RES Tariff Toolbox
User Manual

for

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A member of the MRC Group of Companies
Abuja, Edinburgh, Helsingborg, Madrid, Milan, Montevideo, Moscow, New York and Rio de Janeiro

+44 (0) 131 220 8280 +234 (0) 802 314 3987 mail@mrc-consultants.com www.mrcgroup-consulting.com

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Acronyms

EBIT	Earnings before interest and tax
EBITDA	Earnings before interest, tax, depreciation and amortization
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EMRC	Energy Market and Regulatory Consultants (member of the MRC)
ERERA	ECOWAS Regional Electricity Regulatory Authority
EUEI PDF	EU Energy Initiative Partnership Dialogue Facility
FCFtE	Free Cash Flow to Equity
FCFtF	Free Cash Flow to the Firm
FIT	Feed in tariff
GHG	Greenhouse Gas
GMG	Green Mini Grid
IIF	Inflation Indexation Factor
IPP	Independent Power Plant
IRR	Internal Rate of Return
kW	Kilowatt
kWh	Kilowatt hour
LCOE	Levelised cost of electricity
MW	Megawatt
MWh	Megawatt hour
NPV	Net Present Value
O&M	Operation and Maintenance
PPA	Power purchase agreement
PV	Photovoltaic
RE	Renewable energy
RES	Renewable Energy Sources
RES-E	Electricity from Renewable Energy Sources
RIF	Revenue Indexation Factor
Var O&M	Variable Operations and Maintenance
VAT	Value Added Tax

1 Introduction

The ECOWAS Regional Centre for Renewable Energy and Energy Efficiency (ECREEE), on behalf of the members of the Economic Community of West African States (ECOWAS) , has requested EU Energy Initiative Partnership Dialogue Facility (EUEI PDF) support for the development of a set of tools (toolbox) to define tariffs for renewable energy and to provide technical assistance for renewable energy tariff calculation.

As a result, EMRC (a member of the MRC Group of Companies) has been commissioned by EUEI PDF to develop a toolbox consisting of several standard tariff models to calculate tariffs for renewable technologies and an associated user manual.

1.1 Structure of this report

This manual is intended to provide you with further detail and descriptions of the toolbox models, included definitions and guidance on the use and implications of key items and concepts.

The report is split into sections in accordance with the individual excel models which are supplied as part of the Toolbox. This means that there is a separate section for **Independent Power Plants (IPPs)** (Section 2), **Green Mini-Grids** (Section 3), **Prosumers** (Section 3) and the **Supply Curve Model** (Section 5). Each section is split into the following subsections:

- **Inputs:** Discusses key inputs and their impact on the results
- **Running the model:** How the user should proceed to run the model
- **Calculations underpinning the calculations:** and methodologies behind the solve
- **Outputs:** Key outputs which can be viewed
- **Key questions:** Includes a list of questions, suggested by regional stakeholders, which the user can use the model to answer and how to interpret them.

There are two models (Section 5) that support the use of these main models, which allow the user to calculate capacity factors from wind data and support fuel unit conversions. Finally, we provide international reference data (Section 7) that can be used to check or validate local data. Finally, the report includes a bibliography (Section 8).

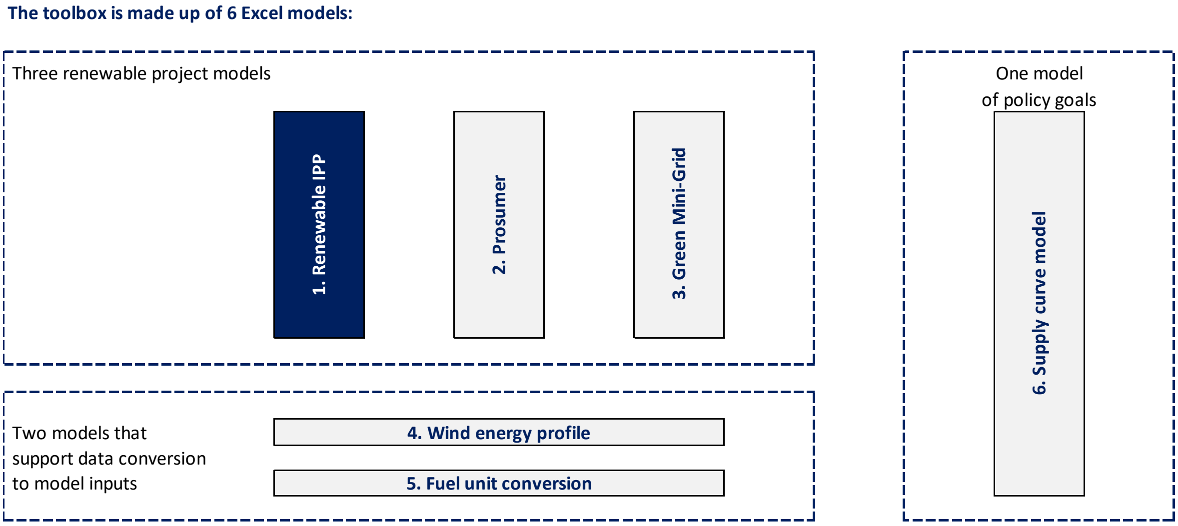
1.2 Structure of the models

The Toolbox is self-contained within four separate Excel models:

- IPP model
- Green mini grid model
- Prosumer model
- Supply Curve model.

Additionally, there are two separate calculation modules to help estimate wind power capacity factors and to convert fuel cost units into currency/MWh.

Figure 1: Toolbox structure



For each of the mini grids, IPP and prosumer projects there is an option to run three different cases. These are:

- A reference project calculation,
- An avoided cost calculation, and
- A supply impact calculation.

The three approaches which can be applied in each of the IPP's, Prosumers and Green Mini-Grids are discussed in more detail.

1.2.1 Reference project

Using the "reference project" module of any of the models will allow the user to consider either (1) a typical project in their country (for example an "average" solar PV project) to support setting feed-in tariffs, or (2) a specific project, for example, if there is a tender to develop in a specific location, or a speculative application from a potential developer that needs to be evaluated.

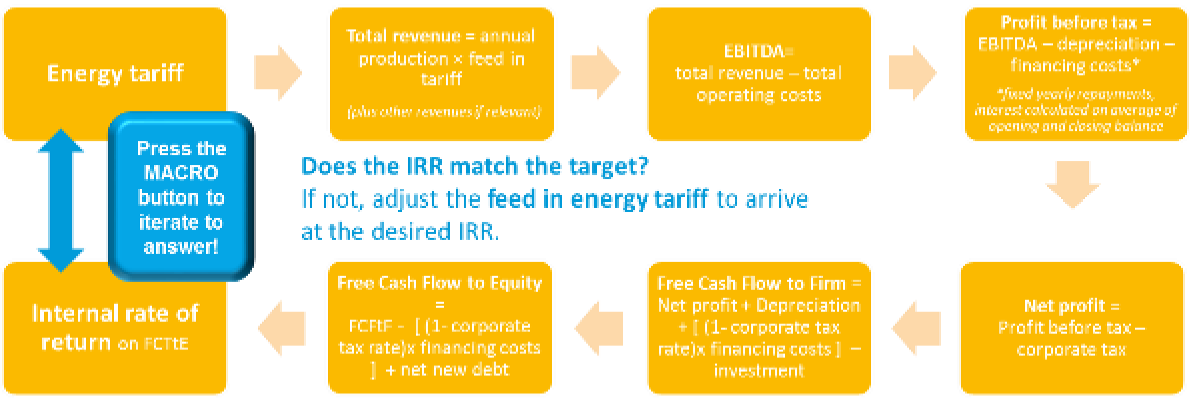
The target of a reference project is to achieve required Project Equity Internal Rate of Return (Equity IRR) by adjusting the relevant electricity tariff (currency units per kWh) for the base year[1].

In order for the model to calculate this tariff level, it requires the following main assumptions:

- Technical characteristics of the project,
- Project reference costs,
- Useful Life/Depreciation,
- Financing,
- Gearing ratio,
- Cost of Debt, and
- Required Return for Equity.

Once the inputs are complete, the user presses a "macro" button to allow the Excel workbook to iterate to an answer. Figure 2 shows how this calculation works, and it is discussed in more detail in Section 2.3 for the IPP model.

Figure 2: reference project calculation



Using the above calculations, a reference project is configured. That is, a reference power plant or mini-grid with certain associated power generation characteristics, performance levels and unit costs is used to compute the tariff required to achieve a certain target internal rate of return to equity (Equity IRR).

In general terms, the model calculates the expected inflows and outflows of money for the project during its useful life to obtain the returns for the developer with a certain tariff level.

[1] After the base year the tariff gets escalated by an indexation factor defined by the user.

For every year in the projection period, the energy output of the plant is computed, then multiplied by the unit tariff to obtain the revenues for the year. Operating costs, investment costs and financing costs are discounted to obtain the free cash flow available to repay the project shareholders. The yearly returns to shareholders are used to calculate the Equity IRR.

The tariff is computed through an iterative process, which changes the tariff level to drive the Equity IRR to its target value. Essentially the model runs itself multiple times, changing the tariff level a little each time, until it finds a tariff level where the Equity IRR matches the target level defined by the user.

This iterative process will yield the tariff associated with the Equity IRR whenever there is a possible solution. If the inputs to the model are such that no solution is possible, the iteration process will yield an error. If this happens, the user should check the inputs to resolve the issue.

1.2.2 Avoided cost

An avoided cost calculation compares two scenarios, one usually looking at a baseline scenario where the project is not implemented and the other looking at the scenario where the project is implemented. The cost associated with the baseline scenario where the renewable project is not implemented will provide the "avoided cost" for the renewable project. In other words, it gives a figure for what would need to be spent to deliver the energy from other sources.

Under this approach, we will obtain the "cost of the alternative", which provides a reference to set tariffs for renewable generation and mini-grids. By knowing the cost of the alternative solution, we know the cost avoided by developing the renewable project. This could be either higher or lower than the cost of developing the renewable project.

Using the "avoided cost" module of any of the models will allow the user to consider either (1) setting feed-in tariffs at a level that ensures that consumers pay no more for renewables than the conventional alternative, or (2) to support policy makers and regulators in understanding the cost implications of a renewable project relative to the alternative.

Since we are taking the alternative solution as the reference, there is no need to consider the unit costs of the renewable project itself to obtain the avoided cost,[2] unless you wish to see the gap between the two. Also, the avoided cost itself can be directly used as a tariff or just considered as a reference level to reason on tariffs, in combination or not with the application of the reference project approach.

[2] But the project costs (investment, operating costs and financing costs) are still required to compute the developer's rate of return for impact assessment calculations.

Avoided cost can be "private avoided cost" or "social avoided cost" depending on whether the cost of externalities is included. Externalities are just an additional cost to be included in the calculations, but measuring and pricing them is complicated. Not all countries will have cost data associated with emissions, for example.

The main assumptions required for this calculation are:

- Baseline generation cost (considering the actual baseline energy mix applicable to the alternative solution) is a common cost too all approaches in the baseline case.
- In the case of distributed generation, the baseline alternative is to be fully supplied at the end-user tariff. In this case the main interest is to evaluate the avoided cost from the standpoint of the prosumer. The baseline generation cost is still calculated and used in the impact assessment section of the distributed generation model; there it is used to calculate the impact on reduced generation required at the main system level (baseline generation mix).
- In the case of mini-grids, alternative supply takes into account the bulk supply tariff (baseline generation costs plus main interconnected system network costs), which include the cost of extending the main system to interconnect the mini-grid area (if applicable).

1.2.3 System impact

A system does not remain unaffected by the development of renewable generation or green mini-grids. There are positive (savings) and negative (revenue losses) impacts across the whole system (power generation, power transmission, power distribution and retailing) as a result of changes. It is essential to be able to compute what would happen in the system's economic balance if a certain level of IPP/prosumer/GMG penetration is targeted and achieved.

Using the "avoided cost" module of any of the models will allow the user to consider either (1) setting feed-in tariffs at a level that ensures that consumers pay no more for renewables than the conventional alternative, or (2) to support policy makers and regulators in understanding the cost implications of a renewable project relative to the alternative.

In the model the following specifics are applied:

- The system impact is calculated in a straightforward fashion. In some cases the system impact is as simple as multiplying the unit tariff by the number of projects of that type that are simulated to be developed.

- The unit cost per item if applied to a user-defined implementation scenario, where the expected volume/number of units of each IPP, prosumer, or green mini-grid is set year by year.
- The outputs provide the economic impact of supporting that particular RES policy under a certain development scenario.

1.3 Functionalities and applications of the models

During the course of the project, we established with stakeholders that the main functionalities of the model are to be able to calculate:

- Cost reflective and technology specific tariffs (e.g.: calculation of the levelled cost of electricity (LCOE) of different renewable technologies),
- The costs avoided as a result of having renewable electricity generation, for example the avoided cost of generating from conventional technologies,
- Expanding the calculation of avoided cost of generation to allow the optional addition of wider social avoided costs (for example, avoided emissions, or the additional cost of balancing variable generation),
- The associated network cost and losses of generation (relevant to the consideration of mini-grids, cross border trade and geographically remote generation),
- The ability to consider different avoided costs in different major grid systems (for example, different avoided costs for the separate islands on Cape Verde),
- The ability to quantify potential PPA duration and indexation options (% forex link for example), and
- Supply curve calculation of renewable energy targets,

These functionalities will help the user to calculate potential:

- Feed in tariffs for grid-connected systems (both national grid and mini-grids),
- Ceiling tariffs or reference prices that could be used for tenders and bilateral negotiations,
- Appropriate tariffs for off-grid mini-grid systems,
- Tariffs at which excess generation by prosumers in net metering/billing systems could be credited,

- The impact of renewable tariffs on system costs and consumer tariffs, these outputs can be used to separately consider the impact on consumer tariffs if the regulator has a suitable model for retail tariffs[3],
- The potential penetration of renewable energy at various levels of support or, conversely, the marginal pricing needed to achieve a desired level of renewable penetration.

As part of the "key questions", we will consider how each of these can be addressed using the model. We also consider some specific questions that were proposed by stakeholders at a regional stakeholder meeting.

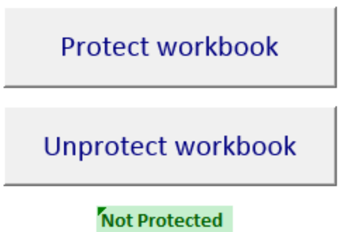
1.4 Protect/unprotect the model

It is possible to protect the models to prevent the accidental editing of calculations. This protection should allow users to change the inputs and run the macros, but not to edit calculation cells.

However, in the future users may wish to add extra functionality to the model to reflect their national situation or changes in policy. This is entirely possible, and can be done by pressing the "unprotect workbook" macro on the Dashboard. This unprotects all cells, so calculations can be edited freely. Once the edits are complete, the user can protect the workbook again by pressing the "protect workbook" macro.

The status of the workbook is indicated beneath the macro buttons (protected/ not protected).

Figure 3: Macro to protect or unprotect the workbook



[3] The model does not calculate the consumer tariffs as it would make it more complex to use, as we would need extra inputs that are not directly related to renewable energy. The outputs of the model can be used to measure the impact on consumer tariffs.

1.5 Reference data

All models are very sensitive to the data used, and any model requires good data to give robust outputs.

It should be noted that the models in the toolbox can work with a fairly minimal set of data, although it allows the user to enter very detailed data if this is available.

Several stakeholders within the ECOWAS region may currently not have sufficient data to fully populate all model inputs. Therefore, reference values or ranges of values have been supplied for each model in Section 7. If users wish to update this in the future, a full set of sources is provided.

In any case, it shall be highlighted that values taken from the reference input data will never fully replace the specific data set required to calculate tariffs in any jurisdiction, costs will vary greatly due to transportation costs and local conditions.

This reference can be used to cross check and validate local information. However, it is not intended to be a replacement for proper diligence in seeking country-specific data. Tariffs should wherever possible be based on data that properly reflects the technical and economic conditions applicable to the environment where renewable generation and mini-grids are to be developed and operated.

2 IPP model

This section looks at the inputs, calculations, outputs and key questions of IPP's.

2.1 Inputs

The inputs for the IPP are split into four sections; general, reference project inputs, avoided cost inputs and system impact. Each of these is discussed in turn below.

2.1.1 General inputs

General inputs are detailed below. These inputs are required to run the model in any configuration.

Table 1: General inputs

Name	Input format	Unit	Description	Impact	Cell reference
Currency unit	String	Text	This input is for display purposes only (i.e. USD, EUR, GBP)	Display only	E10
Inflation	Float	%	This is the inflation projection for the project lifetime. Note the first year of operation has by default zero inflation)	Inflates all O&M costs for the renewable project (including fuel if applicable)	H13:AJ13
VAT	Float	%	The electricity sales VAT in the country being considered	Increases calculated required tariff by VAT (and LCOE for baseline alternatives)	F15
Import duties	Float	%	The import duty level in the country	Later possible to specify which capex items pay import tax	F16
Applicable corporate taxation scheme	String	Text	Drop down box to select tax scheme (profit tax, revenue tax, or the maximum of the two)	Tax applied in financial model of reference project as specified by user selection	F18
Corporate profit tax	Float	%	The corporate profit tax in the country over profit		F19
Corporate income tax	Float	%	The corporate profit tax in the country over revenue or sales		F20

Name	Input format	Unit	Description	Impact	Cell reference
Corporate tax holidays	Float	Years	Any tax breaks given to renewable energy projects	Tax applied in financial model	I19

Note that the decision was made early in the project to allow only one currency in the model. This significantly simplifies the model, to improve ease of use. However, it is still a simplification. Projects will typically have capital and some operational costs in an international currency (USD or EUR) for the capital plant and some operational costs in a local currency. We believe this simplification is justified as the bulk of the costs for a renewable project are capital costs denominated in an international currency, which will typically be financed by loans or equity in that currency. Similarly for avoided costs, the cost of the plant and the fuel is typically denominated in an international currency (such as USD).

The inflation factor applied should be that expected to be relevant to operational costs (fixed and variable Operation and Maintenance, O&M). This may be the inflation rate of an international currency if a long term O&M contract with the installers is expected, or may be a local rate of inflation if there is a significant local labour component.

Inflation is entered separately for fuel costs.

2.1.2 Reference project inputs

Reference project inputs are detailed below. These inputs are required to run the model (1) for a reference or specific renewable IPP project, or (2) to calculate the system impact cost of an IPP. For the second calculation, the avoided cost inputs (Section 2.1.3) are also needed.

Table 2: Reference project inputs

Name	Format	Unit	Description	Impact	Cell reference
Plant Description	String	-	Description of the plant (e.g. technology, scale, location)	For user reference only	E27
Generator Nameplate Capacity	Float	MW	Capacity in MW of the plant	Input to net electricity production	F29
Annual Capacity Degradation	Float	%	The annual capacity degradation factor for the plant	Input to net electricity production	F30
Simulation Horizon (PPA duration)	Integer	years	Number of years the plant will be operational receiving the PPA tariff. It is equal to the PPA	Number of years modelled	F31

Name	Format	Unit	Description	Impact	Cell reference
			duration. Note that the depreciation period is entered separately.		
Capacity Factor	Float	%	Expected electrical output divided by the maximum possible output.	Input to net electricity production	F33
Other Losses	Float	%	e.g. onsite technical losses before injection to the grid	Input to net electricity production	F34
Tariff Indexation Factor 1 (Inflation)	Float	%	Projected inflation for use in indexation (leave blank if no inflation indexation)	Revenue Indexation	H39:AJ39
Weight for Tariff Indexation Factor 1 (Inflation)	Float	%	The weighting given to the inflation factor (for fully inflation-linked enter 100%, for no link enter 0%)	Revenue Indexation	H40:AJ40
Tariff indexation Factor 2 (Exchange Rate)	Float	%	Projected exchange rate change (%) for use in indexation (leave blank if no forex indexation or if denominated in forex)	Revenue Indexation	H42:AJ42
Weight for Tariff Indexation Factor 2 (Exchange Rate)	Float	%	The weighting given to the forex factor (for fully linked enter 100%, for no link enter 0%)	Revenue Indexation	H43:AJ43
Tariff Indexation Factor 3 (Other)	Float	%	Other factor (%) for use in indexation (leave blank if no other indexation)	Revenue Indexation	H45:AJ45
Weight for Tariff Indexation Factor 3 (Other)	Float	%	The weighting given to the other factor	Revenue Indexation	H46:AJ46
Total Tariff Indexation Factor	Float	%	Combines the various indexation factors	Revenue Indexation	H48:AJ48
Baseline GHG emissions	Float	Tonnes CO_2/MWh	The greenhouse gas emissions for the typical grid mix in tonnes of CO_2 equivalent per MWh	Revenue for emissions avoided by renewable technology	F50
GHG price for renewable IPP	Float	Currency/tonne CO_2	This is the price paid to an IPP developer for each tonne of	Revenue for emissions avoided by	F51

Name	Format	Unit	Description	Impact	Cell reference
			greenhouse gases they avoid emitting	renewable technology	
Other revenues	Float	Currency/MWh	The price per MWh for any other revenues the plant would receive	Revenue (could be a tax or charge if negative)	F53
Subsidies	Float	Currency	Absolute figures for nominal subsidy per year (or negative to represent charges)	Revenue (could be a tax or charge if negative)	F56:AJ56
Grants	Float	Currency	Absolute figures for nominal grants per year, can be charged in year 0 to represent upfront grant.	Revenue (could be a tax or charge if negative)	F57:AJ57
OPEX					
Fixed O&M	Float	Currency/year	The fixed O&M costs per year	Operational expenditure, all indexed by inflation	F60
Variable O&M	Float	Currency/MWh	The variable O&M costs per MWh (excluding fuel)		F61
Fuel costs	Float	Currency/MWh	Fuel costs, a separate fuel unit conversion model allows conversion from other fuel units to currency/MWh		F62
Efficiency	Float	%	The fuel conversion efficiency of the plant (only applicable if fuelled)		F63
Other OPEX	Float	Currency/year	Any other Opex costs per year		F64:68
CAPEX					
CAPEX Generation Equipment	Float	Currency	Total cost for size of project – if currency/MWh is desired enter 1MW in "Generator Nameplate Capacity"	Total CAPEX in year 0	F71
Balance of Plant	Float	Currency			F72
Interconnection	Float	Currency			F73
Development	Float	Currency			F74
Interests During Construction	Float	Currency	The interest costs accumulated during the construction period	Total CAPEX in year 0	F75
Other CAPEX	Float	Currency	Any other capex costs to the plant not captured under the other categories	Total CAPEX in year 0	F76:77
Import duties	Integer	1/0 for yes/no	Select yes (1) or no (0) for whether	Total import duties	G71:77

Name	Format	Unit	Description	Impact	Cell reference
			import duties apply to each item	added to CAPEX	
Asset's Useful Life (depreciation period)	Integer	Years	Number of years over which the plant will be depreciated in accounts. Note that the simulation horizon (PPA duration) is entered separately.	Depreciation	F80
Working Capital					
Initial Working Capital Investment	Float	Currency	Initial investment to face short term working capital requirements	Initial investment	F83
Cash Conversion Cycle	Float	Days	Average number of days required to convert investment in inventory into cash from sales.	It serves to size the investments in net working capital over the years.	F84
Batteries					
Levelized cost of storage	Float	Currency/MWh	Levelised cost to provide storage (implicitly includes replacement)	Fixed O&M costs per year	F87
Storage used in average year	Float	MWh/year	Sizing of storage determines cost	Fixed O&M costs per year	F88
Efficiency of storage	Float	%	Reduces output as a result of efficiency losses in storage.	Input to net electricity production	F89
Financing parameters					
Debt to Total Capital	Float	%	The ratio of debt to capital	Debt	F92
Debt term	Integer	Years	The total debt period	Principal repayments	F93
Debt interest rate	Float	%	The pre-tax nominal interest rate on debt	Interest payments	F94
Target Equity IRR	Float	%	Target post tax nominal internal rate of return required for equity	Model macro iterates to find tariff that gives this return to investors	F95
Scenarios					
Capacity Factor	Float	%	% change from base case for each of scenarios 1, 2, and 3. Can be positive	Macro calculates alternative output for each	F99:H99

Name	Format	Unit	Description	Impact	Cell reference
			(increase) or negative (decrease).	scenario if capacity factor was different by that %.	
OPEX	Float	%	% change from base case for each of scenarios 1, 2, and 3. Can be positive (increase) or negative (decrease).	Macro calculates alternative output for each scenario if OPEX was different by that %.	F100:H100
CAPEX	Float	%	% change from base case for each of scenarios 1, 2, and 3. Can be positive (increase) or negative (decrease).	Macro calculates alternative output for each scenario if CAPEX was different by that %.	F101:H101

At the end of the reference project inputs the user can define up to three different scenario. Each scenario is built up applying % variations to the base case inputs for Capacity Factor, OPEX and CAPEX. Variations can be positive (increase over base case) or negative (decrease over base case).

If the calculation is for a generic feed in tariff, users may choose to enter 1MW in "Generator Nameplate Capacity" to allow them to enter standardised cost assumptions in currency per MW.

It is possible to enter fuel costs (for example, biomass costs) for renewable technologies. There is a separate fuel unit conversion tool (see section 6.2) that allows the user to convert the fuel from other units to currency/MWh – for example from USD/tonne to USD/MWh.

Tariff indexation means it is possible to represent any indexation within the feed-in tariff or PPA, for example the regulator may index feed-in tariffs to inflation. It is worth noting that setting indexation to zero may mean the initial tariff is higher to make the generator whole for inflation.

It is possible to enter both grants and subsidies, by the year entered (initial year or during operation). There is a technical difference in the definition between them, as grants are sums that usually do not have to be repaid but are to be used for defined purposes. Subsidies, on the other hand, refer to direct contributions, tax breaks and other special assistance that governments provide businesses to offset operating costs over a lengthy time period. However, there is no difference in how they are used in the model.

Once the inputs are complete, the user presses a "macro" button to allow the Excel workbook to iterate to find the renewable energy tariff (PPA or feed in tariff) that will give the targeted IRR to investors.

2.1.3 Avoided cost and system impact inputs

Reference project inputs are detailed below. These inputs are required to run the model (1) to calculate the "avoided cost" for any new renewable IPP project, or (2) to calculate the system impact cost of an IPP. For the both calculations, the reference project costs (Section 2.1.2) are also needed.

The nine following types of technology can be considered to be in the baseline energy mix: Nuclear, Coal, Hydro, Natural Gas, Light Fuel Oil (LFO), Heavy Fuel Oil (HFO), Solar PV, Wind and Other Renewable Energy Sources (RES). The user is free to re-label the name of these technologies and adapt them to the specific mix of the system under study (in "Lists" sheet). Not all technologies have fuel input cells, so be cautious about which ones are relabelled.

Name	Format	Unit	Description	Impact	Cell reference
Baseline energy mix – information entered for each technology type					
Technical data					
Generation Mix	Float	%	The percentage the technology accounts for in the generation mix (by MWh)	Weighting by technology in avoided cost	F110:N110
Plant Size	Float	MW	The average capacity of the plant	Electricity production	F111:M111
Investment Cost	Float	currency/MW	The total investment cost per MW for the technology	Overnight capex	F112:M112
Lifetime of Investment	Integer	Years	Lifetime of the technology plant from when built	Time in operation	F113:M113
GHG Emissions Factor	Float	tCO2e/MWh	Greenhouse gas emissions per MWh from the technology	Revenue for emissions avoided by renewable technology	F114:M114
Average LCOE (for Other RES)	Float	currency/MWh	Only applicable to the "Other RES" technology type	Input to baseline LCOE	M115
GHG price for avoided cost	Float	currency/tonne CO_2	This is the social price (or carbon tax cost) for each tonne of	Additional avoided cost for	F117

Name	Format	Unit	Description	Impact	Cell reference
			greenhouse gases emitted	emissions avoided by renewable technology	
Financing data					
% Debt	Float	%	The ratio of financing supplied by debt (this is used to then calculate the % equity)	Debt	F121:M121
Cost of Equity (Post-Tax)	Float	%	Target post -tax nominal internal rate of return required for equity	Model finds the LCOE given the cost of equity and debt	F123:M123
Cost of Debt	Float	%	The pre-tax nominal interest rate on debt		F124:M124
Debt Term (Loan Tenor)	Integer	Years	The loan period	Debt repayments	F126:M126
Technology Inputs					
Capacity Degradation Factor	Float	%	The yearly capacity degradation factor applicable to plants of the technology type	Input to net electricity production	F129:M129
Efficiency	Float	%	The efficiency of the plant	Efficiency of energy conversion of fuel for electricity production	F130:M130
Equivalent Full Load Hours	Float	Hours	Equivalent full load house in a year of the plant of the specific technology type	Calculates capacity factor for electricity production	F131:M131
Fuel Cost: for each technology except hydro the user can select either Option 1 OR option 2					
Option 1: Annually Adjusted (% change year on year)					
Fuel Cost, Starting Price	Float	Currency/MWh	The cost of fuel per MWh in the base year	Fuel cost	F136:M136
Fuel Cost, Annual Increase	Float	%	The annual escalation in the cost of fuel per MWh relative to the base year	Fuel cost	F137:M137
Option 2: Linear Function (y = ax + b)					
a (increase per annum)	Float	Currency/MWh	The cost increase per annum which is applied to the fuel cost per MWh	Fuel cost	F139:M139
b	Float	Currency/MWh	The cost of fuel per MWh in the base year	Fuel cost	F140:M140
Non-fuel OPEX					
Initial Year	Float	Currency/MW	Base year OPEX costs which aren't covered	Operational expenditure	F143:M143

Name	Format	Unit	Description	Impact	Cell reference
			under fuel costs per MW		
Annual Increase	Float	%	Yearly increase in non-fuel OPEX costs	Operational expenditure	F144:M144

Depending on whether an average or a marginal energy generation mix is desired, a different configuration of plants and costs to compute the baseline generation cost is required. For example, the regulator might decide to compute just the last technology or plants being dispatched (for example heavy fuel oil generators).

As mentioned above, although not marked as input cells, users can change the titles of technologies if they wish to introduce a different fuel mix.

Many baseline mix technologies have fuel costs (oil, coal, gas etc.). There is a separate fuel unit conversion tool (see section 6.2) that allows the user to convert the fuel from other units to currency/MWh – for example from USD/barrel to USD/MWh.

2.2 Running the model

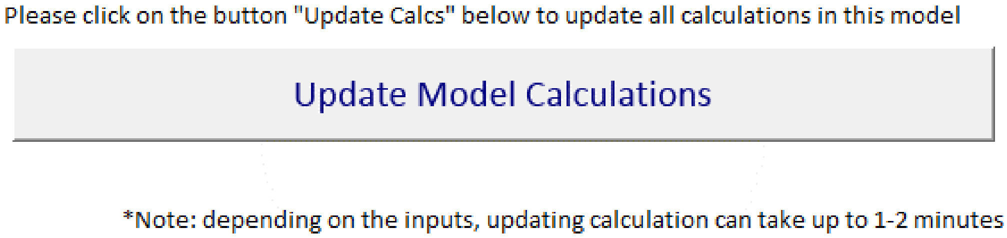
Here is a brief guide to running the IPP model:

1. The version history tab can be used to keep track of cases or scenarios run in the model.
2. Users are advised to start from the dashboard on the DASHBOARD tab.
3. The dashboard contains a macro button linking to the inputs sheet (or users can select the INPUTS tab).

Entry of main inputs to the model: Inputs

4. Input cells are coloured yellow. Selection boxes that allow an input format or assumption to be entered are green. These cells can (and should) be changed by users to match the case or scenario under consideration. Inputs are described in Section 2.1.
5. The underlying calculations are shown on the relevant worksheets. We suggest you avoid changing these calculations unless required. Calculation cells are white. Inactive calculations (for alternative scenarios) are grey.

6. Run the macro on the dashboard to update the model calculations (to iterate to the required feed in tariff).



7. View outputs by pressing the button on the dashboard (or by going to the OUTPUTS tab).

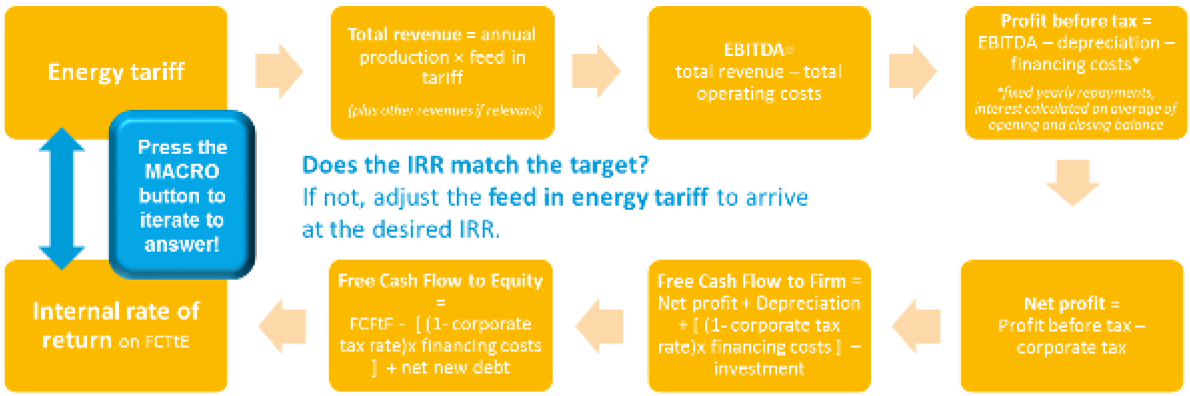
Users can edit the outputs (or any part of the model) to suit their own requirements. See Section 2.4 for the standard outputs. Take care when adding or removing lines as it may affect the macro calculation.

2.3 Calculations underpinning the model

2.3.1 Reference Project

For Large Scale Projects such as IPP's, the aim is to calculate the **base year energy tariff** such that the **target Equity IRR** is achieved over the lifespan of the project. This is done by assessing the project finance and ensuring the internal rate of return on the *free cash flow to equity* matches the target. The overall approach is described in Figure 4.

Figure 4: Process underlying the modelling behind the IPP reference project approach



The associated calculations are given on the Reference IPP worksheet.

The modelling calculates the following information:

- **Yearly net production** given the set of inputs defined such as: capacity, degradation factor, capacity factor and other losses.
    - Production calculation block (rows 7 to 17): This block calculates the yearly net production given the set of inputs defined for the generator such as: capacity, degradation factor, capacity factor and other losses.
    - Net production in year = capacity x (1 - percent annual capacity degradation) x (degradation factor in previous year) x number of hours in year x capacity factor x (1-other losses)
- **Yearly revenues** given the set of inputs defined: revenue indexation factor (RIF), GHG price, baseline GHG emissions (tons/MWh) and other revenues earnt per MWh.
    - Revenue calculation block (rows 19 to 27): This block calculates the total yearly revenues given the set of inputs defined: revenue indexation factor (RIF), GHG price, baseline GHG emissions (tons/MWh) and other revenues earnt per MWh.
    - It also uses the energy tariff which is solved by the use of a goal seek in the macro for the base year. This is therefore an iterative calculation.
    - Yearly revenue = (1+ RIF % variation) x RIF in previous year x [(energy tariff x net production) + (baseline GHG emissions x GHG tariff x net production) + (Other revenues x net production)]
- **Yearly OPEX** given the set of inputs defined: inflation indexation factor (IIF), Variable O&M and Fixed O&M.
    - Operating expenditures calculation block (rows 30 to 43): This block calculates the total yearly OPEX given the set of inputs defined: inflation indexation factor (IIF), Variable O&M and Fixed O&M (can be split into 6 different categories).
    - Yearly total Opex= (1+IIF % variation) x IIF in previous year x [(Var O&M cost x gross production) + Fixed O&M + Other Fixed O&M]
    - Note: opex calculation uses gross production
- **Yearly debt service costs** including principal payments (assuming a fixed yearly repayment) and interest payments (calculated based on the interest rate multiplied by the average of the opening and closing debt in the year).

- Financing costs/Debt service (rows 90 to 100): This block calculates the yearly interest and principal repayments to service the debt defined in the inputs (defined as a percentage of the overall capital).

- Principal payments: these assume a fixed yearly repayment i.e. Total debt divided by total debt term.

- Interest payments: interest payments are calculated based on the interest rate multiplied by the average of the opening and closing debt in same year.

- **Yearly depreciation** (using the straight line approach)

  - **Depreciation *(row 103 to 108):***-this is modelled using straight line depreciation, based on the asset's useful life defined in the inputs.

- **The Project Finance (*rows 58 to 88*):** The project finance block calculates:

  - **EBITDA =** total revenue – total operating costs

  - **EBIT =** EBITDA – depreciation

  - **Profit before tax** = EBIT – financing costs

  - **Net profit** = Profit before tax – corporate tax

  - It then calculates the Free Cash Flow to the Firm (FCFtF) in each year:

  - Free Cash Flow to Firm = Net profit + Depreciation + [(1- corporate tax rate)x financing costs] – investment

  - The FCFtF is then used to calculate the Free Cash Flow to Equity in each year:

  - Free Cash Flow to Equity= FCFtF - [(1- corporate tax rate)x financing costs] + net new debt

When the macro is run, the **energy revenue tariff** is solved such that the **Equity IRR** (based on the FCFtE) matches the target IRR defined in the inputs.

2.3.2 Avoided cost

The calculated avoided cost for the IPP component of the model is the baseline generation cost (the alternative to having the IPP project online).

The associated calculations are given on the Reference IPP worksheet.

The calculation here is similar to the reference project, replicated for each technology in the baseline energy mix.

The difference from the reference project approach is that the calculation gives a current levelised cost of energy (LCOE) based on the net present value of production for each technology.

These are combined by the share of the generation mix to give an overall levelised cost of energy from the baseline mix. This is the avoided cost tariff.

The Avoided Cost worksheet calculates the financial performance of the Reference IPP project, if they are paid the LCOE of the baseline mix (the avoided cost tariff). The resulting Project IRR and Equity IRR are reported.

2.3.3 System impact

For Large Scale Projects such as IPP's, the system impact is equivalent to the cost the IPP tariff has on the system. The unit tariff paid to IPPs times the expected deployment level (energy integrated into the system from IPPs) will provide the financial impact.

Of course that would also mean that incumbent generators might see their sales reduced if the extra generation from RES IPP's is not fully absorbed by demand growth.

2.4 Outputs

2.4.1 Reference project

The outputs show the reference project tariff required to deliver the Equity IRR. This is given inclusive and exclusive of VAT.

The base case is the main model output. In addition, the scenarios outputs give the tariffs obtained in each of the three additional scenarios the user can define as a % change from base case for each of scenarios 1, 2, and 3. These are calculated when the user runs the macro for that set of inputs.

Figure 5: Output tariffs for base case and three scenarios

	BASE CASE			SCENARIO 1	SCENARIO 2	SCENARIO 3		
Reference project tariff:	458.42	EUR/MWh	(VAT excluded)	508.06	448.68	416.83	EUR/MWh	(VAT excluded)
	545.52	EUR/MWh	(VAT included)	604.59	533.92	496.03	EUR/MWh	(VAT included)
	45.84	EUR cents/kWh	(VAT excluded)	50.81	44.87	41.68	EUR cents/kWh	(VAT excluded)
	54.55	EUR cents/kWh	(VAT included)	60.46	53.39	49.60	EUR cents/kWh	(VAT included)

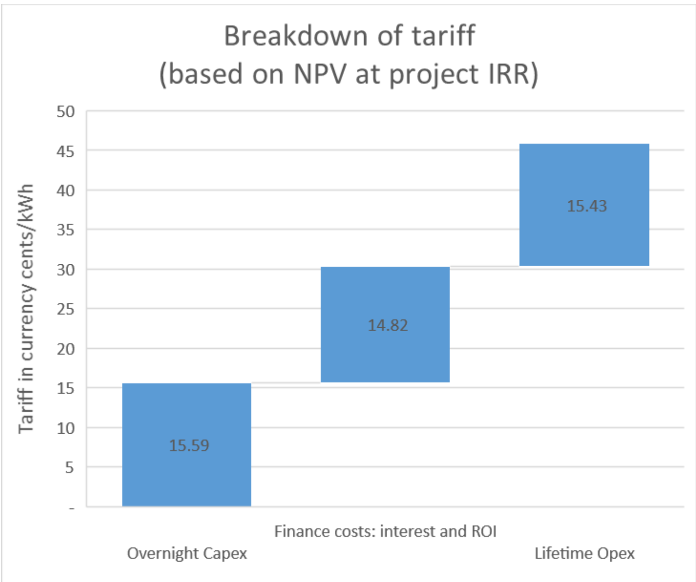
There is an option to add a local currency in the output sheet, so that users can more intuitively see the tariff in a local currency.

There are also 4 graphs showing: tariff evolution, debt repayment schedule, free cash flow to the firm and free cash flow to equity.

Figure 6: Output graphs for the reference project

To aid understanding of the tariff, the outputs also report a breakdown of the net present value (NPV) by the main three categories of expenditure: capex, opex and financing costs. This helps to indicate where the key costs that make up the required tariff.

Figure 7: Breakdown of tariff by categories of costs



The model reports the value of Government tax relief (tax holidays) in aggregate and in net present value. This is calculated by the macro, effectively by comparing the values with the tax holiday (in years) set to zero as well as with the input value. If there are no tax holidays in the inputs, this value is zero.

2.4.2 Avoided cost

For the avoided cost scenario, the model reports the Avoided Cost Tariff and the Equity IRR that investors in the reference project would receive if the project was paid the Avoided Cost Tariff.

2.4.3 System impact

For the first 10 years of output, the model reports the total energy produced by reference IPPs, and the tariff they are paid (in real terms), giving a resulting total tariff cost (in real terms) that the counterparty will have to meet.

The impact in nominal terms is also calculated and available in the impact worksheet. But only the real terms one (not inflated) is shown, as it is usually better to evaluate impacts and their evolution over time in values expressed in the same year (the initial one).

2.5 Key questions

During the course of the project, we established with stakeholders that the main functionalities of the model are to be able to calculate. As part of the "key questions", we consider how each of these can be addressed using the model.

2.5.1 How do I calculate feed in tariffs for grid-connected systems?

The user can calculate feed in tariffs based on either the cost of a reference project or the avoided cost of conventional generation by changing the inputs to match the country specific data and technology under consideration.

2.5.2 Can the model calculate cost reflective and technology specific tariffs?

Yes – the reference project module calculates this tariff.

The inputs will need to be changed for each technology. So the user would (for example) enter the input data for solar PV and run the macro to calculate a solar PV tariff. This model could be saved under an appropriate name (e.g. "Solar PV Tariff 2017 – Model v0-1 - date") as a record of the calculations. The user can then start again with wind technology data, saving that as a new name (e.g. "Wind Tariff 2017 – Model v0-1 - date").

The version history worksheet can be used to keep track of the review process.

2.5.3 What is the most affordable tariff that ensures a fair return on investment for the developer?

The reference project module calculates this tariff, based on an input rate of return. It is important to have good data for all reference project inputs to ensure the calculated tariff both gives a fair return to the investor and is the lowest tariff that ensures that fair return.

2.5.4 Can the model calculate the costs avoided as a result of having renewable electricity generation?

Yes – the avoided costs module calculates this tariff as the avoided cost of generating from conventional technologies.

Since the tariff is based on the avoided cost of the baseline energy mix, it does not depend on the renewable energy technology chosen. The calculation only needs to be performed once for all renewable technologies.

However, the resulting return to the project developer will vary by technology, and so the reference project data should also be changed for each case you wish to consider.

2.5.5 Can you expand the calculation of avoided cost of generation to allow the optional addition of wider social avoided costs?

The challenge of including wider social avoided costs (for example, avoided emissions, or the additional cost of balancing variable generation), is in defining a figure for these costs.

If a cost is available for GHG emissions in currency/CO_2 equivalent, this can be considered in the avoided cost module as an additional social (or actual) avoided cost.

If other costs are available, they can be added to the relevant variable or fixed costs of the baseline energy mix.

On the other hand, if the renewable generation increase the costs of the system, for example if they are variable and lead to an additional cost in balancing the system, the user may wish to represent this cost in the model.

If the renewable generator is required to meet this cost itself (for example by having a battery to mitigate the variability of output), this can be added as a capex and/or a variable or fixed cost.

If the utility faces this cost, this can be applied as a reduction to the avoided cost or an increase to the system impact.

2.5.6 Can you consider different avoided costs in different major grid systems?

Yes. It is possible to consider different avoided costs in different major grid systems (for example, different avoided costs for the separate islands on Cape Verde) simply by rerunning the model for these different systems, just like for each of the different technologies.

Instead of just having "Solar PV Tariff 2017" the user would create "Solar PV Tariff 2017 - Santiago" and "Solar PV Tariff 2017- Boa Vista" etc.

2.5.7 Can you consider potential PPA duration and indexation options?

Yes. The model makes it possible to define the years of project operation (effectively the years it is paid a PPA for) and the indexation of the renewable tariff.

Users can consider scenarios based around these parameters.

2.5.8 Can the model support tenders or bilateral negotiations?

Yes. The model allows you to input project-specific data to calculate ceiling tariffs or reference prices. You can also enter project specific data to evaluate tenders and bilateral negotiations, by essentially mimicking the financial modelling the developer will be carrying out. This can help give confidence in the outcome.

2.5.9 Can the model consider the impact of renewable tariffs on system costs and consumer tariffs?

The model can consider the impact of renewable energy tariffs in a number of ways:

- The IPP model calculates separately the "avoided cost" tariff. The difference between this avoided cost and the actual tariff given to the renewable generator can give an indication of the impact. For example, if the avoided cost tariff is used, the impact on consumer tariffs will be zero. If the "reference project" tariff is used, the difference between the reference project tariff and the avoided cost tariff gives an indication of the likely direction of impact (positive or negative) on consumer tariffs.

- The model also calculates the "system impact": for the first 10 years of output, the model reports the total energy produced by reference IPPs, and the tariff they are paid, giving a resulting total tariff cost that the counterparty will have to meet. This is cash that will need to be available to the utility to meet their obligations under the PPA.

However, the model does not calculate the resulting retail tariffs. For that, a full system retail tariff model is needed. The outputs of the renewable energy tariff model can be an input to that model.

2.5.10 Should tax be included in the project costs?

Yes. Any costs that apply to the project should be reflected in the model. The model includes tax inputs such as corporation tax, VAT and import duties. It is also possible to represent any corporation tax holidays or import duty exemptions.

Figure 8: Taxes input to the model

VAT	19.00%			
Import duties	10.00%			
Applicable corporate taxation scheme	Tax over profits			
Corporate profit tax (over profit or net income)	31.00%	Corporate Tax Holidays	10	Years
Corporate income tax (over revenues or sales)	2.00%			

CAPEX inputs:			Import Duties? (Yes = 1, No =0)
Generation Equipment	USD	3,500,000	1
Balance of Plant	USD	2,000,000	1
Interconnection	USD	500,000	0
Development	USD	1,500,000	0
Interests During Construction	USD	90,000	0
	USD	-	0
Other CAPEX	USD	-	0
Import Duties	USD	550,000.00	

2.5.11 What payment should be made to IPPs when the DisCo doesn't need that energy injection for a certain period? How would the tariff address the issue of guarantees?

The payment regime is given in the PPA. The model assumes that the generator is able to get payment for all of their power up to an entered capacity factor. A "take or pay" clause in a PPA might reflect this capacity factor (e.g. 25%) to give the IPP certainty of revenue.

If the take or pay clause covers less of the project capacity factor (e.g. 15%), the developer is likely to consider scenarios where only this capacity factor is possible, and view the full capacity factor as potential upside. This means the developer will probably need a higher tariff to proceed with the project.

Similarly with sovereign guarantees or Escrow arrangements – these allow the developer to have a better security of payments. Better certainty of payments may be a precondition for some developers. If it is not a precondition, the risk mitigation may reduce the project IRR they require to proceed.

If the grid is likely to not be available for some of the time, or if the counterparty is not fully credit-worthy, regulators and ministries should weigh up the degree of certainty they are prepared to give developers against the cost of tariff they are happy to pay. Giving developers more certainty in a take or pay clause or a sovereign guarantee means they can accept a less high tariff.

The tariff model will not make this policy decision for you, but it does allow you to consider scenarios based on changing the project's capacity factor or Equity IRR.

2.5.12 Can the model include a tariff for use of transmission services for the IPP?

Yes. Any ongoing tariffs that the project pays (such as transmission charges) can be included in Opex. Any upfront costs that the project pays (such as connection charges) can be included in Capex.

2.5.13 Can the model include soft-loans and grants in calculations?

Yes. These form part of the inputs.

Grants or subsidies can be entered per year (in year zero for upfront grants). Soft loans would be entered as part of the financing inputs. If multiple loans are used, the average can be applied.

Figure 9: Grant and soft loan inputs to model

	Year:	0	1	2	3
Subsidies	USD	300,000.00	-	-	-
Grants	USD	350,000.00	-	-	-
Financing inputs:					
Debt to Total Capital	%	70.00%			
Debt term	Years	8			
Debt interest rate (pre-tax nominal)	%	10.00%			
Target Equity IRR (post-tax nominal)	%	15.00%			

2.5.14 Can the toolbox tariff be accepted by IPPs?

It isn't quite this simple.

Whether the tariffs from the toolbox are acceptable to IPPs will depend on the inputs. As with all models, the toolbox is only as good as the data that goes in.

Whether the tariffs from the toolbox are acceptable to IPPs will also depend on the associated conditions – the terms of the PPA, any guarantees, and their confidence in the ability of the utility to pay. Improving all these factors will improve the acceptability to IPPs.

2.5.15 Can the tariff include Greenhouse Gases for carbon credits?

Yes. If carbon credits are expected to apply, the reference project model should include them. These can be added in the inputs. The credits will apply relative to the baseline CO_2 emissions that are avoided (by not using other forms of generation).

Figure 10: Greenhouse gas emissions inputs

Baseline GHG emissions (for any credit)	tonne CO2/MWh	0.75
GHG price	USD/tonne CO2	-

The calculation of the avoided costs can also reflect an estimate of the social avoided cost by emitting less carbon from the baseline technologies.

2.5.16 What is the expected rate of return for a IPP project/shareholder? Sharing data on cost of finance?

It has been suggested that regional stakeholders may wish to share data on the costs of finance – possibly through ECREEE. The cost of finance will be heavily dependent on the perceived risk for the investment country, including the investors perception of the risk profile, the perceived credit-worthiness of the counterparty and any mitigation instruments available (for example, government guarantees).

Some data is available in published reports, for example:

- Report of experience in Kenya and Ghana (Pueyo, Bawakyillenuo, & Osiolo, 2016), and
- Cost of financing used for tariff model in Nigeria (Nigerian Electricity Regulatory Commission, 2016).

2.5.17 How can we include the alternative cost based on import energy that may change by time of day?

It is possible to enter different costs in the baseline energy mix – and these can be weighted based on the actual mix imported.

2.5.18 How can the model consider uncertainties?

The model allows you to consider scenarios. So you can enter high, low and medium assumptions to consider a range of outcomes. There are two ways to do this – automatic and manual.

For three inputs, capacity factor, opex and capex, it is possible to run scenarios to calculate the tariff required to give the equity IRR under three different scenarios. These three scenarios are part of the inputs, and the results are given as different required tariffs to deliver the same IRR in the outputs. You must run the Macro to update these outputs.

Figure 11: Scenario inputs

Scenarios		Scenario 1	Scenario 2	Scenario 3
Capacity Factor	% over Base Case	+0.00%	+20.00%	+10.00%
OPEX	% over Base Case	+10.00%	+0.00%	-20.00%
CAPEX	% over Base Case	+10.00%	+20.00%	-5.00%

Figure 12: Scenario outputs

	BASE CASE			SCENARIO 1	SCENARIO 2	SCENARIO 3		
Reference project tariff:	434.18	EUR/MWh	(VAT excluded)	707.85	434.18	434.18	EUR/MWh	(VAT excluded)
	516.68	EUR/MWh	(VAT included)	842.34	516.68	516.68	EUR/MWh	(VAT included)
	43.42	EUR cents/kWh	(VAT excluded)	70.78	43.42	43.42	EUR cents/kWh	(VAT excluded)
	51.67	EUR cents/kWh	(VAT included)	84.23	51.67	51.67	EUR cents/kWh	(VAT included)

For any input, you can consider the impact on IRR of a different outturn scenario in a manual process. For example, you can enter the central case firstly. Then if you change a parameter (e.g. capacity factor, Capex, project life) but leave the tariff the same (do not press the calculate button) you will see the impact on project IRR if the project has a higher or lower capacity factor than expected.

The process is as follows:

1. INPUTS sheet: Enter central case data in inputs
2. DASHBOARD sheet: Press to calculate tariffs

Please click on the button "Update Calcs" below to update all calculations in this model

Update Model Calculations

*Note: depending on the inputs, updating calculation can take up to 1-2 minutes

3. OUTPUTS sheet: Record the tariff output and Equity IRR from the outputs – the Equity IRR should be the target Equity IRR (in this case 15%).

Reference Project

Tariff:	431.75	USD/MWh	(VAT excluded)
	513.78		(VAT included)
	43.18	USD cents/kWh	(VAT excluded)
	51.38	USD cents/kWh	(VAT included)
Local currency:	GMD		
Exchange rate of USD to GMD: 1 USD equals	46	GMD	
Tariff in local currency:	19,861	GMD/MWh	
	19.86	GMD/kWh	
Equity IRR using Reference Project Tariff:	15.01%	%	

4. INPUTS sheet: Change the input you want to consider a sensitivity around to the lower value in the range. DO NOT recalculate.

5. OUTPUTS sheet: Record the Equity IRR from the outputs – the tariff should be the same, but the Equity IRR will have changed (in this case 5.5%).

Reference Project

Tariff:	431.75	USD/MWh	(VAT excluded)
	513.78		(VAT included)
	43.18	USD cents/kWh	(VAT excluded)
	51.38	USD cents/kWh	(VAT included)
Local currency:	GMD		
Exchange rate of USD to GMD: 1 USD equals	46	GMD	
Tariff in local currency:	19,861	GMD/MWh	
	19.86	GMD/kWh	
Equity IRR using Reference Project Tariff:	5.51%	%	

6. INPUTS sheet: Change the input you want to consider a sensitivity around to the higher value in the range. DO NOT recalculate.

7. OUTPUTS sheet: Record the Equity IRR from the outputs – the tariff should be the same, but the Equity IRR will have changed (in this case 26.4%).

Reference Project

Tariff:	431.75	USD/MWh	(VAT excluded)
	513.78		(VAT included)
	43.18	USD cents/kWh	(VAT excluded)
	51.38	USD cents/kWh	(VAT included)
Local currency:	GMD		
Exchange rate of USD to GMD: 1 USD equals	46	GMD	
Tariff in local currency:	19,861	GMD/MWh	
	19.86	GMD/kWh	
Equity IRR using Reference Project Tariff:	26.44%	%	

2.5.19 How to carry out USD to local currency conversion?

The model is set up so that the inputs are all in one currency for ease of use. The bulk of the costs for renewable energy projects are up front capital costs. These are normally in USD or EUR. Therefore, users may often (but not always) choose to run the model in an international currency. Any text can be entered as an input for currency and will change throughout the model.

Figure 13: Currency in inputs

Currency	EUR

On the outputs sheet, it is possible to then convert the outputs to local currency for ease of reporting and comprehension.

Figure 14: Currency in outputs

Reference Project

Reference project tariff:	431.75	USD/MWh	(VAT excluded)
	513.78		(VAT included)
	43.18	USD cents/kWh	(VAT excluded)
	51.38	USD cents/kWh	(VAT included)
Local currency:	NGN		
Exchange rate of USD to NGN: 1 USD equals	315	NGN	
Reference project tariff in local currency:	136,002	NGN/MWh	
	136.00	NGN/kWh	
Equity IRR using Reference Project Tariff:	26.44%	%	

Avoided Cost (in real terms)

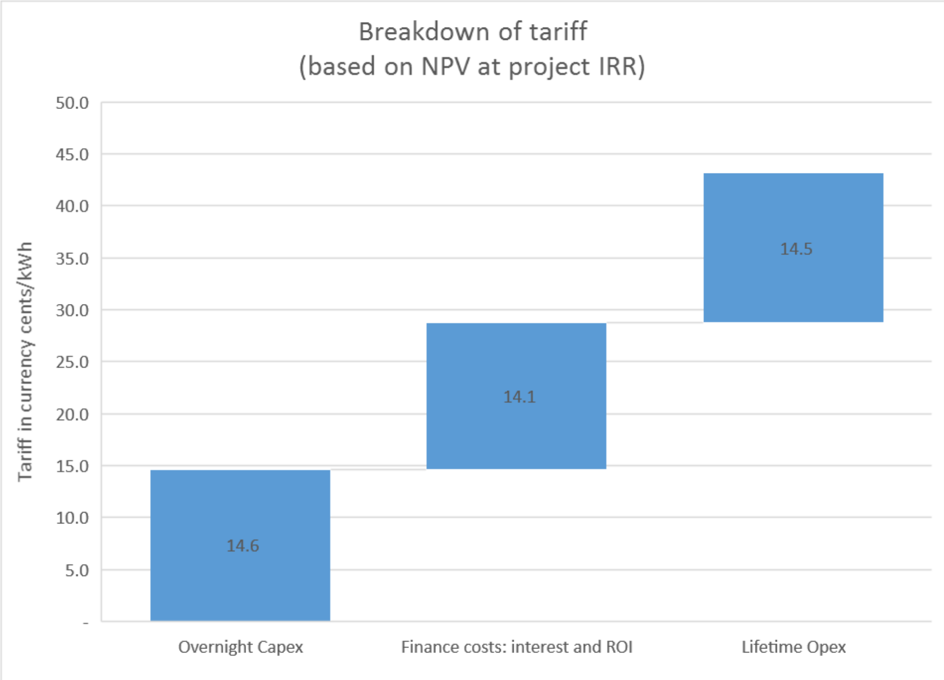
Avoided Cost Tariff (VAT excluded):	98.01	USD/MWh	
Equity IRR using Avoided Cost as tariff:	-7.37%		
Avoided cost tariff in local currency:	30,874	NGN/MWh	
	30.87	NGN/kWh	

2.5.20 What is the range for tariff indexation for IPPs?

The choice of indexation depends on the policy decision, and is at the discretion of the Ministry or Regulator designing the tariff.

If the project inputs are in an international currency (e.g. USD, EUR) it will normally be expected that the project is either paid in international currency or indexed to that currency. An example might be fully indexed to USD, or indexed for the capital cost portion (visible in the graph on the outputs).

Figure 15: Breakdown of tariff (from outputs)

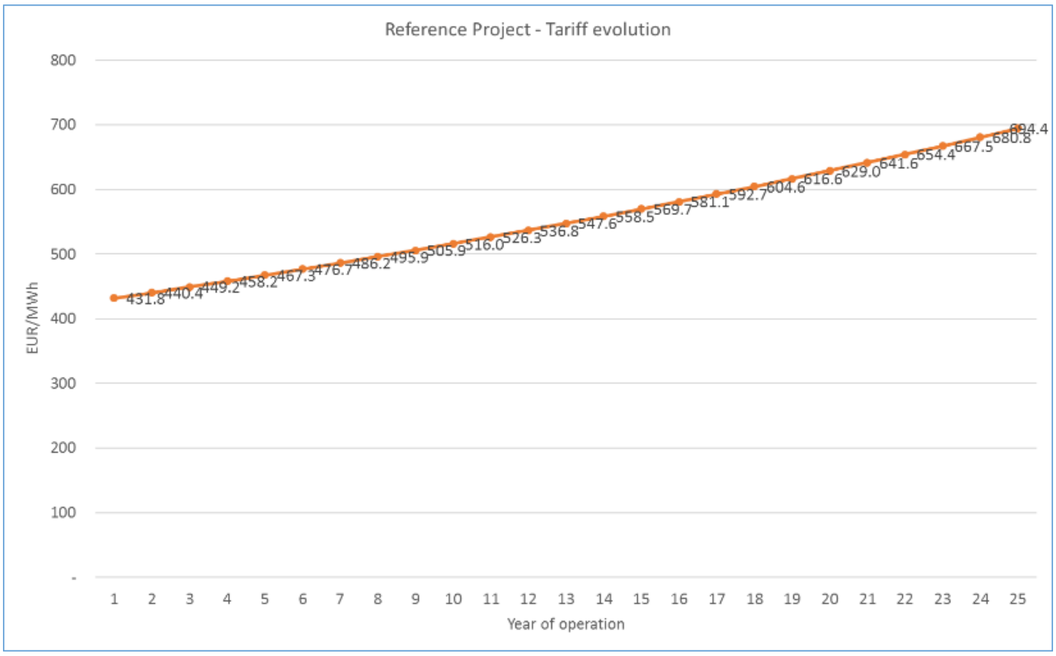


It is also reasonably common to index tariffs (at least partly) to inflation. This has two advantages:

- It means that the project risk is reduced for the developer (who faces ongoing interest and Opex costs in nominal terms),
- It means the initial tariff does not need to be so high to give the same return to the investor, as it will increase year on year. Customers instead see an inflation increase in cost.

The indexation chosen is entered on the inputs sheet. The outputs sheet shows the tariff evolution.

Figure 16: Tariff evolution for an indexed tariff over 25 years



2.5.21 How should the project be treated when fully depreciated?

The choice of treatment following depreciation (typically also the end of the PPA) depends on the policy decision, and is at the discretion of the Ministry or Regulator designing the tariff. If the tariff was well designed, at this point the developer should have recouped all their initial capital cost, repaid their debt and recovered a reasonable return.

It is possible there could be a lower ongoing tariff if both parties agree to extend the PPA. The toolbox could be used to calculate a reasonable level. There may be some initial investment (refurbishment) to ensure the generator can continue to produce power at an affordable level, and ongoing output may be lower (because the plant is older) or the operational expenses could be higher. These inputs could be entered in the toolbox to calculate a fair tariff. There would still need to be an IRR to continue the tariff.

Given the long timescales, it may be reasonable to do this at the end of the PPA rather than in advance.

Alternatively, the developer could have the option to install a new generator of the same technology at the site, if the PPA available for new projects at the time made that attractive. This is a common approach in Europe, where old machines are replaced with new ones that can produce more power on the same land area.

2.5.22 What about decommissioning (end of life) costs?

The environmental permit will normally require the project developer to decommission the plant at the end of its life and to restore the site to its previous condition.

The cost for this should be met by the operator. However, it is not an input for the model. The reason is that with renewable projects the costs of decommissioning are typically met by the value of the materials when the generator is decommissioned.

3 Prosumer model

3.1 Inputs

3.1.1 General inputs

General inputs are detailed below. These inputs are required to run the model in any configuration.

Table 3: General inputs

Name	Input format	Unit	Description	Impact	Cell reference
Currency unit	String	-	This input is for display purposes only (i.e. USD, EUR, GBP)	Display only	E10
Inflation	Float	%	This is the inflation projection for the project lifetime. Note the first year of operation has by default zero inflation)	Inflates all O&M costs for the renewable project	H13:P13
VAT	Float	%	The electricity sales VAT in the country being considered	Increases calculated required tariff by VAT (and LCOE for baseline alternatives)	F15
Applicable corporate taxation scheme	String	-	Drop down box to select tax scheme (profit tax, revenue tax, or the maximum of the two)	Tax applied in financial model of reference project as specified by user selection	F17
Corporate profit tax	Float	%	The corporate profit tax in the country over profit		F18
Corporate income tax	Float	%	The corporate profit tax in the country over revenue or sales		F19
Corporate tax holidays	Float	Years	Any tax breaks given to renewable energy projects	Tax applied in financial model	I18

Note that the decision was made early in the project to allow only one currency in the model. This significantly simplifies the model, to improve ease of use. However, it is still a simplification. Projects will typically have capital and some operational costs in an international currency (USD or EUR) for the capital plant and some operational costs in a local currency. We believe this simplification is justified as the bulk of the costs for a renewable project are capital costs denominated in an international currency, which will typically be financed by loans or equity in that currency. Similarly for avoided costs, the cost of the plant and the fuel is typically denominated in an international currency (such as USD).

The inflation factor applied should be that expected to be relevant to operational costs (fixed and variable Operation and Maintenance, O&M). This may be the inflation rate of an international currency if a long term O&M contract with the installers is expected, or may be a local rate of inflation if there is a significant local labour component.

Inflation is entered separately for fuel costs.

The prosumer model does not allow import tax to be defined. Any import tax will normally be considered as part of the capital costs for smaller installations like prosumers, who do not typically import materials themselves, but instead buy equipment from retailers/dealers that have already imported. The prosumer model is already the most complex (and large) model in the toolbox, so this simplification was considered necessary.

3.1.2 Reference project inputs

Reference project inputs are detailed below. These inputs are required to run the model (1) for a reference or specific renewable IPP project, or (2) to calculate the system impact cost of an IPP. For the second calculation, the avoided cost inputs (Section 3.1.4) are also needed.

Prosumer reference project input information is required for every customer and a maximum of 10 customers can be considered at any one time. If you need more customer classes, simply populate multiple copies of the model (two models could give 20 customer classes, for example).

Please note that the customer categories considered in this module are an editable input, which allows the user the possibility to change categories (this can be done in the "Lists" sheet). Not all customer classes need to be used, and there is even the option to merge all customers into a single group if so desired. You could also specify the technology – for example "Hotel with wind turbine" and "Residential customer with solar PV".

Reference project information for mini-grids includes:

- General information for customers connected to the green mini-grid – the tax status and whether "energy banking is allowed is defined for different groups of customers (i.e. residential, commercial, industrial etc),
- Collection efficiency – what proportion of their bills these customers pay,
- Production inputs – which renewable energy technology the prosumer has installed, the generator type options can be changed on the "lists" sheet if required, there is only one renewable technology per customer type,

- Revenue inputs – expected revenue streams (including feed-in tariff and grants), assuming all energy generated is injected into the grid and paid at the tariff,
- CAPEX (which in the case of prosumers should include all import duties, if applicable) and OPEX inputs,
- Financing inputs (debt and equity), and
- Consumption inputs.

Name	Format	Unit	Description	Impact	Cell reference
General					
Is it a corporate tax paying entity?	String	-	Yes/No	Whether corporate tax applies to the financial model	G26:P26
Is energy banking allowed?	String	-	Yes/No	Energy banking means the consumer avoids more cost from using grid electricity because they "bank" the energy they don't use on the grid.	G27:P27
Banking efficincy	Float	%	Proportion of each kWh exported to the grid that is credited against the prosumers utility bill	Energy banking - % of exported energy that is "banked"	G28:P28
Production inputs					
Generator Type	String	-	The type of technology the prosumer has installed at their site (wind, solar PV, etc).	The generator type options can be changed on the "lists" sheet if required, there is only one renewable technology per customer type	G30:P30
Generator Nameplate Capacity	Float	kW	Capacity of the generator	Generator gross production.	G31:P31
Annual Capacity Degradation	Float	%	The annual capacity degradation factor	Generator gross production.	G32:P32
Project Useful Life	Integer	years	The lifetime of the project	The end of the financial projection.	G33:P33
Production input method	String	-	The user can chose between "standard day",	Depending on the option chosen,	G35:P35

Name	Format	Unit	Description	Impact	Cell reference
			"Standard month", "full year" and "Capacity Factor"	different inputs are required	
Select Generation Profile	Integer	-	The user can select a profile from 10 pre-defined profiles.	Only required if "standard day", "Standard month", or "full year" input modes are selected. Chooses a generator profile from "profiles" sheet to calculate the energy output of the generator (it is also used to populate the "DG Hourly" sheet used in avoided cost calculation)	G36:P36
Capacity Factor	Float	%	Only applicable if "Capacity Factor" selected in production input method	Selected generation profile in "profiles" sheet that determines gross production	G37:P37
Any energy losses that apply	Float	%	Any energy losses that are the responsibility of the prosumer – could be onsite losses or any network losses that are chargeable to generation.	Net production after losses	G40:P40
Revenue inputs					
Tariff indexation factor	Float	%	One indexation factor applies to all prosumers.	Nominal tariff and resulting revenues. Tariff is paid on net production.	F43
Other revenues	Float	Currency/ kWh	Other revenues may include, for example, subsidies or payment for carbon credits.	Revenues (multiplied by production net of losses)	G44:P44
Initial Subsidies (during investment)	Float	USD	Absolute figures for nominal subsidy per year (or negative to represent charges)	Revenue (could be a tax or charge if negative)	G46:P46
Initial Grants (during investment)	Float	USD	Absolute figures for nominal grants per year, can be charged in year 0 to represent upfront grant.	Revenue (could be a tax or charge if negative)	G47:P47
Annual Subsidies (during operation)	Float	USD/year	Absolute figures for nominal subsidy per year (or negative to represent charges)	Revenue (could be a tax or charge if negative)	G48:P48

Name	Format	Unit	Description	Impact	Cell reference
Annual Grants (during operation)	Float	USD/year	Absolute figures for nominal grants per year, can be charged in year 0 to represent upfront grant.	Revenue (could be a tax or charge if negative)	G49:P49
OPEX inputs					
Fixed O&M	Float	Currency/ year	Base year (year 1) fixed O&M costs	Operational expenditure, all indexed by inflation	G52:P52
Variable O&M	Float	Currency/ kWh	Base year Var O&M costs		G53:P53
Other OPEX	Float	Currency/ year	Any other OPEX costs per year for the base year =		G54:P54
CAPEX inputs					
Equipment	Float	Currency	Overnight capex cost of equipment (including any applicable import tax for prosumers)	Total CAPEX in year 0	G57:P57
Installation	Float	Currency	Overnight capex cost of installations	Total CAPEX in year 0	G58:P58
Other CAPEX	Float	Currency	Overnight cost of any other capex	Total CAPEX in year 0	G59:P59
Financing inputs					
Maximum project life (for graphs only)	Integer	Years	Calculated as the maximum project life.	Used to set area for output graphs only	F61
Debt to Total Capital	Float	%	The ratio of debt to capital, set to zero if no loans are likely to be available	Debt	F64
Debt term	Integer	Years	The total debt period	Principal repayments	F65
Debt interest rate	Float	%	The pre-tax nominal interest rate on debt	Interest payments	F66
Target Equity IRR	Float	%	Target post tax nominal internal rate of return required for equity	Model macro iterates to find tariff that gives this return to prosumer investors	F67
Consumption inputs					
Annual consumption growth rate	Float	%	This is uniform across all customers (assumption to manage model complexity)	Rate at which the consumer increases onsite demand, set to zero if no increase.	F71
Consumption input method	String	-	The user can chose between "standard day", "Standard month", "full year" and "Annual Consumption"	Consumption tariff profiles are set on the "profiles" sheet if the user wishes to represent the usage profile of the prosumer (for	G72:P72

Name	Format	Unit	Description	Impact	Cell reference
				more complete calculation of onsite use and export).	
Annual consumption	Float	kWh	Only applicable if user has selected "Annual Consumption"	The single demand tariff applied if the user does not wish to set a time-of-use tariff.	G73:P73
Peak annual consumption	Float	kW	The peak consumption over the year	Generation capacity/peak demand used in the calculation of the generation capacity/peak demand ratio shown in the Reference Prosumer sheet. It is useful in sizing the generator vs the consumption.	G74:P74
Consider savings for self-consumption in equity cashflows?	Boolean	(Yes or No)	It allows the user to choose to consider or not self-consumption in the calculation. If considered, savings in the electricity bill linked to self-consumed energy are treated as a revenue to the prosumer.	In case the avoided cost is higher than the RE tariff, then more self-consumption will bring the required RE tariff down.	F78
Consumption Tariff Indexation rate	Float	%	Demand tariff escalation is assumed uniform across all customers (assumption to manage model complexity)	Indexation of demand tariff costs.	F80
Consumption Fixed Tariff component	Float	Currency/ year	Applies to all input selections, the fixed or "standing" charge for electricity consumers in each category	Used in the calculation of avoided cost. Although it does not change between scenarios, it is useful to see the total impact on bills.	G81:P81
Consumption tariff input method	String	-	The user can choose between "standard day", "Standard month", "full year" and "Average Tariff"	Consumption tariff profiles are set on the "profiles" sheet if the user wishes to represent a time-of-use or seasonal demand tariff.	G82:P82

Name	Format	Unit	Description	Impact	Cell reference
Consumption Energy Tariff component	Float	Currency/ kWh	Only applicable if user has selected "Average Tariff"	The single demand tariff applied if the user does not wish to set a time-of-use tariff.	G83:P83

3.1.3 Profiles worksheet

The inputs required in this sheet are related to the Prosumer data on their:

- **Consumption profiles** (columns F to O):- this is the prosumers hourly consumption profile
- **Generation profiles** (columns Q to Z):- this is the profile of the generator capacity loading level, meaning the % of its nominal installed capacity that is actually generating each hour
- **End-user consumption tariffs** (columns AB to AK):

For each of these profiles, you have the option of inputting data in three different formats:

- Including a **"standard 24 hour profile"** (rows 8 to 31)
- Including a **"standard 24 hour profile for each month of the year"** (rows 37 to 324)
- Including a **"full year profile"** which requires an input for every hour of each day in the year (rows 330 to 9089)

Which input is applied is based on the user selection for

- Production input method: choose from (1) **Capacity Factor** to use the single capacity factor value on the inputs sheet, or (2) select **Standard Day** to use a standard 24 hour profile in the "Profiles" worksheet, or (3) select **Standard Month** to use a standard 24 hour profile for each month of the year in the "Profiles" worksheet, or (4) select **Full Year** to use the "full year profile" which requires an input for every hour of each day in the year.
- Consumption input method: choose from (1) **Annual Consumption** to use the single Annual Consumption value on the inputs sheet, or (2) select **Standard Day** to use a standard 24 hour profile in the "Profiles" worksheet, or (3) select **Standard Month** to use a standard 24 hour profile for each month of the year in the "Profiles" worksheet,

or (4) select **Full Year** to use the "full year profile" which requires an input for every hour of each day in the year.

- Consumption tariff input method: choose from (1) **Average Tariff** to use the single Average Tariff value on the inputs sheet, or (2) select **Standard Day** to use a standard 24 hour profile in the "Profiles" worksheet, or (3) select **Standard Month** to use a standard 24 hour profile for each month of the year in the "Profiles" worksheet, or (4) select **Full Year** to use the "full year profile" which requires an input for every hour of each day in the year.

If limited data is available on profiles, users may prefer to use the capacity factor, average annual consumption and average tariff inputs. These are less intensive in terms of their input requirements. The other options are available to users to increase the modelling accuracy once data becomes available.

3.1.4 Avoided cost and system impact inputs

In the case of prosumers, understanding avoided costs and system impact is different to the method used in the IPP case.

Avoided costs in the case of IPPs are the costs avoided by the system thanks to the presence of the IPP (so avoided generation costs). In the case of prosumers, the same approach can also be used. In this case, the default is to credit the consumer with both the avoided cost of generation from other sources and the avoided cost of transmission losses.

However, there is an alternative way to consider avoided cost. In this second interpretation, the avoided costs refer to the cost savings obtained by the prosumer by installing its own generation. This is done to reflect the fact that under netting schemes (such as net metering), the return perceived by the prosumer is actually the avoided cost in its electricity bill.

The avoided cost for the utility is calculated in the system impact assessment. In the system impact, the costs and benefits associated with a certain prosumer uptake are calculated. The system impact analysis details the financial impact of new prosumers on the generation, transmission and distribution levels for a general case where no banking schemes are present. In banking schemes, depending on their characteristics, ad-hoc additional considerations would be required.

Reference project inputs are detailed below. These inputs are required to run the model (1) to calculate the "avoided cost" for any new prosumer project under net metering schemes or just the avoided cost of energy import, or (2) to calculate the system impact cost of prosumer uptake on the utility. For both calculations, the reference project costs (Section 3.1.2) are also needed.

The nine following types of technology can be considered to be in the baseline energy mix: Nuclear, Coal, Hydro, Natural Gas, Light Fuel Oil (LFO), Heavy Fuel Oil (HFO), Solar PV, Wind and Other Renewable Energy Sources (RES). As previously, these names can be changed by the user.

Name	Format	Unit	Description	Impact	Cell reference
Set avoided cost tariff based on baseline generation mix (@ XXX /MWh)?	Yes/No	-	Dropdown box to choose whether avoided cost tariff is based on the standard (baseline generation mix increased by transmission losses) or a manual input	Selection of avoided cost for calculation of the IRR to the prosumer if this tariff is selected.	G88:P88
Manual input of avoided cost tariff	Float	Currency/ MWh	Manual input for avoided cost if the user chooses to enter their own figure	Selection of avoided cost for calculation of the IRR to the prosumer if this tariff is selected.	G89:P89
Baseline energy mix – information entered for each technology type					
Technical data					
Generation Mix	Float	%	The percentage the technology accounts for in the generation mix (by MWh)	Weighting by technology in avoided cost	F92:N92
Plant Size	Float	MW	The average capacity of the plant	Electricity production	F93:M93
Investment Cost	Float	currency/ MW	The total investment cost per MW for the technology	Overnight capex	F94:M94
Lifetime of Investment	Integer	Years	Lifetime of the technology plant from when built	Time in operation	F95:M95
GHG Emissions Factor	Float	tCO_2e/ MWh	Greenhouse gas emissions per MWh from the technology	Revenue for emissions avoided by renewable technology	F96:M96
Average LCOE (for Other RES)	Float	currency/ MWh	Only applicable to the "Other RES" technology type	Input to baseline LCOE	N97
GHG price for avoided cost	Float	currency/ tonne CO_2	This is the social price (or carbon tax cost) for each tonne of greenhouse gases emitted	Additional avoided cost for emissions avoided by renewable technology	F99
Financing data					

Name	Format	Unit	Description	Impact	Cell reference
% Debt	Float	%	The ratio of financing supplied by debt (this is used to then calculate the % equity)	Debt	F103:M103
Cost of Equity (Post-Tax)	Float	%	Target post -tax nominal internal rate of return required for equity	Model finds the LCOE given the cost of equity and debt	F105:M105
Cost of Debt	Float	%	The pre-tax nominal interest rate on debt		F106:M106
Debt Term (Loan Tenor)	Integer	Years	The loan period	Debt repayments	F108:M108
Technology Inputs					
Capacity Degradation Factor	Float	%	The yearly capacity degradation factor applicable to plants of the technology type	Input to net electricity production	F111:M111
Efficiency	Float	%	The efficiency of the plant	Efficiency of energy conversion of fuel for electricity production	F112:M112
Equivalent Full Load Hours	Float	Hours	Equivalent full load house in a year of the plant of the specific technology type	Calculates capacity factor for electricity production	F113:M113
Fuel Cost: for each technology except hydro, wind and solar PV the user can select either Option 1 OR option 2					
Option 1: Annually Adjusted (% change year on year)					
Fuel Cost, Starting Price	Float	Currency/ MWh	The cost of fuel per MWh in the base year	Fuel cost	F119:M119
Fuel Cost, Annual Increase	Float	%	The annual escalation in the cost of fuel per MWh relative to the base year	Fuel cost	F120:M120
Option 2: Linear Function (y = ax + b)					
a (increase per annum)	Float	Currency/ MWh	The cost increase per annum which is applied to the fuel cost per MWh	Fuel cost	F122:M122
b	Float	Currency/ MWh	The cost of fuel per MWh in the base year	Fuel cost	F123:M123
Non-fuel OPEX					
Initial Year	Float	Currency/ MW	Base year OPEX costs which aren't covered under fuel costs per MW	Operational expenditure	F126:M126
Annual Increase	Float	%	Yearly increase in non-fuel OPEX costs	Operational expenditure	F127:M127
Prosumer increase projection					

Name	Format	Unit	Description	Impact	Cell reference
Numbers of prosumers	Float	Number	The number of prosumers by each customer category, for each year.	Overall cost of the prosumer support	G135:P144
Network costs and loss inputs					
Transmission Charge - Energy Component	Float	Currency/ MWh	Energy transmission charge on energy at the exit (delivery point) of transmission	Reduced transmission payments as a result of distributed generation being used by the prosumer rather than electricity from the network – this cost will have to be recovered by the utility from other customers	F147
Distribution Charge - Energy Component	Float	currency /MWh	Energy distribution charge on energy at the exit (delivery point) of distribution	Reduced distribution payments as a result of distributed generation being used by the prosumer rather than electricity from the network – this cost will have to be recovered by the utility from other customers	F148
Transmission grid losses	Float	%	Transmission grid losses on energy that is transported on the transmission system	The utility benefits because they do not suffer network losses on the energy the prosumer uses themselves onsite	F149
Distribution network losses	Float	%	Distribution network losses on energy that is transported on the distribution system	The utility benefits because they do not suffer network losses on the energy the prosumer uses	F150

Name	Format	Unit	Description	Impact	Cell reference
				themselves onsite	

3.2 Running the model

Here is a brief guide to running the Prosumer model:

1. The version history tab can be used to keep track of cases or scenarios run in the model.
2. Users are advised to start from the dashboard on the DASHBOARD tab.
3. The dashboard contains a macro button linking to the inputs sheet (or users can select the INPUTS tab).

Entry of main inputs to the model: Inputs

4. Input cells are coloured yellow. Selection boxes that allow an input format or assumption to be entered are green. These cells can (and should) be changed by users to match the case or scenario under consideration. Inputs are described in Section 2.1.
5. The underlying calculations are shown on the relevant worksheets. We suggest you avoid changing these calculations unless required. Calculation cells are white. Inactive calculations (for alternative scenarios) are grey.
6. Run the macro on the dashboard to update the model calculations (to iterate to the required feed in tariff).

Please click on the button "Update Calcs" below to update all calculations in this model

Update Model Calculations

*Note: depending on the inputs, updating calculation can take up to 1-2 minutes

7. View outputs by pressing the button on the dashboard (or by going to the OUTPUTS tab).

Access to selected model outputs: Outputs

Users can edit the outputs (or any part of the model) to suit their own requirements. See Section 3.4 for the standard outputs. Take care when adding or removing lines as it may affect the macro calculation.

3.3 Calculations underpinning the model

3.3.1 Reference project

For distributed and microgeneration, the approach is slightly different due to the variety of inputs considered. Generation profiles can be adjusted to consider a simple load factor or average daily/monthly/yearly profiles (useful for solar or wind volatility). Customer profiles and customer demand tariffs can also be adjusted.

The reference project approach remains the same, in that a target IRR is calculated on the generation cash flow.

For each prosumer (maximum of 10 in total) the following calculation blocks apply:

- **Production (i.e. generation) calculation block (*rows 6 to 16*):** This block calculates the yearly net production given the set of inputs defined for the prosumer such as: capacity, degradation factor and other losses.
  - **Net Export production in year =** capacity x (1-degradation factor) x (degradation factor in previous year) x equivalent full load hours x (1- other losses). In case self-consumption is considered, then it is discounted by the self-consumed energy to obtain the net energy injected into the grid.
  - **Equivalent Full Load Hours**: This is dependent on the combination of selected assumptions on the input sheet:
    - The user selects a production input method, in the case where the **capacity factor approach is chosen** then:
      - Capacity Factor only applicable if Capacity Factor is chosen as the production input method for the prosumer in question
      - Equivalent full load hours (row 12) = Number of hours in year x capacity factor
  - in the case where the capacity factor approach is NOT chosen then:

- **The generation profile** is chosen as the production input method for the prosumer in question.
- **Equivalent full load hours**[4] **(row 12) =** Sum of hourly generator capacity loading levels in the year.

- **Production revenue calculation block (*rows 22 to 27*):** This block calculates the total yearly production revenues given the set of inputs defined: revenue indexation factor (RIF) and other revenues earnt per MWh. It also requires an energy tariff which is solved by the use of a goal seek in the macro for the base year.
  - **Yearly revenue** = (1+ RIF) x RIF in previous year x [(energy tariff x net export production) + (Other revenues x net production)]

- **Production costs calculation block (*rows 35 to 48*):** This block calculates the total yearly production costs given the set of inputs defined: inflation indexation factor (IIF), Variable O&M unit cost, Depreciation (which is calculated as straight line when the prosumer is a corporate tax paying entity, otherwise zero), Fixed O&M and other Opex.
  - **Yearly total Opex=** (1+IIF) x IIF in previous year x [(Var O&M cost x gross production) + Fixed O&M + Other Fixed O&M] + depreciation

- **Financing costs/Debt service (*rows 51 to 60*):** This block calculates the yearly interest and principal repayments to service the debt defined in the inputs (defined as a percentage of the overall).
  - **Principal payments:-** these assume a fixed yearly repayment i.e. Total debt divided by total debt term.
  - **Interest payments**:- interest payments are calculated based on the interest rate multiplied by the average of the opening and closing debt in same year.

- **Generation Cash flow *(row 63 to 71):*** This block calculates the net asset value for each year modelled.
  - **Cash flow=** Revenue (including subsidies and grants) – operating expenses + new debt – debt service – taxes – investment

- **IRR (*rows 73 to 75*):** When the macro is run, the energy revenue tariff is solved such that the Equity IRR (based on the generation cash flow) matches the target IRR defined in the inputs.

[4] Note that the above is calculated separately on the profiles sheet based on an average day, average month or full year profile.

3.3.2 Avoided cost

For prosumers, the avoided cost is the cost saved by the customer (or prosumer) in its energy bill due to installing onsite generation.

Energy banking means the consumer avoids more cost from using grid electricity because they “bank” the energy they don’t use on the grid.

Table 4 summarises this.

Table 4: Benefits to consumers from onsite generation

		Without DG	With DG and No Banking	With DG and Energy Banking	With DG and Cash Banking
Net consumption cost	USD	A	B	C	D
Avoided Cost	**USD**	**0**	**A-B**	**A-C**	**A-D**

In more detail:

- Without any onsite generation, they import all their needs from the grid – they have their normal bill.
- With onsite generation, they will use some of the power they generate (that would have cost them B to import) so they have a lower total bill (A-B).
- With onsite generation and “energy banking” or “cash banking” the customer can save more, as any excess generation they export on the grid they can import later on when they need it – effectively treating the grid like a battery. This can either be in kWh or cash terms.
- If the customer is on an average tariff, they will save the same whether they are energy banking or cash banking – the only difference is when there are “time-of day” or other variable tariffs.

It is worth noting that with energy and cash banking the calculation never allows utility bills for the customer to go negative, the lowest that the energy component of a bill can be is zero, therefore if the generation is oversized they still only benefit as through it matched their own consumption. They would also still need to pay any fixed or standing charges.

For each prosumer the following 15 calculations columns are carried out on the DG_Hourly sheet:

- **Gross Consumption** (e.g. Column F):- this retrieves the hourly consumption in kWh from the Profiles sheet
- **Generation unit profile** (e.g. Column G):- depending on the selection made in row 74 of the inputs sheet, this retrieves the specified hours generation factor from the Profiles sheet or considers the defined capacity factor from the inputs sheet row 76.
- **Generation in kWh net of losses** (e.g. Column H):- this calculates the kWh's generated in the hour by using the unit profile multiplied by the capacity reduced by any losses defined in the inputs sheet
- **Net consumption** (e.g. Column I):- in the case where consumption was more than generation, this column calculates the gross consumption minus generation in kWh net of losses
- **Excess generation** (e.g. Column J):- in the case where consumption was less than generation, this column calculates the excess generation minus consumption
- **Self-consumed generation** (e.g. Column K):- this is calculated by gross consumption minus net consumption.
- **Consumption During Generation Hours** (e.g. Column L):- this column reports the prosumers consumption during hours in which it also generates.
- **Consumption cost without DG** (e.g. Column M):- this multiplies the end user tariff in the hour defined in the profiles sheet by the gross consumption in the hour.
- **Net consumption cost with DG** (e.g. column N)):- this multiplies the end user tariff in the hour defined in the profiles sheet by the net consumption in the hour.

The following four columns consider an Energy Banking Approach:

- **Energy Bank** (e.g. column O):- When the energy bank (kWhs) is less than or equal to net consumption of the prosumer, it adds the energy bank level from the previous hour plus excess generation minus net consumption.
- **Energy bank withdrawals** (e.g. Column P):- this simply compares the energy bank level in the current hour versus the previous hour.
- **Net Consumption after banking** (e.g. column Q):- this reduces the net consumption by the energy bank withdrawals.
- **Net Consumption cost after banking** (e.g. column R):- this multiplies the end user tariff in the hour defined in the profiles sheet by the net consumption after banking in the hour.

The cash banking approach (columns S to U) is consistent with the above, except that it looks as the cost in cash terms

3.3.3 System impact

- System impact detailed by value chain segment (generation, transmission, distribution) and additional (not allocated to a particular agent).
- Arguably, the most delicate case is that of Distributed Generation. Distributed Generation being installed at the end-user consumption point, it directly reduces all flows (energy and economic) upstream in the power system.
- The main positive impact is energy loss reduction in the transmission and distribution networks.
- The main negative impact is loss of power output (sales) from incumbent generators, together with a reduction in all regulated charges dependent on energy tariff components.

3.4 Outputs

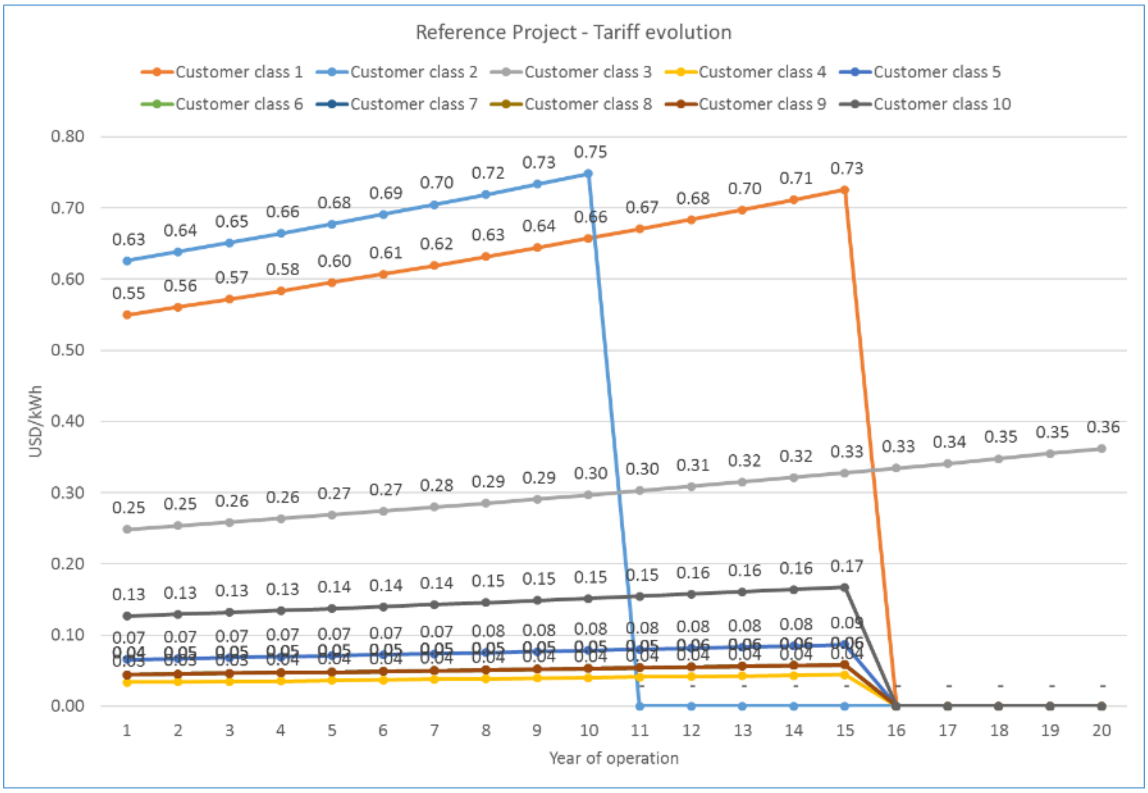
3.4.1 Reference project

The outputs show the reference project tariff required to deliver the Equity IRR. This is given inclusive and exclusive of VAT. The tariff is paid on export generation; but if the option to consider self-generation is not selected, then it is applied to total generation (both that used onsite and that exported to the grid).

The outputs also list for each customer class the gross consumption (in kWh), the onsite generation (in kWh), net consumption imported from the grid (in kWh), excess generation (in kWh) and self-consumed generation (in kWh).

There is also a graph showing tariff evolution for each customer class.

Figure 17: Output graphs for the reference project



3.4.2 Avoided cost

For the avoided cost scenario, the model reports the Avoided Cost Tariff and the Equity IRR that investors in the reference project would receive if the project was paid no tariff, and just received the benefit of reducing their import from the grid, or if energy banking or cash banking were available on their energy bills.

3.4.3 System impact

For the first 10 years of output, the model reports the total energy produced by reference IPPs for the uptake level scenario defined in the inputs, and the tariff they are paid (in real terms), giving a resulting total tariff cost (in real terms) that the counterparty will have to meet.

The impact is expressed in real terms (not inflated) because it is usually easier to evaluate impacts and their evolution over time in values expressed in the currency of the base year.

The system impact is calculated from:

- At Generation Level

- The revenue loss by baseline generators (third party) for the energy the prosumer is self-generating and not buying from the system anymore.
- The revenue loss by baseline generators for the excess energy the prosumer generates and injects into the system, effectively replacing baseline generation.

- At Transmission Level
  - The transmission charges lost by the transmission agent due to the prosumer self-consumption, which is energy that does not need to be wheeled through the grid anymore.
  - The savings on the acquisition of energy for energy loss in the power transmission system linked to the energy the prosumer is self-generating and does not need to go through the network anymore.
- At Distribution Level
  - The distribution charges lost by the distribution agent due to the prosumer self-consumption, which is energy that does not need to be wheeled through the network anymore.
  - The savings on the acquisition of energy for energy loss in the power distribution system linked to the energy the prosumer is self-generating and does not need to go through the network anymore.
- Additional Savings
  - The value of excess energy injected by the prosumer into the system, valued at the unit price of baseline generation. This is equal to the revenue loss by baseline generators. Whether one or the other are present depends on the system situation, in cases of excess generation capacity there is revenue loss; in cases of capacity scarcity, the system is saving on new baseline generation by integrating excess energy from prosumers.
- Additional Costs
  - Net Payment for gross billing FiT: net extra cost of paying the FiT for export energy compared to the previous cost of supplying the prosumer before installing its own distributed generation. It assumes a gross billing scheme, so it is equal to the FiT level applied to all energy generated energy minus the invoice for energy consumption paid by the prosumer.

- Additional Value of Energy Banking received by prosumers: extra value obtained by prosumers under an energy banking scheme, thus extra cost to the system as it means a loss of revenue to the system except the prosumer.
- Additional Value of Cash Banking received by prosumers: extra value obtained by prosumers under a cash banking scheme, thus extra cost to the system as it means a loss of revenue to the system except the prosumer.

3.5 Key questions

3.5.1 What is the price per kWh that renders a mini-solar PV plant feasible/profitable?

The reference project module calculates this tariff, based on an input rate of return. It is important to have good data for all reference project inputs to ensure the calculated tariff both gives a fair return to the investor and is the lowest tariff that ensures that fair return. This calculation offers the possibility to take into account the value the consumer saves by not importing as much electricity, just by choosing "Yes" in the option to consider self-consumption savings in the input sheet.

3.5.2 How is the consumption of the prosumer measured?

In terms of metering, there are a numbers of ways meters can be configured to measure

- The most reliable form of energy metering is to have an import meter measuring the power the prosumer takes from the grid and an export meter measuring the power the prosumer delivers to the grid. If the support is intended for renewable energy only, audits may be needed to check the prosumer is not also generating power from other sources (e.g. diesel).
- There are commonly energy meters installed at the same time as the generator is installed, these energy meters measure the total output of the renewable generator. However, not all manufacturers produce meters that are as accurate as the meters used to measure import and export to the grid, therefore, you may wish to make a regulatory decision to apply the same requirements to the meter measuring electricity output from the generator as to other electricity meters, and have the same options for the utility or regulator to check its accuracy.
- Some import meters can run in reverse if the generation is exported to the grid. This is a form or energy banking based on kWh, commonly called net metering. Sometimes this is even done by accident, and the utility may not know it is happening. It has

disadvantages for the utility as there is no way to see how power is actually flowing on their network. Therefore, separate import and export metering is often used, even if there is a policy decision to value both equally.

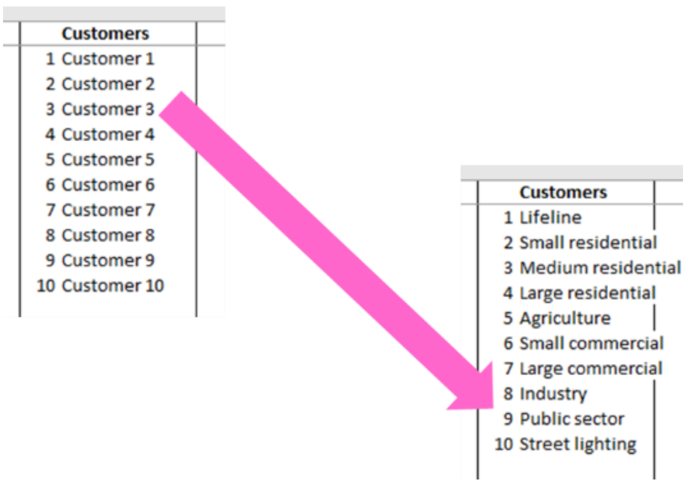
The tariffs represented in the model can represent different ways of paying the prosumer for the energy produced.

- The Feed in tariff (FiT) for the export energy under a reference project approach:
  - With the option to consider self-consumption deactivated ("No" selected) provides the tariff level that should be paid in a gross scheme and also that same FiT could be applied to the excess energy injected into the system. This option would be assuming the same value for electricity generated regardless of its use (injected into the system or consumed by the prosumer).
  - With the option to consider self-consumption activated ("Yes" selected) it provides the tariff level to be applied to export energy only to achieve the target return, after valuing self-consumed energy at the savings in the electricity bill for the prosumer.
- The avoided cost level will provide the value of the saving the prosumer obtains when a netting scheme is in place. In netting schemes there are no tariffs, volumes are exchanged (either energy volumes or energy volumes valued at the end-user tariff).

3.5.3 How can I change names for types of customers?

It is simple to change the customer names using the lists sheet. Simply overwrite the labels to your preferred names:

Figure 18: Example of changing the customer names



The names should automatically change throughout the model to match your preferences. Note the numbers are used in some parts of the model as park of index functions.

3.5.4 How does the tariff design reflect the economic situation of consumers?

This is a difficult question for regulators and ministries to answer, because in this case there are two consumers to consider: (1) the prosumer that has installed renewable generation onsite and (2) the other consumers who buy energy from the utility. The needs of both have to be balanced in policy design.

The model does not tell the user how to set policy, but it can help by showing the system impact of different policy choices. Any extra costs that are incurred as a result of supporting the prosumers will need to be recovered elsewhere, either through electricity tariffs to other consumers or through general taxation.

3.5.5 Should the tariff paid to prosumers be indexed to the consumption tariff or linked to investment?

The model allows the user to choose the indexation for feed in tariffs. This could be (for example) linked to inflation.

For energy or cash banking, the tariff is naturally based on the consumption tariff.

3.5.6 How will the power of the prosumers be curtailed?

Curtailment decisions are a matter for policy. However, typically in other countries, the electrical set-up will be that the prosumer is part of the main grid, so their generation automatically stops (or is islanded) if there is a blackout on their part of the network. This is an important safety requirement, as engineers may be working on the line. If they wish to use generation, they must first fully isolate themselves from the system. Prosumers are not typically controlled beyond this.

3.5.7 Is there always a positive return for prosumers?

Prosumers make a decision to invest in renewable energy for a number of reasons. They may choose to invest because the network is not reliable in their location and they wish to have access to alternative power.

However, there may be advantages to paying for any export that the prosumer puts to the grid. It allows the prosumer to supply their neighbours when they are injecting on to the grid, and they can treat the grid a little like a battery.

The policy decision on how to reward the prosumer for any power they put on to the grid (or if to reward them) may depend on:

- Whether there is already sufficient power generation on the network, as if not there may be a desire to make the most use of additional generation,
- Whether there is a policy decision to support renewables, and
- Any other relevant national factors.

3.5.8 Must prosumer tariffs only support renewable technology?

Not necessarily. The model was designed with renewable technology in mind, but it is possible to edit the generator types on the "Lists" sheet. The choice of technology to support is a policy decision.

If there is a fuel cost, it should be included with the "Variable O&M" in Currency/kWh. The fuel cost conversion tool can be used to convert the fuel cost into the correct units.

Figure 19: Generator type in "Lists" sheet of prosumer model

	Generator Type
1	Solar PV
2	Wind
3	Hydro
4	Thermal
5	Other

3.5.9 Do self-generators use the national grid/network? How can the feed in tariff take this into account? What tariff to charge to feed into the grid?

The consumer who becomes a prosumer will continue to pay any fixed charges for the use of the network, and will also pay for imported energy from the grid (after any net billing that applies). This means these consumers are still paying into the system.

However, the overall amount they are paying does mean there is less revenue to transmission and distribution companies (although they also face fewer network losses). The net position is shown on the system impact calculation.

It all depends on the regulatory scheme of the country: how are network usage costs allocated to generators and consumers and how is the tariff methodology designed to calculate them. In many countries, generators do not pay for use of system, only consumers do. If this logic is applied in a uniform and non-discriminatory manner, prosumer would keep paying network charges as consumers but not required to pay any different or additional extra charge for their role as generators.

The prosumer will still pay the fixed charges (per day or per month or per year) that apply to their tariff class, so this may cover some part of the utility revenue needed.

3.5.10 Can we consider the evolution of prosumers' generation based on feed in tariff incentive?

The model allows the user to input scenarios for the expansion of prosumer generation (numbers of customer by category). This is an input rather than an output of the model, but it does allow the consideration of the overall system-wide impact of introducing the tariff.

4 Green mini grid (GMG) model

This section looks at the inputs, calculations, outputs and key questions of green mini grids.

4.1 Inputs

The inputs for the mini-grids are split into four sections; general, reference project inputs, avoided cost inputs and system impact. Each of these is discussed in turn below.

4.1.1 General inputs

General inputs are detailed below. These inputs are required to run the model in any configuration.

Table 5: General inputs

Name	Input format	Unit	Description	Impact	Cell reference
Currency unit	String	-	This input is for display purposes only (i.e. USD, EUR, GBP)	Display only	E10
Inflation	Float	%	This is the inflation projection for the project lifetime. Note the first year of operation has by default zero inflation)	Inflates customer tariff only. The rest of the model is in real terms and then tariffs are inflated to be nominal (effectively inflation applies to all inputs).	H13:P13
VAT	Float	%	The electricity sales VAT in the country being considered	Increases calculated required tariff by VAT (and LCOE for baseline alternatives)	F15
Applicable corporate taxation scheme	String	-	Drop down box to select tax scheme (profit tax, revenue tax, or the maximum of the two)	Tax applied to financial model of reference project as specified by user selection	F16
Corporate profit tax	Float	%	The corporate profit tax in the country over profit		F18
Corporate income tax	Float	%	The corporate profit tax in the country over revenue or sales		F19
Corporate tax holidays	Integer	Years	Any tax breaks given to renewable energy projects	Tax applied in financial model	F20
Project simulation period	Integer	Years	Number of years the green mini-grid will be operational	Number of years modelled	F22

4.1.2 Reference project inputs

Reference project inputs are detailed below. These inputs are required to run the model (1) for a reference or specific renewable IPP project, or (2) to calculate the system impact cost of an IPP. For the second calculation, the avoided cost inputs (Section 3.3.2) are also needed.

Please note that the customer categories considered in this module are an editable input, which allows the user the possibility to change categories or merge all customers into a single group if so desired. This can be done in the "inputs" sheet.

Reference project information for mini-grids includes:

- Demand information for customers connected to the green mini-grid – this is defined for different groups of customers (i.e. residential, commercial, industrial etc),
- Collection efficiency – what proportion of their bills these customers pay,
- Mini Grid generation inputs – up to five different types of mini grid generation can be defined in the "Lists" sheet,
- Bulk supply over demand – allows the user to specify a proportion of the mini-grid demand that is met by grid electricity (negative to represent selling to the grid at the wholesale price), this will always be zero for an isolated grid,
- Mini Grid Network – input data is required for general aspects of the isolated grid, distribution network and connections,
- Network loss inputs – technical losses on the mini-grid network (can include commercial losses – theft – if required),
- Bulk supply generation inputs – bulk supply from the main grid for mini-grids that are connected to the main interconnected system,
- Batteries – allow flexibility in output if required, but increase the cost of the overall system,
- Financing inputs – for the green mini-grid developer, and
- Grants and subsidies – upfront or annual support.

Unlike the renewable IPP model, the green mini-grid model is calculated in real terms and then the tariff is indexed to inflation to give a nominal output.

CAPEX figures should be inclusive of all applicable taxes and transport costs; in particular, CAPEX figures should include any import duties that may apply to mini-grid equipment.

Table 6: Reference project inputs

Name	Input format	Unit	Description	Impact	Cell reference
Demand information					
Initial customer #	Integer	-	The number of customers in the customer group in the base year	Revenue from fixed charge	E31:35
Customers growth	Float	%	The per annum growth expected for each customer group	Revenue from fixed charge	F31:35
Initial Demand	Float	kWh	The initial demand in the customer group in the base year	Revenue from unit charge	G31:35
Demand growth	Float	%	The per annum growth in demand expected for each customer group	Revenue from unit charge	H31:35
Cost responsibility	Float	%	The split of the total cost covered by each customer group. Note: the sum across the groups should add up to 100%.	Allows cross subsidy between tariff classes	I31:35
Cost to energy charge	Float	%	The proportion of the customer groups billings which are based on energy charges rather than fixed charges.	Allocation of costs between fixed tariff and unit tariff (note that in reality most costs are fixed, but most customers prefer a unit charge)	J31:35
Subsidy for this category only	Float	%	The % of the tariff for the specific customer class that is subsidised	Total revenue and tariff by customer class	L31:35
Collection efficiency					
Collection efficiency	Float	%	The % of money collected from customers over the money billed to customers	Total revenue	F47
Mini Grid generation inputs					
Installed Capacity	Float	kW	The installed capacity	Variable Opex	E41:45
Capacity Factor	Float	%	The capacity factor of the technology in question	Production	F41:45
Useful Life	Integer	Years	The useful life of the specific mini grid generation technology in question	Replaced after useful life	G41:45
Capital Costs	Float	Currency	Cost of capital for the mini grid technology. It shall be	Capex. Replaced after useful	H41:45

Name	Input format	Unit	Description	Impact	Cell reference
			inclusive of any import duties (if any is applicable).	life, later costs	
Fuel Costs	Float	Currency/kWh	Base year fuel cost if applicable (i.e. not applicable for wind, solar, hydro)	Variable Opex	I41:45
Fuel Cost Increase (real p.a.)	Float	%	Annual increase in fuel cost from the initial value (since the model is in real terms, this must be a real % increase).	Variable Opex	J41:45
Fixed O&M Costs	Float	Currency/year	Annual fixed O&M costs in base year	Opex	K41:45
Variable O&M Costs	Float	Currency/kWh	Variable O&M costs in base year	Opex	L41:45
Other OPEX	Float	Currency/year	Any other fixed yearly OPEX costs	Opex	M41:45
Bulk supply over demand					
Bulk supply over demand	Float	%	Proportion of the mini-grid demand that is met by grid electricity (negative to represent selling to the grid at the wholesale price). Note: an entry of 0% would model an isolated mini-grid.	Opex	F47
Mini Grid Network					
Useful Life	Integer	Years	The useful life of the relevant network component.	Replaced after useful life, later costs	E51:53
Capital Costs	Float	Currency	The capital cost of the relevant network component	Capex.	F51:53
O&M Costs	Float	Currency/year	Annual O&M costs of the relevant network component	Opex	G51:53
Service OPEX	Float	Currency/customer/year	Service costs of the relevant network component per customer per year	Opex	H51:53
Other OPEX	Float	Currency/year	Other annual opex costs of the relevant network component	Opex	I51:53
Network loss inputs					
Network losses	Float	%	% loss over the total energy injected into the network	Reduces supply where revenue can be collected	F55
Bulk supply generation inputs					
Bulk supply tariff (energy component)	Float	Currency/MWh	Cost per MWh of power from the bulk supply	Opex	F63
Bulk supply tariff (fixed component)	Float	Currency/year	Cost per year of power from the bulk supply	Opex	F64
Batteries					

Name	Input format	Unit	Description	Impact	Cell reference
Levelized cost of storage	Float	Currency/ MWh	Levelised cost to provide storage (implicitly includes replacement)	Fixed O&M costs per year	F58
Storage used in average year	Float	MWh/year	Sizing of storage determines cost	Fixed O&M costs per year	F59
Efficiency of storage	Float	%	Reduces output as a result of efficiency losses in storage.	Input to net electricity production	F60
Financing inputs					
Inflation rate	Float	%	Used to calculate the real equity return and real interest rate. Note: (please check that it is aligned with overall inflation projection)	Real project returns	F67
Debt to Total Capital (Gearing)	Float	%	The percentage of investments financed with debt	Debt	F68
Debt Term (loan period)	Integer	Years	The repayment period of loans	Principal repayments	F69
Debt interest rate (nominal)	Float	%	The pre-tax nominal interest rate on debt	Interest payments	F70
Post-tax return on equity (real)	Float	%	Target post tax real internal rate of return required for equity	Model macro iterates to find tariff that gives this return to investors	F72
Grants and subsidies					
Initial Subsidies	Float	USD	Absolute figures for nominal subsidy per year (or negative to represent charges)	Revenue (could be a tax or charge if negative)	F79
Initial Grants	Float	USD	Absolute figures for nominal grants per year, can be charged in year 0 to represent upfront grant.	Revenue (could be a tax or charge if negative)	F80
Subsidies during Operation	Float	USD/year	Absolute figures for nominal subsidy per year (or negative to represent charges)	Revenue (could be a tax or charge if negative)	G84:P84
Grants during Operation	Float	USD/year	Absolute figures for nominal grants per year, can be charged in year 0 to represent upfront grant.	Revenue (could be a tax or charge if negative)	G85:P85

There are multiple methods to set cost responsibility across customer categories. All of them try to match as close as possible the burden each type of customer imposes on the network (on capital investment or on operating costs) and their responsibility in the associated costs.

In the case of network investments, since networks are sized to supply a certain maximum peak energy, many methods link responsibility in costs to contributions to peak demand at different voltage levels. Examples of such methods are: coincidental demand at peak hours, non-coincidental peak demand by category, or a mix of coincidental demand at peak and at off-peak hours by customer category.

Another, more complex method, is the Average-Excess Demand. This method uses a weighted average of the average-demand allocators and the Excess-Demand Allocators, based on the system load factor.

In the absence of any specific criterion, an initial estimate for the cost responsibility can be set to equal the fraction of total energy delivered to that customer group. This implies equal cost responsibility per unit of energy delivered to customer categories. Avoided cost and system impact inputs

Reference project inputs are detailed below. These inputs are required to run the model (1) to calculate the "avoided cost" for any new renewable IPP project, or (2) to calculate the system impact cost of an IPP. For the both calculations, the reference project costs (Section 2.1.2) are also needed.

The nine following types of technology can considered to be in the baseline energy mix: Nuclear, Coal, Hydro, Natural Gas, Light Fuel Oil (LFO), Heavy Fuel Oil (HFO), Solar PV, Wind and Other Renewable Energy Sources (RES). The user can replace the titles with their own energy mix if preferred.

Name	Format	Unit	Description	Impact	Cell reference
Baseline energy mix – information entered for each technology type					
Technical data					
Generation Mix	Float	%	The percentage the technology accounts for in the generation mix (by MWh)	Weighting by technology in avoided cost	F101:N101
Plant Size	Float	MW	The average capacity of the plant	Electricity production	F102:M102
Investment Cost	Float	currency/MW	The total investment cost per MW for the technology	Overnight capex	F103:M103
Lifetime of Investment	Integer	Years	Lifetime of the technology plant from when built	Time in operation	F104:M104
GHG Emissions Factor	Float	tCO_2e/MWh	Greenhouse gas emissions per MWh from the technology	Revenue for emissions avoided by renewable technology	F105:M105

Name	Format	Unit	Description	Impact	Cell reference
Average LCOE (for Other RES)	Float	currency/MWh	Only applicable to the “Other RES” technology type	Input to baseline LCOE	N106
GHG price for avoided cost	Float	currency/tonne CO_2	This is the social price (or carbon tax cost) for each tonne of greenhouse gases emitted	Additional avoided cost for emissions avoided by renewable technology	F108
Financing data					
% Debt	Float	%	The ratio of financing supplied by debt (this is used to then calculate the % equity)	Debt	F112:M112
Cost of Equity (Post-Tax)	Float	%	Target post -tax nominal internal rate of return required for equity	Model finds the LCOE given the cost of equity and debt	F114:M114
Cost of Debt	Float	%	The pre-tax nominal interest rate on debt		F115:M115
Debt Term (Loan Tenor)	Integer	Years	The loan period	Debt repayments	F117:M117
Technology Inputs					
Capacity Degradation Factor	Float	%	The yearly capacity degradation factor applicable to plants of the technology type	Input to net electricity production	F120:M120
Efficiency	Float	%	The efficiency of the plant	Efficiency of energy conversion of fuel for electricity production	F121:M121
Equivalent Full Load Hours	Float	Hours	Equivalent full load house in a year of the plant of the specific technology type	Calculates capacity factor for electricity production	F122:M122
Fuel Cost: for each technology except hydro the user can select either Option 1 OR option 2					
Option 1: Annually Adjusted (% change year on year)					
Fuel Cost, Starting Price	Float	Currency/MWh	The cost of fuel per MWh in the base year	Fuel cost	F127:M127
Fuel Cost, Annual Increase	Float	%	The annual escalation in the cost of fuel per MWh relative to the base year	Fuel cost	F128:M128
Option 2: Linear Function (y = ax + b)					
a (increase per annum)	Float	Currency/MWh	The cost increase per annum which is applied to the fuel cost per MWh	Fuel cost	F130:M130

Name	Format	Unit	Description	Impact	Cell reference
b	Float	Currency/MWh	The cost of fuel per MWh in the base year	Fuel cost	F131:M131
Non-fuel OPEX					
Initial Year	Float	Currency/MW	Base year OPEX costs which aren't covered under fuel costs per MW	Operational expenditure	F134:M13$
Annual Increase	Float	%	Yearly increase in non-fuel OPEX costs	Operational expenditure	F135:M135
Network costs and losses					
Transmission Charge - Fixed Component	Float	Currency/MWh	The fixed charge component of the transmission charge, over energy at the exit (delivery point) of transmission	Total Avoided Cost	F138
Distribution Charge - Fixed Component	Float	Currency/MWh	The fixed charge component of the distribution charge, over energy at the exit (delivery point) of transmission	Total Avoided Cost	F139
Transmission Charge - Energy Component	Float	Currency/MWh	The energy charge component of the transmission charge, over energy at the exit (delivery point) of transmission	Total Avoided Cost	F140
Distribution Charge - Energy Component	Float	Currency/MWh	The fixed charge component of the distribution charge, over energy at the exit (delivery point) of transmission	Total Avoided Cost	F141
Transmission grid losses	Float	%	Transmission grid losses on the energy at the entry of Transmission system	Total Avoided Cost	F142
Distribution network losses	Float	%	Distribution network losses on the energy at the entry of Distribution system	Total Avoided Cost	F143
Green Mini-Grid interconnection to the main system	Float	USD	Main system extension direct costs (the equivalent cost to connect to the main system if the mini-grid was not built).	Total Avoided Cost	F147
Additional mini-grid inputs required for System impact					
Number of reference Green Mini-Grids	Integer	Number	Number of reference projects in operation in each year	The avoided cost of all mini-grids together	G155:P155

Name	Format	Unit	Description	Impact	Cell reference
				and the revenue requirement to operate all the green mini-grids	

Depending on whether an average or a marginal energy generation mix is desired, a different configuration of plants and costs to compute the baseline generation cost is required. For example, the regulator might decide to compute just the last technology or plants being dispatched (for example heavy fuel oil generators).

Although not marked as input cells, users can change the titles of technologies if they wish to introduce a different fuel mix.

Many baseline mix technologies have fuel costs (oil, coal, gas etc.). There is a separate fuel unit conversion tool (see section 6.2) that allows the user to convert the fuel from other units to currency/MWh – for example from USD/barrel to USD/MWh.

4.2 Running the model

Here is a brief guide to running the green mini-grid model:

1. The version history tab can be used to keep track of cases or scenarios run in the model.

2. Users are advised to start from the dashboard on the DASHBOARD tab.

3. The dashboard contains a macro button linking to the inputs sheet (or users can select the INPUTS tab).

4. Input cells are coloured yellow. Selection boxes that allow an input format or assumption to be entered are green. These cells can (and should) be changed by users to match the case or scenario under consideration. Inputs are described in Section 2.1.

5. The underlying calculations are shown on the relevant worksheets. We suggest you avoid changing these calculations unless required. Calculation cells are white. Inactive calculations (for alternative scenarios) are grey.

6. In this case, unlike the IPP, there is no need to run a macro – the model calculations will update automatically.

7. View outputs by pressing the button on the dashboard (or by going to the OUTPUTS tab).

Access to selected model outputs: Outputs

Users can edit the outputs (or any part of the model) to suit their own requirements. See Section 4.4 for the standard outputs.

There is an additional macro within the inputs, which allows the user to calculate the subsidy required to deliver a particular average tariff level (for example, to ensure a single national tariff).

4.3 Calculations underpinning the model

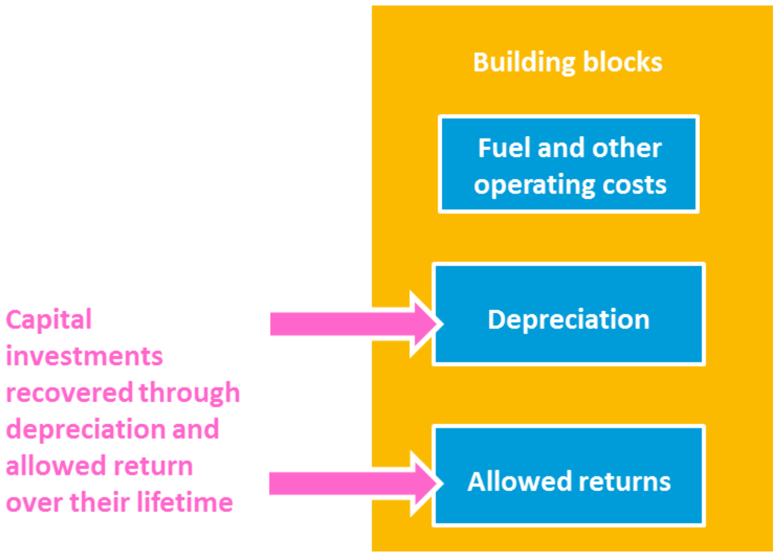
4.3.1 Reference project

For green mini-grids (GMGs), the approach for reference project is slightly different. This is because demand is also a factor in determining tariffs.

Tariffs for the GMG are modelled based on a revenue requirement approach, with building blocks as typically done for regulated network systems. End-users tariffs are obtained allocating revenue requirements across customers and then further split according to fixed and energy components.

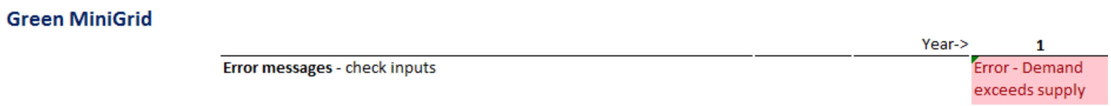
Under this approach, all cost items (Fuel and other O&M, depreciation and allowed returns) are calculated in real terms and used to build up the total required tariff in real terms. Then, for information purposes, inflation can be applied to the tariffs to convert them to nominal terms. This is the usual practice adopted in calculating returns for network regulated businesses.

Figure 20: Building blocks model



If the mini-grid is an isolated system, so it needs to balance both hour-by-hour and over the lifetime. We have two ways of reflecting this in the model:

1. When doing the modelling it is assumed that **thermal power generation is available to balance the system over the year**. The thermal capacity factor is reported in the inputs sheet based on the model calculations. You should check that the capacity factor is realistic for the plant used. If no thermal generation is used in the mini-grid, then the renewable generation will need to cover all demand. If it does not you will see this error in each year on the outputs sheet:



Once the inputs are corrected, the error message will be resolved:

2. The user can also use the inputs to represent any battery storage on the mini-grid. The battery storage will not increase the energy available to meet demand overall, but can shift it (for example, by making solar PV energy also available at night). The batteries or other storage will have a cost to run and an efficiency loss, so this is reflected in the financial model.

The associated calculations are given on the Reference GMG worksheet.

The modelling calculates the following information:

- **Demand (*rows 7 to 22*):** Demand (in energy and number of customers) is projected according to the initial values and year-on-year growth set in the inputs.

- **Generation Mix (*rows 24 to 34*):-** The thermal power generation is used to balance the system, after taking out the % supplied from the bulk system. In case the GMG is isolated, the share from the bulk system will be 0%. Row 34 shows the check that indicates generation and demand are balanced for the GMG. There should be enough thermal power generation capacity entered in the inputs to balance the GMG system.

- **Revenue Requirement**: tariffs for the GMG are modelled through a revenue requirement approach, as typically done for regulated network systems.

  Total Revenue Requirement = (O&M costs + Depreciation + Return on Capital).

- **Tariffs (*rows 153 to 211*):** End-users tariffs are obtained in 2 steps. (1st) allocating the Revenue Requirement to customer categories according to the data entered in the inputs. (2nd) distributing those allocated costs into fixed and energy components, also as per the inputs.

4.3.2 Avoided cost

For mini-grids, the avoided cost is the cost of the alternative scenario, that is to supply those same customers (i.e. demand) from the main system.

It considers the costs of bulk supply generation, transmission losses, transmission charges, distribution losses, distribution charges and main system extension costs (i.e. the additional direct cost to interconnect the GMG is computed).

4.3.3 System impact

The system impact is the projection of the avoided cost applied to the projected GMG development (number of future reference GMG over the years).

This is calculated for the reference GMG defined, in case multiple GMG with different characteristics and tariffs exist. The model should be run for all of them independently with their development scenarios.

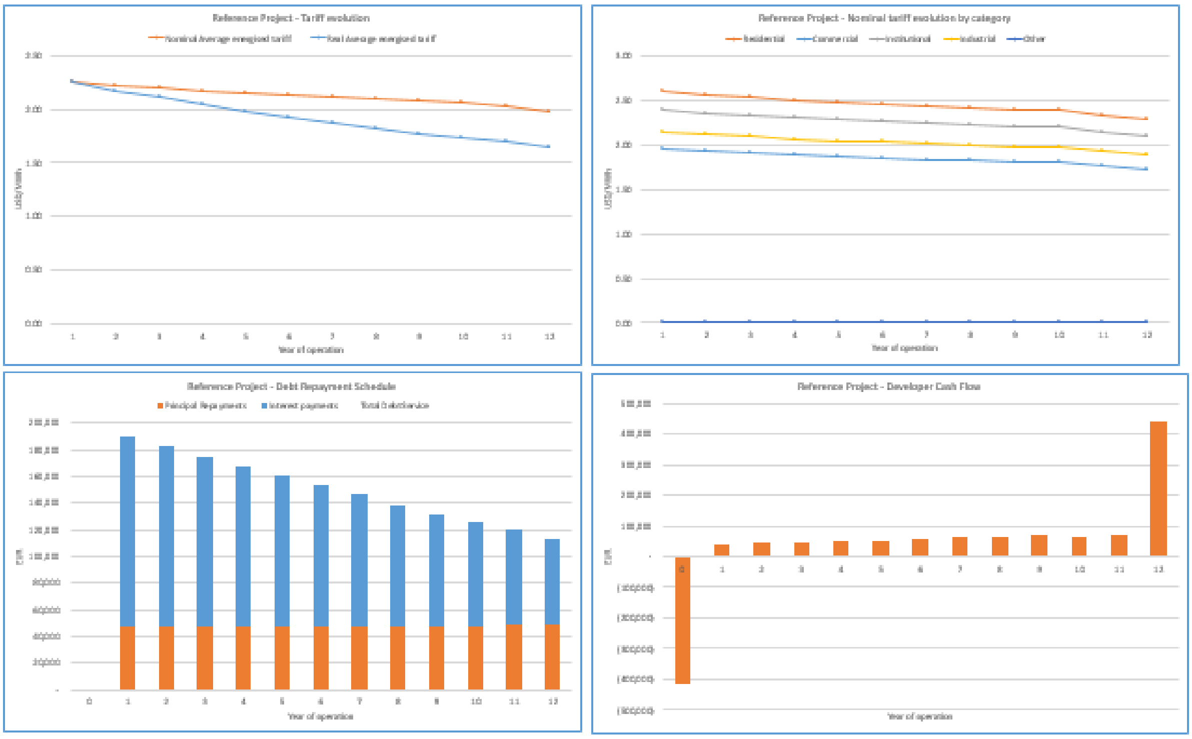
4.4 Outputs

4.4.1 Reference project

The outputs show the reference project tariff by customer class required to deliver the Equity IRR. This is given inclusive and exclusive of VAT.

There are also 4 graphs showing: tariff evolution, debt repayment schedule, free cash flow to the firm and free cash flow to equity.

Figure 21: Output graphs for the reference project



4.4.2 Avoided cost

For the avoided cost scenario, the model reports the Avoided Cost Tariff and the Equity IRR that investors in the reference project would receive if the project was paid the Avoided Cost Tariff.

4.4.3 System impact

For the first 10 years of output, the model reports the total energy produced by reference IPPs, and the tariff they are paid (in real terms), giving a resulting total tariff cost (in real terms) that the counterparty will have to meet.

4.5 Key questions

4.5.1 How to calculate the final tariff to be charge by GMG operators?

The user can calculate GMG tariffs based on either the cost of a reference project or the avoided cost of expanding the existing grid by changing the inputs to match the country specific data and technology under consideration.

To calculate the tariff for a reference project, the inputs will need to be changed for each specific mini-grid application, unless they are expected to be very similar. So the user would (for example) enter the input data for a project targeting a specific location and run the macro to calculate the required GMG tariff to make the project economic. This model could be saved under an appropriate name (e.g. "Location A 2017 – Model v0-1 - date") as a record of the calculations. The user can then start again with wind technology data, saving that as a new name (e.g. "Location B 2017 – Model v0-1 - date").

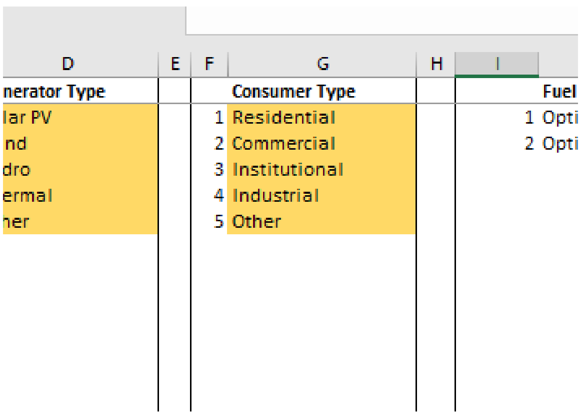
The version history worksheet can be used to keep track of the review process.

The reference project module calculates the tariff, based on an input rate of return. It is important to have good data for all reference project inputs to ensure the calculated tariff both gives a fair return to the investor and is the lowest tariff that ensures that fair return.

The avoided costs module calculates the tariff as the avoided cost of expanding the main interconnected network and increasing generation to meet the demand in that location. Unlike for the IPP, this tariff will be location dependent as it will cost different amounts to expand the network to each location.

4.5.2 How can I change names for types of customers?

It is simple to change the customer names using the Lists sheet. Simply overwrite the labels to your preferred names:



The names should change throughout the model to match your preferences.

4.5.3 Should the independent power generator have a social obligation to ensure the operation and maintenance of a mini-grid?

The choice of how each country sets out the obligations in a green mini-grid is a matter for the national policy.

You could choose to make it possible for green mini-grids to be set up and operated by independent developers, who would also operate the mini-grid. In that case, they would typically have performance obligations in their contract (including operation and maintenance). They would also have a financial incentive to maintain the mini-grid, as otherwise they would not be able to recoup their initial capital costs through the tariffs to customers.

4.5.4 Can the mini-grid tariff take subsidies into account?

Yes. The model allows the user to input both the initial subsidies and grants and any ongoing annual subsidies or grants during operation.

4.5.5 What is the cost of tariff for rural communities as against urban settings?

The model can calculate the tariffs needed for specific mini-grid locations, provided you have the input data. Typically, you may expect urban settings to be covered by a main interconnected system and mini-grids to be applied in rural settings. Therefore, the GMG required tariff can be compared to the national tariff.

4.5.6 What is the billing type if a flat tariff is applied? (subscription type)

The model allows the user to specify how much of the total cost is recovered through fixed charges and how much through unit charges. If you set the "costs to energy charge" to zero you will see the impact of charging just a fixed charge.

Cost to energy charge	Cost to fixed charge
100.00%	0.00%
75.00%	25.00%
75.00%	25.00%
75.00%	25.00%
75.00%	25.00%

Since the developer faces high capital costs, they may prefer a model that allows them to recover those costs reliably.

However, we would sound a note of caution: if a developer see the same revenue whether they produce electricity or not, they may be less focused on maintenance and production if the income is all on a fixed charge. Therefore, we would normally expect a combination of both fixed and energy payments.

4.5.7 How can a mini-grid tariff be in accordance with the uniform tariff principle?

Once the mini-grid tariff is determined in a neutral manner, what is obtained can be called "technical tariff". This technical tariff is necessarily unique to the mini-grid studied and therefore does not need to match the uniform tariff in the country.

What happens is that once that technical tariff is determined, the applied tariff does not need to match it. The applied tariff for the mini-grid can be set at the uniform tariff level as long as a compensation mechanism is in place to make up for the gap in between the technical tariff and the applied tariff.

There are multiple options, but the easiest one is to calculate the uniform tariff for all system costs (including the mini-grid costs). Then that uniform tariff is applied to all electricity consumers, regardless of whether they are served from the main interconnected system or from a mini-grid. Since the mini-grid operator is only collecting the uniform tariff (applied tariff), which is usually lower than the technical tariff the operator would be entitled to receive, the main interconnected system operator (who is over-collecting money, because the uniform tariff in his case is higher than it would be required for him) should transfer the difference to cover the gap of the mini-grid operator. Alternatively, the subsidy could be provided by Government or by donor finding. Whatever the source, it is useful to be able to calculate the subsidy needed.

The mini-grid model supports this approach, because it allows the user to calculate the technical tariff required by the mini-grid, and then to calculate the subsidy needed to reduce this tariff to the national tariff.

The user simply enters the desired average tariff for the mini-grid, and presses the "Calculate Subsidy macro button. The macro goal seeks the required subsidy by iteration and enters the results in the per year subsidy in the inputs.

The desired tariff must be entered for all years, otherwise the macro will assume blank years need a subsidy to bring the tariff to zero!

Figure 22: Macro to calculate required subsidy

		Year:	1	2	3
Subsidies during Operation	EUR/year		8,084.06	9,180.65	11,462.03
Grants during Operation	EUR/year		-	-	-

If so desired, you can enter a Target Tariff per year and then click the Calculate Subsidy button below to automatically calculate the subsidy level required to obtain the target tariff

Calculate Subsidy

		Year:	1	2	3
Target Average Tariff (real terms, taxes excluded)	EUR/kWh		2.60	2.50	2.40

To reverse this step, simply delete the subsidy.

An additional feature is that you can choose to subsidise individual customer categories only.

If this is required, the user enters the % subsidy on the tariff (for example, if the required tariff is 40 cents/kWh and the user wishes this to be reduced to 20 cents/kWh for a particular consumer group, they would set the subsidy to 50% for that consumer group).

Figure 23: Subsidy for a given category

Subsidy for this category only %
50.00%
0.00%
0.00%
0.00%
0.00%

In this case, the user can see the required subsidy per year in the outputs.

4.5.8 Can you have a different tariff by time of day?

The model is not designed to have different tariffs by time of day because (1) it is a significant increase in calculation time (like that in the prosumer model) and (2) that would require a lot more information about the consumers consumption profile than is typically known for a new mini-grid, which is often in an area that has not been reliably supplied in the past. For simplicity and ease of use, this function was not added.

An operator may desire to have a different tariff, for example to encourage more use when the sun is shining and solar panels are generating. Provided the average tariff he proposes (weighted by use at that time) matches the average tariff from this model, that may be acceptable. It is up to policy makers and regulators to decide if that is appropriate for the specific application.

4.5.9 What is the impact of production cost over national power generation tariff?

The detailed calculations of the mini-grid tariffs separately calculate required revenues (O&M, Depreciation and Return on Capital) for the generation and the network activities that are inherent to a mini-grid. But mini-grids should be understood as a single business, at least at the time of their conception, and there are general costs that are not directly linked to generation or to networks, but are general to the mini-grid operation.

In the calculations the user will be able to check the average energised tariff for the mini-grid, as well as its two components: average generation tariff and average network tariff, after allocating general costs on a proportional basis.

4.5.10 Avoided cost – can it consider charging phones, etc., diesel gensets?

Avoided cost calculation already takes that into account, as it is including the alternative costs of generation associated with what is defined as baseline. If the baseline is defined to include diesel genset or other forms of alternative supply (past, present or future) then the avoided cost will also include them.

The model takes into account as externality only the reduction in GHG emission obtained from replacing baseline generation by renewable energy generation. The range of other possible externalities is very broad and their valuation should be done ad-hoc. For example, improved quality of life from lower noise and diesel fumes.

4.5.11 What tariff model would best address the need to assure the sustainability of the grid and the problem of affordability by the consumers who would be of the low-income category?

This is a policy issue, social and energy policy are involved. The objective of the toolbox is to provide the information on the technical tariff that is required to make the business sustainable for the project developer/operator. That is a key input to policy design, but not the only one. That technical tariff needs to be compared with i) the tariff paid by other consumers in the country and ii) the willingness-to-pay for electricity of the consumers that will be served by the mini-grid.

It is important to keep in mind that the tariff charged to mini-grid consumers (applied tariff) does not need to equal the technical tariff. As long as an adequate scheme is set in place to ensure the mini-grid developer/operator recovers the recognised revenue, multiple schemes are possible to apply affordable tariffs to mini-grid consumers.

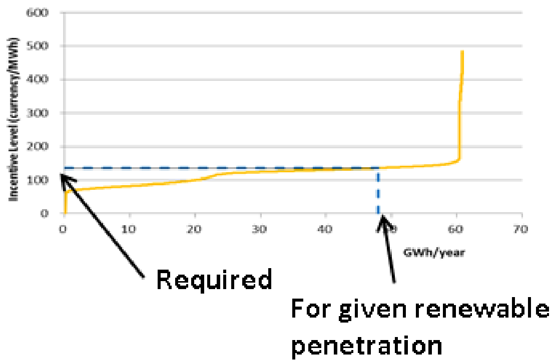
4.5.12 Appropriate tariffs (cost reflective or with the option for defined subsidies to reach a desired "maximum tariff") for off-grid mini-grid systems or other contexts where wider network or other costs need to be considered?

It is a good exercise to first calculate a neutral tariff without any form of subsidy or grant, to know the non-subsidized technical tariff level that would be required by the project. Then the user can change the input on grants/subsidies to the mini-grid project and observe the evolution of output tariffs until it feels the resulting tariff is within this desired "maximum tariff" threshold.

The model offers the user the option to automatically obtain the subsidy that would be required every year to obtain a certain applicable tariff level (maximum tariff). This can be done in the "Inputs" sheet, at the end of the Reference Project section.

5 Supply Curve Model

The objective of the supply curve model is to identify a required incentive level to reach a certain renewable energy penetration level in a year given various renewable energy technologies which are available (wind, solar PV, concentrating solar power (CSP), geothermal and biomass).



5.1 Approach

A target IRR defined for each renewable technology plant, and a number of simulations are run for each renewable energy technology in which the investment costs, load factor, fuel and O&M costs are assumed to follow a uniform distribution in between a minimum and maximum range.

For each simulation, an energy tariff is calculated which allows the target IRR to be achieved. The supply curve is then built up on the cumulative large set of renewable energy tariffs associated to each individual project. This effectively constitutes a supply curve of the potential renewable energy market.

5.2 Inputs

Name	Input format	Unit	Description	Impact	Cell reference
Basic data					
Currency unit	String	-	This input is for display purposes only (i.e. USD, EUR, GBP)	Display only	B46
Base Year	Integer	Date year	Start date for cost inflation (e.g. 2016)	The year when real prices are based and also the year on which inflation starts (if inflation is activated). Cost inputs should be	C46

Name	Input format	Unit	Description	Impact	Cell reference
				expressed in prices of the Base Year.	
Project - Year #0	Integer	Date year	Start date for projection (e.g. 2017)	This is the year for which the supply curve is calculated, it is also the year before the assumed entry into operation of the simulated renewable projects (which is Year 1).	D46
#Years (available projection data)	Integer	Years	Duration of overall projection, maximum of 60 years	Years used to project future cashflows and thus calculate the LCOE of individual projects.	E46
Capital Structure					
Equity Ratio	Float	%	The percentage of investments financed with equity.	The higher the equity ratio, the higher the average required return, and thus higher LCOE.	F46
Cost of Equity	Float	%	Target IRR (post-tax nominal) required for equity	Model macro iterates to find tariff that gives this return to investors in the individually simulated projects used to build the supply curve.	G46
Loan rate	Float	%	Interest rate (pre-tax nominal)	Interest payments to be passed-through into the tariffs.	H46
Loan Maturity	Integer	Years	The repayment period of loans	Principal repayments to be passed-through into the tariffs.	I46
Tax Structure					
VAT	Float	%	The electricity sales VAT in the country being considered	Increases calculated required tariff by VAT (and LCOE for baseline alternatives)	K46
Profits tax	Float	%	The corporate profit tax in the country over profit	Tax applied to financial model of each project. In the supply curve approach no fiscal or tax incentives are modelled. This assumption is made to manage the complexity of the model.	L46
Other taxes	Float	Unit/MWh	Any tax expressed on electricity output	Tax applied to financial model of each project	M46
Amortization period	Integer	Years	Depreciation period (for profit and taxation purposes)	Depreciation period	N46

Name	Input format	Unit	Description	Impact	Cell reference
Inflation parameters					
Real/Nominal	String	-	Selection sets the model to consider values to be in real or nominal terms, and thus consider or not inflation.	Calculation using inflation on a year by year basis or not.	O46
Expected annual inflation factor	Float	%	This is the inflation projection for the project lifetime. Note the first year of operation has by default zero inflation)	Inflation applies to energy and capacity prices used in revenue forecasts and to non-fuel OPEX.	P46
Technical data for 5 technologies					
Technology name	String	-	Name to identify the technology type	Display only	B51:55
Total Potential	Float	MW	Maximum potential installed capacity in country for technology type. Typically a physical potential based on national studies.	Sets the threshold to not be overshot. If a target is set above threshold, not result is found.	C51:55
Avg Plant Efficiency	Float	%	Fuel conversion efficiency (zero for unfuelled plants).	Input to net electricity production	D51:55
Internal Consumption	Float	%	Internal electricity consumption (not available to export to grid).	Input to net electricity production	E51:55
Degradation - 1st yr	Float	%	The yearly capacity degradation factor applicable to plants of the technology type	Input to net electricity production	F51:55
Degradation - 2nd-6th yr	Float	%	The yearly capacity degradation factor applicable to plants of the technology type	Input to net electricity production	G51:55
Useful life	Integer	Years	Lifetime of generation.	Period considered to calculate LCOE for each project.	H51:55
Capacity factor (min/max)	Float	%	The capacity factor for the technology in question.	Input to net electricity production (and range used in simulations)	J51:K55
Investment Cost:					
Investment cost	Float	Currency/ kW	Overnight capital costs (min/max range)	Capital costs (and range used in simulations)	C60:D64
Non-fuel O&M Costs:					

Name	Input format	Unit	Description	Impact	Cell reference
Fixed O&M Cost	Float	Currency/ kW year	Annual expected operations and maintenance costs (min/max range)	Operational costs (and range used in simulations)	C69:D73
Other costs					
Fuel Cost	Float	Currency/MWh	Expected fuel cost (min/max range) – fuelled plant only.	Operational costs (and range used in simulations)	C78:D82
Right for use of land	Float	Currency/ kW	Cost of right for use of land	Capital costs	H78:82
Grid connection	Float	Currency/ unit	Cost of grid connection	Capital costs	I78:82
Construction parameters					
Construction Period	Integer	Years	Construction period (max 3 years)	Capital cost profile	J78:82
Year -2	Float	%	% of construction cost in year -2 (3 years before operation)	Capital cost profile	K78:82
Year -1	Float	%	% of construction cost in year -1 (2 years before operation)	Capital cost profile	L78:82
Year 0	Float	%	% of construction cost in year 0 (year before operation)	If construction period is set to 1, this is automatically 100%, else it is calculated as the difference between 100% and the cumulated progress in year -1 and -2.	M78:82
Cost Drivers Percentiles	Float	%	Percentages that represent how costs are distributed in the range between the Min and the Max.	They define what values projects can take in between the Min and the Max range.	C89:F92

Technical data can be entered for five renewable technologies. The technology titles can be changed by the user.

5.3 Running the model

Here is a brief guide to running the supply curve model:

1. The version history tab can be used to keep track of cases or scenarios run in the model.

2. Users are advised to start from the dashboard on the Supply Curve Control Panel tab, which contains both the inputs, outputs and macros to run the model.

3. Input cells are coloured yellow. Selection boxes that allow an input format or assumption to be entered are green. These cells can (and should) be changed by users to match the case or scenario under consideration. Inputs are described in Section 2.1.

4. The underlying calculations are shown on the relevant worksheets. We suggest you avoid changing these calculations unless required. Calculation cells are white. Inactive calculations are grey.

5. Run the macro at the top of the worksheet to update the model calculations (to run all the scenarios that give the range of possible projects).

Calculate energy tariffs

6. You will see a progress bar showing the project simulations.

7. The results are shown in two graphs.

Users can edit any part of the model to suit their own requirements. However, we would recommend only expert users familiar with macros do so for this model.

5.4 Calculations underpinning the model

- For each renewable energy technology a total of 256 simulations are carried out (1,280 simulations in total).
- In each simulation the investment costs, load factor, fuel and O&M costs are uniformly adjusted using the cost driver percentiles.
- Each simulation is a financial model for that project, much like those for the renewable IPP reference project model.
- For each combination of inputs for each generator, an energy tariff is solved which allows the target IRR (cell J46) to be achieved.
- By clicking the macro all 1,280 simulations are solved (a progress bar shows the status of the solves).

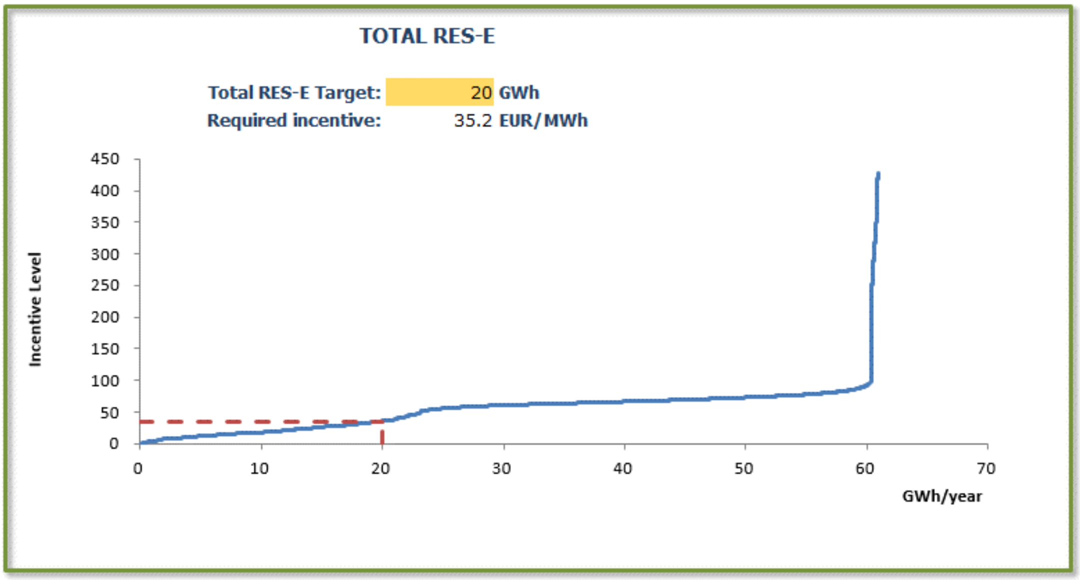
5.5 Outputs

5.5.1 Across all technologies

The first graph shows the total electricity from renewable energy sources (RES-E). It is a supply curve, and by entering a target renewable generation (in GWh), and the chart will output the required incentive to achieve this.

- Once the macro is solved, cell C21 can be adjusted to reflect a desired RES-E target.
- Cell C22 will then show the required incentive which will be required to reach such levels of renewable penetration.

This is the price required to archive the target renewable energy level (the target renewable level is met by finding the price needed to meet the required returns for each simulated project that forms the supply curve).



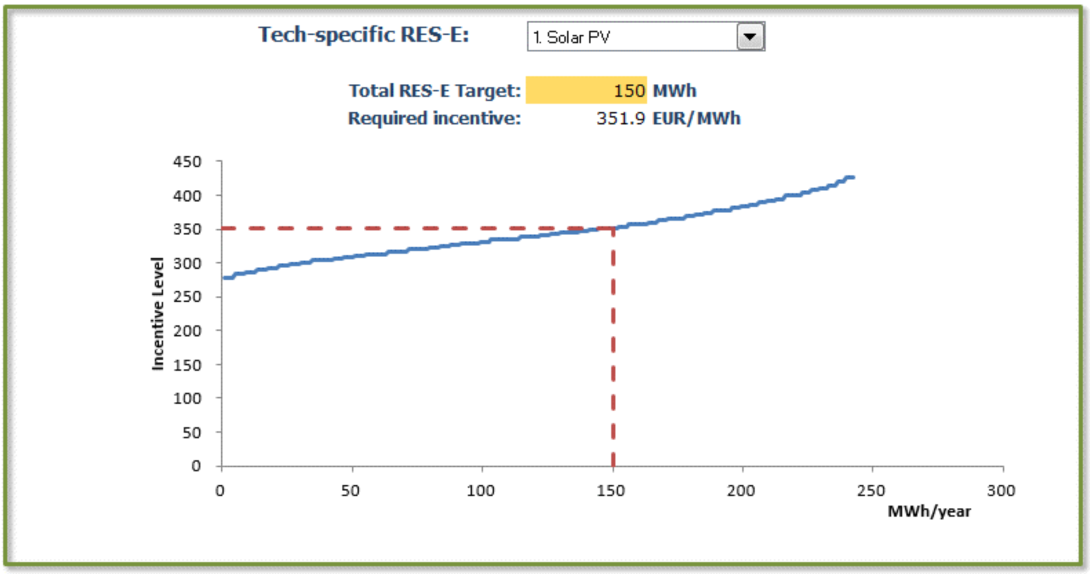
5.5.2 Technology specific

The second graph allows the user to consider technology-specific tariffs. It is a supply curve, and by entering a technology-specific generation target (in MWh), the chart will output the required incentive to achieve this.

- If you want to see the required incentive tariff required for a specific technology type, this can be done by selecting the specific technology on the toggle.
- Once the macro is solved, cell N21 can be adjusted to reflect a desired RES-E target.

- Cell N22 will then show the required incentive which will be required to reach such levels of technology-specific renewable penetration.

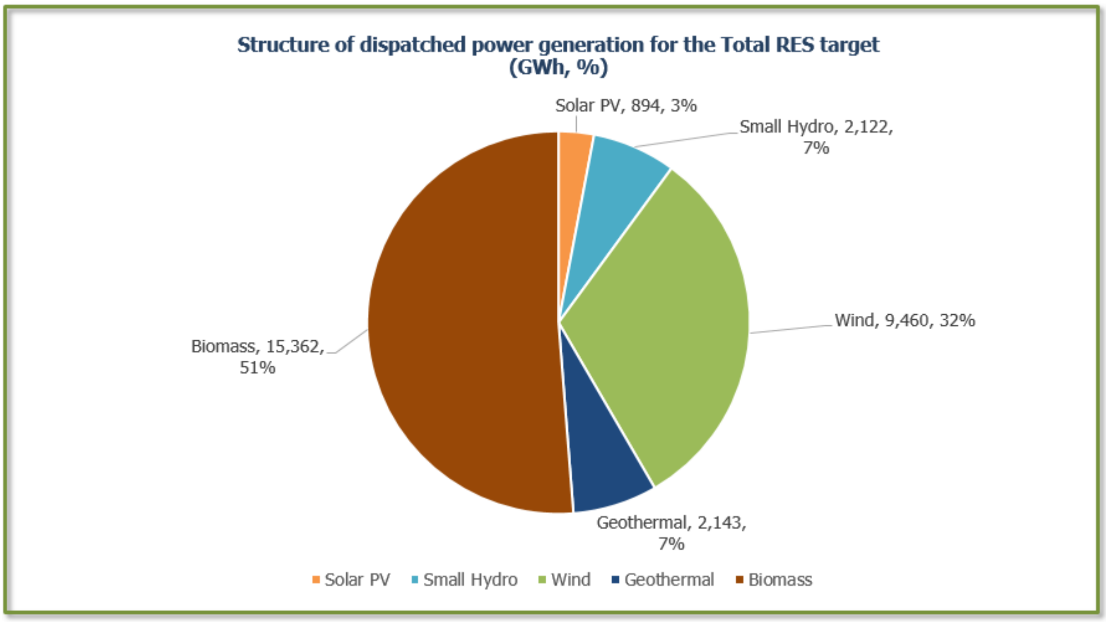
As before, this is the payment required to achieve the target.



5.6 Energy mix for RES-E target

The third chart is a pie chart of the electricity mix that makes up the target renewable generation (in GWh) set in cell C21.

Figure 24: Power generation sources making up the target



5.7 Key questions

From the key questions, this model can be used to calculate the marginal pricing needed to achieve a desired level of renewable penetration.

It is possible to calculate not only overall renewable energy penetration target pricing but also set specific targets for different technologies.

This analysis does not replace the reference project or avoided cost analysis that should also be carried out to value specific developments, but it completes them providing a more general view on the aggregate of the power system.

6 Additional supporting workbooks

There are two workbooks that help convert input data into the formats required for the other models:

- One model helps the user estimate wind power capacity factors. This is useful if you have wind speed data and wish to calculate an estimated capacity factor.
- The other model helps the user to convert fuel costs (which may be in a wide variety of units) into the units of currency/MWh that are required for the other models.

6.1 Wind power capacity profiles

This model helps the user estimate wind power capacity factors. This is useful if you have wind speed data and wish to calculate an estimated capacity factor.

6.1.1 Inputs

Table 7: General inputs

Name	Input format	Unit	Description	Impact	Cell reference
Project name	String	Text	Name of project or other identifier	For user reference only	C5
Location	String	Text	Location of project or other identifier	For user reference only	C6
Wind Turbine Data					
Type	String	Text	Type of turbines that would be built at that location (for reference project)	For user reference only	C9
Manufacturer	String	Text	Manufacturer of turbines that would be built at that location (for reference project)	For user reference only	C10
Power capacity	Float	MW	Power capacity of reference turbine (must be consistent with power aero data)	For user reference only, not used in calculations	C11
Wind measurement data (met mast)					
Metering height	Float	metres	Height of mast used to collect wind speed data	Used to calculate Weibull Parameters to give probabilistic wind distribution around mean	C14
Rotor height	Float	metres	Height of rotor of the proposed reference wind turbine (hub height)	Used to calculate Weibull Parameters	C15
Average speed	Float	m/s	Average (arithmetic mean) wind speed measured	Used to calculate Weibull Parameters	C16

Name	Input format	Unit	Description	Impact	Cell reference
Stand dev	Float	m/s	Standard deviation of wind speed measured	Used to calculate Weibull Parameters	C17
Hours in Year	Integer	hours	Input parameter, will typically be 8,766 hours to take into account leap years	Used to scale up probability adjusted output by hours in year to give expected MWh.	C18
Range	Float	m/s	Lower and upper bounds of wind speed from manufacturer's power curve	Power output based on wind speed.	A29:C44
Power aero	Float	kW	Power aero for that wind speed range from manufacturer's power curve	Power output based on wind speed.	F29:F44

6.1.2 Running the model

The model is simple to run, simply enter the required inputs and the outputs will be calculated automatically. The main model is on a single worksheet, with further sheets for version history and cover page.

6.1.3 Calculations underpinning the model

The model assumes a probabilistic (Weibull) distribution of wind speeds based on the average wind speed and standard deviation. This allocates a probability of measurements in each of the ranges in the power curve.

The Weibeull distribution, that is, the wind power density function, is defined by two parameters: shape "k" and scale "c". The numerical method selected to determine those parameters is the empirical method of Lysen[5], In this method:

- Parameter "k" is calculated as:

$$k = \left(\frac{wind\ speed\ standard\ deviation}{average\ wind\ speed}\right)^{-1.086}$$

- Parameter "c" is obtained as:

[5] Introduction to Wind Energy, E.H. Lysen, 1983.

$$c = average\ wind\ speed \cdot \left(0.568 + \frac{0.433}{k}\right)^{-1/k}$$

Wind data is then extrapolated from the metering height (h1) to the rotor height (h2) using the logarithmic method (where hr is a reference height of 10m for which the formula parameters were obtained):

$$c2 = c1 \cdot \frac{h2}{h1}^{\left(\frac{0.37-0.088\cdot\ln(c1)}{1-0.088\cdot\ln(\frac{h1}{hr})}\right)}$$

$$k2 = k1 \cdot \frac{1 - 0.088 \cdot \ln(\frac{h1}{hr})}{1 - 0.088 \cdot \ln(\frac{h2}{hr})}$$

The power aero from the manufacturer gives the expected kW output in that wind speed range.

The power aero is multiplied by the probability of wind speeds being in that range to give a probability adjusted output. The probability adjusted output is then multiplied by hours in the year to give the expected electricity output in MWh.

6.1.4 Outputs

The model reports annual energy production outputs as follows:

- Wind energy delivered in MWh,
- Capacity factor (%), and
- Equivalent Full Load Hours.

These outputs are useful as inputs in the other models.

6.2 Fuel Unit Conversion Tool

This model helps the user to convert fuel costs (which may be in a wide variety of units) into the units of currency/MWh that are required for the other models. For example, the user may wish to convert procurement of heavy fuel oil in US$/barrel or coal in US$/tonne into US$/MWh so it can be used in their renewable IPP model.

6.2.1 Inputs

Name	Input format	Unit	Description	Impact	Cell reference
Fuel Type	String	Text	Name of project or other identifier, selection box.	Selects the fuel parameters for conversion	D5
Heating Value: Standard or User Defined?	String	Text	Select whether to enter a heating value or use one from a predefined list in "Fuel Data - heating values" sheet	Input to conversion calculation to currency/MWh	D6
Lower Heating Value (LHV) or Higher Heating Value (HHV)?	String	Text	Select whether to use higher or lower heating value	Changes conversion calculation to currency/MWh	D7
User defined entry (for LHV or HHV)	Float	User can select units	If user defined selected above, input figure, and select the applicable units.	Allows user to enter their own heating value. Units for the heating value can be selected in drop down boxes F9 and F10.	D9
Fuel Price Input	Float	User can select units	User input figure for fuel cost, and select the applicable units.	Input to convert units into currency/MWh. Units for the fuel price input can be selected by entering the currency in cell F15 and selecting the unit in drop down box F16.	D15

6.2.2 Running the model

The model is simple to run, simply enter the required inputs and the outputs will be calculated automatically. The inputs and outputs are on a single worksheet, with further sheets for the detailed conversion of heating values and conversion of units, as well as the usual version history and cover page.

6.2.3 Calculations underpinning the model

While the model is simple, some of the underlying calculations are less simple because of the number of units that are typically used in the energy sector.

The worksheet "fuel data – heating values" uses standard data (Argonne National Laboratory, 2016) and converts it to a format the model can "read".

The worksheet "unit conversion calculations" uses information on fuel density and standard conversions to create a matrix that can convert the units of any fuel between energy, volume and mass units that are commonly used to price energy commodities.

The input and output sheet accesses these conversion factors to allow the user to convert easily between these units.

6.2.4 Outputs

The output is a single fuel cost figure in currency/MWh that is used as an input to the other models. For this toolbox we always want the output in currency per MWh. In fact, for other conversions a different output unit can be chosen, which gives the model the widest possible applicability.

7 Reference Input Data

We have been asked to collate some reference input data to support ECOWAS countries in populating the model.

The data provided is extracted from the reference sources given. In some cases we have converted unit, but we have not validated the data. EMRC does not warrant the accuracy of this information, nor its suitability to be applied in any particular case. Users of the model should use due caution and refer to the data sources before deciding if this input data is applicable to their circumstances. In most cases, national data that takes into account local logistical and other considerations should be preferred to generic international information.

7.1 Reference Technology Costs

In the tariff models, we neglect scrap values at the end of life, as they have been estimated to be close to decommissioning costs and the discounted value of the difference at the end of life is expected to be very small (Pueyo, Bawakyillenuo, & Osiolo, 2016).

7.1.1 Wind

Production Inputs

Input	Unit	Min range	Max range	Source (and notes)
Annual Capacity Degradation	%	1.4%	1.8%	Based on UK data, depends on wind speed (Pueyo, Bawakyillenuo, & Osiolo, 2016)
Project Useful Life	Years	25	25	International (IRENA, 2015)
Capacity Factor	%	18%	54%	International (IRENA, 2016b), 30% average (Pueyo, Bawakyillenuo, & Osiolo, 2016)

OPEX Inputs

Excludes country-specific cost of importing equipment and labour.

Input	Unit	Min range	Max range	Source (and notes)
Fixed O&M	USD/year	1.5%	3%	% capex per year (IRENA, 2016b)

CAPEX Inputs

Excludes grid connection costs (country specific).

Input	Unit	Min range	Max range	Source (and notes)
Installed cost	USD/MW	1,560,000	2,540,000	Upper range from Kenya and Ghana (Pueyo, Bawakyillenuo, & Osiolo, 2016), lower range global average (IRENA, 2016b)

7.1.2 Solar PV

Production Inputs

Input	Unit	Min range	Max range	Source (and notes)
Annual Capacity Degradation	%	0.5%	0.5%	No range given (Pueyo, Bawakyillenuo, & Osiolo, 2016)
Project Useful Life	Years	10	25	(IRENA, 2016a)
Capacity Factor	%	10%	30%	(IRENA, 2016b)

OPEX Inputs

Excludes country-specific cost of importing equipment and labour. Excludes battery systems.

Input	Unit	Min range	Max range	Source (and notes)
Fixed O&M	USD/year	10,000/MW	30,000/MW	O&M costs for utility-scale plants in the United States (IRENA, 2016b) – or 1% of capex (Pueyo, Bawakyillenuo, & Osiolo, 2016)

CAPEX Inputs (utility scale)

Excludes grid connection costs (country specific). Excludes battery systems.

Input	Unit	Min range	Max range	Source (and notes)
Total installed cost (Africa)	USD/MW	1,400,000	3,000,000	Likely achievable only close to major ports where transport costs are low and there is access to civil engineering expertise (IRENA, 2016a)

CAPEX Inputs (rooftop grid connected >1kW)

Excludes grid connection costs (country specific). Excludes battery systems.

Input	Unit	Min range	Max range	Source (and notes)
Total installed cost (Africa)	USD/MW	2,000,000	3,000,000	Based on systems mostly concentrated in North Africa and South Africa (IRENA, 2016a)

7.1.3 Biomass

Production Inputs

Input	Unit	Min range	Max range	Source (and notes)
Annual Capacity Degradation	%	0.3%	0.4%	As a rule of thumb you may deduct 2.5 – 3.5 % during the lifetime (e.g. from 40% to 37%).
Project Useful Life	Years	20	25	(IRENA, 2015) (IRENA, 2012) (ARUP , 2016)
Capacity Factor	%	85	85	(IRENA, 2012)

Non-Fuel OPEX Inputs

Excludes country-specific cost of importing equipment and labour.

Input	Unit	Min range	Max range	Source (and notes)
Fixed O&M	USD/MW/year	3%	6%	% capex per year (IRENA, 2012)
Fuel costs – agricultural residues	USD/MWh	3.5	11.4	USD 20 – 50/tonne for agricultural residues. Higher heating value for agricultural residues 15.8 – 20.5 MJ/kg. (IRENA, 2012)
Efficiency	%	36%	36%	For stoker (IRENA, 2012)
Variable O&M	USD/MWh	5	12	Lower limit (IRENA, 2012), upper limit (ARUP , 2016)

CAPEX Inputs

Excludes grid connection costs (country specific).

Input	Unit	Min range	Max range	Source (and notes)
Installed cost	USD/MW	3,171,000	4,594,000	Based on an exchange rate of $1.29/£1 (ARUP , 2016)

7.1.4 Small Hydro

Production Inputs

Input	Unit	Min range	Max range	Source (and notes)
Annual Capacity Degradation	%	0	0	No significant degradation (Parsons Brinckerhoff, 2011)
Project Useful Life	Years	30	30	No range given (IRENA, 2015)
Capacity Factor	%	34%	50%	Kenya and Ghana (Pueyo, Bawakyillenuo, & Osiolo, 2016)

OPEX Inputs

Excludes country-specific cost of importing equipment and labour.

Input	Unit	Min range	Max range	Source (and notes)
Fixed O&M	USD/year	1.5%	2.8%	% of capex per year (Pueyo, Bawakyillenuo, & Osiolo, 2016)

CAPEX Inputs

Excludes grid connection costs (country specific).

Input	Unit	Min range	Max range	Source (and notes)
Installed cost	USD/MW	2,500,000	3,200,000	Kenya and Ghana (Pueyo, Bawakyillenuo, & Osiolo, 2016)

7.1.5 Battery Storage

Production Inputs

Input	Unit	Min range	Max range	Source (and notes)
Levelized cost of storage (mini-grid)	USD/MWh	372	507	Based on a lithium ion battery in a microgrid system, storing around 1,400 MWh/year (Lazard, 2016)
Levelized cost of storage (commercial)	USD/MWh	624	1,234	Based on a lithium ion battery in a commercial system,

Input	Unit	Min range	Max range	Source (and notes)
				storing around 50 MWh/year (Lazard, 2016)
Efficiency of storage	%	92%	93%	Lithium ion battery (Lazard, 2016)

7.2 Financing inputs

Some data is available, for example:

- Report of experience in Kenya and Ghana (Pueyo, Bawakyillenuo, & Osiolo, 2016), and
- Cost of financing used for tariff mode Nigeria (Nigerian Electricity Regulatory Commission, 2016).

However, this is very country dependent so we have not provided the breakdown here.

7.3 Baseline Energy Mix

The proportion of each technology in the generation mix and plant size is very country dependent. Exiting plant should be based on actual data where available.

7.3.1 Coal

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	3,535,000	3,535,000	Advanced super critical with SO2 and NOx controls (National Renewable Energy Laboratory, 2016)
Lifetime of Investment	Years	32	40	(Mott MacDonald, 2010)
GHG Emissions Factor	tCO_2e/MWh	0.786	0.990	(Houses of Parliament, 2011)
Capacity Degradation Factor	%	2.9%	3%	(Mott MacDonald, 2010)
Efficiency	%	42.9%	44.9%	(Mott MacDonald, 2010)
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	45%	100%	(Mott MacDonald, 2010)
Non-fuel OPEX, Initial Year	USD/MW			
– Fixed	USD/MW	32,000	32,000	(National Renewable Energy Laboratory, 2016)
– Variable	USD/MWh	5	5	(National Renewable Energy Laboratory, 2016)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.2 Stored Hydro

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	1,005,000	4,251,000	Lower range (Pueyo, Bawakyillenuo, & Osiolo, 2016) Upper range (ARUP , 2016)
Lifetime of Investment	Years	30	30	In fact, lifetimes are longer, but electromechanical plant may need to be replaced at this point.
GHG Emissions Factor	tCO_2e/MWh	0	0	Zero carbon.
Capacity Degradation Factor	%	0	0	No significant degradation (Parsons Brinckerhoff, 2011)
Efficiency	%	100%	100%	Not relevant for hydro
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	50%	60%	(Pueyo, Bawakyillenuo, & Osiolo, 2016)
Non-fuel OPEX, Initial Year	USD/MW	1%	1.7%	Lower range (Pueyo, Bawakyillenuo, & Osiolo, 2016) Upper range (ARUP , 2016)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.3 Natural Gas – Open Cycle Gas Turbine

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	$869,000	$869,000	USA (National Renewable Energy Laboratory, 2016)
Lifetime of Investment	Years	20	20	USA (National Renewable Energy Laboratory, 2016)
GHG Emissions Factor	tCO_2e/MWh			
Capacity Degradation Factor	%	3,5 %	3,6 %	(Mott MacDonald, 2010)
Efficiency	%	38.3%	42.2%	LHV (LeighFisher Ltd, 2016)
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	5%	30%	USA (National Renewable Energy Laboratory, 2016)
Non-fuel OPEX, Initial Year				
– Fixed	USD/MW	7,000	7,000	USA (National Renewable Energy Laboratory, 2016)
– Variable	USD/MWh	13	13	USA (National Renewable Energy Laboratory, 2016)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.4 Natural Gas – Combined Cycle Gas Turbine (CCGT)

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	$1,017,000	$1,017,000	USA (National Renewable Energy Laboratory, 2016)
Lifetime of Investment	Years	20	35	USA (National Renewable Energy Laboratory, 2016), (LeighFisher Ltd, 2016)
GHG Emissions Factor	tCO_2e/MWh	0.365	0.488	(Houses of Parliament, 2011)
Capacity Degradation Factor	%	3.5%	3.6%	(Mott MacDonald, 2010)
Efficiency	%	58.8%	60.7%	LHV (LeighFisher Ltd, 2016)
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	48%	87%	USA (National Renewable Energy Laboratory, 2016)
Non-fuel OPEX, Initial Year				
– Fixed	USD/MW	14,000	14,000	USA (National Renewable Energy Laboratory, 2016)
– Variable	USD/MWh	3	3	USA (National Renewable Energy Laboratory, 2016)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.5 Heavy Fuel Oil

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	650,000	1,400,000	Lower range (Baurzhan & Jenkins, 2017), upper range (AF Mercados EMI, 2012)
Lifetime of Investment	Years	20	20	(Department of Business, Energy and Industrial Strategy, 2016a)
GHG Emissions Factor	tCO_2e/MWh	0.778	0.778	(Baurzhan & Jenkins, 2017)
Capacity Degradation Factor	%	1%	1%	(Baurzhan & Jenkins, 2017)
Efficiency	%	34%	42%	(Department of Business, Energy and Industrial Strategy, 2016a), (Baurzhan & Jenkins, 2017)
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	1%	84%	Depends on whether run as peaking or baseload.
Non-fuel OPEX, Initial Year	USD/MW			
– Fixed	USD/MW	13,000	13,000	(Department of Business, Energy and Industrial Strategy, 2016a)
– Variable	USD/MWh	3	4	(Department of Business, Energy and Industrial Strategy, 2016a), (Baurzhan & Jenkins, 2017)

Input	Unit	Min range	Max range	Source (and notes)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.6 Light Fuel Oil

Input	Unit	Min range	Max range	Source (and notes)
Investment Cost	USD/MW	650,000	1,100,000	Lower range (Baurzhan & Jenkins, 2017), upper range (AF Mercados EMI, 2012)
Lifetime of Investment	Years	20	20	(Department of Business, Energy and Industrial Strategy, 2016a)
GHG Emissions Factor	tCO_2e/MWh	0.778	0.778	(Baurzhan & Jenkins, 2017)
Capacity Degradation Factor	%	1%	1%	(Baurzhan & Jenkins, 2017)
Efficiency	%	35%	42%	(Baurzhan & Jenkins, 2017)
Equivalent Full Load Hours	Hours/year	Calculate from capacity factors.		
Capacity Factor	%	1%	84%	Depends on whether run as peaking or baseload.
Non-fuel OPEX, Initial Year	USD/MW			
– Fixed	USD/MW	13,000	15,000	(Department of Business, Energy and Industrial Strategy, 2016a), (Baurzhan & Jenkins, 2017)
– Variable	USD/MWh	3	4	(Department of Business, Energy and Industrial Strategy, 2016a), (Baurzhan & Jenkins, 2017)
Non-fuel OPEX, Annual Increase	%	N/A	N/A	Inflation only

7.3.7 Fuel Costs – International Oil, Gas and Coal

Our fuel prices are taken from a publicly available source in the UK (Department of Business, Energy and Industrial Strategy, 2016b). These are only a guide and will need to be adjusted to reflect local costs, such as transportation costs and any price regulations.

Gas

Gas is provided in p/therm in the source used (Department of Business, Energy and Industrial Strategy, 2016b). Other sources may quote $/mmbtu. We recommend converting to US$/MWh (or other chosen currency) so that units used in the model are consistent. Fuel conversion factors are readily available in textbooks or online.

Input	Unit	Min range	Max range	Source (and notes)
Fuel Cost, Starting Price	USD/MWh	12	22.96	UK 2017
Fuel Cost, Annual Increase	%	3.7%	4.9%	Real. Should be increased by the inflation rate used in the model.

Oil

Oil is provided in US$/bbl in the source used (Department of Business, Energy and Industrial Strategy, 2016b).

Input	Unit	Min range	Max range	Source (and notes)
Fuel Cost, Starting Price	USD/MWh	13.53	36.48	UK 2017
Fuel Cost, Annual Increase	%	4.8%	6.2%	Real. Should be increased by the inflation rate used in the model.

Coal

Coal is provided in US$/tonne of steam coal in the source used (Department of Business, Energy and Industrial Strategy, 2016b).

Input	Unit	Min range	Max range	Source (and notes)
Fuel Cost, Starting Price	USD/MWh	4.30	6.26	UK 2017
Fuel Cost, Annual Increase	%	3.3%	6.4%	Real. Should be increased by the inflation rate used in the model.

7.3.8 Others for Baseline Energy Mix

Note that small hydro, wind and solar PV data is available in section 7.1 above.

Renewable LCOE can be used to enter any technologies not defined in the other categories.

7.4 Mini Grid Costs

Mini-grids are very specific projects and it is not adequate to extrapolate generic standard reference costs. Location and technical characteristics of the mini-grid should be tailored for each project.

Instead, it is advisable to rely on the application of mini grid design tools such as HOMER (http://www.homerenergy.com/HOMER_pro.html). This kind of engineering software includes equipment databases and allow the user to specify a mini-grid configuration in detail.

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