Tunisia:
Derisking Renewable Energy Investment 2018

METHODOLOGY AND ASSUMPTIONS

June 2018

This document sets out the methodology, assumptions and data that have been used in performing the modelling for the DREI Tunisia 2018 study.

The modelling closely follows the methodology set out in the UNDP *Derisking Renewable Energy Investment Report* (UNDP, 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 tools (in Microsoft Excel) created for the DREI framework. The financial tools are denominated in 2018 EUR and cover a core period from January 1, 2018 (approximating the present time) to December 31, 2030 (the horizon for Tunisia's envisioned RE targets). Generation technologies may have asset lifetimes which extend beyond 2030, and this is captured by the financial tools.

The 2018 DREI Tunisia study is part of the wider project "NAMA support for the Tunisian solar plan" and updates the *Tunisia: Derisking Renewable Energy Investment* (2014) analysis and report ("DREI Tunisia 2014").

> The **Full Results** of the 2018 update study, a **Key Points** document, the financial models, as well as the original DREI Tunisia 2014 analysis and reports are available to download at: www.undp.org/DREI

A1. Risk Environment (Stage 1)

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

- 8 structured interviews with investors in wind energy and solar PV in Tunisia - 6 with equity investors or developers, 2 with debt investors.
- 1 structured interview with a RE investor in the best-in-class country.
- A number of informational interviews with and inquiries to other public and RE actors

Interviews with local investors were conducted by the UNDP project team in Tunisia between July 2017 and February 2018.

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 20 underlying barriers as presented in Table 1, which is an update of the barriers-risk-instrument table produced for the DREI Tunisia 2014 study (UNDP, 2014).

Table 1: Risks, barriers, public instruments table (Part I)

BARRIERS				PUBLIC INSTRUMENTS			
				Policy Derisking Instruments		Financial Derisking Instruments	
Risk Category	Description	Underlying Barriers	Key Stakeholder Group	Activity	Description	Activity	Description
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 energy markets and access to it	*Market access and prices:* limitations related to energy market liberalization; uncertainties related to access, the competitive landscape and price outlook for renewable energy; limitations in design of standard PPAs and/or PPA tendering procedures	Power sector policymakers, legislators, regulators	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) Further Implement PPA tendering*, including well-designed standard PPA		
		Market distortions: such as high fossil fuel subsidies		*Policy derisking instruments addressing this barrier, e.g. ongoing fossil fuel subsidy reform are not included in this analysis. Outside scope of analysis*			
2. Permits Risk	Risk arising from the public sector's inability to efficiently and transparently *administer* renewable energy- related licensing and permits	*Bureaucracy:* Labour-intensive, complex processes and long time-frames for obtaining licences and permits (generation, EIAs, land title) for renewable energy projects	Public sector administrators	Streamline processes for permits	Establish a one-stop-shop for renewable energy permits; reduction of process steps; clear timelines for processing; harmonisation of requirements		
		Transparency: Perceived corruption. No clear recourse mechanisms		Contract enforcement and recourse mechanisms	Enforce transparent practices and fraud avoidance mechanisms; establish effective recourse mechanisms, with clear timelines for resolution		
3. Social Acceptance Risk	Risks arising from lack of awareness and resistance to renewable energy from end-users, special interest groups	*Awareness* : Lack of awareness of renewable energy amongst key stakeholders including: end-users, local residents and special interest groups (e.g. unions)	End-users, general public, media, special interest groups	Awareness-raising campaigns	Implement active publicity, media and awareness campaign targeting key stakeholder groups		
		Resistence: Social and political resistance related to NIMBY concerns, special interest groups		Promote community based projects	Establish favourable local (e.g. municipal) policies and pilot community owned renewable energy projects); assist in establishing appropriate legal vehicles for community models		
4. Resource & Technology/ Developer Risk	Risks arising from use of the renewable energy resource and technology (resource assessment; construction and operational use; hardware purchase and manufacturing)	*Resource assessment and supply* : inaccuracies in early-stage assessment of renewable energy resource ; where applicable (e.g. bioenergy), uncertainties related to future supply and cost of resource	Project developers, supply chain	For wind energy only: assistance on resource assessment	For wind energy only: dissemination of national resource assesment findings		
		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.)		Technology support and O&M assistance	Industry conferences; grant funding for pre-feasibility studies (depending on technology); training, apprenticeships and university programmes to build skills (planning, construction, O&M)		
		Purchase of hardware : purchasers' lack of information on quality, reliability and cost of hardware; lack of suitability of hardware to local climatic and physical conditions		For solar PV only: research and development into technology standards	For solar PV only: Support to pilot projects on solar PV in desert environments		

* Note: This instrument can be/have elements of a direct financial incentive

Source: authors; adapted from Derisking Renewable Energy Investment (Waissbein et al., 2013) and updated from DREI Tunisia 2014 study (UNDP, 2014).

Table 1: Risks, barriers, public instruments table (Part II)

BARRIERS				STUDY'S PUBLIC INSTRUMENTS			
				Policy Derisking Instruments		Financial Derisking Instruments	
Risk Category	**Description**	**Underlying Barriers**	**Key Stakeholder Group**	**Activity**	**Description**	**Activity**	**Description**
5. Grid/ Transmission Risk	Risks arising from limitations in grid management and transmission infrastructure	*Grid code, management and connection:* Lack of standards for the integration of intermittent, renewable energy sources into the grid; limited experience or suboptimal track-record in grid management and stability; lack of responsiveness and delays in connection of new renewable energy sources to the transmission network	Transmission/ grid operator (utility)	Strengthen transmission operator's operational performance, grid management and formulation of grid code	(i) Develop a grid code for new renewable energy technologies; (ii) sharing of international best practice in grid management; (iii) capcacity building for the supervision centre to organise/ control dispatching	Include a "take-or-pay" clause in the standard PPA	"Take-or-pay" clause in PPA whereby an IPP is reimbursed for grid failure (black-out, brown-out) and/or curtailment (due to mismatches in grid management of supply/demand)
		Transmission infrastructure: inadequate or antiquated grid infrastructure, including high transmission losses, and lack of lines from the renewable energy source to load centres; uncertainties for construction of new transmission infrastructure		Policy support for national grid infrastructure planning and development	Develop and regularly update a long-term national transmission/grid plan to include intermittent renewable energy	*Financial derisking instruments addressing this barriers, e.g. public loans for grid infrastructure, are not included in this analysis. Outside scope of analysis.*	
6. Counterparty Risk	Risks arising from the utility's poor credit quality and an IPP's reliance on payments	Limitations in the utility's credit quality, corporate governance, management and operation track-record or outlook; unfavourable policies regarding the utility's cost-recovery arrangements	Utility	Strengthen the utility's performance	Establish international best practice in the utility's management, operations and corporate governance; implement sustainable cost recovery policies	Government guarantees or backing for PPA payments	Government (Ministry of Finance) letter of support for PPA payments to IPPs
7. Financial Risk	Risks arising from general scarcity of investor capital (debt and equity) in the particular country, and investors' lack of information and track record in utilty-scale 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	Investors (equity and debt)	Domestic financial sector reforms	Promote domestic financial sector policy favourable to long-term infrastructure, including project finance	Financial products by development banks to assist project devekioers to gain access to capital/funding	Public loans from international financial institutions to IPPs
		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 with project finance structures		*Policy derisking instruments addressing this barriers, e.g. sponsoring industry conferences, are not included in this analysis, following investor feedback.*			
8. Currency/ Macro-economic Risk	Risks arising from the broader macroeconomic environment and market dynamics	*Uncertainty due to volatile local currency*; unfavourable currency exchange rate mouvements	National level			Risk sharing to address currency risk	Partial indexing of local currency tariffs in PPAs, so that IPPs are reimbursed for local currency depreciation of tariff
		Uncertainty around inflation, interest rate outlook due to an unstable macroeconomic environment					
9. Political Risk	Risk arising from a mix of cross-cutting political, economic, institutional and social characteristics in the particular country which are not specific to utility-scale renewable energy	*Limitations and uncertainty* related to conflict, political instability, economic performance, weather events/natural disaster, legal governance, ease of doing business, crime and law enforcement, and infrastructure in the particular country	Macro risk				
		Uncertainty due to high political instability; poor governance; poor rule of law and institutions				Financial derisking instruments addressing this category, e.g. , political risk insurance, are not included in this study, given its non applicability in the Tunisian context	
		Uncertainty or impediments due to government policy (currency restrictions, corporate taxes)					

Source: authors; adapted from Derisking Renewable Energy Investment (Waissbein et al., 2013) and updated from DREI Tunisia 2014 study (UNDP, 2014).

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.

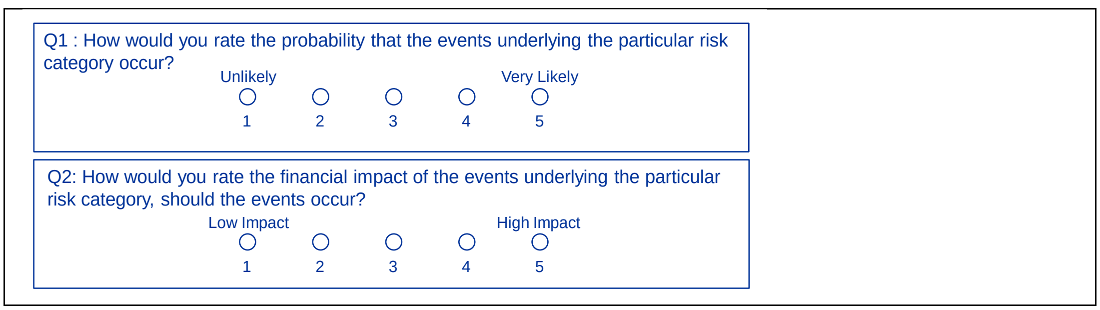
Box 1: Methodology for quantifying the impact of risk categories on higher financing costs

1. Interviews

Interviews were held with debt and equity investors active in wind energy and solar PV in Tunisia, 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 1.
- 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 1: Interview questions to quantify the impact of risk categories on the cost of equity and debt



2. Processing the data gathered

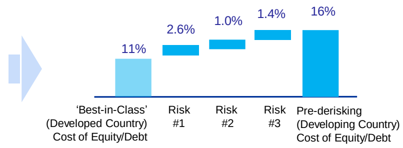
The data gathered from interviews are then processed. The methodology involves identifying the total difference in the cost of equity or debt between the developing country (Tunisia) and the best-in-class developed country (Germany). This figure for the total difference reflects the total additional 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 2.

Figure 2: Illustrative simplified application of the methodology to determine the impact of risk categories on increasing financing costs

Cost of equity					
Developing County	16%				
Best-in-class Developed Country	11%				
Total Difference	5%				
Average 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					
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%
					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 renewable energy in Stage 3.

Box 2: The eight investment assumptions for wind energy in Tunisia

1. Provide scores based on the current investment environment in Tunisia today
2. Assume you have the opportunity to invest in a 5-30 MW[1] on-shore wind park
3. Assume 2-3 MW class turbines from a quality manufacturer with proven track record (eliminating certain technology risks)
4. Assume a build-own-operate business model
5. Assume a comprehensive O&M contract
6. Assume that well-maintained transmission lines with free capacities are located within 10km of the project side
7. Assume an EPC construction sub-contract with high penalties for breach of contract
8. Assume a non-recourse, project finance structure

Box 3: The eight investment assumptions for solar PV in Tunisia

1. Provide scores based on the current investment environment in Tunisia today
2. Assume you have the opportunity to invest in a 1-10 MW[1] solar PV plant
3. Assume a high-quality c-Si PV panel manufacturer with proven track record (eliminating certain technology risks)
4. Assume a build-own-operate business model
5. Assume a comprehensive O&M contract
6. Assume that well-maintained transmission lines with free capacities are located within 10km of the project side
7. Assume an EPC construction sub-contract with high penalties for breach of contract
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' is removed for

[1] Assumptions on plant size, which are smaller than typical for a DREI analysis for utility-scale, were aligned with guidance on plants given in the first round of the Tunisia RE tender.

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 8 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) does not distinguish between answers from investors with focus on wind energy and from 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, in order to bring simplicity to the analysis and to avoid multiple result sets, the interview answers from all 8 investors were analysed together to produce one set of risk waterfalls.

- Due to the small number of debt investors in the sample, answers from equity investors and from debt investors were combined to produce the risk waterfalls.

Public Cost of Capital

The modelling assumes a Tunisian public cost of capital of 7%.

The modelling is also based on an assumed 10-year US treasury bond yield of 2.4%, reflective of yields at the end of 2017/early 2018.

A2. 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) and includes the following modifications:

- Following analysis on fossil fuel subsidies, the public instrument "fossil fuel subsidy reform" addressing market distortion (part of "power market risk") is excluded from this study.
- 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.

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 EUR 16,000 per FTE, and (ii) external consultancies/services at EUR 300,000, EUR 100,000, and EUR 50,000 per large, medium, and small contract, respectively. An annual inflation of 7% is assumed for FTE and an inflation of 3.7% for 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 13-year period from 2018 to 2030. Data have been obtained from local experts and the project team's in-house experience. See Tables 8 and 9 for the cost estimates of policy derisking instruments in the Full Results document.

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 2. Since policy derisking instruments 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 financial derisking instruments' effectiveness is provided in Table 4 of the Full Results document.

Table 2: The modelling assumptions for policy derisking instruments' effectiveness

Risk Category	Policy Derisking Instrument	Effectiveness	Discount for time effect	Comment
Power Market Risk	• Ongoing legislative reform to put in place effective policies/ revise them • FiT/PPA tender • Independent regulator	75%	50%	Interview responses: very high effectiveness (but doubts regarding practicability).
Permits Risk	• Streamlined process for permitting (e.g. dedicated one-stop shop for RE permits) • Enforcement and recourse mechanism	50%	50%	Interview responses: high effectiveness.
Social Acceptance Risk	• Awareness-raising campaigns • Promote/ pilot community-based approaches	50%	50%	Interview responses: high effectiveness.
Developer Risk	• Resource assessment (only for wind energy) • Research and development into technology standards (Support to pilot projects on solar PV in desert environments) • Technology support and O&M assistance	50%	50%	Interview responses: high effectiveness.
Grid / Transmission Risk	• Transparent, up-to-date grid code • Grid management/ planning (develop and update long-term national transmission/ grid plan to include intermittent RE) • Capacity building for the supervision centre to organise/ control dispatching	25%	50%	Interview responses: moderate effectiveness.

Counterparty Risk	• Strengthen the utility's management • Implementing sustainable cost recovery policies	50%	50%	Interview responses: high effectiveness.
Financial Sector Risk	• Domestic financial sector reform	50%	50%	Interview responses: high effectiveness.

Financial 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 Tunisia'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 3 below.

Table 3: The modelling assumptions on costing of financial derisking instruments

Risk Category	Financial derisking instrument	Description of modelling assumptions
Grid/ Transmission Risk	Take-or-Pay Clause in PPA[2]	• Assumes 1% of annual production is lost due to grid management (curtailment) or transmission failures (black-out/brown-out) • Assumes 100% of IPP's lost revenues due to grid management or transmission failures are reimbursed by take-or-pay clause (costs are assumed by the government)
Counterparty Risk	Government (sovereign) guarantee	• Assumes the Tunisian Ministry of Finance provides a "Letter of Support" for each PPA entered into between STEG and the IPP • The public cost of this type of guarantee are modelled as opportunity cost to GoT from setting aside 3-months' worth of PPA payments at 4.6% cost of capital (public cost of capital of 7% minus 10y US Treasury bond rate of 2.4%)
Financing risk	Public loan	• Assumes an annual interest rate of 4% and a loan tenor of 20 y. • The public costs are assumed to be 25% (loss reserve) of the face value of the loan to the IPP.
Currency/ Macro Risk	Partial indexing	• Assumes a hedging premium of 2.8% • Assumes 50% of tariff is indexed to hard currencies and 50% of exposure is hedged by government

- *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

[2] 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.

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 4 below. The qualitative investor feedback on financial derisking instruments' effectiveness is provided in Table 4 of the Full Results document.

Table 4: The modelling assumptions for financial derisking instruments' effectiveness

Risk Category	Financial Derisking Instrument	Effectiveness	Discount for timing effect	Comment
Grid/ Transmission Risk	Take-or-Pay Clause in PPA	75%	0%	Interview responses: high effectiveness
Counterparty Risk	Government (sovereign) Guarantee	25%	0%	Interview responses: high effectiveness.
	Public loan	25%	0%	Authors' assumption: public "buy-in", especially from international donors, reduces also counterparty risk
Financing Risk	Public loan	0% [Impact via concessional interest rates]	-	Interview responses: high effectiveness.
Currency/ Macro Risk	Partial Indexing	50%	0%	Interview responses: moderate/high effectiveness.

A3. 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

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

Where,
% Equity Capital = portion of the investment funded by equity investors
O&M Expense = operating & 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 Tunisia at 25% was used (CLM&co 2017). No tax credits, or other tax treatment, are assumed.

Baseline Energy Mix Levelised Costs and Emissions

A 100% build margin is used, in line with the DREI Tunisia 2014 analysis (UNDP, 2014). That is, we assume that due to the high growth rate in the electricity demand, capacity expansions are mandatory. Hence, the modelling compares LCOE's for newly installed capacity of conventional technologies with LCOE's for newly installed renewable technologies. It is assumed that no conventional power plant will be shut down prematurely in favour of renewable energy generation. A private sector perspective to baseline investment is used and as such private sector financing costs are modelled. This reflects the fact that Tunisia is seeking to attract private-sector investment irrespective of energy technology. At least, it is assumed that newly installed conventional capacity in Tunisia would be comprised of 100% combined cycle gas turbines, because this is the most favourable technology in the Tunisian context. The modelling assumptions for CCGT are shown below in Table 5.

Table 5: The modelling assumptions for the baseline energy technology (CGGT)

Technology Item	**Assumption**	**Source/Comments**
Initial investment cost	643,697 EUR/MW	Information taken from new CCGT projects (http://fossilfuel.energy-business-review.com/news/mitsubishi-sumitomo-to-build-gas-fired-combined-cycle-power-plant-in-tunisia-230617-5852117) cross-checked by Tunisian experts (2018)
Initial O&M cost excl. fuel	15,313 EUR/MW	STEG
O&M Inflation	2%	Authors
Lifespan	25 y	Schmidt *et al*., 2012
System Efficiency	54% (HHV)	STEG
Capacity Factor	82.5%	STEG
Emission Factor	0.374 tCO_2e/MWh	Authors, based on IPCC
Financing Item		
Capital structure	25% equity, 75% debt (debt = 100% commercial loan)	Authors
Cost of Equity	14.45%	Based on CoE for RE (=17%), 15% discounted to account for market maturity of fossil thermal plants
Loan terms	6.8%, 12.5-year tenor	CoD: Based on CoD for RE (=8%), 15% discounted to account for market maturity for CCGT plants; tenor: half the lifespan of asset
Depreciation allocation	Straight line, 100% depreciable	Authors

- Fuel costs have been extrapolated using the latest projections for the European natural gas price by the World Bank (World Bank, 2018). This starts at EUR 15.94 per MWh excl. VAT in 2018 and ends at EUR 18.14 per MWh excl. VAT in the year 2030, from where it the trend is extrapolated to 2042 to cover the full life time of the baseline asset (25 y). The starting point of ca. 16 EUR/MWh is in good agreement with the actual gas price for Tunisian large consumers who do not profit from subsidies (ca. 17 EUR/MWh excl. VAT in 2015, as published by STEG). Hence, the baseline LCOE modelling assumes unsubsidized fuel cost. Furthermore, 19% Tunisian VAT need to be added to the World Bank gas price projections before calculating the fuel cost.

Wind Energy – Technology specifications

The technical assumptions for the wind energy LCOE calculation are set out in Table 6 below.

Table 6: The modelling assumptions for wind energy technology specifications

Technology Item	Assumption	Source/Comments
2030 wind energy installed capacity	940 MW	Envisioned target in Tunisia's updated PST, Authors
Turbine size	2-3 MW class	Authors
Park size	5-30 MW	Authors
Core investment costs, including balance of plant costs (civil works, transformers), 2023 Cost	1,135,540 EUR/MW	IRENA (2016): exponential interpolation of data between the average investment cost in 2015 and the forecasted investment cost in 2025 yields a midpoint investment cost of 1,135,540 EUR/MW for 2023 that serves as an estimate for an average investment cost over the modelling period. Investment cost in IRENA (2016) include grid interconnection cost.
Annual O&M costs at start of operation Annual increase	24,264 EUR/MW/y 2%	Based on the IRENA forecast of the composition of LCOEs (Opex/Capex) of 13%/87% for a weighted average cost of capital of 10% for 2025 (IRENA, 2016). We assume an Opex/Capex ratio of 13.5%/86.5% in the overall expenditures, since the WACC is 9.3% in the modelling case.
Lifetime	20 years	Authors
Wind energy capacity factor	35 %	STEG
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 7 below.

Table 7: The modelling assumptions for solar PV technology specifications

Technology Item	Assumption	Source
2030 solar PV installed capacity	835 MW	Envisioned target in Tunisia's updated PST, Authors
Solar PV technology	C-Si	Authors
Park size	1-10 MW	Authors
Core investment costs, including balance of plant costs (civil works, transformers), 2023 Cost	636,627 EUR/MW	IRENA, 2016: exponential interpolation of data between the average investment cost in 2015 and the forecasted investment cost in 2025 yields a midpoint investment cost in 2023, that serves as an estimate for an

		average investment cost over the modelling period. The projections for Solar PV installed costs have been reduced by 15% to account for the rapid cost reductions observed as of today (May 2018) in the utility-scale solar PV sector worldwide (Authors' assumption). Investment cost in IRENA (2016) include grid interconnection cost.
Annual O&M costs At start of operation Annual increase	16,065 EUR/MW/y 2%	Based on the IRENA forecast of the composition of LCOEs (Opex/Capex) of 13%/87% for a weighted average cost of capital of 10% for 2025, we assume an Opex/Capex ratio of 13.5%/86.5% in the overall expenditures, since the WACC is 9.3% in the modelling case.
Lifetime	20 years	Authors
Solar PV capacity factor	19.4 %	STEG
Emission Factor	0 tCO_2e/MWh	Authors (only direct emissions from RE asset are considered)

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 8 below.

Table 8: The modelling assumptions for wind energy and solar PV terms of finance

Finance Item	Assumption		Source/Comments
	BAU	Post-derisking	
Capital structure	30% equity, 70% debt	27.5% equity, 72.5% debt	Authors
Cost of equity	17%	13%	This study
Debt structure	100% commercial loan	30% concessional public loan, 70% commercial loan	Authors
Loan terms	Commercial: 8%, 11-year tenor	Commercial: 5.8%, 12-year tenor Concessional: 4%, 20-year tenor	Commercial: Tunisian investors Concessional: Authors assumptions
Depreciation allocation	Straight line, 95% depreciable		Authors (5% non-depreciable reflects land)

A4. Stage 4 - Evaluation

Wind Energy and Solar PV Sensitivities

The modelling performs one type of sensitivities for wind energy and solar PV.

Table 9 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.

Table 9: The modelling approach to sensitivities of key input assumptions for wind energy and solar PV

Sensitivity	Assumptions/Approach	Source/Comment
Investment Costs	Wind energy Base case (2023 cost): 1,135,540 EUR/MW Sensitivity: 1,375,00 EUR/MW Solar PV: Base case (2023 cost): 636,627 EUR/MW Sensitivity: 1,000,000 EUR/MW	Base case: IRENA, (2016) projection. 2023 is selected as this reflects the mid-point of the 2017-2030 modelling period. Sensitivity: Average 2017/2018 investment cost as reported by Tunisian developers that were interviewed for the present study.
O&M Costs	Wind energy Base case (2023 cost): 24,264 EUR/MW Sensitivity: 29,117 EUR/MW Solar PV: Base case (2023 cost): 16,065 EUR/MW Sensitivity: 19,278 EUR/MW	Base case: derived from IRENA, (2016), see Tables 6 and 7 Sensitivity: Assuming 20% higher O&M costs
Capacity Factor	Wind energy: Base case: 35% Sensitivity: 40% Solar energy: Base case: 19.4% Sensitivity: 25%	Base case: STEG Sensitivity: Authors assumption
Fuel Costs	Wind energy and solar PV: Base case: World Bank's projections (European natural gas price) Sensitivity: +/- 20% of base case	Authors
Financing Costs	Wind energy and solar PV: Base case: CoD: 8%, CoE: 17% Sensitivity: +/- 1% of base case	Authors

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