CHARGING INFRASTRUCTURE BUSINESS CASE ASSESSMENT TOOL USER GUIDE

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Introduction

The Charging Infrastructure Business Case Assessment Tool (CIBCAT) has been developed by Cenex in collaboration with ICF, on behalf of the International Zero-Emission Vehicle Alliance and is supported by its members (Austria, Baden-Württemberg, British Columbia, California, Canada, Chile, Connecticut, Costa Rica, Germany, Maryland, Massachusetts, the Netherlands, New Jersey, New York, New Zealand, Norway, Oregon, Québec, Rhode Island, the United Kingdom, Vermont, and Washington).

The tool is designed to assess the business case for a project to install public charging at a single site in any market across the globe. The focus is on the business case for public charging over a ten-year period (the assumed lifespan of the chargers). The tool includes options for on-site Photovoltaic (PV) and Battery Energy Storage System (BESS). However, it only assesses these at a high level, assessing the savings from offsetting grid electricity with energy from the PV, and revenue from exporting excess PV energy to the grid. The BESS is assessed for an approximate reduction in peak capacity, and assistance with the self-consumption of PV energy. A full stochastic energy arbitrage assessment with the BESS is beyond the scope of this tool.

Getting Started

The tool runs in MS Excel as a standalone spreadsheet and will require macros to be enabled when your first open it. The green worksheet tabs contain model inputs, and brown contain the outputs.

To run the model, you must complete all the light green input cells, then click on the 'Run' button on one of the output sheets before viewing the results.

The tool comes with data sets for several case study countries (Netherlands, India, China, Canada). These can be loaded into the model from the 'Case Study Country' selector at the top of the 'Input' sheet. You can of course input your own data or make changes to one of the case study countries once loaded. A summary of the inputs is provided at the top of the sheet. You should also decide which scenario to run using the selector towards the top of this sheet. The options are:

- Grid Only: Only chargepoints are specified for the project. All electricity is provided from the grid.
- Grid + PV Only: Both chargepoints and a PV array is specified for the project. Electricity for charging is provided by either the PV or the grid. Any excess PV energy is exported to the grid.
- Grid + PV +Battery: Chargepoints, PV and a battery energy storage system are specified for the project. Electricity for charging is provided either by the PV or the grid. The battery energy storage system is used to store excess generation from the PV for later use, and to reduce the peak power consumption from the site.

Choosing the second or third scenario will reveal additional inputs further down the sheet. Ensure that these input cells are completed too. Finally, you can choose which grid capacity calculation method you want (see Set up Costs for further details on this). With these options selected, you can then review the results on either of the brown output sheets, but before you do click one of the 'Run' buttons that are found on either of these sheets.

Reading the Results

The 'Year Data Output' sheet gives the yearly outputs from the project including a cashflow statement. In this sheet you can view a summary of the forecast annual energy demands of the project. Summary costs and revenues for each year are also provided. There are also two charts at the bottom of the sheet that can be used to view the results.

The 'Output' sheet provides the net present value (NPV) of the project over a ten-year period (cell C8). By entering a targeted NPV in cell D8, you can also calculate them maximum possible infrastructure CAPEX that still hits the NPV target. The return on investment (ROI) over ten years is also provided. The sheet also contains a chart showing the cumulative cash flow (in nominal terms) and a yearly cost and revenue breakdown. Charts to compare chargepoint utilization and import electricity prices against revenue are also provided.

Notes on Inputs

Whilst not all inputs are required to get the tool to produce results, care should be taken to provide sufficient inputs to produce sensible results. Brief descriptions of inputs are given below, starting with those on the Input sheet.

Business Case Assumptions

This includes the concept of ownership model. The ownership model chosen determines the percentage of the costs and revenue that the project owner takes on. The potential ownership models available in the model are,

- Own and Operate – The project invests all capital costs, cover all operational costs and retain all ownership, control, responsibility, risk and revenue.
- External Operator - is a medium-high risk and medium-high revenue Commercial Arrangement. It provides a high level of control over the chargepoints to the project, who typically have invested the capital cost and retain ownership of the assets, but operational responsibilities are transferred to the service provider in exchange for a part of the revenue.
- Lease Model - is a low risk-low revenue option where the project (as the landowner in this case) retains little control over the resulting service by leasing land it owns to a service provider.
- Concession - is a flexible approach that shares aspects of capital cost, operational costs, control and risk between the project and their service provider(s)
- Iceberg – The model is applicable when the project pays for and retains all ownership except the groundworks, which are contracted out to an infrastructure provider.

The parameters for these are given in the table below. Whilst full costs and revenues should be entered as inputs, only the percentages determined by the ownership model will be output in the results.

Ownership Model	Hardware Ownership [HO]	Groundworks Ownership [GO]	Back office [BO]	Electricity Cost [EC]	Revenue [R]	Maintenance Contract [MC]
Own and Operate	100%	100%	100%	100%	100%	100%
External Operator	100%	100%	0%	100%	90%	100%
Lease Model	0%	0%	0%	0%	20%	0%
Concession	0%	100%	0%	0%	30%	0%
Iceberg	100%	0%	100%	100%	100%	100%

A breakdown of which costs and revenues are contained within each cost category, is provided in the model inputs sheets in the Cost Allocation column.

This section also includes:

ZEV infrastructure incentive – a one-off incentive at the start of the project.

Low carbon fuel credits – an incentive provided per kWh or energy dispensed by EV charging stations. There are two rates depending on if the energy is provided by the grid, or by the on-site PV (if present).

Project Financing

Use this section to enter details of a loan to fund the project if required. The loan amount you specify may cover some or all the project capital costs. The repayment periods can be a maximum of 10 years (which is the period that the model covers). An interest rate for the loan must be specified here too, which can differ from the NPV discount rate. Note that within the repayment calculation, interest and repayments are assumed to be monthly.

Set up Costs

This includes a list of possible costs to consider that are incurred at the start of the project. All are absolute costs, except for Network connection/upgrade costs.

Any known network connection costs that are deemed not to scale with power, should be included within the 'Installation and make-ready infrastructure' cost. Any network connection cost that scale with import power, can be entered in Network connection/upgrade costs as a per kW cost. The maximum possible cost (Max grid upgrade cost) is given at the top of the input sheet (calculated as the total chargepoint power multiplied by the Network connection/upgrade cost) and is provided for information. However, the model calculates the actual upgrade cost based on the Grid Capacity Calculation Method selected (near the top right of the Input sheet).

If 'Maximum grid capacity' is selected, then the combined maximum rated power of all the chargepoints is used to calculate the required grid connection and associated upgrade cost.

If '99th percentile' is selected, then the 99th percentile from a simulation of the charging demand is taken as the peak import in each year (see Peak Import (kW) row in Year Data Output sheet). The maximum Peak Import power over the 10 years of the project is then used to determine upgrade costs. With this option, the Peak Import in each year may be mitigated by the BESS and PV (if included).

Note that the 'Financing and capital expenditures' input is separate from any interest charges that are incurred from loans (if they are specified in the Financing)

Annual Costs

This is a list of possible costs that are incurred each year.

Inputs for Chargers

Here you can select the chargepoint operating hours. See charger operating hours below for further details.

You can enter details for up to three different types of chargers. For each you must specify the charger output power, the number of chargepoints (in the project) and the per charger CAPEX.

A charger efficiency number applies to all chargers and is used calculate losses between energy that goes into the charger, and that which is delivered to the vehicle. These energy losses are paid for by the project but are not charged to the chargepoint user.

Reliability for the chargers is also required. This is used by the model to calculate a reduction in the annual revenue from the chargepoints due to unreliability. A value is calculated that represents the percentage of time that: given a charger is expected to be utilized, is it either working, or is another charger on site available to be used instead. For further details see the Charger Reliability Methodology section.

Non-energy Income

These optional inputs allow you to enter additional revenue on a per year or per charger per year basis.

PV Inputs and Advanced PV Inputs

If you are running a scenario with PV then all the inputs in these sections (with the exception of cost inputs) are required. The latitude, longitude and time zone are required to calculate the PV generation profile. Enter the PV rated capacity to provide the rated maximum power output of the array. The tilt of the PV array and orientation must also be entered. Orientation will typically be 180 (south) for locations in the northern hemisphere and 0 (north) for the southern hemisphere.

Sky clearness is a factor that can be used to 'tune' the output of the PV array to account for local weather. It must be between zero and one. The annual generation from the PV array can be found in cell D15 at the top of the sheet.

Battery Inputs

Battery energy storage system (BESS) input costs are broken down into per kW costs (i.e. those that scale with the output power of the BESS) and per kWh costs (i.e. those that scale with storage volume of the BESS). The power and storage volume of the BESS must also be specified here. The total calculated costs for the BESS can be found at the top of the sheet.

Assumptions

The currency can be specified here, using the dropdown list in the cell, or with a value entered directly. The start year of the project can also be specified here.

The annual inflation rate should be entered. This applies to all future annual non-energy costs in the model.

The nominal discount rate should be entered which should represent the cost of capital. This is used to calculate the project NPV.

Yearly Inputs Sheet

This sheet holds the electricity prices for each year, which should be input as nominal values.

Import electricity price is the price paid for energy imported from the electricity grid.

Export electricity price is the price received for energy exported to the electricity grid (from the PV).

Resale electricity price is the price received for energy provided to vehicles from the chargepoints.

Electricity standing charge is a fixed annual fee for an ongoing connection to the electricity network.

Grid capacity charge (also known as a demand charge) as an annual network charge based on the maximum power used by the site in the year.

Chargepoint utilisation should be entered, which represents an energy-based utilisation for the operational hours of the chargepoints. For example, if a utilisation of 20% is entered for a given year, and the charger operating hours profile active in the model has the charger active for 10 hours in the day, then the charger will be utilised for only 2 hours in the day. However, if a utilisation profile is activated that has the charger active for the whole day, then the charge would be utilised for around 4.8 hours in the day.

Charger operating Hours

On this sheet you can view the different charger operating hours profiles. These profiles specify when the charger could be used, and when it can't be used. Three custom profiles can be entered, by entering either 1 or 0 in each green input cell.

Assumptions

The following key assumptions have been made when creating the tool.

- The technology lifespan is 10 years, with NPV calculated over the same duration.

- A single utilization profile is used and applies to all chargepoints.

- Utilization events (i.e., events of vehicles charging from a chargepoint) within charger operating hours profiles are from a uniform distribution.

- Charger operating expenses (OpEx) applies to all chargepoints equally.

- Grid upgrade costs are applied on a per kW basis.

- Electricity prices are constant throughout each day and year.

- Chargepoint utilization is a fixed value for each year, and has no seasonal or within week variation.

- When calculating solar yield, only four typical days (one in each season) are simulated.

- The total power reduction due to a BESS is assumed to be evenly distributed across the hours where there is charging demand in a day. Also, the battery can only be fully charged and discharged one time in a day.

Reference Section

This section provides a more detailed reference of the tool and its methodology.

Tool Methodology

The tool is based around a discounted cashflow model, with the result being a project Net Present Value. The user inputs to the tool project set up costs (CapEx) and forecast annual costs. The numbers and types of chargepoints are selected by the user, as well as optional photovoltaics (PV) and battery electric storage system (BESS) (with associated costs). Finally, electricity prices and forecast annual utilization and reliability of the chargepoints are entered. From this information, the tool simulates the charger usage, energy volumes, associated costs, and revenues for each year. These results are then used to populate a discounted cashflow model. An illustration of the calculation flow in the tool is provided in Figure 1.
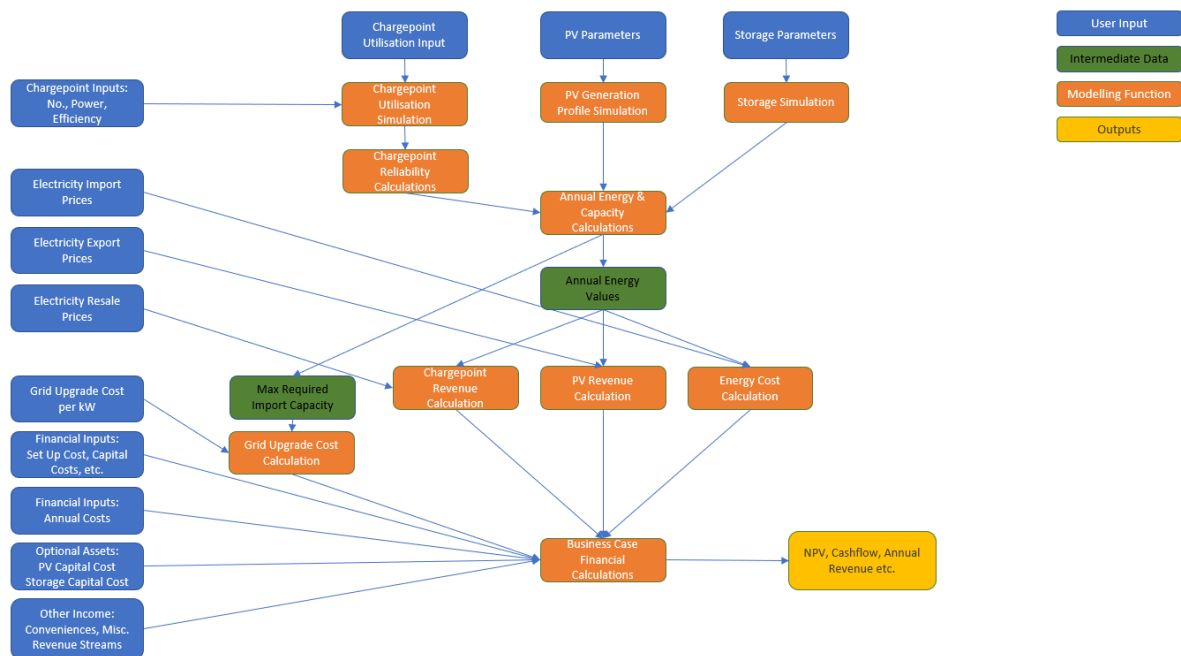

Figure 1: Tool methodology diagram

The user can specify a PV array on the site of the chargepoints. The energy from which is used to power the chargepoints with any excess exported to the grid. A BESS may also be specified, which will be used to store excess energy from the PV for later use by the chargepoints.

The simulation of chargepoint usage in the tool is important, firstly to produce a realistic maximum power capacity demand from the chargepoints (assuming there is no energy management), and secondly for scenarios that include PV, to produce realistic annual estimates of energy imported, consumed from PV, or exported to grid. The tool runs a Monte Carlo simulation of possible utilization of chargepoints based on an annual utilization target and a within day profile of when the chargepoint may be used. In each simulation for each hour in the within day profile, usage of the chargepoint is determined by drawing from a uniform distribution. From the Monte Carlo simulations, average energy is used to determine energy costs and revenues, whereas for the import capacity the maximum power is taken (to represent the fact that the chargepoints need

sufficient power in all simulations). For scenarios that include PV, simulations are performed for typical spring, summer, autumn, and winter days.

The energy provided from PV is determined through a complex relationship between coordinate of the site, solar declination angle, and sunshine hours. A user–provided value for sky clearness, ranging from 0 to 1, is also included. Note that energy flows between PV, BESS and chargepoints are not modelled stochastically, rather a straightforward deterministic approach is developed. A fully accurate simulation of the energy is beyond the scope of this tool. Nevertheless, the approach taken should provide sufficient accuracy for a high–level business model assessment.

Charger Reliability Methodology

The utilisation of chargepoints is reduced by a reliability metric which is provided by the user. This means that the revenue generated by chargepoints will be reduced due to chargepoint being occasionally out of service. If a reliability of 95% is chosen, then the revenue from chargepoints will be reduced to no less than 95% of the possible total revenue. The actual reduction depends on the number of chargepoints, their reliability and their utilisation, and is shown in detail below.

This methodology shows a way of reducing the possible energy delivered by a group of chargepoints based on unreliability and unavailability.

Let Z be the event that given the first charger is utilised, it is working or at least one other charger is working and not utilised.

Let X be event that the first charger is working.

Let $\bar{X}$ be the event that the first charger is not working.

Let Y be the event that any other charge is working and not utilised.

Let V_n be the event that n other chargers are working and not utilised.

Let n be the number of chargers at the site.

Let R be the reliability of the chargers, and U be the utilisation of the chargers.

The probability table for a single charger is given below.

Charger Status	Probability (single charger)
Working and available	R(1-U)
Working and utilised	RU
Broken and available	(1-R)(1-U)
Broken and utilised	(1-R)U

If n = 1 then probability of the charger working $P(X) = R$ so

$P(Z_1) = R$

There are no other chargers.

If n = 2 then $P(X) = R$

$P(\bar{X}) = 1-R$

And $P(Y|\bar{X}) = R(1-U)$

So, $P(Z_2) = R + (1-R)R(1-U)$

If n = 3 then $P(X) = R$, $P(\bar{X}) = 1-R$

And $P(Y|\bar{X}) = P(V_2) + P(V_1)$

$P(V_2) = (R(1-U))^2$

$P(V_1) = 2(R(1-U)(1-R(1-U)))$

So $P(Z_3) = R + (1-R)[(R(1-U))^2 + 2(R(1-U)(1-R(1-U)))]$

For n charge points…

$$P(Z_n) = R + (1-R)\sum_{i=1}^{n-1}\big(R(1-U)\big)^i(1-R(1-U))^{n-1-i}\binom{n-1}{i}$$

So, on an expected basis, annual energy delivered can be multiplied by $P(Z_n)$

Results Components

The table below provides a breakdown of the components that make up each of the financial results.

Category	Financial Result	Components
Costs	Total CAPEX (EUR)	Land acquisition cost, Financing of capital expenditures, Permitting and administrative costs, Site development and construction costs, Network connection/upgrades costs, Installation and make-ready infrastructure, Total Infrastructure CAPEX, Charger CAPEX, PV CAPEX, PV installation cost, Energy storage volume CAPEX, Energy storage power CAPEX, Energy storage installation cost, Battery management system cost.
	Total electricity costs (EUR/Year)	Costs of purchasing electricity.
	Total non-electricity costs (EUR/Year)	Back office, Land lease cost, Insurance, Charger OPEX, PV OPEX, Battery OPEX.
	Total costs (EUR/year)	Total of the above costs.
Revenue	ZEV infrastructure incentives (EUR	ZEV infrastructure incentives
	Electricity charging revenue (EUR/Year)	Revenue from resale of electricity for charging.
	Export PV electricity revenue (EUR/Year)	Revenue from export of PV electricity to grid.
	Low carbon fuel credits (EUR/Year)	Low carbon fuel credits applied to electricity resold for charging.
	Non-electricity revenue (EUR/Year)	Ancillary revenue streams, Conveniences
	Total revenue (EUR/year)	Total of the above revenue.