Final report

State Fragility initiative

International Growth Centre

الجهاز التنفيذي
The Executive Bureau

Improving electricity services in Yemen

Priorities and options

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November 2021

DIRECTED BY
LSE
UNIVERSITY OF OXFORD

FUNDED BY
UKaid
from the British people

Acknowledgements

We would like to thank the following people for their support and inputs during the preparation of this paper:

Afrah Al-Zouba, Wagdi Mana, Saleh Fadhl (The Executive Bureau for the Acceleration of Aid Absorption and Support for Policy Reforms); Abudl-Hakim Fadhel, MohamedAl-Khadher, Khalil Abdulmalek, Mohamed Al-Shoa'abi, Rami Al-Shaibani, Omar Al-Farouq, Hussein M. A. Taleb, Ahmed Zaki, Khaled Faisal (Ministry of Electricity and Energy); Abdulkader A. Basalah, Mohamed T. Al-Abyad, Abdulwasea Al-Qadasi, Mansour Dammaj, Mohamed A. Q. Al-Hajaji, Salem Alwaledy, Sameer S. A. Abdulkareem, Maged S. M. Kasim, Galal Nasher, Mahmoud S. Mousaid, Nassr Mukred, Nashat Own, Khalid M. A. Ba-Horaish, (Public Electricity Corporation – Aden & Hadhramout); Saif Alramah (General Authority for Rural Electrification); Waleed A. Al-Abasi (Prime Minister Office); Nada Aman (Ministry of Oil and Minerals); Shuaib Al-Zaghir (Ministry of Planning and International Corporation); Abdul Qadir A. Abdulrahim (Ministry of Finance); Najib M. A. Noman, Osama A. A. Hazem (Ministry of Water and Environment); Ali Al-Walidi (Ministry of Public Health and Population); Abdullah Othman (Ministry of Education); Entesar Al- Arasha (Yemen Oil Company - Aden Branch); Farooq Moshen (Aden Refinery Company); Khaled Ali Awman (Supervision and Monitoring Committee of the Fuel Grant); Joern Huenteler (World Bank); Khaldoun Mohammed (UNOPS); Zaid M. Alhimi, Abdu M. Seid (Norwegian Refugee Council - Yemen); Hasseeb Al-Athwari (Al-Sadi Trading Group); Hamza A. A. Alnaqeep, (Alnaqeep for Energy Solutions); Waheed A. B. Al-Absi (Power On for Renewable Energy Systems and Solutions); Anthony Biswell; Rafat Al-Akhali and Sarah Logan (International Growth Centre).

ACRONYMS AND ABBREVIATIONS

ERRY	Enhanced Rural Resilience in Yemen
FAO	Food and Agriculture Organization
FSRU	Floating Storage Regasification Unit
HFO	Heavy Fuel Oil
ILO	International Labour Organization
IRG	Internationally Recognised Government
LNG	Liquified Natural Gas
MoEE	Ministry of Electricity and Energy
MoPIC	Ministry of Planning and International Cooperation
NGO	Non-government organization
PEC	Public Electricity Corporation
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photovoltaic
S/S	Substation
SME	Small and medium enterprises
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOPS	United Nations Office for Projects Services
USD	United States Dollar
WB	World Bank
WFP	World Food Programme
WHO	World Health Organization
YER	Yemeni Rials
YIUSEP	Yemen Integrated Urban Services Emergency Project
YPC	Yemen Petroleum Company

Units of Measurement

km	kilometre
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
mm^2	square millimetres
MVA	megavolt ampere
MW	megawatts
MWh	megawatt-hour
W	Watt

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1 Executive summary

The public electricity system in Yemen is in a very poor condition. The war has damaged or destroyed generation capacity and transmission and distribution networks across the country. The public grid has been severely damaged in Houthi-controlled areas, leaving the majority of governorates in those areas without public electricity supply. In the Internationally Recognised Government (IRG)[1]-controlled governorates, the public grid is still functioning in most areas, but is sporadic and unreliable. Almost 90% of those with access to electricity rely on sources other than the public grid for their electricity – mostly small-scale solar home systems that provide little more than lighting and phone charging. Those still connected to a functioning grid in the government-controlled areas enjoy low tariffs but receive electricity for only a few hours a day. The Public Electricity Corporation (PEC) is fragmented and financially incapable of supporting the maintenance and investments needed to improve performance.

The collapse of the electricity system and the lack of a stable fuel supply due to the war have contributed to the misery affecting millions. Without electricity, health clinics have not been able to store medicines or operate medical equipment, water facilities have not been able to pump clean water and farmers have not been able to irrigate crops. Education facilities (e.g., schools, universities, and institutes) have been unable to provide quality education and a good environment for learning. This all contributes to the humanitarian crisis.

Fuel supply is at the core of the problem – competitive supply and more efficient fuel use is central to the solution. Yemen's power system is heavily dependent on diesel and Heavy Fuel Oil (HFO). Access to fuel has been severely affected by the war and by the policies adopted to restrict imports to Red Sea ports. The government decision in 2018 to liberalise imports has boosted supply to the market, as has the agreement with the Kingdom of Saudi Arabia to provide fuel to the power plants. However, to ensure a good fuel supply to the power plants through the private sector, the government should provide guarantees (e.g., Letters of Credit or an escrow account) for fuel payments to provide assurance of payment for imports. In the medium-term, major projects to rehabilitate the Aden refinery and to switch to alternative fuels and technologies (e.g., natural gas and renewable energy) will reduce costs. In the short run, more may be achieved by measures to enhance the competitiveness of supply and to incentivise the efficient use of fuel.

The public electricity grid has effectively collapsed. Before the war, there were around 1,500 megawatts (MW) of generation capacity attached to the national grid; by 2021 this had fallen to less than half of the total capacity. Most cities that have functioning public electricity rely now on isolated power plants[2]; the total generation capacity in government-controlled areas now amounts to around 1,181 MW. However, the utilisation of this capacity is still very low – often around 50% – largely due to fuel supply shortages and the poor state of the power plants. Almost half of this capacity comes from power purchased from the private sector. However, the Power Purchase Agreements for this electricity are based on capacity, rather than actual generation, so the private sector have no incentive to generate additional electricity nor to maximise efficiency e.g., by generating more electricity using other fuels, such as HFO.

[1] The names 'IRG' and 'government' are used interchangeably.
[2] Only limited capacity is transmitted from Aden to Lahj, Abyan and Al-Dale'a governorates as a result of the issues in the transmission lines and the insufficient generation capacity in Aden.

Technical and non-technical electricity losses are huge. Almost half of the electricity is lost in the electricity system. This reflects the poor state of the transmission, and particularly the distribution network, as well as the large number of illegal connections to the public grid. For electricity that is billed, collection rates are very poor. In government-controlled governorates, only 52% of the amount billed was received 2020, but there are wide differences in collection performance across governorates. There are also big differences in payment by type of consumer – households only pay two-thirds of their bills, but government institutions are the lowest, only paying 12% of their electricity bills in 2020.

The government's approach to rehabilitating generation, transmission, and distribution should focus on value for money. Currently, there is a focus on implementing large capital projects. While these may be important, there are many much smaller investments that could yield significant improvements in capacity and coverage. The government should prioritise investments based on the additional capacity and customers they reach per million dollars, not their overall size.

Electricity tariffs in the government-controlled areas are very low, making financial sustainability difficult – one solution may be reforming tariffs 'at the margin'. Tariffs are a small fraction of the cost of electricity supply making it impossible for PEC to invest for the future. However, raising tariffs significantly would add further hardship for the Yemeni people in the midst of a humanitarian crisis. One solution may be to allow providers to supply additional electricity, over and above current supply, at commercial rates. This could be done for particular customer categories (e.g., businesses), certain geographical areas, or at selected times of day. This would allow supply to expand to meet latent demand from those that wish to pay, without providing an additional burden for those that cannot pay.

The government should consider giving PEC branches greater autonomy to innovate – or even introduce a concession model to encourage investment. Changing the structure of the current electricity supply would provide an incentive for concession holders to expand supply to meet demand and to improve metering, billing, and collection. Tariff regulation along with adopting social protection measures could also protect poor consumers while enabling concessions to be profitable when they expand supply and improve services.

More attention needs to be paid to improving off-grid supply. The bulk of the population live in rural areas and do not have access to the public grid. International organisations have helped to provide solar energy solutions for health clinics, schools, and water facilities and have encouraged the development of a market for distributed renewable electricity. However, the need is huge. The government should work with international and local partners to build the capabilities to meet the energy needs of all Yemeni citizens, both on- and off-grid areas, and devote resources accordingly.

International experience suggests four things are key for improving electricity provision in fragile settings. First, it is important to focus on restoring livelihoods. Second, rehabilitating basic services for all is key. Third, facilitating small-scale innovative solutions by the private sector can speed up the response (e.g., hybridisation with solar). And finally, it is important to pay close attention to inclusion and ensure that key groups are not left out of the process of recovery.

The approach to restoring the electricity sector in Yemen needs to be pragmatic and matched to the current reality. Rather than focusing on large capital investments to improve electricity supply for urban areas, there is an urgent need to work on improving basic services, facilitating private sector participation, and ensuring inclusion. Significant

improvements could be achieved at modest cost by implementing the recommendations outlined in Box 1.

Box 1 Recommendations

- Prioritise rehabilitation of generation, transmission, and distribution infrastructure, based on a ranking of best return (MWs added, customers reached, economic value created/ USD spent).
- Ensure an incentive for more efficient use of existing fuels by revising Power Purchase Agreements (PPAs).
- Encourage switching to lower cost fossil fuels e.g., natural gas.
- Invest in zero 'fuel cost' renewable energy solutions e.g., solar and wind – both utility-scale and distributed and mini-grid solutions where appropriate.
- Create a regulatory framework that allows commercial supply at the margin e.g., by operating concessions.
- Pilot mechanisms to improve billing and collection e.g., through incentives for concessions or local utilities, install prepaid meters, etc.
- Reduce the electricity losses e.g., by disconnecting or legalising the consumers who are illegally connected to the distribution networks.
- Develop a framework for future tariff reforms and communicate with the public on how such reforms are necessary to achieve improvements in service.
- Publish contracts for all energy investments and purchases.
- Devote resources to scaling up off-grid electricity provision for community facilities e.g., water pumping for household supply, health clinics, and hospitals.
- Leverage the existing linkages between MFIs, banks, accredited solar providers, and community groups to expand electricity for productive use e.g., for farmers.

2 Introduction

The public electricity system in Yemen is in a very poor condition. Before the war, there were 1,500MW of generation capacity attached to the national grid – already the lowest in the region – and the national grid brought power to most cities in the country. By 2021, capacity on the whole national grid had fallen to less than half of the capacity with most cities relying on isolated power plants due to the damage to transmission lines. The public grid has been severely damaged in Houthi-controlled areas, leaving the majority of the governorates in those areas without public electricity supply. For the government-controlled governorates, the public grid is still functioning in most areas, but is sporadic and unreliable. Total generation capacity in 2021 amounts to around 1,181 MW, from both public and private power plants.

The solar photovoltaic (PV) energy systems have expanded at an unprecedented level during the war; almost 75% of those with access to electricity rely mainly on small-scale solar home systems to provide little more than lighting and phone charging.[3] Most of the solar PV systems were installed in the central and north areas of the country where the public national grid has collapsed. The average size of the solar systems that are used by households in the urban areas is around 250 Watts (W), while the size of the solar systems in rural areas is less than 100 W – some households use much smaller systems with capacities less than 30 W.[4] As a result of the lack of national standards and quality control for the imported solar PV components, a considerable number of poor-quality and fake solar PV products are imported, which makes the lifetime of the solar systems very short. The batteries, which account for the highest share of the off-grid systems cost, usually fail first and can put the users' safety at risk. The issue of importing counterfeit products also causes the loss of foreign exchange at a time when the country is facing economic challenges. Moreover, due to the fuel crisis, the solar water pumps have been used widely by many farmers and communities, with a substantial number of solar powered pumps installed in Al-Hodeidah and Hadhramout.

Meanwhile, the cost of high quality and appropriately sized solar home systems for consumers is extremely high, putting it out of the reach of many people. At the same time, those still connected to a functioning grid in government-controlled areas enjoy very low tariffs but receive electricity for only a few hours a day. The Public Electricity Corporation (PEC) is fragmented and financially incapable of supporting the maintenance and investments needed to improve performance. As an attempt to reduce the cost of producing electricity in government areas, the MoEE has announced several tenders to install utility scale solar PV power plants in several governorates under a build-own-operate-transfer (BOOT) model.

The fragile state of Yemen's electricity sector should be seen in the broader context of the war, which has had a catastrophic impact on welfare of the Yemeni people. The ongoing conflict has destroyed livelihoods and displaced millions of people. In May 2021, the United Nations (UN) estimated that 47,000 people are already in famine-like conditions, while 5 million people face death from hunger and malnutrition.[5] The collapse of the electricity system and the associated fuel crisis due to the war has also contributed to the misery affecting millions. Without electricity, health clinics have not been able to store medicines or power medical equipment, water fields have not been able to pump clean water, farmers

[3] World Bank, 2020a.
[4] MoEE, 2021.
[5] UN OCHA, 2021a.

have not been able to irrigate crops, and educational institutions have struggled to operate effectively. This has all contributed to the country's humanitarian disaster.

The International Growth Centre (IGC) has been working with the Executive Bureau for the Acceleration of Aid Absorption and Support for Policy Reforms (EB) in the Office of the Prime Minister of the Internationally Recognised Government (IRG) of Yemen to provide analysis and support to the government's efforts to recover from the crisis. This report describes the current status of the electricity sector and puts forward recommendations for how to rehabilitate and restore the sector. It is based on three sources of evidence: first, an extensive review of the literature about how other countries have attempted to recover their electricity sectors from similar situations; second, a comprehensive review of the existing literature, both in English and Arabic, on the sector in Yemen, including the collation of the most recent official data on the sector; and, finally, a set of interviews with a wide range of stakeholders in Yemen – more than 35 interviews were conducted, including with senior officials in the PEC, Ministry of Electricity and Energy (MoEE), ministries for health, water supply, and education, Yemen Petroleum Company (YPC) - Aden branch, Aden Refinery, the private sector, multilateral and bilateral donors, and NGOs during May and June 2021.[6]

The evidence gathered suggests that there are significant weaknesses in the approach currently being taken to restore the electricity sector, particularly the focus on attempting to source finance for large-scale investments, mainly in generation capacity, in an attempt to restore the sector to its pre-conflict state. The experience of other countries suggests that this approach is slow and often unsuccessful. A more effective approach would be to recognise the reality of this sector today and to implement a set of much cheaper structural reforms to shift the incentives of domestic actors, encouraging them to generate additional electricity 'at the margin'. This would mean enabling the private sector to supply, and customers to purchase, additional electricity, over and above that which the state can supply, at rates which provide a commercial return to the providers. This does not mean privatisation – the public grid should remain the bedrock of supply, at least in urban areas and when public electricity is available. However, it would ensure that, where they wish to, households and businesses can access the additional electricity that they want. Moreover, if the incentives are set up for this to happen, the benefits can be shared and used to help support the rehabilitation of the public grid. If the institutional structure is right, then it is possible for additional private supply to complement, rather than substitute, public supply while lowering the burden on the state.

The structure of the report is as follows. Section 3 describes international experience with rehabilitating electricity in conflict affected settings. Section 4 then examines the challenges of rehabilitating Yemen's on-grid electricity, looking at each part of the electricity supply chain – fuel supply, electricity generation, transmission, and distribution. The current reality is described, drawing on the most recent data available, and potential options for reforms are laid out. Section 5 discusses the governance and regulation of the sector and puts forward a set of ideas for structural changes. Section 6 examines the challenges of providing electricity to off-grid areas. Although it was not possible to conduct interviews in rural areas, interviews were conducted with those closely engaged with implementing projects in off-grid areas, as well as with senior officials in the respective ministries, with a focus on the health, water and education sectors. Section 7 concludes, outlining the weaknesses of the current approach to rehabilitating the sector and summarising the key recommendations, as well as proposing an appropriate sequence for reforms.

[6] Some interviews were conducted in person; others were conducted remotely due to travel, security or COVID restrictions.

3 International experience in rehabilitating electricity in conflict-affected settings

3.1 Experience of other countries

Before discussing the challenges of rehabilitating the electricity sector in Yemen specifically, it is worth looking at the experience of other countries that have been affected by conflict. This section is a brief summary of the international literature's lessons and recommendations about rehabilitating electricity in conflict-affected settings.

In the immediate aftermath of conflict, it is extremely difficult to attract private investment. As Schwartz et al. (2014) put it, authorities tasked with reconstruction "… confront a bitter paradox – they can neither absorb fully reconstruction aid nor can they attract much private investment to infrastructure sectors that could offset the state's low absorptive capacity." The difficulty in attracting private investment arises because investments in energy infrastructure traditionally entail large capital costs which are paid back through tariffs over a long period of time. Given the highly uncertain environment that prevails in conflict and post-conflict environments, many private investors are not willing to take the risk since they are not sure that they will be paid back (Bray, 2005). This can become self-fulfilling if the lack of private investment means that the circumstances of daily life cannot be improved, leading to anger and a resumption of conflict. Schwartz, et al. (2014) point to a critical role for international donors in such contexts, both to fund investments, but also to reduce the risk faced by private investors.

Looking specifically at the rehabilitation of energy infrastructure in post-conflict energy planning in the Middle East, Ahmad et al. (2019) point to several factors that influence decision making on post-conflict energy policies including:

- **Access to conventional energy sources.** The existence of oil and gas reserves can be a double-edged sword, both providing resources for reconstruction, but also itself being a source of conflict.
- **The impact of the conflict on the economy.** War not only destroys key assets and livelihoods, but also means that the country has a very low credit rating and high-risk premium, making borrowing for recovery challenging.
- **Tribalism and regionalism.** In an environment in which local leaders are attempting to control ports or oil fields (Al Batati, 2013; Mojalli & Murdock, 2015), reconstruction is particularly hard, since many groups will not agree to relinquish control over key assets and will be extremely sensitive to any unequal allocation of benefits from reconstruction efforts.
- **Degradation of human resources and institutional capacity.** Conflict often gives rise to a significant loss of human resources and institutional capacity as individuals leave the country or are no longer able to continue their work. This, in turn, can affect the quality and timeliness of decision-making.
- **Geopolitical and border issues.** Frequently, as in Yemen, the conflict is enmeshed in wider geopolitical battles, making resolution and reconstruction particularly difficult.
- **Donor policies.** Donor countries may have their own agendas in supporting reconstruction which need to be considered by the authorities. Predictability, risk reduction and non-partisan behaviour are key for donor funding to support the shift from the emergency phase to development.

Unfortunately, such factors can result in an approach to infrastructure rehabilitation that fails the people (Box 2).

Box 2 Lebanon: A cautionary tale

The rehabilitation of infrastructure after Lebanon's civil war (1975-1990) stands as a cautionary tale of how *not* to proceed. Lebanon's focus on its national utility to the exclusion of other providers made its system vulnerable to the failures of that institution. Political factors have prevented any adjustment of tariffs since the mid-1990s, with the result that the utility is bankrupt and cannot invest in an improved service. At the same time, more than half of Lebanon's national debt results from the large subsidies provided to the utility. Equity considerations were largely ignored during reconstruction, with the bulk of resources going to Beirut, creating resentment elsewhere in the country (O'Driscoll, 2018). On the other hand, low tariffs, and the lack of credibility in government made investment in renewable technologies difficult, hampering the energy transition. Only in parts of the country where policies have understood the complex nature of the local political economy has it been possible to construct an effective electricity service (Ahmad et al., 2020).

Overall, Ahmad et al. (2019) conclude that **key features of successful post-conflict electrification planning** include:

1. A clearly established system to **prioritise** the areas to electrify and the projects to be selected;
2. A long-term multi-year vision that **coordinates** grid extension and off-grid efforts;
3. The design and effective implementation of an **institutional framework** that clearly establishes the roles and responsibilities of the public and private agents involved.

It is important that the vision and framework put in place is realistic and feasible given the context and resources available for the reconstruction process. Leadership is also key. Foster & Rana (2020) show that reforms are more likely to be successful if there is clear leadership e.g., by a Reform Committee, with high-level political support.

Another critical issue for reconstruction planning is the issue of **sequencing**. The experience of other countries suggests that it is best first to focus on a combination of rehabilitation of *existing* infrastructure – particularly where small investments can make a big difference in either coverage or quality, as well as facilitating small-scale, bottom-up investments by communities to enable them to rapidly recover some degree of functionality. Typically, short-term reconstruction is initially funded by governments and multilateral institutions, then local, diaspora and regional investors tend to come in ahead of global companies. For example, Bray (2005) notes that in post-conflict Cambodia the main providers of electric power were small local entrepreneurs and Thai companies. Such local investors have a better understanding of the context and are able to undertake more appropriate investments and better manage the relevant risks.

Finally, the evidence suggests that **continuous monitoring** of the progress of, and challenges caused by, reconstruction is essential. Electricity, by its nature, is a political commodity. Not everyone benefits from rehabilitation and reconstruction equally in the short-term. In conflict situations, such efforts may be misconstrued as an attempt to prioritise particular communities or groups over others, leading to resentment. It is important that those leading reconstruction efforts continuously communicate with and listen to affected communities. As Earnest & Dickie (2012)'s study of post-conflict reconstruction in Kosovo

puts it, “success … depends on the ability to understand the complexities of the political environment, to coordinate projects in an effective manner, and involve a wide range of community stakeholders. Consultations among key stakeholders with a direct relationship to the project are critical to ascertain what they perceive as essential components of project planning systems and processes to achieve beneficial social and economic change.”

3.2 Implications for Yemen

The experience of other countries suggests a mixed approach is likely to be most appropriate for Yemen. Four key lessons emerge:

- **Focus on livelihoods.** The government should focus first on rehabilitating those elements of public infrastructure where small investments are likely to lead to the largest short-term gain. Smaller investments, particularly in more resilient technologies such as solar power, should be prioritised over large investments that may be vulnerable should conflict resume. A particular focus should be to encourage the resumption of livelihoods for ordinary people (farming, trade, services) which will also help to promote stability.
- **Rehabilitate basic services for all.** Access to certain basic services depends on electricity, most importantly water and health care, but also schools. Investing in ensuring continued access to electricity for basic services helps to protect the population from disease and ill health and restore confidence in the capacity of the state.
- **Facilitate small-scale innovative solutions by the private sector.** The government will not have the capacity to restore a high-quality service rapidly for the entire population. To ensure that the benefits of reconstruction are as widely shared, the government should facilitate the private sector to provide solutions in areas where it is unlikely to be able to provide service in the short-term. Attention should focus on leveraging local investors and the diaspora who are more likely to have a good understanding of the context.
- **Pay close attention to inclusion.** There is a natural tendency to measure progress by MW of power restored or number of people reconnected. But *who* is connected – and *where* – also matters. In particular, the government should ensure that key groups of people are not left out of the process. This includes those off-grid in rural areas, as well as women.

4 Rehabilitating grid-connected electricity supply in Yemen

This section looks at each element of the electricity supply chain, from fuel supply to generation, transmission and distribution, and the overall governance of on-grid electricity. In each area, we provide an account of our current understanding of how the system is functioning based on existing literature and our interviews. This is followed by a discussion of the various proposals that have been made regarding the functioning of each part of the supply chain and a set of suggested priorities, both for public investment and for how to better engage the private sector.

4.1 Fuel supply

4.1.1 Understanding the current reality

Even before the war, Yemen relied on fuel imports for around two-thirds of its demand. The remainder was satisfied by Yemen's two refinery companies – the Aden Refinery Company and Marib refinery. The Aden Refinery was established in 1951 with a designed capacity of 5 million tons of crude oil per year and was upgraded in the 1960s to 8 million tons per year.[7] However, by the time the war started, the capacity of the Aden Refinery was only 60,000 barrels/day (8,185 tons/day) and the war resulted in the suspension of all activities. For now, Marib refinery is still operating and supplying the local market – it has a capacity of around 10,000 barrels/day (1,364.2 tons/day).[8]

Before the war, fuel was supplied and distributed by the Yemen Petroleum Company (YPC)[9] at highly subsidised prices. In 2015, as a result of the armed conflict, fuel supply declined dramatically and this was reflected in YPC's sales figures. Between 2014 and 2015, YPC's sales declined from 6,664 million litres to 2,340 million litres (see Table 1). Almost all sectors experienced large reductions in supply, with major implications for their ability to function. The electricity sector was no exception: in 2014, it accounted for 24% of YPC's sales of fuel, but sales to the sector reduced by 77% in 2015.

Table 1 Decline in fuel sales by YPC resulting from the onset of the war[10]

Sector	Fuel sales (million litres)		% change
	2014	2015	
Private stations	3,821	1,518	-60.3
YOPDC's stations	402	123	-69.0
Government agencies	83	48	-42.2
Other factories	52	9	-82.7
Cement factories	137	25	-81.8
Power electricity plants	1,594	366	-77.0
Associations and private companies	338	136	-59.8
Airlines companies	125	24	-80.8
Others	112	71	-65
Total	6,664	2,340	-65

Prior to the war, the provision of subsidised fuel, both to the population and to key sectors, represented a major burden on the government's budget. In 2014, fuel subsidies amounted to more than USD 2.2 billion, of which 37.6% (USD 838.5 million) was for the electricity

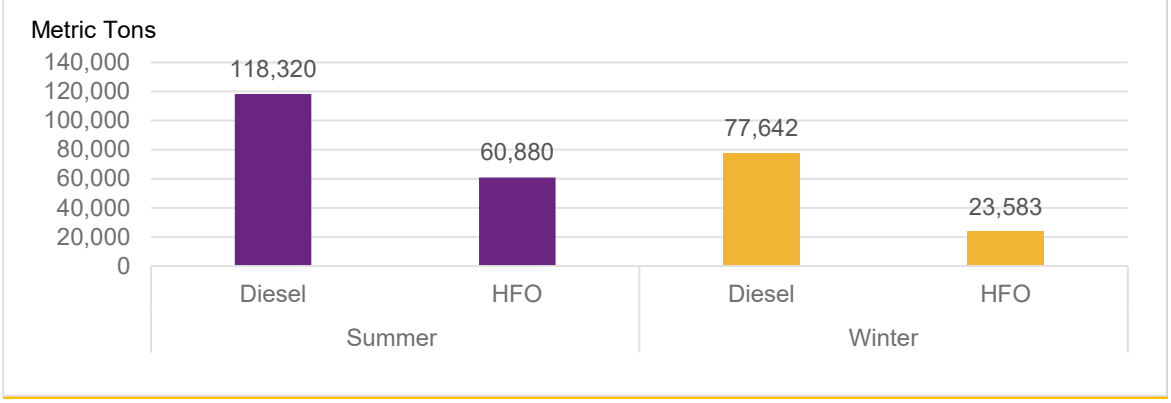
[7] Aden Refinery Company.
[8] MoPIC, 2016.
[9] Also known as Yemen Oil Products Distribution Company.
[10] MoPIC, 2016.

sector.[11] Even now, the prices at which fuel is sold to public power plants have not yet been liberalised, making subsidies a major financial constraint for the government. This, combined with the collapse in supply resulting from the war as well as the low collection rate has meant that the government has not been able to supply sufficient fuel to the electricity sector.

In 2018, in an attempt to remove the fuel supply monopoly, the government allowed the private sector to import fuel and distribute it in the market. There are now several local importers in Yemen.[12] The government also created a committee to be responsible for tendering for the fuel needed for the electricity sector. This committee consists of members from the Aden Refinery Company, Ministry of Electricity and Energy, Yemen Petroleum Company (YPC) - Aden branch, among other entities. In the initial period of its operation, in 2018, the committee succeeded in purchasing fuel for the electricity sector at lower prices. However, the inability of the government to pay the private importers their dues in a timely manner made private importers unwilling to apply for further tenders, which led to a fuel supply crisis in the electricity sector again. The problems of imports are further compounded by the instability of the exchange rate and the inability of fuel importers to obtain foreign currency from local banks or to transfer it abroad to exporters.

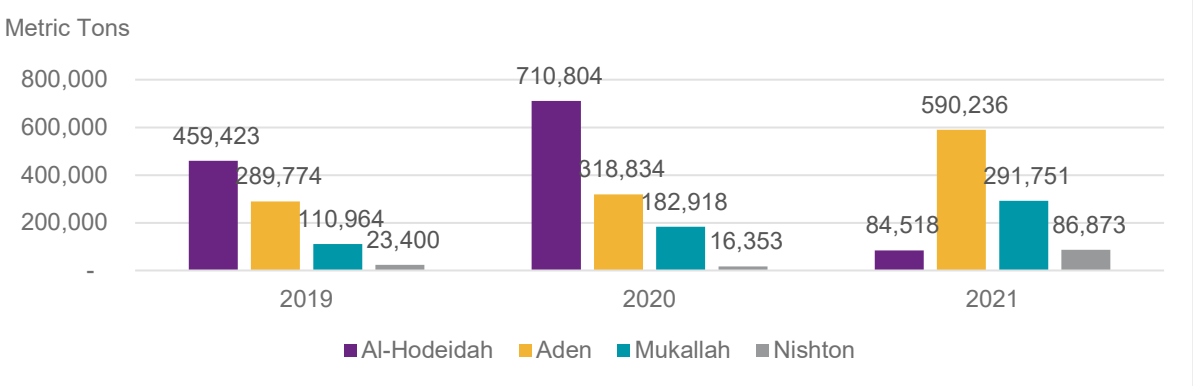
Since 2018, Saudi Arabia has supported the electricity sector in Yemen through the provision of two fuel grants. In late 2018 and during 2019, Saudi Arabia granted the Yemeni electricity sector 190,391 metric tons of diesel and 86,021 metric tons of heavy fuel oil (HFO).[13] In early 2021, Saudi Arabia pledged to support the Yemeni electricity sector with 909,591 tons of diesel and 351,304 tons of HFO.[14] By July 2021, three batches had been received (198,253 metric tons of diesel and 104,021 metric tons of HFO).[15] This fuel is being distributed to more than 80 power plants in government-controlled areas through dedicated committees that ensure an effective fuel supply to the power plants. Priority is being given to large-scale power plants that ensure grid stability as well as to private generators from whom PEC purchases electricity. Figure 1 shows the amount of fuel needed for the power plants in the IRG controlled areas in winter and summer, while Figure 2 shows the fuel imports through the Yemeni ports during the first quarters of the last three years.

Figure 1 Fuel needs for the power plants



[11] MoPIC, 2016.
[12] This can be compared to the situation before the war when there were several international companies who apply for tenders to supply the fuel at competitive prices.
[13] In addition to the Saudi grants, the UAE, in September 2019, also granted 127,470 metric tons of diesel.
[14] Unlike previous grants, this fuel must be purchased at the local rate in Saudi, which means the grant/subsidy value is the difference between the international and the local rate in Saudi Arabia.
[15] Saudi Fuel Grant Platform, 2021.

Figure 2 Fuel imports through Yemeni ports[16]



4.1.2 Existing proposals for reform and suggested priorities

There are two approaches to tackling the fuel supply problem that the country faces:

(i) Major projects

Most existing plans for improving access to fuel focus on large, capital-intensive projects that will add to the existing sources of fuel. Two projects have been considered:

1. Rehabilitation of Aden Refinery
2. Investing in a Regasification and Storage Unit in Aden

Aden Refinery is old and deteriorated during the war although some rehabilitation has taken place. If resources could be found for completing its rehabilitation, it would, in theory, be possible for Aden Refinery to produce significant volumes of petroleum products for the local market and beyond. This could dramatically improve fuel supply and reduce the foreign exchange burden of importing fuel (or dependence on fuel grants). However, there are major challenges with this proposal. First, it would be necessary to secure a reliable supply of crude oil. This could come from Marib or from Hadhramout export terminal, but these are not close by and transportation would add to the cost of supply. It is far from clear whether the costs of refining oil domestically in a coastal location that does not have its own crude oil supply will be lower than the costs of importing fuel. Moreover, such an initiative would require large-scale investment.

Investing in a Floating Storage and Regasification Unit (FSRU)[17] or onshore Liquified Natural Gas (LNG) import infrastructure is an innovative approach to shifting power generation from liquid fossil fuel to natural gas. Such a shift could potentially significantly reduce the costs of electricity generation, especially for the gas-fired power plants in Aden. Moreover, such an investment would be less vulnerable to threats to its fuel supply associated with the ongoing conflict. However, again, this would be a huge investment and would require private sector participation. Passing the Public-Private Partnership (PPP) Law and associated regulations would be necessary to provide the private sector with the basis to participate (see Box 3). Even then, to attract private investors to such a project requires the off-taker of electricity to have financial credibility. If electricity will be sold at below cost, this would not be sustainable in the longer-term. Thus, the feasibility of this solution depends, in large part, on tariff reforms (discussed below) and on its ability to supply other clients e.g., industries who can afford to pay the full commercial price.

[16] Supreme Economic Council, 2021.
[17] The FSRU is a quicker solution and requires lower investment compared to the onshore infrastructure. The FSRU can be rented for specific period.

(ii) Changing incentives to lower the cost of supply and encourage efficient use

Fuel grants provide a mechanism of continuing electricity supply at low prices without a major increase in the indebtedness of the government. However, such grants are not a sustainable solution to Yemen's fuel supply problems.

Indeed, the quantity of electricity that can be supplied at subsidised prices is determined, in large part, by the size of the fuel grant rather than by the actual demand for electricity. Specifically, private importers are willing to import as much fuel as Yemen needs if (and only if) they are able to sell it for commercial prices. Indeed, they already import fuel, but instead of selling it for electricity supply, they sell it in the local markets. Currently, tariffs lie far below the cost of electricity supply, making importation of fuel for generating electricity unprofitable. If tariffs were made to reflect full costs, this could dramatically increase supply, as generators would be able to source fuel and run at full capacity. We show in the next section that existing capacity is running at a very low level, opening up the prospect of a significant increase in supply, if fuel were to be available.[18] However, such an approach would also have implications for affordability as electricity prices would rise significantly, which could have political ramifications. In our discussion of tariffs below, a model is presented that might overcome some of these challenges.

More generally, the current mechanisms for fuel importation effectively preclude the implementation of value for money procedures, leading to significantly higher costs. Specifically, the government, through the central bank, are not able to provide Letters of Credit to the importers because of the severe fiscal constraints facing the government. Without a Letter of Credit, most international exporters are not willing to export fuel to the government. This tends to give an advantage to local importers with political connections who have access to alternative, informal mechanisms for guaranteeing payment. If an importer has a *de facto* monopoly, it allows them to charge very high prices for the fuel they supply. The Saudi fuel grant temporarily solves this problem by providing an alternative source of supply.

A longer-term solution would be for the government to create – and fund – a special escrow account for fuel imports. Then, when PEC or any other public body wished to import fuel, it could request tenders from international firms. International firms would be willing to bid and compete for such tenders because they could be confident of getting paid because a bank could issue a Letter of Credit to the escrow account. This would enable international exporters to deliver fuel with confidence that the escrow account would pay. By facilitating the use of Letters of Credit and stimulating international competition for the supply of fuel, the government would receive significantly better prices for the fuel that it imports, although it would still remain constrained by the available of funds for fuel imports.

[18] This assumes that the low-capacity utilisation is entirely due to fuel shortages. It is likely that a significant part of the low utilisation is due to technical failures which require investment in rehabilitation. Nonetheless, it seems likely that removing fuel shortages would give rise to a substantial increase in generation.

Box 3 Public-private partnerships in practice: The case of Tanzania's Songas

Public-private partnerships can be effective tools for fostering private sector participation in innovative infrastructure investment, service provision and reform in the energy sector. The methodologies used vary depending on the country context and should be tailored according to the specific context to be effective.[19] **The main building blocks of effective PPPs are**:

1. **Enabling institutions that are strong** through every stage of the project cycle; including managing risks, building government reputation as a credible investment partner, and ensuring contractual commitments are fulfilled.
2. **A regulatory framework** which facilitates proper planning, as well as a legislative framework that provides a clear, fair, predictable, and stable legal environment, and a clear definition of what is meant by a PPP.
3. **Use of regulations for planning and procurement.** PPP units can be an effective institutional tool for planning, including assessing affordability, fiscal impact, risk management and value for money, and for overseeing procurement.
4. **Good fiscal accounting and reporting framework**, which is crucial for good financial management and the success of a PPP programme.[20]

In the mid-1990s the United Republic of Tanzania had several failed IPP contracts due to a non-competitive procurement process that resulted in costly contracts which became embroiled in corruption charges. After lengthy court battles, Tanzania adopted a new policy that allowed the public utility to play a leading role in the development of generation projects through a competitive procurement-based PPP model. Bids were invited under the 1991 Power System Master Plan, which resulted in the Songas gas power project. Commissioned 16 years ago, Songas was conceived as a least-cost power supply project and has become a world-class example of a successful energy PPP in Africa. Its success is based on:

1. Careful review and approval of the project in 2001, followed by financial close and construction.
2. Good institutional management and investor relationships, improving the government's reputation and resulting in timely implementation of the project.
3. Fiscal accounting, enabling the Tanzanian government to maintain ownership of approximately 40% through shares held by public entities (TANESCO, TPDC, TDFL).

The partnership provided approximately USD 72 million to the government through dividends, USD 63 million in corporate tax, and saved the economy more than USD 5 billion since its operations began. It demonstrated the commitment by the Ministry of Energy to provide affordable and reliable power. The success also created a pathway for future PPPs and other investments by boosting confidence that Tanzania is a safe place for investment with the necessary regulatory environment and institutional capacity for successful projects.[21]

[19] World Bank, PPP LRC.
[20] Chaponda, 2013.
[21] ESI Africa, 2020.

4.2 Generation

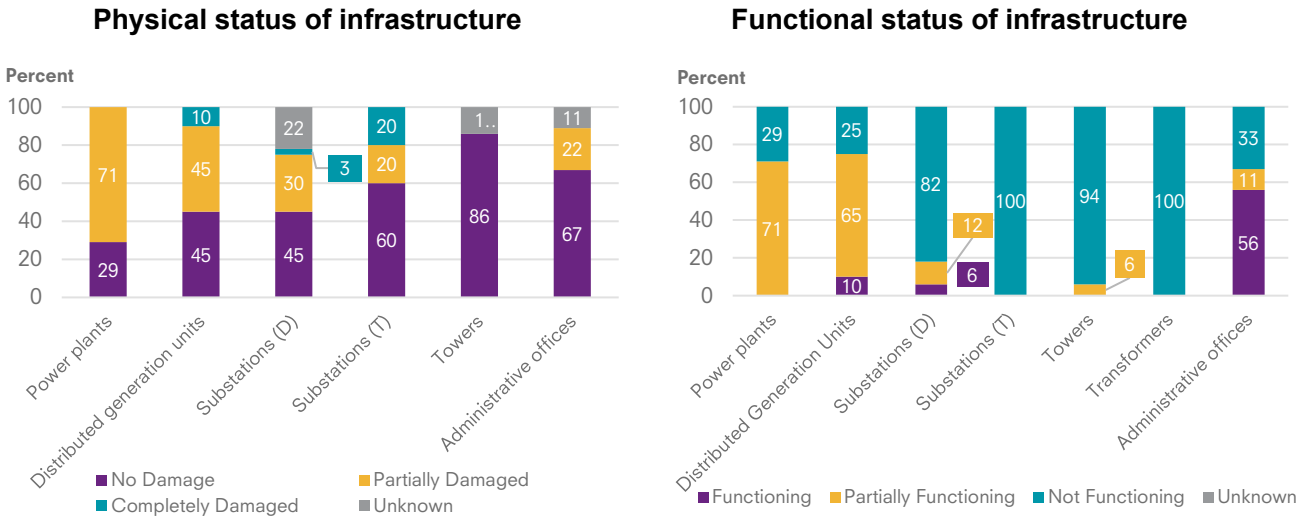
4.2.1 Understanding the current reality[22]

Prior to the commencement of the war, Yemen's public electricity generation system was already suffering from numerous problems. Many of the power stations were old and in a poor state of repair, with minimal levels of investment for many years. With the exception of the large, 340MW gas power plant in Marib, almost the entire electricity system was operated on diesel or HFO at great cost. Tariffs are extremely low – far below the cost of production – leading to large subsidies which burdened the national budget. These subsidies also made it difficult for the national utility, PEC, to raise capital to invest in new plants or rehabilitate old ones, perpetuating the poor state of the infrastructure. The grid infrastructure was also relatively old and in a poor state of repair. Before the war, numerous studies conducted by international consultancy firms (e.g., Fichtner; McKinsey; Lahmeyer International[23]) proposed major levels of investment in both generation and upgrades in transmission and distribution systems around the country, none of which came to fruition.

Significant parts of the generation capacity have been damaged or destroyed by the war. The same is true for major elements of the transmission system, in particular, the line connecting the Marib power station to Sana'a and the rest of the country. Distribution networks in local cities have also been heavily damaged.

The World Bank's Dynamic Needs Assessment (2020) shows that over a quarter of the assessed power plants are not functioning and most of the remainder have experienced at least partial damage.[24] The transmission system has effectively collapsed entirely and there is also extensive damage to the distribution network making most of it non-functional. Figure 3 shows the physical and functional assessment of power sector infrastructure.

Figure 3 Physical and functional status of the power sector infrastructure[25]



[22] This section draws on the analysis by Almohamadi (2021).
[23] Lahmeyer International GmbH operates now under the name of Tractebel Engineering GmbH
[24] World Bank, 2020b.
[25] World Bank, 2020b.

In government-controlled areas total generation capacity now amounts to around 1,181 MW. In some areas, there are no functioning power plants at all (see Box 4).

Box 4 Life with limited power: The experience of Taiz governate

Taiz governorate is located in southwestern Yemen and, with 3.4 million people, is the third largest governorate in terms of the population. Before the war, it was a commercial and industrial hub, with a wide variety of economic activities including food processing, packing, cement manufacture, etc.[26]

Prior to the war, Taiz had two power plants - Al-Mokha (160 MW) and Osifera (16 MW) – both connected to the national grid and with total energy demand of around 111MW.[27] Due to the war, the national grid collapsed and the power plants and associated assets were damaged and looted. The fuel shortage, as well as the lack of maintenance and rehabilitation, has meant that the power plants have not functioned since the outbreak of the war (except for a few limited occasions).

Consequently, solar systems have been the source of electricity for the majority of people. Several businesses have started selling solar panels, batteries, lamps, inverters, charge controllers, and accessories. Most people can only afford to purchase small systems for lighting and charging mobiles purposes, so the market is flooded with poor quality products. The 12 Volt DC solar systems (without inverters) have become popular and so many suppliers have started selling 12 Volt DC appliances (e.g., fans, TVs, etc). The limited electricity available usually does not power home appliances, so families have to wash clothes by hand, buy limited amounts of groceries as it is difficult to store food in refrigerators, and buy ice blocks from shops if they want to drink cold water/juices.

At the same time, private investors have installed diesel generators in several locations supplying electricity at a commercial tariff of up to 400 YER/kWh, in addition to subscription fees of around 1,000 YER paid every 2 weeks (as of May 2021). Only businesses and people with high incomes can benefit from this service. The PEC branches in Taiz regulate the prices charged by private generators and require them to light the main streets to improve security. Large industries rely on their own diesel generators, but diesel is not always available, while many farmers have replaced their diesel pumps with solar-powered water pumps.

A significant part of all the electricity provided is purchased by PEC from local diesel generators through power purchase agreements. Table 2 shows the share of publicly provided and privately purchased electricity by governorate for the government-controlled areas of the country.

[26] UN Habitat, 2020.
[27] MoEE, 2018; RCREEE, 2017b.

Table 2 Installed vs. available capacity of power plants, 2021[28]

Area	Installed capacity (MW)	Available capacity (MW)[29]	PEC power plants (MW)	Purchased energy (MW)	Max demand (MW)
Abyan (includes Lodar)	76.65	40.1	22.1	18	70
Aden	618.8	265.2	150.2	115	560
Al-Mahrah	64.2	46.15	46.15	0	60
Hadhramout - Alsahel	287.5	206	101	105	350
Hadhramout - Alwadi	210.5	131.5	81.5	50	
Lahj	65	48	16	32	70
Marib	432.2	397	345	52	85
Shabwah	53.96	42.7	14.7	28	70
Socotra	4.5	4.5	4.5	0	10
Taiz (Al-Mokha)	160	0	0	0	20
Total	**1,973**	**1,181**	**781**	**400**	**1,295**

Many of the functional generation facilities are severely underutilised. This is partially due to damage, difficulties in obtaining equipment for repairs and maintenance, and fuel shortages. Table 3 shows the utilisation of the power plants by governorate.[30] Typically, utilisation is around 50% - in other words, many power plants are idle much of the time, primarily due to lack of fuel and inappropriate maintenance.

Table 3 Capacity utilisation of power plants by governate in 2020[31]

Area	Available capacity (MW)	Theoretical max output (MWh)	Sent energy (MWh)	Capacity usage %
Abyan (including Lodar)	39.7	347,772	167,479	48%
Aden	279	2,444,040	1,595,971	65%
Al-Dale'a	0	0	26,420[32]	
Al-Mahrah	41	359,160	182,084	51%
Hadhramout - Alsahel	213	1,865,880	939,193	50%
Hadhramout - Alwadi	106.1	929,436	750,028	81%
Lahj	54.7	479,172	213,189	44%
Marib	410	3,591,600	618,979	16.7 (61%)[33]
Shabwah	39	341,640	140,931	41%
Socatra	4.5	N/A	N/A	-
Total	**1,187.00**	**10,358,700.00**	**4,634,274.00**	**50% (55%)**

[28] PEC, written communication (data of 2021).
[29] Although the available capacities of the power plants are far below the installed capacity, the actual capacities are less than the available capacity, e.g., only 45 MW out of 345 MW is evacuated from the Marib power plant due to the limited capacity of the transmission lines.
[30] This is the sent energy as a share of the maximum electricity output of the available capacity.
[31] PEC data 2021.
[32] Al-Dalea receives the electricity from Aden then resent it to the local grid.
[33] Considering the available capacity in Marib only 45 MW.

The difficulties in accessing fuel for generation creates a financial burden for the government. However, this is exacerbated by the fact that the current electricity tariffs are a small fraction of the high cost of electricity supply. Table 4 shows the currently applicable tariff schedule. Tariffs have not been adjusted since 2010, more than a decade ago (apart from a recent upwards revision of the commercial, industrial, public buildings and water pumps tariff).

Table 4 Electricity tariffs by category of consumer[34]

Type of consumers	Old Tariff		New Tariff (since 2020)	
	Block	Yemeni Rial (YER)[35]/kilowatt hour (kWh)	Block	YER/kWh
Urban houses	0 - 200 kWh	6	0 - 200 kWh	6
	201 – 350 kWh	9	201 – 350 kWh	9
	351 – 700 kWh	12	351 – 700 kWh	12
	More than 700 kWh	19	More than 700 kWh	19
Rural houses	0 - 100 kWh	9	0 - 100 kWh	9
	More than 100 kWh	19	More than 100 kWh	19
Commercial (small)	Increasing tariff	22,25,30	Uniform rate	50
Commercial (large)	Uniform rate	30	Uniform rate	70
Hotels (small)	Increasing tariff	22,25,30	Uniform rate	70
Hotels (large)	Uniform rate	30	Uniform rate	70
Agriculture	Uniform rate	30	Uniform rate	60
Industries (small)	Uniform rate	22	Uniform rate	70
Industries (large)	Uniform rate	35	Uniform rate	70
Water corporation Pumps	Uniform rate	30	Uniform rate	70
Government (public buildings)	Uniform rate	30	Uniform rate	70
Mosques (Urban)	0 - 200 kWh	6	0 - 200 kWh	6
	201 – 350 kWh	9	201 – 350 kWh	9
	351 – 700 kWh	12	351 – 700 kWh	12
	More than 700 kWh	19	More than 700 kWh	19
Mosques (Rural)	0 - 100 kWh	9	0 - 100 kWh	9
	More than 100 kWh	19	More than 100 kWh	19

In 2020, the cost of producing electricity in Aden from existing power plants is YER 256 per kWh. Even the recently increased rates (mentioned above) cover about one third of production cost. The vast majority of residential consumers on the public grid are charged less than 10% of its production cost. The consequences of this for PEC's finances are severe. Table 5 shows the electricity sold in Aden broken down by category of customer. It also shows the rate at which customers were billed and what they actually paid, as well as the annual arrears accumulated as a result and the total arrears outstanding.

[34] PEC data 2021.
[35] The exchange rate was YER 940/USD in Aden as of May 2021. Due to the weak economic situation, which in turn led to exchange rate fluctuations and volatility, it exceeds YER1400/USD in November 2021, https://yemenexch.com/.

The overwhelming majority of Aden's 187,260 subscribers are residential. They typically consume 3,623 kWh of electricity each year. They are billed on average YER 19/kWh, but they only actually pay around two-thirds of the bill. As a result, they accumulated an additional YER 4.2 billion of debt in 2020. At the end of 2020, the accumulated arrears amounted to YER 36 billion for residential consumers in Aden. A much smaller number of large consumers are charged close to the new tariff of YER 70/kWh and almost all do pay this. However, the worst payers by far are government entities. Although each government entity consumes more electricity than the average large consumer and are charged almost the full rate, they pay only 12% of their bills. As a result, a further YER 30.5 billion has been accumulated in arrears by government entities. Overall, in Aden, the bills are little over one sixth of the actual cost of electricity – and little over a half of those bills are actually paid. Other governorates are in a similar position (see Annex 1). The collection rate in Abyan and Al-Dale'a is only around 30%. On average (across customer categories) YER 31/kWh is charged for electricity, but only 52% of this is paid, resulting in the annual accumulation of YER 36 billion in debt.

Table 5 Rates paid for electricity by consumer category in Aden in 2020[36]

Type of consumer	Number of subscribers	Sold electricity (kWh)	Average electricity sold per subscriber (kWh/sub)	Sales per unit (YER/ kWh)	Proportion of sales actually paid	Annual accumulation of arrears (YER million)	Total arrears (YER million)
Residential	177,653	643,607,973	3,623	19	66%	4,219	35,891
Large consumer	1,641	72,376,589	44,105	71	96%	199	721
Government	2,231	*119,390,496*	53,514	67	12%	6,981	30,555

4.2.2 Using existing infrastructure

There are two ways of improving performance using existing infrastructure:

(i) Using more of existing capacity

To use existing capacity more effectively, it is necessary to understand why this capacity is not used at present. There are two main reasons: first, many power plants and their associated distribution network have been damaged as a result of the war or have ceased to function as a result of a lack of maintenance; second, existing capacity does not run because of a lack of fuel. We put forward recommendations in both areas.

(ii) Rehabilitating existing facilities

PEC has a detailed list of power plants and is aware of the capacity of each facility. To allocate resources efficiently for rehabilitation, it is necessary to have a detailed costing for the work required for each power plant, as well as a costing for the rehabilitation of each of the components of the distribution network in each city. Some elements of this have already been calculated. Table 6 shows the proposed capital expenditure programme for Aden generation stations. It shows both the existing level of capacity, the cost of rehabilitation, and the expected capacity after rehabilitation. Additional MW of capacity per USD million is also presented.

[36] Authors' calculations based on PEC data.

Table 6 Capital expenditure required for rehabilitating the power plants in Aden[37]

Power plant	Current capacity (MW)	Expected cost of rehabilitation (USD)	Expected generation capacity after maintenance (MW)	Additional MW/USD million
Al-Hiswa	40-45	12,583,696-13,583,696	100-110	4.78
Al-Hiswa 2 (gas)	0	10,000,000-15,000,000	50	4
Al-Mansora	27	3,000,000	45	6
Khormaksar	0	720,000- 1,200,000	5	5.2
Al-Mala'ab	10	450,000	18	23.1
Shehenaz	20		20	
Hojef 2	1.6		3.2	
Al-Tawahi	3.2		4	
Total	**101.8-106.8**	**26,753,696 – 33,233,696**	**245-255.2**	

Given the shortage of capital for public investment, two criteria should be used for determining the most appropriate investments:

(I) Capacity added per USD million of rehabilitation

Some investments, both in generation and distribution, are likely to give rise to far more capacity being brought online than others. For example, where there is a functioning generator but the transformer or other equipment in the distribution network is broken thus preventing connection to customers, a relatively small investment may be able to bring online substantial capacity. PEC should do a detailed accounting for each of the feeder areas in each city of the cost of rehabilitation and the amount of capacity that would be brought online. This would allow interventions to be ranked by the capacity added per USD invested.

(II) Customers added per USD million of rehabilitation

In some instances, the addition of a certain amount of capacity will only serve a small number of large consumers (e.g., where the rehabilitation would supply a major industrial area). In others, rehabilitation will enable the connection of a large number of additional consumers. Policymakers will need to make judgements about the priority that should be placed on small vs large consumers. On the one hand, prioritising residential supply will benefit more people; on the other, providing power to businesses and larger users may have a stronger benefit for the economy and the preservation of jobs. To help policymakers make these judgements, rehabilitation investments should also indicate the number of additional consumers that each package of works would serve (and, if possible, the value of economic activity undertaken by these consumers).

For on-grid supply, undertaking the works that have the highest value for money in terms of capacity added and customers connected is likely to provide the most effective short-term boost in capacity.

[37] Interview with PEC staff and authors' calculations.

4.2.3 Expanding capacity

In addition to efforts to rehabilitate existing generation, transmission, and distribution capabilities, it will be important to expand capacity through new investments. There are two ways in which this can happen:

(i) Major public projects

In 2018, the IRG of Yemen signed a memorandum of understanding with General Electric to construct a large gas-fired power plant in Aden (264MW). This project will have a dramatic impact on the availability of power for customers in the city. The project is supervised by PetroMasila and is a major government priority. Work is ongoing to construct the necessary transmission lines to evacuate the power from the plant and to do the commissioning process. There has also been discussion about the possibility of constructing a Regasification and Storage Unit for Aden which would enable the use of cheaper gas-fired power along the lines of similar projects in the region. However, the capital requirements for such a project would likely be extremely high and no detailed plan has yet been released.

Given the sharp decline in the cost of solar PV technologies over the last decade and the huge potential of solar energy resources in Yemen, the government also needs to pay more attention to encourage the investment in utility-scale solar power plants and to attract private investments. Adopting strong policies, a comprehensive regulatory framework, and support schemes such as Feed-in Tariff or competitive auctions, as well as reducing the potential risks and providing acceptable guarantees for the private investors will play an important role to accelerate the investments in the market.

These projects notwithstanding, expanding capacity through major public projects during a time of conflict is extremely difficult. The capital budget is highly constrained by the many demands placed upon it. At the same time, the size of the budget is necessarily much lower due to the collapse in revenue, both from oil exports and tax and non-tax revenue from the population. Together, this means that the country must resort to extensive borrowing for such projects. However, access to credit from international lenders is also highly constrained during the conflict and the rates at which the government can borrow are much higher. Access to international finance is also affected by macroeconomic instability, high inflation, and the volatility in the exchange rate. The government is therefore reliant on concessional lenders, either from the region or international actors. Accommodating the procedures and interests of such lenders can absorb a great deal of scarce expertise in government.

For these reasons, while there is a plethora of plans for major investment in the sector dating from before the war, few have come to fruition. Given the ongoing conflict, it seems likely that getting to financial closure for such major investments will continue to be difficult, and challenges associated with implementing major infrastructure projects during a period of ongoing conflict will remain. (By way of comparison, Annex 2 provides details on the approach taken by Egypt to tackle its power sector problems, however, Egypt's context is quite different from that facing Yemen at present).

(ii) Encouraging private investment in additional supply

An alternative, complementary, approach to expanding supply would be to encourage the private sector – both domestic and foreign – to invest in electricity supply. Around 34% of all the available capacity comes from private producers. The power purchase agreements pay typically around USD 0.038/kWh of *capacity*, not of electricity produced. This means that if the government is not able to deliver fuel to the private generators, the generators still get paid as though they were producing at 100% capacity. Under this arrangement, producers

have no incentive for expansion since they are paid for full capacity regardless.[38] There is also no incentive for the private generator owner to minimise fuel use, for example by hybridising generation with solar PV. What is needed is a mechanism for changing the incentives of private operators so that it is profitable for them to expand supply if demand exists, and which makes it more profitable for them to minimise fuel use. One approach would be to experiment with a concession system in selected areas. Box 5 details the steps in establishing a concession system.

Box 5 Concession system for supply of electricity

Setting up a concession system can follow the following step-by-step approach:

1. Conduct a detailed assessment of the rehabilitation needs of existing generation plants and the distribution network in the selected areas to work out the extent of damage and the costs for repair in each area.
2. After an accurate picture of the costs is available, it would be possible to tender one or more concessions, encouraging international participation to promote transparency and competition, but also ensuring that local firms participate in bids e.g., as joint venture partners.
3. Winners would be responsible for investing in the distribution network in their area, but ownership of the network would stay with PEC. Concessionaires would be reimbursed for verified investments in the local network.
4. The concessionaire would be responsible for billing and collection and would be allowed to introduce technology to enable customers or feeder areas to be switched off if payment is not made.
5. To ensure affordability and political acceptability, tariffs would be held at PEC levels for power provided by public facilities.
6. Concessions would be allowed to invest in generation and to feed this power into the distribution network. When PEC power fails, or is lower than demand, the concessionaire can supply the additional power. Concessionaires would be responsible for sourcing and paying for the fuel for any additional generation provided.
7. The tariff the concessionaire charges for this additional power would be determined by a formula agreed with PEC that reflects true costs (including fuel) plus a margin. Bills for customers would show this transparently.
8. Concessions would have Key Performance Indicators (KPIs) which they would be required to achieve as part of their contract. These would be independently monitored with their performance published annually.
9. Concessions would last for several years (to encourage investment) and would re-tendered on their expiry to ensure accountability for performance.

Such an approach would combine the advantages of a public network with the flexibility and innovation provided by the private sector. Experience from several countries suggests that raising tariffs is extremely unpopular politically and should be done with great caution. At the same time, evidence suggests that there is often a pent-up demand for additional electricity and that some customers are willing to pay the additional cost for electricity when they need it. In some of the Houthi-controlled areas, the problem of supply has been ‘solved’ by turning over generation and distribution entirely to the private sector. This provides substantial new investment and an improvement in supply – but also extremely high costs for consumers and duplication of distribution networks. A concession model would incentivise private investment

[38] They have also little incentive to supply more electricity to PEC since the government is heavily in arrears in the payment of private generators.

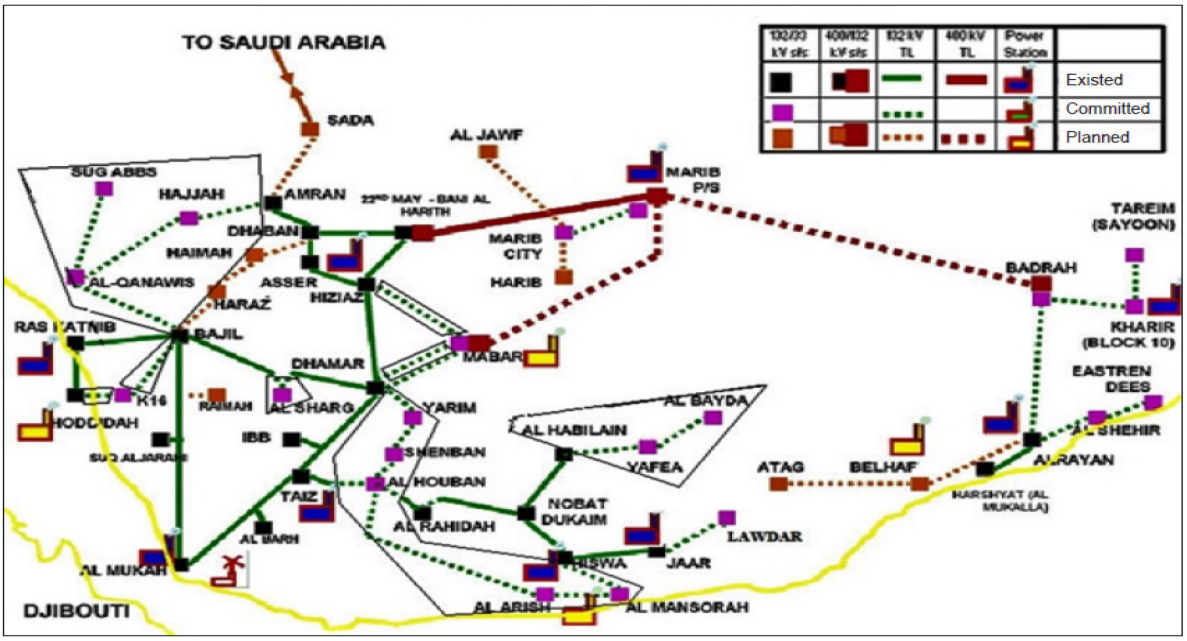
but would also avoid duplication of the distribution network, ensure that tariffs for public electricity remain low, and encourage concessionaires to reduce fuel usage.

4.3 Transmission and distribution

4.3.1 Transmission

The grid in Yemen mainly uses 132 kV transmission lines; there is only one double circuit 400kV transmission line connecting Marib gas-fired power plant to Sana'a (Bani Al-Harth). Figure 4 shows the pre-war transmission network. Prior to the war, the national grid was transmitting electricity from all the key power plants in Yemen to 13 cities. However, due to the war, the transmission system has collapsed, especially in the northern and central governorates where most of the transmission lines are located.

Figure 4 Yemen's transmission grid before the war[39]



Currently, there are only two major transmission lines functioning in the government-controlled areas, namely Al-Hiswa (in Aden)-Ja'ar (in Abyan), 70km, and Al-Hiswa-Nobat Kudaim-Alhabilain (Lahj), 97 km. The Aden-Ja'ar transmission line is functioning with a single circuit (240 mm^2). The current cross-section of this line is small, so it needs to be replaced with a line with a bigger cross-section (e.g., 400 mm^2) double circuit to transmit high power. The PEC estimated that the cost of rehabilitating this line is around USD 5.138 million, including the costs of installation and testing equipment. As the transmission line Aden-Ja'ar was installed in 1987, it also needs rehabilitation to remedy corrosion issues. There are towers that need to be replaced at an estimated cost of USD 2.170 million. There was also a plan to extend this line from Ja'ar to reach Lodar (also called Lawdar) – the PEC even purchased the necessary equipment before the war; all that is needed are the funds to cover the installation costs. The Aden-Al-Habilain transmission line is also functioning with a single circuit only; it had formerly been double circuit but was damaged in the war. There is also a need to rehabilitate this line to transmit more power to Lahj and Al-Dale'a.

More recently, a transmission line is being constructed to connect Al-Hiswa with Al-Mansora. The project was supposed to be funded by the Kuwait Fund for Development, but it was

[39] See Ministry of Electricity and Energy website.

suspended due to the war. The government is therefore financing the construction of the transmission line from Al-Hiswa to Al-Mansora to connect with the newly constructed Petro-Masila power plant (264 MW).

In addition to the above projects, there is also a 132 kV transmission line project being implemented in Hadhramout – from Kharir (block 10) to the Qorio area. The length of this transmission line is 27 km, including two substations (S/S) with a capacity of 80 MVA each. This project will help to solve the issue of the voltage drop associated with transmitting power to these areas. In Marib, there is also a project which aims to upgrade the 132 kV transmission grid to better utilise the energy produced by Marib gas power plant by installing larger substations and related equipment. Table 7 shows PEC's assessment of the most urgent needs for transmission projects.

Table 7 PEC priority transmission projects[40]

#	Needs	Name of substations/transmission lines
1.	Protection relays and testing equipment	132 kV Al-Hiswa, Ga'ar, Dukim and Alhabilain S/S
2.	DC batteries and chargers (110&50 Volt)	132 kV Al-Hiswa, Ga'ar, Dukim and Alhabilain S/S
3.	Overhaul maintenance for 132 kV Gas Insulated Switchgear (GIS)	132 kV Al-Hiswa S/S
4.	Overhaul maintenance for 132 kV GIS	132 kV Al-Mokha S/S
5.	Protection relays and testing equipment	400 kV Marib S/S
6.	33 kV & 11 kV switchgears	132/33/11 kV Alhabilain S/S
7.	132 kV double circuit transmission line/single core 400mm^2 (70km) - All Aluminium Alloy Conductors (AAAC)	Aden/Abyan (Al-Hiswa/Ga'ar)
8.	132 kV double circuit transmission line/400 mm^2 (conductor & insulator with accessories)	Al-Hiswa/Dukim/Alhabilain
9.	Underground cables (24 km, 400 kV) -	Sahn Alwatan – Marib

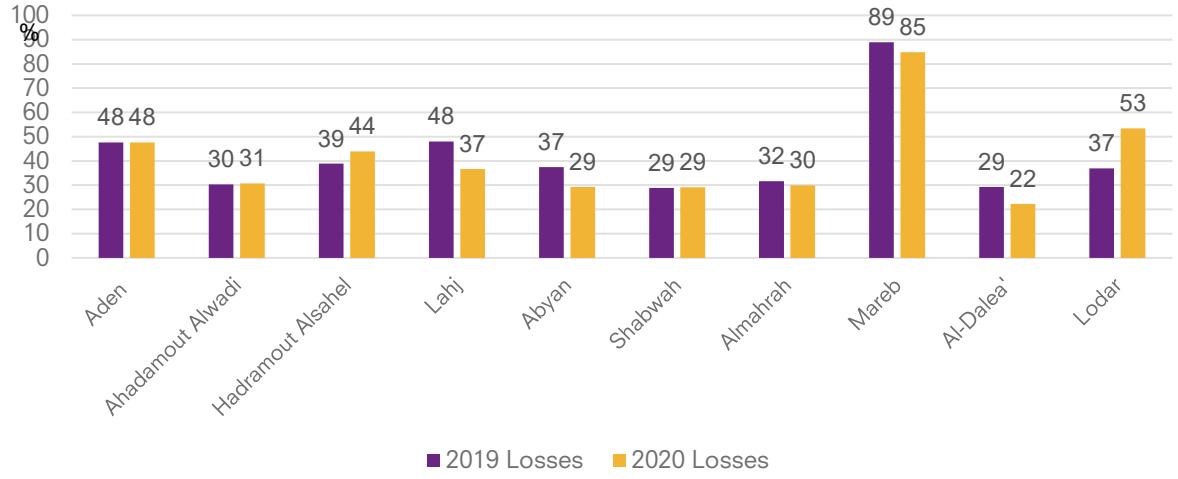
4.3.2 Distribution[41]

Before the war, only around 40% of households were connected to the distribution grid, the lowest rate in the Middle East and North Africa region. Despite its limited coverage, the distribution sector was responsible for most of the technical and non-technical losses in sector, which amounted to 39% in 2013.

Due to the war, the distribution sector suffered from severe damage and looting and deteriorated from the already low level at the beginning of the war. Some of the remaining assets are extremely overloaded contributing to even higher losses (see Figure 5). A key priority, therefore, will be the rehabilitation and upgrading of the distribution network to lower the costs of the distribution of electricity. Studies have recommended rehabilitating distribution networks in Aden and other cities (e.g., Fitchner 2010), but progress to date has been limited.

[40] PEC, 2021.
[41] The distribution network operates at 33 kV and below (i.e.,11 kV, 0.4 kV and 220 V).

Figure 5 Electricity losses in 2019 and 2020[42]



In Aden, for example, the distribution network needs considerable investment to be able the absorb the full capacity that will be generated by the PetroMasila power plant. Table 8 summaries the top priorities for distribution investments related to the 33 kV voltage level. It is estimated that these requirements will cost around USD 19.7 million in addition to the cost of the installations and civil work. Moreover, the 11 kV and lower voltage level also need to be enhanced and rehabilitated.

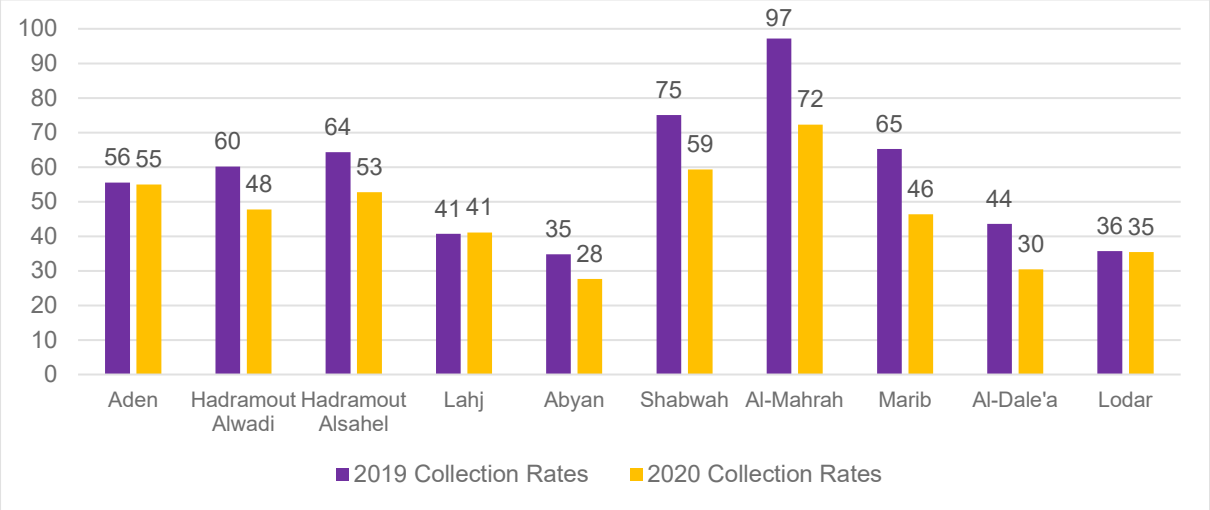
Table 8 Top priorities for the 33 kV distribution network in Aden[43]

#	Materials needed	
1.	Establish 132/33 kV and 33/11 kV Substation in Al-Hiswa	Power transformer (132/33 kV, 100 MVA)
		33 kV Switchgear
		11 kV Switchgear
		Power transformers (2*31.5 MVA, 33/11 kV)
2.	Establish 33/11 kV Substation in the location of Al-Mansora substation (132/33 kV)	2 Switchgears (33 kV)
		Power transformers (2*31.5 MVA, 33/11 kV)
		33 kV Switchgear
		11 kV Switchgear
3.	33 kV Switchgear in Almala'ab	
4.	Establish 33/11 kV Substation in the location of Khormaksar substation (132/33 kV)	2 Switchgears (33 kV)
		Power transformers (2*31.5 MVA, 33/11 kV)
		11 kV Switchgear
5.	2*3*800 mm^2 cable (CU/XLPE, 7 km, total 42 km) from Khormaksar - Hojef	
	33 kV Switchgear	
	Power transformers (2*31.5 MVA, 33/11 kV)	
6.	Power transformers (2*31.5 MVA, 33/11 kV), in Al-Mansorah	
7.	2*3*800 mm^2 cable (CU/XLPE, 2.5 km, total 15 km) from Khormaksar - Shehenaz	
8.	Fiber optic cable (15 km)	
9.	Cable (CU/XLPE, 15 km, 400 mm^2, 33 kV) for connecting the new substations	
10.	Cable (CU/XLPE, 15 km, 630 mm^2, 33 kV) for connecting the new substations	
11.	Other accessories for the substations and cables	

[42] PEC data on losses.
[43] PEC Aden, 2021.

PEC branches in the regions are responsible for the distribution of electricity to the end-users, as well as for all commercial/retail-related tasks, including reading the meters, billing and collecting payments. Unfortunately, illegal connections and non-payment of electricity bills have increased dramatically since the onset of the war leading to very low collection rates (see Figure 6). The financial constraints of PEC branches have made it impossible for them to provide energy meters to new subscribers. This has led to many individuals to connect illegally as their only way of accessing the national grid. Even where meters exist, the performance of meter readers has been very poor, with large numbers of zero and estimated readings. It has also been extremely difficult to collect payment from customers, particularly from households. As a result of lack of stability and security, some subscribers refuse to pay bills and even attack inspection teams if they try to disconnect the electricity service. Many public facilities also fail to pay their electricity bills.

Figure 6 Collection rates in 2019 and 2020



4.3.3 Priorities for reform

The key priorities for reform in the transmission and distribution sectors are outlined in Box 6.

Box 6 Priorities for reform in the transmission and distribution sectors

Transmission

- Rehabilitate the transmission lines and substations that were damaged during the war, especially those which will have a major impact on service (e.g., Hiswa-Ja'ar, Hiswa – Noubat kodim- Alhabilain).
- Upgrade the transmission assets to be able to absorb the electricity coming from the new generation projects (e.g., the 264 MW PetroMasila power plant) as well as to match the loads resulting from urban expansion and population displacement.
- Follow up with the donors/lenders about pledges the aims to support the rehabilitation of key transmission projects.
- Conduct periodic protective maintenance, especially for the assets that are located in the areas where the corrosion risks are high e.g., in the coastal areas.

Distribution

- Assess the damage and the needs in the distribution sector in the governorates.
- Upgrade the distribution infrastructure to match current and future generation capacities; this will also reduce electricity losses.
- Provide energy meters to all new subscribers to prevent customers from making illegal connections.
- Collaborate with financial institutions to collect payments of electricity bills.
- Consider providing performance-related incentives to the PEC staff who are responsible for the meter reading and billing process.
- Improve the capacity of PEC's staff, especially those who play an important role in reducing electricity losses and improving collection.
- Consider distributing more energy to the consumers who are committed to pay the bills (e.g., businesses) as this will improve the financial position of PEC.

5 Governance and regulation: Structural reforms

5.1 Decentralisation of PEC

Theoretically, PEC is one utility that supplies electricity for all of Yemen. But in practice, PEC is already split between Houthi-controlled areas and areas under government control. Furthermore, some PEC regional offices in the governorates that are controlled by the government are not in reality managed by central PEC based in Aden. Prior to the war, all PEC regional offices in the governorates were (at least in principle) managed by PEC to enable central management of the entire electricity system and revenues were collected by PEC at the governorate level and remitted to the centre. However, with the exception of a small number of governorates, this is no longer true. PEC offices in several governorates, even in government-controlled areas, tend to keep the revenue that they collect and do not pay the cost of the fuel that was purchased by the government.

One response to this situation would be to attempt to reassert control over such governorates, enforcing their compliance. In reality, this is likely to make little difference. The central government has few sanctions that it can apply. Having a central PEC is a good idea – particularly for planning and regulatory purposes – but, for operational purposes, governorates are likely to cooperate with the centre only in so far as they see real value in doing so. Until a comprehensive peace settlement has been agreed, it is unlikely that all regional PEC branches will be able to return to the organisational structure prior to the war.

The current fragmented state of the utility is unfortunate, but understandable given the circumstances. However, the failure to formally recognise the current situation makes matters worse. This is true because it is still formally and legally the case that the central PEC must approve new generation capacity and investments in transmission and distribution assets. Legally, regional PEC offices do not have the authority to innovate and invest to try and improve provision. This was illustrated recently when the PEC in Taiz governorate attempted to experiment with greater private sector involvement in provision. This was not necessarily a bad idea from an operational perspective, but it was unpopular with certain segments of the population. The legal affairs department of the local council informed the governor that the reform was not legal because it had not been approved by the regulatory board and the Minister of Electricity and Energy. This episode sent a strong signal to senior officials in regional PECs that experimentation may result in legal sanction, whereas, in the current context, local level experimentation may be exactly what is needed.

One solution to this problem would be to improve the institution capacity and to legally empower PEC branches in at least some selected governorates with the authority to operate as a concession. They would not own the generation and distribution assets – but they would be allowed to use them – and, critically, they would be given the permission to invest in new generation capacity and distribution infrastructure, as well as to rehabilitate existing infrastructure, on a commercial basis. Such concessions would be given the right, formally, to keep the revenues from bill collection and to enforce collection. The tariff would be regulated by central PEC – but would be adjusted – possibly over a period of time – to reflect costs (see more on tariff reform below).

Such an arrangement would also give concessions a strong incentive to minimise costs and operate more efficiently, as well as to seek out and serve customers. Concessions would be a separate legal entity with a long-tenure (perhaps 20 years) and would be allowed to borrow to fund their investments. Large generation assets would continue to be approved by central

PEC, along with the operation of transmission infrastructure across governorates and, critically, the impartial regulation of tariffs.

Note that this proposal is not for a comprehensive, legal unbundling of the sector as often proposed in the 'standard model' of power sector reform. Such a process would take a long time and experience of the implementation of this model has been mixed at best.[44] Rather, what is proposed is a selective, legalisation of the *de facto* autonomous status of PEC in certain governorates. Allowing them the authority to conduct their own affairs legally might encourage creative solutions and facilitate investment much more rapidly than an approach that relies on waiting for resources from the centre or operating outside of the law.

5.2 Concessions

As noted above, a more radical approach would be to delineate a set of private concessions for particular areas. These would enable the concession holders to rehabilitate existing generation, add new generation facilities, and invest in the distribution network to improve supply. However, concession holders will not be willing to do this unless they have a legally binding long-term contract and that they are able to increase tariffs to cover the costs of the improved service (see below). Establishing concessions could be time consuming, since it would be necessary to precisely delineate which assets were under the control of the concessionaire and which remained the responsibility of PEC and to put this into a legally binding form.

Nonetheless, the advantage of a concession mechanism is that it would allow the injection of external capital into the process of rehabilitation and maintenance. In addition, concessions tend to have a much better performance regarding billing and collection. Billing and collection are sensitive issues. However, international experience suggests that the acceptability of comprehensive billing and collection is closely related to the quality of service provided. Hence a concession would have strong incentives to both undertake parallel improvements in service quality and in billing and collection to maximise their return from investments.

If a concession model was adopted, then it is likely that many of the PEC operational staff would be transferred to the concessionaire. PEC – either centrally, or regionally if PEC is decentralised – would then play the role of planner and regulator. The creation of a concession might also be sensitive, particularly since the concessionaire would almost certainly wish to reserve the right to make adjustments, including possible downsizing, of staffing at some point. Conversely, a concessionaire is more likely to be able to pay good salaries and to pay salaries on time, so some staff might prefer such a transition. The government would have to manage any such structure change with good communication and political sensitivity.

5.3 Procurement

Law No. (23) of 2007 Concerning Tenders, Auctions and Government Storehouses is the law used for procurement in the electricity sector. Currently, the Cabinet of Ministers is responsible for approving tenders above YER 250 million, with the Ministry of Electricity and Energy responsible for tenders between YER 150 million and YER 250 million; and PEC responsible for tenders between YER 50 million and YER 150 million. PEC regional branches are responsible for all tenders below YER 50 million. The depreciation of the Yemeni Rial over the course of more than a decade, and particularly since the onset of the war, means that these procurement thresholds no longer make much sense. It would be

[44] Ghanadan & Eberhard, 2007; Gratwick & Eberhard, 2008; McCulloch et al., 2017.

better to adjust them upwards or institute a mechanism whereby they would maintain their value over time.

However, there are more significant flaws in the procurement process than simply the level of the financial thresholds. As noted above, the PEC branches in many governorates are effectively operating autonomously. Some governorates that have financial resources, e.g., oil-producing governorates, are directly contracting energy producers or undertaking procurements.

Moreover, the electricity crisis in recent years means that private energy producers have a strong bargaining position relative to the PEC. This results in a relatively uncompetitive bidding process and higher prices for consumers. As noted above when discussing fuel procurement, the government has attempted to introduce greater competition and this had a beneficial impact on prices. But unless it can find a mechanism for guaranteeing payment of contracts, the likelihood is that the number of bidders will be small and consequently higher cost than might otherwise be the case.

To address the problems with the procurement system the government could:

- Modify the thresholds of the tenders announced by MoEE and PEC and its regional branches to reflect markets rate of the Yemeni Rial against the USD.
- Provide the Supreme Energy Council with more authority to expedite procurement processes.
- Facilitate the use of Letters of Credit to pay manufacturers (as discussed above)
- Publish contracts to ensure transparency over awards
- Consider mechanisms for establishing guaranteed forms of payment to maximise competition.
- Prepare a shortlist of trusted manufacturers and allow for flexible release of payments to manufacturers.
- Allow PEC to conduct direct orders from manufacturers to reduce costs, especially for the big orders and when the savings will be high.

5.4 Power purchase agreements

Regardless of whether concessions are created or not, there is likely to be a continued need to purchase power from small-scale private generators.[45] However, the current PPA arrangements are inefficient and costly. The existence of the Saudi fuel grant provides PEC with an opportunity to change the nature of the PPAs with the private sector. It should consider:

- Ensuring that payment is by kWh actually delivered (not capacity).
- Exploring the options of providing a two-tier PPA in which a much higher rate is provided for suppliers that will generate electricity using their own fuel.
- Enabling and encouraging private suppliers to invest in hybrid options e.g., with solar by guaranteeing them a rate based on diesel for an interim period (so that if investments are made in cheaper sources of energy, the supplier can reap the profit from this investment).

[45] If a concession is created, the concessionaire may choose to buy out generators in their area or to enter into a PPA with them.

- Encourage private suppliers to produce electricity from cheaper fuel (e.g., natural gas) and renewable energy sources, which are abundant in Yemen.

The implementation of new PPAs will require delicate negotiations with suppliers. The government and PEC should be clear that maintaining the *status quo* is not an option and that suppliers that refuse to engage meaningfully in the reform agenda will be deprioritised for future PPAs. However, the overall approach should be a constructive one; the aim is to shift to a mechanism that will provide higher (not lower) profits for suppliers, conditional on improved supply and performance. Table 9 shows the cost of purchased energy, not including fuel, per month in 2021 (data up until September 2021).

Table 9 Monthly cost of purchased energy in the governates in 2021[46]

Governorates	Capacity (MW)	Cost of purchased energy (USD)
Abyan	18	453,168
Aden	115	2,760,901
Hadhramout - Alshahel	105	3,087,504
Hadhramout - Alwadi	50	1,915,200
Lahj	32	790,560
Marib	52	1,287,360
Shabwah	28	763,200
Total	**400**	**11,057,893**

PEC should also survey the generation capabilities of major manufacturing and industrial facilities. Many of these have invested in their own supply to ensure reliability but may have the capabilities to export surplus power to the grid. Consideration should be given to signing PPAs with such entities to supplement the power being provided by bespoke diesel power suppliers.

All of these improvements in the performance of private suppliers will only be possible if there are complementary changes in the structure of tariffs, as discussed below.

5.5 Tariff reform at the margin

As noted above, tariffs for electricity are extremely low relative to the cost of supply, with the result that economic subsidies are very high. However, such subsidies are calculated assuming that the government has to pay the international price for imported fuel (i.e., diesel and HFO). In fact, the Saudi fuel grant means that financial subsidies are currently much less, since the government is only required to pay at the Saudi local rate for fuel – only amounts of fuel additional to this have to be sourced at the international price.

While the existence of the fuel grant makes it possible in theory to maintain low electricity tariffs without imposing an intolerable strain on the budget, this is clearly not a sustainable long-term solution. Ultimately, a financially sustainable electricity sector in Yemen should have tariffs which reflect, at least to some extent, the actual cost of electricity supply. However, in the extremely challenging circumstances faced by people in Yemen today, a significant increase in tariffs is unlikely to be politically acceptable.

Fortunately, there is a potential approach that may enable tariffs to reflect costs in part, while protecting households from large tariff increases. This approach is known generically as “reform at the margin” because it entails maintaining existing tariffs, but allowing electricity

[46] PEC, 2021.

providers in certain places, under certain conditions, or at certain times to provide additional electricity – over and above that which is currently being provided – at commercial prices.

Annex 3 provides a detailed description for how such tariff reforms might be operationalised.

6 Improving access and quality for those off the grid in Yemen

This section looks at the reality of provision to populations who are off the public grid, including the impact of the decline of the public grid on water and health services. It describes the various projects which are being undertaken to provide electricity to off-grid populations and some of the key lessons learned from these exercises. Finally, it puts forward a set of proposals about how the IRG might better meet the electricity needs of the off-grid population.

6.1 The current reality

Before the beginning of the war in 2015, around 40% of Yemen's population had access to electricity, which was far below the regional average of 85%. There were huge inequalities in access between rural and urban areas. While only around a quarter of the population lives in urban areas, around 85% of the urban population has access to electricity. By contrast, only 23% of the rural population had access to electricity. Of those with electricity access, around half of the population was connected to the public grid, while the other half gained access through other private electricity sources including diesel generators operating for few hours for lighting purposes and to power less-intensive energy appliances.[47]

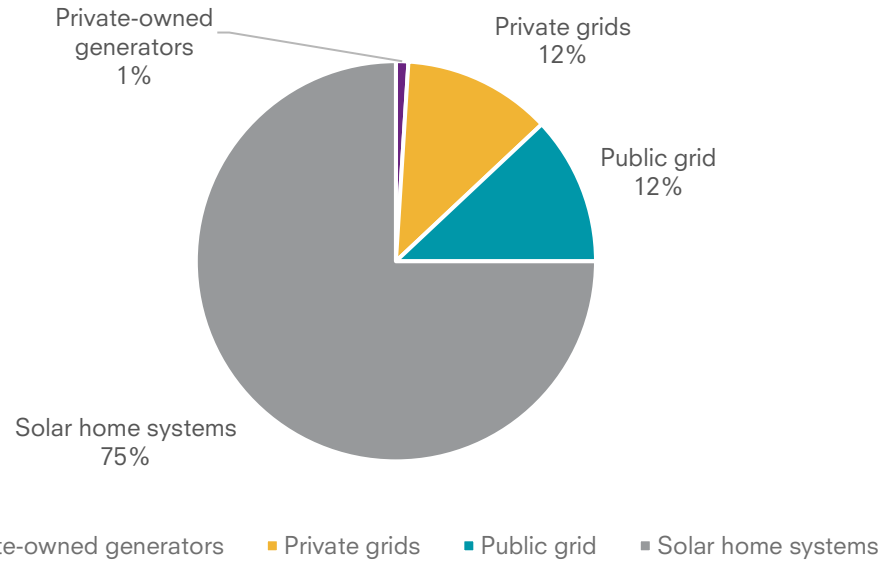
The onset of the war in 2015 had a catastrophic impact upon electricity provision. The public network almost collapsed. A large share of the generation, transmission, and distribution capacity has been destroyed or damaged, 55% of electricity infrastructure was damaged; 8% completely destroyed.[48] A recent phone survey commissioned by the World Bank found that, as of the end of 2019, only around 12% of the population now rely mainly on public electricity. Night-time light emissions visible from satellite imagery indicate a reduction in electricity consumption of about 75%.

This collapse primarily affected the public grid supply of electricity. One of the consequences has been the rapid growth of off-grid solar supply. In effect, on-grid customers have become off-grid and have looked to solar home systems to try and provide some minimal level of coverage. As a result, three-quarters of households with access to electricity obtain their power from solar systems (see Figure 7). However, the dominance of solar is not a story of success, but rather of the collapse of the grid, such that solar power represents a much larger share of a dramatically reduced overall supply.

There are also major regional differences across the country. In Houthi-controlled areas, the public grid has, in effect, collapsed. This has resulted in dramatic expansion of solar power – but with high prices and little or no regulation of quality, The authorities in these areas have simply let the private sector supply electricity to the population at market rates. By contrast, in the government-controlled areas, the public system still functions in the majority of the cities, providing electricity for a few hours each day with heavily subsidised tariffs as before. As a result, the expansion of solar home systems (or indeed other renewables) has been much slower, especially in the urban areas.

[47] UNDP, 2014.
[48] World Bank, 2019.

Figure 7 Main source of electricity for households in 2019[49]



In off-grid areas – both rural and peri-urban areas – electricity provision has traditionally been limited. However, electricity is vital for many services. We examine the impact on two critical issues, water and health services, below.

6.2 Water services

One of the most important uses of electricity in Yemen is pumping water. Yemen is one of the driest countries on earth with a per capita water availability roughly 1.3% of the world average.[50] Water for households in cities and towns is obtained by pumping water from reservoirs to water stations (or water fields) which then pump the water to individual homes. For example, there are three main water fields in Aden: Al-Manasrah, Bir Nasser and Bir Ahmed, all supplied by the Bir Ahmed reservoir. In 2017, it was reported that the cost of damage to Aden's water system reached USD 59 million. In July 2018, water pumps were only operating for 8 hours per day compared to 22 hours per day pre-conflict. In April 2021, due to the structural damage, frequent power outages and ballooning fuel prices, water pumps were only functioning every three days for 2-4 hours.[51]

The combination of war damage and the loss of electricity has been dire. It is estimated that 16 million people need humanitarian assistance to have access to drinkable water, basic sanitation, and hygiene facilities; out of these 16 million, there are 11.6 million people in urgent need. The collapse of water and sanitation systems in urban areas, deteriorating water supply and sanitation conditions in rural areas, and lack of personal hygiene and access to drinkable water all contributed to cholera outbreaks in several areas in Yemen. Many water systems that depend on electricity or fuel within conflict-affected areas either depend on humanitarian support or are not functioning. Therefore, access to clean and safe water has significantly decreased, which has led many people to use unimproved water sources because they lack the means to purchase trucked or bottled water. Drinking unimproved water carries a high risk of diarrheal disease which, in turn, causes malnutrition and an increased risk of death. In addition, the high number of displaced people within the high-risk districts puts additional pressure on water supply.[52]

[49] World Bank, 2020a.
[50] Conflict and Environment Observatory, 2021.
[51] UN OCHA, 2021b.
[52] UN OCHA, 2017.

In rural areas, water pumps play the same crucial role pumping water from underground cisterns, pits and other water harvesting mechanisms. The scarcity and high price of fuel have made pumping by using traditional diesel pumps difficult and expensive. However, it has also induced very rapid growth in the use of solar water pumps. While this has provided desperately needed power in a context where electricity has been lacking, it has also created other problems.

Agriculture in Yemen is largely dependent on pumping groundwater. For many years the groundwater extraction rate has been well in excess of its recharge rate, raising concerns about long-term water availability. Recent evidence suggests that the rapid growth in the use of solar water pumps around the country is leading to an acceleration of groundwater depletion. The Conflict and Environmental Observatory indicated the lowest level of groundwater in the west of Yemen[53] since satellite records began in 2002, and the sharp recent decline in groundwater coincides with the expansion of solar water pumps.[54] In the short run, the wider use of solar water pumps may help with the severe food security challenges facing the country, but a strategy will need to be developed to ensure the sustainable use of groundwater to avoid much worse outcomes in the future.

6.3 Health services

The majority of the Yemeni population have limited access to appropriate health care services, both because of the security situation in many areas and due to the socio-economic hardships faced by many Yemenis. It is estimated that about 19.7 million people are in need of health assistance.[55]

However, obtaining support is extremely difficult because many health facilities are not functional. As of July 2020, about 50% of Health Facilities were fully functional, 37% partially functional and 13% non-functional.[56] The electricity and fuel supply were among the major issues that affect the sustainable operation in the health sector. Table 10 shows the extent to which health facilities have had to close across all governorates. Overall, around 12% of facilities in urban and rural areas are shut, but there are strong regional variations.

[53] The study looks at areas west of 47 degrees – home to 90% of the country's population.
[54] Conflict and Environment Observatory, 2021.
[55] UN OCHA, 2019.
[56] WHO, 2020b.

Table 10 Number of health facilities in Yemen[57]

Governorate	Overall		Urban		Rural	
	Open	Closed	Open	Closed	Open	Closed
Abyan	162	29	17	0	145	29
Aden	55	14	50	14	5	-
Al-Dale'a	196	12	11	0	185	12
Al-Mahrah	48	20	12	3	36	17
Hadhramout	365	77	91	9	274	68
Lahj	242	22	11	1	231	21
Marib	89	53	12	5	77	48
Shabwah	202	23	28	2	174	21
Socotra	25	2	4	1	21	1
Taiz	439	57	39	6	400	51
Amran	293	17	20	2	273	15
Dhamar	373	12	21	0	352	12
Al-Hodeidah	407	53	59	9	348	44
Sa'adah	141	45	10	2	131	43
Sana'a	295	26	8	1	287	25
Al-Baydha	138	47	12	1	126	46
Al-Mahwit	201	5	7	0	194	5
Hajjah	307	49	14	5	293	44
IBB	375	29	34	1	341	28
Raymah	147	9	2	0	145	9
Al-Jawf	80	41	12	3	68	38
Sana'a City	81	12	73	10	8	2
Total	**4,661**	**654**	**547**	**75**	**4,114**	**579**

Even for those health facilities that remain open, it is difficult for them to provide the same level of service, with many reporting difficulties in health workers getting transport and in transporting medicines and supplies.[58] Around 19.7 million people are in need of health assistance and almost 20% of the Yemen's 333 districts have no doctors.[59] As a consequence, the majority of public health facilities are currently relying on the humanitarian support that is provided by international organisations such as the World Health Organization (WHO), United Nations Office for Projects Services (UNOPS) and a wide variety of NGOs.

6.4 Existing projects

The IRG has been working with international partners to restore essential services, including through facilitating their access to electricity. This has been done through several projects, including the World Bank-funded Yemen Emergency Electricity Access Project and Yemen Integrated Urban Emergency Services Project (implemented by UNOPS) and Enhanced Rural Resilience in Yemen (ERRY) Project (implemented by UNDP).

(I) World Bank/UNOPS Yemen Emergency Electricity Access Project and Yemen Integrated Urban Emergency Services Project

The USD 50 million World Bank Yemen Emergency Electricity Access Project has focused on two areas: the provision of small-scale solar solutions for rural and peri-urban households

[57] UN OCHA, 2020.
[58] WHO, 2020a.
[59] Reliefweb, 2019.

and restoring electricity supply to critical service facilities in peri-urban and rural areas. The latter is primarily achieved through the provision of rooftop solar solutions, but in some cases has entailed the rehabilitation of diesel generators or power rentals. To complement this rural project, the World Bank also launched a USD 150 million Yemen Integrated Emergency Urban Services project which includes a component to restore electricity to key urban services. Table 11 shows the overall progress of the combined projects until May 2021.

Table 11 Number of public facilities supported by the Emergency Electricity Access Programme and the Yemen Integrated Emergency Urban Services Project[60]

Facilities	Urban	Rural	Total[61]
Schools	81	233	314
Universities	6	0	6
Health centres/facilities	98	218	316
Hospitals	43	0	43
Water field/wells	5	37	42
Street-lights	5	0	5
Total	**238**	**488**	**726**

Projects have been implemented across the entire country and have focused on health centres and facilities, hospitals, and schools. In addition, some projects have rehabilitated major water fields in urban areas (and individual wells in rural areas), as well as street-lights and universities. Almost all of the urban projects have been completed, whereas over half of the rural projects are still under tender or in the implementation stage. Typical solar PV projects are small in the rural areas – around 5-20 kWp. However, the projects in urban areas are much larger – particularly where a diesel generator is being rehabilitated or power rental supplied (e.g., for hospitals and water wells). Overall, the project has added 5.4 MWp of power in rural areas, 5.8 MWp of solar in urban areas, plus 4.8 MVA of diesel power as well as buying 24,140 MWh of rental power.

It is also possible to get a sense of the distribution of projects, as well as the extent to which they meet the need. Table 12 focuses on health facilities in the governorates in Yemen. It shows both the number of health facilities overall, as well as the number of projects undertaken by UNOPS in the health sector in these governorates.

[60] Authors' calculations based on data from UNOPS.
[61] Includes the projects that are under implementation and those in the tendering process (two projects in the urban areas and 273 projects in rural areas).

Table 12 Number of health facilities and UNOPS interventions in the health sector[62]

Governorates	No. of health facilities[63]			UNOPS Interventions in the Health Sector		
	Rural	Urban	Total	Rural	Urban	Total
Abyan	174	17	191	7	2	9
Aden	5	64	69	0	26	26
Al-Dale'a	197	11	208	13	2	15
Almhahrah	53	15	68	17	0	17
Hadhramout	342	100	442	24	13	37
Lahj	252	12	264	12	0	12
Marib	125	17	142	0	0	0
Shabwah	195	30	225	13	0	13
Socatra	22	5	27	0	0	0
Taiz	451	45	496	10	0	10
Amran	289	22	311	9	5	14
Dhamar	364	21	385	16	7	23
Al-Hodeidah	393	68	461	2	17	19
Sa'adah	175	12	187	11	2	13
Sana'a	312	9	321	16	0	16
Al-Baydha	172	13	185	10	0	10
Al-Mahwit	199	7	206	12	0	12
Hajjah	338	19	357	4	0	4
IBB	369	36	405	11	0	11
Raymah	155	2	157	3	0	3
Al-Jawf	106	16	122	0	0	0
Sana'a City	10	83	93	0	26	26
Total	**4,698**	**624**	**5,322**	**190**	**100**	**290**

Table 12 shows that solar PV systems in the health sector totalled in 290 until May 2021. However, the need is still huge as the installed systems (including those under implementation) represent only 5% of the number of facilities. Since almost half of the facilities are struggling with access to energy, this suggests that, while the project has clearly been successful, it has only covered a small fraction of the need.

(II) UNDP Enhanced Rural Resilience in Yemen (ERRY) Project

The phase one of the ERRY project is a three-year project funded by the European Union and implemented by four UN agencies: the United Nations Development Programme (UNDP), the International Labour Organization (ILO), the World Food Programme (WFP), and the Food and Agriculture Organization (FAO). The overarching objective of the programme is to enhance the resilience and self-reliance of crisis-affected rural communities by supporting livelihoods stabilisation and recovery, local governance, and improving access to sustainable energy. The first phase of the ERRY Project was implemented in four governorates: Abyan, Hajjah, Al-Hodeidah, and Lahj.

UNDP's project documentation states that the project has provided over 200 solar energy systems for schools, health facilities, and offices. In addition, solar-powered refrigerators have been provided to health facilities to enable them to store vaccines, and four solar-powered water systems were installed in cholera-affected locations to provide over 6,000 individuals access to clean water. The project has also equipped small businesses and

[62] UNOPS, 2021
[63] UN OCHA, 2020.

marketplaces with solar energy systems and encourage women and youth to establish solar micro-grid businesses.[64]

UNDP have also undertaken an impact assessment and lesson learning exercise based on the experience of ERRY (UNDP, 2019). They report significant improvements due to the project including:

- **Education**: a large increase in the number of students, improved attendance, better learning environment.
- **Health**: increased number of out-patients, improved obstetric and basic emergency care, reduced travel costs.
- **Water, sanitation, and hygiene (WASH)**: functioning water supplies, reduced time to collect water, reduced water borne disease, reduced operation and maintenance costs.
- **Agriculture**: reduced operation and maintenance costs, contributed to sustaining farming jobs.
- **Productive assets, markets, and employment**: increased number of hours able to work, improved work and living conditions, significant savings relative to diesel.

In addition to the above major projects by the World Bank/UNOPS, UNICEF[65] and UNDP and its partner agencies, there are a wide range of other initiatives. For example, the Norwegian Refugee Council installed 37 solar-powered water supply systems in both rural and urban areas in six governorates in 2020. Other agencies focus on ensuring fuel supply for existing diesel generators in facilities. For example, in 2019, WHO in coordination with health authorities and partners, delivered more than 12 million litres of fuel to 189 health facilities in all governorates, helping to keep the health system functional and provide access to health care.[66]

6.5 Extending the approach to off-grid power

There are two aspects to consider when approaching how off-grid power in Yemen could be extended and improved. The first relates to the provision for critical services and facilities; the second concerns the provision of off-grid power to households and small businesses.

6.5.1 Facilities provision

The projects described above by the World Bank/UNOPS, UNDP and others have made a real difference to the viability and operation of critical services in Yemen, notably water fields, hospitals and health facilities, and schools. However, as the figures illustrate, the current rate of provision is barely scratching the surface of the problem. Even the largest project of the World Bank/UNOPS has managed to support around 5% of the health facilities in the country; it seems likely that coverage of schools and water wells is similarly sparse. It is therefore welcome that in June 2021 the World Bank announced a further USD 50 million extension of the Yemen Integrated Urban Services Emergency Project (YIUSEP).

However, the challenge of the scale of the need remains a key problem. UNOPS has taken care to work closely with the relevant authorities throughout implementation of the projects to ensure that the locations chosen are both technically feasible and meet the needs of the maximum number of vulnerable and needy people. However, at the national level, it is

[64] UNDP, 2021.
[65] UNICEF Yemen, 2019.
[66] Reliefweb, 2019; UNICEF Yemen, 2019.

probably fair to say that the authorities have not prioritised off-grid provision in its overall approach to rehabilitation of the electricity sector. Rather the emphasis has been on the restoration of large-scale power infrastructure for urban areas. However, it is also essential that significant resources – both financial as well as policy and human resources – should be devoted to expanding and extending the roll-out of off-grid provision, particularly for critical services in rural areas. This is likely to have a much bigger humanitarian impact in the short-run and help to address the substantial inequalities across the country.

Going forward, the government should insist that donors not only devote their technological and management expertise to the delivery of improved services, but that they also help to reform and build Yemeni public institutions that have the capability to organise and deliver such services in the future, so that the role of ensuring equitable and effective service delivery for the entire population should gradually revert to Yemeni actors and institutions.

6.5.2 Households and small and medium-sized enterprises (SMEs) electricity provision

The World Bank projects, as well as the UNDP project and others, have tried to encourage the development of a private sector ecosystem around solar power. In Houthi-controlled areas, solar power has boomed. This is not a story of success, but rather one of desperation. The Houthi authorities liberalised the price of fuel in 2015 and, as a result, electricity generation from diesel has become extremely expensive. Consequently, those that could afford to purchase solar home systems have done so in order to obtain some modicum of electricity supply in an environment where the public grid has collapsed and diesel-fuelled supply is unaffordable.

The situation in areas controlled by the IRG is different. In those areas, the public electricity network still attempts to supply power, at least in certain areas. As a consequence, solar power has not spread as widely and quickly in areas that can still obtain power from the public grid.[67] However, if households and small and medium-sized enterprises (SMEs) invest in solar systems for their own purposes, this will boost their welfare and productivity immediately – much more quickly than the time that it will take to rehabilitate the public system. Furthermore, it provides households and SMEs with options. If public electricity is available, they can use it; if it is not, they can use electricity from their solar system. This allows them to obtain the amount of electricity that is consistent with their needs and their ability to pay. In addition, households and SMEs that invest in their own solar provision will reduce their demand for electricity from the grid. Since the cost of supply greatly exceeds the price at which electricity is sold, reduced demand improves the financial sustainability of PEC, enabling it to concentrate resources on delivering electricity where it is most needed.

For these reasons, the IRG should pro-actively encourage the development of standalone/mini-grid solar or hybrid systems for households and small businesses. Government can help by ensuring a policy environment that is conducive to off-grid solar power. Doing this will entail:

- Levying zero taxation on solar systems, including all parts of the system (not just solar panels) and, in particular, on deep-cycle batteries, inverters and cabling/connections necessary to construct effective systems.
- Ensuring zero customs duties on solar systems and, as important, quick transit times through customs for such systems.

[67] EADP, 2019.

- Providing households and SMEs with some way of identifying quality providers of solar systems. There are a huge number of poor-quality solar systems available, many of which are likely to break down after a short period of time. Adopting standards for imported products, or certifying providers based on transparent and objectively verified technical quality criteria and letting everyone know about such a certification scheme, will provide a valuable signal to those thinking of buying.
- Adopting a regulatory framework that promotes sustainable mini-grids and protects consumers' interests.
- Removing restrictions related to the import of solar panels and batteries, whether at the ports or during the transportation between governorates.

Re-orienting government focus towards the provision of essential services for all and encouraging and facilitating self-provision of solar systems will make a significant difference in meeting the needs of Yemeni households and businesses both on- and off the grid.

7 Conclusions and recommendations

The electricity system in Yemen is in a severe crisis. In the north and central governorates, the public grid has been severely damaged, leaving ordinary Yemenis to fend for themselves with expensive private/public electricity or solar home systems if they can afford them.[68] In government-controlled areas, the public grid still functions, albeit at a much-reduced level. Old assets, combined with extensive damage due to the war and severe financial constraints means that coverage is limited and reliability is poor, with frequent and long blackouts. While the PEC still functions, it is fragmented, with branches in several governorates working more closely with local councils. In an attempt to protect the public from further hardship, tariffs have been held at very low levels; but the consequence of this is that the utility is heavily loss-making and struggles to make the investments necessary even to rehabilitate existing facilities.

The government has managed to finance the construction of a major new power plant and transmission and distribution infrastructure in some cities (e.g., Aden, Hadhramout); when these are all commissioned, they will make a major difference to electricity supply. Moreover, the government's success in securing a further fuel grant from Saudi Arabia will enable the continuation of the existing level of supply without the need for a major tariff adjustment in the near term. The government is to be commended for its focus on the sector and its attempts to manage a complex crisis.

Nonetheless, there are some important weaknesses in the approach being taken towards the rehabilitation of the electricity sector. Specifically:

1. **It leaves out the bulk of the population.** The focus of efforts to improve the electricity supply has been on urban areas or those with financial resources, e.g., from the export of oil. Ensuring that all populations are included in the reform process is important, both for ensuring human development outcomes and to bolster trust in the government.
2. **It locks in dependence on fossil-fuel imports.** The focus of the response has been on large-scale power plants running on fossil fuels. Leaving aside concerns about climate change (which is inevitably a secondary concern given Yemen's humanitarian and energy crises), locking in electricity generation based on oil or gas leaves the government vulnerable to the exigencies of world prices for these commodities. A greater focus on renewables would not only be cheaper – it would also contribute to Yemen's energy security.
3. **It pushes the financial sustainability issue down the road but fails to solve it.** The government's success in obtaining a further Saudi fuel grant has given welcome relief to the sector. However, the fundamental issue of the costs of supply being far above the prices charged – and the resulting unsustainable financial position of PEC – has not disappeared. As soon as the fuel grant is finished, these problems will return.
4. **It is susceptible to corruption.** A focus on large-scale infrastructure projects inevitably raises the risk of corruption, particularly in an environment where the previous legal and bureaucratic controls in the procurement system no longer function well.
5. **It does not encourage the private sector to find more efficient solutions.** The current approach is focused on delivery by the state. While it is essential that the state delivers, particularly on things that the private sector cannot or will not do, it is equally

[68] The public electricity is available only in Sana'a city or Al-Hodeidah but with limited capacity.

important to encourage private actors to find more efficient solutions. In the current, financially constrained circumstances, the state may achieve as much (or more) by changing the incentives for private actors than through its own activities.

6. **It does not effectively engage citizens in designing and delivering the solutions/reforms.** Most of the discussions around energy policy have been between the government, investors, donor governments and international institutions. This approach runs the risk that some solutions or reforms adopted will not be acceptable to the population or may not be well matched with their needs.

The experience of other countries that have endured similar situations suggests that it is best first to focus on a combination of **rehabilitation of existing infrastructure** – particularly where small investments can make a big difference in either coverage or quality – as well as **facilitating small-scale, bottom-up investments by communities** to enable them to rapidly recover some degree of functionality. If Yemen wishes to achieve a far wider coverage of benefits from electrification (including in rural areas), improvements in reliability and a move towards a financial sustainable sector and a utility with the resources to maintain assets and invest for the future, it needs a new approach. Such an approach would need to:

- Engage communities in the reform process to ensure that the needs of all citizens are met.
- Reduce dependence on diesel and encourage greater exploitation of renewable resources.
- Facilitate greater private sector engagement and encourage competition to lower costs substantially.
- Ensure transparency and accountability for public investments and policies adopted.
- Strengthen institutional capacity in the energy sector, especially in energy planning, project implementation, and setting regulations and supporting policies.
- Provide a credible medium-term plan to move to financial sustainability.

7.1 Policy recommendations and the way forward

- Providing public resources for integrated packages of rehabilitation/new plant and associated transmission/distribution infrastructure, based on a **ranking of best return** (MWs added/USD spent).
- Ensure an **incentive for more efficient use of existing fuels** e.g., by revising the nature of PPAs.
- Encourage **switching to lower cost fossil fuels,** e.g., natural gas.
- Invest in zero 'fuel cost' **renewable solutions** e.g., solar and wind – both utility-scale and distributed and mini-grid solutions where appropriate. This requires creating an enabling environment for investment, including adopting a legal and regulatory framework and providing incentives and financing mechanisms.
- **Improve access to electricity** e.g., by identifying the rural off-grid areas with high electricity demand that will be feasible for private investments.
- Create a regulatory framework that allows commercial **supply at the margin** e.g., by operating concessions and allowing commercial tariffs at certain times of day or for specific consumers (e.g., businesses).
- Pilot mechanisms to **improve billing and collection** e.g., through introducing incentives for concessions or local utilities.

- Develop a **framework for future tariff reforms** and communicate how such reforms will be linked to improvements in service.
- **Publish contracts** for all energy investments and purchases.
- Devote far greater resources to **scaling up off-grid provision for community facilities** e.g., water pumping for household supply, health clinics, and hospitals.
- Leverage the existing linkages between MFIs, banks, accredited solar providers and community groups to **expand electricity for productive use** e.g., for farmers.

Annex 4 shows the benefits and challenges associated with a range of potential reforms.

The above recommendations represent a comprehensive agenda for rehabilitation and reform of the reform of the electricity sector in Yemen. Understandably, the overwhelming emphasis to date has been on the first of these activities – funding the rehabilitation of existing assets and investments in supply. However, for the reforms to lead to sustainable improvements, it is essential that the other actions are also tackled. Realistically, not all actions can be done at the same time. It is therefore proposed that the reforms should be sequenced as follows:

Immediate change

- Rehabilitation of the existing infrastructure
- Incentives for efficient use of fuel

The immediate priority is rehabilitation of existing generation, distribution, and transmission equipment. However, it is also essential to immediately start to improve incentives for efficient use of fuel, particularly by private providers, through renegotiation of PPAs.

Short-term reforms (within one year)

- Expansion of off-grid provision for facilities
- Preparation of a regulatory framework for concessions
- Billing and collection
- Publishing contracts

During the course of the first year, the government should clearly signal its intention to focus more on ensuring off-grid provision for public facilities, notably health centres and water fields. The government should work with international donors to expand this vital and effective programme of work. At the same time, it should prepare the regulatory basis for piloting concessions in PEC branches, or specific areas, and put in place mechanisms to support them in billing and enforcing collection and payment. Finally, the government should indicate its commitment to transparency and anti-corruption by publishing all public contracts for rehabilitation and new generation.

Medium-term reforms (within three years)

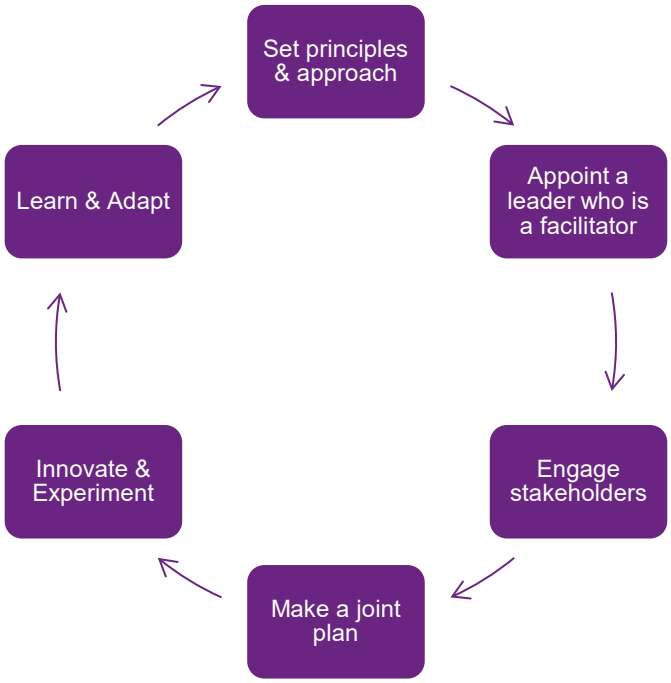
- Tariff reforms
- Switching fuels
- Expanding renewables for off-grid areas

Over the next three years, the government should develop a realistic forward plan for the rehabilitation of the sector. None of the aspirational plans written prior to the war are suitable – they simply do not reflect the reality of Yemen today. Rather, such plans should focus on achievable near-term solutions that can be funded primarily from domestic and diaspora resources, with the support of the international community. These include measures to shift

away from diesel to more efficient generation, scaling up of renewables solutions (notably utility-scale solar projects for the grid and distributed solar solutions for productive use) and developing and, critically, communicating a plan for gradual tariff reform linked with improvements in service delivery over time. Such a sequence of measures is feasible and sustainable and would result in significant improvements in the welfare of the Yemeni people.

Finally, a comprehensive reform process needs to start by identifying a set of approaches and principles (e.g., functionality, equity, and fiscal sustainability). To ensure effective implementation and acceptance, a senior political leader is needed to facilitate the reform possess, supported by technical and non-technical advisors. It is important to engage all the stakeholders to work together to develop a joint action plan for the reform. The stakeholders list should include technical and non-technical people from public and private sectors in addition to consumers. Pilot projects, experiments and innovative ideas should be considered during the reform process. Periodic evaluation of the reform process would enable learning and continuous improvements (see Figure 8).

Figure 8 Reform process cycle



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Annex 1 Rates paid for electricity by governorate in 2020[69]

Governorate	Number of subscribers	Sold energy (kWh)	Sales (YER)	Average electricity sold per subscriber (kWh/sub)	Sales per unit (YER/kWh)	Proportion of sales actually paid	Annual accumulation of arrears (YER million)	Total arrears (YER million)
Aden	187,260	835,375,058	25,644,114,215	4,461	31	55%	11,399	67,198
Hadhramout - Alwadi	115,156	519,422,700	15,944,002,660	4,511	31	48%	8,168	27,279
Hadhramout - Alsahel	134,598	527,092,220	17,322,277,856	3,916	33	53%	7,873	34,103
Lahj	86,292	135,095,933	4,018,784,735	1,566	30	41%	2,382	16,115
Abyan	37,422	94,302,636	2,682,709,779	2,520	28	28%	1,918	10,864
Shabwah	57,351	99,883,842	2,506,051,498	1,742	25	59%	1,080	3,816
Al-Dale'a	48,350	20,538,573	472,734,254	425	23	30%	301	3,407
Al Mahra	19,166	127,515,732	3,476,182,049	6,653	27	72%	843	2,296
Marib	21,105	94,239,441	3,494,271,636	4,465	37	46%	1,864	5,295
Lodar	27,618	15,975,791	353,689,384	578	22	35%	229	2,825
Total	**734,318**	**2,469,441,926**	**75,914,818,066**	**3,363**	**31**	**52%**	**36,057**	**173,199**

[69] Authors' calculations based on PEC data.

Annex 2 The power sector reform experience of Egypt[70]

The electricity sector in Egypt has been controlled by the government since its nationalization in 1962, although several IPPs were developed later. The institutional structure consists of the Ministry of Electricity and Renewable Energy (MERE), Electricity Utility and Consumer Protection Regulatory Agency (Egypt ERA), Egyptian Electricity Holding Company (EEHC) (includes 9 distribution and 6 generation companies), Egyptian Electricity Transmission Company (EETC) as well as three authorities responsible for renewable energy, nuclear and hydropower projects.

From 2011, Egypt experienced frequent electricity outages and severe shortages in energy supplies. Several factors have worsened this problem, including increased energy demand, a decline in natural gas production, and obsolete generation and transmission infrastructure, as well as limited investment in the energy sector due to the large debts owed to gas production companies (reaching USD 6.2 billion) which halted the development of newly discovered gas fields or the exploration of new oil and gas resources.

Since 2014, Egypt has undertaken major reforms to respond to the fuel and power shortages including:

1. **Adopting a gradual comprehensive fuel and electricity reform plan to ensure that prices reflect the cost of production by 2022**. This has been accompanied by a social protection system that provides cash transfers (and other non-energy consumer subsidies) to the poor. The reforms were announced publicly and the government attempted to build public consensus around the necessity of reform by providing clear justifications for the price increases.
2. **Prioritising increasing natural gas imports**. A new import facility was built on the Gulf of Suez (at El Shokhna) and two floating regasification units were built. In 2015, Egypt announced the discovery of large natural gas fields; these started production in 2018 which reduced gas imports significantly.
3. **Expanding generation capacity through a 'fast track' scheme for immediate projects and a longer-term development plan**. This included expediting the installation of a 3.2 GW gas power plant that was already planned and installing a new 3.6GW plant, as well as converting open cycle gas turbine plants to combined cycle plants. In addition, three 4.8GW combined-cycle power plants (costing Euro 6 billion) were added to the overall capacity, improving generation capacity dramatically.
4. **Accelerating the transition to renewable energy by encouraging independent private sector renewable energy projects.** Egypt passed Law no. 203/2014 which launched a feed-in-tariff programme for both solar photovoltaic (PV) and wind energy. This led to private sector development of 1,465 MW of solar PV (Benban Solar Complex) and 250 MW of wind projects in the Gulf of Suez from 2015 to 2017 and 1,500 MW by the end of 2019. These efforts increased total generation capacity to 58.4 GW by 2018/2019, while peak demand was 31.4 GW, providing a reserve margin or around 80%.
5. **Adopting a net metering programme** to encourage customers to install solar plants to satisfy all or part of their electricity needs and allowing them to feed any surplus into the grid.
6. **Rescheduling the accumulated debt** to foreign gas production companies

[70] KAPSARC, 2020; World Bank, 2020c.

The World Bank argues that the Egyptian experience of energy sector reform offers several useful lessons:

- Tariff reform requires prior improvements in power supply and service quality. This is an essential pre-requisite to build trust and credibility of subsidy reforms.
- Providing policy clarity through a medium-term reform timetable announced prior to the reform helps to reduce uncertainty.
- Coordination between electricity and gas sector planning and reform is critical as gas and electricity prices are closely related.
- It is necessary to have policy clarity regarding which sectors should be targeted for private sector investments (renewables and oil and gas in Egypt's case) versus those that will be retained for public sector investments. This helps to ensure stakeholder alignment, generate interest from the private sector, and secure an efficient bidding process with timely commissioning of assets.
- Strong political commitment combined with stable tenure of technocratic leadership makes it possible to take difficult sector reform decisions while seeing them through to implementation, despite the absence of strong civil society dialogue.

However, it is important to highlight certain unique factors that enabled Egypt to install additional generation over a short period:

- Egypt enjoys political and economic stability and good infrastructure, financing options and technical capacity.
- New discoveries of natural gas helped Egypt to enhance its generation capacities with further gas-fired power plants using cheap, locally available fuel.
- The existence of incentives and supporting policies and a low level of regulatory uncertainty attracted private sector investment in the sector.
- The land for energy projects was available and accessible.
- Energy demand in Egypt is high since it has a large population and many energy-intensive economic activities.

Annex 3 Approaches to tariff reform 'at the margin'

There are four different ways in which tariff reform at the margin might be undertaken:

(i) By customer type

The easiest way in which to do tariff reform is to move certain customer categories onto cost reflective tariffs while others remain in different tariff categories. For example, it is already the case that commercial and industrial customers pay YER 70/kWh – far above the level paid by residential customers (although still far below cost recovery). Frequently, it is more feasible to move a relatively small number of industrial and commercial customers onto higher cost reflective tariffs than to change the general tariff level. This can be accompanied by a high quality and more reliable service for these customers.

One challenge with this approach is that many large customers are particularly sensitive to unreliable power, therefore, they may have already made provision for their own power supply. Further raising tariffs on such groups tends to accelerate their exit from the public network and lose valuable customers for the utility. Moreover, imposing high tariffs on the remaining functioning enterprises increases their costs, which may have implications for their own profitability and levels of employment. This option, therefore, is best adopted where it is possible to credibly commit to a significantly improved service for such customers in a way that boosts their productivity, to avoid their exit from the system.

(ii) By fuel supply

Another way of enabling reform at the margin is to exploit the finite supply of fuel in the fuel grant. Some of this fuel is provided to the private sector to operate diesel generators. As noted above (and discussed further below), it would be possible to change the nature of PPAs with such private sector providers so that they are only paid for the kWhs that they actually produce. If this was done, then it would not be necessary to supply fuel to private providers for 24/7 generation – some lower amount could be provided, since PEC would only pay for the kWhs actually supplied. However, a revised PPA could also agree a much higher rate of compensation for private providers that are prepared to source their own fuel. Thus, the bulk of the payment to private providers would be at the existing 'low' PPA rate – for generation with fuel provided by PEC, but PEC would have the option of requesting additional power which would be paid at a rate that included the cost to the private supplier of sourcing fuel.

This approach would have several advantages. First, it would allow rationing of the fuel grant which would enable it to last longer. Second, it would encourage the private supplier to set up mechanisms to source their own fuel, which is ultimately a more sustainable approach. Third, it would provide private providers with a strong incentive to generate efficiently and to minimise fuel use, since they would be paying for the additional fuel. And, finally, if the higher rate for the additional generation was chosen appropriately, it would provide an incentive for private providers to generate additional power, whereas currently there is no such incentive.

The downside of this approach is that for PEC to be able to afford to pay the marginal additional generation at a much higher, fuel cost inclusive rate, the tariff would have to be adjusted upwards. However, because the intention would only be to compensate private suppliers at the higher rate for the *additional* power (over and above the power they are obliged to generate based on the fuel they receive for free), the necessary tariff rise could be quite small. This would then allow customers to decide how much additional electricity they want. The more they demand, the more additional electricity will be needed and so the

higher the overall bill – but rather than the quantity of electricity available being determined by PEC, such an arrangement would allow consumers to choose whether they want to pay more and buy higher cost electricity at the margin, or consume less and pay less. Experience from other countries suggests that quantity constrained systems often have significant latent demand for electricity – meeting this demand is often regarded as an important improvement in service.

Unfortunately, reform at the margin by constraining the fuel supply means that the tariff that is applied depends on the extent of additional demand by those able to pay. It is therefore somewhat unfair to poorer customers, since, if better off customers demand significant additional power, the tariff for *all* customers will rise, including the poor.[71] Nonetheless, reform at the margin by fuel supply is a viable way of incentivising additional supply while also marginally raising tariffs to pay for the additional supply generated.

(iii) By location

A more controversial but technically easier to implement approach to reform at the margin is to come to an agreement with a particular community or area supplied by the same feeders or sub-stations. Ensuring accurate metering at the feeder level is relatively straightforward. Higher tariffs could then be applied to the selected area(s) but based on a commitment to significantly higher reliability of supply (e.g., a certain number of hours per day guaranteed). To avoid this area taking power from the rest of network, the additional power could be contracted from private suppliers at a higher rate – as above – drawing on the additional tariff revenue raised.

The challenge with this approach is political. Areas may not wish to have a higher tariff imposed on them. And even if there is some democratic or consultative process whereby people get a say about whether their area should be included or not – the final decision will be imposed on all of those served by that feeder or sub-station, whether they voted for the change or not. This can lead to resentment and opposition, depending on the size of the tariff rise.

(iv) By time of use

A final approach to tariff reform at the margin is to discriminate by time of use. In this arrangement, customers can obtain electricity at their usual tariff if it is consumed at certain times of day. However, between designated hours, the tariff is significantly higher.[72] This higher tariff would have to be well advertised so that people have the option of turning off appliances or lowering their consumption during this period if they wish. As above, private suppliers producing during this period would receive a significantly higher tariff for electricity generated from their own resources during this period (i.e., not from fuel granted to them).[73] Again, this would provide an incentive for additional generation and supply, improved fuel efficiency and a modest increase in the overall bill since consumption during only part of the day would be charged at the higher price.

Time of day tariff reforms have the advantage that, if households have meters, it enables them to choose whether they wish to consume the high-priced electricity or not (location, fuel supply and customer type reforms cannot provide this choice).[74] However, the choice of the

[71] Theoretically, one could solve this problem by having tariff thresholds for different levels of consumption at the household level – but this would require metering technology that is unlikely to be present in Yemen.
[72] Equally tariffs could be adjusted for different seasons.
[73] PPA contracts can be devised to ensure that this is the case.
[74] Ideally this reform would be done with time-of-use meters, but it would be possible to implement without these by calculating aggregate use by time of day at the feeder level and applying this pro-rata to all bills in the affected area.

time period for the higher tariff can be politically sensitive: the impact on overall supply will be highest if it is done during the time of peak demand – but this will also increase bills the most. Careful consideration and consultation should be undertaken with communities to find a timing that is most acceptable to people (usually the time at which they most want additional power). Several countries in the region have started to use Time of Use/day tariffs, including Egypt, Morocco, Tunisia, and Jordan.[75]

Note that all of these tariff reform 'at the margin' approaches are agnostic about the source of additional power. While currently additional power from the private sector is almost all from diesel generators (except for two power plants which use gas and HFO in Hadhramout), PPAs could be adjusted to gradually reduce payments per kWh to suppliers over time to encourage them to invest in efficiency and in cheaper forms of generation, such as solar power and HFO. The big advantage of all of these reform mechanisms is that the power supplied is still injected into the existing distribution grid. No inefficient and unregulated parallel distribution network is created.

[75] RCREEE, 2017a.

Annex 4 Benefits and challenges of various reforms

Reform	Benefit	Challenges
Generation and service reforms		
PPA revision	Saves fuel or money (or both)	Getting private sector to accept the PPA
Utility scale solar projects	Power capacity increase without additional fuel cost Cost reductions	Need Long-term contracts and payment guarantees
Expanding Solar Home Systems (SHSs)	Improves access and service	Parallel to main system Requires incentives, standards and financing mechanisms
Tariff reforms		
General	Saves large amounts of money	Places a major burden on the population. Politically dangerous
Time of day	Saves money, depending on choice; allows for commercial supply at the margin Uses distribution network	May be unpopular – but allows increased supply Needs specific energy meters
Spatial	Saves money, depending on choice; allows for commercial supply at the margin Uses distribution network	Areas for selection would have to be carefully selected
Supply led	Enables marginal supply within current structure	May be unpopular since people's bills will rise
Billing and collection		
Requiring government departments to pay	Signals that government expects all to pay	Budget has to be allocated transparently Systems for payment need to be put in place and enforced
Enforcing collection from households	Significant improvement in financial sustainability of utility(ies)	Risk of violence
Structural reforms		
Status quo	No structural changes needed	No improvement in service
Concessions	Significant structural change required to allocate assets and determine new rules legally	Significant improvement in service – but higher tariffs
Mixed model	Allows one to pilot concessions and adjust based on success or failure	Less widespread benefits – but less political risk

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