Netherlands Enterprise Agency

unicef | for every child

Wind Energy Feasibility Study for Water Supply Systems in Yemen

With support from
Dutch Disaster Risk Reduction & Surge Support (DRRS)

Contents

Disclaimer

No rights can be derived from this report. Despite the fact that the report has been compiled with all due care, RVO accepts no liability for damages resulting from any inaccuracies and/or implementation or use based on the contents of the report.

List of abbreviations

CAPEX	Capital Expenditure
DRRS	Dutch Disaster Risk Reduction and Surge Support
LCOE	Levelized Cost of Electricity
MDTF	Multi-Donor Trust Fund
OPEX	Operational Expenditure
PPP	Public Private Partnership
RVO	Rijksdienst voor Ondernemend Nederland
UNICEF	United Nations International Children's Emergency Fund Yemen
UN-OCHA	United Nations Office for the Coordination of Humanitarian Affairs
WASH	Water, Sanitation and Hygiene
WB	World Bank
YER	Yemeni Rial

Summary

Yemen stands as one of the globe's most water-deprived nations, as more than 50% of the population lacks adequate access to safe and satisfactory water for everyday use (Human Rights Watch, 2023). Yemen grapples with physical water scarcity due to minimal rainfall and the lack of consistently available rivers. However, it’s crucial to recognize that the challenges extend beyond mere rainfall scarcity and the absence of rivers; economic obstacles arising from conflicts also hinder the establishment and upkeep of essential water infrastructures (Al-Mashreki M, 2013, as cited in (Noaman A, 2019).

The primary water supply originates from groundwater through wells and boreholes, with merely 0.3% sourced from desalination facilities in Aden. Due to the extensive exploitation of groundwater, the rate of depletion surpasses the rate of replenishment by approximately 0.9 million cubic meters (GIZ, 2018). Runoffs and springs in catchment areas are the main sources of groundwater recharges. Most of the wells in Yemen are pumped using diesel generators or grid electricity. Yemen's energy consumption for water demands still requires massive improvements, with its power supply as one of the key aspects. Solar energy is currently being explored to power the water supply facilities, however, it has not been implemented at a sufficient amount.

The government of Yemen asked UNICEF Yemen to support them in exploring how wind energy could support the demand for 16 water facilities located in 14 governorates in Yemen. Rijksdienst voor Ondernemend Nederland (RVO)/Dutch Disaster Risk Reduction and Surge Support (DRRS)) along with United Nations International Children’s Emergency Fund Yemen (UNICEF) wished to support the government of Yemen in assessing the option of wind energy for the powering water facilities in Yemen. An Excel-model was made to create tailor-made solutions per water supply station.

This model provides solutions using wind and solar data, turbine and solar panel characteristics, power-curves, energy demands, Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) data. The output consists of various energy profiles as well as CAPEX, OPEX and Levelized Cost of Electricity (LCOE) results per station. This tool allows the user to understand the energy coverage in Yemen by simply changing parameters in the given dashboard. The tool is easily modifiable by the user which makes it user-friendly.

After evaluating the 16 facilities, Taiz-Al Mokha district could be the most suitable location for wind turbines due to its strong average wind speeds over longer periods of time. However, while this district has the most reliable wind speeds, one important issue when looking at the hour-to-hour analysis, wind energy cannot meet the demand for every hour. Expensive batteries may solve this problem partially, but there will still be days when alternative sources of energy is required.

The rest of locations have low to moderate suitability, mainly due to the low wind speeds and strong daily and seasonal variability. In most cases, large wind turbines (> 100 meters high) would produce too much energy during wind periods and too little energy at periods with low wind speeds. This would result in a highly inefficient system to power a water supply station (which requires a stable energy supply).

The high CAPEX of wind energy (also compared to low CAPEX of solar), does not make wind energy the first choice. Additionally, the expertise for construction and maintenance already exists for solar panels in Yemen while more time and resources will need to be spent to build a team of experts for wind turbines. Furthermore, large wind turbines require high cranes, specialized trailers and wide, gentle roads (no steep slopes, tight turns) for transportation. Solar panels, on the other hand can be transported by generic truck.

1. General Background

Yemen, a nation grappling with numerous challenges, has endured a tumultuous decade and remains deeply entrenched in conflict. Amidst this turmoil, Yemenis are struggling to meet their basic needs for food, water, and shelter (International Committee of The Red Cross, 2022). Yemen grapples with physical water scarcity due to minimal rainfall and the lack of consistently available rivers.

1.1. Social, economic and political context

Traditionally, Yemenis have met their water needs through manually or electrically pumped groundwater from wells. However, geopolitical complexities have severely damaged the energy infrastructure, making electricity and diesel unaffordable for many (Relief Web, 2021). Currently, only 74.9% of Yemenis have access to electricity, and their power supply relies heavily on non-renewable fuels (diesel) which is expensive (The World Bank, 2021).

In terms of pricing, the average tariff for public water stands at 210 Yemeni Rial (YER) per cubic meter, whereas water from private suppliers commands a significantly higher price, ranging from 4 to 5 times more at around 1000 YER per cubic meter. The energy crisis as mentioned above exacerbates the situation, leading to interruptions in power supply for clean water supply in numerous areas. Consequently, governorates with low collection fees, such as Dhamar, Sana’a, and Hajjah, find it increasingly challenging to procure fuel, resulting in decreased water production and supply (GIZ, 2018).

1.2. Stakeholders and institutional context

For this study, stakeholder information was not listed as part of the scope. Therefore no stakeholder engagement was conducted.

1.3. Area Information

Yemen, located on the southeastern tip of the Arabian Peninsula, shares borders with Saudi Arabia to the north and Oman to the east. To the west lies the Red Sea, and the Bab-el-Mandeb Strait connects the Red Sea to the Gulf of Aden. Yemen has a diverse topography with jagged peaks, arid plateaus, and narrow coastal plains with mountains domination. The Western Highlands have fertile land and sufficient rainfall, while the Central Highlands are made up of a plateau with a drier climate but still sufficient rainfall in wet years.

The northern region is dominated by the Empty Quarter (Ar Rub' al Khali), one of the largest sand deserts globally. In the east, plateaus like Hadramawt receive significantly less rainfall and are much drier. The coast plain of Aden, Mokha, and Hodeydah forms a narrow strip of flat land known as the Tihamah that borders the Red Sea.

There are no permanent rivers in Yemen. Instead, the country is dotted with wadis, which are dry valleys prone to flash floods in the event of heavy rainstorms. This intermittent flow of water has a significant impact on the surrounding landscape and terrain (Nations Online, 2024) .

For this study, we consider the following governorates in Yemen. Some of these locations have more than 1 water facilities and the data for the number of working wells and the energy required in (kW) was provided to us by a local subconsultant. This data was collected in 2024.

The locations of the water facilities are seen in Figure 1 below.

Figure 1: Overview of the selected water facilities across Yemen

1.3.1 *Wind as a resource in Yemen*

Wind turbine output increases with wind speeds following a specific wind curve called a power curve. At low speeds (below 6m/s), little to no power is generated. As the wind speed increases, at 6m/s to 13m/s, the power output also exponentially increases. Lastly, after 13 m/s, the power output plateaus. This is a typical relationship between wind speed and the power output of a turbine. Therefore, it is valuable for us to understand wind speeds and patterns in Yemen.

After assessing the wind profile, the 14 locations are ranked in Table 5.3, starting with the highest potential for wind energy. The spatial of wind speeds of the locations are also considered for the overall ranking (not shown).

Table 1: Ranked locations based on wind speed and variation.

No	Location	Wind speed at 10 m elevation	Wind speed at 50 m elevation	Wind speed at 100 m elevation
1	Taiz Mokha	6.31	9.53	9.53
2	Taiz City	6.68	7.81	7.81
3	Saada	6.43	7.93	7.93
4	Sanaa South	6.04	7.42	7.42
5	Amran	5.64	7.81	7.81
6	Aden	4.35	6.77	6.77
7	IbbJiblah	5.84	6.67	6.67
8	Lahij	7.1	7.27	7.27

No	Location	Wind speed at 10 m elevation	Wind speed at 50 m elevation	Wind speed at 100 m elevation
9	Ibb Yarem	5.65	6.66	6.66
10	Sanaa East	5.44	6.73	6.73
11	Hodeydah	4.16	5.5	6.5
12	Dhamar	4.76	5.71	6.45
13	Hadramawt	4.5	5.51	6.39
14	Abyan	3.97	4.95	5.75

Through detailed analysis, we identified several locations conducive to wind power generation, particularly at elevations around 100 meters where wind speeds are higher. Notably, wind distribution is concentrated in the South West region, specifically near Taiz and Hadramawt Sahara.

2. Analysis

2.1. Cause of problem

Upon a deeper look, we were able to identify the following factors that further impact water scarcity:

a. **High Population Growth**: Yemen's rapid population increase has led to heightened water consumption, straining the existing resources.
b. **Water Source Shortage:** Groundwater overdraft over an extended period has depleted water sources, exacerbating scarcity.
c. **Dependency on Groundwater:** The lack of sustainable water supply facilities forces Yemenis to rely heavily on groundwater for sanitation needs.
d. Limited Electricity: Yemen's poverty conditions restrict access to electricity, hindering electric water pumping.
e. **Climate Vulnerability:** The country faces unpredictable climate patterns, including prolonged droughts and erratic rainfall.

Yemen's energy consumption for water demands still requires massive improvements, with its power supply as one of the key aspects. The majority of the power demand is currently met by non-renewable fuels making them expensive and sporadic as explained previously. However, due to depleted conventional supplies caused by regional tension and infrastructure damage from prolonged violence, Yemen has since been in a severe energy crisis.

2.2. Consequences of problem

Rapid population growth has significantly intensified the pressure on the finite water resources in Yemen. The population is currently reaching 29.3 million with a growth rate of 2.3% per annum (Noaman A, 2019).

Less than 15% of the water generated is allocated for domestic consumption, primarily utilized for potable purposes. The predominant portion, approximately 84%, is channeled towards agricultural needs, with the remainder allocated for industrial and mining operations (GIZ, 2018).

In contrast with other nations where the water supply is sufficient to cover fluctuating daily demands, most of the regions in Yemen only have freshwater pumped only for several hours a day. Governorates may have significant differences in the period of water pumping. In Al Hudaydah, water can be pumped for 22 hours while in Lahj the water pumping is restricted to only 8 hours. These variations depend on the availability of water, fuel, or other energy sources, and the condition of the water facility.

2.3. Current solutions

Solar energy is currently being explored to power the water supply facilities, however, it has not been implemented at a sufficient amount. Data suggests that solar energy currently contributes 6-10% of the energy demand required for water pumping. To date, 100-200 Wp solar panels are being used in urban areas, and less than 100Wp solar panels are being used in rural areas (Generac, 2024).

As part of this project, we also explore the feasibility of using wind energy to power the water supply facilities. We have already ranked the locations in accordance with average speed and its spatial variation for each location in Table 1. To understand the yield for each individual location, we developed a Wind Power Tool in MS Excel.

2.3.1 Wind Power Tool

Each water supply location has its own wind profile (strength, daily and seasonal variations) as well as energy needs. Also, per location several solutions are possible (variation in turbine types and battery options). A 'Wind Power Tool' was developed in order to assess the best solutions matching the local conditions and energy needs. To compare wind options with solar options, solar calculations were also included in the Wind Power Tool.

The Wind Power Tool was developed using MS Excel. The output shows the amount of power generated from the custom parameters as well as financial outputs such as the LCOE and the cash flow for business case consideration. The dashboard of the wind power tool shown in the figure below.

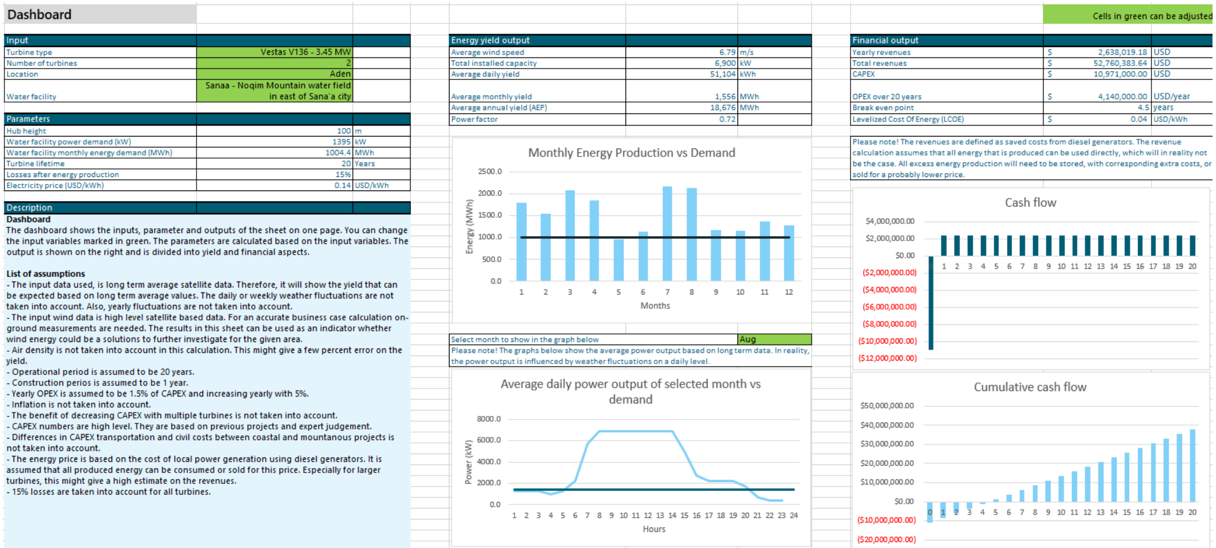

Figure 2: Wind Power Tool

2.4. Results from the Wind Power Tool

To demonstrate the results that can be derived from the Wind Power Tool, we consider the location of Taiz Al Mukha as an example.

2.4.1 *Wind Intermittency*

In this report, intermittency is represented using green and red colours. Green indicates when demand of a water supply station is met, while red indicates it is not. The vertical axis represents the 24 hours in a day, while the horizontal axis represents the 365 days in a year.

For all energy options, batteries with a customized capacity were added. In many wind or solar farms, batteries are used to stabilize the output or to provide energy during hours with now wind or solar. As batteries are expensive, most battery systems are relatively small and only used to bridge short periods of time (hours, rather than days).

The reference battery type used was Lithium Ion, with a single capacity 500 kW per container, and can be arranged to store the power up to 2.5 MW by stacking them together. In Taiz Al Mukha, the battery capacity selected was 500 kW as the demand was only 120 kW. Where analysing other location with higher demand, higher battery capacity will be adjusted accordingly.

Using the wind-speed data derived from POWER DAVE NASA for the year 2022, **Error! Reference source not found.** shows the intermittency using one wind turbine at the elevation of 100m at Taiz Al Mukha. As shown in the figure there are many periods where demand is not met in May-June and July-October (red lines), especially during the night. In **Error! Reference source not found.** a 500kW battery has included showing that batteries significantly reduce the under-production.

It is important to note that the intermittency do not consider start-up time and examine each hour in isolation to determine whether the demand is met.

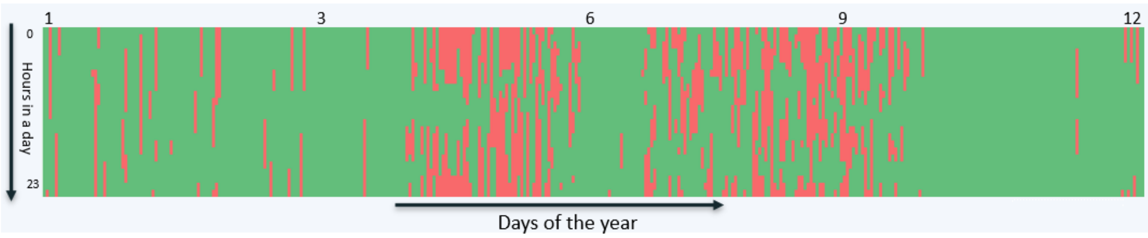

Figure 2 Wind intermittency in Taiz Al Mukha without battery

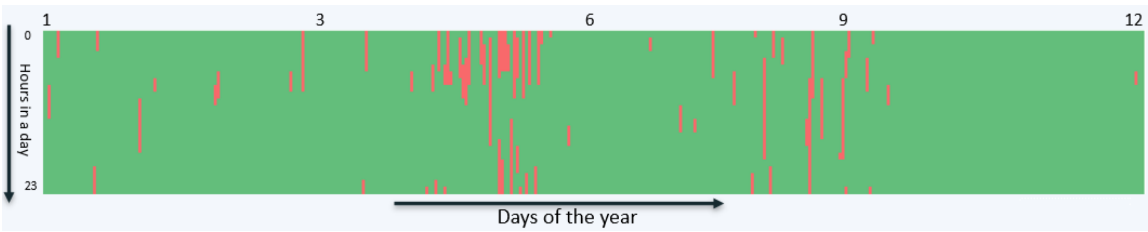

Figure 3: Wind intermittency in Taiz Al Mukha with 500 kW battery

2.4.2 *Financial Determination*

Table 2 shows the selected technologies and their properties that was considered for Taiz Al Mukha and Table 3 elucidates the corresponding CAPEX and OPEX that was derived for each scenario.

Table 2: Sample of Technology Mix

Demand	Solar Technology	Wind Technology	Battery
120 kW/hour	Sunket SKT600	Vestas 3,45 MW	Lithium Ion
3 water supply stations	500 Modules Total	1 Turbine gear	500 kW capacity (1 container)

Table 3: CAPEX and OPEX from selected technology mix

	Wind	Wind + Battery	Solar	Solar + Battery
CAPEX	$5.388.210,00	$5.719.725,00	$540.000,00	$871.515,00
OPEX	$3.232.926,00	$3.431.835,00	$180.000,00	$522.909,00
Total	$8.621.136,00	$9.151.560,00	$720.000,00	$1.394.424,00

It is evident that solar panels are significantly cheaper than a wind turbine leading to a shorter period of return of investment.

2.5. Lessons learned from elsewhere

2.5.1 *Hybrid solutions*

In the Middle East, we know that solar irradiance is more predictable that wind variability with almost 6 hours of daily sun-light hours without any interruptions. In several places around the world, a hybrid option of both wind and solar combined is chosen to optimize on the energy yield.

Although this can address the issue of energy intermittency, hybrid solutions are more expensive, need large amount of space and takes longer installation time.

2.5.2 *Financial considerations*

Wind, in general requires high initial investment and the variability of wind in Yemen makes wind energy is far less predictable than solar. Often, incorporating hundreds of solar panels proves to be significantly more cost-effective compared to installing a single turbine, especially in places where the variability of wind is high and the variability of solar irradiance is low, like in the case of Yemen.

2.5.3 *Transportation*

Both wind turbines and solar panels are factory made abroad and would need to transported in Yemen. For wind turbines, specially designed large ships are needed. While turbine tower casings produced in short sections, turbine blades (up to 100 meters long) are made in one shape and need to be shipped and transported whole. This requires Yemen to have a functioning port which can berth and offload such large cargo.

After reaching the port, the turbines need to transported by road to the chosen locations. When topography allows (no steep mountains and gentle curved roads with no obstacles), blades are mostly transported by long flatbed trailers. However, in more challenging terrain conditions (narrow bends, undulating roads), blades are often transported by specialized blade-lifting trucks that allow blades to circumnavigate obstacles by turning and/or lifting. These blade lifting trucks are not present in Yemen and it is unlikely that these trucks will be imported for only transporting a few turbines.

2.5.4 *Construction*

Construction of a turbine also imposes serious challenges just like transportation. The nacelle (the ‘head’ or the turbine with the generator and drivetrain) and the turbine blades must be hoisted on top of the 75-100 meters high turbine casing. Additionally, foundation and anchoring of the turbine also needs to be considered. For the construction of wind turbines a workspace of 50x100 meters is required to allow for cranes, trucks and lay-down of long turbine blades.

Furthermore, Electricity generated by wind turbines cannot be directly fed into the water supply station, but must be stabilized and the frequency and voltage must be adjusted to the requirements of the pumping station. This requires transformers, batteries and other electric equipment which requires trained staff for construction and maintenance.

As wind turbines are typically placed on mountain tops and ridges, while pumping stations may be expected to be in valleys (close to the aquifer), transmission lines are needed to connect the turbine to the pumping station.

2.5.5 *Operational and Maintenance*

Maintenance checks for the turbine also must be done by well-trained personnel as the workspace is dangerous (working on heights). This may pose a challenge as there are probably no trained local 'wind' engineers available. This cannot be avoided as maintenance and routine inspections for wind turbines is required every six months.

2.5.6 *Biodiversity and environmental issues*

Wind turbines have a few biodiversity and environmental risk. Some of the risks are more prevalent in coastal areas while other are more prevalent in mountainous areas.

Table 4: Biodiversity risk, impact and mitigation

Risks	Impact	Area Affected (Mountainous /Coastal/Both)	Mitigation
Bird and Bat Fatalities	These fatalities can have lasting effects on vulnerable species and even ecosystems	Both	Properly sited wind farms (away from migration routes) and technologies (early warning, scaring techniques) can minimize these risks.
(Large) wind farms require substantial space for installation and operation.	Habitat loss can affect local biodiversity, especially for endangered species.	Both	Strategic site selection and planning are essential.
Turbine noise and vibrations can impact	Disruption to animal behaviour, nesting, and feeding patterns.	Both	Proper design and placement can reduce these effects

nearby community and wildlife			

2.5.7 *Permitting*

The table below highlights the typical permits required for the installation of wind turbines.

Table 5:Typical permit needed for wind turbines

Permits	Details
Building Permit	• Required for the physical installation of the turbine tower, foundation, and associated structures. • Ensures compliance with local building codes and safety standards.
Zoning Permit	• Addresses land use and location. • Verifies that the proposed turbine adheres to zoning regulations. • May include considerations like setbacks from property lines, noise limits, and visual impact.
Electrical Permit	• Needed for connecting the turbine to the electrical grid. • Ensures proper wiring, grounding, and safety measures.
Environmental Permit	• Required if the turbine installation impacts natural resources (e.g., wetlands, wildlife habitats). • Ensures compliance with environmental laws.
Aviation Administration Permit	• If the turbine exceeds a certain height (typically 200 feet), you'll need clearance from the Aviation Administration and/or air force. • Ensures safe air traffic.
Utility Interconnection Agreement	• If government plan to connect the turbine to the grid, work with their utility company. • Obtain an agreement specifying technical requirements and procedures.

3. Conclusions and recommendations

3.1. Conclusions

There is sufficient wind in some locations in Yemen, notably the Taiz region has sufficient wind to consider wind farms. However, in most other locations, only high reaching turbines (> 100 meters) may reach their optimal performance, while these locations are still subject to strong daily and seasonal variations.

Wind energy is not the first choice for water supply in Yemen:

a. In most locations, wind energy is not a very efficient source of energy for water supply due to high seasonal and daily intermittency (too much or too little wind) while demand is constant;
b. Technical challenges: large turbines require specialist tools (trucks, large cranes) and expertise. Many mountain roads are not suitable for heavy, wide loads and long trailers (turbine blades over 70 meters long);
c. CAPEX: investments in wind are 5-10 times higher than solar. Also, solar costs are going down, wind turbines costs are going up.

Solar is the most likely renewable option for water supply in Yemen:

a. More predictable in energy production;
b. Low CAPEX and OPEX compared to wind turbines, lower LCOE;
c. Easy to scale and fine-tune to the energy demand;
d. Easy to transport (containers), install and maintain.

The downside of solar panels is the large footprint when the energy demand is high.

Batteries are expensive and (at the current market prices) are not a viable solution for the long periods of underperformance of wind and solar. Batteries may expand the operational hours with a few hours, but (from financial perspective) cannot bridge days of energy underperformance.

3.2. Recommendation

3.2.1 Immediate (now)

In specific conditions, water storage may be a good alternative for electrical (battery) storage. During periods of energy overproduction, water can pumped into reservoirs and tanks. Next, this stored water is used during periods of energy underproduction. The storage tank or reservoir must be on an elevated terrain (or on top of a tower) to allow water to flow under gravity into the supply system. In smaller networks, such a system may work as stored water volumes are limited. For larger networks, huge reservoirs or tanks are required. Nevertheless, storing water is (currently) cheaper than storing electrical energy.

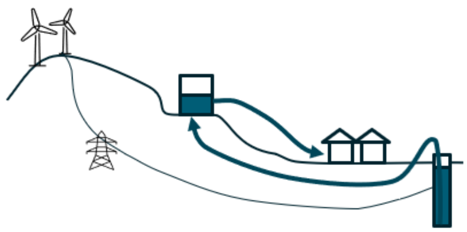

Figure 5: Scheme of water storage in a water supply system

3.2.2 *Short term (0-2 years)*

The most efficient immediate solution for Yemen would be to continue using the solar farms while relying on diesel generators for times solar energy is not able to meet the demands. This is investment costs and time for solar panels is relatively small and Yemen already has the expertise to operate and maintain solar farms. Additionally, although a battery would be a low-carbon solution to answer more efficiently handle intermittency, they are expensive and have a long start up time. Diesel generators on the other hand are cheaper and have a relatively small start-up time.

3.2.3 *Medium term (2-5 years)*

A mechanical wind turbine without electricity supply could be an option for direct ground water pumping in remote areas with wind potential in immediate time. The mechanical wind turbine could pump water bank in shallower aquifer and distributes the water directly to the network or reservoir.

Locations like Lahij to Abyan could use this options where the wind on those area are not strong enough to produce electricity or strong wind may located away from the aquifer map. Direct use will allow well water to be pumped into a tank, but it will not allow powering a water supply line. Direct use is therefore useful for remote, rural villages with a communal well.

3.2.4 *Long term (>5 years)*

While wind energy may not be the first choice for water supply for now, there is a potential for wind farms in (notably) Taiz district for energy production with careful planning and construction. Building large wind farms in this district would have ‘economy of scale’ advantages. This district is also accessible and has sufficient space for wind farms.

The water supply stations may also be connected to such a grid, but the wind energy production should be focused on general use rather than water supply only.

Powering desalination (reversed osmosis) by wind energy may also be an future option after the water supply in most Yemeni governorates are running properly. This process requires energy and desalination may be adjusted depending on wind conditions.

4. References

1 Albara M. Mustafa, A. A.-M. (2018). Risk Assessment of Hazards Due to the Installation and Maintenance of Onshore Wind Turbine. Advances in Science and Engineering Technology International, 1-7.

2 Clifford, B. (sd).

3 Clifford, B., & Triebert, C. (2016). Yemen's Bombed Water Infrastructure: An OSINT Investigation. Opgeroepen op 2024, van https://www.bellingcat.com/news/mena/2016/02/05/yemens-bombed-water-infrastructure/

4 Ding, G. a. (2017). Sustainable Water Management - A Strategy for Maintaining Future Water Resources. Encyclopedia of Sustainable Technologies(https://doi.org/10.1016/b978-0-12-409548-9.10171-x.), 91-103.

5 Fore, H. (2018). Drinking water systems under repeated attack in Yemen.

6 Generac. (2024). Generac. Opgeroepen op 2024, van https://www.generac.com/Industrial/GeneracIndustrialPower/media/library/Downloads/SBE500-LFP-SpecSheet-2023-v2_1.pdf

7 Givebrite. (2024). Givebrite. Opgeroepen op 2024, van https://campaigns.givebrite.com/100-water-wells-4-yemen/jasmine-3151 [Accessed 24 Apr. 2024].

8 GIZ. (2018). Yemen Water Sector. Deutsche Gesselschaft fur Internationale Zussammenarbeit (GIZ) GmbH.

9 GIZ. (2018). Yemen Water Sector Damage Assessment Report of Twelve Water Supply and Sanitation Local Corporations (LCs) and Their Affiliated Branch Offices and Utilities. GIZ.

10 Global Petrol Prices. (2023). Global Petrol Prices. Opgeroepen op 2024, van https://www.globalpetrolprices.com/Yemen/electricity_prices/

11 Global Solar Atlas. (2024). Global Solar Atlas. Opgehaald van https://globalsolaratlas.info/map

12 Global Wind Atlas. (2024). Global Wind Atlas. Opgehaald van Global Wind Atlas: https://globalwindatlas.info/en

13 Google Earth. (2024). Opgeroepen op 2024, van https://earth.google.com/

14 Gun, J. v. (1995). The Water Resources of Yemen. Van der gun Hydro-consulting.

15 Human Rights Watch. (2023). Human Rights Watch. Opgeroepen op 2024, van https://www.hrw.org/news/2023/12/11/yemen-warring-parties-deepen-water-crisis#:~:text=Yemen%20is%20one%20of%20the

16 IACS. (2018). Guidance and Information on Bulk Cargo Loading and Discharging to Reduces The Likelihood of Overstressing the Hull Structure. In Bulk Carriers (p. 1). IACS.

17 International Commitee of The Red Cross. (2022, June). ICRC. Opgehaald van ICRC: https://www.icrc.org/en/document/water-situation-yemen

18 International Growth Centre. (2021). Improving Electricity Services in Yemen. London.

19 JICA. (2010). Introduction of Clean Energy by Solar Electricity Generation in The Republic of Yemen. In Final Report.

20 Nations Online. (2024). Map of Yemen. Opgeroepen op 2024, van https://www.nationsonline.org/oneworld/map/yemen-topographic-map.htm.
21 Noaman A, a. F. (2019). Fanack Water. Opgeroepen op 2024, van https://water.fanack.com/yemen/#_ftn1
22 Relief Web. (2021). Relief Web. Opgeroepen op April Friday, 2024, van https://reliefweb.int/report/yemen/assessing-impact-war-yemen-pathways-recovery
23 Solar Feeds. (2024). Solar Feeds. (Solar Feeds) Opgeroepen op 2024, van https://www.solarfeeds.com/product/skt580600m10/
24 The Water Diplomat. (2022). Water Diplomat. Opgeroepen op 2024, van https://www.waterdiplomat.org/story/2022/01/saudi-attacks-water-facilities-yemen
25 The World Bank. (2014). The World Bank. Opgeroepen op 2024, van https://data.worldbank.org/indicator/ER.H2O.INTR.PC?end=2019&locations=YE&start=1990&view=chart [Accessed 8 Apr. 2024].
26 The World Bank. (2021). Opgeroepen op April Friday, 2024, van https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=YE
27 UNDP. (2014). Policy Note - Prospect of Solar Energy in Yemen (1 ed.). UN.
28 UNICEF. (2018). Assessment study and feasibility of the existing solar projects and potential for up-scaling the use of solar energy systems for water production in Water Sector. UNICET.
29 Vestas. (2024). Transport Guideline. Vestas.
30 Vestas. (2024). Vestas V136 - 3.45 MW Product. (Vestas) Opgeroepen op 2024, van https://www.vestas.com/en/products/4-mw-platform/V136-3-45-MW
31 VESTAS Manual. (2006). Safety Regulations for Operators and Technicians V90-3MW/V100-2.75 MW.
32 Vestas Manual. (2024). Electrical Pre Design. VESTAS.
33 Wind Watch. (2010). Wind Watch. Opgehaald van https://www.wind-watch.org/documents/wind-turbines-minimum-distances-from-residential-premises-bill/
34 WINDExchange. (2024). WINDExchange. Opgehaald van https://windexchange.energy.gov/projects/permitting
35 WorldData. (2023). World Data. Opgeroepen op 2024, van https://www.worlddata.info/asia/yemen/climate.php.

Annex I: Official Request (Max 3 pages)

Appendix that includes the official request for support.

Annex II: Terms of Reference (Max 1 page)

Appendix that includes the original (and possibly changed) Terms of Reference.

Annex III: Opportunities for follow-up (Max 1 page)

UNICEF Yemen wants to follow up this project into wind power tool further development and training for people who work for humanitarian organizations. Further discussion has not conducted yet.

Annex IV: Planning DRRS visit (Max 3 pages)

Appendix that includes the planning of the DRRS team visit and the contact information of the parties the team spoke to.

for every child,

Whoever she is.

Wherever he lives.

Every child deserves a childhood.

A future.

A fair chance.

That’s why UNICEF is there.

For each and every child.

Working day in and day out.

In more than 190 countries and territories.

Reaching the hardest to reach.

The furthest from help.

The most excluded.

It’s why we stay to the end.

And never give up.

unicef

for every child