OFFSHORE OIL AND GAS AND THE ENERGY TRANSITION: ASSESSING THE POLICY FUTURE FOR OFFSHORE WIND ENERGY IN TEXAS

A Thesis

by

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ABSTRACT

The energy sector, including transportation, accounts for about 75% of greenhouse gas emissions nationally. As a result, national efforts in line with globally-centered climate mandates have set standards to ensure that emissions are controlled, and renewable forms of energy enhanced. Of these renewable energy enhancements, offshore wind energy shows one of the greatest potentials to assist in reaching the goals in the Paris Accords. However, till date there remains only two active offshore wind farms in Rhode Island and Coastal Virginia, despite the State of Texas being the national leader in onshore wind energy. This thesis examined the potential for offshore wind energy in Texas by drawing parallels between the offshore oil and gas and wind sectors using technological innovation systems (TIS) framework and a timeseries modeling approach. The discussions of the seven functions in the TIS showed that as a very mature industry, offshore oil and gas has had immense support from the State. Also, the current growth trajectory of onshore wind is heavily attributed in part to non-market renewable energy strategies and drivers by the State in the late 1990s. In answering the question of whether a policy future for offshore wind exists, a hypothetical case was made by modeling reduction scenarios in conventional fuels should global and national mandates intensify for renewable energy generation. Since wind production requirements may increase as reductions hypothetically happen, justification for offshore wind in the Gulf of Mexico was shown to likely meet Texas' future renewable electricity needs. Furthermore, it was identified that a future policy for offshore wind may exist in the not-too-distant-future for the State. Lessons from Block Island Wind Farm and the TIS assessment were contextualized as (pre)conditions and recommendations to kick-start an offshore wind industry in Texas.

DEDICATION

I dedicate this thesis first and foremost to God Almighty for giving me the strength and fortitude to complete this work. Secondly, this thesis would not have been possible without the tireless support and efforts of my husband, Dr. Nana Ansah Akuffo and the motivation from my girls, Mireya and Miranda Akuffo during the writing of this research. They inspire me every day.

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Contributors

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NOMENCLATURE

AC	Alternating Current
ACP	American Clean Power Association
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARIMA	Autoregressive Integrated Moving Average
ARRA	American Recovery and Reinvestment Act
AWEA	American Wind Energy Association
BEV	Breakthrough Energy Ventures
BI	Block Island
BOEM	Bureau of Ocean Energy Management
BP	British Petroleum
BSEE	Bureau of Safety and Environmental Enforcement
CCS	Carbon Capture and Storage
CEO	Chief Executive Officer
CO2	Carbon Dioxide
COVID-19	Coronavirus Disease 2019
CREZ	Competitive Renewable Energy Zone
CRS	Congressional Research Service
CVOW	Coastal Virginia Offshore Wind
CZMA	Coastal Zone Management Act
DM	Dallas Morning
DOE	Department of Energy
DOI	Department of the Interior
EIA	Energy Information Administration
EIS	Environmental Impact Statement
EOR	Enhanced Oil Recovery
EPA	Energy Policy Act
ERCOT	Electricity Reliability Council of Texas
EU	European Union
EVs	Electric Vehicles
FERC	Federal Energy Regulatory Commission
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
GOM	Gulf of Mexico
GOP	Grand Old Party (The Republican Party)
GW	Gigawatts

HC	Houston Chronicle
IBM	International Business Machines
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ITC	Investment Tax Credit
KWH	Kilowatt Hour
LCOE	Levelized Cost of Electricity
MW	Megawatts
MWH	Megawatts Hours
NDC	Nationally Determined Contributions
NEPA	National Environmental Policy Act
NIMBY	Not-In-My-Backyard
NMFS	National Marine and Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOX	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NRR	Natural Resource Revenue
NWRC	National Wind Resource Center
NYSERDA	New York State Energy Research and Development Authority
OCS	Outer Continental Shelf
OCSLA	Outer Continental Shelf Lands Act
OEM	Original Equipment Manufacturers
O&G	Oil and Gas
OPEC	Organization of the Petroleum Exporting Countries
OTC	Offshore Technology Conference
PPA	Purchasing Power Agreement
PTC	Production Tax Credit
PUC	Public Utilities Commission
R&D	Research And Development
REC	Renewable Energy Credit
RES	Renewable Energy Standards
RFI	Request for Interest
RFS	Renewable Fuel Standards
RI	Rhode Island
RPS	Renewable Energy Portfolio Standard
RRC	Texas Railroad Commission
SAMP	Special Area Management Plan
SB	Senate Bill
SLA	Submerged Lands Act

SOX	Sulfur Oxides
TCEQ	Texas Commission on Environmental Quality
TETF	Texas Emerging Technology Fund
TIS	Technological Innovation System
TLP	Tension Leg Platforms
TW	Terawatt
TX	Texas
UCLA	University of California, Los Angeles
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USDS	United States Department of States
USFWS	United States Fish and Wildlife Service
WETO	Wind Energy Technology Office
WMO	World Meteorological Organization

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

1. INTRODUCTION

The current energy needs of the United States of America (U.S.) and the global transitioning to a more energy efficient and lesser emissions future from conventional-based fossil fuels have resulted in gradual federal and state regulatory actions toward decarbonization. However, the same trends are not observed in the offshore wind energy sector, which is a growing and resilient renewable source of energy that can be harnessed to boost the mix of Texas' energy requirements. Until now, there is not a single wind farm offshore in Texas. In fact, in the whole of the U.S., there are only two offshore wind farms, Block Island in New Shoreham, Rhode Island, and Coastal Virginia Offshore Wind (CVOW) project, both situated in left-leaning States. The purpose of this thesis therefore is to understand the nature of the offshore oil and gas industry in Texas and to draw parallels with the renewable wind energy sector. If an energy transitioning agenda is to be pursued, then more policy efforts must be geared toward renewables. Technological development and innovation are used as lenses to draw parallels and to understand the evolution of both sectors. The analytical framework of technological systems of innovation is utilized through a content analysis qualitative research approach to discuss the interlinkages between certain key energy actors involved in business, regulation, and knowledge development in the sector. The second part of the assessment used a timeseries approach to make predictions and a case for offshore wind energy and whether a policy future for offshore wind energy exists in Texas. This is the introductory Chapter, and it presents the background, research questions, analytical framework, and methodology, which guided the research.

1.1. Background to the Study

1.1.1. The Winter Freeze and U.S. Energy Goals

In the week of February 15th, 2021, Texans woke up to power outages brought on by a winter storm not witnessed in the last 50 years. Climate-driven weather impacts caused a shortage in the electricity grid, coupled with frozen generators and boilers, which ordinarily would have supplied enough energy to meet the surge in demand. This brought on a 'state of emergency' sanctioned by current President Joe Biden and Governor Greg Abbott. The impact of a lack of electricity supply, which affected Texans goes to demonstrate the importance of different energy sources. Although the State initially blamed renewable sources (especially frozen wind turbines) for the deficit, natural gas was also culpable (Douglas & Ramsey, 2021). Over the last several decades, governments around the world have collectively pledged to slow global warming through frameworks such as the Montreal Protocol, Agenda 21, Kyoto Protocol and the Paris Accords (or Agreement), amongst others. Countries have agreed to develop mechanisms to reduce greenhouse gas (GHG) emissions unto the earth's atmosphere. Despite these intensified efforts, GHGs emissions have precipitated global warming to unprecedented heights. From 1981, the rate of increase in temperature has more than doubled to about (0.18°C / 0.32°F) than it did in the 1800s (NOAA, 2020). This has intensified in the U.S. with emissions from fossil fuel combustion contributing about 75- 80% of total emissions (EIA, 2020b).

On the other hand, considerations must be made of the growing demand for energy to meet supply needs because of economic and population growth requirements. In the 1970s, the U.S. framed its energy goals on three tenets: energy security, energy efficiency and sustainable production and consumption of energy, while protecting the environment (see Congressional Research Service, Yacobucci, 2016). These energy policy goals have prompted the country to adopt strategies that enhance energy and renewable energy independence, such as clean energy standards, renewable portfolio standards and incentives under the American Clean Energy and Security Act of 2009 and the Clean Air Act (1970) with its amendments to curb GHGs emissions.[1] Also, nationally, the oil and gas industry has undergone a metamorphosis in production with technological improvements in hydraulic fracturing and horizontal drilling unlocking the potential of resources from unconventional shale formation in a bid to meet rising energy demand. These technologies have made natural gas relatively cheaper in the U.S., despite the environmental impacts such extraction causes.

[1] The renewables portfolio standard (RPS) is "a policy instrument that ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources" (Langniss & Wiser, 2005).

The rise in production of these fossil-based fuel sources due to the technology it utilizes has also corresponded with increased consumption and demand for renewable energy precipitated by federal and state policy incentives that bolstered teething renewable energy industries. See Figure 1.1 in section 1.1.2, which shows general energy consumption trends in the U.S. as well as trends in renewable energy sources. There is a lot at stake in policy, especially with the energy transitioning agenda at the federal level vis-à-vis state level strategies in implementation.

1.1.2. The Profile of Texas' Energy Mix

Nationally, the U.S. uses and produces many different energy sources from primary conventional fossil fuels, i.e., petroleum, natural gas, and coal to nuclear and renewable energy sources, and from secondary sources. Fossil fuels are the main energy source for the country. Figure 1-1 extracted from the EIA, (2020a) website shows the following: 35% of the nation's energy originates from petroleum, 34% from natural gas, 9% from nuclear power, 10% from coal, and 12% from renewable sources in 2020.

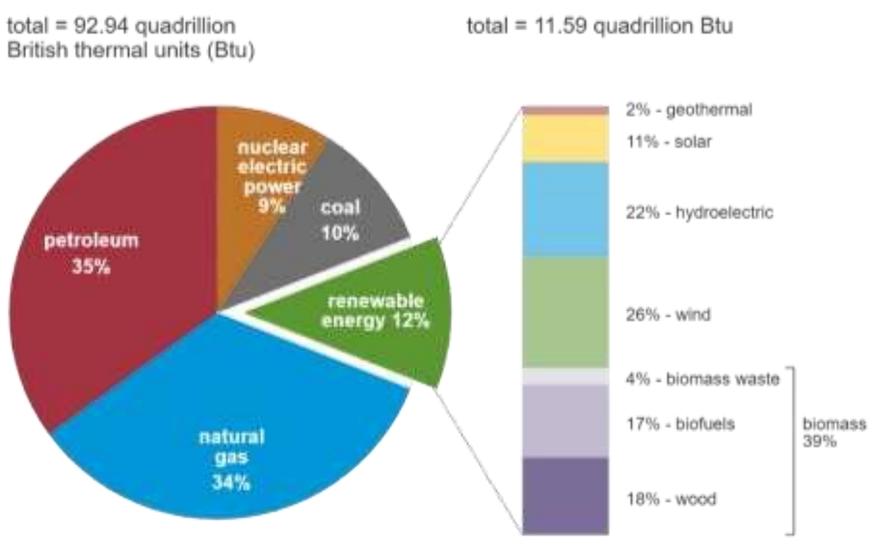

Figure 1-1: U.S. Primary Energy Consumption by Energy Source (2020)
Source: EIA (2020a)

In 2020, energy (petroleum) production fell by 96 quad British Thermal Units (btu) more than 5% from 2019 due to the spate of COVID-19 cases and protocols implemented to curb the virus (EIA, 2020a). Although, for the first time, energy production exceeded consumption in 2019, by 2020, this was reversed. In 2020, coal production also fell by 50% of what it was in 1998 and natural gas and renewables increased to fill in the gap (EIA, 2020a). In terms of the Gulf of Mexico (GOM), it accounts for about 25 percent of domestic oil production and 15 percent of natural gas. Also, the market for renewable energy, particularly solar and wind has become competitive. In 2019, wind accounted for most of the U.S. new electricity generating capacity (of about 26%). The EIA projects that 39.7 gigawatts (GW) capacity of electricity generation will be added by developers and power plant owners of solar and wind, adding new capacity (EIA, 2020a).

At the state level, Texas produces more electricity than any other - more than double the amount that the State of Florida produces from a variety of sources. In 2020, it accounted for 43% of the nation's crude oil production and 26% of its marketed natural gas production. Texas was also sixth in the nation in terms of per capita energy consumption and is also the nation’s third-largest net energy supplier. Figure 1-2: Texas Net Electricity Generation by Source (2021) shows net electricity generation for June 2021.

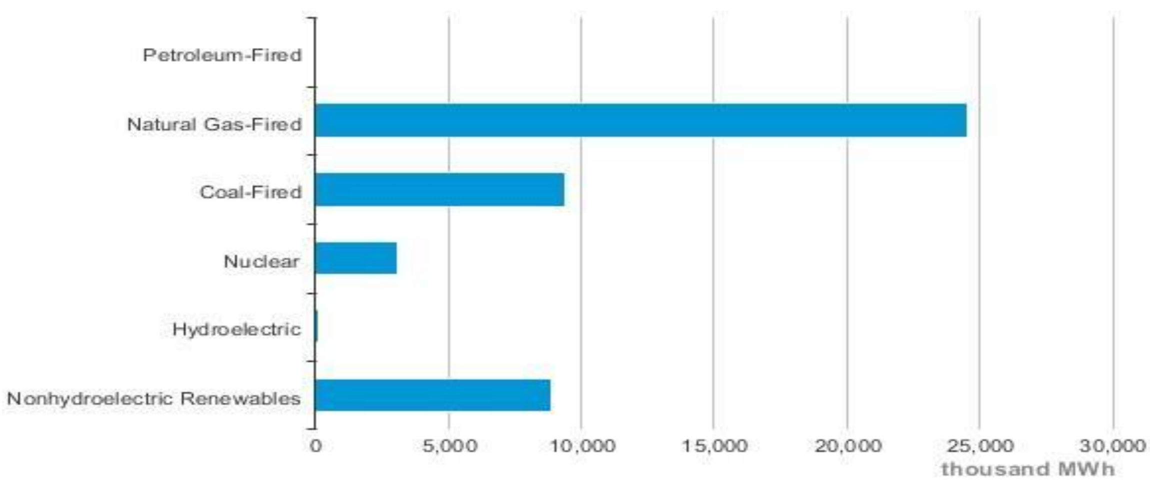

Figure 1-2: Texas Net Electricity Generation by Source (2021)

Source: (EIA, 2021b)

Texas has an annual energy production and consumption of 11% and 10% respectively of the entire U.S. energy capacity (EIA, 2021a). Figure 1-3: Texas Energy Consumption (2019) highlights energy consumption by source for 2019 in Texas.

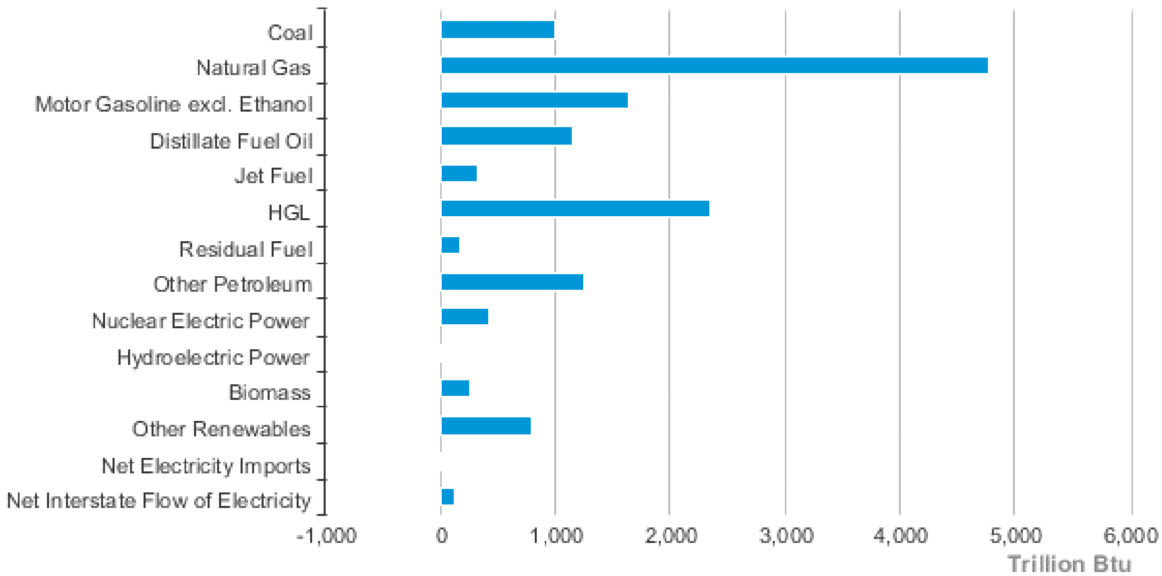

Figure 1-3: Texas Energy Consumption (2019)

Source: EIA (2021a)

The point is that Texas has a significant footprint in both offshore oil and gas and the renewable energy industry. Majority of the renewable energy production comes from wind. It leads the nation in wind energy powered generation, producing about 25% of total wind production for electricity (Linowes, 2018). A large segment of offshore energy production in the Gulf of Mexico contributes to the national reserve as well as to the State of Texas. In terms of wind, it has over 150 installed wind farms onshore and a total capacity of about 31,000 MW as of 2020 (EIA, 2021a; Powering Texas, 2020). With such a huge potential, why have great strides not been made in expanding the offshore wind capacity in the State? Assessing the situation in Texas therefore presents a good testing ground to discuss the policy implications for offshore renewable wind energy and to draw lessons from the Block Island Offshore Wind Farm and the offshore oil and gas sector. Also, the nature of offshore technologies, for example platforms and semi-submersibles, also indicate that to a certain extent the transition from offshore oil and gas to wind and other renewables may not be as difficult as anticipated, as wind becomes very competitive and as mandates remain to forge a mature renewable energy industry.

1.2. Literature Review

Since this thesis is focused on the policy aspects of energy and the transition, this section discusses literature on energy policy and legislation guiding the U.S. and the energy transition. It highlights Texas' renewable energy agenda in the 1990s and how that enabled it to succeed as the wind energy leader nationally.

1.2.1. Evolution of U.S. Energy Policies

To understand the policy drive of Texas, it is important to review how national energy policy impacts the position of the State in relation to energy production. Nationally, the three main U.S. energy policy goals are energy security assurance, maintaining a low cost of energy to meet demand, and environmental protection in the pursuit of energy extraction and consumption (Yacobucci, 2016). Most states' energy laws are framed around several issues, i.e., the type of resource, its availability and geography, the cost of extraction, and the impact on the environment and the market (i.e., the demand) for the commodity in administering energy resources. Prior to 2010, the U.S. was a net importer of natural gas, until it recently became a dominant player in the global industry. This feat was precipitated by the 1973 embargo placed by the Organization of the Petroleum Exporting Countries (OPEC) on the United States. This initiated a search for energy security in the U.S. and led to a rebalancing of global powers by States, who were mainly producers of petroleum resources and wanting to get out of the shadows and control of OPEC. The U.S. Congress passed the Energy Policy and Conservation Act (1975), which abolished the exportation of crude oil to enhance domestic energy security. The Act directed the president to ban crude oil exports and established a fuel economy standard for the transportation industry, as well as an agency to store and monitor petroleum reserves for the country in times of scarcity in the Gulf of Mexico (Joskow, 2001; Vann, 2014).

I. From 1970s to 1990s

From 1978 to 1982, U.S. petroleum usage was down from 18.8 million barrels per day to 15.2 million (Congressional Research Service- CRS, 2007). The sharp decline, which was caused by increasing crude oil prices, led to the expansion of other sources of energy, such as natural gas, gasoline (blended with ethanol) and voluntary conservation. OPEC operating as a monopoly decided to reduce its production to maintain its high oil prices, but other oil producers filled in the gap by over supplying the market to capture the rents from the high prices. Eventually, the high oil surplus caused prices to drop to historical lows of under $10 per barrel by 1986. The effect that Saudi Arabia had as swing power within the OPEC made them powerful allies with the U.S. However, when that relationship soured, the U.S. reframed its policy mandate to ensure energy security and local capacities for transportation and electrification to reduce its dependence on foreign states (Yacobucci, 2016).

In 1990, after the invasion of Kuwait by Iraq, a leading oil producer, prices per barrel rose from $16 to $36 (Bamberger, 2004). The instability in oil prices and shortage of domestic oil supply resulted in President George H.W. Bush proposing a federal energy policy aimed at guaranteeing energy security by increasing oil and gas supply, nuclear power production and research to boost reserves of fossil fuel to meet future demand (Joskow, 2001). By 1993, the Energy Policy Act of 1992 (EPAct92) had been passed by the outgoing Bush administration. The focus of the policy was on promoting improvements in energy efficiency, renewable energy, alternative-fuel vehicles, and new technologies for extracting and using conventional energy sources according to Yacobucci (2016).

II. Energy Policies from the 2000s until Date

Joskow's (2001) review of energy policies notes that the years after the EPAct92 were crisis free, with the federal government working with States to establish guidelines for implementing the requirements in the policy. However, by 2003- 2004, growing environmental quality concerns, and issues around energy security motivated a review of energy policy in the past decade and led to the passing of the 2005 Energy Policy Act. The Act, according to Joskow (2001) was supply-sided and driven by the Bush administration with the intention of bolstering the production of oil and gas to achieve energy security through tax incentives. According to Yacobucci (2016), the incentives, which totaled about $14.5 billion were to enhance oil and gas and boost coal production, while facilitating electricity generation and transmission.

The Act also introduced a federal renewable fuel standards (RFS) program initiated standardizing fuel requirements across the U.S. The RFS required that transportation fuels contain a minimum of biofuel - about 10%- 25% to enable the U.S. cut its GHG emissions (Ibid). By 2007, the Energy Independence and Security Act was also passed to further enhance greater energy independence, security, and to ensure and an increased production of clean renewable fuels. Also included in the policy was consumer protection in energy usage; energy efficiency standards on appliances; buildings and vehicles; and the provision of enough funding to promote research and development (R&D) in renewable energy sources. A major evolution here was including energy efficiency standards and performance for Federal Government buildings. The Act required renewable energy sources to be included in the grid, while standardizing energy efficiency for all buildings, and increasing federal RFS to contain 36 billion gallons of biofuels in transportation fuel by 2022 (CRS, 2007).

1.2.2. The Energy Transition and Texas' Pursuance of Wind and Other Renewables in the 1990s

Before discussing the post-2007 policies that laid the foundation for the transition, it is important to recognize the global momentum that initiated this transition. Many global frameworks, such as the United Nations Framework Convention on Climate Change (UNFCCC) had countries commit to stabilizing GHGs concentrations “at a level that would prevent dangerous anthropogenic interference with the climate system” (UNFCCC, 1992). Rising GHG emissions led to the landmark Paris Accords in 2015 by the United Nations to limit global temperature increase in this century to 2^0C, while pursuing the means to limit the increase to 1.5^0C. The goal of the Accord is for assenting countries to mitigate their impacts on climate change and foster sustainable development initiatives for the benefit of all mankind. Within this framework, the energy sector has been recognized as important to realizing the goals of the transition. Hence, the focus on energy transition in the climate change agenda. Currently, the most common definition for ‘energy transition’ is a pathway towards transformation of the global energy sector from fossil-based to zero-carbon by the second half of this century according to (IRENA, n.d.)

At the heart of the transition is the need to reduce energy-related CO2 emissions to limit climate change. Decarbonization of the energy sector requires urgent action on a global scale, and while a global energy transition is underway, further action is needed to reduce carbon emissions and mitigate the effects of climate change nationally. Renewable energy and energy efficiency measures can potentially achieve 90% of the required carbon reductions. In the aftermath of the financial crisis post 2008, other bills were passed to support the operationalization of the 2007 energy policy. Investments in the integration of renewable energy into the electric grid system was a highlight in the American Recovery and Reinvestment Act (ARRA) post 2008. The ARRA approved approximately $35.2 billion for the U.S. Department of Energy to upgrade and restructure the department (Yacobucci, 2016).

From 2015- 2016, two prominent policies on the energy sector were the Energy Policy and Modernization Act of 2012 and the North American Energy Security and Infrastructure Act of 2015. These two policies have been instrumental in furthering the earlier energy policy agenda of the past two decades. These policies premised on energy efficiency and the third priority of conservation from the first energy policy in 1975, aim to enhance energy efficiency in federal buildings, industrial processing centers, and schools across the nation (Yacobucci, 2016).

I. Texas and Renewable Energy: Why Texas decided to pursue Wind in the 1990s

In terms of renewable energy policy, Texas began its transition about a decade before most states initiated renewable energy incentives and mandates. Texas in the mid-1990s recognized the impacts that air pollution posed to the State and convened a panel to strategize on reducing environmental pollution while promoting cleaner and abundant energy security. The panel's report showed that Texas could "provide both environmental and economic benefits and maintain its position as a world energy leader," and hence passed standards for energy efficiency and renewable energy under both a Republican president and governor (Maguire, 2016). The State's legislature set a goal of the adding 2,000 megawatts of renewable power in 5 years (Diffen & Smith, 2010). To facilitate the building of the renewable industry, its house passed a $7 billion bill requiring 3,600 miles of new transmission lines to support the wind sector in West Texas under Competitive Renewable Energy Zones (CREZ). This laid the foundation for Texas, a leader in wind energy. Texas set the targets and let the market figure out how to meet them (Maguire, 2016).

All in all, the various energy policies under the two main political ideologies of Democratic and Republican values operated differently; however, they all seemed to be framed around the very first policy goals set out in the energy policy of the U.S. in 1975. We see a gradual transition from maintaining energy security to increasing the U.S. strategic petroleum reserves. The decade after the 1990s was uneventful except on the international front when the Clinton Administration signed the Kyoto Protocol but did not ratify it. In the energy policy space, nothing much happened under his administration. Nonetheless, a clear distinction can be seen in the way supply-side policies such as government incentives to bolster fossil fuels development is a major feature in the energy policy agenda of Republican governments.

Conversely, Democratic leaning governments have majorly focused on enhancing renewable energy sources and providing alternatives to reduce GHG emissions and climate change. In certain instances, demand-driven policies, which foster competition have been a feature in energy policy. This is particularly true from the year 2000 onwards, when aging transmission infrastructure coupled with grid inefficiencies warranted the restructuring of the energy management systems in the country (see Joskow, 2001). Improving energy infrastructure and technological development should be a key goal if any policy mandate is to be successful, especially since the infrastructure to integrate even renewable energy must be improved for the next decade (Vann, 2018, p. 2). This is the key rationale for the research's focus on technology development and energy transition for the wind sector in Texas.

1.3. Defining the Research Problem

The United Nations Framework Convention on Climate Change (UNFCCC's) Paris Accords as well as national goals and state clean energy efforts cannot be achieved without investments in technology and innovation to support the transition. The energy transition is very critical to the Texas economy since the renewable energy sector can simultaneously create jobs, lower carbon emissions, and contribute to local economic development. Within that ambit, it is necessary to pinpoint the importance and role that enabling technologies play in both offshore oil and gas and the renewable energy sector. The International Renewable Energy Agency's (IRENA) (2016) roadmap for renewable energy indicates the central role that technology plays in the evolution of the sector in terms of the energy transition. An accelerated deployment of energy efficiency and renewable energy technologies are the key elements for energy transformation (International Energy Agency- IEA & IRENA, 2017, p. 10). That deployment would build on enabling energy policy frameworks that consider energy systems thinking, encompassing energy supply and demand (IRENA, 2018). Much of this will comes from concerted efforts and partnership between oil and gas and renewable energy players. However, in 2021, as subsidies and tax incentives to support the renewable energy sector are being exhausted for wind, new alliances are needed from camps such as the offshore oil and gas sector to sustain the momentum of the transition. Hence, the validation for this study, especially in a State like Texas where the wind characteristics are suited for onshore and offshore wind projects, coupled with rising energy demands and population growth. In this regard, what policy future can be identified to catapult a non-existent sector (such as offshore wind) to a burgeoning sector like onshore wind or is there even a policy future for offshore wind?

1.4. Research Objective and Questions

From the above discussions, wind energy, one of the largest renewable sources in the U.S. and Texas specifically, which presumably should have grown at an unprecedented rate, has only overtaken coal in production in Texas recently (EIA, 2021a). Texas, the energy capital of America has implemented forward looking policies toward renewable energy; however, to what extent has the renewable energy transition been enhanced by the institutions that implement these policies? It is important to note that Texas has a matured oil and gas industry that has been in place for almost a century. There are lessons that can be drawn from offshore oil and gas for a potential offshore wind energy industry if the conditions are right. As a result, the primary objective of this thesis is to examine the development of the offshore oil and gas sector and the potential future for transitioning to an expanded wind energy capacity offshore in Texas. The thesis is structured in four parts with three research questions intending to be answered in each Chapter. This introductory Chapter is the first part, the next three chapters are structured in light of the following questions:

- What is the history of offshore oil and gas policy in Texas and how has the introduction of new technologies changed the industry, and what are the similarities between the sector and offshore wind energy?
- What motivations and policy incentives have driven the development of the offshore oil and gas and wind sectors in Texas and how have these influenced both industries and the energy transition?

- What lessons in policy and business can facilitate the growth or lack thereof of a future offshore wind energy in the transition? A secondary question, which arises from this is whether there exists a policy future for offshore renewable wind energy in Texas?

The reason for the first question is that similarities between the two industries can help to better position wind for offshore wind expansion. If technologies within the sector are similar, then it can eventually be one industry that has the potential to pivot to offshore wind within the transition and if they are two industries, then more policy effort will be required to merge the two industries. Also, in terms of identifying whether a policy future exists for wind, there is need to understand how offshore oil and gas have successfully matured in the State and what policy motivations and incentives led to these successes, and what lessons can be drawn for offshore wind. Hence the second question for this research. The third question ties everything together by discussing the policy lessons for the renewable energy industry and the rationale for acceptance. To assess the policy future for an energy source requires that there is general acceptance of renewable energy sources and an understanding of the policy incentives that have allowed it to thrive in Texas. Here, the thesis models deficits that are likely to arise should global and national mandates compel states to adopt renewable technologies. Because the State has efficiency gains from offshore oil and gas, a case for a potential future of the offshore wind sector is made for Texas.

1.5. Analytical Framework: Rationale for Technological Innovation System

For this thesis, the technological innovation system (TIS) framework was used as the analytical framework to guide the assessment of how technological innovation in the offshore oil and gas and renewable wind sector evolved in Texas, in terms of functionality and the incentives that drove the success or lack thereof of these industries. The technology-specific features of the TIS system according to Bento & Fontes (2015) make it an attractive framework for inquiring about competition between new and emerging technologies, and incumbent technologies, as well as for comparisons between global and national systems. Carlsson & Stankiewicz (1991) define TIS as a dynamic network of agents or actors interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology. The authors further contend that a TIS is made up of three components, the actors who consist of firms and organizations; the networks that work within supply and value chains, and the institutions that manage the entire set-up of an industry (Carlsson and Stankiewicz, 1991). The networks are the associations that channel knowledge either directly in the market or through non-market related influences. The role of institutions is to create the rules, norms and regulation that enable the interaction between actors. Institutions can greatly hinder or encourage the growth (or lack thereof) of an emerging technology (See Jacobsson & Bergek, 2004).

To analyze technological evolution in the renewable energy sector, some researchers use the TIS approach to enable a detailed assessment of the functioning of actors and agents, institutions and networks that constrain or induce innovation in energy (Edsand, 2017; Esmailzadeh et al., 2020; Jacobsson & Bergek, 2004). These comprise of functions that influence the generation and diffusion of a given technological artifact and are dependent on the actors, networks, institutions, and infrastructure that make up its structure (van der Loos et al., 2021, p. 2). Bergek et al. (2008) and Hekkert et al. (2007) identify seven functions that influence the generation and diffusion of technological innovations in an industry or for a knowledge product. These seven functions are presented with a description of the meaning of each function in Table 1-1: Functions within the Technological Innovation System (TIS).

Table 1-1: Functions within the Technological Innovation System (TIS)

FUNCTION	DESCRIPTION
F1: Entrepreneurial Activity	Private sector engagement in the industry, including incumbent diversification, startup activity and full-scale product demonstration

Table 1-1 Continued

FUNCTION	DESCRIPTION
F2: Knowledge Generation	Production of knowledge can occur at research institutes, such as polytechnic universities, independent research centers or within private companies in R&D departments. This is known as 'knowledge by searching'. 'Knowledge by doing, using and interacting' occurs through knowledge gained whilst developing commercial projects.
F3: Knowledge Diffusion	Knowledge diffusion is the exchange of knowledge and can occur between the varying actors that produce knowledge. It can be facilitated by networking organizations, R&D and commercial project collaborations.
F4: Guidance of the Search	Guidance of the search is the visions set forth either by the government in support of a new technology or from within the industry itself
F5: Market Formation	Market formation is the concrete establishment of a new market, often mandated by the government in the initial phases of development and supported by policy measures, subsidies, tax breaks, etc. Commercial market formation occurs once the technology has matured.
F6: Resource Mobilization	Public resource mobilization dedicates financial and human resources towards supporting a new technology, such as through tax breaks, subsidies, funding for research institutes, etc. Private resource mobilization occurs within companies that either invest in or diversify into a new technology. This can be either human or financial resources.
F7: Counteracting Resistance to Change/Legitimacy	Legitimacy is the private, public and civil society acceptance of a new technology. Actors can either resist change or increase legitimacy for new technologies through the formation of networks or coalitions. Such coalitions may lobby for or against specific policies, or more generally place an issue on the political or public agenda.

Sources: Table is extracted from van der Loos et al. (2021) and Hekkert et al. (2007)

Van der Loos et al. (2021) in using this framework to assess the evolution of wind energy in Netherlands and Norway contend that the seven functions are neither linear nor path dependent. However, the function interacts at different phases within the evolution of a technology with positive or negative feedback loops. This makes it an ideal framework to distinctly identify what is happening within and between functions. The energy sector in Texas is quite a complex and critical component of the growth of the economy since it contributes about 9% to the State's GDP (Allen, 2022). Conventional forms of energy have been the basis for this growth and have in the past and are currently being supported by the institutions that have been setup to regulate the industry. The rise of the renewable sector in the U.S. and the impact of carbon dioxide emissions on the global warming potential of the earth have catapulted renewable sources and particularly wind to the forefront of energy issues in Texas, which produces more wind generated energy than any other state. However, the transformation of the energy sector rests on an interplay of policy initiatives and various actors' interactions with innovation to induce technological transformation in the sector. Hence, for a critical component like the energy sector, assessing the nature of the technological transformation occurring within the sector would be vital in answering whether there is a policy future for offshore wind energy in Texas.

In terms of using the TIS framework, few studies have assessed how innovation and technological development are influencing the transition within the offshore oil and gas and wind industries. In the case of Texas there are no such studies. A search through the internet reveals a growing number of studies that have utilized the TIS framework to assess the energy sector based on these seven functions globally. Several authors have expanded them and used them in the assessment of energy systems in different contexts (van der Loos et al., 2021; Esmailzadeh et al., 2020; Edsand, 2017; Bento & Fontes, 2015; Jacobsson & Bergek, 2004). Esmailzadeh et al., (2020) conduct a review of the different indicators making up a TIS system to apply it to the case of Iran's renewable energy program. The assessment of the indicators for the TIS framework by the authors is the most up-to-date information on the TIS framework.

The thesis utilized an abridged version of Esmailzadeh et al. (2020) TIS themes to assess technological development happening within the offshore oil and gas sector and the transition to renewable energy in Texas. Since the focus of this research is offshore energy, the themes are adapted to consider elements of collaborations and partnerships between the two sectors. The themes/indicators are teased from Table 1.1 but are then tweaked to suit the study's research objectives. Hence, Table 1-2: Themes for the Evaluation of Innovation System Functions is a slightly abridged version of the indicators or (themes) under each category in the TIS framework. The most relevant themes that apply to the unique context of this research are presented in the Table.

Table 1-2: Themes for the Evaluation of Innovation System Functions for Offshore Oil and Gas and Wind Energy

FUNCTIONS	THEMES/ INDICATORS	REFERENCES
F1: Entrepreneurial Activity	New Wind Energy Projects and Technologies	(Wieczorek & Hekkert (2012)
	Offshore O&G Technologies	
	Wind Energy Infrastructure	
	Wind Energy Startup	
F2: Knowledge Generation	Offshore O&G Projects and Research Partnerships	Hekkert et al. (2007); Bergek et al. (2008)
	Offshore O&G - Wind Energy R&D Partnerships and Collaborations	
	Wind Energy Projects and Research Partnerships	
F3: Knowledge Diffusion	Knowledge Exchange between Offshore O&G & Wind Energy Companies	Hekkert et al. (2011)
	Offshore O&G Companies Piloting Offshore Wind Projects	
	Offshore O&G - R&D Partnerships and Collaborations	
	Wind Energy R&D Partnerships and Collaborations	
F4: Guidance of the Search	Offshore O&G Policy or Vision for New Entrants	Hekkert et al. (2011; 2007)
	Policies for Wind Energy Technologies and Development	
	Policy Motivation for Offshore O&G - Wind Energy	
	Offshore O&G Policy or Vision for New Entrants	
F5: Market Formation	Offshore O&G Market Incentives, Subsidies, Tax Breaks, Tax Credits	Esmailzadeh et al. (2020); Hekkert et al. (2011)
	Partnerships (O&G - Wind Energy) for Market Formation	
	Wind Energy Market Incentives- Subsidies, Tax breaks & Tax Credits	
	Offshore O&G Market Incentives, Subsidies, Tax Breaks, Tax Credits	

Table 1-2 Continued

FUNCTIONS	THEMES/ INDICATORS	REFERENCES
F6: Resource Mobilization	Federal and State Funding to Support O&G	Hekkert et al. (2011); Bergek et al. (2008)
	Federal and State Funding to Support Renewable Wind Energy	
	Foreign and Private Partnerships	
	Foreign Financing and Investment into Offshore O&G and Wind Energy	
	Private Financing and Investment into Offshore O&G and Wind Energy	
F7: Counteracting Resistance to Change/Legitimacy	Resistance to Offshore O&G	Edsand (2017); Hekkert et al. (2007)
	Resistance to Wind Energy	
	Social Acceptance of Offshore O&G	
	Social Acceptance of Wind Energy	

Source: Adapted from multiple sources and Esmailzadeh et al., (2020, pp. 6–7)

These themes/indicators and phrases are what the researcher relied on in the assessment of the TIS in Chapter Four.

1.5.1. Scheme of Analysis

Bergek et al., (2008) define a scheme for TIS assessment to guide how innovation research is designed. The scheme of analysis consists of several steps to guide researchers and analysts (see Figure 1-4: A Method of Analysis for Technological Systems of Innovation) in utilizing the framework. This is extracted from Oltander & Perez Vico (2005).

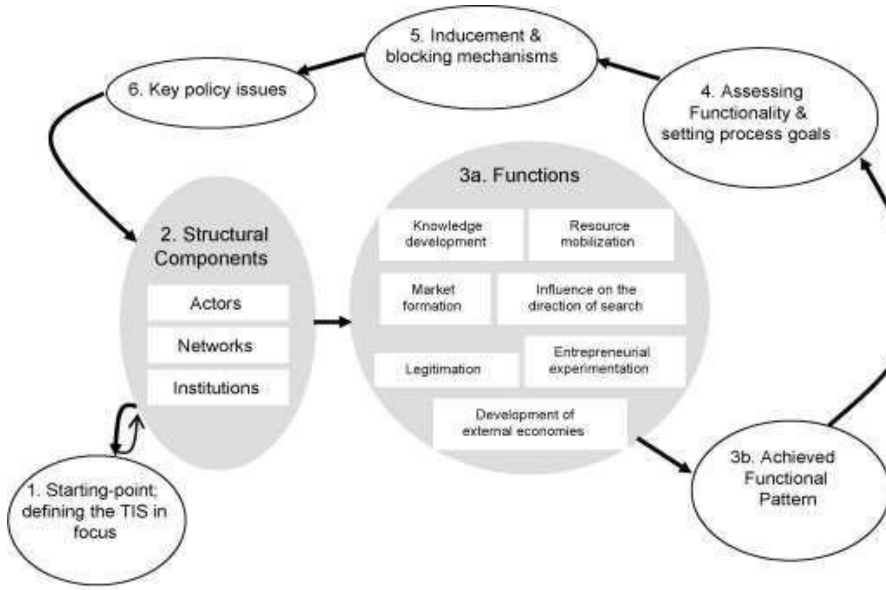

Figure 1-4: A Method of Analysis for Technological Systems of Innovation

Source: Oltander & Perez Vico (2005) cited in Bergek et al. (2008, p. 411)

In the Figure 1-4: A Method of Analysis for Technological Systems of Innovation, the first step is the starting point and requires defining the TIS systems and boundary of analysis. The second, is to identify the structural components (i.e., actors, networks, and institutions) that make up the system. The third step is to describe how each of the seven functions plays out in the system. The fourth and fifth steps assess process goals of how well the functions are fulfilled and set process goals in terms of a “desired” functional pattern step, and through that identify the drivers that either induce or constrain the development towards the desirable functional pattern. Finally, the sixth step, key policy issues related to the inducement and blocking mechanisms in technological innovation in an industry is discussed with recommendations for improving the system.

The above process (in Figure 1-4) is utilized for this research. The purpose is to provide an enhanced description and analysis of the involvement of the structural components, (i.e., the actors, networks, and institutions) in the offshore energy sector and how that has shaped the development of the industry. The structural components, in the sector are broad for both industries, comprising offshore oil and gas and wind industry players, companies, manufacturers of technologies, suppliers upstream, midstream, and downstream, as well as industry associations, regulators, policy makers, and research institutions, venture capitalists, financiers and knowledge-based institutions.

A key advantage of using this method is that it helps researchers to compare cases along quantitative and qualitative dimensions to portray variation in insights about a specific problem. This process will aid in answering the second and third research questions identified for the thesis. For this research, it is important to state that it's a snapshot into the potential offshore wind energy industry, hence the focus is not solely broad technologies within oil and gas, but rather on how the offshore oil and gas sector is somewhat creating a bridge or reaching out to a somewhat nursing industry like wind and the potential for growth and expansion. Chapter Two discussed drill and platform technologies to highlight the similarities between the two sectors and the nature of each industry. A working definition of TIS for this thesis is made to include a sub-system or a sectoral system of analysis. This means that the thesis focuses on knowledge fields exclusive to the sector and how several sectors cut across between the various themes. Bergek et al., (2008), point that this is often the case "…when the focus is a more "generic" knowledge field that several sectors make use of". This is the approach often taken by policy makers and since this is a policy enquiry, the approach is justified.

1.6. Research Methodology and Structure for the Thesis

In terms of using the framework, step one has been achieved by defining what TIS is and how it applies uniquely to the energy industry (i.e., to offshore oil and gas and wind). To address the research problem, Chapter 2 conducted a review of the history of offshore energy policies at the federal and state levels to highlight the critical issues and constraints to regulation. This is to help situate the context of technology and how that has shaped the history of the sector in the latter parts of the thesis write up. Data for this review is sourced from secondary sources, including manuals, guidelines reports and energy legal and policy documents from the department of energy, Bureau of Ocean Energy Management (BOEM), Environmental Protection Agency and the Texas Railway

Commission, Energy information Administration, Offshore oil and gas and Renewable Energy Association Websites, EIA, amongst others.

With regards to research questions 2 and 3, primary data is obtained from the two most popular newspaper sources in Texas, Dallas Morning News (DM) and Houston Chronicle (HC) using a content analysis qualitative research approach to analyze the news articles. According to Holsti (1969, p. 14), content analysis is "any technique for making inferences by systematically and objectively identifying special characteristics of messages." It is very useful in analyzing historical material to tracking trends over time and identifying evolving themes and drivers of a particular phenomenon. A thorough description of the entire research methods used for this thesis is provided in Chapter Three where the test for validity and reliability of the data is discussed in greater detail. Using the TIS framework, news articles and data gathered from the Department of Energy (DOE), the American Wind Energy Association (AWEA), American Clean Power Association, senior oil and gas companies piloting offshore wind energy projects in their energy portfolio, are also analyzed using the content analysis framework to understand the policy motivation and drivers from an industry perspective and the policy imperatives that have impacted the sector. In applying the conceptual TIS framework, the software NVivo is utilized by coding the various themes under the framework. This is achieved in Chapter Four within the broader context of the energy transition and the challenges facing the industry.

The sub-question under question 3 is addressed using time series modeling of the energy data sources in Texas' energy mix to make a simple prediction for renewable generation sources should renewable energy mandates target scaling-back natural gas to meet the country's 100% renewable generation for the electricity sector by 2035. Chapter Five which discusses the policy future makes a case for offshore wind in Texas, discussing lessons from Block Island Offshore Wind Farm and the pre-conditions that must be laid out for an offshore wind future. The (pre)conditions are in and of themselves regarded as recommendations needed to enhance the development of an offshore wind energy sector in Texas. These are outlined based on the actors within the networks and institutions in an innovative system for a potential offshore wind sector. The concluding Chapter summarizes the main arguments in this thesis, discussing the limitations to the study and recommendations for future research.

2. OFFSHORE OIL AND GAS AND WIND TECHNOLOGIES IN TEXAS

2.1. Introduction

This Chapter sets out to answer the first research question of the history of offshore oil and gas in Texas. The legal frameworks of the offshore oil and gas sector and some of the challenges to managing the sector are discussed. This is a review of the literature to identify the similarities between the two sectors using technologies as a proxy, and or whether this is an evolving sector that has the potential to pivot to offshore wind within the transition. However, if they are two separate industries, then more policy effort will be required to merge the two industries. It commences with a history of offshore oil and gas, legal frameworks, offshore oil and gas and wind technologies and a comparison of oil and gas technologies currently being used, as well as what is utilized in the only offshore wind farm in the U.S. The CVOW is a new pilot project consisting of 2 wind turbines, hence the thesis does not delve into its development. Importantly, the purpose of this review is to assist in answering whether there is a policy future for offshore wind energy in Texas. If these are highly intertwined industries where technologies can be modified or re-engineered for offshore wind development, then there is a future to be expected in enhancing wind energy development offshore in Texas.

2.2. History of Offshore Oil and Gas Mining

The offshore oil and gas sector is one of the biggest industries in Texas and has traditionally been facilitated by strong institutions and supply-centered policies that strengthened its value chains. In the U.S., production of oil and gas offshore commenced in the late 1890s. In 1881, oil wells were drilled from platforms in the fresh waters of the Grand Lake St. Mary's in Ohio. Wells & Wells (2011) point out that the wells were developed by small local companies, such as Bryson, Riley Oil, German American, and Banker's Oil, who drilled wells from piers extending from land out into the channel. The timeline from the 1890s until the late 20th century consisted of technological innovations and revolution in the oil and gas industry offshore. Some of these included early submerged drilling activities, which occurred on Lake Erie in the 1900s and Caddo Lake in Louisiana in the 1910s (Offshore Energy, 2010). Texas commenced well drilling off the coastline in the tidal zones into the Gulf of Mexico (GOM). Its first company, the Texas Company, developed the first mobile barges for drilling in the GOM. Shortly thereafter, wells were drilled in tidal zones along the Texas and Louisiana gulf coast (Ibid).

A recount of the history of offshore oil and gas by Offshore Energy (2010) argued that “when offshore drilling moved into deeper waters of up to 100 feet, fixed platform rigs were built, until demands for drilling equipment was needed in the 100- to 400-foot depth of the GOM, the first jackup rigs began appearing from specialized offshore drilling contractors such as ENSCO International". It is important to recognize the role that the GOM has played in pioneering many modern technologies currently used in offshore oil and gas drilling. The Blue Water Drilling Company in Texas accidentally invented the first semi-submersible in 1931, when pontoons were not sufficient to support the weight of the rig that they were planning to install in the GOM- hence it was towed between locations on the sea by a draught. It however maintained enough balance between the top of the pontoons and the underside of the deck leading to the discovery that these rigs could float on the sea (American Oil & Gas Historical Society, 2010). The Blue Water Drilling Company and Shell partnered to develop the floating technology further. After the first semi-submersible technology, the four-column submersible Blue Water Rig No.1 became operational in the GOM, many industry players have successfully designed specific floating and mobile drillers to support offshore oil and gas mining (Ibid). As of 2010, there were in existence over 620 mobile offshore drilling rigs (Jack-ups, semi-submersibles, drilling ships, and barges) available for service in the competitive rig fleet in the continental shelf across the world (Offshore Energy, 2010).

2.3. Overview of the Legal Frameworks for Offshore Oil and Gas

It is important to highlight some of the challenges within the legal frameworks and how the bifurcation of legal responsibilities within the continental shelf have delayed and, in some cases, hindered the progress of business entities and technological developments. To explain this, the concept of territorial ocean borders is discussed first. The definition of which aspects within the ocean is considered offshore is determined by State and Federal laws, as well as international law. Although steeped in customary International Law[2], the Federal Law, which governs offshore oil and gas development defines which portion of the sea is regarded as the continental shelf (ocean bearing natural resources). This includes all submerged lands lying seaward and outside of areas under State control (Vann, 2014). It constitutes 200 nautical miles of the coastline seawards from the baseline to the continental shelf. Of this, state lands along the coast are determined to include waters and land laying 3 miles from the coastline into the ocean. In some rare cases like in Florida and Texas, an additional 3 marine miles is included in the coastline as part of the State's sovereign rights (Ibid).

Vann's (2018) assessment of the offshore oil and gas regime in the U.S. posited that coastal nations have the exclusive sovereign rights to explore and exploit the natural resources in their demarcated continental shelf from which the breadth of the territorial sea is measured to where the outer edge of the continental margin does not extend up to that distance. Beyond this boundary to about 200 miles is the federal government's territory. In terms of the legal connotations, these demarcations are supported by the regime of the applicable State. For state lands, the Submerged Lands Act (SLA), which governs these lands defines areas lying three geographical miles from the coastline as belonging to the State. From this point, federal law under the Outer Continental Shelf Lands Act (OCSLA) applies and provides a comprehensive leasing program for the rent of resources

[2] The U.N. International Convention on the Law of the Sea, 1994, Art 76 (1) demarcates the continental shelf of a coastal State as comprising everything on and beneath the ocean to a distance of 200 nautical miles from the baselines of a coast as belonging to the State. Although the U.S. has not ratified this convention, the interpretation of Federal law upholds this distance and anything beyond this as international borders.

within the ocean. States along the coast have different regulations, which guides the management of the land (Ibid).

2.3.1. Sovereignty and Ownership

The Submerged Lands Act (SLA) (43 U.S.C. §§ 1301 et seq.) defines and protects the rights of coastal states to the demarcated boundary line by granting the states the right to title of natural resources, which are located within the coastal submerged lands and to three miles of their coastlines (except for Texas and Florida's Gulf of Mexico coastlines, which have in addition three marine leagues extra). The act states that: *"…the right and power to manage, administer, lease, develop, and use the said lands and natural resources all in accordance with applicable State law be, and they are, subject to the provisions hereof, recognized, confirmed, established, and vested in and assigned to the respective States or the persons who were on June 5, 1950, entitled thereto under the law of the respective States in which the land is located, and the respective grantees, lessees, or successors in interest thereof" (43 U.S.C. § 1311(a)).*

The SLA grants the State absolute control within its own supreme law to utilize and regulate the interest as it so determines. The passing of the Outer Continental Shelf Lands Act by Congress grants the federal government about 1.7 billion acres of waters for it to manage (Vann, 2018). However, in the context of oil and gas development, besides sovereignty, certain federal laws affect the management of offshore oil and gas. The different environmental management acts such as the National Environmental Policy Act significantly impacts the regulation of submerged lands and federal lands in the outer continental shelf of the United States.

As has already been established, the OCSLA, and additionally the DeepWater Royalty Relief Act govern offshore oil and gas development on the outer continental Shelf in the U.S. It gives the Secretary of the Interior the right to manage and grant leases for oil and gas on offshore federal lands. It achieves this through a competitive bidding process after consideration of all information and an environmental impact assessment of the potential threat and concerns under the National

Environmental Policy Act. According to CRS (2019), the Act provides guidelines for lease management and exploration of the oil and gas activities in the outer shelf in a safe and environmentally sound manner. They contend that the OSCLA's approach is based on five phases: (1) five-year leasing program; (2) individual lease sales; (3) geological and geophysical exploration; (4) plans for explorations; and (5) development and production. Its basic purpose is the management of federal natural resources in an expedited, judicious, and orderly way to enhance the national energy policy goals and a lower dependence on foreign energy resources for development (Vann, 2018, CRS, 2019).

2.3.2. Management of the Outer Continental Shelf

The lease process commences with the U.S. Bureau of Ocean and Energy Management (BOEM) (operating within the Department of Interior), who then investigates an area for leasing and having done all the necessary environmental due diligence submits the areas under consideration to the Secretary, after which the list is made public (in the federal register) as a call for bidders (BOEM, n.d.). The OCSLA defines the extent of the information needed in the lease application and after the grant of the lease, the leaseholder is afforded the right to develop and produce oil and gas subject to other applicable environmental laws. This lease is separate from the certificate, which is needed for actual drilling, which the lessee must also obtain from the BOEM. This approval process must be preceded by a detailed drilling plan to be permitted by a district supervisor at BOEM. The leasing process administered by the BOEM, consists of a five-year planning program, pre-leasing and sale, exploration, development and finally production (BOEM, 2017). Figure 2-1: Proposed Program for Leasing (2019- 2024) illustrated to showcase the areas currently under planned leasing activity by the BOEM.

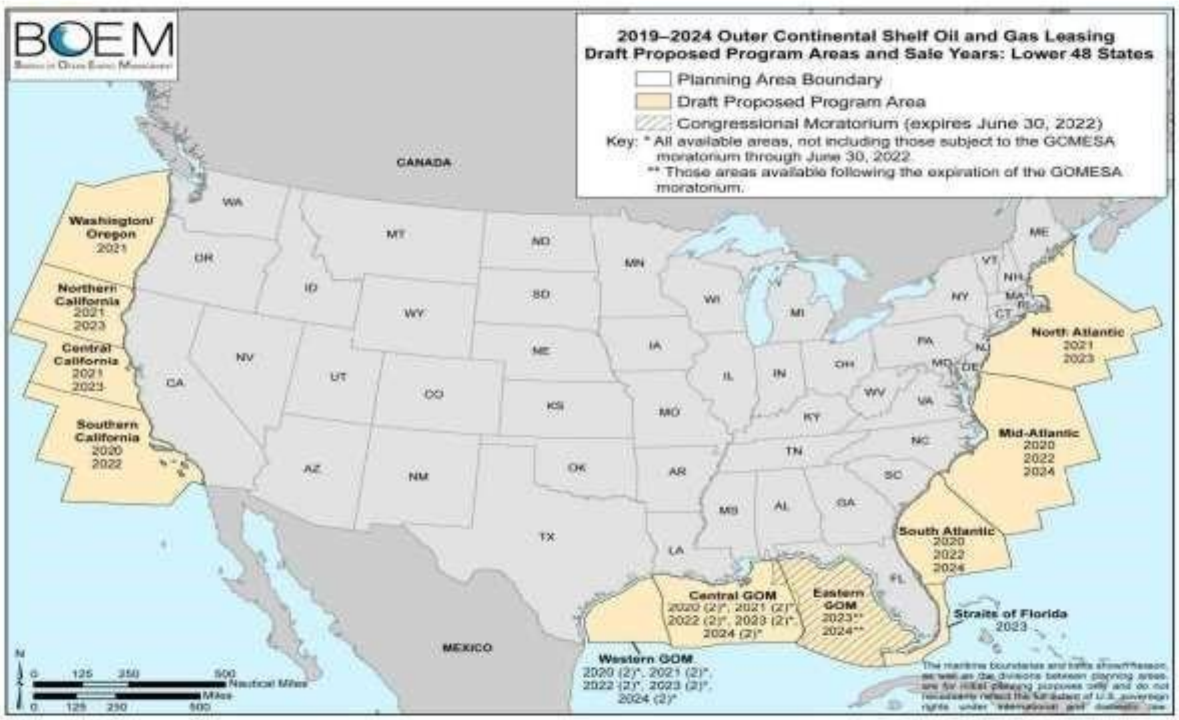

Figure 2-1: Proposed Program for Leasing (2019- 2024)

Source: BOEM OCS Leasing Draft Program cited in (CRS, 2019)

Vann (2018) posits that each five-year program establishes a schedule of proposed lease sales. The BOEM under the direction of the Secretary of the Interior manages the application processes regarding leasing in the OCS. The Secretary's under the advice of governors of affected states determines what the energy needs of the nation would be and internalizes the (social, environmental, and economic) impacts on his decision to establish a program in the OCS as well. The five-year program must go through the president and congress for comments and final approval by the Secretary. Any revisions or review of the program is subject to the secretary discretion once a year (Ibid). The BOEM under its Renewable Energy Program governs the development of such resources on the outer continental shelf. This is based on stipulations in the Energy Policy Act (EPA). BOEM develops the guidelines for regulating leases, easements, and rights-of-way on the outer continental shelf regarding renewable energy. The BOEM (2017) notes that they maintain responsibilities for the responsible development of renewable energy resources through conscientious planning, stakeholder engagement, comprehensive environmental analysis, and sound technical review.

Aside from the OCSLA, other comprehensive federal regulatory regimes govern ocean resources located in federal waters. This includes a cross-section of different laws on health, safety, and environment, resource conservation, and requirements for production-based royalties, and in some cases, royalty relief and development. Beyond the federal laws, the Texas Railroad Commission (RRC) established in 1891 regulates oil and gas production and holds the lion's share of oil and natural gas regulatory authority in Texas (RRC, n.d.). During the 1990s, the State of Texas decided to make natural-resource protection more efficient by consolidating programs in the State. According to the TCEQ (n.d.), this action led to the creation of the Texas Natural Resource Conservation Commission as a comprehensive environmental protection agency for Texas. Its name was later changed to the Texas Commission on Environmental Quality (TCEQ), and it is now responsible for air and water quality testing and permitting and several other environmental management tasks. These agencies together forward the federal agenda on state lands in Texas. Finally, the Texas general land office manages the state's oil and gas leases and royalty program.

2.3.3. Challenges with Offshore Oil and Gas Legal Frameworks

The above discussions provided an overview of the nature of the legal frameworks that govern the management of the offshore oil and gas sector, as well as offshore renewable energy. Although the regime is clear in terms of the delineation of rights to ownership and application of federal laws, there are several challenges, which arise in administering these resources.

The first issue is obvious, i.e., the multiplicity of laws, coupled with the main SLA and OCSLA makes it a more complicated process to administer these resources. Here, the main laws set the boundaries between the state and federal laws; however, there exist other complex federal laws that impact the administration of offshore oil and gas interests. The Congressional Research Service's discussions about the challenge to the legal framework also pointed to how multiple statutes, which govern aspects of offshore oil and gas development give rise to legal challenges especially with the National Environmental Policy Act (CRS. 2019).

In terms of its lease management, the National Environmental Policy Act (NEPA) regulations require the Environmental Protection Agency to publish notice of an intent to prepare an environmental impact statement (EIS) and its draft plans, at each stage of the leasing process in offshore oil and gas development. There have been instances where NEPA's decision regarding an EIS and its analysis have led to a stalling of the leasing process in offshore development. This resulted in lawsuits against the Agency by the Department of the Interior (DOI) because the NEPA process is significantly featured in the OCS leasing process. Although this causes intermittent breaks in annual leasing sales, Vann's (2018) discussions of this issue showed that the courts have sometimes argued that a more detailed environmental analysis would eventually be conducted in the final stages of the leasing sales; thus, allowing sale procedures to continue. In some cases, the courts have maintained that the Secretary's failure to fully assess certain cumulative environmental impacts violated the NEPA requirements (Ibid).

Another challenge worth noting is the contention about how leasing programs are affected and managed by changes in governmental administrations. During the Obama Administration, a five-year program for offshore leasing for 2017-2022 introduced by the Secretary was adopted by the BOEM to focus on new exploration and production in the GOM and off the coast of Alaska. However, by January 2018, the incoming Trump Administration had scrapped the leasing program for 2017-2022 and introduced a new five-year leasing program for 2019-2024. The proposed program included 47 lease sales, except in the North Aleutian Basin in Alaska. The Administration also introduced the U.S.' first national offshore Energy Strategy to further the development of offshore oil and gas development in the OCS (BOEM, 2017; Vann, 2018). It further revoked the Obama Administration orders and decisions regarding the OCS (Offshore Energy, 2019). The different policy approaches by the different administrations in the U.S. makes the governance and administration of the OCS and to some extent areas under the SLA quite challenging.

The thought process behind this Trump era rules per Vann (2018) is to incentivize the creation of about 840,000 jobs, increase government revenue to about $200 billion per year by 2035 and the U.S. productive capacity of crude oil. However, the lack of consistency in the rolling out of the five-year leasing program heightens uncertainty within the sector. The current Biden Administration canceled all offshore oil and gas lease sales under the former administration's program after suspending oil and gas leasing of federal lands and waters pending a review of the program that would have auctioned off over 78 million acres in the Gulf of Mexico (Center for Biological Diversity, 2021). Although the intentions might be good, what is observed generally, is a lack of well fashioned offshore oil and gas policy to ensure continuity and management of the sector throughout the different administrations in the U.S.

Overall, the discussions above indicate that State level motivation for continuing offshore development to an extent, seems greater with the federal government's program being hamstrung by political leanings or whims of who is in power, i.e., whether republican or democratic government. Although this is the case from our earlier discussions, what we also see in Texas is greater motivation for the industry to thrive with supply sided incentives by the state government, which encourages the development of the sector. For example, the Texas Railroad Commission (RRC) recently approved a 10-year H13 tax credit for the use of a 'green' enhanced oil recovery (EOR) technology for oil and gas industry players. The AssurEOR program developed by Locus Bio-Energy Solutions provides a cost-effective and sustainable biosurfactant treatment for recovery of oil and gas in depleted wells. It is assumed that as a tax break, it can help save oil and gas companies millions in taxes annually (Locus Bio-Energy Solutions, 2020).

As to whether this translates to the inherent motivation that drives businesses to innovate to remain competitive, it is not very clear. Conclusively, the legal framework plays a role and motivation in the development or retardation of a sector. For the offshore oil and gas industry, it is opined that the State's motivation and drivers for growing the sector, when it is greatest, enhance the development of the sector as well as the technological innovations in the sector. The next section discusses offshore oil and gas and wind energy technologies.

2.4. Offshore Oil and Gas and Wind Technologies

2.4.1. Offshore Technologies in Common between the Two Sectors

Offshore oil and gas production contributes significantly to U.S. energy demands. A vast majority of this comes from the Gulf of Mexico, where offshore technologies have often been tested. Due to the risks associated with offshore mining, technology and innovation are essential in mitigating these. The most common forms of drilling structures and advanced technologies are drilling barges and drillships, jackup platforms, semi-submersible platforms, submersible units, compliant tower, Comdeep platform, Fixed Platform, Floating Production System, SPAR Platform and subsea Production Systems. Also, much of the technical skill needed for offshore wind platforms are very identical to offshore oil and gas, since platforms are used in both cases. This expertise according to Klein (2020) extends to floating wind technologies or similar floating platforms, which have been adapted from the oil and gas industry.

There are three main technologies that are common to both sectors. These are the semisubmersibles, tension leg platforms (TLP) and spar buoys. The TLPs are secured permanently in the ocean floor by tethers or tendons (tension leg) per each structure. All vertical motion of the platform is eliminated. The semi-submersibles platform consists of large columns stabilized to primarily provide floatation stability. The spar-buoy is designed as columns to provide adequate water plane area to support all anticipated loading conditions and are spaced to support topside modules. Out of the three technologies, the type of technology selected is dependent on the wind speed of the area, the historical weather patterns (hurricanes), geo-hazard, and the size of the turbine. Figure 2-2: Illustration of Three Offshore Wind Energy Technologies illustrates the three main platform technologies used in anchoring offshore wind towers and turbines.

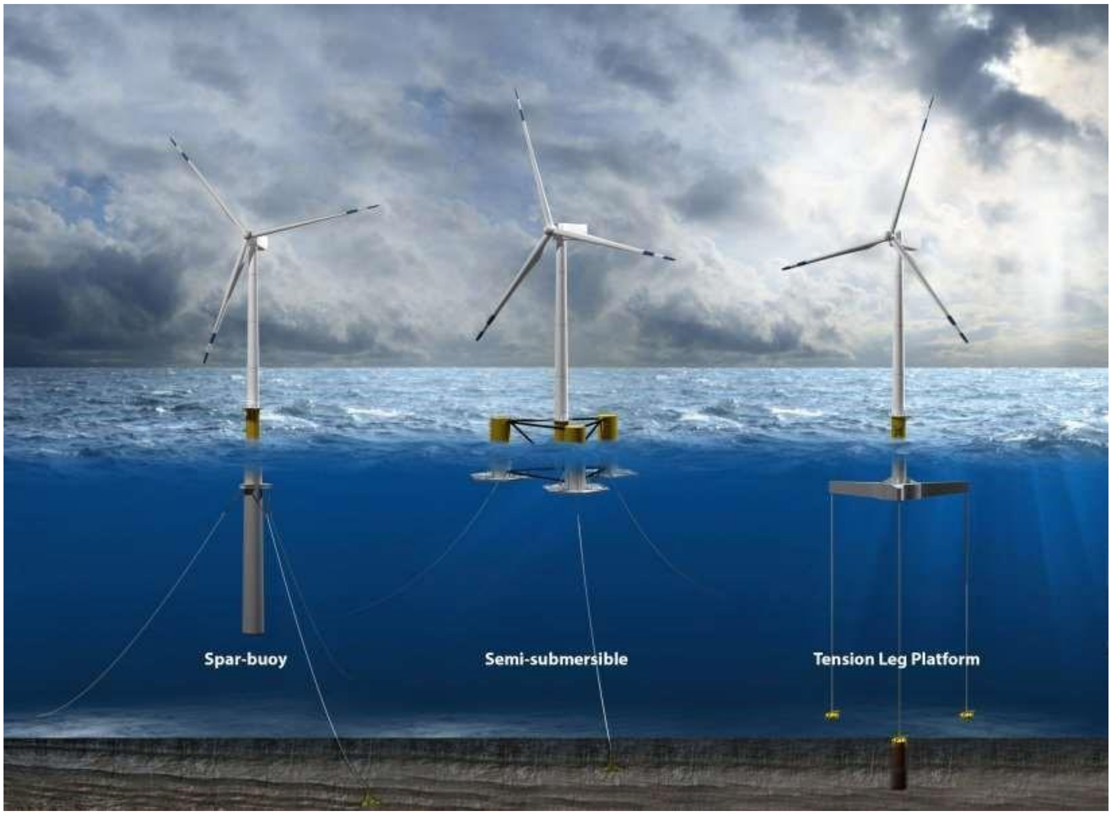

Figure 2-2: Illustration of Three Offshore Wind Energy Technologies

Source: [Illustration of three different platforms used in wind energy being developed by the Department of Energy and Industry Players. Illustration by Josh Bauer, NREL 49054, cited in (Department of Energy, 2020a)]

2.4.2. Semi-submersible and Block Island Wind Farm

Because most semi-submersible technologies are used in deep water offshore, these are selected for the discussions in this section. Block Island is the first and only commercial offshore wind farm in the U.S commissioned in 2016. The wind farm consists of five turbines generating about 125,000 megawatt hours of electricity annually. It was conceived as part of a broader project extending into Massachusetts, to potentially provide 1.3 terawatt hours (TW·h) of electricity per year or 15 percent of all electricity in the State (Green City Times, 2018). It is a fairly new project with the Biden administration having set an ambitious goal of getting 30,000 MW of energy from offshore wind by 2030. This is part of a larger target of cutting down the U.S. carbon emissions from the energy sector by half.

For this Chapter, semi-submersible is selected as the technology in common between the two sectors for assessment, aside from wind turbines, which is the main technology driving the wind sector. Although the U.S. offshore wind is a relatively new industry compared to the offshore oil and gas sector, it is expected to grow rapidly (this is discussed in Chapters Four and Five). Block Island has paved the way for the growth of the sector in the face of immense backlash when the project was initially conceived (Buck, 2019). In situating the earlier literature review in Chapter one and in this Chapter, what this case study shows in the context of policy is that the political agenda of the ruling party does have a strong influence on the extent (or pace) of technological development. Figure 2-3 shown below is telling of the budget spent by the DOE's Office of Wind Technology. The Obama Administration's period of governance witnessed the largest spend recorded in history to boost wind energy technologies at the federal level.

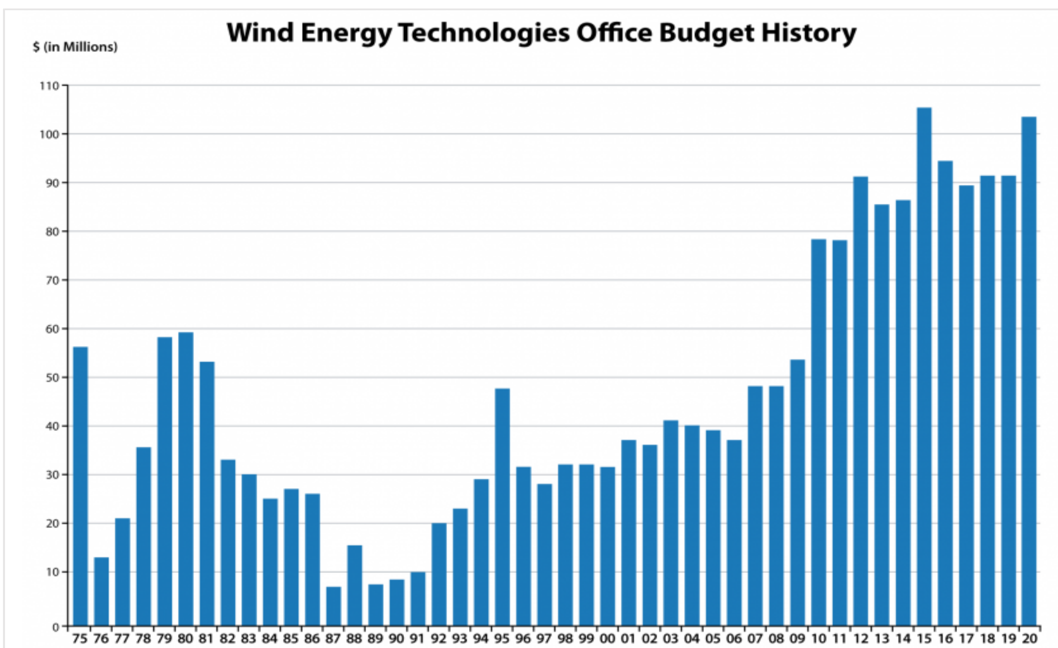

Figure 2-3: DOE's Wind Energy Technologies Budget History (1975- 2020)
Source: Department of Energy (2020b)

At the State level, Texas' $7 billion dollar investment into development of transmission lines to convey wind energy from West Texas from 2005- 2012 brought increased investments into the sector. Currently, offshore wind farms have become very attractive with several projects such as Vineyard Wind 1, Empire Wind, and Sunrise Wind farms, amongst others currently under construction, with estimated completion between 2023 and 2025 off the east coast of the United States (AWEA, 2020). Similar levels of transmission infrastructure investment would be needed to move wind energy offshore to onshore. The Biden administration is keen on green energy and is creating the policy motivation and incentive to make wind energy very competitive at the federal level. Additionally, the political environment plays a role in terms of social acceptance of wind as a source of energy (Buck, 2019). For offshore oil and gas companies such as BP that uses semi-submersible technology offshore, it has partnered with Equinor to develop a 50GW offshore wind energy farm by 2030 in Massachusetts and New York (British Petroleum, 2021a).

Buljan (2021) notes that there are currently about 34 proposals for offshore wind development in the U.S. Most of these are situated in the North-eastern part of the US, with about 27 of these projects already in the planning and development phases. The GOM has no offshore wind projects, despite totaling about 26 GW of wind's installed capacity. There are no offshore wind farms planned in the Gulf of Mexico yet. Although, request for interest has been initiated by the BOEM. The similarities in offshore infrastructure and the increasing investments toward renewables-backed electricity markets means that potential avenues for more renewable sources should be explored. What is evident from this review, which is further expanded in the discussions in Chapter Four is that because of the similarities the sectors share, a few players from big oil and gas companies are finding offshore wind very lucrative and are gearing up for more investments into renewables and expansion of their renewable energy portfolio. In terms of divestments from offshore oil and gas, the Norwegian Company, Equinor (formerly Statoil) has been a champion of re-engineering offshore infrastructure for offshore wind in recent times (Equinor, 2021).

2.5. Chapter Summary

The Chapter presented the nature of the legal framework for offshore O&G, its history and evolution and the challenges facing the sector. The technologies in common between the two sectors were discussed to highlight the similarities between offshore wind and O&G. Despite the immense cost differentiation between the two, there are opportunities for the sector to pivot to offshore wind to kickstart an innovation system for offshore wind in Texas. Already, Texas has pioneered innovation in wind prior to the late 2000s unlike any other state, through programs such as the National Wind Resource Centre (NWRC) that work with a consortium of industry partners, trade organizations, academic institutions and in partnership with national laboratories to pioneer research in wind (The State of Texas: Governor, 2014). The platform of learnings already exists for the sector to expand offshore. However, before discussing this in-depth in Chapter Four through the TIS framework, the next Chapter presents the research methods and how data was initially selected and reduced for the content analysis using the NVivo software.

3. METHODS

3.1. Research Methods

In answering research questions 2 and part of 3 of this thesis, the study conducted a content analysis of popular newspaper articles that are most common to the State of Texas, and which address issues of offshore oil and gas and the energy transition from different perspectives. For the second part of question 3 (whether a policy future exists for offshore wind), the thesis forecasts natural gas, wind and coal for Texas coupled with consumption to model scenarios for wind as the state reduces its reliance on natural gas and increases its renewable energy sources (wind). Coal and natural gas are fossil fuels, which emit a lot of carbon dioxide, carbon monoxides, SOx and NOx. Wind energy is a clean and renewable energy source and with the state's unique position in onshore wind production, justification is made for increasing production, which may come from more wind sources, potentially offshore wind should the policy environment be right for the sector. The research methods are divided into two parts. The first part discusses the content analysis methodology and the second the timeseries modeling.

3.2. Part One: Content Analysis

These newspapers and newswires included editorials, opinion pieces and regular articles and columns submitted to the publication houses. These news articles are readily available in the public domain through subscription and were sourced from the Texas A & M University Library website. At the guidance of a Librarian, the researcher used the Library's EBSCOhost database to search for daily news articles on the two most popular media publications in Texas, i.e., "the Dallas Morning News" (DM) and the "Houston Chronicle" (HC). These two newspapers were selected because of their popularity and reliability in reporting daily news happenings within Texas. The keywords that were used for the search on EBSCOhost were: "renewable energy" OR "energy transition" OR "offshore oil and gas" OR "wind energy" AND "Technologies" AND "Texas". The study included only news articles in Texas and published in English within a 12 year time frame from January 2009 to August 2021. The timeframe was selected to coincide with the introduction of a sweeping legislation by the Obama administration to transition the sector to a more renewable energy focused sector and the lower carbon emissions from the energy sector. Duplicates and non-related articles that showed up in the search were eliminated through an assessment of the (i) "title of the article" and (ii) "date of publication" within the two newspaper sources. See Figure 3-1, which shows a flow diagram of how the news articles were selected for the study and the actual number of news articles coded for each newspaper.

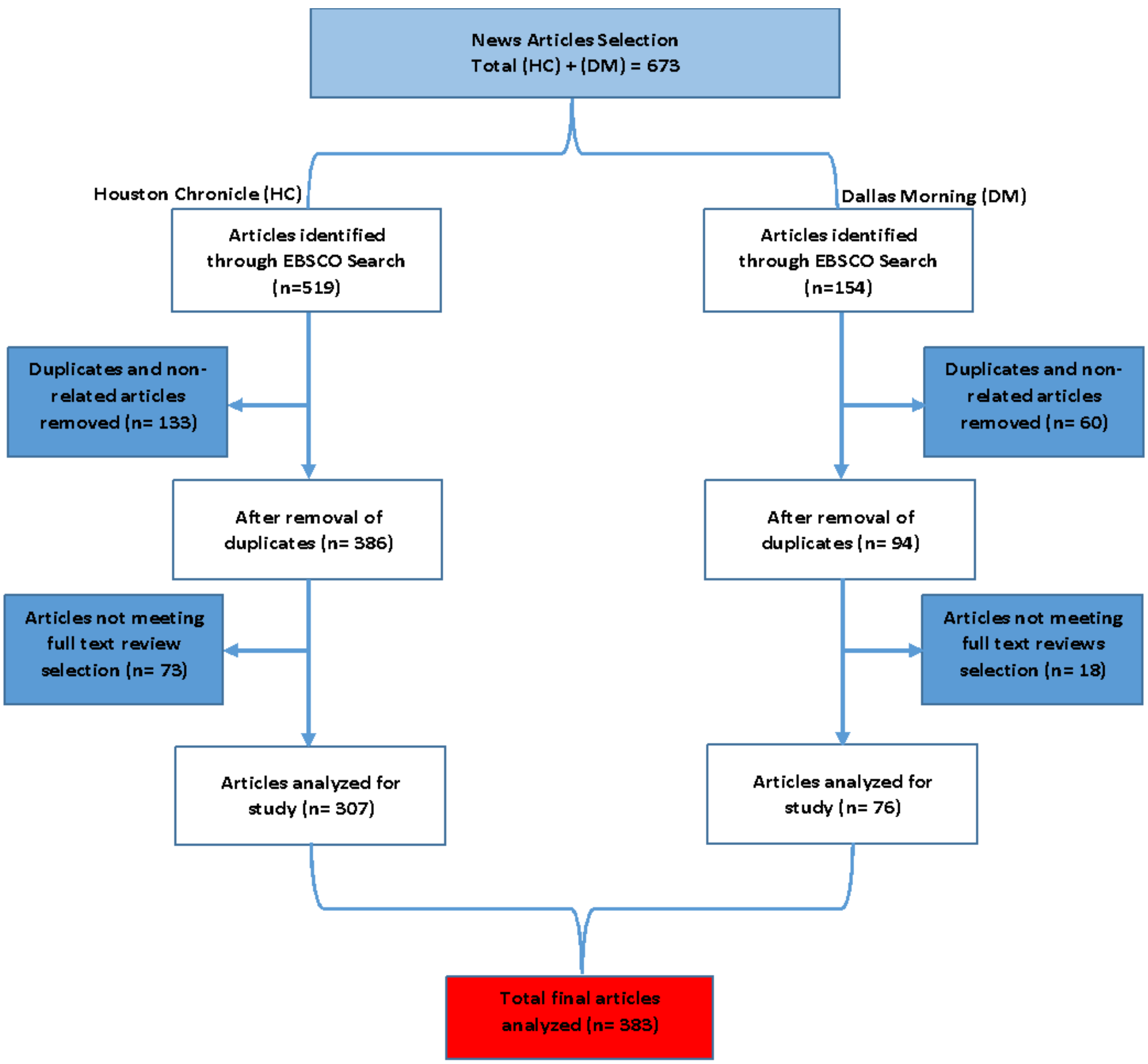

Figure 3-1: Flow Diagram Showcasing the Selection of News Articles for Coding

In terms of reliability and bias of these news articles and sources, the researcher relied on "Ad Fontes media rating methodology". This is a trusted framework for measuring newspaper bias and transparency. It is regularly used to review articles and news programs to rate them in terms of bias and reliability parameters. For Dallas morning, the mean score for reliability and bias is (44.03) and (2.54) respectively (See Ad Fontes Media, n.d). Houston Chronicle's scores were (44.85) for reliability and (-3.28) for bias. These are averagely good scores on a scale of 1- 100. A score above 42 is good as noted by the rating method. For bias, they interpret the scores on a scale of -42 to + 42. A higher negative score signifies a more leftist's paper and higher positive score is right leaning. Since the two papers are closer to (0), it shows they are more neutral and balanced papers. The neutrality elements are one of the major reasons why the two newspapers were selected for the study. The news articles statistics is presented in Table 3-1 below together with the file and classifications and number of referenced texts that were coded.

Table 3-1: News Articles' Statistics for Coding

Files Classification	***Houston Chronicle***	***Dallas Morning***	***Totals***
Opinion Pieces/ Columns/ Editorials	51 (20%)	17 (29%)	68
Regular Articles	262 (80%)	59 (71%)	321
Case Classification	***Combined Totals***		
Government related articles	-	-	71
Institutions/ regulation	-	-	24
Organization/ Industry	-	-	186
Persons (opinion- related articles)	-	-	109

3.2.1. Rationale for using Content Analysis for the First Part of the Research

To evaluate the TIS framework, the study utilized a qualitative content analysis research approach. This approach as indicated in the introduction is systemic thinking in coding large volumes of news articles with the aim of identifying patterns and relationships between what has been reported or authored of relevance to the goals of one's research. This qualitative method involves three main processes, conventional (grounded theory), directed (or conceptual), or summative (Hsieh & Shannon, 2005). The study employed the directed or conceptual framework where the research relies on a known theory and searches through literature to find evidence of the theme in a theory and the patterns associated with the themes. The conceptual content analysis for research helps prove the existence or non-existence of a theory within the context of the research aims and goals. In this research studies, this research methodology helped in applying the TIS framework to both the offshore oil and gas and wind energy sectors. The TIS framework is critical for understanding how certain industries evolve. For this research, it was useful in understanding the evolution of offshore oil and gas and wind energy sectors, drawing lessons for an offshore wind sector, and understanding the patterns of technology development within the context of the energy transition. The conceptual content analysis requires a thorough understanding of the concept and devising themes that relate to the concept and analyzing texts by reading, coding, and re-coding and in some cases reducing the scope of the dataset by reducing the elements being coded to interpret the data.

3.2.2. Coding Methodology and Framework

With regards to coding methodology, this commenced with firstly screening all the news articles from HC and DM and classifying the papers based on the newspaper name. Under each theme for the TIS, certain sub-themes/indicators were identified as critical to that particular theme. These were then coded through a line-by-line coding of themes in NVivo. After identifying some patterns in the first coding process, files (articles) were classified as cases under the following case files presented in Figure 3-2.

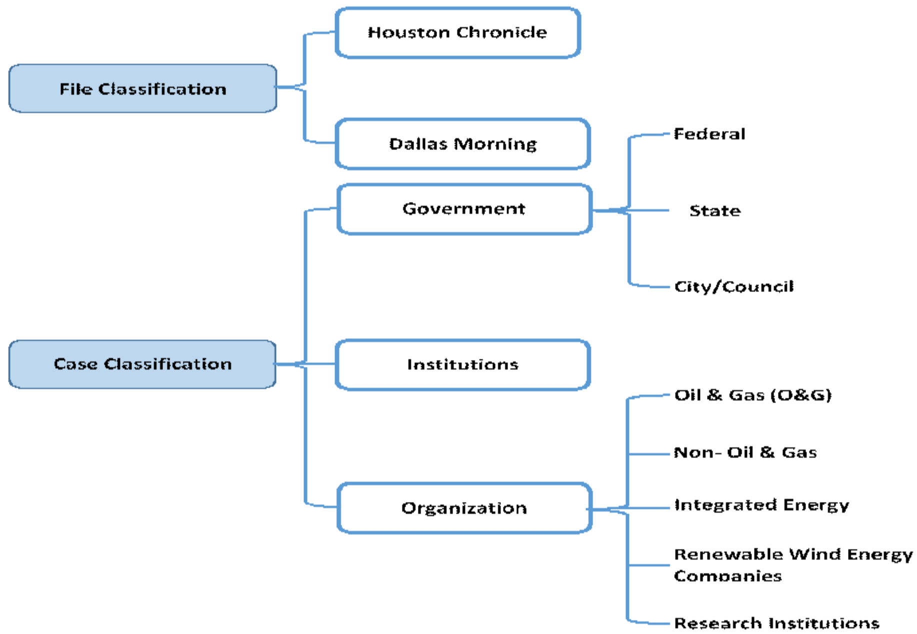

Figure 3-2: File and Case Classifications Framework for Coding

Because the research objectives of the thesis are also crafted around the energy transition and renewable energy, there was another set of coding done under section 'words and phrases' for 'drivers of the energy transition' and 'acceptance and opposition to renewable energy'. The above described activity was done during the preliminary coding to understand the data and patterns. The second cycle coding revolved around screening the codes and the references to understand the emerging categories under each theme. Some of the earlier codes used were recorded and others even deleted when it was realized that they did not have any connection to the research's objectives. To ensure validity and reliability of the coding process, a recheck of the coded texts to the themes and sub-themes was done. Although a grounded constructivist approach was not utilized in this research some of the procedures for data gathering, cleaning and reducing the data were all done following the protocols in grounded theory. Also, as a single coder, validity and reliability can only be attained by being very transparent about the coding process and reporting all findings in an unbiased manner (Chun Tie et al., 2019). The final list of code, i.e., the codebook is presented in Appendix 3-A.

The final cycle of coding and analyses was conducted by running queries, text and word searches and drawing meanings and patterns within and between the coded themes. It is important to mention that coding is an iterative process and very subjective, hence the researcher frequently checked and rechecked the coding process to ensure that all data and coding process is noted and reported in the research to ensure transparency. Memoing was also critical in reflecting on the patterns that were identified in the data analysis and drawing meanings from the perspectives identified in the content analysis. Finally, the key assumption, in the assessment of the data was to firstly consider both sectors as distinct and with separate innovation systems. However, as the analysis progressed, and more emphasis in the articles shifted to the concerns of the energy transition, this assumption was almost invalidated as it became obvious that the wind energy sector is at a bridging phase with quite significant investments and divestments into renewable energy sources in electricity markets. This was particularly the case for wind and solar, and as offshore oil and gas have infrastructure in common with wind, it is only a matter of time before there is a total bridging of the two sectors as one.

3.3. Part Two: Timeseries Modeling using ARIMA

For the second part of the analysis, energy production of renewables and conventional fuels are predicted by modeling scenarios of target reductions in natural gas as mandates increase. Here, the Autoregressive Integrated Moving Average (ARIMA) model is used to make future predictions of a time series data using its own past values in R studios. This approach is usually used when assessing non-seasonal series or for a series where data has a pattern of linearity and not random sampling of events. There are two types of ARIMA time series modeling: 1) univariate type, which consists of training the data to use its own values to make future predictions, and 2) multivariate type, which makes predictions based on external data and variables that inform the main variables to be modeled. For the simple modeling done in Chapter Five, the univariate type is used because we wanted to make a simple forecast of the deficit that might result should natural gas and coal reduce as a result of global and national mandates that might impact the State. The State's energy mix (energy supplied) consist of about 12 sources, recently including battery storage (See EIA, 2021). The most significant sources that contribute more than 88.2% of the State's energy sources are three – coal, natural gas and wind. Natural gas contributes the highest share of about 52% in 2020. Coal was quite significant from the 1980s- 2000s, but its impact on the environment and climate change have resulted in stricter state laws that have limited its generation. Because of this deficit, wind and natural gas capacity have increased to fill the gap left by coal overtime. The three sources are modeled together with consumption over time from 2021- 2050. In the modeling, hypothetical reduction targets for natural gas which must be met by renewable energy generation overtime is included in the prediction. The next two Chapters present the analyses and discussions on offshore oil and gas and wind energy using the TIS framework and the modeling, and whether a policy future exists for offshore wind in Texas.

4. ANALYSIS AND DISCUSSIONS OF THE TIS FRAMEWORK FOR WIND AND THE OFFSHORE OIL AND GAS SECTORS

4.1. Introduction

This Chapter discusses the TIS framework and results from the content analysis conducted in NVivo. It discusses the nature of the two sectors, the emergence and growth and development of the wind technologies in Texas and what drivers motivated the stellar growth of the sector. Because the sector is currently at a crossroads, what is observed from the analysis of the articles is that despite wind renewable energy and offshore oil and gas being two separate sectors, there is an evolution happening, i.e., a 'bridging of sorts' with the two becoming one sector within the energy transition. The second part of the Chapter discusses lessons from offshore in the context of the TIS framework's inducement and blocking mechanisms generally. This is situated within the energy transition and four offshore O&G companies' approaches to diversifying their renewable energy portfolios. The offshore oil and gas industry seems to be at the cusp of either fully embracing the energy transition's process goal, which is net-zero carbon emissions from fossil fuels by 2050; or, for those that see it as a threat, reject it outrightly with very little efforts toward defining realistic targets. The selection of the four companies was teased from companies that featured greatly in the content analysis as well as companies, such as Equinor, which divested into renewables long before renewable energy transition became a pertinent issue in policy.

4.2. Thematic Framework for the Results and Discussions

The analysis of the TIS themes for the offshore oil and gas and wind sectors generally showed a lot of policy and economic drivers for the current phase in the energy transition and the phase of development. The overarching framework that emerged from the assessment is presented in Figure 4-1. The scope of assessment was to initially consider the two sectors as separate entities to identify commonalities and areas of learnings, however they seemed to merge as affirmed by van der Loos et al., (2021) as in the case of Norway post the maturation phase in innovation. Overall, F1: entrepreneurial activity, F4: guidance of the search, F5: market formation, and F6: resource mobilization were strongly correlated for the wind sector. The results of the references and files coded for the Study are shown in Appendix 4-A. The discussions that follow are complemented with extracts of the content analysis and industry data from the American Clean Power Association (ACP), America Wind Energy Association (AWEA), the Department of Energy (DOE), the International Energy Agency (IEA), policy documents on renewable energy in the State of Texas, national renewable energy laboratory's (NREL) Wind Exchange Platform documents, energy majors company data, and general industry literature on wind/offshore wind energy sectors.

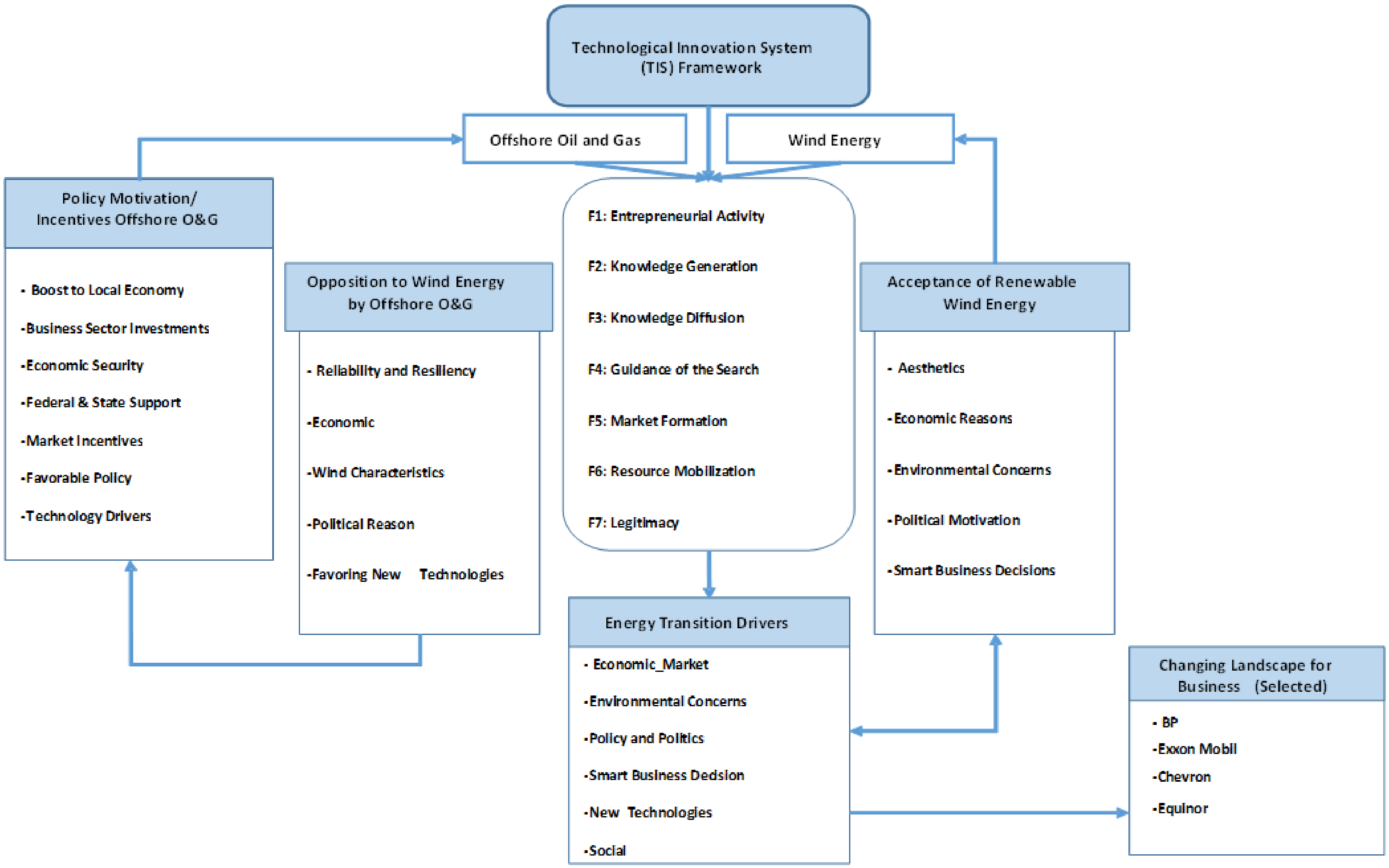

Figure 4-1: Diagram of the General Thematic Framework

4.2.1. The Emergence of a Wind Technological System of Innovation in Texas

Although renewable energy technologies, particularly wind, contribute significantly to Texas' economy much of these gains did not happen overnight. There were many intentional policy actions and efforts by the State legislature and the federal government towards the sector in the early years (Diffen & Smith, 2010). In 1999, the State's Senate Bill 7 (SB 7), i.e., Texas' first Renewable Energy Policy ushered in the Renewable Energy Portfolio Standard (RPS) and its renewable energy credit (REC) system in 2005 under Senate Bill 20. The RPS involved a mandatory purchase of a certain percentage of electricity per kilowatt hour (KW.h) from renewable sources such as wind, biomass, solar tidal, geothermal, etc. Nationally, there were proposals for an RPS policy, but this did not pass the house committee stages in 1997 (Ibid). Texas strategically passed SB7 to create the environment for early wind development, focusing largely on incentivizing the market for wind entrepreneurs. The goal of initiating this policy was to increase the wind capacity of the State. With good wind characteristics in Northwest Texas and to incentivize developers and utilities to buy into wind, the Senate set in motion Senate Bill 20 in 2005. The objective of the bill was to build transmission lines under the CREZ that would connect rural North West Texas to South Texas where electricity was desperately needed to meet renewable energy goals set by the State. The CREZ program included 3,600 circuit miles of new transmission lines and 18,500 MW of wind power capacity (Diffen & Smith, 2010; Hitaj, 2013; Maguire, 2016; Wiser & Bolinger, 2009).

Nationally, the Energy Policy Act of 1992 (EPA92), which had within its ambit environmental protection sought to invest heavily in renewable sources particularly wind in the 1990s to support a more sustainable and clean energy environment. The DOE's wind energy program's strategy aimed at expanding wind knowledge base, designing new and innovative wind systems to create a market environment of lower cost and higher efficiency turbines for the wind sector (IEA, 2000). Like the case of Texas, the federal government set wind energy capacity targets and goals, such as generating at least 5% of the nation's electricity demand at a capacity of 80,000MW by 2020. Some of these targets and the production tax credit (PTC) under the EPA92 and federal renewable portfolio standards for states motivated the emergence of the wind energy sector. In 1999, Texas set a 10 year target of producing 2000 MW by 2009, which the State surpassed. See Figure 4-2 below of the wind generating capacity of the State from 2003- 2009.

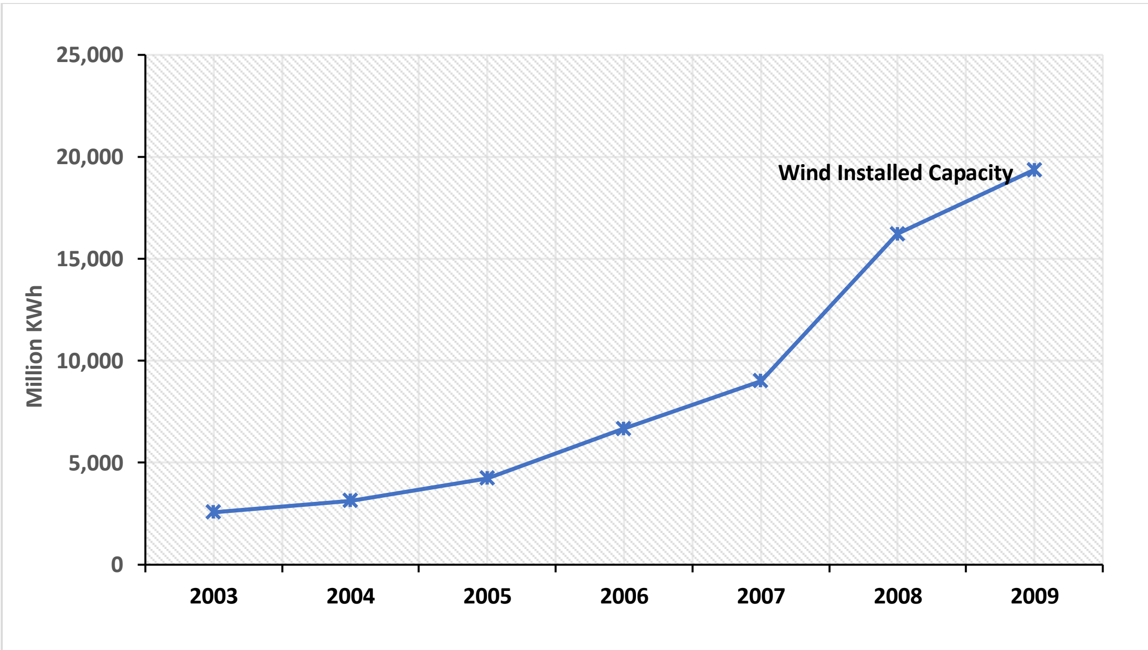

Figure 4-2: Wind Energy Generation in Texas during the Formative Phase (2003- 2009)
Source: Statista (2021b)

4.2.2. The Formative Phase of Wind Energy Development in Texas

By 2009, Texas' wind capacity had exceeded the goals set by the State with additions of 2,292 MW. Coupled with federal incentives under the ARRA and some of the interventions of the 1992 energy policy act, Texas dominated the 28 other states in which new large-scale wind turbines were installed by 2009 (Wiser & Bolinger, 2009). Some of these included the PTC of 2.2¢//kWh in 2012 and further raised to 2.3¢/kWh in 2013 under the Obama Administration. From 2009, Texas continued to set incremental goals and targets for the wind sector achieving the 2020 goal for wind 5 years early (Powering Texas, 2020; Weis, 2018). Lawmakers set an ambitious goal of 10,000 MW of renewable wind capacity by 2025. In 2005, the State legislature amended its RPS mandate to require that 5,880 MW (or about 5%) of electric consumption to come from renewable sources. Many of these goals were attained by the wind energy sector alone by 2015. Overall, the State surpassed this 2015 goal in 2005 and the 2025 goal in 2009 (Powering Texas, 2020). A lot of these incentives and goals during wind's formative stage were driven by the State. In drawing parallels with the offshore oil and gas sector, what is also seen is how the offshore oil and gas sector has been affected by different government policies under different administrations. Some of the policy agenda for offshore oil and gas sometimes have been in opposition to the expansion of renewable energy, particularly wind and has in the past (from 2009- 2012) caused frictions between the two sectors at the federal level (see also similar arguments by Walz & Köhler (2014) for the case of Germany and China).

Conclusively, it is evident that the intermesh of both federal and state policies nationally and in Texas kickstarted the emergence of the industry, although Texas was ahead of most states in terms of policy outlook for wind. Also, the DoE's wind energy program's research and investments into wind turbine development from the mid-1990s to early 2000s seemed to have motivated many wind manufacturing companies and new entrants into the industry (Wind Energy Annual Report, IEA, 2000). In 1999, for example, there were only a handful (6) of U.S. owned wind turbine companies manufacturing turbines for the market (IEA, 2020). Most of the PTC and investment tax credit for wind stimulated the emergence and formation of technological systems within the wind industry. Diffen & Smith (2010) contend that the impacts of the PTC could only be felt within the lulls in wind power capacity additions in the 3 years (2000, 2002, and 2004); these were also the times the PTC a year prior were retroactively extended to continue stimulating market formation in wind (See Figure 4-2).

I. How Wind Development Works in Texas (Mapping Actors and Networks)

In discussing the TIS framework, it is important to recognize the "…network(s) of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology" (Carlsson and Stankiewicz 1991, p. 111). The authors note that it has three components: actors, networks, and institutions. These are not necessarily technology-specific but may be shared by several technological innovation systems. Bergek et al., (2008) points that the researcher should map out the sector and its new entrants to lay the foundation for how the sector is evolving. In terms of the actors and networks involved in the wind energy industry, Figure 4-3 maps networks and agents involved in the TIS within the wind industry. Most of the wind incentives in the State of Texas are geared towards private developers and institutions that either generate large scale wind farms or "distributed" wind for power companies.

An important element that needs to be pointed out in the case of Texas is its unique case in terms of the RPS. This is because not all states that went that route enjoyed significant gains in wind development. The sector's evolution is peculiar with the nature of its electricity markets and onshore wind characteristics influencing wind market formation and development. The State's Electric Reliability Council of Texas' (ERCOT's) unique setup, position and decentralized market structure make for easier ways to ensure that mandates are adhered to. ERCOT is a non-profit organization that is solely responsible for regulating grid lines within Texas. Because of the deregulated grid and its limited state lands (the state has more private lands), most wind developers usually do not go through a state permitting process (Weis, 2018). The developer negotiates a wind right through a lease and/or an easement in some cases with the landowner but subject to local zoning setback and turbine height restrictions and placements regulations.

The State has no siting rules with the only permitting requirement warranted being when the site is near military bases and airports or within critical flight paths. Also, in instances, where the location is noted for an endangered species habitat, then NEPA is activated, and the developer would have to provide means to lessen the impacts of the development through an environmental impact statement and plans for mitigation. Figure 4-3 highlights the major actors, stakeholders, and networks within the TIS framework for wind. The State legislature is the oversight for Texas Public Utilities Commission (PUC). The PUC regulates the electricity market and defines guidelines for ERCOT, which controls 90% of Texas' electricity load and transmission. For policy actors that stimulate the TIS, their role is to provide the enabling environment through policies that facilitate the development and utilization of wind. Wind developers work with turbine manufacturers to determine industry requirements for wind towers and rotor blades specific to the needs of the project.

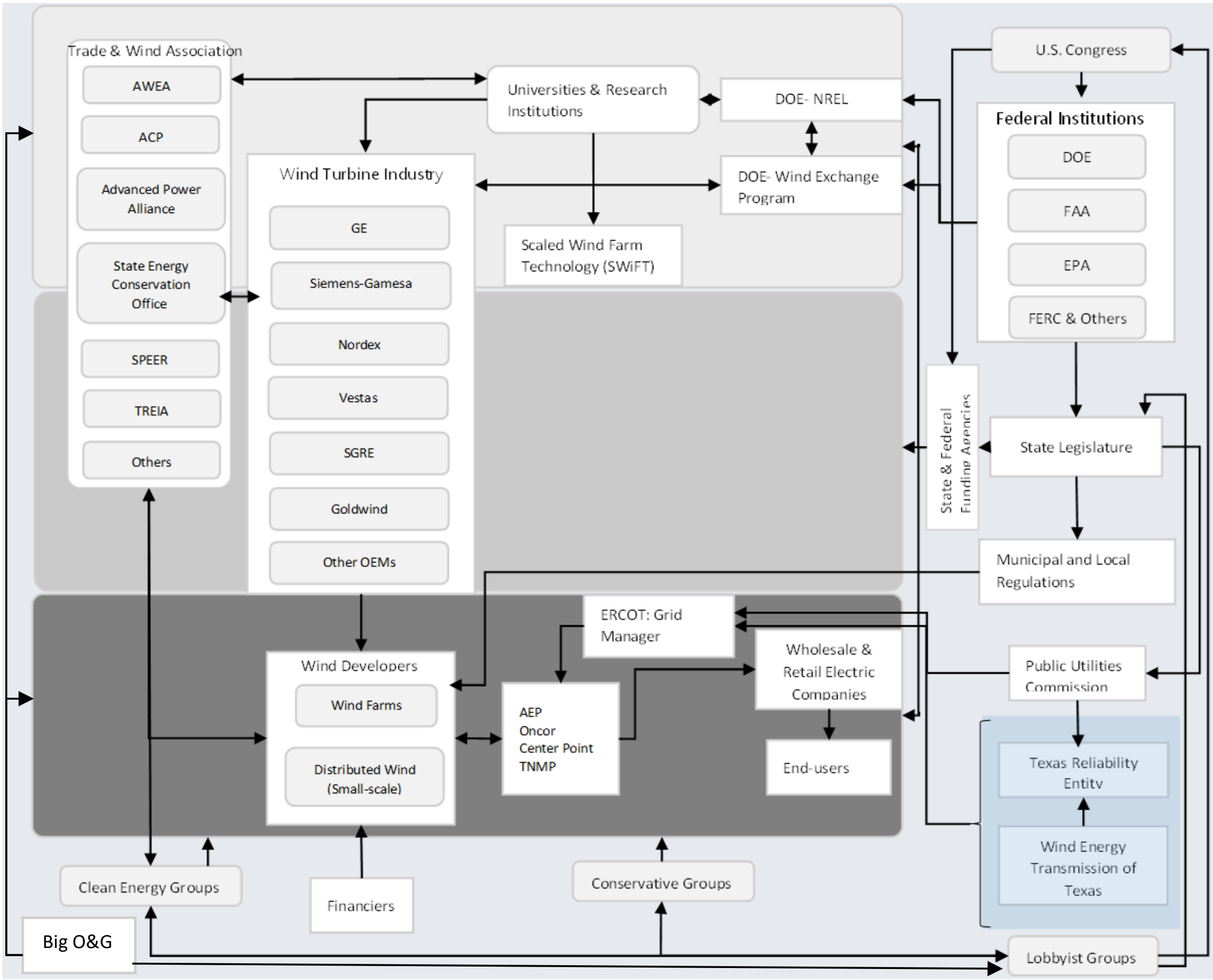

Figure 4-3: Mapping Actors and Networks within the TIS Framework for Wind Energy in Texas

Source: Flow chart is adapted to Texas's Context. Original from (Gosens & Lu, 2013)

Federal and state policy incentives for the industry stimulate wind businesses and research into new innovations for the sector. As was noted earlier, Texas' RPS was significant to create appropriate system-building activities in the early phase of wind development. Arguably, the setup of wind's innovation system is very simple since the environment, unlike most states in the U.S., is deregulated with very little interference from the Federal Energy Regulatory Commission (FERC). This makes RPS mandates a bit more successful in the State unlike in others (see similar arguments by Shrimali and Kniefel 2011, Hitaj 2013, and Maguire 2016).

4.2.3. Growth and Development of the TIS for Wind Energy

Aside from the emerging and formative phases, the growth and development phases consistently experiment to drive innovation. All the TIS themes are discussed under this section with the goal of identifying some of the notable blocking and inducing mechanisms for innovation in both oil and gas and wind sectors. The discussions of the mechanisms themselves are covered within the context of the energy transition in Section 4.3.

I. Entrepreneurial Activity (F1)

Regarding wind energy (and not offshore wind) in Texas, the sector has seen a jolt of new entrants and technologies aimed at lowering the carbon footprint of the State. From 1999 through 2012, both the state-led incentives and the RPS led to about 69% of the wind power capacity built in the United States within that period (DoE, 2013). In a Department of Energy Report, it was contended that the RPS is one of the main drivers of renewable wind energy, especially in the electricity markets, hence a great motivator for new entrants into wind. In the case of Texas, it does not buck the regular trend of a conservative State that pushes only an oil and gas agenda but also instituted the policy incentives akin to the oil and gas industry for the renewable wind energy sector to thrive. In charting the attribute government to the sub-themes in entrepreneurial activity, what is observed is a robust policy support for renewable wind energy. See Appendix 4-B which shows the different political divisions and percentage coverage under entrepreneurial activity (Federal versus State) for wind.

In terms of offshore oil and gas, it is a mature industry in Texas with the first offshore oil and gas well in 1908 (Offshore Energy, 2010). Over decades, state lands (ocean within 9 nautical miles seaward) in the GOM have been very active for offshore oil and gas leasing. Currently, there are more than 1,862 platforms in the Gulf of Mexico according to the Bureau of Safety and Environmental Enforcement with more than (72) big to medium multi-national and many local companies operating in the GOM region (BSEE, 2021). For the TIS framework, although the selected news articles did not provide a clear indication of the current number of companies within the offshore oil and gas and wind sectors, it provided information on the nature of entrepreneurial activity and the transformation happening within the sectors. The signals were evident that there is a lot of leasing interest in the GOM. Despite the stringent regulatory environment after the BP oil spill in 2010 in the GOM, the Trump administration reversed the policy disincentives for offshore oil and gas introduced by the Obama Administration in 2016. This policy shift has renewed interest in the Gulf. The extracts below show how mid-to-senior players are gearing themselves for offshore oil and gas in 2018.

Extract (Houston Chronicle, 27 April 2018, *Offshore Sector Going through Transformation as OTC Marks 50th Year*)

> Apart from Big Oil, some smaller companies with private equity backing such as Fieldwood Energy and Talos Energy, both of Houston, are growing in the Gulf, on both the U.S. and Mexico sides. Fieldwood just emerged from a short-lived bankruptcy to acquire the Gulf assets of Noble Energy, also of Houston. Fieldwood typically focuses on shallow waters but is expanding to deepwater areas.
>
> European oil majors, including Royal Dutch Shell and BP, have announced new Gulf of Mexico projects since the oil bust. But those projects aren't what they once were. BP's Mad Dog Phase 2 project was authorized in 2016 at $9 billion, a scaled-down version of the original $20 billion platform proposed before the oil prices crashed.

Post 2015, there was a lot of uncertainty about offshore oil and gas within the industry. Coupled with the mounting pressures to have the industry climate change compliant, many O&G companies were hesitant to incorporate renewable energy into their ‘modus operandi’. ExxonMobil earlier on refused the transition and investments in renewables (Osbourne, 2015 in DM, *Exxon CEO Holds Line on Climate Change at Annual Meeting*). With a change of leadership and ethical investors joining the board of directors, the company has changed its tune. Overtime, most big players have invested, additionally some small companies have also divested into renewable sources particularly wind and offshore wind. The extract from the Houston Chronicle affirms the industry position on wind.

Extract (Houston Chronicle, 1 May 2018, *No Longer Just Drill, Baby, Drill*).

> Offshore wind has gained particular interest because developing the projects is similar to engineering offshore oil and gas platforms, oil and gas executives said. Statoil, a Norwegian company, has emerged as a pioneer in offshore wind farms and, most recently,

> floating wind turbine facilities that can be built even farther offshore where the winds are stronger. Statoil has invested $2.6 billion in renewables over the past five years.

Globally, the offshore drilling market value in 2018 was about $31.26 billion and is projected to reach $56.97 billion by 2026 (Statista, 2021a). Coupled with the integration of renewable energy sources in many businesses' portfolios, entrepreneurial development is primed for the wind energy sector in the coming decades, especially for offshore wind (American Clean Power, 2020). The reason for this is that many states and businesses have set clean energy goals and targets and for these to be reached, bridging the two sectors, and eventually metamorphosing into one sector would be the eventual outcome between offshore oil and gas and wind. This is assuming that the energy transition happens at a faster rate than anticipated. Bergek et al. (2008), Herkkert et l., (2007) and van der loos et al., (2020) agree that this tends to happen in the growth and maturity stage for most technological systems. Van der loos et al., (2021) observed this phenomenon within Norway when Statoil (Equinor) made its first move into offshore in 2007 and eventually became the industry standard with its divestment into renewable energy.

For the wind energy sector, the bridging has already started, induced by both market and state incentives. Existing state RPS policies, which according to the DoE will require roughly 110 GW of renewable capacity by 2035- this including 95 GW of new renewable capacity beyond already installed capacity for each state's RPS means that the projected growth of wind may have to increase to fill in the gap in electricity demand (DoE, 2013). Although accelerated investments into new technologies is quite a costly undertaking, technological development policies and strategies to stimulate the market to a certain extent have been instituted. Hence, in terms of the inducement mechanisms, these are well poised for innovation. That said, for Texas, policy incentives for wind particularly may be ending with the Senate not extending tax credits for the sector in 2020. Under Senate Bill 3, much of the early policy incentives and stimulation by the state will be terminated in 2021 (Wallace, 2021). This is discussed in further details in the last section of this Chapter.

II. Knowledge Development (F2) and Diffusion (F3)

Knowledge development (F2) is normally placed at the heart of a TIS according to Bergek et al., (2008) and Carlsson et al., (2002) together with diffusion. F2 usually denotes explicit and tacit knowledge or specifically knowledge base, evolution, development and how knowledge informs market structure and formation. The offshore oil and gas industry is quite a complex and a high-technology driven sector and hence new techniques and technologies discovered through research & development are vital for the sector to meet its business commitments and shareholder value. Under this theme, the knowledge base is critical in terms of breadth and depth of knowledge research. Under themes F2 and F3, project collaborations and partnerships by the offshore oil and gas sector with the wind industry was the prime focus in stimulating knowledge generation in wind energy.

Hendry & Harborne (2011) and McDowall et al. (2013) contended that knowledge development in the wind energy sector represents some sort of '*bricolage*' of different R&D-based activities and learnings. There is a lot of transfer of knowledge from offshore oil and gas platform development to offshore wind (as was discussed in Chapter Two). However, for onshore wind specifically, wind patents and wind energy investments are used as indicators for knowledge development and how knowledge diffuses in terms of private interactions or responses to public policy. Figures 4-4 and 4-5 show graphs of wind energy patents and global wind investments. The DOE's Wind Technology Office (WETO) is heavily involved in the development and licensing of wind technologies. In terms of wind patents, more than 170 patents can be tied to DOE-funded research (DOE, 2021a). Many of the wind turbine innovations and breakthroughs globally were driven by the U.S. and in part by DOE sponsored funding in the 1990s and 2000s.

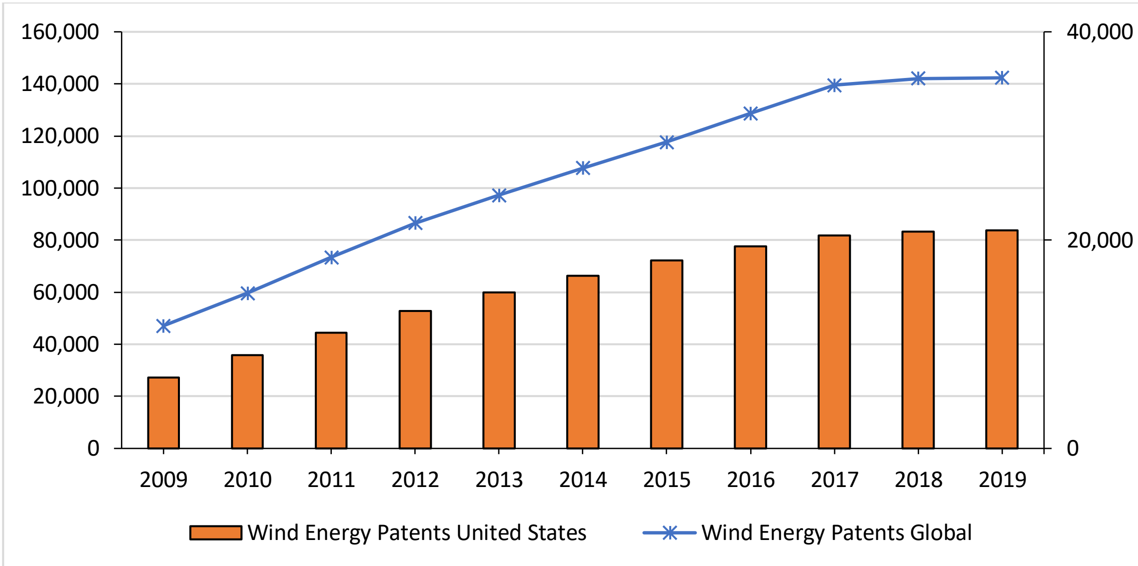

Figure 4-4: Wind Energy Patents in the United States versus Global (2009- 2019)

Source: IRENA (2021)

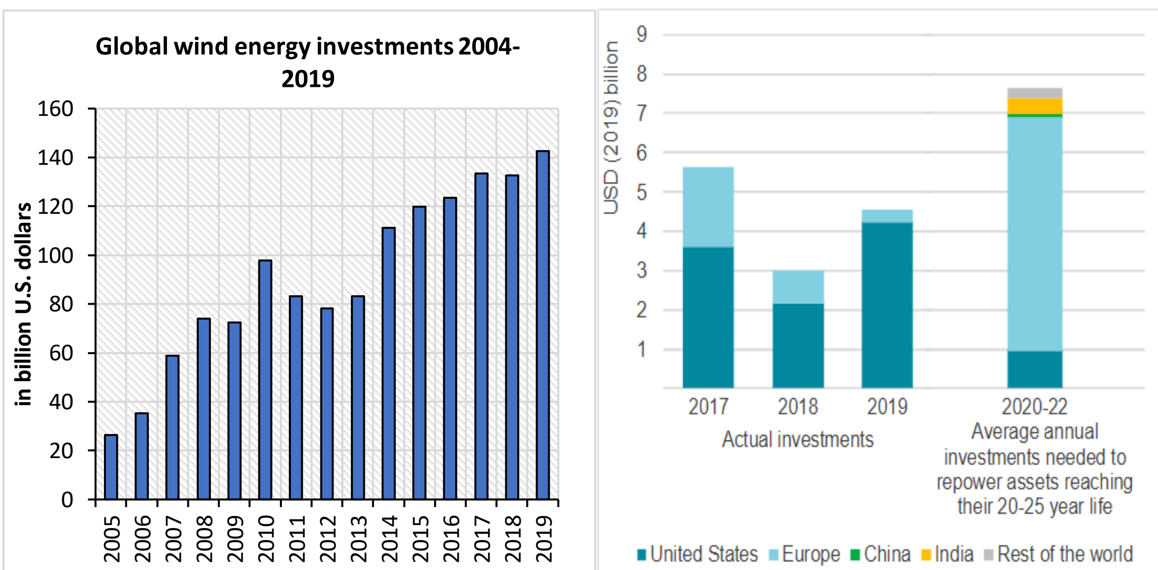

Figure 4-5: Global Wind Energy Investments and Wind Repowering and Potential Investments on Future Wind Farms Reaching End of Life

Sources: Statista (2021a) and IEA (2020)

The U.S. leads in terms of wind energy patents and citations associated with commercial wind companies nationally and globally, although the total number of patents is less than a third of the total global number of registered patents (see Figure 4-4). Investments driven by the federal government have enabled collaborations/ public-private partnerships between businesses, universities, and research institutions and laboratories to leverage national testing and production facilities to strengthen knowledge diffusion (DOE, 2021b). This has resulted in the levelized cost of wind having fallen from $0.60 cents per kilowatt-hour in 1980 to $0.38/KWh in 2014, making the sector more competitive (Shahan, 2014).

Knowledge diffusion (F3) is not happening just within the sector, but traditional oil and gas companies are also being driven by policy, environmental and societal pressures to divest in renewable sources (Larson, 2021). From the content analysis, what is observed is that prior to 2008, there was strong resistance from traditional offshore oil and gas industry players to investing in the knowledge development of the sector. However, a shift is seen from between (2011- 2015), when federal government mandates and global pressures on the impact of the GHG on the world's climate seem to force the hand of many industry players to invest in renewable technologies. Renewable energy R&D spending in the past decade has gone up by about 1%- 3% in green technologies. It was especially high at 3% in 2019 (Bousso, 2018; IEA, 2020). Some extracts highlighted from the news articles on BP and Exxon Mobil CEOs in 2018 reaffirms the shift to renewable energy commitments with investments in research and innovation based organizations to develop new knowledge products for this niche market.

Extract (Houston Chronicle, 1 May 2018, *No Longer Just Drill, Baby, Drill*)

> Already, the world's biggest oil companies, including Exxon Mobil, Royal Dutch Shell and BP, are spending of billions of dollars on wind, solar, biofuels and other alternative energy sources as both their investors and customers ask for more renewables, industry leaders said during a panel discussion this week.

Extract (Houston Chronicle, 1 March 2021, *Fight Energy Transition, Amazon and BP Leaders Say*)

> BP CEO Bernard Looney said he agreed with Jassy, saying that the British oil major is investing heavily in offshore wind in the U.S. and solar in the U.K. to achieve its net-zero emissions goal by 2050. The company has partnered with Amazon to provide the technology giant with

> renewable energy while using its cloud technology to help BP innovate into alternative energy, Looney said.

Many energy seniors, such as BP, ExxonMobil, Chevron, ConocoPhillips, Shell and Equinor have partnered and invested in future energy markets and formed alliances/ partnerships with research institutions and universities in the U.S., coupled with traditional venture and seed capital financing companies. In 2018, for example, as part of BP's strategy for a low carbon future, it partnered with Equinor to pilot the first large-scale offshore wind energy project in Massachusetts and invested in a variety of renewable energy technologies. Chevron also initiated a Future Energy Fund of about $100 million for technological innovations in breakthrough technologies towards the transition (Murray, 2020). Because electricity driven renewables are easier to enter, many O&G companies have made investments in wind and solar, which are the most common. However, there is significant focus on research and development into bio-fuels and new emerging and enabling technologies, such as hydrogen, and carbon capture technologies (Ibid).

Carlsson et al., (2002) notes that technological change is a cumulative process with new knowledge base and technologies resulting from the intermeshing of new and existing technologies as well as from partnership and collaborations with more advanced players in the growth and development phases in the TIS. From the content analysis in NVivo, the data showed that the knowledge base was expanded in the entire value chain for wind. In reaffirming this point, Table 4-1 drawn from querying knowledge generation and distribution against industry classifications for organization (O&G, Non-O&G, Integrated Energy and Research) indicated a strong correlation between the themes.

Table 4-1: Correlation of Knowledge Generation and Diffusion Themes with Industry Classifications

	A. Organization: Industry = Oil & Gas	B. Organization: Industry = Research	C. Organization: Industry = Integrated Energy	D. Organization: Industry = Non-Oil &Gas
F2: Knowledge Generation	58.22%	50%	36.87%	31.63%
F3: Knowledge Diffusion	41.78%	50%	63.13%	68.37%

Table 4-1, which summarizes the query of the coded texts in NVivo shows a reference of how "Oil and Gas" companies have committed to investing in research across the industry. Diffusion is strongest for integrated energy, which comprises oil and gas companies that have renewable wind energy as a critical component of their energy portfolio. For diffusion, understanding the developments upstream, midstream, and downstream facilitates new applications in production across the various streams. Specifically, in the growth phase, part of wind technology developments of wind turbines and blades and its diffusion really took off in 2007. The American Wind Energy Association (2020) notes that at that time there were only about 100 domestic manufacturing facilities servicing 42 states nationally. Currently, there are over 500 of these facilities in 42 states, which is enabling the deployment and diffusion of wind technologies. For onshore this has enabled the sector to expand from 2,500 MW in 2000 to over 105,500 MW as of 2019 and for Texas specifically about 116 MW in 2000 to 32,686 MW in 2021 (EIA, 2021c; Malewitz, 2014).

III. Guidance of the Search (F4) and Market Formation (F5)

The guidance of the search theme considers the nature of incentives and/or pressures that impact an organization or industry/sector whether internally or through external factors such as regulation and policy. For this research, the focus was on identifying whether there is a clear policy vision for O&G and wind energy. In terms of functions, Bergek et al. (2008) suggest that the theme be measured based on growth potential, the extent of regulatory pressures, tax credits, subsidies or incentives and articulation of interest by leading players in a sector. For the offshore oil and gas sector in Texas, there has been positive and negative policy influences on the sector. Internally, the State has provided strong support for the industry with taxes and subsidies that have been in existence from the 1920s (Michaels and Souder, 2009 in Dallas Morning). See also Erikson et al., 2017 for an overview of oil and gas subsidies and credit. Externally, the federal government has dealt either a hard or soft hand to the sector depending on the government in power (as discussed in Chapter One). Regarding this point, for example, the BP Deep Water Horizon Spill in the Gulf resulted in tighter regulations by the Obama Administration. Some rationalize that the hand the government dealt them after the spill was unfair for the industry. The extract below expresses the sentiments by the DOE Secretary Salazaar and sheds light on the administration's stance.

> Extract (Houston Chronicle, 1 October 2010, *Drilling Oversight Beefed Up*)
>
> "Over the coming months, you can expect a dynamic regulatory environment as we continue to raise the bar for offshore oil and gas development," Salazar said in a speech. "We will be as clear and straightforward as possible as we implement these changes, but the oil and gas industry should expect a dynamic regulatory environment as we bring the U.S.'s offshore programs up to the gold standard."

The administration tightened safety restrictions as was expected, implemented a moratorium on leasing in the GOM that had a rippling effect on the industry. Tax inversion rules were introduced, subsidy and tax incentives for drilling and amongst others were to be eliminated by the administration at the displeasure of the GOP and many conservative lobbyist groups (See Dallas Morning, 2 February 2010, *Drilling Oversight Beefed Up*). The Trump Administration era in 2017 took an opposite stance and reversed all the Obama-era rules against the offshore oil and gas industry. A key policy decision that caused friction between offshore oil and gas, and renewable energy was the administration's motivation for wanting to bring back coal on the agenda and to withdraw the U.S. from the Paris Agreement in 2017. Had these policy motivations succeeded, it would have been one of the greatest disincentives and blocking mechanisms to the growth of the wind sector as well as other renewable sources.

With regards to wind energy, the policy direction and guidance to support the growth of the sector has come from both the industry and policymakers in Texas and the federal government (as was earlier discussed). Running a matrix query to determine a relationship between 'guidance of the search' and classification policy and politics under energy transition, the content analysis indicated that for wind energy, the motivation for growth was driven by policy over politics in the beginning. In 1999, the State deregulated its electricity, introduced market incentives for wind and initiated a $7 billion dollar Competitive Renewable Energy Zone (CREZ) project to upgrade the grid infrastructure for wind energy. About a decade after the project, the State met its target and doubled its wind goals. Both market and policy forces influenced the growth of the wind sector (See Dallas Morning, 9 June 2017, *What Happened to the Texas That Wanted to Lead in Clean Energy and Actually Did It*)

Under the strategic leadership of both republican and democratic administrations, the policy vision for onshore wind energy was laid in both creating the market incentives with tax subsidies and credit for industry, the infrastructure upgrading under the CREZ, and interest motivated by wanting to reduce the impact of negative environmental hazards, pollution and GHG emissions. Running a query on 'guidance of the search' and code on policy show a strong correlation, with the policy incentive 'tax credit for every kilowatt-hour of power produced' being a major motivator (or inducement) for why a lot of wind companies were incentivized to enter the market.

For market formation (F5), the nature of the market depends on the time/period of existence. Onshore wind is a mature industry in Texas, whereas for offshore the market is non-existent. Installed wind capacity in Texas in 2020 was about 29, 407MW with operational wind turbines of 15,359 (Powering Texas, 2020). (See Appendix 4-C, which provides offshore manufacturers by market share for 2020 and future disclosed pipeline for original equipment manufacturers- OEM). Texas' industry is buoyed by the renewable energy tax credit program as earlier alluded to with current industry players such as BP, Alston, Facebook, General Motors, Amazon, Home Depot, Exxon Mobil amongst others investing in the onshore wind energy industry. Many of these players have integrated energy strategies aimed at meeting commitments of lowering their emissions and targets set for a net zero carbon economy by 2050. In terms of offshore oil and gas in the Gulf, smaller offshore oil and gas players have become active, with the extract below from a panelist at the OTC affirming the interest of smaller players upstream, such as Talos and Fieldwood Energy.

Extract (Houston Chronicle, 27 April 2018, *Offshore Sector Going through Transformation as OTC Marks 50th Year*)

> Apart from Big Oil, some smaller companies with private equity backing such as Fieldwood Energy and Talos Energy, both of Houston, are growing in the Gulf, on both the U.S. and Mexico sides. Fieldwood just emerged from a short-lived bankruptcy to acquire the Gulf assets

> of Noble Energy, also of Houston. Fieldwood typically focuses on shallow waters but is expanding to deepwater areas.

Both sectors' motivation and drivers for market formation are different. The Trump Administration rolling back the Obama Administration era's rules of tax incentives and subsidies made the offshore market attractive and resuming the leasing of the GOM led to new entrants coming into the market. For onshore wind, one of the main drivers has been the policy environment that was created in the late 1990s and early 2000s, and the federal renewable energy credit program, which enabled the sector to thrive and move from a nascent industry to a current bridging market, where many players are partnering and divesting into wind and renewables.

Despite all these incentives and policy motivation, in 2020, there were calls by the State legislature to end the renewable energy mandates and subsidies for wind that have supported the industry for the past decade. The aftermath of the winter freeze in 2020 led to the introduction of senate bills 2 and 3 to counteract the reliability and resiliency issues of a compromised grid during extreme winter events (Wallace, 2021). Conservative groups and oil and gas trade associations have held that the sector's support must end to enable the market to work efficiently. As a result of the passing of the bill, many of the subsidies for wind which will be available for renewal in the year 2021 will not be renewed when the cycle ends. At the federal level, the new Biden administration under its new green deal aims to increase offshore wind capacity, increase renewable energy sources, and lower GHG emissions in the U.S. Some of the federal incentives may create the environment for offshore wind markets. Although, without consensus from the State's legislature, it may be difficult for a market to be initiated in Texas.

IV. Resource Mobilization (F6)

The resource mobilization theme (F6) is hedged on the ability of the system to mobilize financing, funding, and human capital to sustain an industry or knowledge product. For this thesis, the indicators used in the content analysis of the news articles relied heavily on funding/financing from federal, state, private and foreign partnerships, and joint ventures. The results for the coding for the various elements are presented in Figure 4-6.

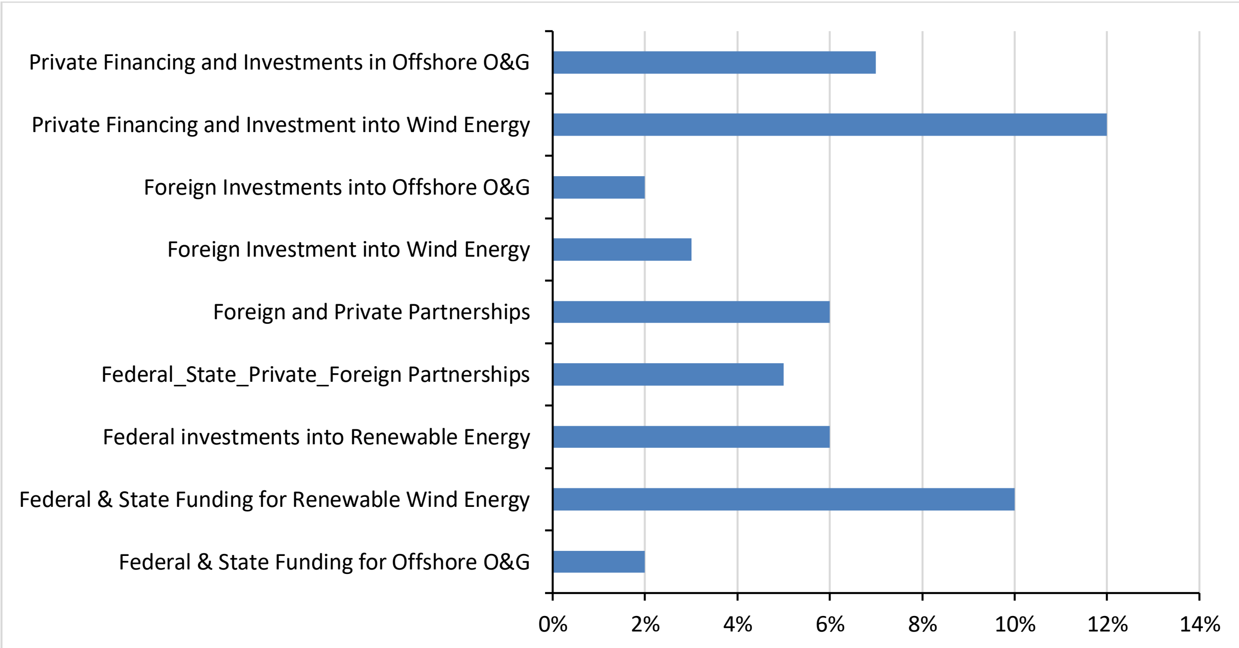

Figure 4-6: Percentage of Coded Text under Resource Mobilization in NVivo

Federal, state, and private financing reporting for both offshore oil and gas were the highest in terms of the number of coded text and by coverage. At the federal level, the U.S. Department of Energy's Wind Energy Technologies Office (WETO) funds research nationally to enhance the knowledge generation and deployment of offshore wind/wind technologies (as was alluded earlier). In 2018, the office provided about $41 million for offshore wind R&D consortium (DOE, 2018). Federally, there is oil and gas funding to support Universities and Research programs in Texas. In fact, the Obama Administration tried to limit funding for fossil energy programs, which include the Strategic Petroleum Reserve, by 20 percent, repealing eight tax incentives for oil and gas producers, with the aim to raise $36.5 billion for the U.S. Treasury according to the Dallas Morning (Michaels, 2010).

At the state level, funding from offshore oil and gas revenue goes into so many projects for the State, including the Texas Permanent School fund, amongst others. There are many tax subsidies for the offshore oil and gas and the industry generally (See Erickson et al., 2017; Geiger and Hamburger, 2010). From the analysis conducted in NVivo, cross tabulating the results of financing and funding in terms of what is being reported in the news and against attributes such as industry (comprising of O&G, Non-Oil and Gas, Renewable Energy Wind Companies, Integrated Energy and Research) show an interesting trend.

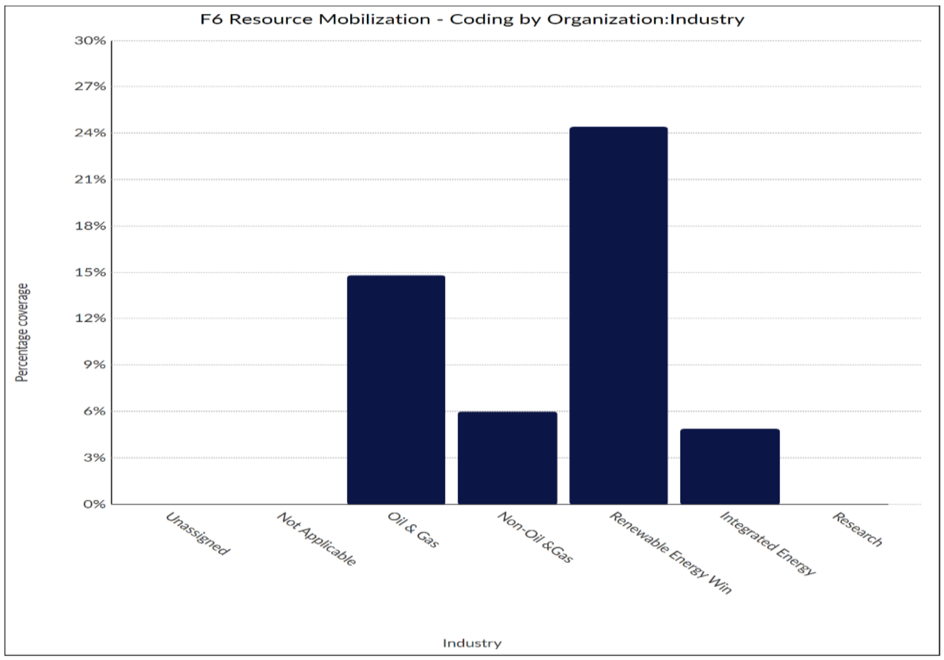

Figure 4-7: Resource Mobilization Coding against Industry Classification

Majority of the federal/ state and to a large extent private venture capital financing companies are targeting more renewable energy sources, particularly wind projects in Texas (Powering Texas, 2020) (See Figure 4-7, which shows where mobilized resources are being geared towards from the content analysis). Specifically for offshore wind, Appendix 4-D shows announced domestic infrastructure investments to support offshore wind in the east coast. Majority of the commitments made is going to renewable wind/ offshore wind sources (24.1%) and oil and gas (15%). This trend is also present in global investments into renewable energy. Figure 4-8 extracted from BloombergNEF (2021) shows the level of new investment in renewable energy on the global scale.

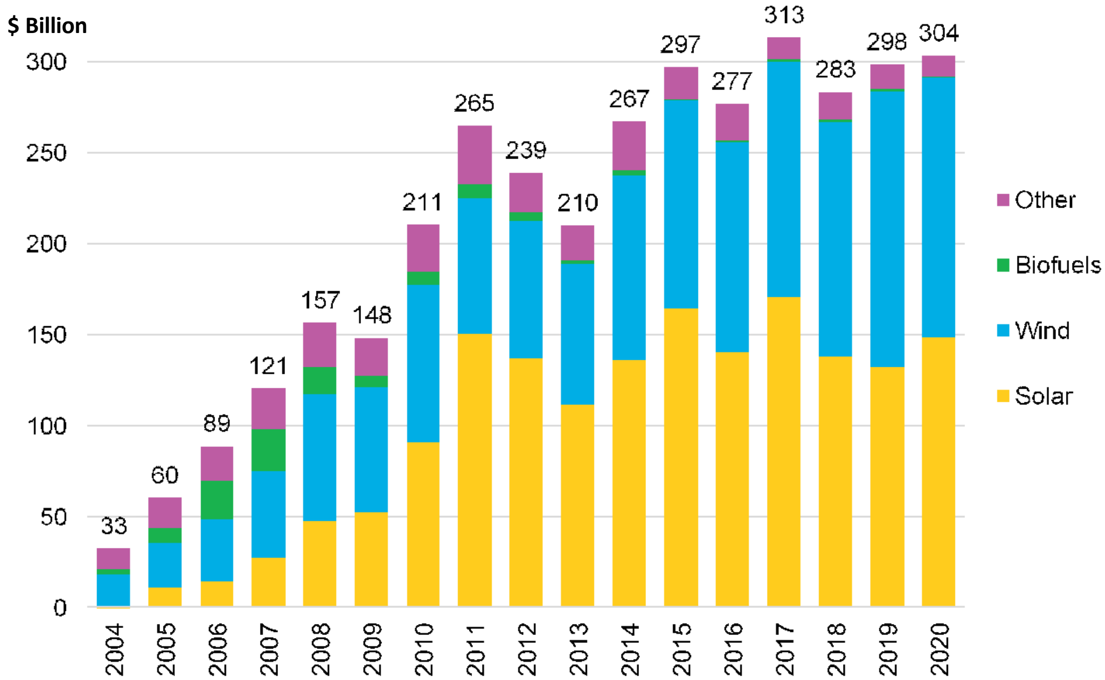

Figure 4-8: New Investment in Renewable Energy by Sector (Global)

Source: Bloomberg NEF (2021); 'Other' includes energy storage technologies, etc.

Foreign partnerships and investments in both offshore oil and gas and wind energy are also very significant with China, India, Norway and amongst others investing and mobilizing resources into the industry in Texas. Globally, China has the largest investments in renewable energy followed by the United States and is also the largest producer of wind and solar energy (See Global Trends in Renewable Energy Investment 2019; UNEP, 2019). As new mandates are set at the federal level towards renewable energy with the current Biden administration, investments into wind and other sources of renewable energy are likely to increase to meet deadlines for net zero carbon emissions between 2035- 2050.

V. Legitimacy (F7)

In Bergek et al. 's (2008) steps to analyzing the TIS framework, they note that legitimacy revolves around social acceptance and compliance of an industry or technology in focus with relevant institutions. They acknowledge that "a new technology and its proponents need to be considered appropriate and desirable by relevant actors in order for resources to be mobilized" (Ibid, p.19). From the earlier discussions on the various themes, wind energy and offshore wind to a certain extent is accepted socially by different camps for different reasons. These were the themes used under legitimacy in the TIS framework, i.e., whether wind/offshore wind and oil and gas is socially accepted or resisted. Most of the texts analyzed showed support for wind energy and the extracts below highlights some of the examples. These are presented under three perspectives, i.e., perspectives of government, business, and institutions.

For both offshore O&G and wind, government incentives motivated the development of the market to the current stage of maturation. The two sectors are also at the bridging stage where legitimacy is not just social acceptance or compliance within the industry, but also about private interests, who have become invested in sharing the gains of the industry. On the part of business in Texas, if one uses the offshore technology conference's (OTC) company representation as an indicator of legitimacy, it can be observed that there is an increasing interest in renewable wind energy. The HC in the coded texts reported that at the OTC there is growing consensus by oil and gas companies about the environmental impact of their activities. Hence, they are pioneering innovation to transform their businesses (see 1 May 2018, Houston Chronicle, *No Longer Just Drill, Baby, Drill*). "…consumers are buying electric vehicles, companies are investing in energy efficiency and clean power, and some 200 nations are taking steps to lower greenhouse gas emissions to meet the goals of the Paris climate agreement" (ibid).

From analyzing the two industries, what is evident is the strong push towards renewable wind energy and other forms of renewable sources being driven by both regulation, public sentiments and currently, the move to smart business and green investing. Majority of the big players that were featured in the articles and presented in the TIS, such as Exxon Mobil, Shell, BP, Equinor and Chevron have integrated their normal business agenda within the energy transitioning agenda by incorporating renewables and setting net zero carbon emissions goals by 2050. This said, social legitimacy of wind continues to be a major constraint to the development of small wind ventures and more public sensitization of impact of fossil fuels and their emissions on the climate may allay such fears. The next section discusses how well the TIS is functioning within the context of the energy transition.

4.3. Analysis of the TIS Framework within the Context of the Energy Transition

Bergek et al., (2008) and Oltander & Perez Vico (2005) purport that to determine how well the TIS is performing you must look at the phase of development of the TIS against other TIS. In this regard, steps 1- 4 outlined in Chapter One have been achieved. This section looks at steps 5- 6, i.e., what have been the blocking mechanisms and inducements for offshore oil and gas companies transitioning to more renewable wind energy options and finally some process goals and policy lessons for wind. For industry, because (four) seniors were mentioned often in the content analysis, their approaches in the context of the energy transition drivers and their far reaching impacts on the industry are discussed. Before delving into the section, a word query of 'technology' was conducted in NVivo to assess how the term resonates within the offshore oil and gas sector and the energy transition. The result of the query is presented in Figure 4-9.

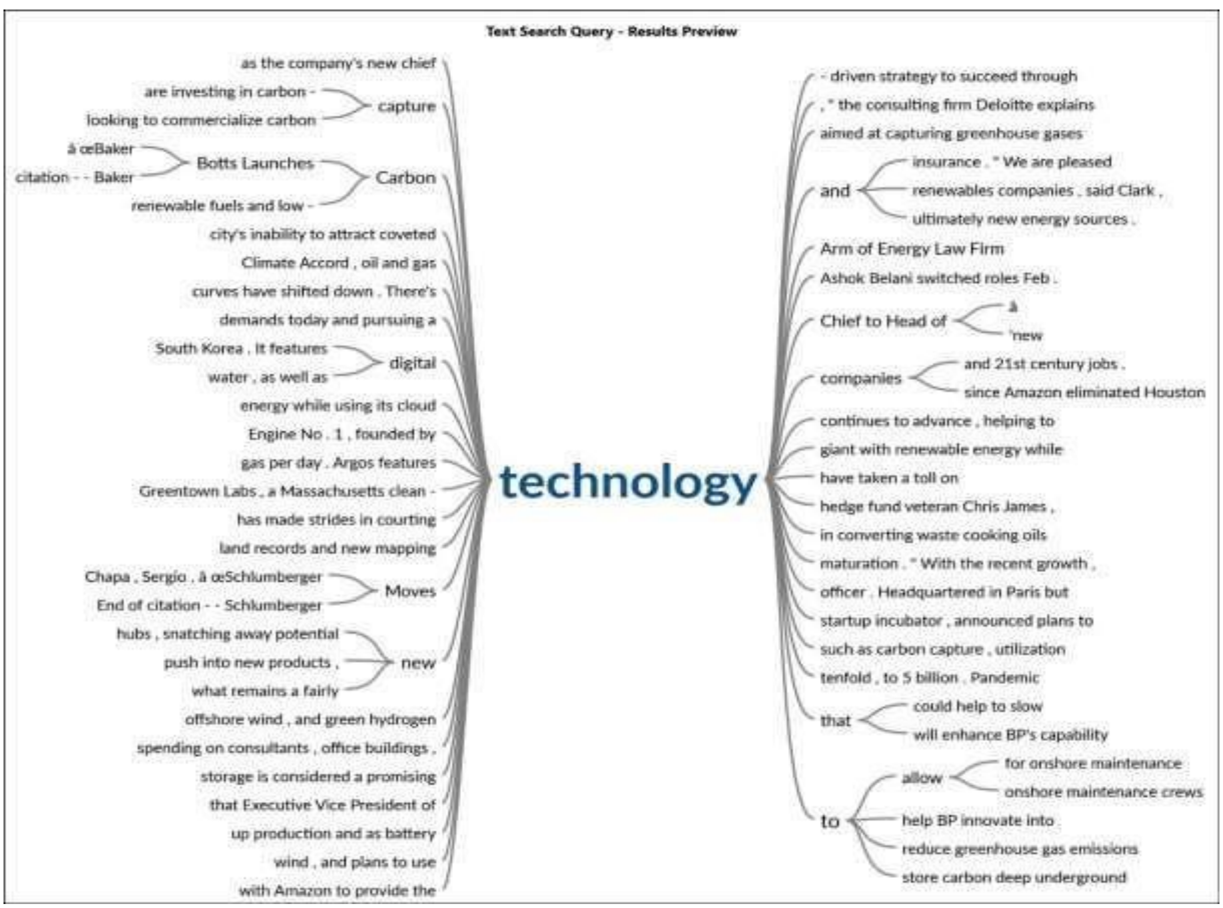

Figure 4-9: Word Tree of 'technology' within the TIS Coded Text

The results presented in the Figure 4-9 is data query spanning over a decade (2009- 2021). The 'technology' word tree presented shows how the language of the energy industry has changed especially, within the context of GHG/carbon dioxide emissions reduction and the energy transition. Companies within the offshore oil and gas supply chain are also predominantly involved in the transition with the 'technology' focus on carbon emissions reduction and capture Also, a word query of both renewable energy and energy transition yielded about 578 and 64 references in the data sample (n= 383) respectively. The increasing reference to renewable energy and technologies within the transition highlight the changes happening in the industry. The discussions that follow are drawn from the individual themes within the TIS framework. Initially, the assumption prior to the literature in Chapter Two was that the sector was so distinct that it was separate from the offshore wind sector, i.e., two sectors. However, the above discussions of the TIS process and indicators further revealed that the two separate entities are at a bridging point within the transition. Bergek et al. (2008) noted this phenomenon as a bridging phase within the evolution of technologies in an industry.

4.3.1. The TIS Framework: Lessons from Offshore Oil and Gas for Wind Energy

Going back to the TIS framework for offshore oil and gas industry, the sector is a matured one and as noted under the discussions in guidance of the search and market formation, policy influence greatly affects how well the industry is performing. Another issue, which was not discussed within the functions, was how oil and gas prices greatly affected the functioning of the system. Although some of the uncertainties within the industry are often unforeseen and planned for within offshore oil and gas, in the coming years, new technologies that will mitigate the impact of the sector has on the environment and make the greatest difference in how well the TIS functions. The offshore oil and gas sector's growth and development phase was quite different from wind in that its' TIS had undergone a relatively shorter maturation time unlike offshore oil and gas. Entrepreneurial activity/experimentation (F1) for offshore O&G was a longer process with technological development, i.e., platform innovation driven primarily by industry because of the profit motive. A 'niche' was first formed by industrial innovations towards how best hydrocarbons can be extracted with minimal safety and environmental concerns, while the ‘regime’ was created by policy after industry advancements. Hence, policy always lagged after technological innovations. In its mature phase, government regulation evolved due to the goal of energy security and efficiency, and this propelled more inducements such as policy incentives and subsidies for oil and gas companies than for most industries in Texas and nationally.

Although, the TIS for offshore oil and gas performed well and the needs of each theme did meet national energy policy goals (or process goals) in this instance, there were cracks that showed when minimalist environmental and safety interventions and oversight (from the 1980s until the 2000s) resulted in the greatest environmental disaster - the Deepwater Horizon spill till date in the Gulf. The legitimacy of offshore oil and gas was subject to negative perceptions. Bergek et al., (2008) contended that “legitimacy is not a given, however, but is formed through conscious actions by various organizations and individuals in a process of legitimation…” (Ibid, p.10). The negative perceptions about the industry were further influenced by the climate change landscape, which emphasized reductions in fossil fuels due to GHG emissions’ impact on the environment. Many blocking mechanisms were set because of the negative effect of the sector by environmental institutions, pressure groups, climate activism groups, who have become ‘prime movers’ in the TIS and have rallied government to reform the sector post 2010.

From then onwards, the legitimacy for offshore oil and gas was questioned and government policy under democratic administration aimed at stricter regulation across the value chain and a championing of greener alternatives. The lesson here is that internal contradictions and external forces worked towards destabilizing the regime and creating greater avenues for the development and maturity of renewables, particularly onshore wind. That said, the very nature of U.S. energy policy itself is an inducement mechanism for offshore oil and gas development at the state level and especially for a State like Texas where the economy is interlinked with benefits/royalties and spillovers from the oil and gas on the greater economy. As was discussed in the functions, this is changing as uncertainties regarding renewable technologies change and technologies become cheaper making renewable sources cost competitive.

For wind energy, it is important to distinguish the phase of the development, where some functionality matches the needs of that phase. In its formative phase, what is seen is a lot of guidance (F4) and market incentives and subsidies (F5) ushered by policy makers, as was the case in Texas under the CREZ and the renewable energy tax credit program by the federal government and state Tax credit mandates to support the sector. As the sector grew from 2010- 2015, what is observed with this growth is an increasing knowledge diffusion (F3) instigated at the national level by the DoE and its institutional and industry partners innovating and refining technological improvements for wind, especially in wind turbine capacity and blade enhancements. (See Figure 4-10 which shows improvement in installed wind capacity).

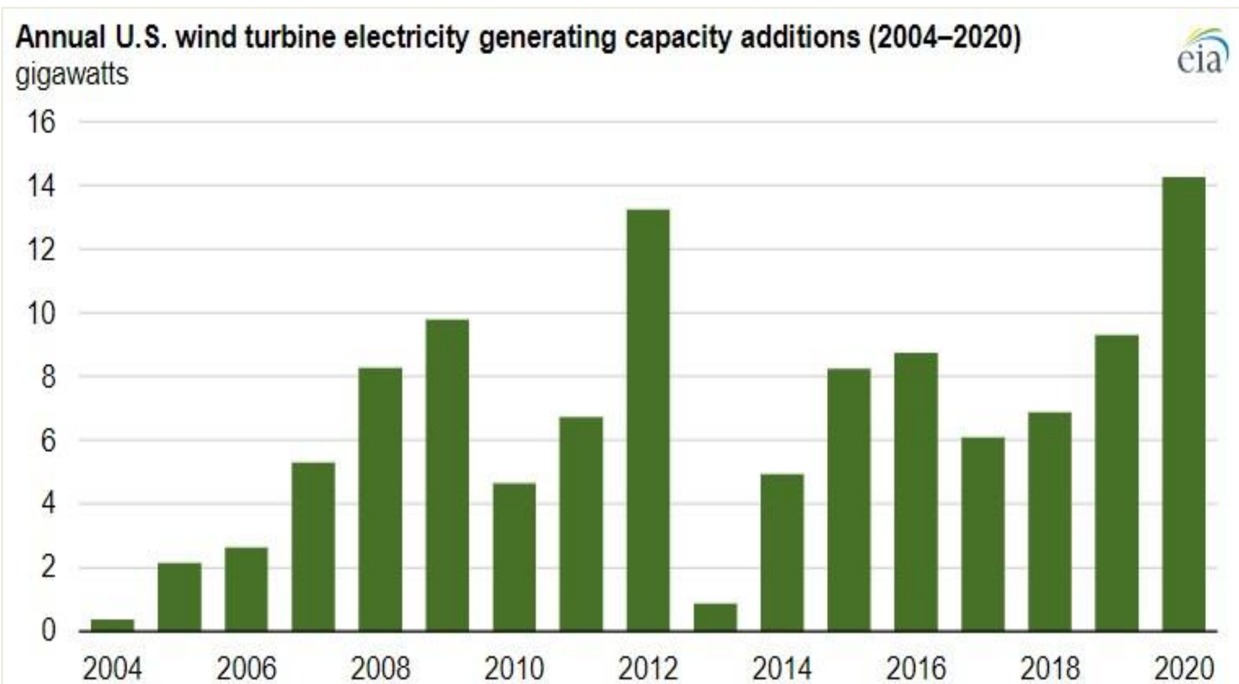

Figure 4-10: U.S. Wind Turbine Generating Capacity (2004- 2020)

Source: EIA (2021b)

Knowledge generation and knowledge diffusion (F2 & F3) in the sector have been enhanced by resources mobilized (F6) by the government (federal and state) in the U.S. The policy incentives that drove the sector enhanced market forces to work in favor of wind. Although like offshore oil and gas, for wind, policy involvement in technological innovation was government driven first before industry collaborations and partnerships enhanced technology diffusion. Assertively, there was initially strong positive feedback within the niche albeit with weak regime support and external influences from offshore oil and gas in the emerging phase. This matured phase is rather different as a feedback loop with industry has been established and bridging of the two sectors has happened for wind and solar as O&G players seek to diversify their energy portfolio. Figure 4-11 illustrated below and adapted from Walz et al. (2016); Walz & Köhler (2014) provide a visual representation of blocking and inducing mechanisms for wind within the offshore O&G regime.

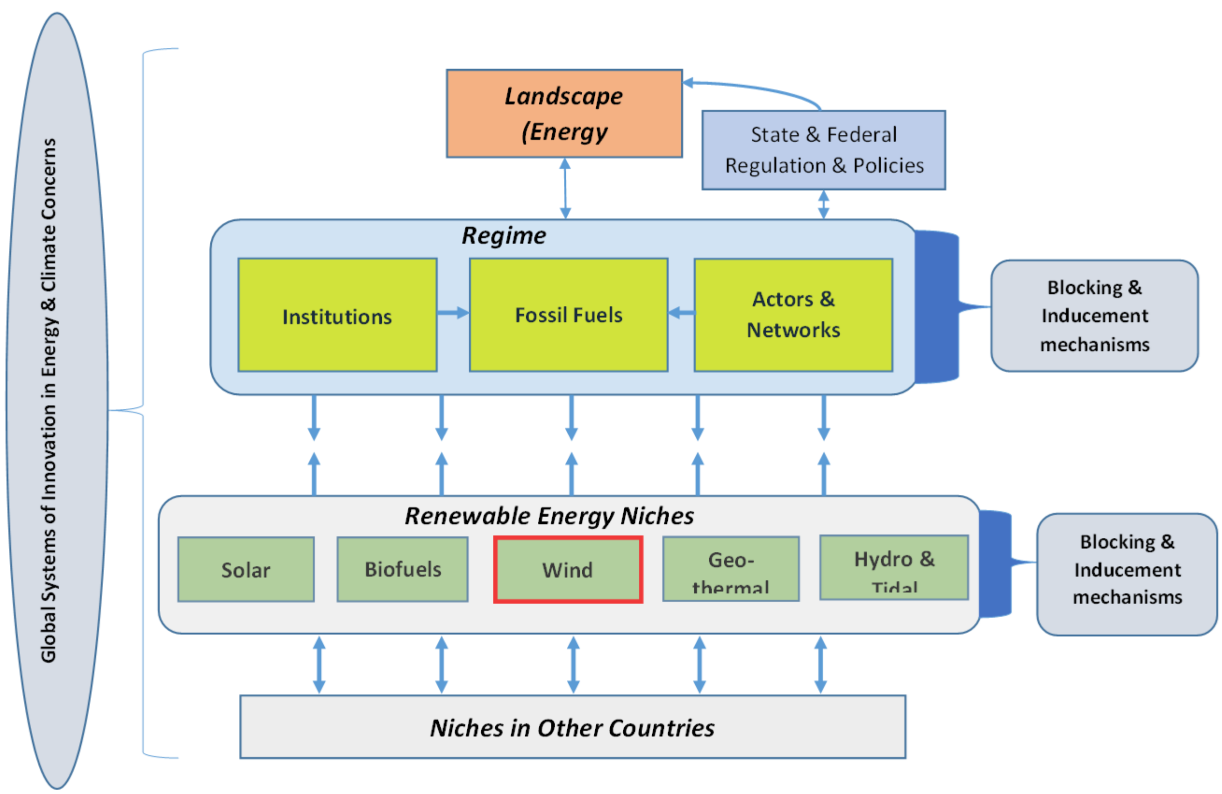

Figure 4-11: Levels of Aggregation of Technological Innovation System

Source: Walz et al. (2016)

From Figure 4-11, despite the blocking mechanisms for renewable energy niches, the regime is being shaken by the climate change landscape at the national and state levels. That said, the specificities of technologies in the regime point to a rather strong regime as noted by Walz et al., (2016) in the case of Germany. Legitimacy (F7) of renewable energy, despite its shortcomings of resiliency, boosted by policies for market formation (F5) enabled faster diffusion of knowledge (of wind turbines) leading to competitiveness of manufacturers. For the case of the TIS, the energy transition is a strong disruption that might change the nature of the industry.

4.3.2. The Energy Transition and the Offshore Oil and Gas Industry

The transitioning from fossil fuels to renewable sources towards a low carbon future is happening at an unprecedented rate. However, there are also many uncertainties within the industry and societally because without the right incentives and cost competitive renewable technologies, this growth may be slowed down in the transition. Walz et al. 's (2016) TIS assessment of wind turbines for Germany and China noted that sometimes strong disruptions may disrupt entrenched and stable regimes. The energy transition is seen as such a disruption that is changing the landscape of the offshore oil and gas regime. The term “energy transition” started to appear frequently from 2011- 2015 and became a more popular part of the energy industry lexicon post-2015, coinciding with the adoption of the Paris Climate Agreement, although the term has been in use since the 1970s.

From the content analysis, some of the common drivers pushing offshore oil and gas in the transition, which was noted as inducement mechanisms (in Figure 4-11) for renewables included: market incentives enabled by policy; environmental concerns from GHG emissions by the energy industry; societal pressures about the destruction of the environment by ‘big oil’; politics; and smart business decision.

To trace the impact such a disruption is having on industry, a matrix correlation of the drivers with the industry classification is queried in NVivo and results are presented in Table 4-2.

Table 4-2: Matrix Correlation Table between Industry and the Energy Transition Drivers

Column Percentages

Industry (Type)	A. Technological Developments	B. Social	C. Smart Business Decision	D. Politics	E. Policy	F. Environment	G. Economic_Market
Oil & Gas	61.86%	9.92%	52.84%	61.02%	28.14%	58.79%	26.24%
Non-Oil & Gas	0%	0%	0%	0%	0%	4.76%	2.93%
Renewable Energy Wind & Others	28.06%	43.26%	7.75%	38.98%	71.86%	3.75%	45.71%
Integrated Energy	10.08%	33.84%	32.37%	0%	0%	18.22%	11.13%
Research	0%	12.98%	7.05%	0%	0%	14.47%	13.98%

The Table 4-2 shows the frequency of the coding of industry players (in the first column) with the drivers against the common themes/drivers within the energy transition. The highest industry motivation in terms of percentages is driven by technological development, ‘politics’, environmental concerns, and smart business decisions. What was interesting from analyzing the transition drivers was how the industry is responding to the change happening within the context of the TIS. In 2011, there was a lot of uncertainty about offshore oil and gas within the industry, many companies initially refusing outright integration or merging their ‘modus operandi’ with renewable energy. However, this trend is reversing with industry pioneering innovation in renewable energy. The four global senior offshore oil and gas companies and how they are responding to the transition is presented in Table 4-3.

In terms of the relation between industry and the energy transition, Table 4.3 is illustrated to show which players are vested in the transition. A few companies are committed to net zero carbon emissions by 2050, which has become a process goal for the transition (see the new mandates under COP26, UNFCCC, 2022). Many players have set targets and goals to commit to reducing their scope 1 and 2 emissions according to the IEA (2020). However, if you dig deeper to where their investments are being directed in terms of these commitments, they are halfhearted promises for the transition (see Appendix 4-E, which shows the nature of investment strategy towards the energy transition by selected companies by the IEA). Besides what is noted in Table 4-3, some of the specific commitments include

BP aiming to reduce scope 1 and 2 emissions by 3.5 Mt CO2-eq by 2025; Equinor cutting emissions by 40%; Chevron's goal of reducing its emissions' intensity for oil by 5-10% and for gas by 2-5% by 2023; and Eni's goal of emissions reduction by 43% in its upstream services by 2025. The takeaway from this is that for scope 3, which is out of the control of energy companies, there is a strong motivation for investments in carbon capture technologies to remove carbon at source before it gets into the value chain.

Table 4-3: Approaches to Renewable Energy Transition by Four Offshore Oil and Gas Seniors

Oil and Gas Companies	*Year Renewable Energy was incorporated*	*Renewable energy portfolio**	*Initiatives and Programs on Wind (US)*	*Incentives that motivated this shift*	*R & D vision for renewable energy*	*Partnerships with industry*	*Commitments to net-zero CO2 emissions*
Exxon Mobil	2015	Wind & Solar, Renewable bio-fuel (diesel), starting in 2022	12-year Partnership with Orstead for Solar and Wind	Policy and market drivers; Shareholder drive towards ethical and green investments	Policy stipulates affordable, scalable solutions for transportation, power generation and manufacturing. Focus is on bio-fuels and carbon capture technologies.	Partnerships with universities and research institutions including, University of Texas, MIT, Sandford University, Singapore Energy Center; industry, IBM, and with the DOE.	No
BP	1980	Broad spectrum- Wind & Solar, Bio-fuels	- Equinor partnership to develop four wind assets offshore - ONYX InSight, digital and predictive maintenance solutions to the wind industry	Policy and market drivers; BP oil spill disaster	Policy focus is on role of electricity and hydrogen; Generally, on energy systems and the role of natural gas in a low carbon world	Multi-country partnerships in Trinidad, North Africa, Mauritania & Senegal, Middle East, India, and Asia Pacific; Universities and Research Centers internationally and industry	Net-zero CO_2 emissions by 2050; Reduce oil and gas production by 40% in the next 10 years

Table 4-3 Continued

OIL AND GAS COMPANIES	YEAR RENEWABLE ENERGY WAS INCORPORATED	RENEWABLE ENERGY PORTFOLIO*	INITIATIVES AND PROGRAMS ON WIND (US)	INCENTIVES THAT MOTIVATED THIS SHIFT	R & D VISION FOR RENEWABLE ENERGY	PARTNERSHIPS WITH INDUSTRY	COMMITMENTS TO NET-ZERO CO2 EMISSIONS
CHEVRON	2015	Solar, wind and Geothermal	Chevron Technology Ventures partnered with Moreld Ocean for floating offshore wind turbine technology	Environmental impacts of climate change; Paris Agreement but did not invest until 2016.	R&D policy focus is on advancing emerging energy technologies, developing scalable and economical new energy resources	Partnerships with the DOE's National Energy Technology Laboratory; Industry partnerships with Schlumberger, New Energy, Microsoft, and Clean Energy Systems; and international partnerships with Singapore National Research Foundation	No
EQUINOR	2000	Wind, offshore Wind and Solar	Partnered with BP on Empire Wind and Beacon Wind projects	Smart business Decision; Market incentives; divested in renewables 2007	Policy focus is on technology and innovation in existing and new energy value chains. Low carbon solutions and renewable energy sources.	Partnership with New York State Energy Research and Development Authority (NYSERDA) to deliver the 816 MW Empire Wind project; international collaborations	Net-zero CO_2 emissions by 2050
*** Most of these companies invest in Carbon Capture and Storage (CCS) & hydrogen technologies**							

Sources: Annual sustainability reports were sourced from the following: (BP, 2021b; Chevron, 2021; Equinor, 2021; ExxonMobil, n.d.)

IEA (2020) notes that within the industry, the core responses to the transition are happening in four areas: 1) reducing emissions from core oil and gas operations 2) investing in carbon capture technologies 3) moving from traditional oil to more low carbon fuels and gas, and 4) divesting from fuel to other energy sources. Despite the responses, the spate at which these are happening is not as fast paced as it should be when one juxtaposes it with the urgency of the process goals within the transition (i.e., net zero emissions by 2050 and maintain earth's temperature at 1.5^{0}C). That said, company approaches, and commitments are different but for the industry, it still signals some work in progress towards the off taking of renewable energy, especially in electricity markets and its demand for wind and solar (IEA, 2020). The current trajectory may not be enough to reach the 1.5^{0}C temperature in the Paris Accords, hence more innovation and new technologies are needed to reduce the impacts that fossil fuels have on the environment. As the industry players are also 'prime movers' within renewable energy niches, their interconnection with the TIS is critical in changing the landscape, in terms of the development and diffusion of technologies. Also, besides the global and national mandates toward the transition, there is a strong push recently from the green car revolution as demand for electric vehicles (EV) increase nationally. Consumers are becoming more aware of the impacts of transportation on the environment as car manufacturers respond with commitments toward providing electricity fueled cars (Motavalli, 2021). Government regulation may also modify energy systems for transportation as EV sales drive more charging stations and demand for green energy (Kerry, 2021).

4.4. Intersection of Technological Innovation for Offshore Oil and Gas and the Wind Energy Sector

In terms of the above analysis of the TIS framework, where are the commonalities between the two sectors and what should be the focus for policy makers regarding wind in the transition? The nature of offshore O&G technologies makes the sector a low hanging fruit in terms of expanding their portfolio to offshore wind since it requires a reskilling of its workers and adapting old technologies to newer contexts. There is an intersection between the two sectors. If discussions by Walz et al.

(2016) have taught us anything, it is that for a ‘regime’ to shift to allow ‘niches’ to thrive, there must be an overwhelming acceptance in both the economic case for the renewable technology and the social, as well as the political economy factors that must be present to drive an eco-innovation. As this is happening with the two sectors, the commonalities which exist between offshore O&G and wind are discussed below.

Firstly, the two sectors intersect in terms of their asset structure. Walz et al. (2016) and Lema et al. (2015) suggest that a lot of technologies within the offshore O&G sector are characterized by very long lifetime assets that are capital intensive, for example power stations, grid, roads, rail, etc. This makes the ease of the transition a costly endeavor to shift its focus onto a new industry that is emerging. However, what is different for offshore oil and gas and again a lesson for wind is that these sectors have common end users, for example (electricity markets) if the strategy is towards that or it may be a different market such as transportation, then depending on the business strategy, restructuring asset financing to support a ‘niche’ sector such as wind to help lower emissions and broaden their renewable energy portfolio may present medium to long term benefits for the industry.

Also, the State of Texas in the early stages of wind’s technological development laid the grid infrastructure that was compatible with wind and other renewable energy sources. Texas’ $7 billion dollar investment into the development of transmission lines was a critical feature of wind’s success in the lone star state. Currently, offshore wind farms have become very attractive as was indicated in Chapter Two. The asset and infrastructure needed must be built if the sector is to emerge in Texas. Markard (2011) refers to this as the path dependency of the technical “systemness” in Walz et al. (2016). The grid infrastructure was upgraded and built in Northwest Texas, where characteristics of the wind environment allowed for wind energy to thrive and to be conveyed to the Southern parts of Texas. Thus, to meet the requirements of the energy transition, investments into the needed infrastructure from the ocean to interconnect with the grid system would be critical. This is a matter of policy and the economics of the project. On both fronts and nationally, the Biden administration is keen on green energy and is further enhancing the policy motivation and incentive to make wind energy very competitive at the federal level with its green agenda, goals and targets for electric vehicles, investments into new technologies, rejoining the Paris Agreement, and the recent passing of the 1.2 trillion infrastructure bill, which can help overcome some of the infrastructure constraints in the energy transition.

Additionally, in terms of legitimacy for offshore oil and gas and wind, the political environment has been instrumental in how these sectors are socially accepted. Offshore oil and gas' environmental impact and record are less than stellar, but then again Texas' economy is highly intertwined with the sector. Meaning that even within the landscape of climate change and policy targets set by federal, state and city level institutions, acceptance for wind and even offshore may not just happen, except through efforts to launch the lower carbon emitting potential of such energy sources for electricity markets. This regime-niche clash or as Walz et al. (2016) puts it, regime-niche constellation is characterized by two systems, those that are part of the existing innovation system and those that are drivers of the eco-innovation and are often not part of the existing innovation system. For wind in Texas, there has been a gradual albeit slow acceptance and process of bridging with many off takers through purchase agreements by offshore oil and gas companies and other industries with providers of wind energy.

Furthermore, the energy sector in Texas is unique in terms of the characteristics of the actors that interplay to shape the political economy dynamics of the state. This is especially with regards to diffusion and the galvanizing of interest for manufacturers and those involved in the supply chain for offshore wind. The market incentives, although prime, have micro-scale supply chains making the sector highly capital intensive. In the U.S. the three main manufacturers of wind turbines, General Electric, Vestas, and Siemens have more than 70% share of the market size for turbines (EIA, 2016). See wind turbine generating capacity and share of manufacturers in Figure 4-10 and Figure 4-12: Manufacturers of Installed Wind Energy Technologies.

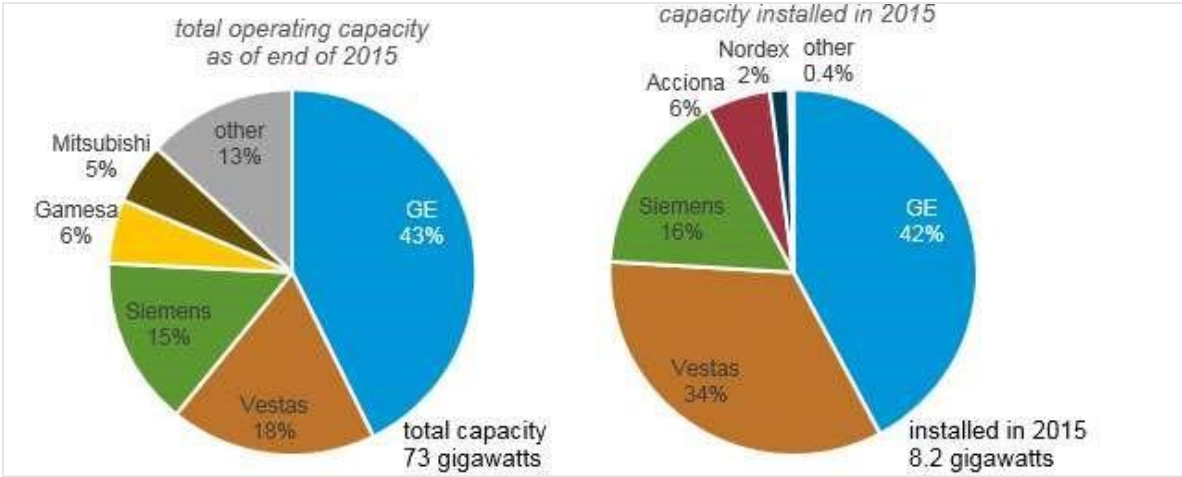

Figure 4-12: Manufacturers of Installed Wind Energy Technologies

Source: EIA (2016)

These top three manufacturers also manufacture equipment for offshore oil and gas, particularly metallic parts for platforms and semi-submersibles used in deep sea mining. This is another commonality between the two sectors. Thus, the two sectors are more alike and to a certain extent can be viewed as having the potential to transition to offshore wind energy. It is not to say that other renewables do not present favorable options, but that infrastructure for wind can be easily adapted from offshore oil and gas for wind.

In essence, the bridging observed in the TIS demonstrates that the two sectors might eventually become one sector, with offshore oil and gas pivoting to offshore wind to help meet the process goals within the transition. What is being posited here is that the severity of climate change impacts and national policy goals, may motivate policy action to steer and enhance technological innovation in the wind sector, driven by the offshore oil and gas sector and the economics of the case. However, when it comes to each individual project, states decide the particulars - policies, political support, and contract with utilities (Buck, 2020). Policy incentive to drive an eventual co-evolution to more offshore wind energy investments might be needed in the long haul to catalyze the industry. Similarly for offshore oil and gas technologies, in playing catch-up, the State of Texas incentivized new players into the oil and gas sector after hydraulic fracturing became cost competitive from 2005 onwards. Thus, how a state chooses to embrace offshore wind energy and create the policy incentive and support to drive innovation in the sector, is what will enhance wind energy as part of the energy transition agenda.

4.5. Chapter Summary

The Paris Agreement process goal of limiting the temperature increase to 1.5 °C above pre-industrial levels by 2050 may not be reached looking at the current pace at which the world utilizes fossil fuels. As a result, the just ended COP26 refocused the debate on accelerating the phasing out of carbon intensive fossil fuels such as coal, switching to EVs and encouraging investments into renewables. The much-needed technological innovation to facilitate the achievement of these may have to be sped up. For Texas, the Chapter showed that it has a natural and competitive advantage with wind since it is recognized as the leader in onshore wind energy and hence has the potential to expand offshore wind. Two recent studies by the National Renewable Energy Laboratory (NREL) have modeled the potential for offshore wind in the GOM. The studies argued that 508 GW of wind energy can be feasibly generated offshore (Musial et al., 2020; 2021). This will be equivalent to half of the total U.S. power generation capacity. In terms of the GOM region, the conditions are ripe for offshore wind farms, but the State has yet to lease certain portions of the GOM for wind energy companies. Even more so is the needed funding and policy incentive at the state level to kickstart a burgeoning Technological Innovative System for the industry, which may assist with the energy transition agenda of the State. In this regard, the policy environment is critical in shaping the future of offshore wind energy. On the business side, much more can be done to encourage entrepreneurial activity and new entrants into the market. Opportunities exist for learnings from offshore oil and gas, knowledge sharing and transfer and joint commercialization within the sector, as was noted earlier in the case of BP. Understanding the policy incentives and motivation pre and post construction in the case of Block Island Wind Farm and drawing lessons from the offshore oil and gas industry can provide a deeper understanding of the policy future of offshore wind energy in Texas.

5. THE POLICY FUTURE OF OFFSHORE WIND ENERGY IN TEXAS

As for the future, your task is not to foresee it, but to enable it.

– Antoine de Saint Exupéry, *Citadelle,* 1979

5.1. Introduction

The TIS framework used in the assessment in the previous Chapter juxtaposed the offshore oil and gas sector with the wind sector to highlight the motivations, incentives, and policy intersections with technological innovation. This Chapter answers the third research question on whether a policy future exists for offshore wind energy and what lessons from Block Island Offshore Wind Farm can inform the growth potential of Texas' offshore wind sector. As indicated in the earlier chapters, the Paris Accords' process goal of maintaining a 1.5^{0}C temperature by 2050 may not be realizable unless drastic efforts are applied to scaling-up renewable energy systems with policy support. Within this ambit, many states have set ambitious goals and targets of carbon neutrality and net-zero carbon emissions between 2030- 2050 for the electricity sector.[3] Using a target-based approach, the first section of this Chapter makes a case for offshore wind energy. Hypothetical scenarios and targets are devised for the State as it scales back its consumption of natural gas to meet potential state and federal mandates for the energy transition in the next 30 years using ARIMA for the predictions for the electricity sector. The second part draws lessons from Block Island Offshore Wind Farm's development for Texas. Some of the policy lessons in the TIS framework are also extended as potential strategies and requirements/conditions that would be needed to enhance the future policy of Texas' offshore wind environment.

[3] For a list of states with renewable standards, see NCLS (2021).

5.2. Making a Case for Offshore Wind in Texas

As of 2018, more than 15 states have expanded their RPS and Clean Energy Standards aiming for 100% net-zero GHG emissions by 2045 (NCLS, 2021). Besides this, the Biden administration has also set nationally determined contributions (NDC) of reducing GHG emissions by 50- 52% below 2005 levels by 2030. Key sectors where emissions are high and seem to be targeted by government policy are transportation (contributing 27%) of all U.S. emissions and the energy sector, about 73% from fossil fuel combustion (EIA, 2020b). To reduce emissions from the energy sector, the government has further set a target of 100% clean and renewable generation of electricity by 2035 (Kerry, 2021). This is a highly ambitious goal that would require a fundamental change in all industries, as well as a paradigm shift in how energy systems are designed and used. (Kerry, 2021: 6-7). To understand the potential impacts of such national and global mandates toward the energy sector, the next section presents a simple modeling using energy production and consumption to make a case for wind, particularly the need for the commencement of an offshore wind industry for Texas. Some of the findings of the seminal NREL study on offshore wind for the GOM region by Musial and Others (2020) is relied on in further discussions of whether a future exists for the sector in Texas. It is suspected that as the State rallies to meet federal and global mandates of reduction of GHG emissions by 2050, offshore wind and other renewables, particularly solar, would be very important for Texas besides onshore wind.

5.2.1. A Simple Modeling for Texas' Electricity Generation

To answer the question of whether there exists a policy future for offshore wind energy in Texas, the section considers the major energy sources for electricity generation to make a forecast of renewable generation should production of 'natural gas' potentially reduce. The Autoregressive Integrated Moving Average (ARIMA) Model is used because the series' own values can be used to make predictions of future values. The ARIMA (p, d, q) is defined such that p is the order of the autoregressive part, d is the degree of the first differencing involved, and q is the order of the moving average part. The first type, i.e., the univariate method, which consists of training the data to use its own values to make future prediction is relied on for the forecasting. The reason why the univariate method was used is because we wanted to make a simple model and a case for renewables should there be reductions in conventional sources. Although the multivariate type makes model prediction more robust, the researcher decided to use a very simple model to make this prediction (See section 3.3 of Chapter Three for the rationale for using this). To use ARIMA, two conditions must be satisfied: 1) the data must be in a series or be regularly collected over a period with no randomness of events; and 2), the data must be non-seasonal and stationary, meaning that the observed data variables should have a constant mean, variance, and correlation over time. For the prediction, data for the period 1990- 2020 is used. Of the 12 sources that contribute to Texas' electricity mix, the most significant sources out of these, which contribute to more than 88.2% of the State's energy sources are used in the modeling. The selected sources are coal, natural gas, and wind. Natural gas contributes the highest share of about 52.1%, coal 16.6%, and wind 19.5% in 2020. Figure 5-1 highlights the three main energy sources which contribute a percentage share of (>10%) to total electricity generated as well as consumption in Texas.

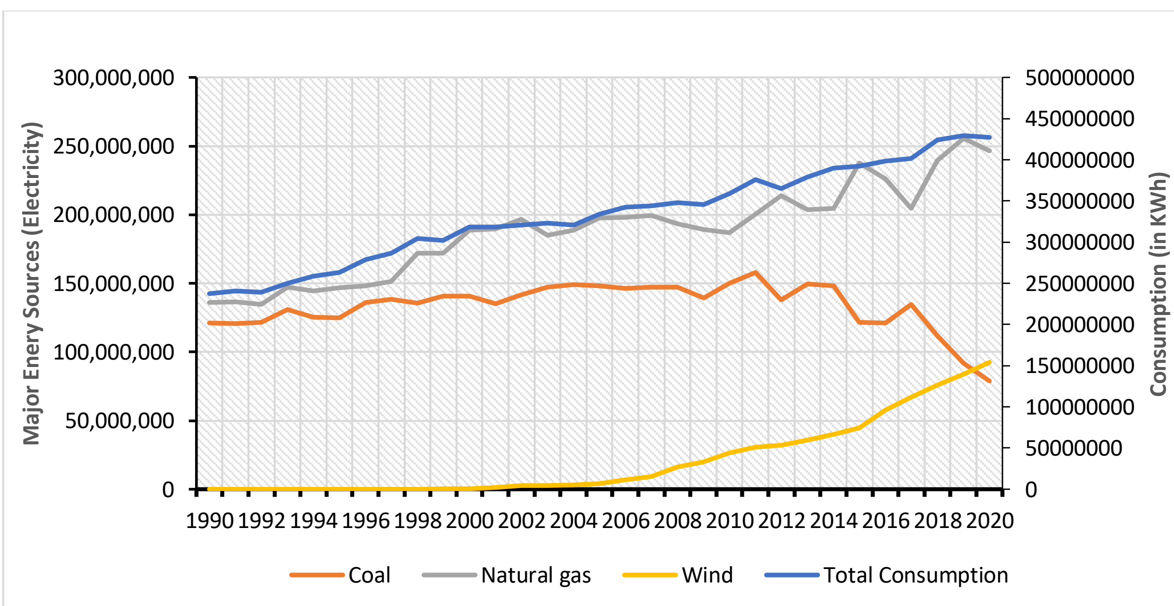

Figure 5-1: Consumption and Major Energy Sources Trends

Data from (EIA, 2022a)

The energy mix that fuels the State's electricity sector has tended to shift away from conventional fuels with declines in coal. Because of its negative environmental impacts, natural gas and wind energy generation capacity have increased to fill in the gap (see Figure 5-1). In a report by McKinsey & Co, it was noted that the growth of renewables such as wind is essential in understanding the energy transition and why primary energy demand curve will plateau around 2030, followed by a 20-year decline (See Sharma et al., 2019).[4] As coal has declined, and the States' energy portfolio requires 25% contribution from renewable energy sources, wind energy market capacity generation has increased overtaking coal for the first time in 2020. For the data sources, the EIA's database was sourced for the modeling. The variables considered for the modeling are as follows:

- Total Electricity Consumption (all end-users) (KWH)
- Major Energy Sources (Natural gas, Wind and Coal), which contribute more than 10% share to the State's energy mix (all in KWH).

The point of the modeling is to assess how much wind energy would be needed to fill in the gap if we have timeline scenarios of natural gas reduction. Thus, using percentage changes if the State hypothetically and gradually wean itself from natural gas by 15% (from 2021- 2030), 25% (2031- 2040) and by a further 35% (2041- 2050), what deficits would be created for assumedly wind to fill this gap. Because Texas is an Oil and Gas State and natural gas is a cleaner source of fuel than oil, we do not anticipate the State will totally discard natural gas even by 2035 or 2050. That is why the percentage total of the scenarios is only 75% reduction (between 2021- 2050). We still expect at least 25% or more to be sourced from natural gas with carbon capture technologies to be maintained till 2050. Also, in the interim for the scenarios, from now until 2025, the policy projections don't predict a 15% decrease in natural gas. So, it is assumed that the status quo may remain, then from 2027- 2030 (the 15% may apply) and the other scenarios continue.

[4] The Clean Air Act, Title IV set a cap (or limit) on coal because of these negative impacts on the environment and has had a downward spiral effect on the industry, causing volatility in the market because of regulatory shocks.

I. Modeling Configuration

Although price is a function of market supply and demand factors (Brigida, 2014; Hartley et al., 2008) and especially relevant in energy in Levelized Cost of Electricity calculations, the approach taken for this modeling relies solely on generation capacity (KWH) and on its relationship with consumption. It is important to point out that many studies by the IEA, IRENA, and the World Bank have forecasted complicated models globally and for various regions on energy sources and the transitions vis-à-vis the direction in which renewables are likely to go in the context of achieving the Paris Agreement goals by 2050. The EIA has also conducted research in this regard at the national level post-2030 to 2050, but none of these have tended to focus on state-specific sources for the electricity sector. In using ARIMA, the focus is simply an autoregression of past values for the forecast.

Exploratory Data Analysis

The exploratory data (descriptive statistics) for the three sources and consumption are presented in Appendix 5-A. In terms of the model, Pearson's correlation, which shows the statistical significance of the variables with consumption and determines whether all variables (natural gas, wind, coal, and consumption) are linear is presented in Table 5-1.

Table 5-1: Correlation Coefficients between Consumption and Major Energy Sources

Variables	Correlation value	P-value
Coal and Consumption	-0.1703477	< 0.3596
Natural Gas and Consumption	0.9599146	< 2.2e-16
Wind and Consumption	0.9461565	< 9.375e-13

The three energy sources with consumption are statistically relevant with high correlation values and confidence intervals for the model. For coal, there is a strong inverse relationship with a consumption of (-0.1703477). As consumption is increasing, there is less demand for coal since generation capacity trends down compared to the other sources that are positively correlated.

Testing for Non-stationarity in the Time Series Data

To satisfy the first condition under ARIMA, we must test for stationarity of the variables to be forecasted. Fitting an ARIMA (***p, d, q)*** model requires the series to be stationary. A stationary time series is one whose statistical properties such as the mean, variance and autocorrelation structure are time invariant and hence do not depend on the time at which the series is observed. Autocorrelation measures the linear relationship between lagged values of a time series. Conversely, a non-stationary time series is when values and associations between and among variables do vary with time. To test for stationarity, the Augmented Dickey-Fuller (ADF) test is conducted on all variables before forecasting. We assume a null hypothesis where the time series is non-stationary (H_0) versus (H_1), where it is stationary. The results are presented in Table 5-2.

Table 5-2: ADF Testing for Stationarity

Variables	Dickey-Fuller	P-Values
Coal	2.8539	0.99
Natural Gas	-1.5742	0.7367
Wind	1.1684	0.99
Consumption	-2.2256	0.4859

From the ADF testing (in Table 5-2), the p-values are all above .05, meaning that our time series is indeed non-stationary, so the null hypothesis (H_0) is accepted. As indicated earlier, ARIMA provides a good fit to model the data because it describes the autocorrelations in the data to predict future values. This assumes that the forecast of the next period depends on past values of the same time series. Given that we have non-stationary time series data, we will need to “difference” the data until a stationary time series is obtained. For the study, the auto-ARIMA function in R studios, which already factors in the order of differencing to result in a (*p, d, q)* model is used for the prediction. The Hyndman-Khandakar algorithm for automatic ARIMA modeling in R is premised on the following conditions for (*p, d, q*):

1. The number of differences $0 \leq d \leq 2$ is determined using repeated ADF tests
2. The values of *p* and *q* are then chosen by minimizing the Akaike Information Criterion (AIC) after differencing the data *d* times. Rather than considering every possible combination of *p* and *q*, the algorithm uses a stepwise search to traverse the model space.

II. Results of the Modeling

Based on the time series from 1990 to 2020, by using the ARIMA model, we predict years 2021 through to 2050. The forecast estimates are provided with confidence bounds: 80% confidence limits shaded in darker blue, and 95% in lighter blue (see Figure 5-2). For stationary models (i.e., with *d=0*), forecast intervals converge i.e., the long-term forecast standard deviation will go to the standard deviation of the historical data, for (*d >1*), the forecast intervals will continue to grow into the future. Table 5-3 shows the results of the modeling.

Table 5-3: Results for ARIMA (p, d, q) Forecasting

Variables	**ARIMA *(p, d, q)***	**AIC**
Coal	(1, 0, 0) with non-zero mean	1095.35
Natural Gas	(0, 1, 1) with drift	1065.46
Wind	(1, 2, 0)	929.07
Consumption	(0, 1, 1) with drift	1036.95

The results reported in Table 5-3 tell us the model that best fits our times series corresponding to the variables coal, natural gas, wind, and consumption. The AIC reported allowed us to compare the fit of different models for each variable and ascertain if the models are adequate. The smaller the AIC, the better the model.

For coal, the model ARIMA (1,0,0) with a non-zero mean suggests that our variable has a mean different from zero; therefore, the long-term forecasts will go to the mean of the data. For the variables natural gas and consumption, the results ARIMA (0,1,1) with drift suggests that their long-term forecasts will follow a straight line as shown in Figure 5.2. Lastly, for the variable wind, the ARIMA (1,2,0) implies that the long-term forecasts will also follow a straight line as shown in Figure 5-2. Figure 5-2 is a graphical representation of the energy sources and their forecast from 2021- 2050.

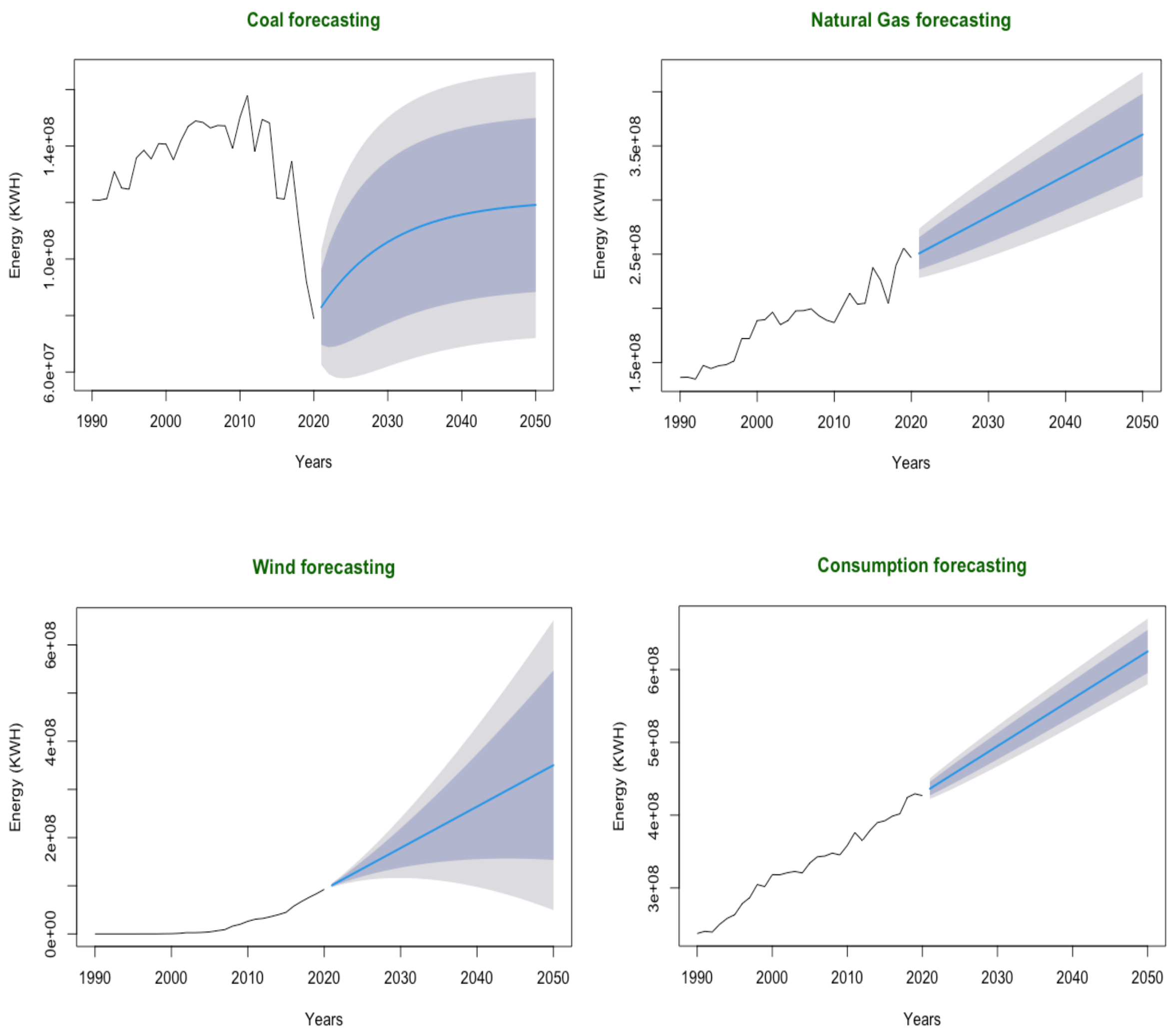

Figure 5-2: Energy Sources and Consumption Forecasting (2021- 2050)

The energy sources (production/KWH) and consumption (KWH) forecasts are put into one graph and illustrated in Figure 5-3.

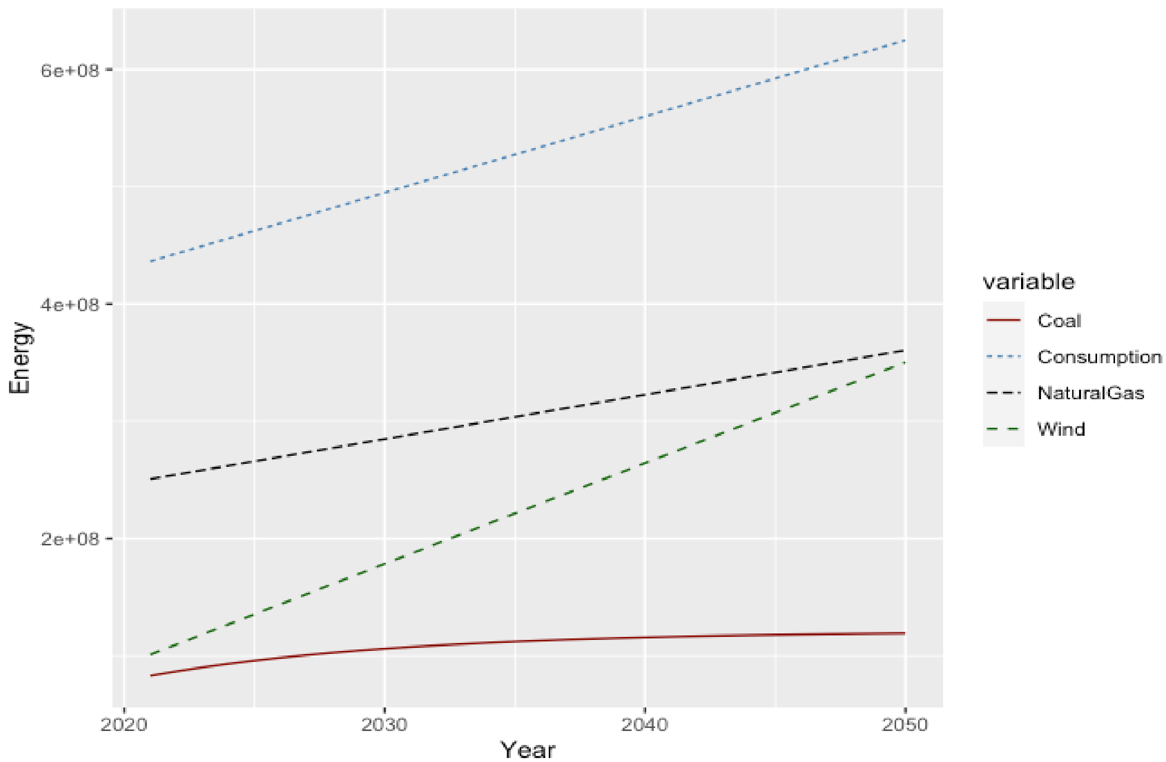

Figure 5-3: Forecasting Energy Sources (Production) and Consumption in KWH

The forecast for coal does not show a trend upwards but rather it remains somewhat constant over the 30-year period. The possibility of legislation affecting coal further is highly likely to occur as many coal plants are shut down and replaced with more energy efficient and lesser CO_2 emissions energy sources (American Clean Power Association, 2020; EIA, 2021d). To plot what deficits will likely occur as natural gas is reduced to meet global and national mandates of renewable electrification, the percentage changes over the different hypothetical scenarios, i.e., 15% (2021-2030), 25% (2031- 2040) and 35% (2041- 2050) are applied to the forecasted energy sources and is depicted in Figure 5-4.

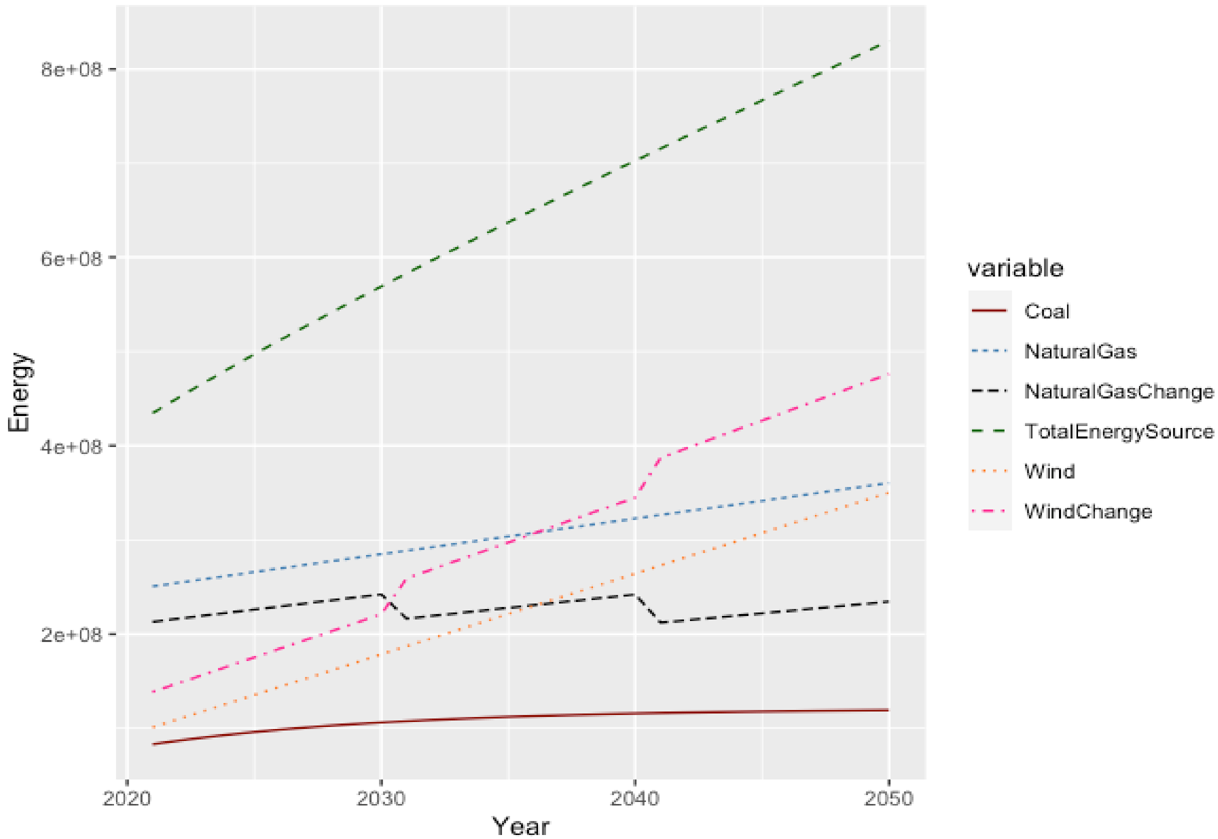

Figure 5-4: Percentage Change in Energy Sources as Natural Gas Reduces (2021-2050)

From 2022 onwards, whatever decrease is anticipated with fossil-based fuels would have to be absorbed principally by wind and other renewable options, including nuclear for Texas' electricity sector. Although nuclear energy production has remained fairly constant over time - the NREL nuclear program is also positioning itself for 'small nuclear' sources that can contribute to current energy systems as the U.S. transitions to a net-zero carbon economy. See Figure 5-5, which shows all energy sources for electricity, including biomass and wood for Texas.

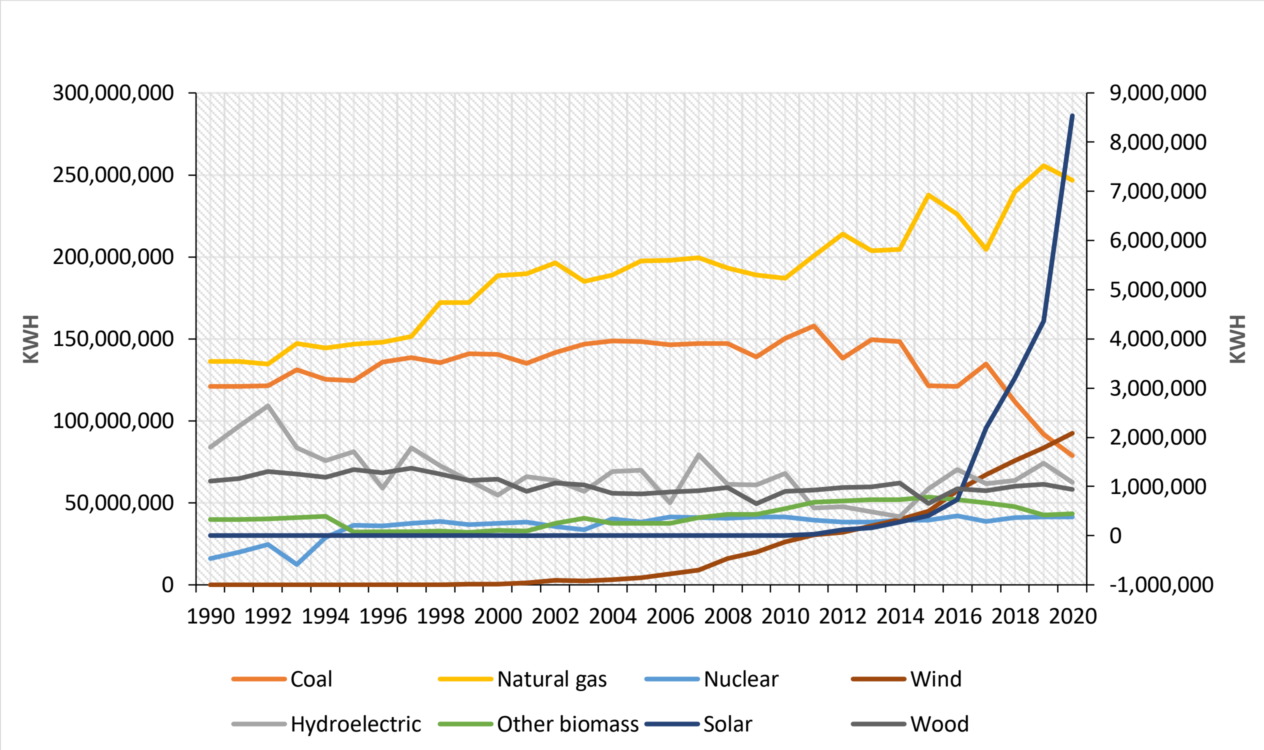

Figure 5-5: Major Energy Sources in Texas' Electricity Mix (KWH)

Source: EIA (2020)

Also, commitments to cut emissions to 50-52 percent below 2005 levels and to reach carbon pollution-free electricity by 2035 may not be realistic now unless new sources such as offshore wind is scaled up drastically in Texas to help meet these goals, as well as nationally. The modeling showed that more gains would be made past 2040, when the State potentially increases wind capacity by 35% with a subsequent reduction in natural gas production that also incorporates carbon capture technologies. Wind has the best prospects in pivoting to offshore wind since the State has made great strides in wind generation over the years. Despite these assertions made, it is important to highlight that forecasts not based on exogenous factors that have greater influences on energy systems remain at best forecasts. The only guarantee in the transition is creating the enabling framework to allow renewable sources to thrive amidst the understanding that these are still non-dispatchable sources that would require some dispatchable conventional sources in aiding the intermittency issues that these face. Additionally ramping up of battery storage technologies can also assist in addressing the non-dispatchability concerns that renewable energy sources face.

5.2.2. Is there a Policy Future for Offshore Wind in Texas?

From the above discussions, the premise laid is that wind in general has very good prospects in Texas. However, whether there is a policy future for offshore wind in Texas would be dependent on: (1) the policy environment and how the legislature perceives that offshore wind will benefit the State; and (2) the economics of the offshore wind project over its lifecycle.

The economics of the project is very important besides showcasing that there will be deficits in the electricity sector if mandates push for a scaling back of natural gas in Texas' energy mix. To briefly assess this, one can use Levelized Cost of Electricity (LCOE) calculations. The LCOE is the best standard available in the industry, which puts all costs per KWh, i.e., capex, opex, capacity factor and production capacity of the technology over the life of the entire project. It helps compare different energy alternatives into a single standard of assessment, i.e., ($/KWh or $/MWh). The LCOE calculations for common renewable sources, which are projected to increase in the next five to ten years from the EIA's 2022 assessments are illustrated in Figure 5-6. Data is based on 2020 assessments for capital and operational costs, while factoring in inflation for the projections.

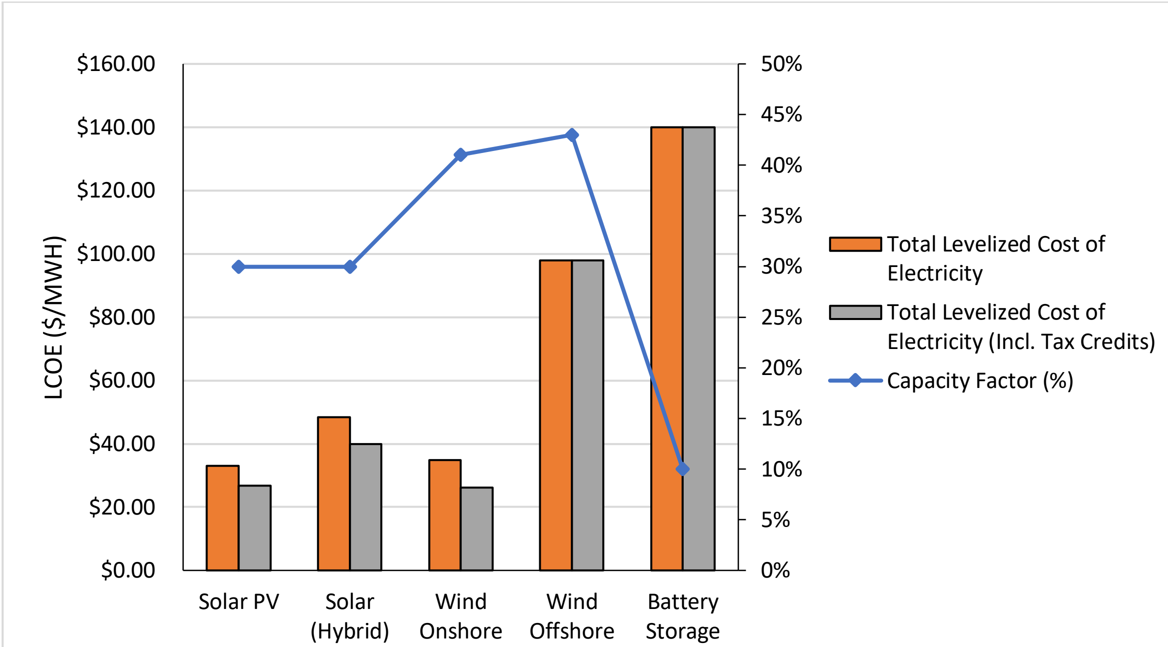

Figure 5-6: Levelized Cost of Electricity for Selected Renewable Technologies

Source: (EIA, 2022b)

The dollar per MWh for most current technologies coming online by 2024 from Figure 5-6 indicate that onshore wind is still a cheaper option compared to offshore wind ($98.01/MWh) and battery storage ($140.07/MWh). Although natural gas, i.e., (existing plant) not shown in the graph is cheaper now, new plants are more expensive. In terms of dollar per megawatt hour, new plants costs (about $41- $61/MWh) compared to onshore wind of $22- $42/MWh (Larzard, 2021). For newer generation, onshore wind is price competitive with both natural gas (combined cycle) and coal. Solar PV is also becoming price competitive. Offshore wind according to Sherman et al., (2020) and Wiser et al., (2021) is likely to be near price competitive with other renewables between 2027-2030. Musial et al., (2021) indicated in their report that it may come as low as having an LCOE of $56/MWh on average by 2030 depending on the regulatory environment and the type of wind turbine infrastructure that is installed. The current Biden administration's investment tax credit (ITC) of 30% for new generation of offshore wind is going to propel more investments into wind. Amongst most renewable sources, offshore wind has the highest generation capacity factor in the GOM making it a sustainable source of energy should the industry be established and mature in the coming decade (Musial et al., 2020). Although, this is still very dependent on whether the unit life cycle cost of production per KWh/MWh is worth it in the immediate to medium term to warrant a regime change in the electricity industry and, whether federal enforcement of the GHG emissions reduction targets and the 100% carbon pollution-free power sector by 2035 can enhance this.

In terms of the ‘policy environment’ to foster offshore wind, this would have to be motivated by how the Texas legislature views the benefits from offshore wind energy to the State’s electricity mix. Most coastal states in the GOM, such as Texas, Oklahoma, Louisiana have significant GHG footprint in large part due to their heavy fossil fuels and manufacturing industries. Some of the benefits that make offshore wind different is that it can help abate the effects of pollution, reduce the impacts on climate and global warming in the long term, and further curb the negative effects of water resource usage in the extraction and processing of conventional fossil fuels. Hence, as Polevka (2017) notes, the commercial development of offshore wind can assist states to provide unrestrained and reliable large-scale electricity as well as a buffer to much of the emissions states produce. Also, it can facilitate the retirement of heavy polluter industries, such as coal (devoid of carbon capture technologies) that emit dangerous GHGs into the atmosphere as the nation tries to meet the 100% renewable electricity generation by 2035.

Another benefit for offshore wind is the fact that the ocean (both state and federal waters) presents a huge potential for expanding wind energy generation capacity in Texas and opposition to wind by communities that have a strong dislike for onshore wind under not-in-my-backyard (NIMBY) beliefs can be assuaged by offshore wind. This makes the policy future for offshore wind ripe in Texas. This is because the abundance of wind in coastal regions provide an avenue of unrestrained ocean access if careful ocean planning between the BOEM, BSEE, Army Corp of Engineers and the US Coast Guard, the Fish and Wildlife Service (USFWS) and National Marine and Fisheries Service (NMFS), EPA, Texas’ General Lands Office and other legislative and state agencies concerned with offshore assets allow for ease of leasing waters for wind farms. Wang et al.

(2019) contend that current assessment of its suitability shows that offshore winds track data proves to a certain extent that it might be able to solve the problems of the duck curve[5] since winds are strongest in the afternoon and evenings. Hence when there are power surges due to a ramping up of electricity from waning solar (between 4pm- 6pm), offshore can fill in the gap and reduce the reliance on fossil fuel back-up generators.

All in all, cost is becoming competitive for offshore wind, which is anticipated would be parallel with other renewable sources by 2027- 2030. That said, there are unforeseen exogeneous impacts such as regional agglomeration effects that may potentially bring these costs even further down. Within the past decade, Europe's levelized cost of electricity for offshore wind has decreased drastically as countries have embraced offshore wind. Costs have reduced by 60% in the past three years in Europe to about $53.40- $63 per MWh currently compared to $169 per megawatt-hour in 2014 (Wind Europe, 2022). Technological improvements in turbine size development have also ushered more offshore development in coastal states in Europe as regional supply chains have been developed and streamlined, overcoming significant capital costs that were great impediments to the growth of the sector. Spillover effects may reduce global inefficiencies and increase economies of scale that could potentially transform offshore wind supply chains in the U.S.

In the case of Texas both the economic and physical characteristics for offshore wind in the GOM has been conducted by NREL and BOEM (See Musial et al. 2020). The resource potential for offshore wind is the highest in the GOM region at 508 GW compared to other offshore renewable options, such as tidal, wave, ocean currents and Solar PV, and hence can assist the nation in deploying 30 GW of offshore wind by 2030 (Musial et al. 2016). Despite the unique challenges identified in the GOM in the report, such as frequent hurricane events, slower wind speeds and softer and shallow

[5] The duck curve is a graphical representation of a phenomenon that happens to areas and grid dependent on wind and particularly solar when peak demand results in a ramping up of dispatchable energy sources between 4pm-6pm in the evenings. Because there is no sun in the evenings, with many people switching on appliances, there is heightened demand on the grid, causing diesel, gas and sometimes coal powered plants to work more to meet this peak demand.

soils, the NREL study contended that utility scale generation can best be achieved in the GOM as cost is scaled down in the region. As already mentioned, regional agglomeration effects and economies of scale from the east coast are likely to impact costs and technological improvements in turbine size development would help deploy less wind turbines but at a higher capacity generation. A good thing with the GOM's shallower soils is that cost for installation would be significantly lower than deeper offshore wind turbines coupled with a milder climate and lower labor cost, and access to the existing supply chains and technological repurposing from the already existing oil and gas industry in the State. In terms of economic impacts, the NREL study modeled a 600 MW offshore wind farm across three sites in Texas. It was found that the farm can result in a potential creation of 4,650 jobs in construction and operation, and an annual GDP contribution of 445 million within the 3- 5 years that construction subsists for most offshore wind projects. Furthermore, a further $14 million addition can be gained as benefits to the region to annual GDP when the offshore wind project is in operation. (See Musial et al., 2020).

To conclude, a policy future for offshore wind in Texas is likely in the not-too-distant future as the BOEM in 2021 already published a Request for Interest (RFI) in the GOM regarding offshore wind and other offshore renewable technologies (Federal Register, 2021). This is to generate interest and feedback about parties that would potentially be interested in leasing parts of the GOM for offshore renewable energy development. The economics of the project and national mandates may also heighten interest in offshore wind as nationally the U.S. transitions to a net-zero carbon future. As potential benefits outweigh the costs, Texas policymakers may have to consider creating the enabling environment to foster the development of offshore wind resources. As Chapter Four posited, both offshore oil and gas and offshore wind are two sectors that would eventually merge at some point because of the technologies in common. Offshore oil and gas companies have existing infrastructure that can be easily repurposed for utility-scale offshore wind that can help with reducing their energy costs while providing electricity on a large scale for many households in Texas. As Rushton (2022) notes "companies already producing oil and gas in the Gulf of Mexico have a head start on developing offshore wind energy in the region. They have significant infrastructure in place, much of which can be repurposed for offshore energy production. In addition, oil and gas companies have access to the technical know-how needed to operate offshore wind farms." The next section discusses Block Island Offshore Wind Farm's development in New Shoreham, Rhode Island and lessons that will enable a policy future for offshore wind in Texas.

5.3. History of Block Island's Offshore Wind Farm

The first offshore wind farm, Block Island, was initiated in 2006 when the Rhode Island (RI) State legislature planned a 15% supply of electricity from offshore wind. Deep Water Wind company won the bid in 2008 to develop the offshore wind farm in two stages. The first stage was to construct a 5 turbine or 30 MW of GE Haliade H150 model capacity generation in Block Island, and secondly, to expand this with the construction of a 150- 200 turbines full scale wind farm in Martha's Vineyard. The farm located in a Special Area Management Plan (SAMP) renewable energy zone is about 4.8 km south-east from Block Island and 25.7 km south of Rhode Island's mainland (Power Technology, 2016). The five (6 MW) turbines connect to each other via a submarine cable and further interconnect with the transmission cable carrying loads of 34.5 kilovolt (AC) to the coastal load station in New Shoreham (McCann, 2020). The turbine structure is the jacketed type as the distance is still in shallow waters. Until now, only the first 30MW wind farm has been built and is active, coming online in 2016. For Block Island, federal and state permitting applications for siting were granted. In terms of the structural durability, because of the location of the farm (in state waters), the BOEM managed the leasing process. The Army Corps of Engineers was mandated to assess the structural durability of the transmission lines and wind farm, in concert with agencies such as the Coast Guard, the Fish and Wildlife Service, National Marine and Fisheries Service and the EPA for environmental due diligence and monitoring of the project. In terms of the state agency monitoring, the Coastal Resources Management Council together with the above listed federal regulatory agencies opened the project for comments with the filed permitting application processes. Polevaka (2017) notes that the Deep Water project underwent rigorous environmental monitoring, with about 21 listed federal and local permits that needed approval for the project to proceed.

By 2013, most of the permits received approval together with a general social acceptance or legitimacy for the project, which was sought after the Block Island Council requested for comments for or against the impact of the development. Other state and local permitting processes for underground cables in the ocean to transmit the generated electricity gained support and approval from the planning and zoning boards. Also, approvals at the local level for the implementation of the necessary research equipment, as well as the coastal load station to connect to the grid were gained. Despite Block Island being a demonstration-scale offshore windfarm, it ushered in the future of offshore wind. According to McCann (2020), the farm powers about 1% of the State's household or 17,000 homes. Other benefits include less fuel and water usage hence reduced energy bill (by about 40%) and has resulted in the replacement of New Shoreham's diesel-fired plant. It has further improved reliability issues in the areas connected to the load station and resulted in reductions in carbon dioxide emissions for the State (Ibid).

5.3.1. Lessons from Block Island's Offshore Wind Farm

From the above history of Block Island (BI) Offshore Wind Farm, there are many lessons that can be gleaned from the construction to operation of the wind farm. Importantly, non-market strategies drove the success of BI Offshore Wind Farm. Furthermore, the State's leadership support towards renewable energy was instrumental in its success. Polevaka (2017) purports that much of the successes have been entirely due to progressive energy policy reforms, political leadership, and marine spatial planning by the Rhode Island legislature. Some of the policy lessons for the wind farm's success are discussed in detail in the ensuing section.

I. Creation of the Renewable Energy Standard (RES)

The State's Renewable Energy Standards (RES) required from 2004 that utilities supply at least a certain percentage (<35%) of electricity from renewable energy sources with the ultimate target being 38.5% of renewable energy by 2035 (DSIRE, 2018). This set-in motion a quest for how they could achieve the standard with a task force declaring that 95% of their renewable energy needs could be met with offshore wind; thus, making offshore wind "the only feasible method for the State to meet the legislative goal" (Polevka, 2017). The task force's recommendations on offshore wind further set-in motion a series of policies aimed at meeting the RES. The State went ahead to conduct a feasibility study of whether offshore wind would be appropriate and economically feasible, as well as where to potentially site the farm. To make it an inclusive process and obtain buy-in from all stakeholders, the findings of the report were shared with local citizens, including pro-groups, opposition groups and ocean assets users to discuss the merits of an offshore wind farm in Block Island. After strong local support and legitimacy of the project, the Governor's office and the Block Island Town Council put in a request for proposals for companies interested in building the offshore wind farm. When Deepwater came onboard as a developer, the State signed a joint agreement with them to help the developer manage the complex permitting process. It is important to note that much of the success of offshore and onshore wind projects relies on two things: 1) being able to adequately secure permits and 2) ensuring that the developer secures offtake agreements with the power company to develop the necessary infrastructure (transmission) lines to move the generated energy to consumers. If any of this fails, then the project inadvertently is likely to fail.

II. Effective Planning through a Special Area Management Plan

Another key to the success of most wind and energy projects in general is ensuring stakeholder buy-in. The RI government was proactive in involving all stakeholders, especially those with direct interest in ocean assets such as the fishing industry and environmental groups that monitor ocean resources in the debate about whether the project should continue. Many stakeholders' meetings were held to discuss the findings of the wind assessment/feasibility report. Polevka (2017) notes that based on the inputs from the meetings and the need to bring coherence and orderliness in the gamut of regulatory processes at the federal, state and local jurisdictional levels, the State's Coastal Resources Management Council led a formal process of spatially mapping out the marine resources at the location of the farm. All stakeholders were involved in the planning, which resulted in the development of the Rhode Island Ocean Spatial Area Management Plan (SAMP). Mapping out areas for offshore wind farms with community support was critical in deterring future litigation to stop the project by environmental groups as is typical in wind development projects. Notably, the creation of the SAMP aided in the acceleration of the project's development since it already mapped out the agencies that the Deepwater would likely need permitting from and included them in the earlier management plan discussions. The SAMP has been critical since it goes beyond the offshore wind farm to cover a specialized renewable energy zone for future offshore wind development projects in the State.

III. Having a Long-Term Contracting Standard

Besides the RES, commendable support from the State's legislature resulted in pro-offshore wind policies that aimed at ensuring long term demand for offshore wind in Rhode Island. To support the offshore wind project, offtake contracts requirements bills were initially passed, which mandated utility companies to purchase electricity from the farm via a long-term Power Purchase Agreement (PPA) in so far as the generated capacity was commercially reasonable. Although this faced initial setback, the Rhode Island Senate amended the bill to mandate the national grid to purchase and guarantee the buying of the electricity from the farm. This non-market strategy "gave Deepwater Wind guaranteed demand for its offshore wind" (Polevka, 2017; p.3). Three provisions passed to support Deepwater. These included: a 10-to-15-year PPA with utilities annually; requiring the national grid company to enter a PPA with Block Island Offshore Wind to construct new subsea cables connecting the farm to the load station and then unto the grid; and finally making a provision for future offshore wind projects of up to 150MW to be sourced by utilities also under a 15-year contract if the Utilities Commission so determines (Ibid). This long-term contracting standard is the greatest driver and lesson that enabled the success of the offshore wind farm. Most wind energy projects are dependent on having PPA to secure capital financing for the project. Because the State acted as guarantor and passed legislation requiring utility companies to source from offshore wind, the offtake agreement ushered in a new dispensation of State-mandated contract type of PPA, where renewably generated energy must be purchased by utilities under the supervision of the State's utilities commission.

All in all, Block Island Offshore Wind Farm was successful based on intentional policy support similar to onshore wind in the case of Texas in the early 2000s. Much of the success according to Polevka (2017) has been because of the good combination of policy support, a commendable and comprehensive spatial management plan for its OCS, stakeholder buy-in which was strategically initiated to gain the support of the local populace and prevent future roadblocks (or litigation) by opposers of offshore wind, and the political will and determination of the State's leadership to guarantee a long-term contracting standard. These special treatment policies facilitated the successful development of the Block Island Wind Farm and therefore ought to be closely considered by other states seeking to launch offshore wind industries.

5.4. Conditions for an Offshore Wind Sector in Texas

Similarly, to how Texas invested heavily in onshore wind beginning in the late 1990s, for an offshore wind industry to commence in the State, there must be significant policy motivation and investments in the sector. The European Union, which has the largest number of offshore wind turbines in the world begun the implementation of successive goals and targets for renewable energy production by singling out offshore wind and applying generous incentives, subsidies, and other support mechanisms such as long-term PPA contracts with utilities and investment in the grid infrastructure to handle AC from offshore wind. Once an offshore wind infrastructure is built and offtake agreements have been signed, it can produce very low-cost energy over time and act as a hedge against the fluidity in prices of conventional fossil fuels. In this regard, the *National Offshore Wind Strategy* argues that benefits from offshore wind will require overcoming very critical challenges in three strategic areas: 1) reducing the costs and technical risks associated with domestic offshore wind development; 2) supporting stewardship of U.S. waters by providing regulatory certainty and mitigating environmental risks of offshore wind development; and 3) increasing understanding of the benefits and costs of offshore wind energy (DOE & DOI, 2016). Some of these were discussed in section 5.2.2. This section continues the discussion on (pre)conditions/ requirements that are essential for the development of an offshore wind industry in Texas. It centers the discussions around the three agents and networks within innovative systems, i.e., business, regulation, and knowledge-based and research institutions discussed in Chapter Four, as well as highlighting some of the lessons from Block Island's Offshore Wind Farm.

5.4.1. Industry: Business

A precondition for renewable energy supply chains to evolve for a State like Texas is to secure more investments for cleaner technologies on a large scale. Generous incentives and subsidies toward research innovation in business can catapult any industry from nascent to mature (as was the case with onshore wind). These types of investments push the envelope of knowledge generation and diffusion as this leads to the interactive sharing of knowledge between different groups and networks in innovation systems. Generating knowledge in this sense is a big determinant of success and as noted by Li et al. (2022), the understanding of the emergence of renewable energy technologies must involve all key actors involved in knowledge creation (R&D) and knowledge diffusion amongst industrial players. Moving from venture capital financing to scaling up and as well laying the foundation of green banks for energy in the space can also bring in the needed capital for learnings. This will help develop hierarchy of networks, driven by the acceleration in the rate of knowledge creation and the rate of knowledge diffusion. As David and Foray (2005) poignantly put it "what is created is a network society, where the opportunity and capability to get access to and join knowledge- and learning-intensive relations determine the socio-economic position of individuals and firms". In 2015, Microsoft's former CEO, Bill Gates launched the Breakthrough Energy Ventures, which is a billion-dollar fund aimed at investments in the renewable energy space where much-needed capital for start-up and scaling up ventures have been technically difficult. For Texas this environment must be ripe in order for economies of scale and agglomeration effects to happen and reap benefits from offshore wind. Already, Environment Texas Research & Policy Center has called for the Texas Legislature to initiate the formation of a taskforce on siting offshore wind in two Texas towns (Port Isabel and Port Arthur) (Environment Texas, 2021). Complemented by the current 34 proposals for offshore wind development in the U.S, business has a lot to gain, and the foundation and policy support must be initiated by a partnership between business and policy.

5.4.2. Government: Policy and Regulation

Renewable Energy Standard (RES)

In the case of onshore wind, a major condition that has led to greater wind generation capacity has been renewable energy targets required for the electricity sector. This has been motivated by clean energy initiatives and renewable energy standards starting with the Energy Policy Act of 2005 and American Recovery and Reinvestment Act (2009). Texas' requirements for wind began in the late 1990s and for offshore wind to kickstart in the State, similar policy motivations would have to be instituted. Rhode Island's legislature also setup Renewable Energy Standards in 2004 and extended it in 2016 to source a large percentage of electricity from renewable sources in response to growing concerns of the negative environmental impacts of fossil fuels. The publication of the NREL study by Musial and others (2020), where specifically three hypothetical sites (Galveston, Port Isabel and Port Arthur) were recommended in Texas suggests that the time to consider offshore wind is now. Texas' State legislature may need to spearhead these efforts if much of the gains from offshore wind are to be realized and to incentivize the creation of this new and potential market. Lobbyist groups and a wide array of stakeholders, including non-profits, coastal local authorities, the broader energy industry networks, and citizens may have to push for this agenda of new RES that embraces a potential offshore wind segment in the State.

State-driven Funding

A precondition for private sector development to thrive is venture capital financing. Also, at the state level, government investments into fund mechanisms directed toward broader infrastructure and emerging innovation in energy is essential to the development of offshore wind. In 2005, the State's leadership setup a state-run initiative called the Texas Emerging Technology Fund (TETF), which was a $200 million initiative aimed at investments into R&D and expediting the development and commercialization of new and disruptive technologies. Emerging renewable energy technologies were not excluded from the funding conditions. In fact, until date, the fund has invested more than $12 million in wind technology firms and R&D firms involved in onshore wind research projects. From this fund, the National Wind Resource Center was formed to develop wind power research and multi-stakeholder collaboration with national laboratories, research and academic institutions and industry representatives. A lot of the gains from this help expand breakthrough research in onshore wind, and for a potential offshore wind industry, the State legislature may need to create the policy motivation for similar state-driven funding set aside for the development of offshore wind resources in Texas. Because of the similar technologies shared in common with oil and gas in the State, lobbying with reason for funding to support the development of a nascent industry like offshore wind in Texas would be advantageous and a win-win for oil and gas players.

Ocean Spatial Planning and Special Renewable Zones (SRZ)

Just like it was with the CREZ, which identified certain areas in North West Texas to supply wind energy to highly populated areas in Texas, the State legislature needs to fashion policies regarding special renewable areas/zones in the GOM for offshore wind. The BOEM has issued a request for interest in the GOM for offshore wind and for Texas much of the ocean wind resources which were modeled in the NREL study lay within State boundaries. Offshore wind depending on how deep the site is may fall under state or federal jurisdiction. The Submerged Land Act assures 3 miles and a further 3 marine miles (9 nautical miles) as state lands. Much of the potential projects will fall within the state's jurisdiction. A coastal zone management plan is warranted under both SLA and the Coastal Zone Management Act (CZMA). For potential successful implementation of offshore wind projects, consideration of existing resources and ocean users of areas sectioned out for offshore is needed. It is incumbent on the State legislature to work with state and federal agencies to spatially plan for an offshore wind industry by mapping out potential wind sites, wind assets and ecosystem features within the GOM. The point is that there are many stakeholders whose buy-in may need to be sought for such an endeavor. Thus, initiating such a process on the back of good political will and capital would assist in bringing the wide array of stakeholders that must be consulted to ensure the maximum level of accuracy and political support for the process.

Long-Term Contracting Standard for Offshore Wind Energy

A critical component of the success of Block Island Offshore Wind Farm was the State mandating the PPA with the national grid to compulsorily buy wind power generated from Block Island. These long-term contracting standards and arrangements are the lifeline of offshore wind energy projects. RI's legislature according to Polevka (2017) passed a Long-Term Contracting Standard for Renewable Energy that was predicated on 1) electric power distributors soliciting 10 to 15 year contracts for renewable energy annually from clean energy producers, 2) a financial PPA where a retail utility company aside from the agreement also had to assist in the construction of the wind farm under a special type of financial PPAs, and 3) state-wide long standing agreement with the State's utility commission to require utility scale offshore wind from power producers together with State's electricity distributors. This helped to significantly reduce the project's risk and ensure that renewable power being produced now and, in the future, would be sourced for consumers by utilities. Although some of these special PPA dispensation may not be agreeable in Texas, since the State's electricity system is heavily deregulated, a PPA that puts both developers and utilities on a competitive footing may work in the State. Otherwise, the creation of such special dispensation PPAs would have to have tax incentives and subsidies that absolves some of the risks on the part of utilities. Federally, the national government has spearheaded efforts with Biden's 30% ITC for offshore wind projects commencing between 2016- 2026. All in all, for a State like Texas embracing these may take time, unless standards of enforcement become more stringent, then the State's legislature may have to lean towards mandating compulsory special dispensation offtake agreements for required renewable generation for its electricity sector.

5.4.3. Knowledge-Based Institutions

A precondition for successful future investments in offshore wind is enhancing partnerships amongst research, knowledge-based institutions (KBIs), and industry. As it was with turbine developments of the 1990s and 2000s, improvements in rotor blade development over time led to significant reduction in size and cost. More corporate-federal-KBIs collaborations are increasingly necessary for the future of offshore development in Texas. Nationally, the DOE has pointed out that to accelerate offshore wind development in the U.S., these partnerships are essential to the functioning of innovation systems across various energy sector niches. It has piloted many initiatives on offshore wind to leverage cost share funding with many of its institutional partners led by NREL. A big part of this agenda which is timely for Texas is the launch of three technology demonstration scale and resource characterization projects for offshore wind. This will increase the confidence bar in pre-commercial technologies, which in turn over time decrease costs of offshore wind assets.[6] These projects will support offshore wind development by demonstrating innovative technologies not previously commercially used in the U.S. for offshore wind, and by improving the ability to forecast energy production. At the industry level, a few oil and gas majors have started making significant investments in offshore wind assets as they bring their expertise in an industry that has traditionally been high cost but highly rewarding. There is a new wave as was argued in Chapter Four as big offshore oil and gas players start to leverage their expertise in advancing renewable

[6] The DOE announced in 2020 that it was going to invest $21 million in three demonstration scale offshore wind projects to help increase cost and build confidence in the market.

energy. There are currently many institutions in Texas that are gearing-up with federal and some industry support on technology development, environmental safety, and monitoring of offshore wind resources and ocean resources generally in the State. The Ocean Energy Safety Institute is one of such important research institutes that has collaborated with the federal government, academia, industry, and other non-market agencies to improve environmental management, safety, and monitoring of offshore energy assets in the GOM. The success of such initiatives would be hinged on non-market actors such as State actors, who provide the political leadership, will and needed policies to enable the thriving of new industries.

5.5. Chapter Summary

This Chapter sought to answer the question of whether a policy future exists for Texas by modeling hypothetical scenarios of the State's energy mix and gradual reductions in natural gas should global and national mandates force more renewable energy generation. Deficits in generation from natural gas may have to come from other renewable sources, particularly wind as it is the State's greatest competitive advantage in the renewable space. Because of the matured potential of its wind industry, the Chapter argued a case for offshore wind in Texas as one of the greatest untapped potentials of its ocean assets in the GOM. Considering the economics of the project, i.e., the levelized cost of electricity and the policy environment, it was suggested that a policy future exists for offshore wind in the not-too-distant future. The seminal NREL study by Musial et al. (2020) presented a hypothetical 600 MW offshore wind farm in three sites in Texas and concluded that despite the unique characteristics of the GOM, an offshore wind farm is economically feasible. Some of the lessons from Block Island Offshore Wind Farm were discussed to highlight the considerations and foundation that the State may have to lay if an offshore wind industry is envisaged in the next decade. Although the approach taken by the Rhode Island legislature has been very much state-driven and non-market strategies, our earlier discussions in Chapter Four showed that Texas' wind industry was initially driven as well by non-market strategies, such as its RPS, which quickly catapulted into a market-led industry. For Texas, three conditions are relevant for offshore wind's future: (i) setting up unique RES or target for onboarding offshore wind into the State's electricity mix; (ii) long-term contracting standard for offtake agreement that provides a guarantee for future offshore wind development; and (iii) spatially planning and setting-up a renewable energy zone within its territorial waters where the transmission infrastructure is built to connect from the ocean to consumers onshore, just as it was with the CREZ in North West Texas. The establishment of these policy (pre)conditions can assist the State in launching its new offshore renewable energy industry.

6. CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

6.1. Conclusions

The world is indeed on the edge of an environmental precipice of continuing with business-as-usual when it comes to conservative fuels, or fully embracing the energy transition agenda. The under 2^0C of global temperature, which has motivated the energy transition agenda will not be realizable if practical and intentional actions are not directed toward curbing negative impacts from fossil fuels in this decade (IPCC, 2022). This thesis sought to answer three questions that would be important in the debate on the energy transition – all aimed at building a premise for whether a policy future for offshore wind energy exists in Texas. As the energy capital of the world and national leader in wind energy, Texas' offshore oil and gas sector is uniquely positioned to pivot to an offshore wind industry. The first two research questions, which were addressed in Chapters Two and Four's literature review and content analysis of the offshore oil and gas, and wind sectors demonstrated that the two sectors although separate are highly intertwined industries where technologies can be repurposed for a potential offshore wind industry in the State. The policy motivation and drivers identified in the TIS framework for offshore oil and gas and wind in Texas also suggested that non-market incentives are critical for any future of renewables in the State. The TIS assessment showed that as a mature industry, offshore oil and gas' legitimacy has been questioned overtime by the negative environmental consequences of their activities, thus prompting a 'regime change' by the climate change landscape.

There were lessons on motivation and drivers for the offshore oil and gas sector that also hold true for a future offshore wind energy industry because of the common elements of ocean assets. Most of the same rules by the BOEM, BSEE and other federal and state regulatory agencies apply to offshore wind despite there not being a standardized approach to offshore wind development across states. For states in the GOM, the boundary of the OCS affords them more leeway in governing their coastal borders than those in the East Coast. Texas's unique extension of the OCS further gives it even more leeway in terms of the size of ocean assets for development compared to any other state in the U.S. The third research question and its sub-question were answered by demonstrating that deficits in natural gas should state and federal mandates hypothetically increase may lead to gaps in electricity generation for the State. Hence, ramping-up more wind and other renewable options is the solution to the 100% carbon pollution-free electricity by 2035 being advanced by the Biden Administration.[7] Because offshore wind has the greatest resource potential in the GOM of 508 GW amongst most renewable energy sources, it presents the most logical option for future development and expansion to meet renewable energy consumption needs in Texas. The levelized cost of electricity for different renewables as well as the potential benefits of offshore wind were discussed to make a case for offshore wind. Also, since the DOE and the Biden Administration have a goal of increasing offshore wind by 30GW from a mere 42MW with many non-market incentives, it was shown that a policy future for offshore wind may exist for the State in the not-too-distant future. Although currently not cost-competitive with onshore wind, as more offshore projects come online, coupled with government-backed incentives, costs are likely to be competitive by 2030 according to Musial et al., (2021).

Some important (pre)conditions which must be laid out for a future of offshore wind in Texas were also discussed in Chapter Five premised on the lessons from Block Island Offshore Wind Farm's development. With its unparalleled benefits such as reduced energy costs and lower emissions from offshore wind, the State's political leadership may need to create the enabling environment now if developers are to partake in federal incentives like the 30% ITC touted by the current Federal Administration for projects coming online by 2026. Texas' economy is poised to reap immense benefit from offshore wind in terms of direct and indirect contributions according to the NREL study by Musial et al., (2020). Although the conditions discussed in Chapter Five are

[7] See *The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050* by Kerry (2021)

indeed lessons and recommendations that can facilitate and kickstart a future in offshore wind for the State, timely interventions through the establishment of a taskforce for offshore wind is the first critical step. This will open the much needed conversations with a wide array of stakeholders, including coastal towns, ocean users, advocacy groups, broader energy industry players and Texans about the possibility and potential of an offshore wind industry. More importantly, the Public Utility Commission of Texas and the Electric Reliability Council of Texas' roles are critical in terms of regulation and the grid infrastructure to support the uptake of new renewable sources of energy such as offshore wind. Furthermore, since the BOEM has issued a request for interest for offshore wind in the GOM, business as a critical component of technological innovation system may consider investing in a potential future for offshore wind if the economics and policy motivations are right. As already noted in the thesis, these are highly intertwined industries where technologies can be modified or re-engineered for offshore wind development. Hence, there is a future to be had in enhancing wind energy development offshore in Texas. Conclusively, much of the gains from the transition would not be harnessed if in the next decade bold steps in curbing GHG emissions are not amplified. Thus, how a state chooses to embrace offshore wind energy and create the policy incentives and support to drive innovation in the sector, are what will enhance broader wind energy benefits as part of the energy transition agenda.

6.2. Recommendations for Future Research

The study utilized a mixed methods approach to answer three distinct questions about the history of offshore oil and gas and the similarities between offshore oil and gas and wind energy resources in Texas, the motivations and drivers that enabled the wind industry to thrive, and whether there is a policy future for offshore wind in the State. In answering the first two research questions, the TIS was employed in a unique way through a content analysis of newspaper articles from 2009 to 2020. Although this methodology provides a good way to assess and explore different perspectives of how technological systems of innovation evolved in both industries, it is recommended that future research on the TIS framework and the energy sector in Texas employs a rigorous data collection method such as interviews to collect data. This was a major limitation of this study and future research should incorporate interviews of focal players and agents within the research scope to acquire more in-depth knowledge about the seven functions within the TIS framework. Also, focusing on different regime change issues besides technologies such as policy impacts, supply chain and networks within the wind industry and offshore oil and gas would provide further insights and more lessons for a potential offshore wind future in Texas.

Also, for the ARIMA modeling where a univariate approach was used, it is recommended that future research go beyond this by incorporating the multivariate method of assessment where other exogenous variables that impact energy sources and consumption are factored into the modeling. Modeling in costs, conventional and renewable energy prices, population and GHG emissions, spate of technological development of other renewable energy options in Texas vis-à-vis the hypothetical scenarios in Chapter Five can also shed greater light on future consumption trends, deficits, and how demand for other renewable energy options are likely to trend. Such predictions for the future can assist the State in evaluating and providing more support to renewable energy sources that may need non-market incentives to boost capacity generation.

Finally, the deep synergies that exist between offshore oil and gas and wind have not been extensively explored and future research can do a deep dive into this vis-à-vis how big majors are gearing up as the world transitions to a net-zero carbon economy. Specifically, further research can dissect what the challenges are for energy majors in integrating renewable energies to their portfolios and what the future holds for conventional fossil fuels as research on carbon capture technologies and battery storage systems intensify in the industry. The issue of the life cycle assessment of wind turbines is also pertinent to the discussions in the energy transition since past legacies of wind turbines left negative environmental footprints. Hence, a life cycle analysis of the benefits and costs of offshore wind needs to be conducted including ways to mitigate negative impacts from a lack of recycling when wind turbine blades are decommissioned. Because Europe has extensive expertise in offshore wind and has major oil and gas players that have partly divested into offshore wind assets, with other non-energy companies interested in this space, the time is very ripe for further research on how companies leapfrog with expertise, industry good will and infrastructure to either assist in the transition or hold it back.

6.3. Limitations of the Study

Initially, the thesis methodological approach was to conduct interviews with a wide array of stakeholders involved in the offshore oil and gas and wind energy space, however, due to resource constraints and the fact that the researcher started this study at the height of the COVID-19 pandemic, this approach was not pursued. To overcome this challenge, meetings with the researcher's Advisor and Dr Jenna Lamphere resulted in the choice of a conceptual (or directed) content analysis methodology for the TIS framework's assessment. Content analysis is quite a subjective research method that requires the researcher to be honest and forthright about the coding process, i.e., how the data was selected, coded, and analyzed. Using this methodology of assessing keywords related to the energy transition, oil and gas, renewable energy, and technologies in two news articles (Houston Chronicle and the DM) from (2009- 2020) was convenient but limited by the researcher's bias at times and the scope of the sample size being a bit narrow. To overcome this, the researcher documented the entire coding process, and additionally drew on a wide and broader literature to support all assertions being made from the data. To get a good gauge about big energy majors' approach to the sector and complement the content analysis, four major companies' sustainability and annual reports for the same time periods were assessed to support the analysis and conclusions in Chapter Four. In terms of the second methodology, which was using ARIMA econometric modeling to highlight the deficits in natural gas, the univariate approach used is a limited way to forecast, especially as the forecasted data is based on its own values. Although a better approach would be including exogenous variables in the forecasting, the goal for that Chapter was to show that no matter the reductions that happen in natural gas, as mandates intensify, wind and other renewables would have to be ramped-up to meet the deficit in electricity generation; hence, the reason why the univariate model was used despite its limitations. All in all, this study provides one of the first exploratory studies on the interlinkages between offshore oil and gas and wind sectors within the context of the energy transition in Texas, and as such should be viewed as contributing to an emerging field of study.

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APPENDIXES

Appendix 3-A: Code List for Content Analysis in NVivo

Code List	Files	References
TIS FUNCTIONS AND SUB-THEMES		
F1 Entrepreneurial Activity	44	76
New Wind Energy Projects and Technologies	28	41
Offshore O&G Projects & Technologies	9	9
Wind Energy Infrastructure	10	14
Wind Energy Startups	9	10
F2 Knowledge Generation	19	23
Offshore O&G Projects and Research Partnerships	7	8
Offshore O&G_Wind Energy R & D Partnerships and Collaborations	7	7
Wind Energy Projects and Research Partnerships	7	8
F3 Knowledge Diffusion	25	36
Knowledge Exchange_Offshore O&G & Wind Energy Companies	2	2
Offshore O&G Piloting Wind Projects	7	7
Offshore O&G_R & D Partnerships and Collaborations	13	13
Wind Energy R & D Partnerships and Collaborations	13	14
F4 Guidance of the Search	27	37
Offshore O&G Policy or Vision for New Entrants	1	1
Policies for Wind Energy Technologies and Development	21	23
Policy Motivation for Offshore O&G_Wind Energy	12	13
F5 Market Formation	20	26
Offshore O&G Market Incentives_Subsidies, Tax Breaks, Tax Credits	0	0
Partnerships (O&G_Wind Energy) for Market Formation	2	2
Wind Energy Market Incentives- Subsidies, Tax breaks & Tax Credits	17	23
F6 Resource Mobilization	40	57
Federal & State Funding for Offshore O&G	2	2

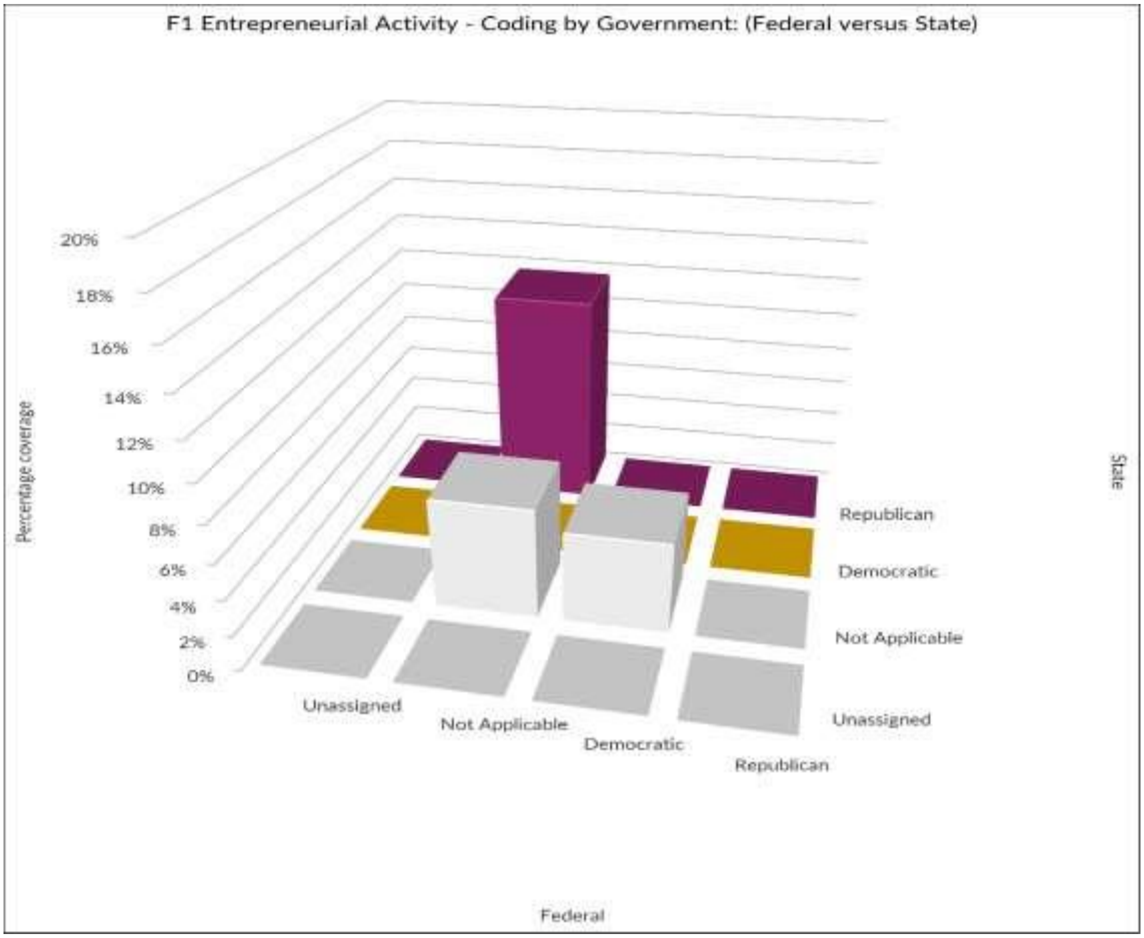
Federal & State Funding for Renewable Wind Energy	9	10
Federal investments into Renewable Energy	3	6
Federal_State_Private_Foreign Partnerships	5	5
Foreign and Private Partnerships	4	6
Foreign Investment into Wind Energy	3	3
Foreign Investments into Offshore O&G	2	2
Private Financing and Investment into Wind Energy	11	12
Private Financing and Investments in Offshore O&G	7	7
State and Private Financing into Wind Energy	2	2
F7 Legitimacy	15	23
Resistance to Offshore O&G	8	12
Resistance to Offshore Wind Energy	4	7
Social Acceptance of Offshore O&G	0	0
Social Acceptance of Offshore Wind_Wind Energy	4	4
Words and Phrases		
Renewable Energy	106	203
Rationale_Opposition to Wind Energy from O&G	54	88
Reliability and Resiliency	5	5
Political reasons	23	30
Favoring New Technologies over O&G	4	4
Environmental Concerns	8	9
Economic Reasons	23	37
Business _Management Decision	3	3
Rationale_ Acceptance of Wind Energy in Texas	69	115
Smart Business Decision	22	23
Political Motivation	3	3
Lowering cost of electricity	12	12
Environment	34	37
Economic	27	38
Aesthetics	2	2
Energy Transition	129	236

Drivers of the Energy Transition	128	234
Technological Developments	21	21
Social	13	13
Smart Business Decision_Transforming Business	22	25
Politics	10	10
Policy	31	41
Environment	43	48
Economic_Market Forces	56	76
Oil & Gas (INCL. OFFSHORE)		
Incentives_Policy Motivation for O&G	48	64
Technology Drivers	13	14
Political Reasons	7	8
Policy Requirements	5	8
Market Incentives_Subsidies_Tax Credits	2	2
Diversifying Portfolio_Renewable Energy	8	9
Business Sector_Investments and Scientific Breakthroughs	13	13
Boost to Local Economy_Jobs	5	5
Challenges facing O&G Companies	50	64
Regulation & Policy	23	26
Political Reasons	3	4
Negative Environmental Impacts from Offshore O&G	3	3
Negative Demand	3	3
Competition from Renewable Energy	2	2
Changing their Business Agenda_Lowering Carbon Emissions_Climate Change	9	9

Appendix 4-A: Total Number of References and Files Coded for the Study

Themes	*Files*	*References*
Offshore Oil and Gas		
Challenges facing O&G Companies	50	64
Incentives_Policy Motivation for O&G	48	64
TIS Framework for Wind		
F1 Entrepreneurial Activity	44	76
F2 Knowledge Generation	19	23
F3 Knowledge Diffusion	25	36
F4 Guidance of the Search	27	37
F5 Market Formation	20	26
F6 Resource Mobilization	40	57
F7 Legitimacy	15	23
Words and Phrases		
Energy Transition	129	236
Renewable Energy	106	203
Totals	**523**	**845**

Appendix 4-B: Entrepreneurial Activity- (Coding Federal Versus State)



Appendix 4-C: Offshore Wind Manufacturers by Market Share for 2020 and Future Disclosed Pipeline for Original Equipment Manufacturers (OEMs)

Original Equipment Manufacturers	Operating	Announced	Total
Unreported	1,181.8	221,278.1	**222,459.9**
Siemens Gamesa	18,142.7	23,180.3	**41,323.0**
Vestas	6,132.5	10,642.2	**16,774.7**
GE Energy	580.5	7,576.4	**8,156.9**
Sewind	221.0	3,409.0	**3,630.0**
Goldwind	1,312.5	1,947.9	**3,260.4**
MingYang	551.5	2,520.0	**3,071.5**
Senvion	1,416.2	0.0	**1,416.2**
CSIC	420.0	960.0	**1,380.0**
Envision Energy	1,037.2	300.0	**1,337.2**
Doosan Heavy Industries	103.5	1,200.0	**1,303.5**
Adwen	1,020.0	0.0	**1,020.0**
Sinovel	159.0	600.0	**759.0**
DEC	0.0	500.0	**500.0**
Bard	400.0	0.0	**400.0**
Hitachi Ltd	0.0	325.9	**325.9**
Unison	0.0	205.0	**205.0**
Yinhe	0.0	200.0	**200.0**
Other	227.5	63.9	**291.4**

Source: Department of Energy (2021)

Appendix 4-D: Announced Domestic Infrastructure Investments to Support Offshore Wind Industry (2017- 2020)

Investment Type	Amount	Company(s)	Location	Year Announced
Manufacturing: Steel	$76,000,000	US Wind & Ørsted	Maryland	2017
Manufacturing: Foundations	Not specified	Ørsted & EEW	Paulsboro, New Jersey	2019
Manufacturing: Foundations	Not specified	Equinor	Port of Coeymans, New York	2019
Manufacturing: Towers & Foundations	Not specified	Marmen & Welcon	Northeast US	2019
Manufacturing: Blades	$200,000,000	Siemens Gamesa	Virginia	2020
Manufacturing: Cables	$4,000,000	Marmon Utility	Seymour, Connecticut	2019
Manufacturing: Cables	Not specified	Nexans	Not specified	2019
Ports; Transmission infrastructure	$650,000,000	Anbaric	Brayton Point, Somerset, Massachusetts	2019
Ports	$157,000,000	Ørsted & Eversource, CT Port Authority	New London, Connecticut	2020
Ports	Not specified	Vineyard Wind	Bridgeport, Connecticut	2019
Ports	$13,200,000	Ørsted	Tradepoint Atlantic, Maryland	2019
Ports	$26,400,000	US Wind	Tradepoint Atlantic, Maryland	2017
Ports	$50,000	Vineyard Wind	New Bedford, Massachusetts	2019
Ports	Not specified	Ørsted	Atlantic City, New Jersey	2019

Ports	$60,000,000	Equinor	New York (Multiple Ports)	2019
Ports	$10,000,000	Ørsted & Eversource	New York (Multiple Ports)	2019
Ports	Not specified	Ørsted & Eversource	Port Jefferson, New York	2019
Ports	$40,000,000	Ørsted & Eversource	Port of Providence and North Kingston, Rhode Island	2018
Supply chain	$15,000,000	Ørsted	New Jersey	2019
Supply chain	$1,500,000	Ørsted & Eversource	Rhode Island	2019
Supply chain	$10,000,000	Vineyard Wind	Massachusetts	2018
Turbine testing facility	$35,000,000	MHI Vestas	Clemson University, South Carolina	2017
Vessel construction: Crew transfer vessel	Not specified	Ørsted & WindServe Marine	North Kingstown, Rhode Island	2019
Vessel construction: Crew transfer vessel	Not specified	Ørsted & WindServe Marine	North Kingstown, Rhode Island	2019
Vessel construction: Crew transfer vessel	Not specified	Atlantic Wind Transfers & Blount Boats	Warren, Rhode Island	2019
Vessel construction: Crew transfer vessel	Not specified	Atlantic Wind Transfers & Blount Boats	Warren, Rhode Island	2019

Source: AWEA (2020)

Appendix 4-E: Business Investment Strategy Towards the Energy Transition by Selected Seniors (IEA, 2020)

Company	Enhancing traditional oil and gas operations			Deploying CCUS		Supplying liquids and gases for energy transitions		Transitioning from fuel to "energy companies"			
	Reducing methane emissions	Reducing CO_2 emissions	Sourcing renewable power	For centralised emissions	For EOR	Low-carbon gases	Advanced biofuels	Solar PV and wind generation	Other power generation	Electricity distribution/retail	Electrified services / efficiency
BP	●	●	◐	◐	◐	●	◐	●	◐	◐	●
Chevron	●	◐	●	●	◐	◐	◐	◐	○	○	◐
Eni	●	◐	●	◐	◐	◐	●	●	●	●	◐
ExxonMobil	●	◐	●	●	◐	◐	◐	○	○	○	○
Shell	●	●	●	●	◐	●	◐	●	●	●	●
Total	●	●	●	◐	◐	●	●	●	●	●	●
CNPC	◐	○	◐	◐	●	◐	◐	●	○	○	○
Equinor	●	●	●	●	◐	◐	◐	●	○	◐	◐
Petrobras	◐	◐	●	●	●	●	◐	◐	●	◐	○
Repsol	●	●	◐	◐	◐	◐	◐	●	●	●	◐

Notes: PV = photovoltaic. **Full circle** = growth area supported by observed strategic investments (e.g. M&A) and/or capital/operational expenditures in commercial-scale activities; **half circle** = announced strategy and/or minor investments, venture capital and/or research and development (R&D) spending; **empty circle**= limited evidence of investment activity. **For methane and CO_2 emissions**, which are not based on project and spending data, assessments reflect the presence and strength of methane reduction and emissions intensity targets, as well as evidence of their implementation, the emissions intensity trend of new investment, transparent reporting of absolute emissions and sources, and linking of executive and staff compensation to achieving goals. Power generation and efficiency investments in the Transitioning category pertain to projects destined for commercial sales (not own use). Electrified services include battery storage and EV charging. Low-carbon gases include low-carbon hydrogen and biomethane.

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IEA (2020)

Appendix 5-A: Descriptive Statistics for Energy Sources and Consumption

Summary of the descriptive statistics of the variables to be modeled. The minimum and maximum variables and quartiles are shown below for data points (1990- 2020) in KW.h..

```
      Year           Coal              Natural gas            Wind              Consumption
 Min.   :1990   Min.   : 78825275   Min.   :134639387   Min.   :        0   Min.   :237415127
 1st Qu.:1998   1st Qu.:123135616   1st Qu.:161782770   1st Qu.:    81813   1st Qu.:294273844
 Median :2005   Median :138088223   Median :189589117   Median : 4237209   Median :334258262
 Mean   :2005   Mean   :133548230   Mean   :188244199   Mean   :21059726   Mean   :332790062
 3rd Qu.:2012   3rd Qu.:147060676   3rd Qu.:204155206   3rd Qu.:34043897   3rd Qu.:377441185
 Max.   :2020   Max.   :157896535   Max.   :255630021   Max.   :92440997   Max.   :429343404
```