RETHINKING
YEMEN'S ECONOMY

PRIORITIES FOR THE RECOVERY AND REFORM OF THE ELECTRICITY SECTOR IN YEMEN

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Sabeen Street in Sana'a decorated in preparation for Houthi-mandated public commemorations of Mawlid al-Nabi (the Prophet Mohammed's Birthday), October 30, 2019//Photo Credit Asem Alposi

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ACRONYMS AND ABBREVIATIONS

BOOT	Build-own-operate-transfer
BOT	Build-operate-transfer
GARE	General Authority of Rural Electrification
HFO	Heavy fuel oil
LFO	Light fuel oil
MoEE	Ministry of Electricity and Energy
NLCRI	Night time light change rate index
OHL	Overhead lines
OPEC	Organization of the Petroleum Exporting Countries
PEC	Public Electricity Corporation
PPA	Power purchase agreement
PV	Photovoltaic
RFO	Residual fuel oil
SS	Substation
TNL	Total night light
YOPDC	Yemen Oil Products Distribution Company
YR	Yemeni rial

UNITS OF MEASURE

Btu	British thermal unit
GW	Gigawatt
GWh	Gigawatt-hour
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
MVA	Megavolt ampere
MW	Megawatt
MWh	Megawatt-hour
toe	Tonne of oil equivalent

EXECUTIVE SUMMARY

Electricity is the backbone of any economy and one of the necessities of modern life. Poor electricity services in Yemen, even before the war, have been one of the key barriers to sustainable economic development and basic service provision (e.g., water supply, health care, education). This paper aims to lay out the top priorities for restoring electricity sector services and reforming the sector after the war. The paper starts with an assessment of the electricity status prior to the war. It subsequently discusses the impact of the war on the electricity sector performance and the 1990s Power Sector Reform Model, followed by an identification of the key barriers faced by the sector.

The paper argues that the electricity sector, or power sector, in Yemen suffers from several chronic technical, political, economic and social challenges. These challenges are: 1) high dependency on diesel; 2) high electricity losses; 3) finance constraints; 4) lack of skilled employees; 5) security issues; 6) poverty and affordability issues; 7) inefficient and aging power plants; 8) corporatization and commercialization related issues; 9) unattractive market for private investments; 10) absence of supporting policies, laws and regulatory framework; and 11) absence of a clear vision on the form of the electricity sector after the war.

The paper concludes with a set of top priorities aimed at restoring the pre-war capacity of the sector and then further reforming the electricity sector towards improved performance. The immediate to short-term recommendations include adopting a realistic and practical recovery plan; securing funds for rehabilitating the infrastructure; reviewing the electricity tariff; reducing the technical and non-technical electricity losses; purchasing electricity when needed through a competitive process and via least-cost options such as gas and renewable energy; securing the fuel supply and the salaries of sector staff; resuming all suspended projects; finding sustainable and feasible solutions for the electricity supply in each governorate to avoid the challenges associated with the centralized grid; and installing sustainable stand-alone solar systems, compatible for connection to the national grid (when restored).

The medium to long-term priorities include specific recommendations under five categories, relating to 1) the legal and regulatory framework; 2) institutional arrangements; 3) capacity and performance; 4) private sector participation; and 5) technical issues.

1 | INTRODUCTION

1.1 | Overview

Yemen, with a population of 30.4 million, is one of the least electrified countries in the Middle East and North Africa (MENA) region.[1] It suffers from longstanding political and economic instability that has hindered its socio-economic development, and access to adequate basic services continues to be one of the daily challenges that face the overwhelming majority of Yemenis.[2] The lack of access to electricity for vital service facilities and households alike has contributed to the deterioration of the quality of public services provision (e.g., water supply, health care, education) and the overall well-being of Yemenis.

Even prior to the ongoing war, less than half of the population had access to public electricity. As of 2014, the rural population accounted for about two-thirds of total inhabitants, but only 23 percent had access to electricity compared with 85 percent of the urban population.[3] The maximum annual electricity consumption per capita in Yemen never exceeded 255 kilowatt-hours (kWh), a significantly lower usage compared to the annual average of 2,900 kWh in the MENA region and 3,100 kWh/year worldwide.[4] Furthermore, both the availability and reliability of electricity access were notably substandard due to fuel shortages and the frequent sabotaging of the transmission towers connecting the Marib power plant, Yemen's largest, to Sana'a and the national grid.[5]

Although the installed capacity of the Public Electricity Corporation (PEC) was around 1.5 gigawatts (GW), the available capacity was around 1 GW in 2012 and 2013. This capacity barely supplied the 2 million subscribers, which was supplemented with purchased

1) Central Statistics Organization (CSO), "A summary table of the most important results of data and indicators of population projections (2005–2025) in accordance with the assumptions and different alternatives [AR]," http://www.cso-yemen.com/content.php?lng=arabic&id=553 (accessed August 7, 2020).

2) United Nations Human Settlements Programme (UN-Habitat), Regional Office for the Arab States, "Republic of Yemen National Report" (submitted to the "Third United Nations Conference on Housing and Sustainable Urban Development (Habitat III)"), 2016, http://habitat3.org/wp-content/uploads/Yemen-National-Report-September-2016.pdf (accessed August 7, 2020).

3) Walid Ali, Fuad Al-Kadasi, and Kishan Khoday, "Policy Note: Prospects of Solar Energy in Yemen," United Nations Development Programme (UNDP), Environment and Energy, January 2014, http://www.undp.org/content/dam/yemen/E&E/Docs/UNDP-YEM-Prospects%20of%20Solar%20Energy%20in%20Yemen-%20Policy%20Note.pdf (accessed August 7, 2020).

4) World Bank, "Electric power consumption (kWh per capita)," *DataBank*, https://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC (accessed August 7, 2020).

5) Dawud Ansari, Claudia Kemfert, and Hashem Al-Kuhlani, "Yemen's Solar Revolution: Developments, Challenges, Opportunities," 2019, p. 4, https://eadp.eu/uploads/WP201902_Yemen_Solar_EN.pdf (accessed August 7, 2020).

electricity provided by private suppliers through PEC. The supply to demand gap, around 376 MW in 2012 has continued to widen because of population growth and the limited generation, which was further hampered during the ongoing war.[6] Due to its pre-existing fragility combined with the destructive effects of the war, the electricity sector incurred considerable physical and non-physical damages, leading to the current collapse of the national electricity grid.

This paper aims to identify the priorities for restoring the electricity services and reforming the performance of the sector. It begins by discussing the status of the sector prior to the war, from 2000 onwards. The paper then assesses the impact of the war on sector performance and the evolution of local markets. It also addresses the sector's key challenges and potential investment opportunities and concludes with a set of recommendations on the immediate, short, medium and long-term priorities for the recovery and reform of the sector.

1.2 | Methodology

This paper utilized both quantitative and qualitative research methods to quantify and evaluate the sector's performance and incorporate several qualitative factors. An extensive literature review covering the period of 2000 to 2020 was conducted, as well as collection of additional relevant data from various reliable sources, including reports and documents of the Ministry of Electricity and Energy (MoEE) and PEC, academic papers and international organizations' reports. To fill the remaining knowledge gaps and verify the quality of the collected data, several semi-structured and in-depth interviews were conducted with thirteen senior experts and staff from the MoEE, PEC, the General Authority of Rural Electrification (GARE) and other organizations in Aden, Sana'a, Hadhramout and Marib. See Appendix 1 for the list of interviewees. Following the data collection process, the numerical data was examined and presented in tables and charts, including averages and ranges, while the qualitative data was analyzed to highlight the situation of the sector and its evolvement. After the initial draft of the paper, several rounds of reviews were undertaken, followed by circulating key sections with local sector experts who provided constructive comments, which were carefully considered and incorporated.

6) Public Electricity Corporation (PEC), 2012 Annual Report [AR].

2 | PRE-WAR STATUS

This section covers the period preceding the armed conflict, from 2000 to 2014. It mainly explores technical, institutional and legal aspects of the sector, among other key technical and non-technical performance indicators.

2.1 | Generation, Transmission and Distribution

Generation

Pre-war, the generation subsector consisted mainly of three components. First, the power plants that fed the national grid and connected the main cities of Sana'a, Aden, Taiz, Hodeidah, Dhamar, Rada', Yarim, Ibb, Al-Dhale, Lahj, Abyan, Amran, Al-Mahwit and Hajjah. Second, the off-grid/isolated power plants in Hadhramout (Al-Sahel and Al-Wadi). Third, small diesel generators distributed around the country and managed by the Secondary Cities Department under the PEC. In addition, the PEC also purchased electricity from private producers to satisfy the unmet demand through the grid or to supply off-grid areas such as Al-Mahrah, Shabwa and Marib.[7] The overall public installed generation capacity in 2013 was 1.5 GW, which means that the power sector in Yemen had a highly limited capacity compared to other countries of the region.

Box 1: Installed capacity vs. population in the Arab countries*

Country	Population (thousands)	Installed Capacity (MW)
Jordan	6,560	3,333
UAE	8,200	27,280
Bahrain	1,275	3,934
Tunisia	10,942	4,274
Algeria	38,900	15,098
KSA	29,994	58,462
Sudan	37,188	3,136
Syria	21,720	9,879
Iraq	35,057	27,110
Oman	3,957**	4,938
Palestine	4,225	126
Qatar	2,045	8,755
Kuwait	3,965	15,719
Lebanon	5,000	2,258
Libya	6,282	9,455
Egypt	86,125	31,039
Morocco	33,000	7,342
Yemen	25,235***	1,535

Source: Arab Union of Electricity, 2013.

** Includes countries covered by AUE*

*** National Centre for Statistics and Information*

**** Central Statistics Organization (CSO)*

7) PEC, 2012 Annual Report.

As most of the Yemeni power plants were outdated and inefficient, the actual capacity of the plants was far below the nominal capacity. In 2013, the actual capacity was about 1 GW. The Marib I gas power plant represents 40 percent of the actual capacity of the PEC power plants and 51 percent of generated energy. Figure 1 below shows the installed versus actual capacities of power plants/generators of electricity systems, including the purchased power. Figure 2 shows the energy produced by those power plants per type of fuel, which are gas, residual/heavy fuel oil (RFO/HFO), and light fuel oil (LFO), namely, diesel.[8] Table 1 lists the installed versus actual capacities of PEC power plants in 2013.

Figure 1: Installed vs. actual capacity, 2013

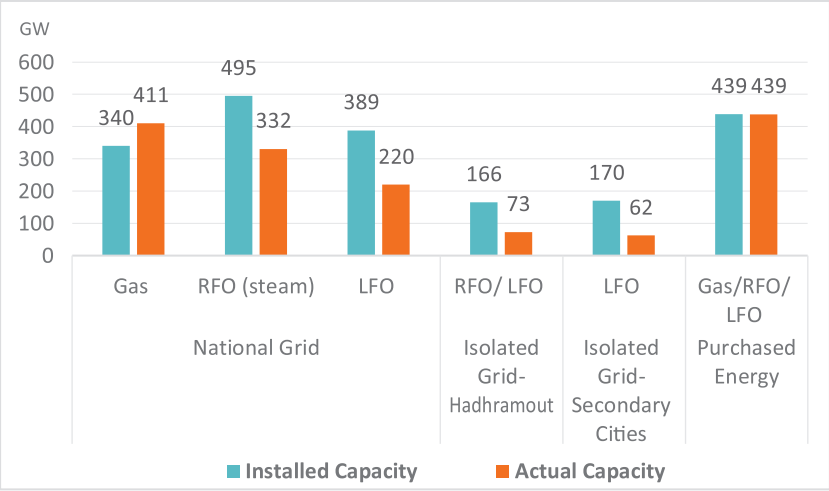
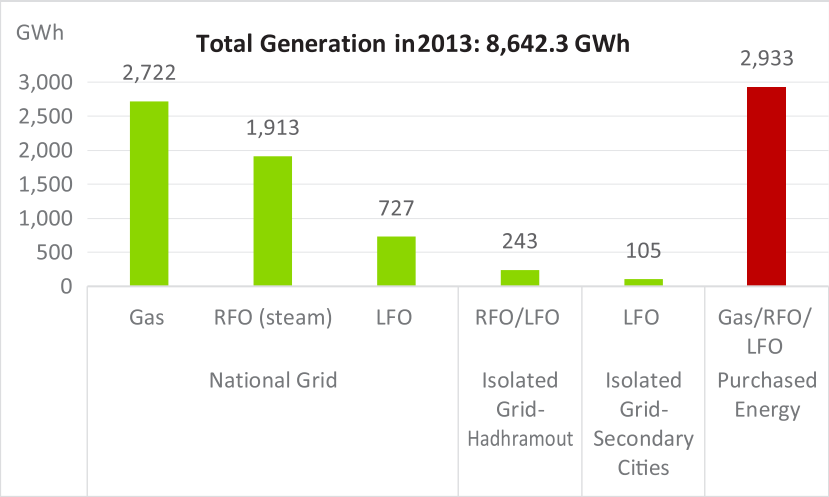


Figure 2: Generated electricity, 2013



Source: Public Electricity Corporation (PEC), written communication (data of 2013).

8) Capacity versus energy: Capacity is the maximum output an electricity generator can physically produce, measured in watts—kilowatts (kW), megawatts (MW) or gigawatts (GW). Energy is the amount of electricity a generator produces over a specific period of time, measured in watt-hours—kilowatt-hours (kWh), megawatt-hours (MWh) or gigawatt-hours (GWh).

Table 1: Installed vs. actual capacity of PEC power plants, 2013

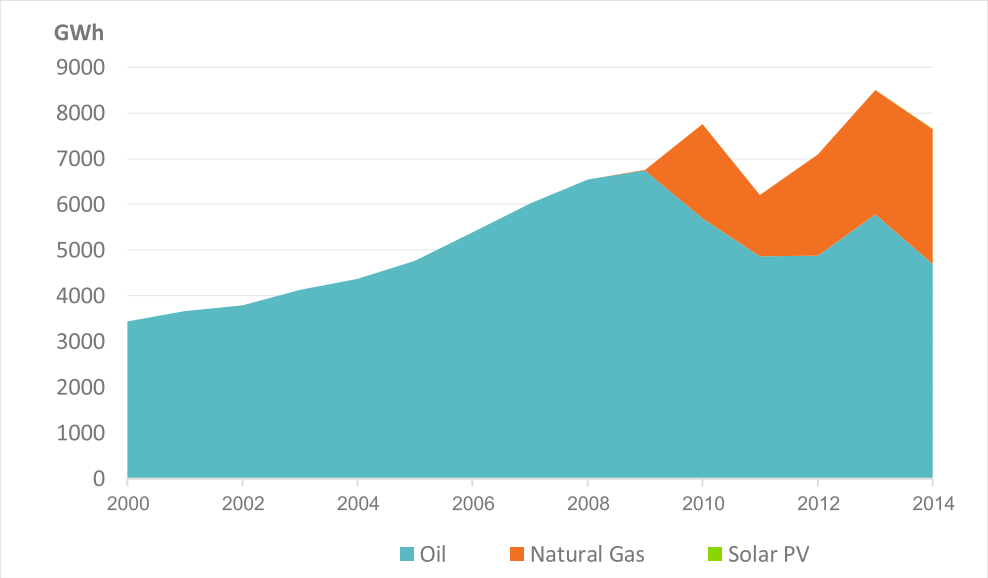
Grid	Plant Name/Location	Fuel	Installed Capacity (MW)	Actual Capacity (MW)
Main National Grid	Marib 1	Gas	340*	411
	Ras Katheb – steam*	RFO (i.e., HFO)	150	105
	Al-Mokha – steam	RFO	160	126.5
	Heswa – steam	RFO	185	100
	Mansoura 1	LFO (Diesel)	64	20
	Mansoura 2	RFO/LFO	70	17
	Khormaksar	LFO	14	14
	Thahban 1	LFO	21	10.4
	Thahban 2	LFO	25	8.3
	Sana'a	LFO	12.5	6.7
	Heziaz 1	LFO	30	26.1
	Heziaz 2	RFO/LFO	70	50
	Heziaz 3	RFO/LFO	30	30
	Osaifirah	LFO	15	13
	Alhali	LFO	20	18
	Alkornish	LFO	7.5	3
	Ga'ar	LFO	10	3.2
Total Main National Grid			1,224	962.2
Isolated Grids	Hadhramout (Al-Wadi & Al-Sahel)	RFO/LFO	165.6	73
	Secondary Cities	LFO	170	62
Total			**1,559**	**1,097.2**

Source: PEC, written communication (data of 2013).

** The designed capacity of Marib I gas power plant is 498 MW (three turbines, 163 MW each), while the actual capacity in the summer is 340MW, due to the high altitude and temperature.*

Before 2010, Yemen's electricity generation capacity was relatively low and mainly relied on HFO and LFO/diesel. Then the generation subsector witnessed considerable improvement in its capacity, especially with the new addition of 340 MW from the Marib I gas power plant in 2009. This enhanced diversification of the energy mix was produced from the lowest-cost, locally available resources. Figure 3 illustrates the evolvement of electricity generation from 2000 to 2014.

Figure 3: Electricity generation evolvement from 2000 to 2014



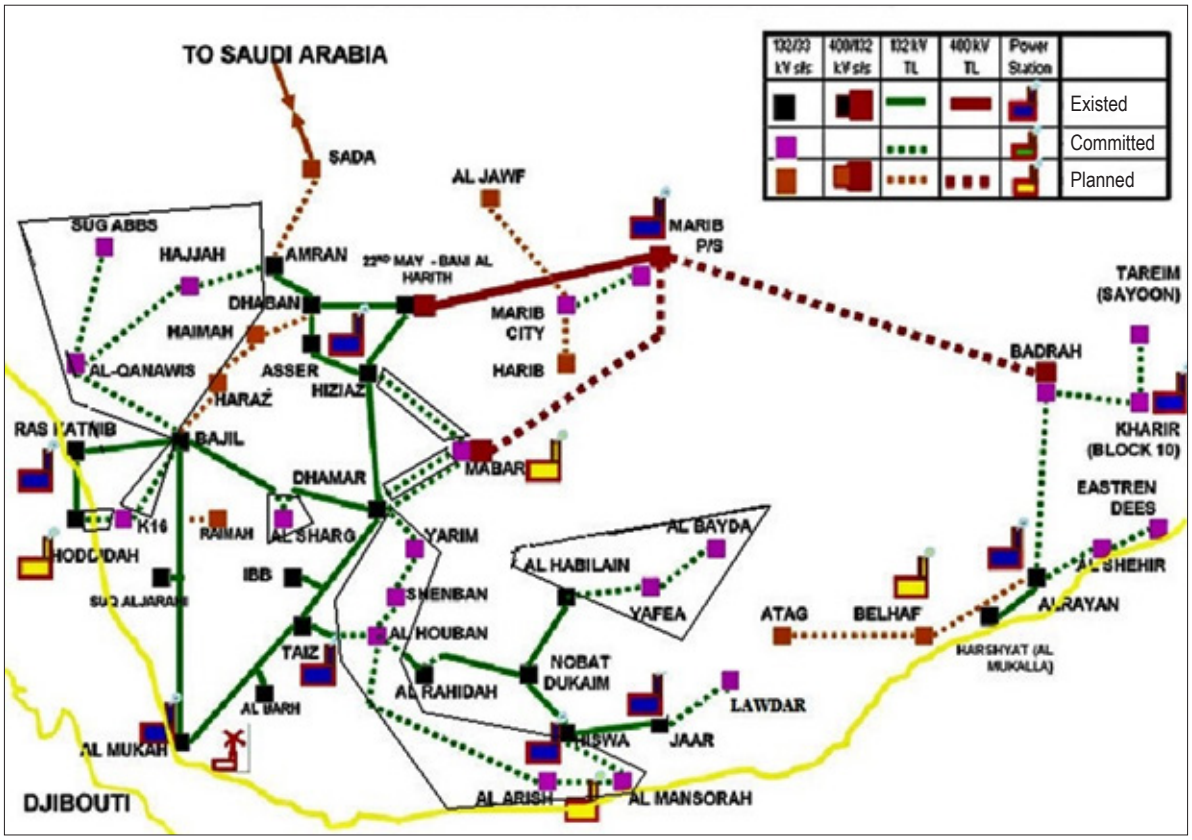
Source: International Energy Agency (IEA), "Electricity generation by source, Yemen 1990–2018," World Energy Balances 2020, https://www.iea.org/data-and-statistics?country=YEMEN&fuel=Energy%20supply&indicator=ElecGenByFuel (accessed August 7, 2020).

Transmission

The pre-war transmission system in Yemen consisted of 132 kilovolts (kV) systems that connected 13 cities. In addition, 400 kV transmission systems were used for transmitting power from the Marib I gas power plant to step-down transformers located in Bani Hareth, Sana'a. Generally, the power plants connected to the national grid generate electricity at voltage levels of 10.5 kV, 11 kV, 13.8 kV, and 15 kV; then, these voltages were stepped up to the transmission voltage level (i.e., 132 kV and 400 kV) in order to transmit the power to the covered demand locations. Figure 4 maps the transmission lines across the country, as well as planned transmission line projects. Figure 4 also shows several projects committed to expanding the grid in several areas, but these were suspended because of the war. These key pre-war projects were Amran–Bajil (Hodeidah), through Hajjah and Al-Qanawis (Hodeidah); as well as Dhamar–Aden, through Yarim (Ibb) and Al-Houban (Taiz).[9]

9) MoEE, "Schemes."

Figure 4: Existing and planned transmission lines



Source: Ministry of Electricity and Energy (MoEE), "Schemes," https://moee-ye.com/site-ar/%d8%a7%d9%84%d9%85%d8%ae%d8%b7%d8%b7%d8%a7%d8%aa/ (accessed August 7, 2020).

The transmission sector assets consisted of high voltage transformers/substations, overhead lines (OHL) and towers. Table 2 lists the assets of the voltage levels 400 kV and 132 kV.

Table 2: Components of the transmission grid, 2013

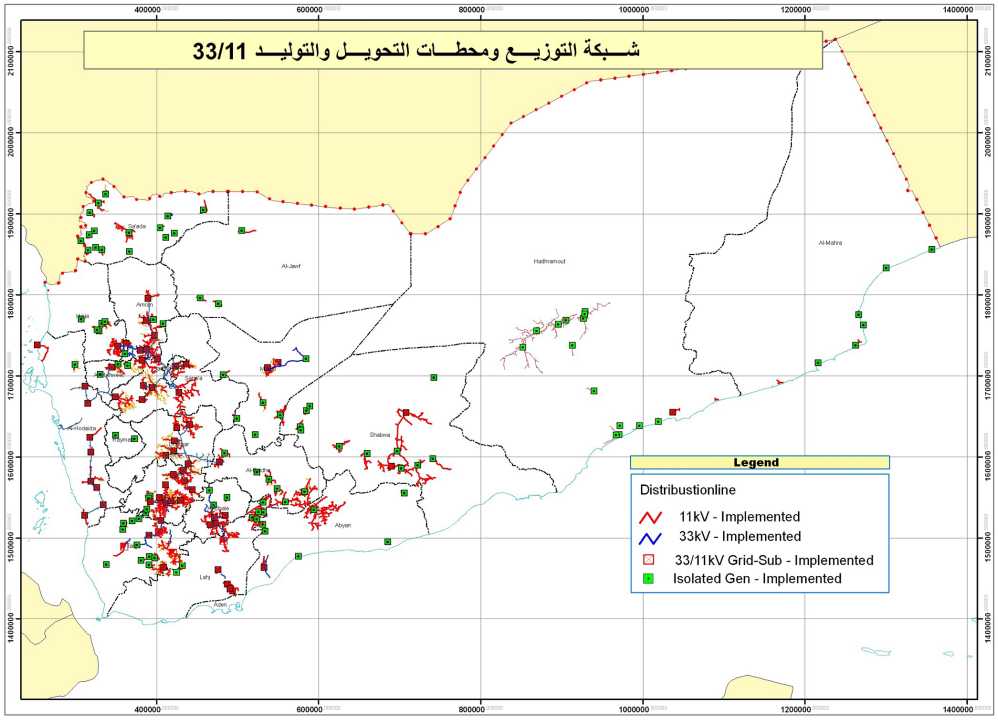
No. of Transmission Substations and Capacity			T.L. Length and No. of Towers		
Voltage	No. of Transformers	Total Capacity MVA	Voltage	Length km	No. of Towers
400/132 kV	2	1,200	400 kV	194	490
132/33 kV	35	1,322	132 kV	1,214	3,537

Source: MoEE, "Schemes."

Distribution

The pre-war distribution network mainly used a 33 kV voltage level to transmit power from the transmission network to the covered demand locations. Administratively, 27 distribution areas were serving the main governorates and cities. Figure 5 maps the distribution grid, along with all the power stations and substations.

Figure 5: Distribution network



Source: MoEE, "Schemes."

Table 3 shows the details of the assets related to the pre-war distribution sector. These assets include the number and capacity of 33/11 kV and 33/0.4 kV substations (SS), in addition to the length of the overhead and underground distribution lines.

Table 3: Components of the distribution network, 2013

33/11 kV SS		Length of Transmission Lines of 33 kV		Transformers 33/0.4 kV		Length of Transmission Lines of 11 kV		Transformers 11/0.4 kV	
No.	Total Capacity MVA	OHL (km)	Underground (km)	No.	Total Capacity MVA	OHL (km)	Underground (km)	No.	Total Capacity MVA
179	2,178	4,234	441	1,245	93.5	12,115	1,204	16,451	3,264

Source: PEC, 2012 Annual Report.

Rural Electrification Initiatives

In response to significant gaps in electricity access in the rural areas, the government had several ongoing projects, programs and initiatives. However, plans to expand the renewable energy applications into scattered rural communities, located far off the national grid and thus in need of alternative, cost-effective options of connection, made minimal progress due to the absence of any strategic vision and legal/regulatory support. Before the Electricity Law No. 1 of 2009 created the General Authority for Rural Electricity, the PEC was the main body responsible for implementing the rural electrification program in Yemen. The Power Sector Development Strategy Note, issued in 1997 and updated in 2006, was one of the drivers of the nationwide rural electrification program.[10]

One of the ambitus projects that the government was seeking to achieve, is a project for rural electrification, to be implemented in 12 rural areas spanning 12 governorates; namely, Taiz, Ibb, Hodeidah, Al-Baydha, Lahj, Abyan, Al-Dhale, Al-Mahwit, Sana'a, Dhamar, Amran and Hajjah. This project was funded by multiple parties: the Government of Yemen, the World Bank, the Islamic Development Bank, the French Development Agency, and the German government, among others. The objectives of the project were the following:[11]

1. Implementing the first phase of the national strategy for rural electricity, approved by the Council of Ministers in July 2008.
2. Increasing rural electricity access from 20 percent to 30 percent during the project period, specified as six years, 2009 to 2015.
3. Connecting 12 rural areas in 12 governorates to the national grid. In addition, electrifying remote off-grid areas in those governorates—areas deemed inaccessible because of their isolated locations—using renewable energy systems, specifically solar home systems (SHS).
4. Constructing 11/33 kV lines, substations, transformers and network materials, including meters and civil works based on high technical standards.
5. Providing technical assistance for the institutional building of electricity and energy services providers in the identified 12 rural areas, in addition to building the capacity of the General Authority for Rural Electricity.

10) World Bank, "Project Information Document (PID): Appraisal Stage" (Report No.: AB2983, project name: "RY-Rural Energy Access"), April 8, 2009, http://documents1.worldbank.org/curated/en/840631468340298535/pdf/Project0Inform1nt010Appraisal0Stage.pdf (accessed August 7, 2020).

11) Ministry of Energy and Electricity (MoEE), "Rural Electricity Project [AR]," December 22, 2009, https://bit.ly/3fLbTpq (accessed August 7, 2020).

The Electricity Law No. 1 of 2009 created the General Authority for Rural Electricity (GARE), designated as a financially and administratively independent entity, responsible only for electrifying rural areas located outside the main and secondary cities through cost-effective solutions, via both on- and off-grid applications. The intention was to provide electricity via collaboration with distributors/service providers, including cooperative associations and investors, among others.

Efficiency

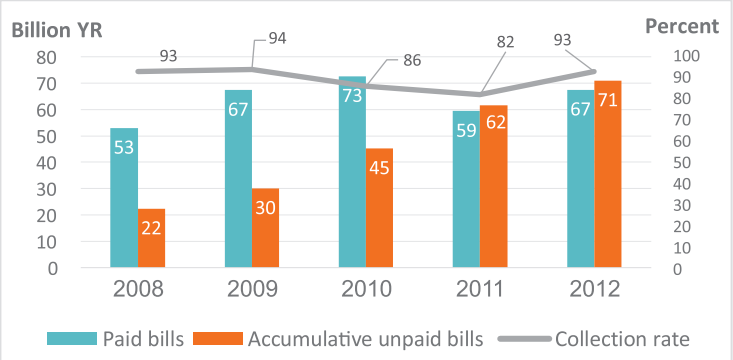
With the exception of the Marib I gas power plant, installed in 2009, all electricity power plants owned by the PEC were inefficient and outdated, and fired by RFO/LFO.[12] These liquid fossil fuels were uneconomical and increased the government's overall financial burden as the electricity was sold below actual cost.

Pre-war, more than 40 percent of the generated electricity was lost in the transmission and distribution system. The technical and non-technical losses of the distribution sectors only totaled 36 percent (2,329.1 gigawatt-hours (GWh)) in 2012, and 39 percent in 2013. Significant losses were found in Sana'a (up to 840 GWh), Aden (up to 393 GWh), Hodeidah (up to 289 GWh) and Hadhramout Al-Sahel (up to 187.4 GWh). In the generation subsector, average losses were around 5.5 percent between 2008 and 2013. The Public Utility Corporation also faced challenges in bill collection, especially after the political crises began in 2010. The total amount of accumulated unpaid bills came to Yemeni rial (YR) 70 billion (~$326 million at USD/YER 215) in 2012.[13] Figure 6 plots the collection rate and the total amount of electricity bills and the accumulative unpaid bills from 2008 to 2012, and Figure 7 shows electricity losses in the distribution and generation subsectors.

12) World Bank, "Republic of Yemen: Restoring and Expanding Energy Access" (Report No: ACS22319, Power Sector Reengagement Note), June 2, 2017, p. 3, http://documents.shihang.org/curated/zh/655811496412539032/pdf/P158449-Output-Yemen-Power-Sector-Reengagement-Note.pdf (accessed August 7, 2020).

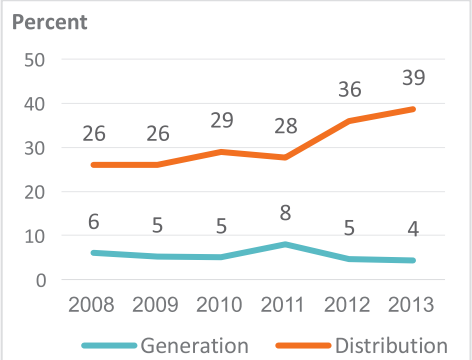
13) PEC, 2012 Annual report and written communication.

Figure 6: Collection rate & amount of paid and unpaid energy bills



Source: PEC, 2012 Annual report.

Figure 7: Electricity losses



Source: PEC, written communication (data of 2008-13).

In addition, while the average specific energy consumption of power generation in the region was 220 to 224 tonnes of oil equivalent (toe)/ GWh in 2003 and 2009 respectively, the specific energy consumption in Yemen was 283.1 toe/GWh in 2003 and 263.2 toe/GWh in 2009.[14] lthough there was a slight improvement in the later years, the specific energy consumption remained significantly high. This was mainly due to, among other factors, the absence of a renewable energy contribution in Yemen's overall energy mix, which in turn increased greenhouse gas emissions.[15]

2.2 | Electrification Rate

Yemen is the country with the lowest electricity access rate in the MENA region.[16] In contrast to a rapid population growth rate of 3 percent annually, the electrification rate increased at a much slower pace. Pre-war, only 46 percent of Yemenis had access to electricity.[17] As of 2014, only Aden, Hadhramout and Sana'a city enjoyed electricity coverage of more than 75 percent, while more than half of the governorates had an access rate under 50 percent. Figure 8 illustrates the public electricity access rates in the governorates in 2014.

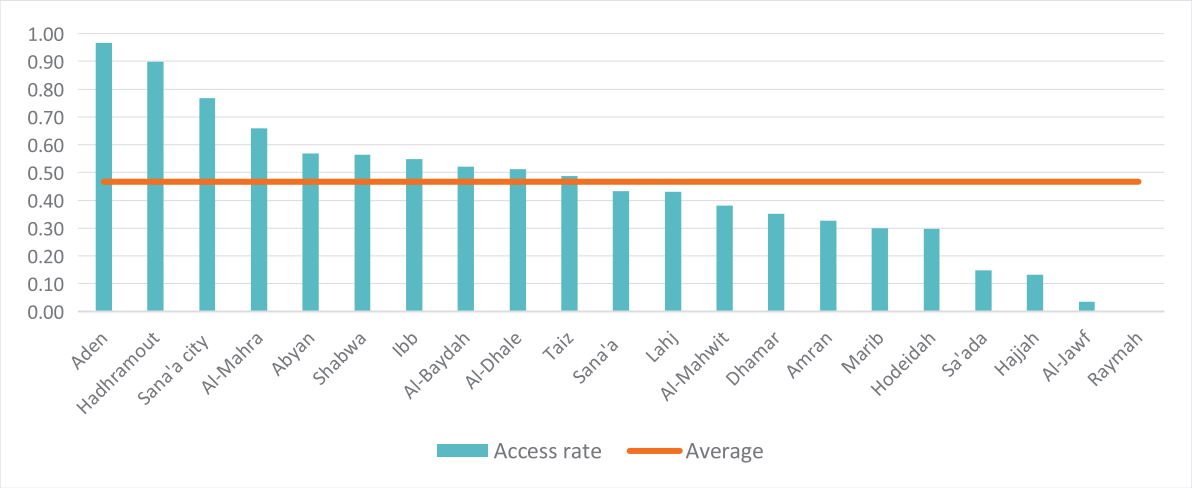
14) Rafik Missaoui, Hassen Ben Hassine, and Adel Mourtada, "Energy Efficiency Indicators in the Southern and Eastern Mediterranean Countries" (Regional Report), October 2012, p. 41, https://www.climamed.eu/wp-content/uploads/files/RS_ee-indicators-in-the-southern-and-eastern-mediterranean-countries_2012_en.pdf (accessed August 7, 2020).

15) Ali M. Al-Ashwal, "Energy Efficiency and Conservation Indicators in Yemen," SpringerOpen, April 1, 2016, p. 5, https://link.springer.com/content/pdf/10.1186/s40984-016-0016-0.pdf (accessed August 7, 2020).

16) Ali et al., "Policy Note: Prospects of Solar Energy in Yemen," p. 4.

17) EnergySolve International (Pvt) Ltd., "Yemen: Energy Efficiency Institutional Framework & 3 Year DSM/EE Action Plan," 2009, http://documents.worldbank.org/curated/en/637361468181746454/pdf/705820ESW0P1140t000Final000March030.pdf (accessed August 7, 2020).

Figure 8: Electrification rates in the governorates, 2014



Source: PEC, written communication (data of 2014).

Although around 75 percent of the Yemeni people live in rural areas, only 23 percent of the rural population had access to electricity in 2014.[18] Additionally, the availability, reliability and quality of the electricity services were very poor. As all sectors (health, water, commercial and industrial as well as residential) suffered from electricity outages, most consumers had diesel or petrol generators as backup. Almost all the large industries were not connected to the national grid and relied on their own power stations.[19] It goes without saying that energy is the mainstay of any economic activity, as well as the enabler for access to all basic services. Despite its relevance for overall development, the electricity sector did not see significant improvement in the electricity coverage over the years preceding the war.

2.3 | Institutional Framework

The electricity sector is officially under the MoEE, which is responsible for setting policy and strategic plans, granting licenses and issuing the relevant decisions, with the exception of setting the tariff. The PEC was the sole electricity supplier and managed the generation, transmission and distribution of subsectors, as well as the collection of electricity

18) Ali et al., "Policy Note: Prospects of Solar Energy in Yemen," p. 4.

19) Al-Ashwal, "Energy Efficiency and Conservation Indicators in Yemen," p. 5.

bills.[20] As per the Electricity Law No. 1 of 2009, the General Authority for Rural Electrification was mainly responsible for the planning and implementation of activities, which aimed to electrify specific off-grid rural areas located outside the main and secondary cities, through development and improvement of the electricity services provision owned and operated by authorized local people.[21]

Also, as per the same law, a temporary regulatory board was created to regulate the electricity activities: setting the tariffs and monitoring compliance with sector regulations; issuing completion rules; encouraging the local and foreign investment; and establishing an independent regulatory authority.[22] Although this regulatory board was intended only for a transitional phase of four years, an independent regulatory authority was not created and the temporary board continued to operate until the beginning of the current war.[23]

The PEC was designed to have financial and administrative independence and to be responsible for managing the electricity sector activities. The electricity sector, however, did not operate with a commercial orientation, and therefore relied on financial allocations provided by the government to implement any needed investment, as well as operational costs not met by incoming revenues.

Regarding decision-making, several government entities engaged in sector-related activities. Prior to the war, the Supreme Council for Energy had several responsibilities, including reviewing and setting the strategies and policies for the electricity sector and finding solutions for the energy deficit and alternatives for the purchased energy. This council, headed by the prime minister, consisted of the Minister of Electricity and Energy, Minister of Planning and International Cooperation, Minister of Finance, Minister of Oil and Mineral Resources and the Cabinet Secretary. The electricity tariff, as per the Electricity Law No. 1 of 2009, must be issued by the prime minister after approval of the council of ministers. In addition, local authorities also worked with the electricity sector regional offices to plan and implement some projects. Concerning fuel, the Yemen Oil Products Distribution Company (YOPDC) was the main supplier, providing the PEC power

20) Sufian, Can Öğütçü, and Matteo Barra, "Energy Investment and Business Climate Report for Observer Countries: The Republic of Yemen," Energy Charter Secretariat, November 2016, p. 12, https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/Yemen_Investment_Report.pdf (accessed August 7, 2020).

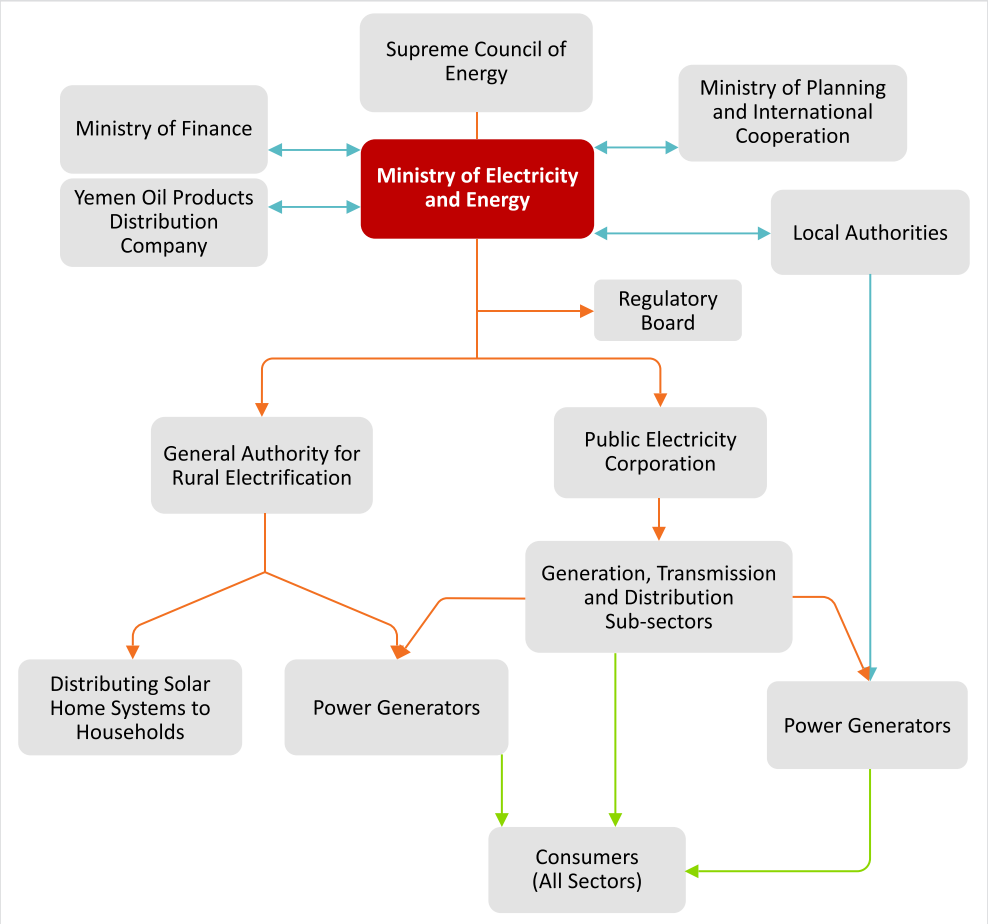
21) Ministry of Legal Affairs, "Electricity Law No. 1 of 2009," March 8, 2009, https://moee-ye.com/site-ar/392/ (accessed August 7, 2020).

22) Ibid.

23) Sufian et al., "Energy Investment and Business Climate Report," p. 12.

plants with the needed fuel at a subsidized price, in coordination with the Ministry of Finance. Additionally, the Ministry of Planning and International Corporation also coordinated with the electricity sector regarding sector plans and donor-financed projects. Figure 9 outlines the interrelations among the entities involved in the electricity sector before the war.

Figure 9: Interrelations among the key national stakeholders



2.4 | Legal Framework

In 2009, Electricity Law No. 1 was issued to better manage the electricity sector though several measures, including boosting local and foreign private sector investment in generation and distribution subsectors; encouraging the use of renewable energy resources; ensuring the competition in electricity generation; and introducing the wholesale and retail market. The law aimed to create the following entities:[24]

24) "Electricity Law No. 1 of 2009."

Electricity Sector Regulatory Board: To act as a regulatory body for electricity sector activities, its role includes setting the tariff and disseminating the necessary instructions for using the transmission system, setting criteria to promote private sector investments.

General Authority of Rural Electrification (GARE): To be a financial and administrative independent entity under the electricity and energy minister's supervision. The main mandate of this authority was to fulfil the national plan of rural electrification through various actions, including planning activities and cooperating with electricity distributes/providers.

Moreover, the law also stipulated to unbundle the PEC into generation, transmission and distribution components:

- Public Corporation for Electricity Generation
- Public Corporation for Electricity Transmission
- Public Corporation for Electricity Distribution

Although Electricity Law No. 1 of 2009 sought to better restructure and enhance the governance of the electricity sector, several important provisions have not been enforced. For example, an independent regulator was not established to control the sector's activities; also, the electricity sub-sectors remained bundled (e.g., vertically integrated).

In addition to Electricity Law No. 1 of 2009, the PEC and GARE were governed by the Presidential Decree No. 87 of 1995 for Establishing the Public Electricity Corporation and the Presidential Decree No. 76 of 2009 for Establishing the General Authority of Rural Electrification.

2.5 | Private Sector Participation and Investment Opportunities

Private investment in the electricity sector was mainly limited to electricity generation. Starting in 2006, the private sector provided a significant share of the overall electricity generation, based on short-term contracts for purchasing electricity from private suppliers.[25] In general, private sector participation functioned to back the PEC generation if there was any deficit.

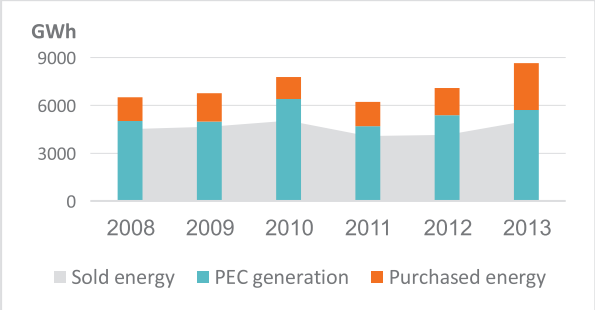
Normally, the PEC contracts the owners of generators, usually on an annual basis, and buys each kWh produced from their generators. It also

25) World Bank, "Republic of Yemen: Restoring and Expanding Energy Access," p. 3.

supplies these private producers with the fuel needed for electricity generation. Although supplying the fuel to the private producers minimizes the risks to the investors, it also puts a considerable financial burden on the government budget because of the large fuel subsidies.

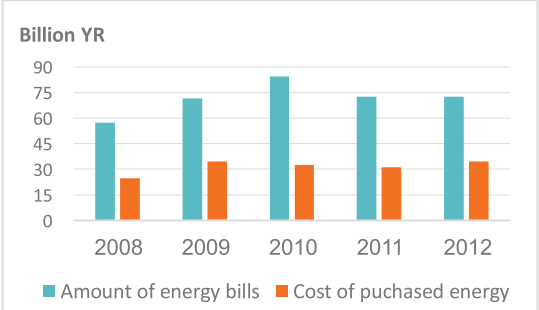
Over the last ten years, the outlay to purchase electrical energy was the largest share of operational costs in the electricity sector amid high electricity losses and low bill collection rate. Figure 10 depicts the pre-war share of purchased electricity in the generation sector in comparison to the PEC's electricity generation and sold electricity, while Figure 11 shows the share of purchased electricity cost and the revenues of the sold electricity.

Figure 10: Purchased energy vs. PEC generation vs. sold electricity 13–2008



Source: PEC, written communication (data of 2008-13).

Figure 11: Share of purchased energy cost, 12–2008



Source: PEC, 2012 Annual Report.

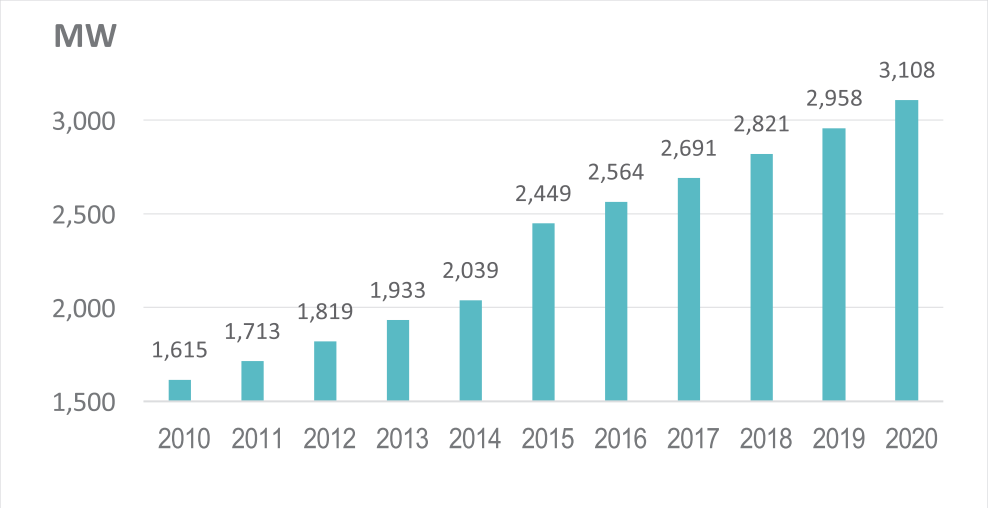
From 2008 to 2013, the amount of electricity sold by the PEC was far below its generation. Thus, the contribution of purchased electrical energy added no real value, as it mainly compensated the PEC against electricity losses, especially in the areas connected to the national grid. It is evident that the priorities should be to return some investment to reduce the technical and non-technical electricity losses to acceptable levels by adopting energy-efficiency measures in the electricity subsectors.

Before the war, when electricity supply was available to some extent, there were vast investment opportunities in electricity generation to satisfy the considerable growing demand, from both traditional and renewable sources. According to a demand forecast conducted in 2009 by the World Bank, for the period 2010 to 2020, the needed capacity in 2020 was predicted to be almost three times the pre-war actual capacity. Figure 12 shows the electricity demand forecast.

Despite the large potential for private sector participation, there remains an urgent need to establish an attractive, competitive and

enabling investment environment. According to the interviews conducted for this paper, prior to the war, the government was working to involve the private sector in public-private partnership projects and drafting a law to this end. However, the law was not approved secondary to the ensuing political turmoil.

Figure 12: Electricity demand forecast



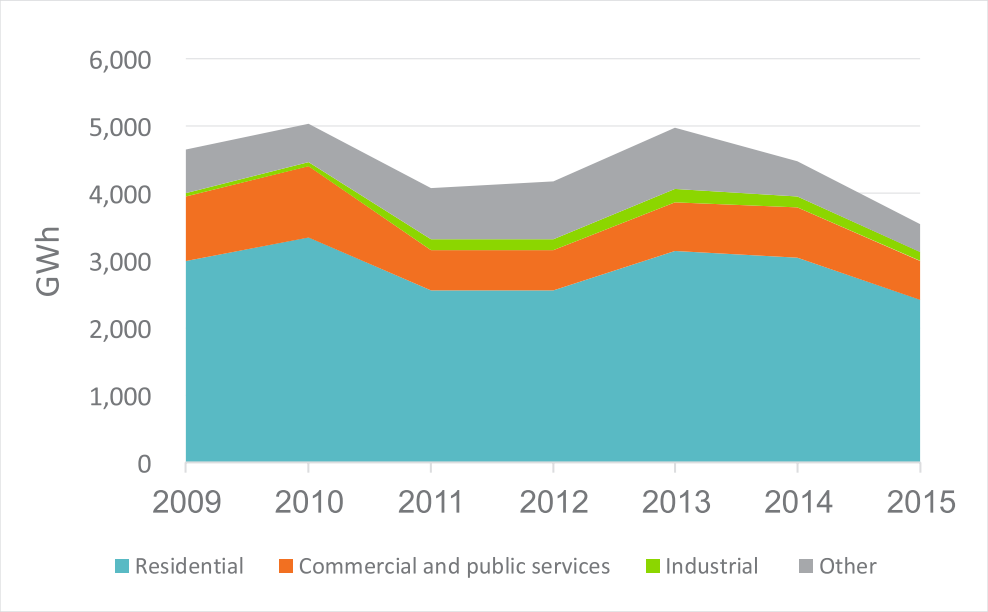
Source: Towfick Sufian, "Post Conflict Reconstruction Strategy Study for the Electricity and Energy Sector of Yemen," 2019, p. 22, https://www.energycharter.org/fileadmin/DocumentsMedia/Occasional/2019-Yemen_paper_final.pdf (accessed August 7, 2020).

2.6 | Residential, Commercial and Industrial Consumption

Despite the low per capita consumption in Yemen, the residential sector consumed most of the electricity generated by the PEC power plants, as well as the purchased electricity. Residential consumption for the period of 2009 to 2015 was around 65 percent, followed by the commercial and public sector (17 percent), other (15 percent) and the industrial sector (3 percent).[26] Because of the limited and unreliable nature of electricity services provision, most industries, commercial shops and service facilities relied on their own diesel generators as main or backup systems. Figure 13 illustrates the electricity consumption per sector from 2009 to 2015.

26) International Energy Agency (IEA), "Electricity final consumption by sector, Yemen 1990–2018," *World Energy Balances 2020*, https://www.iea.org/data-and-statistics?country=YEMEN&fuel=Energy%20consumption&indicator=ElecConsBySector (accessed August 7, 2020).

Figure 13: Electricity consumption per sector, 2009–15

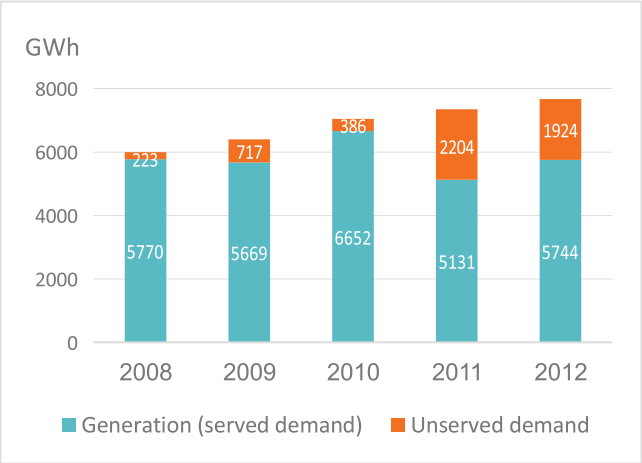


Source: IEA, "Electricity final consumption by sector, Yemen 2009–2015."

2.7 | Supply vs. Demand

Although the annual energy consumption per capita was very low (less than 300 kWh) and less than 2 million subscribers were connected to the national grid as of 2012, the national grid was unable to meet the demand of the connected consumers. The energy gap has further widened over the past years, due to the inability to build new large-scale power plants and to significantly develop the generation subsector. In 2012, the electricity gap was 376 MW, with a 0.88 GW available capacity—it was estimated in 2009 that the overall demand to reach 3.1 GW in 2020. This very conservative forecast did not consider the potential demand by large-scale consumers of the industrial sector or the needs of a growing population. Figure 14 shows PEC generation and the unmet demand that started to increase from 2011.

Figure 14: Served demand and load shedding (unserved demand), 2008–12



Source: PEC, 2012 Annual Report.

2.8 | Electricity Tariff and Cost Recovery

The electricity tariff is considered the most important factor for any potential investor evaluating the profitability of an investment in the sector.[27] In Yemen, the pre-war electricity tariff was heavily subsidized and far below the high cost of supply. This loss in turn placed the PEC in a weak financial situation and resulted in its inability to cover its expenditures or to invest in developing the sector.

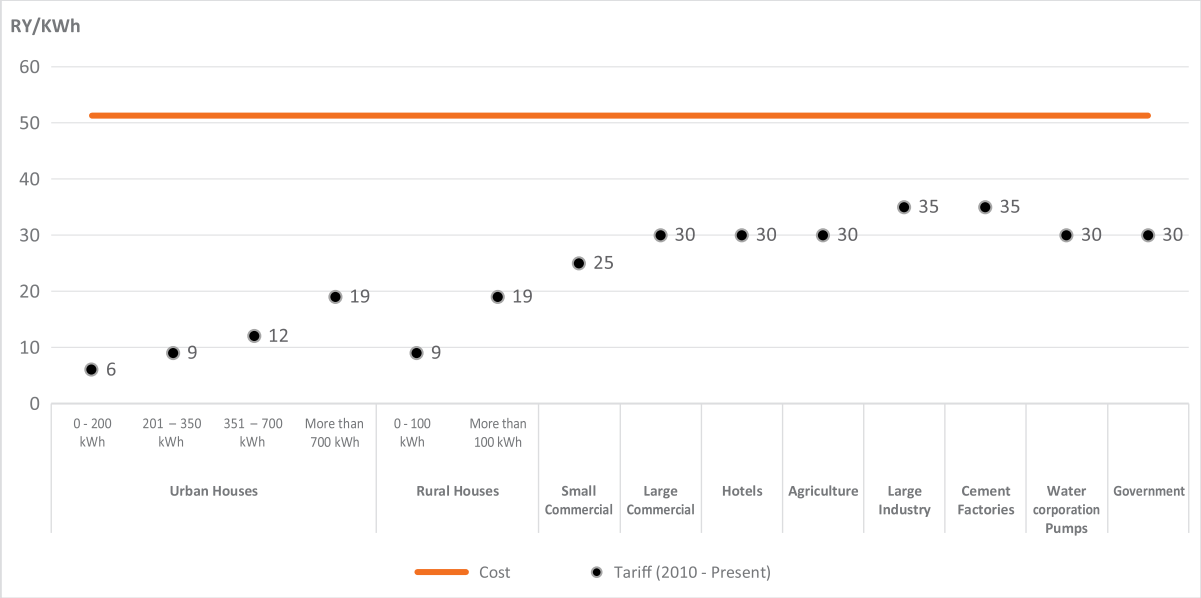
The cost of electricity varies, based on the type of fuel and the power plant used to generate the electricity. The cost of electricity produced by gas plants is the lowest, followed by thermal power plants fueled by HFO. Unsurprisingly, the remaining plants, powered by diesel, have the highest costs, varying according to the particulars of each plant (efficiency, administrative cost, etc.).

In 2014, the average cost of electricity produced by PEC power plants was YR 51.31/kWh, per the local market fuel prices, while the average price for each kWh sold was YR 17 (~USD 0.08). This means that the overall cost recovery rate was significantly low, at almost 33 percent. The YOPDC was supplying the fuel to the PEC with a special subsidy. For example, the government-subsidized price for diesel for the local market was YR 150/liter, while the PEC paid YR 40/liter, making the

27) Luay Al-Khatteeb and Harry Istepanian, "Turn a Light On: Electricity Sector Reform in Iraq," Brookings Doha Center, March 2015, p. 5, https://www.brookings.edu/wp-content/uploads/2016/06/Alkhatteeb-Istepanian-English-PDF.pdf (accessed August 7, 2020).

cost of electricity YR 30.7/kWh.[28] Figure 15 charts the electricity tariff in comparison with the average cost of electricity. The electricity tariffs for different consumers in the sectors were far below the actual cost of electricity, especially residential tariffs.

Figure 15: Electricity tariff vs. average cost of electricity



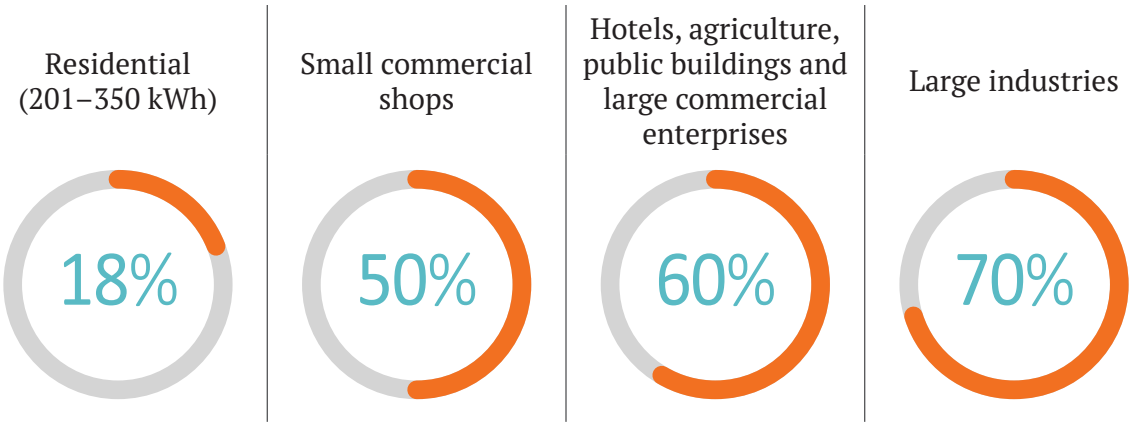
Source: Ministry of Electricity and Energy (MoEE), "Tariffs," https://moee-ye.com/site-ar/%d8%a7%d9%84%d8%aa%d8%b9%d8%b1%d9%81%d9%80%d9%80%d8%a9/ (accessed August 7, 2020).

There is a specific cost recovery rate for each sector. For example, the residential sector was the highest consumer (65 percent, see Figure 13), so most revenues come from the residential sector. However, as the subsidy for the residential tariff was very high, it remained difficult to improve the overall financial situation for the sector, especially because of the low tariff collection rate and the high level of technical and non-technical losses.

Figure 16 shows that the cost recovery rate of the average residential tariff covers a consumption range from 201 to 350 kWh. For comparison, in the lowest consumption block for the residential sector (0–200 kWh), the cost recovery rate was only 12 percent; the highest block tariff was above 700 kWh, with a cost recovery rate of 37 percent. The industrial sector has the highest cost recovery rate (70 percent), followed by the commercial sectors and then public consumption.

28) PEC, 2013.

Figure 16: Cost recovery rates for different tariffs in 2014



3 | A CLOSER LOOK AT STRATEGIC PROJECTS

3.1 | Marib I & II Gas Power Plants

A strategic part of the generation subsector are the two Marib gas power plants. These stations, the first gas-based power plants in Yemen, are aimed at reducing the electricity gap and the country's reliance on expensive and environmentally harmful diesel and HFO-fired power plants. This project consists of two phases: The first is the Marib I gas power plant, constructed by Siemens Power Group and commissioned in 2009. It is located east of Marib city, in Safer, 200 km from Sana'a. The Safer gas field, located 3 km away, feeds the power plant through a gas pipeline. The Marib I plant is based on open cycle technology and consists of three gas turbines, each with a nominal capacity of 163 MW; in summer, however, the actual capacity decreases to 113 MW because of the location's high temperature and altitude, making the annual capacity around 340 MW. A plan for expansion includes seven more turbines and conversion to a combined cycle plant by adding a heat recovery system and steam turbine generators.[29]

The second phase is also located in Safer. The construction of the second power plant, Marib II, began in 2013 with plans to start energy generation in late 2014. Due to political unrest, the project is currently suspended.[30] Marib II is to include three to five open-cycle gas turbines, with a designed plant capacity of 400 MW. This project phase includes expanding the existing transmission substation, in use by the Marib I gas power station, to also transmit the Marib II produced power to Sana'a. This second phase was commissioned by Bharat Heavy Electricals Ltd. and was to be funded by the Saudi Fund, as well as the Arab Fund.[31] Similar to the Marib I gas power plant, plans aim to increase the plant's capacity to 660 MW by converting it to combined-cycle units.

29) Abdul-Malik E. Momin et al., "Enhancement of Marib Gas Turbine Power Station Using Air Cooling Fogging System," *Journal of Science & Technology* 21/1, June 2016, pp. 62–74, https://www.researchgate.net/publication/303979685_Enhancement_of_Marib_Gas_Turbine_Power_Station_Using_Air_Cooling_Fogging_System (accessed August 7, 2020).

30) Sufian et al., "Energy Investment and Business Climate Report," p. 24.

31) Ministry of Electricity and Energy (MoEE), "Marib Phase II Gas Turbine Power Project [AR]," December 21, 2009, https://bit.ly/3fLbTpq (accessed August 7, 2020).

Adding the Marib I & II power gas plants to the power sector would play a crucial role in solving the power deficit and generating inexpensive electricity. It would also diversify the energy mix, thereby decreasing the country's reliance on expensive and environmentally harmful diesel and HFO-fired power plants, and improve the per capita share of electricity.

3.2 | Electricity Interconnection Project with Neighboring Countries

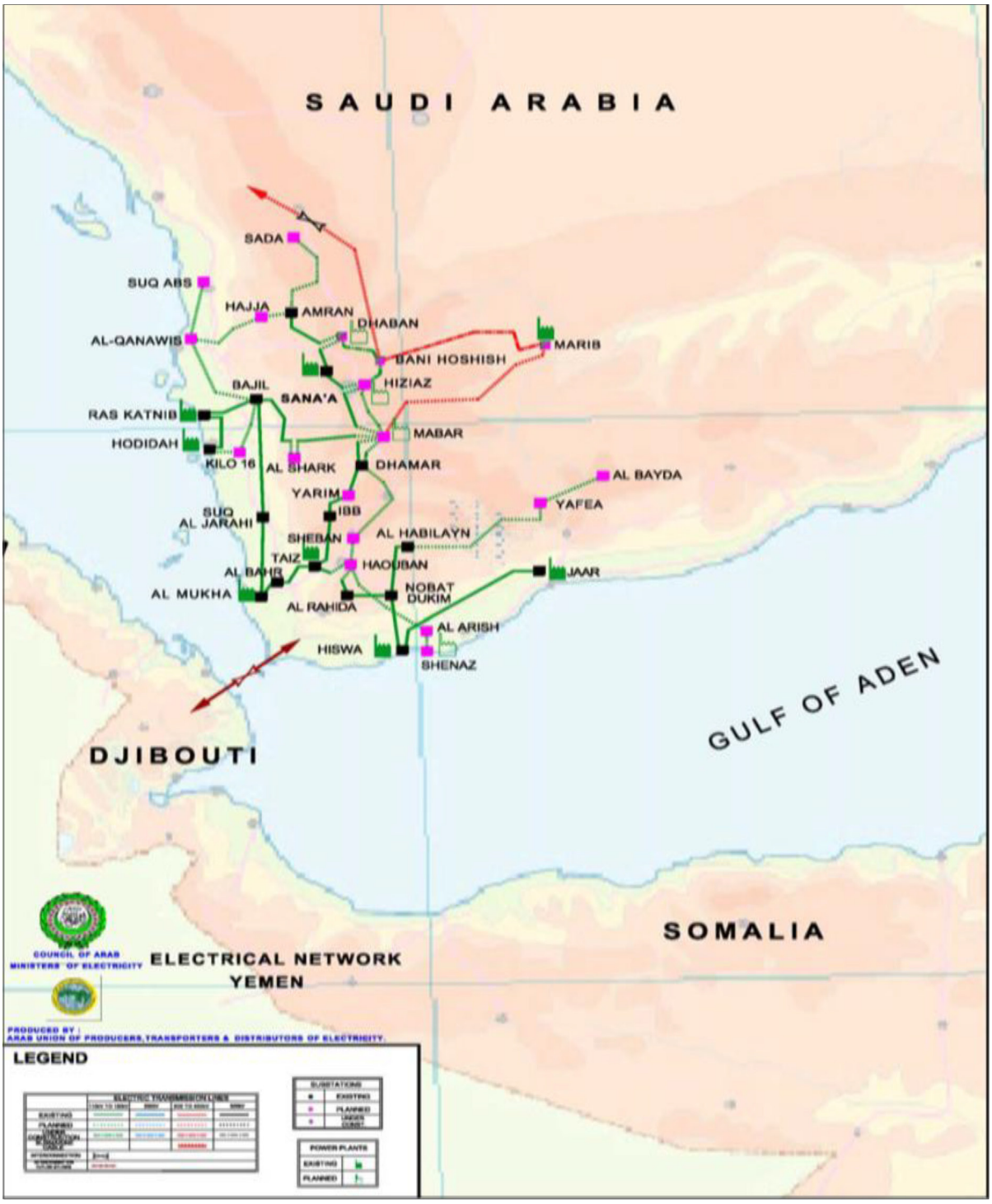
In 2007, Yemen and Saudi Arabia reached an agreement for a $400 million interconnection expansion program to allow transfers of 500 to 1000 MW between the two countries. The interconnection proposed was to reach from Bani Hoshaish to Kudmi, through a 416 km transmission line of 400 kV voltage level, with an alternating current double-circuit. This project has not yet begun because of a lack of financing.[32] A feasibility study, funded by the Arab Economic and Social Development Fund, confirmed the viability of interconnecting the electrical grids of the two countries after several requirements related to the Yemeni grid are met.[33] There is also a potential connection project with Ethiopia, via Djibouti, to purchase electricity from a hydro power plant located in southern Ethiopia (Figure 17). However, this project remains in the negotiation phase.[34]

32) Sufian et al., "Energy Investment and Business Climate Report," p. 29.

33) United Nations Economic and Social Commission for Western Asia (UNESCWA), "Annual Review of Developments in Globalization and Regional Integration in the Arab Countries, 2008" (The seventh annual review), New York: United Nations, December 22, 2008, p. 42, https://www.unescwa.org/publications/annual-review-developments-globalization-and-regional-integration-arab-countries-2008 (accessed August 7, 2020).

34) Sufian et al., "Energy Investment and Business Climate Report," p. 30.

Figure 17: Planned interconnection lines with Saudi and Ethiopia (through Djibouti)



Source: Sufian et al., "Energy Investment and Business Climate Report," p. 29.

4 | RENEWABLE ENERGY APPLICATIONS

Despite the high interest shown by the government in utilizing renewable energy technologies—especially solar and wind energy—to increase the electrification rate, progress has been slow and unsatisfactory.[35] For example, with support from several international donors and consultants, the government prepared several studies and strategies, one being the National Strategy for Renewable Energy and Energy Efficiency developed in 2009. This national strategy set ambitious targets to involve considerable renewable resources in the energy mix. The baseline scenario aims to make renewable energies 15 percent of the total generation mix by 2025 through installing:[36]

- 400 MW from wind energy
- 160 MW from geothermal power stations
- 6 MW from power stations fueled by landfill gas
- 5.5 MWp from PV, electrifying 110,000 rural households
- 200,000 solar water heaters

The spread of domestic applications for renewable energy has been modest despite the significant potential, particularly for rural households. By 2005, the total installed capacity of domestic applications did not exceed 100 kW. Furthermore, there is a limited number of PV applications in the telecommunication and television industries for signal transmission purposes. Several barriers hindered the development of renewable energy sources, including high upfront cost and lack of access to finance; high subsidies for conventional electricity sources; lack of awareness among the public; lack of an institutional, regulatory and legal framework; and lack of infrastructure and trust in solar energy technologies, among others.[37]

Prior to the war, the government, with the support of several lenders, started taking important steps toward implementing the country's first wind farm. The Arab Fund for Economic and Social Development,

35) World Bank, "Project Information Document (PID): Appraisal Stage," p. 2.

36) Ministry of Electricity and Energy (MoEE), General Department for Renewable Energy, "National Strategy for Renewable Energy and Energy Efficiency, June 2009, p. 3, https://taqaway.net/sites/default/files/uploads/documents/doc128.pdf (accessed August 7, 2020).

37) Ali M. Al-Ashwal, "All Renewable Energy Applications in Yemen are Best Practice," *Science and Technology Vision* 1, Islamic World Educational, Scientific and Cultural Organization (ICESCO), May 2005, pp. 45–50, https://silo.tips/download/all-renewable-energy-applications-in-yemen-are-best-practice (accessed August 7, 2020).

in partnership with the World Bank and the Organization of the Petroleum Exporting Countries (OPEC) Fund, approved a loan in 2012 for the construction of a wind farm in Al-Mokha, with a projected capacity of 60 MW and connection to the national grid.[38] However, the project has been suspended because of the political unrest.

4.1 | Beyond Conventional Energy Generation

Most countries worldwide have been creating attractive markets for renewable energy investments by setting official targets and attractive tariffs, as well as adopting policies and mechanisms such as feed-in-tariffs, net metering and auctions.[39] Yemen is still in the initial planning stages, although it possesses significant untapped renewable energy resources that could contribute to solving the power and energy deficit. Wind, solar and geothermal energies have the highest potential for large-scale project investment.

Table 4: Potential investment in renewable energy

Resources	Technical Potentials
Wind	15,237 MW
Solar	53.2 MW solar home systems; 1,824 MW (concentrated solar power); 332.7 MW (solar water heating)
Geothermal	125-250 MW (Dhamar region); 28,500 MW (other regions)
Small hydropower	11-30 MW
Biomass	7.53 MW (landfill gas); 1.04 MW (sewage sludge)

Source: Lahmeyer International GmbH, "Renewable Energy Strategy and Action Plan – Task 1: Renewable Energy Resource Assessment – Draft Report," August 19, 2006, https://bit.ly/3eH7TF0 (accessed August 7, 2020).

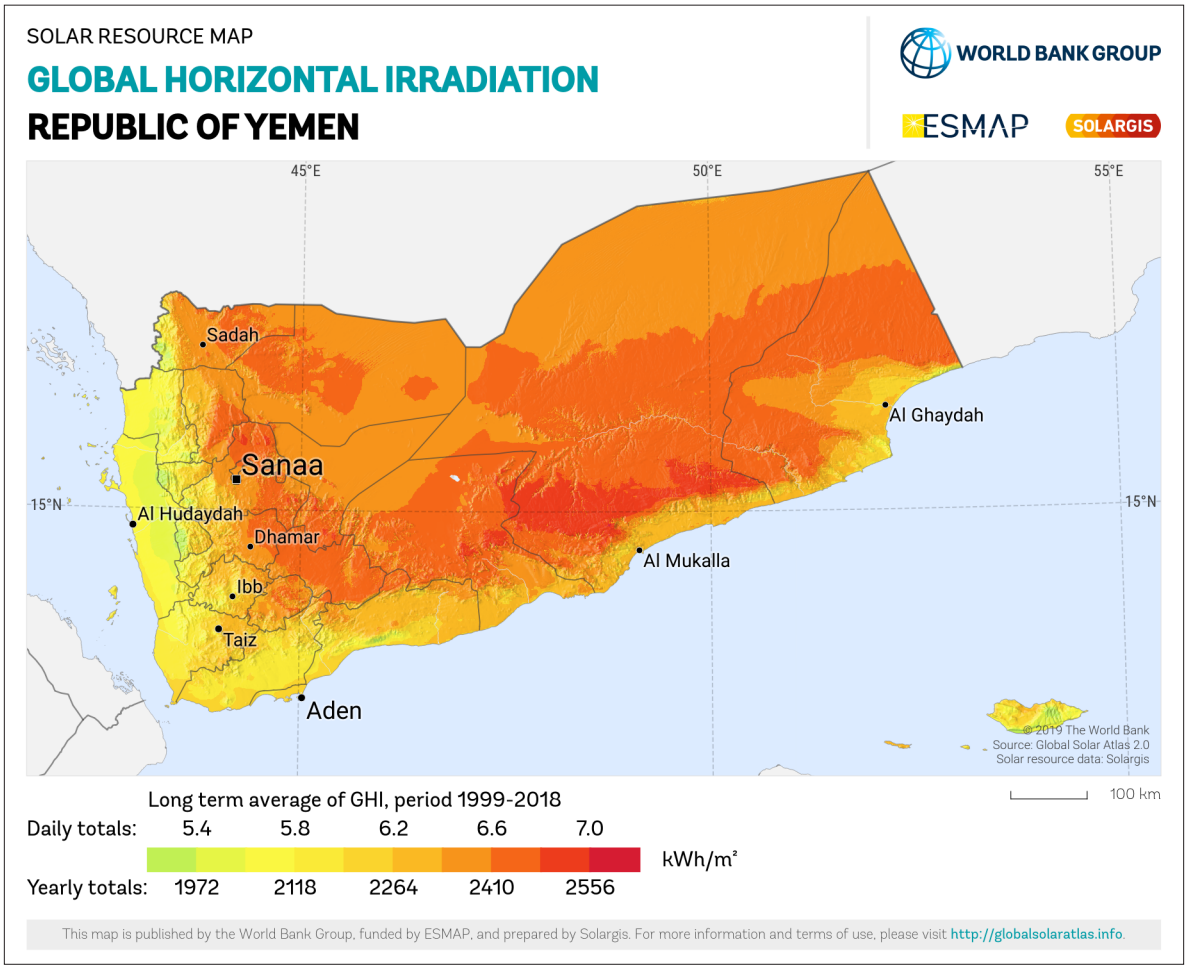
Solar

Yemen is endowed with solar energy radiation ranges between 5.2–6.8 kWh/m2/day. The annual average of daily sunshine falls between 7.3 to 9.1 hours/day. There is vast potential for on-grid and off-grid solar energy applications, which could help bridge the energy gap, especially in rural areas. Both PV and concentrated solar power have the potential for deployment in Yemen. Figure 18 illustrates the solar energy resources in Yemen.

38) Arab Fund for Economic and Social Development (AFESD), "Republic of Yemen: Construction of a 60 MW Wind Farm in the Al-Mokha Area" (PID No. 2133, Loan No. 581), April 17, 2012, http://www.arabfund.org/Default.aspx?pageId=359&pId=2133 (accessed August 7, 2020).

39) International Renewable Energy Agency (IRENA), "Renewable Energy in the Arab Region: Overview of Developments," Abu Dhabi: 2016, p. 5, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Arab_Region_Overview_2016.pdf (accessed August 7, 2020).

Figure 18: Solar resource map of Yemen



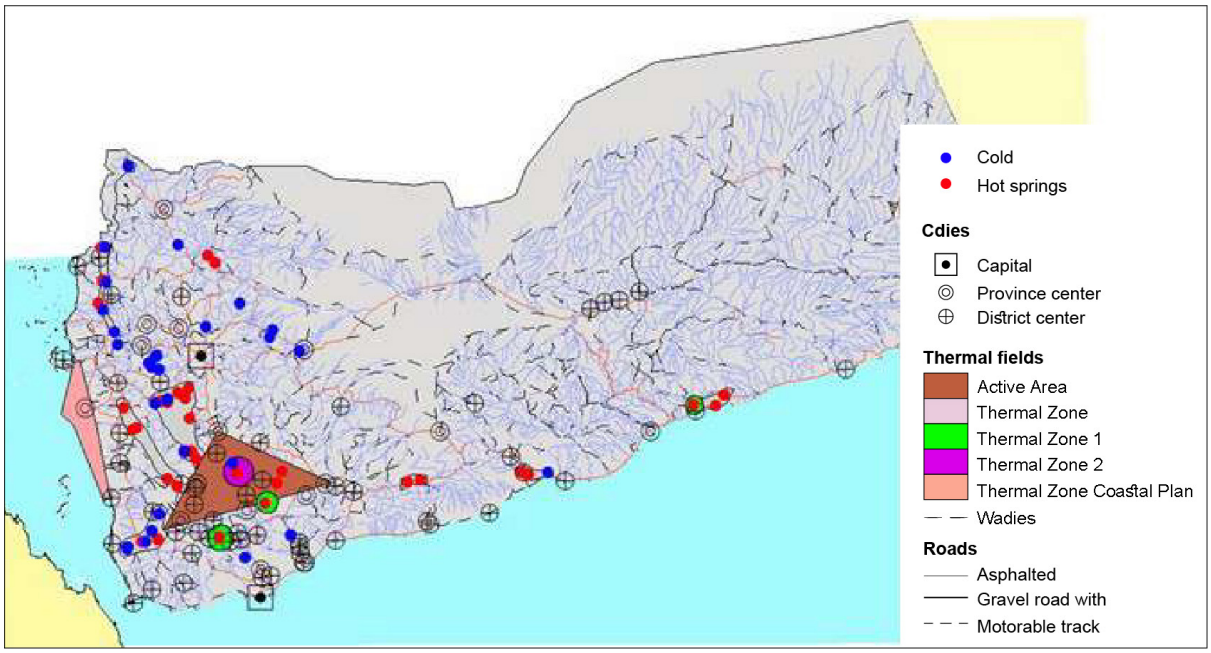
Source: World Bank, "Republic of Yemen: Global Horizontal Irradiation," Global Solar Atlas (Version 2.0), October 23, 2019, https://globalsolaratlas.info/download/yemen (accessed August 7, 2020).

Geothermal

Yemen is located near three tectonic boundaries (the Gulf of Aden, the Red Sea and the Eastern African Rift System) and is considered one of the most active areas worldwide. These three tectonic plates meet in a triple intersection, which creates a high geothermal gradient. In the Red Sea region, the geothermal gradients range between 40°C/km and 77°C/km, while the worldwide geothermal gradient average is only around 30°C/km. There are many geothermal fields or hot springs in Yemen, located in a triangle surrounded by Sana'a from the north, Taiz from the south and Damt (Al-Dhale) from the southeast. Springs are found in Lahj, Abyan and Shabwa, at elevations between 300 and 1300 meters; and from north of Hajjah to southwest of Taiz, at elevations ranging from 200 to 400 meters. Also, near the coast in the Hadhramout,

there are springs and thermal discharges at locations less than 1,000 meters above sea level. The Dhamar field has the highest potential for power generation, as it is situated in a young volcanic field, has steam vents (fumaroles) and is close to the national transmission grid.[40] Figure 19 shows prospective geothermal fields.

Figure 19: Prospective geothermal fields in Yemen



Source: Lahmeyer, "Renewable Energy Strategy and Action Plan".

Wind Energy

Yemen borders both the Red Sea and the Arabian Sea, and has a coastal strip of over 2500 km. The annual coastal wind speed average exceeds 8 meters/second; thus, there is considerable potential for investing in both onshore and offshore wind projects. The region around Al-Mokha is considered one of the best locations for wind farms given the high wind speeds found there.[41] In 2012, the Arab Fund for Economic and Social Development, in partnership with the World Bank and the OPEC Fund, approved a loan to construct a wind farm in Al-Mokha with a capacity of 60 MW. This project, its original completion date being 2014, has been suspended because of the political unrest.[42] Figure

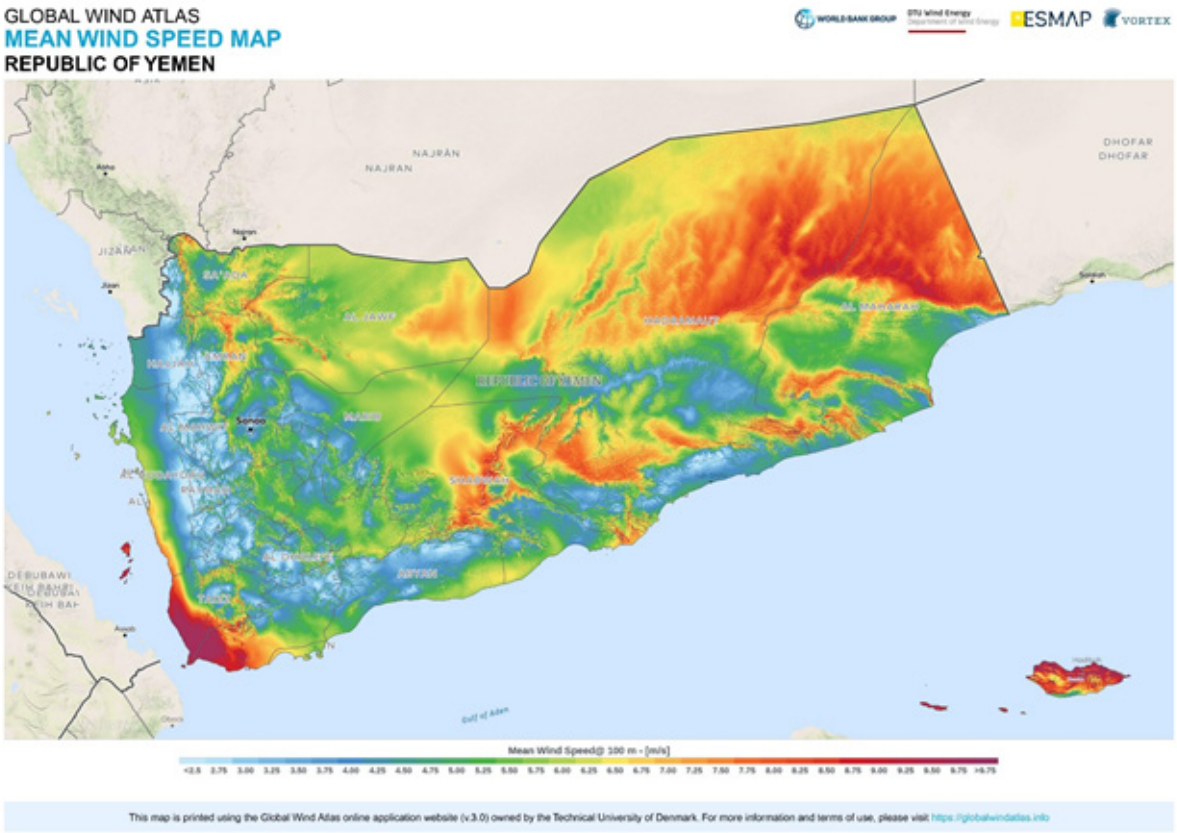
40) Lahmeyer, "Renewable Energy Strategy and Action Plan," pp. 38–40.

41) Abdulkareem Qasem Saleh Qasem, "Applications of Renewable Energy in Yemen," *Journal of Fundamentals of Renewable Energy and Applications* 8/1, February 23, 2018, https://www.longdom.org/open-access/applications-of-renewable-energy-in-yemen-2090-4541-1000254.pdf (accessed August 7, 2020).

42) AFESD, "Republic of Yemen: Construction of a 60 MW Wind Farm in the Al-Mokha Area."

20 shows the wind energy resources in Yemen. The islands, as well as the area located near Bab Al-Mandab (including Al-Mokha), have the greatest wind energy resources.

Figure 20: Mean wind speed map of Yemen



Source: World Bank, "Republic of Yemen: Mean Wind Speed Map," Global Wind Atlas (Version 3.0), 2020, https://globalwindatlas.info/area/Republic%20of%20Yemen (accessed August 7, 2020).

5 | IMPACTS OF THE ONGOING WAR

The public electricity sector has been substantially affected by the ongoing armed conflict and has suffered considerable physical and non-physical damages. The national grid, connecting 13 cities, collapsed, leaving the Yemeni people in the dark, and depriving them of adequate basic services (water supply, health care, etc.). The public power plants are currently not operating at full capacity because of technical issues or fuel shortages. Only the immediate areas surrounding the plants are being supplied, leaving many governorates that are reliant on the national grid without any public electricity supply whatsoever.

In 2016, about 90 percent of the population did not have access to public electricity.[43] As of the end of 2019, and according to a phone survey that was conducted by the World Bank through a Yemeni consulting firm, on a national sample size of 1,000 households, around 12 percent of the population relied mainly on public electricity for their electrical needs.[44] In the health sector, in 2020, only 50 percent of health facilities are functioning, with available services negatively affected by power outages.[45]

A night-time light assessment, a method used to track human activities in conflict countries such as Iraq and Syria, was conducted in Yemen from 2012 to 2017. The idea of this concept is to process satellite images taken at night to evaluate the intensity of the night-time light. The assessment showed that Yemen's total night-time light (TNL) significantly dropped from January 2015 to June 2017, in conjunction with the airstrikes that targeted many areas. People displaced from conflict areas and intentional darkening during air raids may have contributed to these figures, but much of the light decrease was obviously a result of the collapse of the national grid and generator fuel shortages.

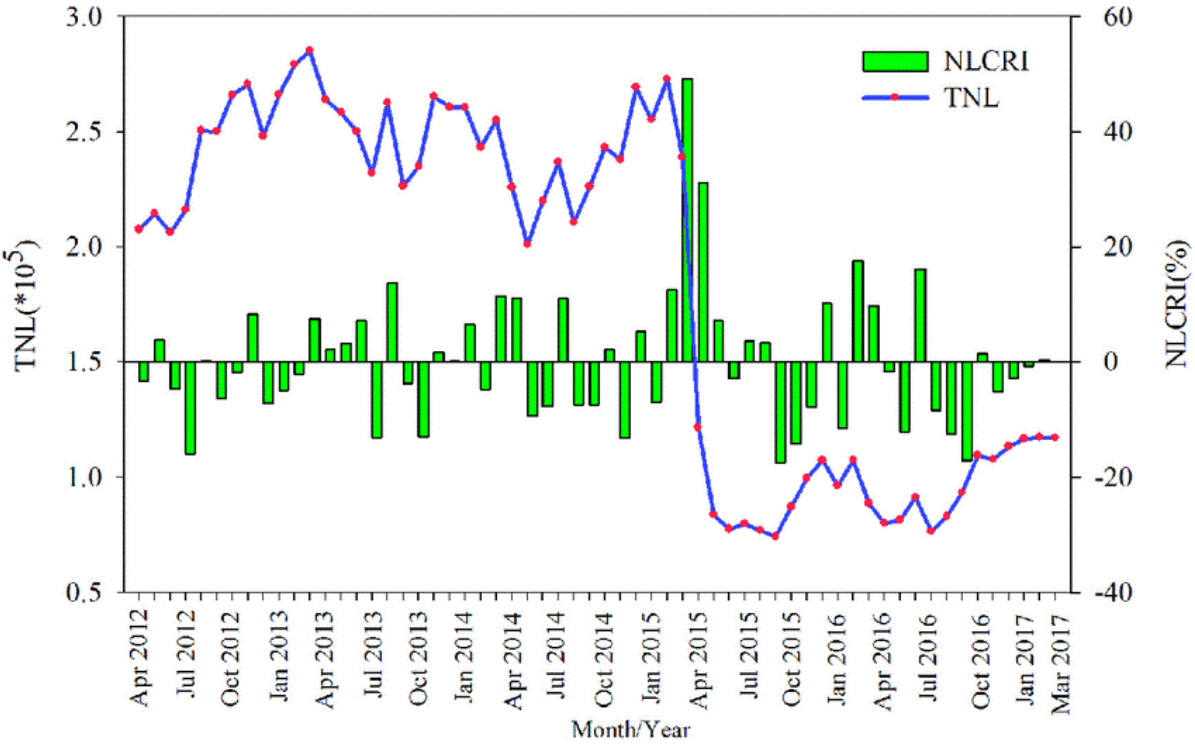
Figure 21 illustrates the fluctuation in TNL from 2015 to 2017, as well as the night-time light change rate index (NLCRI), which represents the changes/growth rate between two defined periods.

43) Ministry of Planning and International Cooperation (MoPIC), "Overall Socioeconomic Developments," *Yemen Socio-Economic Update* 20, November 2016, https://reliefweb.int/sites/reliefweb.int/files/resources/yseu20_english_v8_final.pdf (accessed August 7, 2020).

44) World Bank, "Yemen Dynamic Needs Assessment, Phase 3," 2020, p.98., http://documents1.worldbank.org/curated/en/490981607970828629/pdf/Yemen-Dynamic-Needs-Assessment-Phase-3-2020-Update.pdf (accessed January 22, 2020).

45) UN Office for the Coordination of Humanitarian Affairs (OCHA) Yemen, "Yemen Humanitarian Update" (issue 3), March 2020, https://reliefweb.int/report/yemen/yemen-humanitarian-update-issue-3-march-2020-enar (accessed August 7, 2020).

Figure 21: Night-time light intensity in Yemen, 2012 to 2017



Source: Wei Jiang et al., "Ongoing Conflict Makes Yemen Dark: From the Perspective of Nighttime Light," Remote Sensing, August 3, 2017, https://www.researchgate.net/publication/318959666_Ongoing_Conflict_Makes_Yemen_Dark_From_the_Perspective_of_Nighttime_Light (accessed August 7, 2020).

5.1 | Status of the Electricity Sector's Infrastructure

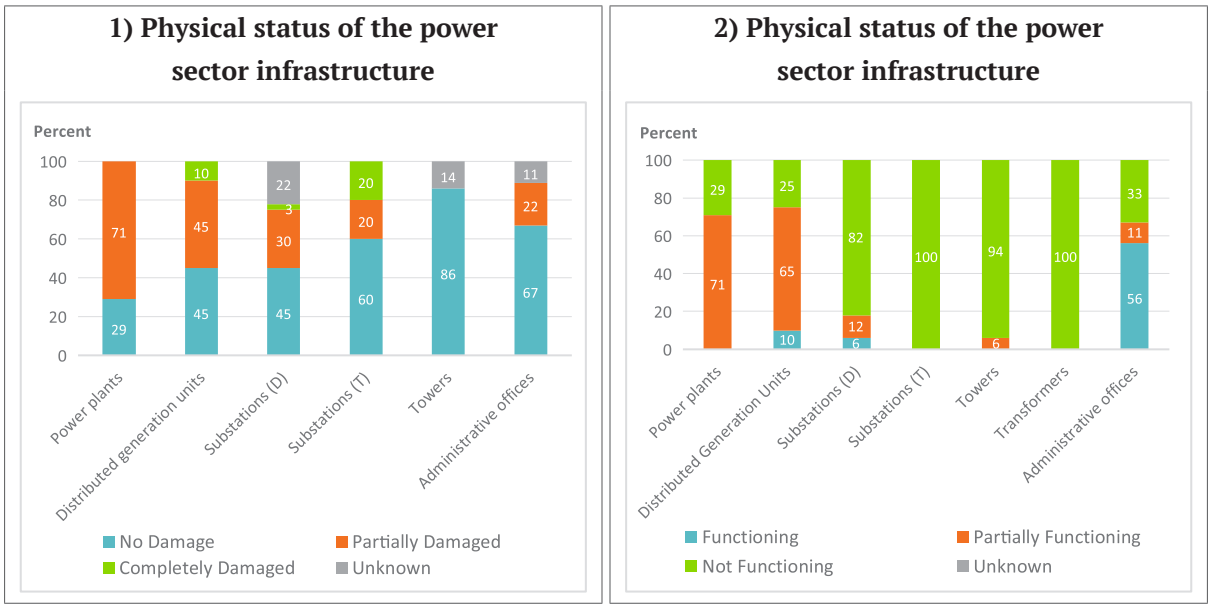
In 2019, a satellite imagery assessment indicated that about 55 percent of transmission lines and power plants were affected by the war, with 8 percent completely destroyed.[46] An updated damage assessment conducted by the World Bank covered 16 cities (Al-Dhale, Aden, Al-Hazm, Amran, Bayhan, Dhamar, Hodeidah, Lahj, Lodar, Marib, Al-Mokha, Rada'a, Sa'ada, Sana'a, Taiz, and Al-Khoka) and focused on the seven largest power plants (including thermal power plants), 20 generators, 33 distribution substations, five transmission substations, 259 towers and nine administration offices, located in the plants.[47] This assessment revealed that 71 percent of the power plants and 45 percent of the distributed generation units were partially damaged, while 29

46) Ghassan Khaled Ismail Al-Akwaa, "Measuring Electricity Access Amidst Active Conflict: Lessons from Yemen," May 7, 2019, World Bank Blog, https://blogs.worldbank.org/energy/measuring-electricity-access-amidst-active-conflict-lessons-yemen (accessed August 7, 2020).

47) Al-Khokha was one of the assessed cities but it was excluded as a result of inadequate data.

percent of the power plants and 45 of the percent distributed generation units were untouched (10 percent of the distributed generation units were fully damaged). Of the distribution substations (D), 45 percent were partially damaged, while 3 percent were fully damaged and no information was available for 22 percent of the substations (D); the transmission substations (T) sustained 20 percent partial damage and also 20 percent complete damage. Damage to transmission towers was relatively low. As for administrative offices, 22 percent were partially damaged and 67 percent were untouched. Regarding the functional status of the electricity infrastructure, it was relatively low compared to the physical status. For example, 29 percent of the power plants and 25 percent of the distributed generation units were not functioning, while the remaining were partially functioning, except 10 percent of distributed generation units that were fully functioning. In regard to the transmission and distribution substations and the towers and transformers, the majority of the assessed assets were not functioning at all.[48] Figure 22 provides more details of the damages and functional status of the power sector infrastructure in the assessed cities.

Figure 22: Physical and functional status of the power sector infrastructure

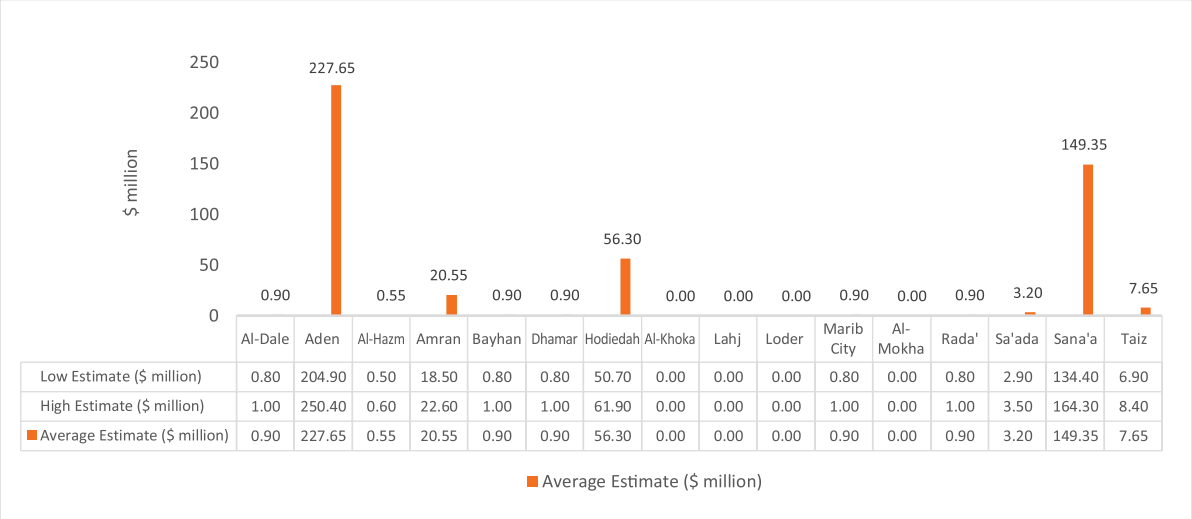


Source: World Bank, "Yemen Dynamic Needs Assessment, Phase 3," 2020, p.9 8.

48) World Bank, "Yemen Dynamic Needs Assessment, Phase 3," 2020, p.98., http://documents1.worldbank.org/curated/en/490981607970828629/pdf/Yemen-Dynamic-Needs-Assessment-Phase-3-2020-Update.pdf (accessed January 22, 2020).

In the assessed cities alone, the estimated cost of the damages was $422–$516 million. The assessment revealed that the highest costs of damage were in Aden, Sana'a and Hodeidah. Figure 23 shows World Bank estimates of the damages in the assessed cities.[49] Appendix 2 includes the physical and functional status of the electricity sector infrastructure in those cities (except towers).

Figure 23: Damage costs as per World Bank estimates



	Al-Dale	Aden	Al-Hazm	Amran	Bayhan	Dhamar	Hodiedah	Al-Khoka	Lahj	Loder	Marib City	Al-Mokha	Rada'	Sa'ada	Sana'a	Taiz
Low Estimate ($ million)	0.80	204.90	0.50	18.50	0.80	0.80	50.70	0.00	0.00	0.00	0.80	0.00	0.80	2.90	134.40	6.90
High Estimate ($ million)	1.00	250.40	0.60	22.60	1.00	1.00	61.90	0.00	0.00	0.00	1.00	0.00	1.00	3.50	164.30	8.40
Average Estimate ($ million)	0.90	227.65	0.55	20.55	0.90	0.90	56.30	0.00	0.00	0.00	0.90	0.00	0.90	3.20	149.35	7.65

Source: World Bank, "Yemen Dynamic Needs Assessment, Phase 3," 2020, p.1 05.

In addition, the institutions in the electricity sector have been fragmented, mainly into two separate ministries affiliated with the two main conflict factions, based in Aden and Sana'a. Because of the poor institutional capacity of the PEC and the MoEE, which was inherent in the sector even before the war, the sector collapsed in the early stages of the conflict.[50] As the pre-war electricity sector was neither commercial nor fully corporatized, and in an overall weak financial position, it quickly became bankrupt once the conflict began. The non-payment of the salaries of government employees, including the PEC and ministry staff, during the initial years of the war also aggravated the situation and led to the further deterioration of electricity services provision. To this day, the electricity sector staff in the Ansar Allah-controlled areas are not paid their full salaries; instead, they receive a half salary, more or less, every two months or so. The situation of the electricity sector staff in the government-controlled areas is somewhat better, as they currently receive their salaries on a regular basis.

49) Ibid.

50) World Bank, "Republic of Yemen: Restoring and Expanding Energy Access," p. 7.

5.2 | Electricity Supply

There is a divergence between the areas controlled by the internationally recognized government and those controlled by Ansar Allah in terms of electricity supply. In the internationally recognized government areas, supply has remained largely the same; meaning, the government-led supply and electricity tariff remains subsidized, with significant reliance on purchased electricity from private producers. For the Ansar Allah-controlled areas, electricity generation has changed to a private-led supply. Before discussing the characteristics of the electricity supply in both regions, it is worth highlighting the current operational status of the key power plants that were previously connected to the grid but are now either non-functional or generating only limited electricity to serve local demand. Table 5 shows the installed capacity of the power plants and compares the available capacity in 2013 with the maximum loads that are available in 2020. The maximum peak of these power plants has only reached 309 MW in 2020.

Table 5: Installed capacities and maximal load of the power plants

Plant Name/Location	Installed Capacity	Available Capacity in 2013	Max. Peak (MW) in 2020
Marib	340*	411	80
Ras Katheb	150	105	40
Al-Mokha	160	126.5	0
Heswa	185	100	88
Mansoura1	64	20	0
Mansoura 2	70	17	18.2
Khor Maksar	14	14	0
Thahban 1	21	10.4	7
Thahban 2	25	8.3	
Sana'a	12.5	6.7	10
Heziaz 1	30	26.1	52
Heziaz 2	70	50	
Heziaz 3	30	30	
Osaifera	15	13	0
Alhali	20	18	8
Alkornish	7.5	3	0
Ga'ar	10	3.2	NA
Total	**1,224**	**962.2**	**303.2**

Source: PEC, Sana'a and Aden, 2020.

Most of the power plants have partially restored their capacity, now equaling 32 percent of the total available capacity in 2013 (303 MW out of 960 MW). After the collapse of the national grid, the restored power plants supplied electricity for local demand in their immediate location, along with the power plants that were isolated from the grid as well as those installed recently by donors. However, given the unsustainable fuel supply and ongoing poor maintenance, the reliability and availability of electricity supply remain significantly low.

Government-Controlled Areas

In government-controlled areas, the MoEE, through the PEC, is the main supplier for electricity. A considerable number of the power plants in the government-controlled areas have resumed their generation capacities, but only supply for local consumption. Despite this, most of the governorates have significantly increased their reliance on purchased electricity. In early 2021, the share of purchased electrical energy was very high in Aden, Hadhramout, Lahj, Abyan and Shabwa. Table 6 outlines the available capacity of the public and the independent producers in January 2021. Despite the high capacity of the purchased electricity, a supply gap remains, especially in Aden and Hadhramout.

Table 6: Operating capacities in the key government-controlled areas, as of 2021

Governorate	Number of Power Plants			Available Capacity (MW)			Max. Demand (MW)	Gap (MW)
	Public	Purchased	Total	Public	Purchased	Total Capacity	in 2019	
Aden	11	4	15	88	135	223	560	-337
Hadhramout	7	9	16	130.7	128.3	259	350	-91
Lahj	6	3	9	15.2	32.5	47.7	70	-22
Abyan	6	3	9	17	17	34	70	-36
Shabwa	3	2	5	22.5	19	41.5	70	-29
Marib	1	6	7	70	70	140	85	+330
Taiz (Al-Mokha)	1	0	1	0	0	0	20	-20
Al-Mahra	7	1	8	39	2	41	60	-19
Socotra	2	-	2	4.5	-	4.5	10	0

Source: Ministry of Electricity and Energy, 2021.

The government continues to purchase electricity from private producers. Further, the electricity tariff remains subsidized: The pre-war tariff is still valid except the tariff of the commercial sector, as there are movements in the ministry and the PEC to increase the tariff for the commercial sector to 70 YR/kWh instead of 30 YR/kWh. The enforcement of the new tariff has started in Aden governorate.

Recently, in May 2020, the Marib I power plant, formerly considered the backbone of the electricity sector, started functioning with 55 MW (out of 340 MW) and fed, for the first time, the local grid (rather than the national grid, as previously done).[51]

Ansar Allah-Controlled Areas

According to the interviews conducted for this paper, the main public power plants in Ansar Allah-controlled areas are located only in Hodeidah and Sana'a city and are functioning at a limited capacity. For Hodeidah, only 39 MW is being generated from the Ras Katheeb power plant, while Al-Hali power plant is functioning with a capacity of 5 MW only. In Sana'a, there is roughly 20 MW generated by Heziaz power plants. The tariff of the electricity generated by the public power plant in Sana'a is 170 YR/kWh, which is more than tenfold the average residential sector tariff before the war. There is thus also an emerging, private-led market for electricity supply, which started in Sana'a and has expanded into the other Ansar Allah-controlled governorates. Electricity prices have not been subsidized since 2015, and several private producers have invested in small diesel generators and grids to supply electricity, with prices reaching up to 300 RY/kWh, subject to the fuel price in the local market.

Per the Ministry of Electricity and Energy in Sana'a, there are around 300 small diesel generators registered in Ansar Allah-controlled governorates.[52] The average capacities of these generators range from 50 kW to 800 kW. Table 7 summarizes the number and total capacities of these private generators that are registered in the ministry. The largest share of such private generators is concentrated in Sana'a city.

51) Ministry of Electricity and Energy (MoEE), "The Minister of Electricity and Energy announces the return of Marib's gas power station to work after a hiatus for years, and reveals the details of the launch of the first and second phases of restoring electricity to Marib [AR]," May 21, 2020, https://moee-ye.com/site-ar/1124/ (accessed August 7, 2020).

52) Mohammed Al-Hakimi, "Yemen: 98% Fossil Fuel Consumption," Holm Akhdar, October 25, 2019, https://holmakhdar.org/reports/490/ (accessed August 7, 2020).

Table 7: Number and total installed capacity of private generators, 2020

Governorate	Number of Diesel Generators	Total Capacity (MW)
Sana'a	6	1
Sana'a city	262	89
Amran	8	2.0
Dhamar	18	7.7
Ibb	28	8.0
Al-Dhale	1	0.2
Al-Mahwit	7	0.8
Hajjah	17	5.8
Taiz	7	1.5

Source: PEC, Sana'a, 2020.

The MoEE in Sana'a is attempting to regulate private producers by requiring licensure, as well as regulating the price of electricity that private producers sell directly to consumers. The last tariff issued by the ministry was a decrease, from 250 RY/kWh to 205 YR/kWh, which considers the drop in world oil prices. Also, some private companies have started working as distributors for the electricity generated by the PEC power plants against specific fees. This is considered a new model for investment in the electricity sector. Moreover, solar energy applications have witnessed high demand and employment in these same areas.

5.3 | Emergence of the Solar Photovoltaic Market

After the collapse of the national grid, the solar PV systems market boomed at an unprecedented rate to become the preferred electricity alternative, especially in the northern and central governorates, where the public power plants were not functioning. As of 2017, small solar PV systems have proliferated and are used as

Box 2: Solar PV generation in the Arab Middle East countries, 2018*

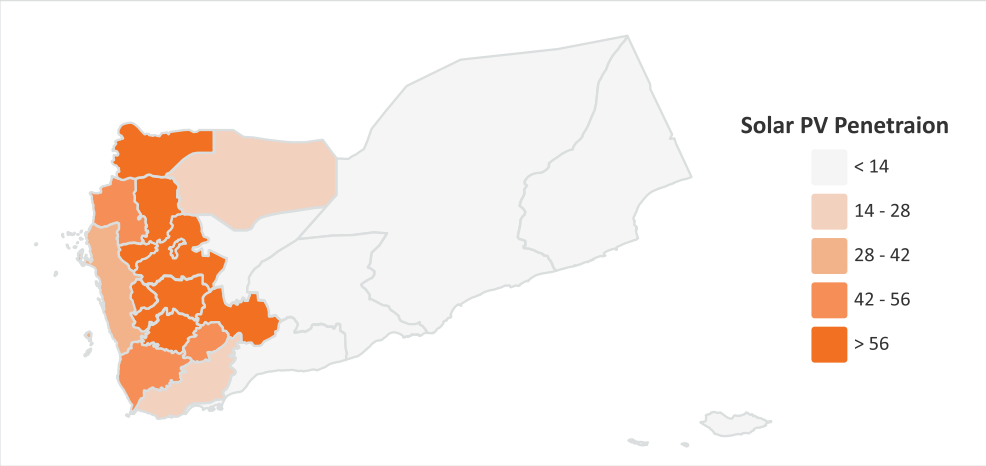
Country	Generation (GWh) in 2018
Bahrain	8
Iraq	377
Jordan	1,476
Kuwait	71
Lebanon	84
Oman	16
Palestine	60
Qatar	8
KSA	65
Syria	2
UAE	1,076
Yemen	732

Source: IRENA, 2020.

** All figures are IRENA estimates expect for Iraq and UAE, which were obtained from official sources.*

an alternative source of electricity by more than half of the Yemeni population—75 percent in urban areas and 50 percent in rural areas. Most of these systems power basic electrical needs, such as lighting and charging of mobile phones.[53] Figure 24 shows the geographical penetration of solar PV deployments as per a survey conducted in 2017 by PERCENT.

Figure 24: Solar PV systems penetration in the governorates



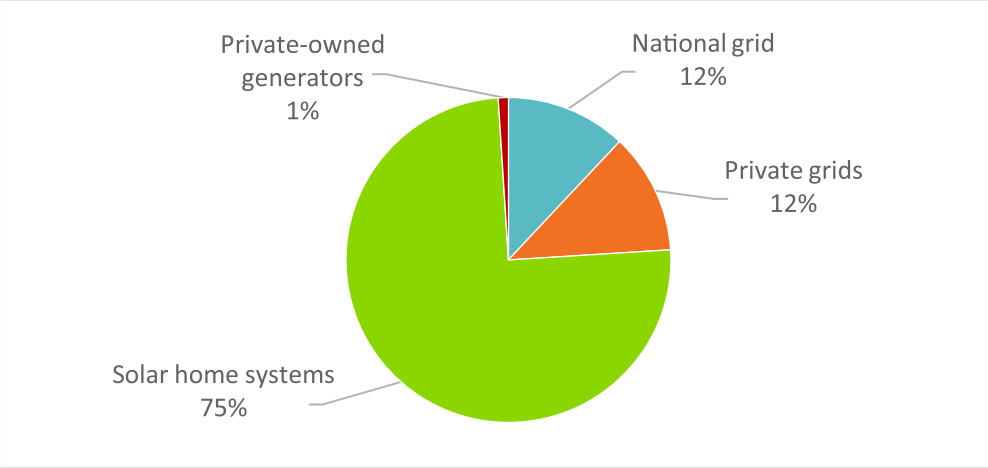
Source: PERCENT Corporation for Polling and Transparency Promotion, "Solar Energy in Yemen," January 2017.

It was reported that the total capacity of solar PV systems imported and installed in Yemen had reached 500 MW by 2018.[54] Based on a phone survey conducted by the World Bank, there is an increase in the number of Yemenis who rely on small solar home systems as their main electricity source. In December 2019, around 75 percent of the population used solar systems, while 12 percent relied on electricity from the national grid, 12 percent used electricity from private grids and only 1 percent used their own generators. Figure 25 shows the main sources of household electricity in 2019.

53) Maged Mahmoud et al., "Assessment of the Status of Solar PV in Yemen," Regional Center for Renewable Energy and Energy Efficiency (RCREEE), May 2017, p. 13, https://www.rcreee.org/sites/default/files/121707-wp-public-p158449-wb-rcreee-solar-pv-in-yemen-report-002.pdf (accessed August 7, 2020).

54) Ansari et al., "Yemen's Solar Revolution," p. 2.

Figure 25: Main sources of electricity for households



Source: Naoko Kojo and Amir Althibah, "Yemen Monthly Economic Update March 2020," World Bank Group, March 2020, p. 7, http://documents1.worldbank.org/curated/en/339571587498517757/pdf/Yemen-Monthly-Economic-Update-March-2020.pdf (accessed August 7, 2020).

Given the high demand for solar PV systems and their guaranteed profits, many businesses have begun to sell solar PV systems, even unspecialized shops such as electronics, appliances and mobile shops. Similarly, many untrained youths now install and maintain PV systems. Because of low purchasing power and an absence of standardization and appropriate financing mechanisms, many Yemenis find themselves only able to purchase cheap products, which usually are of poor quality.[55] Thus, non-specialized sellers and technicians, a lack of standardization and low purchasing power have contributed negatively to market development and sustainability. In most cases, the solar PV systems are not well designed and function for only a short period. Although solar energy provides a survival solution for many households, service facilities and agricultural purposes, there remains a need to address the issue of the quality of the products to properly invest in and use solar PV systems.[56] From the environmental side, there are no appropriate means for the disposal and recycling of the hazardous materials in the exhausted batteries, solar panels or electronic wastes in general.

55) Sara Badiei, "A Glimpse of Light in Yemen: Enabling a Booming Solar Industry through Entrepreneurship and Innovation," World Bank Blogs, March 29, 2018, https://blogs.worldbank.org/arabvoices/glimpse-light-yemen-enabling-booming-solar-industry-through-entrepreneurship-and-innovation (accessed August 7, 2020).

56) Mahmoud et al., "Assessment of the Status of Solar PV in Yemen," pp. 9, 46.

5.4 | Fuel Supply

In 2015, the fuel sales of the YOPDC—the then sole fuel supplier to the electricity sector—decreased by about 77 percent (from 1,594 million liters in 2014 to 366 million liters in 2015). This led to the suspension of the power supply through the public grid in most governorates during the last three quarters of 2015, resulting in a considerable investment to import small diesel generators and solar PV systems. However, the power supply has resumed in early 2016 because of relative improvement in fuel availability.[57] There are also several power plants, especially in Marib and Hadhramout, which benefit from the recently resumed local oil production, according to interviews conducted for this paper. In the last two years, oil production played an important role in increasing government revenue, despite frequent production disruptions and sabotage attacks during the second half of 2019. Table 8 shows the production status of oil companies working in the main basins in Yemen, the Marib-Shabwa and Masila basins.[58]

Table 8: Oil production status

Basin	Block	Company/operator	Production in 2014 (thousand barrels/year)	Production status	
				Mar. 2019	Dec. 2019
Marib–Shabwa	18	SAFER	13,720	Halted	Active
	4	YICOM	60	Halted	In progress
	S1	Petsec (formerly Occidental/TransGlobe)	310	Halted	Active
	5	Jannah Hunt	9,660	Halted	In progress
	43	Jannah Hunt	440	Halted	Halted
	S2	OMV	5,740	Active	Active

57) Ministry of Planning and International Cooperation (MoPIC), "Oil Sector Recovery in Yemen Urgently Needed," *Yemen Socio-Economic Update* 14, May 2016, pp. 1–2, https://reliefweb.int/sites/reliefweb.int/files/resources/yseu14_english_final_1.pdf (accessed August 7, 2020).

58) Naoko Kojo and Amir Althibah, "Yemen Monthly Economic Update December 2019," World Bank Group, December 2019, p. 2, http://pubdocs.worldbank.org/en/360391580209593452/Yemen-Update-Dec-2019.pdf (accessed August 7, 2020).

Basin	Block	Company/operator	Production in 2014 (thousand barrels/year)	Production status	
				Mar. 2019	Dec. 2019
Masila–Hadhramout	14	PetroMasila	10,040	Active	Active
	10	PetroMasila -Conceded from TOTAL in 2016	13,240	Active	Active
	32	DNO - Conceded to Government in 2016	560	Halted	-
	53	PetroMasila - Conceded from DOVE in 2016	1,450	Halted	Active
	9	Calvalley	1,120	Halted	In progress
	51	Nexen	680	Halted	Halted

Source: World Bank, Yemen Monthly Economic Update, based on the Ministry of Oil, December 2019.

Although the government floated the price of the fuel in the past few years, fuel supplied to public power plants is still subsidized. Of the total fuel subsidies, 37.6 percent ($838.5 million out of $2,231 million) in 2014 and 82.9 percent ($79.6 million out of $96 million) in 2015 was provided as fuel subsidy to the sector.[59] Since late 2018, Saudi Arabia and the UAE began to provide the fuel needed for operating the power plants in government-controlled areas. Saudi fuel supplies 63 power plants in ten governorates. According to interviews conducted for this paper, Saudi oil grants from late 2018 to the end of 2019 totaled 190,391.915 metric tons of diesel and 86,021.975 metric tons of HFO. Regarding the UAE grant, which began in September 2019, the amount of fuel received by the end of 2019 was 127,470.733 metric tons of diesel. The government is also importing fuel through private importers via tenders. In the Ansar Allah-controlled areas, fuel is supplied only through private investors who import from abroad.

59) Ministry of Planning and International Cooperation (MoPIC), "Oil Sector Recovery in Yemen Urgently Needed," *Yemen Socio-Economic Update* 14, May 2016, pp. 1–2, https://reliefweb.int/sites/reliefweb.int/files/resources/yseu14_english_final_1.pdf (accessed August 7, 2020).

6 | THE 1990S ELECTRICITY SECTOR REFORM MODEL AND LESSONS LEARNED

During the 1990s, in reaction to inefficient operations, growing subsidies, and financial constraints of the vertically state-owned utilities, several leading international institutions agreed on a new reform model for the power sector that was known as the "Washington Consensus". This model aimed to strengthen the operational and financial performance of utilities, improve the reliability of the electricity supply, and enhance the private sector participation in the power sector in a conducive investment climate and set up the public sector to take on a regulatory role. The 1990s Power Sector Reform Model consists of a package of four structural reform actions, as outlined below.[60]

Regulation (through the creation of an independent regulatory entity) is typically the starting point of any reform journey. Thus, it became a key element of the 1990s reform model. The regulator must be accountable and supported by a strong regulatory framework. The regulatory entity also needs to be credible to gain investors' confidence; legitimate to protect the consumers from abuse of power—via high prices, poor service or both; and transparent to both investors and consumers as regards the how and why of decisions.[61]

Restructuring (corporatization, and full vertical and horizontal unbundling of the utility): This requires separation of the three main functions that have traditionally been combined within the ministries: policymaking, regulatory functions, and service provision. Policymaking should remain with the ministry; regulatory functions with an autonomous regulation entity; and the service provision per a corporatized utility. To unbundle the utility vertically and horizontally, initial steps separate accounting and administrative activities. The vertical unbundling should separate the generation, transmission and distribution sectors; and possibly the retail function. Horizontal unbundling would then follow, to create several stakeholders with potential for competition, especially relevant for the generation and distribution subsectors. Restructuring is a crucial step in engaging

60) Vivien Foster and Anshul Rana, "Rethinking Power Sector Reform in the Developing World," World Bank, 2020, https://www.worldbank.org/en/topic/energy/publication/rethinking-power-sector-reform or https://openknowledge.worldbank.org/handle/10986/32335 (accessed August 7, 2020).

61) Ibid.

the private sector. Liberalization of the electricity sector requires several electricity sellers and buyers to create wholesale and retail markets. Moreover, restructuring helps to improve the governance of the sector and remove any conflict of interest, especially when a sole utility is responsible for more than one function (e.g., transmission and generation together). For instance, the transmission utility buys or prioritizes the grid access for any generation company that offers competitive prices. Private sector participation in the electricity sector gives an opportunity to improve the operational efficiency of the electricity sector.[62]

Private sector participation is the involvement of the private sector in managing or investing in the electricity sector through temporary contracts or permanent asset sales.[63] Participation of the private sector can be implemented through several arrangements, ranging from management and leasing contracts to divestiture. In most cases, private sector participation is introduced after corporatizing the state-owned utility.[64]

Competition reform allows electricity producers to compete to supply public utility, and eventually allows customers to purchase their electricity supply from producers and traders supported by a power exchange. In some countries, retail competition for small customers is facilitated through suppliers of alternative energy. This stage of reform can succeed when there is a sufficient generation capacity through competitive prices.[65]

Based on the World Bank "Rethinking Power Sector Reform in the Developing World" report, a multiyear study concluded in 2020 that aimed to review and update the 1990s reform model, several observations need to be highlighted: 1) The reform model was more successful in the developed countries (i.e., OECD countries) that had reached certain minimum conditions of power sector development and had a supportive political environment. Conversely, its implementation was incomplete in developing countries and not according to the standardized measures of the 1990s reform model. 2) The regulation framework has been adopted in a significant number of countries. But in practice, there were difficulties in implementing it, especially in state-

62) Ibid.

63) Vivien Foster et al., "Charting the Diffusion of Power Sector Reforms across the Developing World," World Bank, November 2017, http://documents1.worldbank.org/curated/en/576801510076208252/pdf/WPS8235.pdf (accessed August 7, 2020).

64) Foster and Rana, "Rethinking Power Sector Reform in the Developing World."

65) Ibid.

owned utilities. Appendix 3 shows the main indicators used to evaluate the regulatory framework's performance. 3) Cost recovery remains an unattainable goal for several developing countries. 4) The private sector has substantially engaged in the generation sector, resulting in enhancing the generation capacity and improving electricity access; but there is limited private sector participation in the distribution and transmission subsectors. Appendix 4 includes a description of different arrangement options for private sector participation. 5) Liberalization measures have been beneficial in a handful of larger middle-income nations, but have proved too complex for most countries to implement. Appendix 5 shows the phases of the competition reform.[66]

The World Bank study concluded with several lessons learned from past reform experiences to be taken into consideration for improved implementation in the future:[67]

1. The reform measures need to be customized as per the political and economic context of the country. The 1990s Electricity Sector Reform Model is well suited where political systems are based on a market-oriented ideology. Economic preconditions include the existence of a relatively large power sector, high electrification rate, good operational and financial data, and a well-functioning framework of tariff regulation. Regarding countries with more challenging environments, the priority should be given to governance reforms and the achievement of financial viability, with the recommendation to postpone structural reforms until the sector reaches a mature stage of development. Appendix 6 includes a set of performance indicators used to assess the quality of governance and management practices in the utilities.
2. The reform measures need to be designed with the purpose of achieving specific outcomes, and not to follow a predetermined process. For some countries, the recent evolvement of policy objectives in the electricity sector includes the adoption of social and environment-targeted policy measures in line with the Sustainable Development Goal 7 for universal electricity access and the Paris Climate Agreement for power sector de-carbonization. Therefore, the 1990s reform model needs to incorporate targeted measures for electrification and decarbonization.
3. It is possible to implement alternative institutional reform measures and achieve good outcomes apart from the 1990s reform model. For example, some countries successfully adopted policies targeting the private sector without unbundling the power sector.

66) Ibid.

67) Ibid.

7 | KEY CHALLENGES TO ELECTRICITY SECTOR RECOVERY AND REFORM

Based on the literature review presented in the previous sections and the interviews conducted for this paper, it is evident that the power sector in Yemen has and continues to experience several chronic technical, political, economic and social challenges, which have stalled any considerable improvement in the sector. As well, the current war aggravates an already fragile situation, adding yet more complexity to the sector's overall challenges. These are as follows:

- **High dependency on fluid fossil fuel:** About 50 percent of electricity generation in Yemen is powered by diesel, which is one the most expensive energy generation options, and has resulted in a significant financial burden for the government. It is also associated with harmful environmental effects, such as greenhouse gas emissions from burning high carbon content fossil fuels.
- **Inefficient and aging power plants:** Most of the main power plants are aging and inefficient, and thus consume more fuel and require frequent maintenance.
- **Absence of a regulatory framework:** There is an absence of any workable regulatory framework, such as laws and regulations for renewable energy deployment or public-private partnerships.
- **Inefficient institutional arrangements:** A long-term history of inefficient institutional arrangements is arguably the origin of several serious issues within the sector. In addition, the absence of an independent regulator hinders attracting private sector investment, as well as sector transparency. Re-unifying the sector institutions fragmented during the war is one of the most important and politically complex challenges for post-conflict reconstruction.
- **Corporatization-related issues:** As the sector has no commercial orientation, there are difficulties reaching full financial independence. Administratively, there is only limited decision-making autonomy, e.g., in setting the tariff, hiring or firing an inefficient employee, etc.
- **Commercializing the tariff:** Liberalization and reform of the electricity tariff is one of the most challenging issues, as it is subject to political considerations and require favorable conditions.
- **High electricity losses and low collection rate:** Around 40 percent of technical and non-technical electricity losses are from the distribution subsector and are partly caused by poor urban planning. Combined with the low fee collection rate and the inability of local public electricity corporations to collect or reschedule subscribers' debt, this serious issue hinders sustainable operations and bleeds the sector's resources.

- **Finance constraints:** Given the limited revenues, there are difficulties financing the rehabilitation, maintenance and purchase of spare parts for the infrastructure throughout the country.
- **Unsustainable fuel supply:** Limited local oil production and refining capacity, and the inability to continue subsidizing fuel prices, will make it challenging to secure the supply of needed fuel, both via the Yemen Oil and Gas Corporation or imports. There is also an uncertainty as to the amount of the national gas reserve.
- **Lack of skilled employees:** During the war, because of the non-payment of salaries, a considerable number of utility personnel, especially skilled engineers/workers, moved on to other jobs with the private sector, non-governmental organizations, or outside the country. It will be a challenge to regain these skilled employees. Moreover, several current and experienced staff are due to retire, but there are no trained replacements available, due to lack of hiring during the last five years.
- **Poverty and affordability issues:** According to UN statistics, around 80 percent of the Yemeni population have been negatively affected because of the war and need assistance and protection.[68] In addition, there is massive unemployment. Such social issues reinforce the need for affordable electricity prices. Therefore, any reform of the electricity tariff will require careful consideration of social protection aspects.
- **Security issues:** There is a high potential for sabotage activities to electricity and oil infrastructures, which in turn will negatively affect the sector's performance. In addition, the reoccurrence of conflict after that war could threaten the sustainability of service provision.
- **Unattractive market:** Because of the absence of necessary enabling conditions, such as incentives and adequate regulations, an attractive investment climate and a competitive market for the private sector are lacking. It will be difficult to attract foreign investors during the conflict or directly after the war due to high inflation, a weak monetary sector, subsidized tariffs and low per capita income.
- **Unclear vision on the form of the electricity sector after the war:** According to the National Dialogue Conference, it was proposed the creation of a new federal state, which could lead to the creation of one utility for each region in Yemen.[69]
- **Change of demographics due to population displacement:** The continuing war has caused a large number of people to leave their villages and cities and relocate to new safe heavens increasing pressure on the host cities public infrastructure including power provision. This has been especially notable in cities such as Mareb and Aden.

68) UN News, "Humanitarian Crisis in Yemen Remains the Worst in the World, Warns UN," February 14, 2019, https://news.un.org/en/story/2019/02/1032811 (accessed August 7, 2020).

69) National Dialogue Conference, "National Dialogue Conference Document [AR]," 2013, pp. 40 and 237, http://www.ndc.ye/ndc_document.pdf (accessed August 7, 2020).

8 | RECOMMENDATIONS

Despite the deteriorating situation of the electricity sector, especially after the war, there is an opportunity to build a stronger electricity sector. This section includes the top priorities for restoring and reforming the electricity sector. However, the applicability of these recommendations relies on a highly supportive political environment and the support of international donors/lenders, as well as effective management from the sector leaders.

8.1 | Immediate to Short Term

The recommendations below are timed for the current situation and the first year following any potential peace agreement or/and political stability. The aim at this stage is to restore the sector to its previous capacity before the war, and prepare a sound foundation for the reform process that must follow the initial recovery phase:

- Adopt a systematic and an executable recovery plan for infrastructure rehabilitation priorities in the generation, transmission and distribution subsector.
- Secure funds, whether from government financial resources or international donors/lenders, to rehabilitate infrastructure damaged during the war, to maintain power plants requiring spare parts, and other corrective and preventive maintenance.
- Rehabilitate essential transmission lines needed to transmit the power from the large power plants to demand locations. These rehabilitation efforts can be timed in line with the recovery plan.
- Look for effective financial and technical solutions/settlements between the concerned entities in the conflicted regions to re-operate the national grid, including the main power plants such as the Marib I gas power plant, as well as the thermal power plants across the Yemeni governorates.
- Work towards the resumption of all suspended projects and regain the support of international donors.
- Purchase electricity from private producers as needed, via a transparent and competitive process, preferably through schemes that result in the PEC owning the infrastructure, such as build-operate-transfer (BOT) and build-own-operate-transfer (BOOT), when it is feasible technically and financially.
- Work towards finding feasible and sustainable solutions for electricity supply in each governorate, both for the current situation and for backup in emergencies when the centralized system fails. This may

include a demand-need-assessment for each governorate. Top priority goes to the governorates/areas that have no generation assets and thus lost access to electricity during the war. One of the best options, especially in hot and conflict-affected areas, is to install least-cost distributed generation systems (i.e., mini-grids), given their operational flexibility and the minimum time needed for installation.

- Enhance the efficiency of the generation and distribution subsectors, reduce the technical losses through proper maintenance, improve the capacity of the overloaded grids' components, and restore the actual capacity of the power plants. For non-technical losses, it is necessary to reduce unauthorized connections to the grid, increase the fee collection and develop the capacity of those who manage the billing and metering. In addition, install prepaid meters.
- Secure sustainable salaries for the electricity sector employees and develop the capacity of the team at all levels and in all fields of specialization: managerial, technical, procurement, etc. This requires needs assessments and capacity building for the current staff.
- Improve managerial practices and ensure there is an effective delegation of capacities for the skilled and qualified directors/managers who lead the departments/units. This means distributing the responsibilities among different levels of management with setting specific goals, indicators of performance and clear job descriptions. Separate the managerial and financial activities of the three subsectors to enhance accountability and to pave the way for restructuring reforms.
- Ensure decision-making autonomy for operations of the electricity sector, especially for the projects that need to be implemented in line with the sector's strategic plans or those that require technical and financial feasibility studies.
- Secure sustainable fuel supplies for the power plants through local supplies, imports and grants.
- Determine the human resources needed and work on re-attracting the well-skilled staff who left during the war. Find replacements for the well-experienced staff who have retired during the past six years or will retire in the near future.
- Update and benefit from the previous studies and strategies conducted by donors and international consultancy firms, such as the Master Plan, National Strategy for Renewable Energy and the Energy Efficiency[70] and Rural Electrification Strategy.
- Encourage consumers and service facilities to install high quality and well-designed solar stand-alone systems that are sustainable solutions, as well as connection compatible, once the grid is again operational. This requires surveying the solar PV market, adopting quality specifications and standards, establishing labs for testing

70) The summary of the 'National Strategy for Renewable Energy and the Energy Efficiency' available at https://moee-ye.com/site-ar/364/ (accessed August 7, 2020).

and checking the compliance of the imported products, alongside facilitating the importation process and exemption of solar PV products from custom duties in all country ports. The improvement of technical and safety awareness is also necessary, as regards the proper use of solar systems and the disposal of used components, such as batteries, solar panels and electronic waste.

- Review the electricity tariff based on a consultancy study that addresses its social and economic dimensions, including affordability for consumers from all sectors, demand load forecast, and others. The study should also include a timeline and achievable milestones that aim to reduce the subsidy in the areas where the electricity is currently subsidized. If the study advises postponing any increase in the tariff, the government should support the PEC to find financing channels to help cover the electricity subsidy in order to meet its operation costs and ensure reliable electricity supply. Also, there is a need for social protection mechanisms that target the poor people who cannot afford the electricity tariff where the electricity tariff is unsubsidized.

8.2 | Medium to Long Term

These recommendations are applicable during the two to five-year period following any potential peace agreement and/or political stability. This stage focuses mainly on reforming the sector in accordance with the relevant steps taken before the war and best international practices. In general, the success of the reform process—especially the restructuring of the sector, the creation of an independent regulator, and the degree of private sector engagement—needs a political commitment translated into an enforceable decree for reform. High-level leaders, supported by a committee of senior experts, should work on initiating, supervising and directing the reform process to obtain stakeholder consensus and ensure smooth reforms that lead to the establishment of a modern electricity sector.

8.2.1 Legal and Regulatory Framework

There are a considerable number of important laws and regulations, drafted and/or adapted before the war, that need to be enforced. The reform process can thus build on previous efforts, as well as develop new laws and decrees, to better govern the sector.

- Approve the public-private partnership law drafted before the war, with updates if needed.
- Amend the previous electricity laws as needed, to accommodate new changes in the sector.

- Adopt the necessary supporting policies, regulations and schemes for engaging the private sector in the electricity generation and distribution sector through BOT and BOOT, among others.
- Approve the renewable energy law, supported by an updated and executable action plan, resources assessment, and mapping. In addition, issue supporting policies, incentives and schemes to encourage the private sector to invest in clean energy through feed-in tariffs, net metering, auctions, right-to-grid access and priority of dispatch, among others.
- Reform the electricity tariff and adjust its structure to include, for example, the time of use and cost of reactive power for large-scale consumers. This may include a gradual removal of the subsidy from the electricity tariff to cover actual costs and generate profit. In addition, there is a need to ensure that low-income consumers will not be affected negatively by increased tariffs.
- Adopt energy efficiency action plans, including measures to reduce energy consumption in the electricity sector, as well as other sectors. Include specific measures for electric equipment, buildings, lighting, and minimum energy performance standards and labels for appliances (e.g., air conditioning and refrigerators).
- Adopt a law for sound waste management of electronics, solar panels and batteries, including procedures of collection and recycling of waste.
- Set a strategic plan including milestones towards liberalizing the electricity market through wholesale and retail markets. Appendix 5 shows the phases of competition reform.
- Initiate the reform process through a legally binding document that gives authority to a political leader who can supervise and direct the reform process. This leader, with the support of technical and non-technical experts, needs to enforce the decrees, unify the stakeholder's opinions, and make sure that the reforms lead to the desired outcomes.

8.2.2 Institutional Arrangement

The Electricity Law of 2009 included the main necessary steps for reforming the structure of the electricity sector. The following points emphasize the importance of enforcing the electricity law, as well as supplementary recommendations:

- Create an independent regulatory entity to ensure an enabling investment environment that can promote fair competition among the stakeholders and protect the consumers. Appendices 3 shows a list of the regulatory performance indicators.
- Resume and build on previous efforts to restructure the General Authority of Rural Electrification and create service providers in the rural areas.
- Unbundle the electricity sector into generation, transmission and distribution subsectors.

- Set a strategic executable plan for the horizontal unbundling of the generation and distribution components to liberalize the electricity market.
- Create financial institutions and mechanisms to finance small and large-scale energy project investments and provide soft loans and subsidies.

8.2.3 Capacity and Performance

Enhancing the capacity of institutions and individuals is key to improving the sector's performance. Thus:

- Improve the governance and managerial practices of the PEC, such as implementing staff performance reviews as per predefined goals, financial auditing by a third party, ability to hire employees and firing of poor performance employees, and others. Appendix 6 shows a list of indicators for the utilities' governance performance.
- Develop innovative solutions to enhance the rural electrification programs. This needs to include accessible financing mechanisms for villagers to buy solar stand-alone systems, as well as mechanisms for investors.
- Enhance the capacity of the electricity sector to deal effectively with donor-supported, large-scale projects, while also attracting new partners and projects. This should include a review of the entire donor collaboration and project implementation processes to make timely decisions and implementations.
- Enhance the capacity of training centers in the electricity sector and ensure staff development across all levels and in all fields.
- Develop the capacity of the technical team to prepare technical and legal documents and regulations, such as standard Power Purchase Agreements (PPA), regulations needed for connecting the renewable energy project to the grid, feasibility studies, and others.

8.2.4 Private Sector Involvement

Perhaps counterintuitively, countries during a conflict or in a post-war transition phase have many investment opportunities, usually centered on the provision of unmet basic services and needs. The private sector can play an important role in infrastructure and economic reconstruction, which in turn results in several positive outcomes, such as an increase of private capital, and job creation while (re)building local capacities and skills. The private sector also generates revenue for the government by paying taxes and other fees. Therefore:

- Adopt appropriate incentives and arrangements for attracting private sector investments. This especially applies to the technologies that generate clean energy (i.e., from renewable energy sources, namely, solar, wind, and geothermal energy) or those with competitive prices, such as gas-fired power plants.
- Engage the private sector in the electricity sector's activities, especially in the generation and distribution sectors, which have significant potential for private sector participation. Appendices 4 shows several arrangements for involving the private sector in the electricity sector.
- Provide fiscal incentives and guarantees to the private sector to minimize possible risks. These include sovereign guarantees in case of premature contract termination; a take-or-pay clause in the PPA to guarantee the purchase of produced power when there is no demand; and a concerted effort to minimize risk for the private sector, especially in the initial post-war years.
- Allocate land for electricity sector investments, especially for renewable energy projects where there are abundant resources.

8.2.5 Technical

Several technical recommendations are needed to improve the electricity services and their quality. The following lists the top technical priorities to enhance the performance generation, distribution and transmission sectors.

- Improve the quality, reliability and availability of electricity supply by regulating the voltage level and reducing the number and period of interruptions.
- Invest in installing power plants in line with previous plans and consider supplying the economic sectors (e.g., industrial and commercial) with a higher share of electricity generation. These sectors, especially energy-intensive industries, rely on electricity generated by diesel generators, an expensive option. Therefore, the cost of electricity produced by the PEC could benefit from the economies of scale of large power plants and generate electricity by least-cost options (i.e., gas), which in turn will be affordable for those sectors.
- Develop the grid code for connecting renewable energy projects to the national grid.
- Work towards the resumption of the interconnection projects with Saudi Arabia and Ethiopia.
- Upgrade, modernize and expand the transmission and distribution infrastructure. One of the main causes of technical losses was overloading the already deteriorated or limited capacity of the electricity infrastructure. Upgrading this network will be an important step towards improving energy efficiency.

- Develop and implement an emergency plan for the electricity supply, to counter unexpected crises and damages to the centralized grid. The plan can include installing distributed generation units in the governorates. Renewable energy power plants are preferred, to avoid the risks of fuel supply, especially during armed conflict and political instabilities.

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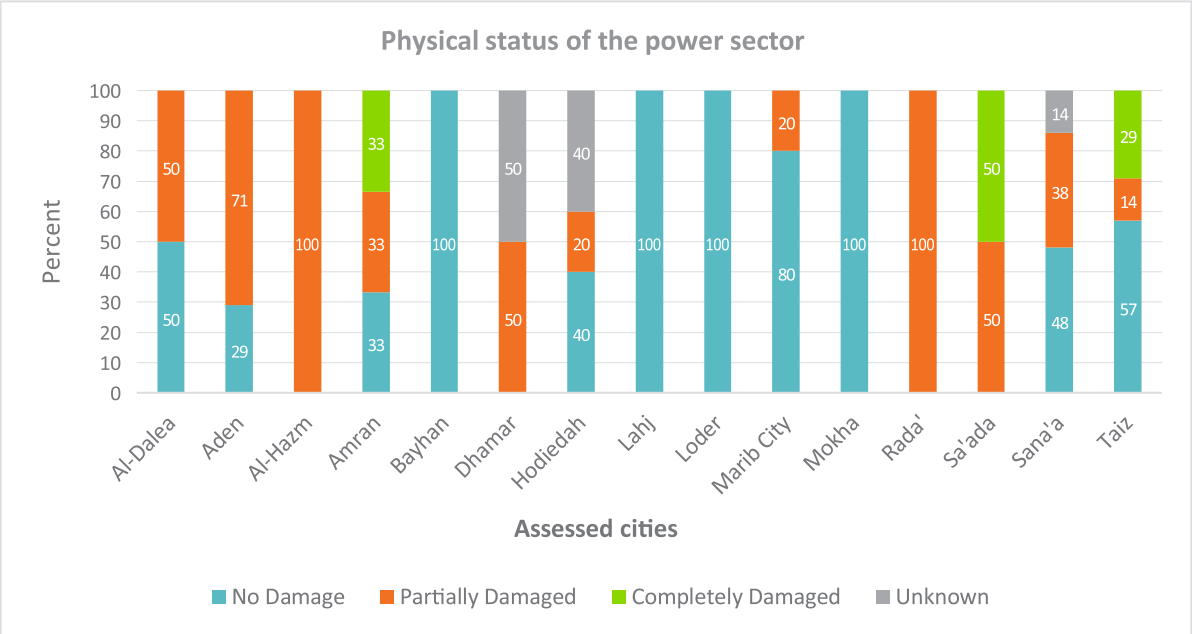
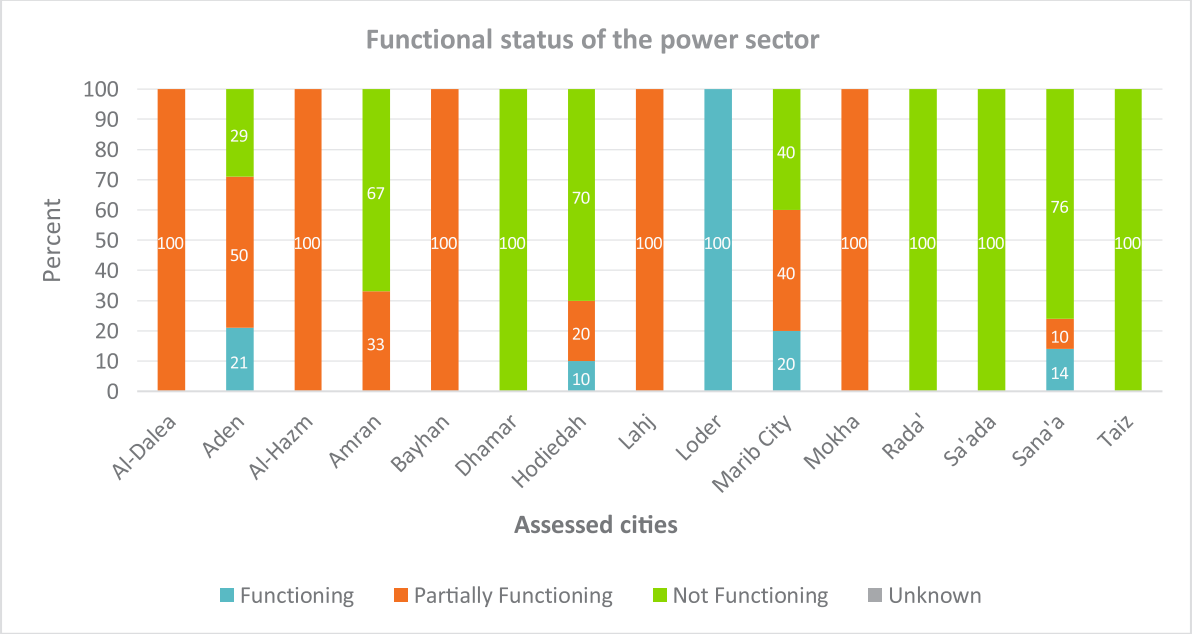
APPENDIX 1: LIST OF INTERVIEWEES

#	Interviewee Name	Title
1	Eng. Yahya Al-Abiad	Former Minister of Electricity and Energy
2	Eng. Khalil Abdulmalek Abdullah	Undersecretary, Minister of Electricity and Energy; Minister of Electricity and Energy, Aden
3	Eng. Saif Hossin Al-Ramah	Director-General Executive, General Authority for Rural Electrification, Aden
4	Eng. Adel Abdullah Abdulghani	Planning Advisor to the Minister of Electricity and Energy; Former General Manager of Planning and Information at the MoEE
5	Eng. Salem A. Bahakim	Freelance Technical Advisor; Former Technical Advisor at the Ministry of Electricity and Energy
6	Eng. Alsharif Mohammed Saeed	Advisor to the Ministry of Electricity and Energy; Former General Manager of Transmission and Substations
7	Eng. Abdulaziz Noman Mukred Mohammed	Vice Managing Director for Generation, Transmission and Control, PEC, Sana'a
8	Eng. Tarek Ismail Taher	Studies and Technical Planning General Manger, PEC, Sana'a
9	Eng. Abdulwassea Kassem Al-Qadasi	General Manager of Transmission and Substations, PEC, Aden
10	Eng. Khalid Mahhfoodh Ahmed Ba-Horaish	Head of Electricity Projects Unit of Hadhramout Governorate, PEC, Hadhramout
11	Eng. Manea Yaslam bin Yameen	Former Head of Monitoring and Supervision Committee for the Fuel Grant, Ministry of Electricity and Energy, Aden
12	Eng. Mohamed Naji Altoloa	General Manager of New and Renewable Energy, Ministry of Electricity and Energy, Sana'a
13	Mr. Abdulrahman Hayel Al-Zuitey	Former Member of Electricity Regulatory Board

APPENDIX 2: PHYSICAL AND FUNCTIONAL STATUS OF THE POWER SECTOR INFRASTRUCTURE IN THE CITIES (EXCEPT TOWERS)





Source: World Bank, "Yemen Dynamic Needs Assessment, Phase 3," 2020, p.1 05

APPENDIX 3: REGULATORY PERFORMANCE INDICATORS

Regulatory Performance Indicators				
Regulatory Governance		**Regulatory Substance**		
Autonomy	**Accountability**	**Tariff Regulation**	**Quality Regulation**	**Market Entry Regulation**
1. Regulates end-user tariffs, quality of supply 2. Makes regulatory decisions legally binding 3. Establishes source of regulatory funding by law 4. Allows determination of own budget 5. Fixes term and removal process of commissioners 6. Prohibits conflicts of interest for commissioners 7. Allows determination of own internal structure 8. Obliges regulator to hire a sufficient number of technical staff 9. Exempts regulator from the public sector pay scale 10. Exempts regulator from public employment rules	1. Formally states regulatory objectives 2. Requires reporting on regulatory activities 3. Requires decisions to be made public 4. Requires third-party evaluation of regulator 5. Incorporates legal appeals process 6. Requires annual reports to be published 7. Requires regulatory decisions to be published 8. Requires stakeholder participation	1. Specifies objectives of tariff setting 2. Establishes tariff setting principles 3. Gives regulator authority to set tariffs 4. Defines cost recovery 5. Specifies tariff-setting methodology 6. Establishes tariff review frequency 7. Excludes illegitimate costs from tariff--setting 8. Requires tariff formula to be public 9. Requires use of accounting standards 10. Avoids pass-through of inefficiency 11. Provides incentives for renewable energy 12. Specifies treatment of stranded assets	1. Promulgates formal quality standards 2. Legally requires standards to be met 3. Provides specification of quality data 4. Requires regular reporting of quality data 5. Requires automated information systems 6. Conducts validation of quality data 7. Publishes quality data 8. Publishes compliance with quality standards 9. Applies fines for violation of standards 10. Applies positive financial incentives to meet standards	1. Monitors compliance with licenses 2. Imposes penalties for license violations 3. Removes license in cases of noncompliance 4. Approves PPAs or other sales contracts 5. Follows specific timeline for PPA approval 6. Holds authority over independent power producer (IPP) procurement process

Source: Foster and Rana, "Rethinking Power Sector Reform in the Developing World," p. 175.

APPENDIX 4: ARRANGEMENTS FOR PRIVATE SECTOR PARTICIPATION IN THE ELECTRICITY SECTOR

Service Contracts	Service Contracts	Management Contracts	Lease Contracts	Concessions	BOT, BOOT, BOO Concessions	Divestiture/ Privatization
Scope	Multiple contracts for a variety of support services (e.g., meter reading, billing, etc.)	Management of entire operation or a major component	Responsibility for the management, operations, and specific renewals	Responsibility for all operations, financing, and execution of specific investments	Investment in and operation of a specific major component (e.g., a transmission line)	Responsibility for all operations, financing, and execution of investments
Asset Ownership	Public	Public	Public	Public/Private	Public/Private	Private
Contract Tenure	1–3 years	2–5 years	10–15 years	25–30 years	Varies	License for 25–30 years
O&M Responsibility	Public	Private	Private	Private	Private	Private
Capital Investment	Public	Public	Public	Private	Private	Private
Commercial Risk	Public	Public	Shared	Private	Private	Private
Relative Level of Risk Assumed by Private Partner	Minimal	Minimal/ Moderate	Moderate	High	High	High

Source: Energy Sector Management Assistance Program (ESMAP), "Private Sector Participation in Electricity Transmission and Distribution: Experiences from Brazil, Peru, the Philippines, and Turkey" (Knowledge Series No. 023/15), Washington, DC: World Bank, April 2015, p. 1 (Table 1: Main Forms and Features of Private Sector Participation), https://openknowledge.worldbank.org/handle/10986/22750 or http://hdl.handle.net/10986/22750 (accessed August 7, 2020).

APPENDIX 5: PHASES OF COMPETITION REFORM

01

MONOPOLY

When a single entity is responsibile for generation, transmission, distribution and retail sales

02

INDEPENDENT POWER PRODUCERS

Same as the monopoly, but private independent power producers (IPPs) are allowed to compete in electricity generation.

03

SINGLE BUYER MODEL

When a single wholesale power trader (e.g. trasmission or distribution/retail entities or combined of both) purchases power from all the electricity generators, and sells to all distributors and any large wholesale customers. The single wholesale power trader has no direct interest in generation.

04

BILATERAL CONTRACTING WITH THIRD PARTY ACCESS

Allowing large customers to purchase power directly from various generators, by wheeling power through the grid on a non-discriminatory basis. A transmission operator or some other entity acts as a single buyer of power for the majority of retail customers.

05

WHOLESALE MARKET COMPETITION

Where multiple generation companies sell the electricity directly to multiple distribution companies and other large-scale customers, supported by an independent systems operator and market operator. Small customers can buy only from their local distributors.

06

RETAIL MARKET COMPETITION

Same as the wholesale market competition, but allowing all large and small customers to purchase power directly from retail companies. This can be achieved after the vertical unbundling of distribution and retail companies, with distribution companies, and providing open access wheeling services to numerous power retailers.

Source: Foster et al., "Charting the Diffusion of Power Sector Reforms across the Developing World," p. 20.

APPENDIX 6: INDICATORS OF UTILITIES GOVERNANCE PERFORMANCE

Corporate Governance (Utility Board)		Utility Management		
Autonomy	**Autonomy**	**Financial Discipline**	**Human Resources**	**Information Technology**
1. Appointment by shareholders or ownership entity state-owned enterprise (SOE) 2. Selection is transparent and competitive 3. Removal at term or through a legal procedure 4. Board is the final decision-making body on: • Corporate strategy • Business plans • Performing objectives • Selection and monitoring of chief executive officer (CEO) • Raising capital from debt or equity • Major capital expenditure • Deciding and implementing tariff adjustments • Human resource decisions	1. Separation of chairperson and chief executive officer (CEO) profiles 2. Existence of company secretary 3. Existence of subcommittees to deal with different issues 4. Existence of an audit committee 5. Existence of a code of ethics or conduct 6. Required to declare a conflict of interest 7. Regulations to protect the rights of minority shareholders 8. Publishing an annual report	1. Utility has a credit rating 2. Liberty to issue new bonds or equity 3. Dividends to shareholders 4. Explicitly defined public service obligations 5. Public service obligations (PSOs) are costed and compensated by the government 6. Requirement to meet financial targets 7. System of internal financial controls 8. Internal audit function 9. Utility subject to state auditing procedures 10. Produces annual financial accounts 11. Audited by a third party 12. Public disclosure of financial accounts 13. Accounting in compliance with national and international standards	1. Conducts annual performance reviews 2. Able to pay bonuses to award good performance 3. Able to fire employees for poor performance 4. Exemption from public employment regulations 5. Exemption from public pay scales 6. Clear policy for training 7. Managers have the authority to hire and fire employees, execute the budget, and implement investment projects 8. Hiring process involves public advertisements, short-listing candidates, interviews, and reference checks	1. Supervisory Control and Data Acquisition (SCADA) system 2. IT system to record/resolve interruptions in supply, support distribution, and energy management 3. Geographic information system (GIS) 4. KPIs for supply quality 5. Advanced metering 6. Accurate customer database 7. Call center for customer complaints 8. Website for submission and follow up of complaints 9. Regular monitoring of customer satisfaction 10. Commercial management system (CMS) and resource management system (RMS) 11. Key Performance Indicator (KPIs) for the commercial cycle and corporate resource management

Source: Foster and Rana, "Rethinking Power Sector Reform in the Developing World," p. 120.

About the Author

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RETHINKING YEMEN'S ECONOMY

The Rethinking Yemen's Economy initiative aims to contribute to peacebuilding and conflict prevention, (economic) stabilization and sustainable development in Yemen by building consensus in crucial policy areas through engaging and promoting informed Yemeni voices from all backgrounds in the public discourse on development, economy and post-conflict reconstruction in Yemen and by positively influencing local, regional and international development agendas. The project is implemented by CARPO – Center for Applied Research in Partnership with the Orient, DeepRoot Consulting and the Sana'a Center for Strategic Studies. It is funded by the European Union and the Embassy of the Kingdom of the Netherlands to Yemen.

For more information and previous publications: www.devchampions.org

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Co-funded by the European Union and the Embassy of the Kingdom of the Netherlands to Yemen

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