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# POWER MANAGEMENT POLICY FOR LEBANESE TELECOM OPERATORS BASED ON RENEWABLE-ENERGY: A RESPONSE TO THE ECONOMIC CRISIS

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## ABSTRACT

The current economic crisis in Lebanon, which started at the end of 2019, has been exacerbated by the significant devaluation of the Lebanese pound falling down to previously unseen levels and creating an acute burden on population as well as government institutions. Furthermore, COVID-19 pandemic has reached a peak in 2021 forcing the Lebanese government to order several lockdowns and establish online teaching for both scholar institutions and universities. This situation has pushed for higher internet data demand, which inevitably led to an increase in the telecom networks' power consumption and operating expenditure. In addition, the recent reduction in electrical power production brought a serious concern as for the interruption of telecom services. In this paper, recommendations to design a power-supply management policy for Lebanese internet and mobile carriers in response to the aforementioned challenges are proposed. The proposed policy relies on the efficient and optimal use of renewable-energy (RE), and provides guidelines on Why, Where, What and to Which Extent RE equipment should be installed on sites to achieve a solution for an uninterrupted telecom service at the lowest cost possible. Some safety recommendations are also included.

**Keywords:** Power-supply management policy, Renewable-energy, Telecom operators, Optimization, Minimum-OPEX, Recommendations.

## INTRODUCTION

Since 1999, the Lebanese pound (LBP) has been linked to the U.S. dollar (USD) at the fixed rate of 1507 LBP per USD (Banque du Liban, 1999), (Banque du Liban, 2021). This constant rate was a fixed policy by the Lebanese Central Bank (BDL) and hence a major assumption the population, stakeholders and the Lebanese economy relied on to import high-end products at a virtually low cost. For example, OGERO (i.e. the backbone internet infrastructure) and the Mobile carriers (Alfa, Touch) have been able to propose high-quality high-tech telecom services for over 20 years thanks to this low and fixed exchange rate. Following the liquidity crisis that started in October 2019, the Lebanese pound devaluated significantly reaching an unprecedented 1/9<sup>th</sup> of its original fixed value in July 2021 (Saliba, 2020), and is expected to continue falling according to (Rickards, 2020). Equipment replacement due to aging and upgrade of hardware parts are imported to Lebanon in USD. At the same time, the Lebanese customers are still paying their bills to OGERO and the mobile carriers in LBP, thus creating a large gap between the stakeholders' gross income and operating expenditure (OPEX). Furthermore, the situation became more pronounced when the fuel oil importations were reduced progressively dropping to 20% in August 2021 (Bassam, 2021) as BDL stopped fuel subsidies (Nasrallah, 2021). This led to a significant decrease in the production capacity of Electricité du Liban (EDL) power plants, and consequently Telecom carriers are now obliged to find alternative ways to power their infrastructure during outage periods.

On the other hand, COVID-19 pandemic reached Lebanon in March 2020 and kept spreading within population until end of May 2020. Online teaching and working-from-home put additional pressure on telecom stakeholders to provide uninterrupted service at an acceptable quality to cater for this peak in data demand. Although the vaccination campaign is progressing, the percentage of the Lebanese population that are now fully vaccinated is barely 15% (COVID, 2021) in August 2021. Consequently, online teaching for scholar institutions or universities is more likely to remain active in the coming academic year, which keeps a high global data consumption.

In conclusion, the Lebanese overall situation is alarming as telecom carriers have difficulties to keep providing internet data service under excessive power outage, increased OPEX and reduced income due to the high currency exchange rate.

In the Information and Communication Technologies (ICT) sector, Access Networks are key structures that provide wired/wireless connectivity for all subscribers through dedicated remote sites (RS) spread nationwide. For instance, Alfa has over 1200 RS across Lebanon of which 70% are in urban areas and 30% in rural areas (Alfa, 2019). According to (Mina, 2019) the typical power consumption of a mobile RS ranges from 1kW to 5kW and averages around ~3kW.

On the other hand, OGERO has around 60 remote centers that host switching and transmission equipment spread over the Lebanese territory. Each center consumes between 10kW to 50kW approximately depending on its capacity (Adhami, 2021).

The national utility grid in Lebanon suffers from frequent power outages as high as ~50% of the time in 2018 (Lebanon, 2020) and has increased during the current crisis to ~80% in 2021 (Torbey, 2021). For this reason, all Lebanese telecom carriers have installed a Diesel generator (DG) on all their centers and remote sites to fill the energy gap and mitigate power outage issues. In fact, although power supply from DG is guaranteed and reliable, it remains highly expensive (Mottakin, 2014) due to its variable operating cost that includes maintenance (periodic and part replacements) as well as high fuel oil consumption. A simple rule of thumb applies here: the less available the grid is, the highest the DG operating cost and hence the OPEX overall access network.

Switching to cleaner and environment-friendly renewable-energy (RE) sources, especially wind and solar has been extensively used and in 2010, there were around 10 million RE-powered mobile RS worldwide according to (Zhang, 2017), most of which are deployed in developed countries. However, RE-based power-supply systems for telecom networks are still under-deployed in most developing countries.

The difficulty that telecom carriers face in implementing RE solutions, resides in the lack of accurate estimation for the OPEX savings that could be achieved. Some stakeholders in developing countries are even reluctant to invest in this direction due to the high capital expenditure (CAPEX) that comes with the acquisition and installation of RE sources. An accurate and extensive mathematical model for the annual OPEX of a mobile RS powered by a hybrid system including wind and solar energies has been proposed by (Mina, 2019). The authors have studied the implementation of a hybrid power-supply system for telecom RS in the case of Lebanon and proved that the system can be optimized to guarantee an OPEX savings of at least 15%.

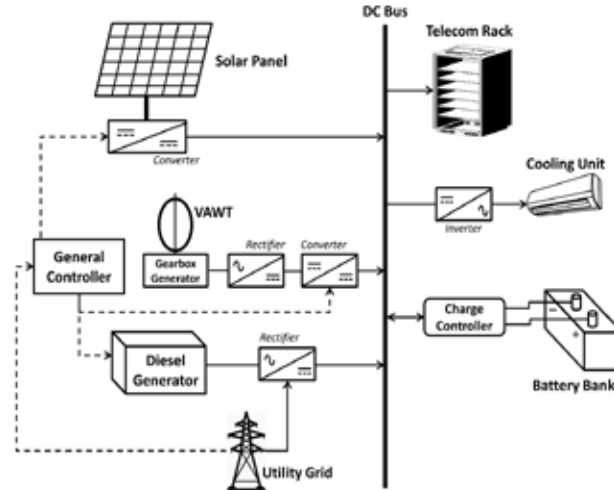
In this paper, a power management policy for Lebanese telecom stakeholders is proposed in response to the previous challenges of the economic crisis to ensure uninterrupted telecom service and data connectivity. The policy relies on the efficient and optimal use of RE sources in a hybrid power-supply system using solar and wind sources namely. This work is based on the system and the promising results obtained in (Mina, 2019). Both qualitative and quantitative recommendations will be presented in this work to provide crucial answers for the decision-making and management processes: **Why, Where, What and to Which Extent RE equipment should be installed on telecom sites?** The recommendations are based on a precise constrained optimization problem introduced in (Mina, 2019) to achieve a feasible solution at the lowest cost possible (minimum OPEX). In addition, some basic recommendations are also included to take into account the safety of the population living nearby the telecom sites.

This paper is organized as follows: The hybrid power-supply system that needs to be installed on remote telecom sites is presented in Section 2. Section 3 formulates the adopted annual OPEX model per site and defines the optimization problem. Section 4 describes the proposed recommendations for the power management policy based on the optimization results.

## HYBRID POWER SUPPLY SYSTEM

The studied power-supply system utilizes four different energy sources: EDL Grid, Wind, Solar and DG to achieve the most cost-efficient and flexible solution. The architecture of the solution ensures that all four sources are connected and can be operational at any time (Figure 1).

Figure 1: *Architecture of the fully-hybrid power supply system from (Mina, 2019) adopted in this work*



A direct current (DC) bus is shared between all sources, a battery bank and the telecom rack. Converters guarantee the electric energy is set to the appropriate fixed level required for the site's load. For instance, rectifiers (AC/DC converters) provide power when AC sources (DG and grid) are active while DC/DC converters are used with RE sources to maintain a fixed DC level despite the variability of the generated power.

The battery bank stores any energy excess produced by RE sources during periods of multiple-source activity, and at the same time provides energy autonomy for the RS in case of incidents or equipment failure, to give technicians sufficient time for troubleshooting and repairing especially on distant sites. The autonomy period is defined arbitrarily depending on the geographic locations of the RS and their accessibility. Discussions with field maintenance engineers showed that at least 48 hours are needed.

It is important at this stage to clarify how the RE sources should be used and what are the issues / constraints that are linked to them.

Solar energy is produced by the photovoltaic effect that produces an electric current proportional to the radiation intensity and the total area of the solar collector with a certain efficiency. The variability of the output power due to change in sun radiation during daytime as well as change in incidence angles between seasons add constraints to the system installation. In this work, for fast response time to the current crisis in Lebanon, we recommend to fix the orientation of the solar panel with respect to sun position at the optimal tilt and azimuth angles of  $56^\circ$  and  $45^\circ$  South-East respectively (Boxwell, 2019).

Wind turbines can be divided into two families: Horizontal-Axis Wind Turbine (HAWT) and Vertical-Axis Wind Turbine (VAWT). A HAWT is widely used for wind energy extraction thanks to its high efficiency when converting from mechanical to electrical energy. However, it is sensitive to wind direction and may not produce power depending on the incidence angle of wind blows (Hemami, 2012). Moreover, HAWT are heavy and large mechanical structures that require wide obstacle-free space to be installed for safety reasons.

On the other hand, a VAWT is capable of capturing winds from any direction, at the cost of a much lower efficiency than HAWT (Hemami, 2012). It has a light structure of the supporting tower because the heavy components are placed on the ground thus exhibiting a low installation and maintenance cost as well as less safety constraints especially in urban regions. Consequently, it is highly recommended in this study to consider VAWT solely.

According to (Hemami, 2012) the output power of a wind turbine is proportional to the cubic power of the instantaneous wind speed and the total area swept by the rotor blades with a certain wind conversion efficiency. Furthermore, due to the high variability of the wind speed (blows, discontinuities) the output power changes significantly and becomes impossible to model. This work follows the weighted average model of the wind speed computed over a month based on real meteorological measurements from (Hassan, 2011) carried out in Lebanon over a year.

## RS ANNUAL OPEX MODEL

The duty-cycle (DC) of a source is defined as the amount of time it is active in producing energy (ON time) and therefore it represents its contribution in the generation of the overall required power. Therefore, the OPEX of a source is proportional to its duty-cycle, the more time it works in a year the higher its OPEX. Moreover, the equipment average lifetimes are introduced into the model by depreciating their purchasing costs (CAPEX) over time to convert them virtually into running cost (OPEX). In this work, the annual OPEX model for a remote site, , is based on the study proposed by (Mina, 2019), and is composed of 3 optimizable components (the duty-cycles  $DC_g$ ,

$DC_w$  and  $DC_e$ ) that are linked to the solar, wind and DG sources. A fourth component is constant and models the EDL grid source, the backup batteries and any auxiliary equipment vital to the function of the system. The model is represented in the following equation:

$$OPEX_{RS/y} = \left[ \frac{\alpha}{I_s} DC_s^2 + \frac{\beta}{v^3} DC_w^2 + C_G DC_G + K \right] \quad (1)$$

where  $C_G$  is the total cost (fixed and variable) of the DG, while  $\alpha$ ,  $\beta$  and  $K$  are constants (Mina, 2019).  $I_s$  and  $v$  represent the solar irradiance ( $kWh/m^2$ ) and wind speed ( $m/s$ ) values respectively.

Taking into consideration the profound and extended nature of the current Lebanese economic crisis, telecom carriers are obliged to find alternative solutions to power their remote sites, while keeping an eye on the OPEX. The previous model is introduced into this study to evaluate as accurately as possible the cost of installing renewable-energy sources in a hybrid power-supply system.

Worth noting that although PV cells have low efficiencies  $< 20\%$ , this drawback is compensated by the long lifetime (20 years) of a typical PV panel (Mina, 2019).

On the other hand, the Diesel generator is the bottleneck of the power system due its high running cost, and low lifetime. For instance, a 5kW RS powered exclusively by an 8kVA DG has an annual OPEX of 15,000\$ (assuming the EDL utility grid is available 50% of the time). This result becomes 25,000\$ since EDL has recently dropped down its production to 20% only.

Introducing RE sources to design a hybrid power-supply system may turn out to be inefficient and expensive without properly optimizing their duty-cycles. The RS annual OPEX in equation (1) is a second-order function of three variables ( $DC_s$ ,  $DC_e$ ,  $DC_w$ ) while  $\beta$ ,  $\gamma$ ,  $I_s$ , and  $v$  are constant parameters for a certain remote site and usually differ from one location to another.

An algorithm is used to minimize the annual OPEX by optimizing the distribution of the power supply breakdown between the existing sources while relying as much as possible on the RE sources and keeping the high-OPEX DG source only for backup. The motivation behind this choice is to respond to the current Lebanese economic crisis and the lack of diesel fuel in the market. This decision is implemented in the optimization by introducing inequality constraints. The OPEX minimization will depend on the RS's power consumption, geographic location, wind speed data, solar irradiance data and grid availability.

The purpose of the optimization algorithm is to compute the optimal combination of values for the duty-cycles of the sources ( $DC_s$ ,  $DC_e$ ,  $DC_w$ ) in order to achieve a minimum annual OPEX while guaranteeing uninterrupted (24/7/365) data connectivity.

Since DG is the most reliable but expensive energy source, due to its high fuel consumption, delicate maintenance and short lifetime (Mina, 2019), the algorithm would obviously tend reduce  $DC_e$  to zero since it targets a minimum OPEX. However, in this case some scenarios may induce an interruption of service: for instance, when EDL grid is OFF during a cloudy day or nighttime and wind speeds are below the minimum cut-in value for wind turbines to start producing power. To avoid this, additional constraints are added to the optimization problem to fix a lower-bound constraint on  $DC_e$ .

It is worth noting that RE sources are not reliable (due to variability issues) and they may be totally inefficient (for example) in regions where wind speeds are low all year around or where solar irradiance is not sufficient to produce a sustainable amount of energy. In such cases, the algorithm tends to avoid using one or both RE sources ( $DC_s=0$  and/or  $DC_w=0$ ).

## OPEX-EFFICIENT POWER MANAGEMENT POLICY

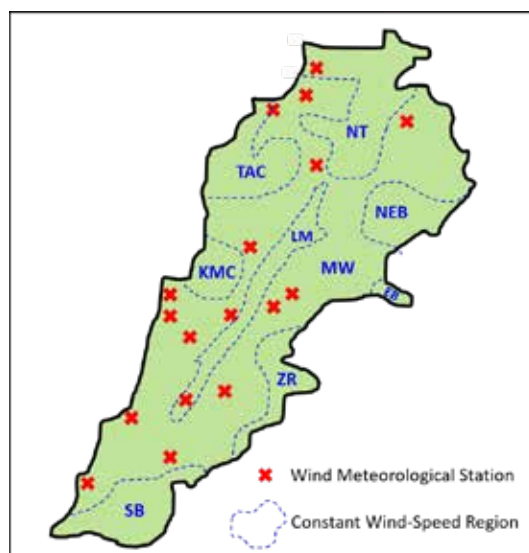
In this section, a power-supply management policy (PMP) is proposed for the telecom carriers (i.e. OGERO, Alfa and Touch) based on the design and installation of a hybrid power-supply system on their remote sites. The PMP will enable decision-makers overcome the challenges of the current situation due to fuel shortage and low EDL grid supply, while ensuring business-as-usual service for their subscribers. The policy relies on the idea of minimizing the OPEX of a RS by optimally distributing and designing the RE sources to be installed on site.

### Solar and Wind Energy Data

While solar irradiance is stable and well measured in any region worldwide, wind speed is more random and exhibits high variation in the same geographic point over a day. Therefore, the first element that needs to be considered is to gather reliable and accurate wind speed data in Lebanon. The proposed PMP recommendations in this work are based on the data gathered from the CEDRO project sponsored by the United Nations Development Program and the Lebanese Minister of Energy and Water described in (Hassan, 2011). The study covered the entire Lebanese inland, with 17 measurement sites (see cross markers in Figure 2) from which simulations are realized to obtain wind speed values at any point on the Lebanese territory. Furthermore, it covered offshore regions up to

20km from the coast. The simulation results were computed using the Mesoscale Compressible Community (MC2) model with some simplifying assumptions made, along with a digital terrain map for accurate wind flow modelling. The results were weighted by frequency of occurrence of a certain value over a month. Finally, at each station, measurements were carried out at three different heights from ground level: 10m, 50m and 80m.

**Figure 2: Proposed Division of Lebanon in Constant Wind-Speed Regions and the Geographic Locations of the Meteorological Stations used in (Hassan, 2011) for Measurements**



The report shows clearly that wind speed values differ significantly between regions: for instance, at 10m height the meteorological station in Tripoli shows a long-term yearly average of only 2m/s while in Qaraoun this value becomes ~4m/s.

In any telecom RS, the equipment are usually mounted on a tower, quite often the tower itself is on the roof of a tall building (in urban areas) or a nearby hill (rural areas). Therefore, it is indeed beneficial to install VAWT since the higher the wind turbine the higher the wind speed (Hassan, 2011). In this work, it is assumed that the windmill will be installed at a reasonable 30m height, and therefore the wind speed values were extrapolated from the data measured at the previous three heights.

To simplify the study, we have subdivided the Lebanese territory into 9 regions for which it is assumed the same wind speed (Figure 2). Table 1 shows the average wind speed for each of these regions. The PMP recommendations proposed in this paper are based on this division.

**Table 1: Average Wind Speed in each region of the proposed division (data from (Hassan, 2011))**

Region	Map Code	Wind Speed (m/s) (average)	Zone	Number of RS (1 Mobile carrier)
Northern Territory	NT	6.1	1	60
Zahleh & Rashaya	ZR	5.8		
Eastern Border	EB	5.5	2	120
Lebanon Mountains	LM	5.5		
Tripoli–Amchit Coast	TAC	5.4		
North–Eastern Border	NEB	5.2		
Southern Borders	SB	5.0		
Moderate Wind	MW	4.1	3	850
Keserwen–Matn Coast	KMC	3.0	4	100

It is possible to further group the regions into 4 zones that have very similar wind speed values (see Table 1). In addition, the approximate number of RS installed in each zone from one Lebanese mobile operator are included in Table 1, to provide some insights on how many RS can effectively benefit from the wind energy.

On the other hand, the solar irradiance values are well measured and archived in (Boxwell, 2019). In Lebanon, they range from 3 in December to 7 in summer season, with an annual average value of 5.0 (including -10% margin). This value is fairly assumed constant for all the Lebanese territory, during daytime.

## Assumptions

With both wind speed and solar irradiance data gathered, the optimization can be run to provide quantitative and clear recommendations for telecom carriers on where and what to install for each region depending on the rented land area for their RS as well as the power consumption of the equipment.

To realize the study some relevant assumptions are taken: First, since the mobile RS power consumption is variable between sites depending on the installed equipment, only minimum, average and maximum values will be considered in this work: low-power (1kW), mid-power (3kW) and high-power (5kW). According to (Mina, 2019), those are sufficient to cover the majority of the cases and are corroborated by measurements. For OGERO centers, the same idea is used with the proper values of 10kW, 30kW and 50kW. Second, since it is difficult to obtain the exact area for all mobile sites, visits were conducted to measure the existing minimum (25m<sup>2</sup>, urban) and maximum (200m<sup>2</sup>, rural). During optimization, all possible values between the previous two will be studied to cover the majority of the cases. For OGERO centers, the center premises (roof, yard) will be used freely with a minimum of 25m<sup>2</sup> and a maximum of 625m<sup>2</sup>.

Using the previous assumptions, optimization of multiple cases were conducted using MATLAB to define the recommendations for a PMP. During algorithm computations, it is assumed that EDL grid is available for 20% of the time only, a figure that corresponds to the current reality in Lebanon.

In the next sections, recommendations of the proposed power management policy for both mobile and OGERO carriers will be presented. First, a set of global recommendations, which are applicable for any site over the Lebanese territory, are proposed and then detailed region-specific recommendations are provided to build the cost-efficient hybrid power-supply system.

### Global recommendations for Mobile Carriers (Alfa, Touch)

#### 1) Do not install horizontal-axis wind turbine in the hybrid system and use instead vertical-axis wind turbine exclusively.

This recommendation helps reducing discontinuities in the generated output power due to sensitivity of HAWT towards wind direction. Moreover, it enhances public safety on site since VAWT has lower and more contained swept area especially in restricted and small urban RS.

#### 2) Request from EDL to make the electricity outage periods occur during daytime more precisely between 9am and 5pm (when solar energy production is at its peak).

This recommendation helps in increasing the efficiency of renewable-energy.

#### 3) For coastal regions with low wind-speed values (e.g. KMC on Figure 2), replace high-OPEX inland RS by installing floating offshore hybrid RS.

This recommendation exploits the high-speed wind blows that occur in the sea (> according to (Hassan, 2011)). A 5km distance from the coast is advised to take into account the radio coverage capability of telecom equipment and to increase the area to service.

#### 4) Replace existing RS in Bekaa valley (within MW region) by installing hybrid RS in EB region with directional antennas to cover the same inland zone.

This special recommendation exploits the much higher wind-speed existing in EB region ( ) to install OPEX-efficient hybrid systems.

### Region-specific recommendations for Mobile Carriers (Alfa, Touch)

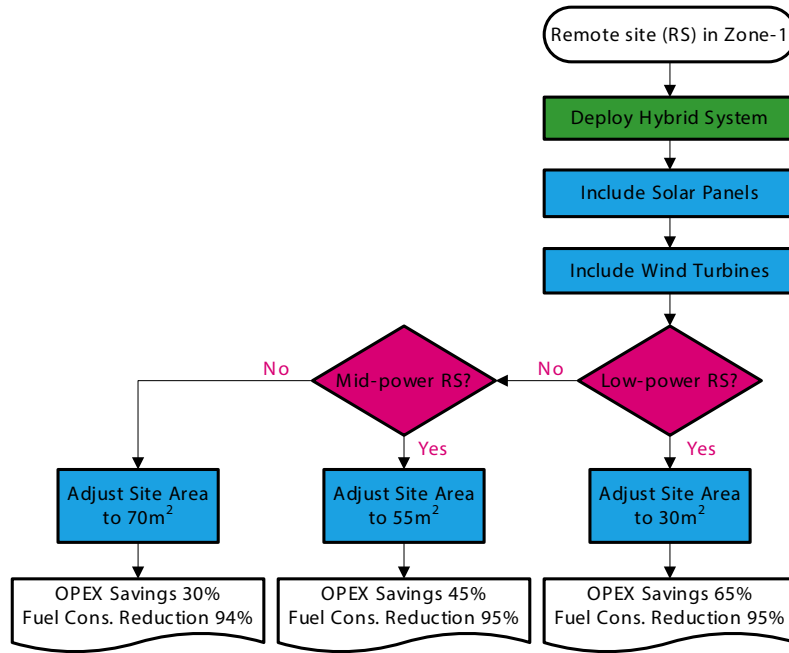
#### Zone-1

- The installation of a hybrid system including both solar panels and wind turbines **is extremely recommended regardless** of the RS power consumption and area, since the optimization results show that RE sources contribute in generating 2/3<sup>rd</sup> of the required power with guaranteed OPEX savings.
- For low-power RS, **adjust the site area** to the optimal value of to achieve 65% OPEX savings and 95% fuel consumption reduction.
- For mid-power RS, **adjust the site area** to the optimal value of to achieve 45% OPEX savings and 95% fuel consumption reduction.
- For high-power RS, **adjust the site area** to the optimal value of to achieve 30% OPEX savings and 94% fuel consumption reduction.

The flowchart in Figure 3 shows the previous recommendations for this region.



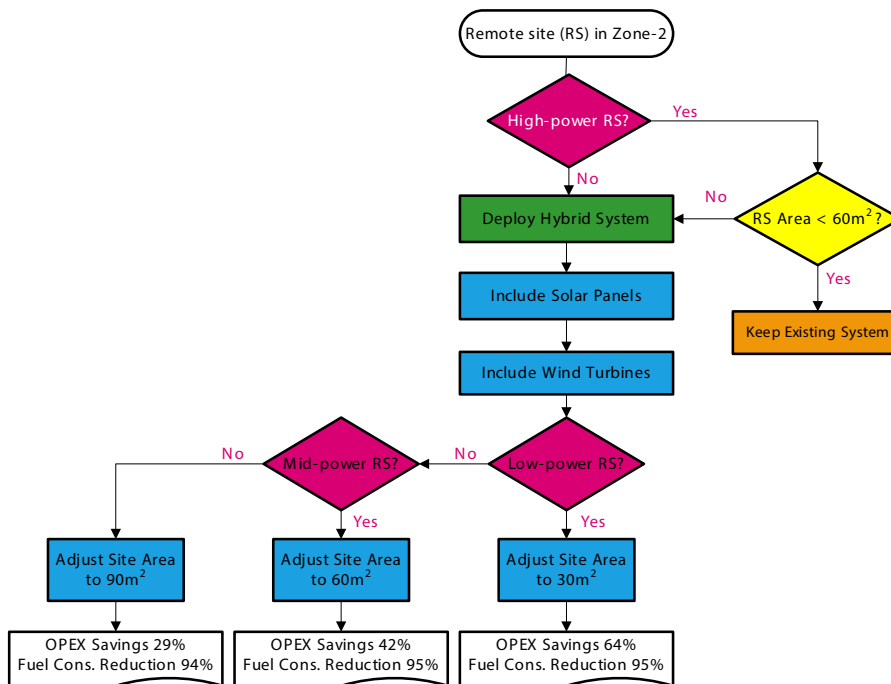
**Figure 3: Flowchart of Recommendations for Zone-1**



## Zone-2

- The installation of a hybrid system including both solar panels and wind turbines is highly recommended regardless of the RS power consumption and area (except for limited cases), since the optimization results show that RE sources contribute in generating the majority of the power with guaranteed OPEX savings.
- Adjust the site area to the optimal value for each type of RS (according to Figure 4) in order to achieve the maximum OPEX savings and fuel consumption reduction.
- It is not recommended to install the hybrid system in the case of high-power RS having areas below (see Figure 4). There will be no OPEX savings.

**Figure 4: Flowchart of Recommendations for Zone-2**



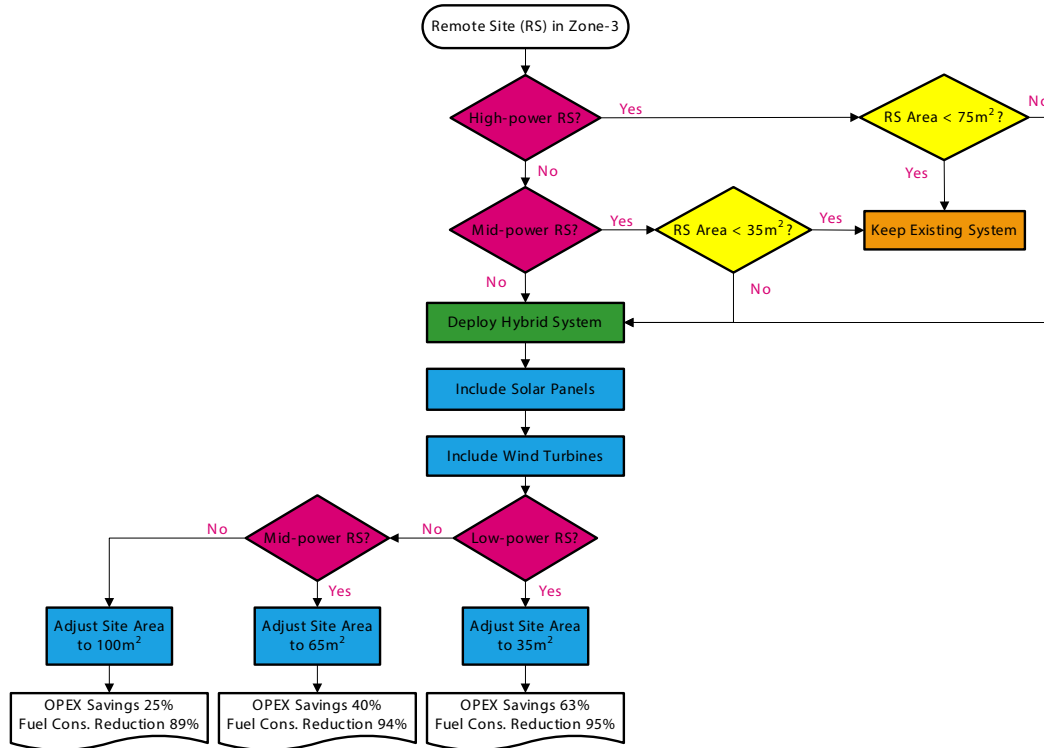
## Zone-3: MW region

- The installation of a hybrid system including both solar panels and wind turbines is recommended in these regions depending on the RS power consumption and area, since the optimization results show that RE sources contribute in generating the majority of the required power with guaranteed OPEX savings.



- Adjust the site area to the optimal value for each type of RS (according to Figure 5) in order to achieve maximum OPEX savings and fuel consumption reduction.
- It is not recommended to install the hybrid system for some RS configurations (see Figure 5). There will be no OPEX savings.

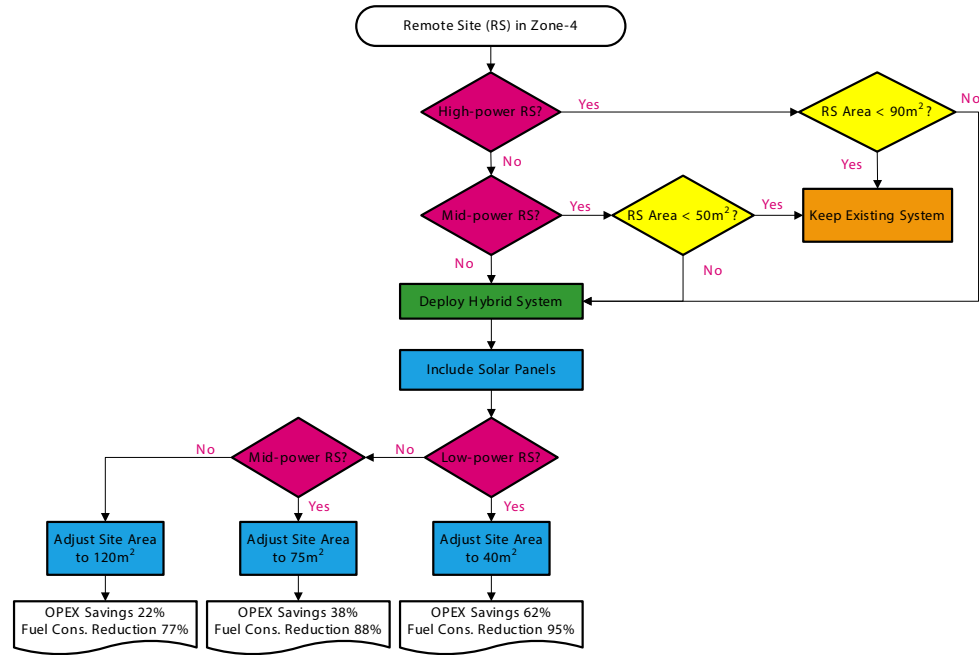
**Figure 5: Flowchart of Recommendations for Zone-3**



#### **Zone-4: KM region**

- The installation of a hybrid system including solar panels only is recommended in these regions depending on the RS power consumption and area, since the optimization results show that RE sources contribute in generating the majority of the required power with guaranteed OPEX savings.
- Adjust the site area to an optimal value for each type of RS (according to Figure 6) in order to achieve maximum OPEX savings and fuel consumption reduction.
- It is not recommended to install the hybrid system for some RS configurations (see in Figure 6). There will be no OPEX savings.

Figure 6: Flowchart of Recommendations for Zone-4



All the region-specific recommendations are further summarized in Table 2.

Table 2: Region-specific recommendations for installing Hybrid Power-Supply Systems in mobile RS

Zone	RS Power	RE Sources to install	Minimum Area (m <sup>2</sup> )	Optimal Area (m <sup>2</sup> )	OPEX Savings (%)	Fuel Cons. Reduction (%)
1	Low	Solar + Wind	25	30	65	95
	Mid	Solar + Wind	25	55	45	95
	High	Solar + Wind	25	70	30	94
2	Low	Solar + Wind	25	30	64	95
	Mid	Solar + Wind	25	60	42	95
	High	Solar + Wind	60	90	29	94
3	Low	Solar + Wind	25	35	63	95
	Mid	Solar + Wind	35	65	40	94
	High	Solar + Wind	75	100	25	89
4	Low	Solar only	25	40	62	95
	Mid	Solar only	50	75	38	88
	High	Solar only	90	120	22	77

Worth noting that increasing the area of a site above the optimal value stated in Table 2, in the objective of installing more solar panels (and hence using more renewable-energy) will lead to less OPEX savings. Therefore, the purpose of the proposed recommendations in this work is to avoid such misconceptions when designing the hybrid system.

## Global recommendations for OGERO

Recommendations 1) and 2) for mobile carriers should be used in the case of OGERO, while recommendations 3) and 4) are not applicable.

Optimization results for OGERO centers with >30kW power consumption showed that the hybrid system becomes cost-inefficient and requires a very large area that is not available (free) at the center itself. Therefore, **for high-power OGERO centers it is not recommended to install the hybrid system.**

## Region-specific recommendations for OGERO

All the region-specific recommendations are summarized in Table 3.

**Table 3: Region-specific recommendations for installing Hybrid Power-Supply Systems in OGERO Centers**

Zone	RS Power	RE Sources to install	Minimum Area (m <sup>2</sup> )	Optimal Area (m <sup>2</sup> )	OPEX Savings (%)	Fuel Cons. Reduction (%)
1	Low	Solar + Wind	25	200	72	97
	Mid	Solar + Wind	175	450	30	97
	High	X	X	X	X	X
2	Low	Solar + Wind	25	225	70	97
	Mid	Solar + Wind	275	500	28	94
	High	X	X	X	X	X
3	Low	Solar + Wind	25	230	68	97
	Mid	Solar Only	400	575	27	85
	High	X	X	X	X	X
4	Low	Solar only	75	250	65	94
	Mid	Solar only	475	625	26	73
	High	X	X	X	X	X

Worth noting that for high-power OGERO centers, although the hybrid system covering the total power consumption is not profitable based on Table 3, nevertheless decision-makers may implement the hybrid solution to provide only half the power for the equipment (equivalent to a mid-power center) since it remains profitable compared to a non-RE power-supply system.

## CONCLUSION

In response to the current economic crisis facing Lebanon, this paper studied the benefits of using renewable-energy sources (mainly solar and wind) as an alternative to the increased EDL electricity shortage and the expensive Diesel generators deployed nationwide. This work is based on the optimization of an OPEX model for a remote site in which a hybrid power-supply system is installed. Clear recommendations were proposed to achieve a cost-efficient power management policy, to be adopted by telecom carriers to provide uninterrupted data connectivity. Both global and region-specific recommendations were presented to enable telecom stakeholders and relevant policy makers to make optimal decisions during this acute crisis. The benefit of adopting hybrid systems for telecom sites has been proven both in terms of OPEX and fuel consumption reduction.

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