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# LEBANON:
# Derisking Renewable Energy Investment

## Selecting Public Instruments to Promote Renewable Energy Investment For The Lebanese National Renewable Energy Action Plan

FULL REPORT

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

gef

Australian Government

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The Low Emission Capacity Building Project is part of the LECB programme, launched in January 2011 as a joint collaboration between the European Union (European Commission and Member States) and the UNDP and encompasses 25 participating countries, one of which is Lebanon. The project is implemented by the Ministry of Environment and managed by UNDP. The project is designed to improve Lebanon's relevant infrastructure, capacity building, information sharing and processes through the development of a greenhouse gas emission inventory system, identification and development of NAMAs, and the design of an MRV system to support the different NAMA types, and the development of the national low emission development strategy. For more information on the LECB project please check www.lowemissiondevelopment.org and www.climatechange.moe.gov.lb.

DREG

UNDP is implementing the Small Decentralized Renewable Energy Power Generation (DREG) Project which is funded by the Global Environment Facility (GEF) and nationally executed by the Ministry of Energy and Water (MoEW) with the Lebanese Center for Energy Conservation (LCEC). The project's objective is to reduce greenhouse gas emissions by the removal of barriers to widespread application of decentralized renewable energy power generation. The project will catalyze the development of the small, decentralized, grid-connected renewable energy power generation market in Lebanon. The target is to facilitate the installation of at least 1.75 MW of new decentralized RE power generation capacity during the lifetime of the project, which would reduce approximately 35,500 tonnes of $CO_2e$ in greenhouse gas emissions (GHG).

CEDRO
Empowering Lebanon with Renewable Energy

Project funded by the EUROPEAN UNION

The UNDP, in partnership with the Ministry of Energy and Water and the European Union, has initiated the fourth phase of the CEDRO Programme (CEDRO 4) funded by the European Union. The CEDRO 4 project includes several sustainable energy projects that are designed to further mature the local market. The project will work on three levels, including: the implementation of model end-use energy efficiency and renewable energy demonstration projects for private sector buildings and facilities; the set-up of an enabling environment for the conversion of other private sector buildings and facilities into energy efficient modalities, and the assistance in the development of a national sustainable energy strategy and action plan.

REPUBLIC OF LEBANON
MINISTRY OF FINANCE

UNDP is implementing the Technical Assistance for Fiscal Management and Reform Project at the Ministry of Finance. The project supports the Ministry of Finance in developing public finance policy and enhancing fiscal management, furthering the efficient achievement of the Ministry of Finance's policy objectives and reform initiatives

LCEC
LEBANESE CENTER FOR ENERGY CONSERVATION
المركز اللبناني لحفظ الطاقة
efficient resources, sustainable achievements

The Lebanese Center for Energy Conservation (LCEC) is the technical arm of the Ministry of Energy and Water in all subjects related to energy efficiency, renewable energy, and green buildings. LCEC offers proven expertise and support to the Government of Lebanon to develop and implement national strategies towards saving energy, saving money, reducing greenhouse gas emissions with the final target being to improve durability, safety and comfort of the Lebanese pollution.

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This publication builds on a series of prior research papers. This includes the original *Derisking Renewable Energy Markets* (Waissbein *et al.,* 2013) report, which sets out the methodology used in this publication.

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## BOXES

# Acronyms

| | |
|---|---|
| **BAU** | Business as usual |
| **BDL** | Banque du Liban |
| **BOO** | Build-Own-Operate |
| **CCGT** | Combined Cycle Gas Turbine |
| **CDM** | Clean Development Mechanism |
| **$CO_2e$** | Carbon Dioxide Equivalent |
| **CoD** | Cost of Debt |
| **CoE** | Cost of Equity |
| **CSP** | Concentrated Solar Power |
| **DREI** | Derisking Renewable Energy Investment |
| **ECN** | Energy Research Centre of the Netherlands |
| **EDL** | Electricité du Liban |
| **EIA** | Energy Information Administration (US) |
| **EPC** | Engineering, Procurement and Construction |
| **EU** | European Union |
| **EUR** | Euro |
| **FiT** | Feed-in Tariff |
| **FTE** | Full-time Employee |
| **GDP** | Gross Domestic Product |
| **GEF** | Global Environment Facility |
| **GoL** | Government of Lebanon |
| **IEA** | International Energy Agency |
| **INDC** | Intended Nationally Determined Contribution |
| **IPP** | Independent Power Producer |
| **IRENA** | International Renewable Energy Agency |
| **kW** | Kilowatt |
| **kWh** | Kilowatt-hour |
| **LCEC** | Lebanese Centre for Energy Conservation |
| **LCOE** | Levelised Cost of Electricity |
| **LEEREFF** | Lebanon Energy Efficiency & Renewable Energy Finance Facility |

| | |
|---|---|
| **MoE** | Ministry of Environment |
| **MoEW** | Ministry of Energy and Water |
| **MRV** | Measuring, Reporting and Verification |
| **MW** | Megawatt |
| **MWh** | Megawatt-hour |
| **NA** | Not Applicable/Available |
| **NAMA** | Nationally Appropriate Mitigation Action |
| **NEEREA** | National Energy Efficiency and Renewable Energy Action |
| **NERA** | National Electricity Regulatory Authority |
| **NREAP** | National Renewable Energy Action Plan 2016-2020 |
| **NREL** | National Renewable Energy Laboratory (US) |
| **O&M** | Operations and Maintenance |
| **PDD** | CDM Project Design Document |
| **PPA** | Power Purchase Agreement |
| **PRI** | Political Risk Insurance |
| **PV** | Photovoltaic |
| **UNDP** | United Nations Development Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **USD** | United States Dollar |

# Forewords

# Forewords

## FOREWORD MINISTRY OF ENVIRONMENT

The fight against climate change requires emission reduction measures at a faster and scaled-up level in order to maintain the expected global temperature rise to as low as possible. This has been enshrined in the newly adopted Paris Agreement. Lebanon, through its nationally determined contribution has committed in playing its fair share by pledging to reduce, by 2030, its greenhouse gas emissions by 15% on a unilateral basis, which can reach up to 30% conditional to support received from developed countries.

In the recent years, Lebanon has witnessed an accelerated scaling up of renewable energy integration into its electricity mix. Cognizant that more can be done, the Ministry of Environment, in collaboration with the Ministry of Energy and Water, embarked in producing the Derisking Renewable Energy Investment report. This is stemmed from the fact that the electricity sector is responsible for over 53% of our national greenhouse gas emissions. This also means that the sector has one of the highest national potentials in achieving emission reduction.

The current report identifies in a systematic approach the various barriers and risks associated with the renewable energy sector. It identifies both the risk environment and the various public instruments, which when applied, will help Lebanon achieve a cost-effective deployment of its renewable energy resources. This in turn will bring Lebanon closer to achieving its 2030 emission reduction targets.

**Tarek El Khatib**
Minister of Environment
Government of Lebanon

## FOREWORD MINISTRY OF ENERGY AND WATER

The Ministry of Energy and Water has been solidly working towards achieving a path of sustainable energy as early as 2009 with the voluntary commitment of the Lebanese Government during the Copenhagen Climate Summit. Through the Policy Paper for the Electricity Sector, published in 2010, targets for renewable energy technologies have been set for 2020.

Through the first National Energy Efficiency Action Plan (2011-2015) and the recently published National Renewable Energy Action Plan (2016-2020), the Ministry of Energy and Water has also provided clear sets of technology target mix for the renewable energy sector in Lebanon for the short-term and with indicative targets for the year 2030. The 2030 targets resonates with Lebanon's commitment under the Climate Paris Agreement, put forward in its Nationally Determined Contribution.

This report is yet another stepping stone in measures that need to be undertaken at the national level in promoting a cost-effective investment atmosphere for the renewable energy sector. The range of cost-estimates are indicative, primarily because of the time-lapse between the year of its publication (2017) and the years for which baseline information was collected (2015-2016), and then because of the rapid decline of cost of renewable energy technologies (including solar panels and wind turbines). These factors are changing the economic equation and making the renewable technology more competitive than ever.

Nevertheless, the report provides a systematic framework that identifies the various barriers and associated risks, and puts in place packages of targeted public interventions to address these risks. The report also offers a decision support tool for Lebanon to become a fertile ground for higher and cheaper renewable energy penetration by reducing, transferring, or compensating for the identified risks.

Gradually, but also steadily, with the implementation of the de-risking measures in Lebanon, the Ministry of Energy and Water aims at achieving a risk-return profile that catalyses further private sector investment at scale, with the end objective of reliable and affordable renewable energy solutions in Lebanon.

**César Abi Khalil**
Minister of Energy and Water
Government of Lebanon

## FOREWORD UNDP

The United Nations Development Programme (UNDP) has long been a trusted partner to Lebanon, and we stand ready to provide continued assistance in the area of energy. For UNDP, energy is critical to human development, and sits at the centre of the recently agreed Paris Climate Agenda and the 2030 Sustainable Development Agenda.

Lebanon is actively engaged in increasing investment in sustainable energy. This offers the promise of a range of high-impact co-benefits: socially, bringing reliable energy to all Lebanon's people; economically, driving new commerce, jobs and growth; and environmentally, improving air quality and reducing emissions.

Lebanon's commitment to sustainable energy is reflected in its recently released National Renewable Energy Action Plan (NREAP), as well as its Intended Nationally Determined Contribution (INDC) under the United Nations Framework Convention on Climate Change (UNFCCC). In both cases, Lebanon has established ambitious targets that send out a clear, inspirational signal to all stakeholders.

This report addresses a key question for Lebanon: given its ambitious goals, how can the government of Lebanon most cost-efficiently attract private sector finance to meet its investment targets in renewable energy? The report identifies a tailored package of public instruments to specifically target investment risks, thereby catalyses investment and bringing energy generation costs down. The report's innovative methodology, quantitative approach and transparent assumptions aim to assist Lebanon in an informed discussion between stakeholders.

We hope the report can make a contribution to the realisation of Lebanon's plans for energy, and bring clean, secure and affordable renewable energy to Lebanon's citizens.

**Adriana Dinu**
Executive Director, UNDP-Global Environmental Finance (UNDP-GEF)
United Nations Development Programme

# Key Points for Decision-Makers[1]

The objective of this report is to analyse the most cost-effective public derisking measures to promote private sector investment in large-scale wind energy and solar PV in Lebanon. The report sets out the results from a quantitative, investment-risk informed modelling analysis. Modelling data has been obtained from structured interviews with private sector investors and developers. The report was prepared in close coordination with both the Ministry of Environment and the Ministry of Energy and Water as well as Electricité du Liban (EDL).

## Context and Opportunity for Renewable Energy

Lebanon's power sector is currently characterised by a significant supply-demand imbalance, high generation costs and a lack of financial sustainability. EDL's available installed capacity is 1,616 MW, contrasting with peak demand of up to 3,000 MW. This current installed capacity is almost entirely powered by fuel oil, a relatively expensive source of power. EDL's end-user tariffs are in turn not cost-reflective, with EDL requiring a large annual subsidy, estimated at close to USD 2 billion in 2013, or 4.5% of GDP. Annual electricity demand is projected to grow at around 5% per year[2].

Renewable energy holds strong potential in Lebanon. This report uses 2030 investment targets for Lebanon of 450 MW in wind energy and 300 MW in solar PV, based on the 2030 vision in Lebanon's National Renewable Energy Action Plan (NREAP). Lebanon is well positioned for investment, with good renewable energy resources and a dynamic domestic business and financial sector. Renewable energy has the opportunity to contribute positively to Lebanon's power sector, increasing the reliability of the power supply, decreasing the country's dependence on fuel imports, improving the affordability of the energy mix, and reducing the need for subsidies to EDL. Renewable energy can also support Lebanon's contributions to climate change mitigation under the United Nations Framework Convention on Climate Change (UNFCCC).

## Financing Costs and Risk Environment

The modelling performs a detailed analysis of the financing costs and risk environment for wind energy and solar PV in Lebanon today.

- Financing costs (the cost of equity and the cost of debt) for wind energy and solar PV projects are high in Lebanon. For instance, the present study finds that the cost of equity[3] for large-scale wind energy and solar PV in Lebanon today is 16.0%, compared with 7.0% in Germany.

- These higher financing costs reflect a range of investment risks for wind energy and solar PV in Lebanon. Four risk categories were found to contribute most to higher financing costs: 1) "power market risk" that concerns power market regulation, such as the need for well-functioning, transparent mechanisms for the sale of electricity; 2) "grid and transmission risk" that concerns the reliability of the grid; 3) "counterparty risk" that concerns the reliability of the electricity buyer; and 4) "political risk" that concerns the overall stability and peace.

[1] This 'Key points for decision makers' section summarizes the findings of the report in a succinct manner. As such, references have not been included in this section but are found later in the relevant sections of the full report.

[2] This projection accounts for the recent demographic development related to the immigration of Syrian displaced.

[3] USD-denominated cost of equity.

## Public Derisking Measures

For each of wind energy and solar PV, the modelling examines the selection and cost-effectiveness of public derisking measures to meet the 2030 investment targets. Public derisking measures can be understood as interventions by the government and its partners that address specific investment risks, in the form of policies, programmes or financial products.

- For wind energy, (2030 investment target: 450MW), the modelling identifies a targeted package of public derisking measures with an estimated cost of USD 98 million until 2030. These derisking measures result in the following potential benefits:
  - Catalysing USD 635 million in private sector investment in wind energy
  - Lowering wind energy generation costs due to derisking from USD 11.4 cents to USD 9.4 cents per kWh
  - Creating economic savings related to derisking of wind energy of USD 221 million over 20 years[4]
  - Reducing carbon emissions by 10.0 million tonnes of $CO_2$ over 20 years, relative to the baseline
- For solar PV, (2030 investment target: 300MW), the modelling identifies a targeted set of public derisking measures with an estimated cost of USD 46 million until 2030. When implemented, this results in the following benefits:
  - Catalysing USD 279 million in private sector investment in solar PV
  - Lowering solar PV generation costs due to derisking from USD 10.0 cents to USD 8.2 cents per kWh
  - Creating economic savings related to derisking of solar PV of USD 97 million over 20 years[3]
  - Reducing carbon emissions by 5.2 million tonnes of $CO_2$ over 20 years, relative to the baseline

## Conclusion

Today's investment environment for renewable energy in Lebanon has a number of investment risks that result in high financing costs. The report's methodology systematically identifies public derisking measures to target these risks, thereby lowering financing costs and resulting in lower generation costs.

The modelling demonstrates how investing in public derisking measures creates significant economic savings in achieving the investment objectives in Lebanon's National Renewable Energy Action Plan. The modelling clearly shows that investing in public derisking measures should in every case be more cost-effective for Lebanon, compared to an alternative of paying higher generation costs. Therefore, implementing these public derisking measures is indeed an opportunity for policymakers in Lebanon. The end result can be more reliable, affordable and clean power for Lebanese citizens.

[4] The savings figures quoted reflect the direct economic benefits from public derisking measures, i.e. the aggregate difference in lower generation costs due to derisking over the lifetime of the asset. The savings figures do not include the indirect benefits accruing from a lower need for subsidisation of tariffs due to renewable energy's entry into the power market as a whole.

# Executive Summary

# Executive Summary

## Introduction

The analysis set out in this report forms part of the United Nation Development Programme's (UNDP) support to the Government of Lebanon in increasing the country's security of supply of energy by means of low-carbon technologies. UNDP is providing this support under the umbrella of three projects: 1) the *Low Emission Capacity Building* (LECB) project with the Ministry of Environment (MoE) serving as the national implementing partner and funded by the European Union (EU), and the Governments of Australia and Germany; 2) the *Small Decentralized Renewable Energy Power Generation* (DREG) project implemented with the Ministry of Energy and Water (MoEW) and the *Lebanese Center for Energy Conservation* (LCEC) and funded by Global Environment Facility (GEF); as well as 3) the EU funded fourth phase of the *Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon* (CEDRO 4) programme.

Recently, the MoEW/LCEC has released Lebanon's National Renewable Energy Action Plan 2016-2020 (NREAP; MoEW/LCEC, 2017). Its primary purpose is to further break down the legally-binding target of 12% renewable energy (RE) by the year 2020 (MoEW, 2010). Moreover, the NREAP outlines a vision for a tangible RE target by the year 2030, considering that Lebanon's total energy demand for heat and power is expected to more than double between 2015 and 2030[5]. The NREAP envisages utility scale RE projects to be financed exclusively through private investments. Lebanon's Intended Nationally Determined Contribution (INDC), submitted by the Government of Lebanon (GoL) as part of its commitment under the Paris Agreement, stipulates a 15% RE target (power and heat demand) by 2030, which can reach 20% with proper support.

By systematically assessing the impact of investment risks alongside a menu of public derisking measures, this study aims at contributing to an enabled environment for large-scale renewable energy investments. The focus is set on onshore wind and solar photovoltaic (PV) energy, the two key technologies for achieving the NREAP's 2020 renewable energy target and its 2030 vision, as well as its INDC RE targets.

## Context and Opportunity for Renewable Energy in Lebanon

Lebanon's power sector is currently characterised by a significant supply-demand imbalance, high generation costs and a lack of financial sustainability. Electricté du Liban's (EDL) available installed capacity is 1,616 MW, contrasting with peak demand of up to 3,000 MW. This current installed capacity is almost entirely powered by fuel oil, a relatively expensive source of power. EDL's end-user tariffs are in turn not cost-reflective, with EDL requiring a large annual subsidy, estimated at close to USD 2 billion in 2013, or 4.5% of GDP. Annual electricity demand is projected to grow at around 5% per year[6].

Renewable energy holds strong potential in Lebanon. Lebanon is well positioned for investment, with good renewable energy resources and a dynamic domestic business and financial sector. Renewable energy has the opportunity to contribute positively to Lebanon's power sector, increasing the reliability of the power supply, decreasing the country's dependence on fuel imports, improving the affordability of the energy mix, and reducing the need for subsidies to EDL. Renewable energy can also support Lebanon's contributions to climate change mitigation under the UNFCCC.

[5] Regarding renewable electricity, the 2030 NREAP vision in terms of total installed capacity is 450 MW onshore wind energy, 300 MW solar PV, ca. 473 MW hydro power (today 190 MW), and ca. 320 MW other new REs (distributed PV, CSP, Bioenergy) (MoEW, 2017).

[6] This projection accounts for the recent demographic development related to the immigration of Syrian displaced.

To date there has been limited investment in large-scale renewable energy in Lebanon; in wind energy, there has been no investment; in solar PV, there are two government-owned 1.1 MW plants. In 2013, a procurement process for a 50-100 MW wind farm was initiated; this process has faced delays and is still ongoing. There are longstanding efforts to put in place an appropriate legal framework for large-scale renewable energy, including power sector reform. A new electricity sector regulation, Law 462 (to be viewed in conjunction with amended Laws 288 and Law 54), has existed on paper since 2002, but has never entered into force. This law is aimed at unbundling EDL, allowing private power generation and grid connection through independent power producers (IPPs). On the other hand there have been successful efforts and schemes put in place in small-scale renewable energy. Overall, as informed by interviews for this study, private sector investor interest in large-scale renewable energy is strong.

## The Derisking Renewable Energy Investment Methodology

In 2013, UNDP issued the Derisking Renewable Energy Investment report (the “DREI report”) (Waissbein *et al.,* 2013). The DREI report introduced an innovative methodology (the “DREI methodology”), with an accompanying financial tool in Microsoft Excel, to quantitatively compare the cost-effectiveness of different public instruments in promoting renewable energy investment. The analysis of Lebanon set out in this report is based on the DREI methodology.

A key focus of the DREI methodology is on financing costs for renewable energy. While technology costs for renewable energy have fallen dramatically in recent years[7], private sector investors in renewable energy in developing countries still face high financing costs (both for equity and debt). These high financing costs reflect a range of technical, regulatory, financial and informational barriers and their associated investment risks. Investors in early-stage renewable energy markets, such as those of many developing countries, require a high rate of return to compensate for these risks[8].

In seeking to create an enabled environment for private sector renewable energy investment, policy-makers typically implement a package of public instruments[9]. From a financial perspective, the public instrument package aims to achieve a risk-return profile for renewable energy that can cost-effectively attract private sector capital. Figure 1 on page 17, from the DREI report, identifies the four key components of a public instrument package that can address this risk-return profile.

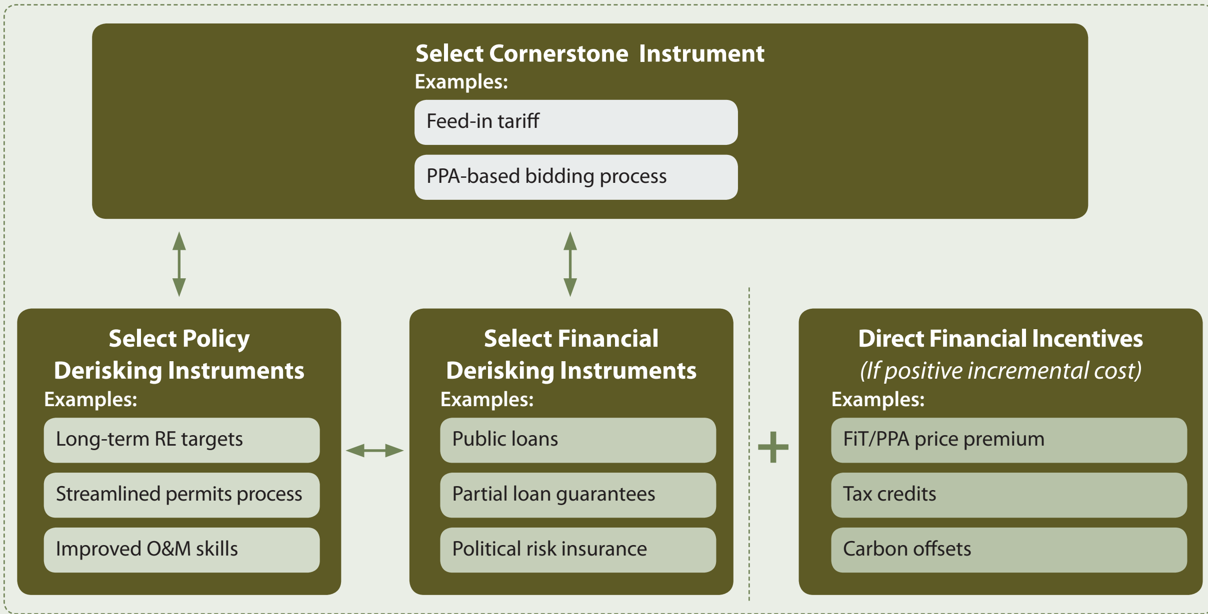
The **cornerstone instrument** is the centrepiece of any public instrument package. For large-scale renewable energy, the cornerstone instrument is typically a Feed-in Tariff (FiT) or a tendering process, either of which allows independent power producers (IPPs) to enter into long-term (e.g. 15-20 year) power purchase agreements (PPAs) for the sale of their electricity. The cornerstone instrument can then be complemented by three core types of public instruments:

[7] For example, in the case of solar photovoltaic, module prices declined by around 80% between the end of 2009 and the end of 2015, while in the case of onshore wind energy, the installed cost went down by 7% each time that the cumulative installed capacity has doubled between of the of onshore wind between 1983 and 2014 (IRENA, 2016).

[8] Indeed, as is shown later in this report, interviews with project developers identified higher financing costs for wind energy and solar PV investment in Lebanon in comparison to Germany, a well-established market. For example, the cost of equity (USD-denominated) is estimated at 16% in Lebanon today, in comparison to 6% in Germany.

[9] Public instruments can be understood to be domestic government interventions in the form of policies and programs. These instruments can be non-financial or financial in nature.

**Figure 1:** Typical components of a public instrument package for large-scale renewable energy




Source: Derisking Renewable Energy Investment (Waissbein *et al.,* 2013)

- **Instruments that reduce risk,** by addressing the underlying barriers that are the root causes of investment risks. These instruments utilize policy and programmatic interventions. An example might involve a lack of transparency or uncertainty regarding the technical requirements for renewable energy project developers to connect to the grid. The implementation of a transparent and well-formulated grid code can address this barrier, reducing risk. The DREI methodology terms this type of instrument "**policy derisking**".

- **Instruments that transfer risk,** shifting risk from the private sector to the public sector. These instruments do not seek to directly address the underlying barrier but, instead, function by transferring investment risks to public actors, such as development banks. These instruments can include public loans and guarantees, political risk insurance and public equity co-investments. For example, the credit-worthiness of a PPA may often be a concern to lenders. In order to address this, a development bank can guarantee the PPA, taking on this risk. The DREI methodology terms this type of instrument "**financial derisking**".

- **Instruments that compensate for risk,** providing a financial incentive to investors in the renewable energy project. When risks cannot be reduced or transferred, residual risks and costs can be compensated for. These instruments can take many forms, including price premiums as part of the electricity tariff (either as part of a PPA or FiT), tax breaks and proceeds from the sale of carbon credits. The DREI methodology calls these types of instruments " **direct financial incentives**".

## Modelling Results

This report, using the DREI methodology, sets out the results of modelling to select public instruments to attract private sector investment in Lebanon to meet the 2030 targets envisioned in the NREAP for large-scale wind energy and solar PV.

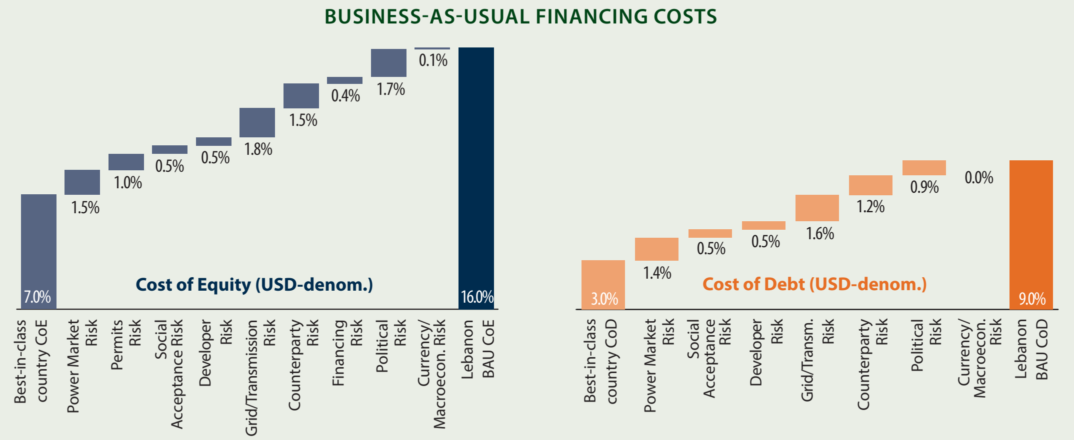
### Risk Environment

Data on the risk environment were obtained from a total of 17 structured interviews held with 12 domestic and international project developers and with 5 domestic debt investors who are considering, or actively involved in, wind energy and solar PV opportunities in Lebanon.

The results estimate that financing costs for wind energy and solar PV in Lebanon today are 16.0% for the cost of equity (CoE), and 9.0% for the cost of debt (CoD)[10]. These are substantially higher than in the best-in-class country, Germany, which are estimated at 7.0% CoE, and 3.0% CoD. Given the longevity of energy assets in general as well as the capital intensity of renewable energy investments in particular, the impact of Lebanon's higher financing costs on the competitiveness of wind energy and solar PV is significant.

Figure 2 shows how a range of investment risks currently contribute to these higher financing costs. The risk categories with the largest impact on elevated financing costs are 1) *power market risk,* which relates to accessing power markets and the price paid for renewable energy, 2) *grid and transmission risk* that concerns the failure-free feed-in of the electricity produced; 3) *counterparty risk* that concerns the credit-worthiness of the electricity off-taker; and 4) *political risk* that concerns a country's general intra- and international stability.

**Figure 2: Impact of risk categories on financing costs for wind energy and solar PV investments in Lebanon, business-as-usual scenario[11]**




Source: interviews with wind energy and solar PV investors and developers; modelling; best-in-class country is assumed to be Germany; see Annex A for details of assumptions and methodology.

[10] USD-denominated cost of equity and debt

[11] The financing cost waterfalls shown here are calculated by differentiating between the answers from equity and from debt investors, but not distinguishing further between investors with focus on wind energy and investors with focus on solar PV. It is recognized that the risk profiles of large-scale wind energy and solar PV can differ. However, the results of the interviews with wind energy and solar PV investors made clear that these differences are minimal in the Lebanese context. As such, the interview answers from equity and from debt investors were not further split into 'wind energy focus' and 'solar PV focus' sub-groups, in order to bring simplicity to the analysis and to avoid multiple result sets. For comparison, cost waterfalls with a distinction between answers from wind energy and solar PV investors are shown in Annex A.

## Public Instrument Selection

The modelling uses 2030 targets for both large-scale wind energy (450 MW) and solar PV (300 MW), based on the NREAP's 2030 vision[12]. It then models the implementation of a package of public instruments, containing both policy and financial derisking instruments, to promote investment to achieve these targets. The instruments are selected in order to specifically address the risk categories identified in the financing cost waterfalls. A list of these public derisking instruments is shown in Table 1. For wind energy, the costs until 2030 for policy derisking instruments are estimated as being USD 6.7 million, and for financial derisking instruments USD 91.4 million[13]. For solar PV, the policy derisking instruments are estimated as being USD 4.8 million, and the financial derisking instruments USD 40.9 million[14].

**Table 1: The selection of public instruments to achieve the envisioned NREAP investment targets for wind energy and solar PV.**

| RISK CATEGORY | POLICY DERISKING INSTRUMENTS | FINANCIAL DERISKING INSTRUMENTS |
|---|---|---|
| **Power Market Risk** | • Long-term, legally-binding RE targets<br>• Establishment of an enabling regulatory framework<br>• FIT/PPA tender (standardized PPA)<br>• Independent regulator for power sector | NA |
| **Permits Risk** | • Streamlined process for RE permits (dedicated one-stop shop)<br>• Contract enforcement and recourse mechanisms | NA |
| **Social Acceptance Risk** | • Awareness-raising campaigns<br>• Stakeholder outreach, including operators of private generators | NA |
| **Developer Risk** | • Capacity building for resource assessment (wind only)<br>• Technology and Operations & Maintenance (O&M) assistance | NA |
| **Grid/Transmission Risk** | • Strengthen EDL's grid management capacity<br>• Transparent, up-to-date grid code<br>• Policy support for grid infrastructure development | • Take-or-pay clause in PPA[15] |
| **Counterparty Risk** | • Strengthen EDL's management and operational performance | • Government guarantee for PPA payments<br>• Concessional public loans to IPPs |
| **Financing Risk** | • Fostering financial sector reform towards green infrastructure investment<br>• Strengthening financial sector's familiarity with renewable energy and project finance | • Concessional public loans to IPPs |
| **Political Risk** | NA | • Political risk insurance for equity investments |
| **Currency/Macroeconomic Risk** | NA | NA |

Source: modelling. See Annex A for a full description of these instruments. "NA" indicates "Not Applicable".

[12] NREAP assumes these targets to be achieved exclusively through private-sector engagement.

[13] Different methodological approaches (e.g., face value, reserve, cost, no-cost) may be taken to costing financial derisking instruments. Here, a cost approach has been taken for the 'take or pay clause in PPA' and 'government guarantee for PPA', totalling USD 55.1m; a reserve approach has been taken for 'public loans' and 'political risk insurance', totalling USD 36.3m. See Section 4.2.4 for sensitivity analyses on costing. See Annex A for details.

[14] Like in the case of wind energy (see previous footnote), for solar PV, too, a cost approach has been taken for the 'take or pay clause in PPA' and 'government guarantee for PPA', totalling USD 25.0m; a reserve approach has been taken for 'public loans' and 'political risk insurance', totalling USD 16.0m. See Section 4.2.4 for sensitivity analyses on costing. See Annex A for details. A "take-or-pay" clause is a clause found in a Power Purchase Agreement (PPA) that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver electricity generated by its renewable energy plant.

[15] A "take-or-pay" clause is a clause found in a Power Purchase Agreement (PPA) that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver electricity generated by its renewable energy plant.

## Levelised Costs

The modelling is performed for two risk environment scenarios; first, a *business-as-usual* scenario, representing the current risk environment (with today's financing costs); and second, a *post-derisking* scenario, after implementing the public instrument packages (resulting in lower financing costs).

The results for generation costs, expressed as the Levelised Cost of Electricity (LCOE), are shown in Figures 3 below:

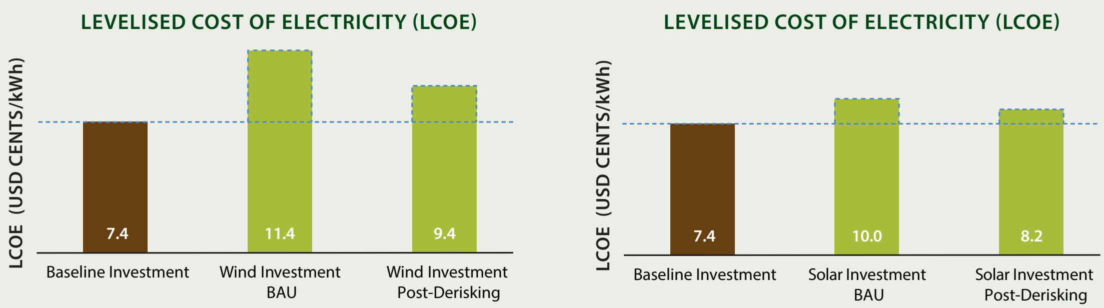
- In the business-as-usual (BAU) scenario, wind energy and solar PV are more expensive than the baseline. The baseline technology mix considers primarily combined cycle gas turbine (CCGT) plants, which Lebanon will likely use to increase its electricity generation capacity, and to a smaller extent also the existing power generation fleet that could be partly replaced by wind energy or solar PV[16]. This approach results in baseline generation costs of USD 7.4 cents per kWh, assuming unsubsidized fuel cost as projected by leading international energy organizations (see Appendix A). In comparison, wind energy in the BAU scenario is estimated at USD 11.4 cents per kWh, and solar PV at USD 10.0 cents per kWh. This means that both wind energy and solar PV require a price premium (USD 4.0 cents per kWh and USD 2.5 cents per kWh, respectively) over the baseline energy technology mix.

- In the post-derisking scenario, the cost of wind energy falls to USD 9.4 cents per kWh, and the cost of solar PV falls to USD 8.2 cents per kWh. As such, following government interventions to derisk the investment environment, and with resulting lower financing costs, the price premium for wind energy and solar PV is reduced by roughly 50% and 70%, respectively.

## Evaluation of Public Instruments' Effectiveness

The DREI methodology uses four performance metrics to analyse the impacts of the selected public instrument package to promote investment, each metric taking a different perspective: the ability to catalyse investment (leverage ratio); the economic savings generated for society (savings ratio); the resulting electricity price for end-users (affordability); and the efficiency in mitigating greenhouse gas emissions (carbon abatement).

**Figure 3: LCOEs for the baseline, wind energy (left) and solar PV (right) investment in Lebanon**




Source: modelling; see Table 13 (wind) and Table 14 (solar PV), as well as Annex A for details of assumptions and methodology.

[16] In other words, renewable energy is compared to a generation mix that is partly composed of yet-to-be-built new technology (build margin) and of existing technology that were to be replaced (operating margin).

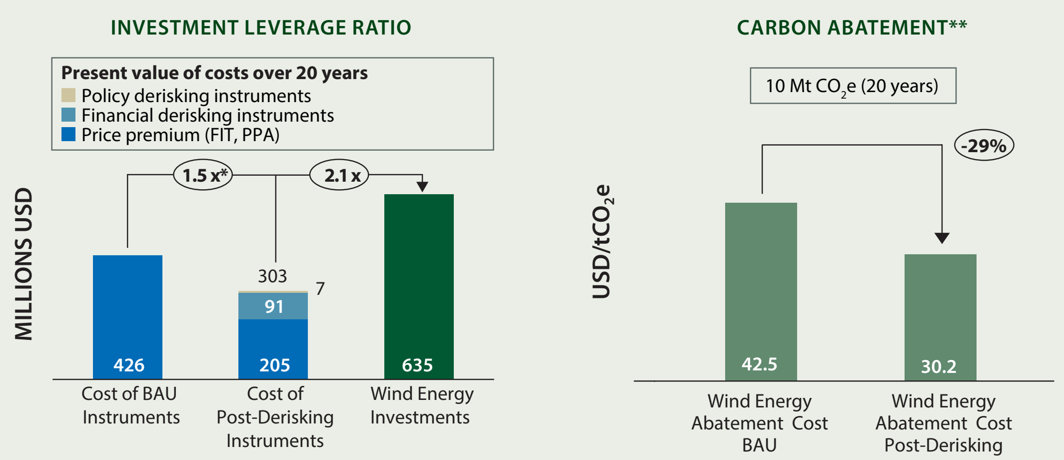
Figure 4 shows exemplarily the results for two out of the four performance metrics, namely the leverage ratio and carbon abatement for wind energy:

- For the leverage ratio, achieving the envisioned 2030 target of 450 MW in installed wind capacity equates to USD 635 million in private sector investment. In the *business-as-usual* scenario, the model estimates that achieving this target will require a direct financial incentive in the form of a price premium over 20 years of USD 426 million. This results in a leverage ratio of 1.5x, i.e. the investments catalysed are 1.5 times the amount spent on the public instruments. In the *post-derisking* scenario, the model estimates that this same investment target can be achieved with a package of derisking instruments valued at USD 303 million, including the price premium. This raises the leverage ratio to 2.1x, indicating a higher efficiency in terms of the use of public instruments.

- For carbon abatement, achieving the 2030 target of 450 MW in wind energy is estimated to result in a total reduction of 10.0 million tonnes of $CO_2e$ over the lifetime of the wind plants. In the business-as-usual scenario, the abatement cost of the investment in wind energy is USD 57.4 per tonne of $CO_2e$. Or, in other words, the cost of public instruments equates to USD 42.5 for every tonne of $CO_2e$ reduced by the investment in wind energy. In the post-derisking scenario, this cost falls to USD 30.2 per tonne of $CO_2e$. This performance metric is helpful in terms of understanding a carbon price that is necessary to promote investment, and in comparing the relative costs of different low-carbon options.

As such, both the leverage ratio and carbon abatement metrics from the modelling on wind energy show improved cost-effectiveness from government measures to derisk the investment environment.

**Figure 4: Performance metrics for the selected package of derisking instruments in promoting 450 MW of wind energy investment in Lebanon**




Source: modelling; see Table 13 and Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

** The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 42.5 per $tCO_2e$ is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD 30.2 per $tCO_2e$ is USD 0.7, USD 9.1 and USD 20.4, respectively.

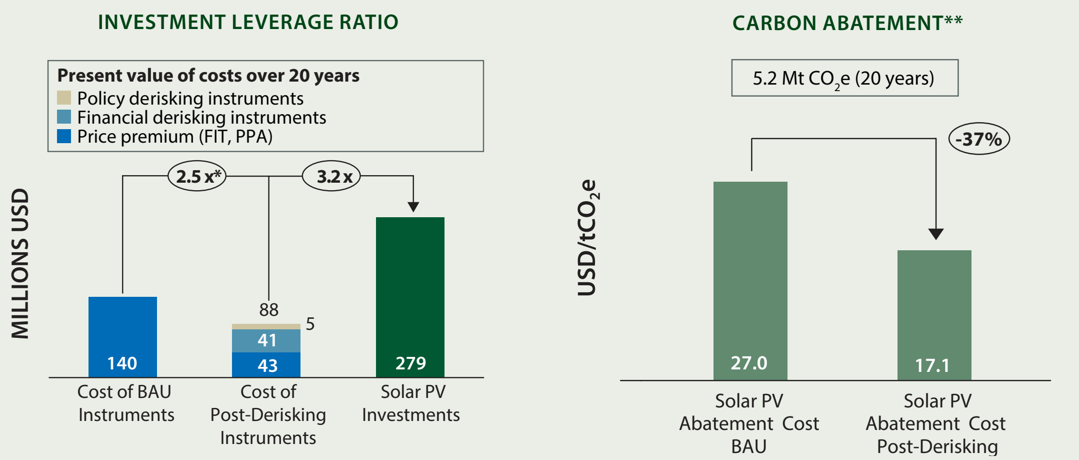
Figure 5 shows selected results for solar PV in Lebanon, this time with the envisioned 2030 target of 300 MW of large-scale solar PV private sector investment. The results demonstrate the beneficial impact of derisking even more strikingly than the case with wind energy. In the post-derisking scenario, the package of derisking measures increases the leverage ratio from 2.0x to 3.2x, while the carbon abetment cost fall by 37% from USD 27.0 to USD 17.1 per tonne of $CO_2$e.

## Sensitivities

Sensitivity analyses can assist in gaining a better understanding of the robustness of the outputs and to be able to test different scenarios. Three broad types of sensitivity analysis have been performed on (i) key input assumptions, such as investment cost, capacity factors and fuel costs, (ii) on public instrument selection and cost-effectiveness and (iii) on the approach to costing financial derisking instruments. The sensitivities on public instrument selection show a range of cost-effectiveness, but that overall implementing public derisking instruments is always more cost effective than paying higher generation costs, across all scenarios.

Detailed results for the sensitivities can be found in Section 4.2.4

**Figure 5: Performance metrics for the selected package of derisking instruments in promoting 300 MW of solar PV investment in Lebanon**




Source: modelling; see Table 14 and Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

** The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 27.0 per $tCO_2$e is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD 17.1 per $tCO_2$e is USD 0.9, USD 7.9 and USD 8.2, respectively.

## Conclusions

The results in this report should not be interpreted as a definitive quantitative analysis of wind energy and solar PV in Lebanon but, rather, as one contribution to the larger policy decision-making process.

### Implications for promoting renewable energy in Lebanon

The results confirm that financing costs for wind energy and solar PV in Lebanon are currently high, particularly in comparison to countries with more favourable investment environments. The cost of equity for wind energy and solar PV in Lebanon today is estimated at 16%, and the cost of debt at 9%[17]. The modelling evaluates nine different risk categories regarding their contribution to these higher financing costs in Lebanon. Four of these – power market risk, grid/transmission risk, counterparty risk, political risk – are large contributors to high financing costs, increasing the cost of equity by more than 1% point (100 basis points) each.

The results identify a comprehensive package of public derisking measures to achieve the 2030 investment objectives for wind and solar PV envisioned in Lebanon's National Renewable Energy Action Plan. These measures, consisting of a collection of policy and financial instruments, systematically target the identified investment risk categories. Table 1 itemises each of the measures. The modelling also estimates the public cost of these measures until 2030.

A key conclusion from the modelling is that investing in derisking instruments is a cost-effective approach for achieving Lebanon's wind and solar PV investment objectives. The derisking measures that are modelled bring down the generation cost of wind energy from USD 11.4 cents per kWh to USD 9.4 cents per kWh, and solar PV energy from USD 10.0 cents per kWh to USD 8.2 cents per kWh.

- For wind energy, in the business as usual scenario, the modelling estimates that a premium price totalling USD 426 million will be required over the next 20 years to achieve the envisioned NREAP target. However, if over the same period a total investment of USD 98 million is made in derisking measures, wind energy will become 18% cheaper and the premium price reduces to USD 205 million, thereby saving USD 221 million in generation costs over the next 20 years[18].

- For solar PV, in the *business as usual* scenario, the modelling estimates that a premium price totalling USD 140 million will be required over the next 20 years to achieve the envisioned NREAP target. However, if over the same period a total investment of USD 46 million is made in derisking measures, solar PV will also become 18% cheaper and the price premium price reduces to USD 43 million, thereby saving USD 97 million in generation costs over the next 20 years[19].

The modelling thus clearly demonstrates that investing in derisking measures is good value for money when compared to paying a premium price for wind and solar PV energy. The results show that the identified derisking measures are cost-effective both collectively, taken as a package of derisking measures, and individually, as single derisking measures. Overall, the results indicate that all derisking instruments that can be immediately implemented should, if possible, be prioritized.

[17] USD-denominated cost of equity and cost of debt.

[18] Net savings of USD 123 million (USD 221 million minus USD 98 million)

[19] Net savings of USD 51 million (USD 97 million minus USD 46 million)

# 1. Introduction

# Introduction

1

The analysis set out in this report forms part of UNDP's support to the Government of Lebanon in increasing the country's security of supply of energy by means of low-carbon technologies. UNDP is providing this support under the umbrella of three projects: 1) the *Low Emission Capacity Building* (LECB) project with the MoE serving as the national implementing partner and funded by the EU, and the Governments of Australia and Germany; 2) the *Small Decentralized Renewable Energy Power Generation* (DREG) project implemented jointly with the MoEW and the LCEC and funded by GEF; as well as 3) the EU funded fourth phase of the *Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon* (CEDRO 4) programme.

In January 2017, the MoEW/LCEC has released Lebanon's National Renewable Energy Action Plan 2016-2020 (NREAP; MoEW/LCEC, 2016). Its primary purpose is to further break down the legally-binding target of 12% renewable energy (RE) by the year 2020 (MoEW, 2010). This share includes both heat and power generation by means of various RE technologies. Moreover, the NREAP outlines a vision for a tangible target of 12.6% RE by the year 2030[20], while Lebanon's total primary demand will have more than doubled between now and 2030. Onshore wind farms and solar photovoltaic (PV) plants are considered the key installations for achieving both the 2020 target and the 2030 vision. In absolute numbers, 200 MW of wind energy and 150 MW of solar PV is targeted by 2020, whereas 450 MW of wind energy and 300 MW of solar PV plants are expected to be operating in Lebanon by 2030[21].

The NREAP envisages utility-scale RE projects to be financed exclusively through private investments, given the timely set-up of an appropriate legal framework. However, like in most developing economies, Lebanon's market for larger RE infrastructure is in its very early days. Regulatory barriers are but one out of a suite of investment risks that force up financing cost and may thus prevent the private sector from engaging in large-scale RE investments at a rate that accelerates RE technology adoption.

On-going and planned initiatives are seeking to promote small-scale renewable energy and energy efficiency investments in Lebanon, including in the green building domain. These are outside the scope of this analysis, with its focus on large-scale renewable energy only, but will be useful precedents. The Central Bank of Lebanon (BDL) initiated the National Energy Efficiency and Renewable Energy Action (NEEREA) incentive scheme that provides subsidized green loans. A similar scheme, the Lebanon Energy Efficiency and Renewable Energy Finance Facility (LEEREFF) is about to be implemented by BDL and MoEW/LCEC with the support of the European Investment Bank and the Agence Française de Développement.

This report, using the Derisking Renewable Energy Investment (DREI) methodology developed by UNDP, sets out the modelling results for systematically assessing investment risks and selecting public instruments to attract renewable energy investment also in large-scale projects. This is crucial to meet the targeted and envisioned renewable energy capacity by 2020 and by 2030, respectively. Ultimately, adding wind energy and solar PV to the grid will increase security of supply with energy that is clean and affordable – to the benefit of Lebanon's people, economy, and environment.

[20] The INDC of GoL outlines a target of 15-20% of RE (power and heat) by 2030. Subsequent NREAPs will take that into account.

[21] Apart from large-scale wind and solar PV, the NREAP 2030 vision assumes 473 MW of hydro power (today 190 MW) and ca. 320 MW of other new REs such as distributed PV, CSP, and Bioenergy (MoEW, 2017).

## 2. Overview of the Derisking Renewable Energy Investment Methodology

# Overview of the Derisking Renewable Energy Investment Methodology

2

In 2013, UNDP issued the *Derisking Renewable Energy Investment* report (the "DREI report") (Waissbein *et al.,* 2013)[22]. The report introduced an innovative methodology (the "DREI methodology"), with an accompanying financial tool in Microsoft Excel, to quantitatively compare different public instruments for promoting renewable energy investment. This section provides an overview of the following aspects of the DREI methodology:

- The methodology's focus on financing costs for renewable energy
- The methodology's approach to identifying a public instrument mix
- The methodology's 4-stage framework

For more detailed information on the DREI methodology, please see the full DREI report.

## 2.1 THE IMPACT OF HIGH FINANCING COSTS ON RENEWABLE ENERGY

A key focus of the DREI methodology is on financing costs for renewable energy. While technology costs for renewable energy have fallen dramatically in recent years[23], private sector renewable energy investors in developing countries still face high financing costs (both for equity and debt). These high financing costs reflect a range of technical, regulatory, financial and informational barriers and their associated investment risks. Investors in early-stage renewable energy markets, such as those of many developing countries, require a high rate of return to compensate for these risks.

Figure 6 below, from the DREI report, illustrates how these high financing costs can impact the competitiveness of renewable energy. The figure shows the results of UNDP modelling to compare the levelised cost of electricity (LCOE) of onshore wind energy and combined-cycle gas in a developed and developing country. The analysis assumes a low financing cost environment for the developed country (cost of equity of 10%; cost of debt of 5%), and a high financing cost environment for the developing country (cost of equity of 18%; cost of debt of 10%). All modelling assumptions (investment costs, operational costs, capacity factors) are kept constant between the developed and developing country – the only assumption that is varied is that relating to financing costs.

In the developed country benefiting from low financing costs, wind power (at USD 6.7 cents per kWh) can be almost cost-competitive with gas (at USD 6.1 cents per kWh). However, in the developing country with higher financing costs, wind power generation (at USD 9.4 cents per kWh) becomes 40% more expensive than in a developed country. In contrast, gas (at USD 6.5 cents per kWh) becomes only 6% more expensive due to these same higher financing costs. As such, in the developing country, wind power is no longer competitive with gas in this high financing cost environment.

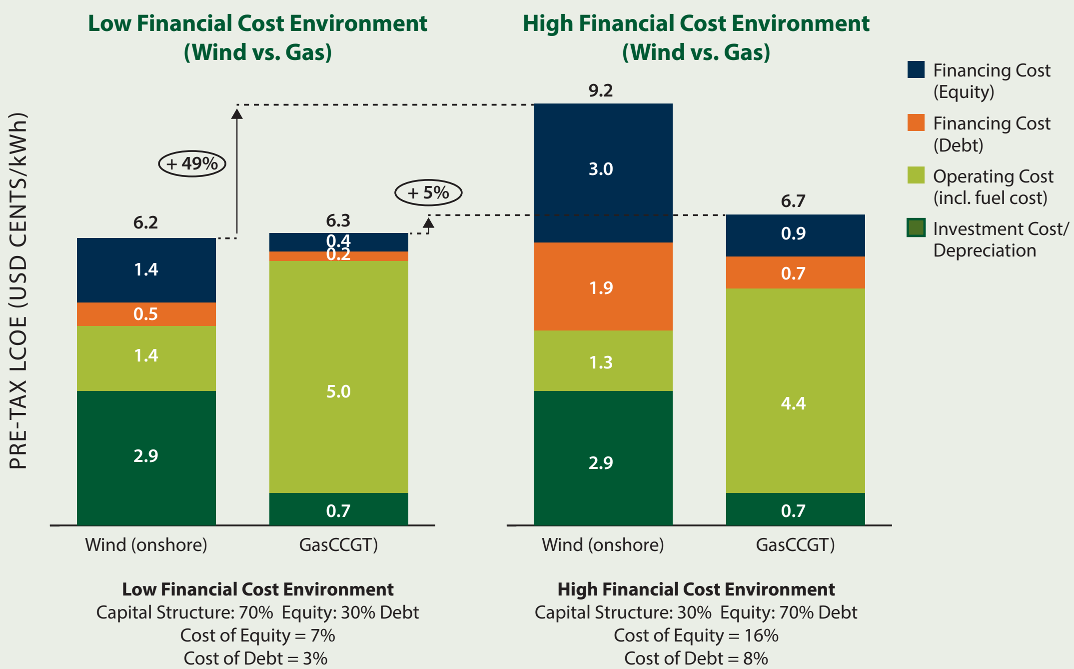
22 Available for download at www.undp.org/DREI.

23 For example, in the case of solar photovoltaic, according to data from Bloomberg New Energy Finance, module costs experienced a 99 percent reduction between 1977 and 2013 (WEC, 2013).

The sensitivity of wind power – and many other forms of renewable energy (Schmidt, 2014) – to financing costs is due to the high upfront capital intensity of renewable energy. Renewable energy's upfront capital intensity is a function of its required initial investment in equipment, for example wind turbines and solar panels. Following this initial investment, renewable energy typically has very low operating costs and does not require any fuel costs. Fossil fuel based energy generation typically has the reverse profile, with low upfront costs and high operating costs and fuel costs[24]. The end result is that high financing cost environments penalize renewable energy when compared to fossil-fuel based power generation.

The theory of change underlying the DREI methodology is that one of the main challenges for scaling-up renewable energy technologies in developing countries is to lower the financing costs that affect renewables' competitiveness against fossil fuels. As these higher financing costs reflect barriers and associated risks in the investment environment, the key entry point for policy-makers promoting renewable energy is to address these risks and therefore lower overall life-cycle costs.

**Figure 6: Comparing wind energy and gas LCOEs in developed and developing countries.**




Source: Derisking Renewable Energy Investment (UNDP, 2013), subsequently updated as of 2017

All assumptions besides the financing costs are kept constant between the low and high financing cost environments.
Wind energy technology assumptions: investment cost: 1,520,000 USD/MW, O&M: 31,600 USD/MW/year, capacity factor: 30%, annual inflation: 2%; Gas (CCGT) assumptions: investment cost: 910,000 USD/MW, O&M: 35,100 USD/MW/year, full load hours: 5,000/year, fuel efficiency: 58%, annual Inflation: 2%; fuel costs are projected using IEA's New Policies Scenario, based on 2016 EU Import Prices for Natural Gas as the starting point. For more detail on data sources, please refer to Annex B.

Operating costs appear as a lower contribution to LCOE in developing countries due to discounting effects from higher financing costs.

[24] For example, based on the analysis shown in Figure 6, investment costs account for approximately 80% of the total lifetime technology costs for wind energy but only account for around 15% of such costs in the case of gas. See Annex A of the DREI report for assumptions.

## 2.2 IDENTIFYING A PUBLIC INSTRUMENT MIX TO PROMOTE RENEWABLE ENERGY

In seeking to create an enabled investment environment for renewable energy, policy-makers typically implement a package of public instruments. Identifying an appropriate combination of instruments can be highly challenging. Moreover, these public instruments can come at a cost – to industry, to consumers or to the tax-payer.

From a financial perspective, the overall aim for policy-makers in assembling a public instrument package is to achieve a risk-return profile for renewable energy that can cost-effectively attract private sector capital. Figure 7 below, from the DREI report, identifies the four key components of a public instrument package that can address this risk-return profile.

The **cornerstone instrument** is the centrepiece of any public instrument package. While there are tens, if not hundreds, of public instruments, only a select handful of instruments have shown themselves to be highly effective at transforming markets. For large-scale renewable energy, the cornerstone instrument is typically a Feed-in Tariff (FiT) or a Power Purchase Agreement (PPA) tender process, either of which allows independent power producers (IPPs) to enter into long-term (e.g. 15-20 year) power purchase agreements with grid operators.

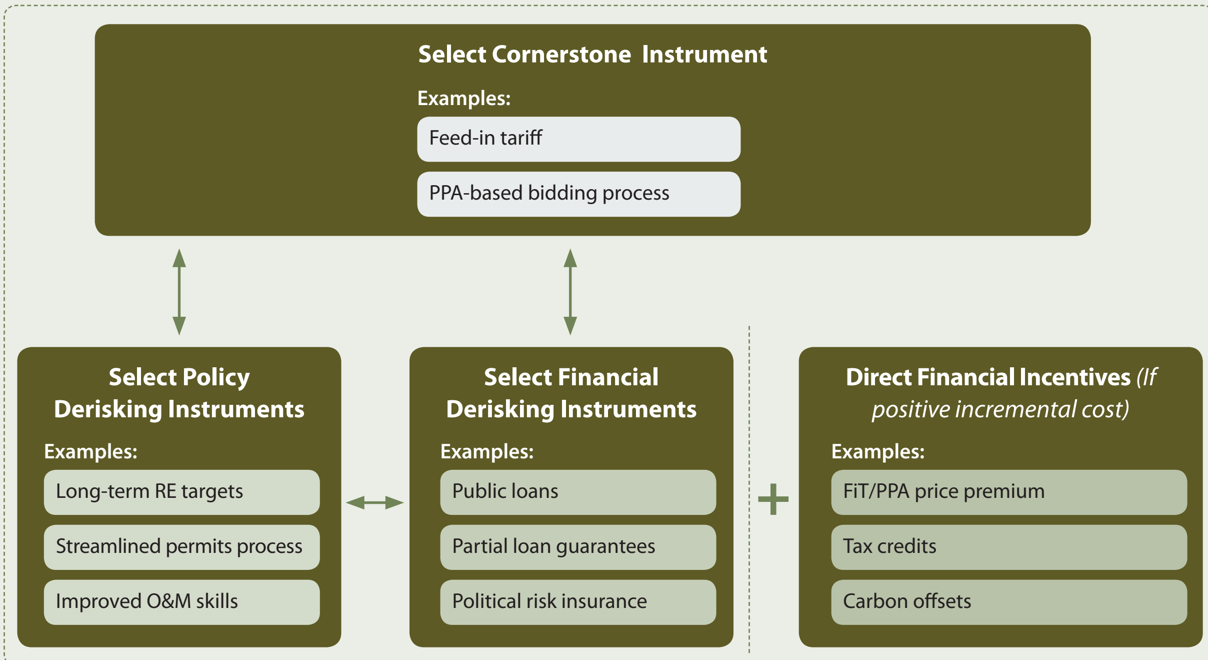
The cornerstone instrument can then be complemented by three core types of public instruments:

- **Instruments that reduce risk,** by addressing the underlying barriers that are the root causes of investment risks. These instruments utilise policy and programmatic interventions. An example might involve a lack of transparency or uncertainty regarding the technical requirements for renewable energy project developers to connect to the grid. The implementation of a transparent and well-formulated grid code can address this barrier, reducing risk. The DREI methodology terms this type of instrument **"policy derisking**".

- **Instruments that transfer risk,** shifting risk from the private sector to the public sector. These instruments do not seek to directly address the underlying barrier but, instead, function by transferring investment risks to public actors, such as development banks. These instruments can include public loans and guarantees, political risk insurance and public equity co-investments. For example, the credit-worthiness of a PPA may often be a concern to lenders. A development bank guarantee can provide banks with the security to lend to project developers. The DREI methodology terms this type of instrument **"financial derisking"**.

- **Instruments that compensate for risk,** providing a financial incentive to investors in the renewable energy project. When risks cannot be reduced or transferred, residual risks and costs can be compensated for. These instruments can take many forms, including price premiums (either as part of a PPA or FiT), tax breaks, and proceeds from the sale of carbon credits. The DREI methodology calls these types of instruments **"direct financial incentives"**.

**Figure 7: Typical components of a public instrument package for large-scale renewable energy**




Source: Derisking Renewable Energy Investment (UNDP, 2013)

## 2.3 THE METHODOLOGY'S FOUR STAGE FRAMEWORK

The DREI report sets out a detailed methodology to support policy decision-making by quantitatively comparing different public instrument portfolios and their impacts.

Selecting public instruments for renewable energy is highly dependent on national circumstances. Each country has its own particular renewable resources, objectives and constraints. Therefore, the methodology is designed to be applied flexibly and to be tailored to a specific renewable energy technology and national context. As illustrated in Figure 8, the methodology is organised into a framework with four stages, each of which is, in turn, divided into two steps.

- **Stage 1: Risk Environment** identifies the set of investment barriers and associated risks relevant to the renewable energy technology, and analyses how the existence of investment risks can increase financing costs.

- **Stage 2: Public Instruments** selects a mix of public derisking instruments to address the investor risks and quantifies how they, in turn, can reduce financing costs. This stage also determines the cost of the selected public derisking instruments.

- **Stage 3: Levelised Cost** determines the degree to which the reduced financing costs impact the renewable energy life-cycle cost (LCOE). This is then compared against the current baseline generation costs in the country.

- **Stage 4: Evaluation** assesses the selected public derisking instrument mix using four performance metrics, as well as through the use of sensitivity analyses. The four metrics are: (i) investment leverage ratio, (ii) savings leverage ratio, (iii) end-user affordability and (iv) carbon abatement.

The intent of the methodology is not to provide one predominant numerical result but is, instead, to facilitate a structured and transparent process whereby key inputs and assumptions are made explicit, so that they can contribute to and inform the design process.

**Figure 8: Overview of the DREI methodology for selecting public instruments to promote renewable energy investment**

| | Step 1 | | Step 2 |
|---|---|---|---|
| Stage 1: Risk Environment | • Determine a multi-stakeholder barrier and risk table for the renewable energy investment | → | • Quantify the impact of risk categories on increased financing costs |
| Stage 2: Public Instruments | • Select one or more public derisking instrument(s) to mitigate the identified risk categories | → | • Quantify the impact of the public derisking instrument(s) to reduce financing costs<br>• Quantify the public costs of the public derisking instrument(s) |
| Stage 3: Levelised Cost | • Calculate the levelised cost of electricity (LCOE) for the baseline energy generation mix in the particular country | → | • Quantify the LCOE for renewable energy investment in the (i) pre-derisking and (ii) *post-derisking scenarios*<br>• Calculate the incremental cost (or savings) by comparing these scenarios vs. the baseline |
| Stage 4: Evaluation | • Analyse the selected public instrument(s) in terms of four key performance metrics | → | • Perform sensitivity analyses on key inputs and assumptions |

Source: Derisking Renewable Energy Investment (UNDP, 2013)

# 3. Current Status of Wind Energy and Solar PV in Lebanon

# Current Status of Wind Energy and Solar PV in Lebanon

3

This section provides a brief overview of the current context, status and objectives for wind energy and solar PV in Lebanon.

| Lebanon General Country Data[25] | |
|---|---|
| **Population 2015:** | 5.9m |
| **Land Area:** | 10,452 sq. km |
| **GDP 2015 (USD):** | $51.2 billion |
| **GDP/capita (USD, PPP) 2015:** | $18,240 |
| **Sovereign rating 2016:** | Highly speculative, B2 (Moody's), B- (S&P) |
| **UNDP HDI 2014:** | 0.769 (67th of 188) |

## 2030 Targets for Wind Energy and Solar PV

There is strong potential for renewable energy in Lebanon. Lebanon is well positioned for investment, with a dynamic domestic business and financial sector. Renewable energy has the opportunity to contribute positively to Lebanon's power sector, addressing unmet power demand and increasing the reliability of supply, decreasing the country's dependence on fuel imports, improving the affordability of the energy mix, and reducing the need for subsidies to Electricté du Liban (EDL). Renewable energy can also support Lebanon's contributions under the UNFCCC (GoL, 2015).

While there is currently a binding target of 12% renewable energy in the generation mix by the year 2020[26],. the recently-published NREAP also outlines the vision of increasing the share of RE for heat and power to 12.6% by 2030. Under consideration of the rapidly growing energy demand in Lebanon, that vision was translated to an installed capacity of 450 MW of wind energy and 300 MW of large-scale solar PV. The modelling presented in this report uses these 2030 investment targets derived from NREAP's 2030 vision. In line with the NREAP, these investment targets are assumed to be fully financed by the private sector.

It is possible to envision even more ambitious investment targets for renewable energy. Lebanon's Intended Nationally Determined Contribution (INDC) to the UNFCCC includes a 2030 scenario with renewable energy at 20% of the generation energy mix, should international support be available (GoL, 2015). There is likely sufficient power demand to absorb such more ambitious renewable energy targets. In light of Lebanon's INDC, the subsequent NREAP, to be released after 2020, shall target 15-20% RE (power and heat) by 2030.

## Power Sector Context

Lebanon's power sector is currently characterised by a significant supply-demand imbalance, continued growth in demand, high generation costs and a lack of financial sustainability.

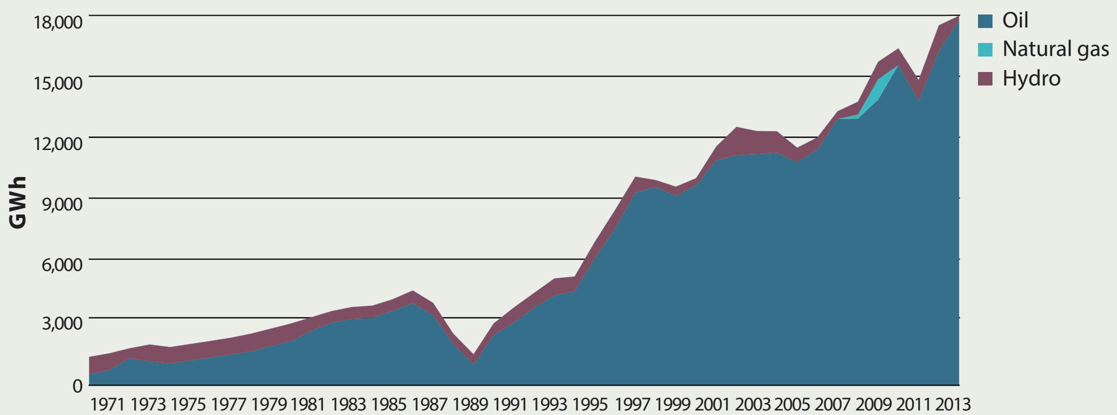
Electricté du Liban's (EDL) available installed capacity is 1,616 MW. Due to the poor state of generation infrastructure this is below the actual installed capacity of 2,300 MW[27]. This in turn contrasts with peak demand of up to 3,000 MW in summer months. Daily power cuts are regular occurrences, and are mitigated by wide-spread back-up diesel generators at larger companies, in informal neighbourhood generators and in individual households. This supply-demand imbalance creates significant challenges for Lebanon's economy and people.

[25] Sources: International Monetary Fund – World economic outlook database, April 2016; Moody's, Standard & Poor's; UNDP.

[26] According to the NREAP, this target is expected to be reached by installing 200 MW of wind energy and 150 MW of solar PV, in addition to 100 MW distributed PV, 50 MW CSP, 1,053,938 m$^2$ SWH, 331.5 MW hydropower, and 1.3 MW geothermal.

[27] Source: 2015 statistics from MoEW, directly communicated to authors.

**Figure 9: Electricity generation by fuel in Lebanon (1971 to 2014)**




Source: OECD/IEA (2016)

As set out in Figure 9, the baseline energy mix is dominated by oil, accounting for over 95% of generation. Demand has been growing steadily and is projected to continue to grow at a rate of 5% per year[28]. Renewable energy currently accounts for 4% of the electricity produced in Lebanon, which is predominantly hydro power and a small share of less than 0.2% of solar PV (mostly distributed PV).

Due in large part to the predominance of fuel oil, a relatively expensive source of power, and exacerbated by aging infrastructure, Lebanon is burdened with high generation costs. Electricity prices to the end-users are not cost-reflective. Tariffs are fixed at around 9.5 USD cents per kilowatt-hour on average across consumer type and day times[29]. The last update of the tariff structure dates back to 1996. Consequently, EDL cannot recover its operating costs and depends on the support by the Government of Lebanon (GoL). The GoL signs import contracts for the fossil fuels that are burned in EDL's power plants. In 2013, EDL received transfers amounting close to USD 2 billion, corresponding to 4.5% of the GDP (MoE, 2015) – a significant strain on the government budget.

## Renewable Energy Resources

Lebanon has significant wind energy and solar potential. Figure 10 shows wind and solar resource maps for Lebanon. Wind sites with strongest wind speeds are found along the eastern and northern borders to Syria (Beqaa and North Governorate) as well as along the mountain ranges, especially the Mount Lebanon range. Solar irradiation is above 1,500 kWh/m$^2$ in all parts of the country[30], and it is especially high in the East.

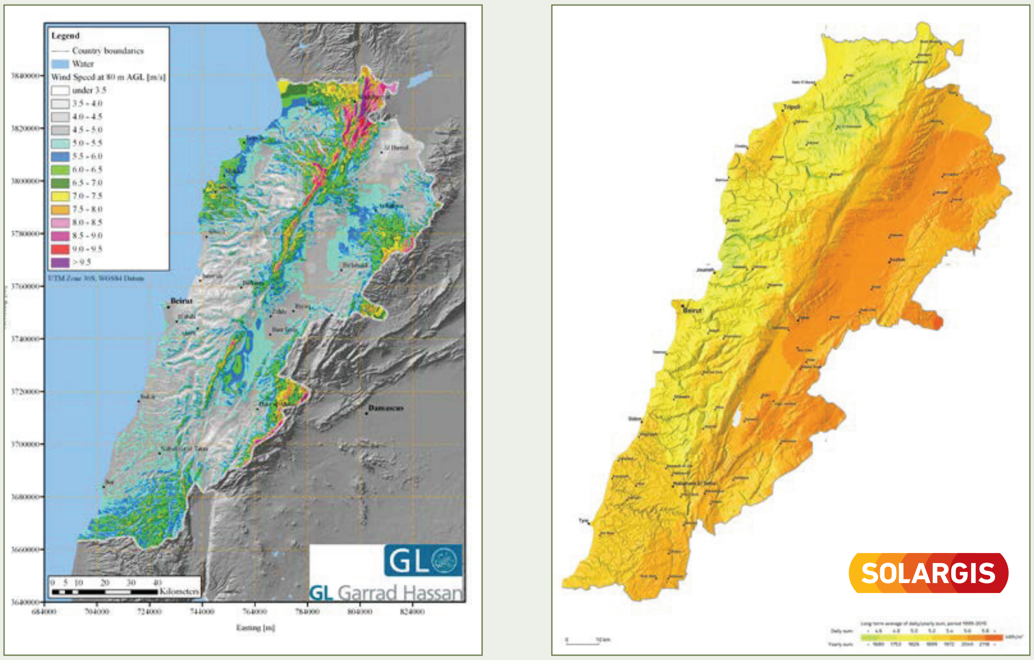
The modelling uses a capacity factor of 25.6% for wind energy, and 19.8% for solar PV. These capacity factors are the area-weighted averages elaborated by UNDP/CEDRO for the NREAP.

[28] Source: the authors, informed by MoEW and local studies. This projection accounts for the recent demographic development related to the immigration of Syrian displaced.

[29] Source: 2014 statistics from MoEW, directly communicated to authors.

[30] To give an indication, 1,500 kWh/m$^2$ is higher than the maximum irradiation available in Germany.

**Figure 10: Resource maps for wind and solar in Lebanon**




Source: CEDRO – The National Wind Atlas of Lebanon (CEDRO, 2011); Global Horizontal Irradiance, GHI, 1999-2015 average daily/yearly sum. Solar resource data obtained from the Global Solar Atlas, owned by the World Bank Group and provided by Solargis.

## Current Status of Wind and Solar PV Investment

To date, there have not been investments in wind farms in Lebanon, neither from the private nor the public sector. The MoEW started a procurement process in March 2013, asking for bids for a 50-100 MW wind farm to be built and operated under a power rental agreement with EDL[31]. Three bids from local developers have been further considered, and this procurement remains ongoing.

As for solar PV, most of the capacity installed to date is distributed and of small-scale. The country's first and large-scale project is the Beirut River Solar Snake that was commissioned last year (1.1 MW, extension up to 10 MW is being considered). This plant is currently owned by GoL and will be transferred soon to EDL. A second plant reaching 1.1 MW peak power as well is connected to the grid in southern Lebanon.

While outside this study's direct focus on large-scale renewable energy, the government via BDL has been putting in place policies and initiatives to promote small-scale renewable energy investments in Lebanon, most notably the above-mentioned **NEEREA incentive scheme** for subsidized green loans and the soon to be

[31] Source: MoEW (2013), Request for Proposal: Wind Energy Power Project.

implemented **LEEREFF facility** (see 1. Introduction). Other initiatives include the **Kafalat Energy** guarantee product that targets green energy investments by eligible small and medium sized enterprises with financial support from the EU under NEEREA and several RE and EE related projects under UNDP management, among them CEDRO and DREG.

With the support of these initiatives, Lebanon's RE industry has focused on solar water heaters and solar panels for buildings and factories not exceeding a few hundred kilowatts peak capacity. A major obstacle for larger-scale projects is the prevailing legal framework.

Law 462 to regulate the electricity sector has existed on paper since 2002, but has never entered into force. This law (to be viewed in conjunction with amended Laws 288 and Law 54) is aimed at unbundling EDL, allowing private power generation and grid connection through independent power producers (IPPs). The law also aims to establish the National Electricity Regulatory Authority (NERA). NERA is envisaged as the actor that prepares necessary power regulations such as grid codes, power purchase agreements (PPAs), and feed-in structures, including feed-in tariffs (FiT) for RE.

Interviews with investors in Lebanon have shown that there is considerable interest today from domestic private sector actors. This interest continues despite the slow pace of power sector reform and procurement activities to date.

# 4. Modelling of Wind and Solar PV Energy Promotion in Lebanon

# Modelling of Wind and Solar PV Energy Promotion in Lebanon

4

This section describes the DREI modelling for promotion of private sector, large-scale investment in wind energy and solar PV in Lebanon. First, a summary of the approach to the modelling is provided. It describes the two scenarios modelled, highlighting key modelling assumptions and setting out the underlying risk categories, as well as the associated barriers and public instruments. It then describes the modelling results, organized in terms of the DREI methodology's four stages.

As in any modelling exercise, the modelling uses a simplified set of underlying data and assumptions that are presented in Annex A. Further in-depth data collection and more comprehensive assumptions can strengthen the robustness of these results.

## 4.1 THE MODEL'S APPROACH

### 4.1.1 Modelling Two Core Scenarios in Lebanon

In order to study different public instrument packages, the modelling compares two core scenarios to achieve the envisioned 2030 investment targets for large-scale wind energy and solar PV: a *business-as-usual* (BAU) scenario and a *post-derisking scenario*. Both scenarios take the prevailing (2016[32]) risk environment in Lebanon as the starting point, while the study period for the financial modelling is set to be from 2017 to 2030 (14 years).

- ***Business-as-usual* scenario.**
  - This scenario assumes that the envisioned 2030 investment target is achieved under today's risk environment in Lebanon.
  - The BAU scenario uses the current financing costs and terms (capital structure and loan tenor) that an investor encounters in Lebanon.
- ***Post-derisking* scenario.**
  - This scenario assumes that the envisioned 2030 investment target is achieved under a derisked investment environment, in which a set of policy derisking and financial derisking instruments are deployed to address current investment risks and associated barriers.
  - As such, the post-derisking scenario uses adjusted financing costs and terms (capital structure and loan tenor) compared to the BAU scenario, reflecting the impact of derisking instruments in reducing the financing costs and improving financing terms.

[32] Data collection has been performed in summer 2016.

### 4.1.2 Key Modelling Assumptions

The application of the DREI methodology entails a significant amount of data gathering and requires a number of assumptions to be made. In order to keep the scope of the modelling manageable, a set of simplified data and modelling assumptions have been used.

The following key issues associated with the modelling merit highlighting:

- **Variability.** An inherent characteristic of wind energy and solar PV is their variability and lack of dispatchability. Energy planners typically need to balance such renewable energy technologies with dispatchable capacity, and LCOE-based comparisons using variable energy sources can have limitations in not capturing this balancing cost, nor generation costs at peak demand. The modelling does not include balancing costs. The assumed targets anticipate that wind energy and solar PV will be less than 2% of Lebanon's projected electricity and heat demand in 2030 (MoEW/LCEC, 2016), and arguably this level can be absorbed into Lebanon's power grid with minimal cost or disruption. .

- **Transmission Lines.** In order to keep the modelling manageable, the modelling assumes that all the wind energy and solar PV sites to meet the envisioned 2030 investment target are within 10 km of the existing grid. Capital costs related to the upgrade and maintenance of the grid infrastructure in Lebanon are excluded from the analysis.

- **Baseline costs.**
  - Renewable energy investments are made in the context of an existing or evolving (with new installed capacity coming online) electricity generation mix. Lebanon is characterized by rapidly increasing energy demand: consequently, new wind and solar PV installations will likely not replace existing capacity. Nevertheless, Lebanon's existing power plant fleet is old and inefficient. Despite the ongoing refurbishment campaign by the GoL, it can be anticipated that new RE installations could at least partly replace the existing fleet. For these reasons, the modelling takes a combined baseline approach (80% build margin, 20% operating margin) to estimating the baseline costs, assuming new plants take the form of combined cycle gas turbine (CCGT) technology (80% of the baseline), and to a smaller extent the currently operating fossil power plant fleet that could be partly replaced by large-scale wind energy or solar PV (20% of the baseline)[33].

  - Private-sector financing costs are used in the build margin share. This reflects an assumption that Lebanon is seeking to attract private sector investment irrespective of the energy technology. For the operating margin share, financial modelling considers ownership, depreciation, remaining lifetime, and fuel type of the existing power plants.

  - The modelling assumes a combined baseline grid emission factor equating to 0.497 tonnes of $CO_2e$/MWh[34].

[33] In other words, renewable energy is compared to a generation mix that is partly composed of yet-to-be-built new technology (build margin) and of existing technology that were to be replaced (operating margin). The operating margin excludes the small share of hydropower 2.5% of total mix in the year 2015), since these plants are most likely not to be replaced by new renewable energy.

[34] Source: Tunisia Bizerte Wind Farm CDM PDD (2012) for CCGT emission factor (0.448 $tCO_2e$/MWh); 2015 Statistics from Ministry of Water and Energy (2016) for operating power plant fleet emission factor (0.694 $tCO_2e$/MWh, excluding hydropower)

- **Unsubsidised baseline fuel costs.** The fuel costs have been obtained from World Bank projections for the gas price and from Energy Information Agency projections for diesel and heavy fuel oil prices. The 2017 starting point together with the projections until 2030 for these fuel prices were cross checked with the Ministry of Finance. These fuel costs are unsubsidised. More generally, it is to be noted that issues of subsidization of existing power generation in Lebanon, whether via subsidies on imported fuel, or non-cost-reflective tariffs, are outside the scope of this exercise and have not been captured in the modelling.

- **Installed costs and O&M costs for wind energy and solar PV.** The assumptions for the installed costs (i.e. the cost of hardware, such as wind turbines and solar panels) and for the operations and maintenance (O&M) costs have particular potential for improving the overall competitiveness of wind energy and solar PV in Lebanon. Globally, the costs of renewable energy hardware have been falling consistently over time, and they are expected to continue to do so. The same is true for O&M costs, which is partly due to technology improvements and better forecasting, and partly also due to the increasing competition for O&M contracts as the number of service providers keeps growing. This study assumes installed and O&M costs for onshore wind energy and solar PV expected to prevail at the end of the year 2023, i.e. the year that reflects the mid-point of the modelling period 2017-2030. The 2023 cost estimates are derived from the latest projections elaborated by the International Renewable Energy Agency and published in June 2016 (IRENA, 2016). The sensitivity analysis that is part of this DREI study will elucidate the impact on the results when assuming the present (2016) installed and O&M costs as provided by Lebanese developers.

The full underlying data-sets and assumptions for the modelling are set out in Annex A

### 4.1.3 Public Instrument Table

The following Table 2 sets out in full the stakeholders, barriers and risk categories for large-scale wind energy and solar PV, and the matching public instruments to address these barriers and risks. This was derived from the generic public instrument table for large-scale, renewable energy in the DREI report (Waissbein *et al.,* 2013). Based on stakeholder consultation and investors' feedback, a small number of changes have been made to the generic table; these changes are described in Annex A.

**Table 2: Risks, barriers, public instruments table (Part I)**

| BARRIERS | | | |
|---|---|---|---|
| **RISK CATEGORY** | **DESCRIPTION** | **UNDERLYING BARRIERS** | **KEY STAKEHOLDER GROUP** |
| **1. Power Market Risk** | Risk arising from limitations and uncertainties in the energy market, and/or sub-optimal regulations to address these limitations and promote renewable energy markets | • *Market outlook:* lack of or uncertainties regarding governmental renewable energy strategy and targets<br>• *Market access and prices:* limitations related to energy market liberalization; uncertainty related to access, the competitive landscape and price outlook for renewable energy; limitations in design of standard PPAs and/or PPA tendering procedures<br>• *Market distortions:* such as high fossil fuel subsidies | Public sector (GoL, Parliament, Concerned ministries) |
| **2. Permits Risk** | Risk arising from the public sector's inability to efficiently and transparently *administer* RE-related licensing and permits | • Labour-intensive, complex processes and long time-frames for obtaining licences and permits (generation, EIAs, land title) for renewable energy projects<br>• High levels of corruption. No clear recourse mechanisms. | Public sector (MoEW , MoE, MoF, other ministries might be involved) |
| **3. Social Acceptance Risk** | Risks arising from lack of awareness and resistance to renewable energy in communities, among end-users, and private generators | • Lack of awareness of renewable energy amongst consumers, end-users, local residents, and labour unions<br>• Social and political resistance related to NIMBY concerns, special interest groups | End-users, general public, private generators |
| **4. Developer Risk** | Risks arising from use of the renewable energy resource and technology (resource assessment; construction and operational use; hardware purchase and manufacturing) | • *For resource assessment and supply:* inaccuracies in early-stage assessment of renewable energy resource<br>• *For planning, construction, operations and maintenance:* uncertainties related to securing land; sub-optimal plant design; lack of local firms offering construction, maintenance services; lack of skilled and experienced local staff; limitations in civil infrastructure (roads etc.)<br>• *For the purchase of hardware:* purchaser's lack of information on quality, reliability and cost of hardware; lack of local industrial presence and experience with hardware (suitability of hardware to local climatic and physical conditions), including skilled and experienced local workforce | LCEC, project developers, Ministry of Industry, Lebanese Standards Institution |

Source: authors; adapted from Derisking Renewable Energy Investment (Waissbein *et al.,* 2013).

| MENU OF SELECTED PUBLIC INSTRUMENTS | | | |
|---|---|---|---|
| POLICY DERISKING INSTRUMENTS | | FINANCIAL DERISKING INSTRUMENTS | |
| ACTIVITY | DESCRIPTION | ACTIVITY | DESCRIPTION |
| Establish transparent, long-term national renewable energy strategy and targets | Regular updates of national energy planning, including national-level resource inventory/mapping, technology options, and renewable energy target formulation | | |
| Establish a harmonized, well-regulated energy market, with cornerstone instruments to address price and market-access risk for renewable energy projects | (i) Ongoing legislative reform to implement well-designed and harmonized policies; (ii) establish an independent energy market regulator; (iii) Implement FiT and PPA tendering, including well-designed standard PPA | | |
| *Policy derisking instruments addressing this barrier, e.g., fossil subsidies reform/assessment of real cost of fossil electricity without fuel subsidies, are not included in this Lebanon analysis following investor feedback.* | | | |
| Awareness-raising campaigns targeting communities and end-users | Working with the media, awareness campaigns, stakeholder dialogue and workshops with end users, policymakers, and local residents. | | |
| Outreach and stakeholder involvement at project sites | Community consultations including piloting models such as in-kind services (energy access, local employment; etc.) or equity stakes in renewable energy projects | | |
| Awareness-raising campaigns | Implement active publicity, media and awareness campaign targeting key stakeholder groups . | | |
| Community-based involvement at project sites | Establish favourable local (e.g. municipal) policies and promote and pilot community based models (e.g equity stakes in renewable energy projects) | | |
| *Policy derisking instruments addressing this barrier, e.g., security plan support for project sites/law enforcement/dedicated stakeholder involvement models, are not included in this Lebanon analysis following investor feedback.* | | | |
| For wind energy only: building capacity of LCEC for resource assessment | For wind energy only: Capacity building and dissemination of top-level, national resource assessment findings; grant funding for on-site resource assessment | | |
| Via LCEC: feasibility studies; networking; training and qualifications | Industry conferences; grant funding for pre-feasibility studies (depending on technology); training, apprenticeships and university programmes to build skills (planning, construction, O&M) | | |
| *Derisking instruments addressing this barrier, e.g., trade fairs, financial products by development banks to assist local manufacturers, are not included in this Lebanon analysis following the definition of the general investment assumptions.* | | | |

**Table 2: Risks, barriers, public instruments table (Part II)**

| BARRIERS | | | |
|---|---|---|---|
| **RISK CATEGORY** | **DESCRIPTION** | **UNDERLYING BARRIERS** | **KEY STAKEHOLDER GROUP** |
| **5. Grid/Transmission Risk** | Risks arising from limitations in grid management and transmission infrastructure in the particular country | • *Grid code and management:* limited experience or suboptimal operational track-record of grid operator with intermittent sources (e.g., grid management and stability). Lack of standards for the integration of intermittent, renewable energy sources into the grid<br>• *Transmission infrastructure:* inadequate or antiquated grid infrastructure, including lack of transmission lines from the renewable energy source to load centres; uncertainties for construction of new transmission infrastructure | Electricité du Liban (as transmission/grid operator) |
| **6. Counterparty Risk** | Risks arising from the utility's poor credit quality and an IPP's reliance on payments | • Limitations in the EDL's (as electricity purchaser) credit quality, corporate governance, management and operational track-record or outlook; unfavourable policies regarding utility's cost-recovery arrangements | Electricité du Liban (as electricity purchaser) |
| **7. Financing Risk** | Risks arising from general scarcity of investor capital (debt and equity) in the particular country, and investors' lack of information and track record on renewable energy | • *Capital scarcity:* Limited availability of local or international capital (equity/and or debt) for green infrastructure due to, for example: under-developed local financial sector; policy bias against investors in green energy<br>• *Limited experience* with renewable energy: Lack of information, assessment skills and track-record for renewable energy projects amongst investor community; lack of network effects (investors, investment opportunities) found in established markets; lack of familiarity and skills with project finance structures | Investors (equity and debt) |
| **8. Political Risk** | Risks arising from country-specific governance and legal characteristics | • Uncertainty or impediments due to war, terrorism, and/or civil disturbance<br>• Uncertainty due to high political instability; poor governance; poor rule of law and institutions<br>• Uncertainty or impediments due to government policy (currency restrictions, corporate taxes) | National level |
| **9. Currency/ Macro-economic Risk** | Risks arising from the broader macroeconomic environment and market dynamics | • Uncertainty due to volatile local currency; unfavourable currency exchange rate movements<br>• Uncertainty around inflation, interest rate outlook due to an unstable macroeconomic environment | National level |

Source: authors; adapted from Derisking Renewable Energy Investment (Waissbein *et al.,* 2013).

| MENU OF SELECTED PUBLIC INSTRUMENTS | | | |
|---|---|---|---|
| **POLICY DERISKING INSTRUMENTS** | | **FINANCIAL DERISKING INSTRUMENTS** | |
| **ACTIVITY** | **DESCRIPTION** | **ACTIVITY** | **DESCRIPTION** |
| Strengthen EDL's operational performance, grid management and formulation of grid code | Dissemination of grid code developed by DREG and CEDRO projects (MoEW), including procedures to connect new RE infrastructure to the grid; sharing of international best practice in grid management | Include a "take-or-pay" clause in the standard PPA | "Take-or-pay" clause in PPA whereby IPP is reimbursed for grid failure (black-out, brown-out) and/or curtailment (due to mismatches in grid management of supply/ demand) |
| Policy support for national grid infrastructure development | Develop and regularly update a long-term national transmission/grid road-map to include intermittent renewable energy | *Financial derisking instruments addressing this barrier, e.g., public loans for grid infrastructure, are not included in this Lebanon analysis. Outside scope of analysis.* | |
| Strengthen EDL's management/ operational performance | Establish international best practice in EDL's management, operations and corporate governance; implement sustainable cost recovery policies | Government (sovereign) guarantees or backing for PPA payments; public loans | Government letter of support for PPA payments to IPPs (potentially to be endorsed by the council of Ministers); governmental/international buy-in to projects via public loans |
| Financial sector policy reforms | Promote financial sector policy favourable to long-term infrastructure, including project finance | Financial products by development banks or the Central Bank, to assist project developers to gain access to capital/funding | Depends on specific financial circumstances. Can include as necessary: public loans; public loan guarantees; public equity |
| Strengthen investors' (debt and equity) familiarity with and capacity regarding renewable energy projects | Industry-finance dialogues and conferences; workshops/training on project assessment and financial structuring (project finance); public-private partnership building | | |
| | | Risk sharing products by development banks to address political risk | Provision of political risk insurance (PRI) covering (i) expropriation, (ii) political violence, (iii) currency restrictions |
| | | *Financial derisking instruments addressing this risk category, e.g., partial indexing of local currency tariffs in PPAs, are not included in this Lebanon analysis following investor feedback.* | |
| | | | |
| | | Risk sharing mechanisms to address currency risk | Partial indexing of local currency tariffs in PPAs, so that IPPs are reimbursed for local currency depreciation of tariff |
| | | | |

## 4.2 THE MODEL'S RESULTS

### 4.2.1 Risk Environment (Stage 1)

#### Interviews

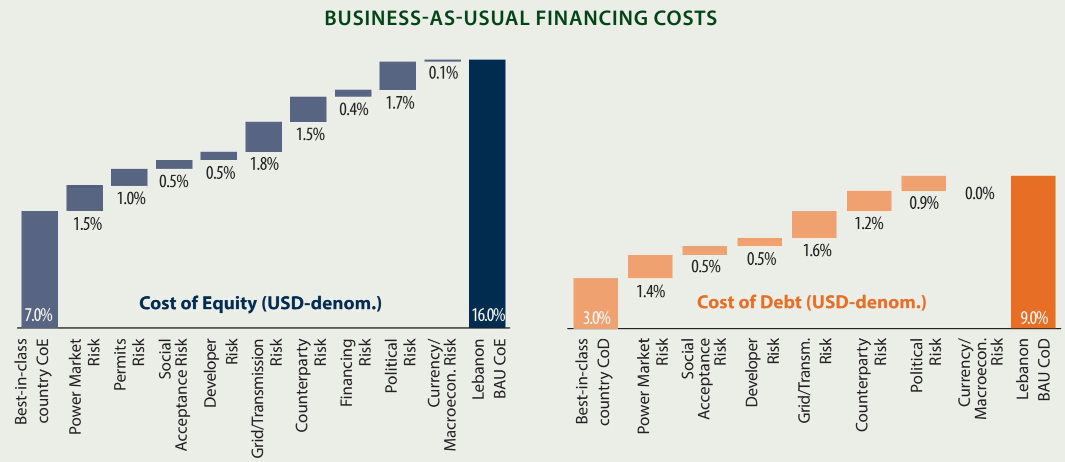
Data for Stage 1 (Risk Environment) of the modelling were gathered from interviews held with 17 project developers and investors who are domestically and internationally active and who are considering, or are actively involved in, large-scale wind and solar PV investment opportunities in Lebanon. Most of the interviews were held face-to-face during a country mission at end of July 2016. A few interviews were held remotely early August 2016. In addition, informational inquiries were placed in person during the country mission and in writing throughout the analytical work to the interviewees and other stakeholders.

#### Financing Cost Waterfalls

The analysis of the contribution of investment risks to higher financing costs in Lebanon is shown in the financing cost waterfalls in Figure 11. This analysis was performed jointly for wind energy and solar PV investors. Definitions of each of the risk categories can be found in Table 2.

A brief summary of the qualitative feedback that wind energy and solar PV developers and investors shared in their interviews is provided in Table 3.

**Figure 11: Impact of risk categories on financing costs for wind energy and solar PV investments in Lebanon, business-as-usual scenario**[35]




Source: interviews with wind energy and solar PV investors and developers; modelling; best-in-class country is assumed to be Germany; see Annex A for details on assumptions and methodology.

[35] The financing cost waterfalls shown here are calculated by differentiating between the answers from equity and from debt investors, but not distinguishing further between investors with focus on wind energy and investors with focus on solar PV. It is recognized that the risk profiles of large-scale wind energy and solar PV can differ. However, the results of the interviews with wind energy and solar PV investors made clear that these differences are minimal in the Lebanese context. As such, the interview answers from equity and from debt investors were not further split into 'wind energy focus' and 'solar PV focus' sub-groups, in order to bring simplicity to the analysis and to avoid multiple result sets. For comparison, cost waterfalls with a distinction between answers from wind energy and solar PV investors are shown in Annex A.

**Table 3: Qualitative investor feedback on risk categories for wind energy and solar PV investment in Lebanon**

| RISK CATEGORY | POLICY DERISKING INSTRUMENTS |
|---|---|
| **Power market risk** | This risk category has a high impact on financing cost. Debt investors speak favourably about the NEEREA scheme that they use to lend to small-scale RE projects and even more to EE and green building measures. Investors generally see a good outlook in Lebanon in terms of the competitiveness of RE since the demand for electricity is much larger than the current supply and RE generates more cheaply than the existing power plants. For the same reason, fossil fuel subsidies (treasury payments to EDL) are not perceived an issue.<br><br>However, scepticism was expressed regarding the political will and power necessary to introduce long term policies and an enabling regulatory environment, for instance the timely enforcement of Law 462 in conjunction with its amendments. The key issues mentioned are indeed the fact that it is, under current jurisdiction, not allowed for private entities to sell electricity to the grid (IPPs are illegal), followed by the uncertainty about how a PPA with EDL would look like, and finally, the lack of a competent regulatory authority for renewable energies. In this context, though, the establishment and involvement of LCEC was mentioned positively by a number of investors. |
| **Permits risk** | This risk category has a low impact on financing costs. Investors' views on this risk category were mixed, in part due to the limited empirical experience of private-sector investors with permits to date. One investor commented that, on paper, the existing process and timelines for permits is clear. However, looking ahead, other investors commented that the new legislation has burdensome requirements for permits, and would welcome streamlining of these requirements. |
| **Social acceptance risk** | This risk category has a low impact on financing costs. In general, investors do not feel that there is significant risk from local communities. Project sites will likely be in areas with low population density, and project developers actively perform outreach in terms of stakeholder engagement, emphasising employment and tax benefits. Investors did comment on possible resistance to renewable energy, for example from STEG trade unions, due to concerns about private sector involvement. |
| **Developer Risk** | This risk category has a low impact on financing costs. Investors view this risk category as an area for which they themselves are responsible and expressed confidence that they can manage these risks directly. Nonetheless, one investor warned against designs of bidding processes which result in unnecessary duplication of detailed wind measurements by developers. Investors generally viewed solar PV as having lower resource assessment risk than wind and acknowledged a degree of uncertainty regarding solar PV technology in desert environments. |
| **Grid integration risk** | This risk category has a high impact on financing cost. The current condition of the grid and its management (incl. the lack of robust grid codes) is perceived as a major threat to the investor's ability of securing revenue by electricity sales. Furthermore, several investors expressed concerns that the EDL would lack the budget to perform preventive maintenance, Another issue mentioned that prevents grid extension is the lack of space in the densely populated areas along the coast as well as difficulties to obtaining permits from local authorities. Note, however, that for this risk category the perceived risk might be enhanced by the experience of frequent power cuts that are associated intuitively with grid instability rather than with the actual lack of generation capacity. |
| **Counterparty risk** | This risk category has a high impact on financing cost. While none of the investors consider EDL to be a trustworthy counterparty, it is also acknowledge that the GoL (via EDL) has never defaulted in the past. The bigger concern for most investors is the likelihood of receiving delayed payments, which would add substantially to their risk. Privatization of EDL was mentioned as a solution. |
| **Financing Risk** | This risk category has a low impact on financing cost. Lebanon's financial sector is perceived to be mature and liquid, according to unanimous investor feedback. Debt investors were uncomfortable with assuming a non-recourse, project finance structure when asked to rate risks around a generic investment opportunity. Investors admitted to have little to no experience with project-based lending, which is the preferred financing structure for large scale RE projects in most parts of the world. |
| **Political risk** | This risk category has a high impact on financing cost. Investors appreciate the ongoing peaceful times and trends towards growth, and some are convinced of Lebanon's strategic importance within the fragile region. However, investors are also concerned about the political status quo and do not take peace for guaranteed (with the short 2006 war showing how little it takes for the complex intra- and international relationships to escalate - this example was mentioned several times). Due to the current Syrian displaced crisis, investors would generally be cautious with projects in regions close to the Syrian borders (Beqaa governorate, Akkar district, …), which unfortunately are collocated with Lebanon's best wind resources. |
| **Currency/ macroeconomic risk** | This risk category has a low impact on financing cost. The economic outlook is viewed mostly positively, with the currency stable, inflation low, and the central bank profitable. Investors confirm that Lebanon has a "dollar-economy", since 1) larger contracts within the private sector are usually signed in US dollar, and 2) the Lebanese pound is pegged to the US dollar since 1997 (at ~1507 LBP/USD). |

Source: interviews with investors (equity investors/developers and debt investors).

The results estimate the business-as-usual cost of financing in Lebanon today for wind energy and solar PV to be 16% for the cost of equity (CoE) and 9% for the cost of debt (CoD)[36]. These are substantially higher than in the best-in-class country, Germany, which is estimated at 7.0% for the CoE and 3.0% for the CoD. Four risk categories – power market risk, grid/transmission risk[37], counterparty risk and political risk – all have a high impact on financing costs. As is shown in later results, over the long lifetime of energy investments, the impact of Lebanon's higher financing costs on the competitiveness of renewable energy is substantial.

## 4.2.2 Public instruments (Stage 2)

### Selection and costing of public instruments

Having identified the key investment risks, a package of public instruments can then be assembled to address them. The modelling adopts a systematic approach to identifying policy instruments: if the financing cost waterfalls (Figure 12) identify an incremental financing cost for a particular risk category, then the matching public instrument (Table 3) is deployed as part of the public instrument package.

**Table 4: The selection of public instruments to achieve the envisioned investment targets for wind energy and solar PV**

| RISK CATEGORY | POLICY DERISKING INSTRUMENTS | FINANCIAL DERISKING INSTRUMENTS |
|---|---|---|
| **Power Market Risk** | • Long-term, legally-binding RE targets<br>• Establishment of an enabling regulatory framework<br>• FIT/PPA tender (standardized PPA)<br>• Independent regulator for power sector | NA |
| **Permits Risk** | • Streamlined process for RE permits (dedicated one-stop shop)<br>• Contract enforcement and recourse mechanisms | NA |
| **Social Acceptance Risk** | • Awareness-raising campaigns<br>• Stakeholder outreach, including operators of private generators | NA |
| **Developer Risk** | • Capacity building for resource assessment (wind only)<br>• Technology and Operations & Maintenance (O&M) assistance | NA |
| **Grid/Transmission Risk** | • Strengthen EDL's performance<br>• Transparent, up-to-date grid code<br>• Policy support for grid infrastructure development | • Take-or-pay clause in PPA[38] |
| **Counterparty Risk** | • Strengthen EDL's management and operational performance | • Government guarantee for PPA payments<br>• Concessional public loans to IPPs |
| **Financing Risk** | • Fostering financial sector reform towards long-term green infrastructure investment<br>• Strengthening financial sector's familiarity with renewable energy and project finance | • Concessional public loans to IPPs |
| **Political Risk** | NA | • Political risk insurance for equity investments |
| **Currency/Macroeconomic Risk** | NA | NA |

Source: modelling. See Annex A for a full description of these instruments. "NA" indicates "Not Applicable".

[36] CoE and CoD are USD-denominated.

[37] In analysing the structured interviews with investors, the authors noted that the contribution of this risk category may be over-represented. In certain cases, interviewees assigned issues related to the lack of generation capacity (black-outs/brown-outs) to 'grid/transmission' risk when in actual fact issues related to lack of generation capacity should be associated with 'power market risk'. Please see definitions of each risk category in Table 3 for clarification.

[38] A "take-or-pay" clause is a clause found in a Power Purchase Agreement (PPA) that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver electricity generated by its renewable energy plant.

The public costs of each selected public instrument are also modelled:

- For wind energy (2030 target: 450 MW), the total public instrument cost (2017-2030) is estimated as being USD 6.7 million in policy derisking instruments and USD 91.4 million[39] in financial derisking instruments.

- For solar PV (2030 target: 300 MW), the total public instrument cost (2017-2030) is estimated as being USD 4.8 million in policy derisking instruments and USD 40.9 million[40] in financial derisking instruments.

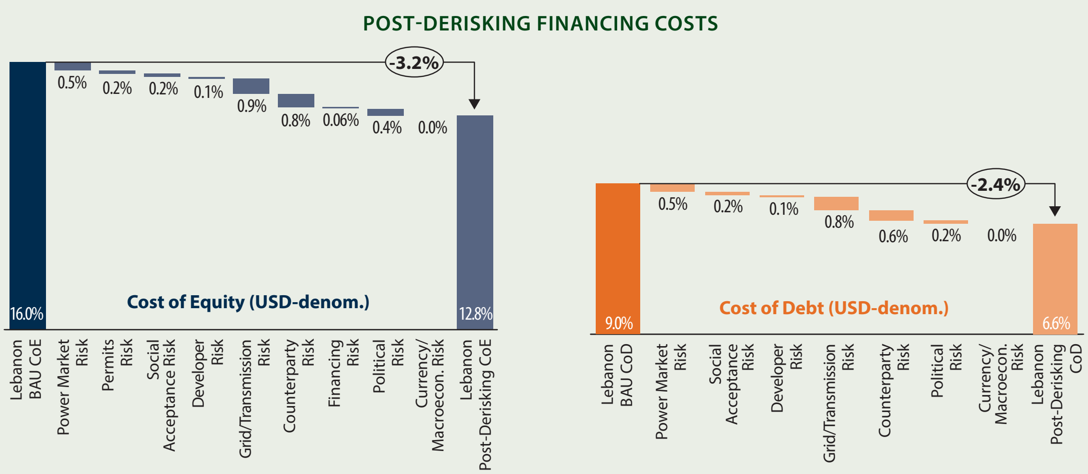
The full breakdown of each selected public instrument and its cost is provided in Table 13 (wind energy) and Table 14 (solar PV). Details of the assumptions and the methodology used to generate the cost estimates are available in Annex A.

## Impact of public instruments on financing costs

The impact of the public instruments on reducing financing cost for wind energy and solar PV in Lebanon are shown in Figure 12. Based on the modelling analysis, the selected package of derisking instruments is anticipated to reduce the average cost of equity until 2030 by 3.2% down to 12.8%, and the cost of debt by 2.4% down to 6.6%.

A brief summary of the qualitative investor feedback on the public instruments discussed in the interviews and on their effectiveness in reducing financing cost in Lebanon is provided in Table 5.

**Figure 12: Impact of public derisking instruments on reducing financing costs for wind energy and solar PV investments in Lebanon**




Source: interviews with wind energy and solar PV investors and developers; modelling; see Annex A for details of assumptions and methodology. Note: the impacts shown are average impacts over the 2017-2030 modelling period, assuming linear timing effects.

[39] Different approaches (e.g., face value, reserve, cost, no-cost) may be taken to costing financial derisking instruments. Here, a cost approach has been taken for the 'take or pay clause in PPA' and 'government guarantee for PPA', totalling USD 55.1m; a reserve approach has been taken for 'public loans' and 'political risk insurance', totalling USD 36.3m. See Section 4.2.4 for sensitivity analyses on costing. See Annex A for details.

[40] Like in the case of wind energy (see previous footnote), for solar PV, too, a cost approach has been taken for the 'take or pay clause in PPA' and 'government guarantee for PPA', totalling USD 25.0m; a reserve approach has been taken for 'public loans' and 'political risk insurance', totalling USD 16.0m. See Section 4.2.4 for sensitivity analyses on costing. See Annex A for details.

**Table 5:** **nvestor feedback on the effectiveness of public instruments to address each risk category in Lebanon**

| RISK CATEGORY | POLICY INSTRUMENTS | INVESTOR FEEDBACK |
|---|---|---|
| **Power market risk** | Policy derisking instrument(s): Long-term RE targets, establish well-regulated energy market, reform of fossil fuel subsidies | *Policy derisking instruments are highly effective:* The instruments proposed are generally perceived highly effective, with the exception of the reform of the fossil fuel subsidies and given that the establishment of clear targets and of a well-regulated energy market is done properly. Particularly for this risk category, some investors struggled to assume exactly that, i.e. that the instruments will be implemented properly. |
| **Permits risk** | Policy derisking instrument(s): Streamline processes for permitting, establish contract enforcement and recourse mechanism | *Policy derisking instruments are effective:* Although, there were mixed views on the effectiveness of enforcing rules for permitting that are fair and clear, mirroring that, some investors did not consider permits risk an issue at all. Some investors considered the permitting process too complex to be managed in a one-stop shop. Rather than creating a new entity, efforts, they suggested, should focus on making the existing system more efficient and reliable. |
| **Social acceptance risk** | Policy derisking instruments: Awareness raising campaigns, community involvement, extra security concepts | *Policy derisking instruments are highly effective:* One investor mentioned that outreach and engagement has to start at the level of the local/regional political leaders and only then, community involvement at the project sites can be effective. Generally, awareness raising and public engagement is considered highly effective, regardless the fact that investors don't see deficits in this type of action in Lebanon - many recalled examples where they have witnessed outreach campaigns. |
| **Developer Risk** | Policy derisking instruments: Building capacity for resource assessment, planning, construction, O&M, R&D | *Policy derisking instruments have limited effect.* Capacity building for governmental institutions with respect to all stages of utility-scale RE project development was highlighted to be effective by a few investors. Others were of a different opinion, arguing that they would only trust their own judgment and assessment (especially regarding resource assessment for wind energy), hence they consider measures to strengthen the governmental agencies' capacity not to be very effective. |
| **Grid integration risk** | Policy derisking instruments: Strengthen EDL's operational performance reg. grid management/grid code, policy support for grid infrastructure development<br>Financial derisking instrument: Include take-or-pay clause in the standard PPA | *Policy derisking instruments are effective:* Investors seem to agree that policy support and technical assistance to EDL can improve the situation. One investor suggested the enforcement of preventive maintenance for the grid (plus the provision of the respective budget) to be added to the menu of derisking instruments.<br>*Financial derisking instrument has limited effect:* Investors unanimously consider a take-or-pay clause a must-have and would, without its inclusion in the PPA, not endeavour an IPP project in Lebanon. Those investors who are familiar with the power barges and their underlying contractual arrangement with EDL mention this as a role model to deal with both grid integration risk and counterparty risk (see below). |
| **Counterparty risk** | Policy derisking instrument: Strengthen EDL's management/ operational performance<br>Financial derisking instrument: Sovereign guarantees for PPA payment; public loans | *Policy derisking instrument is effective:* Several investors explicitly mention that support to strengthen EDL's managerial and operational capacity is important and effective. Others are more sceptical and would rather welcome a thorough reform of the public utility (incl. partial privatization).<br>*Financial derisking instrument has limited effect:* Some investors would argue that a sovereign guarantee is inherently present through the fact that EDL is state-owned. Others would welcome an official buy-in to their investment opportunity from the GoL or an international financial institution because this would increase the pressure on EDL to fulfil the PPA. Some mentioned that public loans, especially from abroad, would have be similarly effective. |
| **Financing risk** | Policy derisking instruments: Financial sector policy reform, strengthen investors' familiarity with and capacity for renewable energy<br>Financial derisking instrument: Financial products to gain access to capital/funding | *Policy derisking instruments have limited effect:* Considering the debt investors' unfamiliarity with project finance terms, there might well be the need to introduce policies for the financial sector that promote long-term, project finance-based lending. Apart from that, only limited effectiveness was attributed to RE capacity building measures for the financial sector.<br>*Financial derisking instrument is highly effective:.* Public loans on some sort of concessional terms are unanimously welcomed by equity investors. The debt investors would stress their positive experience with NEEREA and expect that a scheme for larger loans (beyond the USD 20 million cap under NEEREA) could build on this. |
| **Political risk** | Financial derisking instrument: Risk sharing products to address political risk | *Financial derisking instrument has limited effect:.* Some investors would welcome a MIGA-type[41] political risk insurance, not least due to the positive effect that the involvement of a large international development bank would have on the GoL's commitment towards the project. This involvement could also be in the form of concessional loans to GoL for the support of RE projects. However, investors also raised the concern that PRI might be prohibitively expensive for some projects, which jeopardizes its effectiveness as a derisking measure. |
| **Currency/ macroeconomic risk** | Financial derisking instrument: Risk sharing mechanism to address currency risk | *Financial derisking instrument has little effect:* In line with the fact that the Lebanese pound is pegged to the US dollar, only few investors considered (partial) indexing of the tariff in a standardized PPA useful to increase confidence. The instrument was therefore excluded from the study. |

Source: interviews with investors (equity investors/developers and debt investors). Short description of the public instruments can be looked up in Table 2.

[41] MIGA = Multilateral Investment Guarantee Agency by the World Bank Group, insuring eligible projects in developing countries against losses relating to currency restrictions, expropriation, war and civil disturbance, etc.

### 4.2.3. Levelised Cost (Stage 3)

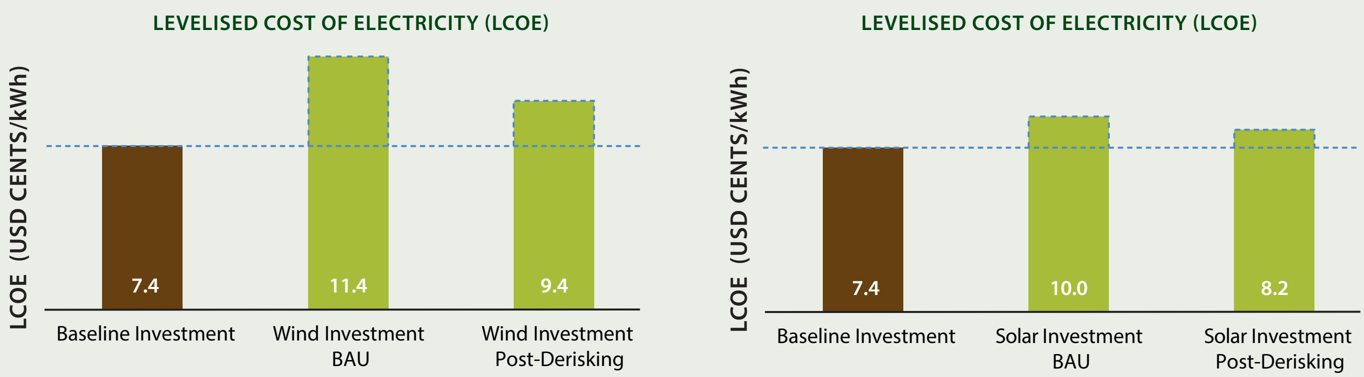
The modelling outputs in terms of LCOEs for wind energy and solar PV are shown in Figure 13.

The marginal baseline LCOE, based on private sector investment in CCGT technology (80% of the baseline mix) and partial replacement of the existing of power plants (20% of the baseline mix), is estimated as being USD 7.4 cents per kWh.

Wind energy is shown to be more expensive than the baseline cost in both the *business-as-usual* and the *post-derisking scenarios*. Nonetheless, the public instrument package reduces the LCOE for wind energy from USD 11.4 cents per kWh (*business-as-usual scenario*) to USD 9.4 cents per kWh (*post-derisking scenario*), reducing the price premium required from USD 4.0 cents per kWh to USD 1.9 cents per kWh.

The findings are similar for Solar PV, where derisking reduces the LCOE from USD 10.0 cents per kWh to USD 8.2 cents per kWh. The price premium required for solar PV can be reduced from USD 2.5 cents per kWh to USD 0.8 cents per kWh.

**Figure 13: LCOEs for the baseline, wind energy (left) and solar PV (right) investment in Lebanon**




Source: modelling; see Table 13 (wind) and Table 14 (solar PV), as well as Annex A for details of assumptions and methodology.

## 4.2.4 Evaluation (Stage 4)

### Performance Metrics

The model's performance metrics, evaluating the impact of derisking on the envisioned 2030 targets for wind and solar PV investment in Lebanon, are shown in Figure 14 and Figure 15.

Each of the four performance metrics takes a different perspective in assessing the performance of the derisking instrument package.

- The **investment leverage ratio** shows the efficiency of public instruments in attracting investment, comparing the total cost of public instruments with the resulting private-sector investment.
- The **savings ratio** takes a social perspective, comparing the cost of derisking instruments deployed versus the economic savings that accrue to society from deploying the instruments.
- The **affordability** metric takes an electricity consumer perspective, comparing the generation cost of wind energy or solar PV in the post-derisking scenario with the original BAU scenario.
- The **carbon abatement** metric takes a climate change mitigation perspective, considering the carbon abatement potential and comparing the carbon abatement costs (the cost per tonne of $CO_2$ abated). This can be a useful metric for comparing carbon prices.

Taken as a whole, the performance metrics for wind and solar PV demonstrate how the deployment of public derisking instruments can significantly increase the competitiveness and affordability of both wind energy and solar PV in Lebanon.

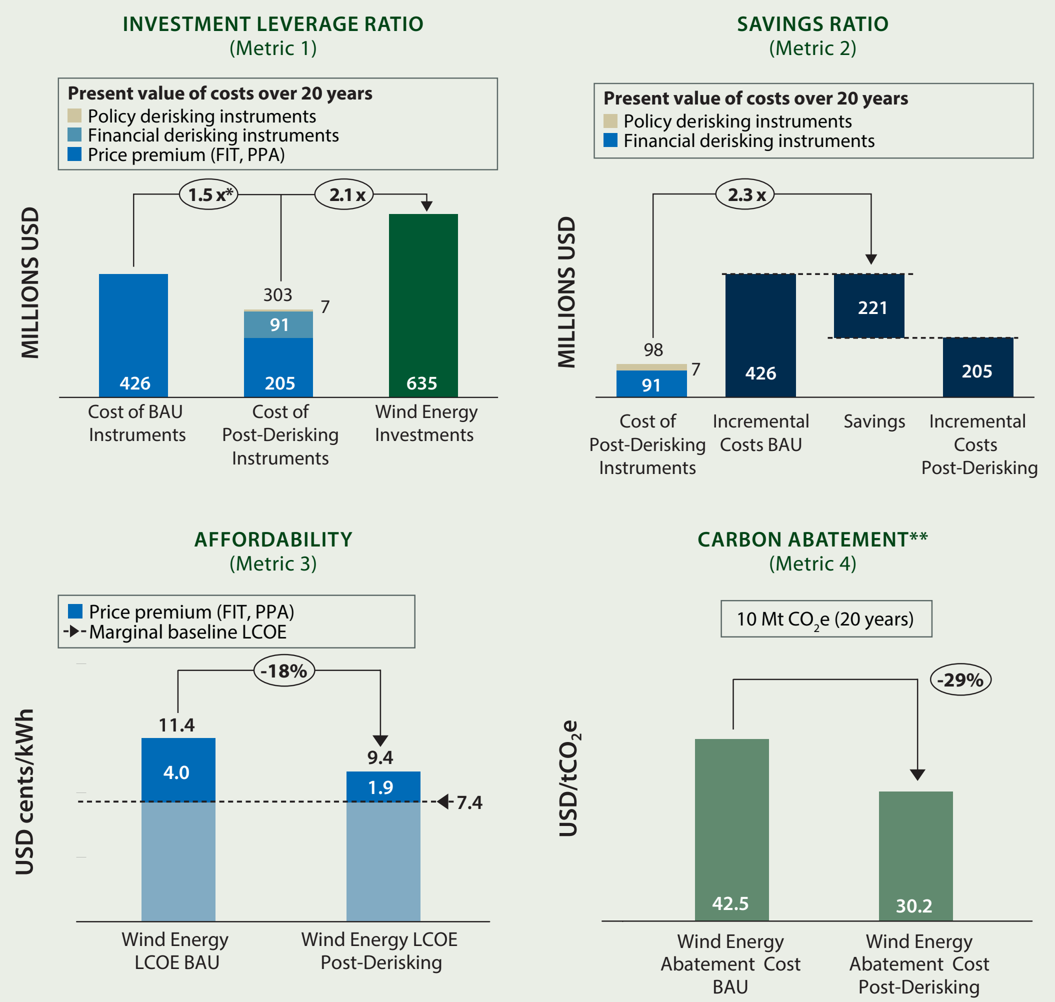
For instance, for both wind energy and solar PV, the investment leverage ratio shows that derisking is an efficient use of public funding.

- For wind energy, the 450 MW 2030 target is estimated to require USD 635 million in private sector investment. The modelling shows that in the *business-as-usual* scenario the amount spent on the price premium leverages private sector investments by a factor of 1.5x. In the *post-derisking scenario*, a package of derisking instruments valued at USD 98 million will reduce the price premium payments from USD 426 million to USD 205 million over 20 years, and this will increase the investment leverage ratio to 2.1x.
- For solar energy, the 300 MW 2030 target is estimated to require USD 279 million in private sector investment. In the *business-as-usual* scenario, with today's risk environment, achieving this target is estimated to require a price premium payment of USD 140 million over 20 years. As such, the investment leverage ratio is 2.0x. In the *post-derisking scenario*, a package of derisking instruments valued at USD 46 million will reduce the price premium payments from USD 140 million to USD 43 million over 20 years. In this case, the investment leverage ratio increases to 3.2x.

Also the other performance metrics shown in Figure 14 and Figure 15 reveal the benefits of upfront derisking:

- The savings from the resulting reduction of the price premium exceed what needs to be spent on the derisking measures, namely by a factor of 2.3x and 2.1x for wind energy and solar PV, respectively.
- Electricity from utility-scale wind farms and solar PV plants becomes 18% cheaper.
- Carbon abatement costs are reduced by 29% and 37% for wind energy and solar PV, respectively.

**Figure 14: Performance metrics for the selected package of derisking instruments in promoting 450 MW of wind energy investment in Lebanon**

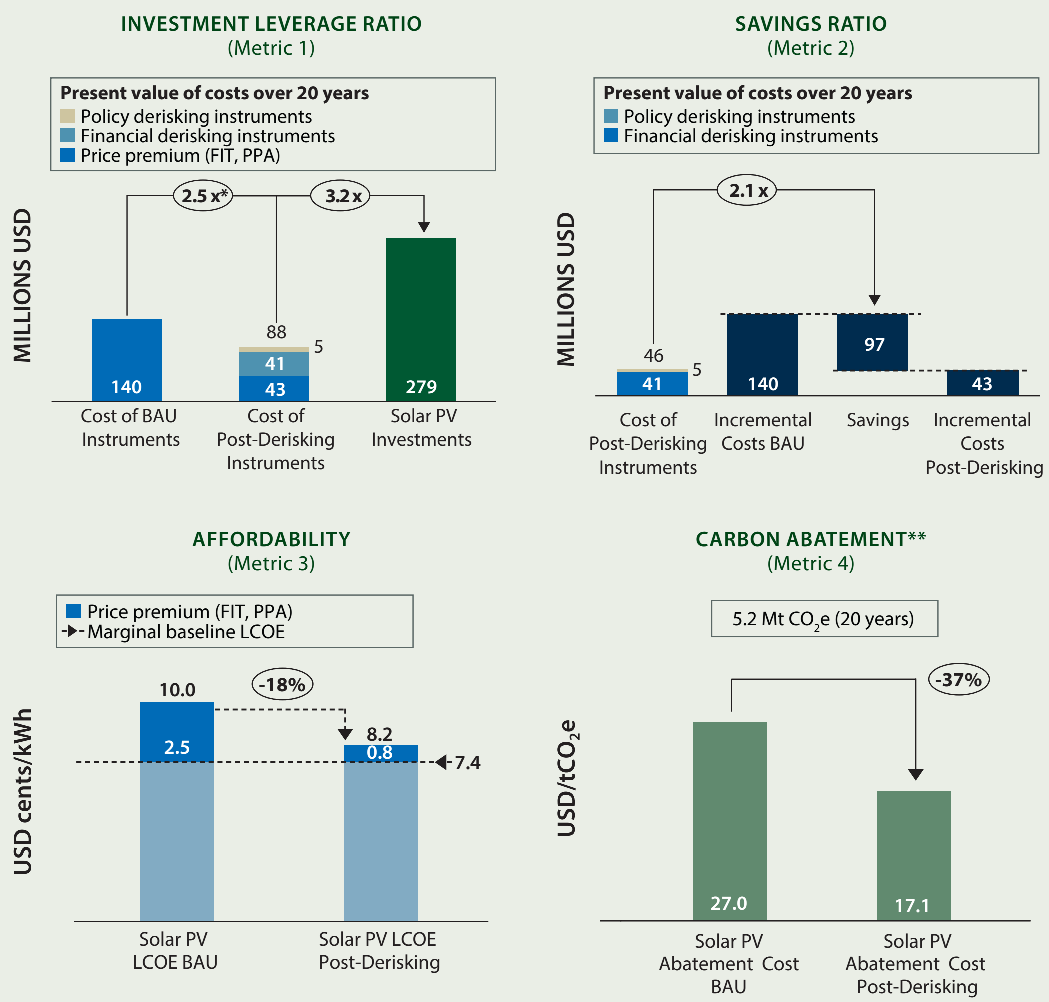



Source: modelling; see Table 13 and Annex A for details on assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

**The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 42.5 per $tCO_2$e is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD 30.2 per $tCO_2$e is USD 0.7, USD 9.1 and USD 20.4, respectively.

**Figure 15: Performance metrics for the selected package of derisking instruments in promoting 300 MW of solar PV investment in Lebanon**




Source: modelling; see Table 14 and Annex A for details on assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

**The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 27.0 per $tCO_2e$ is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD 17.1 per $tCO_2e$ is USD 0.9, USD 7.9 and USD 8.2, respectively.

## Sensitivities

A set of sensitivity analyses has been performed for both wind energy and solar PV. The objective of performing the sensitivity analyses is to gain a better understanding of the robustness of the outputs and to be able to test different scenarios.

Three broad types of sensitivity analysis have been performed:

- Key input assumptions
- Public instrument selection and cost-effectiveness
- Approach to costing financial derisking instruments

### 1. Sensitivity analyses varying key input assumptions.

These have been performed for the following input assumptions: (i) investment and O&M costs, (ii) capacity factor, (iii) fuel costs, and (iv) financing cost (CoE and CoD). The sensitivity analyses give an indication of the degree to which each input parameter affects the outputs. The results for this type of sensitivity are summarized in Table 6 and Table 7.

For instance, an increase in the capacity factor from 25.6% (base case) to 30% (sensitivity analysis) reduces the post-derisking LCOE for wind energy in the base case scenario from USD 9.4 cents per kWh to USD 8.0 cents per kWh.

**Table 6: Wind energy: summary of LCOE outputs for sensitivity analysis on key input assumptions (USD cents/kWh)**

| TYPE OF SENSITIVITY | DESCRIPTION OF SENSITIVITY | BASELINE LCOE | WIND BAU LCOE | WIND POST-DERISKING LCOE |
|---|---|---|---|---|
| **Base Case** | – | **7.4** | **11.4** | **9.4** |
| **Wind Investment and O&M Costs** | Higher investment and O&M costs; uses 2016 investment (1,800,000 USD/MW) and O&M (46,500 USD/MW/y) costs as provided by Lebanese developers<br>(Base case is 2023 estimate: 1,410,000 USD/MW and 31,600 USD/MW/y) | – | 14.9 | 12.3 |
| **Wind Investment Costs** | Higher capacity factor.<br>Sensitivity uses 30%<br>(Base case is 25.6%) | – | 9.8 | 8.0 |
| **Fuel Costs** | 20% higher fuel cost projections<br>20% lower fuel cost projections | 8.6<br>6.3 | 6.4 cents | 5.0 cents |
| **Financing Costs** | 1% point higher financing costs (CoE=17.0%, CoD=10%)<br>1% point lower financing costs (CoE=15.0%, CoD=8%)(Base case is CoE=16.0%, CoD=9 %) | –<br>– | 12.0<br>10.9 | 9.6<br>9.1 |

Source: sensitivity modelling; see Table 13 and Annex A for details of assumptions and methodology.

**Table 7: Solar PV: summary of LCOE outputs for sensitivity analysis on key input assumptions (USD cents/kWh)**

| TYPE OF SENSITIVITY | DESCRIPTION OF SENSITIVITY | BASELINE LCOE | WIND BAU LCOE | WIND POST-DERISKING LCOE |
|---|---|---|---|---|
| **Base Case** | – | 7.4 | 10.0 | 8.2 |
| **Wind Investment and O&M Costs** | Higher investment and O&M costs; uses 2016 investment (1,800,000 USD/MW) and O&M (46,500 USD/MW/y) costs as provided by Lebanese developers<br>(Base case is 2023 estimate: 1,410,000 USD/MW and 31,600 USD/MW/y) | – | 14.3 | 11.8 |
| **Wind Investment Costs** | Higher capacity factor<br>Sensitivity uses 30%<br>(Base case is 25.6%) | – | 9.8 | 8.0 |
| **Fuel Costs** | 20% higher fuel cost projections<br>20% lower fuel cost projections | 8.6<br>6.3 | – | – |
| **Financing Costs** | 1% point higher financing costs (CoE=17.0%, CoD=10%)<br>1% point lower financing costs (CoE=15.0%, CoD=8%)(Base case is CoE=16.0%, CoD=9 %) | –<br>– | 10.4<br>9.5 | 8.5<br>8.0 |

Source: sensitivity modelling; see Table 14 and Annex A for details of assumptions and methodology.

### 2. Sensitivity analyses on public instrument selection and cost-effectiveness.

Two types of sensitivities have been performed on public derisking instruments: (i) on selecting different sub-sets of instruments, and (ii) on the cost-effectiveness of individual instruments. Detailed descriptions for each instrument are found in Table 2. For these sensitivity analyses, the key relationship to analyse is between the cost of the instruments versus their impact on lowering generation costs, and hence the economic savings they create.

The following findings become evident from the results of these sensitivities. First, the sensitivities show that implementing public derisking measures are always cost effective, across all the scenarios. In other words, investment in the cost of derisking instruments is always more than paid back in terms of lower generation costs and economic savings. Second - with an important caveat, below - the findings show a range of the cost-effectiveness across instruments, with policy derisking instruments generally being more cost-effective than financial derisking instruments.

An important caveat is that the modelling cannot tell us whether a particular instrument is necessary; for example, while less cost-effective, financial derisking instruments, such as public loans, may be necessary at this stage of Lebanon's market development; likewise, power market risk activities, which encompass issues such as legislation and bidding processes, while less cost-effective than other policy derisking measures, may similarly be necessary. Therefore selecting and/or eliminating particular instruments based on cost-effectiveness alone may come with risks, and may reduce the chances of meeting Lebanon's full 2030 investment targets.

### *(i) Sub-sets of instruments*

While the base case scenario considers the complete set of instruments listed in Table 4, this type of sensitivity analysis examines the impact and cost-effectiveness of different sub-sets of public instruments: only policy derisking instruments; only financial derisking instruments; and, only instruments targeting those risk categories with the highest impact on financing cost. The key results for this type of sensitivity are summarized in Table 8 and Table 9 below, and shown graphically in Figures 20-22 in Annex B.

**Table 8: Wind energy: summary of key outputs for sensitivity analysis on sub-sets of derisking instruments)**

| SCENARIO | DESCRIPTION OF SCENARIO | POST-DERISKING COST OF FINANCING | | POST-DERISKING LCOE (USD CENTS/kWh) | SAVINGS TO THE ECONOMY (USD MILLION) | SAVINGS TO THE ECONOMY (USD MILLION) |
|---|---|---|---|---|---|---|
| | | EQUITY | DEBT | | | |
| **Base Case** | **Base case instruments** | **12.8%** | **6.6%** | **9.4** | **Policy: 6.7<br>Financial: 91.4<br>Total: 98.1** | **221.2** |
| **Policy derisking only** | Policy derisking instruments only | 14.3% | 7.7% | 10.2 | Policy: 6.7<br>Financial: – | 128.5 |
| **Financial derisking only** | Financial derisking instruments only | 14.5% | 7.9% | 10.1 | Policy: –<br>Financial: 95.4 | 147.7 |
| **High impact risk categories** | Policy & financial derisking instruments addressing only high impact risk categories | 13.5% | 7.0% | 9.9 | Policy: 3.9<br>Financial: 66.6<br>Total: 70.6 | 166.8 |

**Table 9: Solar PV: summary of key outputs for sensitivity analysis on sub-sets of derisking instruments**

| SCENARIO | DESCRIPTION OF SCENARIO | POST-DERISKING COST OF FINANCING | | POST-DERISKING LCOE (USD CENTS/kWh) | SAVINGS TO THE ECONOMY (USD MILLION) | SAVINGS TO THE ECONOMY (USD MILLION) |
|---|---|---|---|---|---|---|
| | | EQUITY | DEBT | | | |
| **Base Case** | **Base case instruments** | **12.8%** | **6.6%** | **8.2** | **Policy: 4.8<br>Financial: 40.9<br>Total: 45.8** | **97.1** |
| **Policy derisking only** | Policy derisking instruments only | 14.3% | 7.7% | 9.0 | Policy: 4.8<br>Financial: – | 56.4 |
| **Financial derisking only** | Financial derisking instruments only | 14.5% | 7.9% | 8.8 | Policy: –<br>Financial: 42.7 | 64.8 |
| **High impact risk categories** | Policy & financial derisking instruments addressing only high impact risk categories | 13.5% | 7.0% | 8.7 | Policy: 2.9<br>Financial: 30.0<br>Total: 33.0 | 73.2 |

### *(ii) Cost-effectiveness of individual instruments*

This type of sensitivity analysis examines the cost-effectiveness of individual instruments, in both the policy derisking instrument and financial derisking instrument categories. In order to have comparability between instruments, the metric used to analyse this sensitivity is the USD cost of each instrument required to lower the LCOE by USD 0.10 cents/kWh[42]. The lower the USD cost of this metric, the more cost-effective the instrument is. Table 10 sets out the results of the sensitivities on individual instrument cost-effectiveness.

**Table 10: Wind and solar PV: summary of results for sensitivity analysis on the cost-effectiveness of individual instruments**

| RISK CATEGORY | POST-DERISKING LCOE (USD CENTS/KWH) | SAVINGS TO THE ECONOMY (USD MILLION) | SAVINGS TO THE ECONOMY (USD MILLION) |
|---|---|---|---|
| **Policy Derisking Instruments** | | | |
| **Power Market Risk** | Various | $1,250,000 | $1,100,000 |
| **Permits Risk** | Various | $1,400,000 | $1,240,000 |
| **Social Accept. Risk** | Various | $870,000 | $850,000 |
| **Resource & Tech. Risk** | Various | $2,610,000 | $800,000 |
| **Grid/Transmission Risk** | Various | $470,000 | $420,000 |
| **Counterparty Risk** | Various | $210,000 | $190,000 |
| **Financing Risk** | Various | $2,860,000 | $3,380,000 |
| **Financial Derisking Instruments** | | | |
| **Grid/Transmission Risk** | Take or Pay Clause | $2,670,000 | $1,420,000 |
| **Counterparty Risk** | Government Guarantee | $33,330,000 | $17,800,000 |
| **Counterparty & Financing Risk** | Public Loans | $7,190,000 | $3,720,000 |
| **Political Risk** | Political Risk Insurance | $5,640,000 | $2,920,000 |

[42] This metric is sensitive to the particular investment target (e.g. 300 MW or 450 MW); therefore it can be misleading, particularly for instruments with variable cost components, to compare this metric across investment targets or technologies.

### 3. Sensitivity analyses on approach to costing financial derisking instruments

The costing of financial derisking instruments is complex, where different approaches can be taken, each with their pros and cons. For example, a conservative costing methodology may cost public loans at their face value, where a USD 50 million loan is assumed to cost USD 50 million. A less conservative methodology may take a loss reserve approach, for example applying a cost of 25% of a USD 50 million loan. A more aggressive costing methodology may assign zero cost to public loans, assuming that the loans should be paid back in full, and that providers of public loans will price in any default risk and cost of capital in the loan's terms and fees.

This sensitivity analysis assumes the same financial derisking instruments in all scenarios, and then examines these alternative costing approaches, analysing a high-cost scenario and a low-cost scenario. The assumptions behind these approaches are provided in Annex A. The key cost figures resulting from the different costing approaches are summarized in Table 11 and Table 12 below, and shown graphically in Figure 23 and Figure 24 in Annex B.

**Table 11: Wind energy: summary of public cost outputs for sensitivity analysis varying costing approach for financial derisking instruments**

| SCENARIO | DESCRIPTION OF SCENARIO | POST-DERISKING COST OF FINANCING | | | | SAVINGS RATIO | CARBON ABATEMENT COST* ($USD/tCO_2$) |
|---|---|---|---|---|---|---|---|
| | | ACTUAL/OPP COST | LOSS RESERVES | FACE VALUE | TOTAL COST | | |
| **Base Case** | **Actual cost for take or pay, and opportunity cost for government guarantee; loss reserves for public loans and PRI** | **55.1** | **36.3** | **0** | **91.4** | **2.3x** | **30.2 (-28.9%)** |
| **High-cost approach** | Actual cost for take or pay; loss reserve for PRI; face value for government guarantee and public loans | 5.0 | 8.6 | 205.6 | 219.1 | 1.0 x | 42.9 (+1.1%) |
| **Low-cost approach** | Actual cost for take or pay, loss reserve for PRI; no cost for government guarantee and public loans | 5.0 | 8.6 | 0 | 13.6 | 10.9x | 22.5 (-47.1%) |

* In parentheses: relative change compared to pre-derisking carbon abatement cost of 42.5 $USD/tCO_2e$.

**Table 12: Solar PV: summary of public cost outputs for sensitivity analysis varying costing approach for financial derisking instruments.**

| SCENARIO | DESCRIPTION OF SCENARIO | POST-DERISKING COST OF FINANCING | | | | SAVINGS RATIO | CARBON ABATEMENT COST* ($USD/tCO_2$) |
|---|---|---|---|---|---|---|---|
| | | ACTUAL/OPP COST | LOSS RESERVES | FACE VALUE | TOTAL COST | | |
| **Base Case** | **Actual cost for take or pay, and opportunity cost for government guarantee; loss reserves for public loans and PRI** | **25.0** | **16.0** | **0** | **40.9** | **2.1x** | **17.1 (-36.7%)** |
| **High-cost approach** | Actual cost for take or pay; loss reserve for PRI; face value for government guarantee and public loans | 2.3 | 3.8 | 91.7 | 97.7 | 0.9x | 28.0 (+3.9%) |
| **Low-cost approach** | Actual cost for take or pay, loss reserve for PRI; no cost for government guarantee and public loans | 2.3 | 3.8 | 0 | 6.0 | 8.9x | 10.3 (-61.7%) |

* In parentheses: relative change compared to pre-derisking carbon abatement cost of 27.0 $USD/tCO_2e$.

## 4.2.5 Summary Data Tables

**Table 13: Summary modelling assumptions for wind energy in Lebanon**

| | |
|---|---|
| **WIND TARGET AND RESOURCES** | |
| 2030 Target (in MW) | 450 |
| Capacity Factor (%) | 25.6% |
| Total Annual Energy Production for Target (in MWh) | 1,009,152 |
| **MARGINAL BASELINE** | |
| Energy Mix | |
| New CCGT: 80% CCGT on LFO: 7% Light Fuel Oil: 6% Heavy Fuel Oil: 7% | |
| Grid Emission Factor ($tCO_2e$/MWh) | 0.497 |
| **GENERAL COUNTRY INPUTS** | |
| Effective Corporate Tax Rate (%) | 15% |
| Public Cost of Capital (%) | 7% |

| | ***BUSINESS-AS-USUAL* SCENARIO** | | ***POST-DERISKING* SCENARIO** |
|---|---|---|---|
| **FINANCING COSTS** | | | |
| **Capital Structure** | | | |
| Debt/Equity Split | 65%/35% | | 70%/30% |
| **Cost of Debt** | | | |
| Concessional public loan | N/A | | 5.5% |
| Commercial loans with public guarantees | N/A | | N/A |
| Commercial loans without public guarantees | 9.0% | | 6.6% |
| **Loan Tenor** | | | |
| Concessional public loan | N/A | | 15 years |
| Commercial loans with public guarantees | N/A | | N/A |
| Commercial loans without public guarantees | 8 years | | 10 years |
| **Cost of Equity** | 16.0% | | 12.8% |
| **Weighted Average Cost of Capital (WACC) (After-tax)** | 10.6% | | 7.6% |
| **INVESTMENT** | | | |
| **Total Investment (USD million)** | $634.50 | | $634.50 |
| **Debt (USD million)** | | | |
| Concessional public loan | $0.0 | | $111.04 |
| Commercial loans with public guarantees | $0.0 | | $0.0 |
| Commercial loans without public guarantees | $412.43 | | $333.11 |
| **Equity (USD million)** | $222.08 | | $190.35 |
| **COST OF PUBLIC INSTRUMENTS** | | | |
| **Policy Derisking Instruments (USD million, present value)** | | | |
| Power Market Risk Instruments | N/A | | $2.88 |
| Permits Risk Instruments | N/A | | $0.93 |
| Social Acceptance Risk Instruments | N/A | | $0.68 |
| Resource & Technology Risk Instruments | N/A | | $0.69 |
| Grid/Transmission Risk Instruments | N/A | | $0.88 |
| Counterparty Risk Instruments | N/A | | $0.16 |
| Financing Risk Instruments | N/A | | $0.44 |
| Total | N/A | | $6.66 |
| **Financial Derisking Instruments (USD million, present value)** | | | |
| Grid/Transmission Risk Instruments | N/A | | $5.01 |
| Counterparty Risk Instruments | N/A | | $50.07 |
| Financing Risk Instruments | N/A | | N/A |
| Public Loans | N/A | | $27.76 |
| Public Guarantees for Commercial Loans | N/A | | N/A |
| Political Risk Insurance | N/A | | $8.57 |
| Currency/Macro Risk Instruments | N/A | | N/A |
| Total | N/A | | $91.40 |
| **Direct Financial Incentives (USD million)** | | | |
| Present Value of 20 year PPA Premium | $426.38 | | $205.16 |

Source: modelling; see Annex A for details of assumptions and methodology
Financing costs are average costs from 2017-2030.

**Table 14: Summary modelling assumptions for solar PV in Lebanon**

| | |
|---|---|
| **SOLAR PV TARGET AND RESOURCES** | |
| 2030 Target (in MW) | 300 |
| Capacity Factor (%) | 19.8% |
| Total Annual Energy Production for Target (in MWh) | 521,132 |
| **MARGINAL BASELINE** | |
| Energy Mix | |
| New CCGT: 80% CCGT on LFO: 7% Light Fuel Oil: 6% Heavy Fuel Oil: 7% | |
| Grid Emission Factor ($tCO_2e$/MWh) | 0.497 |
| **GENERAL COUNTRY INPUTS** | |
| Effective Corporate Tax Rate (%) | 15% |
| Public Cost of Capital (%) | 7% |

| | ***BUSINESS-AS-USUAL* SCENARIO** | | ***POST-DERISKING* SCENARIO** |
|---|---|---|---|
| **FINANCING COSTS** | | | |
| **Capital Structure** | | | |
| Debt/Equity Split | 65%/35% | | 70%/30% |
| **Cost of Debt** | | | |
| Concessional public loan | N/A | | 5.5% |
| Commercial loans with public guarantees | N/A | | N/A |
| Commercial loans without public guarantees | 9.0% | | 6.6% |
| **Loan Tenor** | | | |
| Concessional public loan | N/A | | 15 years |
| Commercial loans with public guarantees | N/A | | N/A |
| Commercial loans without public guarantees | 8 years | | 10 years |
| **Cost of Equity** | 16.0% | | 12.8% |
| **Weighted Average Cost of Capital (WACC) (After-tax)** | 10.6% | | 7.6% |
| **INVESTMENT** | | | |
| **Total Investment (USD million)** | $279.00 | | $279.00 |
| **Debt (USD million)** | | | |
| Concessional public loan | $0.0 | | $48.83 |
| Commercial loans with public guarantees | $0.0 | | $0.0 |
| Commercial loans without public guarantees | $181.35 | | $146.48 |
| **Equity (USD million)** | $97.65 | | $83.70 |
| **COST OF PUBLIC INSTRUMENTS** | | | |
| **Policy Derisking Instruments (USD million, present value)** | | | |
| Power Market Risk Instruments | N/A | | $2.16 |
| Permits Risk Instruments | N/A | | $0.70 |
| Social Acceptance Risk Instruments | N/A | | $0.57 |
| Resource & Technology Risk Instruments | N/A | | $0.18 |
| Grid/Transmission Risk Instruments | N/A | | $0.66 |
| Counterparty Risk Instruments | N/A | | $0.12 |
| Financing Risk Instruments | N/A | | $0.44 |
| Total | N/A | | $4.82 |
| **Financial Derisking Instruments (USD million, present value)** | | | |
| Grid/Transmission Risk Instruments | N/A | | $2.27 |
| Counterparty Risk Instruments | N/A | | $22.69 |
| Financing Risk Instruments | N/A | | N/A |
| Public Loans | N/A | | $12.21 |
| Public Guarantees for Commercial Loans | N/A | | N/A |
| Political Risk Insurance | N/A | | $3.77 |
| Currency/Macro Risk Instruments | N/A | | N/A |
| Total | N/A | | $40.93 |
| **Direct Financial Incentives (USD million)** | | | |
| Present Value of 20 year PPA Premium | $139.72 | | $42.63 |

Source: modelling; see Annex A for details of assumptions and methodology.
Financing costs are average costs from 2017-2030.

# 5. Conclusions and Next Steps

# Conclusions and Next Steps

5

The results in this report should not be interpreted as a definitive quantitative analysis of wind energy and solar PV in Lebanon but, rather, as one contribution to the larger policy decision-making process.

## Implications for promoting renewable energy in Lebanon

The results confirm that financing costs for wind energy and solar PV in Lebanon are currently high, particularly in comparison to countries with more favourable investment environments. The cost of equity for wind energy and solar PV in Lebanon today is estimated as being 16.0%, and the cost of debt as 9%[43]. The modelling starts from nine different risk categories and evaluates to what extent they contribute to higher financing costs in Lebanon. Power market risk, grid and transmission risk, counterparty risk, and political risk are identified as being the most significant risk categories, contributing together an estimated 6.5% to the higher cost of equity and 5.1% to the higher cost of debt.

The results identify a comprehensive package of public derisking measures to achieve the 2030 investment objectives for wind and solar PV envisioned in Lebanon's National Renewable Energy Action Plan. These measures, consisting of a collection of policy and financial instruments, systematically target the identified investment risk categories. Table 4 itemises each of the measures. The modelling also estimates the public cost of these measures until 2030.

A key conclusion from the modelling is that investing in derisking measures is a cost-effective approach to achieving Lebanon's wind and solar PV investment objectives. The derisking measures bring down the generation cost of wind energy from USD 11.4 cents per kWh to USD 9.4 cents per kWh, and solar PV energy from USD 10.0 cents per kWh to USD 8.2 cents per kWh.

- For wind energy, in the *business as usual* scenario, the modelling estimates that premium price payments totalling USD 426 million will be required over the next 20 years to achieve the envisioned NREAP target. However, if over the same period a total investment of USD 98 million is made in derisking measures, wind energy will become 18% cheaper and the premium price payments are reduced to USD 205 million, saving USD 221 million in generation costs over the next 20 years[44].

- For solar PV, in the *business as usual* scenario, the modelling estimates that premium price payments totalling USD 140 million will be required over the next 20 years to achieve the envisioned NREAP target. However, if over the same period a total investment of USD 46 million is made in derisking measures, solar PV will also become 18% cheaper and the premium price payments are reduced to USD 43 million, saving USD 97 million in generation costs over the next 20 years[45].

The modelling thus clearly demonstrates that investing in derisking measures is good value for money when compared to paying a premium price for wind and solar PV energy. The results show that the identified derisking measures are cost-effective both collectively, taken as a package of derisking measures, and individually, as single derisking measures. Overall, the results indicate that all derisking instruments that can be immediately implemented should, if possible, be prioritized.

[43] USD denominated cost of equity and cost of debt.
[44] Net savings of USD 123 million (USD 221 million minus USD 98 million)
[45] Net savings of USD 51 million (USD 97 million minus USD 46 million)

## Annexes

- A. Methodology and Data
- B. Graphical Representation of Sensitivity Analyses (Section 4.2.4)
- C. References

# Annexes

## ANNEX A. METHODOLOGY AND DATA

This annex sets out the methodology, assumptions and data that have been used in performing the modelling described in this report.

The modelling closely follows the methodology set out in the UNDP *Derisking Renewable Energy Investment Report* (2013) ("DREI report (2013)"). This annex is organized in line with the four stages of the DREI report's framework: the Risk Environment Stage (Stage 1), the Public Instrument Stage (Stage 2), the Levelised Cost Stage (Stage 3) and the Evaluation Stage (Stage 4). Both wind energy and solar PV are addressed under each stage.

In addition, the modelling uses the financial tool (in Microsoft Excel) created for the DREI report framework. The financial tool is denominated in 2017 US dollars and covers a core period from January 1, 2017 (approximating the present time) to December 31, 2030 (the horizon for Lebanon's envisioned RE targets). Generation technologies may have asset lifetimes which extend beyond 2030, and this is captured by the financial tool.

The DREI report and the financial tool are available for download at www.undp.org/DREI.

### A.1 Risk Environment (Stage 1)

The data for the Risk Environment Stage come from three principal sources:

- 17 structured interviews with investors in wind energy and solar PV in Lebanon - 12 with equity investors or developers, 5 with debt investors.
- 2 structured interviews with RE investors in the best-in-class country, held by UNDP's DREI work team.
- Multiple informational interviews with and inquiries to the interviewees and other public and RE actors.
- UNDP's (in particular the methodological experts' in New York) experience with, and analysis of large-scale renewable energy.

In order to gather these data, the UNDP project team made a field mission to Lebanon at the end of July 2016. Three structured interviews as well as a number of inquiries were conducted remotely.

#### Deriving a Multi-Stakeholder Barrier and Risk Table

The multi-stakeholder barrier and risk table for wind energy and solar PV is derived from the generic table for large-scale, renewable energy introduced in the DREI report (2013; Section 2.1.1). It is composed of 9 risk categories and 21 underlying barriers. These risk categories, barriers and their definitions can be found in Table 3 in the body of this report.

## Calculating the Impact of Risk Categories on Higher Financing Costs

The basis of the financing cost waterfalls produced by the modelling is structured, quantitative interviews undertaken with wind energy and solar PV investors and developers. The interviews were performed on a confidential basis, and all data across interviews were aggregated together. The interviews and processing of data followed the methodology described in Box 1 below, with investors scoring each risk category according to (i) the probability of occurrence of negative events and (ii) the level of financial impact of these events (should they occur), as well as also scoring (iii) the effectiveness of public instruments to address each risk category. Investors were also asked to provide estimates of their cost of equity, cost of debt, capital structure and loan tenors. Interviewees were provided beforehand with an information document setting out key definitions and questions, and the typical interview took between 60 and 100 minutes.

**Box 1: Methodology for quantifying the impact of risk categories on higher financing costs**

### 1. Interviews

Interviews were held with debt and equity investors active in wind energy and solar PV in Lebanon, as well as in the selected best-in-class country, Germany. The interviewees were asked to provide two types of data:

- Scores for the various risk categories identified in the barrier and risk framework. The two interview questions used to quantify the risk categories are set out in Figure 16.
- The current cost of financing for making an investment today, which represents the end-point of the waterfall (or the starting point in the case of the best-in-class country).

**Figure 16: Interview questions to quantify the impact of risk categories on the cost of equity and debt**

**Q1:** How would you rate the probability that the events underlying the particular risk category occur?

UNLIKELY **1** ○ **2** ○ **3** ○ **4** ○ **5** ○ VERY LIKELY

**Q2:** How would you rate the financial impact of the events underlying the particular risk category, should the events occur?

LOW IMPACT **1** ○ **2** ○ **3** ○ **4** ○ **5** ○ HIGH IMPACT

**(Continued over the next page)**

**Box 1: Methodology for quantifying the impact of risk categories on higher financing costs (Continued)**

## 2. Processing the data gathered

The data gathered from interviews are then processed. The methodology involves identifying the total difference in the cost of equity or debt between the developing country (Lebanon) and the best-in-class developed country (Germany). This figure for the total difference reflects the total additional financing cost in the developing country.

The interview scores provided for each risk category address both components of risk: the probability of a negative event occurring above the probability of such an event occurring in a best-in-class country and the financial impact of the event if such an event occurs (see DREI Report (2013; Section 2.1.1)). These two ratings are then multiplied to obtain a total score per risk category. These total risk scores are then used to prorate and apportion the total difference in the cost of equity or debt.

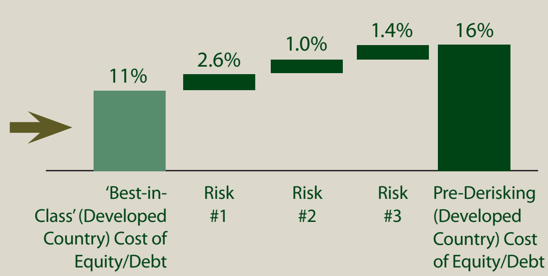
A very simplified example, demonstrating the basic approach, is demonstrated in Figure 17.

**Figure 17: Illustrative simplified application of the methodology to determine the impact of risk categories on increasing financing costs**

| COST OF EQUITY | |
|---|---|
| Developing Country | 16% |
| Best-in-class Developed Country | 11% |
| **Total Diference** | **5%** |

| INVESTOR RISK SCORES FOR COST OF EQUITY | Incremental Score for Probability | | Score for Impact | | **Total Risk Score** |
|---|---|---|---|---|---|
| Risk Category # 1 | 4 | X | 4 | = | 16 |
| Risk Category # 2 | 2 | X | 3 | = | 6 |
| Risk Category # 3 | 3 | X | 3 | = | 9 |
| | | | | **Total Across all Risks** | **31** |

| PRO-RATING RISK SCORES ACROSS COST OF EQUITY | Pro-rated Risk Score | | Total Difference for Cost of Equity | | **Risk Category Cost of Equity** |
|---|---|---|---|---|---|
| Risk Category # 1 | 16/31 | X | 5% | = | 2.6% |
| Risk Category # 2 | 6/31 | X | 5% | = | 1.0% |
| Risk Category # 3 | 9/31 | X | 5% | = | 1.4% |
| | | | | **Total Across all Risks** | **5.0%** |



In addition, the following key steps have been taken in calculating the financing cost waterfalls:

- In order to make interviews comparable, investors were asked to provide their scores while taking into account a list of eight key assumptions regarding wind energy or solar PV investment, as set out in Boxes 2 and 3 respectively. To maintain consistency, these assumptions were subsequently used to shape the inputs in the LCOE calculation for wind energy in Stage 3

**Box 2: The eight investment assumptions for wind energy in Lebanon**

1. Provide scores based on the current investment environment in Lebanon today
2. Assume you have the opportunity to invest in a 50-100 MW on-shore wind farm
3. Assume 2-3 MW class turbines from a quality manufacturer with a proven track record (eliminating certain technology risks)
4. Assume a build-own-operate (BOO) business model
5. Assume a comprehensive O&M contract (eliminating certain technology risks)
6. Assume that transmission lines with free capacities and directly connected to the high-voltage grid of EDL are relatively close to the project site (within 10 km)
7. Assume an EPC sub-contractor, qualified for renewable energy, with high penalties for breach of contract (eliminating certain technology risks)
8. Assume a non-recourse, project finance structure

**Box 3: The eight investment assumptions for solar PV in Lebanon**

1. Provide scores based on the current investment environment in Lebanon today
2. Assume you have the opportunity to invest in a 1-10 MW solar PV plant (eliminating certain technology risks)
3. Assume a high quality c-Si PV panel manufacturer with proven track record
4. Assume a build-own-operate (BOO) business model
5. Assume a comprehensive O&M contract (eliminating certain technology risks)
6. Assume that transmission lines with free capacities and directly connected to the high-voltage grid of EDL are relatively close to the project site (within 10 km)
7. Assume an EPC sub-contractor, qualified for renewable energy, with high penalties for breach of contract (eliminating certain technology risks)
8. Assume a non-recourse, project finance structure

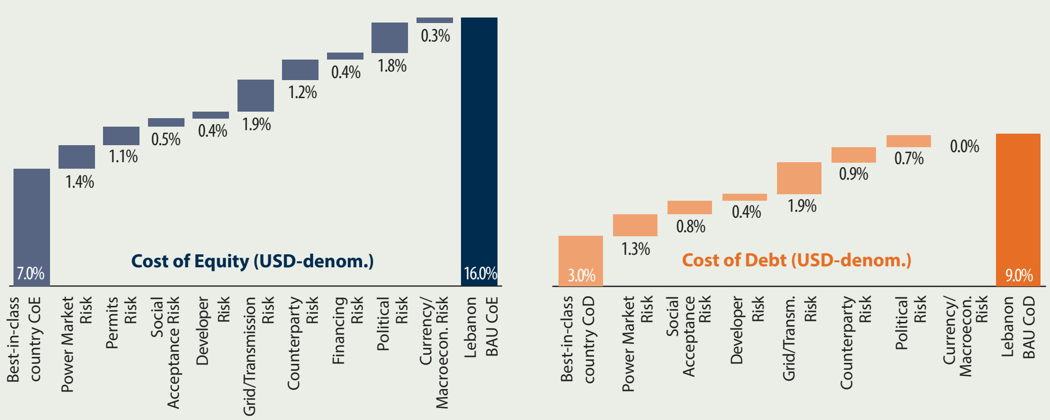
- Equity investors in renewable energy typically have greater exposure to development risks. The modelling uses the full set of 9 risk categories for equity investors. The 'permits risk', 'developer risk' and 'financing risk' categories are removed for debt investors, assuming that banks will have prerequisites, such as having licenses, technical feasibility studies, and equity financing in place, before considering a funding request. As such, the modelling uses 6 risk categories for debt investors.

- The modelling selects Germany as the example of a best-in-class investment environment for wind energy and solar PV. Germany is generally considered by international investors to have a very well-designed and implemented policy and regulatory regime, with minimal risk for all nine of the investment risk categories. In this way, Germany serves as the baseline – the left-most column of the financing cost waterfall.

- The Risk Environment Stage (Stage 1) differentiates between the answers from equity and from debt investors, but it does not distinguish further between investors with focus on wind energy and investors with focus on solar PV. It is recognized that the risk profiles of large-scale wind energy and solar PV can differ, especially for 'developer risk'. However, the results of the interviews with wind energy and solar PV investors made clear that these differences are minimal in the Lebanese context. As such, the interview answers from equity and from debt investors were not further split into 'wind energy focus' and 'solar PV focus' sub-groups, in order to bring simplicity to the analysis and to avoid multiple result sets. For the reader's own judgment, the financing cost waterfalls that distinguish between answers from wind energy and solar PV investors are shown in Figures 18 and Figure 19, alongside Figure 2 of the main report for the ease of comparison.

**Figure 18: Impact of risk categories on financing costs for wind energy investments in Lebanon, business-as-usual scenario**

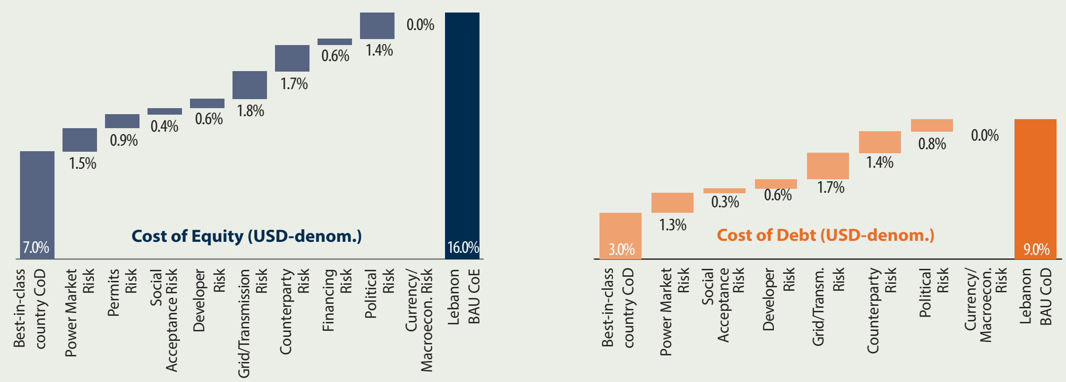
BUSINESS-AS-USUAL FINANCING COSTS, BASED ON ANSWERS FROM WIND ENERGY INVESTORS ONLY




Source: interviews with wind energy investors and developers; modelling

**Figure 19: Impact of risk categories on financing costs for solar PV investments in Lebanon, business-as-usual scenario**

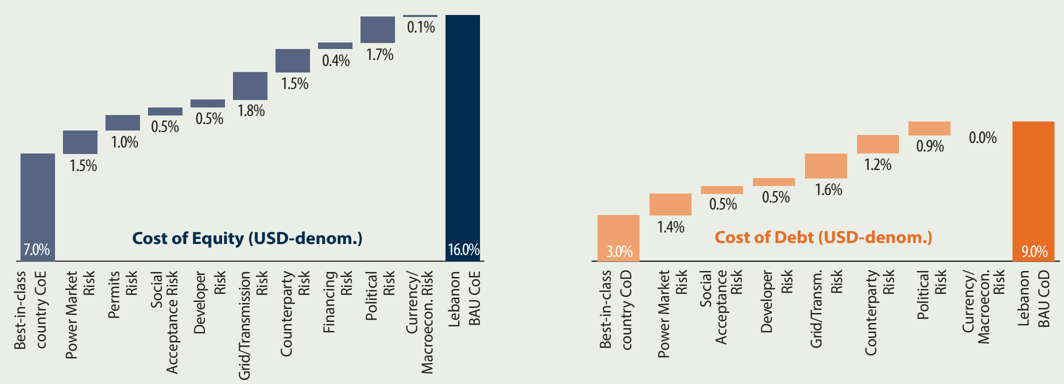
BUSINESS-AS-USUAL FINANCING COSTS, BASED ON ANSWERS FROM SOLAR PV INVESTORS ONLY




Source: interviews with solar PV investors and developers; modelling

**FOR COMPARISON: Figure 2: Impact of risk categories on financing costs for wind energy and solar PV investments in Lebanon, business-as-usual scenario**

BUSINESS-AS-USUAL FINANCING COSTS, BASED ON COMBINED ANSWERS FROM BOTH WIND ENERGY AND SOLAR PV INVESTORS




Source: interviews with wind energy and solar PV investors and developers; modelling

### Public Cost of Capital

The modelling takes a bottom-up approach to the calculation of the public cost of capital. In this case, the public cost of capital is denominated in USD. The bottom-up approach can then be summarized as follows:

***Public Cost of Capital (USD) = Risk-free Rate (USD) + Country Risk Premium***

The risk-free rate is taken as the 10-year US Treasury bond rate and the country risk premium is estimated based on either the country's sovereign credit rating or the credit default swap (CDS) spread over the US, depending on the availability of information. Both input parameters are based on publicly available information, with the US 10-year Treasury bond data available from the US Department of Treasury, and the country risk premium data available from academic sources.

For this analysis, as of November 2016, the 10-year US Treasury Bond rate is estimated at 2%, and the country risk premium was estimated at 5% (Damodaran, 2016), resulting in a 7% public cost of capital for Lebanon.

As the DREI analysis is carried out through its various stages, this bottom-up approach to calculating the public cost of capital is also a reference for the assumed cost of equity and debt assumptions, and is cross-checked in the interviews with industry participants in-country.

## A.2 Stage 2- Public Instruments

### Public Instrument Table

The public instrument table for wind energy and solar PV is derived from the generic table in the DREI report (2013, Section 2.2.1). The table is set out in full in Table 3 and includes the following modification:

- Following investor feedback who did not consider fossil fuel subsidies a risk, the set of policy derisking instruments for fossil-fuel subsidy reform (part of 'power market risk') is excluded from the modelling.
- To acknowledge the fact that Lebanon's energy crisis has produced a striving market for the sales of electricity from neighbourhood-scale private generator networks, who may fear to be taken out of business by new RE installations, the table was first amended by an additional barrier under 'social acceptance risk'. However, investors did not share this concern, and consequently no instruments were modelled that would address the barrier 'social and political resistance related to the (shadow) business of operating private generators during power outages'.
- Financial derisking instruments addressing the 'hardware purchase and manufacturing' barrier under 'developer risk' were excluded from the modelling, as this barrier affects mainly locally manufactured hardware, which are not considered in the general investment assumptions (Boxes 2 and 3).
- Financial derisking instruments addressing the 'transmission infrastructure' barrier under 'grid & transmission risk', e.g., financial products to support grid infrastructure, are excluded in order to keep the modelling exercise manageable.
- Investor feedback revealed the 'currency/macroeconomic risk' to be of no concern in Lebanon. Accordingly, the financial derisking instruments for this category (partial indexing of PPA tariff) was not modelled.

## Policy Derisking Instruments

The following is a summary of the key approaches taken:

- *Public Cost.* Estimates for the public cost of policy derisking instruments are calculated based on bottom-up modelling. This follows the approach for costing set out in the DREI report (2013, Section 2.2.2.). Each instrument has been modelled in terms of the costs of: (i) full-time employees (FTE) at mean yearly costs of USD 52,000 per FTE, and (ii) external consultancies/services at USD 200,000, USD 100,000, and USD 50,000 per large, medium, and small contract, respectively. An annual inflation of 2% is assumed for both FTE and consultancies/service contract costs. Typically, full-time employees are modelled for the operation of an instrument (e.g. the full-time employees required to staff an energy regulator), and external consultancies/services are modelled for activities such as the design and evaluation of the instrument, as well as certain services such as publicity/awareness campaigns. Policy derisking measures are modelled for up to the 14-year period from 2017 to 2030. Data have been obtained from local experts and the UNDP's (in particular UNDP Lebanon) in-house experience. See Tables 8 and 9 for the cost estimates of policy derisking instruments.
- *Effectiveness.* Estimates for the effectiveness of policy derisking instruments in reducing financing costs are based on the structured interviews with investors, and then further adjusted to reflect UNDP's in-house experience. The assumptions for the final effectiveness (after 20 years) are shown in Table 15. As certain policy derisking instruments may take time to become maximally effective, a linear ("straight-line") approach to time effects is modelled over the 20-year target investment period – this is referred to as the discount for time effects in the table. The qualitative investor feedback on policy derisking instruments' effectiveness is provided in Table 6 of the report.

**Table 15: The modelling assumptions for policy derisking instruments' effectiveness**

| RISK CATEGORY | POLICY DERISKING INSTRUMENT | EFFECTIVENESS | DISCOUNT FOR TIME EFFECT | COMMENT |
|---|---|---|---|---|
| **Energy Market Risk** | Long-term targets; regulatory framework; standardised PPA; independent regulator | 75% | 50% | Interview responses: high effectiveness |
| **Permits Risk** | Streamlined process for permits; establish a dedicated one-stop shop for RE permits; contract enforcement and recourse mechanisms | 50% | 50% | Interview responses: moderate effectiveness |
| **Social Acceptance Risk** | Awareness-raising campaigns targeting general public; pilot models for community involvement at project sites | 50% | 50% | Interview responses: moderate effectiveness |
| **Resource & Technology Risk** | Resource assessment; technology and O&M assistance | 25% | 50% | Interview responses: moderate/low effectiveness |
| **Grid/Transmission Risk** | Grid code; grid management studies | 50% | 50% | Interview responses: moderate effectiveness |
| **Counterparty Risk** | Strengthening utility's management & operational performance for existing operations | 50% | 50% | Interview responses: high effectiveness |
| **Financing Risk** | Financial sector reform; strengthening investors' familiarity and assessment capacity for renewable energy | 25% | 50% | Interview responses: moderate/low effectiveness |

## Policy Derisking Instruments

The modelling assumptions for financial derisking instruments are informed by UNDP's in-house experience, including interviews with representatives from international financial institutions and interviews with project developers.

Empirically, the selection, pricing and costing of financial derisking instruments for a particular renewable energy investment are determined on a case-by-case basis, and reflect the particular risk-return characteristics of that investment. The modelling assumptions instead cover the aggregate investments for Lebanon's envisioned 2030 RE targets and represent a simplified, but plausible, formulation for the selection and pricing of financial derisking instruments. The following is a summary of the key assumptions used.

- *Cost*. Estimates of public cost of financial derisking instruments are set out in Table 16 below.

**Table 16: The modelling assumptions on costing of financial derisking instruments**

| RISK CATEGORY | POLICY DERISKING INSTRUMENT | DESCRIPTION OF MODELLING ASSUMPTIONS |
|---|---|---|
| **Grid/ Transmission Risk** | Take-or-Pay Clause in PPA[46] | • Assumes 1% of annual production is lost due to grid management (curtailment) or transmission failures (black-out/brown-out)<br>• Assumes 50% of IPP's lost revenues due to grid management or transmission failures are reimbursed by take-or-pay clause |
| **Counterparty Risk** | Government (sovereign) Guarantee | • Assumes the Lebanese Council of Ministers (or the Ministry of Finance) provides "Letter of Support" for each PPA entered into between EDL and the IPP<br>• The public cost of this type of guarantee are modelled as opportunity cost to GoL from setting aside 12 months worth of PPA payments at 5% cost of capital (public cost of capital of 7% minus 10y US Treasury bond rate of 2%) |
| **Financing Risk** | Public Loan | • Assumes a mix of half concessional (4% and 20-year tenor) and half non-concessional (7% and 10-year tenor) USD loans from multilateral development banks to cover 25% of total debt needs (terms of mix: 5.5% and 15-year tenor). This is to assist developers in gaining access to capital and to win the commitment from the GoL<br>• Public cost:<br>○ Assumes the public cost is 25% (loss reserve) of the face value of the loan to the IPP (World Bank, 2011) |
| **Political Risk** | Political Risk Insurance (PRI) | • Assumes 4 point MIGA-type coverage for equity holders covering expropriation, political violence, currency restrictions, and counterparty risk<br>• Covers 45% of the original face value of the equity invested (to reflect that not all IPPs might seek PRI and full coverage)<br>• Public cost:<br>○ Assumes the public cost is 10% (loss reserve) of the equity amount covered<br>• Private cost:<br>○ Assumes a 20 basis points (0.2%) front end fee<br>○ Assumes a 100 basis points (1%) premium payment, calculated annually |

[46] A "take or pay" clause is a clause found in the PPA that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver electricity generated by its renewable energy plant.

- *Effectiveness.* Estimates for the effectiveness of financial derisking instruments in reducing financing costs are based on the structured interviews with investors, and then further adjusted to reflect UNDP's in-house experience. The figures for effectiveness have full and immediate impact once the instrument is implemented (i.e. no timing discount). The assumptions for effectiveness are shown in Table 17. The qualitative investor feedback on financial derisking instruments' effectiveness is provided in Table 6 of the report.

**Table 17: The modelling assumptions for financial derisking instruments' effectiveness**

| RISK CATEGORY | FINANCIAL DERISKING INSTRUMENT | EFFECTIVENESS | DISCOUNT FOR TIME EFFECT | COMMENT |
|---|---|---|---|---|
| **Grid/Transmission Risk** | Take-or-Pay Clause in PPA | 25% | 0% | Interview responses: high effectiveness, but already factored in (considered a pre-requisite in any PPA) |
| **Counterparty Risk** | Government (sovereign) Guarantee | 25% | 0% | Interview responses: moderate effectiveness |
| | Public Loan | 12.5% | 0% | Interview feedback: public "buy-in", especially from international donors, reduces also counterparty risk |
| **Financing Risk** | Public Loan | 0% [Impact via concessional interest rates] | 50% | Interview responses: high effectiveness |
| **Political Risk** | Foreign Currency Partial Indexing of PPA | 50% | 0% | Interview responses: high effectiveness. However, residual risks remain |

## A.3. Stage 3 – Levelised Costs

### Levelised Cost of Electricity (LCOE) Calculation

The DREI report's (2013) financial tool is used for the LCOE calculations. The financial tool is based on the equity-share based approach to LCOEs, which is also used by ECN and NREL (IEA, 2011; NREL, 2011). Box 4 sets out the LCOE formula used. In this approach, a capital structure (debt and equity) is determined for the investment, and the cost of equity is used to discount the energy cash-flows.

**Box 4: The modelling LCOE formula**

$$\frac{\%\,\text{Equity Capital} * \text{Total Investment} + \sum_{\tau=1}^{T} \dfrac{(\textit{O\&M Expense})_\tau + (\textit{Debt Financing Costs})_\tau - \textit{Tax Rate} * (\textit{Interest Expense}_\tau + \text{Depreciation}_\tau + \textit{O\&M Expense}_\tau)}{(1 + \textit{Cost of}\ \text{Equity})^\tau}}{\sum_{\tau=1}^{T} \dfrac{\textit{Electricity Production}_\tau * (1 - \textit{Tax Rate})}{(1 + \textit{Cost of}\ \text{Equity})^\tau}}$$

Where,
% Equity Capital = portion of the investment funded by equity investors
O&M Expense = operations and maintenance expenses
Debt Financing Costs = interest & principal payments on debt
Depreciation = depreciation on fixed assets
Cost of Equity = after-tax target equity IRR

Tax-deductible, linear depreciation of 95% of fixed assets over the lifetime of investment is used. The standard corporate tax rate for Lebanon at 15% was used[47]. No tax credits, or other tax treatment, are assumed.

## Baseline Energy Mix Levelised Costs and Emissions

The modelling makes a number of important methodological choices and assumptions regarding the baseline. The key steps in the approach taken are set out here:

- A combined baseline approach (80% build margin, 20% operating margin) is used on the basis that Lebanon's power sector is on the one hand characterized by notorious under-supply and rapidly increasing energy demand. As such, new wind energy and solar PV installations will likely not replace existing generation capacity. On the other hand, Lebanon's existing power plant fleet is old and inefficient. While some of the plants are benefiting from a currently ongoing refurbishment program by GoL, others might indeed be taken offline in lieu of new generation capacity.

- For the 80% build margin share of the baseline, a private sector perspective to baseline investment is used and as such private sector financing costs are modelled. This reflects the fact that Lebanon is seeking to attract private-sector investment irrespective of energy technology. In line with recent government funded studies new generation capacity for Lebanon, the modelling uses combined cycle gas turbine technology (CCGT) as the marginal baseline technology. The modelling assumptions for CCGT are shown below in Table 18.

- For the 20% operating margin share of the baseline, a number of assumptions and simplifications are made in order to keep the modelling exercise manageable, while at the same time adequately reflecting Lebanon's current power generation mix. Based on, the amount of energy produced by the different installations, as provided by the MoEW for the year 2015, this mix is split into three sub-groups[48]:

  - CCGT plants running on light fuel oil ('CCGT on LFO'). These are the two plants Deir Aamar at the North Lebanon shore, and Zahrani at the South Lebanon shore. For the sake of simplicity, the rarely-used open cycle gas turbines (OCGT) plants of Tyre and Baalbek are also included in this group.

  - Private residential generators running on light fuel oil ('LFO')

  - Thermal plants (Zouk, Jiyeh, Hrayche), two power barges anchoring offshore in the north of Beirut, and private industrial generators all running on heavy fuel oil ('HFO').

  The modelling assumptions for these four sub-groups of the operating baseline technology mix are shown below in Table 19.

[47] Source: Deloitte International Tax, Lebanon Highlights 2016

[48] Lebanon's hydro power plants are not considered in this marginal baseline approach, since they account for only 2.5% of the electricity generated in 2015, and they would not be replaced by new renewables.

**Table 18: The modelling assumptions for the baseline energy technology (CGGT)**

| TECHNOLOGY ITEM | ASSUMPTION | SOURCE |
|---|---|---|
| **Initial investment cost (USD/MWel)** | 910,000 | Schmidt *et al.*, 2012; cross-checked by Lebanese experts (2016) |
| **Initial O&M cost excl. fuel (USD/MWel)** | 35,100 | Schmidt *et al.*, 2012; cross-checked by Lebanese experts (2016) |
| **O&M Inflation** | 2% | Authors |
| **Lifespan (years)** | 25 | Schmidt *et al.*, 2012 |
| **System Efficiency** | 60% | Authors |
| **Capacity Factor** | 89% | MoEW confidential study (2014) |
| **Emission Factor** | 0.448 $tCO_2e$/MWh | Bizerte CDM PDD (2012)[49] |
| **FINANCING ITEM** | | |
| **Capital structure** | 25% equity, 75% commercial loan | Authors |
| **Cost of Equity** | 13.6% | Same as for RE, 15% discounted to account for market maturity for fossil thermal plants |
| **Loan terms** | 7.65%, 13-year tenor | CoD: Same as for RE, 15% discounted to account for market maturity for fossil thermal plants; tenor: half the lifespan of asset |
| **Depreciation allocation** | Straight line, 100% depreciable | Authors |

**Table 19: The modelling assumptions for the operating baseline energy technology**

| TECHNOLOGY ITEM | ASSUMPTION | | | SOURCE |
|---|---|---|---|---|
| | CCGT ON LFO | LFO | HFO | |
| **Share of generation mix** | 34.4% | 29.9% | 35.7% | MoEW statistics for the year 2015 |
| **Investment cost (EUR/MWel)** | 0 | | | Authors, Lebanon's fossil fuel fired power plants are old and considered depreciated |
| **Current O&M cost excl. fuel (EUR/MWel)** | 38,800 | 38,800 | 53,100 | Authors, based on DREI report (2013), O&M inflation of 2% until 2017 |
| **O&M Inflation** | 2% | | | Authors |
| **Remaining Lifetime (years)** | 15 | 13 | 8 | Authors |
| **System Efficiency** | 43.2% | 33.0% | 41.5% | Authors, based on MoEW statistics for the year 2015 |
| **Capacity Factor** | 53.6% | 30.6% | 62.4% | World Bank, 2009; MoEW experts, Authors |
| **Emission Factor** | 0.694 $tCO_2e$/MWh | | | MoEW statistics for the year 2015 (emission factor is lumped for all assets except hydro, only direct emissions from assets are considered) |
| **FINANCING ITEM** | | | | |
| **Capital structure** | 100% EDL owned | 100% equity | 20% equity, 80% EDL owned | Authors, based on MoEW statistics for the year 2015 |
| **Cost of Equity** | – | 13.6% | 13.6% | Same as for RE, 15% discounted to account for market maturity for respective plants |
| **EDL's cost of capital** | 7% | – | 7% | Same as public cost of capital (EDL is state owned) |
| **Depreciation allocation** | Straight line, 100% depreciable | | | Authors |

[49] Bizerte wind farm CDM PDD (2012). Available at https://cdm.unfccc.int/Projects/DB/DNV-CUK1337768970.01/view

- Fuel prices have been obtained from World Bank projections for the gas price and from Energy Information Agency projections for light fuel oil and heavy fuel oil prices[50]. According to these projections, the 2017 starting values of 15.0 USD/MWh, 50.2 USD/MWh, and 22.2 USD/MWh for natural gas, light fuel oil, and heavy fuel oil, respectively, would increase to 27.8 USD/MWh, 82.5 USD/MWh, and 54.4 USD/MWh. Both the starting values and the projections have been validated by a member of the Ministry of Finance.

## Wind Energy – Technology specifications

The technical assumptions for the wind energy LCOE calculation are set out in Table 20 below.

**Table 20: The modelling assumptions for wind energy technology specifications**

| TECHNOLOGY ITEM | ASSUMPTION | SOURCE |
|---|---|---|
| 2030 wind energy installed capacity | 450 MW | Envisioned target in Lebanon's National Renewable Energy plan (MoEW/LCEC, 2016) |
| Turbine size | 2-3 MW class | Authors |
| Park size | 50-100 MW | Authors |
| Core investment costs, including balance of plant costs (civil works, transformers), 2023 Cost | 1,410,000 USD/MW | IRENA, 2016: from cost reduction curve, showing compound annual decline rate of -1.3% between 2015 and 2025, resulting in a 10% cost reduction between 2015 and 2023. 2023 is the mid-point of the model period from 2017-2030. Investment cost in IRENA, 2016 include grid interconnection cost. |
| Annual O&M costs at start of operation<br>Annual increase | 31,600 USD/MW<br>2% | IRENA, 2016: O&M costs derived from OpEx/CapEx ratio of 13%/87% at a WACC of 10% in 2025. |
| Lifetime | 20 years | Authors |
| Wind energy capacity factor | 25.62% | Area-weighted average from NREAP (MoEW/LCEC, 2016) |
| Emission Factor | 0 $tCO_2e$/MWh | Authors (only direct emissions from RE asset are considered) |

## Solar PV – Technology specifications

The technical assumptions for the solar PV LCOE calculation are set out in Table 21 below.

**Table 21: The modelling assumptions for solar PV technology specifications**

| TECHNOLOGY ITEM | ASSUMPTION | SOURCE |
|---|---|---|
| 2030 wind energy installed capacity | 300 MW | Envisioned target in Lebanon's National Renewable Energy plan (MoEW/LCEC, 2016) |
| Turbine size | C-Si | Authors |
| Park size | 1-10 MW | Authors |
| Core investment costs, including balance of plant costs (civil works, transformers), 2023 Cost | 930,000 USD/MW | IRENA, 2016: from cost reduction curve, showing compound annual decline rate of -8% between 2015 and 2025, resulting in a 49% cost reduction between 2015 and 2023. 2023 is the mid-point of the model period from 2017-2030. Investment cost in IRENA, 2016 include grid interconnection cost. |
| Annual O&M costs at start of operation<br>Annual increase | 24,600 USD/MW<br>2% | IRENA, 2016: O&M costs derived from OpEx/CapEx ratio of 15%/85% at a WACC of 10% in 2025. |
| Lifetime | 20 years | Authors |
| Solar PV capacity factor | 19.83% | Area-weighted average from NREAP (MoEW/LCEC, 2016) |
| Emission Factor | 0 $tCO_2e$/MWh | Authors (only direct emissions from RE asset are considered) |

[49] Source: World Bank Commodities Price Forecast, online interface, released July 26, 2016; US Energy Information Agency, Annual Energy Outlook 2016, online interface, released Sept. 15, 2016.

### Wind Energy and Solar PV – Terms of Finance

The financial assumptions used for both wind energy and solar PV LCOE modelling are set out in Table 22 below.

**Table 22: The modelling assumptions for wind energy and solar PV terms of finance**

| FINANCE ITEM | ASSUMPTION | | SOURCE/COMMENTS |
|---|---|---|---|
| | BAU | POST-DERISKING | |
| **Capital structure** | 35% equity, 65% commercial loan | 30% equity, 70% commercial loan | Authors |
| **Cost of equity** | 16% | 12.8% | This study |
| **Debt structure** | 100% commercial loan | 25% concessional public loan, 75% commercial loan | Authors |
| **Loan terms** | Commercial: 9%, 8-year tenor | Concessional public: 5.5%, 15-year tenor, Commercial: 6.1%, 10-year tenor | Commercial: Lebanese investors, concessional: authors |
| **Depreciation allocation** | Straight line, 95% depreciable | | Authors (5% non-depreciable reflects land) |

## A.4. Stage 4 – Evaluation

### Wind Energy and Solar PV Sensitivities

The modelling performs three types of sensitivities for wind energy and solar PV.

Table 23 below sets out the assumptions and sources used for the sensitivities to key input assumptions, namely investment costs, O&M cost, capacity factor, fuel costs and financing costs (sensitivities of Type 1 in main report).

**Table 23: The modelling approach to sensitivities of key input assumptions for wind energy and solar PV**

| COMPONENT | ASSUMPTION | SOURCE |
|---|---|---|
| **Investment Costs** | Wind energy:<br>Base case (2023 cost): 1,410,000 USD/MW<br>Sensitivity (2016 cost): 1,800,000 USD/MW<br>Solar PV:<br>Base case (2023 cost): 930,000 USD/MW<br>Sensitivity (2016 cost): 1,350,000 USD/MW | Base case: IRENA, 2016 projection, see also Table 20 and Table 21. 2023 is selected as this reflects the mid-point of the 2017-2030 modelling period<br>Sensitivy: Average 2016 investment cost data collected from Lebanese developers |
| **O&M Costs** | Wind energy:<br>Base case (2023 cost): 31,600 USD/MW<br>Sensitivity (2016 cost): 46,500 USD/MW<br>Solar PV:<br>Base case (2023 cost): 24,600 USD/MW<br>Sensitivity (2016 cost): 33,000 USD/MW | Base case: derived from IRENA, 2016, see also Table 20 and Table 21<br>Sensitivity: Average 2016 O&M cost data collected from Lebanese project developers. This data showed a substantial spread. For wind energy, their mean is in line with recent literature (e.g. IRENA, 2016; IEA, 2016). For solar PV, their mean is somewhat higher than expected from literature |
| **Capacity Factor** | Wind energy:<br>Base case: 25.62%<br>Sensitivity: 30% | Authors, informed by the NREAP (30% is the area-weighted average in Lebanon resulting if wind speeds below 7.5 m/s and above 9.5 m/s are discarded) |
| **Fuel Costs** | Wind energy and solar PV: +/- 20% difference to WB (gas) and EIA (LFO, HFO) fuel cost forecasts | Authors |
| **Financing Costs** | Wind energy and solar PV: +/- 1% difference on financing costs from interviews | Authors |

For the sensitivities to different instrument packages (Type 2 in main report), the following sub-sets of derisking instruments were considered (see Table 3 or Table 5 for an overview over all risks and instruments):

- Scenario 'policy derisking only' considers exclusively policy derisking instruments. They address power market risk, permits risk, social acceptance risk, developer risk, grid/transmission risk, counterparty risk, and financing risk.
- Scenario 'financial derisking only' considers exclusively financial derisking instruments. They address gird/transmission risk, counterparty risk, financing risk, and political risk.
- Scenario 'high impact risks' considers both policy and financial derisking instruments addressing power market risk, grid/transmission risk, counterparty risk, political risk. Public loans are not modelled in this scenario, despite their small effectiveness attributed to counterparty risk.

Table 24 below sets out the assumptions used for the sensitivities to two additional approaches for financial instrument costing, namely a more conservative, high-cost approach and a more aggressive, low-cost approach (sensitivities of Type 3 in main report).

**Table 24: The modelling approach to sensitivities for the costing of financial derisking instruments**

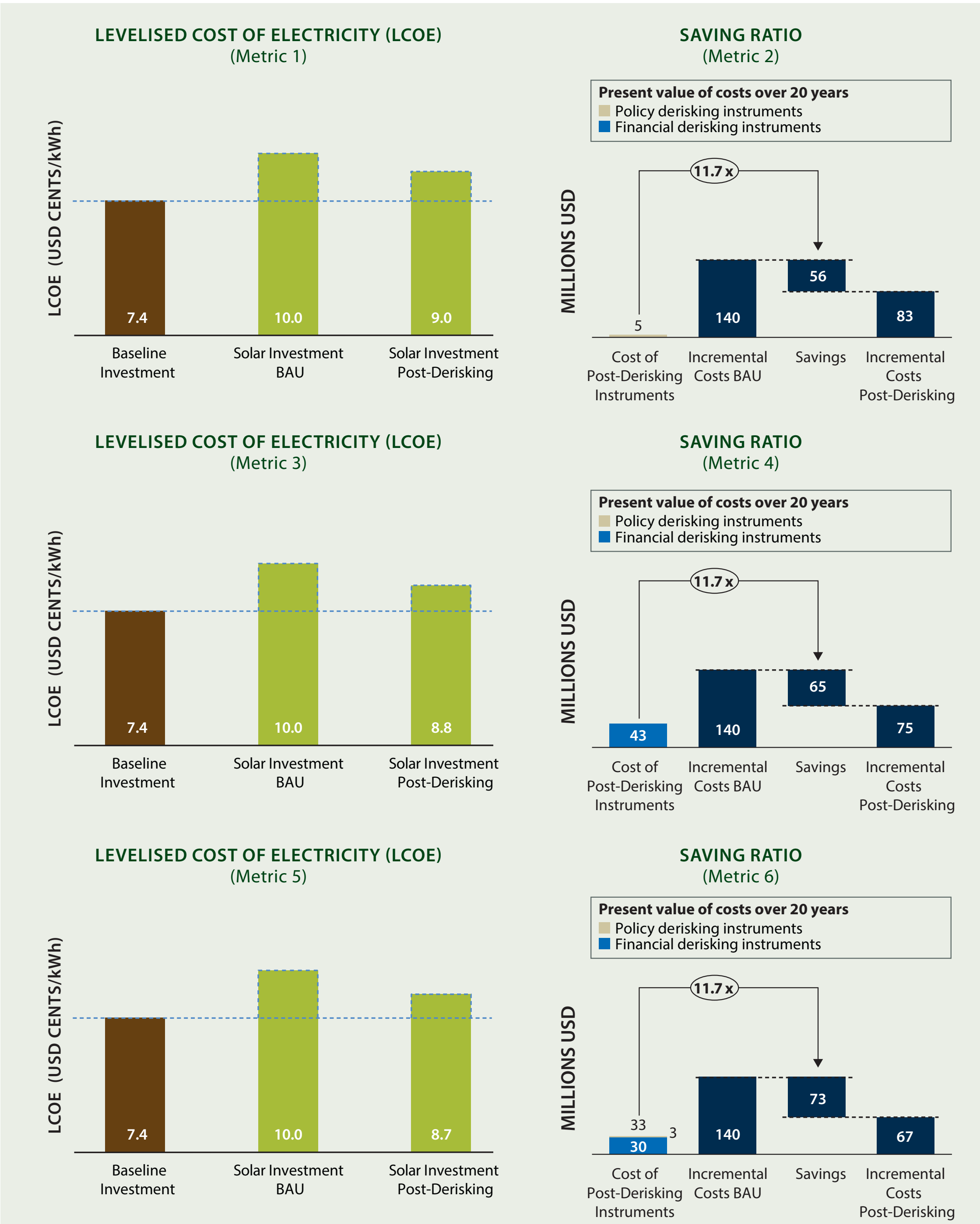
| SENSITIVITY | ASSUMPTIONS/APPROACH | COMMENT |
|---|---|---|
| **Public cost associated to Take-or-Pay clause** | *Base case:* actual cost acc. to author's assumptions<br>*High-cost and low-cost approach:* same as base case | *Base case:* See Table 16 for approach and assumptions behind costing of Take-or-Pay clause in PPA. |
| **Public cost associated to "Letter of support" from GoL to guarantee PPA** | *Base case:* opportunity cost for setting aside12 months worth of PPA payment at 5% cost of capital<br>*High-cost approach:* 100% of 12 months worth of PPA payments<br>*Low-cost approach:* no public cost | *High-cost approach:* assumes that EDL defaults to pay the IPPs during a total of 12 months over the lifetime of the project.<br>*Low-cost approach:* assumes that no public costs are attributed to such a letter. |
| **Public cost associated to public loans** | *Base case:* 25% of face value as loss reserve<br>*High-cost approach:* full face value<br>*Low-cost approach:* no public cost | *High-cost approach:* corresponds to the unlikely case that all of the borrowers will default.<br>*Low-cost approach:* assumes that loans should be paid back in full, and that any default risk and cost of capital are covered through the loan's terms and fees. |
| **Public cost associ-ated to political risk insurance** | *Base case:* 10% of equity covered as loss reserve<br>*High-cost and low-cost approach:* same as base case | *Base case:* See also Table 16 for approach and assumptions behind costing of PRI. |

# ANNEX B: GRAPHICAL REPRESENTATION OF SENSITIVITY ANALYSES (SECTION 4.2.4)

**Figure 20: Wind energy:** summary of LCOE (left) and savings ratio (right) outputs for sensitivity analyses considering only policy derisking instruments (top row), only financial derisking instruments (middle row), and only instruments targeting the four risk categories having the highest impact on financing cost, i.e. market risk, grid/transmission risk, counterparty risk, political risk (bottom row).

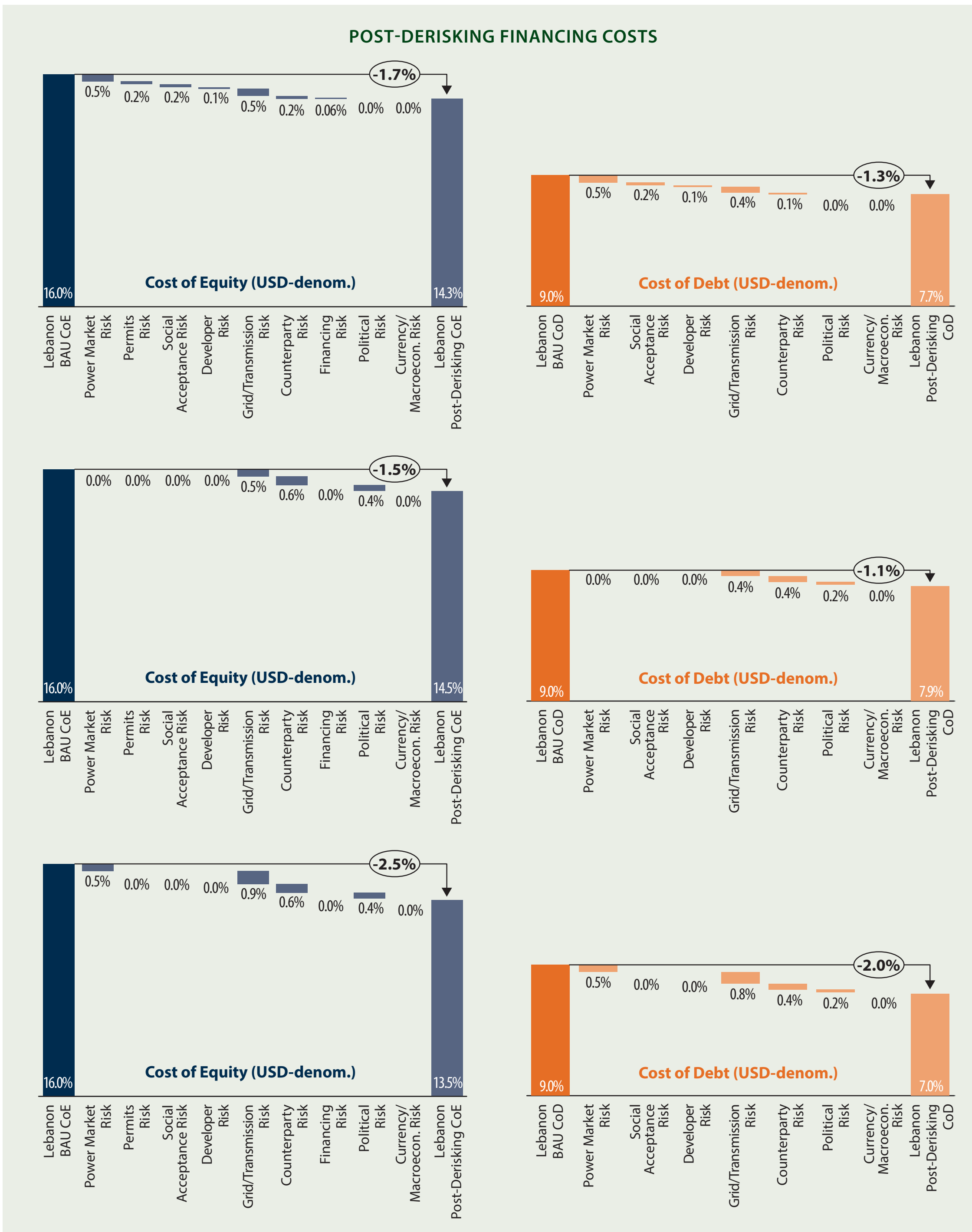

Source: sensitivity modelling; see Figure 13 and Figure 14 for base case scenario, see Table 13 and Annex A for details of assumptions and methodology.

**Figure 21: Solar PV:** summary of LCOE (left) and savings ratio (right) outputs for sensitivity analyses considering only policy derisking instruments (top row), only financial derisking instruments (middle row), and only instruments targeting the four risk categories having the highest impact on financing cost, i.e. market risk, grid/transmission risk, counterparty risk, political risk (bottom row).



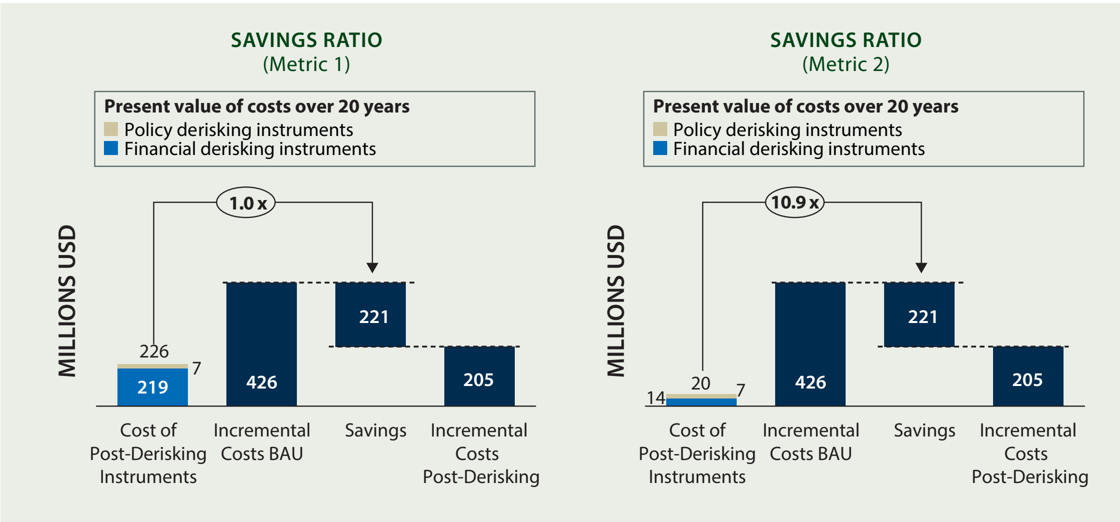

Source: sensitivity modelling; see Figure 13 and Figure 15 for base case scenario, see Table 14 and Annex A for details of assumptions and methodology.

**Figure 22: Wind energy and solar PV:** Summary of impact on financing costs outputs for sensitivity analyses considering only policy derisking instruments (top row), only financial derisking instruments (middle row), and only instruments targeting the four risk categories having the highest impact on financing cost, i.e. market risk, grid/transmission risk, counterparty risk, political risk (bottom row).



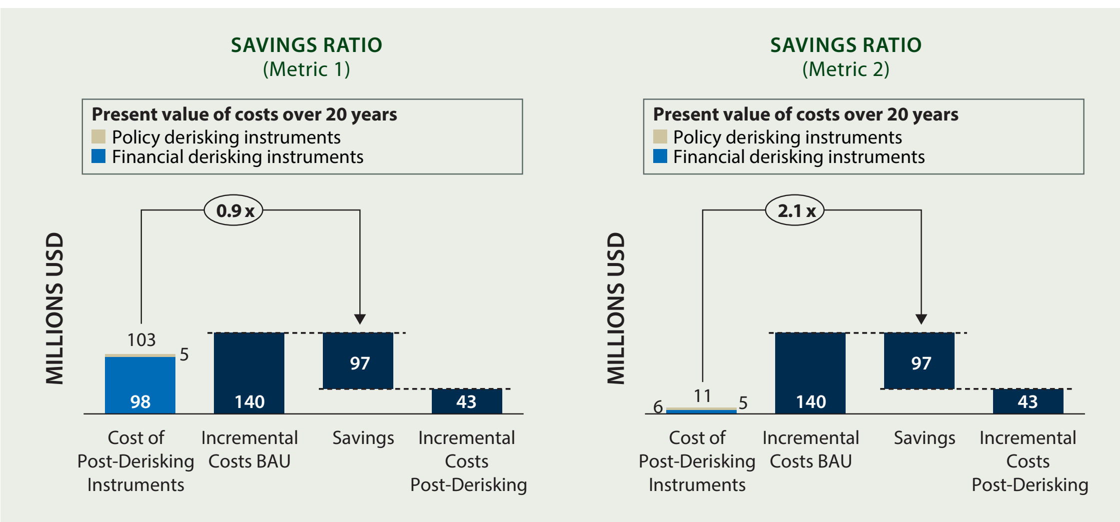

Source: interviews with wind energy and solar PV investors and developers; modelling; see Figure 12 for base case scenario, see Annex A for details of assumptions and methodology. Note: the impacts shown are average impacts over the 2017-2030 modelling period, assuming linear timing effects.

**Figure 23: Wind energy:** Summary of savings ratio outputs for sensitivity analyses using a high-cost (left) and low-cost (right) approach to financial derisking instrument costing.




Source: sensitivity modelling; see Figure 13 and Figure 14 for base case scenario, see Table 13 and Annex A for details of assumptions and methodology.

**Figure 24: Solar PV:** Ssummary of savings ratio outputs for sensitivity analyses using a high-cost (left) and low-cost (right) approach to financial derisking instrument costing.




Source: sensitivity modelling; see Figure 13 and Figure 15 for base case scenario, see Table 14 and Annex A for details of assumptions and methodology.

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