The Case For Distributed Renewable Energy In Developing Countries (Case Study Lebanon)

Cambridge Energy Solutions

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Thank You

This paper draws on work developed at CES and reports published by the World Bank, Lazard, BloombergNEF, and other organizations as documented with each graph.

Many individuals have provided helpful comments, especially: Mr. Nicholas Al Nakhl, Dr. Nabil Bitar, Mr. Bassem Boughannam, Mr. Joe Cavicchi, Dr. Riad Chedid, Dr. Najib Dandachi, Ms. Rosallie Matta, Mr. Dennis Meany, Dr. Saad Mneimneh, Dr. Firas Zebian.

The views presented here are not necessarily attributable to any of those mentioned, and the remaining errors are solely the responsibility of the authors.

About CES

- Cambridge Energy Solutions is a software company with a mission to develop software tools for the participants in electric power markets

- CES-US provides information and tools to assist market participants in analyzing the electricity markets on a locational basis, forecast and value transmission congestion, and to understand the fundamental drivers of short- and long-term energy prices

- CES-US staff are experts on market structures in the US, system operation and related information technology

The Story

- We have received many requests from friends, family, and the industry to address some of the chronic problems facing the Lebanese electric power sector
    - We decided to publish this presentation and **request comments and feedback** from friends in academia and industry in both the US and across the world
- In this presentation:
    - We make the case for distributed utility-scale (large-scale) renewable energy (focusing on Solar PV for Lebanon) as the most efficient, economic, and cleanest source for electricity
    - We discuss the benefits of distributed large scale renewable projects to first meet the incremental needs of demand growth and later displace and replace existing high cost, inefficient and dirty power plants while addressing the issues of intermittency and reliability through energy storage (as a next step)
    - For countries with power shortages and frequent power interruptions, we propose the initial objective should be to reduce rather than eliminate these outages in order to lower the economic cost of unmet energy demand without "gold-plating" the electric system
- Renewable energy is the cheapest and cleanest energy source, can be built in much shorter time periods than traditional thermal generation, and has numerous socio-economic benefits
    - Incentivizes economic development, reduces cost of imported fuel, creates new job opportunities, and reduces healthcare costs

Presentation Outline

- Executive Summary
  - Current Situation – 2017
  - Proposed EDL Plan
  - Our Recommendations
  - Benefits
- Renewable Energy
  - The Cheapest
  - The Cleanest
  - T&D Avoided Costs
  - Distributed, Scalable and Co-located
  - Economic Impact
- Renewable Resources
  - Demand vs Renewable Generation Hourly Shape
  - Wind Resource – Onshore & Offshore
- Resource Planning
  - Optimal mix
  - Cost vs Reliability
  - Integrated Resource Planning
- Appendix A: Levelized Cost of Energy and Capital Cost Comparison
- Appendix B: EDL Proposed Plan and Potential Annual Savings

Executive Summary

Executive Summary – Current Situation: 2017

- Lebanon is plagued with electricity shortages
  - More than 30% of the demand is unserved due to insufficient generation capacity
  - 2200 MW Capacity (further derated to average of 1700 MW in 2017) vs. demand of more than 3500 MW
- High cost of generating electricity
  - Between $0.085/kWh and $0.17/kWh depending on unit and fuel type and price, equivalent $85/MWh to $170/MWh
  - Distributed diesel generation is spread throughout the country (hundreds of generators with less than 1 MW capacity, each with its own distribution lines (these are De facto legal, have very high cost ~$300/MWh, cause high air, land, sound and visual pollution)
- High technical and non-technical losses, 14% and 20% respectively (total 34%)
- Low collection to billings, around one third of billed MWh are not collected
- No accurate accounting: "According to EDL there is another $400m (or thereabouts) unaccounted for" in 2017
- Electricité Du Liban (EDL) relies on government subsidies-- around $1.3Billion in 2017
  - See Appendix B for more information

***2017 is the latest year with full data available,*

the current situation is even worse in terms of outages

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Executive Summary – Current Situation: 2017

Cost Of IPPs

- In 2017, the floating barges at Zouk and Jieh, each with capacity of 187 MW, generated a total of 1,536,262 MWh at a cost of $71/MWh (non-fuel cost) for a total "renting" cost of $107.54 Million
- The total cost of generation from each floating barge including fuel is around $140/MWh
- This annual payment to rent each barge is very high compared to the cost of building a new simple cycle unit (similar technology and same capacity) at cost of $130.9 Million. (187MW*700*1000): Capacity in MW times capital cost per MW
- Every year EDL is paying for each barge 82% of the cost of building new unit ($107.54 Million compared to $130.9 Million)

Executive Summary – Proposed EDL Plan

"Approximately 2,600 MW of new LNG-fired CCGT plants over the next 10 years.
1,050 MW of 'fast-track' generation, such as LNG-fired containerised reciprocating engines. This fast-track generation can theoretically be commissioned in 2020 (initially running on fuel oil) and be in place till around 2024, once most of the CCGT is commissioned.
Approximately 1,500 MW of new renewable capacity, comprising mostly solar PV and wind, but also a small amount of new hydro."

Source: "LEBANON COST-OF-SERVICE AND TARIFF DESIGN STUDY", Final report, MAY 2020, World Bank Group

- Since EDL did not start working on 'fast-track' generation yet, commissioning in 2020 is impossible

Executive Summary – Proposed EDL Plan

Source: "LEBANON COST-OF-SERVICE AND TARIFF DESIGN STUDY"
Final report, MAY 2020, World Bank Group

Table 6 Base case – planned generation expansion

Name	Design capacity (MW)	Max capacity factor (%)	Technology	First year	End year
Fast-track generation					
Fast Track Deir Amar	450	90%	Recip	2020	2024
Fast Track Jieh	100	90%	Recip	2020	2024
Fast Track Zahrani	400	90%	Recip	2020	2024
Fast Track Bint Jbeil	50	90%	Recip	2020	2024
Fast Track Jib Jannine	50	90%	Recip	2020	2024
Gas turbines					
DAPPII PPA (OC)	360	89%	OCGT	2022	2022
DAPPII PPA (CC)	550	89%	CCGT	2023	2028
Zahrani II CCPP (OC)	430	89%	OCGT	2022	2022
Zahrani II CCPP (CC)	650	89%	CCGT	2023	2028
Selaata I CCPP (OC)	500	89%	OCGT	2022	2022
Selaata I CCPP (CC)	740	89%	CCGT	2023	2028
Jieh New CCPP (OC)	360	89%	OCGT	2025	2028
Zouk New CCPP (OC)	360	89%	OCGT	2024	2028
Renewables					
New wind 1	200	40%	Wind	2021	202[illegible]
New wind 2	400	40%	Wind	2024	20[illegible]
New PV 1	180	18%	Solar	2020	20[illegible]
New PV 2	300	18%	Solar	2023	20[illegible]
New PV 3	360	18%	Solar	2024	20[illegible]
Janneh Hydro	54	58%	Hydro	2022	20[illegible]
New Hydro (Daraya, Chamra, Yamouneh, Blat)	33	50%	Hydro	2021	20[illegible]

Executive Summary – Our Recommendations

- Utility/Large-Scale distributed solar power
  - Initial investment of $2.25 Billion for total of 2500 MW solar PV capacity
  - Need to start building solar farms immediately (individual projects can be finished in 12 months)
  - EDL or the government do not need any additional funds to build these projects, the funds that will be used over the next two years to buy fuel oil and diesel can be repurposed to build these projects. The money will be spent, either for the cost of fuel oil for two years, or to realize benefits from these projects for the next 20 years
  - No need to wait for other investors
- Use the new solar and existing capacity to provide electricity during day time, displacing the private diesel generators and inefficient EDL units
- Dispatch hydro and reciprocating engine units to support solar in the early evenings
- Use existing generation capacity (including distributed Diesel units) to provide electricity during night time and when solar generation is low

Executive Summary – Our Recommendations

- Replace the need for the 'fast track' temporary generation with solar capacity
  - Save the capital investment and operating costs for the 1050 MW of "fast track" generation
- Replace the capacity from the two barges with new generation at Deir Ammar
  - Build 400 MW Simple Cycle unit at a cost of $280 Million (construction time within 12-18 months, then convert to Combined Cycle with 200 MW additional capacity)
  - Build LNG facility and convert the entire Deir Ammar to LNG (total 1100 MW)
- Future investments in **Solar + Storage** to meet demand at night and gradually retire inefficient generation starting with private distributed diesel followed by EDL inefficient steam units, as cost of storage continue to decrease
  - Study building more generation at Zahrani (first simple cycle, then convert to combined cycle with LNG for the entire plant) versus adding solar+storage; dependent on LNG prices, oil fuel prices, and cost of storage
- There are limited opportunities for offshore wind, and maybe some for onshore wind. If economic, onshore wind could be helpful as a supply diversity

Executive Summary – Benefits

- For a total investment cost of $2.53 Billion, annual savings of $1.445 Billion can be achieved with payback period of less than 2 years
  - The addition of solar capacity at investment cost of $2.25 Billion yields annual savings of around $1.27 Billion
  - The replacement of the barges with the simple cycle unit, at investment cost of $280 Million, yields operational savings of around $175 Million, ($142/MWh-$85/MWh) * 3.07TWh
- Additional savings of $1 Billion by avoiding the investment cost of the temporary 'fast track' generation
- The annual savings of the proposed solar compared to EDL expansion plan is $571.59 Million
- The new solar capacity lowers dependency on distributed diesel generation and produces enough energy to meet total unserved 6.4TWh of demand
  - The distributed diesel generation will be still needed during evening hours with high demand
- Reduce, but not eliminate, power interruptions and reduce unserved demand
- Time is of essence, the faster these projects are online the higher the savings

Executive Summary – Additional Benefits

- Lower pollution and reduced carbon footprint
- Lower cost of health care and drag on the economy (tourism, sick days, etc.)
- Lower electricity prices to household consumers
- Lower operating cost for economic sectors
- Reduce the need for existing subsidies
- Reduce trade balance deficit
- Public/Private Sector partnerships
- Low development and capital risks
- Better quality of life
- Potential for CO_2 credits from developed countries

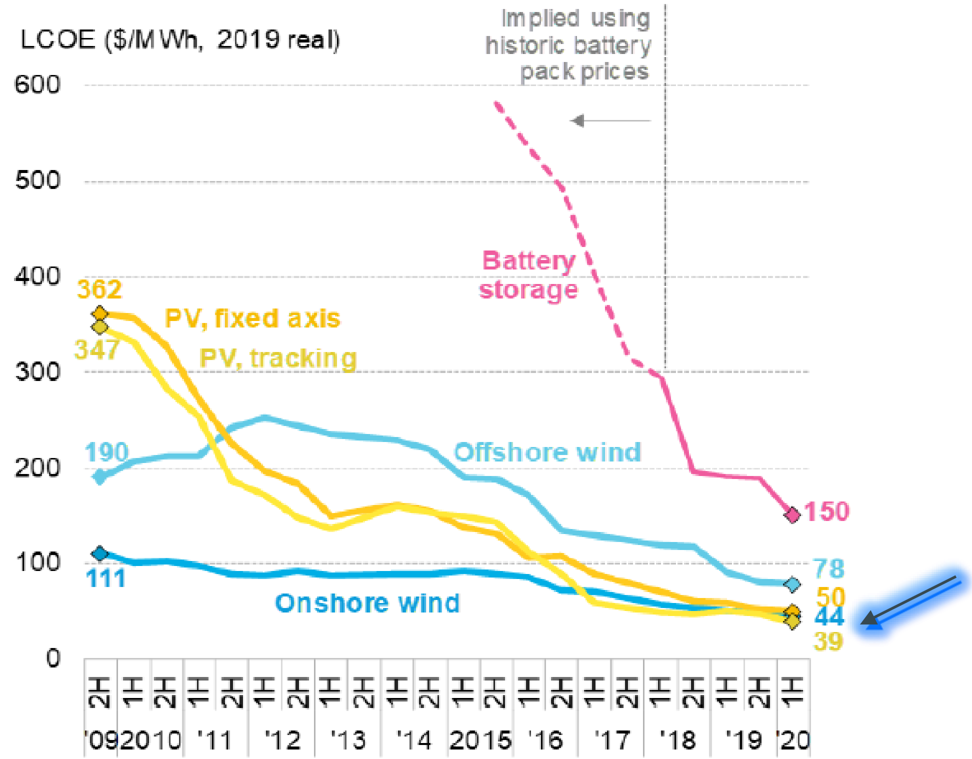
Renewable Energy

Detailed Analysis

Renewable Energy - The Cheapest

- The all-in cost of producing electricity from renewable sources ranges between $40/MWh to $80/MWh (with solar PV falling on the low side of the range) compared to operating cost of $100- $170/MWh from fuel oil (FO) based thermal generation
  - The use of FO is necessary for many countries with no natural gas (NG) production or infrastructure
  - Studying the switch from FO to NG as transition fuel or directly to renewables should be a first priority: keep burning FO vs. switching to NG vs. **all renewables plus storage**
- The cost of energy from renewable sources has been significantly declining for the past 20 years through technological advancement and mass-production
  - This requires electric power planners and policy makers to review their plans and studies on annual basis to capture the savings from new technologies
- The all-in cost can vary by country and region as environmental factors vary; however, solar is largely considered a good resource in the middle east (see slide 26: Lebanese Solar Resource Map)

Figure 2: Global LCOE benchmarks – PV, wind and batteries



Source: BloombergNEF. Note: The global benchmark is a country weighted-average using the latest annual capacity additions. The storage LCOE is reflective of utility-scale projects with four-hour duration, it includes charging costs.

LCOE measures the all-in expense of producing one MWh of electricity from a new project, taking into account costs of development, construction and equipment, financing, feedstock, operation and maintenance.

Renewable Energy - The Cleanest

- Renewable energy sources do not emit any pollutant
  - Fossil thermal power plants emit CO_2, NO_x, SO_x, Mercury, and particulates to varying levels depending on the power plant technology, age, type of fuel burned, heat rate, etc.
  - Environmental-control technologies, such as scrubbers, used to limit the environmental impact of fossil power plants are expensive, increase inefficiency, and are unlikely to be fully implemented in developing countries
- Renewable energy sources do not need a water resource
  - Does not have the siting limitation of water availability
  - Does not adversely affect the water ecosystem by raising the temperature of the nearby water surface when used for cooling
- The positive societal impact and savings (in terms of reducing the country's health cost bill) can be significant by improving the health of the citizens, especially those living near the large thermal and small distributed diesel generation areas

Renewable Energy - T&D Avoided Costs

- Siting 1000 – 2500MW of new fossil fuel generation incurs significant additional costs
  - Need to identify viable site with water access, fuel-delivery access, ideally low population density to limit health impacts
  - Cost of new transmission and distribution construction to deliver power from identified site
  - Cost of technical losses to transmit the energy to the demand centers
- Solar farms can be built in small, distributed projects, from 20 MW to 50 MW, to avoid transmission and distribution costs
  - Locating these 50 projects (for 1000 – 2500MW total) near the demand centers (towns and small cities with no negative health impacts) reduces
    - the capital cost associated with new transmission and distribution construction
    - as well as the technical losses
  - Reducing new line construction combined with lowering power flows on existing lines reduces the need for land in and around urban areas (T&D right-of-way) and can limit the environmental impact of electromagnetic fields on local communities

Renewable Energy - Distributed, Scalable and Co-located

- Solar farms are easily scalable, during both project development as well as post-operational expansion, depending on siting and economic factors
  - Smaller projects (2 MW to 20 MW) can be utilized if there are no significant economies of scale, opportunity for additional deferred distribution upgrades, requirement of lower capital cost per project, or availability of smaller plots of land
  - Larger projects (50 MW to 500 MW) can be utilized at locations that require low interconnection costs and close to major transmission lines that can easily deliver to demand centers
- Can be co-located with existing structures such as commercial industrial and residential building rooftops, parking lots, on water surfaces (lakes and ponds, e.g. Qaraoun), reclaimed landfill (Naameh), abandoned quarries or on land with limited alternative use (drylands, rocky areas, etc..)

Renewable Energy – Economic Impact

Benefits & Savings

- Lowering electricity prices while increasing availability and reliability will have a large positive economic impact across all sectors: residential, commercial, and industrial
  - Increased residential quality of life and reduced cost of living resulting in increased productivity and disposable income
  - Reduced operating cost for manufacturing, tourism, services, etc. resulting in increased competitiveness and profitability
- Relieve treasury and government from direct and indirect subsidies to the power companies, allowing additional government funding to be directed to social programs
- Reduce the trade balance deficit driven fuel oil imports by around $1Billon to $2Billion depending on the price of the fuel oil and power generated at the thermal plants
- Can be developed by the private sector (domestic and/or foreign) and equitability financially secured through Power Purchase Agreements (based on price in $/MWh)
- Can be developed as a diverse portfolio of smaller projects
  - Reduces the risk of investment associated with any individual project
  - Reduces the need for financial guarantees (typically needed for large generation development projects)
  - Allows for steady, incremental development with observable benefits due to reduced project development time and reduced up-front capital costs
  - Allows for stronger competition and higher number of project developers
- Investigate the potential to get CO2 credits from developed countries (EU ETS offset markets)

Renewable Energy – Economic Impact

Opening Markets

- Incentivizes the development of new companies that focus on the design, planning, and construction of renewable generation projects
- Creates new jobs for citizens in an advanced field, using cutting-edge technology with wide-ranging applications
- Employs a wide range of services
  - Skilled manual labor
  - Civil, electrical, mechanical, computer, and environmental engineers
  - Financial professionals and data analysts
- Open markets in neighboring regions and countries for skilled labor and experienced companies
- Allow for the export of design, planning, and construction services

Renewable Resources

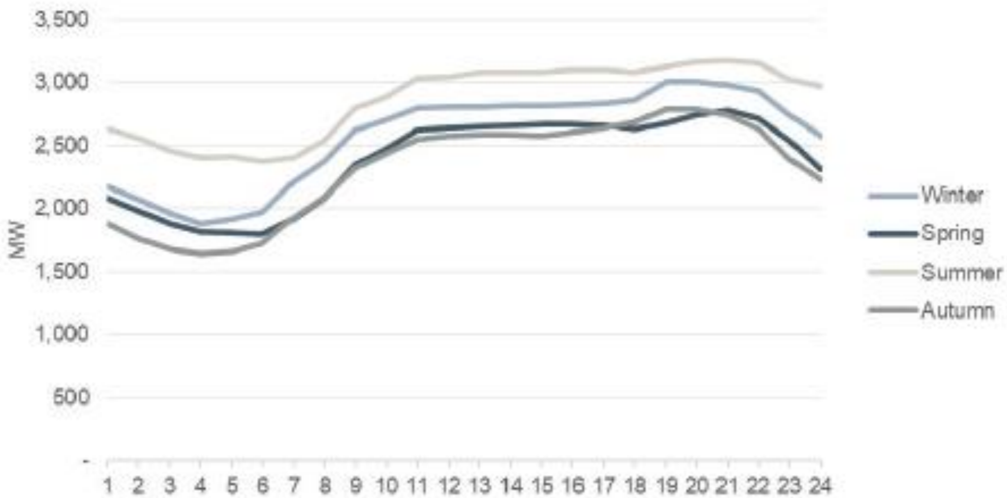
Solar & Wind Availability/Factors

Solar Generation vs Demand Shape

- Solar renewable generation benefits from an hourly generation shape that is generally coincident with a country's or region's demand shape driven by solar-thermal heating
  - Additional renewable resources (wind, dispatchable hydro) along with existing flexible thermal resources (gas turbines, small distributed diesel) can be utilized to meet the demand during high-demand peak hours
  - While the existing thermal generation will be required in the short-term, the development of economic storage combined with PV solar can eventually replace most of the existing inefficient units in serving the peak demand
- Both the demand and renewable generation hourly shapes vary by season and the need for storage and/or supporting generation varies as well
  - Demand side management can help reduce demand during peak hours and avoid power interruption until more storage or price responsive demand is developed
  - Battery storage is the fastest to build but hydro pump storage projects (**large and small**) and other storage technologies like compressed air can be considered in the long term
- A detailed study using hourly demand, expected hourly solar and wind generation for a typical year is needed to study the optimal mix of these resources

Estimated hourly demand shape by season

A1.8 Estimated average demand by season, 2017



Note: Demand share is difficult to estimate due to demand shifting during outages

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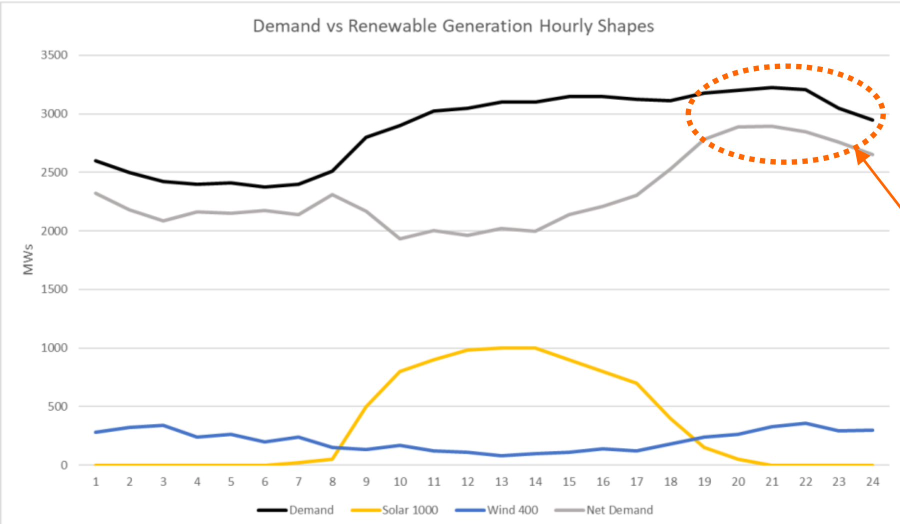
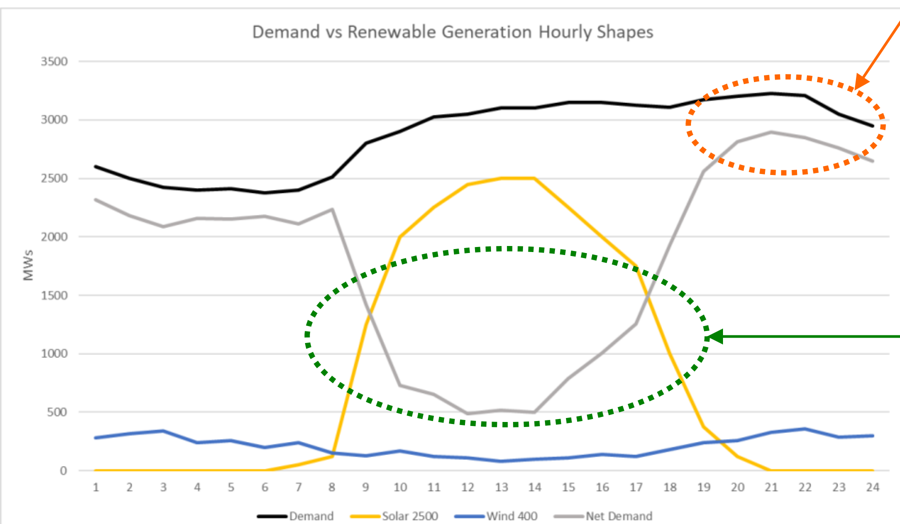
Hourly Demand vs Renewable Generation





Increased need for additional renewable (wind & hydro), flexible thermal, and new energy storage resources

Substantially reduced reliance on thermal resources

Lebanese Solar Resource Map

SOLAR RESOURCE MAP

PHOTOVOLTAIC POWER POTENTIAL

LEBANON

DESCRIPTION

This solar resource map provides a summary of estimated solar photovoltaic (PV) power generation potential. It represents the average daily/yearly totals of electricity production from a 1 kW-peak grid-connected solar PV power plant, calculated for a period of 20 recent years (1999-2018).

The PV system configuration consists of ground-based, free-standing structures with crystalline-silicon PV modules mounted at a fixed position, with optimum tilt to maximize yearly energy yield. The optimum tilt ranges from 26° to 33° towards the equator. Use of high efficiency inverters is assumed. The solar electricity calculation is based on high-resolution solar resource data and PV modeling software provided by Solargis.

The calculation takes into account solar radiation, air temperature, and terrain, to simulate the energy conversion and losses in the PV modules and other components of a PV power plant. In the simulation, losses due to dirt and soiling was estimated to be 3.5%. The cumulative effect of other conversion losses (inter-row shading, mismatch, inverters, cables, transformer, etc.) is assumed to be 7.5%. The power plant availability is considered to be 100%.

The underlying solar resource database is calculated from atmospheric and satellite data with a 30-minute time step, and a spatial resolution of 1000 m.

ABOUT

The World Bank Group has published this solar resource map using data from the Global Solar Atlas (GSA), to support the scale-up of solar power in our client countries. This work is funded by the Energy Sector Management Assistance Program (ESMAP), a multi-donor trust fund administered by The World Bank and supported by 18 donor partners. It is part of a global ESMAP initiative on Renewable Energy Resource Mapping that covers biomass, hydropower, solar and wind. This map has been prepared by Solargis, under contract to The World Bank, based on a solar resource database that Solargis owns and maintains.

To obtain additional maps and information, please visit:
http://globalsolaratlas.info

Map data sources:
Solar resource database and photovoltaic simulation software © 2019 Solargis • Administrative boundaries © 2016 Cartography unit, GSDPM, World Bank Group • Map data © 2016 OpenStreetMap.org contributors • Geonames.org • Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database (http://srtm.csi.cgiar.org) • Cartography © 2019 Solargis
Please refer to the GSA website for full citations of Map data sources https://globalsolaratlas.info/support.

Source: Global Solar Atlas 2.0 • Solargis database version: 2.1 • Map issue date: 2019-10-17

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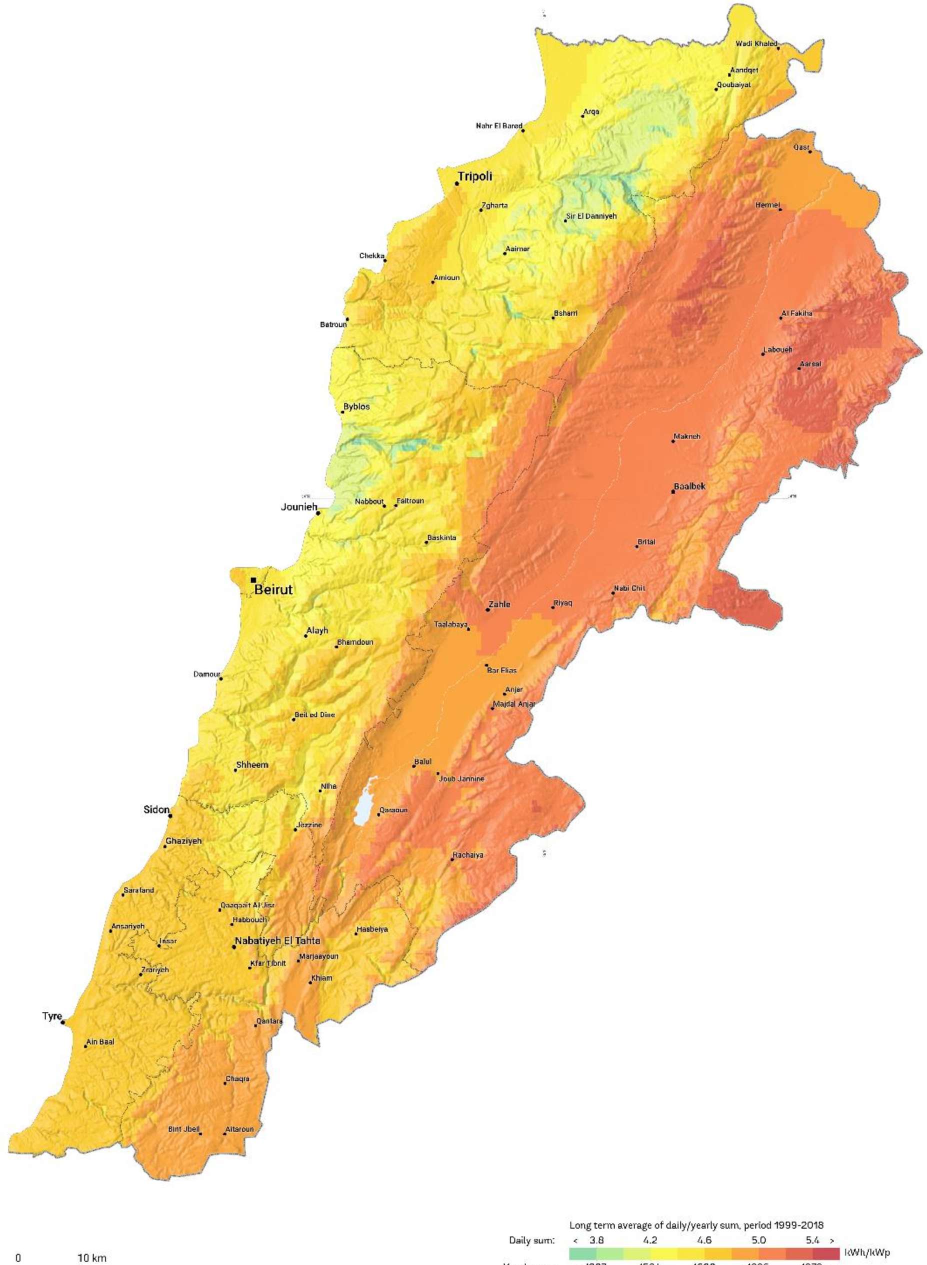
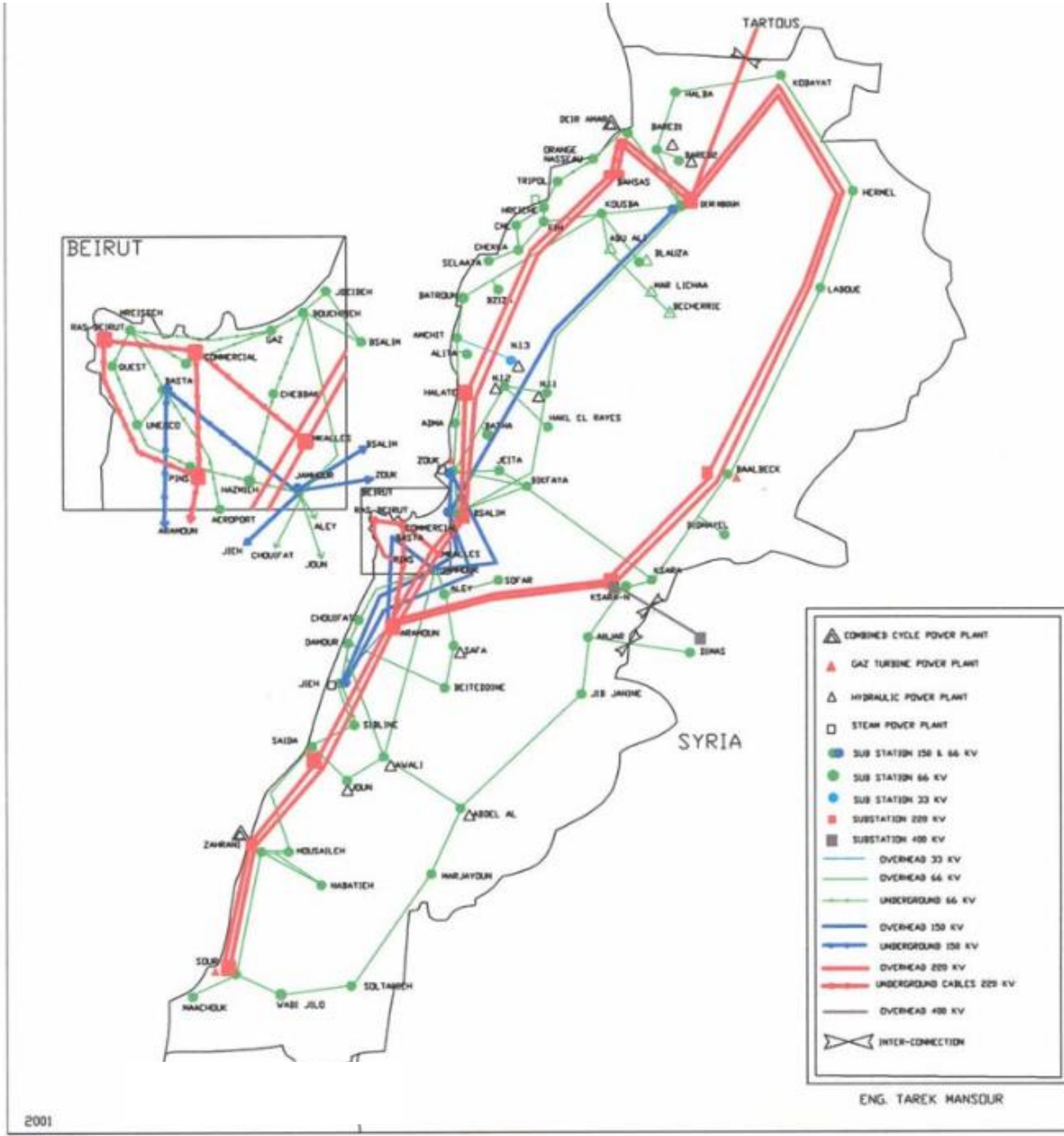
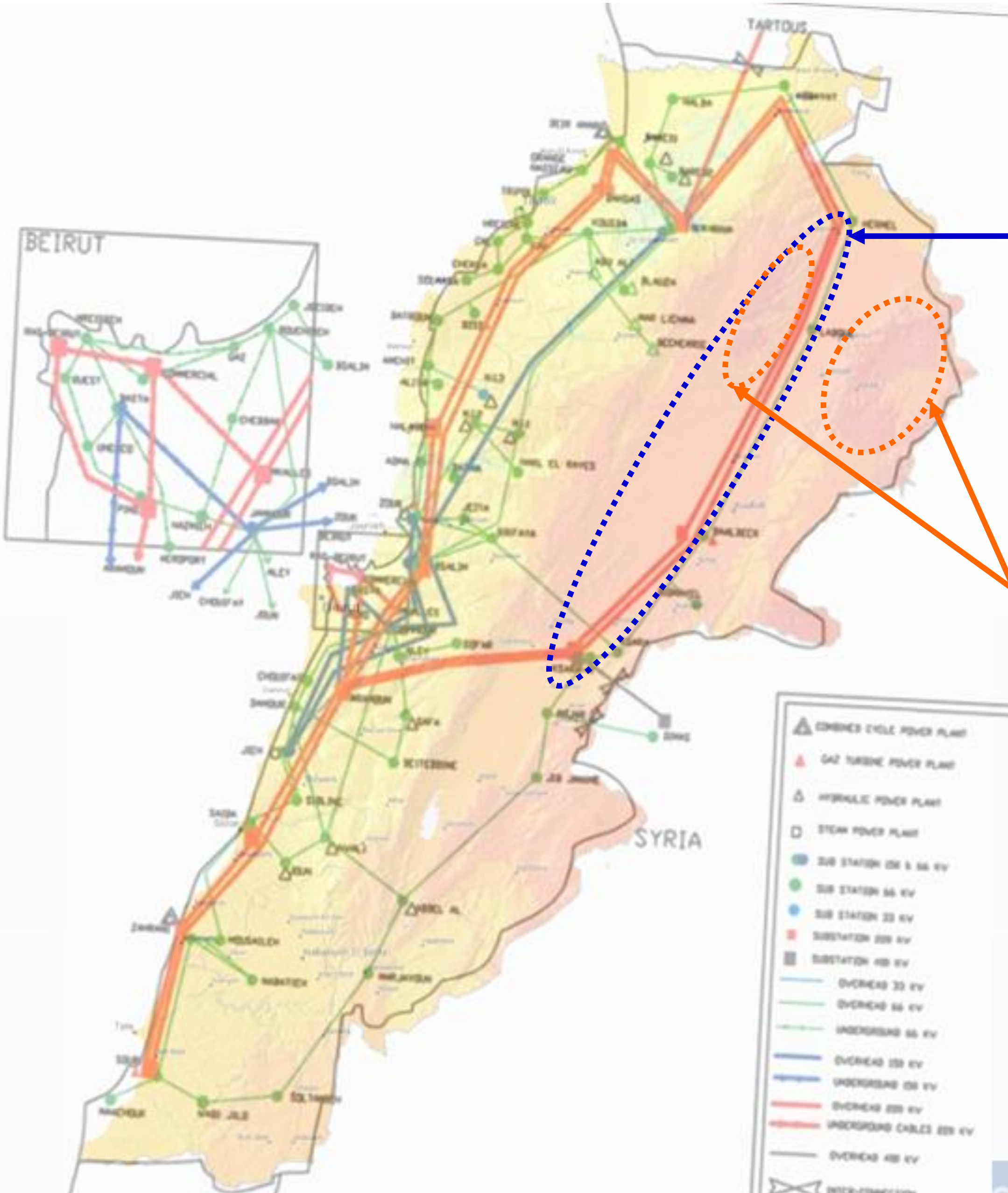
ESMAP SOLARGIS



Lebanese Electric Power Transmission Grid



Lebanese Solar Resource/Transmission Grid Overlay



220KV backbone transmission extends through sunny Bekaa Valley

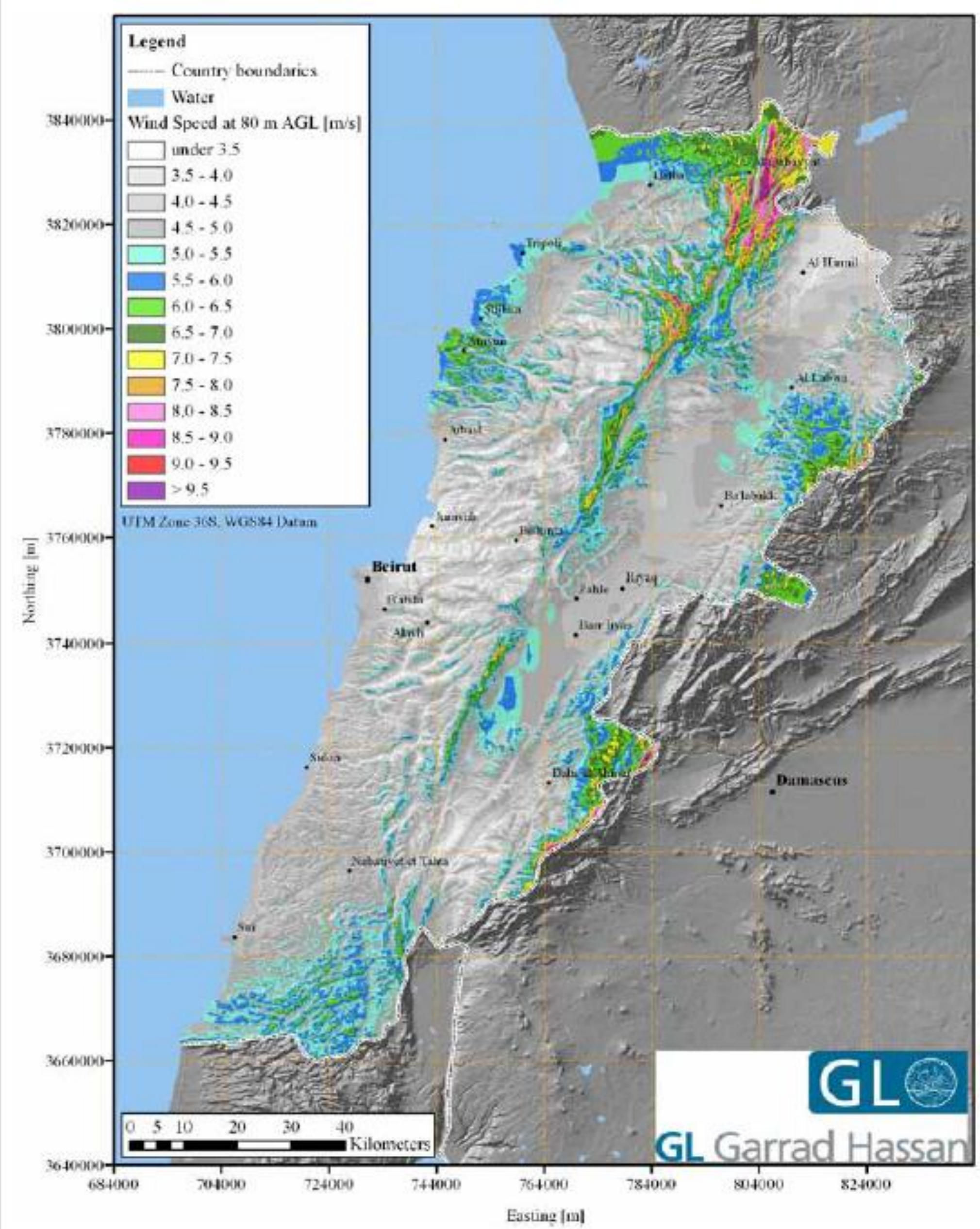
Radial high voltage taps could be utilized to reach areas with the highest solar resource

Wind Resources

Onshore & Offshore

- Wind resources can provide an hourly generation profile that is complimentary to solar resources
    - While wind has a less regular/reliable generation pattern than solar, a distributed mix of wind resources from differing geological regions can be utilized to mitigate large variation in availability
    - Off-shore wind typically has more regular/steady generation pattern and can be further relied upon but with increased capital development costs and complexity
    - Distributed off-shore wind can offset potential transmission and distribution costs by directly supporting coastal demand centers
    - The economies of scale is significantly stronger in wind projects which could discourage distributed projects, hence wind’s “complimentary” role to solar’s “backbone” of renewable energy resources
- Due to the uncertainty in wind generation profiles, supporting wind projects with energy storage (battery) can combine to create an effective alternative in transitioning from inefficient fossil generation sources
- A detailed study with actual wind measurements (for a year or more) is needed to analyze the potential for both onshore and offshore wind at various locations along the coast and throughout the country
    - Further study utilizing a detailed representation of the Lebanese electric power transmission system (.raw file), the latest wind Atlas map of Lebanon (with geocode if available), detailed information on Lebanese generation units (FOM, VOM, heat rates, etc.), hydro hourly generation schedules, and an approximated expected hourly demand shape are needed for a full study of economic feasibility for wind projects and other alternatives using our DAYZER Software

The National Wind Atlas of Lebanon



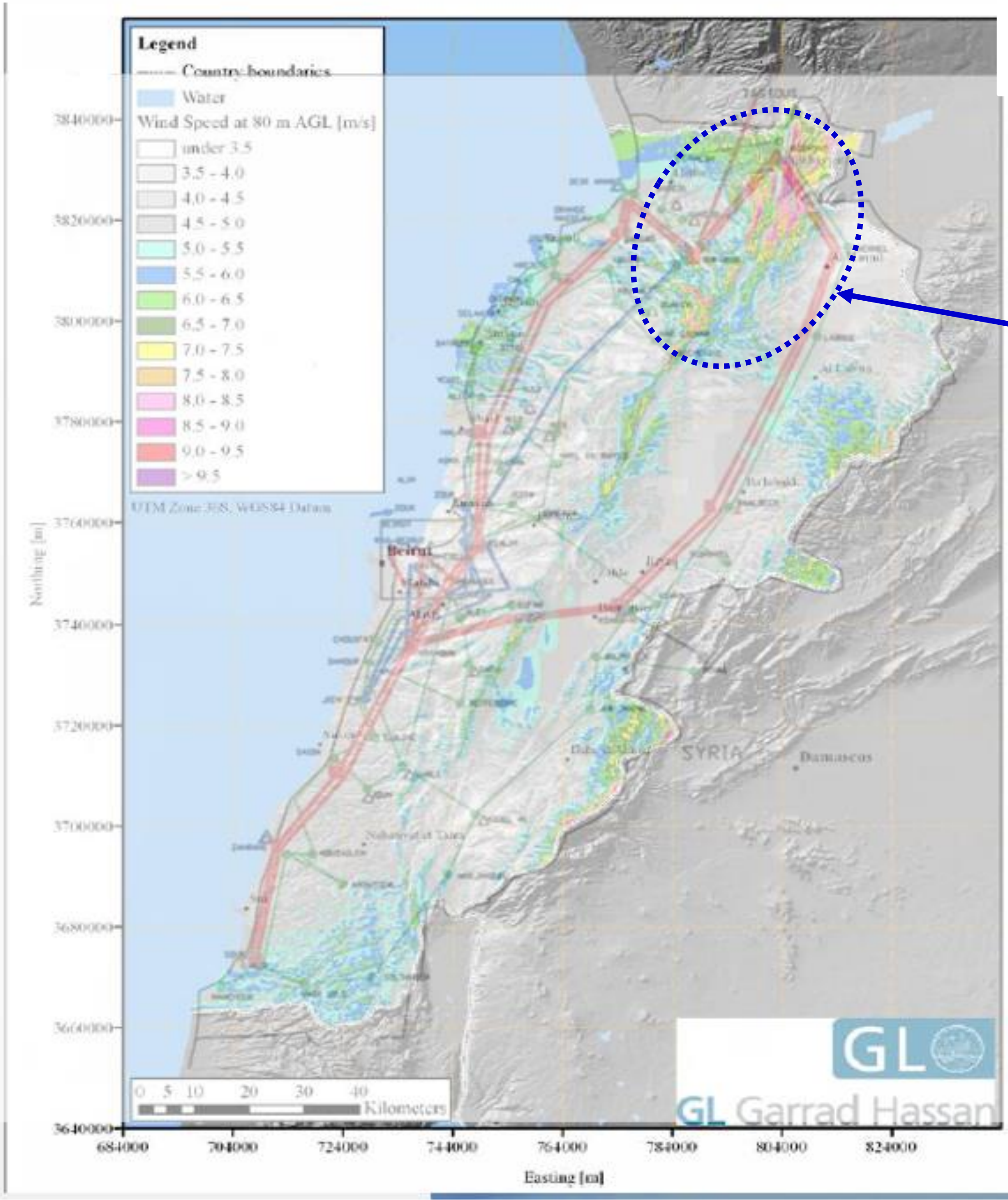
The variation in wind speed is predicted and calibrated based on measurements at few locations (17 locations, only 5 had hourly wind speed data) at 10 meters above ground level, without actual wind shear, but rather modeled shear values.

"The wind flow at 10 m above ground level is subject to significant effects from small local terrain features. As a result this is generally considered to be too low to give a reliable indication of the wind speed at typical turbine hub heights." p.14

Areas with wind speed above 6.5 m/s at 80 m are good candidates for wind farms subject to other conditions on terrain and other factors.

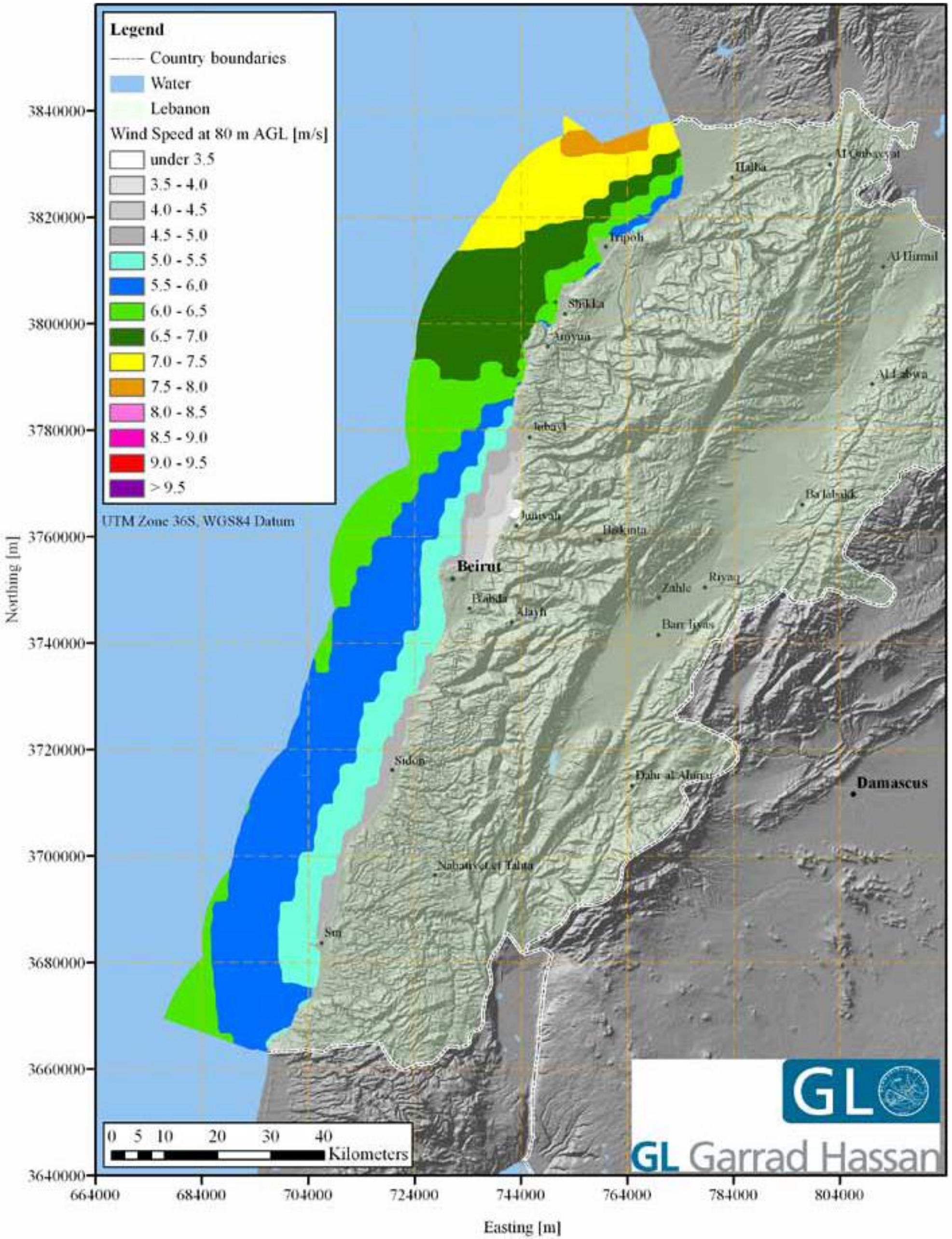
We are not sure if this study has been updated since 2011

Lebanese Wind Atlas/Transmission Grid Overlay



220KV backbone transmission extends through the wind-rich north areas

Lebanese Offshore Wind Estimate



The offshore wind speeds were estimated/predicted using models without offshore measurements.

Depending on the sea depth, different technologies can be utilized (floating versus fixed).

Based on wind speed and distance from shore, there appears to be limited opportunity for economic offshore wind development in Lebanon.

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Existing Wind Studies/Data Unreliable

- With the lack of reliability in the Wind Atlas and offshore wind estimation, we recommend a more detailed study effort to evaluate the viability of wind resources in Lebanon
    - Existing wind data sources might be helpful to provide an initial identification of areas with good wind resource
- A project specific study will be needed for any major offshore or onshore project to minimize investment risk
    - It would be prudent to conduct a detailed wind capacity study at proposed wind projects by measuring the hourly wind speed at the hub height level (80 m to 100m) for a period of at least one year before investing in any project

Resource Planning

Optimization & Reliability

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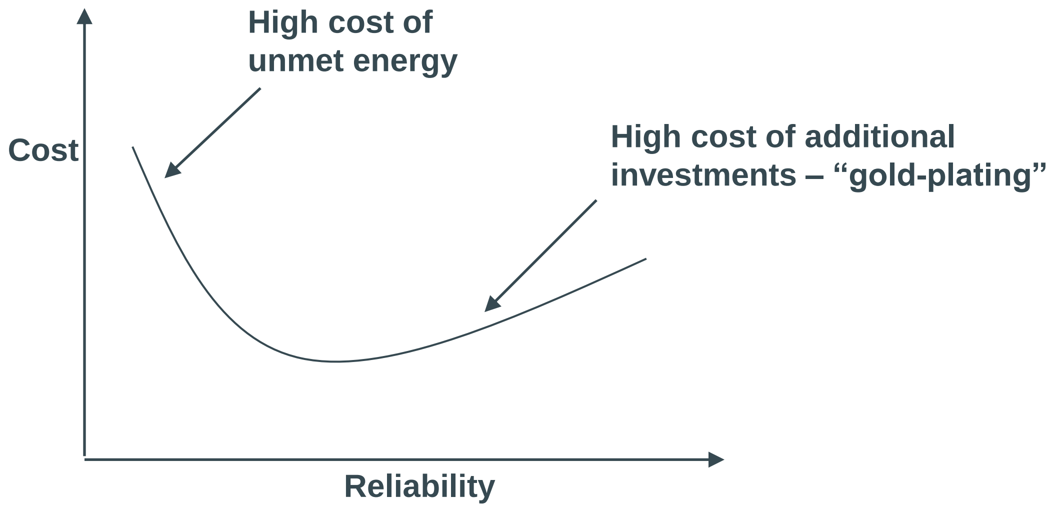
Optimal Generation Mix

How much renewable generation can the system handle?

- For countries with power shortages and frequent power interruptions, the initial objective would be to increase demand service availability and reliability to reduce rather than eliminate the outages
- In an idealized system, 100% of demand can be effectively supplied from renewable generation sources
  - This would require a diverse mix of renewable generation sources with complimentary hourly generation patterns, large investment in energy storage projects, and potential need for advanced power-control electronics (STATCOMs, synchronous condensers)
- In a realistic system, a strong solar generation “backbone” supported by complimentary renewable generation sources (wind/hydro) can effectively reduce electricity costs while increasing reliability and incrementally trend towards 100% renewable generation given sufficient energy storage investment
  - While the cost of developing energy storage projects is high in the short-term, existing thermal generation (and demand-side management) can be utilized to support the renewables during night and/or low-wind hours
  - As the cost of storage continues declines over the next few years, additional storage can be incrementally added to the system to retire inefficient and dirty thermal generation
- For some countries, even at the current higher energy storage costs, the all-in cost of solar plus storage is lower than the operating cost of their existing oil fired units
  - This should indicate an immediate switch to solar and storage be strongly considered

Cost vs Reliability



- The economic cost of power outages is very high (at low reliability). The loss of power paralyzes the economy (industry, tourism, agriculture), could cause loss of life (at hospitals and sick people) and has severe impact on the quality of life of the people. Having local backup generation reduces the burden slightly but still at high cost (equipment cost, fuel cost and environmental cost)
- With more robust renewables and backup from existing generation, the outages and associated costs can be significantly reduced without incurring the high investment cost required for high reliability (have additional generation to meet installed reserves requirements)

Integrated Resource Planning

- Although this presentation focused on the generation supply side, it is also important consider the transmission and distribution systems along with demand to create a comprehensive plan of efficient system operation
    - Demand side management should be studied as an effective way to reduce total cost, increase operating efficiency, and reduce total/peak demand in a controlled manner
    - Proactive transmission and distribution operating guides resulting from detailed studies of the power system can mitigate and prevent instability and preventable demand loss during high-system-stress periods
- Planners and policy makers provide incentives for consumers to invest in energy efficiency
    - Incentivize efficient lights (LEDs) and appliances (AC, water pump, etc.)
    - Incentivize active energy consumption management (scarcity pricing) to avoid or reduce power interruption (turn off lights during the day, avoid water pumping during peak load hours, shift cooling from peak demand hours, etc.)

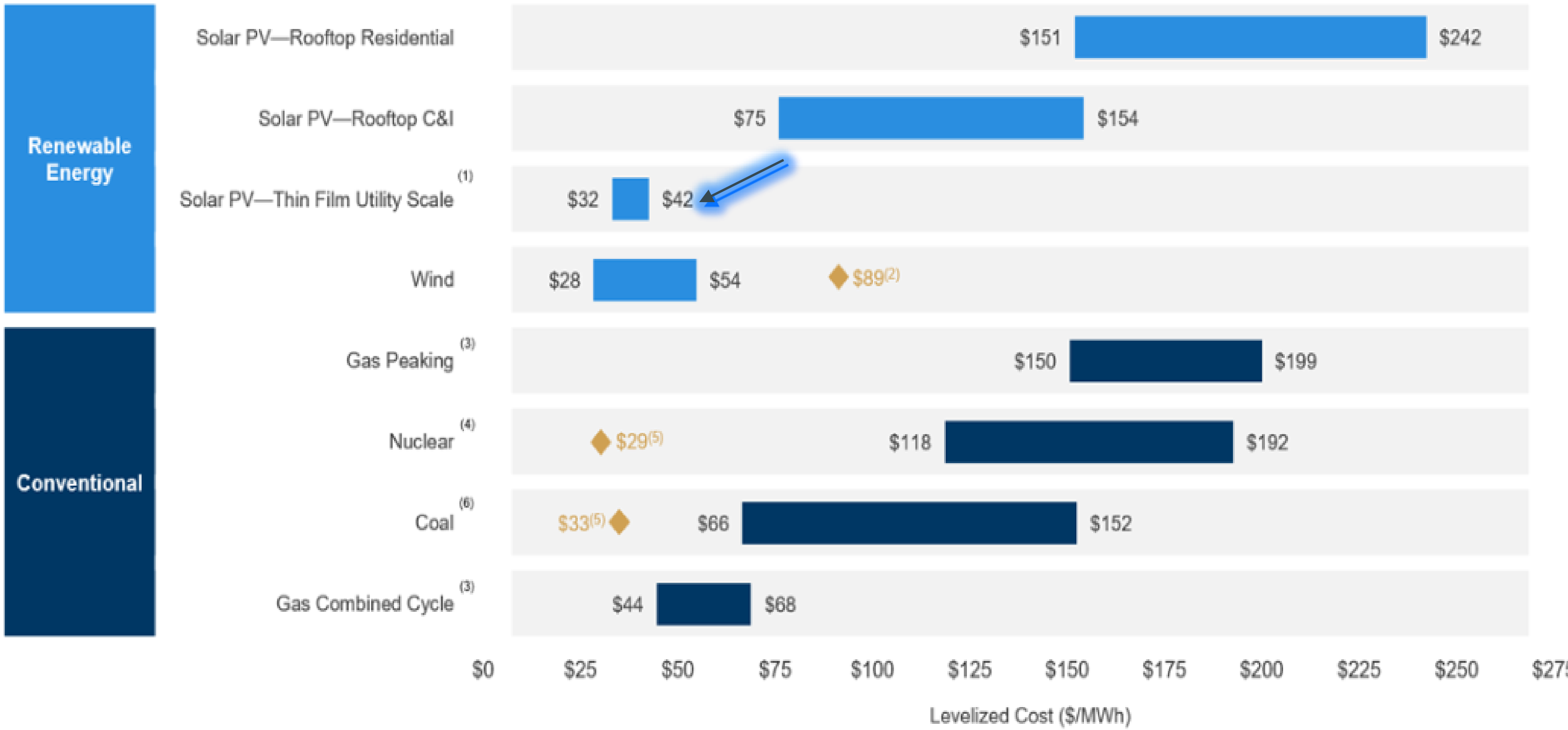
Appendix A

Levelized Cost of Energy and Capital Cost Comparison

https://www.lazard.com/perspective/lcoe2019

Levelized Cost of Energy Comparison—Unsubsidized Analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard estimates.*

Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities. These results are not intended to represent any particular geography. Please see page titled "Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets" for regional sensitives to selected technologies.

(1) Unless otherwise indicated herein, the low end represents a single-axis tracking system and the high end represents a fixed-tilt system.

(2) Represents the estimated implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2.33 – $3.53 per watt.

(3) The fuel cost assumption for Lazard's global, unsubsidized analysis for gas-fired generation resources is $3.45/MMBTU.

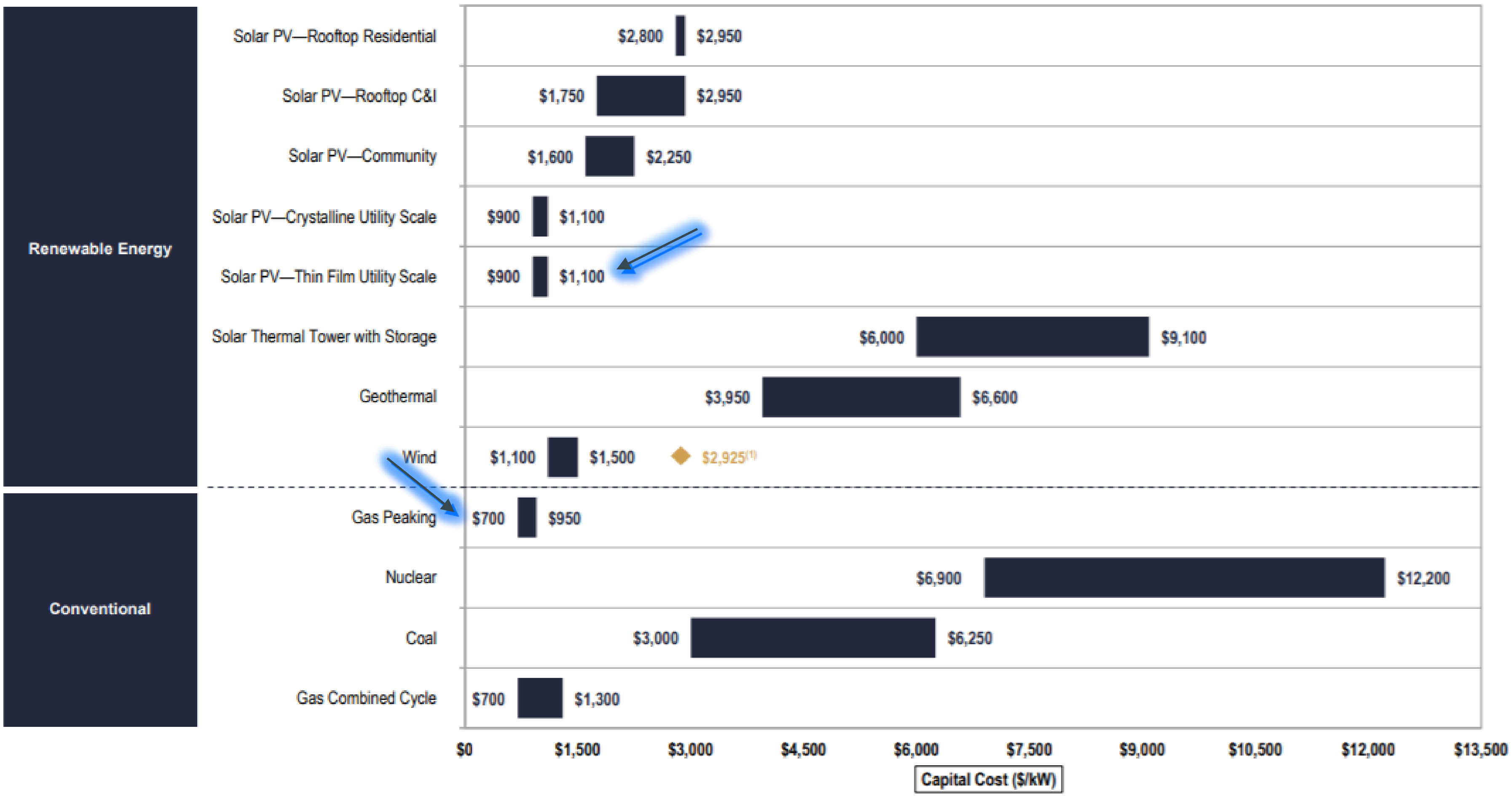
(4) Unless otherwise indicated, the analysis herein does not reflect decommissioning costs, ongoing maintenance-related capital expenditures or the potential economic impacts of federal loan guarantees or other subsidies.

(5) Represents the midpoint of the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned coal plant is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating coal and nuclear assets across the U.S. Capacity factors, fuel and variable and fixed operating expenses are based on upper and lower quartile estimates derived from Lazard's research. Please see page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation" for additional details.

(6) High end incorporates 90% carbon capture and compression. Does not include cost of transportation and storage.

Capital Cost Comparison

In some instances, the capital costs of renewable energy generation technologies have converged with those of certain conventional generation technologies, which coupled with improvements in operational efficiency for renewable energy technologies, have led to a convergence in LCOE between the respective technologies

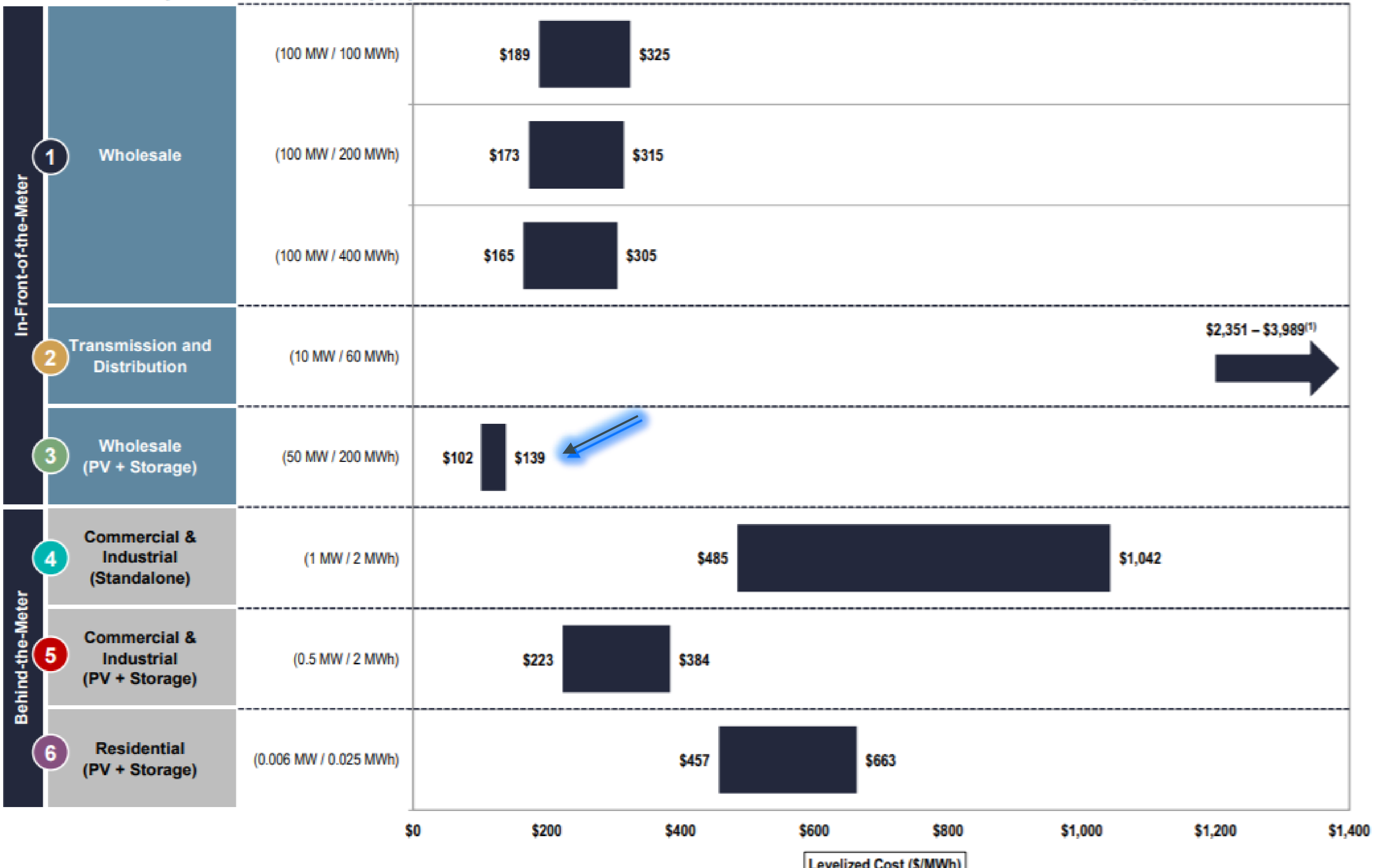


Source: Lazard estimates.

(1) Represents the estimated midpoint of the total capital cost for offshore wind.

Unsubsidized Levelized Cost of Storage Comparison—Energy ($/MWh)

Lazard's LCOS analysis evaluates storage systems on a levelized basis to derive cost metrics based on annual energy output



Source: *Lazard estimates.*

Note: Here and throughout this presentation, unless otherwise indicated, analysis assumes a capital structure consisting of 20% debt at an 8% interest rate and 80% equity at a 12% cost of equity. Capital costs are comprised of the storage module, balance of system and power conversion equipment, collectively referred to as the Energy Storage System ("ESS"), solar equipment (where applicable) and EPC. Augmentation costs are included as part of O&M expenses in this analysis and vary across use cases due to usage profiles and lifespans.

(1) Given the operational parameters for the Transmission and Distribution use case (i.e., 25 cycles per year), levelized metrics are not comparable between this and other use cases presented in Lazard's Levelized Cost of Storage report.

Appendix B

EDL Proposed Plan and Potential Annual Savings

"LEBANON COST-OF-SERVICE AND TARIFF DESIGN STUDY", Final report, MAY 2020, World Bank Group

http://documents1.worldbank.org/curated/en/772521589865844161/pdf/Lebanon-Cost-of-Service-and-Tariff-Design-Study-Final-Report.pdf

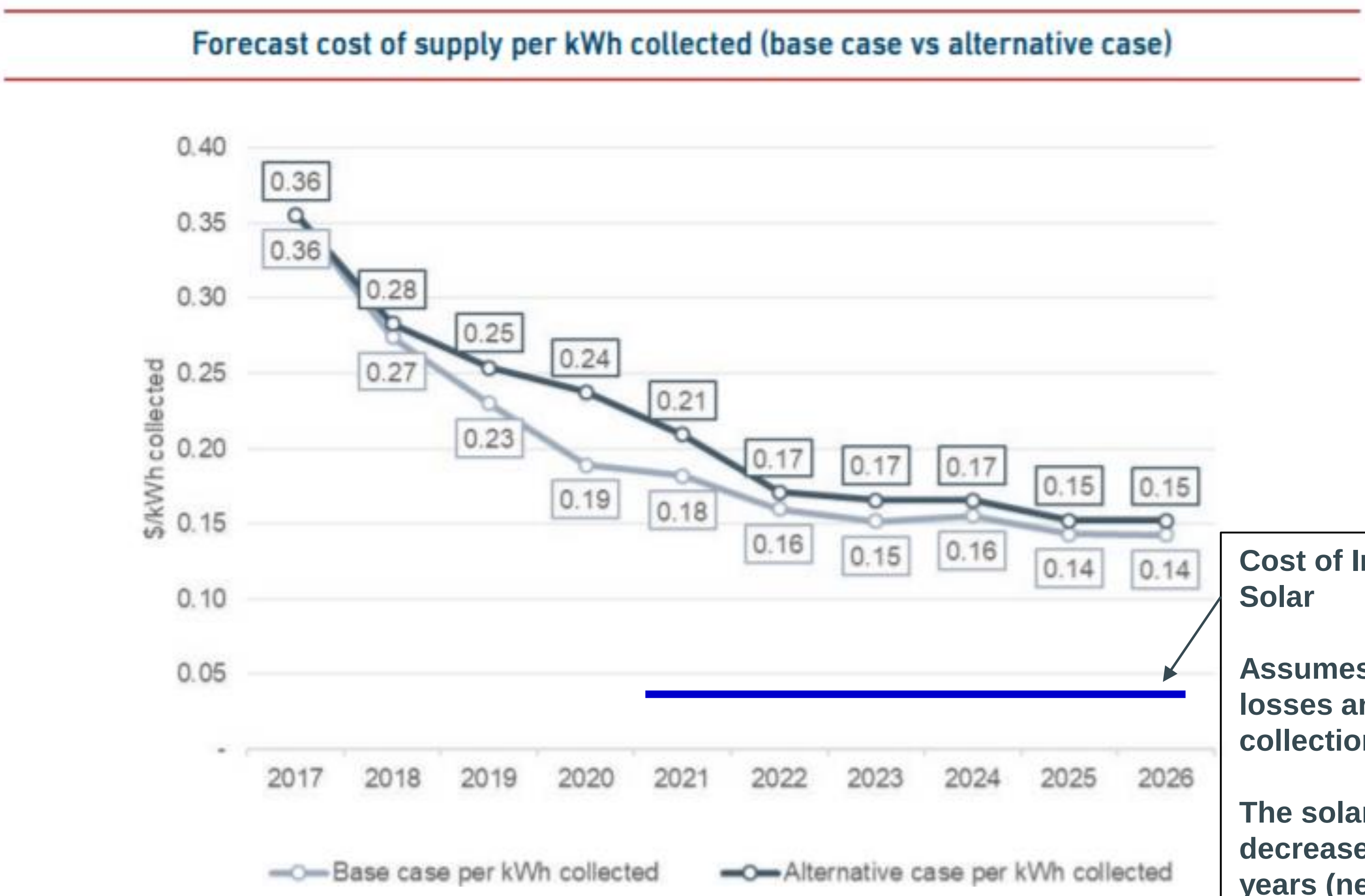
EDL 2017 Actual Cost with Optimistic Plan for Lower Costs

(Eliminates non-technical losses and assumes almost full collections)

Forecast cost of supply per kWh collected (base case)

A Provider of Information and Energy Solutions

Comparing EDL Proposed Plan Cost to Solar Cost ($/Kwh)



Cost of Incremental Solar

Assumes minimum losses and full collection

The solar cost slightly decrease in future years (new projects)

Annual Savings

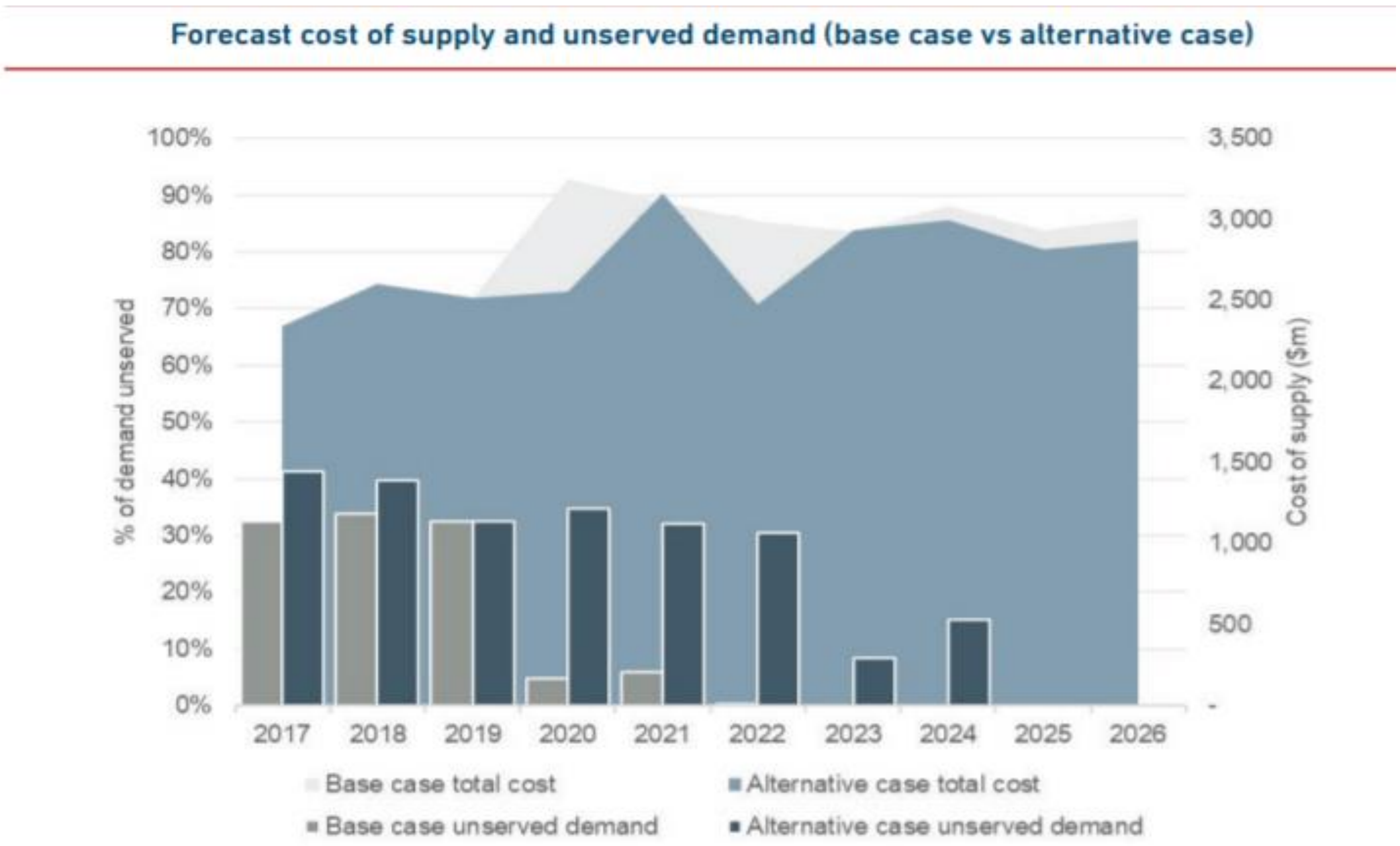
From 2500MW of solar capacity (29% capacity factor)

- Solar generation is projected at 6.351TWh/yr to meet the unserved demand and displace dirty, inefficient thermal generation
  - Maximize the benefits of lower emissions and cost of imported fuel by targeting the dirtiest distributed diesel generation units first then the most expensive and inefficient EDL units
  - Estimated savings of ~$1.27 Billion/yr assuming the conservative average cost of diesel and fuel oil to be ~$200/MWh ($300/MWh for Diesel and $100/MWh for FO)
  - In practice, most of the displaced fuel will be from distributed diesel generation which would result in even higher savings
  - Compared to the **optimistic** EDL expansion plan, we expect savings from solar in 2022 to be around $571Million
    - Using the following calculation for 2022:

      (EDL proposed cost – solar cost - incremental cost of using existing system in 2019)* 1000kW/MW * Solar capacity*capacity factor*hours/year

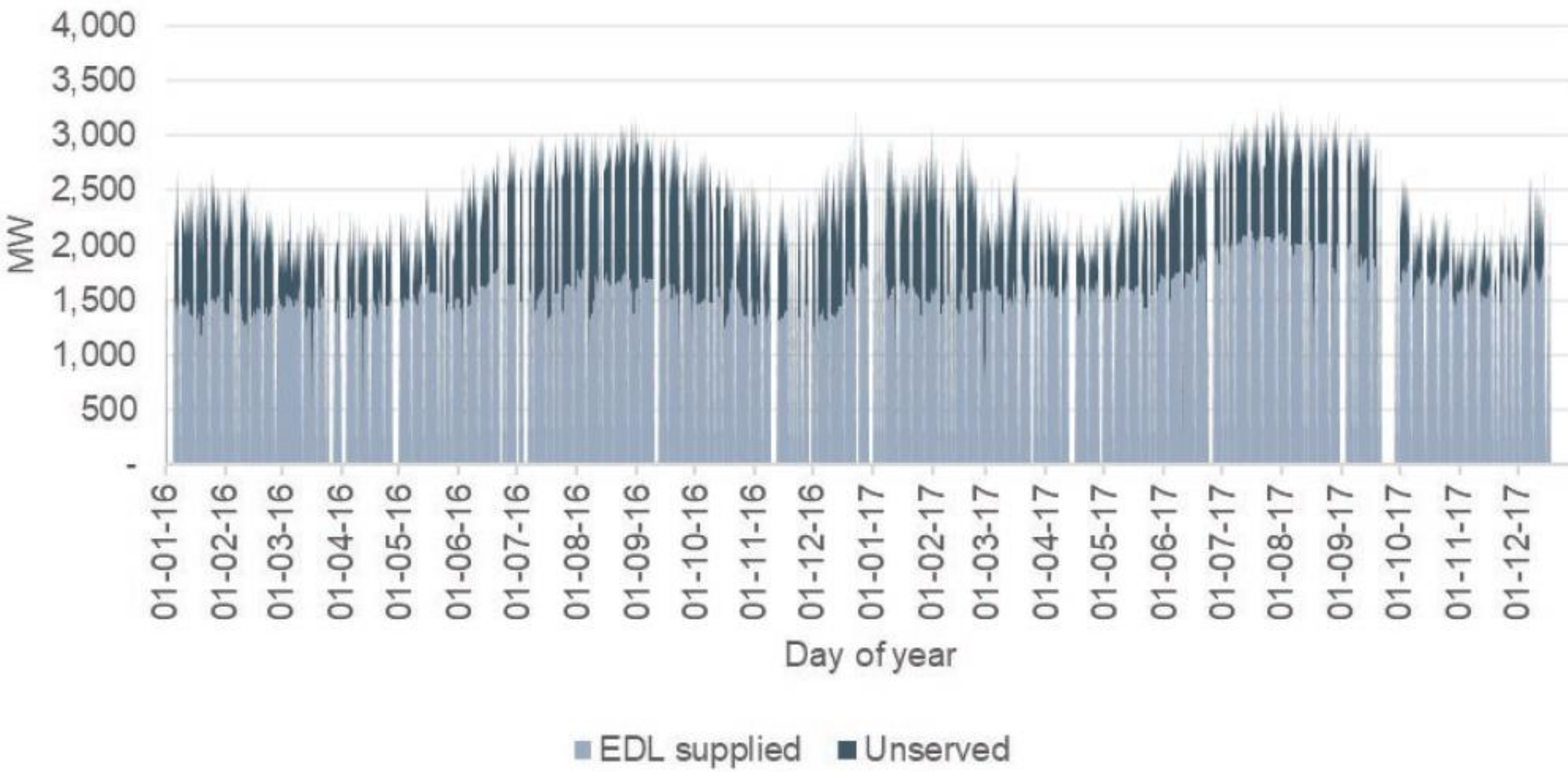
      $$(0.14 - 0.04 - 0.01) * 1000 * 2500 * 0.29 * 8760 = \$571.59 \text{ M}$$
    - If the optimistic EDL expansion plan in 2022 is underestimating the real cost of production then the savings are significantly higher
    - There could be additional costs related to the adjustment of existing flexible thermal generation units (“peakers”) to respond faster as an effective solar generation replacement in the evenings

Realistic EDL Scenario showing high unserved energy



One can argue that building the thermal power plant provides firm power available all the time. However, according to the world bank study, the level of unserved energy remains high until at least 2025. Therefore no real advantage or justification can be attributed to the high-cost EDL plan when compared to the advantages in building solar.

EDL estimated demand and supply, 2016-2017



EDL's Plan Shows Near-Doubling of Tariff to Eliminate Subsidies

Who can or will pay? Whatsapp revolution!

Forecast sector subsidy and assumed average tariff (base case)

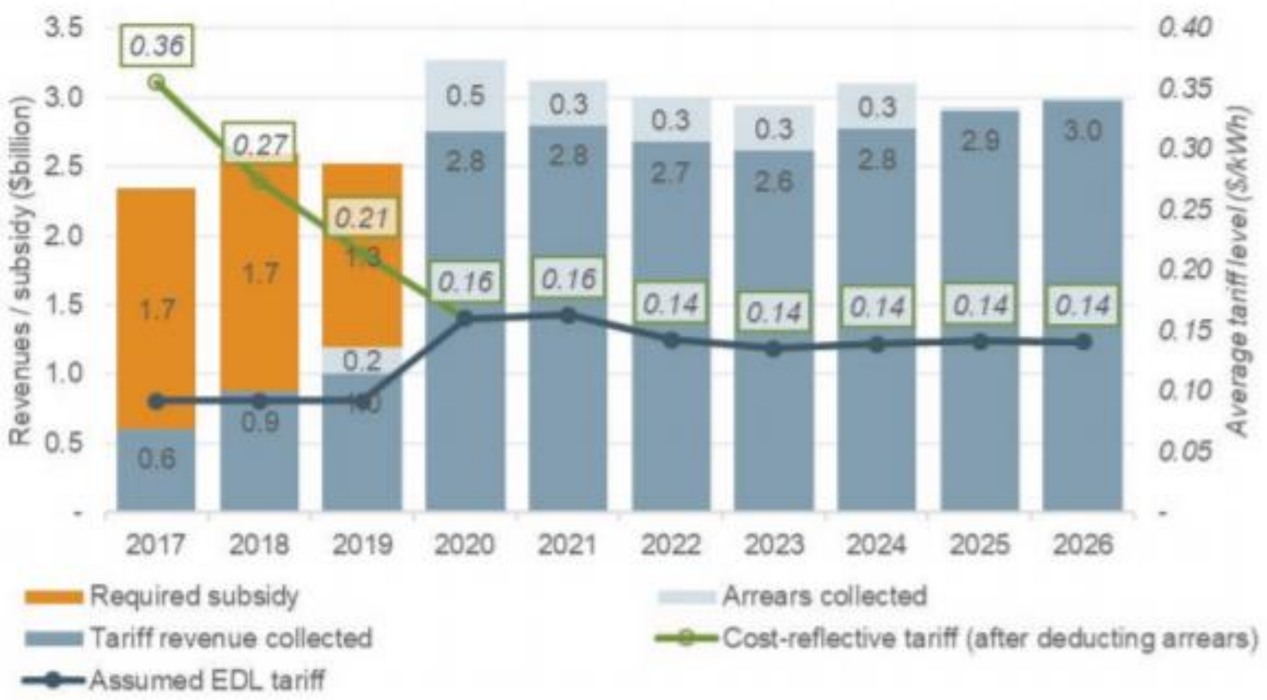
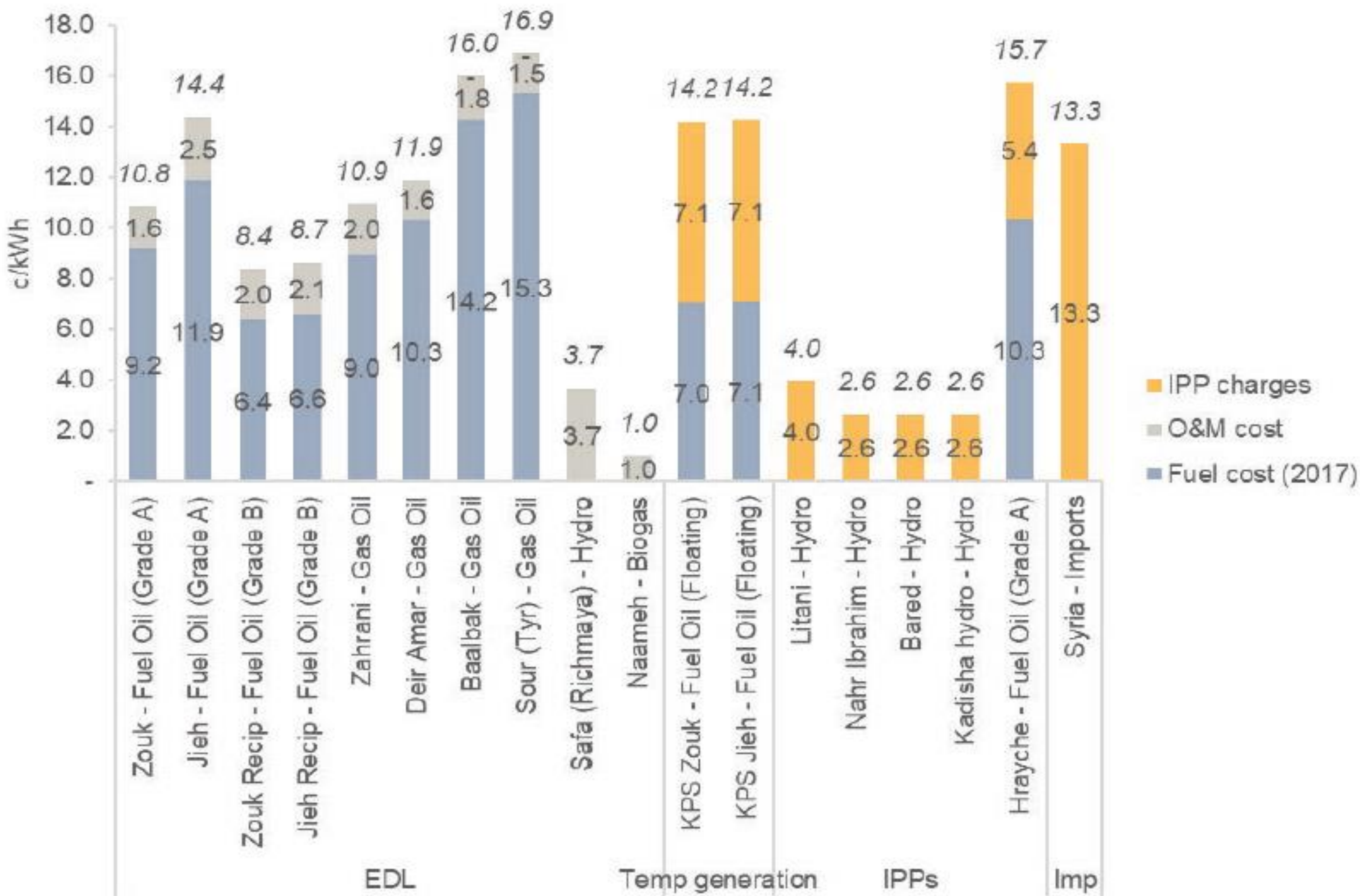


Figure 7 Fuel, O&M, and IPP costs by plant, 2017 (at crude price of $54/bbl)



Source: ECA analysis based on EDL and MEW data