The Lebanese Foundation *for* Renewable Energy

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A NEW ENERGY VISION FOR A NEW LEBANON

Solar, wind and hydro unleash a Green Energy Revolution

A Desolate State

The electricity sector, perhaps more than any other sector in the economy, epitomizes the nepotism, corruption and incompetence that have been the mainstay of Lebanese governance. This is why we have chosen to focus on it.

Its management has been nothing short of catastrophic over the past three decades. Energy has been the main drain on the country's foreign reserves and is the largest contributor to its ever-growing budget deficit. Despite adding close to $40 billion to the national debt in the past 20 years, power cuts still reach 12 hours per day in many parts of the country. More alarming is that more than half of the Lebanese population lives next to very polluting, outdated and ill-maintained heavy fuel power plants that lack proper cleaning and filtering technologies, resulting in substantial increases in cancer and pulmonary diseases.

The failure to fix this crucial sector has resulted in an increased reliance by the public on expensive and polluting diesel generators (providing up to 40% of our energy consumption) and on a constant need for wasteful temporary solutions. For example, Turkish barges, 'temporarily' leased for three years to cover part of the electricity shortfall are costing approximately $500 million every year and are increasingly looking like a permanent solution. These barges and other last-minute patches significantly increase the waste in providing permanent power to the country. As a result, a recently published Strategy&/AUB/LFRE report estimates that the overall cost of electricity in Lebanon, including losses and the cost of backup diesel generators is approximately 35 cents/kWh, one of highest in the world.

The government's new electricity plan is based on an obsolete model *(see Annex B)* and will continue to cause damage to the environment, especially in coastal areas. Instead of promoting green, decentralized production, such plan relies mainly on large, centralized and fossil-fuel plants. The decision to build these power plants seems at times more governed by tribal concerns rather than economic or technical considerations. For example, three Floating Storage Regasification Units-FSRUs- are being planned when only one is needed to store the imported liquefied gas for the new plants (Italy has only one FSRU). The additional cost is close to $400 million dollars, approximately the cost of a 700 MW solar plant.

Respecting the environment also comes second. Selaata, a site selected for one of the new proposed power plants, is located along one of the most beautiful coasts of Lebanon. Mott & McDonald, the consultant who evaluated plant sites for the ministry of energy warned that the area's '*ecology is likely to be of particular importance and sensitivity at the site specifically bird life and marine ecosystem. Water cooling and discharge is likely to be of particular concern given marine sensitivity'.* In addition, the government's plans to revamp or build 6 plants on the coast, some located in proximity to urban areas, will keep affecting public health. Already, in late 2018, Greenpeace listed Jounieh among the world's top 50 polluted cities. Nitrogen dioxide (NO2) emissions there, mainly from the Zouk plant and diesel generators, are the source of multiple diseases and premature deaths.

Even the gas-fired plants (CCGT) being adopted to replace fuel oil-operated plants under the premise that they are cheaper, and cleaner will continue to generate harmful emissions, especially in highly urbanized areas such as in Greater Beirut. Approximately 3.5 million Lebanese will be expected to live there by 2035. Such plants are also expected to produce electricity at double the cost of renewables and will need twice the time to build.

In summary, Lebanon needs to rebuild its electricity sector based on a new model and on purely economic and technical considerations. This will not only lead to substantive savings, but will also promote sustainable development, more balanced fiscal policies, improved protection of the environment and reduced healthcare concerns. It is our contention that such efforts require a 'green' revolution.

The Green Revolution

The challenges notwithstanding, the current energy crisis provides Lebanon with a unique opportunity to immediately leapfrog into green energy. This will be similar to the rapid deployment of mobile phone service in the country at the end of the civil war which at that time leveraged the new GSM technology to provide a quick solution to the lack of a land line network.

Strategic Priorities The study conducted by Strategy&/AUB/LFRE ranked renewable energy as best in terms of cost benefit, environmental and healthcare impact, social development, energy security and reliability *(see fig. 1).*

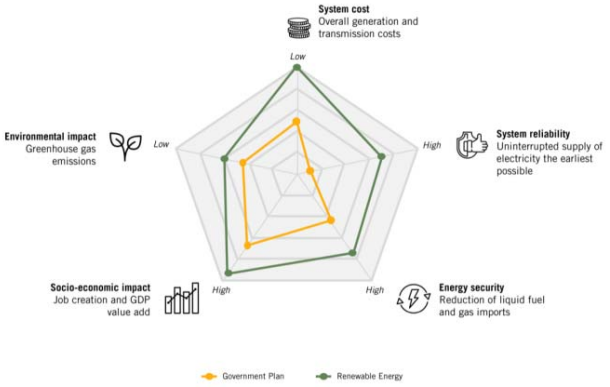


Fig.1: Strategic Priority Score
Source: Strategy&/AUB/LFRE

Cheapest Energy Source Solar, wind and hydro are by far the cheapest sources of energy available now in Lebanon and around the world. Green energy production is four to five times cheaper than electricity produced by our current operating heavy-fuel power plants and two to three times less than gas-power plants (CCGT). A recent AUB/LFRE study on a potential 300 MW solar plant in Tfail in the Bekaa estimates the cost of producing electricity there at 4.2 to 5.3 cents/kWh. Such estimate was validated recently by the outcome of a solar tender by the Ministry of Energy with the lowest bidder offering 5.7 cent/kWh for small 15 MW plants. By comparison gas-fired power plants are expected to cost an estimated 9 cents/kWh as per McKinsey's 2018 Lebanon Economic Vision report.

As a result, adopting a 50% renewable energy target by 2030, will reduce the Levelized Cost of Energy (LCOE) by close to 20 cents/kWh. Compared with the current 35 cents/kWh cost, this represents a decrease of close to 58% *(see chart.1).*

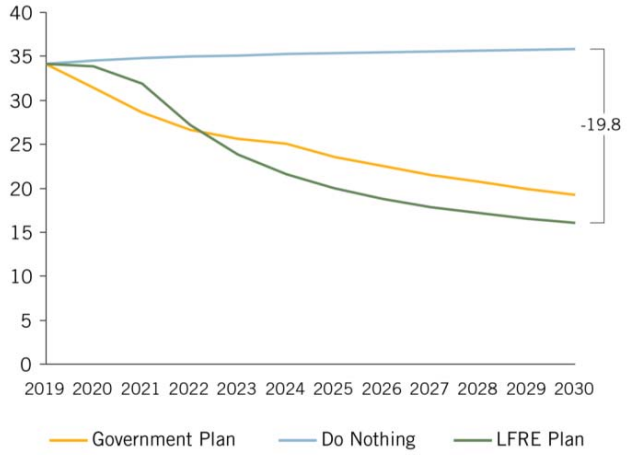


Chart 1: Levelized Cost of Electricity
Source Strategy&/AUB/LFRE

Local Development Sustainable energy will create thousands of jobs and contribute to the economic development of some of the poorest areas in Lebanon. Close to 2/3 of all jobs created will be located in regions such as Hermel, Ras Baalback, Akkar, Tfail and Qaa as well as regions in the south, the Chouf, Aqoura, Rachaya and Taraya. Such regions offer sites well suited for solar and wind energy projects. When implemented, such projects will stimulate the economic activity in these regions.

A Game Changer Lebanon must therefore turn urgently to the large scale adoption of green energy. Gas-operated power plants will still provide energy during peak hours and when renewable energy is intermittent or unavailable. This strategy will serve as an important stepping stone for rebuilding a sustainable economy based on a renewed respect for our environment and a better quality of life for our citizens. As a result, Lebanon's energy transition can target 35% of the country's electricity by 2024-25 and 50% by 2030. By 2040-50, as storing energy becomes competitive, we envision for Lebanon,

as many countries have targeted now, to substantially decarbonize its energy sourcing.

Regulatory Reform In order to rapidly scale up green energy adoption and allow it to become fully integrated into our energy system, Lebanon must remove all barriers hindering its energy transformation. It must therefore modernize a complex and outdated legal system, reduce a burdensome permitting and approval processes and harmonize its different codes and regulations. New policies and incentives must also be encouraged to address a diverse set of market barriers.

It's regulatory system must also be aligned to catalyze private investment and leverage innovation and technology advancement. The goal is to encourage new business models and public/private collaboration for electric utilities, clean energy products and energy conservation.

Reformed pricing structures must also reward investments that improve overall system efficiency (for example for managing loads to reduce peak demand), engage the private sector to invest in clean energy opportunities and place clean and distributed energy at the core of the new electricity model.

Best Practice and Procurement Providing the land (preferably public land), a clear connection to the grid, a transparent legal framework and simple procurement rules will insure competitive pricing and rapid deployment.

Bids must offer a transparent, simple, consistent and rapid tendering and award process. As per the World Bank's "Scaling Solar"program, they must integrate fully balanced and bankable project document templates that will eliminate or reduce negotiation and speed up financing. Such straightforward process will reduce time and transaction costs generated by individually negotiated contracts.

Speed of Execution Solar and wind plants are also much faster to implement. The World Bank's 'Scaling Solar' initiative (scalingsolar.org) provides a 24 months timeline *(see Fig. 2)* to build solar plants. This program recommends 6-8 months for project/bid preparation and tender/award processes, 6 months for financial close and 10-12 months for construction & operation.

Instead of wasting $1 billion on a 5-year temporary plan currently planned to reach 24/7 electricity, for the same cost, Lebanon can deploy in two years, a 1600 MW solar plant, that will represents a cheaper and cleaner solution and will serve the country for the next 30 years.

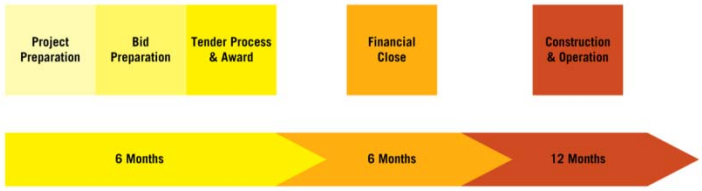


Fig 2: 'Scaling Solar' Timeline
Source: World Bank /IFC, scalingsolar.org

Financing In order to deliver a rapid close and lower financing costs, international institutions can provide competitive financing and insurance to approved winning bidders.

In Conclusion, such 'best practice' approach aims to make privately funded solar and wind projects operational within two years at competitive tariffs. With the proper framework, costs could reach 2.5 to 3 cent/kWh for large renewable plants, on par with Jordan or Egypt.

As per the Strategy&/AUB/LFRE study, we estimate that by 2030 and with the necessary doubling of energy production (from approx. 15 TWh per year today to 29 TWh in 2030), $36.1 billion (more than $3 billion a year) will be saved. This is the result of a new energy model for the country, the reduction in the purchase of fuels and the shortening of deployment time *(see Chart 2)*. Additionally, over the same period, more than $6.4 billion will be saved in avoided health care costs.

The Energy Mix

The government targets 30% renewables by 2030 yet it is setting itself up for failure.

It has been unable to solve the legal, regulatory and administrative hurdles facing the development of private energy projects and unwilling to use the Public/Private Partnership legal framework. Additionally, its procurement process has been inefficient and contrary to best practice. For wind and solar projects for example, developers were required to search for private land despite the availability of public sites and they were not provided with a clear path to connect to the grid (having to deal individually with the MOE, EDL, EDF and expropriation issues). In addition, initial tender documents did not include a bankable Power Purchase Agreement (PPA) template upon which investors could rely upon for pricing and subsequently for financing. Such a complex process, lack of clarity in addition with the need to individually negotiate contracts increased transaction costs and development time. Consequently, eight years later, the wind project in Akkar has yet to be built and its awarded price at an average of 10-11 cents/kWh is double the market price.

For these reasons, Lebanon will reach at best half of its modest 12% renewables objective by 2020 including all existing hydro and installed rooftop (assuming the 400MW of awarded solar and wind projects are built). Even if all of the 1100 MW solar and wind plants planned by 2025 are executed, they will meet only 11% of the country's national energy demand. In contrast, in the United States for example, renewables accounted for 60% of all new energy capacity in 2019 as per Federal Energy Regulatory Commission (FERC).

Also, by prioritizing gas plants in the early stages, Lebanon risks reaching in a few years a similar impasse as Jordan today.

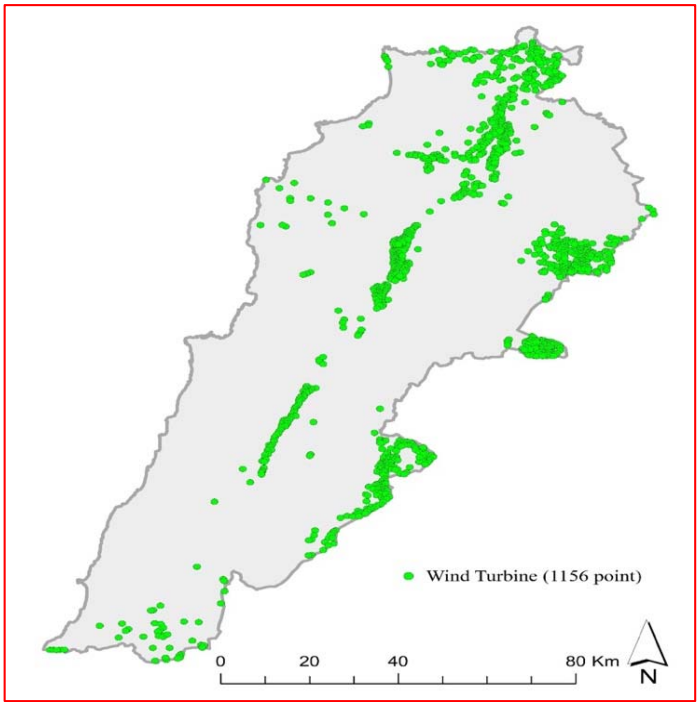
This country is close to reaching its 20% renewables target by 2020. Yet, with solar plants producing electricity at a cost of 2.5 cents/kWh, Jordan is being hindered from adopting further green energy by 'take or pay', 25 years, privatized gas contracts that provide electricity which is four times more expensive.

According to a recent paper on Jordan*: '*thermal power and single-buyer model obstruct further renewables development*' and the '*development of the sector cannot take place without accounting for the broader power sector in terms of the energy mix, implementation of thermal generation regulations, and investment in the grid and other components*'.

To avoid Jordan's predicament, Lebanon must develop an energy mix that prioritizes renewables and massively integrates their deployment in the earliest stages of the electricity master plan.

In addition, Lebanon must actively promote the development of rooftop solar and village and neighborhood micro-grids. Such decentralized on-grid power generation will gradually replace existing diesel generators and reduce losses from the transportation of electricity.

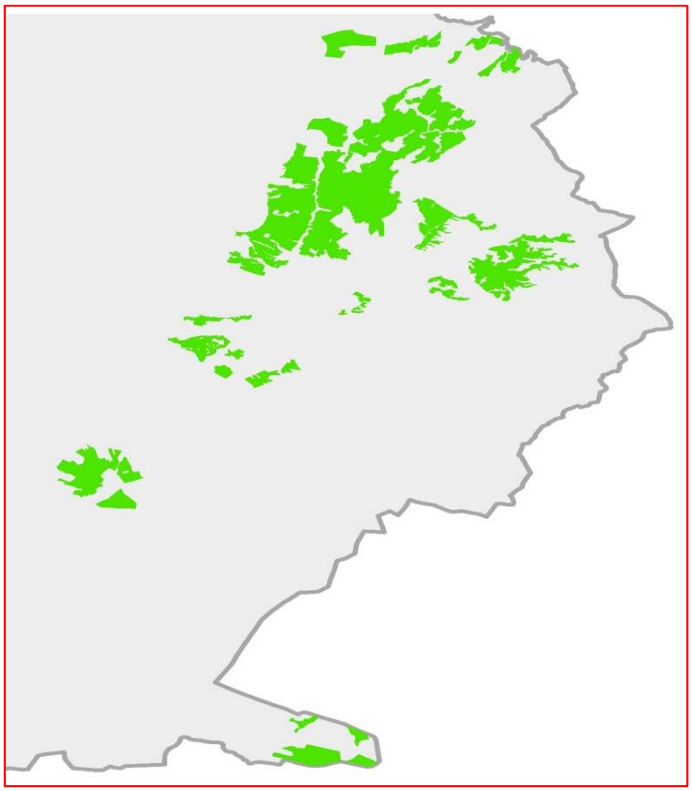
Also, short term energy saving programs for the installation of rooftop solar water heaters and LED lights deployment must be implemented.



Map 2 : Wind Sites
Source : CNRS/LFRE

The Plan

Teaming up with CNRS, LFRE has identified large areas, on public and private land (*see annex C & D for sites selection criteria for solar and wind plants)* that could provide **more than 13,000 MW** of solar energy, **5000 MW of wind** and approximately **2000 MW of hydro and pumped hydro projects**. The most suitable solar sites *(see map 1)* are mainly located in the Bekaa Valley where irradiation is the highest and the availability of large plots of public or relatively inexpensive land is prevalent. Studies are still under way to cover other regions in Lebanon.



Map 1: Solar Sites
Source : CNRS/LFRE

Wind plants are distributed over different areas of the country from north to south (*see map 2).*

As a result of such important potential, green energy can supply 20% of the country's electricity by 2022, 35% by 2024 and 50% by 2030 *(see chart 3).* This will require to build close to 4500 MW of wind, solar and hydro plants in the next five years *(see table 1).* This massive adoption of renewable energy will be further strengthened by leveraging Lebanon's potential for clean pumped hydro-storage, using our existing hydro-power mainly at night and integrating battery storage (which costs has recently fallen dramatically from $1400 per kW to $300 per kW today).

This plan will be implemented in three stages:

a) **Immediately**, considering Lebanon's current energy crisis and the urgent need to provide cheap electricity, wind, solar and hydro projects must be launched in the next months for a total capacity of approximately 2400 MW (600 MW wind, 300 MW hydro and 1500 MW solar) and 350 MWh in battery storage The current grid's limitations to handle renewables must be tackled with a fast track grid upgrade program. Such plan will move in parallel with the two new CCGT plants currently planned in Deir Aamar 2 and Zahrani 2. All projects can be built on public land in Hermel, Qaa, Tfail for solar plants and in Aaqoura, Tfail, Hermel, and the south for wind farms. Prices are expected to range between 4 to 5 US cents/kWh *(see maps 3,4,5 in Annex A).*

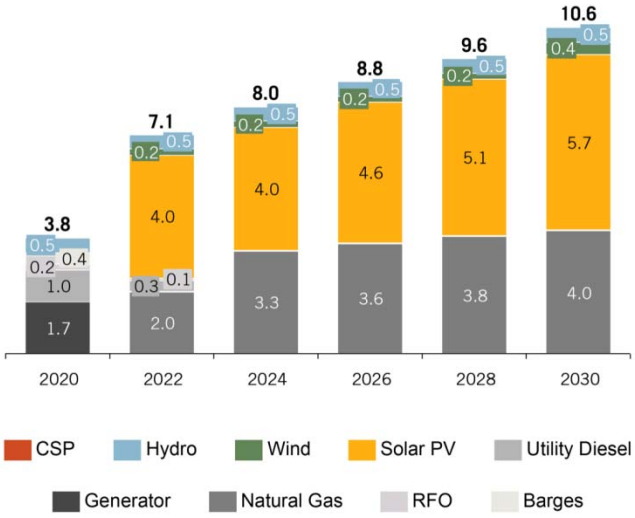


Chart 3: Energy Mix & Ramp up (GW)
Source: Strategy&/AUB/LFRE

Since Lebanon needs to fast track the production of hundreds of megawatts of solar and wind energy production in record time, it must also adopt best practices implemented in projects in the region.

The estimated budget for this emergency plan ranges between $1.8 to $2 billion.

	End 2022	**End 2024**	**End 2030**
Solar	1470	1065	3320
Wind	620	280	520
Hydro	312	568	500
Total	**2402**	**1913**	**4340**

Table 1 : LFRE Renewables Program
Source : LFRE

a) **From 2022 to 2024,** as the grid is upgraded, storage becoming competitive (both pumped hydro and batteries) new tenders or reverse auctions shall be launched for an additional capacity of approximately 1900 MW. With improved market conditions, prices could reach 3 cents/kWh as per Jordan or Egypt.

b) **From 2024 till 2030**, additional green capacity of approximately 800 MW shall be built every year along with pumped hydro storage, smart grid deployment and a better integration to the regional grid network.

Lebanon will benefit from large green energy production and ambitiously promote electrical vehicles. In parallel, CCGT plants will become operational to serve as a base load.

Such plan will allow for the rapid phasing out of diesel generators without the need to provide temporary and costly solutions. Also, it will be reassessed every two to three years to optimize the energy mix, minimize costs and integrate new technologies.

As per McKinsey's recommendations, deploying 4000 MW of solar energy will reduce the number of traditional fossil fuel plants from the currently planned six plants to four or potentially to three, resulting from the adoption of more solar combined with storage.

Thus, through the combined use of renewable energy and storage, a limited number of gas plants along with the implementation of energy saving programs, the government will be able to solve the current electricity deficits and meet the expected growth in demand. With such substantial reduction in its cost base (and potential tariff increases), EDL could reach profitability in the next four to five years.

The 'Smart' Grid Unless the outdated electric grid is fixed and modernized, the electricity from the new power plants, whether traditional fossil fuel or renewable energy plants, cannot be efficiently delivered to the consumer. Unfortunately, this infrastructure has suffered years of neglect.

Given that renewable energy is intermittent, Lebanon must not only upgrade the old power grid but also invest in what is known as a "smart" grid, adopting state-of-the-art technology and innovations in order to produce a more efficient reliable and flexible energy transportation network.

At a minimum, a smart grid will require upgrading the Electric Network Control Center and the integration of new technologies such as smart meters, energy storage, smart inverters, artificial intelligence and Virtual Power Plants. It will allow a two-way flow of electricity with each citizen potentially becoming both an energy producer and a consumer. Upgrading and modernizing the grid must therefore be fast tracked not only to allow for the rapid integration of more renewables but also to reduce technical losses and the theft of electricity.

A smart grid will also be essential for the rapid adoption of electrical vehicles into the electrical network and for leveraging their batteries into the national energy infrastructure.

A New Paradigm

In summary, moving aggressively into green energy can be transformational for Lebanon, a small country that has been blessed with 300 days of sunshine and plenty of valleys and mountains with water and year-long wind currents. Renewable energy can substantially contribute to doubling the energy supply and increasing the reliability and security of the country's sourcing of energy by making it less dependent on imported fossil fuels and saving close to $800 million per year *(see chart 2)* over the government's plan.

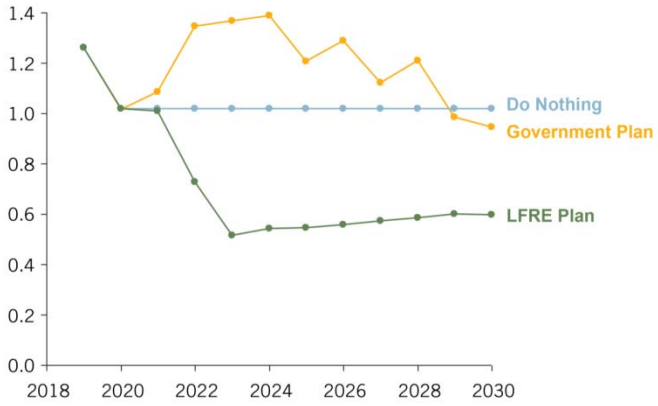


Chart 2: Annual Fuel Cost
Source: Strategy&/AUB/LFRE

Since green energy production is local, it will substantially accelerate economic growth with 15% additional local value add by 2030. With most projects located in rural areas, it will create there new jobs and know-how and help develop some of the poorest regions in the country, promoting for example agriculture, agro-industries and eco-tourism.

Finally, displacing fossil fuel power production from the highly urbanized coast will reduce greenhouse gas emissions by 61% and is expected to save $6.4 billion in health care costs over 10 Years. This has become an urgent imperative given the skyrocketing increase in the incidences of cancer and pulmonary-related diseases in the areas affected by the current fossil fuel plants. The rapid deployment of the smart grid will also accelerate the adoption of electrical vehicles. Fueled by clean energy, this will further reduce the need for imported fuel while substantially improving air quality.

The Green Revolution can contribute to the country's path out of the current economic crisis by preserving hard currency, reducing the government budget deficit, stimulating the economy, preserving the environment and improving the welfare of the population.

By simply switching the paradigm, embracing bold actions and moving away from how we have traditionally done things, we can leverage green energy as the stepping stone to launch a major revival of the country. It will solve the current energy crisis and will lead Lebanon into a more prosperous and healthier future.

The Lebanese Foundation for Renewable Energy (LFRE) launched an initiative in collaboration with AUB, Strategy& and CNRS to promote green energy solutions for Lebanon's energy crisis and evaluate their economic, environmental and social impact. LFRE's members are energy specialists, academics, financiers, engineers, lawyers and business people from both the public and private sectors working benevolently for a better Lebanon.

Unless quoted otherwise, the report published by Strategy&/AUB/LFRE in May 2019 'Lebanon's Electricity Sector –Leapfrogging to Higher Penetration of Renewables' is the source of the data and statistics provided in this paper.

*'Jordan a case study in renewable energy development' by Jessica Obeid: https://castlereagh.net/jordan-a-case-study-in-renewable-energy-development.

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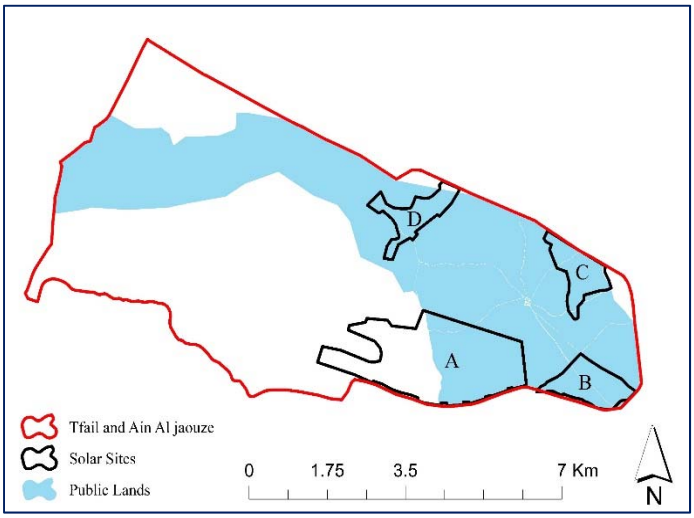
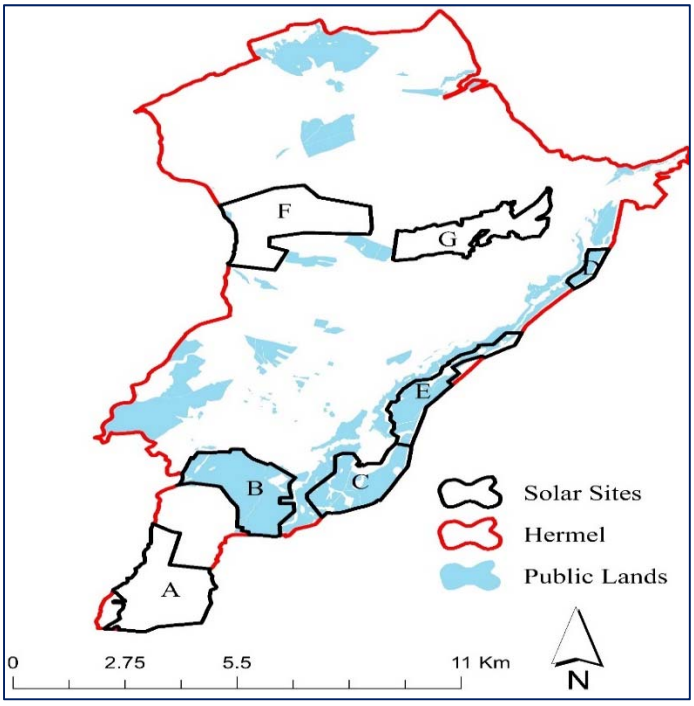
ANNEX A:
2022 EMERGENCY PLAN

Solar Plants:	**1470 MW**
Current 15 MW tender:	180 MW
Hermel Site:	650 MW
Tfail Site:	640 MW

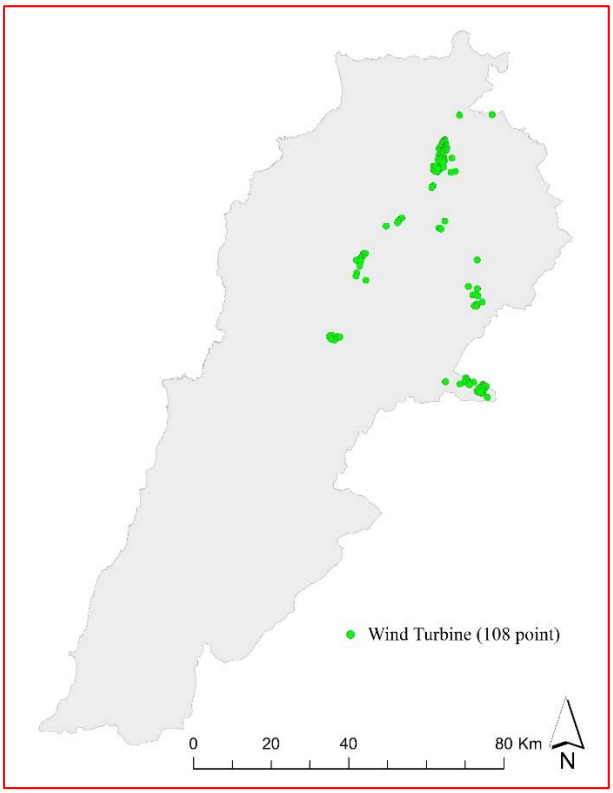
Source: CNRS/LFRE



Map 3: Tfail Solar Site
Source: CNRS/LFRE



Map 4: Hermel Solar Site

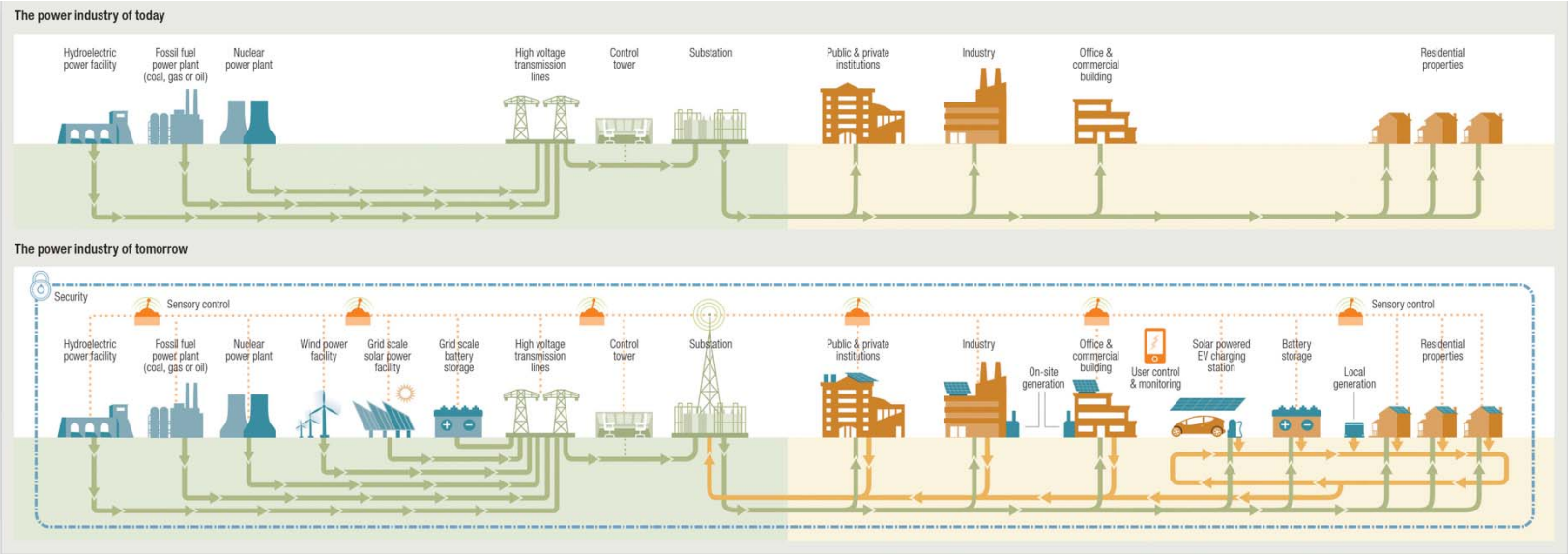


Map 5: Top Tier Wind Sites
Source: CNRS/LFRE

Wind Farms:	**620 MW**
Current Akkar tender:	180 MW
108 Top Tier Turbines:	400 MW

Storage:	**350 MWh**

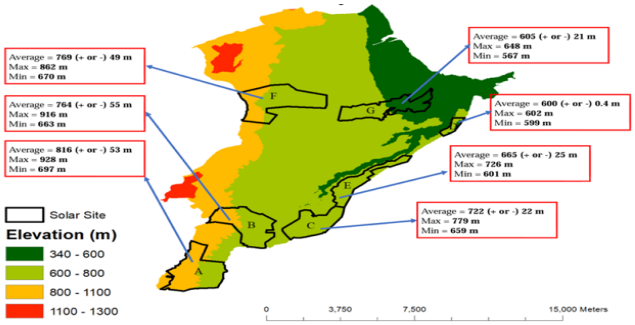
ANNEX B:
POWER INDUSTRY:
TODAY VS. TOMORROW



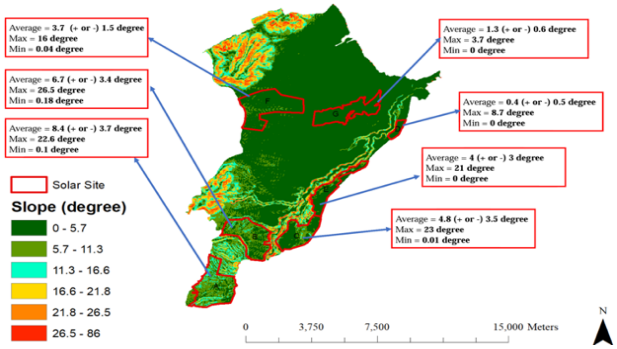
Source: Fortnightly Magazine - October 2015

ANNEX C: SOLAR SITES SELECTION METHODOLOGY

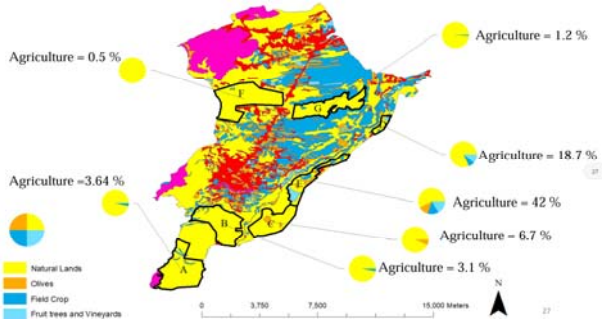
1. Elevation



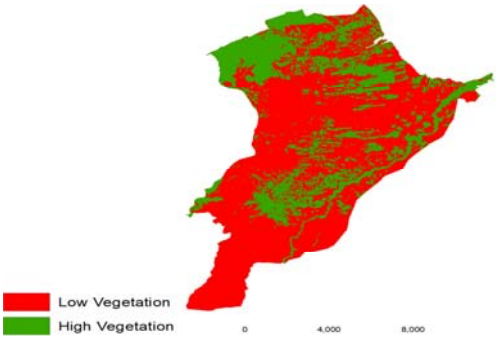
2. Slope



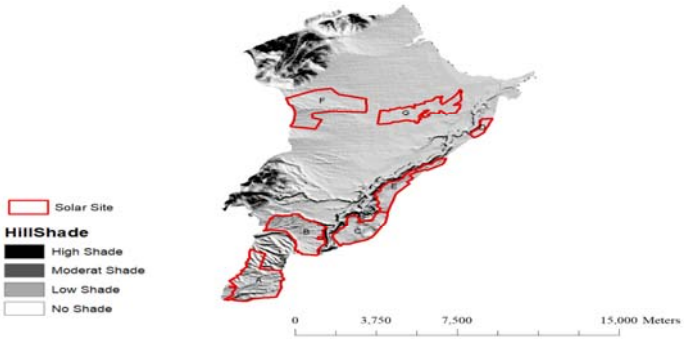
3. Agriculture



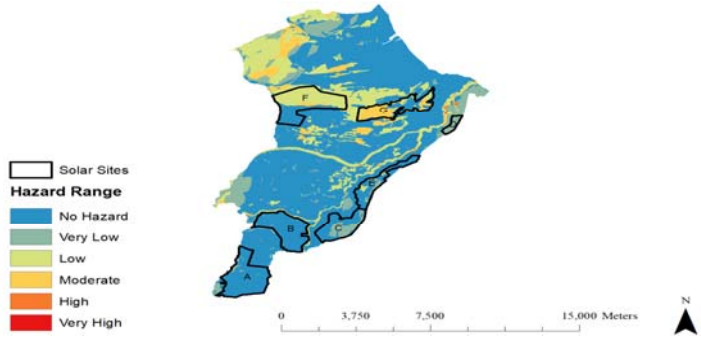
4. Vegetation



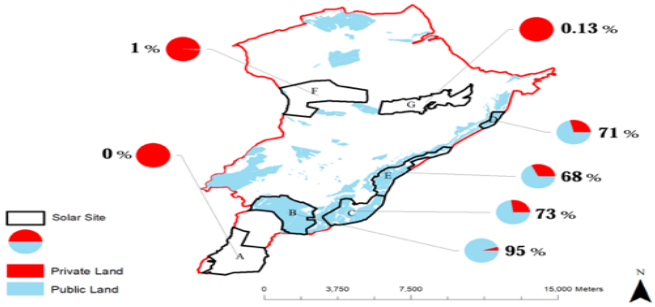
5. Shade



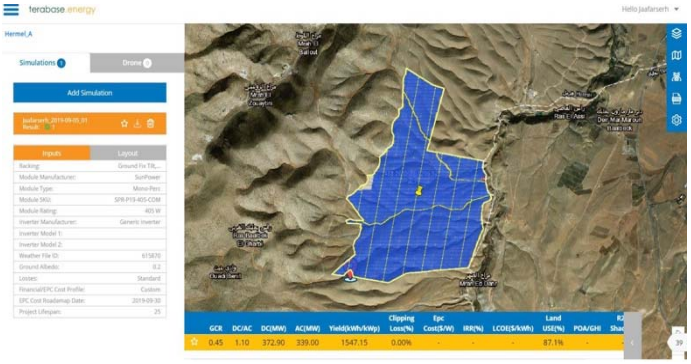
6. Hazard



7. Land Ownership

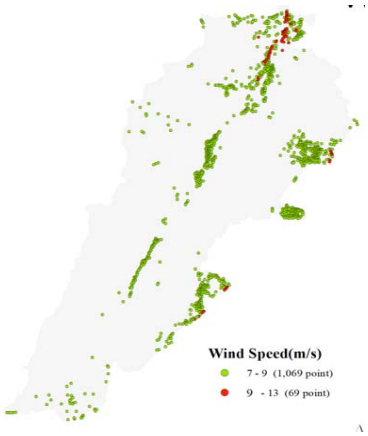


8. Plant Mapping

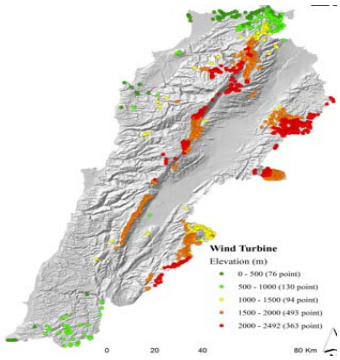


ANNEX D: WIND SITES SELECTION METHODOLOGY

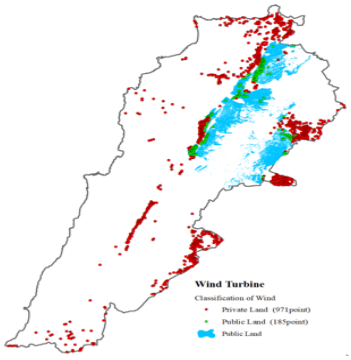
1. Wind Speed



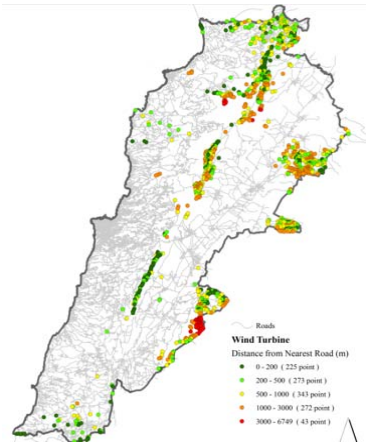
2. Elevation



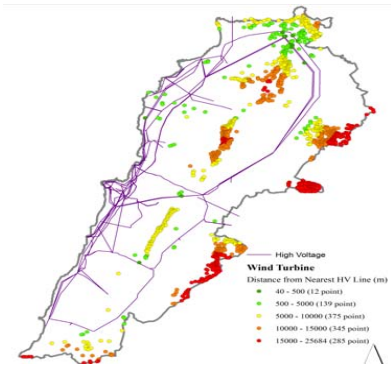
3. Public Land



4. Accessibility



5. Grid Proximity



6. Wind Turbine Selection

Rated power	4,600 kW
Rotor diameter	160 m
Hub height in meter	120 / 143 / 166
Wind class (IEC)	IEC IIIA
WEC concept	Gearless, variable speed, full power converter

Source : CNRS/LFRE