Societal and Technical Issues in the Industrial Development of Saudi Arabia and Egypt

by

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ABSTRACT

Sustained industrial development in developing nations has been an impetus for economic growth and technological advancements for the past several decades, in addition to being a major contributor to poverty reduction. This thesis focuses on the underlying societal and technical issues regarding large-scale project implementation and industrial development in Saudi Arabia and Egypt. The study analyzes these issues in the context of the Saudi Arabian construction industry and the Egyptian solar energy industry, and then extrapolates these to outline the industrial landscape in the Middle East. Several obstacles to development, such as regulatory inefficiencies, regional segregation, and lack of capital investment are identified and analyzed. Technology advances necessary to progress the industry are also determined.

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BIOGRAPHICAL NOTE

Vibin Kundukulam is originally from Duluth, GA, and was an undergraduate student at MIT from 2007 to 2011. He entered the department of mechanical engineering in the fall of 2008. Prior to his work on this thesis, he had previous research experience on material mechanics with Dr. Antoine Jerusalem at IMDEA Materials, a multidisciplinary research center in Madrid, Spain, and research on brain tumors with Professor Forest M. White and Dr. Paul H. Huang of the MIT Department of Biological Engineering. The latter resulted in a paper on glioblastoma cell growth published in Molecular BioSystems (2010). He is a member of Tau Beta Pi, Pi Tau Sigma, and Phi Beta Kappa honors societies and was awarded the AMP Inc. Award for Outstanding Performance in Mechanics and Materials (2010).

Following graduation, the author will pursue his interest in the application of technology to the business world as an analyst with McKinsey & Company's Business Technology Office, after which he will matriculate to Harvard Business School as a member of the Class of 2015.

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Thanks to Professor David E. Hardt at MIT—without his guidance for the past three years and especially for the past few months, this work would not be possible. A thesis on this topic was first suggested to the me by Professor Hardt during a discussion earlier in the year, and he has been very helpful in helping me secure the research positions and select the coursework that have prepared me to complete this project. I appreciate his patience and effort.

Thanks to friends and family, who have remained supportive throughout my four years at MIT and who have helped finance my education. My thirst for knowledge and my passion for engineering and technology started at a young age, and I am able to graduate from this university in large part due to the support of my parents and teachers, from elementary school all the way through college.

Finally, thanks to the countless number of individuals who have helped me reach this point. Their encouragement is very much appreciated.

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1. INTRODUCTION

This section introduces the topic and presents the motivation for the thesis, and also serves to outline the arguments presented in the rest of the document.

1.1 Purpose and motivation for research

Although not necessarily a traditional topic for mechanical engineering theses, the author chose to research industrial development in the Middle East for several reasons. First and foremost, engineering projects in today's world have become incredibly multinational, drawing on personnel, expertise, supply chains, investment, and other resources from a wide variety of countries. Much of engineering, especially its application to real-life megaprojects, is then affected by its development in other countries. Furthermore, many engineering-heavy industries, such as textiles, construction, and metals, have reached maturity in Western nations but are still undergoing substantial change and growth in other countries, including those in the Middle East. There are also many new industries developing in these areas, including several which will be discussed in detail in the ensuing chapters. Studying these can help give insight into industrial development in an international setting, especially in a region such as the Middle East whose economy is largely structured around the export of one good: petroleum. Additionally, the author is extremely fascinated by the nuanced landscape of international development, so this thesis is also the result of personal interest. The end goal of this project is to use this research to build a model for how to approach industrial development in the Middle East from an international perspective.

1.2 Saudi Arabia and Egypt

Why is the Middle East a worthwhile region from which to study industrial development, and given that, why Saudi Arabia and Egypt? First, it is known that industrial development can follow different patterns depending on the region studied. For example, Mauritius has been able to transform itself from a sugar exporter into a diversified economy based on clothing and tourism partly due to the supportive governmental policies for the creation of an export processing zone with duty-free imports. Chile demonstrated economic growth by using its natural resources to spur innovation in salmon farming, wine, and fresh fruit, focusing public-private partnerships on researching technologies that developed these high-value industries. Malaysia, formerly an economy based on commodity exports, has become a leading producer of electronic goods and agro-industrial products. China, of course, has experienced tremendous economic growth based on the production and export of manufactured products, partly owing to increased investment from technologically advanced foreign firms and cheap manual labor.[1]

These countries have been able to achieve rapid levels of development not by strictly adhering to a pre-defined global standard of industrialization, but by trying to make the most out of their own skill sets, needs, and resources. Similarly, there are unique challenges to development in the Middle East that are relatively negligible in many other nations. In addition to those listed in the previous section, unclear regulations, bureaucratic entanglements, and heavy reliance on oil exports all pose obstacles to the emergence of new industries and the integration of existing industries into the global market.[2] Studying how these factors have influenced industrial development in a few Middle Eastern countries can help form a model for the entire Middle East and Northern Africa (MENA) region. Given the recent political and economic turmoil in this area, understanding the development of this region will be highly dependent on its political, geographical, and economic characteristics and can itself be vital to intraregional market integration.

As shown in Figure 1.1, there are roughly twenty countries commonly included in the World Bank definition of MENA, or the Middle East and North Africa subregion.

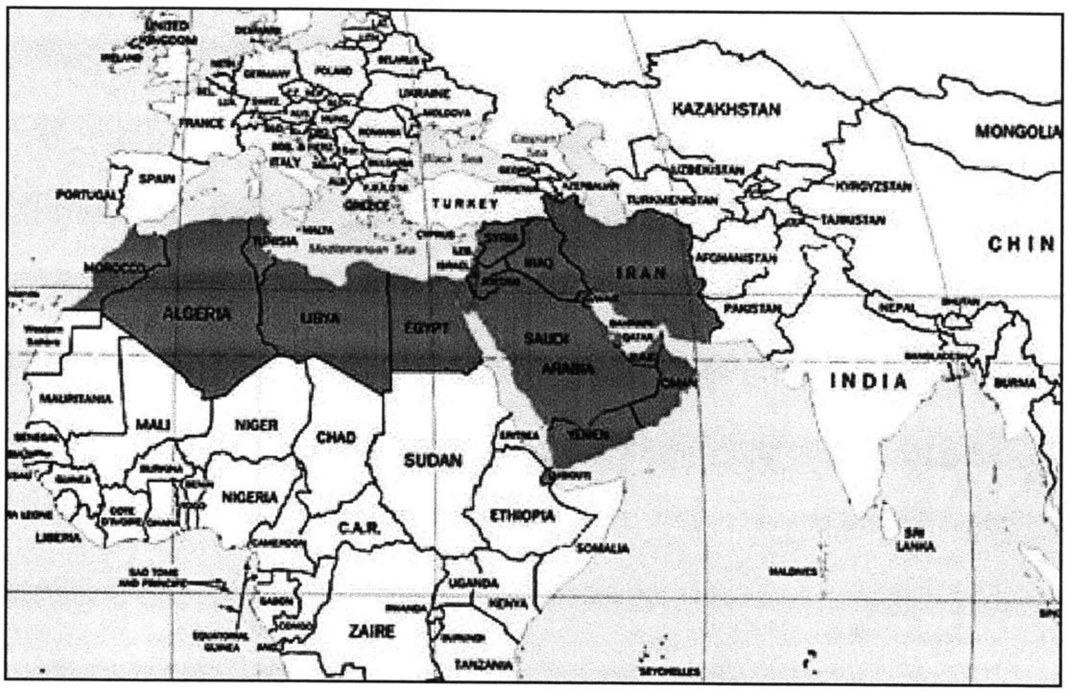

Figure 1.1: Countries included the World Bank definition of MENA.[3]

Instead of cataloguing the most important industries in each of these countries, the author has instead decided to focus on two of them: Saudi Arabia and Egypt. Both countries are generally considered “superpowers” in the Middle East. Saudi Arabia is now part of the G20 group of nations and holds the largest known group of oil reserves in the world, and by virtue of its rapid pace of economic growth its investment in key sectors has an important influence on the world market. Since the succession of King Abdullah bin Abdulaziz to the throne in 2005, the country has been focusing on diversifying its economic base and reducing its dependency on hydrocarbons, which currently account for 90% of its export revenues. Its efforts have included encouraging the growth of the private sector, which will result in job creation for the country's young, growing population, and joining the World Trade Organization in 2005.[4] Egypt has similarly seen substantial GDP growth within the first decade of the 21st century, maintaining a growth rate of 5% in 2009 despite the financial crisis. Despite the remarkable ability of Egypt to reform, however, Egypt remains an underdeveloped country with a per capita GDP of only $5,500, among the lowest in the MENA region.[5]

It is because of these unique characteristics of these two countries, as well as their high-paced economic growth and status within the region, that they have been chosen as the focus of this thesis. Both countries are acutely aware of the advantages of entering the global market and reducing their dependency on oil and in this way can serve as representations of the entire MENA area.

1.3 Overview of manufacturing sectors

A complete description of the industrial development in either Saudi Arabia or Egypt must include a brief survey of the manufacturing industry in either country. The Middle East has an incredible amount of resources at its disposal, both petroleum-based and otherwise, and it has historically been able to produce a large amount of revenue from processing these and exporting goods to other countries. In addition, the development of both the construction and solar energy industries is closely tied to that of the manufacturing industry, as Saudi Arabia and Egypt needs to locally produce cement, PV panels, and related technologies in order to meet rising demand. Manufacturing is also a very energy-intensive sector, and it is partly because of the rising demands of traditional manufacturing activities such as the textiles and metals that the countries such as Egypt and Saudi Arabia have been increasingly turning to renewable energy sources. The manufacturing industry continues to involve as technology makes certain processes and industries more efficient, and as policies change that incentivize or hinder the manufacture of specific goods. This section introduces the manufacturing sectors in both Saudi Arabia and Egypt to round out the overview of the industrial development scene described earlier.

Manufacturing in Saudi Arabia

There are more than 4,000 manufacturing plants established in Saudi Arabia, many of which are run by small to medium-sized companies. As shown in Figure 1.2, manufacturing has hovered around 10-12% of the total Saudi Arabian GDP for the past decade, although there has been a slow, steady growth of this percentage over these years.

Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Percent	10.8%	11.2%	11.1%	11.3%	11.4%	11.7%	12.2%	12.4%	12.6%

Figure 1.2: Manufacturing in Saudi Arabia as a percentage of GDP.[6]

Manufacturing is likely to be one of the largest growing sectors in the Saudi Arabian economy over the next few years, since the Kingdom is currently investing in sectors that produce the most job growth for its young, growing population. There are currently over 3,800 manufacturing enterprises in the country, with 415,000 people working in the sector. Not all of these companies are petroleum-related—Saudi Arabia exported roughly $21 billion worth of non-oil products in 2006. Most of the output is concentrated in a few core industrial cities, such as Riyadh, Jeddah, Dammam, and Jubail. In fact, Jubail has been so successful as an industrial location that the government is planning to expand the city to a second industrial area for over $5.9 billion by 2023.

	2000				2009			
	Number	Capital*	Labor	% Share	Number	Capital*	Labor	% Share
Total Factories	3,443	315,224	398,787	100.0	4,513	394,128	503,469	100.0
Foodstuffs & beverages	546	25,787	69,497	15.9	720	39,206	95,894	15.9
Textiles	72	3,411	12,222	2.1	87	4,368	14,829	2.1
Wearing apparels	52	542	5,809	1.5	75	733	8,199	1.5
Leather products	40	602	3,297	1.2	47	658	4,014	1.2
Wood & its products	46	622	3,831	1.3	53	843	4,052	1.3
Paper & paper products	113	4,802	12,335	3.3	152	7,006	17,277	3.3
Publishing and printing	108	3,578	9,883	3.1	117	3,722	10,344	3.1
Refined petroleum products	65	136,803	22,493	1.9	80	153,814	24,539	1.9
Chemicals & its products	298	29,631	29,043	8.6	475	47,893	39,827	8.6
Rubber & plastic products	356	9,212	35,212	10.3	489	12,750	42,429	10.3
Non-metallic mineral products	577	41,234	60,004	16.8	749	52,684	76,688	16.8
Base metals	257	32,063	36,348	7.5	312	36,814	45,205	7.5
Structural metal products	244	6,125	22,626	7.1	313	8,294	28,499	7.1
Machinery & equipment	181	4,654	20,419	5.3	228	5,110	23,466	5.3
Electrical machinery & apparatus	84	7,936	16,631	2.4	109	9,344	19,169	2.4
Motor vehicles and trailers	97	1,856	9,769	2.8	138	2,399	12,809	2.8
Furniture	261	4,783	24,711	7.6	312	6,449	29,567	7.6
Others	46	1,583	4,657	1.3	57	2,041	6,662	1.3

*in millions of Saudi riyals

Figure 1.3: Breakdown of the manufacturing industry in Saudi Arabia. Labor is given in number of people, not overall cost.[7]

This expansion is expected to create jobs for almost 400,000 people through both direct and indirect employment opportunities. At present non-petroleum manufacturing only provides around 24% of total employment.[8] As Figure 1.4 demonstrates, however, the petroleum industry employs only 7.2% of the industrial workforce despite receiving around 40% of industrial finance.[9]

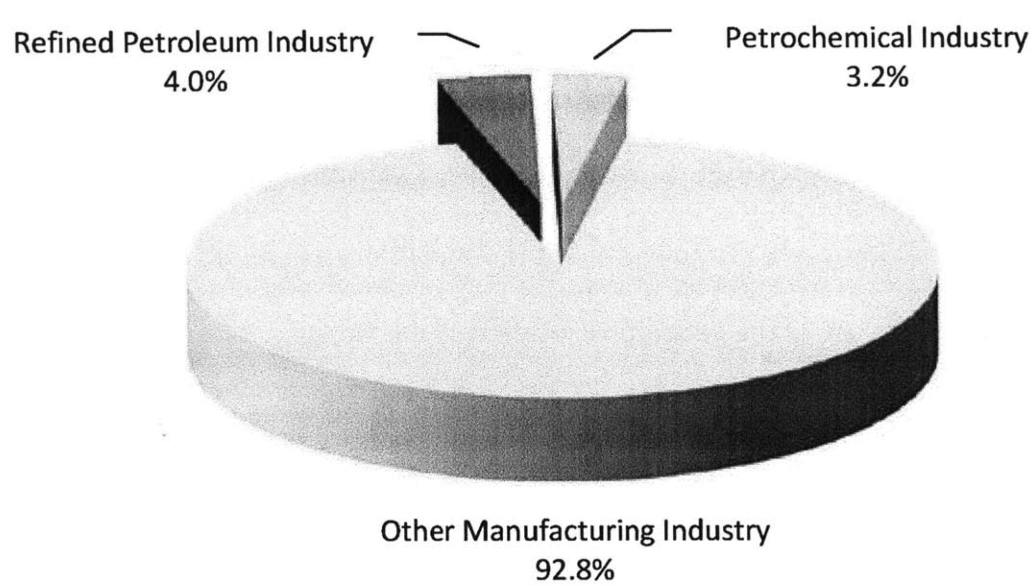

Figure 1.4: Employment in the Saudi Arabian manufacturing sector.[10]

Not surprisingly, petrochemicals and plastics are still the dominant industries in the Saudi Arabian manufacturing sector. However, there are a number of lighter, non-hydrocarbon based industries that are growing at a rapid rate. These include the manufacture of metal products and high-tech items, such as catalyst protection devices. The aluminum industry in particular has taken off, spurred along by a committed investment of $12 billion over the next few years. This investment includes a contract with the Saudi Arabian Mining Company allowing the use of the Kingdom's northern bauxite deposits, and with Alcan allowing the construction of a smelting shelter in the eastern part of the nation. The country has potential of having some of the lowest operating costs in the aluminum production industry, and even now Saudi Arabia produces roughly eight percent of the world's total production of aluminum.[11]

This major investment in the manufacturing sector is part of a national industrial development program led by Prince Faisal bin Turki bin Abdulaziz. The program aims to stimulate the metals, automotive, construction materials, packaging goods, and electronic goods sectors, all of which can attract foreign investment. These industries are high-value sectors requiring a high level of expertise, as opposed to low-skill industries such as textiles. Furthermore, Amr Al-Dabbagh, the governor of the Saudi Arabian General Investment Authority (SAGIA), plans to make use of the geographic location of the Kingdom is his "10x10" development plan. As Saudi Arabia is at a strategic crossroads between the European and Asian markets, it has a lot of potential for industries such as aluminum, fertilizers, steel, and plastics and their export to neighboring countries.[12]

The development of the manufacturing sector in Saudi Arabia is closely tied to the fate of the energy sector, as manufacturing is a very energy-intensive process. SAGIA has identified this as one of the leading challenges facing the Kingdom in the near future, and has invested over $80 billion in pursuing energy-sector capital projects in everything from petrochemical to fertilizers. There has also been significant foreign investment in the manufacturing sector of many Middle Eastern countries over the past two years, with total foreign investment totaling over $18 billion. Saudi Arabia received the bulk of this investment with over $21 billion, followed by Oman and Kuwait with $2.7 billion and $500 million, respectively. Over the past seven years direct foreign investment into the manufacturing sector has totaled over $137 billion, creating around 350 manufacturing projects and 126,000 new jobs.[13]

With its strategic location at the crossroads of Africa and Asia, and its rich supply of natural resources, Saudi Arabia is attractive to many multinational companies as one of the more politically stable countries in the region. One indicator of the improvement of the national competitiveness of local Saudi Arabian industries was the growth in manufactured exports, at an annual rate of 20%. The largest growth in this sector was in the export of machinery and transport equipment. Despite the increase in local production, however, 80% of the labor force in Saudi Arabia is non-national, coming to the area from other countries in the Middle East, such as Oman to carry out manual labor.[14]

Given its dynamism, manufacturing is the sector that is underpinning the entire transformation of the economic structure of the Kingdom, and it is the one that poses the greatest risks if not paid the requisite attention. The industry is scantily diversified and linked geographically, but not structurally or functionally. Additionally, there is an overdependence on expatriate labor that is not cost-effective for a large number of industries. Polarization of manufacturing around Saudi Arabia's urban areas also limits the spatial growth of the sector, which is another issue that must be resolved for the strong growth of Saudi Arabian manufacturing.[15]

Manufacturing in Egypt

Egypt's first industrial program was launched in the late 1950s, and since then much focus has been given to the country's manufacturing sector. The growth of the sector slowed somewhat after the development of the trade, finance, and transportation sectors, but renewed once again in the 1990s following increased liberalization of the sector. During the 1960s, the government created giant public firms to fill in the gap in the manufacturing sector left by private firms which had switched their focus to small workshop activities such as wood, leather, and printing. During those years, the annual growth of labor in manufacturing firms was a steady 8%.

During the 1970s and 1980s, the manufacturing output of Egypt increased by at least 10% annually, spurred on by increased investment by other Gulf countries following the oil boom in 1973. Since then growth has dwindled significantly, yet manufacturing still accounts for roughly 20% of the nation's GDP and 13.8% of the nation's workforce. The biggest sectors of the manufacturing industry include metals, cement, fertilizers, textiles, food, and other consumer goods. Although most of the manufacturing output has traditionally come from the public sector, private sector production has increased to around 65% of the manufacturing output.[16]

The main reason for the steady transition from public-sector to private-sector ownership of the manufacturing industry is the expansion of the private sector following the liberalization of Egypt in the mid-1990s. Growth in the public sector's industrial production declined due to inefficiency surrounding the centralization of state-owned manufacturing industries. A case in point is the textile industry, one of the largest sectors of the Egyptian manufacturing sector. The state-owned section of the industry has been seeing decreased production over the past decade due to outdated machinery and overuse of employees. On the other hand, the privately-held readymade garments section has been enjoying a rapid rate of growth.

A summary of the relative size of each of industry in the Egyptian manufacturing sector is shown in Figure 1.5. The majority of Egyptian manufacturing firms focus on building materials, chemicals, textiles, foodstuffs, and electronics. Together, these industries correspond to roughly 85% of the total labor demand of the manufacturing sector.

The textile industry is one of the most important subcomponents of the Egyptian manufacturing sector. According to the Egyptian Textile Manufacturers Federation, the industry claims over a million workers, around 30% of the country's industrial workforce.[17] However, the public textiles sector has historically had problems with outdated technology, excess labor, and poor quality control. The industry itself is divided into several subsections, with the government controlling almost all of the spinning and weaving enterprises and private sector holding the majority of the readymade garment firms. Since the introduction of national franchising in the 1990s, the private sector has been doing exceptionally well, although it has had to depend on the public sector for all upstream stages of textile production, including the supply of cotton, spinning, and dying of fabric. This control has negatively impacted a sector that could be growing much factor in a more liberal environment. Synthetic textiles are growing the fastest due to their diverse applications, ranging from automobiles to leisure activities.

Activity	Number of Factories	Production Value (millions of Egyptian pounds)	Labor (head count)
Plant & Animal Production	24	337	1,957
Coal Extraction & Processing	4	85	950
Petroleum & Refining & Natural Gas	17	30,037	24,486
Mineral Ore Extraction	2	137	882
Mines & Quarries Exploitation	47	275	6,411
Foodstuffs & Beverages	6,052	96,562	527,280
Spinning & Textile & Clothing & Leather	6,480	41,834	450,281
Wood and its Products	2,598	8,042	33,000
Paper & Paper Products & Printing & Publishing	1,752	9,024	66,042
Basic Chemicals and their Products	3,505	66,517	206,012
Building Materials & Ceramic	2,054	23,611	118,477
Basic Metallic	599	61,506	73,109
Engineering & Electronics	5,777	112,251	281,556
Other Manufacturing Industries	568	7,885	8,674
Lighting Electricity & Power Production and Distribution	33	7,360	20,002
Service & Maintenance Centers	64	59	2,814
TOTAL	**29,576**	**465,523**	**1,821,933**

Figure 1.5: Breakdown of manufacturing sector in Egypt.[18]

In the automobile industry, the end of the public monopoly on passenger car manufacture led to renewed growth of local manufacturing. The seventeen private vehicle factories in and around Cairo, however, still only operate at 30-35% capacity. The industry is closely protected with tariffs, although manufacturers are given an incentive to invest in the automobile industry as they are repaid tariffs commensurate to the local value they add to the industry. Additionally, most of the domestic production of vehicles in the industry is limited assembling subcomponents, not locally producing them.

GM, BMW, Nissan, Hyundai, and Daewoo, among others, produce their local models in their Egyptian factories. In fact, Egypt is the only place outside Germany where the BMW 7 Series line is produced. Foreign car companies often partner with Egyptian manufacturers to produce parts, because imported cars face high tariffs. For example, Daimler AG, Kia, Chrysler LLC, and Peugeot all work with Egypt's El Nasr Automotive Manufacturing Company to manufacture their various vehicles, including the Jeep Cherokee, the Kia Spectra, and the Peugeot 405 and 406. Other local manufacturers include Arab American Vehicles (AAV), Ghabbour Group, and Watania Automotive Manufacturing Company (WAMCO). MCV-Egypt, a group established in 1994 to represent Mercedes-Benz in the commercial automobile sector, produces a number of buses and trucks for both Egypt and the rest of the Middle East region. AvtoVAZ, a Russian car manufacturer, uses a local Suzuki plant in Cairo to produce Ladas for the North African market, including the VAZ-2107 and VAZ-2110 lines.[19]

From 2004 to 2007, the Egyptian automobile market rose more than 300%, most of the increase in the passenger cars segment. This rapid growth will likely slow down or even reverse in 2019, when the Euro-Mediterranean free trade agreement with the European Union will eliminate these tariffs and many companies will find it more profitable to export automobiles to Egypt than to produce them locally. In general, the Egyptian automotive industry will need to better integrate itself into the global automotive supply chain through exports and foreign direct investment.[20]

A few other sections of the manufacturing sector have undergone substantial change within the past decade. Although the cement industry has seen domestic sales drop in recent years, production has actually increased. The excess cement is exported abroad to take advantage of the pound's depreciation. Since 1998, a high degree of liberalization has reduced inefficiencies in the cement industry, ranging from low utilization of production facilities to a high dependence on imports. Egypt's economic reform and privatization policies of the 1990s also broke the monopoly of a few government-controlled television assembly companies. Now, competition between Egyptian firms has increased the number of televisions assembled under license from major multinational television producers, and consumers can choose from a variety of brands and types of television assemblies. This is similar to the cases of the washing machine and refrigerator sectors, both durable goods that have become highly competitive as a result of liberalization.[21]

Egyptian industrialization has been a combined effort of the government, Egyptian companies, and numerous multinational corporations operating in the country. A list of multinational companies operating in Egypt was compiled by Hatem Elsharaway[22], a doctoral student at the University of Gottingen in Germany, and is shown in Figure 1.6. According to his study, two-thirds of the managers of these Egyptian-based multinational corporations reported that the Egyptian economic system and monetary policy had a negative effect on the performance of their companies. The tax laws, custom laws, and importation and exportation laws all had similar perceived negative effects. Roughly half of managers also believed that the religious and cultural beliefs of the Egyptian people had little to no effect on company performance, and that the view of Egyptians towards foreign companies actually improved performance. In other words, a large number of multinational companies feel that the policies of the Egyptian government impair their performances more than any prevalent cultural attitudes in the country.

Nr.	Company	Capital (in thousands of Egyptian pounds)	Foreign Investment (%)	Local Investment (%)
1	Meratex	108500	61	39
2	Fine	140000	55	45
3	XEROX	15602	81	19
4	Novartis	33750	75	25
5	Procter & Gamble	154847	100	0
6	SEPCO	44080	90	10
7	Nestle	73000	100	0
8	Power Egypt	44000	54	46
9	Arabian Company for Cinematic Production	200000	65.5	34.5
10	National Alex. for Steel	1366776	52	48
11	Cadbury	31665	70	30
12	Egyptian Cement Company	812000	75	25
13	Arabian for Animal Production	30500	80	20
14	Peugeot	38485	60	40
15	IPM	60000	55	45
16	Ideal Standards	25975	85	15
17	Henkel	112000	60	40
18	Arabian for Computer Manufacture	70000	70	30
19	Menatel	70000	80	20
20	Easterners for polyester Manufacture	60000	60	40
21	EMAC	47000	80	20
22	Emantite Misr for Fiberglass	50000	63	37
23	Misr International for Nutritional Industries	50000	71	29
24	Inter. PAB	34550	68	32
25	Chipsy	54217	87	13
26	Sovisat	77000	55	45
27	Gonson and Gonson	26400	82	18
28	Nile Communication	35000	73	27
29	Cairo for Chiken	50400	57	43
30	Sky Petroleum Services	317200	79	21

Figure 1.6: A sample of multinational companies in Egypt.[23]

1.4 Two industries: construction and solar energy

Longitudinal case studies of a single event are common in the social sciences, as they can help highlight underlying principles without the expenditure in resources that can occur when examining a large number of topics. They offer concrete, practical knowledge, as opposed to the general, theoretical knowledge obtained from other methods of study. They are also very useful in presenting hypotheses concerning topics with a scant literary base, where testing hypotheses is not as useful as generating them. For these reasons I have chosen to present my arguments on the industrial development in the Middle East in case-based form. The analysis presented in this paper focuses on two specific cases: the construction industry in Saudi Arabia, and the solar industry in Egypt. Just as Saudi Arabia and Egypt serve as a sufficient but not necessarily complete model for the MENA region, so do these industries in their respective nations.

The construction industry has been a focus of Saudi Arabian industrial development for the past four decades, starting with the country's first development plan in the 1970s. At that time, construction was the largest recipient of government spending at 49.6% of the total budget. In addition to the petroleum industry, construction represents a large facet of the engineering-related jobs in the country and a large portion of the energy consumption of the country. In addition, construction contracts are by their nature multinational, with resources and expertise drawn from a number of different countries, including many in the developed world.[24]

Whereas the Saudi Arabian construction industry began its peak developmental period in the 1970s and 1980s, the Egyptian solar energy industry is still in its nascent stage. Egypt is beginning to recognize its rapidly dwindling supply of natural resources, especially the petroleum which forms the mainstay of its economy. The country's strategic location, unparalleled amount of incident solar radiation, and commitment to increasing its renewable energy output has made it very attractive to foreign investors. By 2020, the government expects the renewable energy sector to comprise almost a fifth of the total energy sector. And with solar energy costs expecting to decline over the next few years, Egypt will develop a competitive market approach to solar, in addition to the traditional renewable energy sectors of wind energy and biomass.[25]

Because the objective is to obtain a general overview of industrial development in the Middle East, the author chose to focus on such seemingly disparate industries as construction and solar energy. These two industries highlight a wider range of characteristics than would two similar industries that share more in common. For example, the construction boom in Saudi Arabia occurred roughly twenty to thirty years ago, following the oil shock of 1973. On the other hand, the solar energy in Egypt has made its most significant advancements within the last decade, with plans to build many more utility-scale solar plants within the next few years. These two industries then represent two different periods of time and two different levels of development in the Middle East: one with an industry that matured in the 20th century, and one with an emerging industry that is still maturing.

In addition to the different time periods, there are several other differences between the two cases that make the study more useful. The case on construction naturally focuses on the implementation of large-scale engineering projects, while the case on solar energy focuses on technological advancements and government policies which, while not yet enacted, will affect the future of the industry. Thus one is a study of what has occurred, and one is a study of what is to come. Furthermore, the technologies involved are dissimilar. The solar industry involves investment in high-technology and cutting-edge research, while the construction industry is more dependent on managing existing supplies flows and the ups and downs of the resource market than on innovation. Another difference between the two cases is the nature of government involvement. In the construction industry, the Saudi Arabian government was heavily involved with both funding mega-projects as well as procuring companies for the construction itself. In Egypt, the government is less involved with actually developing the industry, where most of the investment is coming from foreign companies and private investors. Instead, the Egyptian government's role in the growth of the sector has been largely due to the influence of its economic policies. Although both cases involve the engineering industry, these important differences help distinguish the two and allow each of them to provide their own unique insights into industrial development in the Middle East.

1.5 Study methodology

This project will approach the cases studies by addressing each industry one-by-one. First, each industry will be introduced from a historical perspective in order to grasp how the development of the industry has changed over time. This will help draw attention to the effects of subsequent changes in the industry, and how these effects have evolved over the ensuing decades. Specific examples, such as the construction of the King Khalid Military City in Saudi Arabia and use of new technology in the solar industry, will emphasize the geographical, political, cultural, and historical considerations that policymakers and engineers must take into account when observing industrial development in the Middle East. The study will conclude by using this research to outline the future industrial landscape of the Middle East, including suggestions and precautions moving forward.

The data in this study does not lend itself to quantitative analysis, therefore discussion will be limited to a narrative analysis of each industry in their respective contexts. Thus the study ends with a qualitative interpretation of the research findings, and compares and contrasts these interpretations across the Middle East region.

2. CONSTRUCTION MANAGEMENT IN SAUDI ARABIA

2.1 Overview of construction mega-projects

A mega-project is an extremely large-scale construction project that requires resources from a wide variety of sources, both public and private. They are typically very expensive and attract public attention due to their impact on the environment, communities, and local budget. Examples of common megaprojects include the construction of bridges, highways, dams, and military facilities. In the Middle East, such projects are generally multinational since very few developing nations have either the capabilities or experience to handle them alone. These projects transcend the discipline of engineering and require support from people of other backgrounds, including lawyers, politicians, scientists, and industrialists. With their countless delays, huge cost overruns, and potential for conflict, these types of projects require special study as they introduce a whole new level of complexity not found with smaller scale engineering projects.[26]

Why is there a need for mega-projects, especially in a country such as Saudi Arabia? An incredible amount of new infrastructure is needed in developing nations for them to support their burgeoning economies. There is also a continuing need for huge industrial development projects in the private sector. This is especially true in the oil and petrochemicals industry, with high global energy demands increasing the need for Saudi Arabian investment in those sectors. These projects, such as the $27 billion dollar King Abdullah Economic City, would enable Saudi Arabia to create additional value from its petroleum resources.[27]

Large, multinational construction firms are generally organized based around mega-projects, and they usually have several internal divisions specialized in the tasks needed to complete any particular project. For example, Bechtel, the largest engineering company in the US with projects in nearly 50 countries as of 2010, has different operating companies to handle its airport, oil, and defense construction projects. One of these divisions was responsible for constructing the King Fahd International Airport in near Dammam, Saudi Arabia, currently the largest airport in the world in terms of land area (780 km^2). The exact organization of a mega-project should be dependent on the conditions under which the project is established, including the owners, operators, labor unions, and construction contractors involved with overseeing tasks. Perhaps the biggest difference between mega-projects and a multitude of smaller engineering projects is the need to spend huge sums of money effectively and efficiently. Only a few engineering management firms around the world have the ability to gather the necessary resources and manpower to do so.[28]

As a result of unique characteristics of construction mega-projects, there are certain techniques for maximizing construction management performance as well as reducing management control costs. Proper understanding of the organizational forms effective in the Saudi Arabian construction industry requires an overview of the development of that industry, starting in the late 1960s.

2.2 Development of the construction industry

Despite the dependence on oil by Western countries after WWII, Saudi Arabia remained a relatively agrarian-based economy until the late 1960s. In 1968, King Faisal bin Abdul-Aziz created the Central Planning Organization in order to: improve the security and stability of the Kingdom, diversify its economy from crude oil exports, and keep oil prices low enough to discourage the development of alternate energy sources. With input from foreign economic planners, the Central Planning Organization eventually became the Ministry of Planning, which was responsible for the initial set of five-year development plants.[29]

During the first two five-year economic development plans (1970-1975, 1975-1980), Saudi Arabia saw increased revenues from sales of oil and natural gas, although its ability to use this extra revenue was not commensurate with its growth. For example, poor road transportation networks and inadequate berthing facilities meant that goods meant for construction sites often never reached their final destination. The Saudi government recognized the problem, so when they began the second five-year development plan they focused on the creation of infrastructure designed to move people and freight across the country. During this period, the government created the General Ports Authority to improve the efficiency of existing ports in the country. The third development plan (1980-1985) was meant to make agriculture self-sufficient and begin the process of industrialization, but the worldwide recession and oil glut in the early 1980s severely halted the progress of this plan. During this time period Saudi Arabia continued its focus on building basic physical infrastructure and diversifying its income sources. The fourth development plan (1985-1990) continued the diversification of the Saudi economy by encouraging private investment in areas such as manufacturing, agriculture, and finance, and by reducing dependence on foreign labor.[30]

In the twenty years of its first set of economic development plans, Saudi Arabia went from an agrarian-based economy to an oil and oil-products based economy with over 25,000 km of paved highways, an increase in the production of cement and steel rods, and even an increase in literacy rate. Despite this improvement however, there was still a high dependence on foreign labor because programs providing technical training to Saudis were extremely underdeveloped. Also the government still subsidized a large portion of the country's production.[31]

Although the development plans were proposed by King Faisal and organized under the Saudi Arabian government, they required substantial input and support from outside sources. In 1965, the US Army Corps of Engineers, under the Engineer Assistance Agreement, aided Saudi Arabia in constructing numerous mega-projects for the Ministry of Defense and Aviation. These projects included the $218 million port at Ras Al-Mishab and the $6 billion King Khalid Military City in northeastern Saudi Arabia. Under the same agreement, the Corps helped modernize the Saudi Ordinance Corps by assisting with the supply and maintenance of engineering equipment and by training Ordinance Corps Cadets. They modernized and constructed naval bases at Jubail and Jeddah, and upgraded Saudi airfields during the 1979 Peace Hawk program. In all, the USACE's Saudi modernization program was just as intense as any of the country's own private programs. Saudi Arabia sought the help of the Corps because the Kingdom lacked the expertise to manage any of its own mega-projects at the time, and Saudi Arabia wanted to place their trust in a government agency rather than a local private company, given the negative experiences of many of its neighboring countries.[32]

One of the few exceptions to this was the involvement of Bechtel Group, a privately-owned company headquartered in the United States. Bechtel became involved in Saudi Arabia starting in 1943, when Crown Prince Faisal visited the west coast of the US and was impressed with the company's shipbuilding work in California. He then invited Bechtel to his country, where the group built roads and oil pipelines and electrified Riyadh, before stopping work with the Saudi government in 1952 due to a delay in payment. Bechtel had no projects in the country for a few decades, instead concentrating its efforts on surrounding nations such as Syria, Lebanon, and Iraq. Then in the 1970s, it created the Arabian Bechtel Company to re-enter Saudi Arabia and develop oil fields, taking advantage of the boom later in the decade. Bechtel's influence in the country continues today: Saudis trained by the Bechtel Group now hold managerial positions in a number of large Saudi Arabian companies, and the company was recently granted a contract to extend its work on the construction of Jubail Industrial City.[33]

2.3 Jubail as a model for industrial development

Jubail, a planned industrial city in the Eastern province of Saudi Arabia, was a fishing village until its renewal as an industrial area in 1975. Since then, it has seen rapid industrialization and a growth in population to around 150,000. The city is the largest industrial complex in the world by area, and it focuses on the manufacture of petrochemicals, steel, fertilizer, and their support industries. Jubail is home to the Middle East's largest petrochemical company, Saudi Basic Industries Corporation (SABIC), as well as the world's largest water desalination plant. The city has all the infrastructure, housing, shopping, educational, and medical facilities to self-sufficiently support its large population. Bechtel has been managing the Jubail project since the early 1970s and has recently been asked to expand the industrial city into Jubail II, a $3.8 billion project that includes the expected creation of 22 new primary industries.[34]

As shown in Figure 2.1, most of the employment in Jubail is concentrated in the manufacturing sector, as is expected. Similarly, very few workers are employed in social and community services, especially compared to the national level. The remaining industries in Jubail generally share the same employment percentages that are seen in Saudi Arabia as a whole.

Sector	National (%)	Eastern Province (%)	Jubail sub-region (%)
Agriculture & fishing	1.1	0.3	0.1
Mining & petroleum	5.6	15.1	2.7
Manufacturing	11.4	12.8	30.2
Utilities	3.6	3.1	4.0
Construction	28.2	31.7	18.8
Commerce & hotels	21.7	17.9	27.1
Transport & communication	5.1	5.2	1.2
Finance & real estate	4.8	3.6	4.7
Social & community services	18.5	10.4	11.2
Total	100	100	100

Figure 2.1: Employment distribution in various regions of Saudi Arabia.[35]

Transportation-wise, Jubail has three small airports, although all of them are for business or military use. Citizens of the city must use the King Fahd International Airport in Dammam, which is roughly 50 miles from Jubail. It is connected to two other cities by the Dhahran-Jubail Highway to Dhahran in the south of the Eastern Province, and the Abu Hadriyah Highway to Dammam and Kuwait. The city is also served by two seaports—Jubail Commercial Seaport and King Fahd Industrial Seaport—and there are plans to build a railway to connect Jubail with neighboring cities.[36]

There are several important factors that have contributed to the success of Jubail. This includes the numerous financial incentives offered to firms operating in the region, such as exemptions from custom duties on materials and equipment not available in Saudi Arabia, tariff protection, tax holidays, and preferential governmental buyout of Jubail products. The Saudi Industrial Development Fund (SIDF) and Real Estate Development Fund was developed to focus on providing long-term loans to growing Saudi businesses and housing loans to Saudi citizens living in Jubail. Other governmental agencies, including Saudi Aramco and regional electric and water companies, provide essential utilities to Jubail's industrial and urban development. Industrial cities such as Jubail also rely on gas from nearby oil fields as a very cheap energy source.

The development of Jubail highlights several important factors for industrial development throughout Saudi Arabia. First, strong government support for industry is critical—in the same way as was the case in Jubail, the development of many industries in Saudi Arabia, such as the solar energy and textile industries, depends on government subsidies and financial incentives. Jubail has contributed to the diversification of the Saudi economy, something that is needed to a greater extent on the national scale. Industry in Jubail is successful also because of the existence of numerous secondary support industries, which demonstrate the need for small to medium-sized companies in Saudi Arabia's manufacturing sector. Finally, there is need for foreign investment, as most of Jubail's primary and secondary industries were built through joint ventures with investors from USA, China, UK, France, Germany, Italy, and Finland, in addition the city itself being almost entirely built by Bechtel, a US-based multinational corporation.[37]

3. SOLAR ENERGY INDUSTRY IN EGYPT

Just like Saudi Arabia, Egypt is very much dependent on the export of its petroleum resources. Yet it has also begun to diversify its economy, recognizing the importance of developing industries that are both sustainable and nonvolatile. One repeatedly discussed avenue of growth is the development of Egypt's solar energy industry. The renewable energy sector in Egypt has vast potential, can greatly benefit from increased investment in research, and is not nearly as competitive as the oil sector.

Not only is the development of the solar industry in Egypt interesting from an engineering standpoint (what technologies are necessary to make it feasible, etc.), but it is also vital to the energy capabilities of the country. Partly due to its central location in the MENA region, Egypt is already the nucleus of several Mediterranean-wide solar initiatives, which makes it even more important to study the industry's development.

3.1 Overview of the solar energy industry

Egypt currently gets most of its power from natural gas and oil, which is by far the most preferred mode of energy for transportation in the country. Egypt also uses a few dams on the Nile River for hydroelectric power and small turbine farms for some wind energy.

Although Egypt is obviously a very important source of oil in today's world, this is likely to change within the next century. According to recent reports, Egypt's peak production of oil occurred in the mid-1990s, and the country is likely to run out of oil within 30 years. Furthermore, as an industrializing nation with a burgeoning population, Egypt's rate of oil consumption is quickly rising to match its rate of oil production. Most of the areas that Egypt gets its oil from, such as the Gulf of Suez, the Western Desert, the Eastern Desert, and the Sinai Peninsula, are rapidly decreasing in productivity despite advances in oil gathering techniques. In fact, the last major oil field in the country was discovered in Saqqara in 2003 by British Petroleum. Given these factors, Egypt is will likely become an oil importer in the near future.[38]

Although natural gas production has been outpacing natural gas consumption since 2004, the likely near-term shift of Egypt's energy focus from petroleum to natural gas will likely put a strain on this seemingly vast resource supply. Egypt has been rapidly creating new power plants to meet its growing energy demand, and has already spent time working on developing its wind and hydroelectric energy resources within the past half-century. The Egyptian government has set a goal of having 20% of its energy consumption come from renewable energy sources such as solar or wind by 2020, targeting those two sectors because they were the cheapest and most reliable ones back when Egypt was developing its long-term industrialization goals. One way it is incentivizing this growth is by offering an above-market tariff rate to wind farms who sell their extra energy to the government.[39]

Unfortunately, wind energy will not by itself provide enough energy to meet the growing demands of the country. According to the German Aerospace Center (DLR), advances in solar technology will soon make the cost per kilowatt-hour of solar electricity lower than that of wind electricity, resulting in an investment roughly half that of a wind park. As shown in Figure 3.1, the vast majority of the country receives direct solar irradiance at an intensity greater than most of the MENA region. Additionally, the country's peak demand for energy occurs during the time of day and season where the rate of solar energy collection would potentially be the strongest.[40]

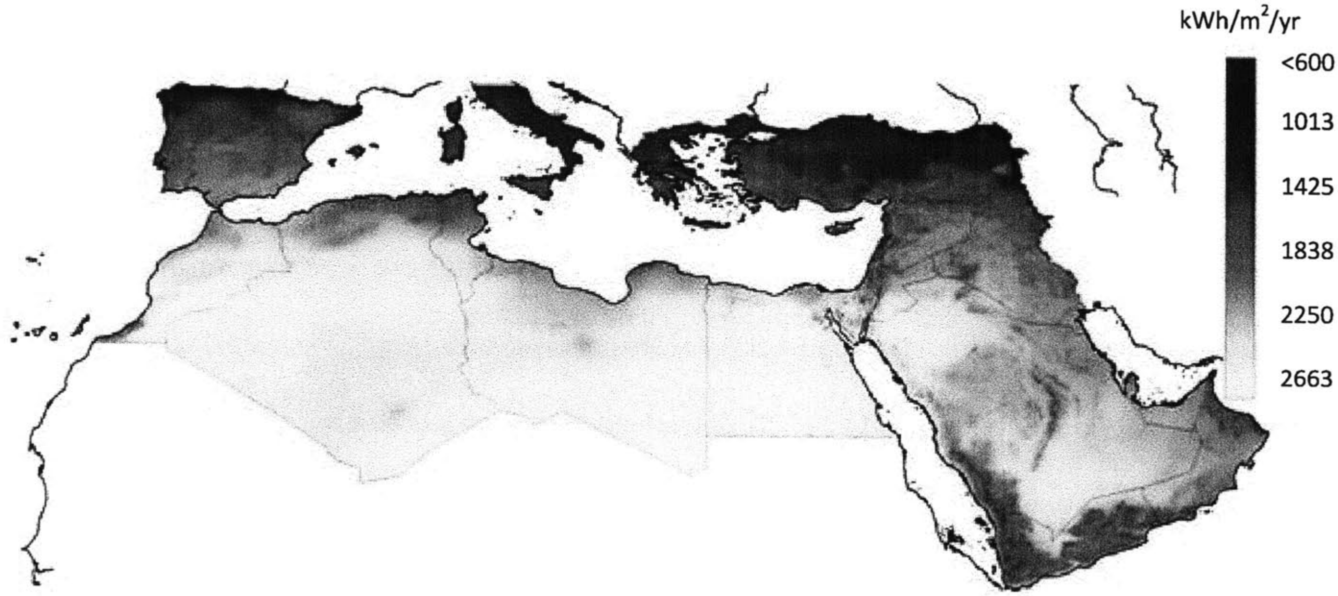

Figure 3.1: Annual direct solar irradiance in the southern MENA region.[41]

3.2 Relationship to Germany

It is of interest to note that a large proportion of the studies on the renewable energy sector in MENA have been conducted by German agencies. The Middle East is a huge market for German technology, so the German government has been very eager to promote its technologies through joint ventures with MENA nations, sensing the tremendous market potential in the region. German industrial research organizations have sought out experts from Saudi Arabia's University of Petroleum and Minerals, which has the largest solar energy program in the Arab world, as well as reaching out to Kuwait's Institute of Scientific Research.

Because of these efforts, the Germans have secured ventures with the United Arab Emirates, Kuwait, and Libya.[42] It is therefore important to take a look at Germany's own solar energy industry, for it will most likely be closely tied to the development of the solar energy sector in Egypt.

Germany has been able to develop its solar energy industry in the last six years from under half a billion euros to close to five billion euros in revenue. The number of people employed in the industry has skyrocketed, and many companies have been investing in the construction, expansion, and modernization of their own solar factories. Figure 3.2 shows the world solar photovoltaic market as of 2010. Germany represents over a third of the world's total PV installation, including five gigawatts of solar photovoltaic technology (PV) installed in 2008, representing over a third of the world's total PV installation. The world's leading supplier of concentrated solar power technology is in Germany, in addition to many companies that supply PV solar panels. German companies have their own research arms dedicated to the advancement of their respective solar technologies. Combined with ongoing research at many independent labs throughout the country, this make for an impressive solar research force in Germany.[43]

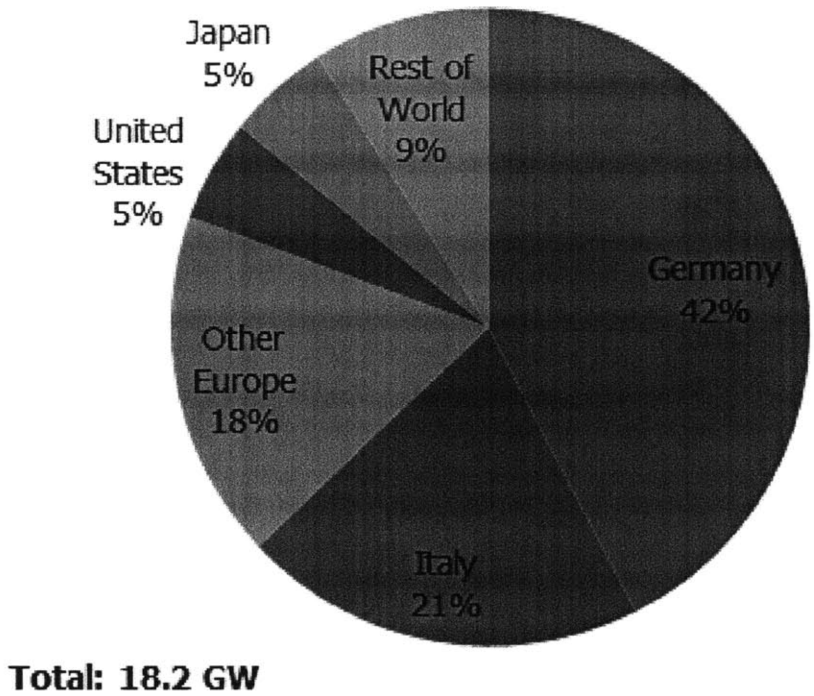

Figure 3.2: World solar photovoltaic market (2010).[44]

Unlike Egypt, the geographical location of Germany does not easily lend itself to solar power. Perhaps one reason why Germany is so successful is that it does not limit itself to the research sector when it comes to solar power. German companies are also involved with the planning and construction of solar plants in other regions, the manufacture of equipment, the integration of solar with existing energy systems, the operation of solar energy pipelines, and the training and monitoring of solar technology workers. Thus German companies are often called upon as consultants for solar projects in other areas in the Mediterranean region, and perform everything from environmental impact studies to financial audits for those projects.[45] Additionally, the 1990 Energy feed law greatly incentivized the production of solar electricity, which attracted most of the world's biggest developers and manufacturers of solar technology to Germany. At a time when the industry was still in its early stages, this initial draw was crucial in building a strong base for Germany's future solar industry.[46]

Compared to Germany, Egypt is lagging in the development of its solar industry. Significantly, Germany is home to more than forty companies that manufacture solar photovoltaic equipment—Egypt is home to none.[47] Furthermore, there is only one lab in Egypt dedicated to the research and development of photovoltaic technology, while Germany has over 70.[48] Given Germany's historic involvement in the MENA region and its strength in the solar market, it is clear that both Egypt and Germany could benefit from more collaborative efforts between the two nations. In 2007, the two countries came together to establish the Egyptian-German Joint Committee on Renewable Energy, Energy Efficiency, and Environmental Protection. Within four years, the committee has increased the capacity for the development of solar projects in Egypt, helped transfer relevant technology between the two countries, and created training opportunities for engineers and technicians in Egypt.[49] Although clearly a step in the right direction, there is plenty more room for collaboration between the country with the largest output of solar technology and the country with the most solar potential.

3.3 Opportunities

Cooperation with Germany, while beneficial for the development of the Egyptian solar industry, is not a prerequisite. The criteria necessary for the successful development of the solar industry in Egypt include the correct set of government and industry policies and the technical knowledge and experts required to guide the industry in its infant stages. Building a well-developed industry is not only dependent on the creation of solar power plants, but also on the advancement of the capabilities of existing solar energy infrastructure and investment in the research to make better solar technologies.

One advantage to developing solar technology in Egypt is that the country's current power plants use the same turbine technology that concentrated solar power (CSP) facilities use. Thus it is not entirely infeasible to use the existing infrastructure to create hybrid plants instead of building solar plants from scratch, would greatly reduce the requisite initial investment. Another hybrid use would be using the land underneath the station for planting of crops, which would reduce the irrigation water requirement in hot and sunny areas like Toshka. Furthermore, planners could combine solar and desalination plants by either using converted electricity or in combined generation with process steam. This would both raise the efficiency of the solar power station and reduce the cost of desalination.[50]

It is important to note that one of the economic drivers of any solar initiative in the Middle East is the ability to develop and export solar power to the European subcontinent, where it is not as readily available as it is in the Egyptian deserts. Although there may be transmission losses of up to 15% on a direct line from Egypt to southern Europe, this is more than compensated by the high level of solar radiation in Egypt and the minimal seasonal variation.[51] DESERTEC, an Italian-based initiative aimed at providing more renewable energy resources to the entire Mediterranean region, has drawn up a plan that has Egypt exporting up to 35 billion euros worth of solar energy to its neighbors on the Mediterranean by 2050. Egypt can profit from this plan both by producing and designing the equipment needed to run solar plants throughout the region, and by exporting excess solar power to other countries. Furthermore, they could bring in additional revenue by selling its extra free carbon emission permits under the Kyoto protocol.[52]

3.4 Enabling Technologies

Having already demonstrated that there is both the potential and need for further development of the solar industry in Egypt, we can now discuss some of the technologies, both existing and emerging, that could aid in this process. The purpose of this section is to understand the effect of new technologies on the growth of the industry in order to gain insight into the relationship between technology and development in the Middle East.

Photovoltaic

Photovoltaic technology (PV) is a method of converting solar energy directly to electricity through the photoelectric effect, where electrons are emitted from a metal (such as silicon) as a result of their absorption of energy from electromagnetic radiation of a short wavelength. In addition to the cells themselves, components of a PV system include a module, controller, battery, and inverter. Together, these help use the electric current generated from a PV cell. Figure 3.3 shows the costs per kWh for various energy sources, including solar PV and

CSP technology. Excluding installation costs, the electricity produced by PV solar panels costs up to 50 cents per kWh, which is substantially more expensive than oil and natural gas and even more expensive than other solar technologies such as concentrated solar power (CSP).[53]

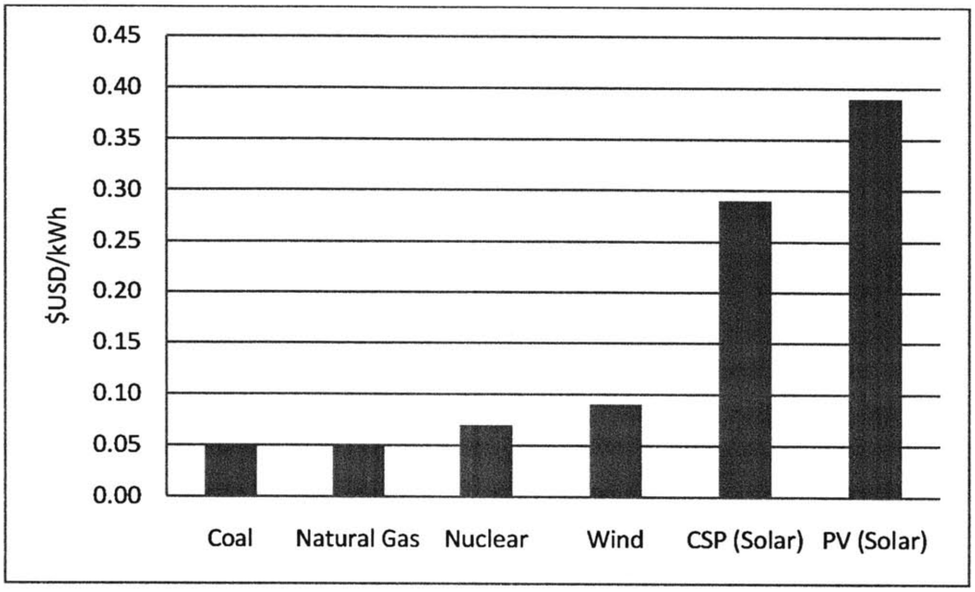

Figure 3.3: Cost/kWh for various energy sources, including PV and CSP.[54]

These costs are likely to decrease with the scaling up of the technology, its efficient manufacture, better cell architecture design, and cheaper raw materials. Even now, PV tends to be more cost-efficient than CSP for smaller applications, such as the roofs of residences. When the price for silicon increased in the early 2000s due to the increase in demand for silicon to build PV panels, more research was focused on developing PV technology that avoided the use of silicon. According to Solarbuzz, a solar market research and analysis firm, the lowest-quoted price for such a thin-film PV module is US$1.76 per watt-peak, compared to the lowest priced crystalline-silicon PV module at US$2.48 per watt-peak. Thin film PV currently holds 14% of the total market, and can be made with cadmium, copper, or gallium.

Concentrated solar power

Another viable technology that can be used to develop the solar industry in Egypt is CSP, or concentrated solar power. Unlike PV cells, which convert the sun's energy directly into usable electricity, CSP plants operate by first using mirrors to focus the sun's energy to produce thermal power, and then routing this thermal power to a generator to produce electricity.

One mechanism to focus the sun's energy is to use parabolic mirrors that heat up a tube located at the mirrors' focus point. Liquid in the tube then travels to a heat exchanger and a steam turbine, where it generates electricity. In general, parabolic troughs are over 100 meters long and are aligned on a north-south axis, so that they can tilt east-west to follow the path of the sun. Because they were first commercially developed in the 1980s, there are more parabolic troughs than any other type of solar technology in the world today, and scientists have been working on ways to develop parabolic mirrors that have the potential to be 30% more effective than conventional troughs.[55]

Another type of concentrated solar power technology is the Fresnel design, which is similar to the parabolic trough design except that instead of a single sheet of metal curved into a parabola, the reflectors are small strips of mirrors that are angled in a way to approximate a parabola's focus. Although it is generally not as efficient as the parabolic trough design, simplifications in the Fresnel design result in a lower overall cost per kWh of produced electricity. However, the Fresnel collectors would need a much larger area of collectors to provide the same solar energy transformation rate as a group of parabolic trough collectors.[56]

There are recent breakthroughs that have increased the efficiency of CSP technology. While many parabolic trough designs use synthetic fluid as the heating element in their designs, the Integration of DSG Technology for Electricity Production project (INDITEP) has sponsored projects aimed at using direct steam generation in the absorber tubes. These would enhance efficiency by up to 15-20%. Direct steam generation has been demonstrated to be feasible by the Center for Energy-Related, Environmental, and Technological Research in Madrid, where scientists produced superheated steam at 400°C and 100 bar in a 500 m test loop.[57]

Other solar technologies

Although the most popular solar energy options on the market, photovoltaic panels and concentrated solar power modules are not the only available technologies. Other less well-developed technologies include power towers, which use flat mirrors called heliostats to focus the sun's energy on a central tower, and Stirling dish systems, which use a satellite-like mirror to focus sunlight onto a Stirling engine. Although these technologies generally focus the sun's energy at a higher temperature than either the parabolic trough or Fresnel systems, they are expensive and difficult to maintain and thus not as economical.[58]

Egypt will make use of advancements in PV and CSP technology, but its true advantage lies in its location on the Mediterranean. Its central location in the MENA region allows it to be a nexus for the transport of energy from the Middle East to southern Europe, and its ability to benefit from this will depend on how efficiently it can transport energy across the

Mediterranean. For example, Egypt has made already several strides in integrating its own natural gas infrastructure with that of its neighboring countries. In 2005, Egypt installed its first liquefied natural gas (LNG) terminal, a modification to natural gas that substantially reduces its volume by turning it into a liquid. This greatly decreases its shipping cost, and in turn allows Egypt to sell natural gas more easily to the global market, where prices are more competitive than on the local market. A few years later, Egypt installed SEGAS, which was the largest single LNG plant in the world in 2005.[59] Egypt's experience with natural gas exemplifies its ability to take advantage of its prime geographical location to be a nexus for the transfer of energy in the Mediterranean region.

While Egypt has already created several ports to expedite the export of liquefied natural gas, it needs to do the same with solar energy. One technology that would make solar energy transmission more feasible is HVDC, or high-voltage direct current transmission lines. As their name suggests, HVDC lines use direct current for the bulk transmission of electrical power instead of the more common alternating current system. HVDC lines would facilitate power transmission between countries that use AC at different voltages or frequencies. Additionally, these lines function better than AC lines as undersea cables, where high capacitance causes losses in the transmission of alternating current. HVDC would limit loss of power during solar energy transmission to less than 5% per 1000 km. Building large-scale CSP plants and using HVDC lines to transmit this power to southern Europe would only cost roughly 5 euro cents per kWh of electricity, a cost comparable to that of oil and natural gas.[60]

Shown in Figure 3.4, DESERTEC is an EU and MENA initiative aimed at creating a sustainable supply of electricity to the region using renewable energy sources, with fossil fuels as a backup. Politically, the initiative depends on the economic cooperation of EU and MENA countries. Technologically, only HVDC transmission has the sufficient efficiency to make it cost-effective to transmit electricity across the Mediterranean Sea. By 2050, the expected investment in solar plants and HVDC transmission lines is expected to be upwards of 400 billion euros.[61]

Figure 3.4: EU-MENA supergrid based on HVDC transmission lines.[62]

4. ANALYSIS

Following the previous overviews of the construction and solar energy industries in Saudi Arabia and Egypt, respectively, this section analyzes the challenges the industries have faced in the past, as well as the challenges that they will face moving forward. The study will first look at the obstacles in the context of their respective industries, and then form a strong foundation from which to extrapolate these models to build a general picture of industrial development in the Middle East.

4.1 Saudi Arabian construction industry

Economic

Modern megaprojects will require innovative financing to help them get started. Managers of construction projects in Saudi Arabia must be aware of the complex array of financing options available to them, ranging from export credit models to private capital.

Political

For firms in the United States, there is often Congressional reluctance to employ the government's civil works efforts to a foreign country. Before entering Saudi Arabia, the United States Army Corps of Engineers had just worked with the Carter administration to maintain its role as the US's primary civil works manager. It was thus criticized when it announced it was planning to extend its work in Saudi Arabia, with detractors arguing that the Corps' Saudi Arabian projects were crippling its domestic capabilities. Furthermore, the Corps had a simultaneous military project underway in Israel. This not only put an additional strain on its resources, but it also created a diplomatic war between loyalties to Saudi Arabia and Israel, two long-time adversaries. On the other hand, Saudi Arabia was a strongly anticommunist country and a leading supplier of oil to the United States, and some thought the projects would strengthen ties between the two countries at little cost.[63]

Problems were not just limited to the public sector. In 1976, the US Department of Justice filed an antitrust suit against Bechtel Group for conspiring to participate in the Arab Boycott, a series of regulations adopted by Arab League nations that prohibited dealing in any way with Israel. The Central Boycott Office in Damascus compiled a roster of blacklisted people and companies that had traded with Israel, and Arab citizens were not permitted to deal with anyone on the list. Bechtel refused to let blacklisted companies work as subcontractors on their construction projects in Saudi Arabia and refused to use Jewish workers and products, thus participating in the boycott.[64] Likewise, the US Army Corps of Engineers avoided stationing Jewish workers in Saudi Arabia, although they manned Jewish personnel on the project from the Division Rear office in Virginia.[65]

Geographical

Obstacles faced by planners in the Saudi Arabia construction industry also occurred outside the political realm. The USACE planners developed the attitude that the Ministry of Defense and Aviation (MODA) of Saudi Arabia was an impediment to the design process of the King Khalid Military City, partly due to the great geographical separation between Saudi Arabia and their offices in Virginia. Additionally, given the particularly difficult environment of Saudi

Arabia, the government furnished precast concrete panels for all construction facilities in order to lower construction contract risk.

Cultural

Not surprisingly, dealing with the construction industry of Saudi Arabia must take into consideration cultural differences between Saudi Arabia and other nations. There were no Saudi planners in Virginia on the USACE side of the King Khalid Military City, and as a result the planners did not understand the Saudi Arabian cultural landscape. Their initial plans for the city, although structurally sound, were not appropriate for Saudi culture. For example, the Ministry of Defense and Aviation rejected the initial design because the size of the living units was not large enough for Saudi families. This delay in construction may have been avoided were there a more comprehensive manager review process.[66] Additionally, large construction projects must take into account labor productivity changes due to religious reasons, such as fasting during the entire month of Ramadan. Hours, even days worth of delays due to a different attitude towards time is also common in the Arab culture.

Management

The construction industry in Saudi Arabia has often been overwhelmed with delays and is often afflicted with cost and time overruns. Alsehaimi and Koskela of the University of Salford conducted a study in which they followed the construction of two projects at a university in Saudi Arabia: the faculty of business and administrative sciences, and general classrooms and laboratories. Their results are shown in Figure 3.5.

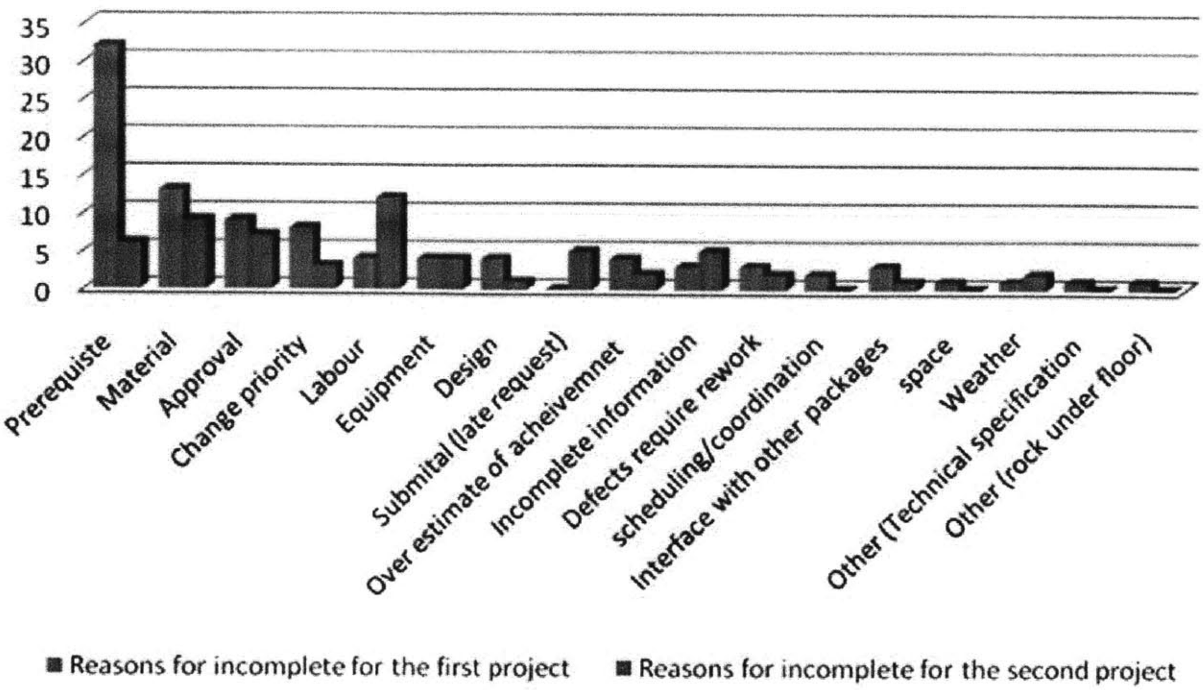

Figure 3.5: Reasons for incomplete tasks in two construction projects. Prerequisite includes all necessary structural assignments being completed.[67]

Poor project management is found to be a dominant reason for the delay in construction projects. Available workforce is often insufficient to meet project demands for skilled labor, especially during the construction boom. Approval required by the client for a bulk purchase of materials is time-consuming and causes delays, was not always punctual, and did not always result in the right materials being delivered. Additionally, involvement of many subcontractors made the coordination of labor a difficult process.[68]

Proper management practices must include process evaluations at the end of each significant phase of construction, and the development of teamwork which involves duties being properly distributed among team members. The global nature of construction contracts also requires that managers of construction projects have an increasingly higher level of interpersonal skills. Organizing resources and having clear lines of communication between subproject leaders is sometimes more challenging than the actual engineering itself, and it requires the capacity to communicate effectively with owners, engineers, and contractors. For example, one of the factors that contributed to the success of the King Khalid Military City project was the excellent communication between the design contractors and project managers.

There is no one style of successful management. The US Army Corps of Engineers performed their master planning almost exclusively in their Middle East Division Rear Office in Virginia, thousands of miles from Saudi Arabia. Part of the reason it maintained this geographic distance was to minimize the size of its ground force in Saudi Arabia until the actual commencement of construction, and part of the reason was military tradition. Bechtel, on the other hand, performed its planning on the ground at Jubail. Because Bechtel immediately split its Saudi projects into a dozen or so subdivisions, it needed to be little less decentralized in structure than the USACE. Regardless of how they were structured, both management systems turned out to be successful.

4.2 Egyptian solar industry

Economic

Perhaps the single most important factor in determining whether solar energy can be used for the industrial development of Egypt is the cost per kWh of electricity generated from the technology. If the cost is low enough, such as around the 5 euro cents per kWh from coal or natural gas, then companies will naturally turn to solar power over petroleum and natural gas. Additionally, they will encourage research and development of more advanced solar technologies, which will further increase the efficiency and decrease the cost of adopting these technologies.

Moreover, there is a limited amount of capital transactions in MENA, partly due to the region's economic isolation both between member countries and with the rest of the world. This is an obstacle to the development of large-scale solar initiatives as they usually require a large amount of upfront capital to purchase the necessary equipment. Although there is a higher initial cost for solar technology, this does not necessarily translate into a higher cost further down the road. Middle Eastern governments must then enact policies that make it more economically feasible for companies to pursue solar projects. This transient support for renewable energy can be considered a public investment into a cheaper, better, and more efficient supply system. Additionally, renewable technologies show decreased costs trends, while the cost for fossil fuels tends to rise over time.

Figure 3.6 shows the total annual difference in electricity expenses between the status quo "business-as-usual" plan and the MED-CSP scenario proposed by the German Aerospace Center. Projected until 2050, this shows a cost savings of approximately $250 billion euros under the plan. Even at present, cost reductions for fossil fuel and nuclear power technologies are hardly noticeable since the technologies involved have been mature for many years and already globally applied. Additionally, many of the cost reductions in fossil fuels have been offset by the necessity of adding in restrictive measures for the sake of the environment, such as filters and chemical gas flue treatment. The details in the MED-CSP scenario chart vary depending on the exact values of fuel prices, escalation rates, and carbon dioxide emissions policies, but all the scenarios analyzed by the center showed a break-even point before 2050, despite the higher initial cost for the MED-CSP plan. The payment for this initial investment could possibly come from those electricity consumers who would most benefit from the plan, as they would save money in the long run.

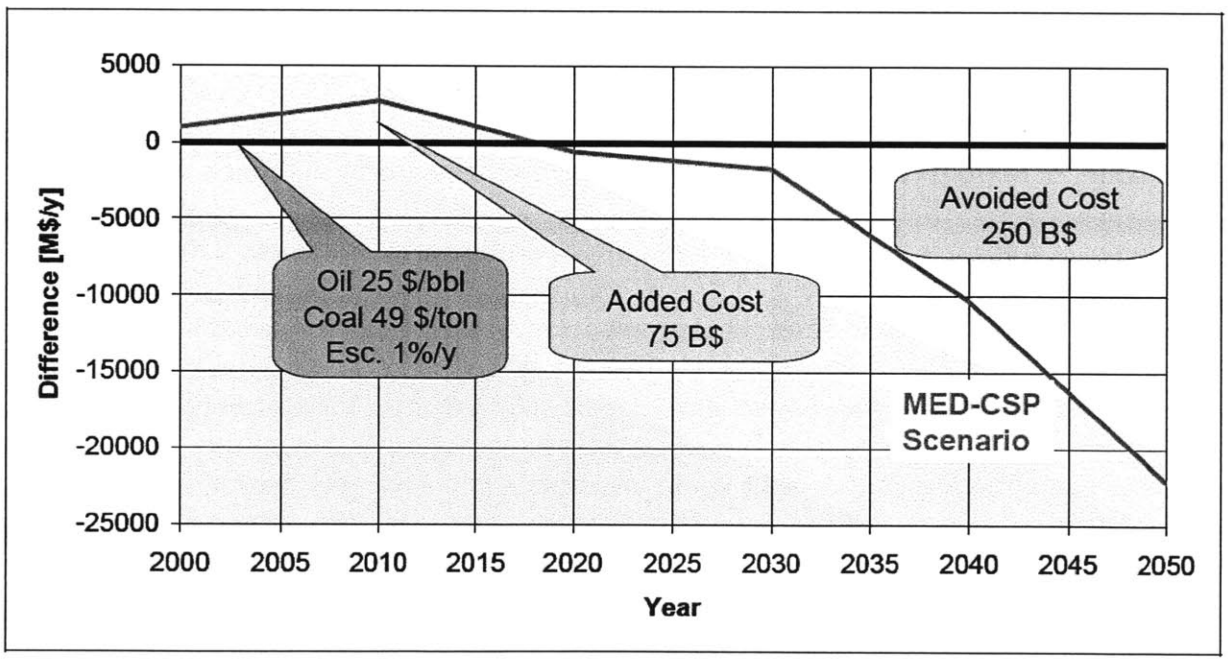

Figure 3.6: Cost difference between Mediterranean-CSP (MED-CSP) scenario and status quo. Despite the initial additional cost of using CSP technology, it more than makes up for itself in the long run. Amounts in the above graph are given in USD.[69]

Economic reforms in Egypt have slowed since September 11, as social concerns started to outweigh any developmental issues. Nevertheless, both private companies and governments have been working together to create policies that promote social responsibility and entrepreneurship in the solar industry. In March of 2010, the US government announced several initiatives at the MENA Power conference in Cairo promoting CSP technologies in the Middle East, specifically in Egypt, Jordan, and Lebanon. In Egypt, TAQA Arabia Group is undertaking a 250 MW project in Upper Egypt using tower technology, while in Jordan eSolar is scoping out plans for a new facility, aiming to determine which technologies are appropriate for the Byblos site.[70]

Furthermore, the World Bank has announced several innovative projects that use hybrid concentrated solar power technology that demonstrate that it is possible to deliver results from using this technology in the MENA region. Together, two plants in Morocco and Egypt have reduced CO_2 emissions by 60,000 tons, reduced dependency on petroleum and other fossil fuels, and created a large number of jobs in the two countries. Additionally, these projects have demonstrated the benefit to private investors who wish to put money towards CSP projects in the Middle East, and to the local industry which can now begin supplying components to this growing industry.[71]

Political

The Egyptian government has planned to introduce a feed-in tariff, under which renewable energy generators are paid a premium for any renewable energy that they produce.

In combination with a more efficient licensing system, this will help boost private investment in the renewable energy sector. The government also plans to reduce the cost of infrastructure investment by supplying areas that are logistically connected to the national energy grid.[72] Besides OPEC, there is little regional economic policy coordination, like done with the EU to the north. Capital is naturally attracted to markets where governmental regulations are clear. Countries that have advanced their judicial systems or modernized their capital law standards, such as Saudi Arabia, have made several positive steps to correcting this. Egypt, on the other hand, this has some room to improve.

Geographical

Egypt's hot climate and proximity to European markets makes it an attractive choice for developing the renewable energy industry. The high intensity of direct solar radiation, ranging from 2,000 to 2,600 kWh/m^2 shows great potential for solar energy development, especially in Upper Egypt. On top of that, the best locations in Egypt have over 2,400 annual hours of direct solar irradiation, compared to only 1,900 hours on average throughout Europe.

Cultural

The Egyptian people have traditionally been happy about developments in the renewable energy sector, as is correlated with a higher rate of job creation.

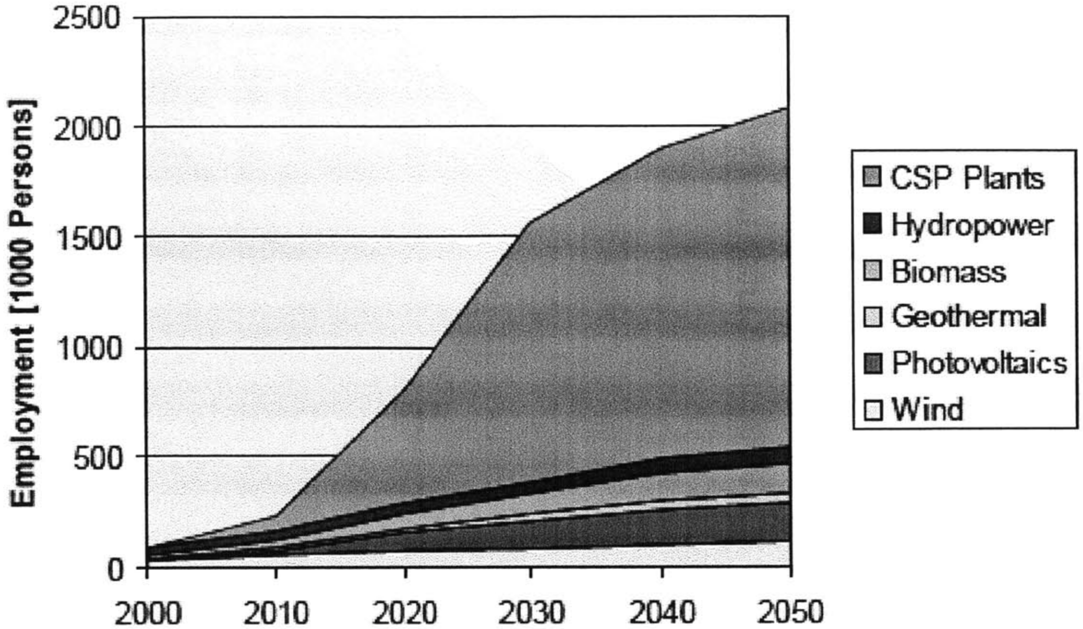

Figure 3.7: Projection of employment in the MENA renewable energy sector.[73]

The data from Figure 3.7 takes into account both indirect and direct gross employment. They are based on studies of the German renewable energy industry, and are calculated from German shares of import, labor productivity, and working hours per person. Using a rough estimate, the data predicts a gross employment of over two million people in the MENA renewable energy sector in the MED-CSP scenario.

Technology

Photovoltaic cells are the most expensive solar technology and so far have only been used in Egypt in off-the-grid applications, such as street lights. These applications do not require a large amount of power, making PV technology economically feasible for them. At high temperatures, PV panels lose efficiency by up to 10%. Given its already low efficiency, this prevents the use of PV in a wide range of large-scale applications. Additionally, since Egyptian companies do not currently manufacture their own PV subcomponents and instead import them from Japan and Germany, maintenance of PV systems would also prove a significant burden on the Egyptian infrastructure. Egyptian local manufacture of PV subsystems, while an appropriate long-term goal for the country, is not foreseeable in the near future given the complexity of the systems and the requisite experienced technicians and engineers required to assemble them. On the other hand, large-scale systems rely on the CSP cheaper thermal storage and greater efficiency to remain economical. CSP technology is also suitable for Egypt's desert-like regions since it can function to temperatures up to 400 degrees Celsius without suffering the same efficiency loss as PV cells.

The adoption of new technologies, such as CSP, will depend on whether that technology can deliver power as requested by the national demand, and whether its supply is relatively unlimited. It will also depend on the existing grid infrastructure and the cost of interconnection, the maximum growth rates of technology production capacities, annual electricity demand, and the replacement of old plants. After the initial phase of finance, success of the technology will depend on whether it is able to meet the growing needs of the population.

It is also very important to ensure that Egypt not only knows how to work with solar technology, but also understands how to build and maintain advanced solar collection systems on its own. Determining which solar technologies would be feasible for Egypt also involves figuring out which ones can be produced locally, since local manufacturing and the related low prices are crucial to the development of a national industry. These subcomponents include, but are not limited to, the reflective material that makes up the mirrors, the absorber tube, and the working fluid.

4.3 Generalization to Middle East

This study's purpose is to use the construction industry in Saudi Arabia and the solar energy industry in Egypt to illustrate general considerations when understanding the industrial development of the Middle East. This section presents some of those reflections.

Economic

The Middle East has attracted outside investment and resources in the past, especially in the construction industry. As the region continues to develop its own industries, it must rely on the finance and technologies of more developed nations and cooperate with them accordingly. Additionally, the government must establish a set of policies that initially provide support for emerging technologies. Over time, the government can gradually reduce the level of these subsidies so as to eliminate those sections of an industry that are not showing any progress.

Getting credit for business operations is one of the greatest barriers to industrial growth in the Middle East, as many banks lack the information to properly screen candidates, resulting in an inefficient allocation of monetary resources. Instituting a policy that mandates shared information among banks would be a step towards solving this problem. Likewise, an efficient exit strategy when a business has reached solvency plays an important role in business operations. With inept regulations, inefficient businesses will continue to thrive "under the radar" and misallocate human resources and capital.

Political

As is clear from the case of the solar industry, one of the difficulties in dealing with countries in the Middle East is a lack of clear policies and regulations that govern industries. Increased violence and political turbulence in some countries also discourages foreign investment and keeps a lot of multinational companies out of the region, which is otherwise very attractive as a potential market. Establishing a regulatory body for an industry can then be seen almost as a prerequisite for growth, especially for the ability of entrepreneurs to start new businesses. In the Middle East, inconsistent enforcement of contracts also includes informal relationships based on family ties and previous transactions. A transparent system of courts must be installed that enforces contracts between creditors, debtors, suppliers, and customers.

Additionally, countries in the Middle East must cooperate with international regulatory bodies and meet global industry goals, such as the energy policies of the Intergovernmental Panel on Climate Change. One way they can do this is to increase their focus on the renewable energy sector, which may not only prove profitable but also demonstrate a commitment to sustainability. This is especially important as most MENA countries are nearing the carbon dioxide emission limits set by most international protocols. Regional cooperation is also important, as countries can cooperate in setting prices in developing industries, much like they did with OPEC several decades ago.

Natural resources

The development of any industry must be conscious of the energy demands of a growing Middle Eastern population and economy. By many predictions, the total energy demand of the Middle East will be the same as that of Europe by 2050. Thus industries must focus on the development of the renewable energy sector now: not only will the increased industrial capacity of the Middle East require more energy sources, but the petroleum supply is likely to dwindle at an exponential rate. The lower the dependency on energy imports, the more opportunities there are for industrial development.

Cultural

Any initiative in the Middle East must include stakeholder participation, instead of being a foreign initiative with little input from the Arab world. They must focus on capacity-building within the community by creating local infrastructure, training personnel, and siphoning the project returns back into the community. In order to be accepted by the people, they have to have significant employment generation since the Middle East has a mushrooming population of young workers.

Technology

The successful industrial development of the Middle East may at first require technology transfer from Europe to the MENA region. After time, the Middle East will be able to develop new technologies on its own, driven by its growing economy. The adoption of technology may also need to overcome cultural, historical, and economic barriers.

5. CONCLUSION

This thesis is not merely a prediction of future trends in the industrial development of the Middle East. The previous chapter enumerates the challenges that must be overcome to reach a desirable state in the future of the MENA region. A lack of industry standards and bureaucratic inefficiencies can be countered with regulatory agencies and a regional cooperation. Private investment from outside the Middle East will spark the growth of many industries, where often companies do not have the capital to be self-propelling. As technology develops, the Middle East will have to work closely with the European Union in collaborating research efforts across the Mediterranean and training technicians in the new technology. Environmental and cultural characteristics also play important parts in the industrial development of the region.

It is clear that intensive international collaboration is important for the industrial development of the Middle East, as many countries in the region lack the capital or expertise to undergo major investments by themselves. Plans such as the EU-MENA MED-CSP scenario, which calls for regional cooperation in the development of the renewable energy sector, are steps in the right direction. Yet, as the history of any nation demonstrates, industrial development is a slow process that cannot happen overnight—unlike many of the tumultuous political revolutions in the Middle East.

Suggestions for future research include looking into other countries and industries in the region, as there may be peculiarities that are not identified in the case studies in this project. It would also be interesting to look into the effect that religion has on industrial development, since many of the current obstacles to development and technology adoption stem from cultural issues. Another example of such an obstacle is gender disparity, especially in the level of engineering education and the available labor force. Finally, a more thorough examination of the environmental effects of development may be needed as loss of natural resources, air and water pollution, and stricter international environmental protocols have a stronger effect on developing industries.

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