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# WATER-ENERGY NEXUS OF WATER AND WASTEWATER SERVICES IN LEBANON

## Volume III:

### ENERGY AUDIT OF THE WATER AND WASTEWATER SECTORS



# **WATER-ENERGY NEXUS OF WATER AND WASTEWATER SERVICES IN LEBANON**

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# List of Acronyms

<b>AHP</b>	Analytical Hierarchy Process
<b>BMLWE</b>	Beirut and Mount Lebanon Water Establishment
<b>BWE</b>	Bekaa Water Establishment
<b>CEDRE</b>	Conférence Economique pour le Développement par les Réformes et avec les Entreprises
<b>CDR</b>	Council for Development and Reconstruction
<b>CIP</b>	Capital Investment Plan
<b>COM</b>	Council of Ministers
<b>COP</b>	Conference of Parties
<b>DU</b>	Degree of Utilization
<b>DSP</b>	Distribution Service Provider
<b>EDL</b>	Electricité du Liban
<b>EE</b>	Energy Efficiency
<b>ESCO</b>	Energy Service Company
<b>GDHER</b>	General Directorate of Hydraulic and Electric Resources
<b>GIS</b>	Geographic Information System
<b>GVC</b>	Gruppo di Volontario Civile
<b>IWRM</b>	Integrated Water Resource Management
<b>IRENA</b>	International Renewable Energy Agency
<b>JHDF</b>	Joint Humanitarian Development Framework
<b>LCEC</b>	Lebanese Center for Energy Conservation
<b>MoEW</b>	Ministry of Energy and Water
<b>MoF</b>	Ministry of Finance
<b>MoI</b>	Ministry of Interior and Municipalities
<b>MCA</b>	Multi-Criteria Analysis
<b>NERA</b>	National Electricity Regulatory Authority
<b>NRC</b>	Norwegian Refugee Council
<b>NRW</b>	Non-Revenue Water
<b>NWSS</b>	National Water Sector Strategy
<b>OMSAR</b>	Office of the Minister of State for Administrative Reform

<b>PV</b>	Photovoltaic
<b>RE</b>	Renewable Energy
<b>RWEs</b>	Regional Water Establishments
<b>SDG</b>	Sustainable Development Goal
<b>UNFCCC</b>	United Nation Framework Convention on Climate Change
<b>VFD</b>	Variable Frequency Drive
<b>WaSH</b>	Water Sanitation and Hygiene
<b>WEF</b>	Water Energy Food
<b>WVI</b>	World Vision International
<b>WWTP</b>	Wastewater Treatment Plant

# Executive Summary

Water and wastewater utilities expend most of their budgets, especially those for their operation and maintenance (O&M), on energy. This is a good news/bad news situation where energy (or electricity) charges are high—the bad news—but these are readily controllable through the identification and implementation of energy efficiency and saving measures through all aspects of the utilities' operations and maintenance processes. Thus, investing in energy efficiency would enable the utility to expand and/or improve its services, reduce operating costs, minimize air pollution as well as greenhouse gas (GHG) emissions, improve energy security and independence, and create more jobs. Further, such measures, especially in Lebanon, will reduce pressure on the electrical and associated utilities, in terms of the need to add or sustain elevated power generation capacity on the national level.

Water service provision is *highly dependent* on the supply of electricity; and due to the extremely intermittent supply in many areas of Lebanon, water provision is frequently disrupted. Lebanon's four Regional Water Establishments (RWEs) have been suffering for decades from a huge deficit to the national electricity utility Electricité du Liban (EDL). This has hindered water and wastewater service development and the sector's overall improvement, forcing their heavy reliance on expensive and polluting private diesel generators to compensate for the irregular EDL supply. Thus, RWEs have no choice but to reduce their energy bills through the implementation of energy efficient measures at their water and wastewater facilities, including treatment plants.

In order to obtain a clear picture of the role of energy in the provision of water (and wastewater) services by the four water establishments as well as the potential for energy efficiency opportunities, a two-step energy analysis was conducted involving a walk-through survey, followed by an in-depth energy audit and assessment. The analysis was performed for 62 stations throughout the country, and was distributed as follows: 39 water pumping stations, and 23 wastewater treatment plants. Available electricity bills of those stations for the past three years (2016, 2017, and 2018) were accessed and analyzed using energy performance assessment tools and key performance indicators (KPIs). These were then benchmarked against best practices and trends in several countries in the region and around the world. This allowed for the identification of the most energy intensive stations, in terms of electricity costs. For water pumping stations, the indicators used were: Energy Use Index kWh/m<sup>3</sup> [EUI], Unitary Energy Cost \$/m<sup>3</sup> [UEC], and Standardized Pump Efficiency (SPE) indicator kWh/m<sup>3</sup>/100m, while the following were used for wastewater treatment plants: kWh/PE/year, kWh/kg.CODremoved or kWh/kg.BODremoved, and degree of utilization (DU).

Analysis of the electricity bills of the RWEs revealed the extent of the high cost of energy incurred in providing potable water. For example, around 20% of the annual budgets of both North Lebanon (NLWE) and Beirut and Mount Lebanon Water Establishments (BMLWE) go for energy consumption. For the BMLWE, this represents 33.6% of its O&M cost. The Beka'a Water Establishment's (BWE) estimated energy costs are higher, nearing 36% of the 2019 total budget, equivalent to 47% of the overall O&M budget. Providing wastewater collection and treatment services is similarly handicapped by high-energy costs. Even though energy bills are borne by the Council of Development and Reconstruction (CDR), the high-energy cost associated with operating and maintaining the plants hinders the process of moving those facilities to the authority of the WEs, whose financial resources are limited.

The water energy audit and development of KPIs for the four RWEs indicated that there is an indirect correlation between the stations that registered high electricity bills and stations' behavior in terms of energy bills (EUI and UEC numbers) on the one hand, and their respective pumps' performance (kWh/m<sup>3</sup>/100m) on the other hand. The latter showed normal behavior within acceptable ranges, while the former, in many instances, exceeded the acceptable maximum limit. In other words, the high-energy cost is not always caused by an inadequate pump performance. This led to the conclusion that the main reason behind this high energy-intensive behavior at the identified stations could be a result of the use of expensive energy sources (i.e. fuel sourcing, such as diesel generator and heavy fuel oil for the utilities) or a consequence of inadequate operation and maintenance (philosophy and program) throughout all the establishments.

An in-depth analysis of stations' energy performance, using *pump performance indicators*, was conducted to assess the pumps' performance to determine the necessary power required to operate efficiently—the latter, mainly, to ascertain whether the selected pump is properly sized. The pump performance indicators grouped pumps into three categories: those whose performance is acceptable or good, those whose performance is unacceptable, and those whose associated data rendered assessment problematic (i.e. could not be assessed). In facilities for the SLWE, it was determined that around 40% of the pumps are operating in an acceptable or good manner, while 26% of pumps were found to be operating unacceptably. Around 50% of NLWE's pumping systems were found not to be acceptable, and only 30% were in a good or acceptable shape. The BWE had the highest percentage (58%) among all establishments for unacceptable pumping systems, while BMLWE had the highest number of audited stations (70%) whose pumps were operating in the acceptable-to-good range.

The above analysis led the research team to focus on the necessity for the development of a set of Operation and Maintenance (O&M) guidelines. To achieve this goal, Dar Al-Handasah Consultants (*Shair & Partners*) generously offered their support by providing a guiding manual (Appendix D) that would facilitate the work of the professional managers and staff in their operation and maintenance work. The guidelines cover the needed O&M measures

for a variety of pumps, along with the valves and strainers maintenance. The team strongly believes that this will help RWEs to move from emergency response maintenance schemes to predictive, and even preventive, maintenance operations and thus, lengthen the servicing lifetime of the equipment. The manual is provided as an appendix to this report.

In addition to the O&M guidelines, a set of technological, design, policy, and planning recommendations are proposed that resulted from a series of consultation meetings with a wide range of experts in the field, and which could be summarized as follows:

## Technology

- The use of high-efficiency electrical motors and very high-efficiency pumps, despite their initial high cost.
- The use of turbines (PATs—pumps acting as turbines<sup>1</sup>) that generate electricity from water pressure: eco-friendly pumping stations, eco-hydro turbines, hydro-powered stations from non-river sources, and very small hydro-powered networks. Similar technologies were adopted in different countries (Bath County, USA, 3003 MW; Guangdong, China, 2400 MW; Huizhou, China, 2400 MW; Okutataragi, Japan, 1932 MW; Ludington, USA, 1872 MW). Also, consider inline micro-turbine in water networks as a source of power supply for instruments such as telemetry and SCADA accessories.
- Pumps and Variable Frequency Drives (VFDs) should be selected, acquired, and installed concomitantly to ensure the conformity between both components. When a retrofitting approach is adopted, and VFDs are installed at a later stage during operation; there is potential for pump deterioration.
- VFDs shall be recommended whenever there is variable pressure and variable flow applications, and could reach 97-98% efficiency, especially for pumping operations less than 100 meters. Trainings for operators on VFDs shall be implemented.

### Some drawbacks of VFDs

- Higher initial cost; larger footprint; sign wave filters; DV Filters needed for depth higher than 100m; special cables needed; no possible retrofitting; and two cooling units needed. VFD application is limited to low and medium lift-pumping stations; verification shall always be conducted to check on available regulation bracket.
- Implement more solar pumping stations wherever possible, which could result in 100% energy savings on pumps and/or site electricity needs. In addition, there should be a focus on water storage implementation (by building more reservoirs) instead of energy storage, since reservoirs cost less.

<sup>1</sup> This could be also implemented at WWTPs using microturbines on the discharge from treatment plants if there is sufficient drop from the final treatment process to an outfall.

## Design Criteria

### Duty point and pump selection

- Duty point shall be calculated taking into consideration exact minor losses.
- Failing to collect data on involved pipeline fittings and appurtenances.
- Safety factor can be exclusively applied to head-loss part, without affecting geometric lift part.
- Considerations of short- and long-term pipe roughness shall be observed in determining the bracket of the duty point, to remain within allowable efficiency and power bracket.

### Design of water networks

- Measures shall be taken to maintain a balanced network, and to restrain flow demand mainly in low areas by the introduction of flow-control valves, pressure-sustaining valves, house connection flow limiters, etc.
- Network design (especially sizing) shall consider energy saving as a key component.
- Network design shall take into consideration the type of house connection (free discharge, orifice).

## Operation and Maintenance

- Develop an operational philosophy for water pumping stations when it comes to water sources' management and energy efficiency measures: a set of guidelines for installation, operation and maintenance of pumping equipment, pumping schedule, capacity building for station operators, emergency action plans, data monitoring and analysis, etc.
- The traditional way of maintaining the motors through winding leads to efficiency loss, each time it is performed. As such, it is more effective to replace broken-down motors with new more energy efficient ones. This approach should be adopted in future maintenance procedures.
- Continuous data acquisition/collection (pressure, flow of wells/stations/network, voltage, amperage, energy consumption per equipment/station, etc.) should be implemented in a specific log book at each pumping station, and data collected shall be centrally stored in one main data bank, and shared with all stakeholders to improve energy efficiency.
- There are different layers for pumping systems efficiency that can be addressed:
  - Energy efficient motors;
  - Usage of VFDs to address power and flow fluctuations, the utilization of leak detectors to avoid unnecessary costs at later stages;
  - Automation to ensure proper control;
  - Proper instrumentation (on pumps, flow meters, pressure gauges, etc.);
  - Proper monitoring (pressure and flow metering at the level of the wells/stations/network/consumers);
  - Improved water systems management (through SCADA systems) for operational and management matters

- Revision of all O&M contracts should be conducted, and a new standardized set should be produced to include the following:
  - The contractor should be held accountable for O&M, diesel costs, volume and hours of water pumping, and data cross-checking. Consequently, O&M contractors should be penalized based on their performance regarding flow pumped, energy efficiency, etc.
  - If the establishment decides to assign an O&M contractor, a full inventory should be done for all the available assets (equipment, spare parts, etc.) before handover. The O&M contractor should continuously update this inventory.

## Planning

- For future projects, Terms of References (ToRs) should define a set of energy efficiency standards, and contractors would be required to comply with these specific standards and specifications (such as the ones mentioned earlier: high efficiency pumps; eco-hydro systems, preventative maintenance, etc.). Furthermore, specifications should be homogenized among the different stakeholders involved in the water sector (CDR, MoEW, RWEs, etc.), and one central monitoring system/managing institution for standards' compliance shall be established (maybe through LIBNOR?).
- Consider asset management (for existing equipment and spare parts) for better preventative maintenance, and start implementing predictive maintenance in RWE's philosophy.
- Planning of new pumping stations and growth assessment shall be made in a modular way, and on a case-by-case basis.
- Proper sizing of water supply network to ensure optimal energy requirements when pumping. Pipe sizes that are too small generate a lot of friction, which leads to the need for higher pressure from pumps, thus needless and excessive pumping.

## Policy

- Pricing is critical to achieve energy efficiency, and thus an appropriate pricing strategy should be developed.
- The Ministry of Energy and Water represented by both EDL and LCEC shall issue publications related to energy efficient standards and specifications for water and wastewater utilities.
- The major challenge for solar energy production (onsite and offsite), as well as hydro-turbines, is the absence of power-wheeling and corporate PPAs, and the absence of grids in some places to connect to (a draft law for power-wheeling is currently being developed between the Ministry and the EBRD, and is expected to be ratified by mid-2020).
- Enforce the role of the Ministry of Energy and Water in terms of supervision, calling for human and capital resources.

As for the wastewater energy audit, three types of treatment processes were identified throughout the 23 audited plants: *extended aeration*, *activated sludge*, and *activated sludge with a trickling filter*. Since the plants varied in size and in the population served (population equivalent [PE]), they were categorized into five main size classes (SC1 to SC5). Each category was then benchmarked against best practices and typical performance values. The main specific energy consumption indicator adopted was the *kWh/PE/year*. Results show that this indicator decreases significantly with increasing plant size. Overall, almost a quarter of the analyzed stations fall within the accepted benchmarking values (Zahle, Ablah, Chekka, and Hammana) for energy consumption.

Further analysis was performed with the inclusion of additional benchmarks, based on the COD or BOD removal (*kWh/kg.CODremoved* or *kWh/kg.BODremoved*), which have also showed similar behavior to the *kWh/PE/year*. Results show that plants that carry out Conventional Activated Sludge and Extended Aeration processes have the lowest energy consumption. On the other hand, Activated Sludge with Trickling Filters processes were characterized by the highest energy consumption, being almost two times higher than the two other processes. An additional layer of analysis involved the use of a fourth indicator, which is *the degree of utilization (DU)*, which describes how much of the available capacity of a WWTP is actually used. DU (optimal range being 80-100%) is inversely related to energy intensity, which decreases as DU increases. Only the Hammana WWTP (managed by the municipality) falls just at the limit of the optimal DU range, while the rest of the plants were all outside the optimal utilization range. Two interesting cases arose during this analysis (the comparison between DU and energy intensity), those of Selaata and Jeb Jennine, both of which had a relatively elevated DU (around 65%), while being less energy intensive than other treatment facilities.

In addition, 14 out of 16 secondary treatment stations operate below capacity, leading to over-sized plants designed for a capacity greater than the actual PE served. Three other plants (Iaat, Chekaa, and Ferzol) were found to operate at levels that exceed their design capacities—this affects the quality of the treated effluent.

Similar to the water energy audit, energy efficiency has been addressed from the operation and maintenance perspective, given its potentially significant impact when applied properly at the existing plants, through measures within and outside the utilities, and also when incorporated in the planning (and design) of any future plants (those under tender/in preparation/in design). In order to complement the value chain, and in addition to the O&M guidelines, a set of technological, policy, and planning recommendations are proposed that resulted from a series of consultation meetings with a wide range of experts in the field. A co-benefit from this approach is that it would greatly support the move, by the operators, away from unplanned emergency maintenance procedures to predictive and preventive maintenance.

# Energy Audit Background

In order to assess the energy use and efficiency at the water establishment level, an energy audit was conducted for all four RWEs. An energy audit is a detailed investigation of how energy is used in utility facilities. The energy-consuming systems are first categorized and analyzed (FRWA, 2007). An energy audit may be referred to in several interchangeable names that have the same meaning: energy assessment, energy survey, energy study, energy analysis, energy evaluation, or energy investigation (Greenberg, 2011). The audit will also aim to gauge the environmental and economic impacts related to energy use and (in)efficiency at the establishment level.

The auditor identifies energy streams for each type of energy source, quantifies those energy streams, evaluates the efficiency of each of those functions, and identifies energy and cost savings opportunities. The first step in performing an audit is to conduct a walk-through of the facility. The purpose of the walk-through is to identify how energy-consuming equipment is being used and the potential for savings (FRWA, 2007).

Basic energy audit goals include the following:

- Define and map the layout of the system;
- Establish goals and benchmarks;
- Perform a walk-through;
- Collect and assemble process data and information;
- Compile information.

## Level 1: Walk-Through Survey

This audit includes analysis of the previous energy bills and process data (typically up to three years if available), a visit to the facility to interview key decision-makers, and basic energy measurements. The result would be an outline of the energy use on site, an energy benchmark, and an analysis of the process operation in each audited station (Greenberg, 2011).

## Level 2: Energy Survey and Analysis

Here the audit builds on a Level 1 audit, and includes a detailed breakdown on energy use by the station and/or process, type and standards of the pumps used, operations, maintenance procedures, management practices, and suggests potential areas of energy savings and improvements in each water establishment.

Level 2 survey would incorporate:

- List of equipment/machinery used in the audited stations and their performance relative to a set of performance indicators.
- Alternative solutions, which can be efficient and cost-effective.
- Operation and maintenance guidelines for improved energy efficiency at the water establishments.

The questions for the walk-through survey are further detailed in Appendix A.

# Energy Performance Assessment

The data collected in the initial walk-through survey will be used to calculate a set of performance indicators. In order to assess the energy performance of the visited stations, the calculated indicators will be compared to benchmarks acquired from the literature. In the energy benchmark, multiple indicators are used in similar studies. However, adopting an indicator depends on several factors, such as the facility being studied (water/wastewater, lifting station, type of load, etc.). These indicators include the specific energy consumption expressed per cubic meter ( $\text{kWh}/\text{m}^3$ ), and the unitary energy cost ( $\text{USD}/\text{m}^3$ ). In the case of wastewater, additional indicators are considered; namely energy consumption per population equivalents ( $\text{kWh}.\text{PE}^{-1}.\text{year}^{-1}$ ), per unit of chemical oxygen demand (COD) removed ( $\text{kWh}/\text{kg COD}$ ), and per unit of biological oxygen demand (BOD) removed ( $\text{kWh}/\text{kg BOD}$ ).

## Water sector

The water sector constitutes mainly of pumping and lifting stations. A major part of the energy consumption is dependent on the pumps' performance and efficiency. In this case, energy efficiency is divided into two parts; pump efficiency and system efficiency. As such, the best indicator to measure the performance of the water supply system is the specific energy consumption, expressed per cubic meter ( $\text{kWh}/\text{m}^3$ ). As for the pump energy indicator,  $\text{kWh}/\text{m}^3.100\text{m}$  will be used.

Benchmarking can be internal or external. Externally, the water sector under study is compared with similar sectors in other countries. Three benchmarks were acquired from the literature: developed region, represented by Western Europe; developed countries, represented by the United States of America and Australia; and developing countries, represented by Jordan. Due to cultural, economic, and climatic similarities, the latter was adopted. The analysis results indicated that energy consumption in water supply systems ranged between  $0.4 \text{ kWh}/\text{m}^3$  and  $0.65 \text{ kWh}/\text{m}^3$ . Similarly, the pump energy indicator ranged between 0.3 and  $0.65 \text{ kWh}/\text{m}^3.100\text{m}$  and was calculated at different pump efficiencies, as shown in the following table:

**Table 1 Pump Energy Indicator at Different Theoretical Efficiencies**

Efficiency (%)	Indicator ( $\text{kWh}/\text{m}^3.100\text{m}$ )
100%	0.273
90%	0.303
80%	0.341
70%	0.389
60%	0.454
50%	0.545
40%	0.681
30%	0.908

As shown in Table 1, values below 0.273 are theoretically not possible, and should be revised for soundness of data, or removed from the analysis if not verified. In general, any value below 0.3 is not possible and should be checked/verified, and all values above 0.65 should raise a flag for either a major inefficiency in operation—thus should receive a high priority energy audit and treatment—or for a problem with data acquired. Values above 0.9 should also be verified or removed, as it is highly unlikely that these values represent an actual operating case.

Internal analysis was conducted as well. After assessing the station's performance with relation to the system energy performance, analysis was made to assess the pumps' energy indicator and deduce the actual performance indicators. As a result, potential energy gaps will be highlighted, such as O&M missing measures, age of the plant, lack of energy efficient measures (i.e. VFD, soft-starters, energy efficient pumps), non-revenue water (NRV), etc.

## **Wastewater sector**

### ***Indicators background***

Wastewater treatment involves physical, chemical, and biological processes. As such, various process characteristics (COD removal efficiency, BOD removal efficiency, Population Equivalent (PE), etc.) are taken into consideration for calculating key performance indicators. The latter include kWh/m<sup>3</sup>, kWh/PEeq/year, kWh/kg.BODremoved, and kWh/kg.CODremoved. Each indicator could be calculated at every treatment level or for the whole treatment plant. In some cases though, some of these indicators could present a major bias. For instance, in a benchmarking study done for over 200 wastewater treatment plants in Italy (Vaccari, Foladori, Nembrini, & Vitali, 2018) drew special attention to the kWh/m<sup>3</sup> indicator. Although widely applied, it resulted with biased KPI, since the influent volume is highly influenced by stormwater and infiltrations.

Recent studies posit that the kWh/PE/year and kWh/kgCODremoved provide analogous conclusions and high positive correlations (Vaccari et al., 2018). As both indicators provide the same information, only one of them will be considered for analysis: kWh/PE/year. Nevertheless, the kWh/kgCODremoved will be used for internal cross-checking, and to highlight additional information.

In addition to the kWh/PE/year, a second indicator will be considered: the degree of utilization (DU) as recommended by the conducted experts' consultations, as described in the literature. The DU is an indication of whether the WWTP is over-loaded or under-loaded. Generally, treatment plant efficiency is associated with a capacity utilization of over 80%. Plants operating beyond 100% DU may sometimes appear more energy efficient, but this may be problematic for the equipment performance, and overall treatment process and effluent quality; worse, energy performances are often linked to heavy under-loading (Rettig et al., 2018).

## Benchmarking methodology

A benchmarking methodology was developed to categorize the wastewater treatment plants in Lebanon and assess their energy performance, according to international benchmarks.

First, two separate classifications were done concomitantly. Audited wastewater treatment plants were categorized based on size (PE range, as in Table 2), and on the treatment process adopted (extended aeration, activated sludge, and activated sludge using a trickling filter).

**Table 2 Size Classification of WWTPs Based on De Haas et al. (2018)**

Size class	PE range
SC1	<1,000
SC2	1,000 - 5,000
SC3	5,001 - 10,000
SC4	10,001 - 100,000
SC5	>100,000

For every treatment plant, all five KPIs were calculated as references (kWh/m<sup>3</sup>, kWh/PEeq, kWh/kg.BODremoved, kWh/kg.CODremoved, and DU [%]). Given the lack of SCADA systems in most plants, indicators could not be calculated per process; however, only the kWh/PE/year was adopted as a main indicator, and benchmarked against international guide and target values for plants with similar sizes and treatment processes (Table 3). The DU was then plotted against the kWh/PE/year to observe the relation between both indicators, and draw conclusions.

**Table 3 Adopted Guide and Target Values for kWh/PE/year per Type and Size (Krampe, 2013; De Haas et al., 2018)**

Class	SC1		SC2		SC3		SC4		SC5	
	Guide	Target	Guide	Target	Guide	Target	Guide	Target	Guide	Target
Extended aeration (EA)	70	38	45	28	38	22	34	20	30	20
Activated sludge (AS)	60	32	40	24	34	20	30	18	27	18
AS- Trickling filter	67	49	39	32	35	29	30	18	26	18

# Energy Audit in the Water Sector

## Section overview

This section details the results of the energy audit, which was conducted by the research team. It covers the walk-through audit, which entailed visiting facilities, such as water pumping stations, water reservoirs, water treatment plants, and administration of the walk-through survey to operators and/or designated establishment employees.

Consultation meetings were held with the director generals of all four RWEs from April until May 2019, where the scope and goals of the study were presented, along with potential outcomes of this project, which will feed the RWEs' strategies, and direct their investment and operations towards improving and optimizing the water-energy nexus.

The first step of the energy audit (walk-through survey) kicked-off on May 27, and covered the areas serviced by BWE, BMLWE, NLWE, and SLWE for both water and wastewater. Overall, the team visited 39 water facilities and 23 wastewater facilities (Table 4).

The results of the energy audits for water and wastewater facilities will be presented in this report.

Establishment	Water station audited	Wastewater stations audited
Bekaa Water Establishment	5	7
Beirut and Mount Lebanon Water Establishment	14	9
North Lebanon Water Establishment	8	3
South Lebanon Water Establishment	12	4
Total	39	23

## Water sector walk-through surveys and observations

Water service provision is *highly dependent* on electricity supply, and due to the extremely intermittent electricity supply in many areas, water provision is continuously interrupted. The following sections show, in detail, how electricity affects each water establishment.

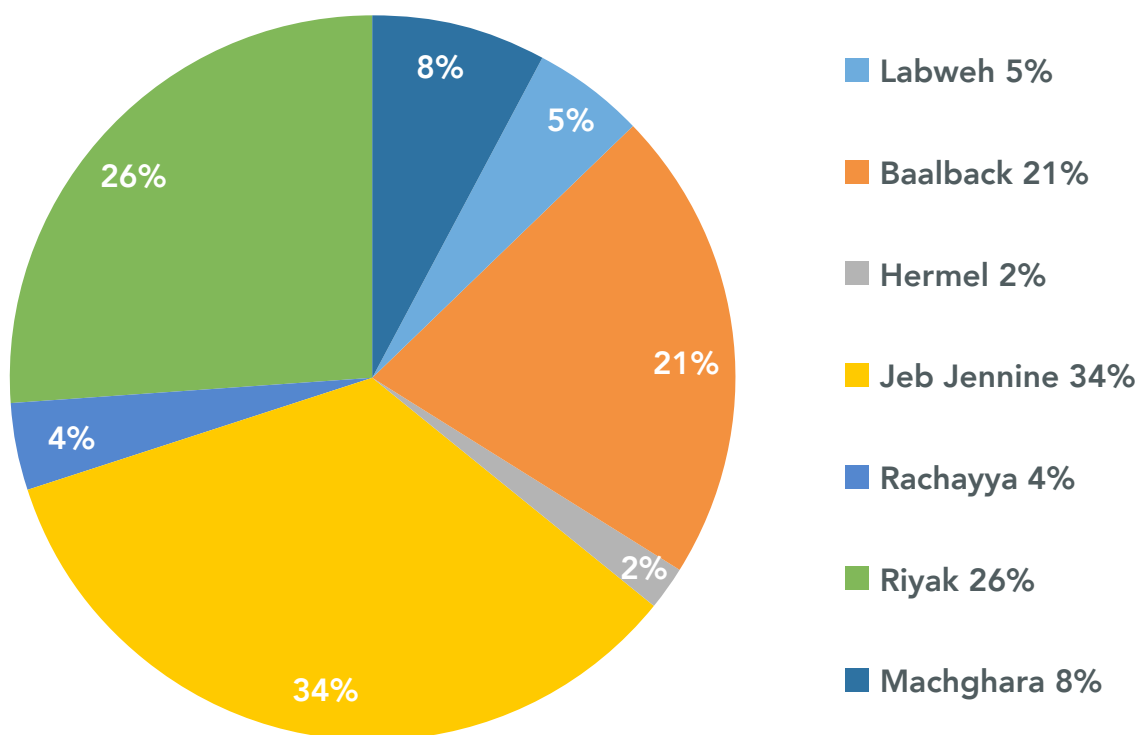
### ***Bekaa Water Establishment***

The energy audit was conducted from May 27 until June 12, 2019, and covered five water facilities (Chamsine, Loussi, Jdita, Zahle, and Ghazze). These facilities were identified as the most energy-intensive stations that fall under the BWE's service area, and thus were visited to better understand their processes, equipment used, and operation and maintenance details.

The visits were informed by the director of stations at the BWE (Khalil Azar) along with a consultant from CDR working at the Establishment (Roy Yazbeck), and were accompanied by an onsite responsible operator from the Suez Company (Ali Arfan), and other operators at the stations.

BWE suffers from a significant financial deficit, due to high illegal water connections and low collection rates. This has led the BWE to default on its payment of electricity bills. It is currently indebted to EDL, a debt exceeding USD 70 million, since its establishment in 2001, and around USD 5 million to Electricité de Zahle<sup>4</sup>. Energy estimates account for around 35.6% of the overall establishment budget (according to the 2019 budget) and can reach up to 47% of the amounts allocated for total O&M operations. The establishment's total electricity bill in 2017 alone, which were the latest bills received during the audit execution, amounts to around LBP 8-8.5 billion (USD 5.6 million)<sup>5</sup>. Figure 1 illustrates the distribution of electricity charges amongst the various regions under the BWE jurisdiction. This large deficit, with the continuously low collection rates (around 30% on average, as per BWE management), has prevented the BWE from investing in infrastructure development projects, and has restricted its use of diesel generators, due to their high operational cost.

**Figure 1. Bills distribution per BWE division in 2017**



<sup>4</sup> Interview with BWE Director General, 2020

<sup>5</sup> LBP/USD exchange rate set at the old rate of \$1 = LBP 1,500.

Overall, BWE suffers from a significant shortage of qualified staff, such as engineers, technicians, and operators. Its relationship with municipalities and local communities, some of which are still managing their own water resources and refraining from accepting the role at BWE, is at times contentious and unclear, which makes the establishment's operations more difficult (Yazbek, 2019). Operators on the ground do not always report to higher management but instead communicate with heads of municipalities or persons of influence in local communities. Corrective maintenance is applied in all stations whereby equipment is only fixed/replaced if it breaks down or fails to perform (Yazbek, 2019). Other issues that were observed include the lack of accurate data across the establishment, mainly due to not reading meters and imprecise metering. SCADA systems are currently unavailable but will be installed at 44 stations in the near future (Yazbek, 2019). The only indicators, which are monitored at the managerial level, are subscription and collection rates.

The above indicate that the establishment is currently operating in 'crisis management mode', where it is operating at a continuous deficit, precluding it from paying electricity bills, providing continuous service, and optimizing its operations in any way.

Results of the BWE's walk-through energy audit can be found in Appendix B (Water).

### ***Beirut and Mount Lebanon Water Establishment***

Consultation meetings with BMLWE were conducted to inform them about the scope of the project, and to set out a schedule for site visits. Field visits took place between June 17 and June 25, 2019, with the assistance of Habib El Asmar and Yara El Ashkar (with Dbayyeh water treatment plant visited on May 29, 2019). Over 14 water pumping stations and treatment plants were visited in the cazas of Beirut, Metn, Keserwan, Jbeil, Baabda, Aley, and Chouf. These were identified as facing some energy-related problems and for being a burden on the establishment. Nine wastewater plants were audited, one of which is in the Beirut area (Ghadir) and the rest are in Chouf, and managed by operators under BMLWE jurisdiction.

When compared to other establishments, BMLWE enjoys a higher bill collection-rate of 75%, and thus higher revenues amounting to USD 110 million in 2018<sup>6</sup>, enabling them to operate in a more advanced manner and to pay their electricity bills. Although electricity problems are similar across establishments, BMLWE operates diesel generators (around 177 at 631,000 kVA capacity) more frequently to make up for intermittent electricity supply, and thus service provision is minimally impacted by electricity outages. On the other hand, some stations enjoy round-the-clock electricity allowing them continuous supply, without the need for diesel generators. There are some exceptions where electricity is either highly intermittent or provided with high-voltage fluctuation, and these stations remain problematic for the

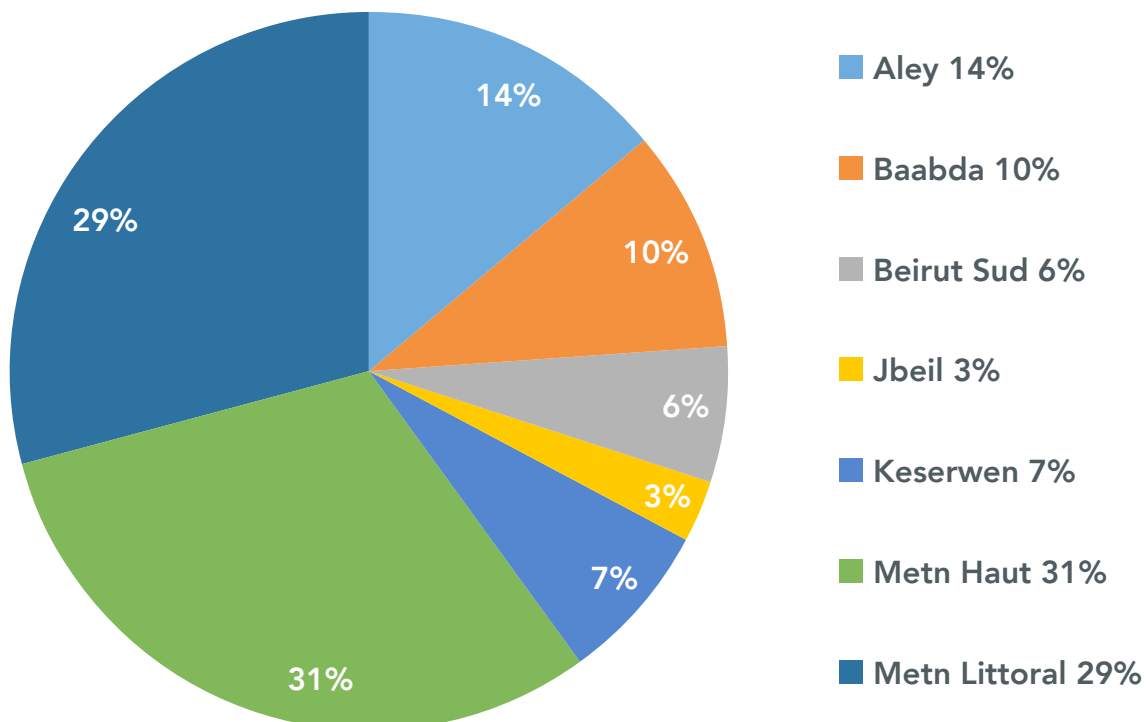
<sup>6</sup> BMLWE data, 2019

establishment. Around USD 3.5 million were spent on diesel fuel in 2018, along with an electricity bill of USD 14.8 million that year<sup>7</sup>. In addition, EDL bills for 2016 and 2017 amounted to USD 12.05 million and USD 12.76 million, respectively. Overall, electricity constitutes 33.6% of O&M cost to the establishment. Table 5 summarizes the electricity charges for BMLWE per region under its jurisdiction, while Figure 2 illustrates the distribution of average bills per region, over the period 2016-18.

Caza	2016 (LBP)	2017 (LBP)	2018 (LBP)
Aley	2,557,954,000	3,265,582,000	4,042,107,000
Baabda	1,865,187,000	1,897,445,000	1,887,852,000
Beirut Sud	1,076,642,000	1,564,312,000	1,127,845,000
Jbeil	586,380,000	413,344,000	619,871,000
Keserwen	1,185,011,000	1,810,473,000	2,345,758,000
Metn Haut	5,562,062,000	4,468,035,000	5,550,074,000
Metn Littoral	5,243,650,000	5,726,160,000	6,651,579,000
TOTAL (LBP)	18,076,888,016	19,145,353,017	22,225,088,018
TOTAL (USD)	12,051,258.67	12,763,568.67	14,816,725.34

\*Note: LBP/USD exchange rate set at the old rate of \$1 = LBP 1,500.

Figure 2. Average BMLWE bills distribution per region (2016-18)



<sup>7</sup> BMLWE data, 2019

Currently, SCADA systems are installed in Beirut, Baabda, Metn, and Keserwan cazas, and enable the establishment to better monitor parameters such as flow, pressure, voltage, etc. Some stations are equipped with Variable Frequency Drive (VFD), which control the frequency of the electrical power supplied to a motor, and thus allow for significant power savings. Decision-making across the establishment is centralized; each operator reports to the head of division, who then reports to the head of department. According to the establishment, there is no communication between municipal and establishment staff.

Results of the BMLWE’s walk-through energy audit can be found in Appendix B (Water).

### **North Lebanon Water Establishment**

The establishment is divided into three separate geographical service areas:

- Northern Area, which includes Minieh, Donnieh, Halba, and Kobayyat.
- Southern Area, which includes Zgharta, Bcharreh, Koura, and Batroun.
- Tripoli Area, which includes Tripoli and the surrounding suburbs: Abou Samra, Qobbeh, Baddaoui, Coastal Tripoli, Mina, Marina Del Sol, and Mejdlaya.

NLWE faces major problems when it comes to electricity shortages as well as an electricity deficit to EDL/Qadisha, amounting to LBP 80 billion (USD 53 million), of which only LBP 22.7 billion (15.2 million) are documented in the electricity bills of 2016, 2017, and 2018 for medium voltage (Table 6).

Figure 3 illustrates the distribution of electricity charges in the various regions, under the jurisdiction of NLWE. In addition, NLWE relies heavily on diesel generators in times of EDL power outages. Electricity constitutes around 20% of the overall budget of the establishment<sup>8</sup>. The establishment, starting in 2018, has set a three-year plan to increase its collection rates from 60% to 75%, and decrease its nonrevenue water (NRW)—currently at 52%. SCADA has been installed in one station, and will progressively be installed in all stations.

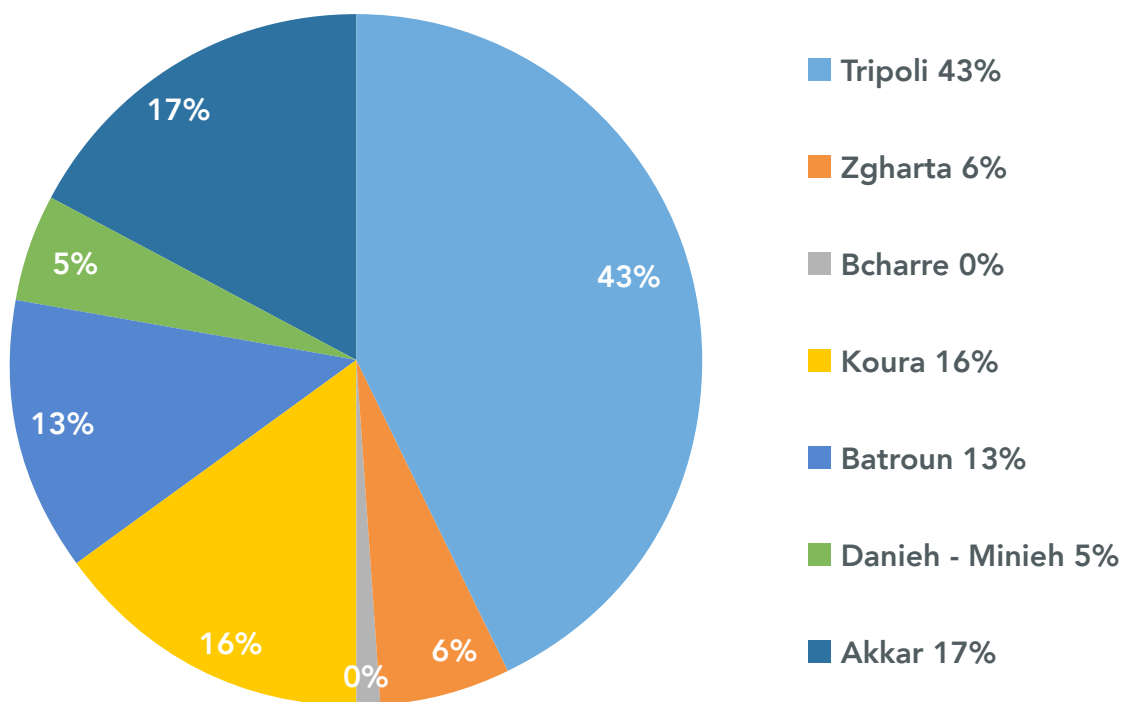
**Table 6 NLWE Medium Voltage EDL/Kadisha Bills (2016-18)**

<b>Caza</b>	<b>2016 (LBP)</b>	<b>2017 (LBP)</b>	<b>2018 (LBP)</b>
Tripoli	2,909,769,000	2,972,197,000	3,042,383,000
Zgharta	416,011,000	424,574,000	518,302,000
Bcharreh	25,888,000	29,123,000	32,670,000
Koura	1,070,480,000	1,132,016,000	1,520,831,000
Batroun	858,945,000	1,098,829,000	1,981,058,000
Minieh - Donnieh	336,428,000	463,261,000	591,682,000
Akkar	1,142,104,000	1,167,542,000	1,140,511,000
TOTAL (LBP)	6,759,625,000	7,287,542,000	8,827,437,000
TOTAL (USD)	4,506,416.67	4,858,361.3	5,884,958

\*Note: LBP/USD exchange rate set at the old rate of \$1 = LBP 1,500.

<sup>8</sup> NLWE data, 2019

Figure 3. Average NLWE bills distribution per caza (2016-18)



The energy audit for water pumping stations began on June 26 and ended on July 30, 2019. It covered the cazas of Tripoli, Akkar, Batroun, Koura, and Zgharta. Eight water-pumping stations and treatment plants were visited. Kamal Mawloud, director of operations at Bahsas station, guided the research team through the operations in Tripoli, and provided insights into operating procedures, while Gaby Nasr and Simon Barakat supported with providing data in all other regions. Financial data (electricity and diesel costs) related to all cazas of northern Lebanon were acquired in coordination and support of Maher Tahsaldar from the establishment’s finance department.

Pumping-station and treatment plant employees covering Tripoli follow standard procedures, whereby parameters are recorded daily, including flow, pressure, voltage, etc. These are compiled into an annual report, which is then shared with the administration, while highlighting challenges and recommendations to improve performance. Indicators relating to electricity and fuel consumption (including a monitoring of the kWh/m<sup>3</sup> indicator) are continuously monitored and benchmarked on a yearly basis. This monitoring system allows for a change of operations, based on the kWh/m<sup>3</sup> performance; for example, the Bahsas station, which is fed primarily by two springs, the Hab and Abou Halka, of which the former is conveyed by gravity. The establishment relies mostly on the Hab Spring except in periods of water shortages, in order to minimize electricity used per meter cube pumped.

This system only applies to Tripoli and is not replicated in other service cazas, which makes it more challenging to access and assess pumping stations’ data and monitor its operations. The main issue in the establishment is poor, time-consuming communication processes between operations and management (headquarters), particularly regarding maintenance

issues and ordering of new equipment. Another issue, which was highlighted, was the lack of alignment between establishment needs and donors' agenda. Energy efficiency is barely considered throughout all the pumping stations, and the main concern is to supply water to subscribers, irrespective of the cost.

Results of the NLWE's walk-through energy audit can be found in Appendix B (Water).

### **South Lebanon Water Establishment**

The energy audit on water-pumping stations took place between August 5 and August 7, 2019, and covered 12 pumping stations in Saida, Nabatiyeh, Zahrani, Jezzine, Tyre, and Bent Jbeil cazas, with the support of Engineers Hassan Roummaneh and Hassan Awkal.

SLWE has a new team of engineers following up on the pumping stations' operations as well as a special team for preventive maintenance of around 50 persons. This covers all electrical and mechanical operations to maintain the equipment to their best condition, such as cleaning, slighting, checking contactors, daily readings, temperature, pressure, valves, fittings, etc. The establishment has also performed energy-check on the efficiency and status of pumps, and renewable energy potential is being assessed in some stations.

Energy cost constitutes a major challenge for the establishment's management, with the total bills for only 2018 amounting to around LBP 9 billion (~6 million USD) *at the audited stations*, some of which pump to extreme high elevations (reaching sometimes 500 m head). Diesel generators are barely used throughout the establishment's stations, due to their high cost as well.

Results of the SLWE's walk-through energy audit can be found in Appendix B (Water).

### **Water Sector Analysis (Level-1)**

A database of all stations was compiled, based on Level 1 performance audits, including the following primary data: electricity bills for the last three years (whenever available); liters of diesel fuel consumed during those years and their respective costs; and total flow (m<sup>3</sup>/h or m<sup>3</sup>/day). The data collected was then used to generate the annual utility consumption (kWh)—wherever it was not available—as well as the diesel consumption (kWh); the total energy consumption (kWh), and total energy cost. Further data processing resulted in the calculation of the two indicators for the given years: the energy use index (EUI) in kWh/m<sup>3</sup>, and the *unitary energy cost* (UEC) in USD/m<sup>3</sup>, which reflect the stations' costs for running them through EDL, along with the private diesel generators whenever EDL current is unavailable. The equations for calculating the two indicators are as follows:

$$EUI = \frac{\text{Total Energy Consumption (EDL + Diesel)}}{\text{Total Flow per day}}.$$

Such that the annual EUI is in kWh/m<sup>3</sup>, Total Energy Consumption is in kWh, and Total Flow per day is in m<sup>3</sup>/d.

$$UEC = \frac{\text{Total Cost (EDL + Diesel)}}{\text{Total Flow per day}}$$

Where annual is in USD/m<sup>3</sup>, Total Cost is in LBP, and Total Flow is in m<sup>3</sup>/d

Once the indicators were determined for stations with available data<sup>9</sup>, stations were hierarchically arranged (from highest to lowest) to reflect their energy intensity.

### North Lebanon Water Establishment

Figures 4, 5, and 6 display the order of water stations in North Lebanon, as per the electricity and diesel bills, the EUI, and the UEC for 2016, 2017, and 2018. It is apparent that the Bohsas plant clearly carries the heaviest energy cost, with around LBP 1.5 billion. This is due to two reasons: the water treatment processes are performed around the clock, and the volume of flow it handles (around 70,000 m<sup>3</sup>/day). Abu Samra, Abu Halka, and Jradeh follow with annual bills of similar amounts of nearly LBP 600 million, on average.

Figure 4. North Lebanon water stations—average energy cost (utility subscription and diesel) between 2016-18

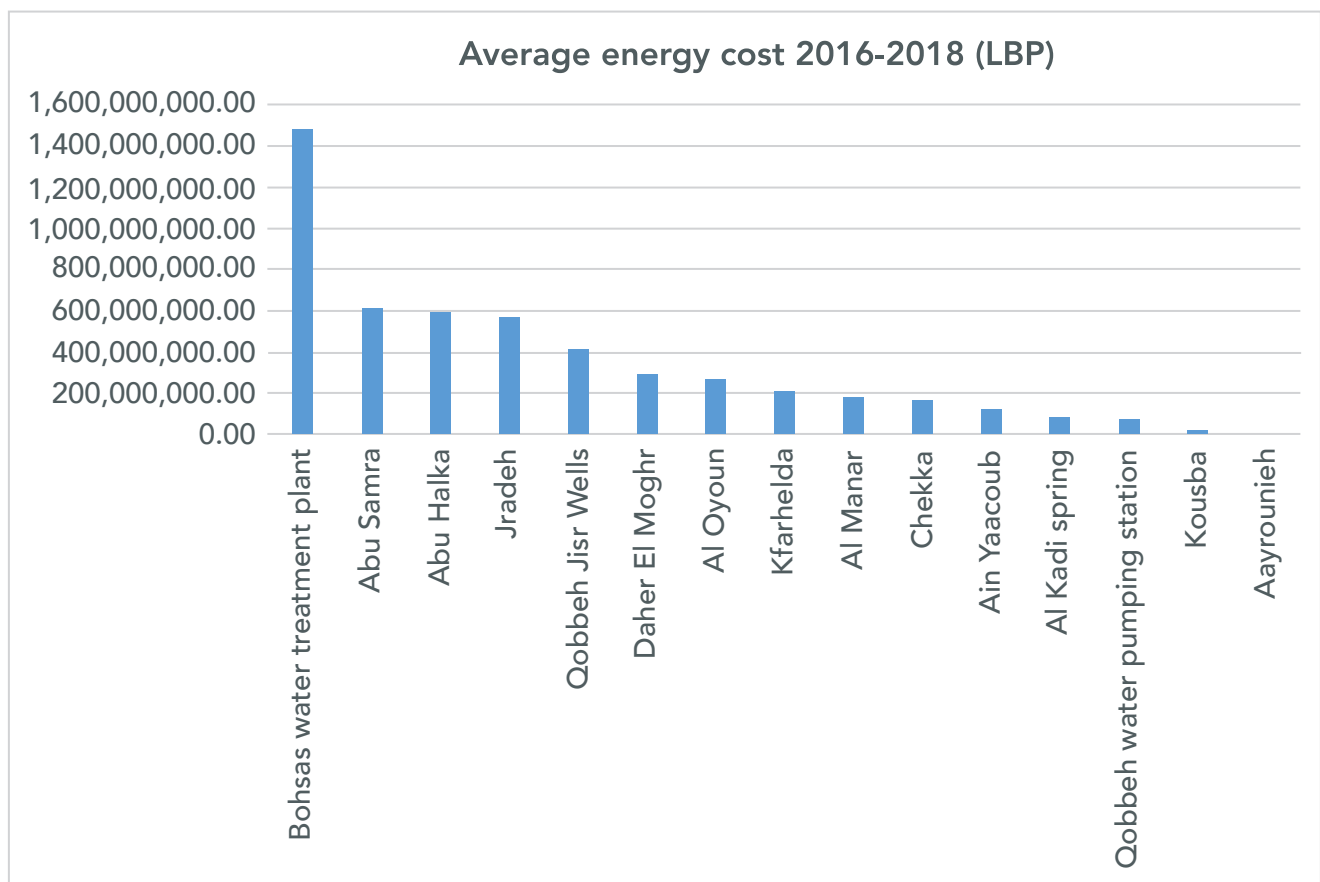


Figure 5 and Figure 6 represent the result of the application of the energy performance assessment; more specifically, they display the benchmarking limits for each of the NLWE audited station's performance indicators (EUI<sup>10</sup> and UEC).

<sup>9</sup> Throughout this analysis, a major limitation has been the lack of data (bills) for some stations; therefore, whenever such a situation was faced for a particular station, it was excluded from the analysis.

<sup>10</sup> The energy consumption benchmark in water supply systems ranges between 0.4 kWh/m<sup>3</sup> and 0.65kWh/m<sup>3</sup>

Figure 5. North Lebanon water stations—energy use index average 2016-17 (kWh/m<sup>3</sup>)

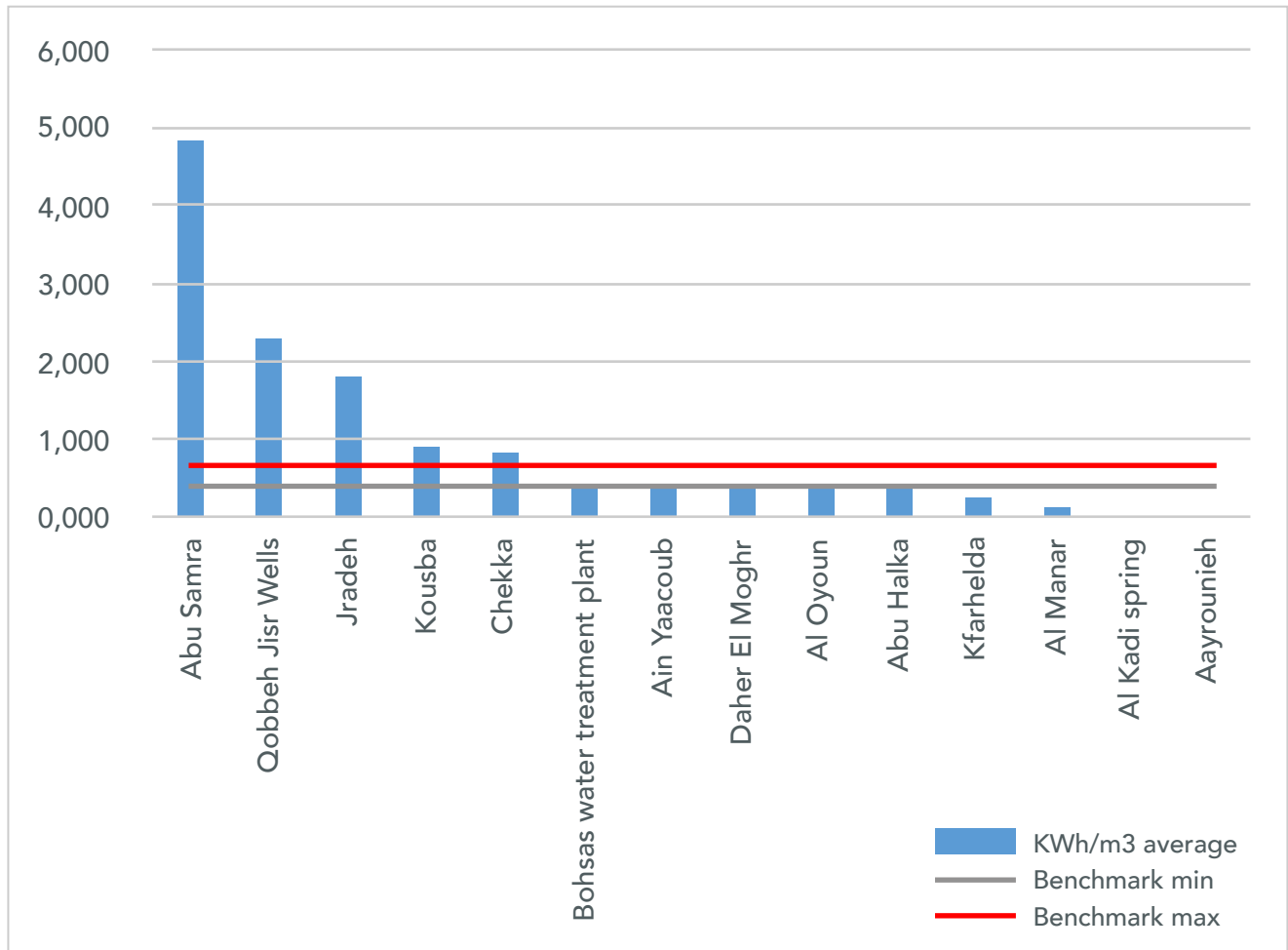
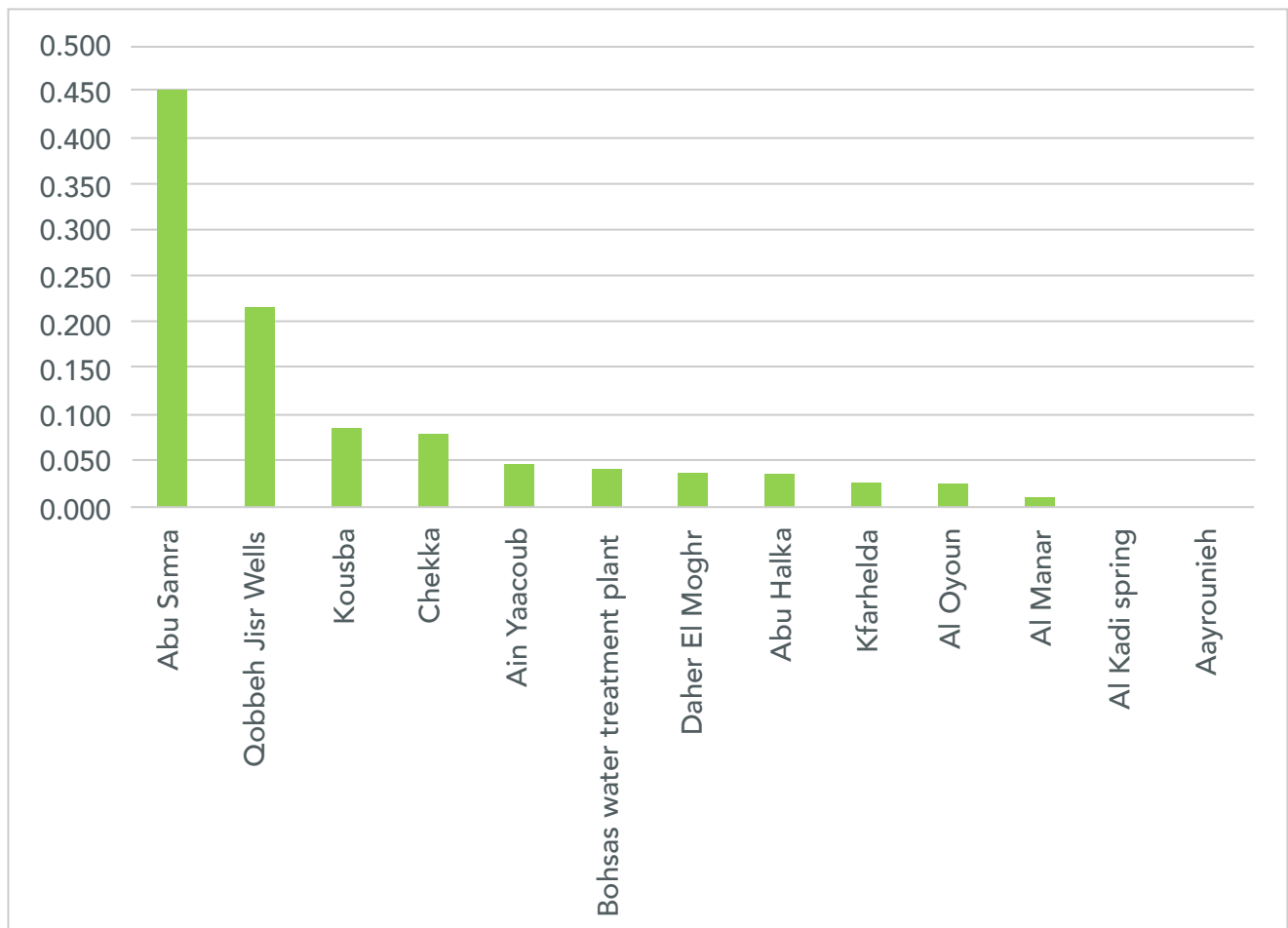


Figure 6. North Lebanon water stations—unitary energy cost average 2016-17 (USD/m<sup>3</sup>)



A closer look at the indicators reveals that Abu Samra and Qobbeh Jisr Wells are the most energy intensive, with EUIs greatly exceeding the typical international index of 0.65 kWh/m<sup>3</sup>, recording 4.8 kWh/m<sup>3</sup> and 2.3 kWh/m<sup>3</sup>, respectively (Figure 5). These results go hand-in-hand with the unitary energy cost findings, as these two stations display the highest numbers exceeding 0.2 USD/m<sup>3</sup> for Abu Samra, and reaching 0.45 USD/m<sup>3</sup> in Qobbeh Jisr Wells (Figure 6). In other words, pumping water from these two stations is energy intensive and expensive, making them hotspots to further analysis.

After identifying the most energy intensive stations, in terms of electricity costs, an in-depth analysis of the pumps' performance was conducted for all audited stations, using the Standardized Pump Energy (SPE) indicator (in kWh/m<sup>3</sup>.100m), derived from the pumps' characteristics (flow, static head, and nameplate power). The result is displayed in Table 7.

**Table 7 NLWE Standardized Pump Indicators**

NLWE standardized pump indicator			
Station	kWh/m <sup>3</sup> per 100m	Benchmark min	Benchmark max
Bahsas	0.372	0.3	0.65
Jisr	0.850	0.3	0.65
Qobbeh	0.561	0.3	0.65
Ayrounieh	0.627	0.3	0.65
Dahr el Moghr	0.494	0.3	0.65
Abu Halka	0.480	0.3	0.65
Al Manar	0.743	0.3	0.65
Abu Samra	0.544	0.3	0.65
Jradeh	0.353	0.3	0.65
Chekka	0.436	0.3	0.65
Kfarhelda	0.562	0.3	0.65
Al Oyoun	0.325	0.3	0.65
Ain Yaacoub	0.555	0.3	0.65

Figure 7. NLWE Standardized Pump Indicators

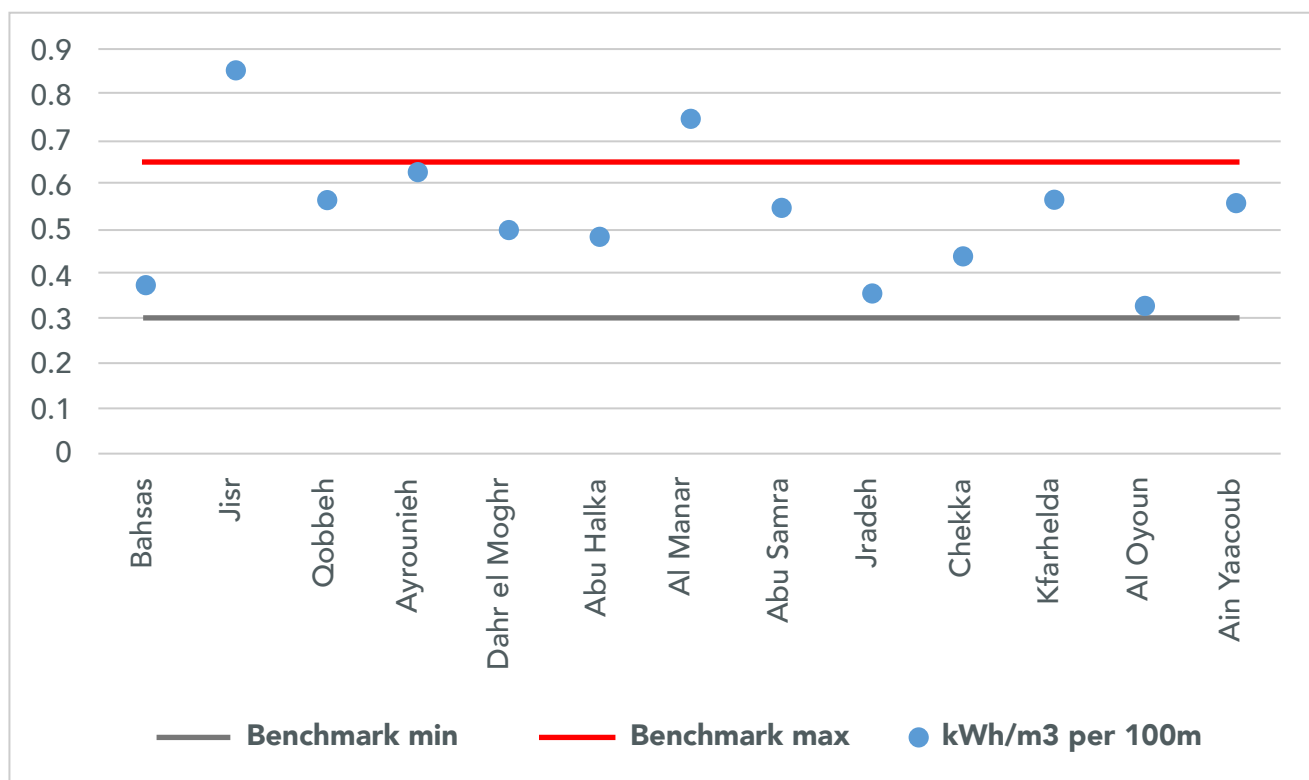
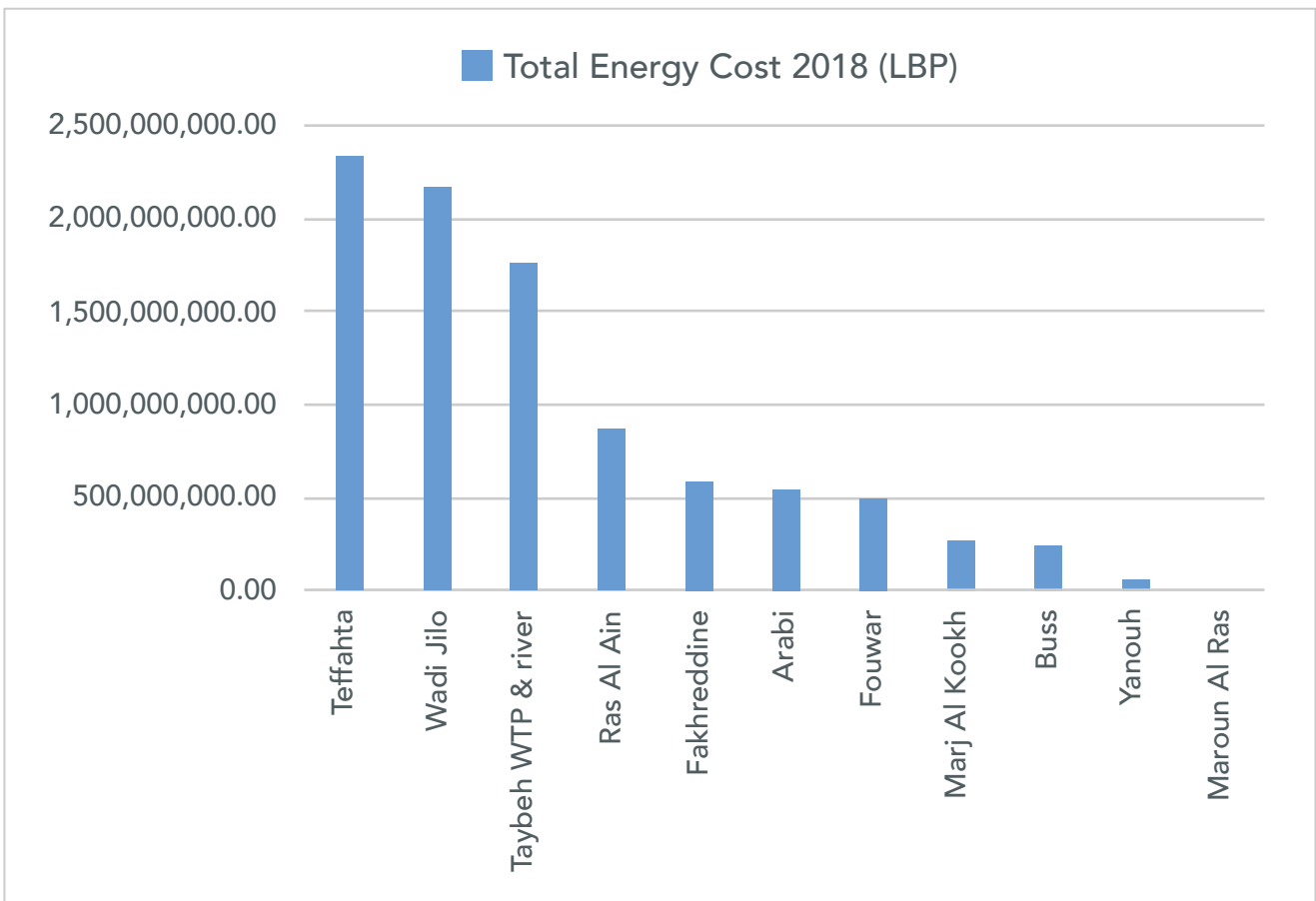


Figure 7 reflects the average SPE for all the available pumps at the audited stations. When compared to the EUI (Figure 5) and UEC (Figure 6) results, the SPE indicator shows that most of the stations' performances fall within the benchmarks' minimum and maximum values. This indicates that the pumps at the most energy-intensive stations are performing within the set benchmarks, and that there is no direct correlation of this indicator with the high-energy cost estimates and the stations' overall performance, in terms of energy bills. This lack of correlation is reflected in the following cases: (a) both the Abou Samra and Jradeh stations have an average EUI indicator higher than the identified optimal range (4.8 and 1.8 kWh/m<sup>3</sup>, respectively), while their respective SPE indicators are well within the benchmarks; (b) the Qobbeh Jisr Wells station has a high EUI of 2.3 kWh/m<sup>3</sup>, and an above-the-limit SPE indicator of 0.85 kWh/m<sup>3</sup>/100m; and (c) the Ayrounieh, Al Manar, and Al Oyouun stations have EUI scores lower than the benchmark, yet their SPE indicators are within the SPE benchmarks albeit at its minimum and maximum benchmarking limits. An initial conclusion presented here is that the high SPE indicator is an indication of inefficiently operated pumps.

### South Lebanon Water Establishment

A preliminary analysis of the total energy cost in 2018 of water stations reveals roughly two main clusters of facilities in the south of Lebanon. The first includes Teffahta, Wadi Jilo, and Taybeh water-treatment plant and river-pumping station with an average total energy cost of around LBP 2,000 million each per year; and the second comprises of Ras Al Ain and Fakhreddine, along with six others, have average total energy costs of nearly LBP 440 million each per year (Figure 8). Most water pumping stations do not rely on diesel generators in the South (except for Arabi and Maroun Al Ras). This implies that the total energy cost is, in most cases, linked to the EDL subscription.

Figure 8. South Lebanon water stations—total energy cost (utility subscription and diesel) 2018



Applying energy performance assessment, and plotting stations in descending order, according to the Energy Use Index (EUI) and Unitary Energy Cost (UEC) index confirms that Teffahta, Wadi Jilo, and Taybeh (WTP and river) are the most energy intensive stations. As displayed in Figure 9, these stations greatly exceed the adopted maximum EUI benchmark of 0.65 kWh/m<sup>3</sup>. Two other stations, Fakhreddine and Ras Al Ain exceed the benchmark's maximum limit but to a much lesser extent than the aforementioned three (both stations scored 0.95 and 0.89 kWh/m<sup>3</sup>, respectively). These results parallel the stations' UEC values, as highlighted in Figure 10, with the Teffahta, Wadi Jilo, and Taybeh (WTP and river) all exceeding 0.2 USD per m<sup>3</sup> pumped.

Figure 9. South Lebanon water stations—energy use index 2018 (kWh/m<sup>3</sup>)

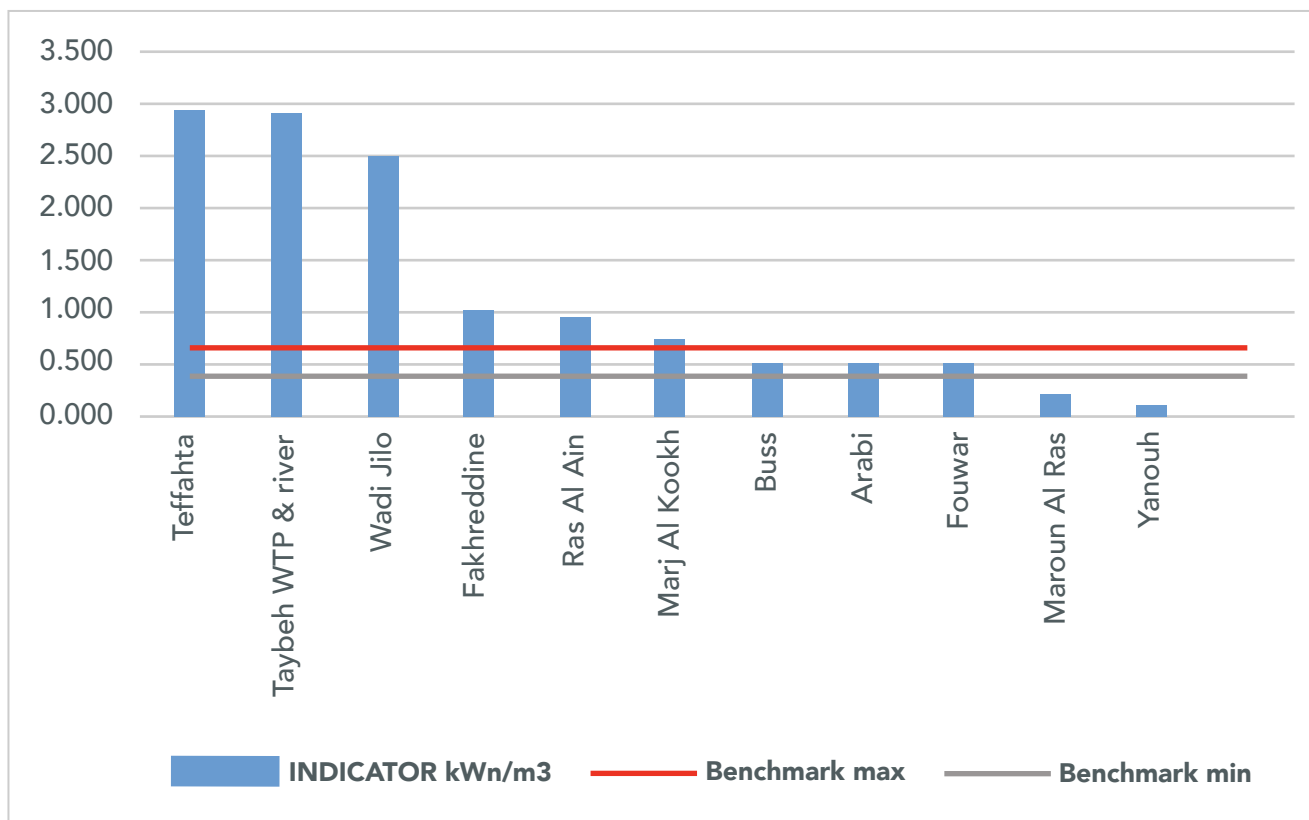
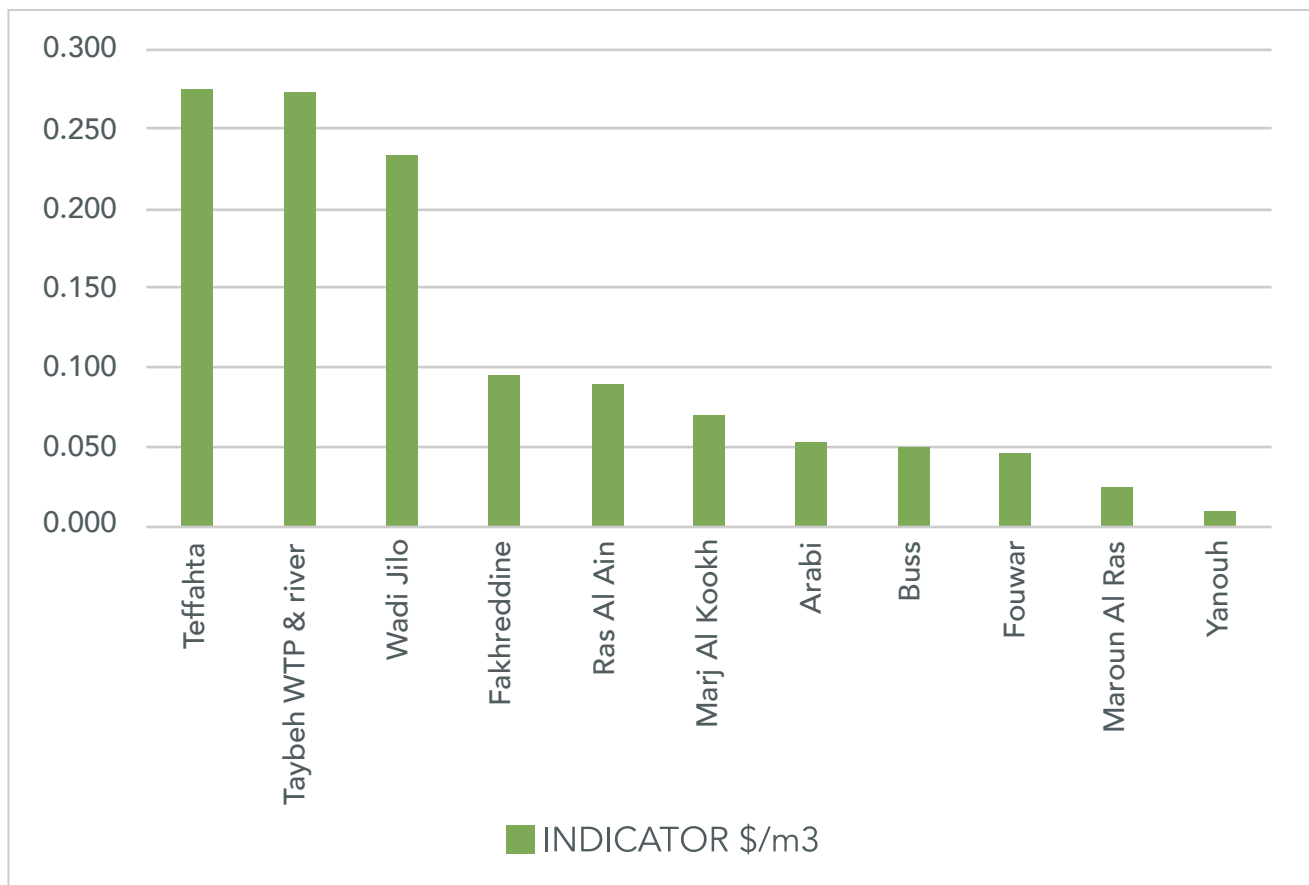


Figure 10. South Lebanon water stations—unitary energy cost 2018 (USD/m<sup>3</sup>)



As with the NLWE, further investigation was performed using the average SPE for all the available pumps at the audited stations. The results are shown in Table 8.

Table 8 SLWE Standardized Pump Indicators

SLWE Standardized Pump Indicator			
Station	kWh/m <sup>3</sup> per 100m	Benchmark min	Benchmark max
Arabi	0.583	0.3	0.65
Fouar	0.507	0.3	0.65
Teffahta	0.440	0.3	0.65
Fakhreddine	0.385	0.3	0.65
Buss	0.413	0.3	0.65
Ras al Ain	0.429	0.3	0.65
Wadi Jilo	0.336	0.3	0.65
Yanouh	0.481	0.3	0.65
Marj al Kookh	0.298	0.3	0.65
Taybeh	0.224	0.3	0.65
Maroun al Ras	0.803	0.3	0.65

Figure 11. Pump matrix with average pump energy indicators in South Lebanon water stations

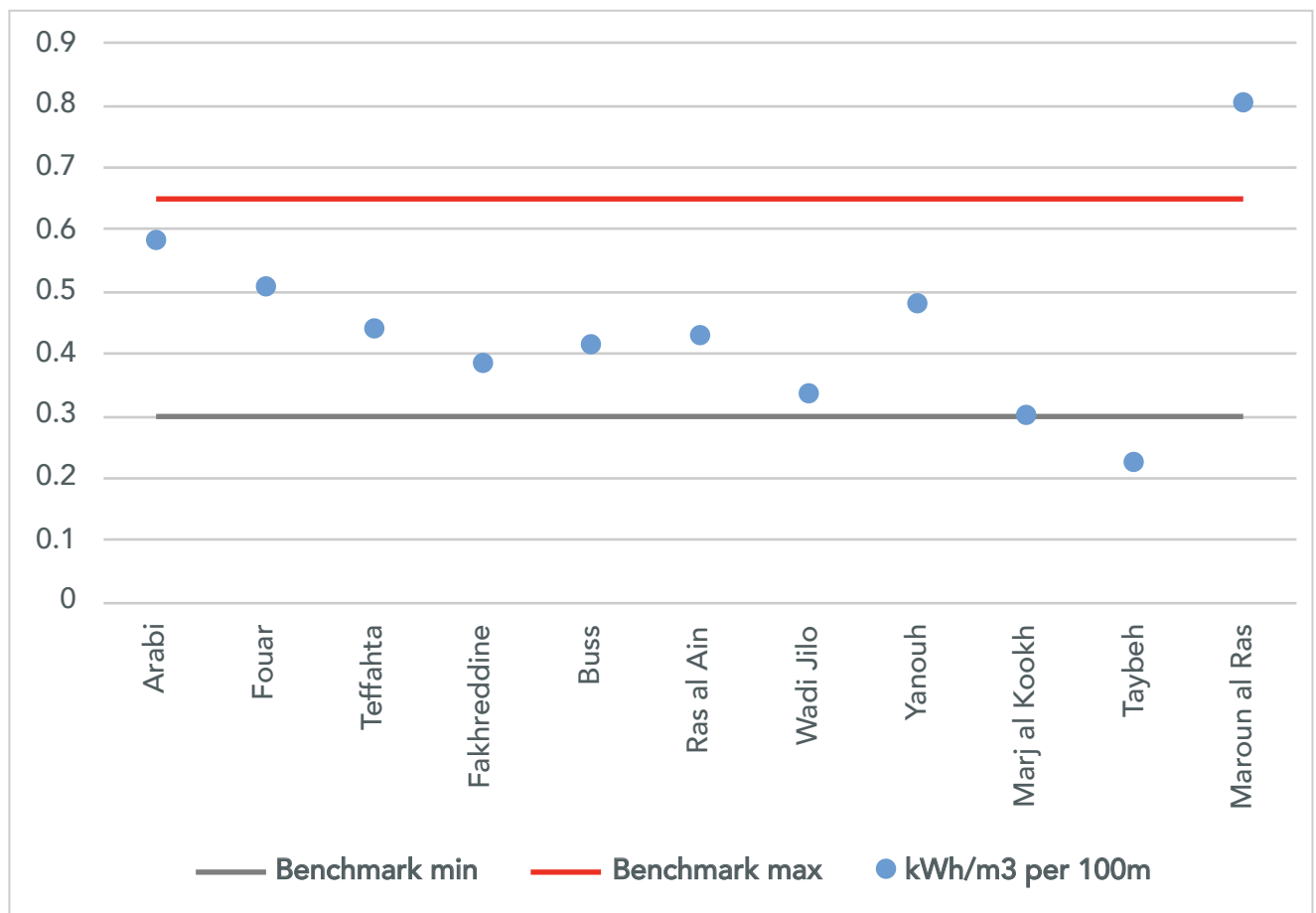


Figure 11 reflects the average SPE indicator of all the available pumps at the audited stations. When compared to the EUI and UEC values, the results show that four out of the five stations, which were identified as the most energy-intensive ones in terms of energy cost (Teffahta, Wadhi Jilo, Fakhreddine, and Ras El Ain), fall within the benchmarking ranges of the SPE indicator, while only Taybeh (treatment plant and river-pumping station) presents an EUI of around 2.93 kWh/m<sup>3</sup>.

On the other hand, Marj El Kookh and Maroun Al Ras, which both have presented acceptable EUI and UEC values, have shown SPE indicator values of 0.298 and 0.803 kWh/m<sup>3</sup>/100m, respectively, both of which are beyond the indicator's designated benchmarks. Here too, this may be an indication of inefficiently operated pumps.

### ***Beirut and Mount Lebanon Water Establishment***

Water stations in Beirut and Mount Lebanon rely on both the utility (EDL) and diesel generators for the stations' energy supply. Out of the 14 audited water-pumping stations, the team had access to the establishment's electricity bills database for 12 (of the 14), with data for both Akoura and Madiq unavailable.

Figure 12 displays the order of BMLWE's water-pumping stations as per the average electricity and diesel bills for 2016, 2017, and 2018. Dbayeh water-treatment plant clearly carries the heaviest energy cost, with an average of around LBP 3.75 billion, due to the water-treatment processes performed around the clock, and the volume of flow that it handles (around 250,000 m<sup>3</sup>/day), serving the coastal Metn and greater Beirut areas. Qornet El Hamra also has a high-energy bill of more than LBP 1 billion, which is most likely due to the continuous operations to elevated heads, around 300m. It should be noted that both Dbayeh and Qornet El Hamra do not use diesel generators, and thus the above costs reflect only EDL consumption.

Dayshounieh Baada and Jisr El Qadi come in at third and fourth most energy intensive stations, with a total energy cost over LBP 600 million; noting that a huge share of this cost is the Jisr El Qadi station (around 85%), attributed to the heavy usage of diesel generators due to the continuous electricity outages. Achrafieh and Qashqoush come next, with an average electricity bill of LBP 500 million.

The EUI and UEC performance indicators are represented in Figure 13 and Figure 14 for the audited water pumping stations at BMLWE.

Figure 12. BMLWE water stations—average energy cost (utility subscription and diesel) 2016-18 (LBP)

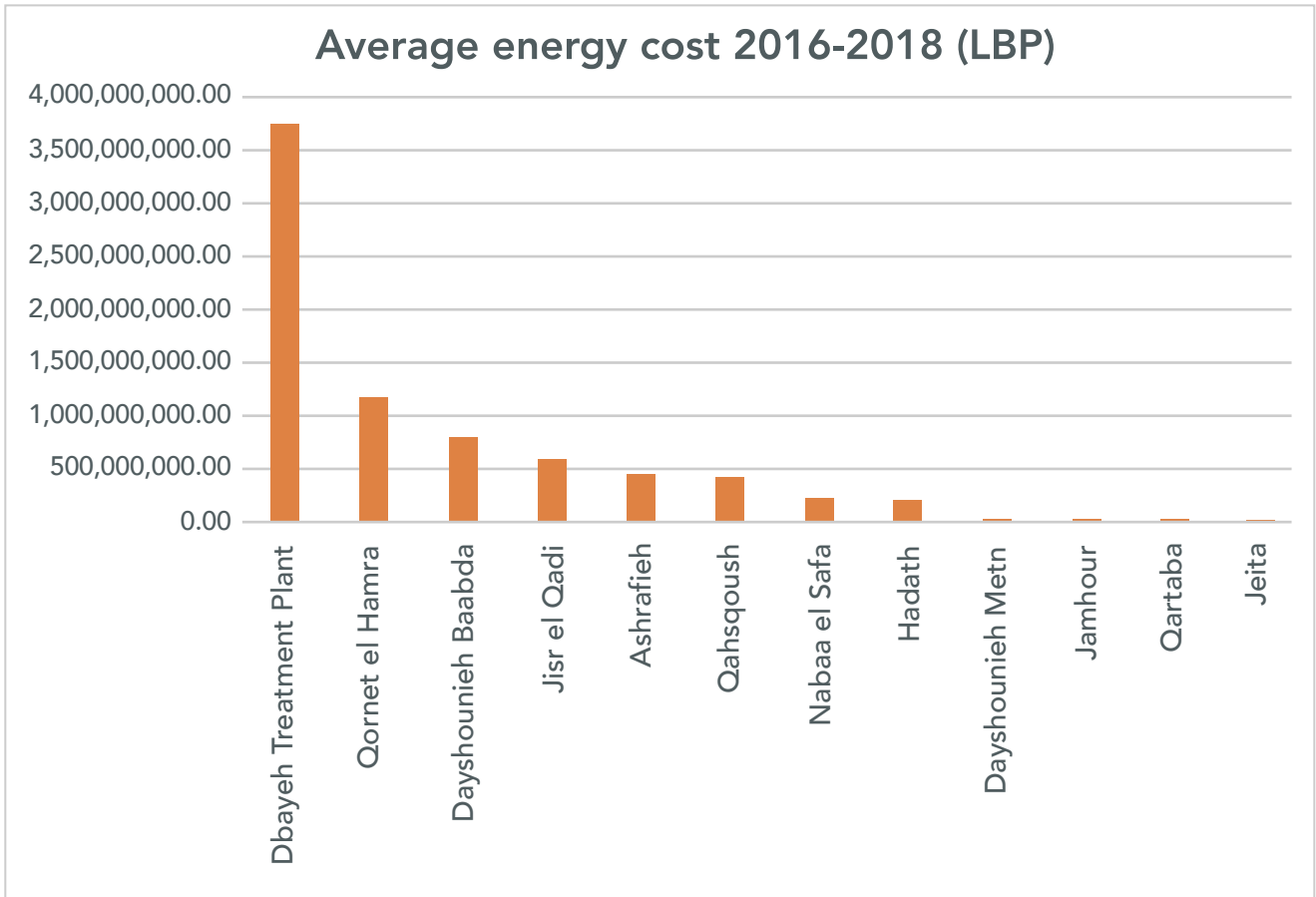


Figure 13. BMLWE water stations—energy use index average 2016-18 (kWh/m<sup>3</sup>)

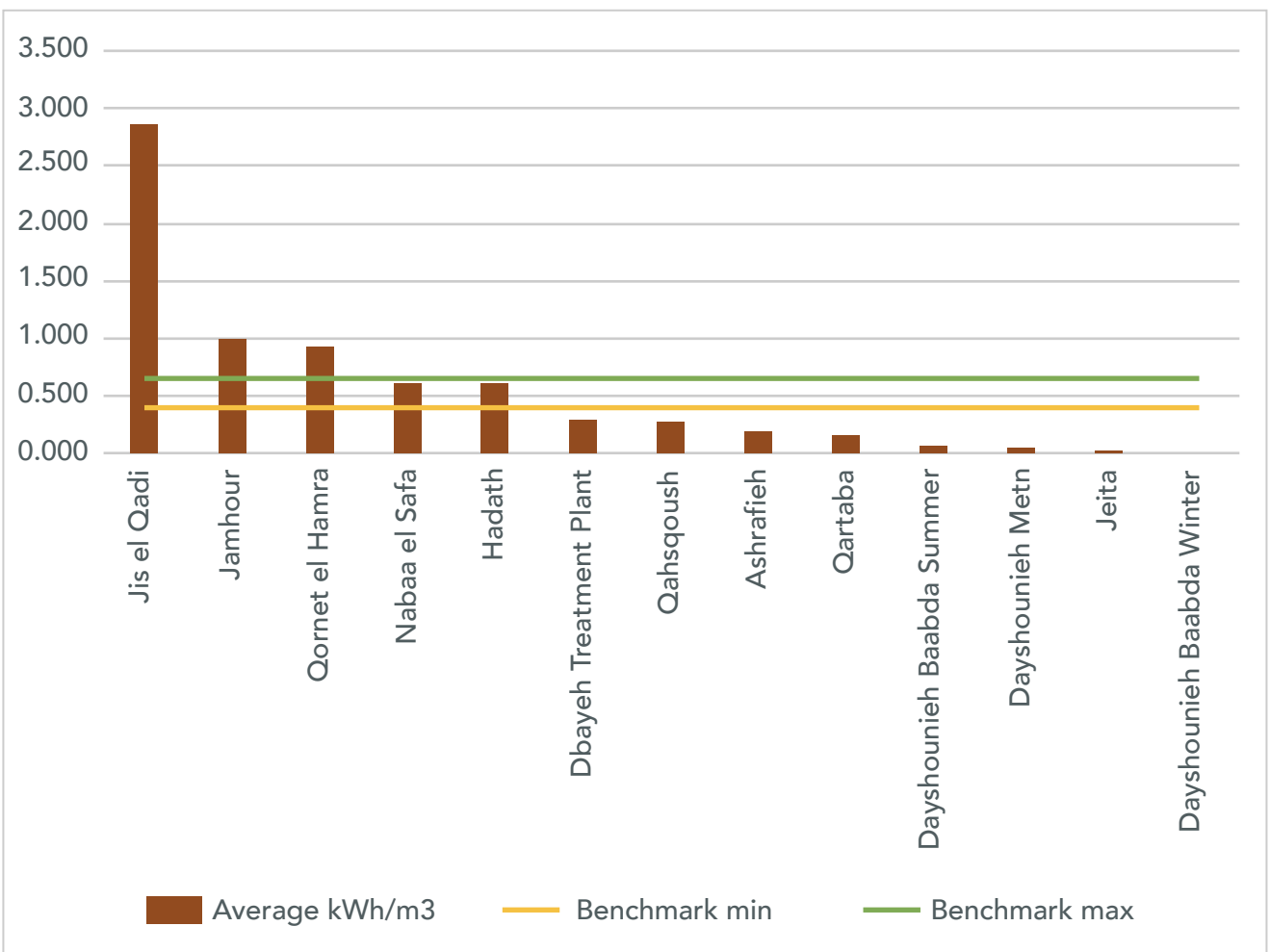
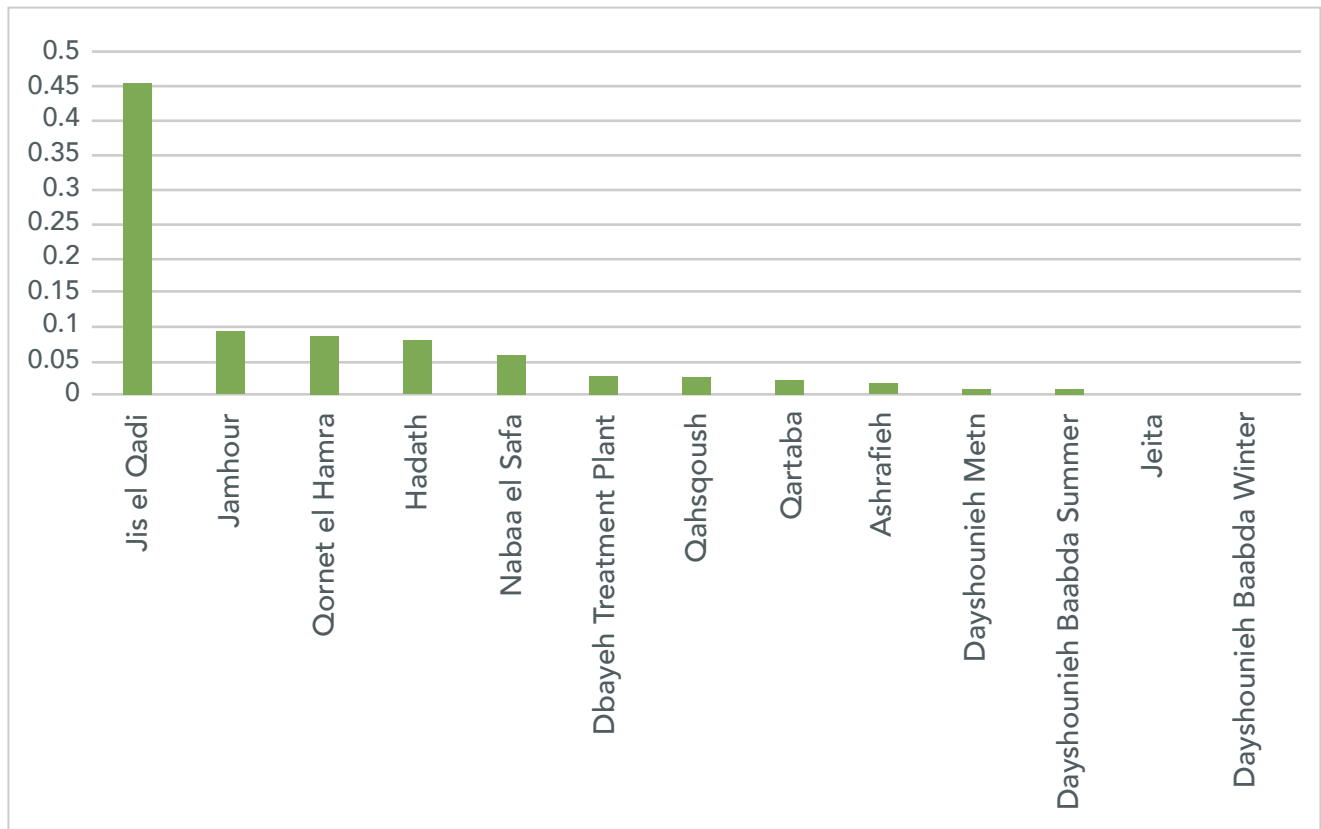


Figure 14. BMLWE water stations—unitary energy cost average 2016-18 (\$/m<sup>3</sup>)



A closer look at the indicators reveals that Jisr El Qadi, Jamhour, and Qornet El Hamra stations are the most energy consuming, with EUIs slightly exceeding the typical international index of 0.65 kWh/m<sup>3</sup> for both Jamhour and Qornet El Hamra (0.989 and 0.921 kWh/m<sup>3</sup>, respectively), while greatly exceeding this benchmark for Jisr El Qadi station, which registered an EUI of 2.86 kWh/m<sup>3</sup>.

Jisr El Qadi and Qornet El Hamra have already been highlighted in Figure 12 as stations with high electricity cost, while Jamhour has shown low energy cost; however, its high EUI represents a higher burden on the establishment. This is paralleled by the UEC indicator, which highlights that those three stations also reveal high cost for each cubic meter of water pumped, with Jisr El Qadi registering the highest index at around 0.45 USD/m<sup>3</sup>.

The SPE indicator was also determined for all the available pumps at the audited stations in a manner similar to what was done for SLWE and NLWE. The results for the various stations are represented in Table 9.

Table 9 BMLWE Standardized Pump Indicators

BMLWE Standardized Pump Indicator			
Station	kWh/m <sup>3</sup> per 100m	Benchmark min	Benchmark max
Qartaba	0.494	0.3	0.65
Akoura	0.416	0.3	0.65
Madiq	0.397	0.3	0.65
Achrafieh	0.354	0.3	0.65
Qornet el Hamra	0.429	0.3	0.65
Qashqoush	0.484	0.3	0.65
Jeita	0.412	0.3	0.65
Jisr el Qadi	0.700	0.3	0.65
Nabaa el Safa	0.419	0.3	0.65
Hadath	0.378	0.3	0.65
Jamhour	0.417	0.3	0.65
Dayshounieh Baabda	0.406	0.3	0.65
Dayshounieh Metn	0.291	0.3	0.65
Dbayeh TP (NEW)	0.473	0.3	0.65
Dbayeh TP (OLD)	0.447	0.3	0.65

Figure 15. Pump matrix with average pump energy indicators in BMLWE water stations

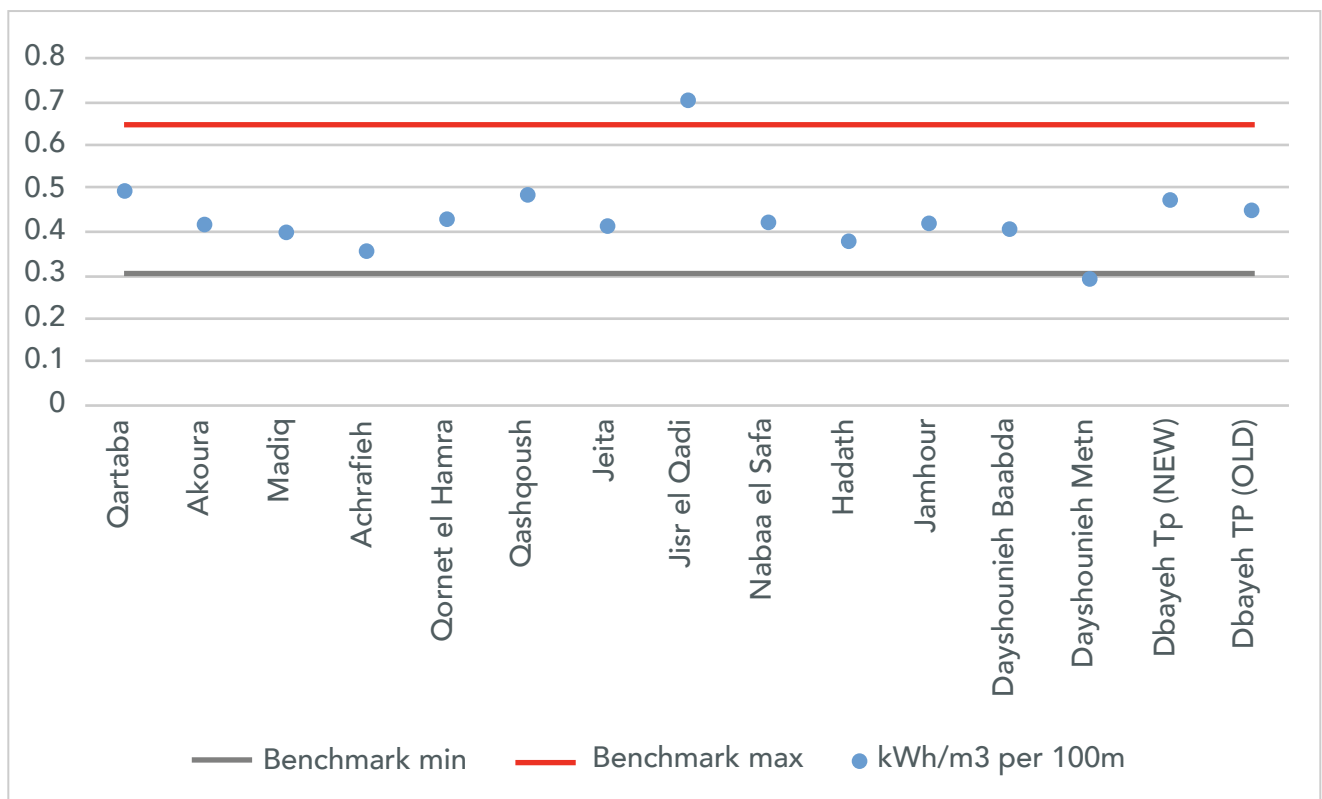


Figure 15 illustrates the SPE indicator scores for all the audited stations, with respect to established benchmarks. It is evident that most of the stations (11 out of 13) fall within the minimum and maximum benchmark values, and the ones highlighted with high EUI and UEC numbers are not reflected in terms of the SPE. As with similar cases in other establishments, the Jisr El Qadi pumping station, which was ranked with the highest EUI and UEC values (2.86 kWh/m<sup>3</sup> and 0.45 USD/m<sup>3</sup>, respectively) had an SPE indicator above the maximum limit for the SPE (0.700 kWh/m<sup>3</sup>/100m). Again, this is probably an indication of inefficiently operated pumps.

### **Bekaa Water Establishment**

Water stations in the Bekaa completely rely on the utility (EDL or EDZ) for energy supply. A first glance at Figure 16 of the total energy costs immediately sets Chamsine pumping station apart, with over LBP 1.3 billion, and only in 2017, spent had round-the-clock electricity and operations. Jdita and Loussi, on the other hand, only receive 12 and 15 hours of electricity per day, respectively, and have energy costs below LBP 400 million. The intermittency of the electricity supply in Jdita and Loussi is represented by an EUI at the limit or below the maximum benchmark. As for Ghazze, this pumping station is hybrid, relying on EDL whenever available, and recently added 176.8 kWp solar-powered pumping. Zahle water-treatment plant’s energy cost is also relatively low, since the station exceptionally relied on EDZ in 2017 for backwash pumps only. The station supplies water by gravity, decreasing the reliance on pumping, and therefore reduces the need to consume electricity.

**Figure 16. Bekaa water stations—total energy cost 2017 (LBP)**

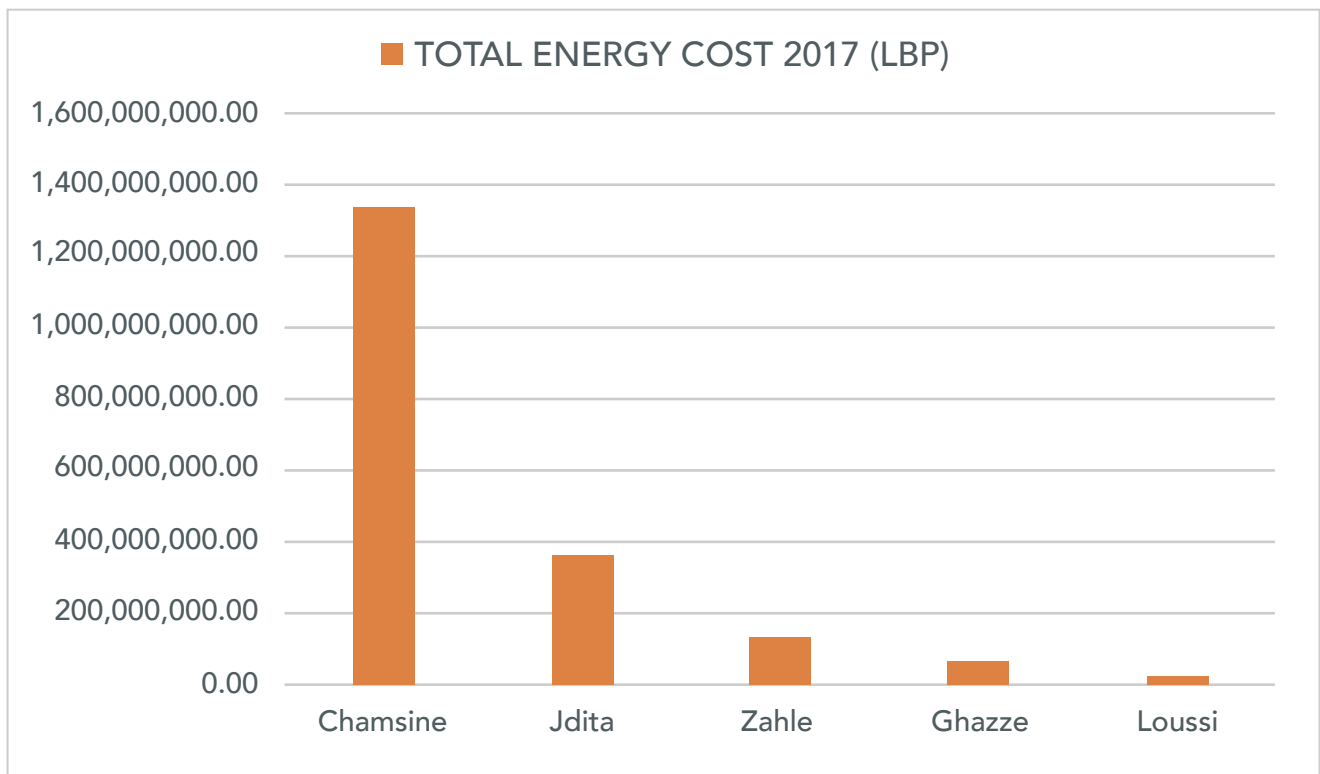


Figure 17. Bekaa water stations—energy use index 2017 (kWh/m<sup>3</sup>)

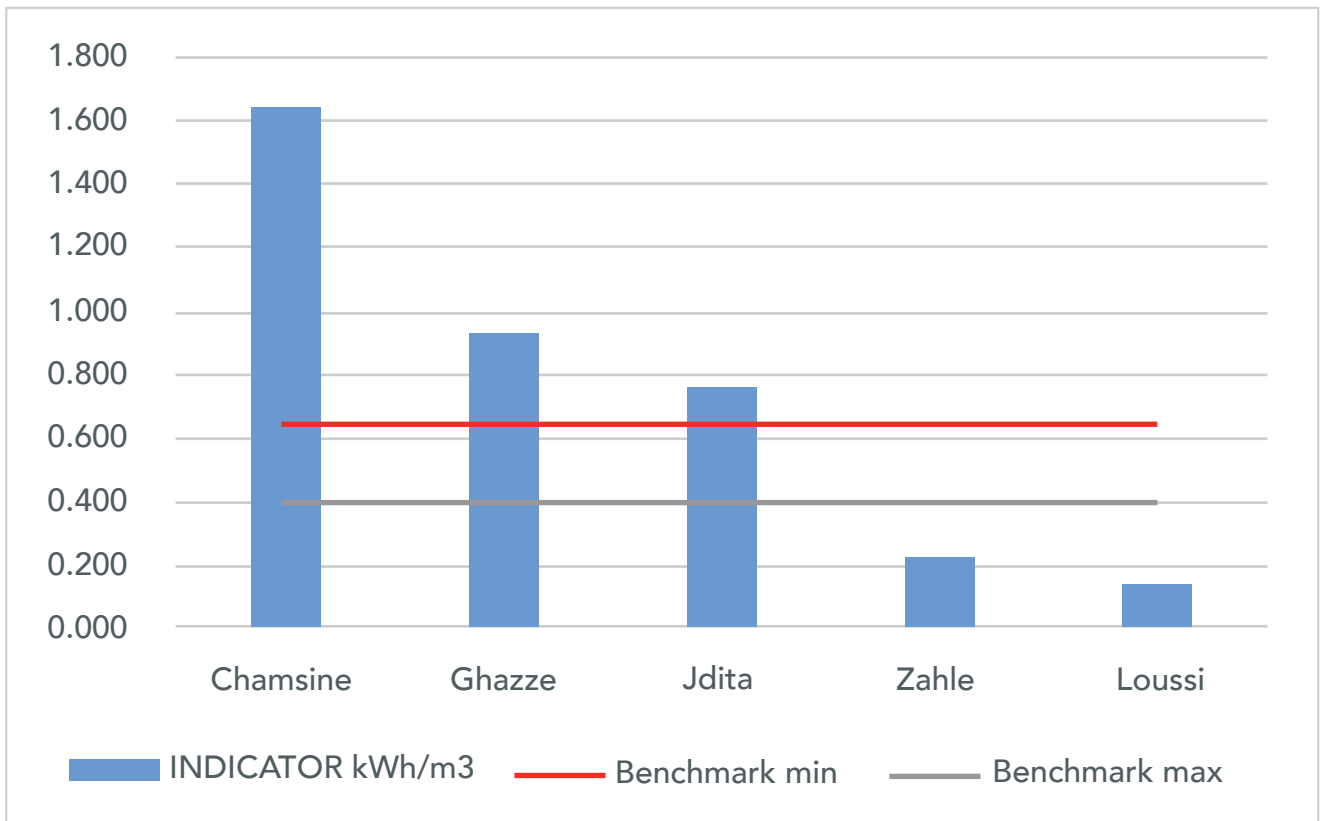
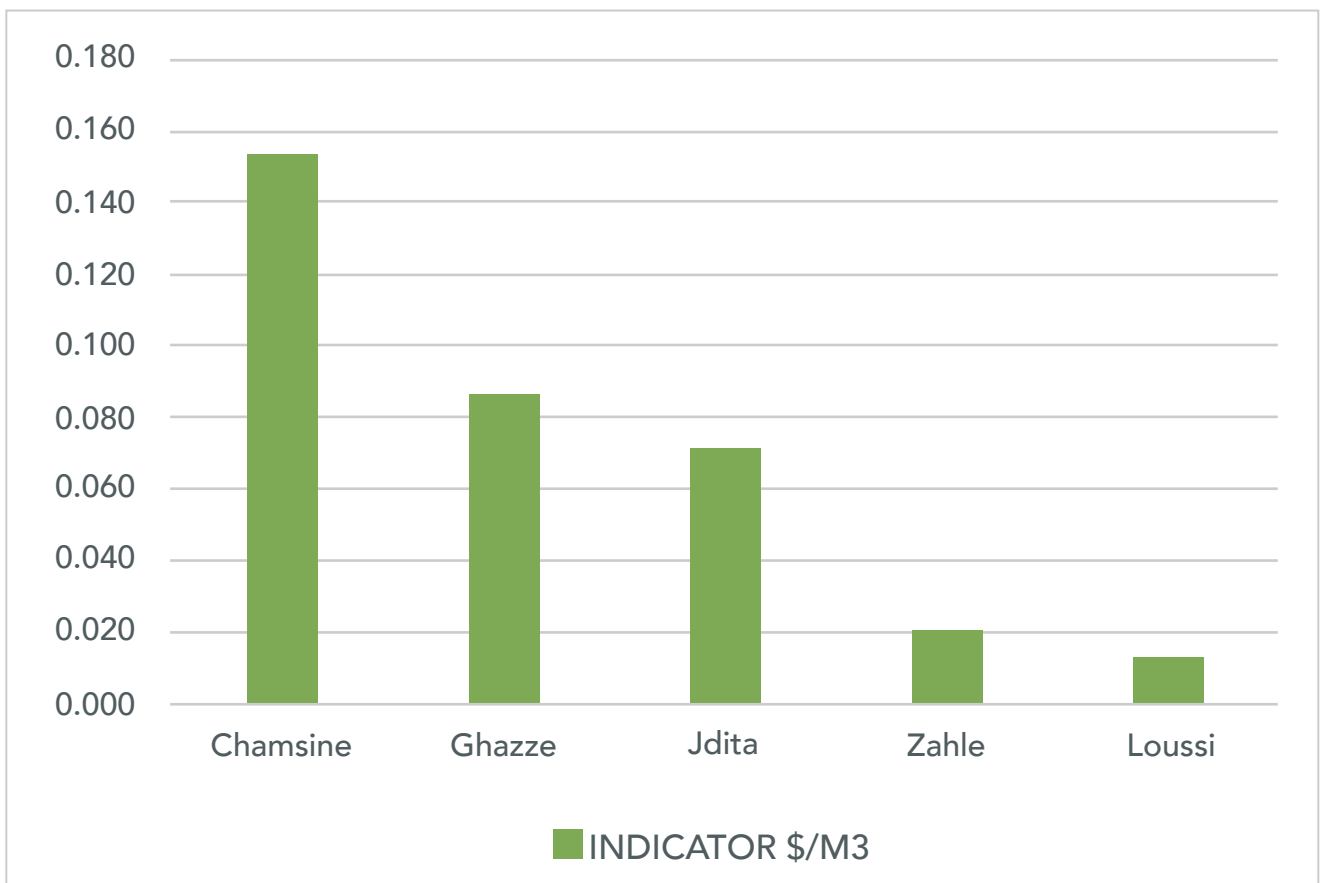


Figure 18. South Lebanon water stations - unitary energy cost 2017 (USD/m<sup>3</sup>)



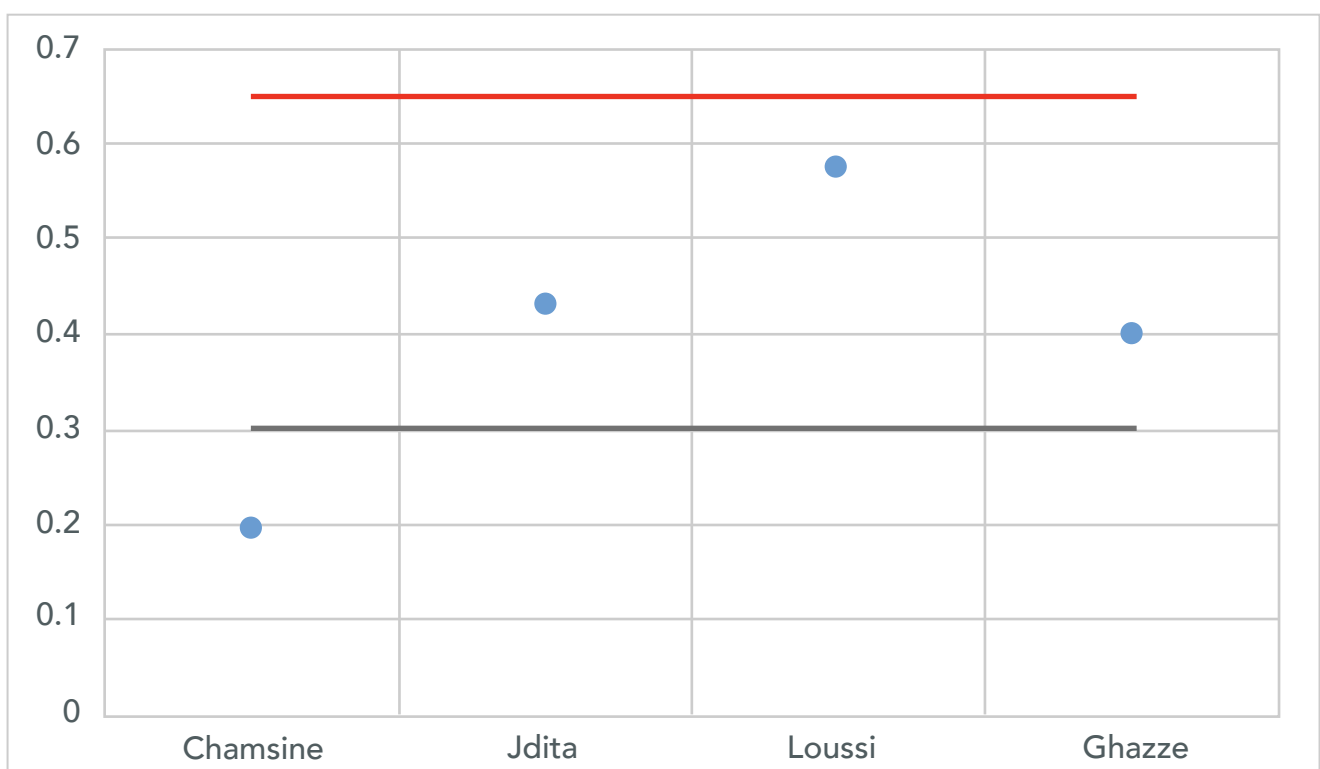
Plotting the audited water pumping stations at BWE, descending order, according to their Unitary Energy Cost (UEC) in Figure 17 and Energy Use Index (EUI) in Figure 18 confirms that Chamsine is the most energy-intensive station, with an EUI of around 1.65 kWh/m<sup>3</sup>, followed by Ghazze and Jdita (0.93 and 0.76 kWh/m<sup>3</sup>, respectively). These stations greatly exceed the adopted maximum benchmark of 0.65 kWh/m<sup>3</sup>. This result goes hand-in-hand with the elevated UEC findings (exceeding 6 cents per cubic meter pumped), which are yet less costly than the NLWE and SLWE energy-intensive stations. Another observation is that the Ghazze station, despite being partially shifting to solar-pumping since October 2018, still reveals high EUI and UEC values, which might be a consequence of operational mismanagement, and the philosophy of how and when to use solar-power for water pumping.

The SPE indicator was also determined for all the available pumps at the audited stations in a manner similar to what was done for the previous water establishments. The results for the various stations are represented in Table 10. The Zahle water treatment station was not considered in this investigation, as it does not rely on pumping; water flows by gravity.

**Table 10 BWE Standardized Pump Indicator**

BMLWE Standardized Pump Indicator			
Station	kWh/m <sup>3</sup> per 100m	Benchmark min	Benchmark max
Chamsine	0.196	0.3	0.65
Jdita	0.431	0.3	0.65
Loussi	0.576	0.3	0.65
Ghazze	0.403	0.3	0.65

**Figure 19. BWE Standardized Pump Indicator**



The matrix above reveals that while the SPE indicator shows that Chamsine pumping station is below the acceptable minimum benchmarking-value (around 0.2 kWh/m<sup>3</sup>/100m), Loussi, Ghazze, and Jdita's pumps are within the acceptable benchmark (0.57, 0.403, and 0.43 kWh/m<sup>3</sup>/100m, respectively), despite being identified among the most energy-intensive ones, and which have presented elevated EUI and UEC.

As for Chamsine, the average pumping energy indicator is significant, and might be a consequence of pumping water at elevated heads and very high flows, revealing efficient operations. Moreover, this station supplies water to 26 villages overall, eight of which are only supplied by springs, leaving around 18 villages completely relying on this station.

Through the solar pumping capability at the Ghazze plant, it is able to provide water to village residents for 18 hours/day, which is beyond their demand. This may explain the acceptable SPE indicator-values and the high EUI and UEC results. To curtail the financial losses entailed by the establishment at this facility, it may be appropriate for it to supply other nearby towns with water, in order to bring down the EUI and UEC and maintain pumping efficiency.

## **Water Sector Analysis (Level-2)**

As highlighted in above, the Level-1 energy audits' analysis for the four regional establishments have shown that the energy cost performance (EUI and UEC indices) of the pumping stations, in terms of electricity bill-patterns, do not conform with pumps' performance indicators (SPE, kWh/m<sup>3</sup>/100m) thus are not interrelated; in other words, one does not automatically lead to the other, and is not a direct consequence of it. Thus, a logical conclusion is that the main reason behind the high energy-intensive performance, at the identified four water establishments, is probably a result of the use of expensive energy sources (i.e. fuel sourcing, such as diesel generator, and heavy fuel oils for utilities), or a consequence of inadequate operation and maintenance, implementation, and philosophy.

The original intent of the project team was to conduct field-based Level-2 audits to examine energy use in all processes, including such elements and activities as:

- Examination of hourly operations and energy consumption patterns;
- HVAC / mechanical systems;
- Lighting in all buildings;
- Electrical systems;
- Motor efficiency;
- Process improvement and operations optimization, which covers reviewing of O&M manuals and discussing operating techniques.

In attempting to comply with the original intent for Level-2 audits, the research team faced a multitude of obstacles, not least was the ongoing turmoil in the country since October 2019, which severely restricted the team’s ability to conduct field-work. With the window for field-work rapidly shrinking, access to equipment became limiting, and the cost of its acquisition exceeded any foreseen estimates. Further access to some facilities was delayed by bureaucratic red tape as well as demonstrations. Thus, field-based Level-2 audits were dropped and replaced by a desktop-based Level-2 audit, and a pumps’ performance assessment for all the audited stations. The main aim of this exercise was to analyze the pumps’ performance, and assess the necessary power required at 85% motor efficiency or less, knowing the nameplate pumps’ characteristics, such as the flow, the total dynamic head, in addition to the pump’s power (in kW).

Using the following formula (ACWA/GIZ, 2015):

$$\eta = \frac{\text{Hydraulic Energy (Output)}}{\text{Electric Energy (Input)}} = \frac{Q \times H}{367 \times P_{EL}} \times 100\%$$

Where  $\eta$  is the overall efficiency

$P_{EL}$  is the pump electrical power in kW,

Q is flow in m<sup>3</sup>/h,

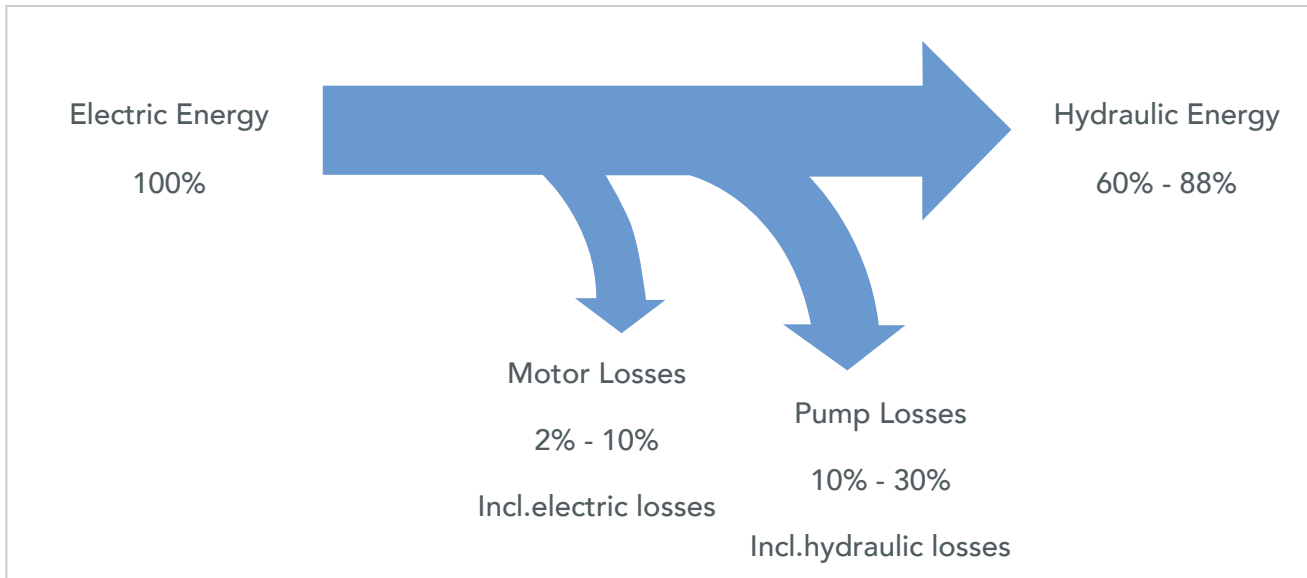
(367) is a conversion factor,

H is head is in meters, and several efficiency values were assumed for this calculation.

Theoretical values of the pump-power needed (in kW) were determined at a series of efficiencies, 85%, 75%, 60%, and 50%. The calculated pump-power values (at the four efficiencies) were then compared to the pump-power inscribed on the nameplate for each pump. This enabled the team to assess the deviation in power ( $\Delta$  kW) between calculated power at each specific efficiency and that of the pump’s nameplate, and estimate the efficiency at which the pump is probably operating. One reason for this effort was the lack of confidence in the inscribed information on the plate; oftentimes pump motors were maintained, refurbished, and even changed without the activity being properly documented. Nevertheless, the exercise has served as a reference or benchmark when calculating the *pump performance indicator*, which assessed the performance of the pump, i.e. its nameplate power at the given head and flow, assuming an 85-90% motor efficiency and a 70-75% pump efficiency, reflecting the current operating performance of the pumps in comparison to the theoretical values. Also considered was the end-target of pumping operations from those stations, whether the water was pumped into an onsite reservoir, an offsite reservoir, or into the network directly.

The rationale behind this categorization arises from the fact that any pump’s electrical energy inputted into the system will be impacted by losses at the motor level by a 2-10% range as well as losses at the level of the pump in the range of 10-30%, including electrical and hydraulic losses, leaving the system with a hydraulic energy of 60-88% (Figure 20).

**Figure 20: Energy conversion through pumps (graphic from Hamburg Wasser)**



Therefore, any performance indicator below 60% would not be acceptable, requiring a review and assessment of the pumping system, in terms of operation and maintenance, lifetime, and energy consumption. In addition, any performance indicator above 88% would raise a question about the accuracy or validity of the data provided, as it would be unrealistic to have pumping systems with performance indicators around 100% or above. This grouping of performance efficiency ranges is illustrated in Table 11.

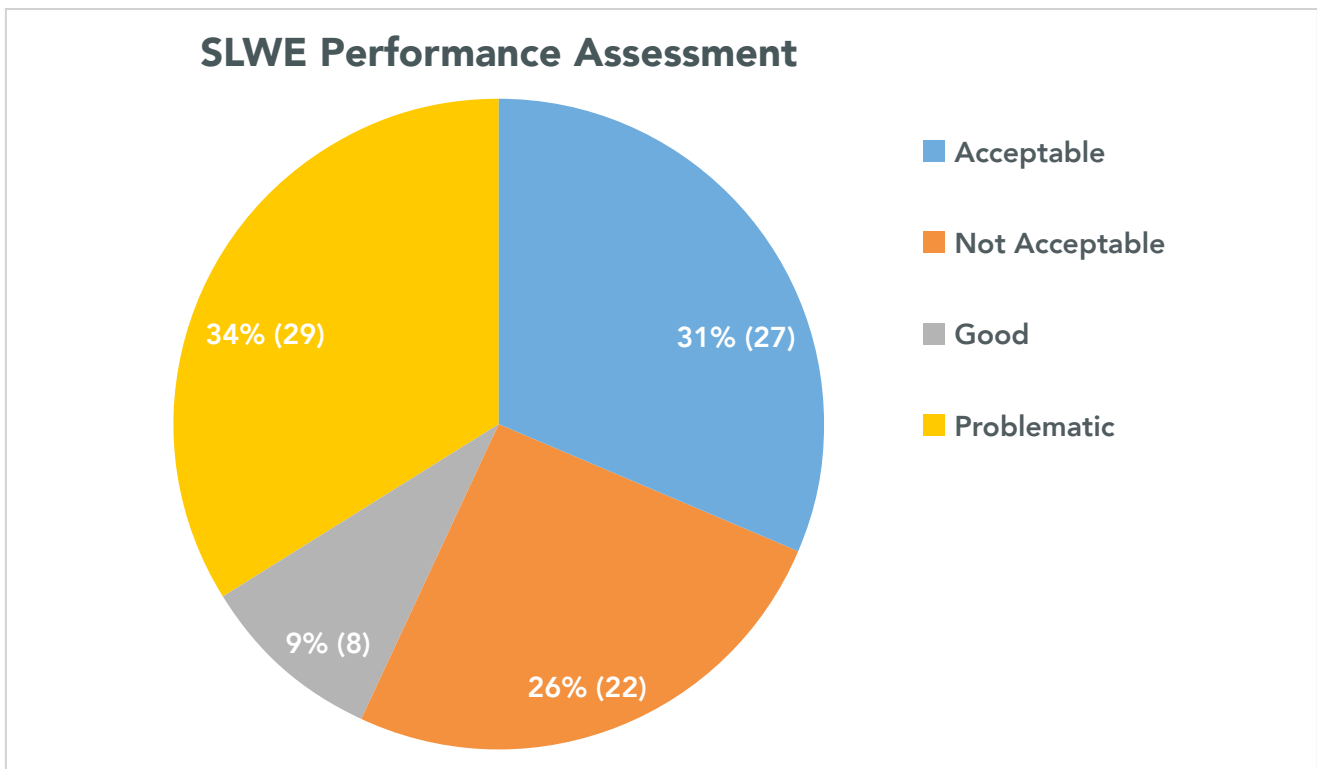
**Table 11 Target Efficiencies for Pumping Systems (Motor and Pump)**

Performance Indicator values	Performance Assessment
< 60%	Not Acceptable
60 - 75%	Acceptable
76 - 88%	Good
> 88%	Problematic

This performance assessment was conducted for all pumping systems at all audited stations, according to the following categorization: if the nameplate power was within the 60-88% recommended efficiency range then the pump was deemed to be performing in an adequate manner, and was thus considered as having an acceptable performance. If the nameplate power was found to be below the 60% recommended efficiency, then the status of the pump, its usage, operation, and efficiency should be investigated.

SLWE data analysis<sup>11</sup> (Figure 21) has revealed that around 40% of the pumps fall in the good and/or acceptable ranges, while the remaining 60% are either not acceptable (26% or 22 pumps), i.e. performing below the 60% performance limit, or problematic (34% or 29 pumps), i.e. exceeding the 88% performance limit. The latter are mainly located at Fouar, Fakhreddine, Buss, Ras EL Ain, Wadi Jilo, Yanouh, Marj El Kookh, and Taybeh. Further investigation and communication with the establishment's management needs to take place to assess those pumping systems individually, and review their data sheets along with their standard operations and maintenance procedures, to identify the main areas for improvement.

**Figure 21. SLWE pumps' performance assessment**

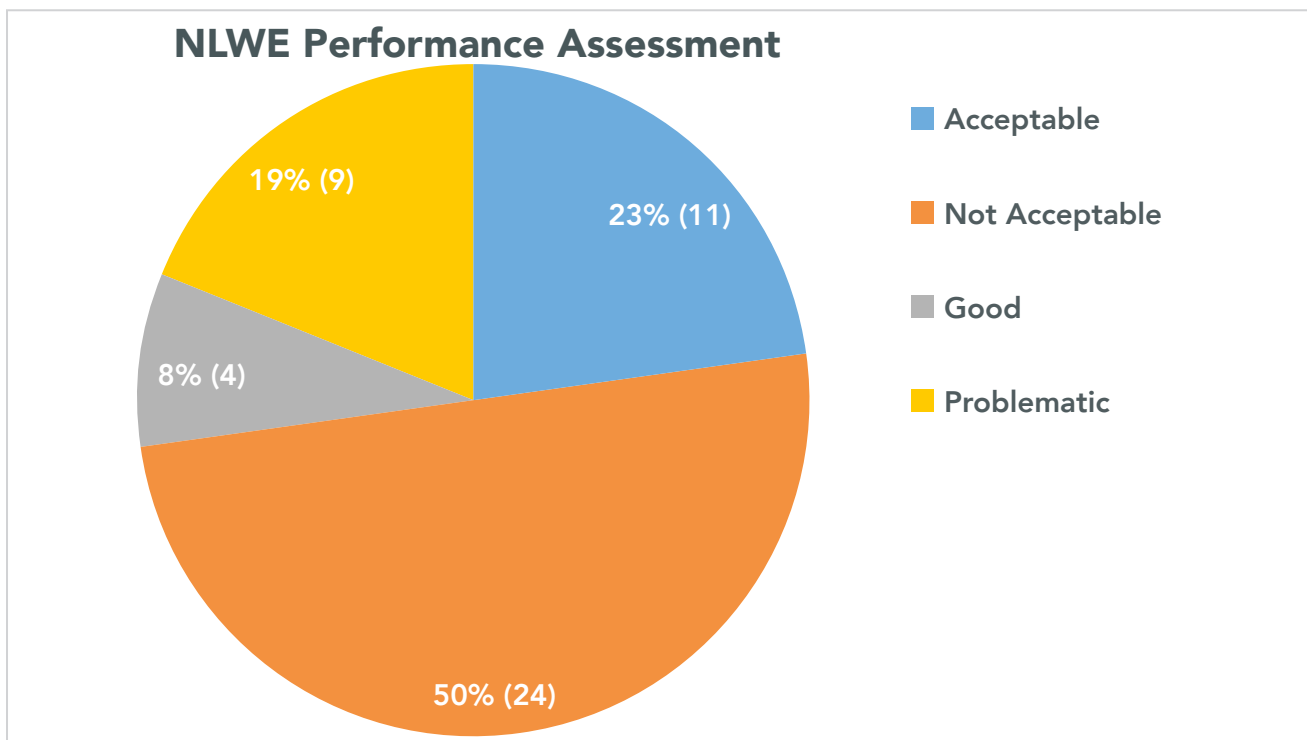


Around 70% of NLWE's pumping systems<sup>12</sup> are not performing well (Figure 22), where 50% (24 pumps) of the stations have a performance assessment below 60%, and therefore are below the acceptable range, and 19% (9 pumps) are identified as problematic. The unacceptable ones are distributed throughout all the audited stations, while the problematic ones are located in Bahsas, Qobbeh, Jradeh, Chekka, and El Oyoun pumping stations.

<sup>11</sup> The assessment has covered 11 pumping stations or 86 pumps.

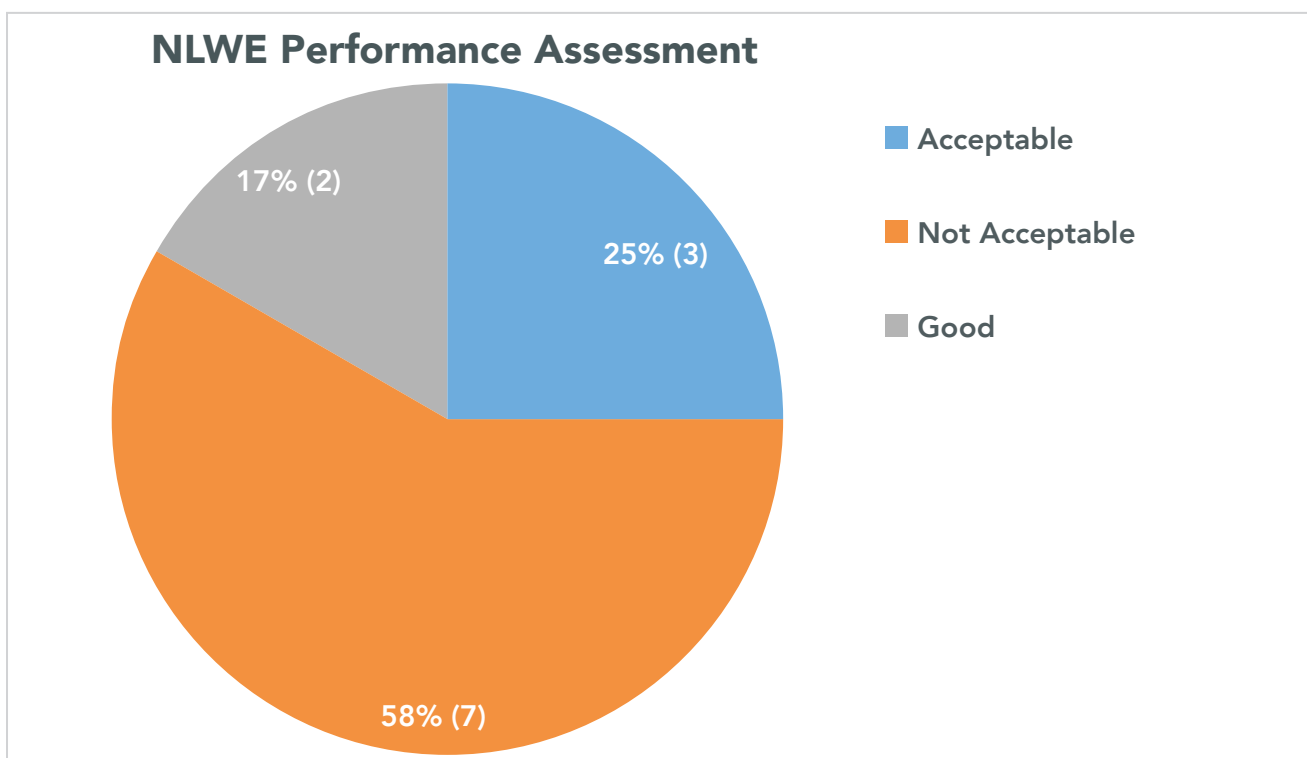
<sup>12</sup> The assessment has covered 13 pumping stations or 48 pumps.

Figure 22. NLWE pumps' performance assessment



BWE (Figure 23) reflects the highest percentage (58%) among all establishments for unacceptable pumping systems<sup>13</sup>, showing a performance assessment below 60% for a total of seven pumps; five located at the Loussi station, and two pumps at the Chamsine station. The remaining latter two pumps show a problematic performance assessment. Thus, a review of the overall pumping systems in Chamsine is necessary. On the other hand, Jdita pumps fall within the acceptable performance-assessment ranges, while problematic pumping systems are absent at the audited stations throughout the establishment.

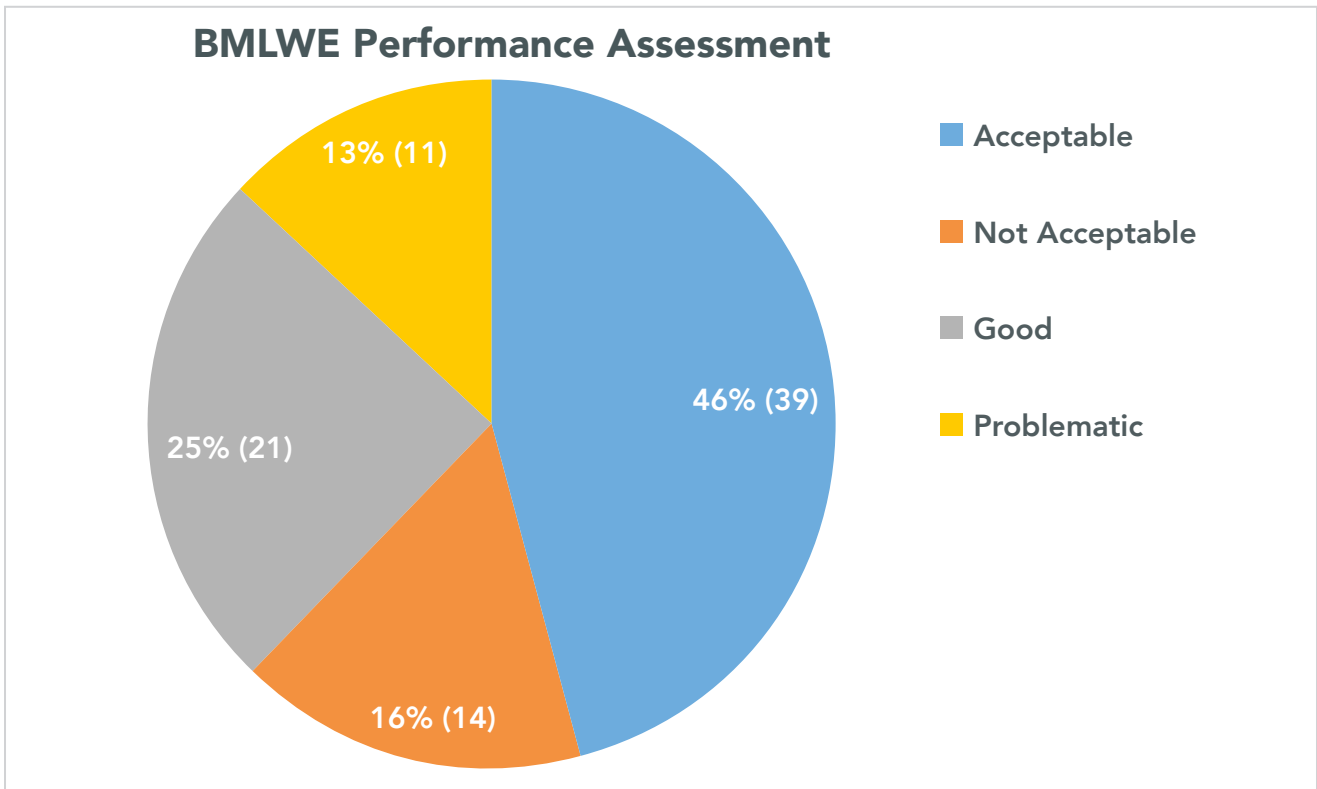
Figure 23. BWE pumps' performance assessment



<sup>13</sup> The assessment has covered 3 pumping stations or 12 pumps.

As for BMLWE, which had the highest number of audited stations<sup>14</sup>, its performance assessment (Figure 24) shows that 46% of the available pumping systems (39 pumps) are within the acceptable 60-75% range, in addition to around 25% (21 pumps), which are in good condition. Both clusters of pumps result in around 70% of the pumps, which have acceptable performance assessment, leaving the remaining 30% between unacceptable and problematic ranges. Those problematic pumping systems (11 pumps) are located at Madiq, Achrafieh, Nabaa El Safa, Hadath, Dayshounieh El Matn, and Dbayeh treatment plants.

**Figure 24. BMLWE pumps' performance assessment**



Snapshot examples from the completed analysis and generated tables at the four RWEs are shown in Figure 25, and the detailed sheets can be found in Appendix H.

<sup>14</sup> The assessment has covered 15 pumping stations or 85 pumps.

Figure 25. Detailed pumps' assessment sheets for the audited stations

	KW (name-plate)	Static head (m)	TDH (m)	Flow (m <sup>3</sup> /s)	CALCULATED kW				Δ kW				Distributing	Performance Indicator Formula (%)	Performance Assessment
					85%	75%	60%	50%	85%	75%	60%	50%			
<b>Bahsas WTP</b>															
Hab Pumps (x6)	37.3	20	23.0	0.13	36	41.8	52.2	62.7	-0.01	0.1	0.40	0.7	Network	76%	Acceptable
Backwash Pumps (x2)	37.3	12	13.8	0.23	40.3	45.7	57.1	68.5	0.08	0.2	0.53	0.8		83%	Good
Qalamoun Pump	74.6	40	46.0	0.07	38.3	43.5	54.3	65.2	-0.49	-0.4	-0.27	-0.1	Network	39%	Not Acceptable
Service Water Pumps (x3)	5.6	5	5.8	0.01	0.4	0.5	0.6	0.8	-0.92	-0.9	-0.89	-0.9		6%	Not Acceptable
Booster Pumps (x3+1 backup)	44.8	27	31.1	0.12	48.4	54.8	68.6	82.3	0.08	0.2	0.53	0.8		83%	Good
Backwash Pumps (x2)	33.6	20	23.0	0.27	80.2	90.9	113.6	136.4	1.39	1.7	2.39	3.1		183%	Problematic
Manar Pumps (x5)	11.9	20	23.0	0.17	49.2	55.7	69.6	83.6	3.15	3.7	4.88	6.1	Off-site reservoir	317%	Problematic
Manar Pumps	11.9	20	23.0	0.07	20.6	23.4	29.2	35.1	0.74	1.0	1.47	2.0	Off-site reservoir	133%	Problematic
<b>Jisir</b>															
Jisir 1	298.3	130	149.5	0.07	133.1	150.9	188.6	226.3	-0.55	-0.5	-0.37	-0.2	Off-site reservoir	34%	Not Acceptable
Jisir 2	298.3	130	149.5	0.08	154.4	175.0	218.8	262.5	-0.48	-0.4	-0.27	-0.1	Off-site reservoir	40%	Not Acceptable
<b>Qobbeh</b>															
Qobbeh Reservoir	33.6	120	138.0	0.01	19.7	22.3	27.9	33.4	-0.41	-0.3	-0.17	0.0		45%	Not Acceptable
Maytam old Well	52.2	150	172.5	0.02	44.2	50.1	62.7	75.2	-0.15	0.0	0.20	0.4		65%	Acceptable
Mou-hajjarin (Hariri) Reservoir well	18.6	20	23.0	0.02	5.9	6.7	8.4	10.0	-0.68	-0.6	-0.55	-0.5	Off-site reservoir	24%	Not Acceptable
Mou-hajjarin (Hariri) Reservoir pump	37.3	200	230.0	0.02	49.2	55.7	69.6	83.6	0.32	0.5	0.87	1.2	Off-site reservoir	101%	Problematic
<b>Ayrounieh</b>															
Fouwar Pump 1	5.2	2.42	2.8	0.01	0.4	0.4	0.6	0.7	-0.92	-0.9	-0.89	-0.9		6%	Not Acceptable
Fouwar Pump 2	5.2	2.42	2.8	0.02	0.5	0.6	0.8	0.9	-0.90	-0.9	-0.85	-0.8		8%	Not Acceptable

A cost saving analysis was also performed to quantify the savings (in USD) that would occur if the unacceptable pumps were operating at acceptable levels, i.e. with a performance indicator or efficiency level of 85%, assuming a 50% availability factor (assuming 12 hours of pumping per day). Even though the exercise was done only on pumps that are within the unacceptable range, the same may be replicated for the problematic ones once data and information are confirmed.

Table 12 summarizes the results of the analysis for all four establishments.

**Table 12 Estimated Yearly Cost Savings at RWEs for Non-Acceptable Pumping Systems**

Water Establishment	Number of Pumps	Estimated Cost Savings at 50% availability factor <sup>15</sup> (USD)
SLWE	21	570,000
NLWE	26	405,000
BWE	7	209,000
BMLWE	14	780,000

The calculated cost-saving estimate highlights the essential role of the continuous operation and maintenance activities at the water-pumping stations, and their impact not only on the lifetime of equipment, but also on the WE's financials, through the associated savings.

Results of the cost-saving exercise clearly highlights the dire need for the development and implementation of proper operating procedures along with the adoption of appropriate management principles and good practices in order to attain viability and sustainability, of not only the water-pumping activities at the WEs, but of the establishments' financial sustainability, and its ability to provide adequate water service provision.

In order to assemble a set of good practices in operations and the maintenance of pumping facilities, the research team sought the input of *Dar Al-Handasah Consultants (Shair & Partners)*, and after several sessions with their sustainability and electro-mechanical team, a guiding manual was produced. This gives the professional managers and staff (especially the operators) engaged in running the water stations a ready reference resource for everyday use. WE's engineers and technicians are urged to always consider these guidelines in relation to their own specific requirements, adapting and applying them within the context of their actual situation; remembering their essential role in ensuring adequate equipment operation, and therefore the impact on energy efficiency.

<sup>15</sup> Assuming 12 hours of electricity supply per day.

*Dar Al-Handasah Consultants (Shair & Partners) O&M Guidelines* developed with the research team can be found in Appendix D.

In addition to the O&M guidelines, a set of technological, policy, and planning recommendations are proposed that resulted from a series of consultation meetings with a wide range of experts in the field, which could be summarized as follows:

## **Technology**

- Consider use of high-efficiency electrical motors and very high-efficiency pumps, despite their high cost.
- Consider use of turbines (PATs – pumps acting as turbines<sup>16</sup>) that generate electricity from water pressure (based on a study by UNDP): eco-friendly pumping stations, eco-hydro turbines, hydro-powered stations from non-river sources, and very small hydro-powered networks. Similar technologies were adopted in different countries (Bath County, USA, 3003 MW; Guangdong, China, 2400 MW; Huizhou, China, 2400 MW; Okutataragi, Japan, 1932 MW; Ludington, USA, 1872 MW). Also, consider inline micro-turbine in water networks as a source of power supply for instruments such as telemetry and SCADA accessories.
- Pumps and Variable Frequency Drives (VFDs) should be selected, acquired, and installed concomitantly to ensure the conformity between both components. When a retrofitting approach is adopted, and VFDs are installed at a later stage during operation, there is potential for pump deterioration.
- VFDs shall be recommended whenever there is variable pressure and variable flow applications, and could reach 97-98% efficiency, especially for pumping operations less than 100 meters. Trainings for operators on VFDs shall be implemented.

### **VFD drawbacks**

- Higher initial cost, bigger space needed, sine-wave filters, DV filters needed for depths higher than 100m, special cables needed, no possible retrofitting, and two cooling units required.
- VFD application is limited to low and medium lift-pumping stations; verification shall always be conducted to check on available regulation bracket.
- Implement more solar-pumping stations wherever possible, which could result in substantial energy savings on pumps and/or site electricity needs. In addition, there should be a focus on water storage implementation (by building more reservoirs) instead of energy storage, since reservoirs cost less.

<sup>16</sup> This could be also implemented at WWTPs using microturbines on the discharge from treatment plants if there is sufficient drop from the final treatment process to an outfall.

## Design Criteria

- Duty point and pump selection:
  - Duty point shall be calculated taking into consideration exact minor losses, failing to collect data on involved pipeline fittings and appurtenances, safety factor can be exclusively applied to head loss part, without affecting geometric lift part.
  - Consideration of short- and long-term pipe roughness shall be observed in determining the bracket of the duty point, supposed to remain within allowable efficiency and power bracket.
- Design of water networks:
  - Measures shall be taken to maintain balanced network and to restrain flow demand, mainly in low areas by the introduction of flow control valves, pressure sustaining valve, house connection flow limiters, etc.
  - Network design shall take into consideration the type of house connection (free discharge, orifice).

## Operation and Maintenance

- Develop an operational philosophy for water-pumping stations when it comes to water sources' management and energy efficiency measures: a set of guidelines for installation, operation, and maintenance of pumping equipment, pumping schedule, capacity building for stations' operators, emergency action plans, data monitoring and analysis, etc.
- The traditional way of maintaining the motors through winding is leading to efficiency loss each time it is performed. As such, it is more effective to replace broken-down motors with new energy-efficient ones. This approach should be adopted in future maintenance procedures.
- Continuous data acquisition/collection (pressure, flow of wells/stations/network, voltage, amperage, energy consumption per equipment/station, etc.) should be implemented, and data collected shall be stored in one main data bank and shared with all stakeholders, to improve energy efficiency.
- There are different layers for pumping system efficiency that can be addressed:
  - Energy efficient motors;
  - Usage of VFDs to address power and flow (?) fluctuations, the utilization of leak detectors to avoid unnecessary costs at later stages;
  - Automation to ensure proper control;
  - Proper instrumentation (pumps, flow meters, pressure gauges, etc.);
  - Proper monitoring (pressure and flow metering at the level of the wells/stations/network/consumers);
  - Improved water systems management (through SCADA systems) for operational and management matters.

- Revision of all O&M contracts should be conducted, and a new standardized set should be produced to include the following:
  - The contractor should be held accountable for O&M, diesel costs, volume and hours of water pumping, and data cross-checking. Consequently, O&M contractor should be penalized based on his performance regarding flow-pumped, energy efficiency, etc.
  - If the establishment decides to assign an O&M contractor, a full inventory should be done for all the available assets (equipment, spare parts, etc.) before handover. The O&M contractor should continuously update this inventory.

## Planning

- For future projects, Terms of References (ToRs) should define a set of energy efficiency standards, and contractors would be required to comply with these specific standards and specifications (such as the ones mentioned earlier: high efficiency pumps; eco-hydro systems, preventative maintenance, etc.). Furthermore, specifications should be homogenized among the different stakeholders involved (CDR, MoEW, RWEs, etc.), and one central monitoring system/managing institution for standards' compliance shall be established.
- Consider asset management (for existing equipment and spare parts) for better preventative maintenance to start implementing predictive maintenance in RWE's philosophy.
- Modular planning of new pumping stations and growth assessment, and on a case-by-case basis.
- Proper sizing of water-supply networks to ensure optimal energy requirements when pumping. Pipe sizes that are too small generate a lot of friction, which leads to the need for higher pressure from pumps, thus needless and excessive pumping.

## Policy

- Pricing is critical to achieving energy efficiency, and thus an appropriate pricing strategy should be developed.
- The Ministry of Energy and Water represented by both EDL and LCEC shall issue publications related to energy-efficient standards and specifications for water and wastewater utilities.
- The major challenge for solar energy production (onsite and offsite), as well as hydro-turbines is the absence of power-wheeling and Corporate PPAs, is the absence of grids in some places to connect to; a draft law for power-wheeling is currently being developed between the Ministry and the EBRD, and is expected to be ratified by mid-2020.
- Enforce the role of the Ministry of Energy & Water in terms of supervision, and calling for human and capital resources.

# Energy Audit in the Wastewater Sector

## Section Overview

Wastewater energy audits were performed between September 2019 and January 2020, covering 23 treatment plants falling under the supervision of all four water establishments. Onsite operators and responsible personnel from O&M contractors (including Subal Group, Suez, and OTV) accompanied the IFI team to provide information on treatment processes and data, maintenance-related matters, technical specifications of equipment, and overall challenges. Further guidance was obtained from managers at the water establishments as well as specific data on electricity consumption and bills, whenever available.

A major design challenge that was observed overall was the choice of the technology and design criteria. Plants are usually designed to serve a specific population size and to treat residential wastewater only. Observations confirmed that many plants are operating beyond their design capacity, with an inflow exceeding the plants' design capacity. Further, many plants receive industrial discharge with inflow wastewater characteristics not accounted for in the plant design, thus disrupting the treatment processes and often short-circuiting them. Other plants are underutilized due to the incomplete network connections to the targeted villages. Another observed problem, which also leads to the disruption of the treatment processes in some plants, is the excessive wastewater inflow in winter due to the combined sewer networks, which are still present in many regions. These flows often exceed the plant's design inflow volume, which is often diluted, forcing the expenditure of disproportionate amounts of energy in the treatment efforts. The lack of accurate information amongst many onsite operators was identified as a key management drawback. This is particularly applicable regarding technical specifications and influent/effluent characteristics as well as the plant behavioral performance when it comes to energy use and energy efficiency. This lacuna is linked to a wider challenge in many stations: inadequate monitoring resulting in unavailable and/or inaccessible data. Moreover, O&M contractors are generally not held accountable for resource expenditures (diesel fuel, water, etc.), which affects the overall costs borne by the establishments. As for electricity and diesel consumption, wastewater treatment plants tend to rely on diesel generators, in addition to utility subscriptions, since the process is energy-intensive in nature.

The following sections summarize the status of wastewater treatment facilities in the four regional water establishments.

# Wastewater Sector Walk-Through Surveys and Observations

## North Lebanon Water Establishment

Three large-scale wastewater treatment plants (WWTPs) that fall under the jurisdiction of NLWE, located in Tripoli, Chekka, and Selaata, were audited at the beginning of November 2019 with the support of Mohamad El Helou from SUEZ, the company operating the facilities under a contract agreement with the CDR. Smaller WWTPs exist in North Lebanon, and are distributed among several villages/cazas but most are managed at the municipal level.

The Tripoli WWTP operates at the pre-treatment level only because influent is insufficient, while Chekka and Selaata are fully operational. All three WWTPs treatment processes are activated sludge, with Tripoli being equipped to generate biogas from the produced sludge; unfortunately, it has not been operational since 2009. What characterized those stations are the effective and advanced O&M procedures, which allow the operating company to follow and monitor all the equipment throughout the process. Preventive maintenance is performed on all equipment and monitoring, and appropriate instrumentation is being used at all levels. In terms of energy, all three plants rely on both EDL and private diesel generators within the stations, even though Tripoli and Chekka benefit from 24h electricity, while Selaata suffers from 12-hour outages. Suez does not directly pay EDL/diesel bills, which are borne by the CDR, as per the agreement between both parties. Therefore, the amounts of money paid could not be determined; however, the annual kWh consumption in each station as well as the liters of diesel purchased, all of which were registered and filed by the company, were made available to the IFI team.

Detailed results of the NLWE's walk-through energy audit can be found in Appendix C (Wastewater).

## South Lebanon Water Establishment

Four wastewater treatment plants (WWTPs) under the jurisdiction of SLWE, located in Saynik (Saida), Sour, Nabatiyeh, and Tebnine, were audited in September 2019, with the support of Engineers Hassan Roummaneh and Maarouf Mezher from the establishment. Saynik operates at the preliminary treatment level only. Sour (equipped with anaerobic digesters) is still not operational; Nabatiyeh and Tebnine utilize extended aeration processes in their treatment of wastewater. Private companies manage the three operational plants, with Tebnine and Nabatiyeh operated by OTV. As part of the O&M contract with the operators, preventive maintenance is performed based on proper monitoring, and the plants are appropriately instrumented.

Plans are ongoing for a potential upgrade of the Saynik plant to secondary and tertiary treatment, as well as for putting the Sour plant into operation in the second half of 2020. In terms of energy, Nabatiyeh fully relies on expensive and polluting diesel generators, as

no EDL current is supplied, while Saynik suffers from 12-hour daily cutoffs, leaving Tebnine with around-the-clock electricity service supply. Average monthly EDL consumption is being documented in Saynik, while detailed monthly consumption per process (pretreatment, odor treatment, sludge treatment, biological treatment, and chlorination) are recorded at both Nabatiyeh and Tebnine. Similar to the North, electricity bills are borne by CDR as part of the operation and maintenance contracts with the companies, thus the cost of electricity at these facilities was not readily available. But using the yearly kWh consumption numbers provided by the operators, the annual cost of electricity was estimated at around LBP 250 million for EDL, and LBP 950 million on diesel generators per year.

Results of the SLWE's walk-through energy audit can be found in Appendix C (Wastewater).

### **Beirut and Mount Lebanon Water Establishment**

Nine wastewater treatment plants (WWTPs) under the jurisdiction of BMLWE were audited between November 2019 and January 2020. These included one large-scale plant located in Ghadir (South Beirut area), operating for pre-treatment only, while the eight others were small-scale plants serving villages in Chouf (Kfarkatra, Mokhtara, Jbaa, Mrosti, Baadaran, Khraybeh, and Maaser El Chouf), and Hammana in Baabda.

The Hammana WWTP is under the supervision of the municipality and not BMLWE, and is managed by a private operator. Its treatment process is conventional activated sludge, and since 2018, is powered by a hybrid system comprising of solar PV, batteries, and EDL supply. The Chouf plants are all managed by a private operator that reports to the establishment. They are similar in size to the Hammana plant but use trickling filter (with activated sludge) treatment processes. The establishment manages the Ghadir facility and the municipality covers electricity bills. Monitoring and instrumentation tools (sensors, SCADA systems, flow meters, etc.) along with detailed equipment specifications are missing in BMLWE's WWTPs, and therefore data is hardly recorded and accessed, and there is a big reliance on the operator's role in transferring the needed information verbally or in writing.

Currently there are no other coastal WWTP (other than Ghadir). However, there are six pump stations in Damour, Khaldeh, Nehmeh, Jiyeh, Bourj Hammoud, and Jounieh, which pump the collected sewage into the sea. These stations account for around 85% of the energy-cost allocated for wastewater at BMLWE. Of the LBP 300-350 million per year electricity charges, LBP 50 million is for the WWTPs and the rest are for the pumping operations. At the Hammana plant, the hybrid system has allowed the total energy cost/bills to be reduced by around LBP 25 million in 2018 (from LBP 32 million to LBP 7 million), in addition to savings of around 65.25 MWh of the energy consumed on the grid as well as a reduction of CO<sub>2</sub> emissions by 72.525 tons of CO<sub>2</sub> equivalent.

Ongoing plans focus on improving the wastewater collection and treatment in Beirut and Mount Lebanon through the construction of several wastewater treatment plants along the coast in the near future, key amongst these is the Bourj Hammoud facility.

Results of the BMLWE's walk-through energy audit can be found in Appendix C (Wastewater).

### **Bekaa Water Establishment**

Five wastewater treatment plants, under the jurisdiction of BWE and located in Zahle, laot, Yammouneh, Jeb Jennine, and Saghbine, were audited in October 2019 along with two other plants in Ablah and Ferzol, managed by their respective municipalities. The Yammouneh WWTP is currently not operational and under rehabilitation. Zahle WWTP (extended aeration/oxidation ditch) is managed by the SUEZ company, and laot (extended aeration/oxidation ditch) is managed by the Braidy company through direct contracts with CDR. Jeb Jennine and Saghbine (both with activated sludge A2O process) are under the direct supervision of the Bekaa Water Establishment. The Ablah and Ferzol plants, which are smaller than the others mentioned, deploy a trickling filter-activated sludge processes.

While Zahle WWTP follows advanced O&M procedures through effective monitoring and measurements throughout the entire treatment process, including the kWh consumption. The operator does not pay the electricity bills (it is unknown whether CDR or the establishment are paying these bills), as such the bills are not monitored and were not made available to the IFI team. The laot plant is currently operating at a level that exceeds its capacity, and only routine oil/filter checks are performed on the relevant equipment, without any preventive maintenance. Jeb Jennine and Saghbine represent a good example on how public institutions are able to manage their utilities and provide needed services in a professional and adequate manner, ensuring that the facilities operate to the required standards of discharge.

The annual EDL electricity bill for laot, Saghbine, and Jeb Jennine can reach up to LBP 400-420 million, in addition to around LBP 180-200 million annual cost for diesel for generators. As for Ablah, the municipality stated that the annual electricity bill for the facility is around LBP 48 million. The energy bills of Ferzol WWTP could not be accessed, despite several requests submitted to the municipality.

Results of the BMLWE's walk-through energy audit can be found in Appendix C (Wastewater).

*Appendix L (wastewater) includes a detailed WWTP Data Collection Sheet for audited plants at the four water establishments, which summarizes the walkthrough surveys' results, the influent/effluent characteristics, total energy consumption along with the applied Key Performance Indicators (KPIs): kWh/m<sup>3</sup> / kWh/PE/year / DU (%) / kWh/(kg.BOD.removed) / kWh/(kg.COD.removed).*

Also, influent BOD (kg/year) and influent COD (kg/year) were calculated using a standard unitary load of 120 g/day COD (chemical oxygen demand) and 60g/day BOD5 (biochemical oxygen demand within five days) per population equivalent (PE).

## Wastewater Sector Analysis

There are no one-size-fits-all Energy Efficiency (EE) indicators in the WWTP industry, as each utility is unique in terms of the types of processes and technology it applies; the type of influent and its characterization; the size of the communities it serves; their location, applicable standards and regulatory requirements as well as the availability and price of energy sources. Each utility would need to evaluate its own goals and commitment to improving EE. Yet, best practices are usually followed. According to the energy use benchmarking methodology conducted by the Water Services Association of Australia (WSAA) and Intelligent Water Network (IWN) for 2015-16, which was followed in this analysis, the audited plants can be categorized per size class. The size class grouping, followed in this study, for all the audited WWTPs is summarized in Table 13.

Size class	PE range	Number of plants	Plant name
SC1	<1,000	5	Jbaa, Mrosti, Maasser, Baadaran, Khreibeh
SC2	1,000 - 5,000	4	Mokhtara, Kfar Atra, Saghbine, Hammana
SC3	5,001 - 10,000	1	Tebnine
SC4	10,001 - 100,000	7	Nabatiyeh, Iaat, Jeb Jannine, Ablah, Ferzol, Chekka, Selaata
SC5	>100,000	4	Saynik, Tripoli, Zahle, Ghadir

The main specific energy consumption indicator adopted is the kWh/PE/year as expressed earlier in *Energy Performance Assessment*, and was calculated for all three types of treatment plants: *extended aeration*, *activated sludge*, and *activated sludge with a trickling filter*. This exercise was performed on 17 stations that had complete data. Results were then benchmarked against the guide and target values, as displayed in Figure 26. The target and guide values are indicative of “Best Practice” and “Typical” (or “average”) performance, respectively. The values applied vary according to plant type and size class, and typically decrease with increasing size class. The remaining primary treatment plants cannot be benchmarked, since guide and target values apply to plants performing biological treatment.

Figure 26. Indicators summary of audited wastewater stations

Station	Type	PE served	Size class	kWh/PE/y	Guide value	Target value	DU (%)	COD Removal (Kg/year)	COD Removal %	kWh/(Kg. COD. removed)
Mrosti	AS - trickling filter	600	SC1	147.45	67	49	30	22891.26	87.11	3.86
Hammana	Activated sludge	5,000	SC2	24.089	40	24	100	268640.00	92.00	0.45
Ghadir	Primary	457,587	SC5	4.1			38.1	2413470.20	12.04	0.78
Jbaa	AS - trickling filter	733	SC1	97.26	67	49	36.7	30329.66	94.47	2.35
Kfarkatra	Extended aeration	1000	SC2	69.5	45	28	27.3	32914.79	75.15	2.11
Maasser	AS - trickling filter	667	SC1	174.05	67	49	22.2	26646.39	91.25	4.35
Baadaran	Extended aeration	333	SC1	106.91	70	38	20	13694.03	93.79	2.60
Khreibeh	AS - trickling filter	667	SC1	107.05	67	49	22.2	27098.96	92.80	2.63
Mokhtara	AS - trickling filter	2,333	SC2	48.1	39	32	77.8	95433.06	93.39	1.18
Tebnin	Activated sludge	7,200	SC3	82.7	38	23	29.7	298636.36	94.70	1.99
Nabatiye	Extended aeration	36,000	SC4	44.19	34	20	55	1542464.38	97.82	1.03
Saynik	Primary	326,789	SC5	7.63	-	-	86.1	#VALUE!	-	-
Zahle	Extended aeration	169,643	SC5	17.6	30	20	50.9	6169390.24	93.90	0.49
Iaat	Extended aeration	99,482	SC4	12.523	34	20	111.4	3754710.07	86.17	0.37
Saghbine	Activated sludge	1,902	SC2	4.44	40	24	57.7	112877.69	96.21	1.63
Jeb Jannine	Activated sludge	41,027	SC4	47.25	30	18	65	2424830.57	95.39	0.85
Ablah	AS - trickling filter	10,714	SC4	32	30	18	60	445260.08	94.88	0.77
Ferzol	AS - trickling filter	13,393	SC4	TBC	30	18	150	#VALUE!	#VALUE!	-
Tripoli	Primary	357,143	SC5	6.8			39.9	10116015.90	47.97	0.15
Chekka	Activated sludge	17,857	SC4	17.6	30	18	147.3	985156.14	98.29	0.64
Selaata	Activated sludge	16,071	SC4	76.1	30	18	62.3	762743.66	96.89	1.60

Overall, less than a quarter of the benchmarked stations fall within the accepted benchmarks: Zahle, Ablah, Chekka, and Hammana. It is worth noting that while the first three stations are relatively large (SC4 and SC5), they do not conform to one specific type of treatment. Specifically, two plants (Chekka [activated sludge] and Zahle [extended aeration]) fall within 10% of the target value, while Ablah (trickling filter) is in line with the guide value but still far from the target value. Only Hammana, which belongs to the SC2 size class, fully complies with the target value. As for the remaining stations, they are all not aligned with their respective guide values.

The median of the ECI (kWh/PE/year) of the entire data sample (all plants) is 65.22 kWh/PE/year, and results show that it decreases significantly with increasing plant size, moving from size class SC1 to size class SC5.

A lower specific consumption in the largest plants is due to the economy of scale, sharing fixed quota of energy consumption on a greater organic load, while small plants undergo frequent transitional periods, which are particularly energy intensive. For these reasons, aggregation and centralization of small into medium-to-large treatment facilities may yield substantial improvements in energy efficiency in the plants.

Comparing the kWh/PE/year indicator with the kWh/(kg.COD.removed), as displayed Figure 27, clearly shows that both indicators behave nearly identically. This positive correlation, in line with what is reported in the literature, reveals that both indicators provide the same piece of information relating to energy-intensity in these wastewater treatment plants. Thus, further inclusion of the alternative benchmarks, based on the COD or BOD removal (kWh/kg.CODremoved or kWh/kg.BODremoved), is unlikely to add significant value to understanding or improving energy efficiency for WWTPs, compared to the primary benchmark kWh/PE/year. Nevertheless, and for the sake of completeness, a few of the results that the analysis has shown concerning those indicators are included in the following paragraphs.

Figure 27. Verification of kWh/PE/year using kWh/(Kg.CODremoved)

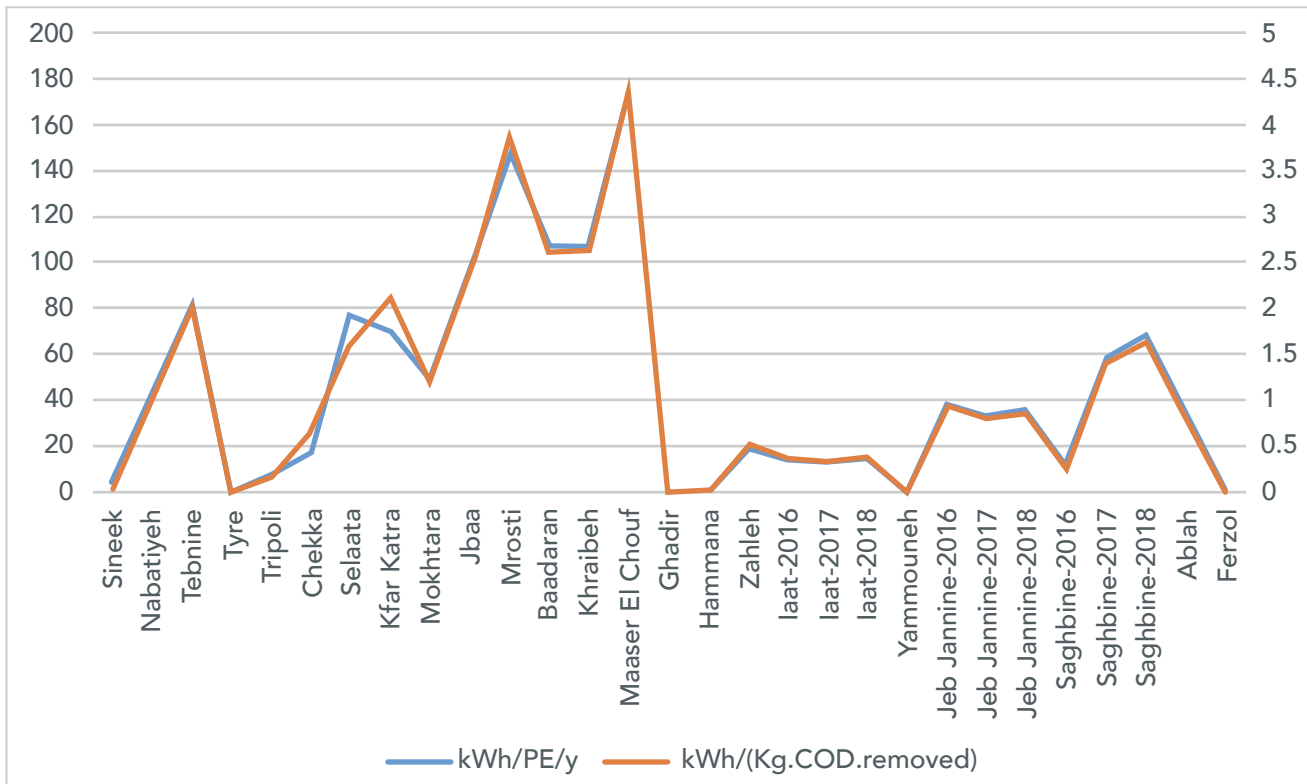


Figure 28 shows the kWh/(kg.COD.removed) performance for all the audited plants, which reflects the fluctuations in the kWh consumption, in relation to the amount (in kg) of COD removed. This fluctuation is a consequence of the variation in the inlet COD and the different types of processes. The highest values for the kWh/(kg.COD.removed) indicator are registered for Maaser El Chouf, Mrostri, and Khraibeh (all belong to the SC1 size class, with a PE <1,000), which are the same as for the kWh/PE/year indicator.

The kWh/(kg.COD.removed) indicator for the various processes at the audited stations was plotted in Figure 29.

Figure 28. kWh/(kg.COD.removed) performance for all plants

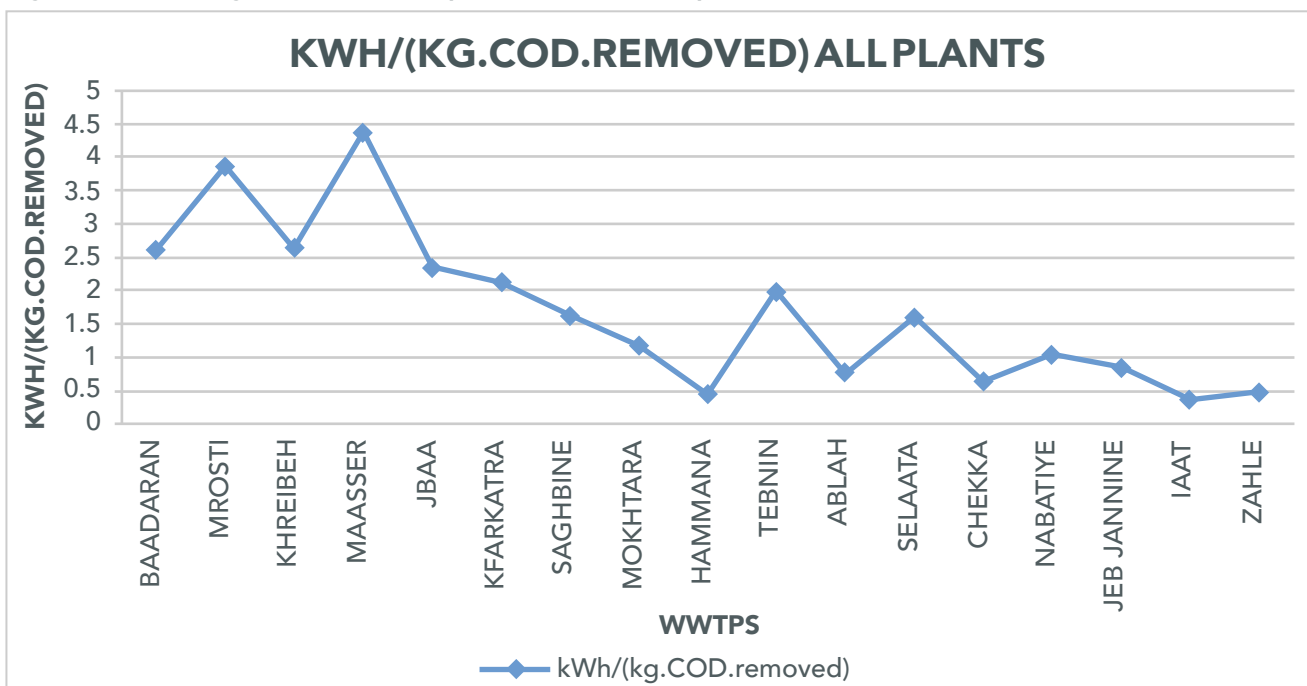
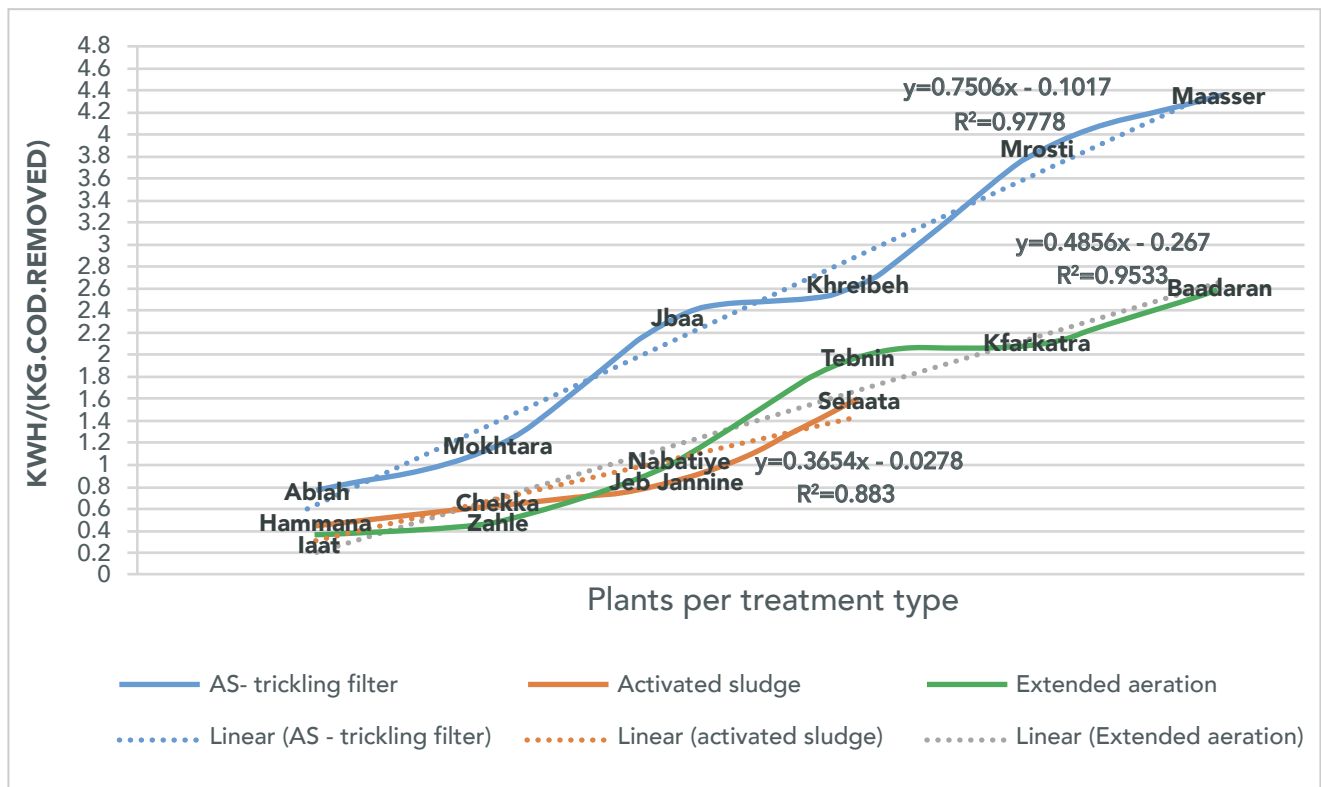


Figure 29. kWh/kg.COD.removed per treatment type

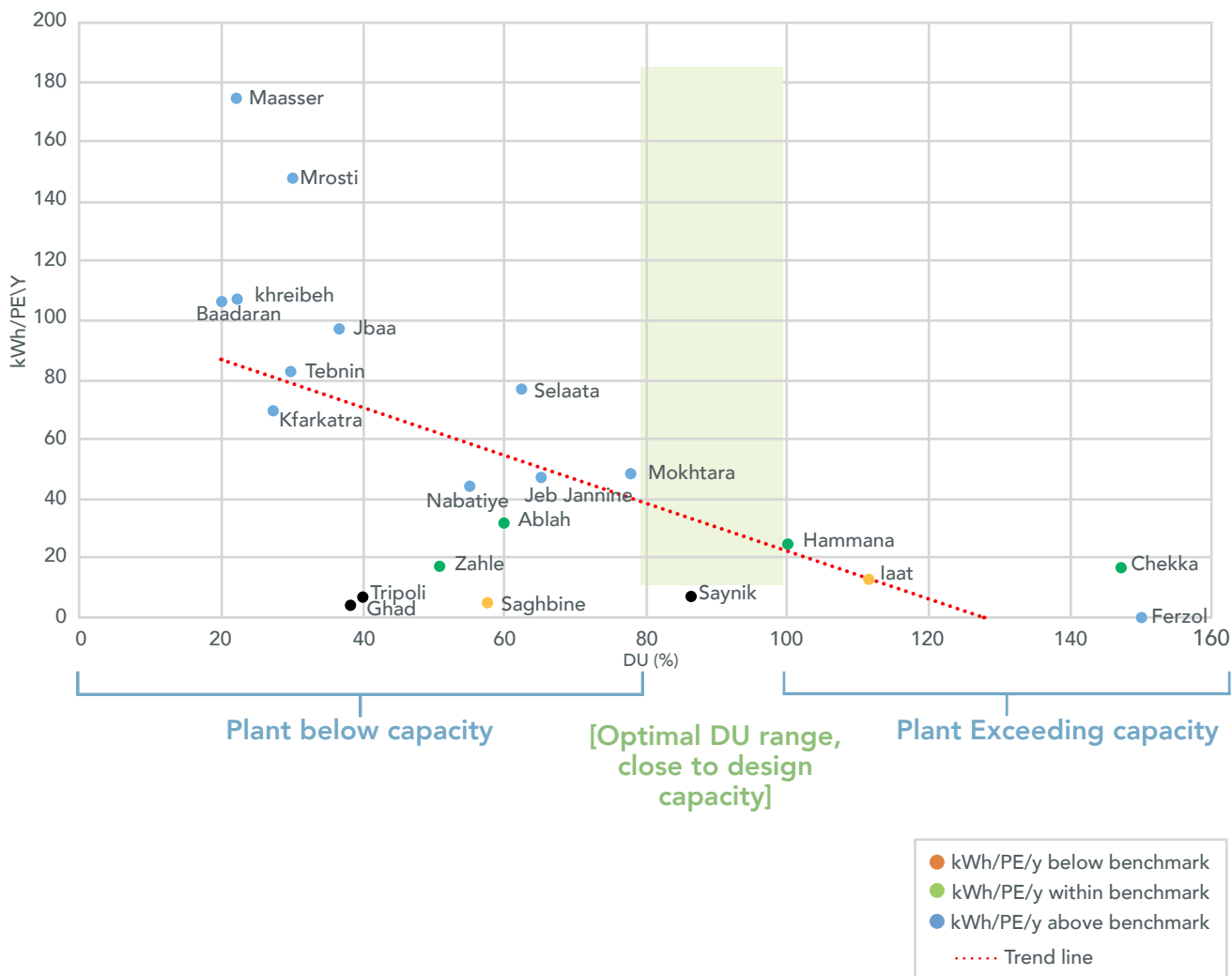


Plants that carry out conventional activated sludge and extended aeration processes show the lowest energy consumption, reaching up to 1.6 kWh/kg.COD.removed for the first (Selaata plant) and around 2.6 kWh/kg.COD.removed for the second (Baadaran plant). On the other hand, and as expected, activated sludge with trickling filters system are characterized by the highest energy consumption, almost twice higher, and reaching up to 4.4 kWh/kg.COD.removed.

An additional layer of analysis was used involving another important indicator, which is the degree of utilization (DU) that expresses how much of the available capacity of a WWTP is actually used, and describes how well the dimensioning of a plant matches real conditions. According to the literature, DU can have a significant impact on the energy performance of the WWTP.

Figure 30 illustrates the energy consumption, represented by the energy intensity indicator (kWh/PE/y), of the WWTPs with respect to their degree of utilization (%). As expected, the general trend is descending, with energy intensity decreasing as the DU increases. All plants conducting only primary treatment (Tripoli, Ghadir, and Saynik) are excluded from this analysis, since benchmarking is applicable for processes, including secondary treatment; however, they are still shown on the graph but annotated in black. As for the remaining stations where data is available, only Hammana WWTP falls at the limit of the optimal DU range, expressed in the literature to be 80-100%, while none of the other plants present such behavior, and all are outside the optimal utilization range.

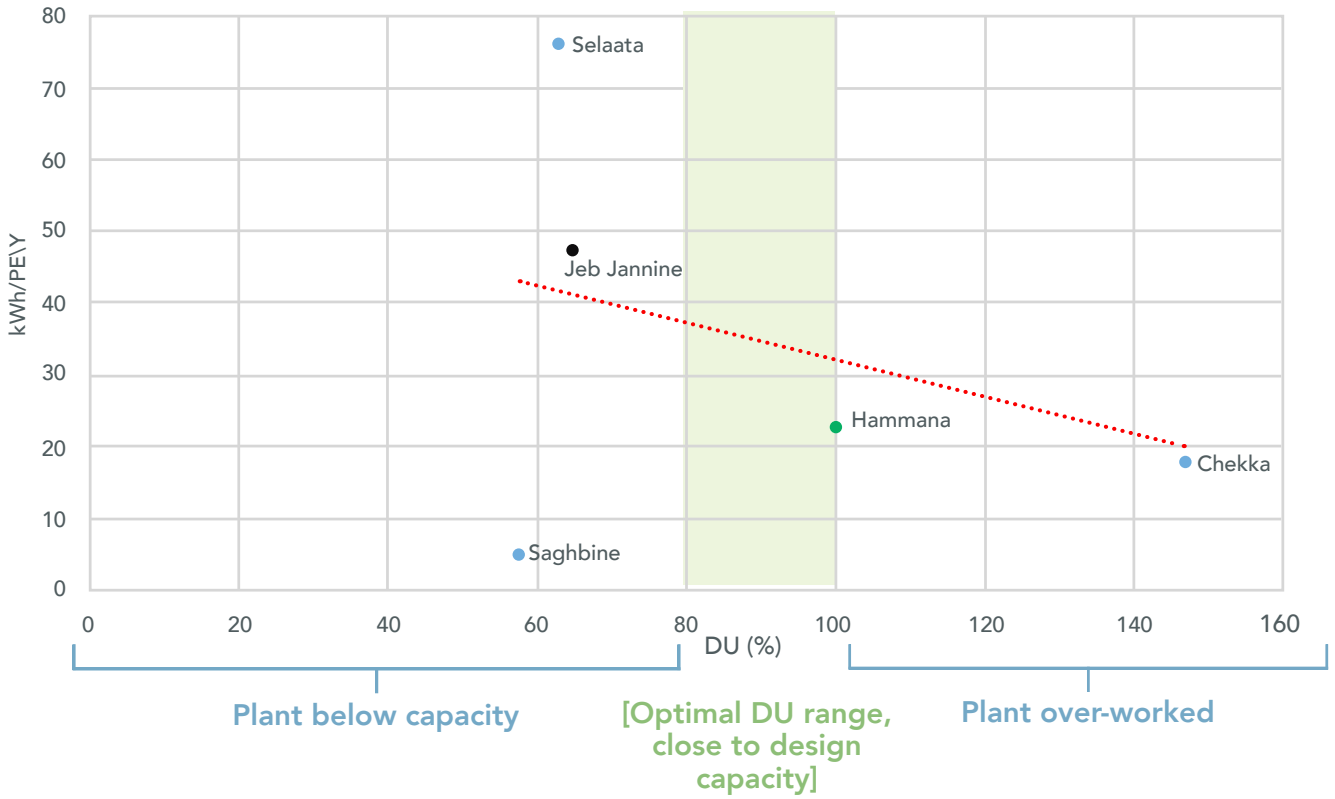
Figure 30. Specific energy consumption (kWh/PE/year) in relation to degree of utilization (DU%)



While operating a plant above its design capacity may favor lower-energy consumption, it could jeopardize the overall treatment process and the quality of the effluent. On the other hand, 14 out of 16 secondary treatment stations operate below capacity, leading to over-sized plants designed for a capacity greater than the actual PE served. Although slight oversizing is necessary to accommodate for fluctuating loads (Vicari et al., 2018), hence the optimal DU range, excessive oversizing may indeed result in greater energy consumption, as displayed by most stations. This is particularly relevant for plants above the trend line, which typically are energy intensive. Nonetheless, Figure 30 identifies Selaata and Jeb Jennine as exceptions to this trend. These plants have a relatively elevated DU (around 65%) compared to other stations operating below capacity. Yet, they are more energy intensive than Ablah and Saghbine, which share similar DUs but lower energy intensities. The reason for this is unknown, thus these two facilities (Selaata and Jeb Jennine), despite being less energy intensive than other treatment facilities, constitute interesting cases to examine in the future through detailed audits using measures proposed in the Level-2 energy audit section. Some factors to consider include the type of wastewater influent, operation of equipment, equipment age and maintenance, and other management factors.

Figure 31. Specific energy consumption in relation to DU in: (a) activated sludge plants, (b) activated sludge with trickling filter, and (c) extended aeration.

(a)



(b)

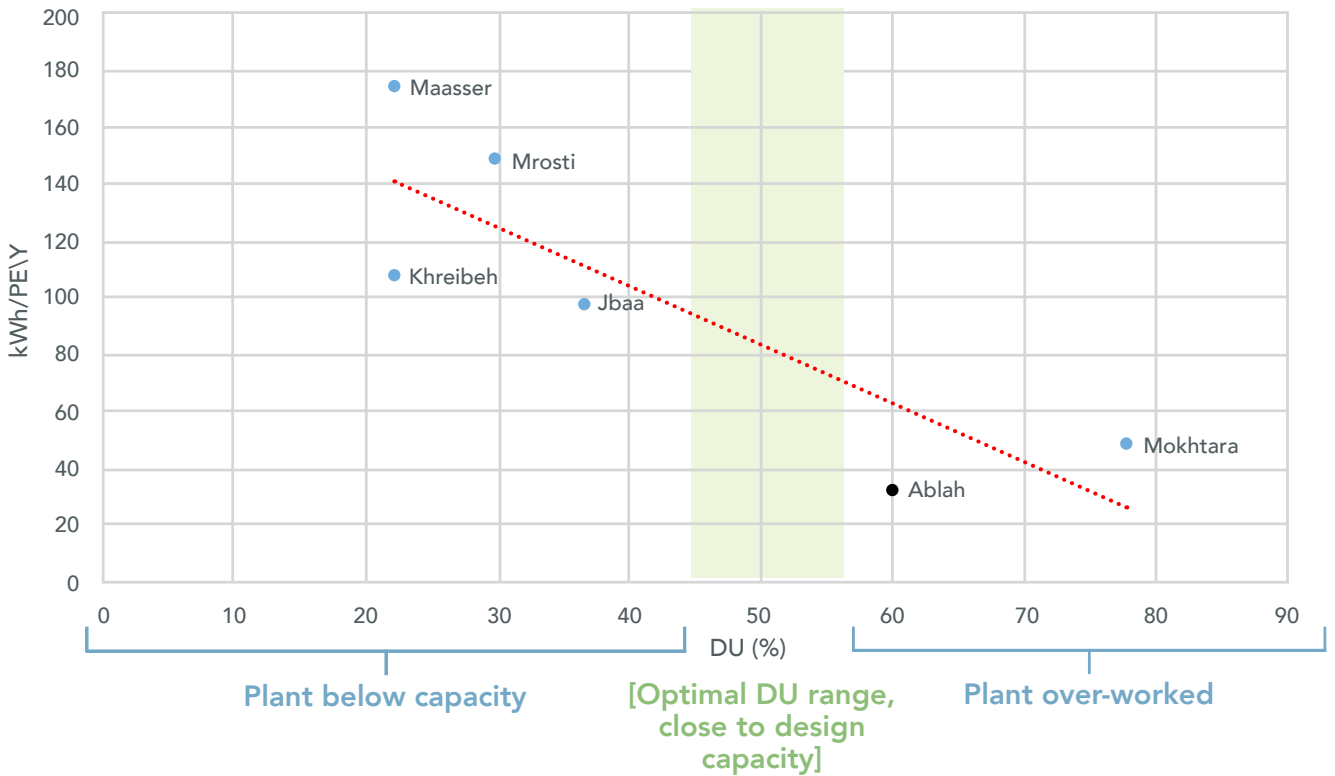
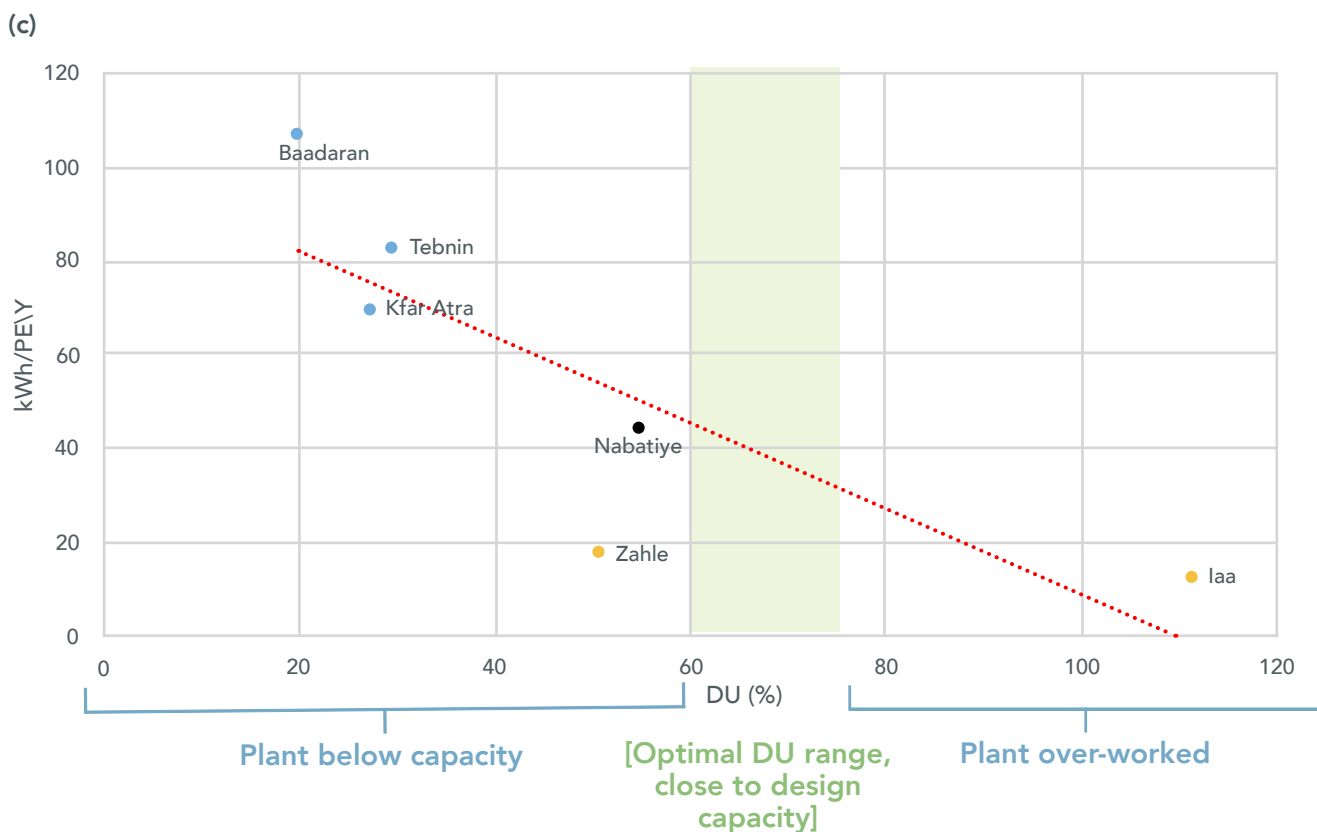


Figure 31. Specific energy consumption in relation to DU in: (a) activated sludge plants, (b) activated sludge with trickling filter, and (c) extended aeration. (continued)

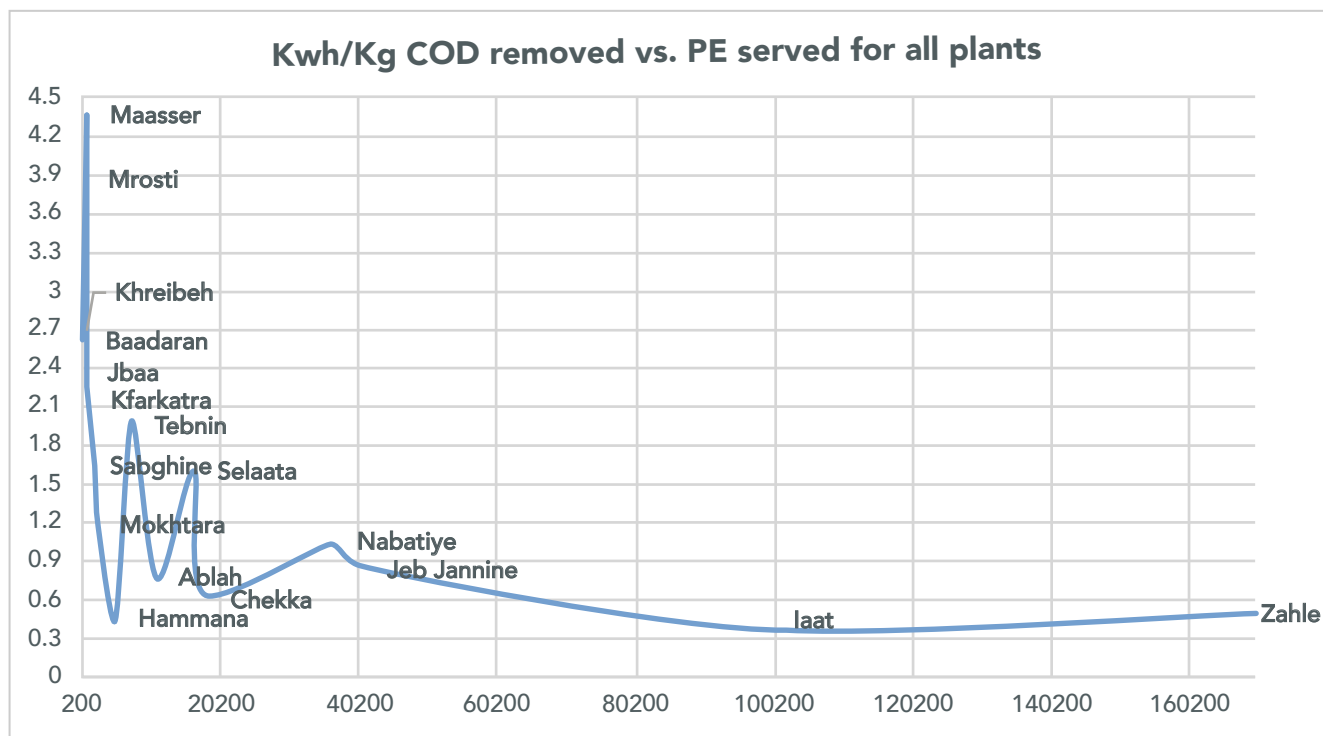


The graphs in Figure 31 represent the data according to the type of treatment: activated sludge, trickling filter, and extended aeration. All three types include plants that consume energy around or outside benchmarks, with the activated sludge process having the lowest kWh/PE/year ranges (20-80), followed by the extended aeration process (10- 120), and then by the activated sludge with trickling filters (30-180). Therefore, solid conclusions can be drawn regarding the impact of the type of secondary treatment on energy- consumption, once equipment used in each treatment process is individually analyzed and assessed. However, taking again into account the size class of the plant, it appears that smaller plants (SC1 and SC2) appear to be more energy-intensive than some of the larger plant (SC4 and SC5), as shown in Table 14. This is further confirmed when analyzing the behavior of the kWh/kg.COD.removed vs. the PE served by each plant, in Figure 31, which shows the high kWh consumption for the treatment plants serving the lowest number of PE; as this number of PE service increases, the kWh/kg.COD.removed decreases significantly.

Table 14 Classification of kWh/PE/year according to Size Class

Station	Type	PE serviced	Size class	kWh/PE/y
Baadaran	Extended aeration	333	SC1	106.91
Mrosti	AS - trickling filter	600	SC1	147.45
Maasser	AS - trickling filter	667	SC1	174.05
Khreibeh	AS - trickling filter	667	SC1	107.05
Jbaa	AS - trickling filter	733	SC1	97.26
Kfar Atra	Extended aeration	1000	SC2	69.5
Saghbine	Activated sludge	1,902	SC2	4.44
Mokhtara	AS - trickling filter	2,333	SC2	48.1
Hammana	Activated sludge	5,000	SC2	24.089
Tebnin	Extended aeration	7,200	SC3	82.7
Ablah	AS - trickling filter	10,714	SC4	32
Ferzol	AS - trickling filter	13,393	SC4	TBC
Selaata	Activated sludge	16,071	SC4	76.1
Chekka	Activated sludge	17,857	SC4	17.6
Nabatiye	Extended aeration	36,000	SC4	44.19
Jeb Jannine	Activated sludge	41,027	SC4	47.25
Laat	Extended aeration	99,482	SC4	12.5233333
Zahle	Extended aeration	169,643	SC5	17.6

Figure 32. kWh/Kg COD removed vs. PE serviced for all plants



## Wastewater Sector In-Depth Analysis<sup>17</sup>

Energy is required at nearly all wastewater treatment stages; however, facilities are not usually designed and operated with energy efficiency as a principal target. This section addresses the importance of creating an environment that would enable the implementation of energy efficiency measures in, both existing and planned, wastewater treatment plants. This can happen in two mutually supportive ways; the first through a modern approach to operation and maintenance; and the second through policies and regulations that set operation and maintenance protocols, especially as related to tenders and contracts that would enforce the implementation of the desired operation and maintenance protocols.

Energy efficiency is most clearly reflected in the operation and maintenance of WWTPs. The significance of making energy-efficiency a corner stone of the operation and maintenance of WWTPs is that it has a direct input into cost recovery (e.g. through lower energy costs and lower

<sup>17</sup> During the inception phase of the study, and in order to better understand and improve energy efficiency in wastewater treatment facilities, it was proposed that an in-depth, more detailed audit (Level-2 audit) would be performed at stations identified as having high-energy consumption during Level-1 audits.

Several logistical challenges prevented the IFI team from completing this work. First, there was a delay in embarking on the Level-1 audits, due to the political upheaval that shut down the country, since October. Second the weather and the Christmas and New Year holidays also prevented the IFI team from deploying to the field to complete the first audits. Consequently, the intended Level-2 audit was also delayed and pushed very close to the deadline of the project, leaving no time for its execution. Secondly, the equipment and instrumentation that would be needed for the Level-2 audits were not readily available and would require a long time to be made available. Finally, pursuant to the findings of the Level-1 audits, it was determined the Level-2 audits would not have been as informative as originally anticipated because of the great variability of factors that influence the energy efficiency of wastewater treatment facilities. The variability includes process type, equipment used in each facility and at each component of the stage of treatment, the characteristics of the influent sewage, location (e.g. elevation) of the facility, etc. Therefore, in lieu of the Level-2 audits, the IFI team elected to present pertinent, feasible operation and maintenance measures that would be beneficial and useful to the operators.

operational costs); improvement of the overall operational performance (e.g. synergy creation, lower maintenance cost, and longer equipment lifetime); and promote sustainability of facilities and their operations (e.g. resource conservation and climate change mitigation).

With this in mind, energy efficiency will be addressed from the operation and maintenance perspective, given its potentially significant impact when applied properly at the existing plants, and also when incorporated in the planning (and design) of any future plants. A co-benefit from looking at energy efficiency through the O&M lens is that it would greatly aid in the move, by the operators, away from unplanned emergency maintenance procedures to predictive and preventive maintenance.

In addition to the O&M angle, WWTPs proposed, as part of the CEDRE conference and the Capital Investment Plan (Harake & Kostopoulos, 2018), will be reviewed with a listing of potential changes in their treatment process, along with recommendations for some O&M procedures (including contracting) and energy consumption in the tender documents.

# Improving Energy Efficiency through the O&M of Existing Plants

This section will be using the benchmarking energy data results and analysis, developed earlier in this study, to help RWEs identify further opportunities for performance improvement in terms of energy consumption and to prioritize investments. It will provide an overview of several general energy-savings strategies that could benefit facility managers/operators and RWEs decision-makers, and which could be readily adopted at existing wastewater treatment facilities.

Based on plant operational information and data collected during the audit, the following energy savings recommendations for the existing WWTPs were developed:

## Equipment /Technology

The main focus in this component is to highlight the equipment that could be retrofitted to an existing WWTP:

- Adjustable speed drives on pumps and blowers for variable flow rate operations;
- Dissolved oxygen (DO) sensors to monitor and control in aeration tanks. DO sensors allow continuous and precise measurement of dissolved oxygen that keeps the waste treatment process functioning properly, and eliminates the need for frequent sampling and laboratory testing. By monitoring DO levels and treatment efficiency, the number of diffusers (in aeration), their configuration and operation can be optimized for better performance and efficiency. This allows managers and engineers to use an additional key performance indicator (KPI), kWh/kg.O<sub>2</sub>, for energy consumption assessment—this will be discussed in the next section:
- Electric load monitoring devices;
- Capacitors to improve power factor;
- Flow and pressure monitoring equipment to detect range of inlet flows to plant;
- Install Variable Frequency Drives (VFDs)<sup>18</sup> for pumps, motors, blowers, etc. This will allow for better control of operation of the equipment, and to increase its lifetime;
- Consider blowers with built-in VFDs whenever possible<sup>19</sup>;
- Installation of sensors to monitor ammonia levels in the effluent, to determine treatment efficiency—energy saving can be applied throughout the process;
- Install motion sensor for lighting in areas not occupied continuously.

<sup>18</sup> A Variable Frequency Drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage supplied to the electric motor.

<sup>19</sup> This is very dependent on the blower type, as some types of blowers will lose significant pressure when operated at reduced speeds, which would cause aeration to not happen.

## Operations

- When available within stations, reduce odor control ventilation operations when possible, and when ventilators are not in use shut them off.
- Control heating and cooling in areas that are not occupied all day.
- Conduct periodic pumps tests and repair or replace inefficient pumps as well as oversized motors.
- Chemical injection of salts in primary sedimentation to reduce aeration requirements (CEPT).
- Periodically perform audits of all installed electrical equipment (pumps, aerators, UVs, etc.), which will allow the identification of the following:

### *Period of operation of the component:*

- There is no fixed range for the equipment. Some equipment lasts for a long time while maintaining good efficiency, while other components might work for a shorter period of time period, losing good operating efficiency. Maintain a log of equipment age, maintenance works and costs, energy-consumption and efficiency, etc. to allow for preventative and even predictive maintenance. Keep updated log sheets of all equipment and operations, and allow for setting energy-efficiency targets and lowering energy consumption.

### *Energy consumption of various components:*

- Different pumps, blowers, etc. have different operation curves, recommended energy efficient operation, etc. Therefore, performing an audit of the equipment includes obtaining all possible information on all the equipment, ranging from motor data on the nameplate, pump/blower/motor operating curves, which includes the optimal energy efficient point of operation. The actual energy consumption of each component is then compared to the obtained theoretical data. This will help determine the equipment that is not operating properly, to make the necessary operational adjustments or equipment replacements, as needed.
- Old and worn out equipment should be replaced with newer equipment that is more energy efficient; e.g. energy efficiency should be a prominent criterion in selecting replacement parts.
- It was observed during the site visits that, often times, minor leaks and malfunctions were not addressed but neglected. This type of activity should desist, and all leaks or malfunctions of existing pumps/motors/blowers must be repaired to maintain the proper operation of the equipment, and to avoid any malfunctions that might cause higher energy consumption.
- In the absence of VFDs, operators must make sure that there is proper power supply to the treatment plant (voltage, frequency, etc.) as this will affect all electrical equipment

durability as well as energy consumption.

- Incoming sewage flow varies with time of day (day vs. time) or season. Therefore, operating programs can be devised in order to adjust operation accordingly. For example, it might not be necessary to continuously operate all pumps, blowers, motors, UV, etc. Some can be shut off for certain periods while maintaining the required treatment efficiency.
- Alternate the operation of installed equipment (if there is a redundancy in the system), which will result in lower energy consumption, and lengthen the lifespan of the installed equipment.
- Proper monitoring procedures and logging of results and organization of data collected from monitoring systems are mandatory, and should be centralized in one unit at the establishment, where archiving and tracking is carried out. Performance curve for pumps and/or motors should be kept at both the facility and the establishment offices for reference to ensure adherence to performance efficiency curves.
- Training programs for all personnel should be carried out periodically, especially with new technologies being introduced. Operators should be well trained to operate, maintain, and monitor the treatment system in terms of energy-efficiency and treatment operation.

# Improving Energy Efficiency through Activities Outside of Existing Plants

Some activities outside the WWTPs can negatively affect the performance of the facilities in terms of treatment results and energy efficiency. Some of the actions that can be carried to mitigate this are:

## Networks

- Combined sewers are still common in many areas in Lebanon. The discharge of these into WWTPs would sporadically increase the volume of the incoming effluent and dilute it, which will negatively affect energy consumption, due to pumping larger quantities, and the fact that dilution of the sewage will affect the plants' treatment efficiency (lower removal leads to higher energy consumption per kg of COD or BOD or N removed). Therefore, it is imperative to separate the two systems—stormwater drainage networks and sewage networks.

Until such a separation can occur, an equalization tank may be introduced into the treatment process into which all incoming effluent will be directed. The effluent from that tank may be pumped into the subsequent treatment at a constant rate, and operation patterns can be devised in order to maximize efficiency.

- In cases where the degree of utilization (DU) is low, if possible, divert sewage flows from nearby regions to the treatment plant to attain a DU of in the range of 80-85%. If that is not possible, equalization tanks must be introduced into the facility to regulate inflows and operation patterns devised to attain the 80-85% DU range. In this scenario, the treatment facility may not need to be operating round-the-clock.
- Leaks in the sewage networks should be fixed for the following reasons:
  - Ensure the design inflow into the WWTP is met.
  - Reduce extraneous inflows:
    - In some areas, high water tables may lead to infiltration of groundwater into the sewage networks, leading to higher incoming-flows.
    - Leaks from water-supply networks or roadway drainage networks may infiltrate into sewage networks, leading to higher incoming-flows

## Other activities

- Water conservation programs to educate people on the importance of water conservation, which will lead to lower sewage production, meaning smaller pumps, air blowers, treatment systems, and therefore less energy consumption.

# Improving Energy Efficiency through the O&M of Future Plants (those under Tender/in Preparation/in Design)

## Design/Planning

- Site selection of WWTPs should prioritize energy efficiency.
- Design of new treatment plants in trains, if and when possible, so that operation of the trains will depend on the actual incoming flow. This might allow for more energy-efficient operation schemes, and maintain the WWTP's desired degree of utilization.
- Ensure that actual (or field-tested) wastewater characterization studies are conducted to determine the sources (industrial, residential, medical, etc.) of influent wastewater, and accurately estimate the expected influent flow rate as well as influent wastewater characteristics, such as BOD, COD, pH, and TSS etc. Treatment plants should be designed for both optimal energy and treatment performance. This is vital, as influent flow rate and characteristics highly affect the energy demand due to excess pumping beyond the pump's best efficiency point or extended blowers' operation to achieve standard effluent characteristics.
- It was shown in this study that small scale WWTPs serving low PEs are less energy efficient than medium-to-large scale facilities; thus, with all things being equal (environmental considerations, associated network costs, etc.), new sewage treatment plants should attempt to maximize the PE served by moving towards medium-to-large-scale facilities.
- Incorporate equalization tanks in the design of future treatment plants. The purpose of the equalization tank is to normalize the flow to the treatment plant, and reduce inflow variability (in terms of volume and quality).
- Ensure proper design of future treatment plants such that actual incoming flow is maintained at approximately 80-85% of the design capacity.
- Sludge treatment: depending on site-specific conditions, incorporate energy production from sludge treatment using such methods as anaerobic digestion.
- Set standards for the WWTPs' operators to be met for energy consumption, based on scale and type of treatment.
- Whenever possible, attempt to implement the more energy-efficient treatment processes. This is subject to many site-specific considerations, including financial constraints, available space, technical ability of operators, availability of spare parts (in case the treatment process is high-tech), etc. As part of the review of the several newly available processes and technologies in the wastewater sector, which are expected, among others of course, to impact the plant's energy consumption. The IFI team identified three recent technologies that may be suitable for the conditions in

Lebanon. These were also recommended during some of the consultation meetings held throughout the project, especially since these technologies have proven to have some energy-efficiency impact on utilities. The technologies are: NERADA, Vortex Force, and MABR, and their details are shown in Appendix L.

## Policy

- RWEs have to agree with LRA on setting tariffs for the treated water discharged into the Litani River.
- Set appropriate tariffs for wastewater collection and treatment. This has to be in conjunction with penalties for illegal discharge of wastewater (domestic, industrial, or other) into sewage networks.
- Enforce the implementation of the desired operation and maintenance protocols in the tenders and contracts to be signed for in future plants.
- Energy efficient motors for the blowers shall be demanded in the equipment's RFPs.
- Contractors should be held accountable for O&M, diesel costs, volume and hours of water treated, and data cross-checking. Consequently, O&M contractors should be penalized (or rewarded) based on the performance regarding flow pumped, energy efficiency, etc.
- If the establishment decides to assign an O&M contractor, a full inventory should be done for all the available assets (equipment, spare parts, etc.) before handover. The O&M contractor should be continuously updated this inventory.

## Networks

- Separate sewage networks from stormwater drainage networks.
- Industrial and medical waste must be treated separately in-situ or in dedicated facilities before being discharged into domestic wastewater systems.

## Equipment

- Installation of VFD for all pumps, motors, blowers, etc.
- Installation of energy efficient equipment, which might be more expensive in terms of capex, but will end up saving energy and expenses in the long run.
- Install a full monitoring and control system to automatically adjust plant operation to optimize energy consumption (SCADA), where absent;
- Installation of sensors and controllers such as:

- DO sensors with controller in order to control operation of the air blowers, in accordance with a specific set of required DO level in the aeration tank. The rationale behind this is as follows:

The total energy demand of a wastewater treatment plant is influenced by various factors. When an activated sludge treatment process is utilized, the largest part of electrical energy is used to supply oxygen for the aeration system for nutrient

removal. DO sensors will allow the use of a new energy benchmarking indicator (kWh/kg.O<sub>2</sub>), which should reflect the energy efficiency in relation to the nutrient removal efficiency. This KPI is usually influenced by the following parameters:

- Year of construction: usually, the newest plants feature the best kWh/kgO<sub>2</sub>.
  - Sludge age: oxygen demand decreases when sludge age decreases, in other words, new sludge does not require a lot of oxygen. Consequently, the ratio kWh/kgO<sub>2</sub> increases, therefore electricity consumption would also increase. This shall not be the trend since we are always looking for energy efficiency.
  - Temperature in aeration tank.
  - COD-fractionation.
  - Use of Primary Clarification.
  - COD/BOD ratio.
  - Share of municipal/industrial wastewater.
- ORP or chlorine sensors and controllers in order to control the operation of chlorine dosage, according to a specific set required for residual chlorine level.

# A Quick Look at WWTP Future Projects

The Capital Investment Plan (CIP) as presented at the CEDRE conference included around 150 WWTPs to be constructed in the coming years for the four water establishments' jurisdictions, for a total amount of USD 2.6 billion. These are distributed as follows:

**Table 15 CIP WWTPs Investment Distributed Among RWEs**

Establishment	Number of WWTPs	Estimated Budget (USD)
Northern Lebanon	70	510,364,202
Bekaa	21	522,452,729
Southern Lebanon	15	562,210,060
Beirut and Mount Lebanon	44	1,071,298,936

A review of the proposed facilities reveals that they all may be grouped into the following categories: Conventional Activated Sludge (CAS), trickling filter, constructed wetlands, and a limited number of moving bed biofilm reactor (MBBR).

No specific rationale was provided for these processes, and no mention was made if energy-efficiency measures and guidelines will be followed in the design, implementation, and O&M of those plants.

Figure 33 summarizes the list of proposed of WWTPs, and the full detailed sheet can be found in Appendix L.

Having said that, and knowing the challenges faced by the water establishments when it comes to WWTPs' energy cost, maintenance, and day-to-day operation, it is very important to reconsider the planning criteria followed in these proposed projects, introduce energy-efficiency at the heart of wastewater treatment planning, and question the feasibility of those selected processes in terms of energy consumption, operational expenditure, and potential energy efficiency measures included in them to contribute to reducing the RWEs' energy costs.

Furthermore, and whenever possible, it is imperative to move towards medium-to-large-scale WWTPs instead of energy inefficient small-scale plants in order to service the highest number of PE possible, as it has been proven from the previous section that the more PE the plant serves, the more energy-efficient it is.

Finally, tenders shall include clear guidelines for equipment purchase and commissioning that take energy-efficiency into consideration as well as the operation and maintenance procedures to follow, along with clear Key Performance Indicators that the operator shall always abide by, especially when it comes to energy. Consequently, contracts for operation and maintenance must be performance-based with attention to ensuring energy efficiency.

Figure 33: List of planned WWTPs at the four RWEs<sup>20</sup>

PROPOSED WWTPs - Updated NWSS 2019 Volume V									
		Sewer Line (Km)	Sewer Line Cost Estimate (USD)	WWTP Cost Estimate (USD)	WWTP Flow (m3/day)	TOTAL (USD)	TOTAL (USD) (with design & supervision)	No. Of WWTPs	Processes / Technologies Used
Northern Lebanon	Akkar Priority 1	665	\$89,775,000	\$15,918,670	12,275	\$105,693,670	\$108,864,480	1	Activated Sludge
	Akkar Priority 2	474.98	\$64,122,300	\$171,754,936	-	\$235,877,236	\$250,029,871	45	Activated Sludge, Trickling Filter, Wetland
							\$358,894,351		
	Koura	112.72	\$15,217,740	\$12,795,658	-	\$28,013,398	\$29,634,202	3	Trickling Filter, Wetland
	Minieh	112.65	\$15,207,210	\$60,546,004	-	\$75,753,254	\$80,298,449	17	Activated Sludge, Trickling Filter, Wetland
	Zgharta	219.6	\$29,735,325	\$10,667,694	-	\$40,403,019	\$41,477,200	4	Trickling Filter, Wetland
<b>TOTAL NORTH</b>							<b>\$510,364,202</b>		
Bekaa	Baalback Priority 1	456	\$61,560,000	\$56,400,000	-	\$117,960,000	\$117,960,000	3	Conventional Activated Sludge, Trickling Filter
	Baalback Priority 2	569	\$76,815,000	\$61,600,000	-	\$138,415,000	\$138,415,000	4	Conventional Activated Sludge
	Baalback Priority 3	204	\$27,540,000	\$11,300,000	-	\$38,840,000	\$38,840,000	7	Conventional Activated Sludge, MBBR
							\$295,215,000		
	Hermel Priority 1	354	\$47,790,000	\$18,500,000	-	\$66,290,000	\$66,290,000	1	Conventional Activated Sludge
	Hermel Priority 2	226	\$30,510,000	\$19,900,000	-	\$50,410,000	\$50,410,000	4	Conventional Activated Sludge, MBBR
							\$116,700,000		
	Zahle & West Bekka Priority 1	116.7	\$15,869,505	\$13,187,218	-	\$29,056,723	\$30,025,888	2	Activated Sludge (Secondary Treatment)
	Zahle & West Bekka Priority 2	97.5	\$13,158,450	-	-	\$13,158,450	\$13,947,957	0	-
							\$43,973,845		
	Rachage Priority 2	268.54	\$36,252,435	\$21,645,936	-	\$57,898,371	\$57,898,371		Feasibility studies for ODR by nazih taleb
Rachage Priority 3	35.3	\$4,765,129	\$3,409,883	-	\$8,175,012	\$8,665,513		Feasibility studies for ODR by nazih taleb	
						\$66,563,884			
<b>TOTAL BEKKA</b>							<b>\$522,452,729</b>		
Southern Lebanon	Sour Priority 3	113.92	\$15,378,688	\$22,855,514	-	\$38,234,202	\$40,528,254		not mentioned
							\$112,992,651		
	Bent Jbeil Priority 1	623.05	\$84,111,858	\$34,634,610	26,093	\$118,746,468	\$122,308,862		not mentioned
	Bent Jbeil Priority 2	337	\$45,537,127	\$18,785,388	-	\$64,322,515	\$68,181,866	1	Activated Sludge
	Bent Jbeil Priority 3	43.82	\$5,915,251	\$8,535,626	3,621	\$14,450,877	\$15,317,930		not mentioned
							\$205,808,658		
	Jezzine Priority 2	0.63	\$85,050	\$85,051	985	\$170,101	\$172,652	1	Activated Sludge
	Jezzine Priority 3	62.96	\$8,499,611	\$4,486,547	-	\$12,986,158	\$15,568,464	7	Activated Sludge, Reed Bed
						\$15,741,116			
Saida Priority 1	839.52	\$113,334,780	\$86,838,773	-	\$200,173,553	\$135,683,966	2		
<b>TOTAL SOUTH</b>							<b>\$562,210,060</b>		
BML	Beirut					\$50,000,000	\$50,000,000		Rehabilitation, Replacement & Upgrade of sewers + Update & review of the Master Plan
	Jbeil Priority 1	167	\$22,495	\$25,725,458	-	\$48,221,168	\$51,114,438	3	Biofilters
	Jbeil Priority 2	204	\$30,813,662	\$13,179,872	-	\$43,993,534	\$46,633,146	3	Activated Sludge
	Jbeil Priority 3	181.14	\$26,065,887	\$14,007,899	-	\$40,073,786	\$42,478,213	3	Activated Sludge, MBBR
							\$140,225,797		
	Baabda & Aley Priority 1	629	\$84,979,981	\$197,702,030	-	\$282,682,011	\$282,682,011	4	Activated Sludge
	Baabda & Aley Priority 2	269.73	\$36,413,493	\$55,435,389	-	\$91,848,882	\$96,954,762	4	Activated Sludge
	Baabda & Aley Priority 3	49.51	\$6,683,493	\$10,975,741	-	\$17,659,234	\$18,718,788	2	not mentioned
							\$398,355,561		
	Priority 1	63.6	\$8,586,627	\$10,957,773	5,148	\$19,544,400	\$22,261,464	1	Activated Sludge
	Priority 2	71.24	\$9,617,637	\$9,922,753	4,477	\$19,540,390	\$20,712,813	1	not mentioned
							\$42,974,277		
	Chouf Priority 1	-	-	-	-	# VALUE!	\$107,477,978	15	
	Chouf Priority 2	8.3	\$1,120,129	\$5,250,000	4,200	\$6,370,129	\$6,561,233	1	Activated Sludge to be upgraded to MBBR
	Chouf Priority 3	101.48	\$13,699,624	\$9,692,742	-	\$23,392,366	\$24,463,263	3	Prefeasibility stages
						\$138,502,474			
Metn Priority 1	251.96	\$34,014,560	\$213,599,673	-	\$247,614,233	\$247,614,233	2	MBR	
Metn Priority 2	116.88	\$15,779,451	\$16,971,514	-	\$32,750,965	\$34,318,674	2	Activated Sludge	
Metn Priority 3	74.36	\$10,037,987	\$8,177,032	-	\$18,215,019	\$19,307,920		not mentioned	
						\$301,240,827			
<b>TOTAL BML</b>							<b>\$1,071,298,936</b>		
							<b>\$2,666,325,927</b>	<b>150</b>	

<sup>20</sup> Data retrieved from the National Water Sector Strategy, 2019.

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# Appendix A

## Walk-Through Survey

1. What is the total volume of water supply per day in dry and normal years?
2. How many wells do you operate for public water supply?
3. How many springs do you tap for public water supply?
4. How many dams are in your jurisdiction; are they for power generation or water supply?
5. How much of your public supply is serviced by surface water?
6. How much of your surface water supply is from dams?
7. What are the sources used for irrigation? (Number of sources and types.)
8. What is the pumping system followed for groundwater, springs, surface water, and dams?
  - a. Probe 1: submerged/vertical/horizontal pump.
  - b. Probe 2: electrical motor used.
  - c. Probe 3: what is the average depth-to-water in the wells used by the RWE?
9. After acquisition, what is the treatment process by source of water?
10. What's the distribution process?
  - a. How many reservoirs do you have?
    - i. How many of these are elevated tanks?
    - ii. How many are closed-surface reservoirs?
    - iii. How many are open reservoirs?
  - b. How many booster pumps do you have?
  - c. To what extent is your water distributed by gravity? (Exact numbers.)
11. Can you give us a walk-through of the operations of your facility? In the process, identifying energy input requirements and the relevant equipment.
12. What is your total electricity consumption?
  - a. What are the main sources of electricity consumption?
  - b. Do you have a breakdown data?
  - c. Can you rank your top five most energy-intensive equipment?
13. Would it be possible to have access to the electricity bills from the last three years?
14. How much do you pay for electricity and fuel per year?
  - a. What is the percentage to your overall costs?
  - b. What percent is your operational cost?
15. What is your source of supply of electricity for water-pumping?

16. In absence of EDL's electricity, what are your alternatives?
  - a.If diesel generators: what are the types used?
  - b.Their capacity?
  - c.Diesel consumption?
  - d.Do you own these private generators or part of a subscription?
  - e.Is there a metering system in place for generators?
17. Are you using renewable energy sources in your establishment? Where / what parts of the operation (pumping, treatment, office power supply, etc.)? How has this been reflected in the electricity bill, and in terms of uninterrupted electricity supply?
18. In what manner is energy-efficiency important to you? What have you done to lower energy consumption?
19. What part(s) of operations would you identify as the first to target when thinking of energy savings?
20. Is there a possibility to reduce the use of energy-intensive equipment?
21. In your opinion, what energy saving measures would be easier to implement? Why? What are the hardest and why?
22. Do you have an estimate on how much energy this would save (both in terms of absolute value, and a percentage of daily rate)?
23. Is there a process in place for identifying and addressing system deficiencies in terms of energy?
24. Are there any seasonal differences in energy consumption? If yes, are there any policies in place to address this difference?
25. Is there any demand management/reduction plan in peak seasons and hours?
26. Do dry years affect your energy consumption? How? Are there internal policies in place to address dry years, and the way to deal with service areas?
27. How do you assess the condition of your equipment? (Standards, metering, maintenance checks, etc.)
28. What percentage of your equipment meet technical standards in terms of operating conditions?
29. Have you ever faced an operation shutdown, due to loss of electricity?
  - a.In this case, do you have an emergency response plans?
  - b.How often does this happen, weekly, monthly, or yearly?
30. How many employees do you have in total? Engineers? Technicians?
  - a.How are they distributed among all stations?
31. How many subscribers are registered, officially?
32. What is the percentage of billing collection? Is there an estimation of the number of illegal beneficiaries?

# Appendix B

## Walk-Through Energy Audits (Water Establishments)<sup>21</sup>

### Bekaa Water Establishment

#### Chamsine

Figure 34. Chamsine water pumping station



<sup>21</sup>Note: the status "NA", shown in some fields of the results section below, indicate that information/data could not be acquired from the establishments, and thus the analysis could not be completed.

## Location

Chamsine, Anjar.

## Areas serviced

26 villages, including Kfar Zabed, Faour, Ain Kfar Zabed, Riit, Oussaya, Deir El Ghazal, Naasa, Bar Elias, El Marej, Al Rawda, Houch Al-Harimah, Khiara, Taaneyel, Deir Zanoun, Majdal Anjar, Masnaa, and Souairi.

## Date audited

27/05/2019

## Description

Located at the peripheries of Anjar, the Chamsine pumping station was funded and rehabilitated by ICRC. It includes two wells and one spring (Chamsine spring), and there are plans to drill five new wells in other locations a few meters away from this station. The station has a direct EDL medium-voltage line 24/7 and thus, does not use the existing diesel generators. The operator handling it has an overview of the overall process, pumps' details, water flow, and distribution network. The station is surrounded by large areas of land, which are reported to be public (property of the Lebanese government). The total plot area, including the constructed station, is 3,142,602 m<sup>2</sup>.

Total Flow (m <sup>3</sup> /day)	Station 2017 kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup>
15,840	9,523,857	1,333,340,000	24h	Medium voltage 3,000 kVA	-	-	1.647	0.154

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Kfar Zabed, Faour	Spring	180	255	120	0.588
Ain Kfar Zabed, Riit, Oussaya, Deir El Ghazal, Naasa	Spring	250	326.4	120	0.638
Bar Elias, El Marej, Al Rawda, Houch Al-Harimah, Khiara, Taaneyel, Deir Zanoun	Well	2*250	142.8	1200	0.146
Majdal Anjar, Masnaa, Sawiri	Well	2*220	142.8	1000	0.154
All pumps					0.196

## Jdita

Figure 35. Jdita water pumping station



### Location

Jdita

### Areas serviced

7 villages: Jdita, Makseh, Chtaura, Taaneyel, Taalabeya, Saadneyel, and Ghallela.

### Date audited

28/05/2019

### Description

Located at the top of the village, Jdita, below the Arab interconnection bridge, which was an area bought by the Government for this purpose; the station includes three wells of medium-depth, funded by UKaid in December 2016. Many operators alternate in shifts (day and night), but their roles are restricted to directing/redirecting the network, opening/closing valves without technical interference, and maintenance. Water is pumped to a reservoir, which supplies water to the villages. An additional reservoir was to be built to supply the village of Jdita; however, the municipality of Kfarselwan (owner of the land) refused, and halted this project. Previous trials for solar PV implementation in the surrounding lands were made but were not successful because the land is private.

Total Flow (m <sup>3</sup> /day)	Station 2017 kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup>
9,312	2,592,292	362,921,000	12/24 hours	Low 600 kVA	1 diesel generator 450 kVA (not in use)	-	0.76	0.071

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Jdita 1	Well	180	153	280	0.420
Jdita 2	Well	180	153	280	0.420
Jdita 3	Well	220	153	319	0.451
All pumps					0.431

## Loussi

Figure 36. Loussi water pumping station



### Location

Sultan Yaacoub El Tahta.

### Areas serviced

19 villages: Loussi, Sultan Yaacoub, Manara, Aila El Fekhar, Ghazze, Mdoukha, Kherbet Rouha, Rafid, Kfardines, Dahr El Ahmar, Mhaydseh, Kawkaba, Ezz El Arab, Jebb Farah, El Samah, El Aqaba, El Bireh, El Khiara, and Tel El Zaane.

### Date audited

28/05/2019

### Description

Built in 1954, this station is supposed to supply water to over 25 villages, but since some of them have their own wells, today it supplies around 15 villages and serves around 3,000-4,000 households. The main problem of the station is electricity, which is intermittent (15 hours/day), and arrives with a poor voltage. The station used to benefit from 24/7 electricity via a presidential decree, but then the situation changed, and electricity is now received from EDL (Joub Jennine), along with several other villages benefiting from the transmission line. At the time of the audit, the plant was not operational due to electricity issues; they had not received electricity for over five days. Operators, which has only three—while the station need at least five—prefer to pump water at night where electricity is more reliable. There seems to be a lack of communication between the operators and the management, which makes the operation more difficult, and they usually multi-task in order to supply water to all connected villages. The municipality of Sultan Yaacoub owns the surrounding land, and used to be agricultural lands.

Total Flow (m <sup>3</sup> /day)	Station 2017 kWh Consumption	Station 2017 Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
3,500	180,021.42	25,203,000	15/24 hours	Medium 1,500 kVA	Not Available	-	0.14	0.013

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Loussi 1	Well	180	102	330	0.535
Loussi 2	Well	100	102	180	0.545
Pump 1	Booster	330	561	100	0.588
Pump 2	Booster	330	561	100	0.588
Pump 3	Booster	330	561	100	0.588
All pumps					0.576

## Ghazze

Figure 37. Ghazze solar pumping station



### Location

Ghazze

### Areas serviced

Ghazze

### Date audited

28/05/2019

### Description

This station is a solar-powered pumping station funded by USAID's Lebanon Water Project (LWP), and put into operation in October 2018. It is formed of two wells (Old and New) that serve the village of Ghazze by pumping to a 300 m<sup>3</sup>-elevated tank/reservoir, and then distributing to the network via two booster pumps. It is an example of how useful solar power can be for small-scale pumps, especially in the Bekaa area, and more specifically with the electricity supply problems in most of the regions. It is a 176.8 kWp plant, and is able to power the new well alone with its two boosters, and both wells in hybrid mode when EDL is available.

Total Flow (m <sup>3</sup> /day)	Station 2017 kWh Consumption	Station 2017 Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
1,400	474,578.6	66,441,000 (compare with 2018 after solar installation)	Hybrid system with solar (176.8 kWp)	Low 165 kVA	-	-	0.92	0.086

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Ghazze 1 (Old)	Well at 200m depth	93.2125	130	280	0.256
Ghazze 2 (New)	Well at 86m depth	44.75	85	125	0.421
Pump (x2)	Booster	29.83	10	200	2.983
All pumps					0.403

## Zahle

Figure 38. Zahle water treatment plant



### Location

Zahle

### Areas services

Zahle

### Date audited

12/06/2019

**Description:** Located at the top of a hill, Zahle water treatment plant receives water by gravity (pipes) from Qaa El Rim spring. The treatment process includes sedimentation, decantation, sand filtration and chlorination, and all the water at the plant flows by gravity, except for the chlorination at the end of process, which need chlorine pumping. The plant received 24/7 EDZ electricity, and there is no use of diesel generators. It is operated by four teams of two employees each that work on a 24h/72h basis (24h working shift then 72h off), who try to maintain the equipment at the station within the available capabilities. SCADA systems for supply management are currently being installed. The plant's electricity consumption is minimal as it supplies water to the town of Zahle by gravity.

Total Flow (m <sup>3</sup> /day)	Station 2017 kWh Consumption	Station 2017 Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
12,000	980,942	137,332,000	24/7 EDZ	Low 250 kVA	-	-	0.22	0.02

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)
Zahle 1	Chlorination Pump	2.2	153	280
Zahle 2	Chlorination Pump	2.2	153	280
Zahle 4	Chlorination Pump	2.2	153	319

# Beirut Mount Lebanon Water Establishment

## Qartaba

Figure 39. Qartaba pumping station



### Location

Qartaba

### Area serviced

Qartaba

### Date audited

17/06/2019

### Description

The water in the station is provided from one well in Qartaba, which supplies the village. It operates around 16-18 hours per day in the summer, and 6-8 hours per day in the winter. The station is small, surrounded by a small piece of public land, while the remaining lands are private.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption (EDL)	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Station kWh Consumption (EDL)	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Station total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
75	2016: 53,728.57	2016: 7,522,000	20 hours per day	Medium Voltage	1 diesel generator: 700 kVA operated 4 hours per day and consuming 16,000 L /year	14,160,000 LBP	2016: 21,682,0 00	2016: 106,528. 57	2016: 0.162	2016: 0.022
	2017: 39,928.57	2017: 5,590,000					2017: 19,750,000	2017: 92,728.57	2017: 0.141	2017: 0.02
	2018: 54.192.86	2018: 7,587,000					2018: 21,747,0 00	2018: 106,992. 86	2018: 0.163	2018: 0.022

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Pump 1	Well	190	350	110	0.494

## Akoura

Figure 40. Akoura pumping station



### Location

Akoura

### Date audited

17/06/2019

### Area serviced

Akoura

### Description

The station supplies water from the Akoura spring, and pumps it to a reservoir located in the village. The pumps operate around 6-9 hours/day during summer, and four hours/day during winter. The operator is only responsible for turning the pumps on and off, and is not responsible for the maintenance of the station, which is conducted by an external company.

Electricity bills related to this station could not be retrieved from the establishment, and therefore analysis could not be applied.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
3,000	NA	NA	12 hours	Medium Voltage	3 diesel generators: 1,000 kVA 400 kVA 200 kVA	156,000 L/ year equivalent to Around 138,060,000 LBP	NA	NA

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Spring	92	260	95	0.372
Pump 2	Spring	110	265	90	0.461
All pumps					0.416

## Madiq

Figure 41. Madiq pumping station



### Location

Madiq

### Areas serviced

Aqaibe, Kfarchiham, Bouar, Safra, Adma, Kfarhbab, Sahel Alma, Jounieh, Ghadir, Wadi Hantouch, Bkirki, Sarba, Zouk Mosbeh, and Zouk Mikael.

### Date audited

17/06/2019

### Description

The station is located in Nahr Ibrahim, and supplies water from six wells with the contribution of the river flow. The station includes chlorination and pumping through large canals and long distances, and operates 24 hours a day.

Electricity bills related to this station could not be retrieved from the establishment, and therefore analysis could not be applied.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
33.33	NA	NA (Accessible through Jbeil Concession and not through the BMLWE)	18-20 hours per day	Medium Voltage	No	-	NA	NA

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Well	80	50	450	0.356
Pump 2-6	Well	34	15	540	0.420
All pumps					0.397

## Ashrafieh

Figure 42. Ashrafieh pumping station



### Location

Ashrafieh, Beirut.

### Areas serviced

Furn Chebak, Badaro, Hotel Dieu, Adib Ishac, Borj Abi Haidar, Badawi, Tahwita, Mar Mkhayel, Mdawwar, Qarantina, Gemayzeh, Saifi, Centre Ville, Sassine, Sioufi, Getawi, and Solidaire.

### Date audited

19/06/2016

### Description

The station includes two buildings, one administrative office, and one pumping station. There are eight big pumps at the station, which receive water directly from Dbayeh water treatment plant. EDL is available around the clock at the station, thus no generators are needed. Water is received in four big cells/reservoirs plus a fifth smaller size one, located in the second building. Water is then moved by gravity to a lower reservoir, which gathers the inlet water to the pumps. All pumping and pipes are linked to SCADA systems, which can be operated from HQ in Badaro. Water is either pumped directly to the network, or to three main reservoirs in Achrafieh, then moved to the network by gravity with an average of 50,000 m<sup>3</sup>/day.

Electricity bills related to this station could not be retrieved from the establishment, and therefore analysis could not be applied.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
2,083.33	2016: 3,471,507.14	2016: 486,011,000	24 hours	Medium Voltage	-	-	2016: 0.190	2016: 0.018
	2017: 3,232,428.57	2017: 452,540,000					2017: 0.177	2017: 0.017
	2018: 3,244,028.57	2018: 454,164,000					2018: 0.178	2018: 0.017

Pump	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Vertical	440	50	2500	0.352
Pump 2	Vertical	210	50	1250	0.336
Pump 3	Vertical	210	50	1250	0.336
Pump 4	Vertical	210	50	1250	0.336
Pump 5	Vertical	210	50	1250	0.336
Pump 6	Vertical	270	80	900	0.375
Pump 7	Vertical	270	80	900	0.375
Pump 8	Vertical	270	80	900	0.375
All pumps					0.354

## Qornet El Hamra

Figure 43. Qornet El Hamra pumping station



### Location

Qornet El Hamra, Mount Lebanon.

### Areas serviced

Ain Aar, Bhannes, Beit el Kiko, Mazraat Yachou, and Deek El Mehdeh.

### Date audited

19/06/2016

### Description

The station includes six series of parallel US motors pumps, each formed from two pumps (12 total). Only three of the six series are operating. There is a current plan to rehabilitate the whole station and procure new pumps. Water is distributed daily to the regions, according to a specific schedule. Each area benefits from approximately six hours of water-service per day.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
1,050	2016: 8,158,150	2016: 1,142,141,000	24 hours	Medium Voltage	-	-	2016: 0.886	2016: 0.08
	2017: 7,648,821.43	2017: 1,070,835,000					2017: 0.831	2017: 0.077
	2018: 9,610,407.14	2018: 1,345,457,000					2018: 1.0448	2018: 0.0975

Pump	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1 (x2)	Vertical	225	300	175	0.429
Pump 2 (x2)	Vertical	225	300	175	0.429
Pump 3 (x2)	Vertical	225	300	175	0.429
Pump 4 (x2)	Vertical	225	300	175	0.429
Pump 5 (x2)	Vertical	225	300	175	0.429
Pump 6 (x2)	Vertical	225	300	175	0.429
ALBP pumps					0.429

## Qashqoush

Figure 44. Qashqoush pumping station



### Location

Qashqoush

### Areas serviced

Dbayyeh water treatment station

### Date audited

19/06/2019

### Description

The Qashqoush station constitutes one spring and seven wells, the latter are mainly used during summer time when there is less supply from the spring. The average daily production from this station is around 30,000 m<sup>3</sup>/day. Water comes from the Faraya mountains to Jeita then to Qashqoush. When wells are operating along with the spring (high production rates), a canal is used to transfer water to Dbayeh Water treatment plant.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
1,250	2016: 3,352,800	2016: 469,392,000	24 hours	Medium Voltage	-	-	2016: 0.30	2016: 0.0285
	2017: 2,906,000	2017: 406,840,000					2017: 0.265	2017: 0.0247
	2018: 2,684,928.57	2018: 375,890,000					2018: 0.245	2018: 0.0228

Pump	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Submerged	93.2125	100	200	0.466
Pump 2	Submerged	49.962	54	210	0.441
Pump 3	Submerged	93.2125	100	180	0.518
Pump 4	Submerged	44.742	80	121	0.462
Pump 5	Submerged	134.226	140	212	0.452
Pump 6	Submerged	82.027	80	260	0.394
Pump 7	Submerged	149.14	160	150	0.621
All pumps					0.484

## Jeita

Figure 45. Jeita pumping station



### Location

Jeita

### Area serviced

Dbayyeh water treatment plant

### Date audited

19/06/2019

**Description:** Jeita water pumping station is located inside the Jeita Grotto Area. Water from the Jeita spring is directed to the station, where it is pumped to Qornet El Hamra and Dbayyeh water treatment stations. There are eight series of pumps in parallel at Jeita, a total of 16 pumps, which were changed and rehabilitated by the USAID in October 2012. The operators usually handle some small technical problems; the maintenance company takes care of the rest.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
833.33	2016: 135,707.1	2016: 18,999,000	24 hours	Medium Voltage	-	-	2016: 0.0186	0.0017
	2017: 133,871.42	2017: 18,742,000					2017: 0.0183	
	2018: 135,071.43	2018: 18,910,000					2018: 0.0185	

Pump	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1 (x16)	Submerged	83	80	252	0.412

## Jisr El Qadi

Figure 46. Jisr El Qadi pumping station



### Location

Jisr El Qadi, Aley.

### Areas serviced

Baysour

### Date audited

24/06/2019

### Description

This pumping station provides water from four wells, located over three kilometers away from the station. Due to acts of vandalism from the local communities, only two wells are currently operational. The water is pumped from the wells to two 300 m<sup>3</sup>-reservoirs, where it is treated to remove turbidity; this is then chlorinated and sent to the booster pump, and then on to the reservoir in Baysour. The station is currently facing major problems with EDL, and electricity is only being supplied at night. Initially the plant operated on four booster pumps, but because they needed a lot of maintenance and were breaking down regularly, two submersible pumps were added to the station, and are operated more frequently; the submersible pumps need less maintenance and have less friction-loss. At the time of the visit, one of the pump was being fixed haphazardly. The station is surrounded by large areas, owned by Waqf El Druz (lands owned by the Druz confessional leadership) which could be used for solar PV energy production that could partially reduce its reliance on EDL.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
100	2016: 334,957.1	2016: 46,894,000	12 hours (currently only at night)	Medium Voltage	3 diesel generators: 1,000 kVA 2x 500 kVA Consuming 578,160 Liters OR 1,907,928 kWh	511,671,600	2016: 2,242,885.1	2016: 2.56	2016: 0.425
	2017: 709,171.43	2017: 99,284,000					2017: 2,617,099.4	2017: 2.98	2017: 0.465
	2018: 751,900	2018: 105,266,000					2018: 2,659,828	2018: 3.036	2018: 0.469

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Well	110	275	90	0.444
Pump 2	Well	110	240	103	0.445
Pump 3	Well	65	400	33	0.492
Pump 4	Well	56	260	42	0.513
Horizontal Pumps (1-4)	Booster	160	450	72	0.494
Submersible Pumps (1&2)	-	260	40	140	-
All pumps					0.700

## Nabaa El Safa

Figure 47. Nabaa El Safa pumping station



### Location

Nabaa El Safa, Chouf.

### Areas serviced

Aley, Heraf, Bmerhin, and Al Hosn.

### Date audited

24/06/2019

### Description

The station takes its water from the Rayaan spring, also known as Nabaa El Safa. The establishment and the municipality both currently operate this station, and pumps for both entities are installed inside the same building. Yet, the operations are completely separate, and they do not pump to the same locations. At the time of the visit, the operator was not present, and could not be reachable by the establishment's focal person. The station is in an overall poor condition, with one pump leaking heavily.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
320	2016: 1,488,764.3  2017: 1,998,757.14  2018: 1,645,092.86	2016: 208,427,000  2017: 279,826,000  2018: 230,313,000	-	Medium Voltage	Three diesel generators: 1 x 1,000 kVA and 2 x 500 kVA	NA	2016: 0.531  2017: 0.713  2018: 0.587	2016: 0.050  2017: 0.067  2018: 0.055

Pump	Source	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Spring	150	340	100	0.441
Pump 2	Spring	75	216	170	0.204
Pump 3	Spring	75	180	100	0.417
Pump 4	Spring	112	150	100	0.747
Pump 5	Spring	45	360	15	0.833
All pumps					0.419

## Hadath

Figure 48. Reverse osmosis plant Hadath



### Location

Hadath

### Areas serviced

Hadath, Chiyah, and Southern Suburb of Beirut.

### Date audited

25/06/2019

### Description

The reverse osmosis (RO) plant operates on two wells, which were previously not operational due to very high salinity levels. Current TDS levels in both wells ranges between 14,000 and 21,000 ppm. The plant includes two RO lines, which operate a multimedia filter, anti-scalant addition, de-chlorination, acid dosing, filtration, and RO membranes for drainage and desalination; the water is then pumped to the Hazmieh reservoir. Due to unavailable data, the plant was initially designed to treat a lower TDS value (over 9,000), and thus the current process takes more time and energy, because operators often combine the treated water with the raw water to lower its TDS value.

Total Flow (m <sup>3</sup> /h)	Station EDL kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Station Energy Cost (LBP)	Total Station kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
208.33	2018: 637,428.57	2018: 89,240,000	12 hours	Medium Voltage	2 diesel generators: 650 kVA Consuming 144,000 L/ year OR 475,200 kWh	127,440,000	216,680,000	1,112,628.57	0.610	0.079

Pump	Source	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Backwashing (x3)	Pump	18.6425	20	260	0.359
Raw Water (x6)	Pump	8.9484	30	90	0.331
High Pressure RO (x6)	Pump	96.941	280	90	0.385
All pumps					0.378

## Jamhour

Figure 49. Jamhour pumping station



### Location

Jamhour

### Areas serviced

Louaize, Yarze, Jamhour, Baabda, Hadath, Hazmieh, and Wadi Shahrour.

### Date audited

25/06/2019

### Description

The station takes water from Ain El Delbeh spring and two wells in Araya and Roueiset El Ballout. The station supplies Baabda, Hadath, Hazmieh, and Wadi Shahrour by gravity, and pumps to Louaize, Jamhour, and Yarze. The station used to provide 1,200 m<sup>3</sup>/day nowadays it provides 780 m<sup>3</sup>/day. A large area is present at the station where solar PV could be installed, and given the small size of the station; it could power all operational pumps.

Electricity bills related to this station could not be retrieved from the establishment, and therefore analysis could not be applied.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
32.5	2016: 281,642.86	2016: 39,430,000	20 to 24 hours	Medium Voltage	1 diesel generator 100 kVA	NA	0.989	0.092

Pump	Source	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Booster	30	120	60	0.417
Pump 2	Booster	30	120	60	0.417
Pump 3	Booster	30	120	60	0.417
Pump 4	Booster	30	120	60	0.417
All pumps					0.417

## Dayshounieh Baabda

Figure 50. Dayshounieh Baabda water treatment plant



### Location

Dayshounieh, Baabda.

### Areas serviced

Hazmieh, Baabda, Hadath, and Beirut Suburbs.

### Date audited

25/06/2019

### Description

Dayshounieh, Baabda, is a water treatment plant, which receives its water from the Dayshounieh spring and eight wells, mostly operating during the summer period. The spring water has usually high turbidity values, and requires treatment before being pumped to the Hazmieh reservoir. The treatment process includes coagulation (ferric chloride), flocculation (slow and fast mixing for floc formation), decantation (floc settling and removal), and chlorination. The treatment capacity of the plant varies between 60,000 m<sup>3</sup>/day in the winter and 8,000 m<sup>3</sup>/day in the summer. The station is characterized by very large spaces above the decanters from both sides, which could be suitable for solar PV implementation (refer to *Volume IV: Renewable Energy Potential And Market Assessment*).

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
8,000 in summer 60,000 in winter	2016: 4,420,100  2017: 4,098,114.29  2018: 2,796,228.57	2016: 618,814,000  2017: 573,736,000  2018: 391,472,000	12 to 18 hours	Medium Voltage	4 diesel generators: 1500 kVA, 1000 kVA, 100 kVA and 60 kVA consuming 310,000 Liters/year or 1,023,000 kWh/year	274,350,000	2016: 893,164,000  2017: 848,086,000  2018: 665,822,000	Summer: 2016: 0.078 2017: 0.073 2018: 0.053  Winter: 2016: 0.010 2017: 0.010 2018: 0.007	Summer: 2016: 0.008 2017: 0.008 2018: 0.006  Winter: 2016: 0.001 2017: 0.001 2018: 0.001

Pump	Source	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	Spring	400	120	800	0.417
Pump 2	Spring	400	120	800	0.417
Pump 3	Spring	400	120	800	0.417
Pump 4	Spring	400	120	800	0.417
Pump 5-13	Well	40	100	110	0.364
All pumps					0.406

## Dayshounieh, Metn

Figure 51. Dayshounieh, Metn water treatment plant



### Location

Mansourieh

### Areas serviced

Mansourieh, Ain Saadeh Dayshounieh, and Beit Merry.

### Date audited

25/06/2019

### Description

Dayshounieh, Metn, is a water treatment plant, which receives its water from the Dayshounieh spring. The plant is currently under rehabilitation, as the filters used for the sand filtration are being replaced. Instead of the treatment process, currently the water bypasses the treatment process, and is, instead, chlorinated and sent directly to two reservoirs in Mansourieh and Beit Merry. The high turbidity from the spring and the lack of current treatment has led to the distribution of colored water to consumers, causing several complaints. The complete treatment process includes coagulation, flocculation, decantation, sand filtration, and chlorination. The main problem for the plant lies in the unstable voltage supplied by EDL. While the average voltage should be around 230 V, it receives voltages varying from 200-260 V.

Total Flow (m <sup>3</sup> /day)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
9,000	2016: 2,300 2017: 4,600 2018: 4,600	2016: 322,000 2017: 644,000 2018: 644,000	12 to 16 hours	Medium Voltage	3 diesel generators: 450 kVA consuming 46,101 liters Or 152,135.6 kWh	40,800,000 LBP	2016: 154,435.6 2017: 156,735.6 2018: 156,735.6	2016: 0.047 2017: 0.048 2018: 0.048	2016: 0.008 2017: 0.008 2018: 0.008

Pump	Source	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Pump 1	From Station to Reservoir	500	480	480	0.217
Pump 2	From Station to Reservoir	500	480	480	0.217
Pump 3	From Station to Reservoir	355	275	275	0.469
Pump 4	From Station to Reservoir	355	275	275	0.469
Pump 5	Spring	14	12	12	9.722
Pump 6	Spring	14	12	12	9.722
Pump 7	Spring	14	12	12	9.722
Pump 8	Spring	14	12	12	9.722
Air Blower (1 & 2)	-	43	-	-	
Backwash Pumps 1&2	-	22	12	425	0.431
All pumps					0.291

## Dbayeh, Metn

### Location

Dbayeh, Metn.

### Areas serviced

Coastal Metn, and Beirut (Talit El Khayat and Achrafieh stations) to Airport Road.

### Date audited

30/05/2019

### Description

Dbayeh water treatment plant is the main station that supplies the coastal metn area and the greater Beirut. It was constructed during the French presence in Lebanon, and the main areas it serves are Jeita Grotto, in addition to several other wells in Ach'ouch area/spring above Antelias, where there is a grotto (15 stairs deep) coming down from Tarchich.

The plant thus treats around 250,000 m<sup>3</sup>/day using the following three main processes: manual cleaning, chlorination, and decantation, where FeCl/Chorure ferrique are added to play with the densities and remove the clusters from the water. With these processes, water is cleaner to a 60-70% extent. After decantation, water passes through 36 filters where air is blown into sand that connects with water. Filters are washed at a rate of four filters/day in the summer, and all filters during winter.

Electricity is available 24/7 and there is one diesel generator at the station, which allows the operation of one line of pumps only. Its capacity is 800 kVA. There are four alternating working teams in Dbayeh station, five persons per rotation, and only one person is responsible for equipment maintenance.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
10,416.67	2016: 23,936,864.3	2016: 3,351,161,000	24 hours	Medium Voltage	One Diesel generator on 800 kVA Capacity	-	2016: 0.262	2016: 0.024
	2017: 26,328,185.71	2017: 3,685,946,000					2017: 0.289	2017: 0.027
	2018: 30,030,964.29	2018: 4,204,335,000					2018: 0.329	2018: 0.031

NEW STATION					
Pumps	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Champville 2	Horizontal	110	160	180	0.382
Champville 2	Horizontal	130	160	190	0.428
Dbayeh 3	Filtration (Horizontal)	75	-	-	-
Small Pump	Submersible	3.75	-	-	-
Small Pump	Submersible	3.75	-	-	-
Dbayeh 4	Submersible	50	50	170	0.588
Dbayeh 5/6	Vertical	750	125	1100	0.545
Dbayeh 7/9	Vertical	800	125	1100	0.582
Dbayeh 10/11	Vertical	375	97	1100	0.351
Dbayeh 12/14/16	Vertical	900	93	2200	0.440
Dbayeh Washing pump (x2)	Horizontal	56.25	-	-	-
Dbayeh Decanter	Horizontal	37.5	-	-	-
All pumps					0.473

OLD STATION					
Pumps	Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Dbayeh 1/2	Horizontal	810	90	2500	0.36
Dbayeh 3/4	Horizontal	750	93	2000	0.403
Dbayeh 5	Horizontal	805	-	2000	-
Dbayeh 6/7	Horizontal	800	-	2700	-
Dbayeh 8/9/10/11	Vertical	375	97	1100	0.703
Dbayeh wash pump (old)	Horizontal	52.2	10	1280	0.408
Dbayeh/Zouk El Khrab	Horizontal	37.5	127	60	0.492
All pumps					0.447

## North Lebanon Water Establishment

### Bahsas

Figure 52. Bahsas water treatment plant



#### Location

Bahsas, Tripoli.

#### Areas serviced

Manar reservoir to serve the following areas: Abou Samra, Qobbeh, Baddaoui, Coastal Tripoli, Mina, Marina Del Sol, and Mejdlaya.

#### Date audited

26/06/2019

#### Description

The station is Tripoli's main treatment plant, and receives water from four different sources: three springs (Hab, Abou Halka, and Rachiine) and one well (around 1,000 m<sup>3</sup>/day). Hab spring is located 3.6 km from the station (between Daher El Ain and Bkeftine), and is the main spring, which feeds the station by gravity. Meanwhile Abou Halka is pumped from a lower point (just before the sea-mouth) to the station, and is mostly utilized when flows from Hab springs are low.

The station operates 24h/day and was first designed and built in 1968 for a capacity of 40,000 m<sup>3</sup>/day. After having suffered severe damage during the civil war, it was reconstructed in February 1999, and upgraded in 2010, adding an additional capacity of 30,000 m<sup>3</sup>/day, amounting to a total treatment capacity of 70,000 m<sup>3</sup>/day. The operation is done in shifts, where two employees handle each shift, and continuously test the water quality. Around 20,000 m<sup>3</sup>/day are sent to Manar reservoir, while the remaining 50,000 m<sup>3</sup>/day flow to Tripoli, Qalamoun, and Qobbeh. The treatment process in both stations includes decantation, filtration, and chlorination. Many empty lands around the treatment plant are available for solar system installation.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generator Consumption	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
2,810	2016: 10,554,085.71	2016: 1,477,572,000	24/7	Medium 2,000 kVA & Low volt	2016: 6,000L OR 19,800 kWh	2016: 4,140,000	2016: 1,481,712,000	2016: 10,573,885.71	2016: 0.429	2016: 0.04
	2017: 10,738,228.57	2017: 1,503,352,000			2017: 24,000 OR 79,200 kWh	2017: 17,920,000	2017: 1,521,272,500	2017: 10,817,428.57	2017: 0.439	2017: 0.0412
	2018: 10,190,135.71	2018: 1,426,619,000			2018: 9,000L OR 29,700 kWh (111 hours)	2018: 7,785,000	2018: 1,434,404,000	2018: 10,219,835.7	2018: 0.415	2018: 0.0388

Station	Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Station 1	Hab Pumps (x6)	Spring	37.3	20	450	0.414
	Backwash Pumps (x2)	Backwash	37.3	12	820	0.379
	Qalamoun Pump	Spring	74.57	40	234	0.797
	Service Water Pumps (x3)	Spring	5.6	5	21.58	5.190
Station 2	Booster Pumps (x3+1 backup)	Booster	44.75	27	437.5	0.379
	Backwash Pumps (x2)	Backwash	33.55	20	979.1	0.171
Pumping to Manar	Manar Pumps (x5)	Well	11.85	20	600	0.099
	Manar Pumps	Well	11.85	20	252	0.235
All pumps						0.297

## Jisr

Figure 53. Jisr water pumping station



### Location

Qobbeh, Tripoli.

### Areas serviced

Pumping to Manar reservoir

### Date audited

26/06/2019

### Description

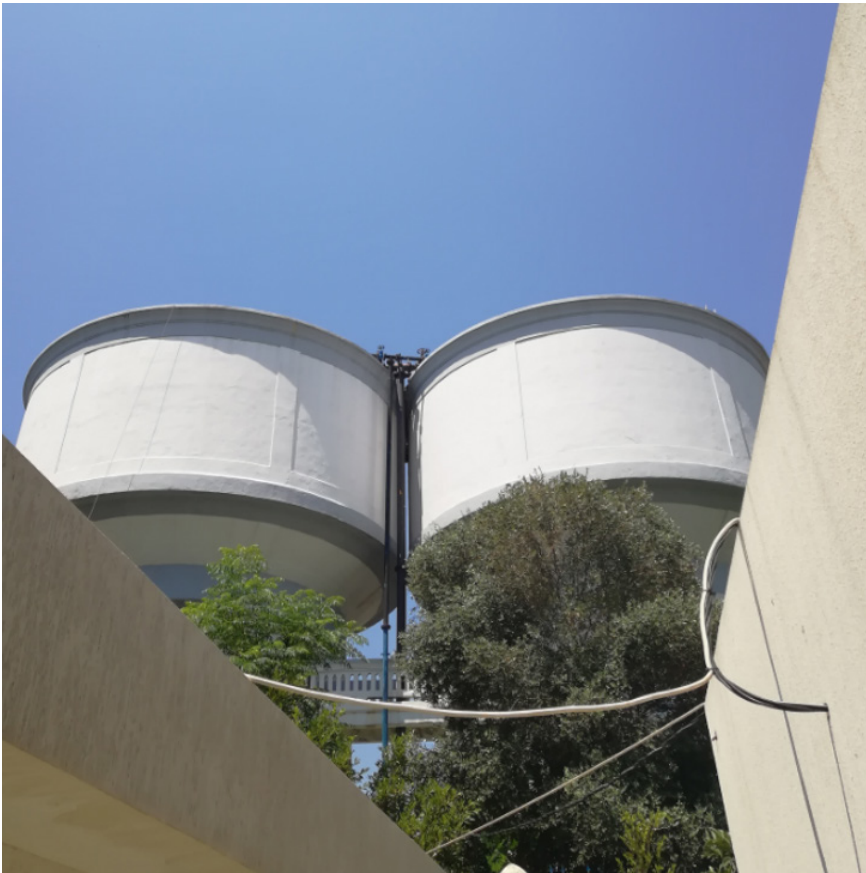
Two wells are located at this station, which lies on the banks of the Abou Ali river. The average production from both wells is between 3,000 to 4,000 m<sup>3</sup>/day, where water is pumped to Manar reservoir, to support the 10,000 m<sup>3</sup>/day pumped from Bahsas station. EDL/Qadisha is available 12/24 hours, however operators have been facing voltage problems for the past two months, where the voltage received is too low to operate the pumps. This station is mostly operated during the summer season, and diesel generators are not used during winter. There is a need to solve this problem by installing VFDs to attenuate the pressure exerted on the pumps, and reduce risk of damage.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generator Consumption	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
145.8	2016: 2,308,828.57	2016: 323,236,050	12/24 hours	Medium 1,000 kVA	2016: 8,000L OR 26,400 kWh	2016: 5,320,500	2016: 328,556,500	2016: 2,335,228.57	2016: 1.828	2016: 0.171
	2017: 3,148,285.71	2017: 440,760,000			2017: 9,000L OR 29,700 kWh	2017: 7,204,500	2017: 447,964,500	2017: 3,177,985.71	2017: 2.488	2017: 0.234
	2018: 3,177,335.71	2018: 444,826,950			2018: 20,000L OR 66,000 kWh (700h)	2018: 19,650,000	2018: 464,477,000	2018: 3,243,335.71	2018: 2.539	2018: 0.242

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Jisr 1	Well	298.28	130	250	0.918
Jisr 2	Well	298.28	130	290	0.791
All pumps					0.850

## Qobbeh

Figure 54. Qobbeh water pumping station



### Location

Qobbeh, Tripoli.

### Areas serviced

Tripoli

### Date audited

26/06/2019

### Description

Funded by the Canadian Development fund in March 2016, this station includes a 600 m<sup>3</sup> capacity reservoir, three wells, and a filtration station. It was constructed during the French mandate, and the rehabilitation design included the use of solar panels to pump water, however due to internal issues among donors, the panels were not included, and a generator was purchased instead. There are three wells around the reservoir: One that is depleted and not operating; one that is new and operating for the Tabbaneh area, directly into the network; and one that pumps water to the reservoir. EDL (Qadisha) is available 10-14 hours/day, and the station can totally shift to solar, since its capacity is small, and land is available. At the station, there is another 200 m<sup>3</sup> capacity reservoir, which distributes to the Hariri Housing Project.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generator Consumption	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
189.84	2016: 487,063.92	2016: 68,188,950	12/24 hours	Medium & Low voltage	2018: 15,051L OR 49,668.3 kWh (1,038h)	13,320,135	2016: 68,188,950	2016: 487,063.92	2016: 0.293	2016: 0.027
	2017: 544,671.43	2017: 76,254,000					2017: 76,254,000	2017: 544,671.43	2017: 0.328	2017: 0.031
	2018: 457,089.29	2018: 63,992,500					2018: 77,312,635	2018: 506,757.59	2018: 0.305	2018: 0.031

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Qobbeh Reservoir	Well	33.55	120	40	0.699
Maytam Old Well	Well	52.199	150	72	0.483
Mouhajjarin (Hariri) Reservoir	Well (x3)	18.64	20	72	1.294
	Pump	37.285	200	60	0.311
All pumps					0.561

## Ayrounieh

Figure 55. Ayrounieh water pumping station



### Location

Ayrounieh, Tripoli.

### Areas serviced

Qobbeh

### Date audited

26/06/2019

### Description

Located on a land owned by the municipality of Tripoli, the station includes a large reservoir of 30,000 m<sup>3</sup>/day, along with a pumping station to serve the Qobbeh area with around 20,000 m<sup>3</sup>/day. Water is provided from the Manar and Jisr wells.

A smaller reservoir was newly constructed nearby the station of 100 m<sup>3</sup>/day that is 22 meters high and serves the Fouar surrounding area (located in the district of Zgharta, and thus considered outside of Tripoli). Water is pumped to this reservoir through two small pumps at the Ayrouniyeh. In addition to the latter, there are seven pumps, which are barely used, since water flows by gravity.

The buildings' and reservoir's rooftop are all empty spaces, and can easily be used to install solar panels that can power the two small pumps, and thus move the entire station to renewable energy.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
791.66	2016: - 2017: - 2018: 17,799.64	2016: - 2017: - 2018: 2,491,950	24/7	Medium	2018: 1000L OR 3,300 kWh (92h)	2018: 865,500	2016: - 2017: - 2018: 3,357,500	2016: - 2017: - 2018: 21,099.64	2016:- 2017: - 2018: 0.003	2016: - 2017: - 2018: 0.0003

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Fouwar Pumps	Booster	5.22	2.42	40	5.939
	Booster	5.22	2.42	55	3.922
Aayrounieh Pumps (x4)	Booster	74.57	30	400	0.621
Aayrounieh Pumps (x3)	Booster	37.285	30	210	0.592
All pumps					0.627

## Daher El Moghor

Figure 56. Daher El Moghor pumping station



### Location

Qobbeh, Tripoli.

### Areas serviced

Qobbeh area

### Date audited

26/06/2019

### Description

This station consists of three separated wells: Dannaoui (pumping to Daher El Moghor area), Saleftaniyye 1 (pumping to Qobbeh area, not always used), and Saleftaniyye 2 pumping to the nearby reservoir, with a 3,200 m<sup>3</sup> capacity.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
610	2016: 1,668,876.8	2016: 230,305,050	12/24	Medium 500 kVA	2016: -	2016: -	2016: 230,305,050	2016: 0.312	2016: 0.029
	2017: 1,727,304.3	2017: 238,368,000			2017: 2,000L	2017: 1,680,000	2017: 240,048,000	2017: 0.323	2017: 0.030
	2018: 2,952,485.5	2018: 407,443,050			2018: - 106h	2018: -	2018: 407,443,000	2018: 0.553	2018: 0.051

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Dahr El Moghr - Dannaoui	Well	111.855	120	252	0.370
Dahr El Moghr – Selftaniyyeh 1	Well	93.2125	130	129.6	0.553
Dahr El Moghr – Selftaniyyeh 2	Well	134.226	120	180	0.621
All pumps					0.494

## About Halka

Figure 57. Abou Halka pumping station



### Location

Bahsas, Tripoli.

### Areas services

Pumps to Bahsas treatment station.

### Date audited

27/06/2019

### Description

Inaugurated in 1999, this station consists of a spring at the sea-mouth, and was developed and funded during the era of late minister Elie Hobeika. Before being discharged to sea, the spring is pumped up to Bahsas treatment station and distributed to Tripoli.

SCADA is installed at this station but still not operational, and the EDL (Qadisha) current is available 24/7, thus the backup diesel generator is rarely used. No full-time employees are present at this station, but operators make daily checks. The land on which the station is built is public land. Along with the empty station rooftop, they can both contribute to a hybrid solar PV generation system to power the small-to-medium pumps at the station.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Consumption	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
1,297	2016: 4,592,857.143	2016: 643,000,000	24h	Medium	2016: 6,400L OR 21,120 kWh	2016: 3,733,500	2016: 646,733,500	2016: 4,613,977.14	2016: 0.406	2016: 0.037
	2017: 4,717,471.43	2017: 660,446,000			2017: 5,000L OR 16,500 kWh	2017: 3,649,500	2017: 664,095,500	2017: 4,733,971.43	2017: 0.416	2017: 0.039
	2018: 3,464,285.71	2018: 485,000,000			2018: 13,000L OR 42,900 kWh	2018: 9,325,500	2018: 494,325,000	2018: 3,507,185.71	2018: 0.308	2018: 0.029

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Abou Halaa 1 (x4)	Submersible	37.285	12	600	0.518
Abou Halaa 2 (x5)	Booster	74.57	40	400	0.466
All pumps					0.480

## Al Manar

Figure 58. Al Manar Water pumping station



### Location

Abou Samra, Manar Public Garden, Tripoli.

### Areas serviced

Tripoli, Abou Samra.

### Date audited

27/06/2019

### Description

Built in 2003, this station used to be a public garden for the municipality. The station was built instead on the roof of the pumping station. It includes a large reservoir of 20,000 m<sup>3</sup> capacity, along with several pumps (eight) that serve the region of Abou Samra and Tripoli city. The source of water is from the Hab spring, after passing through Bahsas for treatment. EDL (Qadisha) is available 24/7, and two to three pumps usually operate together, sending water to the Ayrounieh reservoir and the Abou Samra areas.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
1,230	2016: - 2017: 2,037,400 2018: 1,800,000	2016: - 2017: 285,236,000 2018: 252,000,000	24h	Medium	2016: 5000L OR 16,500 kWh 2017: 8,000 L OR 26,400 kWh 2018: -	2016: 3,960,000 2017: 6,400,500 2018: -	2016: 3,960,000 2017: 291,636,500 2018: 252,000,000	2016: 16,500 2017: 2,063,800 2018: 1,800,000	2016: 0.002 2017: 0.191 2018: 0.167	2016: - 2017: 0.018 2018: 0.016

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Manar Pumping Station (x5)	Booster	149.1	50	450	0.663
Manar Pumping Station (x3)	Booster	67.1	15	330	1.356
All pumps					0.743

## Abou Samra

Figure 59. Abou Samra water pumping station



### Location

Abou Samra

### Areas serviced

Abou Samra, Tripoli.

### Date audited

27/06/2019

### Description

Built in 1965, this pumping station includes a reservoir with a 700 m<sup>3</sup> capacity that serves part of Tripoli. This area is higher in altitude than Manar and requires pumping.

Water flows from four surrounding wells: Hallab, Welli, Saadoun, and Hawout. EDL (Qadisha) provides 10-14h, and the plant has no diesel generators.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
103.5	2016: 4,598,432.143	2016: 643,780,500	10-14 hours	Medium 200 kVA & Low voltage	NA	NA	2016: 643,780,500	2016: 4,598,432.143	2016: 5.071	2016: 0.473
	2017: 4,360,692.86	2017: 610,497,000					2017: 610,497,000	2017: 4,360,692.86	2017: 4.8	2017: 0.448
	2018: 4,185,889.29	2018: 586,024,500					2018: 586,024,500	2018: 4,185,889.29	2018: 4.6	2018: 0.43

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Sankari	Well	149.14	190	176.4	0.445
Hallab	Well	93.2123	120	68.3	1.137
Saadoun	Well	93.2123	125	151.2	0.493
Weli	Well	93.2123	120	151.2	0.514
All pumps					0.544

## Jradeh

Figure 60. Jradeh Water pumping station



### Location

Jradeh

### Areas serviced

Anfeh, Zakroun, and Kaleh (Koura).

### Date audited

29/07/2019

### Description

This pumping station consists of eight submersible pumps, drawing water from eight wells to an onsite 100 m<sup>3</sup> capacity reservoir. Then five booster pumps lift water to three reservoirs in the region: one in Anfeh (m<sup>3</sup>), Zakroun (2,500 m<sup>3</sup>) and Kaleh (4000 m<sup>3</sup>). There is a 270 kVA diesel generator onsite, but it is rarely used since EDL is available 24/h.

Total Flow (m <sup>3</sup> /h)	Station EDL kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
257.16	2016: 4,499,378.57	2016: 629,913,000	24h	Medium Voltage	-	-	2016: 629,913,000	2016: 4,499,378.57	2016: 1.997	2016: 0.186
	2017: 3,398,178.57	2017: 551,345,000					2017: 551,345,000	2017: 3,398,178.57	2017: 1.748	2017: 0.163
	2018: 3,730,757.14	2018: 522,306,000					2018: 522,306,000	2018: 3,730,757.14	2018: 1.873	2018: 0.155

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Kaleh 1	Submersible	22.4	31	120	0.602
Kaleh 2	Submersible	22.4	31	120	0.602
Las 1	Submersible	96.941	130	NA	-
Las 2	Submersible	96.941	130	NA	-
Anfeh 1	Submersible	126.023	169	227	0.328
Anfeh 2	Submersible	126.023	169	227	0.328
Regional Reservoir 1	Booster	250	426	NA	-
Regional Reservoir 2/3/4	Booster	315	426	NA	-
Regional Reservoir 5	Booster	280	426	NA	-
All pumps					0.353

## Chekka

Figure 61. Chekka water pumping station



### Location

Chekka

### Areas serviced

Chekka

### Date audited

29/07/2019

### Description

In this station, two wells supply water to a reservoir with a capacity of 100 m<sup>3</sup>. Water is then pumped to another reservoir in Kfarhazir with a capacity of 2,500 m<sup>3</sup> via booster pumps. There are four booster pumps; two are operational, and the other two remain on standby.

There is one diesel generator with a capacity of 800 kVA; however, it is rarely used since EDL is available 24/7.

Currently, the first spring is not used due to infrastructure damage caused by recent floods. However, in normal operating conditions, a 50 hp pump is located at a 50 meters depth that supplies water to the pumping station at a rate of 45 l/s. A 200 kVA backup generator is available but not in use.

As for the second well, a 75 hp pump is placed at 120 m depth, and discharges water at a flow rate of 45 L/s through an 8" pipeline.

Total Flow (m <sup>3</sup> /h)	Station EDL kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
162	2016: - 2017: 673,942.86 2018: 2,787,785.71	2016: - 2017: 94,351,950 2018: 390,289,950	24h	Medium voltage line (380-390 V)	2016: - 2017: 12,400 L OR 40,920 kWh 2018: 7,600L OR 25,080 kWh	2016: - 2017: 9,964,500 2018: 7,522,500	2016: - 2017: 104,316,450 2018: 397,812,500	2016: - 2017: 714,862,50 2018: 2,812,865.71	2017: 0.504 2018: 1.982	2017: 0.049 2018: 0.187

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Chekka Well 1	Booster	45	70	144	0.446
Chekka Well 2	Booster	67.113	140	144	0.333
Kfarhazir (x4)	Booster	130.5	250	115.2	0.453
All pumps					0.436

## Kousba

Figure 62. Kousba water treatment plant



### Location

Kousba, Koura district.

### Area Serviced

This treatment plant serves many villages in Koura.

### Date audited

29/07/2019

### Description

This water treatment plant mainly serves villages in Koura. It treats and supplies 570 m<sup>3</sup>/day. Its source of water is the Kadisha spring (Abou Ali). Water is supplied by gravity into a reservoir, which then passes through the different treatment stages, including pre-treatment, decantation, filtration via four sand filters and finally chlorination. The treatment process is not energy intensive, since low pumping activities are used throughout the process. The highest energy-consuming step is backwashing the sand filters (two filters/night).

EDL is available 24/7 with no backup generators onsite.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
23.75	2016: 95,650	2016: 13,390,950	24h	Medium and low voltage	-	-	2016: 13,390,950	2016: 95,650	2016: 0.460	2016: 0.043
	2017: 119,692.86	2017: 16,756,950					2017: 16,756,950	2017: 119,692.86	2017: 0.575	2017: 0.054
	2018: 344,985.71	2018: 4,829,550					2018: 4,829,550	2018: 344,985.71	2018: 1.658	2018: 0.155

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Filters (x2)	Backwash pumps	30	-	-	-

## Kfarhelda

Figure 63. Kfarhelda water treatment plant



### Location

Kfarhelda, Batroun.

### Areas serviced

Mar Yaacoub, Kfarhelda, and Beit Chelala.

### Date audited

29/07/2019

### Description

This treatment plant was built in 1967 and renovated in 1990. In December 2018, it was supplied with new booster pumps. This station treats and supplies 15,000-16,000 m<sup>3</sup>/day. Its main source of water is a spring called Nabeh El Delleh and Ghawawit. The treatment process consists of chlorination, followed by decantation (three decanters), and finally filtration (eight filters). After that, water is stored in a reservoir and pumped via booster pumps to regional reservoirs (Mar Yaacoub, Kfarhelda, and Beit Chelala).

EDL is available 24/7 through a direct medium-voltage line. As such, there are two backup diesel generators (500 kVA each) but are rarely used.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
625	2016: 1,698,028.57  2017: 1,899,307.14  2018: No Bills	2016: 237,724,000  2017: 265,903,000  2018: No Bills	24h	Medium Voltage line	2 Diesel generators (each 500 kVA) 2016: 94,900 L OR 313,170 kWh 2017: 69,500 L OR 229,350 kWh 2018: 19,000 L OR 62,700 kWh	2016: 61,839,000  2017: 51,535,500  2018: 18,001,500	2016: 299,563,000  2017: 317,438,500  2018: 18,001,500	2016: 2,011,198.57  2017: 2,128,657.14  2018: 62,700	2016: 0.367  2017: 0.389  2018: NA	2016: 0.036  2017: 0.039  2018: NA

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Filters (x2)	Backwash pumps	2x15	-	-	-
Mar Yaacoub 1	Booster	250	480	90	0.579
Mar Yaacoub 2	Booster	250	543	79.2	0.581
Mar Yaacoub 3	Booster	250	480	90	0.579
Kfarhelda	Booster	41	150	36	0.759
Beit Chelala	Booster	30	150	36	0.556
Deir Bella 1	Booster	111.855	450	54	0.489
Deir Bella 2	Booster	149.14	450	65	0.510
All pumps					0.562

## Al Oyoun

Figure 64. Al Oyoun water pumping station



### Location

Halba

### Areas serviced

Serves around 42 villages, among them: Rahbeh, Mechmech, Bzal, Cheikh Taba, Bebnine, Hrar, and Ain Taba.

### Date audited

30/07/2019

### Description

This station includes four wells that were drilled in the year 2000, and became fully operational in 2008. Usually two wells operate together, and water is pumped to three elevated reservoirs. Each reservoir is located at an elevation of 250 m and has a volume of 3500 m<sup>3</sup>. All pumps are equipped with an autotransformer starter.

EDL is available 24/7, but electricity problems occur either due to sudden cut-offs or to voltage instability, especially in winter. A back-up diesel generator with a capacity of 1,500 kVA is used in such cases.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
834.04	2016: 2,480,850	2016: 347,319,000	24h	Medium Voltage line (6,000 V)	1 diesel generator (1,500 kVA)	2016: 18,400,500	2016: 365,719,500	2016: 2,566,650	2016: 0.351	2016: 0.033
	2017: 2,923,957.14	2017: 409,354,000			2016: 26,000L OR 85,800 kWh	2017: 13,275,000	2017: 422,629,000	2017: 2,981,707.14	2017: 0.408	2017: 0.039
	2018: -	2018: No bills			2017: 17,500L OR 57,750 kWh	2018: 9,642,000	2018: 9,642,000	2018: 31,350	2018: -	2018: -
					2018: 9,500L OR 31,350 kWh					

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well 1	Submersible booster	111.855	110	252.625	0.403
Well 2	Submersible booster	93.21	110	245.583	0.345
Well 3	Submersible booster	111.855	110	-	-
Well 4	Submersible booster	93.21	110	335.83	0.252
All pumps					0.325

## Ain Yaacoub

Figure 65. Ain Yaacoub Water Pumping Station



### **Location**

Halba

### **Areas serviced**

Serves around eight villages in the Halba area.

### **Date audited**

30/07/2019

### **Description**

This station has two wells that supply water to two reservoirs; each has a capacity of 2500 m<sup>3</sup>. Both pumps are equipped with an autotransformer starter. Water is supplied to each village for four hours every two days.

EDL is not available all the time (10-12 h/day). As such, pumps are operated only during these hours. There is a back-up generator onsite with a capacity of 1,000 kVA, but it is only used in emergencies.

Total Flow (m <sup>3</sup> /h)	EDL Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost (LBP)	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
211	2016: 832,927.54	2016: 114,943,950	10-12 h/day	Medium Voltage	1 diesel generator (1,000 kVA)	2016: 52,375,000	2016: 167,319,450	2016: 1,081,728.21	2016: 0.585	2016: 0.06
	2017: 1,809,898.55	2017: 134,821,950			2017: 37,332,500	2017: 172,153,950	2017: 1,126,693.93	2017: 0.610	2017: 0.062	
	2018: -	2018: -			2016: 79,000L OR 260,700 kWh	2018: 31,660,500	2018: 31,660,500	2018: 107,250	2018: -	2018: 0.011
					2017: 49,600L OR 163,680 kWh					
					2018: 32,500L OR 107,250 kWh					

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well 1	Submersible booster	134.226	242	96	0.578
Well 2	Submersible booster	149.14	242	115	0.536
All pumps					0.555

## Al Kadi

Figure 66. Al Kadi spring water pumping station



### Location

Zgharta

### Areas serviced

This station serves the Zgharta area via two main lines:

- Zgharta and Kfarhatta
- Ardeh, Rachiine, and Meryata

### Date audited

30/07/2019

### Description

This station was built around 70 years ago, and was recently rehabilitated. Every day, one service line is directly supplied with water 15 hours/day, at a flow rate of 4000 L/sec (14,400 m<sup>3</sup>/h). There are five pumps onsite, however only three pumps operate, while the other two remain on standby. All pumps are equipped with a soft-starter.

There is a backup diesel generator onsite, with a capacity of 600 kVA, but it is not used as EDL is available 24/7.

Moreover, in dry seasons, this station sometimes receives water from Al Kadi spring station.

Total Flow (m <sup>3</sup> /h)	Station kWh Consumption	Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	Total Energy Cost (LBP)	Total kWh Consumption	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
14,400	2016: 920,835.71	2016: 128,917,000	24h	Medium voltage line	1 Diesel generator (600 kVA)	-	2016: 128,917,000	2016: 920,835.71	2016: 0.007	2016: 0.001
	2017: 880,707.14	2017: 123,299,000					2017: 123,299,000	2017: 880,707.14	2017: 0.007	2017: 0.001
	2018: -	2018: -					2018: -	2018: -	2018: -	2018: -

\* No data available on pump specifications.

## South Lebanon Water Establishment

### Arabi

Figure 67. Arabi water pumping station



#### Location

Saida

#### Areas Serviced

Fouar reservoir

#### Date Audited

05/08/2019

#### Description

This station is a lifting station that draws water from four wells directly to a reservoir (Fouar) via submersible booster pumps. The station has five wells, but one is not operating. EDL is not available 24/7. As such, two diesel backup generators (each 500 kVA) are available, and used to cover power cuts. However, in such cases, only three wells can be operated. All pumps are equipped with an autotransformer starter.

Total Flow (m <sup>3</sup> /h)	2018 EDL Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Total kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
791.67	3,254,514.3	455,632,000	12 hours/day	Medium Voltage	2*500 kVA Generators consuming 106,000 Liters OR: 349,800 kWh	3,604,314.3	93,810,000	1.058	0.053

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well #1 (Non-Operational)	Submersible booster	-	-	-	-
Well #2	Submersible booster	94	-	179	-
Well #3	Submersible booster	135	140	240	0.402
Well #4	Submersible booster	306	113.5	310	0.507
Well #5	Submersible booster	94	140	164	0.440
All pumps					0.583

## Fouar

Figure 68. Fouar water pumping station



### Location

Saida

### Areas Served

Saida area

### Date Audited

05/08/2019

### Description

This is a pumping station that supplies water to all Saida area. The station's main source of water includes five wells inside the station, a well outside the station, and the Kfarwa spring. Water is pumped to an onsite reservoir (Fouar reservoir) with a volume of 5000 m<sup>3</sup> at a rate of 19,000 m<sup>3</sup>/day. Water is then treated by filtration, flocculation, and chlorination, before being supplied to the network.

EDL is available 24/7. A diesel backup generator with a capacity of 500 kVA is available for sudden power blackouts, but is rarely used. When used, it can power three out of the five pumps available.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
791.67	3,496,271.4	489,478,000	24h	Medium voltage line	-	-	0.504	0.047

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well #1	Submersible	135	110	145	0.846
Well #2	Submersible	68	110	135	0.458
Well #3	Submersible	75	110	281	0.243
Well #4	Submersible	75	110	100	0.682
Well #5	Submersible	75	110	40	1.705
Well #6 (Non-Operational)	Submersible	-	-	-	-
Well #7	Submersible	68	159	130	0.329
Filtration (x2)	Backwash pumps	22.371	-	Negligible	Negligible
All pumps					0.507

## Teffahta

Figure 69. Teffahta water pumping station



### Location

Zahrani

### Areas Serviced

Qaaqaiyat Al Jisr, Babliah, Baysariyeh, Sarafand Aadloun, Kawthariyyet El Siyyed, Khartoum, Ghassaniyyeh, and Sharkieh.

### Date Audited

05/08/2019

### Description

This pumping station dates since the year 2000, and includes eight submersible wells, supplying water to more than 30 villages. Water is pumped to a 1000 m<sup>3</sup> reservoir; it is then treated by gas chlorination, and finally distributed to the villages. Not all villages could be supplied by gravity, for this reason, three booster pumps are used to supply water at the required head and flow rate.

EDL is available 24/7 and could run all eight submersibles together. However, sometimes voltage problems are faced, and two diesel generators (each with a capacity of 1,500 kVA) are used for backup. But in such cases, only three pumps are operated together.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
645.83	16,718,207.1	2,340,549,000	24h	Medium	-	-	2.96	0.275

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well #1	Submersible	149	410	82	0.443
Well #2	Submersible	238.6	400	137	0.435
Well #3	Submersible	149	405	86	0.428
Well #4	Submersible	149	405	83	0.443
Well #5	Submersible	149	370	85	0.474
Well #6	Submersible	149	400	89	0.419
Well #7	Submersible	149	400	88	0.423
Well #8	Submersible	60	428	28	0.501
Boosters (x3)	Booster pump	238.6	NA	583.2	-
All pumps					0.440

## Fakhreddine

Figure 70. Fakhreddine Water Pumping Station



### Location

Nabatiyeh

### Areas Serviced

Rujum, Kfar Jaouz, Choukine, Mayfadoun, and Doueir.

### Date Audited

05/08/2019

### Description

Built in 1994, this station receives water from eight wells. Water is pumped to an onsite reservoir, with a capacity of 200 m<sup>3</sup>. Water is then pumped to two other reservoirs in the region, which supply water to the villages by gravity. This station includes eight submersible pumps, four horizontal booster pumps, and five vertical submersible booster pumps. However, when operated to maximum capacity, two submersible pumps are operated along with four horizontal booster pumps. Two pumps are equipped with a VFD, and the rest are equipped with an autotransformer starter.

EDL is available 24/7, and there is no backup diesel generator onsite.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
563 (Summer)	4,195,242.9	587,334,000	24h	Medium	-	-	0.85	0.08
375 (Spring)							1.28	0.12

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Well #1 (inside the station)	Submersible	74.57	400	40	0.466
Well #2 (inside the station)	Submersible	74.57	400	45	0.414
Well #3 (outside the station)	Submersible	93.2125	372	81	0.309
Well #4 (outside the station)	Submersible	149.14	384	104	0.373
Well #5 (outside the station)	Submersible	111.855	-	90	0.317
Well #6 (outside the station)	Submersible	93.2125	372	79	0.856
Well #7 (outside the station)	Submersible	134.226	296	53	0.976
Well #8 (outside the station)	Submersible	149.14	294	52	0.466
Horizontal pump to Rujum Reservoir	Booster	74.57	200	64.8	0.575
Horizontal pump to Rujum Reservoir	Booster	74.57	200	100.8	0.370
Horizontal pump to Rujum Reservoir	Booster	149.14	200	190.8	0.391
Horizontal pump to Rujum Reservoir	Booster	161.82	200	190.8	0.424
Vertical pump to Rujum Reservoir	Submersible Booster	111.855	200	201.6	0.277
Vertical pump to Rujum Reservoir	Submersible Booster	93.21	200	NA	-
Vertical pump to Rujum Reservoir	Submersible Booster	111.855	200	201.6	0.227
Vertical pump to Rujum Reservoir	Submersible Booster	111.855	200	201.6	0.227
Vertical pump to Rujum Reservoir	Submersible Booster	111.855	200	201.6	0.227
Vertical pump to Rujum Reservoir	Submersible Booster	134.23	200	NA	-
Vertical pump to Rujum Reservoir	Submersible Booster	74.57	200	NA	-
All pumps					0.385

## El Buss

Figure 71. El Buss water pumping station



### Location

Tyre

### Areas serviced

This station serves the coastal line of the Tyre area.

### Date audited

06/08/2019

### Description

Built in 2001, this treatment plant receives its water via three main lines, two by pumping and the third by gravity. It treats and supplies around 9,000 m<sup>3</sup> of water on a daily basis. Water goes through a full treatment process, then it is stored in an underground reservoir before it is sent to the network. The treatment process includes repartition, decantation (two units), filtration (eight sand filters), and finally chlorination. Two out of three booster pumps are usually operated together for water supply.

EDL is available 24/7, but sometimes electricity problems occur, such as voltage instability. Two backup diesel generators (500 kVA and 250 kVA) are used in such cases.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
375	1,737,685.7	243,276,000	24h	Medium Voltage line	-	-	0.53	0.05

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Supply	Booster	133.5	125	375	0.285
Supply	Booster	133.5	125	250	0.427
Supply	Booster	133.5	125	150	0.712
Filters	Backwashing	11.186	-	298.8	-
Filters	Backwashing	11.186	-	313.2	-
All pumps					0.413

## Ras El Ain

Figure 72. Ras El Ain Water Treatment Station



### Location

Tyre

### Areas Serviced

Various villages in Sour caza (Seddikin, Hanawai, Mansouri, etc.).

### Date audited

06/08/2019

### Description

This station receives its water from Ras El Ain spring. It treats and supplies 18,000 m<sup>3</sup> on a daily basis. Water is treated and then supplied to different areas. The treatment process includes decantation (two decanters), filtration (eight filters), and finally chlorination. Three pumps are equipped with VFDs, and the rest are equipped with a star-delta starter.

EDL is available 24/7. In cases of electricity problems, two backup diesel generators are used, each with a capacity of 1,050 kVA.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 EDL Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
750	6,280,621.4	879,287,000	24h	Medium Voltage line	-	-	0.96	0.09

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Buss 1	Booster	52.2	40	190.8	0.684
Buss 2	Booster	52.2	40	190.8	0.684
Seddikin 1	Booster	170	400	90	0.472
Seddikin 2	Booster	170	400	90	0.472
Seddikin 3	Booster	300	225	180	0.741
Seddikin 4	Booster	335	225	180	0.827
Seddikin 5	Booster	170	400	90	0.472
Seddikin 6	Booster	170	400	90	0.472
Hanawai 1+1'	Booster	149.14	290	298.8	0.172
Hanawai 2+2'	Booster	149.14	290	298.8	0.172
Mansouri 1	Booster	160	350	90	0.508
Mansouri 2	Booster	160	350	90	0.508
Mansouri 3	Booster	160	350	90	0.508
Network Collector 1	Filtration	75	40	450	0.417
Network Collector 2	Filtration	75	40	450	0.417
Network Collector 3	Filtration	18.5	20	378	0.245
Filters	Backwash	11.186	-	102	0.109
Filters	Backwash	11.186	-	102	0.109
All pumps					0.429

## Wadi Jilo

Figure 73. Wadi Jilo water pumping station



### Location

Tyre

### Areas serviced

Several villages are supplied via two main lines, Aytate and Chahabiyye: Chehabiyyeh, Bazouriyeh, Jabal Hanin, Yanouh, Wadi Jilo, and Aytate.

### Date audited

06/08/2019

### Description

Built in 1990, this station has five wells and supplies 16,000 to 17,000 m<sup>3</sup> of water on a daily basis. The Aytate line is supplied directly via two booster pumps. As for the Chehabiyyi line, water is sent to an elevated reservoir and supplies five villages as well. These pumps are equipped with soft-starters, as for the rest, they are equipped with a star-delta starter.

EDL is available 24/7. If electricity problems occur, two backup diesel generators, each with a capacity of 700 kVA, are used.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators Supply	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
666.67708.33	15,532,264.3	2,174,517,000	24h	Medium Voltage line	-	-	2.5	0.233

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Aytate B1	Booster	200	180	250	0.444
Aytate B1	Booster	200	180	250	0.444
Chahabiyye B1	Booster	250	395	105	0.603
Chahabiyye B2	Booster	156.5	395	126	0.314
Chahabiyye B3	Booster	162.5	395	126	0.327
Chahabiyye B4	Booster	200	395	126	0.402
Chahabiyye B5	Booster	200	395	126	0.402
Chahabiyye B6	Booster	200	395	126	0.402
Chahabiyye B7	Booster	200	395	126	0.402
Chahabiyye B8	Booster	200	395	126	0.402
Chahabiyye SB1	Submersible Booster	170	350	230	0.211
Chahabiyye SB2	Submersible Booster	170	350	230	0.211
Chahabiyye SB3	Submersible Booster	170	350	230	0.211
Chahabiyye SB4	Submersible Booster	170	350	230	0.211
Well (F1)	Submersible	110	123	144	0.621
Well (F2)	Submersible	75	123	144	0.423
Well (F3) Not operational	Submersible	92	-	-	-
Well (F4)	Submersible	130	150	288	0.301
Well (F5)	Submersible	92	140	216	0.304
All pumps					0.336

## Yanouh

Figure 74. Yanouh water pumping station



### Location

Tyre

### Areas serviced

Several villages via two main lines, Maarakeh and Wadi Jilo.

### Date audited

06/08/2019

### Description

This station is formed by five wells and supplies around 10,000 m<sup>3</sup>/day. It serves several villages via booster pumps through two main supply lines, Maarakeh and Wadi Jilo. This station includes five submersible pumps and six booster pumps. Usually, two wells and three booster pumps are operated together. All pumps are equipped with an autotransformer starter.

EDL is available 24/7. As such, no backup diesel generators are used at the station.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators Supply	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
416.67	405,171.43	56,724,000	24h	Medium Voltage line	-	-	0.11	0.01

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Well 1	Submersible	200	174	180	0.639
Well 2	Submersible	190	150	220	0.576
Well 3	Submersible	190	187	300	0.339
Well 4	Submersible	210	206	130	0.784
Well 5	Submersible	210	198	300	0.354
Maarakeh (x4)	Boosters	200	250	185	0.432
Wadi Jilo	Booster 1	132	40	430	0.767
Wadi Jilo	Booster 2	132	40	505	0.653
All pumps					0.481

## Marj El Khookh

Figure 75. Marj El Khookh water pumping station



### Location

Marjayoun

### Areas serviced

Qlaiya, Marjayoun, and Khiam.

### Date audited

07/08/2019

### Description

This lifting station has three wells, each equipped with a submersible pump. Water is drawn to an onsite reservoir with a capacity of 800 m<sup>3</sup>. Water is treated by gas chlorination at the station. After that, water is pumped via submersible booster pumps to three elevated reservoirs at Qlaiya, Marjayoun, and Khiam, which then supplies water to nearby villages by gravity. All pumps are equipped with an autotransformer starter.

EDL is not available all time, and there is a backup diesel generator on site. However, the available transformer on site has limited capacity. As a result, the maximum operation capacity of the station is one submersible well pump alongside two submersible booster pumps.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators Supply	2018 Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
300	1,971,035.7	275,945,000	16h	Medium Voltage line	NA	NA	0.75	0.07

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/ m <sup>3</sup> /100m)
Well 1	Submersible	93.21	-	200	-
Well 2	Submersible	93.21	-	210	-
Well 3	Submersible	93.21	-	198	-
Qlaiya (x2)	Submersible Booster	111.855	150	250	0.298
Khiam (x2)	Submersible Booster	111.855	150	250	0.298
Marjayoun(x2)	Submersible Booster	134.226	180	250	0.298
All pumps					0.298

## Taybeh

Figure 76. Taybeh water treatment station



### Location

Bent Jbeil

### Areas Serviced

Al Taybeh, Al Oudayssi, Robb Tlatine, Deir Seryane, Adcheet Al Kassir, Houla, Meiss Al Jabal, Bleeda, Mhaybeeb, Bani Hayyane, Markaba, Kabrikha, Touline, Majdal Selem, Chakra, Baraacheet, Aynata, Aytaroune, Maroune Al Rass, Beit Yahoune, Kawneene, part of Bent Jbeil, Al Kantara, Kfarkila, Almane, Al Sawwaneh, and Talloussa.

### Date audited

07/08/2019

### Description

This treatment plant receives its water from the Taybeh river. Water treatment stages include pre-Ozonation, flocculation, decantation (four decanters), and finally filtration (eight filters). In seasons when water has a high turbidity, this station does not operate.

EDL is available 24/7. However, a backup diesel generator is available. This station's electricity bill combines both the treatment plant as well as the pumping station.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	Diesel Generators Supply	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
491.67	12,622,921.4	1,767,209,000	24h	Medium Voltage line	-	-	2.93	0.27

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Filter (x2)	Backwash	29.828	-	-	-
Filter Air compressor (x2)	Backwash	101	-	-	-

## Taybeh River

Figure 77. Taybeh River pumping station



### Location

Bent Jbeil

### Areas serviced

This station supplies water to the Taybeh water treatment plant.

### Date audited

07/08/2019

### Description

This lifting station draws water from the Taybeh river and supplies it to the Taybeh water treatment plant. The station does not operate in winter due to high water turbidity (December-February). This station has three sets of pumps; one is operational while the other two are being upgraded. Operational pumps are equipped with a direct online starter.

EDL is available 24/7. There is a backup diesel generator. However, it cannot be used in cases of sudden electricity cuts due to its limited capacity.

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Set 1 (A)	Submersible booster	447.42	540	370	0.224
Set 2 (B)	Submersible booster	447.42	540	370	0.224
Set 3 (C)	Submersible booster	447.42	540	370	0.224
Set 3 (D)	Submersible booster	447.42	540	370	0.224
All pumps					0.224

## Maroun Al Ras

Figure 78. Maroun Al Ras station



### Location

Marjayoun

### Areas serviced

Maroun Al Ras

### Date audited

07/08/2019

### Description

This station receives water from Al-Taybeh lifting station, and is equipped with two pumps (one operational, while the other remain on standby). Water is then pumped to an elevated reservoir, which then supplies water to Maroun Al Ras via gravity. The station operation mainly depends on the supply from Al-Taybeh lifting station (mainly three times/week; 20 hours/day).

EDL is not available all the time (maximum 12 hours per day). Also, electricity problems occur, such as voltage problems and sudden cuts. In these cases, a backup diesel generator with a capacity of 105 kVA is used.

Total Flow (m <sup>3</sup> /h)	2018 Station kWh Consumption	2018 Station Electricity Bill (LBP)	EDL Supply	Transmission Line Voltage	2018 Diesel Generators kWh Consumption	2018 Total kWh Consumption	Diesel Fuel Cost	kWh/m <sup>3</sup> Indicator	\$/m <sup>3</sup> Indicator
35	46,757.14	6,546,000	12 hours/day	Medium voltage line	105 kVA Generator consuming 6,000 Liters OR: 19,800 kWh	66,557.14	5,310,000	0.217	0.025

Pump	Source/Type	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping Energy (kwh/m <sup>3</sup> /100m)
Maroun Al Ras	Booster	52.2	200	25	1.044
Maroun Al Ras (standby)	Booster	41	200	33	0.621
All pumps					0.803

# Appendix C

## Walk-Through Energy Audits (Wastewater Facilities/ Treatment plants)<sup>22</sup>

### Bekaa Wastewater Establishment

#### Zahle

Figure 79. Zahle wastewater treatment plant



#### Location

Zahle

#### Areas serviced

Zahleh

#### Date Audited

27/05/2019

#### Description

Zahle WWTP became operational in 2018, treating wastewater through returned activated sludge process and UV treatment. The installed capacity of the plant is 37,300 m<sup>3</sup>/day. It collects combined sewage (residential and industrial) and storm-water from seven villages by gravity, with the exception of the village of Saadnayel, where a lift station is installed. Aeration consumes over 26% of overall energy-consumption, which is the highest at the plant. The

<sup>22</sup> Note: the status "NA" shown in some fields of the results section below indicate that information/data could not be acquired from the establishments, and thus the analysis could not be completed.

plant has two lines of operations, but is only operating on one. It receives 24,000 m<sup>3</sup>/day in the winter, and 17,000 m<sup>3</sup>/day in the summer. The flow has gradually increased over the years as connections to the plant have increased.

Blowers are operational for around seven hours/day with VFDs installed. Sludge is thickened, digested, dewatered, and finally sundried and left onsite. Around 70 tons of sludge are generated every month.

EDL is available around the clock through a medium-voltage line. In case of cut-offs (around six hours per week), two diesel generators (1,400kVA and 1,800 kVA) are used.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDZ Bills (LBP/year)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost	Total Station Consumption (kWh/year)
19,000	205000	419,355,160 (Unbilled)	2,995,394	24h	1 x 1,400 kVA 1 x 1,800 kVA Used only on emergency and are turned on for testing.  1,124 L/month 3,709.2 kWh/month	NA	2,995,394 (including Solar PV)

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
3170406.977	6169390.244	17.65	0.4319	0.9448	0.4855

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blowers	3	Centrifugal Compressors	560	24,000	-
Pumps	4	Submersible centrifugal pumps	50	1317	9

## laat

Figure 80. laat wastewater treatment plant



### Location

Baalback-Hermel

### Areas serviced

Baalback, Douris, Ansar, Jemariyyeh, and Ain Bourday.

### Date Audited

03/10/2019

### Description

Constructed in 2000, this wastewater treatment plant started operating in 2007. This treatment plant is currently operating at its maximum capacity of 12,000 m<sup>3</sup>/day. It receives combined sewage (residential and industrial) and storm-water, and serves a population of around 100,000 persons. There are daily as well as seasonal flow fluctuations, where the flow reaches in winter a maximum value of 30,000 m<sup>3</sup>/day. The treatment level is tertiary via chlorination and does not include N-P removal. Blowers are operational around the clock, and are not VFD driven nor do they operate based on DO sensor. No VFD or soft-starters are installed on RAS and WAS pumps.

Sludge is thickened, digested, dewatered and finally sun dried and left onsite. Around 400 Tons of sludge are generated every month.

EDL is available around 18 hours/day. There are two diesel generators on site. The first has a capacity of 250 kVA and is no longer operational (overused), while the second DG has a capacity of 500 kVA and is currently being used.

The plant is under ongoing rehabilitation and there are plans for future capacity expansion.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDZ Bills (LBP/year)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost	Total Station Consumption (kWh/year)
11142	99482	2016: 136,029,455	2016: 971,638.96	18	1 x 500 kVA 117,828 L/year	NA	2016: 1,360,471.36
		2017: 116,460,727	2017: 831,862.33		2019: 388,832.4 kWh/year		2017: 1,220,694.736
		2018: 139,905,225	2018: 999,323.036				2018: 1,388,155.436

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
2044968.494	3754710.068	13.3542	0.3266	0.6496	0.3538

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)
Blower	3	Diffuser	90	3595
Blower	1	Aerobic digestion	30	NA
Pump	3	RAS	11	NA
Pump	2	WAS	3.4	NA

## Yammouneh

Figure 81. Yammouneh wastewater treatment plant



### Location

Baalback-Hermel

### Areas serviced

Yammouneh

### Date Audited

03/10/2019

### Description

Built in 2002, this treatment plant serves the village of Yammouneh but has been put on standby for rehabilitation. "New Lebanon", constructed by Al Bunyan company. BWE ensures operation, while "New Lebanon" carries out maintenance.

The plant is currently non-operational and no data was acquired or available for further analysis and investigation.

## Jeb Jannine

Figure 82. Jeb Jannine wastewater treatment plant



### Location

Western Bekaa

### Areas serviced

Lala, Jeb Jannine, Kamed El Lawz, Sultan Yaacoub, Kherbet Kanafar, Kefrayya, Ain Zebde, Mansoura, Aana, Tal Zhub, Deir Tahnish, Ghazze, Hawsh El Harimi, and Khiara.

### Date Audited

04/10/2019

### Description

Built in 2007, this treatment plant serves 15 villages in the Western Bekaa area. It has a capacity of 15,000 m<sup>3</sup>/day, and currently it receives around 10,000 m<sup>3</sup>/day. It receives combined sewage (residential and industrial) and storm-water, and serves a population of around 90,000 persons. There are daily as well as seasonal fluctuations in influent flow and characteristics (BOD, COD, TSS, and pH). The treatment level is tertiary via chlorination, and includes N and P removal. A2O (Anaerobic, Anoxic, and Oxidative) wastewater treatment process is adopted. Blowers are operational around the clock and are not VFD driven nor do they operate based on DO sensor. No VFD or soft-starters are installed on RAS and WAS pumps. However, all pumps and blowers are equipped with an autotransformer starter.

Sludge is thickened, digested, dewatered, and finally sundried and left onsite.

EDL is available around 22 hours/day. There are two diesel generators onsite (each 450 kVA) and operate approximately 674 hours/month. Also, diesel generators are used at eight surrounding pumping stations, which pump pump-sewage to the plant.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDZ Bills (LBP/year)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost	Total Station Consumption (kWh/year)
6500	58036	2016: 270,202,818  2017: 226,217,091  2018: 249,912,955	2016: 1,930,020.13  2017: 1,615,836.36  2018: 1,785,092.54	22	1 x 500 kVA  2019: 7,082 L/month (for Jeb Jennine and pumping stations)  Or 280,447.2 kWh/year	NA	2016: 2,210,467.33  2017: 1,896,283.56  2018: 2,065,539.74

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
1228645.472	2424830.571	35.5182	0.8688	1.6777	0.8500

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blower	4	Diffuser/Aerobic Tank	90	3792	-
Blower	3	Aerobic digestion	90	3213	-
Pump	3	RAS	14	820	92
Pump	2	WAS	2.6	80	35
Pump	2	Scum	1.22	10	12.3
Pump	4	Recycle	13.9	569	6.28
Pump	3	Lift	45	500	18.5
Compressors	2	Dewatering			
Mixers	4	Anaerobic	2.8	-	-
Mixers	12	Anoxic	2.8	-	-
Mixers	2	Mixed Liquor sumps	2.5	-	-
Pump	8	Flow boosters in aeration Tank	4	-	-

## Saghbine

Figure 83. Saghbine wastewater treatment plant



### Location

Western Bekaa

### Areas serviced

Saghbine

### Date Audited

04/10/2019

### Description

This treatment plant serves the village of Saghbine. It has a capacity of 520 m<sup>3</sup>/day, and currently it is receiving around 400-500 m<sup>3</sup>/day. It receives combined sewage (residential) and storm-water, and serves a population of around 90,000 persons. The treatment level is tertiary via chlorination, and includes N and P removal. A2O (Anaerobic, Anoxic, and Oxic) wastewater treatment process is adopted. Blowers are operational around the clock, and are not VFD driven nor do they operate based on DO sensor. No VFD or soft-starters are installed on RAS and WAS pumps. However, all pumps and blowers are equipped with an autotransformer starter.

Sludge is digested, dewatered, and finally sundried and left onsite. EDL is available around 22 hours/day. There is one diesel generator on site (70 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDZ Bills (LBP/year)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost	Total Station Consumption (kWh/year)
300	2679	2016: 3,284,455  2017: 21,503,636  2018: 25,148,288	2016: 23,460.4  2017: 175,025.97  2018: 179,630.63	22	1 x 500 kVA  2019: 100 L/month  Or 3,960 kWh/year	NA	2016: 27,420.4  2017: 178,985.97  2018: 183,590.63

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
57656.3319	112877.6901	45.8853	1.1224	2.1317	1.0888

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blower	3	Diffuser/Aerobic Tank	30		
Blower	2	Aerobic digestion	11		
Pump	3	RAS	1.95	25	8.12
Pump	2	WAS	1.3	10.4	6.47
Pump	4	Recycle	1.95	50.2	4.38
Pump	2	Lift	3	26	11.7
Pump	2	Scum	1.7	2.8	12.3

## Ablah

Figure 84. Ablah wastewater treatment plant



### Location

Bekaa, Zahle.

### Date audited

30/10/2019

### Description

Built in 2012, this station treats residential wastewater from the following villages: Niha, Nabi Ayla, and Ablah. It has a maximum capacity of 2000 m<sup>3</sup>/day, while it currently receives an average of 1200 m<sup>3</sup>/day. The process used for biological treatment is the trickling filter. The treatment process is as follows: stabilization tank, coarse screening, fine screening, primary clarifier (x3), trickling filter pumping station, trickling filter (x2), final clarifier (x3), and finally chlorine channel. Sludge is pumped from the primary and secondary clarifiers to the anaerobic digester. After digestion, the sludge is pumped to a drying bed. Note that sometimes secondary sludge is sent by gravity to the stabilization tank, where it settles in the primary clarifier, and sent to the digester using the primary clarifier pumps. This is usually done to save energy and operation-cost by using less of the secondary clarifier pumps. Soon, a composting process will be adopted, where sludge will be then mixed with crushed grape-vine twigs, and then fermented. Around 63 m<sup>3</sup> of sludge are produced every year.

A PV project was proposed for this treatment plant, but it was cancelled later on. Moreover, an artificial lake was built near the treatment plant, and was intended to supply irrigation water to farmers. However, this is also currently on hold due to a lawsuit with a landowner near the lake.

EDZ is available 24/7. There is a backup diesel generator onsite with a capacity of 100 kVA; however, it's not used.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators	Diesel Fuel Cost
1200	10714	48,000,000 LBP/year 342,857.14 kWh/year	24	100 kVA	0

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
223835.96	445260.082	32	0.782	1.531	0.770

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Pump	3	Submersible/Influent	5.6	65	9.4
Pump	2	Horizontal end suction/ Primary Clarifier	1.5	28.3	6.5
Pump	2	Submersible/Secondary Clarifier	3.35	13.9	9
Pump	4	Submersible/Trickling Filter pump station	11	187	10
Pump	8	Horizontal end suction/ Anaerobic digester (2/unit)	0.75	28.3	1.8
Ventilation Fans	4	Backward Inclined Centrifugal/Trickling filter	0.55	6918	-
Pump	1	Horizontal end suction/ Plant water	5.5	14.76	60
Pump	1	Submersible-grinder/ Septage receiving pump	3.7	36	7.9
Pump	1	Peristaltic Tube pump/ Chemical feed	0.147	Manual	-
Mixers	2	Anaerobic digester	2.5	-	-

## Ferzol

Figure 85. Ferzol wastewater treatment plant



### Location

Bekaa, Zahle.

### Date audited

30/10/2019

### Description

This station treats wastewater coming from the village of Ferzol. It has a maximum capacity of 1000 m<sup>3</sup>/day, while it currently receives an average of 1500 m<sup>3</sup>/day. There are future upgrading plans to increase the plant's capacity to 2263 m<sup>3</sup>/day, which is opposed by the operator because CDR is proposing to change the treatment process to CAS. The current process used for biological treatment is the trickling filter. The treatment process is as follows: stabilization tank, coarse screening, fine screening, primary clarifier (x2), trickling filter pumping station, trickling filter (x2), final clarifier (x2), and finally chlorine contact-basing. Sludge is pumped from the primary and secondary clarifiers to the anaerobic digester. After digestion, the sludge is pumped to a drying bed (six drying beds). Note that sometimes secondary sludge is sent by gravity to the stabilization tank, where it settles in the primary clarifier and sent to the digester using the primary clarifier pumps. This is usually done to save energy and operation-cost by using less of the secondary pumps. Soon, a composting process will be adopted, where sludge will then be mixed with crushed grape-vine twigs and then fermented.

EDZ is available 24/7. There is a backup diesel generator onsite with a capacity of 100 kVA; however, it's not used.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	Diesel Generators	Diesel Fuel Cost
1500	13400	NA	24	100 kVA	0

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
NA	NA	NA	NA	NA	NA

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Pump	3	Submersible/Influent	3	54	
Pump	3	Horizontal end suction/ Primary Clarifier	1.5	28.3	NA
Pump	1	Submersible/Secondary Clarifier	3.375	27.79	NA
Pump	1	Submersible/Secondary Clarifier	3.375	208.4	NA
Pump	4	Submersible/Trickling Filter pump station	12.75	108	NA
Pump	4	Horizontal end suction/ Anaerobic digester (2/unit)	1.5	28.3	NA
Pump	1	Submersible-grinder/ Septage receiving pump	3.68	0.2	NA
Ventilation Fans	4	Backward Inclined Centrifugal/Trickling filter	0.55	6918	-

## Beirut Mount Lebanon Wastewater Establishment

Hammana (managed by Hammana municipality and not BMLWE)

Figure 86. Hammana wastewater treatment plant



Figure 87. Hammana wastewater treatment plant



**Location**

Hammana, Baabda.

**Areas Serviced**

Hammana

**Date Audited**

09/06/2019

**Description**

Hammana WWTP was constructed in 1969. It was updated in 2001 to a Return Activated Sludge (RAS) process, and a second renovation in 2014 took place on the blowers. It receives 1,000 m<sup>3</sup>/day and serves Hammana village only (5,000 citizens). There is no mixing between the storm-water and wastewater.

The municipality pays all the expenses related to the plant, and a private company (TripleE) handles the O&M. EDL is not available around the clock, and prior to 2017, there was a 150 kVA diesel generator that was used as a backup, consuming between 4,000 to 6,000 liters in the summer, and over 10,000 liters per year operating mostly between April and November to an average cost of USD 16,436, used alongside EDL at around USD 5,440.

In 2017, UNDP, funded by the Kingdom of the Netherlands, installed a hybrid PV plant with a capacity of 45 kWp, and a battery bank with a capacity of 190 kWh, both helping to power the plant for around 10 hours per day (six hours/day with the PV system, and 4-5 h/day with the batteries), and then EDL current is used to charge the batteries again. In other words, the plant currently operated 38% of the time on EDL, 40% of the time on PV, 22% on batteries (14%PV +8% EDL), and without using the diesel generator.

In 2018, this hybrid system reduced the total energy cost/bills by USD 16,890, in addition to savings of around 65.25 MWh of the energy consumed as well as a reduction of the CO<sub>2</sub> emissions by 72.525 metric tons of CO<sub>2</sub> equivalent.

The main processes are: pre-treatment, primary treatment (sedimentation), biological treatment, sludge treatment (RAS, WAS), and sludge is either used for agriculture or sent outside.

Before Solar:

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	EDL Cost (LBP/year)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Total Station Energy Cost (LBP/year)
1000	5,000	120,450	12	8,160,000	One Diesel Generator on 150 kVA capacity	24,654,000	32,814,000

After Solar (45 kWp/yard of 1,450 kWh/kWp):

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	Station Consumption-EDL (kWh/year)	EDL Supply (hours)	EDL Cost (LBP/year)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Total Station Energy Cost (LBP/year)	Energy consumed through the solar system (kWh/year)	Energy consumed through EDL (kWh/year)
1000	5,000	120,450	12	7,479,000	One Diesel Generator on 150 kVA capacity NOT USED ANYMORE	-	7,479,000	65,250	55,200

Reduction in yearly energy consumption [MWh]	65.25
Yearly Cost Savings [\$]	16,890 [25,335,000 LBP]
Réduction in CO2 Emissions [tCO2-eq]	72.525

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
139,716.456	268,640	24.089	0.33	0.862	0.448

Equipment	Quantity	Type/Use	Power (kW)	Flow (m <sup>3</sup> /hour)
Blowers	2	Complete Roots blower KBAP 80 type	5.5	400 (at 3.1m (0.3bar pressure))
Blowers	2	Complete Roots blower KSS 125A type	11	1000 (at 250 mbar pressure)

## Kfarqatra

Figure 88. Kfarqatra wastewater treatment plant



### Location

Chouf

### Areas Serviced

Kfarqatra

### Date Audited

09/12/2019

### Description

Built in 2012, this treatment plant has a capacity of 500 m<sup>3</sup>/day, but it currently treats around 50 m<sup>3</sup>/day (combined collection system). A tertiary level treatment process is adopted. The biological treatment: two aeration tanks (extended aeration). The aeration blowers are manually operated and equipped with a soft-starter.

EDL is available 10-12 hours/day. A diesel backup generator is available onsite (60 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDZ Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost	Total Station Consumption (kWh/year)
50	333	2016: 6,268,000	2016: 44,771.43	10-12	1 x 60 kVA and a 2,000L reservoir	NA	2016: 6,268,000
		2017: 10,799,000	2017: 77,135.71				2017: 10,799,000
		2018: 12,121,000	2018: 86,578.57				2018: 12,121,000

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
21,230.833	32,914.793	208.486	3.808	3.273	2.111

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)
Pump	2	RAS/WAS	2	40
Pump	1	Dosing	1.5	3.47 L/hour
Blowers	2	Surface Aerators	7.5	-
Mixers	2	Aeration Tank	1.5	-
Clarifier Mixer	1	Clarifier	0.55	-
Flowmeter	1	-	0.05	-

## Mokhtara

Figure 89. Mokhtara wastewater treatment plant



### Location

Chouf

### Areas serviced

Mokhtara

### Date Audited

09/12/2019

### Description

This treatment plant was constructed in 2007 and began operation 2008. The Mokhtara treatment plant has a capacity of 450 m<sup>3</sup>/day, but it currently treats around 300 m<sup>3</sup>/day (split collection system). A tertiary level treatment process is adopted. The biological treatment includes a trickling filter followed by an aeration tank. The aeration blowers are manually operated and equipped with a soft-starter.

EDL is available 11 hours/day. A diesel backup generator is available onsite (57 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
350	2333	2016: 6,509,000  2017: 5,985,000  2018: 7,768,000	2016: 46,492.85  2017: 42,750  2018: 55,485.71	11	1 x 53 kVA Consuming 9,855 L/year OR 32,521.5 kWh/year	8,721,675	2016: 79,014.35  2017: 72,271.5  2018: 88,007.21

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
49,986.36	95,433.06	48.122	0.878	2.246	1.7659

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blower	2	Diffuser	11.18	275	-
Pump	1	RAS/WAS	4.1	35	18
Pump	2	Lifting	2.6	18	8
Pump	2	Chlorination	-	-	-
Motor	1	Trickling Filter	0.75	NA	NA

## Jbaa

Figure 90. Jbaa wastewater treatment plant



### Location

Chouf

### Areas Serviced

Jbaa

### Date Audited

09/12/2019

### Description

This treatment plant was constructed in 2007 and began operation 2008. The Jbaa treatment plant has a capacity of 300 m<sup>3</sup>/day, but it currently treats around 110 m<sup>3</sup>/day (split collection system). A tertiary level treatment process is adopted. The biological treatment includes a trickling filter followed by an aeration tank. The aeration blowers are manually operated and equipped with a soft-starter.

EDL is available 20 hours/day. A diesel backup generator is available onsite (65 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
110	733	2016: 7,640,000  2017: 7,153,000  2018: 6,986,000	2016: 54,571.428  2017: 51,092.857  2018: 49,900	20	1 x 57 kVA Consuming 5,900 L/year OR 19,470 kWh/year	5,221,500	2016: 74,041.428  2017: 70,562.857  2018: 69,370

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
15,790.40	30,329.658	97.265	1.776	4.517	2.3517

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blower	2	Diffuser	12.6	275	-
Pump	2	Lifting	4.1	35	18
Pump	1	RAS/WAS	2.6	18	8
Pump	2	Chlorination	0.372	-	-

## Mrosti

Figure 91. Mrosti wastewater treatment plant



### Location

Chouf

### Areas Serviced

Mrosti

### Date Audited

09/12/2019

### Description

This treatment plant was constructed in 2008 and began operation 2009. The Mrosti treatment plant has a capacity of 225 m<sup>3</sup>/day, but it currently treats around 90 m<sup>3</sup>/day (split collection system). A tertiary level treatment process is adopted. The biological treatment includes a trickling filter followed by an aeration tank. The aeration blowers are manually operated and equipped with a soft-starter.

EDL is available 20 hours/day. A diesel backup generator is available onsite (65 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
90	600	2016: 9,097,000  2017: 5,996,000  2018: 5,453,000	2016: 64,978.57  2017: 42,828.57  2018: 38,950	20	1 x 57 kVA Consuming 11,985 L/year OR 39,550.5 kWh/year	10,606,725	2016: 104,529.07  2017: 82379.07  2018: 78,500.5

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
12,560.294	22,891.263	147.449	2.693	7.0435	3.865

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Blower	2	Diffuser	12.6	275	-
Pump	2	Lifting	4.1	35	18
Pump	1	RAS/WAS	2.6	18	8
Pump	2	Chlorination	0.75	-	-

## Baadaran

Figure 92. Baadaran wastewater treatment plant



### Location

Chouf

### Areas Serviced

Baadaran

### Date Audited

14/01/2020

### Description

This treatment plant began operating in 2001, following a tertiary level treatment process. The plant's capacity is designed to reach 250 m<sup>3</sup>/day, but it currently treats 50 m<sup>3</sup>/day of municipal wastewater (combined collective system). The biological treatment system is extended aeration using two helicopters, followed by clarification, sludge decantation, and chlorination.

EDL is available for 12 hours on average. One 65 kVA diesel generator is available onsite. The plant is not equipped with any automation system.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
50	333	NA	NA	12	1 x 63 kVA Consuming 10,800 L/year OR 35,640 kWh/year	9,558,000	NA

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
-	-	7.63	0.122	-	-

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Pump	2	Lifting	4.1	40	18
Pump	1	RAS/WAS	2.6	18	8
Pump	1	Sludge	1.12	?	?
Pump	1	Chlorination	0.75	-	-
Pump	2	Filtering	1.4	-	-
Mixer	1	Clarifier	0.18	-	-
Mixer	2	Aeration Helicopter	5.5	-	-

## Khraybeh

Figure 93. Khraybeh wastewater treatment plant



### Location

Chouf

### Areas Served

Khraybeh

### Date Audited

14/01/2020

### Description

The plant has been operational since 2008, following a tertiary level treatment process. It has a capacity of 450 m<sup>3</sup>/day, but currently treats 100 m<sup>3</sup>/day of municipal wastewater (combined collection system). The technology adopted is activated sludge, using a trickling filter to reduce the BOD<sub>5</sub>. Aeration is achieved using two blowers and diffusers. Part of the sludge is held in a sludge holding tank, and returned for aeration after clarification. The method adopted for disinfection is chlorination.

EDL provides electricity for 12 hours a day. One diesel generator (72 kVA) is available onsite.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Station total Consumption (kWh/year)
100	667	2016: 6,785,000  2017: 11,359,000  2018: 7,673,000	2016: 48,464.285  2017: 81,135.71  2018: 54,807.14	12	1 x 72 kVA Consuming 3,000 L/year OR 9,900 kWh/year	2,655,000	2016: 58,364.285  2017: 91,035.71  2018: 64,707.14

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
4.9667	2.6336	107.0535	1.9553	14,369.4736	27,098.955

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Pump	2	Lifting	4.1	30	18
Pump	1	RAS/WAS	2.6	18	8
Pump	2	Filtration	7.5	NA	NA
Pump	2	Chlorination	0.7457	-	-
Air Blowers	2	Aeration Tanks	11.1855	NA	NA
Motor	1	Trickling filter	0.75	NA	NA

## Maaser El Chouf

Figure 94. Maaser El Chouf wastewater treatment plant



### Location

Chouf

### Areas Serviced

Maaser El Chouf

### Date Audited

14/01/2020

### Description

The plant began operating in 2007 and serves around 500 household units in the village of Maasser. Although designed to treat a maximum 450 m<sup>3</sup>/day, the plant's flow reaches 100 m<sup>3</sup>/day through a combined collection system. Maasser WWTP provides tertiary wastewater treatment using activated sludge as a biological process. A trickling filter is deployed to reduce BOD<sub>5</sub> before reaching the aeration tank. The process is followed by clarification. Part of the sludge is held in a sludge holding tank and returned for aeration. The treated water is disinfected via chlorination.

EDL provides electricity for 12 hours. One diesel generator (72 kVA) is used onsite for backup. Empty roofs and the land surrounding the plant could be leveraged for potential solar PV applications.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Station total Consumption (kWh/year)
100	667	2016: 8,360,000  2017: 10,527,000  2018: 9,681,000	2016: 59,714.28  2017: 75,192.85  2018: 69,150	12	1 x 72 kVA consuming 14,550 L/year OR 48,015 kWh/year	12,876,750	2016: 107,729.28  2017: 123,207.85  2018: 117,165

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
14,334.54	26,646.387	174.051	3.179	8.0947	4.3545

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Pump	2	Lifting	4.1	35	18
Pump	2	RAS/WAS	2.6	18	8
Pump	2	Filtration	7.5	NA	NA
Pump	2	Chlorination	0.74	-	-
Air Blower	1	Aeration tanks	11.185	NA	NA
Air Blower	1		12.6	NA	NA
Motor	1	Trickling Filter	0.75	NA	NA

## Ghadir

Figure 95. Ghadir wastewater treatment plant



### Location

Ghadir, Baabda.

### Areas serviced

Choueifat, Southern Beirut (Damour to Khalde), Qobbeh (Khaldeh hills), Southern Suburb, and Sabra (Eastern Beirut).

### Date Audited

28/11/2019

### Description

Being operational since 1997, this plant is for preliminary treatment only. It has a design capacity of 180,000 m<sup>3</sup>/day, while the actual volume of sewage treatment ranges between 80,000 m<sup>3</sup>/day (in summer) and 165,000 m<sup>3</sup>/day. It receives combined sewage (residential and industrial) and storm-water, and there are plans to build a new treatment plant performing primary, secondary, and tertiary treatment near this facility to the seaside.

EDL is available around the clock, and three generators (2 x 625 kVA and 1 x 250 kVA) are used as backup.

At the inlet, seven screw pumps lift the received water to the station, where coarse screening is performed. Then, water is sent to an aerated de-gritting tank, where heavy particles float and are removed. Pre-treated water is then discharged into the sea while waste is collected, dried, and disposed in the nearby landfill.

Preventive (mechanical and electrical) maintenance is performed continuously.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
68,638	457,587	2018: 214,164,720  2019: 259,323,120	2018: 1,529,748  2019: 1,852,308	24h	1*250 kVA 2*640 kVA Consuming 7,350 L/year OR 24,255 kWh/year	6,504,750	2018: 1,554,003  2019: 1,876,563

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
NA	2,413,470.199	4.1	0.0749	NA	0.777

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Screw Pumps	7	Lifting	29.89	1,150	9
Bar Screen Motors	5	Coarse Screening Area	1.1	-	-
Belt Motor	1	Coarse Screening Area	1.1	-	-
Screw Compactors	1	Coarse Screening Area	2.98	-	-
De-gritting motor	1	De-gritting Area	2.24	-	-
Pumps for sand removal	4	De-gritting Area	2.24	50	4
Classifier Motor	1	De-gritting Area	2.98		
Blowers	3	Air Blowers	18	960	4
Booster Pumps	3	To Sea Outfall	186.425	4950	10.5

## Lifting Stations

The following sites consist of lifting stations only. Therefore, the only relevant indicator is pump efficiency. Wastewater is either discharged into the sea, or in the case of Damour, Khalde, and Nehme are pumped to the Ghadir wastewater treatment plant.

### Damour

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
2016: 84,264.3	2016: 11,797,000	Medium (1,000 kVA)	400 kVA 1,500 L/year	1,327,500
2017: 90,557.1	2017: 12,678,000			
2018: 78,900	2018: 11,046,000			

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>3</sup>	100	40	60	1.66

### Khalde

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
2016: 676,421.4	2016: 94,699,000	Medium (630 kVA)	400 kVA 19,000 L/year	16,815,000
2017: 143,714.3	2017: 20,120,000			
2018: 167,435.7	2018: 23,441,000			

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>5</sup>	42	0	60	0.7

## Nehme

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
2016: 80,992.8	2016: 11,339,000	Medium (630 kVA)	400 kVA 7,500 L/year	6,637,500
2017: 87,892.8	2017: 12,305,000			
2018: 128,721.4	2018: 18,021,000			

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>5</sup>	42	NA	60	0.7

## Jiyyeh

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
0	No EDL	No EDL	21,400 L/year	18,939,000

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>2</sup>	20	28	70	0.28

## Burj Hamoud

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
NA	NA	Medium (430 kVA)	38,000 L/year	33,630,000

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>4</sup>	70	16	1,000	0.07

## Jounieh

Station kWh consumption	Station electricity bill (LBP/year)	Transmission line	Diesel generator consumption	Diesel Cost (LBP)
2016: N/A	2016: N/A	250 kVA	86,560 L/year	76,605,600
2017: 584,728.6	2017: 81,862,000			
2018: 1,488,864.3	2018: 208,441,000			

Pump	Power (kW)	Head (m)	Flow (m <sup>3</sup> /h)	Pumping energy (kWh/m <sup>3</sup> )
x <sup>3</sup>	130	40	700	0.18

# North Lebanon Wastewater Establishment

## Tripoli

Figure 96. Tripoli wastewater treatment plant



### Location

Tripoli, Northern Lebanon.

### Areas serviced

Balamand (via Nahr el Bared), Koura, Zgharta (in progress), Tripoli, and its suburbs til Naher El Bared camp.

### Date Audited

21/11/2019

### Description

Built in 2009, and originally designed for primary and secondary treatment as well as sludge incineration and biogas production, this WWTP began operating in 2014, fulfilling cocooning and pre-treatment only, due to continuous low influent and load factor. It is only operated for pre-treatment activities. The Tripoli WWTP serves the coastal areas from Nahr Edl Bared in the north to Balamand, including Tripoli and its suburbs. It has a design capacity of 135,000 m<sup>3</sup>/day, and the ability to serve around 1 million people, but is currently receiving 53,926 m<sup>3</sup>/day on average, and is serving 218,000 people. It receives combined sewage (residential and industrial) and storm-water. If operating normally, it includes primary and secondary treatment as well as sludge treatment: thickening, dewatering in centrifuge, incineration (where ash is disposed in bags).

Treated water is discharged one mile away into the sea. Preventive maintenance is performed continuously on all equipment as part of the cocooning contract, and all pumps are equipped with VFDs and monitored through SCADA Systems.

EDL is available 24/7 through a medium-voltage line; there are three backup diesel generators (1,600 kVA each) and three biogas boilers (1,300 kVA), each (not operational yet). Solar is a potential that should be explored, especially for tertiary use. Around 12 to 15 employees work at this plant.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
53,926	218,000	1,468,253.33	24h	3*1,600 kVA Consuming 3,059.652 L/year OR 9,701.7 kWh/year	2,707,804.976	1,477,955.03

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
4,760,478.072	10,116,015.9	6.873	0.0761	0.314	0.148

Equipment	Quantity	Power (kW)	Head (m)	Flow (m <sup>3</sup> /hour)
Inlet Pump	3+1	215	16.82	3107
Inlet Pump sup	1+1	50	16.82	600
Intermediate tube pump	3+1	75	7.3	3294
Treated Water Pump	3+1	80	7.7	3108
RAS	6+2	37	7.76	1240
WAS	4+2	5.9	6.35	225
Aeration Blowers 25100 Nm <sup>3</sup> /h	2	815	-	25100 Nm <sup>3</sup> /h
Aeration Blowers 12500 Nm <sup>3</sup> /h	1+1	429	-	12500 Nm <sup>3</sup> /h
Biogas compressors	3+1	55	-	660 Nm <sup>3</sup> /h
Odor removal Fans	2+1	19	-	28500 Nm <sup>3</sup> /h
Incinerator Cooling air on exchangers	2	75	-	52856 Nm <sup>3</sup> /h
Fan EXHAUSTER on INCINERATION UNIT	2	150	-	40600 Nm <sup>3</sup> /h
Centrifuge	2+1	150	-	1725 kg/h

## Chekka

Figure 97. Chekka Wastewater Treatment Plant



### Location

Chekka, Northern Lebanon.

### Areas serviced

Chekka, Bednayeel, Kefraya, Ras Nhach, Heri, and Anfeh.

### Date Audited

21/11/2019

### Description

This plant was rehabilitated in 2017, after being cocooned for a decade. It has a design capacity of 1,800 m<sup>3</sup>/day but is currently overloaded with an influent ranging around 2,563m<sup>3</sup>/day, on average. This overload is due to the fact that the plant is located in an industrial zone. It receives combined sewage (residential and industrial) and storm-water, and there is a plan to expand it in the future.

The process includes two lines of primary and secondary treatment as well as sludge treatment (thickening, dewatering in centrifuge), which is currently stored in bags (30% dryness) and kept at the station. Tertiary treatment (UV disinfection) is performed via a flow detector. Preventive maintenance is performed continuously on all equipment, and all pumps are equipped with VFDs and monitored through SCADA systems.

EDL is available 24/7 through a low-voltage line, and there is one backup generator (850 kVA capacity). Rooftops could be equipped with solar for tertiary use. Around seven employees work at this station.

Around 600 kg of sludge is generated per day of operation at this facility.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
2,563	36,000	1,168,526.88	24h	1*850 kVA Consuming 32,793.5 L/year OR 108,218.54 kWh/year	95,773,414.41	1,276,745.42

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
489,942.4849	985,156.1387	17.638	0.678	1.296	0.644

Equipment	Quantity	Power (kW)	Flow (m <sup>3</sup> /hour)	Head (m)
Inlet Pump	1+1	11	7	276
RAS	3	10	10.64	110
WAS	1+1	2.2	20	11 to 16
Aeration Blowers 2210 Nm <sup>3</sup> /h	2+1	90		2210 Nm <sup>3</sup> /h
Odor removal Fans	1+1	11		13500
Centrifuge	1+1	24		
UV Units	2	13.2		

## Selaata

Figure 98. Selaata wastewater treatment plant



### Location

Batroun, Northern Lebanon.

### Areas serviced

Batroun, Selaata, Kouba, Hamat, Wajh El Hajar, Abrine, Kfaraabida, and Jdabra.

### Date Audited

21/11/2019

### Description

Located on the coastal village of Selaata, this plant has a design capacity of 3,200 m<sup>3</sup>/day, but is currently receiving around 2,000 m<sup>3</sup>/day. The influent arrives both by gravity (from Hamat) and through pumping from the rest of the villages. The process includes two lines with primary and secondary treatment, but only one is currently operational. Tertiary treatment (UV disinfection) is performed via a flow detector, and sludge is treated (thickening and dewatering in centrifuge) and kept at the station. Around 500 kg of sludge is generated per day.

The process is automated, has DO sensors, and linked to SCADA. All blowers and pumps are equipped with VFDs. EDL is available for 12 hours, and there is one backup diesel generator of 850 kVA capacity. An initial solar study for rooftops was performed, but not executed. Six employees work at this station.

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption (kWh/year)	Diesel Fuel Cost (LBP/year)	Total Station Consumption (kWh/year)
2,013	16,000	388,685.268	12h	1*850 kVA Consuming 92,401.32 L/year OR 237,600 kWh/year	81,775,168.2	626,285.268

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
383,731.8851	762,743.656	76.1253	1.6577	3.1741	1.5969

Equipment	Quantity	Power (kW)	Head (m)	Flow (m <sup>3</sup> /hour)
Inlet Pump	2+1	15	9.23	266
RAS	3	10	5.5	140
WAS	1+1	3.8	11.4	22
Aeration Blowers 2210 Nm <sup>3</sup> /h	2+1	110		2880 Nm <sup>3</sup> /h
Odor removal Fans	1+1	7.2	-	13900 m <sup>3</sup> /h
Centrifuge	1+1	37.5		117 kg MS/h
UV Units	3	19.8	-	-

# South Lebanon Wastewater Establishment

## Nabatiyeh

Figure 99. Nabatiyeh wastewater treatment plant



### Location

Nabatiyeh

### Date Audited

09/05/2019

### Description

Built in 2005, this wastewater treatment plant became operational in 2012, and serves seven villages in the Nabatiyeh area. The O&M contractor is OTV. The station has a maximum capacity of 10,000 m<sup>3</sup>/day, but it is currently operating at around 5500 m<sup>3</sup>/day (combined collection system). This treatment plant provides tertiary treatment level with nitrogen removal. The biological treatment method applied is suspended growth via an oxidation ditch (two units). Lifting pumps operate based on a level-sensor and are equipped with a VFD. Similarly, blowers are VFD driven, and operate based on a DO sensor and Redox sensor. Moreover, around 250 tons are generated every month, dewatered, thickened, mixed with lime, and disposed in landfills. A SCADA monitoring system is installed.

EDL is not available. The plant runs on backup diesel generators 24/7 (1,000 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	DG Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators	Diesel Fuel Cost (LBP/year)
5,500	36,000	1,569,276	NA	1,000 kVA (24/7)	816,000,000

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
781,007	1,542,464	44.2	0.79	2.04	1.03

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> hour)	Head (m)
Pump	3	Lifting	27	146.25	12.6
Blower	3	Diffuser	At 50%: 153 At 100%: 190	At 50%: 3480 At 100%: 5480	-
Pump		RAS	13	440	7.5
Pump		WAS	5.5	35.7	12.42

## Sayneek

Figure 100. Sayneek wastewater treatment plant



### Location

Saida

### Date Audited

09/05/2019

### Description

Built in 2013, this wastewater treatment plant became operational in 2018, and serves 71 villages in the Saida caza. The station has a maximum capacity of 65,000 m<sup>3</sup>/day, however, currently it is operating at an inflow rate of 56,000 m<sup>3</sup>/day. This treatment plant serves for pretreatment only (screening and grit & grease removal). Lifting pumps operate based on a level-sensor, and are equipped with an autotransformer starter. After pretreatment, water is discharged to the sea via three VFD driven pumps. There are plans for a potential upgrade to secondary and tertiary treatment.

EDL is only available around 12 hours/day. There are three backup generators onsite (1 MVA, which is rarely used, and 2 x 500 kVA, where one operates while the other remains on standby).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Bills (LBP/year)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Station total Consumption (kWh/year)
56000	326789	172,200,000	1,230,000	12	2 x 500 kVA 117,000 L/year Or 386,000 kWh/year	115,440,000	1,616,000

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
-	-	7.63	0.122	-	-

\*Note: BOD and COD removed were not noted for this treatment plant because no biological treatment was applied. This is a pretreatment station.

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> hour)	Head (m)
Pump	4	Lifting	55	1108.8	11
Pump	1	Lifting	35.2	820	11
Pump	3	Booster	183	1728	26

## Tebnin

Figure 101. Tebnin wastewater treatment plant



### Location

Bent Jbeil

### Date Audited

09/05/2019

### Description

This wastewater treatment plant is designed to treat 3200 m<sup>3</sup>/day, however it is currently operating at approximately 950 m<sup>3</sup>/day. Tertiary treatment level is adopted with nitrogen removal. The biological treatment method is suspended growth via an oxidation ditch (two units). Lifting pumps operate based on a level-sensor, and are equipped with a soft-starter. Similarly, blowers are VFD driven, and operate based on a DO sensor and Redox sensor. Approximately, 53 tons of sludge is generated every month, dewatered, thickened, and disposed of in landfills.

EDL is available 24/7. There are two backup diesel generators (each 500 kVA).

Total Flow (m <sup>3</sup> /day)	PE (Population Equivalent)	EDL Station Consumption (kWh/year)	EDL Supply (hours)	Diesel Generators Consumption	Diesel Fuel Cost (LBP/year)	Station total Consumption (kWh/year)
950	7200	561,060	24/7	1 x 500 kVA 8,004 L/year Or 26,413.2 kWh/year	14,880,000	587,473.2

BOD <sub>rem</sub> (Kg/year)	COD <sub>rem</sub> (Kg/year)	kWh/PE.yr	kWh/m <sup>3</sup>	kWh/Kg.BOD <sub>rem</sub>	kWh/Kg.COD <sub>rem</sub>
156,202	298,636	82.72	1.71	3.81	1.99

Equipment	Quantity	Type	Power (kW)	Flow (m <sup>3</sup> hour)	Head (m)
Pump	3	Lifting	12	135	9.5
Blower	3	Diffuser	110	2,750	-
Pump		RAS	9	220	7.7
Pump		WAS	1.5	20.5	5.97

## Sour

Figure 102. Sour wastewater treatment plant



### Location

Sour

### Date Audited

09/05/2019


### Description

Dating since 2012, this treatment plant is in the commissioning phase and expected to be operated and maintained by around May or June 2020, by OTV. It has a capacity of 36,000 m<sup>3</sup>/day, and includes preliminary, primary, secondary, and tertiary treatment, in addition to sludge treatment and anaerobic digestion. Moreover, CHP engines are installed to generate electricity and heat from sludge digestion. Lifting pumps are VFD run, based on level sensors. Similarly, aeration blowers are VFD run, based on DO sensors. This station does not include nitrogen or phosphorus removal. Noteworthy, a SCADA monitoring system is installed.

EDL is available 24/7. There are two backup diesel generators (1,600 kVA and 1,200 kVA), and a biogas generator (500 kVA).

# Appendix D

## Level-2 Energy Audit: O&M Guidelines

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>			PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
			PROJECT NUMBER
COMPUTER DATA	ISSUE DATE	SHEET <b>1 of 6</b>	

### Task Description

#### Monthly


- 1.00 Check pump operation via control panel. Report findings.
- 2.00 Check pump operation for undue noise and vibration. Report findings.
- 3.00 Check bearing temperature with an accurate temperature device, ensure it is below 180°F. If hot, inspect for over lubrication or misalignment.

#### Motor

- 4.00 Check the direction of rotation.
- 5.00 Check grease and lubricated bearings for moisture and oxidation. If any contamination is present, remove and clean bearings. Grease up again with the proper type grease, as recommended by the manufacturer.
- 6.00 Inspect bearings as per manufacturer's recommendation.

#### Electrical

- 1.00 Ensure correct operation of all control panel indicator lamps. Replace any faulty lamp as necessary.
- 2.00 Tighten all terminal connections and main cable in the motor and pro-star.

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
		PROJECT NUMBER
		SHEET <b>2 of 6</b>
COMPUTER DATA	ISSUE DATE	

## Task Description

### Quarterly

- 1.00 Carry out tasks as detailed for *Monthly*.
- 2.00 Check for leaks at fittings, and around flanges and connections. Repair any leak, and replace any defective part.

### Isolation Valves

- 3.00 Examine and test for full and free travel, checking for any leakage.

### Strainer

- 4.00 Check the screen of the strainer for build-up of solid material. Clean as required.

### Regulating Valves


- 5.00 Check operation of valves. Valves should be fully closed then fully opened. (Note the number of turns to fully close, so that the valve can be reset to its original position.) If operation of valve is stiff, lubricate as necessary, repeat opening and closing until clear, and then return valve to its original position.

### Pressure Sustaining and Check Valve

- 6.00 Ensure correct operation.

### Pump

- 7.00 Check for inadequate suction; discharge and shut-off heads against commissioning data.

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>		 PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE	SHEET <b>3 of 6</b>

## Task Description

### Quarterly (Cont'd)

#### Bearings

8.00 Check for inadequate lubrication and overheated bearings<sup>23</sup>.

Inspect lubricating system. Repair as necessary.

9.00 Check grease, lubricate bearings for saponification. Inspect grease for whitish colour. If this occurs, wash bearings with a bearing-cleaning solvent, and replace the grease with the proper type, as recommended by the manufacturer.

#### Motor

10.00 Check for endplay of shaft. Report on condition, and advise on any necessary remedial work.

11.00 Check for presence of dirt, moisture, and other accumulations. Clean as necessary.

12.00 Check for noisy running. Determine cause, and repair as necessary.

13.00 Check holding-down bolts for rigidity and security.

#### Piping System

14.00 Check for evidence of strain on pipes and pump casing.

15.00 Check and ensure correct operation of all flexible connections, repairing or advising on the necessity of replacing damaged components.

16.00 Check condition of all associated insulation and covering. Repair and report any defects.

<sup>23</sup> Maximum bearing temperature is 180°F

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
		PROJECT NUMBER
		SHEET <b>4 of 6</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

## Task Description

### Quarterly (Cont'd)

17.00 Inspect all piping supports for soundness and effective support of load.

### Electrical

#### Motor

- 1.00 Check and record motor running current<sup>24</sup>.
- 2.00 Inspect and tighten the electrical terminals.
- 3.00 Check wiring insulation and flexible connections. Secure and tighten as required.

#### Piping System

- 4.00 Check high discharge pressure switch and calibrate if necessary.

### Bi-annually

- 1.00 Carry out tasks as detailed for *Quarterly*.

### Pump


- 2.00 Inspect all piping supports for soundness and effective support of load.

### Electrical

#### Motor

- 1.00 Check / tighten main cable terminal connections and monitoring / sensing circuits at the RTD terminal on the motor, and in the pro-star relay, all the way through.

<sup>24</sup> Rated current.

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
		PROJECT NUMBER
		SHEET <b>5 of 6</b>
COMPUTER DATA	ISSUE DATE	

## Task Description

### Annually

- 1.00 Carry out tasks as detailed for Bi-Annually.
- 2.00 Calibrate all pressure and temperature gauges.

### Pump

- 3.00 Check and tighten as required, report on condition of holding down bolts.
- 4.00 Remove rotating element and inspect for wear. Replace defective parts.
- 5.00 Clean out stuffing box piping. Remove any deposit or scaling.
- 6.00 Check seals and bearings for any damage. Adjust or replace as necessary.
- 7.00 Inspect pump-casing and report any defect.

### Electrical

#### Motor

- 1.00 Test IR insulation resistance of stator windings, between phases and phase-to-earth, using a 2500V megaohmmeter (preferably motor driven) for 60s, immediately after the shutdown of the machine, whilst the windings are hot and dry. The temperature should be recorded, and IR measurements converted to a base temperature for future comparison.

Always disconnect all voltage sources, surge arrestors, capacitors, or other low insulation sources before making a test. Lead-in cables can be tested as part of the circuit, whilst line-side circuit breaker or contactor is open.

- 2.00 Clean dust and dirt on the motor stator.

PMI SCHEDULE DESCRIPTION: <b>Horizontal Split Case Water Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-01</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>6 of 6</b>

## Task Description

### Annually (Cont'd)

- 3.00 Examine and report condition of all associated wiring-facility and wiring, ensuring security of termination.

### Electrical Services

- 4.00 Inspect and clean all circuit breaker contact surfaces.
- 5.00 Check and clean enclosures, switches, and push buttons.

### Two Yearly

- 1.00 Carry out tasks as detailed for *Annually*.

### Motor

- 2.00 Clean out and renew the grease. An un-vented bearing should be packed, only half full.

(Sealed bearings need no attention for five years.)

## Electrical

### Motor

- 1.00 Retighten all RTD alarm connections and test.

PMI SCHEDULE DESCRIPTION: <b>Booster Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-29</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>1 of 2</b>

## Task Description

### Quarterly

- 1.00 Ensure pump-base is level, and pipe work is not strained.
- 2.00 Examine and check units for leaks; repair and report findings.
- 3.00 Examine all associated pipe work connections for leaks, report findings.
- 4.00 Inspect and report on condition of pump-glands, advising on the necessity to replace any faulty item.
- 5.00 Check pump and motor alignment. Ensure tightness of couplings.
- 6.00 Test unit and report any excessive noise or vibration. Report results. Ensure that vibration is not transmitted to pipes by checking the flexible connections. Replace defective items.
- 7.00 Clean strainer.
- 8.00 Lubricate pump motor-bearings, as per manufacturer's recommendations.

### Electrical

- 1.00 Check and inspect control and safety switches. Repair as necessary.
- 2.00 Examine and ensure the pump to cut in/out at predetermined correct pressures.
- 3.00 Test and ensure all pressure controls and associated components are operating correctly. Log all settings. Replace any faulty indicator lamp. Advise on the necessity to replace any faulty component.

PMI SCHEDULE DESCRIPTION: <b>Booster Pump</b>		PMI SCHEDULE NUMBER <b>ME-PMI-29</b>
		PROJECT NUMBER
		SHEET <b>2 of 2</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	


## Task Description

### Annually

- 1.00 Carry out tasks as detailed for *Quarterly*.
- 2.00 Examine and ensure all motor ventilation air-ways are clear, remove all dirt and dust by vacuum cleaning.
- 3.00 Examine delivery pressure gauges, replacing if faulty.
- 4.00 Check and tighten holding-down and retaining bolts. Report on condition.
- 5.00 Examine and ensure locking keys, bolts, etc. are secure.
- 6.00 Clean pump, vessels, associated bases and cabinets, ensure security of panels and doors, replacing any damaged gaskets and retaining devices.
- 7.00 Examine and ensure drain-pipes are free from obstruction.
- 8.00 Examine and ensure the pump is delivering its correct head pressure by use of test gauges. Record details.
- 9.00 Examine, check, and report on condition of all anti-vibration mounts, repair/replace any damaged item.

### Electrical

- 1.00 Examine and report on condition of all associated wiring, tests for electrical security of terminals.
- 2.00 Electrically test for earth continuity and insulation resistance, report results.
- 3.00 Test and ensure the correct operation of all motor starters.

PMI SCHEDULE DESCRIPTION: <b>Submersible Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-31</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>1 of 4</b>

## Task Description

### Specific Precautions

- Disconnect the power supply to the pump, and pit before servicing, whether for periodic inspections or emergency repairs.
- In case of severe vibration or unusual noise, shut off the pump at once, then determine the cause.
- If frequent tripping of overload protection device occurs, a qualified electrician should be called to analyse and correct problem.
- If sump covers are removed, provide warning signs and barriers to prevent injury to personnel.
- Do not raise, lower, or support the unit by means of the electrical power cable, or the moisture sensor cable.

### Monthly

#### Electrical

- 1.00 Check each pump operation via control panel Hand/Off/Auto switch. Report findings.
- 2.00 Ensure correct operation of all control panel indicator lamps. Replace any faulty lamps as necessary.

#### Quarterly

- 1.00 Carry out tasks as detailed for Monthly.
- 2.00 Examine and test all associated isolation, and check valves for full and free travel, checking for leakage. Adjust or repack valve-glands, as required. Lubricate valve-stems as necessary.
- 3.00 Ensure pit covers are safe, and not deteriorated or damaged.

PMI SCHEDULE DESCRIPTION: <b>Submersible Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-31</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>2 of 4</b>

## Task Description

### Quarterly (Cont'd)

- 4.00 Clean out cover-seating rebate, check seals, or re-grease as required, and refit covers. Remove any surplus grease and ensure that holding bolts (if fitted) are secure.
- 5.00 Clean the sump of accumulated abrasive particles.
- 6.00 Clean the interior of control cabinet of oil, dirt, and moisture.
- 7.00 Remove rust spots, and spots from the control cabinet. Repaint all bare spots.
- 8.00 Inspect unit operation. Report any excessive noise or vibration, or any rough operation, logging on load motor current.

### Pump

- 1.00 Check pump-motor stator-housing, and seal chamber for presence of liquid being pumped. If it exists, inspect for worn or damaged seals, O-rings, etc. Replace defective items.
- 2.00 Check and ensure that pump inlet is clear and free from obstruction, repair and clean inlet strainer as necessary. Thoroughly flush with water until it becomes clear.
- 3.00 Check for inadequate suction, discharge, and shut-off heads against normal operating standards, as per manufacturer's manuals.

### Motor

- 4.00 Check for endplay of shaft motor. Report on condition, and advise on any necessary remedial work.
- 5.00 Check for presence of dirt, moisture, and other accumulations. Clean as necessary.

PMI SCHEDULE DESCRIPTION: <b>Submersible Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-31</b>
		PROJECT NUMBER
		SHEET <b>3 of 4</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

## Task Description

### Quarterly (Cont'd)

#### Piping System

- 1.00 Check for evidence of strain on pump casing.
- 2.00 Check and ensure correct operation of all flexible hoses (if applicable) and connections, repairing or advising on the necessity to replace damaged components.

#### Electrical

- 1.00 Inspect failure to start when switch makes contact. Repair as necessary.

#### Float Switches

- 2.00 Inspect float switches and control cables. Check for cuts or damages caused by debris entering system. Check for attack by corrosive material entering the system. Check for condition of clamps and supporting pipe. Adjust as necessary. Report on condition. Advise on need of any remedial work.
- 3.00 Check condition of alarm system. Ensure correct high and low level alarm<sup>25</sup>.
- 4.00 Check condition of contacts of electrical equipment. Repair or replace as necessary.
- 5.00 Ensure correct operation of all level control; float switches, or probes. Check for bend rods, binding, or other damages. Adjust or replace as necessary.

<sup>25</sup> The minimum water level for continuous operation is to have the cooling fins completely immersed. For intermittent operation, the minimum water level should be at least 1" above the top of the casing.

PMI SCHEDULE DESCRIPTION: <b>Submersible Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-31</b>
		PROJECT NUMBER
		SHEET <b>4 of 4</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

## Task Description

### Annually

- 1.00 Carry out tasks as detailed for *Quarterly*.
- 2.00 Ensure security and condition of slide rails. Maintain as necessary.
- 3.00 Ensure security of lifting cable connections, and that cable is not badly corroded. Fix or replace as necessary.
- 4.00 Check pump base-guides for wear. Report on condition.

### Pump Casing and Impeller

- 5.00 Clean impeller. Inspect for any damage, cracks, or breaks. Report on condition. Advise on the necessity of any remedial work.
- 6.00 Rotate the impeller by hand to insure that it turns freely. If not, check for wear or damage on ball bearings, or shaft. Replace defective bearings. Report on condition of shaft.
- 7.00 Inspect level of oil in the seal-chamber by unscrewing the plug. Add oil to the manufacturer's recommendations, if necessary.

### Electrical

- 1.00 Examine condition of all associated wiring. Test for electrical security of terminals. Repair as necessary.
- 2.00 Carry out insulation test on motor windings. Report results. Advise on the necessity of any remedial action.

PMI SCHEDULE DESCRIPTION: <b>Centrifugal Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-44</b>
		PROJECT NUMBER
		SHEET <b>1 of 3</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

## Task Description

### Monthly

- 1.00 Examine pump unit and adjacent pipe work, together with associated connections for leaks and corrosion, report findings.
- 2.00 Externally clean pumps and motors.

### Quarterly

- 1.00 Carry out tasks as detailed for *Monthly*.
- 2.00 Test unit for excessive noise or vibration. Repair as necessary.
- 3.00 Examine and record delivery and suction gauges together with thermometers. Report any defects.
- 4.00 Examine all pipe work and valve insulation. Repair any damaged sections or items.
- 5.00 Test all manually-operated valves, ensure full and free travel and correct setting, check for leakage, adjust or repack valve-glands, as required. Remove all deposits and lubricate valve.
- 6.00 Ensure security of all brackets, supports, and fixings.
- 7.00 Lubricate pump and motor to manufacturer's recommendations.
- 8.00 Examine pump-drain points, and ensure they are clear and free from any foreign matter.
- 9.00 Clean strainer.

PMI SCHEDULE DESCRIPTION: <b>Centrifugal Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-44</b>
		PROJECT NUMBER
		SHEET <b>2 of 3</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

## Electrical

- 1.00 Inspect motor electrical terminals. Tighten if required.
- 2.00 Check and record full load running current.
- 3.00 Check and ensure correct operation of controls, controllers, and switches.

## Annually

- 1.00 Carry out tasks as detailed for *Quarterly*.
- 2.00 Examine and ensure motor ventilation airways are clear, remove all dirt and dust by vacuum cleaner.
- 3.00 Check and tighten as required, report on condition of holding-down bolts.
- 4.00 Check and clean anti-vibration mounts. Repair or replace as necessary.

## Electrical

- 1.00 Check motors winding-insulation. Report condition.
- 2.00 Examine and report on condition of all associate wiring-facility and wiring, ensuring security of terminations.
- 3.00 Electrically test for earth continuity and insulation resistance, report results.
- 4.00 Test and ensure the correct operation of all motor starters.

PMI SCHEDULE DESCRIPTION: <b>Centrifugal Pumps</b>		PMI SCHEDULE NUMBER <b>ME-PMI-44</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>3 of 3</b>

### Every Four Years

- 1.00 Replace mechanical seal.
- 2.00 Replace pump trundle wheel-bearing and pump lower-bearing.
- 3.00 Replace motor bearing and motor-winding.

PMI SCHEDULE DESCRIPTION: <b>Valves</b>		PMI SCHEDULE NUMBER <b>ME-PMI-45</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>1 of 2</b>

## Task Description

### Weekly

- 1.00 Check pressure-regulating valves; ensure their proper functioning. Repair or replace as required.

### Monthly

- 1.00 Check all valves, flanges, connections, etc. for leakage, damage, or corrosion. Report defect, and repair as necessary.

### Quarterly

- 1.00 Carry out tasks as detailed for *Monthly*.
- 2.00 Check all valve support brackets for security, and tighten as necessary. Report conditions of supports.
- 3.00 Check condition of all insulation. Report any defects.
- 4.00 Check operation of valves (Gate, Butterfly, Check, Float, etc.). Valves should be fully closed then fully opened. (Note the number of turns to fully close, so that valve can be reset to its original position). If operation of valve is stiff, lubricate as necessary, repeat opening and closing until clear, and then return valve to its original position. Report any irregularities.
- 5.00 Examine all valve-glands packing for leakage and adjust or repack as required.

PMI SCHEDULE DESCRIPTION: <b>Valves</b>		PMI SCHEDULE NUMBER <b>ME-PMI-45</b>
		PROJECT NUMBER
		SHEET <b>2 of 2</b>
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	

### **Bi-annually**

1.00 Carry out tasks as detailed for *Quarterly*.

#### *Air Cushioned Check Valve*

1.00 Lubricate the cylinder lever-pin, the bracket-pin, and the pneumatic cylinder.

2.00 Add a few oil drops to the top and bottom ports of the cylinder by removing the breather cap.

PMI SCHEDULE DESCRIPTION: <b>Strainer</b>		PMI SCHEDULE NUMBER <b>ME-PMI-47</b>
		PROJECT NUMBER
COMPUTER DATA	ISSUE DATE <b>MAY 2019</b>	SHEET <b>1 of 1</b>

## Task Description

### Monthly

- 1.00 Clean and wash strainer.
- 2.00 Check for leakage.

Appendix E1: BWE Sheet – Data Collected from the Establishment ([Available Online](#))

Appendix E2: BMLWE Sheet – Data Collected from the Establishment ([Available Online](#))

Appendix E3: NLWE Sheet – Data Collected from the Establishment ([Available Online](#))

Appendix E4: SLWE Sheet – Data Collected from the Establishment ([Available Online](#))

Appendix F1: NLWE Top Energy Consumers ([Available Online](#))

Appendix F2: SLWE Top Energy Consumers ([Available Online](#))

Appendix F3: BMLWE Top Energy Consumers ([Available Online](#))

Appendix F4: BWE Top Energy Consumers ([Available Online](#))

Appendix G: Normalized Pumps Calculation Sheet – All four RWEs ([Available Online](#))

Appendix H: Detailed Pumps’ Analysis – All four RWEs ([Available Online](#))

Appendix I: WWTPs Data Sheet - Data Collected from the Establishment ([Available Online](#))

Appendix J: WWTPs Benchmarking Methodology ([Available Online](#))

Appendix K: WWTPs Data Collection sheet ([Available Online](#))

Appendix L: CIP Planned WWTPs in all RWEs ([Available Online](#))

# Appendix M

## WWTPs Efficient Treatment Processes

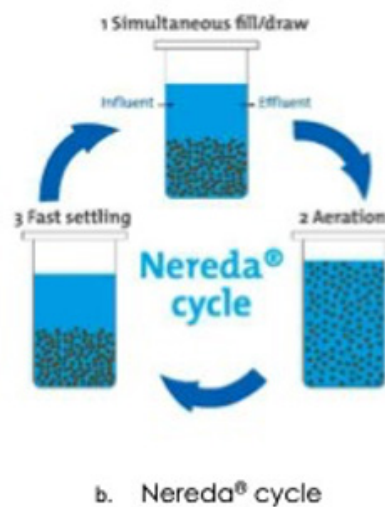
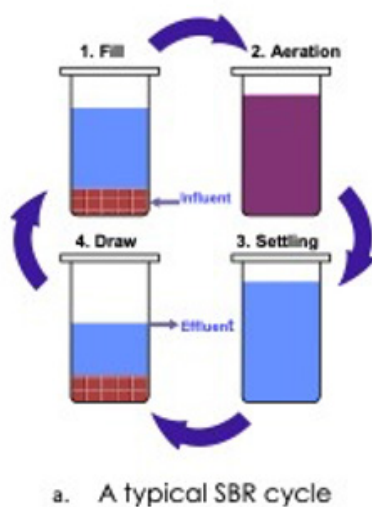
### NERADA Technology

NERADA technology, developed in 2003, is considered as the mature version of aerobic granular sludge treatment. NERADA uses less energy and chemicals, and costs less in terms of capital and operations due to its compactness—it requires 75% less land, compared to traditional facilities.

The main principle of this technology is the formation of biomass granules, rather than flocs. The granules have better property conditions for settling (when it comes to anaerobic, aerobic, and anoxic conditions), and thus fewer tanks are needed and can replace the activated sludge process.

It is a three-step optimized sequencing batch reactors (SBR) cycle:

- Pumping wastewater into the reactor and drawing the effluent (simultaneous process).
- Aeration phase for biological processes to occur. The bacteria would accumulate on the granules, due to their aerobic outer layer. There is formation of nitrate, which is then denitrified, due to the anoxic properties of the core of the granules. This also leads to the uptake of phosphorus.
- Sedimentation stage: separating the sludge and clear effluent. The sludge settles faster, thus less time needed.



There are three major advantages to this technology: cost-effectiveness, ease of operation, and sustainability. These are detailed below.

- **Economic:** simple design with less space needed, costs are lowered due to lower energy consumption and lower sludge production (by around 30%), less mechanical and chemical equipment, less maintenance needed, lower capital expenditures, and lower OPEX and CAPEX.
- **Practical:** easy to operate as it is fully automated, can be remotely controlled, and has a reliable process performance, one single tank doing the work (instead of many).
- **Sustainability:** less usage of chemicals, less construction materials needed, more efficient than standard systems, and lower carbon footprint.

Traditional CAS or SBR plants can be converted into NERADA.

## **Vortex Force: Aerator for Sewer Odor and Corrosion Control**

### **Technology principle**

- Aeration device that draws and mixes air into sewage flow.
- Transforms anaerobic conditions that produce odors, and oxidizes the H<sub>2</sub>S and other odor producing compounds in the sewage flow.
- It works according to vortex motion:
  - ◊ **Vortex Top Form:** incoming flow is split into two streams, each being directed into a vortex channel. The upper vortex directs the flow in a clockwise direction, while the lower vortex is counterclockwise.
  - ◊ **Vortex Drop Shaft:** The flow is then discharged to the energy dissipation pool, where any air not dissolved into the flow is allowed to bubble out of the flow, and the energy of the discharge is dissipated.

### **Main advantages**

- Increases concentration of DO in sewage (downstream benefits).
- Connected with flanges and supports (easy to build).
- **Cost-saving:** requires less chemical feeds, biofilters, and air scrubbers (less odor), reduces corrosion, improves wastewater quality, and less maintenance required.
- Can be put in place no matter the size of the plant, based on factors such as pressure, speed, flow rates, etc.
- **Different application:** sewer main discharge, sewer wells and tanks, and irrigation ponds.

## Membrane Aerated Biofilm Reactor (MABR)

Wastewater treatment plants are an essential part of urban infrastructure. Typically, microorganisms remove nutrients and pollutants. These require oxygen to break down the waste in the water (conventionally done by pumping air through diffusers to create bubbles, which is a very intensive process). The bubbles rise rapidly and microorganisms do not receive the optimal level of oxygen, totaling around a 70% loss in efficiency.

The Membrane Aerated Biofilm Reactor (MABR) is a new technology for wastewater treatment. It allows the operations of treatment plants to become more efficient, without the need for additional space. The membrane aerated biofilm reactor is deployed as a drop-in module, thus there is no need to pump the oxygen. This membrane can retrofit into the existing aeration basins. It increases biological capacity and can replace the old system, if needed. The membrane aerated biofilm reactor habitat creates an optimal environment for the usage of many biofilms at once. The latter absorb and consume carbon and nitrogen-based pollutants. Air is fed at low pressures through hollow membranes to deliver oxygen directly to the bacteria. This system increases the efficiency of forced aeration up to seven times. Bacteria are grown under natural conditions of growth, which offers higher rates of nutrient removal (75% energy savings, 50% sludge reduction) along this resilient process. Additionally, the system increases the amount of water that can be treated by 50% within the same biological tank.

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WATER-ENERGY  
NEXUS OF WATER  
AND WASTEWATER SERVICES  
IN LEBANON

**Volume III:**  
ENERGY AUDIT OF THE WATER  
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