Toolbox for Renewable Energy Tariff Design in West African Countries

Abuja, 20-21 July 2017

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Part A

Welcome and Introduction

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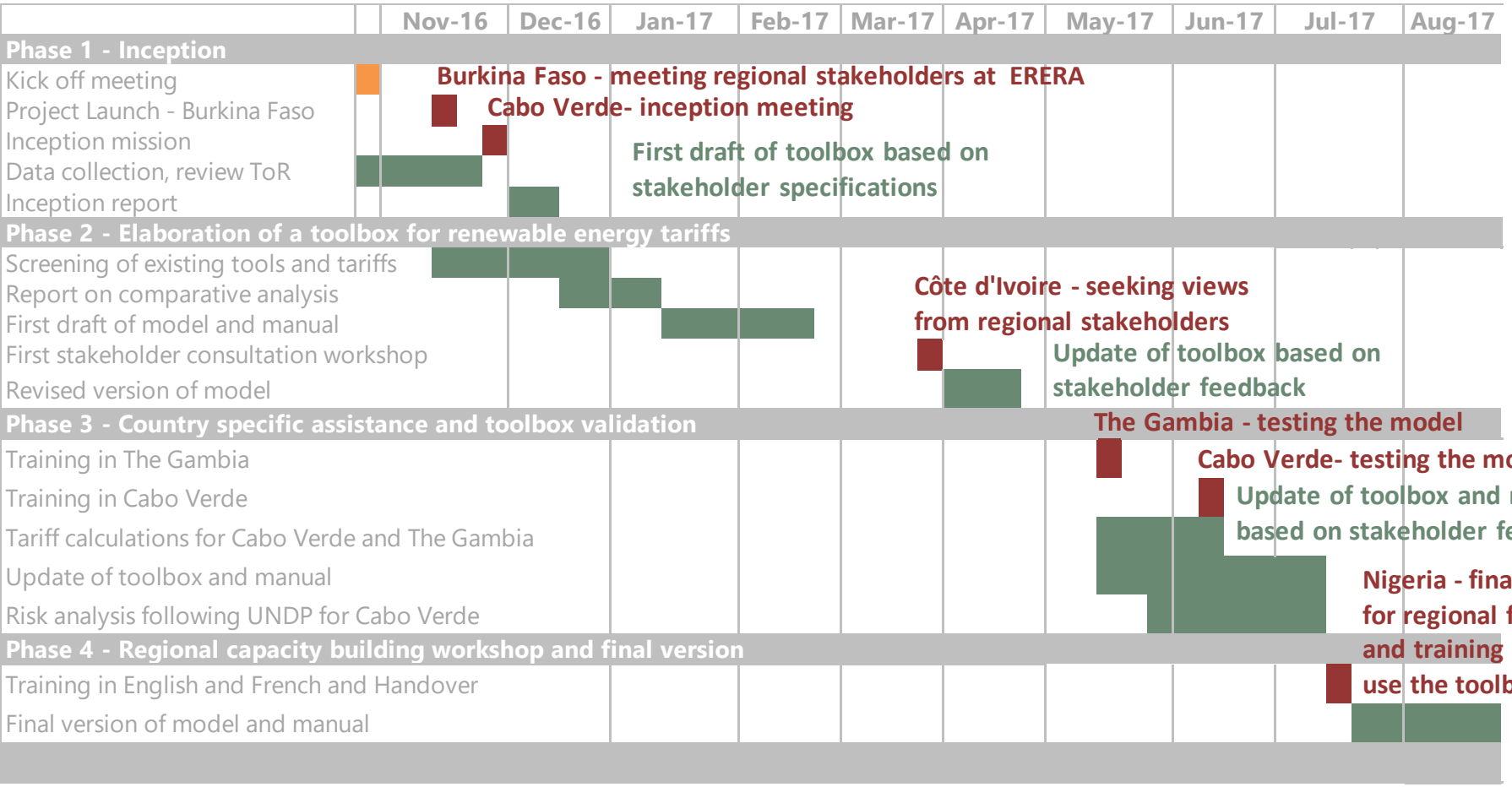
Development of a toolbox to support ministries, regulators and utilities to define tariffs for renewable energy systems

- **ECREEE**, on behalf of ECOWAS, requested **EUEI PDF** to provide technical assistance for the development of a toolbox (set of tools) to define tariffs for renewable energy systems.
- Screening and **comparative analysis** of existing tools and tariffs
- Consultation with **regional stakeholders** about the requirements

Prosumers | Renewable IPP | Green Minigrid

- Development of a **model** and **user manual** (toolbox)
- Validation ("beta testing") of toolbox with **regional stakeholders** and for specific applications in **The Gambia and Cabo Verde**
- Today and tomorrow we are seeking a wider validation of toolbox and will give **training** in the use of the toolbox

The process so far:



Objectives and topics of the training

Objective for today and tomorrow

- Give you a practical introduction to all the models in the toolbox and how they can be used
- Transparent and open discussion of models
- Test the toolbox and manuals meet the needs of regional stakeholders – we need your opinion and any ideas to make it most useful for you!
- **Si vous préférez français, il y a une autre session!**

Next steps after today and tomorrow

- The consultants will adjust models in the toolbox based on feedback
- The materials are all available now, and revised versions will be issued to all attendees (email link) in the coming weeks

Please keep your laptops with you today and tomorrow

The materials are available to download:

https://www.dropbox.com/sh/v7ocar7dodx5uyh/AABuASpL_-qJz_Byq1SuJ85fa?dl=0

(you can copy the link from the agenda)

(Or… USB stick)

EUEI PDF have your email details to send a link to a revised version following any agreed changes

Agenda – Today

Time	Activity
8.30 AM	**Registration**
9 AM	Opening session
9.15 AM	Introduction
9.30 AM	Overview of the toolbox
10.15 -10.45 AM	**Coffee break**
10.45 AM	Renewable Energy IPP Model Using the wind speed tool with the IPP model.
12.30PM – 2PM	**Lunch**
2 PM	Avoided cost in the IPP model Using the fuel cost tool to populate the avoided cost model
2.45 PM	Discussion, questions and comments – on the renewable energy IPP model
3.15 – 3.45	**Coffee break**
3.45 PM	Supply curve model
4.30 PM	Discussion, questions and comments – on the supply curve model
4.45 PM	Quick quiz – Using the supply curve and IPP models
5 PM	**Summary and close-out of the day**

Agenda – Tomorrow

Time	Activity
9 AM	**Welcome and Recap**
9.30 AM	The prosumer model
10.15 -10.45 AM	**Coffee break**
10.45 AM	Exploring the different tariff options and approaches in the prosumer model
11.30 AM	Discussion, questions and comments – on the prosumer model
12NOON – 1PM	**Lunch**
1 PM	Introducing the green mini-grid model
2 PM	Discussion, questions and comments – Using the green mini-grid model
2:30 – 3 PM	**Coffee break**
3 PM	Presentation – Recap of the toolbox
3.15 PM	Quick quiz – Using the renewable energy toolbox
3.30 PM	Discussion, questions and comments on the toolbox overall.
4pm	**Summary and close-out of the programme**

Part B

Introduction to the toolbox

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Just a few questions for the toolbox to help answer

(from other regional stakeholders, you will have your own!)

Price per kWh?

Impact of the duration of the PPA on the tariff?

Tariff structure that assembles the generator-distributor-client characteristics/needs?

How will the mini-grid tariff be in accordance with the uniform tariff principle?

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

Impact of production cost over national power generation tariff?

- ## Flexibility

  Adaptable to natural resources and ability to pay in any country

  Enabling policy makers to balance needs of renewable investors, needs of power utilities and needs of consumers

- ## Ease to learn and use

  Keeping the model and manual simple to use / but enough detail to still be robust……. finding the right balance

What the 6 models in the toolbox can do:

Input – wind energy profile

Input – fuel cost conversion

Renewable IPP

- Calculate feed-in tariff based either on cost of a **"reference project"** (target return on investment) or **"avoided cost"** (cost of current generation mix).

Prosumers

- Calculate feed-in tariff based either on cost of a **"reference project"** (either a feed in tariff or "energy banking") or **"avoided cost"** (all energy met by grid supply).

Green Mini-grid

- Calculate feed-in tariff based either on cost of a **"reference project"** (building blocks approach) or **"avoided cost"** (full cost of extending grid, or alternative supply).

- Or answer the question – for a given tariff and project(s), what is the cost to consumers?

Supply Curve

- Given cost projections, what is the cost to meet a specific renewable energy target?

User manual

RES Tariff Toolbox
User Manual
for
10 July 2017
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Part C

Introducing the renewable IPP tool

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Reference Project:

What feed in tariff will make a project viable?

- **Target**

  To achieve required Internal Rate of Return (IRR) for a ”reference” (standard or specific) project.

  - **By adjusting**

    The applied feed in tariff (currency per kWh) for the base year.

Price per kWh?

What is the price per kWh that renders a particular power plant feasible/profitable?

Impact of the duration of the PPA on the tariff?

Press the MACRO button to iterate to answer

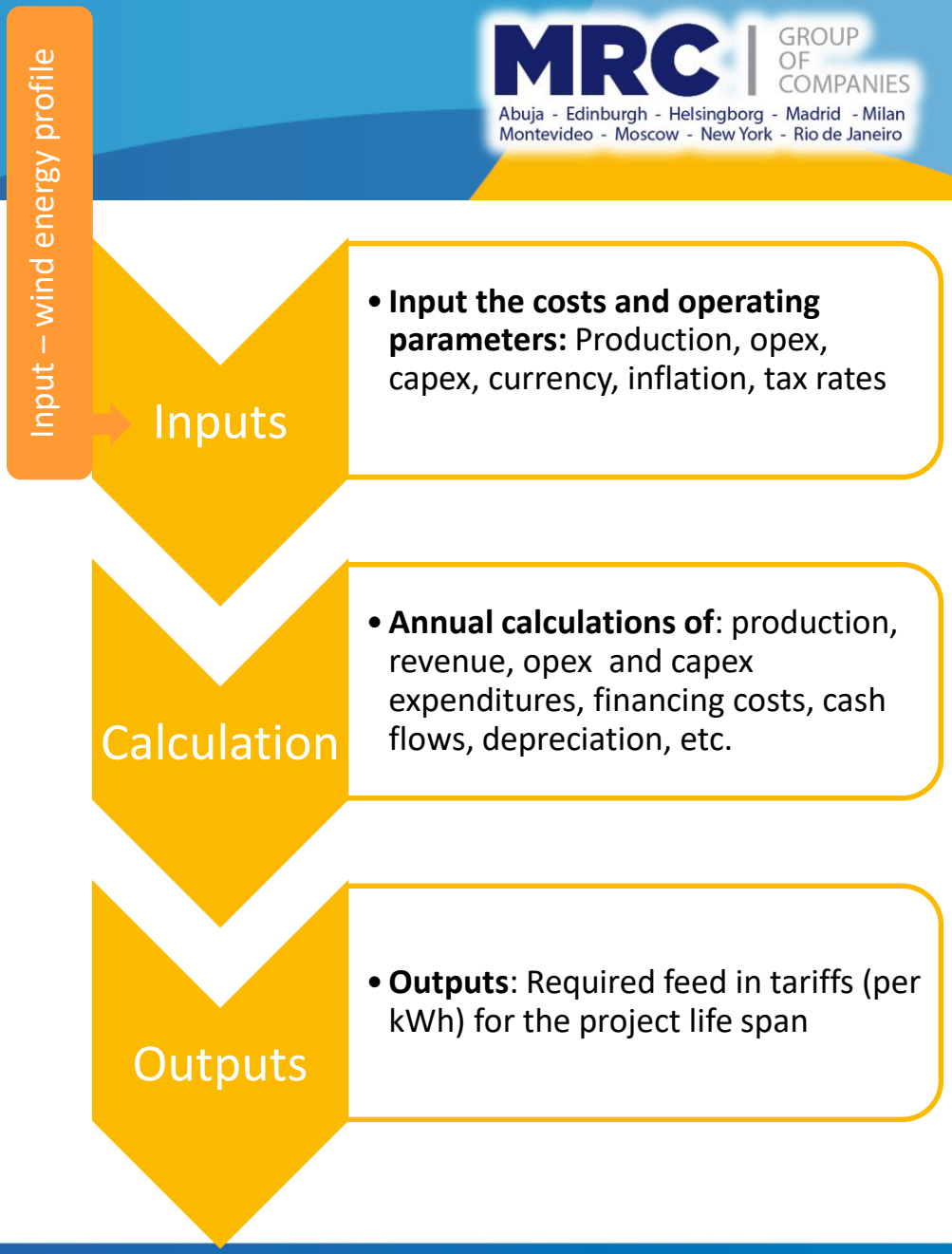
Feed in tariff based on country-specific “typical” project costs.

Or, to support negotiations and tenders by mimicking the developer’s own calculations.

Reference Project

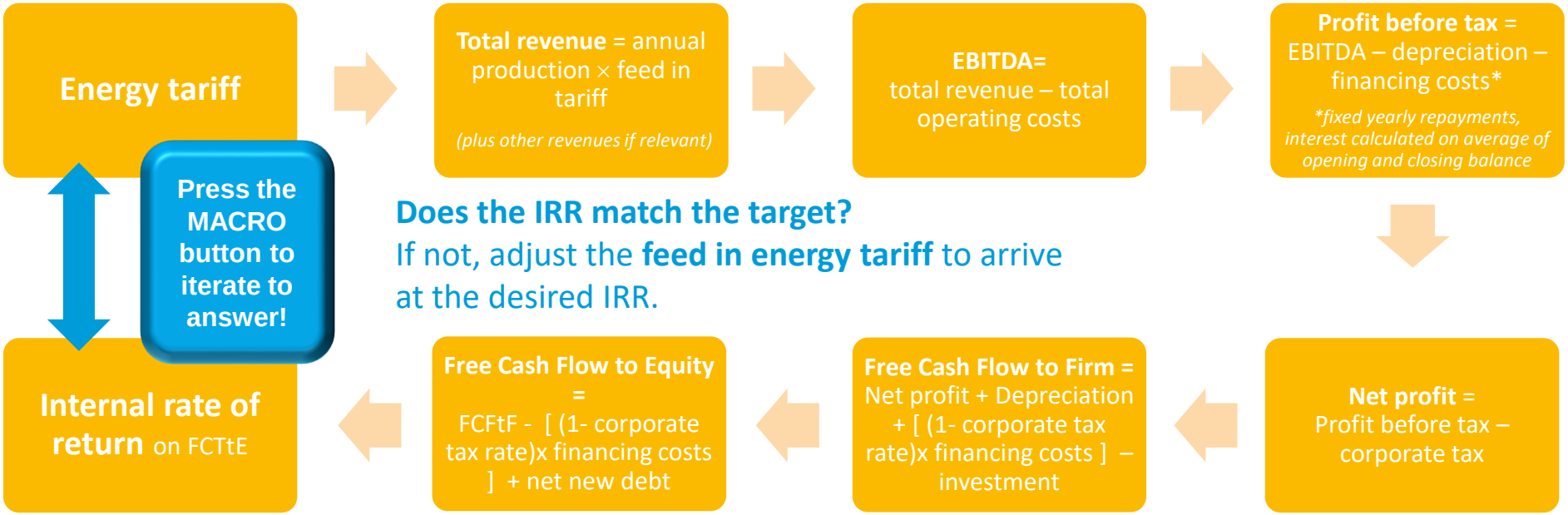
Main input assumptions:

- Project technical characteristics
- Project reference costs
- Useful Life (depreciation)
- Financing:
  - Gearing ratio
  - Cost of Debt
  - Required Return for Equity



Calculations

- 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 matches the target.



Part D

Representing a reference renewable energy project in the IPP model

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Worked example – 5 MW solar PV feed in tariff

Worked example – 5MW solar feed in tariff

Reference Project Approach

Renewable IPP

Inputs

- **Input the costs and operating parameters:** Production, opex, capex, currency, inflation, tax rates

- Inputs are most significant part of ensuring feed in tariff is correct.
- Country-specific data where possible:
  - E.g. standard costs for solar PV available from reference sources, add an estimate of import costs and any applicable import and other taxes.
  - Project (and PPA) lifespan
  - Financing parameters – what is available? Local financing? “Soft loans”?

Worked example – 5MW solar feed in tariff

Reference Project Approach

Renewable IPP

Inputs

- **Input the costs and operating parameters:** Production, opex, capex, currency, inflation, tax rates

Calculation

- **Annual calculations of**: production, revenue, opex and capex expenditures, financing costs, cash flows, depreciation, etc.

Outputs

- **Outputs**: Required feed in tariffs (per kWh)
- Can see additional costs relative to avoided cost of conventional generation (next section).

Worked example – 5 MW solar PV feed in tariff

We have provided the inputs for a 5 MW solar PV reference project.

Exercise 1: What is the price per kWh that renders a particular power plant feasible?

- Run the Macro to find the feed in tariff that delivers the required return to investors

Exercise 2: What is the impact of the duration of the PPA on the tariff?

- Change the project duration from 15 years to **20 years**
- Run the Macro to find the feed in tariff that delivers the required return to investors
- What is the difference from exercise 1? Why?

Keep this model open – we will use it again

Worked example – 5 MW solar PV feed in tariff

Exercise 3: What is the impact of the indexing the PPA on the initial tariff?

- Set the project indexation to equal inflation.
- Run the Macro to find the feed in tariff that delivers the required return to investors.
- What is the difference in the initial feed in tariff from exercise 2? Why?
- Discussion:
  - Why might investors like an inflation indexation?
  - How do you think consumers may feel about indexation?
  - How do you feel about inflation indexation on balance?

Keep this model open – we will use it again

Worked example – 5 MW solar PV feed in tariff

Exercise 4: Using the scenarios to consider the impact of capacity factor assumptions.

- The capacity factor is assumed to be 20% in our scenarios so far.
- Use the "scenario 1" input to consider a scenario that has a 50% lower capacity factor (-50%).
- Use the "scenario 1" input to consider a scenario that has a 50% higher capacity factor (+50%).
- What is the impact on the required feed in tariff?

You can now close this model! Thank you.

Part E

Using the wind capacity factor tool

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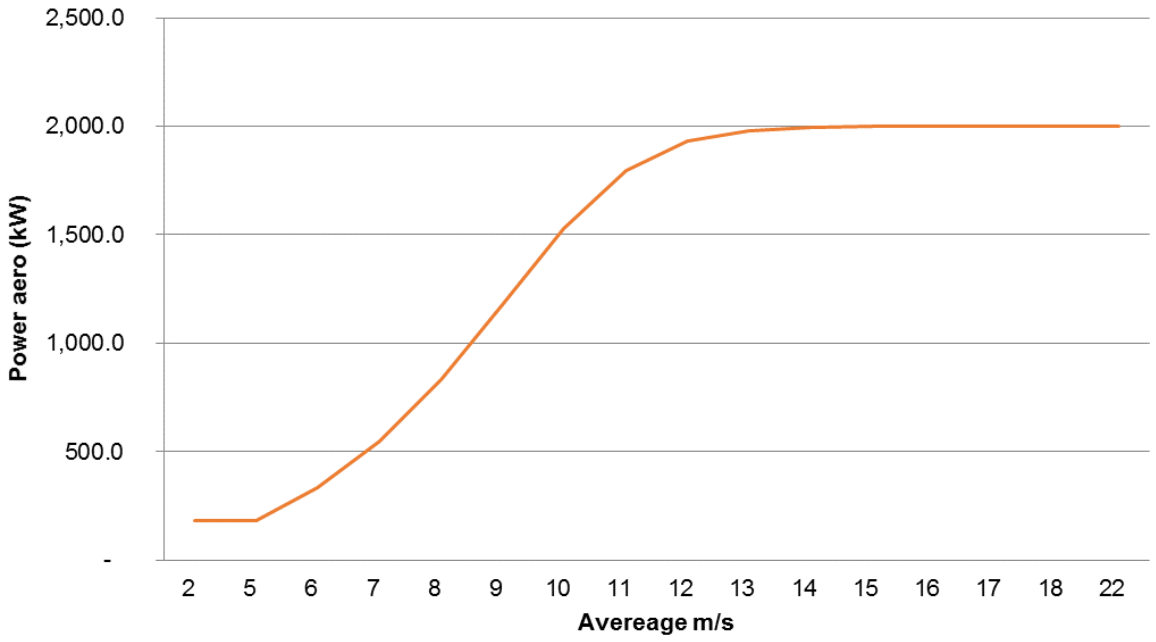
Input – wind power curve

- The power curve from the manufacturer gives the expected kW output in each wind speed range.



Input – wind power curve

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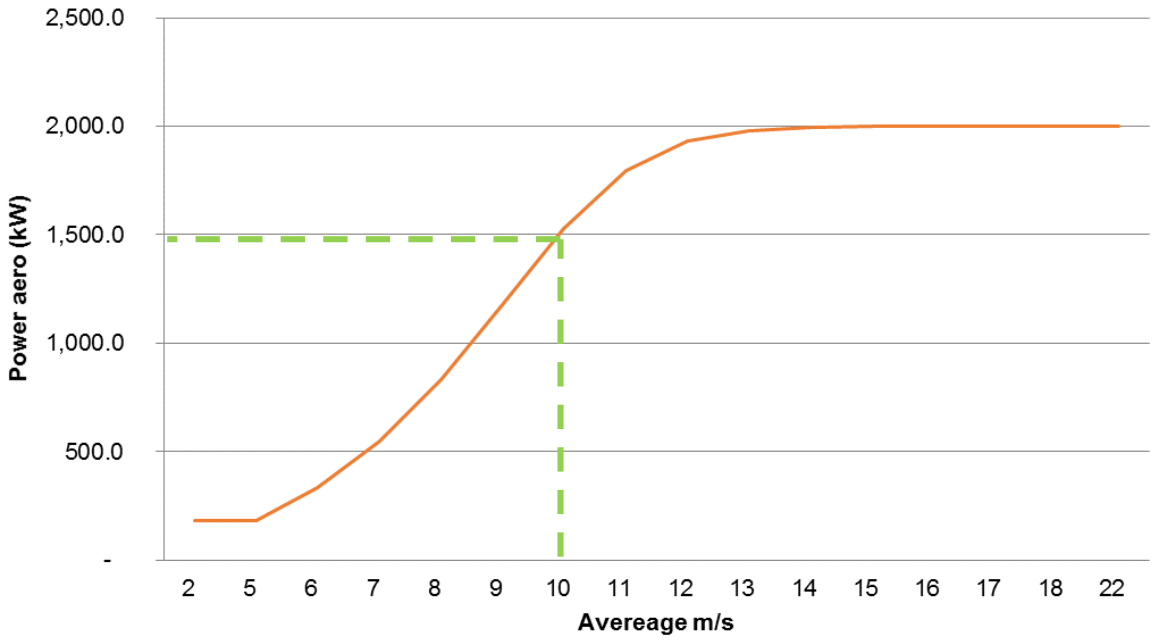
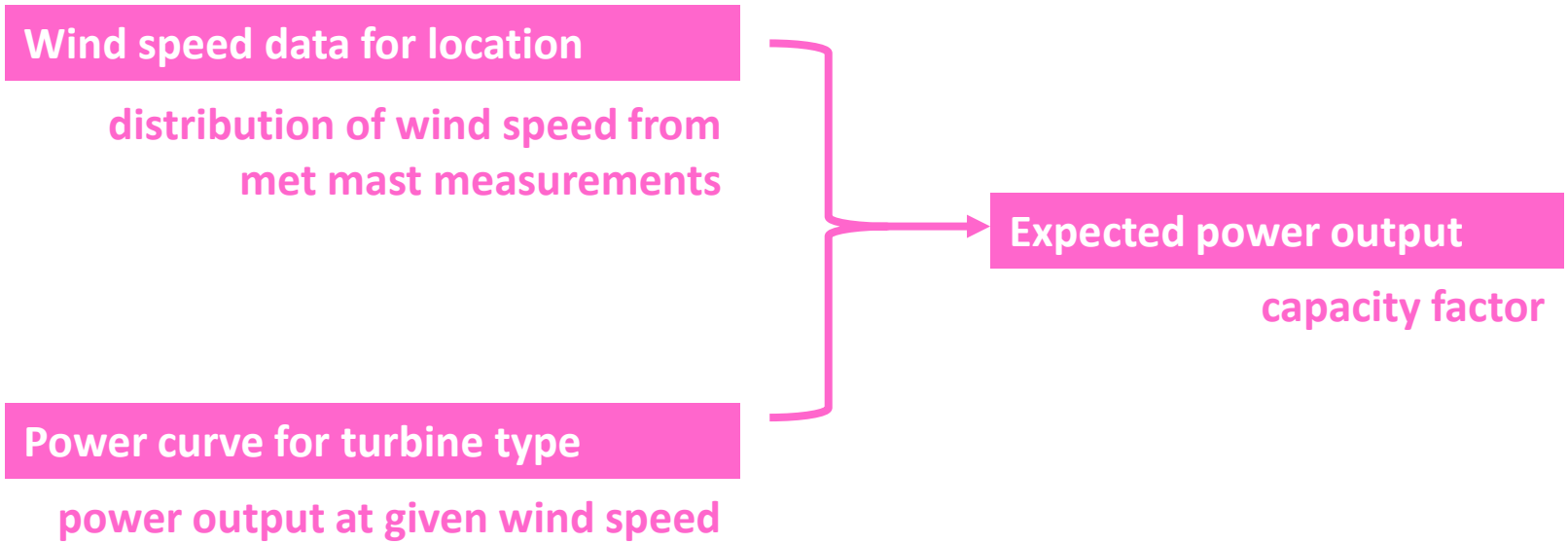


If the wind is blowing at 10 m/s the output of this 2 MW turbine will be about 1.5 MW

Wind power capacity profiles

- This model is useful if you have wind speed data and wish to calculate an estimated capacity factor for wind energy.



Worked example – 2 MW wind feed in tariff

Worked example – 2 MW wind feed in tariff

We have provided the inputs for a 2 MW wind reference project, but it is missing the capacity factor.

Exercise 5: Calculate the capacity factor

- Use the wind speed tool to calculate a capacity factor
- We can use the Gamesa turbine inputs that are already here
- Change the following inputs:
  - Measurement height = 10 metres
  - Average wind speed = 4 m/s
  - Stand dev = 1 m/s
- What is the capacity factor?

Worked example – 2MW wind feed in tariff

Reference Project Approach

Renewable IPP

Inputs

- **Input the costs and operating parameters:** Production, opex, capex, currency, inflation, tax rates

Wind capacity factor

Calculation

- **Annual calculations of**: production, revenue, opex and capex expenditures, financing costs, cash flows, depreciation, etc.

Outputs

- **Outputs**: Required feed in tariffs (per kWh)
- Can see additional costs relative to avoided cost of conventional generation (next section).

Worked example – 2 MW wind feed in tariff

Exercise 6: What is the impact of the capacity factor of the wind turbine on the tariff?

- Change the capacity factor to match the output of the wind capacity factor tool.
- Run the Macro to find the feed in tariff that delivers the required return to investors

Exercise 7: What is the impact of choosing a higher wind area?

- What is the capacity factor if the wind speed was actually 5 m/s?
- What is the new required feed in tariff?
- Why is it important for regulators and investors to have good wind resource measurements?

Keep this model open – we will use it again

Part F

Representing the avoided cost of a renewable energy project in the IPP model

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Avoided Cost:

What feed in tariff will make a project cost no more than the alternative?

- Avoided cost compares two scenarios, a baseline scenario where the project is not implemented and the other looking at the scenario where the project is implemented.
- The cost or tariff associated with the baseline scenario will provide the “avoided cost” tariff for the renewable project.

Price per kWh?

Impact of production cost over national power generation tariff?

Used to monitor the difference in cost between the existing mix and the cost of a new energy mix including any new renewables projects.

Can give a “cost neutral” feed in tariff based on country-specific “typical” costs for the current generation mix

Avoided Cost

How is the baseline tariff calculated?

- 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
- Avoided cost can be “private” or “social”. Depends on if the cost externalities are included…
- These are just an additional cost (e.g. cost of carbon emissions) but measuring and pricing them is complicated.

Overall LCOE (current)

Specific LCOE for each technology in the baseline scenario is calculated

✖

Generation mix

Each technology’s contribution to the generation mix

↓

Overall LCOE for baseline

i.e. avoided cost

Avoided Cost – as applied to large scale projects (IPP)

- The calculated **avoided cost** for the IPP component of the model is the baseline generation cost if the IPP was not there.
- 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 **marginal** (last and most expensive) plants being dispatched if these would be reduced by having extra renewables. For example heavy fuel oil generators.
  - Or a regulator may prefer to use an **average** energy mix if the renewable plant will supplement (but not reduce) the existing supply mix.

What would that unit of power cost a consumer if the IPP was not there?

Worked example – avoided cost in a fuel oil system

Worked example – avoided cost in fuel oil system

Continue with the 2 MW wind project, with 44% capacity factor.

- Sometimes we consider the avoided cost of the full baseline mix, and sometimes we consider the marginal plant – the last plant to run.
- In this system, we are assuming 20% hydro, 30% natural gas and 50% HFO. The marginal plant is HFO.

Exercise 8: What is the avoided cost when comparing against just the marginal plant (HFO)?

- Change the percentages to be 100% HFO and 0% for the other technologies. What difference does it make to the avoided costs?
- When do you think it is appropriate to consider marginal plant, and when is it best to consider the full baseline mix?

Keep this model open – we will use it again

Part G

Using the fuel cost tool

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Fuel Cost Tool

This model helps the user to convert fuel costs to a standard format

- Convert fuel specific costs (which may be in a wide variety of units) into the units of currency/MWh that are required for the models.

Use the fuel cost tool!

How do I convert the cost of heavy fuel oil from $/barrel to $/MWh?!

Note: Prices and heating values for solid fuels should only be expressed as "per unit of mass"

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

Worked example – avoided cost in a fuel oil system

Worked example – avoided cost in fuel oil system

Continue with the 2 MW wind project, with 44% capacity factor, and 100% HFO fuel mix.

Exercise 9: Imagine that you have just signed a new HFO contract at 50 USD/ barrel – what does this mean for avoided cost?

- Use the fuel conversion tool to convert 50 $/barrel to $/MWh – use the standard conversion factor.
- What is the price in $/MWh?
- Update the avoided cost in the model you still have open for the 2 MW wind project, with 44% capacity factor, and 100% HFO fuel mix.

You can now close this model! Thank you.

Part G

Using the supply curve tool

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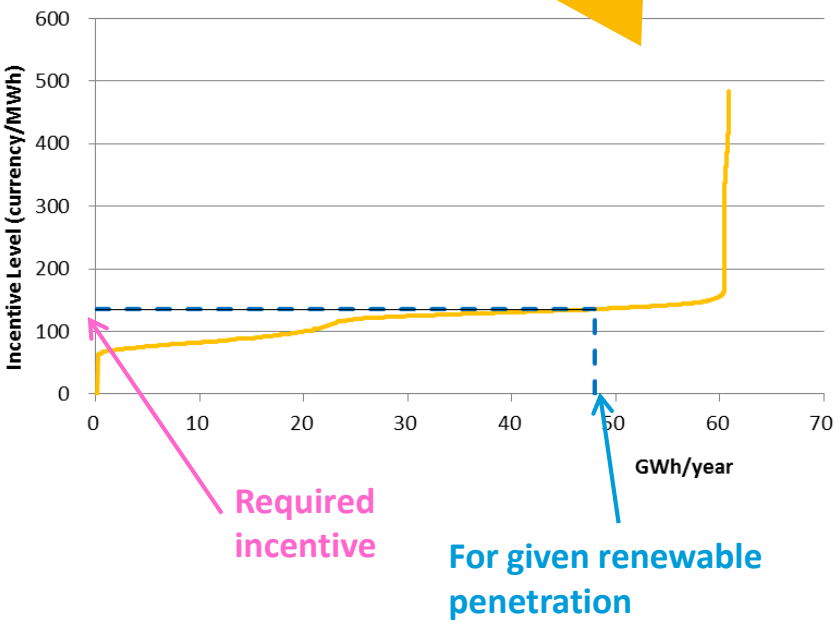
Supply Curve Overview

Main aim

- Identify a required incentive level
- In order to reach a certain renewable energy penetration level
- Using a mix of available renewable energy which can be developed in the country (i.e. wind, solar PV, concentrated solar power, geothermal and biomass)

Given cost projections, what is the cost to meet a specific renewable energy target?



Supply Curve

Calculations of the model

- **Target IRR** defined for each renewable technology plant.
- Run a number of simulations for each renewable energy technology in which the costs are **uniformly adjusted** (i.e. investment, fuel and O&M costs, and load factor).

Run simulation with central parameters…

Run several simulations with range of capex values…

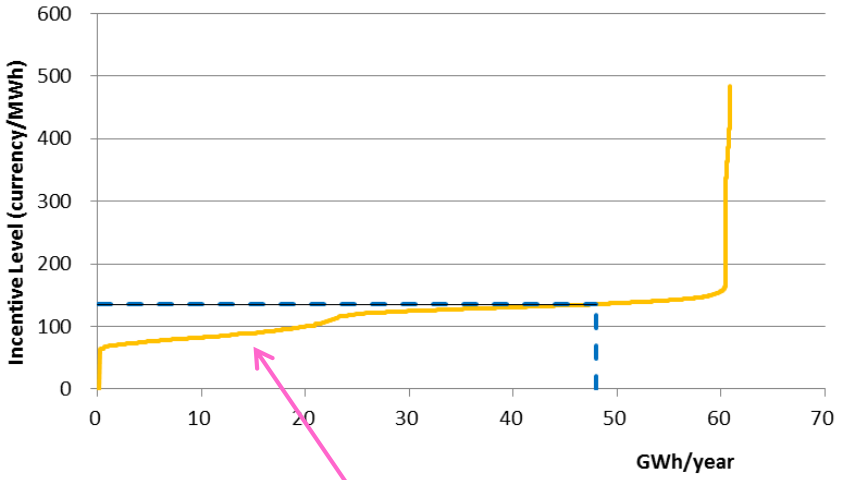
Run several simulations with range of opex values…

Like building lots of different projects with different inputs

Supply Curve

Calculations of the model

- For each simulation, **an energy tariff** is calculated which achieves the target IRR.
- The supply curve is then built up on the cumulative renewable energy generation achieved for a given energy tariff level.

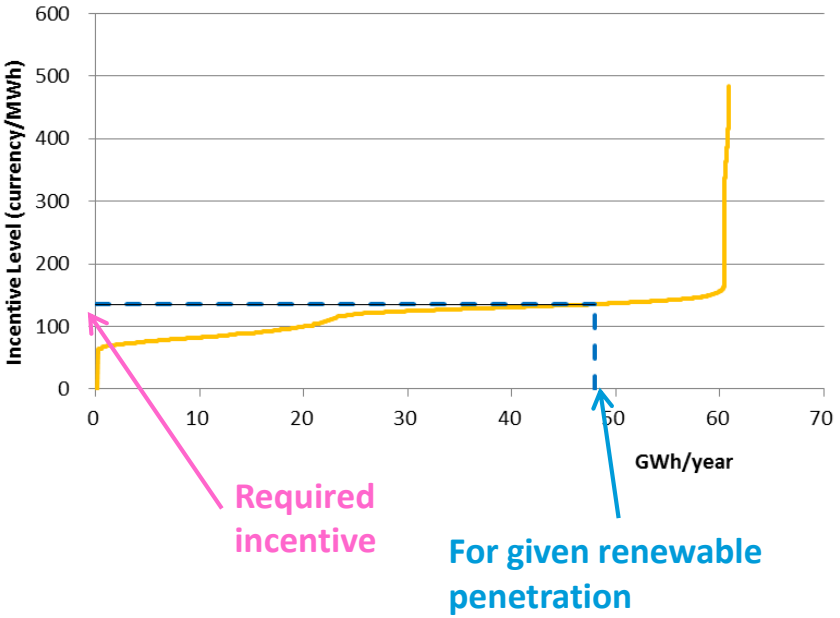


Each point on the curve is an individual simulation result... ... a single project!

Supply Curve Overview

- By setting a renewable energy target (in GWh) you can identify a required incentive level

Given cost projections, what is the cost to meet a specific renewable energy target?



Worked example – supply curve

Worked example – supply curve

Exercise 10: The Government has set a target of 200 GWh from renewable energy sources – what is the cost on the supply curve?

- Your team completed the model, just run the macro to see the cost.
- Is this the cost for all renewable energy?
- Look at the cost of delivering 10,000 MW of each technology on the other graph.

Exercise 11: You have commissioned a study that shows a higher wind energy resource – 20,000 MW. What difference does this make to the cost of meeting the Government's objective?

- Change the resource estimate and run the macro.

You can now close this model! Thank you.

Quick Quiz

Day 1: Using the supply curve and IPP models

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Part A

Recap of Day 1

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6 models in the toolbox:

Input – wind energy profile

Input – fuel cost conversion

Renewable IPP

- Calculate feed-in tariff based either on cost of a **"reference project"** (target return on investment) or **"avoided cost"** (cost of current generation mix).

Prosumers

- Calculate feed-in tariff based either on cost of a **"reference project"** (either a feed in tariff or "energy banking") or **"avoided cost"** (all energy met by grid supply).

Green Mini-grid

- Calculate feed-in tariff based either on cost of a **"reference project"** (building blocks approach) or **"avoided cost"** (full cost of extending grid, or alternative supply).

- Or answer the question – for a given tariff and project(s), what is the cost to consumers?

Supply Curve

- Given cost projections, what is the cost to meet a specific renewable energy target?

We have reviewed:

Input – wind energy profile

Input – fuel cost conversion

Renewable IPP

- Calculate feed-in tariff based either on cost of a **"reference project"** (target return on investment) or **"avoided cost"** (cost of current generation mix).

- Or answer the question – for a given tariff and project(s), what is the cost to consumers?

Supply Curve

- Given cost projections, what is the cost to meet a specific renewable energy target?

So today we focus on:

Prosumers

- Calculate feed-in tariff based either on cost of a **"reference project"** (either a feed in tariff or "energy banking") or **"avoided cost"** (all energy met by grid supply).

Green Mini-grid

- Calculate feed-in tariff based either on cost of a **"reference project"** (building blocks approach) or **"avoided cost"** (full cost of extending grid, or alternative supply).

- Or answer the question – for a given tariff and project(s), what is the cost to consumers?

Agenda – Day 2

Time	Activity
9 AM	**Welcome and Recap**
9.30 AM	The prosumer model
10.15 -10.45 AM	**Coffee break**
10.45 AM	Exploring the different tariff options and approaches in the prosumer model
11.30 PM	Discussion, questions and comments – on the prosumer model
12NOON – 1PM	**Lunch**
1 PM	Introducing the green mini-grid model
2 PM	Discussion, questions and comments – Using the green mini-grid model
2:30 – 3 PM	**Coffee break**
3 PM	Presentation – Recap of the toolbox
3.15 PM	Quick quiz – Using the renewable energy toolbox
3.30 PM	Discussion, questions and comments on the toolbox overall.
4pm	**Summary and close-out of the programme**

Part B

Prosumer model

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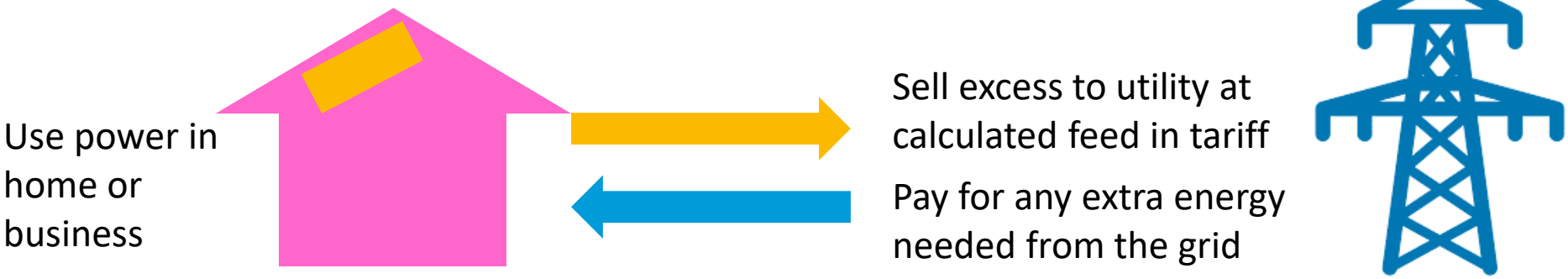
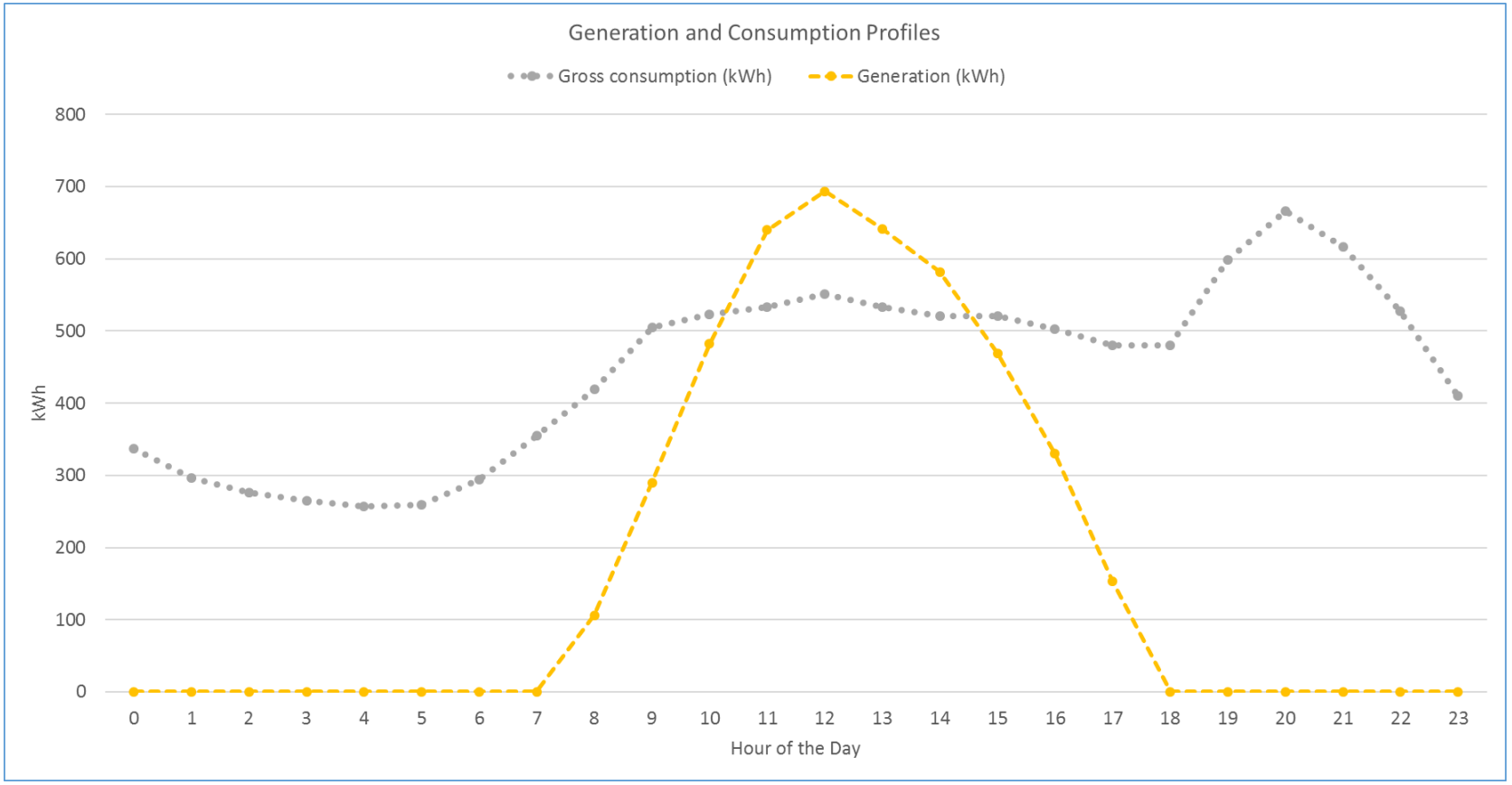
The Prosumer Model

The prosumer model considers on-site generation which can be either consumed or sold to the grid.

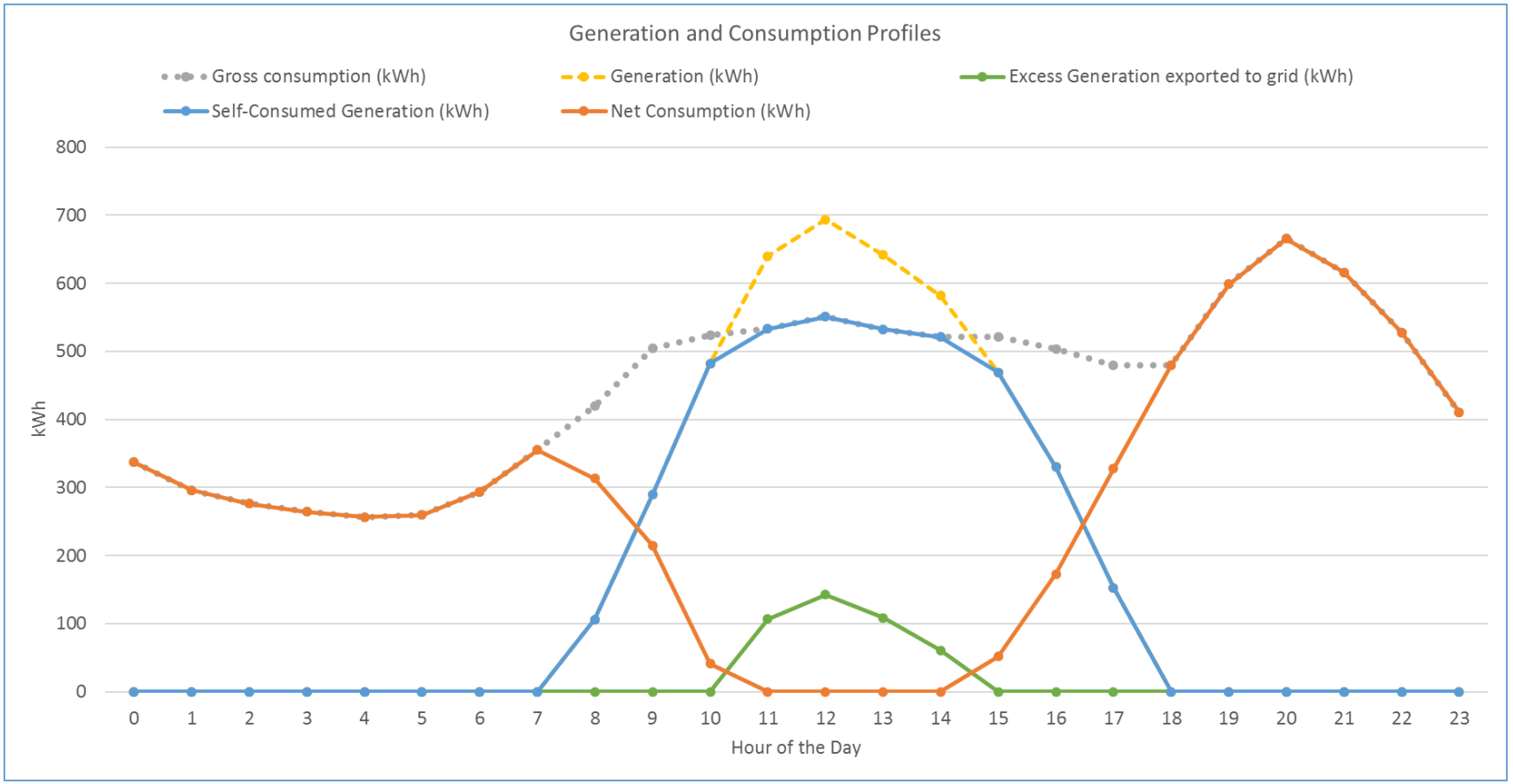
- **Reference Project-** IRR is calculated on the generation cash flow from the **feed-in-tariff** plus lower bills because of any generation they use on-site (taking less from the grid)



Example of a prosumer project



Resulting self-consumption and export

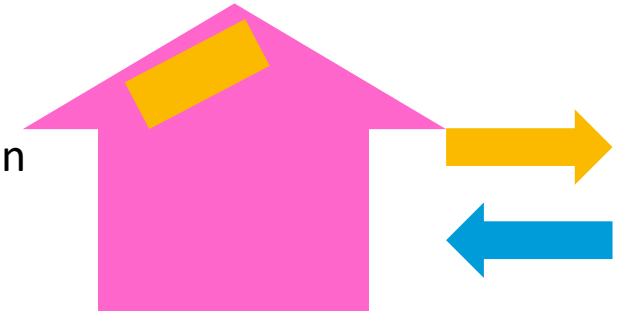


The Prosumer Model

- **Avoided Cost-** the avoided costs refer to the cost savings obtained by the prosumer by installing its own generation and the **benefit from "energy banking"** on the grid (set against future bills)

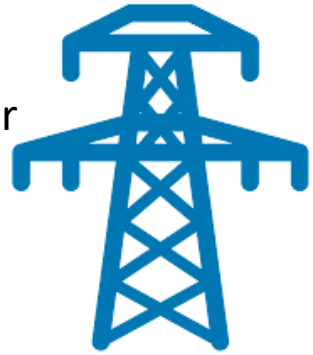
It may be possible for prosumers to "bank" any credit for energy between periods and get a net bill from the utility.

Use power in home or business



Excess credited by the utility at the same tariff as the customer pays for energy from the grid

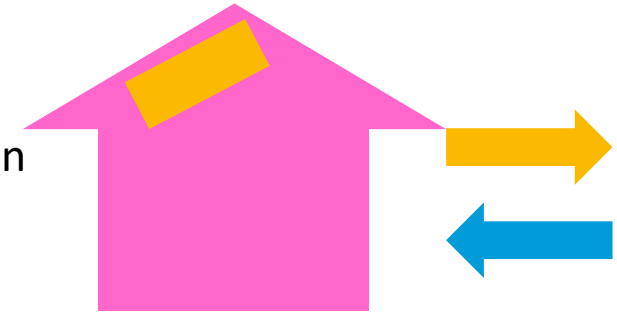
Bills are reduced by kWh "banked" with the utility



The Prosumer Model

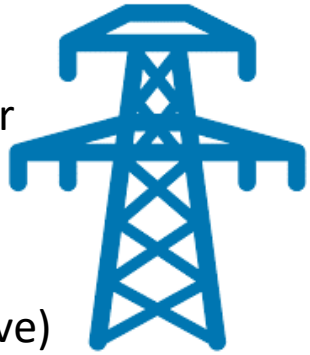
- **Avoided Cost-** **”energy banking”** (kWh) and **”cash banking”** are both options
  - They are the same if the unit costs are constant, but different if units cost different amounts at different times of day.
  - Utility bills can’t go negative (incentive against oversizing)

Use power in home or business



Excess credited by the utility at the same tariff as the customer pays for energy from the grid

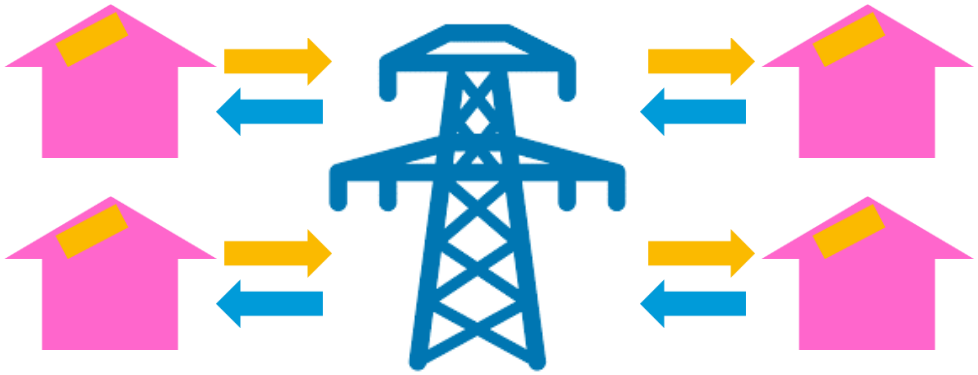
Bills are reduced by kWh “banked” with the utility (but can’t go negative)



The Prosumer Model

- **System impact**
  - 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 lower **energy losses** in the transmission and distribution networks.



The main negative impacts are lower output (sales) for incumbent generators, and a **reduction in regulated revenue** dependent on the energy tariff.

Part C

Using the prosumer model

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Using the prosumer model

Prosumer reference project input information is required for every customer and a **maximum of 10 customers** can be considered at any one time

Following inputs are required per prosumer

- General inputs
- Collection efficiency
- Production inputs (including **generation profiles -** the profile of the generator capacity loading level, meaning the % of its nominal installed capacity that is actually generating each hour)
- Revenue inputs CAPEX and OPEX inputs,
- Financing inputs (debt and equity), and
- Consumption inputs (entered as prosumers hourly consumption profile)

Generation and consumption profiles

Standard Day

Applies a defined 24 hour generation profile for every day of the year

Standard Month

Applies a defined 24 hour generation profile for every month of the year

Full Year

Applies an individual profile for each hour of the year

Capacity Factor

Applies a single capacity factor

User's choice

Standard Day

Applies a defined 24 hour consumption profile for every day of the year

Standard Month

Applies a defined 24 hour consumption profile for every month of the year

Full Year

Applies an individual profile for each hour of the year

Annual Consumption

Applies the single Annual Consumption defined in the inputs sheet

Worked example – prosumer support

Worked example – prosumer

Exercise 12: The Government has asked you to calculate the tariffs needed to support residential customers who are generating their own energy.

- Your team has populated the model for you. Run the macro and make a note of the feed in tariffs for residential customers (customer 1 to 4).

Exercise 13: The Government has decided to offer an up-front grant of USD 1,000 for all residential customers. They ask you to calculate how much they should reduce feed in tariffs to compensate?

- Add the grants for residential customers (customers 1 -4)
- Run the macro – what are the new tariffs?

Keep this model open – we will use it again

Worked example – prosumer

Exercise 14: The Government is considering having a net billing scheme for household renewable energy instead?

- Change the energy banking from “no” to “yes” for residential customers.
- What return will these customers get from Energy Banking or Cash Banking?
- Why are both the same?

You can now close this model! Thank you.

Part B

Mini-grid model

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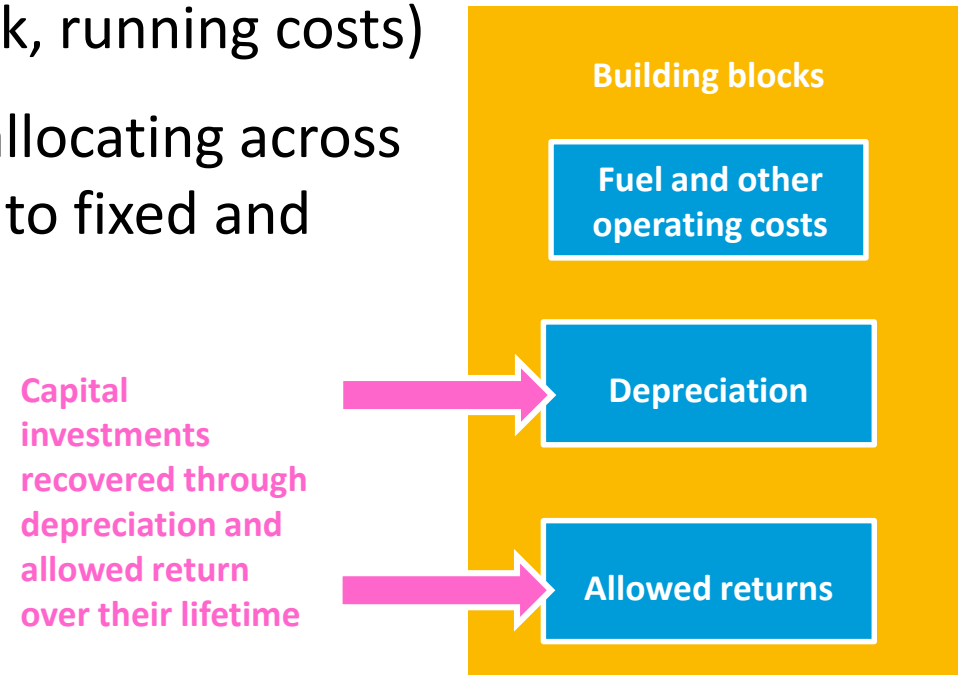
Green Minigrid Model

Building blocks approach for reference project

- Tariffs are based on revenue requirement for each part (generation, network, running costs)
- Customer tariffs obtained by allocating across customers and split according to fixed and energy components.



Avoided Cost and Supply Impact

as applied to minigrids

- In the case of minigrids, alternative supply includes the cost of **extending the main system to interconnect the minigrid area**
- Other options could consider the cost of self generation in that area (small diesel generators, restricted access etc.)
- **System impact –** is the projection of the avoided cost applied to the projected GMG development.

Part C

Using the mini-grid model

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Using the mini-grid model

The model also considers use of batteries - allows flexibility in output if required, but increases overall cost of the system.

Amongst standard inputs there are:

- **Bulk supply inputs** –
  - Demand inputs allow the user to specify a proportion of the mini-grid demand that is met by grid electricity
  - Generation inputs- bulk supply from the main grid for mini-grids that are connected to the main interconnected system,

- Note: 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.

Responsible cost setting across customers

- **Aim**: 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.

- i.e. Since networks are sized to supply a certain peak demand, many methods use customer contributions to peak demand at different voltage levels.

How to set customer share of capital investment or on operating costs?

Consider one of the many common methods such as: coincidental demand at peak hours, non-coincidental peak demand by category

Worked example – mini-grid support

Worked example – mini-grid

Exercise 15: You are setting the tariffs for a new mini-grid that has some commercial and some domestic customers. What are the tariffs for residential and commercial customers.

- Your team has populated the model for you. Make a note of the feed in tariffs for residential and commercial customers in year 1.

Exercise 16: You are concerned the tariff is too high for residential customers. Change the balance so that commercial customers meet 70% of the costs and residential customers 30%. What difference does this make?

- What do you think of the new tariffs?

Keep this model open – we will use it again

Worked example – prosumer

Exercise 17: You decide the tariff for commercial customers is too high, so you decide to introduce a central subsidy to keep the tariff at 20 cents/kWh for both residential and commercial customers.

- Change the target tariff to 0.2 USD/kWh
- Run the macro to calculate the subsidy.
- What subsidy is required each year for this mini-grid?

You can now close this model! Thank you.

Part D

Recap

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What the 6 models in the toolbox can do:

Input – wind energy profile

Input – fuel cost conversion

Renewable IPP

- Calculate feed-in tariff based either on cost of a **"reference project"** (target return on investment) or **"avoided cost"** (cost of current generation mix).

Prosumers

- Calculate feed-in tariff based either on cost of a **"reference project"** (either a feed in tariff or "energy banking") or **"avoided cost"** (all energy met by grid supply).

Green Mini-grid

- Calculate feed-in tariff based either on cost of a **"reference project"** (building blocks approach) or **"avoided cost"** (full cost of extending grid, or alternative supply).

- Or answer the question – for a given tariff and project(s), what is the cost to consumers?

Supply Curve

- Given cost projections, what is the cost to meet a specific renewable energy target?

User manual

RES Tariff Toolbox
User Manual
for

10 July 2017

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- ## Flexibility

  Adaptable to natural resources and ability to pay in any country

  Enabling policy makers to balance needs of renewable investors, needs of power utilities and needs of consumers

- ## Ease to learn and use

  Keeping the model and manual simple to use / but enough detail to still be robust……. finding the right balance

Review how the models help answer questions:

Given cost estimates, what is the cost to meet a specific renewable energy target?

Impact of the duration of the PPA on the tariff?

Price per kWh?

Tariff structure that assembles the generator-distributor-client characteristics?

How will the mini-grid tariff be in accordance with the uniform tariff principle?

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

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Thank you for your attention!

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