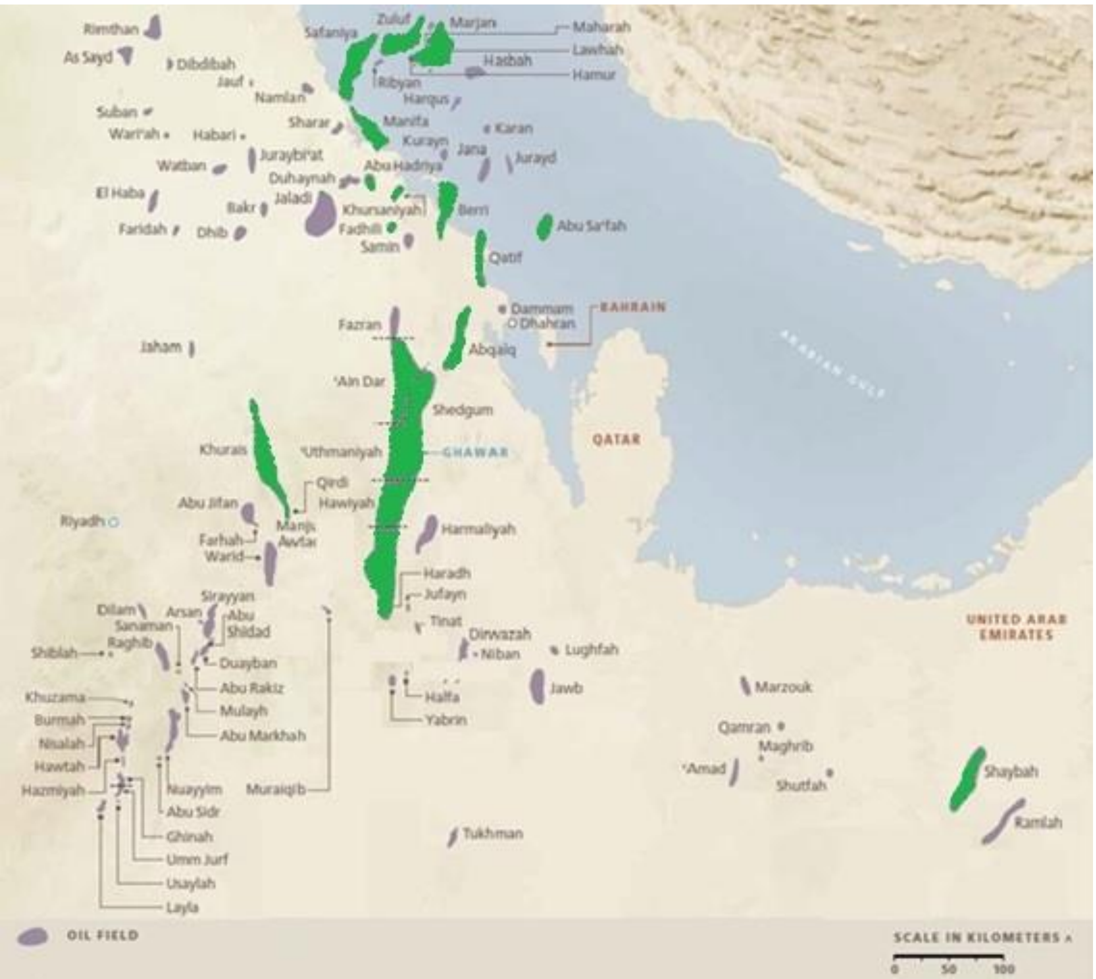

Figure 4.5. Oil Fields and Royal Family

King of the oil fields, Ghawar is the largest recoverable conventional oil field ever discovered. Compared to the supergiant size of Ghawar, the public knowledge of this field remains insignificant. Since Saudi Aramco keeps data undisclosed, there is no detailed information about the field; therefore, to investigate the production behavior, official reports, and published researches were analyzed to create the whole picture.

The field is 280 km long and 26 km wide (Powers, 2012). Ghawar was first discovered in 1948 and the started production in 1951. As the reservoir characteristics are shown in Figure 4.2, Ghawar consists of five different sub-fields. These fields are Ain Dar, Shedgum, Uthmaniyah, Hawiyah and Haradh from north to south. As moving to north, oil quality increases. Permeability, oil viscosity, oil productivity, and reservoir thickness decreases as moving to the south.

Table 4.2. *Field Reservoir Characteristics of Ghawar Sub-Fields* (Mearns, 2007)

Field	*Ain Dar/Shedgum*	*Uthmaniyah*	*Hawiyah*	*Haradh*
Discovery	1948	1951	1953	1949
Location		Onshore		
Reservoir		Arab Carbonate		
Crude Type		Arab Light		
Crude Grade (^{o}API)	34	33	32	32
Sulfur Content (%)	1.71	1.91	2.13	2.15
Production Capacity (mbpd)	2,000	1,500	600	900
Thickness (feet)	199	180	180	140
Average Porosity (%)	19	18	17	14
Average Permeability (Md)	655	220	220	52
Productivity (Bopd/psi)	140	92	45	31

The Ain Dar/Shedgum fields are evaluated as one field since they have similar properties. The area is located in one of the most prolific parts of the Ghawar field. Ain Dar and Shedgum were discovered in 1948 and 1952 respectively. Uthmaniyah is another prolific part of Ghawar. Some resources analyze the region as dividing to North and South Uthmaniyah. The northern part was so prolific that, the production was peaked at 1.9 MMbpd in 1973. Also, the field was discovered and first produced in 1951. Haradh was first discovered in 1949, and production started in 1951. Hawiyah is the latest part discovered. The first discovery was in 1953 and this region produced quite less than the northern parts Haradh is located at the Southernmost portion of the Ghawar complex and covers an area 75 km long and is 26 km at its widest section. The field consists of three sub-segments of approximately equivalent reserves. Therefore, the region can be divided into three subparts as Haradh-I, Haradh-II and Haradh-III (Simmons, 2005).

Ghawar is not called “King of Oilfields” for no reason. According to the study conducted in this thesis, as the end of 2018, Ghawar Field’s cumulative production is estimated to be at 80.15 billion bbl. As Table *4.3* shows the amount is only less than the production of the US and Russia. Even Saudi Arabia produced less than Ghawar if its share is excluded. Therefore, if Ghawar were a separated country from Saudi Arabia, it would have been the third country in terms of cumulative production between 1960-2018.

Table 4.3. *Crude Oil Production (1960-2018)*

Rank	*Region*	*Production (billion bbl)*
3rd	Ghawar	80.15
4th	Iran	71.64
5th	Saudi Arabia	67.26
6th	Venezuela	56.71
7th	China	50.37
8th	Kuwait	45.09
9th	Iraq	42.66
10th	Mexico	42.16

As Figure 4.6 illustrates, Ghawar has been producing consistently since the first-day production started. Even though, the field is very mature, still producing with a large amount of production rate. As Saudi Arabian government increased its stake and finally owned the company 1988, during that period the operators and shareholders pushed fields so hard that Ghawar production decrease to 1.1 MMbpd from 5.77 MMbpd peak level.

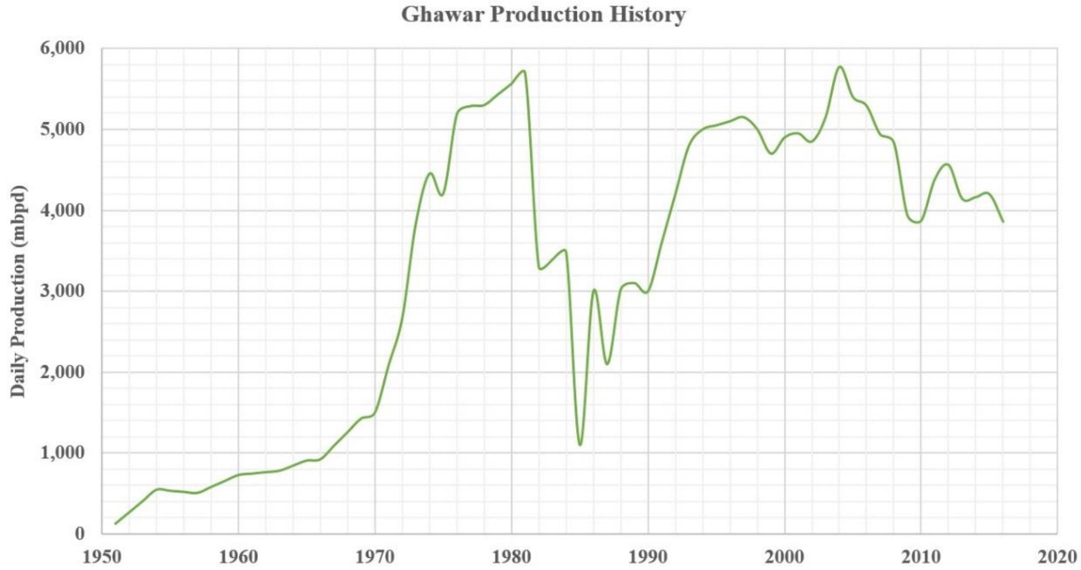

Figure 4.6. Ghawar Crude Oil Production History (1950-2018)

The Queen, Abqaiq is one of the most mature oil fields in Saudi Arabia. The field is approximately 59 km in length and 11 km in wide. This onshore field was discovered in 1941 and production began in 1946. Abqaiq lies in the northeast section of Ghawar and the rock properties are very similar to the north end of Ghawar in terms of permeability and quality. Crude oil produced in this field is classified as Arab Extra Light with 36^{o} API and 1.32 % sulfur content (Powers, 2012). As Figure 4.7 illustrates Abqaiq enjoyed its peak production in the early 1970s and still producing around 400 mbpd.

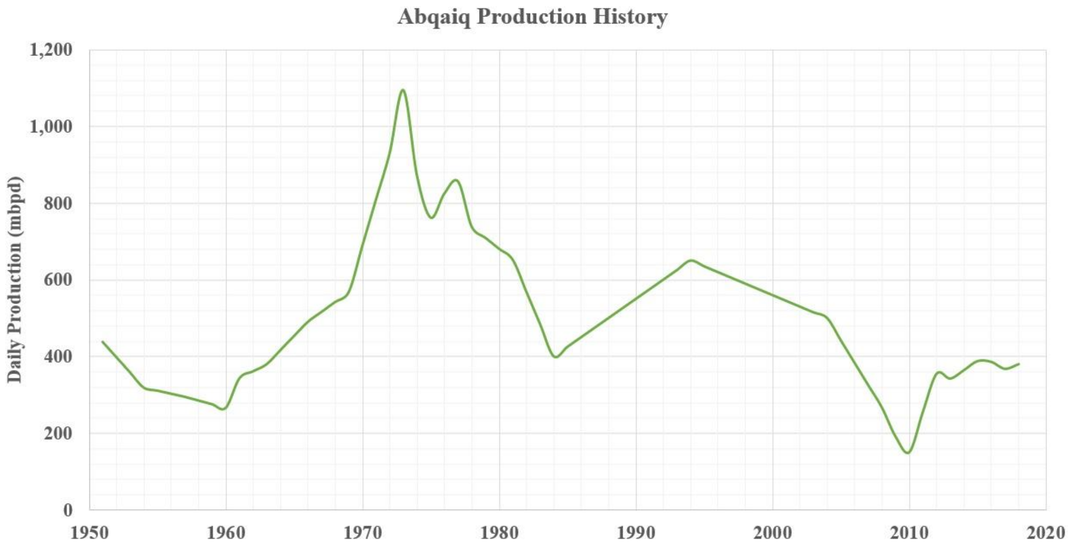

Figure 4.7. Abqaiq Crude Oil Production History (1950-2018)

The 2nd Queen, Safaniya is the largest conventional offshore field. It was first discovered in 1951 off the coast of Arabian Peninsula about 200 km north of Dhahran. Safaniya is 50 km by 15 km in size and both discovered and commenced production in 1957. Reservoir section is very high-quality sandstone as opposed to Ghawar which is limestone. API gravity of the crude oil produced is 27° (Simmons, 2005).

As Figure 4.8 illustrates, the field has been producing for long years. After the 2000s, production has increased by horizontal well applications. This application decreased the water cut and increased production per well (Zubail et al., 2012).

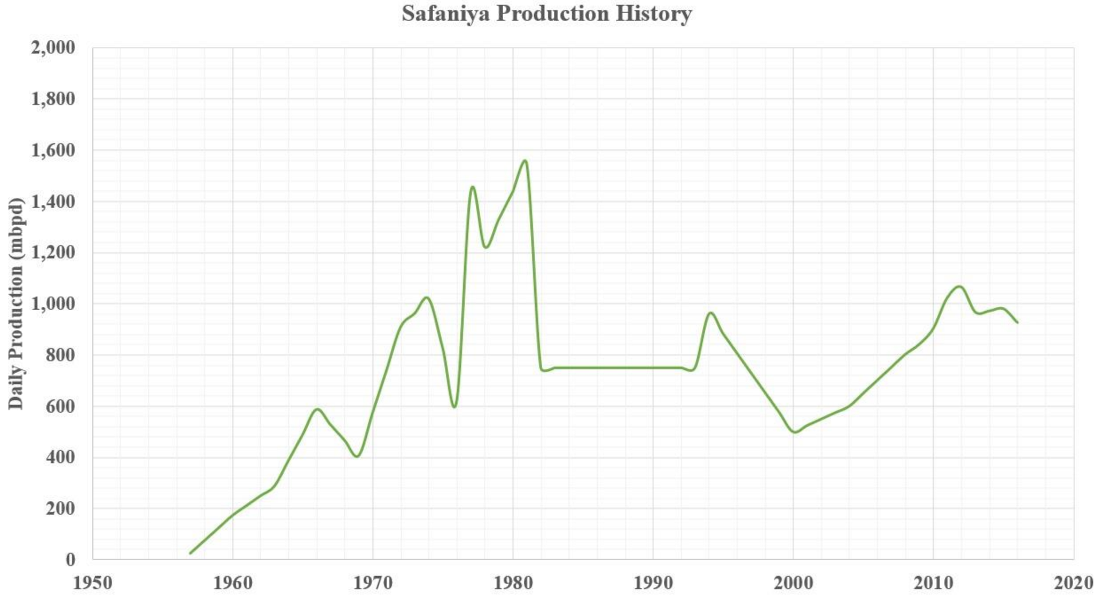

Figure 4.8. Safaniya Crude Oil Production History (1950-2018)

Abu Sa'fah is located 48 km off the shore from mainland Saudi Arabia. The field was discovered in 1963 and started production in 1968. The production is shared with Bahrain. Abu Sa'fah crude oil is heavy and sour with 28.6^o API with 2.36% sulfur content (Ali et al., 1981).

Berri is located both onshore and offshore along the western edge of the Arabian Gulf. The field was first discovered in 1964 and the production started in 1967. Producing formation is carbonate as Ghawar and Abqaiq. API gravity is 38^o and sulfur content is 1.17%. Figure 4.9 shows the oil production history of the field. The field was shut off in 1982 after 15 years of production. Berri started to produce in 1993 with horizontal drilling applications taken place in 1991 (McMurray, 2011). Since then, the field has been producing around 250 Mbpd.

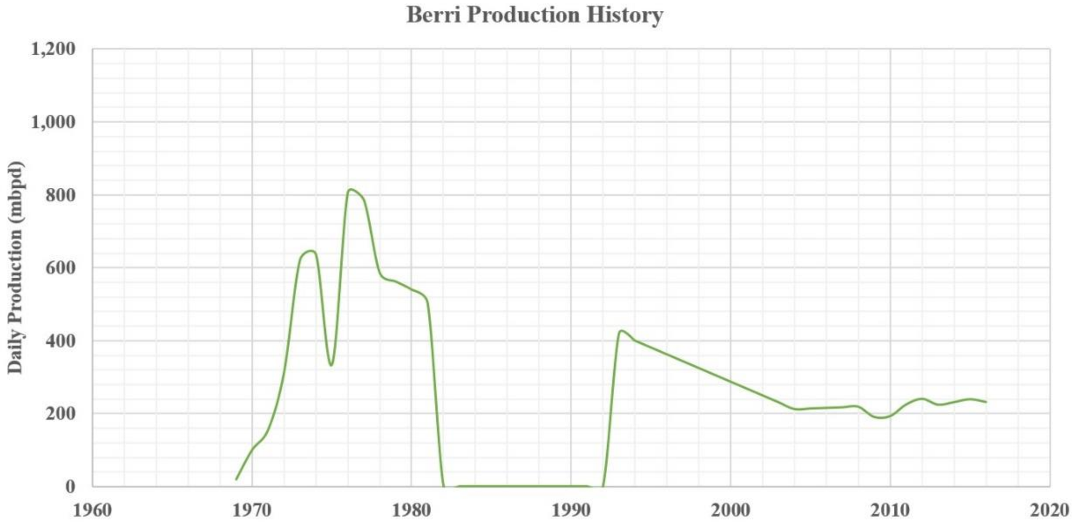

Figure 4.9. Berri Crude Oil Production History (1950-2018)

Khurais shows similarity with Abqaiq, Berri, and Ghawar and while the field is just located in the west of Ghawar. The field was discovered in 1957 and started production in 1961. Produced crude oil API gravity is 36^o (Al-Somali et al., 2009). Cumulative production was only 0.42 billion bbl until 1993 which is very little compared to other major fields. After the developments and the addition of Abu Jifan and Mazalij fields production started with 1.2 MMbpd and increased its capacity to 1.5 MMbpd by mid-2018.

Khursaniyah is smaller compared to other fields. The field consists of three different sub-fields; Khursaniyah, Abu Hadriya, and Fadhili. The information related to this field is limited while the API gravity of crude oil produced is 35^o.

Manifa is one of the oldest offshore fields which was first discovered in 1957. The field is in 255 km northwest of Dhahran with 45 km in length and 18 km in width. Also, Manifa is estimated to be the world's fifth biggest offshore oil field. Crude oil produced in this field is Arabian Heavy crude with 29^o API with 3% sulfur (Xia et al., 2014). Production was halted in 1984 and mothballed for a long time until 2007

(Simmons, 2005). Now the field has been producing with 900 Mbpd capacity since 2013.

Marjan is located 14 km offshore in the Arabian Gulf. The field was discovered in the mid-1960s and oil production started in 1973. Crude oil produced is Arabian medium crude with 31^o API and crude contains sulfur as high as 13%. Smaller fields near Marjan is adjoined with the field in terms of cumulative production.

Qatif was first discovered in 1945 and started production in 1951. Crude oil produced is Arabian Light with 38^o API and 1.59% (McKetta Jr, 1990). The field was mothballed between 1982 and 2004. On August 9, 2004, production at Qatif commenced again. The major problem about Qatif is that hydrogen sulfide ranging as high as 10% to 20% in production zones. Half of the possible new drill sites were rejected since sites were too hazardous (Simmons, 2005).

Shaybah was discovered in 1967; however, production did not start until 1998. The field is the only significant new discovery put into production in the past three decades. It is located 550 km southeast of Dhahran which is near the Dubai border. The region has a very tough climate with temperatures reaching up to 52 ^{o}C, wind speed records more than 40 mph and dunes can grow up to 1,000 ft high. Although the remote location and harsh terrain acclimate causes higher operational cost for the Shaybah field, with the developments in the field, production increased consistently to 1 million bpd as of 2018 (Powers, 2012). The produced crude oil is extra light with 42^o API.

Zuluf is one of the northernmost fields in Saudi Arabia and located about 56 km offshore in the Arabian Gulf. The field was discovered in 1965 and the first production started in 1973. Although the production zone is the same as Safaniya, produced crude oil has 34.5^o API Gravity and 1.65 % sulfur content (Aljubran et al., 2017).

4.3 Export Destination

Saudi Arabia is the world's leading crude oil exporter since 1990. The kingdom exported 7,69 million bpd of crude oil in December 2018. Also, the total export and loading capacity is 13 MMbpd including the world's largest offshore oil exporting port, the Port of Ras Tanura on the Persian Gulf that has 6.5 million bpd of capacity. Additionally, Saudi Aramco plans to raise its export capacity to 15 million bpd with the Muajjiz oil terminal addition.

Saudi Arabia's main export destinations are Japan (world's 4^{th} biggest crude oil importer), the US (1^{st} crude oil importer), China (2^{nd} crude oil importer), South Korea (5^{th} crude oil importer) and India (3^{rd} crude oil importer). Singapore, South Africa, France, Spain and Italy forms the top ten. These destinations are mentioned as the *target market.*

Table 4.4. *Top Ten Saudi Arabia Crude Oil Export Destination (Target markets)*

Country	*Saudi Arabia Export Share*	*Worldwide Import Share*	*Worldwide Import Ranking*
Japan	*21.0 %*	*7.3 %*	*4^{th}*
China	*17.0 %*	*18.3 %*	*1^{st}*
US	*15.0 %*	*16.3 %*	*2^{nd}*
South Korea	*14.0 %*	*7.1 %*	*5^{th}*
India	*12.0 %*	*9.4 %*	*3^{rd}*
Singapore	*3.3 %*	*2.5 %*	*11^{th}*
South Africa	*2.7 %*	*0.8 %*	*20^{th}*
France	*2.2 %*	*2.6 %*	*10^{th}*
Spain	*2.0 %*	*2.9 %*	*9^{th}*
Italy	*1.9 %*	*3.1 %*	*8th*

CHAPTER 5

STATEMENT OF THE PROBLEM

When it comes to oil it is difficult to reach reliable data and make an accurate economic forecast. Since Saudi Arabia is the de-facto leader and swing producer of the oil business and Saudi Aramco is on the verge of the initial public offering (IPO) the condition of the fields and future production is more important than ever.

The primary key for forecasting the future crude oil market of a country is to monitor the production behavior and evaluate the potential substitutes.

This study aims to draw a future of Saudi Arabian crude oil market by investigating the oil fields and potential substitutes in the market. This will help to lighten the global crude oil industry. For this purpose, fields were evaluated within production behavior methods, other major producers were analyzed according to their replacement power over Saudi Arabian crude and finally, scenarios were discussed according to these possible replacements.

As to be explained in further chapters, both evaluations were analyzed through engineering methods.

CHAPTER 6

METHODOLOGY

In this thesis, the methodology is divided into two parts. First is to analyze the fields' reservoirs and future production behavior. Second is to evaluate the potential substitutes and rank them.

6.1 Reservoir Evaluation

In this section, there are seven steps to analyze the reserves and production. Most methods are inspired by Campbell's oil analysis methods.

1. Past Production

The first step of the analysis is to gather and plot past production. Table *6.1* illustrates an example of past production of Ghawar between 1951-1955. Computed parameters are,

a) Daily average production (Mbpd) during the year in Column B

b) Annual production (MMbbl) in Column C

$$ap = dp * 0.365 \quad [6.1.]$$

Where ap is annual production (MMbbl) and dp is daily production (Mbpd).

c) Cumulative production (MMbbl) in Column D

$$cp_i = cp_{i-1} + ap_i \quad [6.2.]$$

Where cp is cumulative production (MMbbl) and i is the year.

d) Depletion rate (%) in Column E

$$D = \frac{cp}{URR} \quad [6.3.]$$

Where D is depletion rate (%) and URR is "Ultimate Recoverable Reserves" which is estimated in the following step.

e) Remaining Recoverable Reserves (MMbbl) in Column F

$$RRR = URR - cp \qquad [6.4.]$$

Where RRR is "Remaining Recoverable Reserves", the remaining reserves that can be produced.

Table 6.1. *Past Production Sheet Illustration*

Column A	*Column B*	*Column C*	*Column D*	*Column E*	*Column F*
Year	***Production Rate***			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1951	126	46	46	0.04 %	127,154
1952	266	97	143	0.12 %	127,057
1953	405	148	291	0.24 %	126,909
1954	545	199	490	0.40 %	126,710
1955	532	194	684	0.56 %	126,516

2. Study Discovery Trends

The second step is to plot a graph showing annual/cumulative vs. cumulative production (Hubbert Linearization or derivative logistics) and extrapolate it to zero (Campbell, 2013). This trend can be estimated if there is enough past production data to reach URR. For the fields with insufficient past production data, other approaches were used.

3. Estimate Future Production

In this step, as the end of 2018, daily production, URR, cp and RR are already calculated. For the production estimation for the following years, the annual decline rate is necessary. Most of the fields' decline rate is already known and the others are estimated by similar reservoir properties.

$$ap_i = ap_{i-1} * (1 - d) \quad [6.5.]$$

Where d is the annual decline (%) and i is the year.

The annual declines are directly taken from official reports of Saudi Aramco and shown in Table *7.3*.

4. Estimate Future Production from Unexplored Reserves

This step is to estimate the potential unexplored fields and their reserves. Discovery vs. year trend is investigated to draw a future. After that, Höök's approach to production behavior of OPEC giant fields explored after the 2000s were used (Höök, 2008). This approach fits in Saudi Arabia since 96% of the oil produced from giant fields. Production parameters of an unexplored field are illustrated in Table *6.2*.

Table 6.2. *The Behavior of OPEC Giant Fields Explored After 2000* (Höök, 2008)

Depletion at peak	*14.1 %*
Decline rate	-10.2 %
Cum. Prod./ URR at peak	40.6 %
Discovery to First Oil	2.1 years
First Oil to Decline	17.0 years
Plateau	5.0 years

5. Estimate the Future Production from Other Fields

In this step, production of the other fields is forecasted by investigating other fields' production over total production ratio vs. years relation.

6. Potential Production Expansion as Scenario

This step consists the potential developments. If the field's depletion rate at 2049 is less than 90%, the production gap is considered as field development. For development cost analysis, previous developments in Saudi Arabia are considered.

7. Compile the Totals of the Fields

This step concludes the sum of other steps and the possible scenarios.

6.2 Substitutes

The *substitute* is defined as a potential competitor. There are three different elimination criteria to be classified as a substitute. These are sufficient crude oil production, net export capacity and similar crude oil type.

a) Daily production (> 650,000 bpd)

Firstly, the countries eliminated through their daily crude oil production. Countries with less than 650,000 bpd of production volume as May 2019 were eliminated.

b) Crude oil trade balance (net exporter),

Secondly, the crude oil trade balances of these countries were analyzed. From the remained countries according to daily production, the ones with the trade deficits or trade balance with less than 250,000 bpd in crude oil were also eliminated.

c) Crude oil type (Similarity to Arab Light and Arab Medium)

Thirdly, the remaining producers are analyzed by their produced crude oil types. According to production analysis conducted, as of the end of 2018, average API Gravity of produced crude oil of Saudi Arabia was 33.9^{o} (14.0% Arab Extra Light, 58.5% Arab Light, 8.8% Arab Medium and 18.7% Arab Heavy). Therefore, since the light and medium crude is the major part of Saudi Arabia crude oil export market, countries with producing mostly heavy crude oil are eliminated.

After these criteria, remaining countries were classified as a *substitute*. The substitutes were ranked according to various classification methods. These are common market share, competition level, proven reserves, geopolitical risks and production costs. Average results from each criterion were graded as the final grade.

Maximum grade over one criterion is graded as 100 and the minimum as 0.

$$Grade = \frac{Result - MIN}{MAX - MIN} \quad [6.6.]$$

a) Common Market Share

Common market share is defined as the ratio of “Substitute’s total crude oil exported to target markets” to “Total amount of crude oil exported by Saudi Arabia to target markets”.

$$Common\ Market\ Share = \frac{Substitute's\ Crude\ Oil\ Exported\ to\ Target\ Market}{Saudi\ Arabia'\ Crude\ Oil\ Exported\ to\ Target\ Markets} \quad [6.7.]$$

b) Competition Level

If the substitute’s export ratio to Saudi Arabia export ratio for the destined target market is higher than 35%, a substitute is defined as a major competitor for the destination. This criterion shows the competition severity of the substitute.

If $\frac{\text{Substitute export on the target market}}{Saudi\ Arabia's\ export\ on\ target\ market} < 35\%$, no competition [6.8.]

$\frac{\text{Substitute export on the target market}}{Saudi\ Arabia's\ export\ on\ target\ market} > 35\%$, major competition [6.9.]

$$Competition\ level = \sum_{i=1}^{n} c_i * es_i \quad [6.10.]$$

Where $c_i = 1$ if the substitute is a major competition, [6.11.]

$c_i = 0$ if the substitute is not a major competition [6.12.]

Where $es_i = \frac{Saudi\ Arabia\ crude\ oil\ export\ to\ target\ market}{Saudi\ Arabia\ crude\ oil\ export\ in\ total}$ [6.13.]

i is the target markets, where n is equal to ten.

c) Proven reserves

Proven reserves are overviewed by the total reserves to check if the substitute can compete for a long time with Saudi Arabia. Substitutes' reserves are graded over their proven crude oil reserves.

d) Geopolitical Risks

Oil investment including exploration and trade favors stable and developed markets with political stability. The countries with economic stability and a proper regulatory environment, encourage private sector participation. Markets with large and accessible reserves offer the greatest rewards globally for upstream investment. For the classification, BMI's Upstream Oil and Gas Risk/Reward Index was used. The analysis comprises; oil reserves, discovery rate, hydrocarbon production and growth, state asset ownership, competitive landscape, Infrastructure integrity, royalties, income tax, license type, bureaucratic environment, legal environment risk, economic and political risk index, operational risk index.

e) Production Costs

This analysis outlines the average cost to produce one barrel of oil including capital expenditures (CAPEX) and operational expenditures (OPEX). Rystad Energy (2016) and Wall Street Journal (WSJ, 2019) (Rystad Energy, 2019; The Wall Street Journal, 2016) were used as sources to determine the costs.

CHAPTER 7

RESULTS AND DISCUSSIONS

This section presents the results of the analysis conducted within the scope of this thesis. Analysis carried out in accordance with the methodology as described in METHODOLOGY to obtain the results. Detailed results can be found in C.

7.1 Saudi Arabia Crude Oil Production Forecast and Cases

This part represents the production forecast and the potential forecast of Saudi Arabia crude oil production. In this section, 12 major oil fields and the other fields as a whole were analyzed. Results are explained in Royal Family Hierarchy. Then four case is analyzed.

Case 0: Production forecast with existing fields,

Case I: Addition of unexplored fields,

Case II: Addition of field development,

Case III: Addition of both unexplored fields and field development.

7.1.1 Saudi Arabia Crude Oil Production Forecast

As Figure 7.1 suggests, according to derivative logistics analysis (ap/cp vs. cp) URR of Ghawar Field is projected as 127.2 billion bbl. The analysis takes the production data between 1987-2018 and the coefficient of determination is 0.6019. (Highest URR ever suggested was by Powers, with 120 billion bbl.)

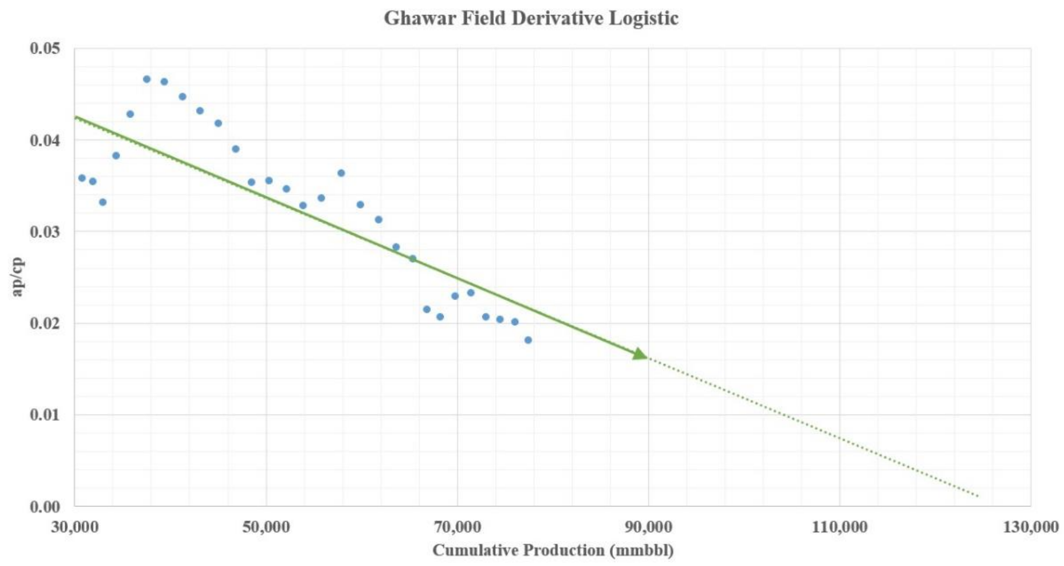

Figure 7.1. Ghawar Hubbert Linearization

Figure 7.2 illustrates the water vs. cumulative production Ghawar Field by using the production and water cut data between 1993-2004. The graph shows that URR estimation is rational since water cut would reach 70% when URR is 127.2 billion bbl which is equal to 2:1 water/oil ratio.

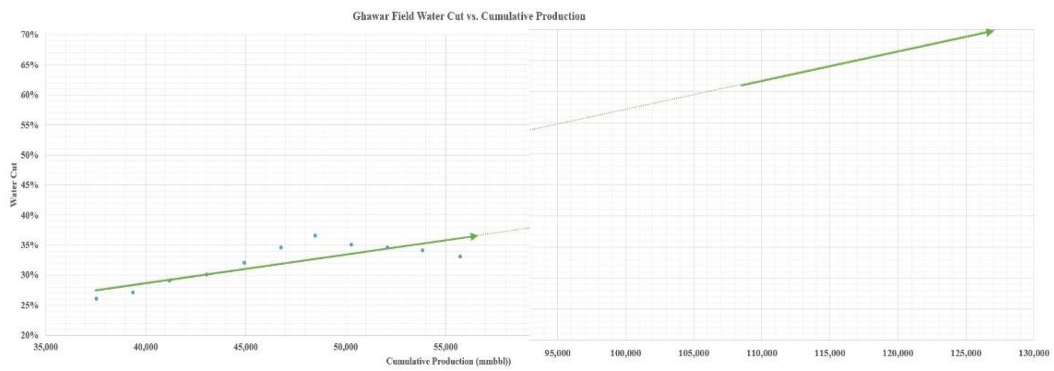

Figure 7.2. Ghawar Water Cut vs. Cumulative Production

Figure 7.3 illustrates the Ain Dar/Shedgum derivative logistics. Cumulative production is 47 billion bbl with 0.854 of the coefficient of determination. The highest limit suggested for the field by official reports was between 40.8-51.0 billion bbl (Baqi & Saleri, 2004).

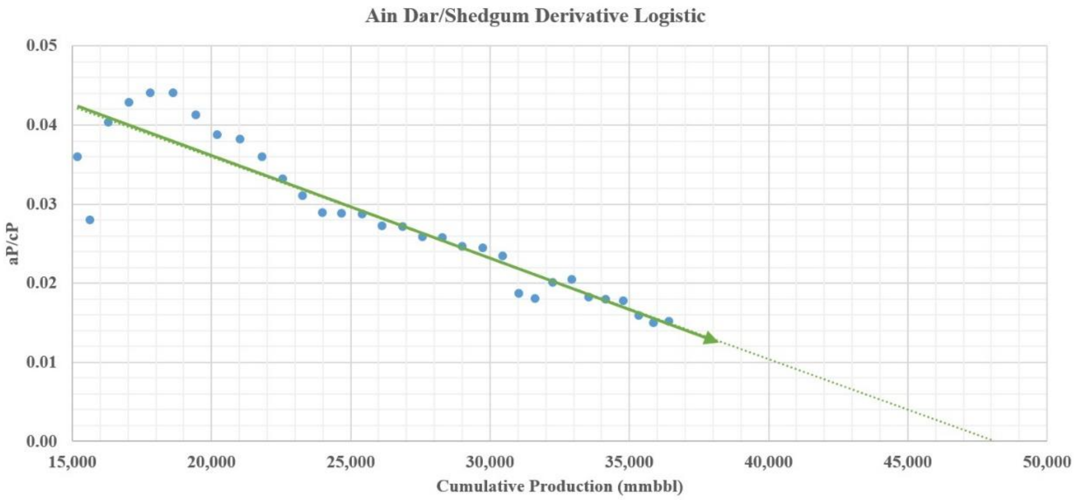

Figure 7.3. Ain Dar/Shedgum Hubbert Linearization

The second biggest sub-part of Ghawar is Uthmaniyah which has 45 billion bbl of URR according to Figure 7.4 while the coefficient of determination is 0.7395 with the production data between 2004-2018. The highest URR suggestion was 43 billion bbl was (Mearns, 2007).

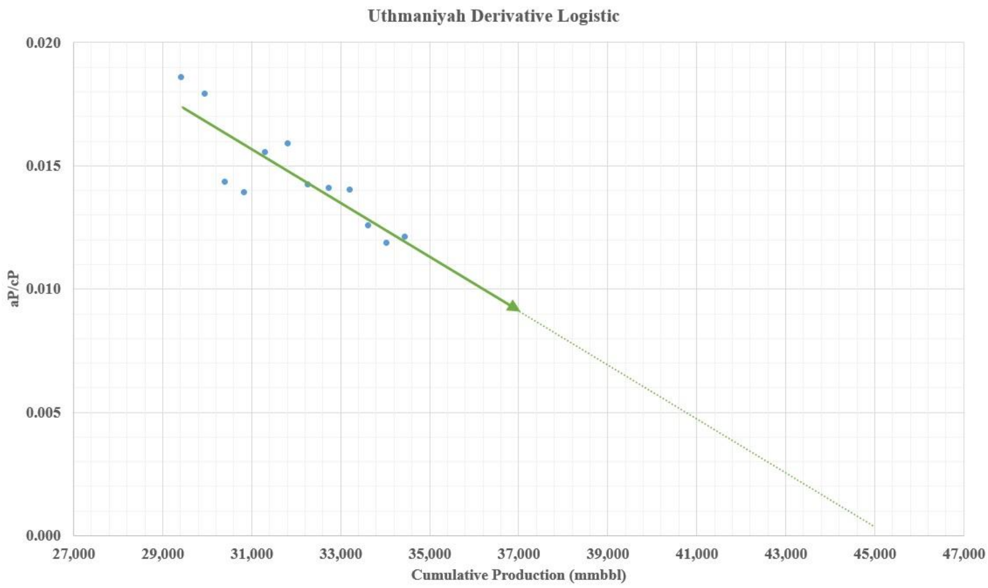

Figure 7.4. Uthmaniyah Hubbert Linearization

The other subparts of Ghawar are Hawiyah and Haradh. There is little information about these two fields. The reason is that both fields have started producing recently.

Major suggestions done for both fields are shown in Table *7.1*. The analysis uses the highest approximations which are verified for Ain Dar/Shedgum and Uthmaniyah. Therefore, URR of Hawiyah and Haradh are 16 and 18 billion bbl respectively. Mearns uses oil saturation map over the years, Staniford additionally uses water oil contact change over the years to estimate the reserves of sub-fields of Ghawar.

Table 7.1. *Sub-Fields of Ghawar*

Approach	*Ain Dar/Shedgum*	*Uthmaniyah*	*Hawiyah*	*Haradh*	*Total*
Staniford	34	34	11	18	97
Mearns (Base)	33	36	14	14	97
Mearns (High)	38	43	16	16	113
Aslanoglu	48	45	16	18	127

To estimate the URR of Abqaiq, the same approach as Ghawar is applied. As Figure 7.5 and Figure 7.6 shows, Hubbert Linearization is analyzed, then it is verified by water cut vs. cumulative production for the estimated total production. URR is estimated as 16.75 billion bbl according to the projection. Water oil ratio is expected to be 2:1 which shows that cumulative production which is considerable.

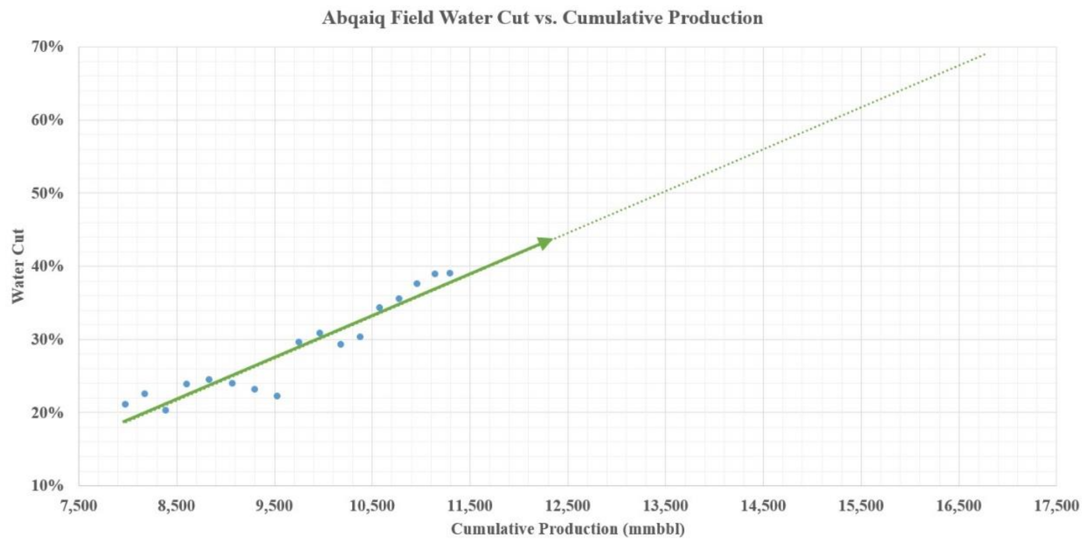

Figure 7.5. Abqaiq Hubbert Linearization

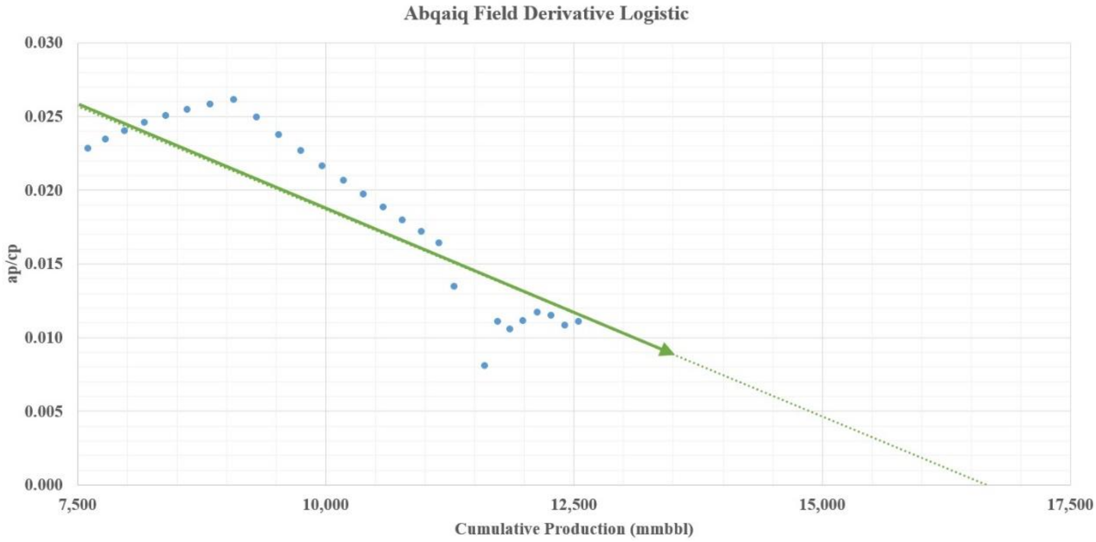

Figure 7.6. Abqaiq Water Cut vs. Cumulative Production

URR of Safaniya Field is estimated by using the production data between 1994-2018 as it is seen in Figure 7.7. Extrapolation shows that total cumulative production could be as high as 49 billion bbl according to derivative logistics. URR is verified by two different ways,

- 2004 production data: Cumulative production by 2004 is 12,045 billion bbl, depletion is 26% equal to 46.3 billion bbl)
- URR is suggested to be as high as 55 billion bbl by experts (Aleklett et al., 2010).

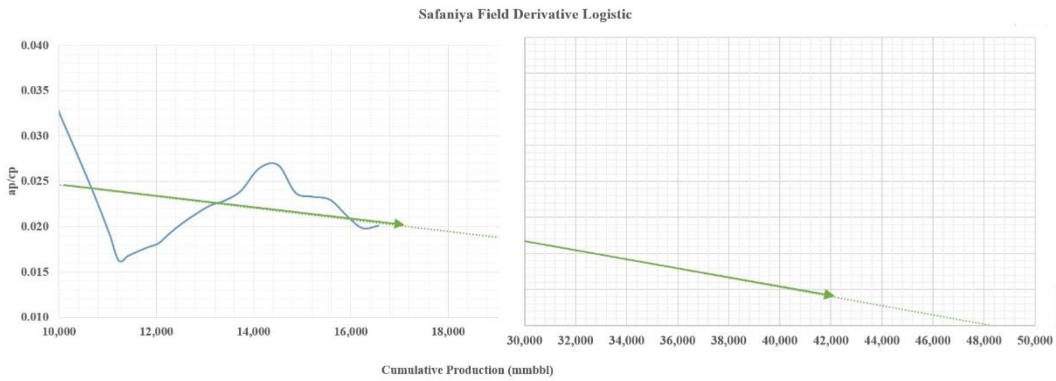

Figure 7.7. Safaniya Hubbert Linearization

Berri Field's URR is estimated to be 10.8 billion bbl according to Hubbert Linearization which is seen in Figure 7.8. This is verified by 2004 production and depletion data as well as other suggestions by experts. (12.4 billion bbl and 12 billion bbl respectively)

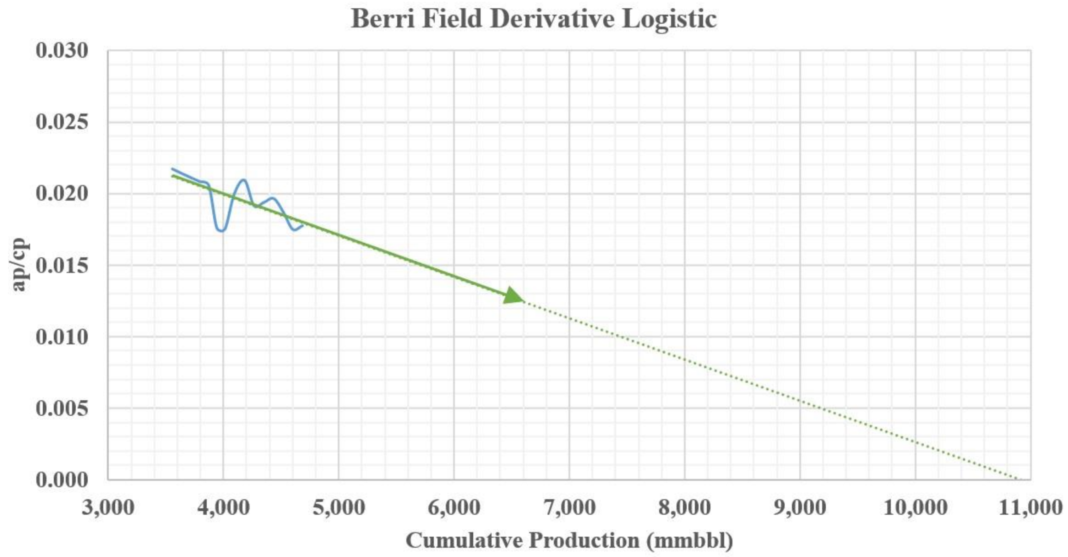

Figure 7.8. Berri Hubbert Linearization

Table *7.2*. shows the URR estimation by using the Eq. 6.3. According to the table, Abu Sa'fah, Marjan, Shaybah and Zuluf have 7.83 billion bbl, 13.48 billion bbl, 19.90 billion bbl and 24.74 billion bbl respectively.

Table 7.2. *URR Estimation by Cumulative Production Data, 1.1.2004*

Field	*Cumulative Production*	*Depletion Rate*	*URR*
Abu Sa'fah	1.64 billion bbl	21 %	7.83 billion bbl
Marjan	1.75 billion bbl	13 %	13.48 billion bbl
Shaybah	1.00 billion bbl	5 %	19.90 billion bbl
Zuluf	3.96 billion bbl	16 %	24.70 billion bbl

Two of the fields; Manifa and Qatif Fields' productions till 2018 and depletion levels are quite low comparing the URR suggestions by the experts. Therefore, the lowest value is considered. URR of Manifa and Qatif are 17.0 billion bbl and 8.4 billion bbl respectively.

Production data of Khurais and Khursaniyah are very few that it is difficult estimate for the potential cumulative production. Therefore, the URR value is taken from the reliable sources. Khurais' URR is 28.8 billion bbl according to estimation of OIP 38 billion bbl and expected recovery is 60% considering the reservoir properties of the field (Powers, 2012). Khursaniyah is a small field comparing the others, then the field is the sum of three fields; Khursaniyah, Abu Hadriya and Fadhili which is 7.14 billion bbl in total.

Future production from the other fields is forecasted by using the other fields' ratio over total production during the years. Figure 7.9 illustrates the trend, where the ratio is 5.8 % as 2018 and the next 30 years is projected by using the trend over total production. Largest production is from Nuayyim Field. The crude is Arab Light with 50^{o} API and low (0.02%) in sulfur content. Therefore, another crude type is considered as Arab Light because of the large share of Nuayyim.

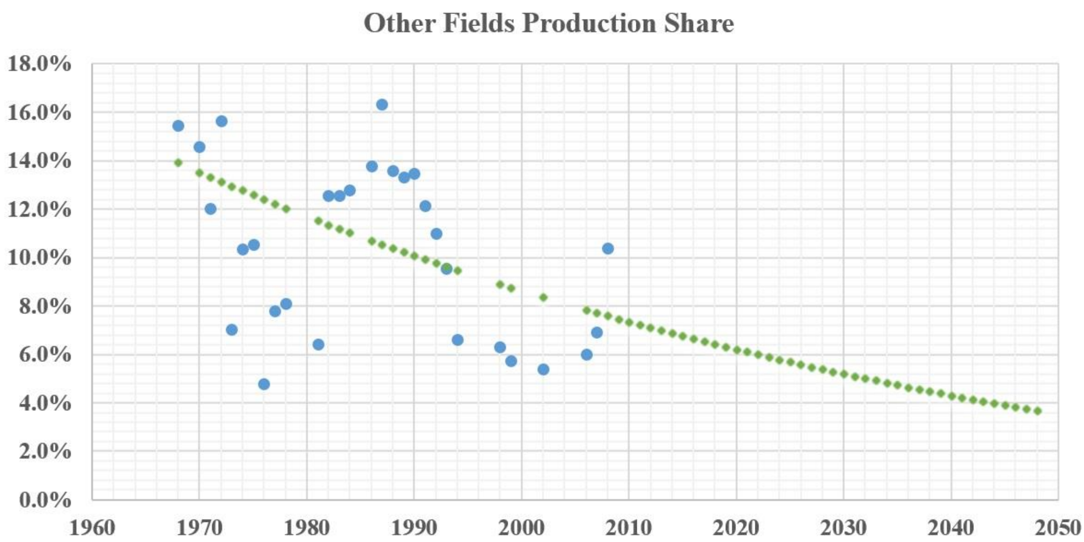

Figure 7.9. Other Fields' Production Ratio Over Total Production

Table *7.3*. shows the production and reservoir properties of the major 12 fields and other fields. So far expected RRR is 208.7 billion bbl where Reserve/Production ratio is 57.1 years.

Table 7.3. *Production Properties of 12 Major Oil Fields, as of 1.1.2019*

Field	*URR (MMbbl)*	*RRR (MMbbl*	*Annual Decline*	*Production (Mbpd)*	
				Peak	2019
Ghawar	127,200	47,055	2.0 %	5,772	4,050
Abqaiq	16,750	3,923	2.8 %	1,094	405
Safaniya	49,000	32,436	1.5 %	1,544	972
Abu Sa'fah	7,800	4,737	1.0 %	300	243
Berri	10,800	6,114	4.1 %	807	243
Khurais	22,800	18,894	2.2 %	1,500	1,272
Khursaniyah	7,140	3,623	4.1 %	467	426
Manifa	17,000	14,965	1.5%	900	900
Marjan	13,400	10,344	1.5%	400	365
Qatif	8,400	5,849	1.0%	444	405
Shaybah	19,900	15,502	1.0%	900	810
Zuluf	24,700	18,439	1.8%	658	551
Others	39,100	26,834			710

7.1.2 Scenarios

As mentioned before, crude oil production forecast is analyzed over four different scenarios. These are; Case 0, Case I, Case II and Case III.

Case 0 is the production forecast over existing conditions of the field. This case consists of no field development or oil exploration activity. Therefore, the total expenditure is zero for the case.

Case I considers the existing production and the additions from undiscovered fields. Average exploration expenditure per year of Saudi Aramco is $600 million (Whitley

& Shakuntala, 2014). Assuming that the producible reserve discovery trend between 1948-2018 (Figure 7.10) applies the same for the future and field production behavior is considered as Höök's model (Table 6.2), 16.61 billion bbl production is expected to be added to cumulative production. Total exploration cost for 30 years would be $ 24.34 billion where the unit cost is $1.47/bbl.

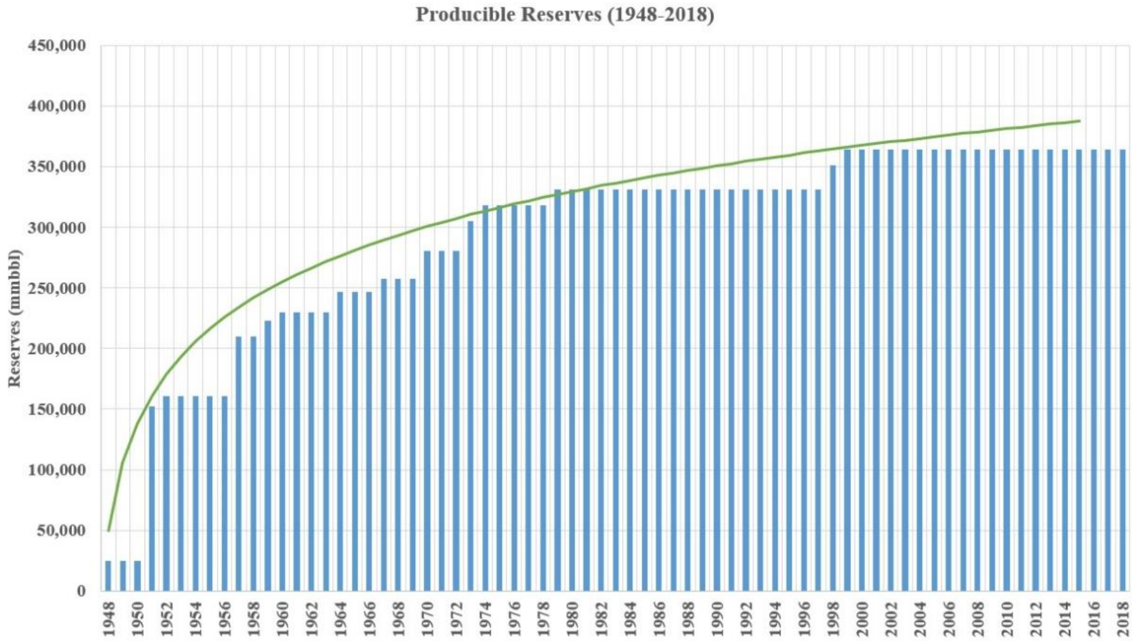

Figure 7.10. Model for Undiscovered Fields

Case II is the case that field development is considered. Recent development costs are taken as reference (Jaffe & Elass, 2007). According to this scenario, total field development would cost $72.1 billion in return of totally 48.07 billion bbl production (Table 7.4). Cost per additional bbl production is equal to $1.50/bbl in this case. (Annual inflation for the following years is considered as 2% as per OECD's projection.)

Table 7.4. *Case II (Field Development Scenarios)*

Field	*Year*	*Expansion (Mbpd)*	*Cost ($ billion)*
Hawiyah	2023	620	6.84
Haradh	2023	651	7.19
Safaniya	2023	900	7.73
Safaniya	2028	900	8.53
Safaniya	2033	900	9.31
Abu Sa'fah	2023	196	1.34
Berri	2023	590	4.01
Marjan	2023	397	3.41
Manifa	2023	397	3.41
Qatif	2023	138	0.94
Shaybah	2023	693	7.65
Zuluf	2023	650	5.59
Zuluf	2028	650	6.17

Case III considers both discoveries and field developments. As can be seen in Table *7.5*, totally 64.68 billion bbl crude oil could be added to future production if $96.35 billion is invested.

Table 7.5. *Cases Overview*

Case I cost	Case II cost	Case III cost
16,614 MMbbl	48,066 MMbbl	64,680 MMbbl
$24.34 billion	$72.11 billion	$96.35 billion
$1.47/bbl	$1.50/bbl	$1.49/bbl

Figure 7.11 shows the future production for the cases. Without any development or exploration production is expected to decrease below six mbpd in 2045. The case I could maintain the crude oil production above ten mbpd until 2040, and 8.5 MMbpd until 2048. Saudi Arabia is expected to produce over 15 MMbpd in 2023 if necessary

steps are taken to develop the fields. Both exploration and field developments could carry the production to the peak of 16.5 MMbpd in 2029.

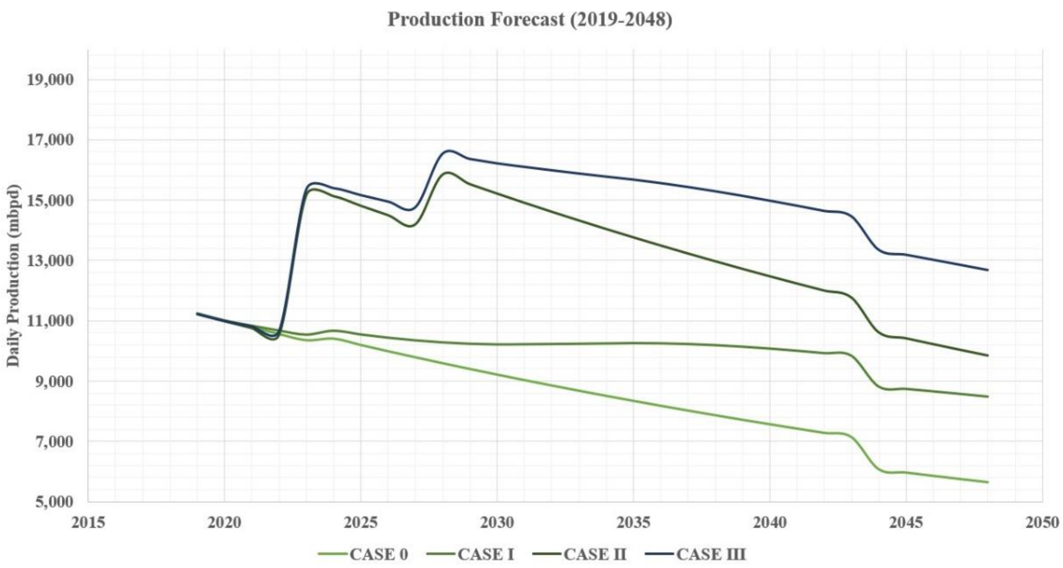

Figure 7.11. Production Forecast Scenarios for Different Cases

7.2 Potential Substitutes and Scenarios

As Table *7.6* shows by following the Methodology of Substitutes section, 15 of the largest 27 producers are qualified as potential substitutes. Firstly, Malaysia, Ecuador and Egypt eliminated because of their relatively lower production. Secondly, producers as the US, China, UK, Indonesia and India are eliminated for their crude trade deficits. Thirdly, Canada and the major Latin American producers as Brazil, Venezuela and Colombia are eliminated because all these countries produce mostly heavy crude oil.

Therefore, potential substitutes are listed as Russia, Iraq, UAE, Iran, Kuwait, Mexico, Nigeria, Angola, Norway, Kazakhstan, Libya, Algeria, Oman, Azerbaijan and Qatar. These countries qualified and referred to as the *substitute*.

Table 7.6. *Substitutes Elimination*

Country	Production (Mbpd)	Trade Balance (Mbpd)	Crude Type
Russia	10,598	5,081	Light
Iraq	4,724	3,804	Light
UAE	3,061	520	Light
Kuwait	2,710	2,128	Light
IR Iran	2,370	1,922	Medium
Nigeria	1,733	1,738	Light
Mexico	1,709	1,274	Medium
Angola	1,471	1,670	Light
Norway	1,403	1,373	Light
Kazakhstan	1,356	1,386	Light
Libya	1,174	1,000	Light
Algeria	1,029	668	Light
Oman	1,000	888	Light
Azerbaijan	708	655	Light
Qatar	615	503	Light
Canada	3,496	1,851	Heavy Crude
Brazil	2,607	757	Heavy Crude
Venezuela	741	1,835	Heavy Crude
Colombia	852	614	Heavy Crude
US	12,200	-7,357	
China	3,906	-7,567	
UK	1,033	-179	
Indonesia	704	-32	
India	684	-4,308	
Egypt	631	91	
Malaysia	617	166	
Ecuador	529		

According to the methodology defined in Chapter 6.2 for substitute ranking, four different criteria are considered. These I: common market share, II: competition level, III: proven reserves, IV: geopolitical risks and V: production costs.

As Table *7.7* illustrates UAE has the largest common market with Saudi Arabia. Then they are was followed by Iraq, Kuwait and Russia. Iran is the fifth country which is affected by recent sanctions. In the second criterion, Iraq was the largest competitor of Saudi Arabia in target markets with a big difference. Then, Russia, Iran, UAE and Angola were in the first five. When it comes to proven reserves, the criterion III, Iran is in the top of the ranking with 155.6 billion bbl crude oil reserve amongst the substitutes. Iraq is just behind Iran with 147.2 billion bbl reserve. These two countries are followed by Kuwait, UAE and Russia. according to their proven reserves. On the other analyze, Norway is the best country to invest if risk and reward analysis is considered. Russia, Azerbaijan, UAE and Qatar the other countries in top regarding the geopolitical risks. Considering the last criterion Kuwait has the least production costs with $8.5/bbl while the country is followed by Iraq, UAE, Iran, Qatar and Oman respectively which shows that consisting the substitutes Middle Eastern producers have the lowest production costs.

Table 7.7. *Substitutes Ranking*

Country	Criteria					Criteria					**Total**
	I	II	III	IV	V	I	II	III	IV	V	
Iraq	33.8%	42.5%	147.2	51.1	10.7	81.5	100	94.4	39.2	92.0	**81.4**
UAE	41.0%	23.2%	97.8	60.9	12.3	100	52.5	61.5	67.0	86.2	**73.5**
Iran	18.0%	23.5%	155.6	49.3	12.6	40.7	53.3	100	34.1	85.1	**62.7**
Russia	25.6%	23.8%	80.0	62.7	17.3	60.4	54.1	49.7	72.2	68.1	**60.9**
Kuwait	25.9%	9.8%	101.5	51.3	8.5	61.1	19.5	64.0	39.8	100	**56.9**
Qatar	15.4%	3.7%	25.2	59.9	15.0	34.0	4.5	13.2	64.2	76.5	**38.5**
Oman	8.5%	10.1%	5.4	52.0	15.0	16.2	20.2	0.0	41.8	76.5	**30.9**
Nigeria	15.2%	13.2%	37.5	55.9	31.5	33.6	28.0	21.4	52.8	16.7	**30.5**
Azerbaijan	5.0%	4.2%	7.0	61.3	20.2	7.2	5.8	1.1	68.2	57.6	**28.0**
Kazakhstan	4.9%	5.3%	30.0	59.1	27.8	7.0	8.5	16.4	61.9	30.7	**24.9**
Mexico	11.9%	11.9%	6.5	52.6	29.0	25.1	24.8	0.8	43.5	25.7	**24.0**
Angola	16.6%	17.7%	8.4	50.4	35.4	37.0	39.0	2.0	37.2	2.5	**23.6**
Algeria	3.1%	1.8%	12.2	52.4	20.4	2.2	0.0	4.5	42.9	56.9	**21.3**
Norway	2.2%	2.5%	6.4	72.5	36.1	0.0	1.7	0.7	100	0.0	**20.5**
Libya	10.5%	4.8%	48.4	37.3	23.8	21.4	7.3	28.6	0.0	44.6	**20.4**

When all these criteria are considered Iraq is the first substitute of Saudi Arabian crude oil with total points of 81.4. Country performed well in all criteria except geopolitical risks. Iraq has been suffering from the regional conflict as Syrian War. But still, Iraq seems like the best replacement. UAE is second in the ranking with 73.5 points. The Emirates have the most common market and low production costs with moderate scores in the other criteria. Therefore, takes the second place as a favorable contender. These countries are followed by Iran and Russia respectively with 62.7 and 60.9 points. Iran is in the top three even though their exports have decreased to target markets because of the recent sanctions. Russia is above average in all the criterion. The federation has a strong position in the crude oil production market. Kuwait is the fifth candidate for replacing the Saudi Arabian crude oil. The disadvantage of the country is the low amount of competition in target markets and risky environment.

Also, Qatar, Oman and Nigeria compose threat to share of Saudi Arabian crude oil in the market even though they cannot fully replace. Azerbaijan, Kazakhstan, Mexico, Angola, Algeria, Norway and Libya are ranked respectively according to their total points.

According to the results, in the scenario that Iran's total crude export to target markets are doubled (the peak point of recent five years) which is possible if production is increased by developments and sanctions are lifted. Iran's overall score point becomes 81.3 and shares the top spot with Iraq.

Table 7.8. *The Case that Iran's Export is Doubled*

Country	*Criteria*					*Criteria*					
	I	II	III	IV	V	I	II	III	IV	V	**Total**
Iraq	33.8%	42.5%	147.2	51.1	10.7	81.5	100	94.4	39.2	92.0	**81.4**
Iran	36.0%	47.1%	156	49.3	12.6	87	100	100	34	85.14	**81.3**
UAE	41.0%	23.2%	97.8	60.9	12.3	100	52.5	61.5	67.0	86.2	**73.5**

In the second scenario, if Russia increases its export to 477 Mbpd from 191 Mbpd to Japan, 305 Mbpd from 225 Mbpd to South Korea and 259 Mbpd from 62 Mbpd to India. Russia's possibility of replacing Saudi Arabian crude oil increases that total score becomes 76.6 as Russia spots the second place. Berument suggests that India's crude oil import from Russia is expected to increase between 92,500 bpd to 405,000 bpd where Kanal Istanbul is expectedly increasing the trade towards India (Berument et al., 2018). Crude export to Japan and South Korea is via the port of Kozmino, De Kastri and Sakhalin Island. The trade volume could be expanded If oil pipeline capacity or volume of Arctic trade route are expanded.

In such scenario, Russia crude oil export volume could increase to,

- Japan 191 Mbpd to 477 Mbpd,
- South Korea 225 Mbpd to 305 Mbpd,
- India 62 Mbpd to 259 Mbpd.

Table 7.9. *The Case that Russia Influences More on Asian Markets*

Country	*Criteria*					*Criteria*					**Total**
	I	II	III	IV	V	I	II	III	IV	V	
Iraq	33.8%	42.5%	147.2	51.1	10.7	81.5	100	94.4	39.2	92.0	**81.4**
Russia	**39.3%**	**41.4%**	80	62.7	17.3	**95.7**	**97.2**	49.7	72.2	68.1	**76.6**
UAE	41.0%	23.2%	97.8	60.9	12.3	100	52.5	61.5	67.0	86.2	**73.5**

The neighbor countries, Qatar and Oman are weak in the common trade market. Nigeria, Angola and Mexico are suffering from high exploration and production costs. Caspian countries Azerbaijan and Kazakhstan are remote from target markets. While Norway provides a healthy investment environment for oil investors, export options and proven reserves are limited. Also, Libya needs to lower the geopolitical tensions in the region.

CHAPTER 8

CONCLUSIONS

- Largest conventional crude oil field, Ghawar and the offshore field Safaniya have totally 47 and 32 billion bbl remaining recoverable reserves respectively while Saudi Arabia has still 208.7 billion bbl crude oil to be produced.
- The mature oil fields of the kingdom, Ain Dar/Shedgum, Uthmaniyah and Abqaiq are close to depletion.
- Production trend shows that unless production is not enhanced, total crude oil production volume could decrease to 9.1 MMbpd by 2030 and 5.65 MMbpd by 2048.
- Saudi Arabia has a few options to increase the total crude oil production. First is to focus on oil exploration which will be expected to cost $24.34 billion for the next 30 years. Possible outcome is 16.16 billion bbl production increase with a $1.47/bbl investment. This would protect the production over 10 MMbpd limit until 2043.
- Second option is to develop the existing fields. If the target is to reach 15 MMbpd, this is the only possible scenario. Production could reach 15 MMbpd by 2023 with $48.10 billion investment starting from now until 2023. To keep the production in this level another $24.01 billion field development is necessary by 2033. This scenario would keep the production over 10.0 MMbpd by 2048 with a $1.50/bbl extra production cost.
- If the aim is to keep 15 MMbpd production till 2040 and 12.5 MMbpd to 2048, the total expenditure of $96.35 billion is necessary for exploration and development costs. This investment would add $1.49/bbl to current costs.

- As a substitute, Iraq could be a perfect replacement for Saudi Arabia if regional peace is constituted. UAE is another substitute which is behind Iraq.
- Iran needs field development to increase its production and exports. Also, if the sanctions are lifted, the country would be a great substitute as Iraq.
- Russia needs to increase its export capacity on the ports in the east as well as Novorossiysk to get involved more in Asian markets.
- Kuwait is another country which needs to influence more in Asian markets.

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APPENDICES

A.WORLD FACTS

Table A.1. *1967-1975 Crude Oil Production, Mbpd*

	1967	1968	1969	1970	1971	1972	1973	1974	1975
S. Arabia	2,805	3,043	3,216	3,799	4,769	6,016	7,596	8,480	7,075
M. East	10,055	11,275	12,461	13,779	16,164	17,942	21,053	21,705	19,438
OPEC	16,353	18,197	20,204	22,643	24,544	26,153	29,802	29,523	26,011
World	35,377	38,351	41,680	45,198	47,901	50,396	55,033	55,416	52,749

Table A.2. *1976-1984 Crude Oil Production, Mbpd*

	1976	1977	1978	1979	1980	1981	1982	1983	1984
S. Arabia	8,577	9,200	8,301	9,533	9,901	9,808	6,483	4,539	4,079
M. East	22,047	22,223	21,123	21,569	18,345	15,556	12,930	11,150	10,518
OPEC	29,369	29,745	28,336	29,475	25,454	21,079	17,889	15,941	15,273
World	57,191	59,581	59,954	62,464	59,395	55,676	53,285	52,118	52,698

Table A.3. *1985-1992 Crude Oil Production, Mbpd*

	1985	1986	1987	1988	1989	1990	1991	1992
S. Arabia	3,175	4,784	3,975	5,100	5,065	6,413	8,118	8,332
M. East	9,725	12,103	11,920	14,150	15,134	16,077	15,892	17,563
OPEC	14,423	17,107	16,276	18,590	20,111	21,756	21,901	23,659
World	52,285	55,111	54,635	56,910	57,804	59,106	58,702	59,323

Table A.4. *1993-2001 Crude Oil Production, Mbpd*

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001
US	6,847	6,662	6,560	6,465	6,452	6,252	5,881	5,822	5,801
Russia	6,911	6,184	6,034	5,862	5,956	5,886	5,906	6,246	6,727
S. Arabia	8,048	8,049	8,023	8,102	8,012	8,280	7,565	8,095	7,889
Iraq	659	749	737	740	1,384	2,181	2,720	2,810	2,594
China	2,924	2,942	2,996	3,173	3,254	3,207	3,212	3,228	3,297
Canada	1,296	1,351	1,380	1,401	1,414	1,428	1,346	1,392	1,377
UAE	2,159	2,167	2,148	2,161	2,161	2,244	2,049	2,175	2,115
Kuwait	1,882	2,007	2,007	2,006	2,007	2,052	1,873	1,996	1,947
IR Iran	3,425	3,596	3,595	3,596	3,603	3,714	3,439	3,661	3,572
Brazil	643	668	693	784	842	975	1,098	1,231	1,293
M. East	18,265	18,809	18,856	19,012	19,604	21,116	20,283	21,410	20,777
OPEC	24,060	24,498	24,612	24,877	25,616	27,931	26,369	27,999	27,234
World	59,123	59,861	60,445	61,565	62,932	65,141	63,233	65,825	65,406

Table A.5. *2002-2010 Crude Oil Production, Mbpd*

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010
US	5,744	5,649	5,441	5,184	5,086	5,074	4,998	5,349	5,475
Russia	7,402	8,122	8,803	9,045	9,242	9,437	9,356	9,493	9,694
S. Arabia	7,093	8,410	8,897	9,353	9,208	8,816	9,198	8,184	8,166
Iraq	2,126	1,378	2,107	1,853	1,957	2,035	2,281	2,336	2,358
China	3,393	3,407	3,485	3,617	3,674	3,736	3,802	3,795	4,076
Canada	1,446	1,459	1,405	1,360	1,346	1,388	1,349	1,217	1,227
UAE	1,900	2,248	2,344	2,378	2,568	2,529	2,572	2,242	2,324
Kuwait	1,746	2,108	2,289	2,573	2,665	2,575	2,676	2,262	2,312
IR Iran	3,248	3,742	3,834	4,092	4,073	4,031	4,056	3,557	3,544
Brazil	1,454	1,496	1,477	1,634	1,723	1,748	1,812	1,950	2,055
M. East	18,618	20,408	21,981	22,722	22,901	22,362	23,142	20,869	21,031
OPEC	24,932	27,544	30,568	31,812	32,076	31,655	32,598	29,406	29,720
World	64,012	67,192	70,504	71,422	71,517	71,157	71,661	68,753	69,635

Table A.6. *2011-2018 Crude Oil Production, Mbpd*

Country	2011	2012	2013	2014	2015	2016	2017	2018
US	5,643	6,497	7,466	8,753	9,408	8,857	9,355	11,658
Russia	9,787	9,953	10,047	10,088	10,111	10,292	10,349	10,736
Saudi Arabia	9,311	9,763	9,637	9,713	10,193	10,460	9,959	10,643
Iraq	2,653	2,942	2,980	3,110	3,504	4,648	4,469	4,465
China	4,052	4,074	4,164	4,208	4,289	3,983	3,823	3,770
Canada	1,261	1,309	1,382	1,400	1,263	1,186	1,212	3,520
UAE	2,564	2,653	2,797	2,794	2,989	3,088	2,967	3,223
Kuwait	2,659	2,978	2,925	2,867	2,859	2,954	2,704	2,802
IR Iran	3,576	3,740	3,575	3,117	3,152	3,651	3,867	2,758
Brazil	2,105	2,061	2,024	2,255	2,437	2,510	2,622	2,670
Middle East	23,005	24,107	23,845	23,511	24,494	26,608	25,693	
OPEC	30,589	32,896	32,027	31,094	32,024	33,441	32,515	
World	70,214	72,677	72,803	73,364	75,095	75,388	74,687	

B.SAUDI ARABIA CRUDE OIL PRODUCTION HISTORY

Table B.1. *Ghawar Water Cut*

Year	*Production*			*Water Cut*
	Daily (Mbpd)	*Annual (MMbbl)*	*Cumulative (MMbbl)*	
1993	4,800	1,752	37,557	26%
1994	5,000	1,825	39,382	27%
1995	5,050	1,843	41,225	29%
1996	5,100	1,862	43,087	30%
1997	5,150	1,880	44,967	32%
1998	5,000	1,825	46,792	35%
1999	4,700	1,716	48,507	37%
2000	4,900	1,789	50,296	35%
2001	4,950	1,807	52,102	35%
2002	4,850	1,770	53,873	34%
2003	5,150	1,880	55,752	33%

Table B.2. *Abqaiq Water Cut*

Year	Production			Water Cut
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)	
1989	525	192	7,981	21%
1990	550	201	8,182	23%
1991	575	210	8,392	20%
1992	600	219	8,611	24%
1993	625	228	8,839	24%
1994	650	237	9,076	24%
1995	635	232	9,308	23%
1996	620	226	9,535	22%
1997	605	221	9,755	30%
1998	590	215	9,971	31%
1999	575	210	10,181	29%
2000	560	204	10,385	30%

Table B.2. *Continued*

2001	545	199	10,584	34%
2002	530	193	10,777	36%
2003	515	188	10,965	38%
2004	500	183	11,148	39%
2005	442	161	11,309	39%

Table B.3. *Ghawar Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1951	126	46	46	0%	127,154	100%
1952	266	97	143	0%	127,057	68%
1953	405	148	291	0%	126,909	51%
1954	545	199	490	0%	126,710	41%
1955	532	194	684	1%	126,516	28%
1956	519	189	873	1%	126,327	22%
1957	506	185	1,058	1%	126,142	17%
1958	580	212	1,270	1%	125,930	17%
1959	653	238	1,508	1%	125,692	16%
1960	727	265	1,774	1%	125,426	15%
1961	745	272	2,045	2%	125,155	13%
1962	762	278	2,324	2%	124,876	12%
1963	780	285	2,608	2%	124,592	11%
1964	843	308	2,916	2%	124,284	11%
1965	906	331	3,247	3%	123,953	10%
1966	921	336	3,583	3%	123,617	9%
1967	1,090	398	3,981	3%	123,219	10%
1968	1,258	459	4,440	3%	122,760	10%
1969	1,427	521	4,961	4%	122,239	10%
1970	1,500	548	5,508	4%	121,692	10%
1971	2,084	761	6,269	5%	120,931	12%

Table B.3. *Continued*

1972	2,668	974	7,243	6%	119,957	13%
1973	3,841	1,402	8,645	7%	118,555	16%
1974	4,453	1,625	10,270	8%	116,930	16%
1975	4,205	1,535	11,805	9%	115,395	13%
1976	5,189	1,894	13,699	11%	113,501	14%
1977	5,287	1,930	15,629	12%	111,571	12%
1978	5,300	1,935	17,563	14%	109,637	11%
1979	5,431	1,982	19,546	15%	107,654	10%
1980	5,563	2,030	21,576	17%	105,624	9%
1981	5,694	2,078	23,654	19%	103,546	9%
1982	3,300	1,205	24,859	20%	102,341	5%
1983	3,390	1,237	26,096	21%	101,104	5%
1984	3,480	1,270	27,366	22%	99,834	5%
1985	1,100	402	27,768	22%	99,432	1%
1986	3,000	1,095	28,863	23%	98,337	4%
1987	2,100	767	29,629	23%	97,571	3%
1988	3,020	1,102	30,732	24%	96,468	4%
1989	3,100	1,132	31,863	25%	95,337	4%
1990	3,000	1,095	32,958	26%	94,242	3%
1991	3,600	1,314	34,272	27%	92,928	4%
1992	4,200	1,533	35,805	28%	91,395	4%
1993	4,800	1,752	37,557	30%	89,643	5%
1994	5,000	1,825	39,382	31%	87,818	5%
1995	5,050	1,843	41,225	32%	85,975	4%
1996	5,100	1,862	43,087	34%	84,113	4%
1997	5,150	1,880	44,967	35%	82,233	4%
1998	5,000	1,825	46,792	37%	80,408	4%
1999	4,700	1,716	48,507	38%	78,693	4%
2000	4,900	1,789	50,296	40%	76,904	4%
2001	4,950	1,807	52,102	41%	75,098	3%
2002	4,850	1,770	53,873	42%	73,327	3%
2003	5,150	1,880	55,752	44%	71,448	3%

Table B.3. *Continued*

2004	5,772	2,107	57,859	45%	69,341	4%
2005	5,400	1,971	59,830	47%	67,370	3%
2006	5,292	1,932	61,762	49%	65,438	3%
2007	4,936	1,802	63,563	50%	63,637	3%
2008	4,838	1,766	65,329	51%	61,871	3%
2009	3,934	1,436	66,765	52%	60,435	2%
2010	3,870	1,412	68,178	54%	59,022	2%
2011	4,384	1,600	69,778	55%	57,422	2%
2012	4,562	1,665	71,443	56%	55,757	2%
2013	4,142	1,512	72,955	57%	54,245	2%
2014	4,162	1,519	74,474	59%	52,726	2%
2015	4,199	1,533	76,007	60%	51,193	2%
2016	3,860	1,409	77,415	61%	49,785	2%
2017	3,679	1,343	78,758	62%	48,442	2%
2018	3,801	1,387	80,145	63%	47,055	2%

Table B.4. *Ain Dar/Shedgum Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1951	100	37	37	0%	47,964	100%
1952	200	73	110	0%	47,891	67%
1953	300	110	219	0%	47,781	50%
1954	400	146	365	1%	47,635	40%
1955	450	164	529	1%	47,471	31%
1956	450	164	694	1%	47,307	24%
1957	450	164	858	2%	47,142	19%
1958	450	164	1,022	2%	46,978	16%
1959	450	164	1,186	2%	46,814	14%
1960	450	164	1,351	3%	46,650	12%
1961	450	164	1,515	3%	46,485	11%

Table B.4. *Continued*

1962	450	164	1,679	3%	46,321	10%
1963	450	164	1,843	4%	46,157	9%
1964	500	183	2,026	4%	45,974	9%
1965	500	183	2,208	5%	45,792	8%
1966	500	183	2,391	5%	45,609	8%
1967	510	186	2,577	5%	45,423	7%
1968	780	285	2,862	6%	45,138	10%
1969	970	354	3,216	7%	44,784	11%
1970	1,070	391	3,606	8%	44,394	11%
1971	1,175	429	4,035	8%	43,965	11%
1972	1,400	511	4,546	9%	43,454	11%
1973	2,000	730	5,276	11%	42,724	14%
1974	2,200	803	6,079	13%	41,921	13%
1975	2,250	821	6,900	14%	41,100	12%
1976	2,200	803	7,703	16%	40,297	10%
1977	2,600	949	8,652	18%	39,348	11%
1978	2,500	913	9,565	20%	38,435	10%
1979	2,200	803	10,368	22%	37,632	8%
1980	2,600	949	11,317	24%	36,683	8%
1981	2,450	894	12,211	25%	35,789	7%
1982	2,250	821	13,032	27%	34,968	6%
1983	1,500	548	13,580	28%	34,420	4%
1984	1,080	394	13,974	29%	34,026	3%
1985	1,050	383	14,357	30%	33,643	3%
1986	800	292	14,649	31%	33,351	2%
1987	1,500	548	15,197	32%	32,803	4%
1988	1,200	438	15,635	33%	32,365	3%
1989	1,800	657	16,292	34%	31,708	4%
1990	2,000	730	17,022	35%	30,978	4%
1991	2,150	785	17,807	37%	30,193	4%
1992	2,250	821	18,628	39%	29,372	4%
1993	2,200	803	19,431	40%	28,569	4%

Table B.4. *Continued*

1994	2,150	785	20,216	42%	27,784	4%
1995	2,200	803	21,019	44%	26,981	4%
1996	2,150	785	21,803	45%	26,197	4%
1997	2,050	748	22,552	47%	25,448	3%
1998	1,980	723	23,274	48%	24,726	3%
1999	1,900	694	23,968	50%	24,032	3%
2000	1,950	712	24,679	51%	23,321	3%
2001	2,000	730	25,409	53%	22,591	3%
2002	1,950	712	26,121	54%	21,879	3%
2003	2,000	730	26,851	56%	21,149	3%
2004	1,956	714	27,565	57%	20,435	3%
2005	2,000	730	28,295	59%	19,705	3%
2006	1,960	715	29,011	60%	18,989	2%
2007	1,998	729	29,740	62%	18,260	2%
2008	1,958	715	30,454	63%	17,546	2%
2009	1,592	581	31,035	65%	16,965	2%
2010	1,566	572	31,607	66%	16,393	2%
2011	1,774	648	32,254	67%	15,746	2%
2012	1,846	674	32,928	69%	15,072	2%
2013	1,676	612	33,540	70%	14,460	2%
2014	1,684	615	34,155	71%	13,845	2%
2015	1,699	620	34,775	72%	13,225	2%
2016	1,544	563	35,339	74%	12,661	2%
2017	1,472	537	35,876	75%	12,124	1%
2018	1,520	555	36,431	76%	11,569	2%

Table B.5. *Uthmaniyah Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
2004		0	27,300	61%	17,700	
2005	2,200	803	28,103	62%	16,897	3%
2006	2,156	787	28,890	64%	16,110	3%
2007	1,498	547	29,437	65%	15,563	2%
2008	1,468	536	29,973	67%	15,027	2%
2009	1,194	436	30,409	68%	14,591	1%
2010	1,175	429	30,837	69%	14,163	1%
2011	1,331	486	31,323	70%	13,677	2%
2012	1,384	505	31,828	71%	13,172	2%
2013	1,257	459	32,287	72%	12,713	1%
2014	1,263	461	32,748	73%	12,252	1%
2015	1,274	465	33,213	74%	11,787	1%
2016	1,158	423	33,636	75%	11,364	1%
2017	1,104	403	34,039	76%	10,961	1%
2018	1,140	416	34,455	77%	10,545	1%

Table B.6. *Hawiyah Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2004		0	3,000	19%	13,200
2005	600	219	3,219	20%	12,981
2006	588	215	3,434	21%	12,766
2007	576	210	3,644	22%	12,556
2008	565	206	3,850	24%	12,350
2009	459	168	4,018	25%	12,182
2010	452	165	4,183	26%	12,017
2011	512	187	4,369	27%	11,831
2012	532	194	4,564	28%	11,636
2013	484	176	4,740	29%	11,460
2014	486	177	4,918	30%	11,282
2015	490	179	5,096	31%	11,104
2016	463	169	5,266	33%	10,934
2017	441	161	5,427	33%	10,773
2018	456	166	5,593	35%	10,607

Table B.7. *Haradh Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1995	0	0	0	0%	18,000
1996	300	110	110	1%	17,891
1997	300	110	219	1%	17,781
1998	300	110	329	2%	17,672
1999	300	110	438	2%	17,562
2000	300	110	548	3%	17,453
2001	300	110	657	4%	17,343
2002	300	110	767	4%	17,234
2003	600	219	986	5%	17,015
2004	600	219	1,205	7%	16,796
2005	600	219	1,424	8%	16,577
2006	588	215	1,638	9%	16,362
2007	864	315	1,954	11%	16,046
2008	847	309	2,263	13%	15,737
2009	689	251	2,514	14%	15,486
2010	678	247	2,762	15%	15,238
2011	768	280	3,042	17%	14,958
2012	799	292	3,333	19%	14,667
2013	725	265	3,598	20%	14,402
2014	729	266	3,864	21%	14,136
2015	735	268	4,132	23%	13,868
2016	695	254	4,386	24%	13,614
2017	662	242	4,628	26%	13,372
2018	684	250	4,877	27%	13,123

Table B.8. *Abqaiq Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1951	438	160	561	3%	16,189	28%
1952	398	145	707	4%	16,043	21%
1953	359	131	838	5%	15,912	16%
1954	319	116	954	6%	15,796	12%
1955	311	114	1,068	6%	15,682	11%
1956	303	111	1,178	7%	15,572	9%
1957	295	108	1,286	8%	15,464	8%
1958	285	104	1,390	8%	15,360	7%
1959	276	101	1,491	9%	15,259	7%
1960	266	97	1,588	9%	15,162	6%
1961	343	125	1,713	10%	15,037	7%
1962	361	132	1,845	11%	14,905	7%
1963	380	139	1,984	12%	14,766	7%
1964	417	152	2,136	13%	14,614	7%
1965	453	165	2,301	14%	14,449	7%
1966	490	179	2,480	15%	14,270	7%
1967	516	188	2,668	16%	14,082	7%
1968	542	198	2,866	17%	13,884	7%
1969	568	207	3,073	18%	13,677	7%
1970	689	251	3,325	20%	13,425	8%
1971	810	296	3,621	22%	13,129	8%
1972	931	340	3,960	24%	12,790	9%
1973	1,094	399	4,360	26%	12,390	9%
1974	870	318	4,677	28%	12,073	7%
1975	762	278	4,955	30%	11,795	6%
1976	825	301	5,257	31%	11,493	6%
1977	856	312	5,569	33%	11,181	6%
1978	738	269	5,838	35%	10,912	5%
1979	709	259	6,097	36%	10,653	4%

Table B.8. *Continued*

1980	681	248	6,346	38%	10,404	4%
1981	652	238	6,584	39%	10,166	4%
1982	568	207	6,791	41%	9,959	3%
1983	484	177	6,968	42%	9,782	3%
1984	400	146	7,114	42%	9,636	2%
1985	425	155	7,269	43%	9,481	2%
1986	450	164	7,434	44%	9,316	2%
1987	475	173	7,607	45%	9,143	2%
1988	500	183	7,790	47%	8,960	2%
1989	525	192	7,981	48%	8,769	2%
1990	550	201	8,182	49%	8,568	2%
1991	575	210	8,392	50%	8,358	3%
1992	600	219	8,611	51%	8,139	3%
1993	625	228	8,839	53%	7,911	3%
1994	650	237	9,076	54%	7,674	3%
1995	635	232	9,308	56%	7,442	2%
1996	620	226	9,535	57%	7,215	2%
1997	605	221	9,755	58%	6,995	2%
1998	590	215	9,971	60%	6,779	2%
1999	575	210	10,181	61%	6,569	2%
2000	560	204	10,385	62%	6,365	2%
2001	545	199	10,584	63%	6,166	2%
2002	530	193	10,777	64%	5,973	2%
2003	515	188	10,965	65%	5,785	2%
2004	500	183	11,148	67%	5,602	2%
2005	442	161	11,309	68%	5,441	1%
2006	384	140	11,449	68%	5,301	1%
2007	325	119	11,568	69%	5,182	1%
2008	267	97	11,665	70%	5,085	1%
2009	191	70	11,735	70%	5,015	1%
2010	151	55	11,790	70%	4,960	0%
2011	256	93	11,883	71%	4,867	1%

Table B.8. *Continued*

2012	355	130	12,013	72%	4,737	1%
2013	343	125	12,138	72%	4,612	1%
2014	364	133	12,271	73%	4,479	1%
2015	388	142	12,413	74%	4,337	1%
2016	386	141	12,554	75%	4,196	1%
2017	368	134	12,688	76%	4,062	1%
2018	380	139	12,827	77%	3,923	1%

Table B.9. *Safaniya Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1951	438	160	561	3%	16,189	28%
1957	27	10	10	0%	48,990	100%
1958	76	28	38	0%	48,962	74%
1959	125	46	83	0%	48,917	55%
1960	174	64	147	0%	48,853	43%
1961	212	78	224	0%	48,776	35%
1962	251	91	316	1%	48,684	29%
1963	289	105	421	1%	48,579	25%
1964	389	142	563	1%	48,437	25%
1965	488	178	741	2%	48,259	24%
1966	588	215	956	2%	48,044	22%
1967	528	193	1,149	2%	47,851	17%
1968	467	171	1,319	3%	47,681	13%
1969	407	149	1,468	3%	47,532	10%
1970	574	210	1,677	3%	47,323	12%
1971	742	271	1,948	4%	47,052	14%
1972	909	332	2,280	5%	46,720	15%
1973	962	351	2,631	5%	46,369	13%
1974	1,019	372	3,003	6%	45,997	12%

Table B.9. *Continued*

1975	827	302	3,305	7%	45,695	9%
1976	621	227	3,531	7%	45,469	6%
1977	1,435	524	4,055	8%	44,945	13%
1978	1,221	446	4,501	9%	44,499	10%
1979	1,329	485	4,986	10%	44,014	10%
1980	1,436	524	5,510	11%	43,490	10%
1981	1,544	564	6,074	12%	42,926	9%
1982	750	274	6,347	13%	42,653	4%
1983	750	274	6,621	14%	42,379	4%
1984	750	274	6,895	14%	42,105	4%
1985	750	274	7,169	15%	41,831	4%
1986	750	274	7,442	15%	41,558	4%
1987	750	274	7,716	16%	41,284	4%
1988	750	274	7,990	16%	41,010	3%
1989	750	274	8,264	17%	40,736	3%
1990	750	274	8,537	17%	40,463	3%
1991	750	274	8,811	18%	40,189	3%
1992	750	274	9,085	19%	39,915	3%
1993	750	274	9,359	19%	39,641	3%
1994	960	350	9,709	20%	39,291	4%
1995	883	322	10,031	20%	38,969	3%
1996	807	294	10,326	21%	38,674	3%
1997	730	266	10,592	22%	38,408	3%
1998	653	238	10,831	22%	38,169	2%
1999	577	210	11,041	23%	37,959	2%
2000	500	183	11,224	23%	37,776	2%
2001	525	192	11,415	23%	37,585	2%
2002	550	201	11,616	24%	37,384	2%
2003	575	210	11,826	24%	37,174	2%
2004	600	219	12,045	25%	36,955	2%
2005	651	237	12,282	25%	36,718	2%
2006	701	256	12,538	26%	36,462	2%

Table B.9. *Continued*

2007	752	274	12,813	26%	36,187	2%
2008	802	293	13,106	27%	35,894	2%
2009	842	307	13,413	27%	35,587	2%
2010	903	330	13,743	28%	35,257	2%
2011	1,024	374	14,116	29%	34,884	3%
2012	1,065	389	14,505	30%	34,495	3%
2013	967	353	14,858	30%	34,142	2%
2014	972	355	15,213	31%	33,787	2%
2015	980	358	15,570	32%	33,430	2%
2016	926	338	15,909	32%	33,091	2%
2017	883	322	16,231	33%	32,769	2%
2018	912	333	16,564	34%	32,436	2%

Table B.10. *Abu Sa'fah Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1973	109	40	140	2%	7,660	28%
1974	121	44	184	2%	7,616	24%
1975	60	22	206	3%	7,594	11%
1976	100	37	242	3%	7,558	15%
1977	130	47	290	4%	7,510	16%
1978	135	49	339	4%	7,461	15%
1979	139	51	390	5%	7,410	13%
1980	131	48	438	6%	7,362	11%
1981	123	45	482	6%	7,318	9%
1982	115	42	524	7%	7,276	8%
1983	109	40	564	7%	7,236	7%
1984	102	37	601	8%	7,199	6%
1985	96	35	636	8%	7,164	6%
1986	90	33	669	9%	7,131	5%

Table B.10. *Continued*

1987	85	31	700	9%	7,100	4%
1988	80	29	729	9%	7,071	4%
1989	75	27	757	10%	7,043	4%
1990	70	26	782	10%	7,018	3%
1991	66	24	806	10%	6,994	3%
1992	62	23	829	11%	6,971	3%
1993	58	21	850	11%	6,950	3%
1994	150	55	905	12%	6,895	6%
1995	165	60	965	12%	6,835	6%
1996	180	66	1,031	13%	6,769	6%
1997	195	71	1,102	14%	6,698	6%
1998	210	77	1,179	15%	6,621	7%
1999	225	82	1,261	16%	6,539	7%
2000	240	88	1,349	17%	6,451	6%
2001	255	93	1,442	18%	6,358	6%
2002	270	99	1,540	20%	6,260	6%
2003	285	104	1,644	21%	6,156	6%
2004	300	110	1,754	22%	6,046	6%
2005	300	110	1,863	24%	5,937	6%
2006	300	110	1,973	25%	5,827	6%
2007	300	110	2,082	27%	5,718	5%
2008	300	110	2,192	28%	5,608	5%
2009	230	84	2,276	29%	5,524	4%
2010	226	82	2,358	30%	5,442	3%
2011	256	93	2,451	31%	5,349	4%
2012	266	97	2,549	33%	5,251	4%
2013	242	88	2,637	34%	5,163	3%
2014	243	89	2,726	35%	5,074	3%
2015	245	89	2,815	36%	4,985	3%
2016	232	85	2,899	37%	4,901	3%
2017	221	81	2,980	38%	4,820	3%
2018	228	83	3,063	39%	4,737	3%

Table B.11. *Berri Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*	*Ap/cp*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)			
1969	19	7	7	0%	10,793	
1970	100	37	43	0%	10,757	
1971	155	57	100	1%	10,700	
1972	313	114	214	2%	10,586	
1973	622	227	441	4%	10,359	51%
1974	637	233	674	6%	10,126	35%
1975	334	122	796	7%	10,004	15%
1976	807	295	1,090	10%	9,710	27%
1977	787	287	1,378	13%	9,422	21%
1978	586	214	1,591	15%	9,209	13%
1979	563	205	1,797	17%	9,003	11%
1980	540	197	1,994	18%	8,806	10%
1981	504	184	2,178	20%	8,622	8%
1982-1992	0	0	2,178	20%	8,622	0%
1993	420	153	2,331	22%	8,469	7%
1994	400	146	2,477	23%	8,323	6%
1995	381	139	2,616	24%	8,184	5%
1996	362	132	2,749	25%	8,051	5%
1997	344	125	2,874	27%	7,926	4%
1998	325	119	2,992	28%	7,808	4%
1999	306	112	3,104	29%	7,696	4%
2000	287	105	3,209	30%	7,591	3%
2001	268	98	3,307	31%	7,493	3%
2002	250	91	3,398	31%	7,402	3%
2003	231	84	3,482	32%	7,318	2%
2004	212	77	3,560	33%	7,240	2%
2005	214	78	3,638	34%	7,162	2%
2006	215	79	3,716	34%	7,084	2%
2007	217	79	3,795	35%	7,005	2%

Table B.11. *Continued*

2008	219	80	3,875	36%	6,925	2%
2009	190	69	3,945	37%	6,855	2%
2010	193	70	4,015	37%	6,785	2%
2011	225	82	4,097	38%	6,703	2%
2012	240	88	4,185	39%	6,615	2%
2013	224	82	4,266	40%	6,534	2%
2014	231	84	4,351	40%	6,449	2%
2015	239	87	4,438	41%	6,362	2%
2016	232	85	4,523	42%	6,277	2%
2017	221	81	4,603	43%	6,197	2%
2018	228	83	4,686	43%	6,114	2%

Table B.12. *Khurais Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1970-1979	26	9	95	0%	22,705
1980	68	25	120	1%	22,680
1981	144	53	172	1%	22,628
1982	122	45	217	1%	22,583
1983	104	38	255	1%	22,545
1984	88	32	287	1%	22,513
1985	75	27	315	1%	22,485
1986	64	23	338	1%	22,462
1987	54	20	358	2%	22,442
1988	46	17	375	2%	22,425
1989	39	14	389	2%	22,411
1990	33	12	401	2%	22,399
1991	28	10	411	2%	22,389
1992	24	9	420	2%	22,380
1993-2008	0	0	420	2%	22,380

Table B.12. *Continued*

2009	918	335	756	3%	22,044
2010	903	330	1,085	5%	21,715
2011	1,024	374	1,459	6%	21,341
2012	1,065	389	1,848	8%	20,952
2013	967	353	2,201	10%	20,599
2014	972	355	2,555	11%	20,245
2015	980	358	2,913	13%	19,887
2016	926	338	3,251	14%	19,549
2017	883	322	3,573	16%	19,227
2018	912	333	3,906	17%	18,894

Table B.13. *Khursaniyah Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2003	82	30	1,860	26%	5,280
2004	78	28	1,888	26%	5,252
2005	74	27	1,915	27%	5,225
2006	70	26	1,941	27%	5,199
2007	67	24	1,966	28%	5,174
2008	63	23	1,989	28%	5,151
2009	403	147	2,136	30%	5,004
2010	396	145	2,280	32%	4,860
2011	449	164	2,444	34%	4,696
2012	467	170	2,614	37%	4,526
2013	424	155	2,769	39%	4,371
2014	426	155	2,925	41%	4,215
2015	430	157	3,081	43%	4,059
2016	406	148	3,230	45%	3,910
2017	387	141	3,371	47%	3,769
2018	400	146	3,517	49%	3,623

Table B.14. *Manifa Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1964	40	15	15	0%	16,985
1965	77	28	43	0%	16,957
1966	113	41	84	0%	16,916
1967	48	18	101	1%	16,899
1968	57	21	122	1%	16,878
1969	66	24	146	1%	16,854
1970	76	28	174	1%	16,826
1971	85	31	205	1%	16,795
1972	94	34	239	1%	16,761
1973	103	38	277	2%	16,723
1974	112	41	318	2%	16,682
1975	122	44	362	2%	16,638
1976	131	48	410	2%	16,590
1977	140	51	461	3%	16,539
1978	134	49	510	3%	16,490
1979	129	47	557	3%	16,443
1980	123	45	602	4%	16,398
1981	118	43	645	4%	16,355
1982	114	41	687	4%	16,313
1983	109	40	727	4%	16,273
1984-2012		0	727	4%	16,273
2013	403	147	874	5%	16,126
2014	405	148	1,022	6%	15,978
2015	735	268	1,290	8%	15,710
2016	695	254	1,543	9%	15,457
2017	662	242	1,785	11%	15,215
2018	684	250	2,035	12%	14,965

Table B.15. *Marjan Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1969	19	7	7	0%	10,793
1970	100	37	43	0%	10,757
1971	155	57	100	1%	10,700
1972	313	114	214	2%	10,586
1973	622	227	441	4%	10,359
1974	637	233	674	6%	10,126
1975	334	122	796	7%	10,004
1976	807	295	1,090	10%	9,710
1977	787	287	1,378	13%	9,422
1978	586	214	1,591	15%	9,209
1979	563	205	1,797	17%	9,003
1980	540	197	1,994	18%	8,806
1981	504	184	2,178	20%	8,622
1982-1992	0	0	2,178	20%	8,622
1993	420	153	2,331	22%	8,469
1994	400	146	2,477	23%	8,323
1995	381	139	2,616	24%	8,184
1996	362	132	2,749	25%	8,051
1997	344	125	2,874	27%	7,926
1998	325	119	2,992	28%	7,808
1999	306	112	3,104	29%	7,696
2000	287	105	3,209	30%	7,591
2001	268	98	3,307	31%	7,493
2002	250	91	3,398	31%	7,402
2003	231	84	3,482	32%	7,318
2004	212	77	3,560	33%	7,240
2005	214	78	3,638	34%	7,162
2006	215	79	3,716	34%	7,084
2007	217	79	3,795	35%	7,005

Table B.15. *Continued*

2008	219	80	3,875	36%	6,925
2009	190	69	3,945	37%	6,855
2010	193	70	4,015	37%	6,785
2011	225	82	4,097	38%	6,703
2012	240	88	4,185	39%	6,615
2013	224	82	4,266	40%	6,534
2014	231	84	4,351	40%	6,449
2015	239	87	4,438	41%	6,362
2016	232	85	4,523	42%	6,277
2017	221	81	4,603	43%	6,197
2018	228	83	4,686	43%	6,114

Table B.16. *Qatif Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1951-1966	33	12	190	2%	8,210
1967-1978	80	29	540	6%	7,860
1979	150	55	595	7%	7,805
1980	115	42	637	8%	7,763
1981	40	15	652	8%	7,748
1982-2003	0	0	652	8%	7,748
2004	100	37	688	8%	7,712
2005	200	73	761	9%	7,639
2006	300	110	871	10%	7,529
2007	300	110	980	12%	7,420
2008	400	146	1,126	13%	7,274
2009	306	112	1,238	15%	7,162
2010	376	137	1,375	16%	7,025
2011	426	156	1,531	18%	6,869
2012	444	162	1,693	20%	6,707

Table B.16. Continued

2013	403	147	1,840	22%	6,560
2014	405	148	1,988	24%	6,412
2015	408	149	2,137	25%	6,263
2016	386	141	2,278	27%	6,122
2017	368	134	2,412	29%	5,988
2018	380	139	2,551	30%	5,849

Table B.17. *Shaybah Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1979	150	55	595	7%	7,805
1998	210	77	77	0%	19,823
1999	500	183	259	1%	19,641
2000	490	179	438	2%	19,462
2001	510	186	624	3%	19,276
2002	495	181	805	4%	19,095
2003	520	190	995	5%	18,905
2004	492	180	1,174	6%	18,726
2005	560	204	1,379	7%	18,521
2006	560	204	1,583	8%	18,317
2007	560	204	1,787	9%	18,113
2008	560	204	1,992	10%	17,908
2009	582	212	2,204	11%	17,696
2010	572	209	2,413	12%	17,487
2011	648	237	2,650	13%	17,250
2012	674	246	2,896	15%	17,004
2013	613	224	3,119	16%	16,781
2014	615	225	3,344	17%	16,556
2015	621	227	3,571	18%	16,329
2016	772	282	3,852	19%	16,048

Table B.17.Continued

2017	736	269	4,121	21%	15,779
2018	760	277	4,398	22%	15,502

Table B.18. *Zuluf Production History*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1974	41	15	15	0%	24,685
1975	82	30	45	0%	24,655
1976	102	37	82	0%	24,618
1977	121	44	126	1%	24,574
1978	141	51	178	1%	24,522
1979	313	114	292	1%	24,408
1980	486	177	469	2%	24,231
1981	658	240	710	3%	23,990
1982-1993	400	146	2,462	10%	22,238
1995-2003	400	146	3,958	16%	20,742
2004	407	149	4,107	17%	20,593
2005	450	164	4,271	17%	20,429
2006	450	164	4,435	18%	20,265
2007	450	164	4,599	19%	20,101
2008	450	164	4,764	19%	19,936
2009	344	126	4,889	20%	19,811
2010	339	124	5,013	20%	19,687
2011	384	140	5,153	21%	19,547
2012	399	146	5,299	21%	19,401
2013	363	132	5,431	22%	19,269
2014	364	133	5,564	23%	19,136
2015	368	134	5,698	23%	19,002
2017	500	183	6,073	25%	18,627
2018	517	189	6,261	25%	18,439

Table B.19. *Others Production History*

Year	Production			Ratio	Model
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1951	438	160	160		
1952	398	145	305		
1953	359	131	436		
1954	319	116	553		
1955	311	114	666		
1956	303	111	777		
1957	295	108	884		
1958	285	104	989		
1959	276	101	1,089		
1960	266	97	1,186	18%	29%
1961	304	111	1,297	19%	28%
1962	342	125	1,422	20%	28%
1963	380	139	1,561	20%	27%
1964	417	152	1,713	19%	26%
1965	453	165	1,878	19%	25%
1966	490	179	2,057	19%	25%
1967	516	188	2,245	19%	24%
1968	440	161	2,406	15%	23%
1969	568	207	2,613	18%	23%
1970	520	190	2,803	15%	22%
1971	544	199	3,002	12%	22%
1972	931	340	3,342	16%	21%
1973	513	187	3,529	7%	20%
1974	844	308	3,837	10%	20%
1975	762	278	4,115	11%	19%
1976	393	143	4,258	5%	19%
1977	746	272	4,531	8%	18%
1978	738	269	4,800	8%	18%
1979	344	126	4,926	4%	17%
1980	70	135	5,061	4%	17%

Table B.19. *Continued*

1981	652	238	5,299	6%	16%
1982	777	284	5,582	13%	16%
1983	775	283	5,865	13%	15%
1984	772	282	6,147	13%	15%
1985	770	281	6,428	21%	15%
1986	768	280	6,708	14%	14%
1987	765	279	6,987	16%	14%
1988	763	278	7,266	14%	13%
1989	760	278	7,543	13%	13%
1990	758	277	7,820	13%	13%
1991	756	276	8,096	12%	12%
1992	753	275	8,371	11%	12%
1993	751	274	8,645	10%	12%
1994	564	206	8,851	7%	11%
1995	378	138	8,989	5%	11%
1996	191	70	9,059	2%	11%
1997	177	65	9,123	2%	10%
1998	512	187	9,310	6%	10%
1999	455	166	9,476	6%	10%
2000	398	145	9,621	5%	10%
2001	412	151	9,772	5%	9%
2002	427	156	9,928	5%	9%
2003	441	161	10,089	5%	9%
2004	363	132	10,221	4%	9%
2005	441	161	10,382	5%	8%
2006	520	190	10,572	6%	8%
2007	598	218	10,790	7%	8%
2008	929	339	11,129	10%	8%
2009	154	56	11,186	2%	7%
2010	151	55	11,240	2%	7%
2011	142	52	11,292	2%	7%
2012	130	48	11,340	1%	7%
2013	378	138	11,478	4%	7%

C. SAUDI ARABIA CRUDE OIL PRODUCTION FORECAST

Table C.1. *Ain Dar/Shedgum Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	1,620	591	37,022	77%	10,978
2020	1,584	578	37,600	78%	10,400
2021	1,550	566	38,166	80%	9,834
2022	1,515	553	38,719	81%	9,281
2023	1,482	541	39,260	82%	8,740
2024	1,449	529	39,789	83%	8,211
2025	1,418	517	40,306	84%	7,694
2026	1,386	506	40,812	85%	7,188
2027	1,356	495	41,307	86%	6,693
2028	1,326	484	41,791	87%	6,209
2029	1,297	473	42,265	88%	5,735
2030	1,268	463	42,728	89%	5,272
2031	1,240	453	43,180	90%	4,820
2032	1,213	443	43,623	91%	4,377
2033	1,186	433	44,056	92%	3,944
2034	1,160	424	44,480	93%	3,520
2035	1,135	414	44,894	94%	3,106
2036	1,110	405	45,299	94%	2,701
2037	1,085	396	45,695	95%	2,305
2038	1,062	387	46,083	96%	1,917
2039	1,038	379	46,462	97%	1,538
2040	1,015	371	46,832	98%	1,168
2041	993	362	47,195	98%	805
2042	971	354	47,549	99%	451
2043	950	347	47,896	100%	104

Table C.2. *Uthmaniyah Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	1,215	443	34,898	78%	10,102
2020	1,194	436	35,334	79%	9,666
2021	1,174	429	35,763	79%	9,237
2022	1,154	421	36,184	80%	8,816
2023	1,134	414	36,598	81%	8,402
2024	1,115	407	37,005	82%	7,995
2025	1,096	400	37,405	83%	7,595
2026	1,078	393	37,799	84%	7,201
2027	1,059	387	38,185	85%	6,815
2028	1,041	380	38,565	86%	6,435
2029	1,024	374	38,939	87%	6,061
2030	1,006	367	39,306	87%	5,694
2031	989	361	39,667	88%	5,333
2032	972	355	40,022	89%	4,978
2033	956	349	40,371	90%	4,629
2034	939	343	40,714	90%	4,286
2035	923	337	41,051	91%	3,949
2036	908	331	41,382	92%	3,618
2037	892	326	41,708	93%	3,292
2038	877	320	42,028	93%	2,972
2039	862	315	42,343	94%	2,657
2040	848	309	42,652	95%	2,348
2041	833	304	42,956	95%	2,044
2042	819	299	43,255	96%	1,745
2043	805	294	43,549	97%	1,451
2044	791	289	43,838	97%	1,162
2045	778	284	44,122	98%	878
2046	765	279	44,401	99%	599
2047	752	274	44,675	99%	325
2048	739	270	44,945	100%	55

Table C.3 .*Hawiyah Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	486	177	5,770	36%	10,430
2020	478	174	5,945	37%	10,255
2021	470	171	6,116	38%	10,084
2022	462	168	6,285	39%	9,915
2023	454	166	6,450	40%	9,750
2024	446	163	6,613	41%	9,587
2025	438	160	6,773	42%	9,427
2026	431	157	6,931	43%	9,269
2027	424	155	7,085	44%	9,115
2028	417	152	7,237	45%	8,963
2029	409	149	7,387	46%	8,813
2030	402	147	7,534	47%	8,666
2031	396	144	7,678	47%	8,522
2032	389	142	7,820	48%	8,380
2033	382	140	7,959	49%	8,241
2034	376	137	8,097	50%	8,103
2035	369	135	8,231	51%	7,969
2036	363	133	8,364	52%	7,836
2037	357	130	8,494	52%	7,706
2038	351	128	8,622	53%	7,578
2039	345	126	8,748	54%	7,452
2040	339	124	8,872	55%	7,328
2041	333	122	8,994	56%	7,206
2042	328	120	9,113	56%	7,087
2043	322	118	9,231	57%	6,969
2044	317	116	9,346	58%	6,854
2045	311	114	9,460	58%	6,740
2046	306	112	9,572	59%	6,628
2047	301	110	9,681	60%	6,519
2048	296	108	9,789	60%	6,411

Table C.4. *Haradh Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	729	266	5,143	29%	12,857
2020	717	262	5,405	30%	12,595
2021	704	257	5,662	31%	12,338
2022	692	253	5,915	33%	12,085
2023	681	248	6,163	34%	11,837
2024	669	244	6,408	36%	11,592
2025	658	240	6,648	37%	11,352
2026	647	236	6,884	38%	11,116
2027	636	232	7,116	40%	10,884
2028	625	228	7,344	41%	10,656
2029	614	224	7,568	42%	10,432
2030	604	220	7,788	43%	10,212
2031	593	217	8,005	44%	9,995
2032	583	213	8,218	46%	9,782
2033	573	209	8,427	47%	9,573
2034	564	206	8,633	48%	9,367
2035	554	202	8,835	49%	9,165
2036	545	199	9,034	50%	8,966
2037	535	195	9,229	51%	8,771
2038	526	192	9,421	52%	8,579
2039	517	189	9,610	53%	8,390
2040	509	186	9,796	54%	8,204
2041	500	182	9,978	55%	8,022
2042	491	179	10,158	56%	7,842
2043	483	176	10,334	57%	7,666
2044	475	173	10,507	58%	7,493
2045	467	170	10,678	59%	7,322
2046	459	167	10,845	60%	7,155
2047	451	165	11,010	61%	6,990
2048	443	162	11,172	62%	6,828

Table C.5. *Abqaiq Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	405	148	12,697	76%	4,053
2020	394	144	12,841	77%	3,909
2021	383	140	12,981	77%	3,769
2022	372	136	13,116	78%	3,634
2023	362	132	13,248	79%	3,502
2024	351	128	13,376	80%	3,374
2025	342	125	13,501	81%	3,249
2026	332	121	13,622	81%	3,128
2027	323	118	13,740	82%	3,010
2028	314	114	13,855	83%	2,895
2029	305	111	13,966	83%	2,784
2030	296	108	14,074	84%	2,676
2031	288	105	14,179	85%	2,571
2032	280	102	14,281	85%	2,469
2033	272	99	14,381	86%	2,369
2034	265	97	14,477	86%	2,273
2035	257	94	14,571	87%	2,179
2036	250	91	14,662	88%	2,088
2037	243	89	14,751	88%	1,999
2038	236	86	14,837	89%	1,913
2039	229	84	14,921	89%	1,829
2040	223	81	15,002	90%	1,748
2041	217	79	15,081	90%	1,669
2042	211	77	15,158	90%	1,592
2043	205	75	15,233	91%	1,517
2044	199	73	15,306	91%	1,444
2045	194	71	15,376	92%	1,374
2046	188	69	15,445	92%	1,305
2047	183	67	15,512	93%	1,238
2048	178	65	15,577	93%	1,173

Table C.6. *Safaniya Production Forecast*

Year	Production			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	972	355	16,919	35%	32,081
2020	957	349	17,268	35%	31,732
2021	943	344	17,612	36%	31,388
2022	929	339	17,951	37%	31,049
2023	915	334	18,285	37%	30,715
2024	901	329	18,614	38%	30,386
2025	888	324	18,938	39%	30,062
2026	874	319	19,257	39%	29,743
2027	861	314	19,572	40%	29,428
2028	848	310	19,881	41%	29,119
2029	836	305	20,186	41%	28,814
2030	823	300	20,487	42%	28,513
2031	811	296	20,783	42%	28,217
2032	799	291	21,074	43%	27,926
2033	787	287	21,361	44%	27,639
2034	775	283	21,644	44%	27,356
2035	763	279	21,923	45%	27,077
2036	752	274	22,197	45%	26,803
2037	740	270	22,467	46%	26,533
2038	729	266	22,734	46%	26,266
2039	718	262	22,996	47%	26,004
2040	708	258	23,254	47%	25,746
2041	697	254	23,509	48%	25,491
2042	687	251	23,759	48%	25,241
2043	676	247	24,006	49%	24,994
2044	666	243	24,249	49%	24,751
2045	656	239	24,489	50%	24,511
2046	646	236	24,725	50%	24,275
2047	637	232	24,957	51%	24,043
2048	627	229	25,186	51%	23,814

Table C.7. *Abu Sa'fah Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	243	89	3,152	40%	4,648
2020	241	88	3,240	42%	4,560
2021	238	87	3,327	43%	4,473
2022	236	86	3,413	44%	4,387
2023	233	85	3,498	45%	4,302
2024	231	84	3,582	46%	4,218
2025	229	84	3,666	47%	4,134
2026	226	83	3,749	48%	4,051
2027	224	82	3,830	49%	3,970
2028	222	81	3,911	50%	3,889
2029	220	80	3,992	51%	3,808
2030	218	79	4,071	52%	3,729
2031	215	79	4,150	53%	3,650
2032	213	78	4,227	54%	3,573
2033	211	77	4,305	55%	3,495
2034	209	76	4,381	56%	3,419
2035	207	76	4,456	57%	3,344
2036	205	75	4,531	58%	3,269
2037	203	74	4,605	59%	3,195
2038	201	73	4,678	60%	3,122
2039	199	73	4,751	61%	3,049
2040	197	72	4,823	62%	2,977
2041	195	71	4,894	63%	2,906
2042	193	70	4,964	64%	2,836
2043	191	70	5,034	65%	2,766
2044	189	69	5,103	65%	2,697
2045	187	68	5,171	66%	2,629
2046	185	68	5,239	67%	2,561
2047	183	67	5,306	68%	2,494
2048	182	66	5,372	69%	2,428

Table C.8. *Berri Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	243	89	4,775	44%	6,025
2020	233	85	4,860	45%	5,940
2021	223	82	4,942	46%	5,858
2022	214	78	5,020	46%	5,780
2023	206	75	5,095	47%	5,705
2024	197	72	5,167	48%	5,633
2025	189	69	5,236	48%	5,564
2026	181	66	5,302	49%	5,498
2027	174	63	5,365	50%	5,435
2028	167	61	5,426	50%	5,374
2029	160	58	5,485	51%	5,315
2030	153	56	5,541	51%	5,259
2031	147	54	5,594	52%	5,206
2032	141	51	5,646	52%	5,154
2033	135	49	5,695	53%	5,105
2034	130	47	5,742	53%	5,058
2035	124	45	5,788	54%	5,012
2036	119	44	5,831	54%	4,969
2037	114	42	5,873	54%	4,927
2038	110	40	5,913	55%	4,887
2039	105	38	5,952	55%	4,848
2040	101	37	5,988	55%	4,812
2041	97	35	6,024	56%	4,776
2042	93	34	6,058	56%	4,742
2043	89	32	6,090	56%	4,710
2044	85	31	6,121	57%	4,679
2045	82	30	6,151	57%	4,649
2046	78	29	6,180	57%	4,620
2047	75	27	6,207	57%	4,593
2048	72	26	6,234	58%	4,566

Table C.9. *Khurais Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	1,272	464	4,371	19%	18,429
2020	1,244	454	4,825	21%	17,975
2021	1,217	444	5,269	23%	17,531
2022	1,190	434	5,703	25%	17,097
2023	1,164	425	6,128	27%	16,672
2024	1,138	415	6,543	29%	16,257
2025	1,113	406	6,949	30%	15,851
2026	1,089	397	7,347	32%	15,453
2027	1,065	389	7,735	34%	15,065
2028	1,041	380	8,115	36%	14,685
2029	1,018	372	8,487	37%	14,313
2030	996	364	8,851	39%	13,949
2031	974	356	9,206	40%	13,594
2032	953	348	9,554	42%	13,246
2033	932	340	9,894	43%	12,906
2034	911	333	10,226	45%	12,574
2035	891	325	10,552	46%	12,248
2036	871	318	10,870	48%	11,930
2037	852	311	11,181	49%	11,619
2038	834	304	11,485	50%	11,315
2039	815	298	11,783	52%	11,017
2040	797	291	12,074	53%	10,726
2041	780	285	12,358	54%	10,442
2042	763	278	12,637	55%	10,163
2043	746	272	12,909	57%	9,891
2044	729	266	13,175	58%	9,625
2045	713	260	13,435	59%	9,365
2046	698	255	13,690	60%	9,110
2047	682	249	13,939	61%	8,861
2048	667	244	14,183	62%	8,617

Table C.10. *Khursaniyah Production Forecast*

Year	Production			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	426	156	3,672	51%	3,468
2020	409	149	3,821	54%	3,319
2021	392	143	3,964	56%	3,176
2022	376	137	4,102	57%	3,038
2023	360	132	4,233	59%	2,907
2024	346	126	4,359	61%	2,781
2025	331	121	4,480	63%	2,660
2026	318	116	4,596	64%	2,544
2027	305	111	4,707	66%	2,433
2028	292	107	4,814	67%	2,326
2029	280	102	4,917	69%	2,223
2030	269	98	5,015	70%	2,125
2031	258	94	5,109	72%	2,031
2032	247	90	5,199	73%	1,941
2033	237	87	5,286	74%	1,854
2034	227	83	5,369	75%	1,771
2035	218	80	5,448	76%	1,692
2036	209	76	5,524	77%	1,616
2037	201	73	5,598	78%	1,542
2038	192	70	5,668	79%	1,472
2039	184	67	5,735	80%	1,405
2040	177	65	5,800	81%	1,340
2041	170	62	5,862	82%	1,278
2042	163	59	5,921	83%	1,219
2043	156	57	5,978	84%	1,162
2044	150	55	6,033	84%	1,107
2045	143	52	6,085	85%	1,055
2046	138	50	6,135	86%	1,005
2047	132	48	6,183	87%	957
2048	127	46	6,229	87%	911

Table C.11. *Manifa Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	900	329	2,363	14%	14,637
2020	887	324	2,687	16%	14,313
2021	873	319	3,006	18%	13,994
2022	860	314	3,320	20%	13,680
2023	847	309	3,629	21%	13,371
2024	834	305	3,933	23%	13,067
2025	822	300	4,233	25%	12,767
2026	810	296	4,529	27%	12,471
2027	798	291	4,820	28%	12,180
2028	786	287	5,107	30%	11,893
2029	774	282	5,389	32%	11,611
2030	762	278	5,667	33%	11,333
2031	751	274	5,941	35%	11,059
2032	739	270	6,211	37%	10,789
2033	728	266	6,477	38%	10,523
2034	717	262	6,739	40%	10,261
2035	707	258	6,997	41%	10,003
2036	696	254	7,251	43%	9,749
2037	686	250	7,501	44%	9,499
2038	675	247	7,748	46%	9,252
2039	665	243	7,991	47%	9,009
2040	655	239	8,230	48%	8,770
2041	645	236	8,465	50%	8,535
2042	636	232	8,697	51%	8,303
2043	626	229	8,926	53%	8,074
2044	617	225	9,151	54%	7,849
2045	608	222	9,373	55%	7,627
2046	598	218	9,591	56%	7,409
2047	589	215	9,806	58%	7,194
2048	581	212	10,018	59%	6,982

Table C.12. *Marjan Production Forecast*

Year	Production			Depletion	RRR
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)	Rate	(MMbbl)
2019	365	133	3,189	24%	10,211
2020	359	131	3,320	25%	10,080
2021	354	129	3,449	26%	9,951
2022	348	127	3,576	27%	9,824
2023	343	125	3,701	28%	9,699
2024	588	215	3,916	29%	9,484
2025	579	211	4,127	31%	9,273
2026	570	208	4,335	32%	9,065
2027	562	205	4,541	34%	8,859
2028	553	202	4,743	35%	8,657
2029	545	199	4,942	37%	8,458
2030	537	196	5,138	38%	8,262
2031	529	193	5,331	40%	8,069
2032	521	190	5,521	41%	7,879
2033	513	187	5,708	43%	7,692
2034	505	185	5,893	44%	7,507
2035	498	182	6,074	45%	7,326
2036	490	179	6,253	47%	7,147
2037	483	176	6,430	48%	6,970
2038	476	174	6,603	49%	6,797
2039	469	171	6,774	51%	6,626
2040	462	169	6,943	52%	6,457
2041	455	166	7,109	53%	6,291
2042	448	163	7,272	54%	6,128
2043	441	161	7,434	55%	5,966
2044	435	159	7,592	57%	5,808
2045	428	156	7,748	58%	5,652
2046	422	154	7,902	59%	5,498
2047	415	152	8,054	60%	5,346
2048	409	149	8,203	61%	5,197

Table C.13. *Qatif Production Forecast*

Year	*Production*			*Depletion*	*RRR*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)	*Rate*	*(MMbbl)*
2019	405	148	2,698	32%	5,702
2020	401	146	2,845	34%	5,555
2021	397	145	2,990	36%	5,410
2022	393	143	3,133	37%	5,267
2023	389	142	3,275	39%	5,125
2024	385	141	3,416	41%	4,984
2025	381	139	3,555	42%	4,845
2026	377	138	3,693	44%	4,707
2027	374	136	3,829	46%	4,571
2028	370	135	3,964	47%	4,436
2029	366	134	4,098	49%	4,302
2030	363	132	4,230	50%	4,170
2031	359	131	4,361	52%	4,039
2032	355	130	4,491	53%	3,909
2033	352	128	4,619	55%	3,781
2034	348	127	4,746	57%	3,654
2035	345	126	4,872	58%	3,528
2036	341	125	4,997	59%	3,403
2037	338	123	5,120	61%	3,280
2038	335	122	5,242	62%	3,158
2039	331	121	5,363	64%	3,037
2040	328	120	5,483	65%	2,917
2041	325	119	5,602	67%	2,798
2042	321	117	5,719	68%	2,681
2043	318	116	5,835	69%	2,565
2044	315	115	5,950	71%	2,450
2045	312	114	6,064	72%	2,336
2046	309	113	6,176	74%	2,224
2047	306	112	6,288	75%	2,112
2048	303	110	6,398	76%	2,002

Table C.14. *Zuluf Production Forecast*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
2019	551	201	6,462	26%	18,238
2020	541	197	6,660	27%	18,040
2021	531	194	6,854	28%	17,846
2022	522	190	7,044	29%	17,656
2023	512	187	7,231	29%	17,469
2024	503	184	7,415	30%	17,285
2025	494	180	7,595	31%	17,105
2026	485	177	7,772	31%	16,928
2027	476	174	7,946	32%	16,754
2028	468	171	8,116	33%	16,584
2029	459	168	8,284	34%	16,416
2030	451	165	8,449	34%	16,251
2031	443	162	8,610	35%	16,090
2032	435	159	8,769	36%	15,931
2033	427	156	8,925	36%	15,775
2034	419	153	9,078	37%	15,622
2035	412	150	9,228	37%	15,472
2036	404	148	9,376	38%	15,324
2037	397	145	9,521	39%	15,179
2038	390	142	9,663	39%	15,037
2039	383	140	9,803	40%	14,897
2040	376	137	9,941	40%	14,759
2041	369	135	10,075	41%	14,625
2042	363	132	10,208	41%	14,492
2043	356	130	10,338	42%	14,362
2044	350	128	10,465	42%	14,235
2045	343	125	10,591	43%	14,109
2046	337	123	10,714	43%	13,986
2047	331	121	10,835	44%	13,865
2048	325	119	10,953	44%	13,747

Table C.15. *Other Fields Production Forecast*

Year	*Production*		
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)
2019	710	259	12,425
2020	678	247	12,672
2021	647	236	12,908
2022	618	226	13,134
2023	603	220	13,354
2024	588	215	13,569
2025	561	205	13,773
2026	535	195	13,969
2027	511	186	14,155
2028	487	178	14,333
2029	465	170	14,503
2030	444	162	14,665
2031	423	155	14,819
2032	404	147	14,966
2033	386	141	15,107
2034	367	134	15,241
2035	350	128	15,369
2036	334	122	15,491
2037	318	116	15,607
2038	303	111	15,718
2039	289	105	15,823
2040	275	100	15,923
2041	262	96	16,019
2042	250	91	16,111
2043	238	87	16,198
2044	227	83	16,281
2045	217	79	16,360
2046	207	75	16,435
2047	197	72	16,507
2048	188	69	16,576

Table C.16. *Production Model for Unexplored Giant Fields*

Year	*Production*			*Depletion Rate*	*RRR (MMbbl)*
	Daily (Mbpd)	Annual (MMbbl)	Cumulative (MMbbl)		
1	Development				
2					
3	46	17	17	1.68%	983
4	53	19	19	1.92%	981
5	60	22	22	2.19%	978
6	68	25	25	2.50%	975
7	78	28	53	5.34%	947
8	89	32	86	8.59%	914
9	102	37	123	12.30%	877
10	116	42	165	16.53%	835
11	132	48	214	21.36%	786
12	151	55	269	26.87%	731
13	172	63	332	33.15%	668
14	172	63	394	39.44%	606
15	172	63	457	45.72%	543
16	172	63	520	52.01%	480
17	172	63	583	58.29%	417
18	155	56	639	63.94%	361
19	139	51	690	69.00%	310
20	125	46	736	73.56%	264
21	112	41	776	77.64%	224
22	101	37	813	81.31%	187
23	90	33	846	84.61%	154
24	81	30	876	87.57%	124
25	73	27	902	90.23%	98
26	65	24	926	92.61%	74
27	59	21	948	94.76%	52
28	53	19	967	96.68%	33
29	47	17	984	98.41%	16
30	43	16	1,000	99.96%	0

Table C.17. *Crude Oil Production Forecast, Fields (Ghawar to Khursaniyah)*

Year	Ghawar	Abqaiq	Safaniya	Abu Sa'fah	Berri	Khurais	Khursaniyah
2019	4,050	405	972	243	243	1,272	426
2020	3,973	394	957	241	233	1,244	409
2021	3,898	383	943	238	223	1,217	392
2022	3,824	372	929	236	214	1,190	376
2023	3,751	362	915	233	206	1,164	360
2024	3,680	351	901	231	197	1,138	346
2025	3,610	342	888	229	189	1,113	331
2026	3,542	332	874	226	181	1,089	318
2027	3,474	323	861	224	174	1,065	305
2028	3,409	314	848	222	167	1,041	292
2029	3,344	305	836	220	160	1,018	280
2030	3,281	296	823	218	153	996	269
2031	3,219	288	811	215	147	974	258
2032	3,158	280	799	213	141	953	247
2033	3,098	272	787	211	135	932	237
2034	3,039	265	775	209	130	911	227
2035	2,982	257	763	207	124	891	218
2036	2,925	250	752	205	119	871	209
2037	2,870	243	740	203	114	852	201
2038	2,816	236	729	201	110	834	192
2039	2,763	229	718	199	105	815	184
2040	2,711	223	708	197	101	797	177
2041	2,659	217	697	195	97	780	170
2042	2,609	211	687	193	93	763	163
2043	2,560	205	676	191	89	746	156
2044	1,583	199	666	189	85	729	150
2045	1,556	194	656	187	82	713	143
2046	1,530	188	646	185	78	698	138
2047	1,504	183	637	183	75	682	132
2048	1,478	178	627	182	72	667	127

Table C.18. *Crude Oil Production Forecast, Fields (Manifa to Total)*

Year	Manifa	Marjan	Qatif	Shaybah	Zuluf	Others	Total
2019	900	365	405	810	551	710	11,229
2020	887	359	401	802	541	678	10,997
2021	873	354	397	794	531	647	10,770
2022	860	348	393	786	522	618	10,549
2023	847	343	389	778	512	603	10,347
2024	834	588	385	770	503	588	10,398
2025	822	579	381	763	494	561	10,187
2026	810	570	377	755	485	535	9,982
2027	798	562	374	747	476	511	9,781
2028	786	553	370	740	468	487	9,586
2029	774	545	366	733	459	465	9,395
2030	762	537	363	725	451	444	9,209
2031	751	529	359	718	443	423	9,027
2032	739	521	355	711	435	404	8,849
2033	728	513	352	704	427	386	8,676
2034	717	505	348	697	419	367	8,506
2035	707	498	345	690	412	350	8,340
2036	696	490	341	683	404	334	8,178
2037	686	483	338	676	397	318	8,020
2038	675	476	335	669	390	303	7,865
2039	665	469	331	663	383	289	7,714
2040	655	462	328	656	376	275	7,567
2041	645	455	325	649	369	262	7,423
2042	636	448	321	643	363	250	7,282
2043	626	441	318	636	356	238	7,144
2044	617	435	315	630	350	227	6,081
2045	608	428	312	624	343	217	5,969
2046	598	422	309	617	337	207	5,861
2047	589	415	306	611	331	197	5,754
2048	581	409	303	605	325	188	5,650

Table C.19. *Crude Oil Production Forecast, MMbpd*

Year	CASE O	CASE I		CASE II		CASE III	
	Total	Unexplored	Total	Developed	Total	Developed	Total
2019	11,229	0	11,229	0	11,229	0	11,229
2020	10,997	0	10,997	0	10,997	0	10,997
2021	10,770	54	10,824	0	10,770	54	10,824
2022	10,549	114	10,664	0	10,549	114	10,664
2023	10,347	183	10,529	4,835	15,182	5,018	15,365
2024	10,398	260	10,658	4,746	15,144	5,006	15,404
2025	10,187	347	10,534	4,637	14,824	4,984	15,172
2026	9,982	446	10,428	4,531	14,513	4,977	14,959
2027	9,781	559	10,340	4,428	14,209	4,987	14,768
2028	9,586	686	10,272	6,275	15,860	6,961	16,547
2029	9,395	831	10,226	6,146	15,541	6,978	16,372
2030	9,209	996	10,205	6,021	15,229	7,017	16,226
2031	9,027	1,184	10,210	5,898	14,925	7,082	16,109
2032	8,849	1,368	10,218	5,779	14,628	7,148	15,997
2033	8,676	1,551	10,227	5,663	14,339	7,214	15,890
2034	8,506	1,731	10,237	5,549	14,055	7,280	15,786
2035	8,340	1,909	10,249	5,438	13,778	7,347	15,687
2036	8,178	2,064	10,242	5,330	13,508	7,394	15,572
2037	8,020	2,198	10,218	5,224	13,244	7,423	15,442
2038	7,865	2,315	10,180	5,121	12,987	7,436	15,301
2039	7,714	2,415	10,129	5,020	12,735	7,435	15,150
2040	7,567	2,501	10,068	4,922	12,489	7,423	14,990
2041	7,423	2,574	9,997	4,826	12,249	7,400	14,822
2042	7,282	2,635	9,917	4,732	12,014	7,367	14,649
2043	7,144	2,687	9,831	4,640	11,784	7,327	14,471
2044	6,081	2,729	8,810	4,551	10,631	7,280	13,360
2045	5,969	2,763	8,733	4,463	10,433	7,227	13,196
2046	5,861	2,790	8,651	4,378	10,238	7,168	13,029
2047	5,754	2,811	8,566	4,294	10,048	7,105	12,860
2048	5,650	2,826	8,477	4,212	9,862	7,039	12,689

D.SUBSTITUTES

Table D.1. *Crude Oil Exporters and Top 5 Target Markets*

Country	Japan	China	US	S. Korea	India
Saudi Arabia	40.00%	13.00%	13.00%	27.00%	17.00%
Algeria	0.30%	0.00%	0.90%	0.00%	1.00%
Angola	0.00%	12.00%	1.70%	0.00%	3.80%
Azerbaijan	0.00%	0.00%	0.00%	0.00%	5.00%
Iran	2.00%	7.50%	0.00%	1.00%	11.00%
Iraq	1.60%	8.60%	7.70%	10.00%	19.00%
Kazakhstan	0.70%	0.00%	0.00%	1.40%	0.90%
Kuwait	6.90%	4.40%	1.90%	13.00%	5.30%
Libya	6.00%	0.90%	0.90%	1.00%	0.00%
Mexico	1.50%	0.00%	8.00%	2.20%	3.30%
Nigeria	0.00%	0.30%	4.50%	0.10%	9.70%
Norway	0.00%	0.40%	0.60%	0.00%	0.00%
Oman	0.90%	7.70%	0.00%	0.40%	1.70%
Qatar	7.30%	0.00%	0.00%	5.90%	1.60%
Russia	5.70%	14.00%	0.00%	7.00%	1.40%
UAE	24.00%	2.60%	0.30%	8.20%	8.00%

Table D.2. *Crude Oil Exporters and Other Target Markets*

Country	Singapore	S. Africa	France	Spain	Italy
Saudi Arabia	18.00%	46.00%	12.00%	9.70%	8.60%
Algeria	0.80%	0.00%	10.00%	2.20%	2.00%
Angola	0.00%	21.00%	1.40%	3.80%	1.30%
Azerbaijan	0.00%	0.00%	2.40%	1.40%	19.00%
Iran	0.00%	0.00%	11.00%	6.30%	12.00%
Iraq	1.70%	0.00%	0.60%	5.60%	12.00%
Kazakhstan	0.40%	0.00%	15.00%	6.20%	5.70%
Kuwait	11.00%	0.00%	0.30%	0.00%	4.60%
Libya	1.10%	0.00%	6.80%	8.80%	7.80%
Mexico	0.00%	0.00%	0.00%	13.00%	0.30%
Nigeria	0.10%	26.00%	9.70%	15.00%	2.70%
Norway	0.00%	0.00%	9.00%	4.20%	1.10%
Oman	0.30%	0.10%	0.00%	0.00%	0.00%
Qatar	20.00%	0.00%	0.00%	0.00%	0.00%
Russia	1.90%	0.00%	11.00%	4.20%	12.00%
UAE	27.00%	0.00%	0.50%	0.00%	0.00%